Delaware Department of Natural Resources and Environmental Control, Division of Energy & Climate

CLIMATE MITIGATION AND ADAPTATION PLANNING (CMAP)

Summary Report

October 9, 2017

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ACRONYMS AND ABBREVIATIONS

AHJ	Authority Having Jurisdiction
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BCA	Benefit Cost Analysis
BFE	Base Flood Elevation
CBECS	Commercial Buildings Energy Consumption Survey
CDD	Cooling Degree-Day
CMAP	Climate Mitigation and Adaptation Planning
CO_2	Carbon Dioxide
CSP	Concentrating Solar Power
DelDOT	Delaware Department of Transportation
DEOS	Delaware Environmental Observing System
DFE	Design Flood Elevation
DFM	Division of Facilities Management
DNREC	Delaware Department of Natural Resources and Environmental Control
DSM	Demand Side Management
ECM	Energy Conservation Measure

EO	Executive Order
FDC	Flood Design Class
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
Ft	Feet
HDD	Heating Degree-Day
HVAC	Heating, Ventilation, and Air Conditioning
IBC	International Building Code
IRLSS	Indian River Life Saving Station
kWh	Kilowatt-hour
lb	Pound
LiDAR	Light Detection and Ranging
NAVD88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
REC	Renewable Energy Certificate
SFHA	Special Flood Hazard Area
SLR	Sea Level Rise
SREC	Solar Renewable Energy Certificate
USACE	United States Army Corps of Engineers

EXECUTIVE SUMMARY

The Delaware Department of Natural Resources and Environmental Control (DNREC) has engaged Arcadis U.S., Inc. on a pilot program to assess three state-owned facilities, which include the Delaware Department of Transportation (DelDOT) Central District Maintenance and Operations Headquarters, Delaware State Parks Indian River Life Saving Station (IRLSS), and Delaware State Police, Troop 6 (State Police).

The purpose of the pilot project is to proactively address the possible consequences of climate change to ensure reliable and uninterrupted services to Delaware citizens. This is accomplished by identifying and implementing cost-effective climate resiliency measures in public use and critical function facilities. For the scope of this report, climate resiliency measures include flood risk mitigation and energy conservation. Delaware initiated this first-of-its-kind project to merge energy and flood risk assessments into a climate vulnerability assessment to support the state's efforts for preparing for climate change.

The study objective is to assess climate-related risks for three state-owned facilities, overlaying findings with the building typologies to identify vulnerabilities and possible solution strategies. An additional objective is to describe a methodology to find flood risk mitigation and energy conservation measures that can be scalable to other state-owned facilities and aid as a decision-making tool for different stakeholders. This methodology is detailed in Section 2 of this report. The end goal of this project is to provide information to enable a more resilient and cost-effective operation of assets, providing long-term benefits to the State of Delaware, its citizens, and visitors.

FLOOD RISK ASSESSMENT

The objective of any flood mitigation plan for buildings is to provide redundancy and business continuity during extreme weather events, such as storm surge or extreme rainfall. As a part of the flood risk assessment, Arcadis determined the Design Flood Elevation (DFE) at each of the sites. The DFE was obtained by adding: Base Flood Elevation (BFE) as established in the Federal Emergency Management Agency's (FEMA's) Flood Insurance Rate Maps (FIRMs) which includes tidal and wave effects; freeboard per the State of Delaware's EO41 minimum requirements of 1.5 feet (ft); and the projected Sea Level Rise (SLR) to the 2080s to account for climate change.

The DFE was calculated to the 2080s for each of the sites. Assuming that the mitigation projects would commence by the end of the decade, the assets would remain protected for 60 years, which exceeds FEMA's 50-year standard. The methodology to determine the DFE is detailed in this report in Section 2.1.2. The DFE was then compared with topographic information from the site to determine the vulnerable assets within the site.

Additionally, the rainfall depth projection was obtained for each of the sites for a 24-hour (hr), 10-year rain event. This rain event, referred to as conveyance volume in the State of Delaware's Sediment and Stormwater Regulations (DNREC, 2014), is a standard rain event for flood risk assessments. Rain events are used to design drainage infrastructure and as rainfall patterns change, existing drainage infrastructure might not be sufficient to handle the runoff volume. Climate change models predict that rainfall will increase by 3 to 10 percent with every degree-Celsius (1.8 F) of increase in global temperature. In Delaware, the temperatures are expected to increase between 3.5 and 9.5 F by the end of the century depending on the carbon emissions rate (Hayhoe, Stoner, & Gelca, 2014). Surcharged drainage can result in flooding risk to assets during heavy rain events. Projected data for future rain events was gathered for each site. However, studying the flood risk from rain events is beyond the scope of this report since it requires an extensive hydrologic study of the drainage system of the catchment where each asset is located.

Table 1 below summarizes the DFE that was determined, first floor elevations and projected rainfall for each of the sites.

Description	DelDOT	State Police	IRLSS
Design Flood Elevation (feet, NAVD88)	11	61	8.8 - 14
First Floor Elevation (feet, NAVD88)	28	127*	8
24hr,10yr rainfall depth (inches)	5.2	4.8	5.3
*Approximate grade elevation, no available first floor elevation data			

Table 1 – Summary of flood risk findings

The table above shows that DelDOT and State Police sites are above the DFE; first floor elevations are at elevations +28 feet and +127 feet, respectively, while the DFEs are +11 feet and +61 feet respectively. Moreover, since the sites are at a higher elevation relative to the surroundings, rainfall runoff is unlikely to accumulate and cause flooding. Further hydrologic studies would be required to confirm this statement. The flood risk to these sites is minimal and no flood risk mitigation strategies are required. Historical records confirm this statement. In stark contrast to the other two facilities, the IRLSS is at risk from flooding at the calculated DFE. Similarly, further hydrologic studies would be required to evaluate how rainfall would exacerbate flood risk at this location. Historically heavy rainfall has not flooded the site. Appendices A, B and C detail the flood risk assessment results at each site. DelDOT and State Police facilities are expected to have business continuity through the projected 2080s DFE. The IRLSS might require relocation because even if the site was protected in isolation, access could be continuously impeded by tidal action as sea level rises.

Energy assessments were carried out with changes in temperatures projected to the year 2045. Since business continuity in the year 2045 can be attained for all sites from a flood risk perspective, implementing adaptation measures to the changes in temperature and energy efficiency would result cost-effective. The investment in energy conservation measures at the sites can be validated since the sites can continue to operate through the investment payback period.

ENERGY ASSESSMENT

As a part of the energy assessment, Arcadis evaluated energy efficiency opportunities and climate change projection analyses at each of the three sites. Below are the results of the energy assessment with identified energy opportunities and climate change projections of future energy use and energy costs.

The Energy Conservation Measures (ECMs) were broken down into two categories as follows:

1. ECMs where exact quantities and total costs and savings were known. The identified ECMs in this category and associated costs, energy savings, and carbon dioxide (CO_2) reductions results are presented below in Table 2.
2. ECMs where exact quantities and total costs and savings are not known. These are referred to as unit cost ECMs because all quantities are not known, such as the number of lighting fixtures within

each building. These identified ECMs and associated costs, energy savings, and CO_2 reductions results are presented on a unit cost basis below in Table 3. The total costs, energy savings, and CO_2 reductions can be calculated by multiplying the quantity of units (e.g., light fixtures, lamps, etc.) by the unit costs, energy savings, and CO_2 reductions.

CATEGORY ONE: TOTAL COST ECMS			
Description	Cost/Savings/Payback		
	DelDOT	State Police	IRLSS
Measure Costs ($)	$1,000	$1,000	$5,120
Estimated Annual Operating Savings ($)	$2,484	$956	$388
Simple Payback Period (Years)	6.0	1.0	13.2
Annual Electricity Savings (kWh)	23,432	10,386	3,526
Annual Natural Gas Savings (therms)	0	0	0
Total CO2e Reduction (lbs)	20,118	8,917	3,027

Table 2 – Total Cost Energy Opportunity Summary Table

CATEGORY TWO: UNIT COST ECMS			
Description	Cost/Savings/Payback		
	DelDOT	State Police	IRLSS
Unit Cost Measure Costs ($)	**$1,344**	**$846**	**$83**
LED Lighting	$894	$606	$83
Occupancy Sensors	$300	$240	-
DHW System	$150	-	-
Unit Cost Estimated Annual Operating Savings ($)	**$433**	**$430**	**$65**
LED Lighting	$241	$367	$65
Occupancy Sensors	$27	$63	-
DHW System	$166	-	-
Unit Cost Payback Period (Years)	**3.1**	**2.0**	**1.3**
LED Lighting	3.7	1.7	1.3
Occupancy Sensors	11.2	3.8	-
DHW System	0.9	-	-
Unit Cost Annual Electricity Savings (kWh)	**3,731**	**4,670**	**592**
LED Lighting	2,134	3,984	592
Occupancy Sensors	236	686	-
DHW System	1,361	-	-
Unit Cost Annual Natural Gas Savings (therms)	**51**	**0**	**0**
LED Lighting	0	0	0
Occupancy Sensors	0	0	-
DHW System	51	-	-
Unit Cost Total CO2e Reduction (lbs)	**3,796**	**4,010**	**508**
LED Lighting	1,832	3,421	508
Occupancy Sensors	203	589	-
DHW System	1,761	-	-

Table 3 – Unit Cost Energy Opportunity Summary Table

Below are the results of the analysis of climate change projections for mean cooling degree days (CDD) and mean heating degree days (HDD) to estimate future cooling and heating loads for each site through 2045. Associated changes in total energy costs were also estimated based on National Institute of Standards and Technology (NIST) predictions of utility rate escalations and an estimated annual inflation of 3.5% through 2045. Results of these analyses are shown in Table 4 and Table 5 below.

Site	Baseline Climate Change Indicator		Projected Climate Change Indicator	
	2016 Mean CDD Baseline	2016 Mean HDD Baseline	2045 Mean CDD	2045 Mean HDD
DelDOT	1,506	4,511	1,892	3,784
State Police	1,411	4,750	1,747	3,977
IRLSS	1,558	4,106	1,968	3,360

Table 4 – Climate Change Projection Summary Table

Site	Average Electric Consumption (kWh/year)	Average Natural Gas Consumption (therms/year)	Baseline Energy Costs		Projected Energy Costs	
			2016 Total Cooling Cost	2016 Total Heating Cost	2045 Total Cooling Cost	2045 Total Heating Cost
DelDOT	573,800	27,911	$2,802.40	$12,884.00	$10,078.63	$34,040.52
State Police	253,680	7,315	$3,266.00	$4,962.68	$11,572.73	$14,027.18
IRLSS	92,250	N/A	$803.00	$3,300.00	$2,903.36	$7,730.52

Table 5 – Energy Cost Projection Summary Table

As shown in Table 4, the overall trend in CDD increases through 2045, and the overall trend in HDD decreases through 2045 for all three sites analyzed. Overall energy costs increase as well due to the NIST projections of rising utility rates and annual price inflation through 2045, as shown in Table 5. More specific analysis and discussion of methodologies employed as part of this study can be found in Section 2.2.

Detailed results of each site's climate vulnerability assessments can be found in the attached appendices.

1 INTRODUCTION AND PROJECT OVERVIEW

1.1 Introduction

The State of Delaware, being a low-lying coastal state, is vulnerable to flooding, storm surge, tidal wetland losses, and other weather-related impacts. In August 2011, the St. Jones River flooded downtown Dover during Hurricane Irene causing damage to local businesses. In September 2014, The Great Marsh near Lewes was inundated by a high tide. In October 2015, a nor'easter caused tidal flooding throughout the state resulting in rivers overtopping their banks.

Different government agencies such as the National Oceanic and Atmospheric Administration (NOAA), FEMA, and the United States Army Corps of Engineers (USACE) monitor the effects of climate change. These agencies publish relevant information for coastal communities such as flood hazard maps, projections of SLR, increases in rainfall frequency and intensity and increases in temperature. Figure 1 depicts a portion of the state that would be flooded under different Sea Level Rises (SLR) scenarios.

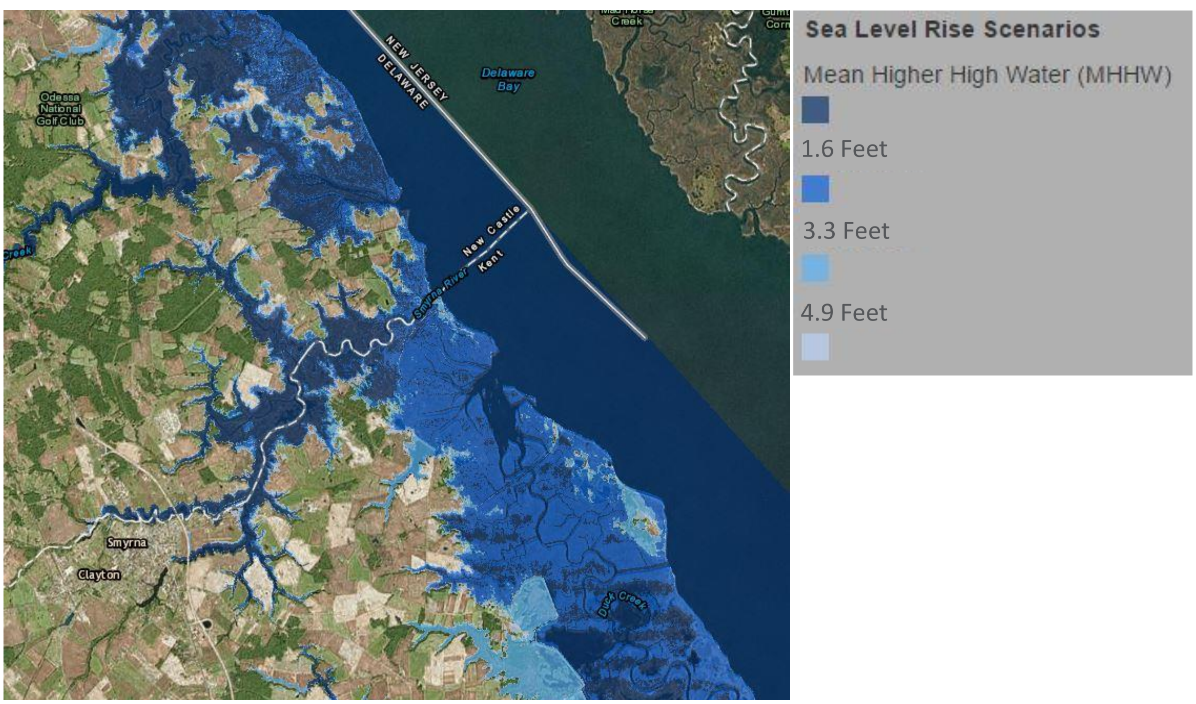

Figure 1 – Delaware Sea Level Rise Inundation Maps (State of Delaware, 2017)

In order to prepare for climate change risks, federal and state governments have published Executive Orders (EO) to motivate action on improving resiliency. The federal EO 11988 "requires federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of flood-plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative". EO 13690 delineates the minimum design criteria for the mitigation of structures within the floodplain, which is discussed in further detail in the design criteria section of this report. EO 41 approved by Governor Markell in September 2013 directs the state of Delaware to address the causes and consequences of climate change by: reducing greenhouse gases emissions, increase resiliency to climate impacts and avoid and minimize flood risks that increase State liability and decrease public safety.

As a response to these mandates, the State of Delaware has carried out studies and developed reports and tools to understand the impacts of climate change (Delaware Coastal Programs, 2012; Division of Energy and Climate, 2014; Delaware Flood Avoidance Workgroup, 2016). Specifically, the Delaware Climate Projections Portal is a web-based data library developed and maintained by the University of Delaware for the State of Delaware to provide electronic access to downscaled climate projection data developed by ATMOS Research and Consulting. All of the data points were produced through a statistical downscaling methodology. It contains downloadable climate change projection data for fourteen different weather stations in Delaware. The downloadable data for each weather station includes 55 climate indicators for temperature, rainfall, growing season, dry days, heat indices, and energy (cooling degree-days and heating degree-days) between the year 1950 and 2100. Each of these 14 stations within the State of Delaware are strategically located, developing unique geographic and climatic zones. Cooling degree-days (CDD) are defined as the number of degrees that a day's average temperature is above the minimum threshold of 65°F. Similarly, heating degree-days (HDD) are defined as the number of degrees that a day's average temperature is below the minimum threshold of 65°F. In addition to the Delaware Climate Projections Portal, the Delaware Environmental Observing System (DEOS) was used to analyze historical data. Specifically, DEOS operates over 50 environmental monitoring platforms, and imports over 200 additional environmental monitoring platforms throughout the state. State assets are at risk of damage and higher cost of operation due to climate change effects including: sea level rise, increased frequency and intensity of rainfall, and increasing temperatures. This assessment focuses on those three climate change effects, because these effects would pose the highest threat to affecting operability of state assets.

1.2 Project Overview

The purpose of the pilot project is to proactively address the possible consequences of climate change to ensure reliable and uninterrupted services to Delaware citizens. This is accomplished by identifying and implementing cost-effective climate resiliency measures in public use and critical function facilities. For the scope of this report, climate resiliency measures include flood risk mitigation and energy conservation. Delaware initiated this first-of-its-kind project to merge energy and flood risk assessments into a climate vulnerability assessment to support the state's efforts for preparing for climate change.

Arcadis U.S. Inc. (Arcadis) performed assessments for the Climate Mitigation and Adaptation Planning (CMAP) pilot project at three sites. The three sites are: Delaware Department of Transportation, Central District Maintenance and Operations Headquarters (DelDOT); Delaware State Police, Troop 6 (State Police); and, Delaware State Parks, Indian River Life Saving Station (IRLSS). Figure 2 displays the locations of the sites.

Figure 2 – Location of Climate Vulnerability Assessment sites

2 SITE ASSESSMENTS AND METHODOLOGY

2.1 Flood Risk Assessments and Methodology

Flood risk cannot be eliminated, but it can be reduced. Understanding factors that contribute to risk will help reduce long-term risk. It is particularly important that facility managers and decision-makers have a realistic understanding of the flood risk context for facilities over their anticipated lifespan. This part of the report orients decision-makers to flood risk concepts and aids in understanding the risk and vulnerability assessment findings included in the site-specific appendices to this report. With the support of the findings of technical experts, decision-makers will ultimately decide which mitigation measures to pursue and with what degree of urgency.

The objective of any flood mitigation plan for buildings is to provide redundancy and business continuity during extreme weather events, such as storm surge or extreme rainfall. The level of risk reduction depends on the chosen annual statistical chance of occurrence, (e.g., the 100-year (yr) storm surge with a 1% chance of occurrence each year) and the type of solutions. Resiliency will increase when following a systematic approach, assessing both the building interior and internal critical components as well as first lines of defense that are usually implemented to close off external water entry points. Second lines of defense for buildings targets critical internal electrical components, such as switchgear and switchgear rooms as well as other building assets such as sump pumps or fuel storage. Redundancy of electrical equipment can be achieved by limiting the chance of exposure to water, if the first line of defense or components of the first line of defense fail. This can be achieved by elevating electrical components above the designed flood line or by dry flood-proofing below-grade rooms that contain electrical equipment.

2.1.1 Assessments

2.1.1.1 Understanding Flood Sources

The most commonly referenced sources of flooding are riverine and coastal flooding, though public facilities are also at risk of flooding from run-off resulting in ponding and sheet flow. Floods may be slow to rise or happen quickly, as in a flash flood event.

Riverine flooding results from the accumulation of runoff from rainfall, such that the volume of flow exceeds the capacity of waterway channels and spreads out over the adjacent land. Figure 3 below shows an example of riverine flooding in downtown Dover.

Figure 3 – Riverine flooding in downtown Dover (Delaware Flood Avoidance Workgroup, 2016)

Coastal flooding is largely influenced by storm surges associated with tropical cyclonic weather systems (e.g., hurricanes, tropical storms, tropical depressions, typhoons, extratropical storms (nor'easters)), tsunamis and wind-driven wave action. This type of flooding causes normally dry, low-lying land to be flooded by sea water. Figure 4 captures the effects of coastal flooding on Route 1 connecting the communities of Bethany Beach and Dewey Beach.

Figure 4 – Coastal flooding on Route 1, Delaware (Murray, 2017)

Sheet flow is flooding from rainfall runoff resulting from a combination of inadequate drainage and impervious surface. Sheet flow is an overland flow of water that takes the form of a thin, continuous film and is not concentrated into channels larger than rills. It can also result in ponding if there are depressions in the landscape that collect runoff. Areas subject to ponding and sheet flow may not be depicted on local or FEMA flood maps and may best be determined through a review of topography, historical losses, or analysis by a technical expert. Figure 5 below depicts ponding that occurred on Hubbard Avenue in Frederica, Delaware.

Figure 5 – Ponding due to runoff, Delaware (Bittle, 2015)

2.1.1.2 Understanding Historical Losses

While it is possible to develop an understanding of the flood risk context of a site through evaluation of the facility alone, records of historical losses provide a practical foundation on which to base the evaluation. Further, public expenditure to implement mitigation projects can often be more easily justified through the lens of historical loss, as opposed to expected loss determined through modeling or professional judgment.

Stakeholders with working knowledge of historical impacts to the facility are best equipped to provide this information. All flood impacts, no matter how small, should be captured. Frequently recurring small flood events indicate a high probability of repeated flooding. These events can be used by technical specialists to better understand flood risk at a site. Once mitigation measures are identified, funding experts can use this information to justify public expenditure. Figure 6 depicts damages during Hurricane Gloria near the IRLSS site.

Figure 6 – Indian River Life Saving Station during Hurricane Gloria Sept 1985. Photo: Robert D. Henry

2.1.1.3 Understanding Flood Risk

Flood risk can be understood as the correlation of two components: the probability of a flood event happening and its consequence to an asset. The probability of flooding is generally correlated with the associated depth of flooding. As the expected magnitude of a flood event increases, the probability decreases. For example, a 100-year flood event has a 1% probability of happening in a single year while a more severe 500-year flood event has a 0.2% probability of happening in a single year.

FEMA has developed mapping systems that correlate flood depths in certain areas to probability of flooding (see Section 2.1.1.5 below (Understanding Design Flood Elevation) for further detail). Flood events due to excess impervious surface and drainage issues are often correlated with probabilities based on rainfall intensity and duration. NOAA has developed charts with Intensity Frequency Duration curves that provide rainfall probabilities based on inches of rain over a given timeframe. Figure 7 is an example of projected rainfall depths at Dover.

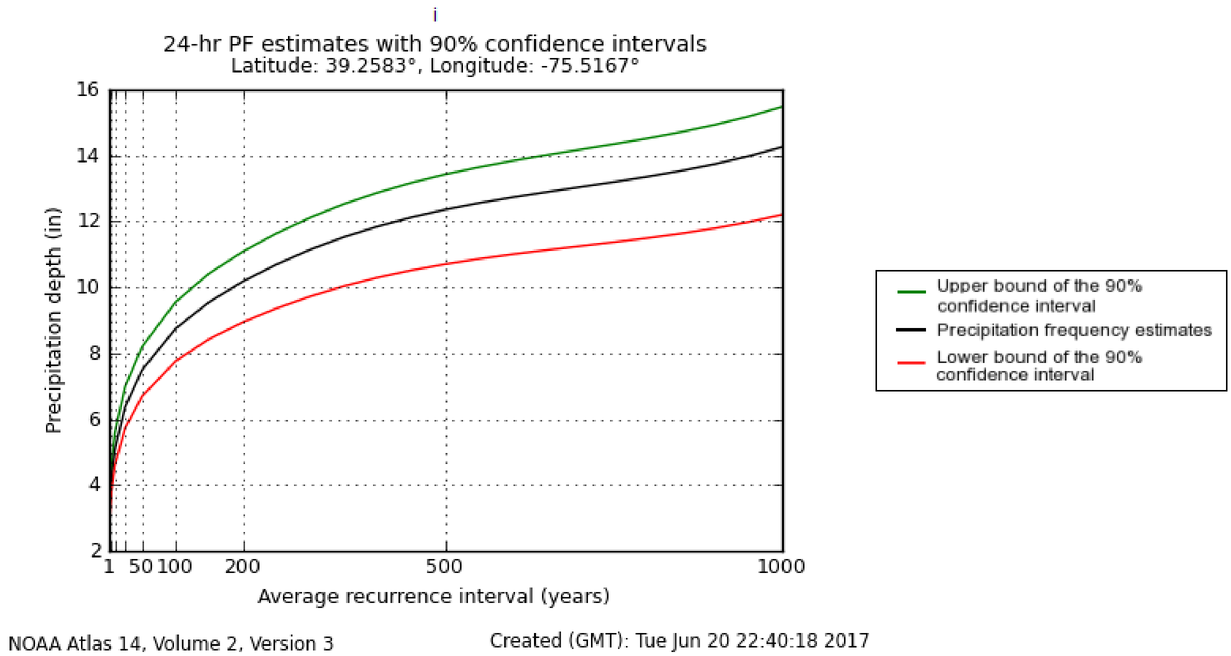

Figure 7 – 24hr rainfall depth plot at Dover, Delaware

The horizontal axis in Figure 7 is the expected recurrence of a heavy rain event per interval of years, for example once per year, once every fifty (50) years, once every one hundred (100) years, etc. The vertical axis is the expected rainfall in inches. The curves are the result of the model that estimates the rainfall, with the estimated rainfall frequency in the middle and an upper and lower bound to account for the uncertainty in the model.

Consequence of flood impact could include many factors, ranging from property damage to regional economic loss, which might occur as a result of industry disruption and small business collapse. For public facilities, consequences increase with the increased importance of a facility to the community, particularly as the community prepares for, responds to, or recovers from a hazard event. For example, if a hospital service is interrupted, health services to the community would be interrupted. Most, if not all, of these consequences can be quantified should decision makers find it necessary or helpful to do so. All expected consequences should be described, at the least, in order to support the decision-making process. This is further detailed in Section 2.1.1.6 (Understanding Criticality) below.

Once probability and consequence of flood impact are known and understood, it is then possible to begin the process of determining whether and to what extent mitigation is appropriate, as well as to begin prioritizing potential mitigation actions; see Sections 2.1.2.2 (Performance Criteria) and 2.1.2.3 (Design Flood Elevation) for more detail.

Climate change exacerbates flood risk. Climate change models for Delaware predict that temperatures will increase between 3.5 and 9.5˚F by the end of the century, depending on the carbon emissions rate. As a consequence, rainfall will increase by 3 to 10 percent with every degree-Celsius (1.8 ˚F) of increase in global temperature. As sea levels continue to rise, the risk of coastal flooding is increased with higher tides and higher water surface elevations for storm surge events. Models to understand the way in which the increase in SLR and rainfall will change river levels is currently under research.

2.1.1.4 Understanding Vulnerability to Flood Hazard

Example factors that contribute to a facility's flood vulnerability include age and condition of facilities, construction type, location, structure elevations, as well as site flood probability and type of flooding (for example, fast-moving water will cause different damage compared to standing water). The simplest way to determine facility's vulnerability to overland flooding is by determining whether it is in a Special Flood Hazard Area (SFHA) as designated by FEMA. Quantifying vulnerability begins with cataloguing flood depths that correlate to various flood probabilities on the site and comparing this with the lowest elevations of the facility itself. Flood elevations for the 1-percent annual chance event are given as the Base Flood Elevation (BFE) on recent FIRMs. Elevations that correlate to additional flood probabilities can often be located within the Flood Insurance Study (FIS) published by FEMA or the local floodplain administrator.

2.1.1.5 Understanding Design Flood Elevation

The DFE is in summary the addition of: the BFE, the projected SLR and freeboard. It provides information for the elevation to which a site and the assets within should be protected to minimize the flood risk. The following sections explain in further detail each one of these components and more details on how the DFE is obtained can be found in Section 2.1.2.3 (Design Flood Elevation) below.

FEMA Base Flood Elevation

FEMA's FIRMs illustrate areas in the SFHA, or areas that are at risk of flooding due to coastal storm events and changes in riverine levels.

The BFE corresponds to the elevation that water is expected to rise during a flood event having a 1% chance of being equalled or exceeded in any given year, including tidal and wave action. It is also referred to as the 100-year flood event. The BFE is used by the National Flood Insurance Program (NFIP) as the standard for floodplain management and to determine the need for flood insurance. Figure 8 describes the meaning of each one of the zones.

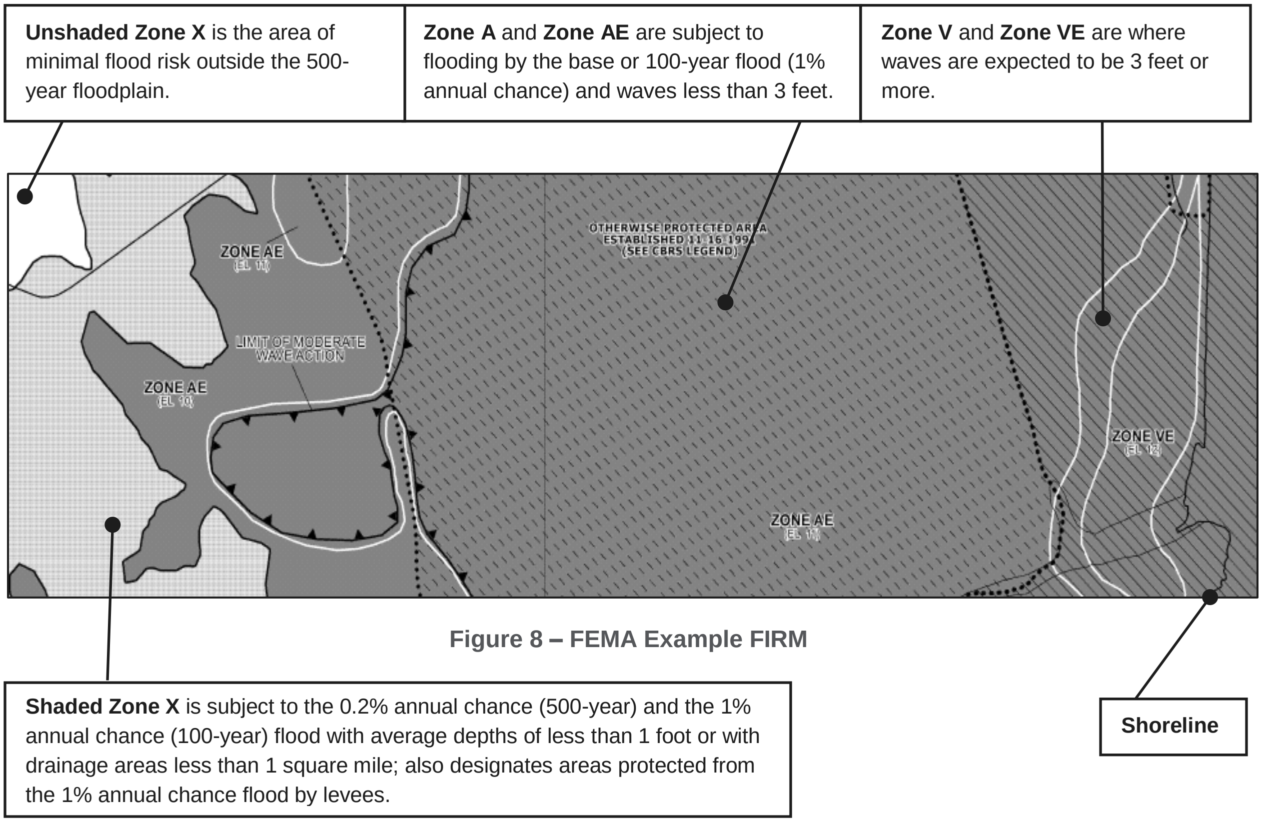

Figure 8 – FEMA Example FIRM

For essential facilities (see Section 2.1.1.6 below - Understanding Criticality) the 500-yr stillwater elevation, published in the FIS by FEMA, must also be taken in consideration when defining the DFE. The 500-yr still water elevation is Zone X shown in Figure 8. The American Society of Civil Engineers (ASCE) recommends essential facilities to be elevated to the highest of the BFE+2 or the 500-year flood elevation. Note that the FIS 500-year storm elevation does not include tidal and wave action. Additional studies are required when determining a DFE for a 500-yr storm event, including determining wave heights and time series, and wave run-up depending on the type of flood barrier.

Sea Level Rise

In Delaware, SLR increases the risk of flooding posed to infrastructure and ecosystems resulting from coastal storm events. The eustatic SLR rate was approximately 0.07 inches per year (7 inches over the last 100 years). The rate of change in Delaware nearly doubles this rate. The tide gauge in Lewes recorded 0.013 inches of increase per year (13 inches over the last 100 years) (Delaware Coastal Programs, 2012). Different environmental entities publish SLR projections including NOAA (NOAA, 2017), USACE (USACE, 2017) and DNREC (Delaware Coastal Programs, 2012) in the specific case of Delaware. There are uncertainties inherent in the projection of SLR, and therefore low, medium and high scenarios are included in the projections. The SLR estimate published by NOAA, DNREC and USACE for the 2050s through the 2100s for the State of Delaware are shown in Table 6.

Year	Estimate	NOAA (ft)	USACE (ft)	DNREC (ft)
2050s	Low	0.9	0.6	0.7
	Int-Low	1.1	-	-
	Int	1.9	1	1.2
	Int-High	2.6	-	-
	High	3.6	2.2	1.8
	Extreme	4.2	-	-
2080s	Low	1.3	0.8	1.3
	Int-Low	1.7	-	-
	Int	3.2	1.5	2.5
	Int-High	4.7	-	-
	High	6.5	3.9	3.8
	Extreme	8	-	-
2100s	Low	1.6	1.1	1.7
	Int-Low	2	-	-
	Int	4.4	2.2	3.6
	Int-High	6.9	-	-
	High	9.6	5.7	5.4
	Extreme	11.8	-	-

Table 6 – Sea Level Rise Estimates in Feet

A standard lifespan of a building is at least 50 years; therefore, any climate adaptation measure should have a similar projected lifespan, which brings the lifespan of any project that would commence by the end of the present decade close to the 2080s.

When comparing the values shown in Table 5, NOAA predicts the highest SLR (3.4ft) by the 2080s, followed by DNREC (2.5ft). When mitigating risk, using the most conservative and updated information available is recommended. The most recent set of data shown in Table 6 was published by NOAA in 2017 and is also the most conservative. Therefore, this data set was used as the basis for this assessment.

Freeboard

Freeboard is defined by FEMA as a factor of safety expressed in feet above the BFE. It compensates for unknown factors that could contribute to flood heights greater than the BFE. A facility's flood insurance premium, determined by NFIP, is influenced by the relationship between the building elevation and the BFE. Therefore, the introduction of additional freeboard exceeding the minimal requirements should result in a reduction in flood insurance premiums.

Per the EO 41 in the State of Delaware, all state agencies are required to incorporate measures to adapt to increased flood height and SLR. When structures are within a SFHA, the minimum freeboard is 1.5 feet above the current BFE.

2.1.1.6 Understanding Criticality

Criticality refers to the relative importance of a facility or service. This report uses the occupancy categories (Flood Design Class) established in ASCE 24 Flood Resistant Design and Construction (ASCE,2015) to assign criticality for facilities. As mitigation assessments become a higher priority for facilities, a greater understanding of the characteristics of the facility and its assets is necessary. Information needs may progress from basic information about the type of service provided, to elevations of specific critical assets. Table 7 below summarizes the Flood Design Class (FDC) descriptions (ASCE, 2015).

FDC	Nature of Occupancy
1	Buildings and structures normally unoccupied and pose **minimal** risk to the public (e.g., temporary structures, storage buildings, small parking structures, certain agricultural structures)
2	Buildings and structures that pose **moderate** risk to the public (e.g., residential, commercial and industrial buildings)
3	Buildings that pose a **high** risk to the public should they be damaged (e.g., theaters, concert halls, religious institutions, museums, schools, community centers, power generating stations, structures related to toxic or explosive substances, etc.)
4	Buildings that contain **essential** facilities and services necessary for emergency response and recovery (e.g., hospitals, fire, rescue, vehicle garages, police stations, emergency shelters, public utility facilities required in emergencies, buildings containing substances that pose a threat to the public if released, etc.)

Table 7 – Buildings and structures flood design class

Unless overridden by a local authority, the FDC determines the freeboard that a new structure or the mitigation of an existing one should have. The freeboard for FDCs 1, 2 and 3 is +1ft, while FDC 4 is +2ft.

2.1.1.7 Prioritizing Systems and Assets

Similar to categories for buildings, a criticality category can be established for systems and assets to identify the most critical elements of a facility. For critical or particularly large public facilities at risk of flooding, it is often useful to categorize and prioritize certain individual assets (e.g., emergency generators, motor control centers). This is done to help technical assessors determine what portions of a facility are most exposed and whether mitigation can or should be accomplished at the asset or system scale, as opposed to the larger scale of structure or campus. An example is shown in Table 8 below.

Criticality Category	System and Asset Category Explanation
1	**Non-essential** equipment for the functioning of the facility or replaceable assets (e.g. decorative elements, etc.)
2	**Minor importance** equipment and systems providing non-vital services to the facility (e.g. furniture, office equipment, etc.)
3	**Important** functions/services to the facility that do not serve as critical facility equipment (e.g., security systems, vital storage, elevators and escalators for evacuation, and lighting)
4	**Critical** assets/systems that serve life safety purposes, hazardous material-storage purposes, and provide significant value to historic or cultural understanding (e.g., fire-protection systems, electrical systems, ventilation equipment, IT systems and historic/cultural artifacts or displays)

Table 8 – System and asset criticality categories

2.1.1.8 Understanding Consequences

Consequence analysis is valuable to obtain a better understanding of a facility's hazards and may be used as a basis for identifying ways to mitigate those hazards. When combined with the flood probability, vulnerability of the facility, and criticality of the service provided, the facility at risk has been comprehensively assessed.

Consequence analysis involves evaluating and quantifying, where possible with available resources, potential flood impacts to a facility. Example consequences include damage to property, employee job interruption and loss, negative impacts to the environment, injuries or loss of life, and service interruption. The consequence of a flood event is determined independently of its probability.

FEMA defines loss of service as "Cost and direct economic impacts that occur when physical damages are severe enough to interrupt the function of a building or other facility." Loss of service is often the most important cost to consider and can be characterized as a function of time down, such as hours or days. Service loss can be estimated through historical service loss, FEMA depth damage functions, and professional judgment.

2.1.2 Methodology

2.1.2.1 Project Area Existing Conditions

Understanding the existing conditions of a site that is being assessed is crucial to determining the mitigation options available to the site. The following information is relevant to performing a flood risk assessment:

FIRM and rainfall depth

> If there is no record of flooding at a site, reviewing a FIRM is the first step in understanding the flood risk of a site. Depending on the flood zone in which the site is located, the level of exposure to coastal or riverine flooding can be understood. These maps provide a BFE to which factors like freeboard and SLR are added to determine a design flood elevation.
>
> If drainage is inadequate, intense rain events can also damage a site performance by causing high levels of ponding and damaging equipment. Historical evidence of stormwater backflowing through

manholes or into low lying areas of a structure is a clear indicator of inadequate drainage. Impervious surfaces such as roads and other paved surfaces exacerbate the ponding and sheet flow effects. Hydraulic modeling is required to understand the size of the catchment that contributes to runoff in a specific site and what the optimal condition of the drainage system would be to manage it.

Moreover, the risk of flooding from a storm surge event can be intensified by a rain event occurring simultaneously. Modeling both events to occur simultaneously results in a more resilient mitigation by capturing two different effects in climate change: increase in frequency and intensity of rain events and storm surge events. In order to conduct this hydrologic modeling, detailed information of the drainage infrastructure of the area's catchment would be required. This type of modeling would be outside the scope of this phase of the CMAP project and therefore such modeling was not conducted.

Topography and building elevations

The terrain elevations of the site area are key to understanding the flood risk for the site. With this information at hand, the flood depth at the site can be determined in case of a storm event. By understanding the site topography, the paths for floodwaters can be identified and mitigated, and the best locations for mitigation systems can be identified. On the other hand, first floor elevations and basement elevations at a site are required to identify critical assets within the building. Site plans, land surveys and light detection and ranging (LiDAR) are great sources of information. Figure 9 below shows an example of relevant elevations for a flood risk assessment performed by Arcadis in 2016 at a hospital site.

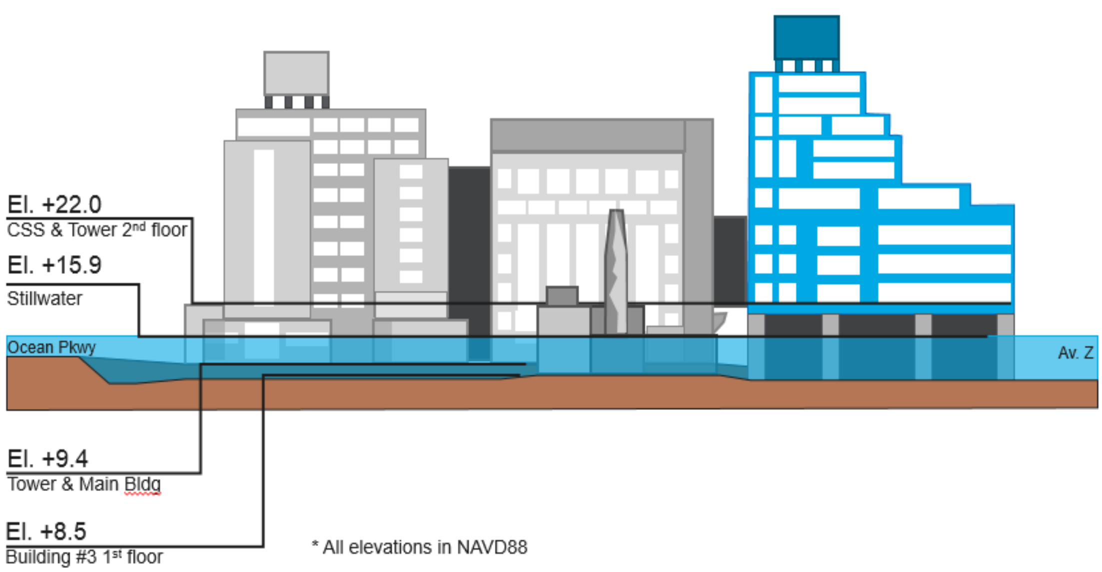

Figure 9 – Schematic of elevations at a site

Subsurface utilities

Floodwater can penetrate into a site, a building basement or into the first floor through sanitary, stormwater and other utility lines. Once identified, mitigation for these utilities can be conceptualized. Moreover, subsurface utilities might also pose challenges for certain types of mitigation during construction. As-builts, design drawings and surveys are ideal sources of information.

Geotechnical information

As the design of mitigation alternatives is developed, in depth information for the site is required. The groundwater table at a site, as well as tidal influence in the groundwater level, becomes very relevant when determining seepage cutoff features or quantifying volumes that could be captured by infiltration. Soil properties such as composition and strength are required to design structurally sound mitigation alternatives. Soil boring samples are the best way to acquire this information.

Identify the critical assets and vulnerabilities

A vulnerability assessment provides an overall scope for the mitigation effort. Identifying critical assets and site vulnerabilities allows the determination of the level of mitigation that should be pursued. The mitigation level could range from protecting individual assets or systems to protecting an entire building, campus, or community. Critical assets are those that are indispensable for the building to remain in operation or cannot be replaced, as shown in Table 8. Vulnerabilities can include subsurface utilities, structural damage, windows, etc. Site inspections and utility surveys are the best sources of information. Figure 10 depicts an example of the mapping of an electrical system a hospital, to understand the relative elevation of the components of the system with respect to the DFE.

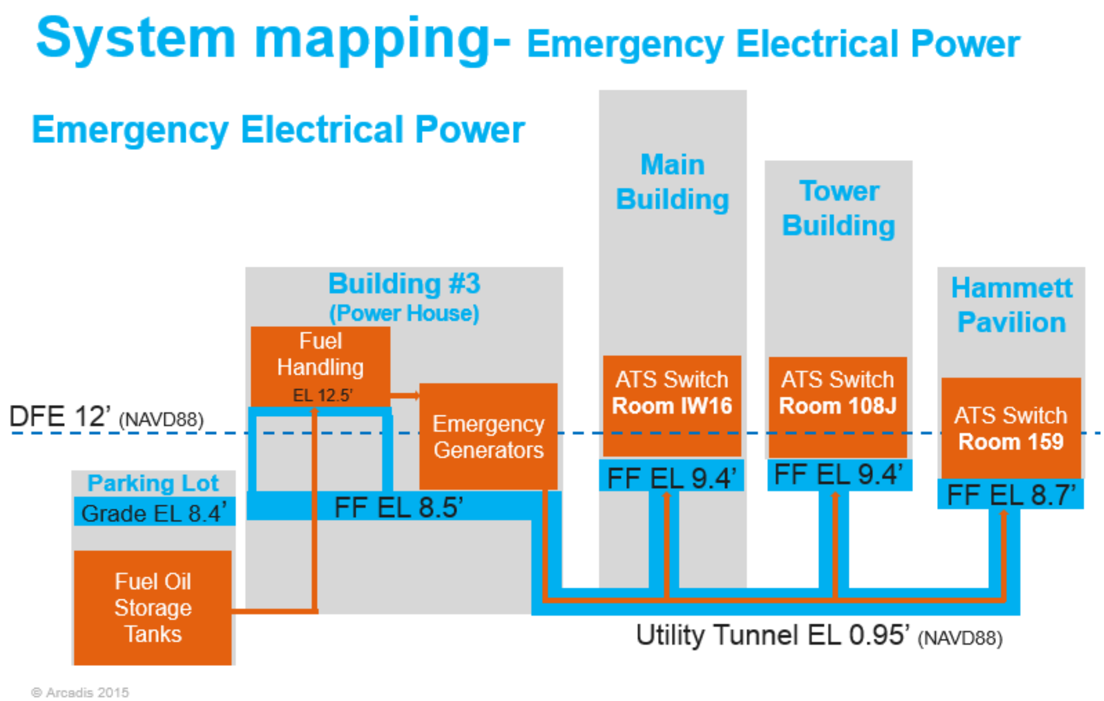

Figure 10 – Example of system mapping of a critical asset (emergency electrical power)

2.1.2.2 Performance Criteria

When evaluating flood mitigation strategies, the end goal is to effectively protect the site from flooding. However, these alternatives should also meet criteria that relate to how the users, stakeholders, and the community surrounding the site interact with it. This concept is referred to as performance criteria: the capability of a facility to carry out its function when flood mitigation strategies are deployed during a storm event. For example, if a public asset like a museum is effectively protected from SLR, but the roads leading to it are flooded, then the facility is rendered inaccessible to the public. The flood-mitigation strategy would therefore be inadequate, because the facility would not be able to perform its intended function of receiving visitors.

The performance criteria for the project can be understood by defining the expected functions of a facility during a storm event. For example: is it expected that staff will be available to deploy flood-mitigation systems before the event? Can the operation of the facility be interrupted during a storm event? Will the facility be evacuated or will it be used as a shelter? Should the facility be accessible to vehicles entering and exiting at all times during a storm event? What functions can be interrupted and for how long? Should the flood-mitigation options be entirely passive (with no human intervention)?

The performance criteria should capture the concerns of different stakeholders while keeping in mind the essential task that the site must carry out in an uninterrupted manner. Going back to the previous example, a museum could evacuate all occupants before a storm event, deploy the flood-mitigation systems, and close for the duration of the storm. However, a hospital should be able to shelter patients and have the capability of assisting the community during a storm event. Therefore, the flood-mitigation alternatives should be such that access is never interrupted and evacuation of the occupants is not required for a hospital. Figure 11 shows a flood protection system deployed during a storm event at a hospital.

Figure 11 – Example of a hospital campus mitigation (Photo credit: FloodBreak)

2.1.2.3 Design Flood Elevation

This section describes the methodology to determine the DFE for most sites. It is important to note that every site is different and has particular factors that might modify the procedure of determining a DFE. These factors might include local building codes, stakeholders input, project budget, etc. When federal funds are used for the project, the DFE should meet or exceed guidelines such as the EO 13690. In general, the DFE= BFE + freeboard + SLR. The BFE is obtained from the FIRMs. The SLR projections are commonly obtained from NOAA, USACE or local environmental departments like DNREC in the State of Delaware. Defining the SLR scenario to use involves a decision-making process based on budget and feasibility. As a starting point, a project life of 60 years is considered, which in the case of this report is close to the 2080s SLR projection. The freeboard is based on international standards such as ASCE 24 (ASCE, 2015) and local or federal regulations. In the State of Delaware, state agencies are required to have a minimum of 1.5 feet above the BFE plus SLR, per EO 41. Figure 12 below summarizes the DFE elements. The flowchart in Figure 13 summarizes the general process of defining a DFE with specific parameters that apply to the State of Delaware including SLR projections and local regulations for freeboard.

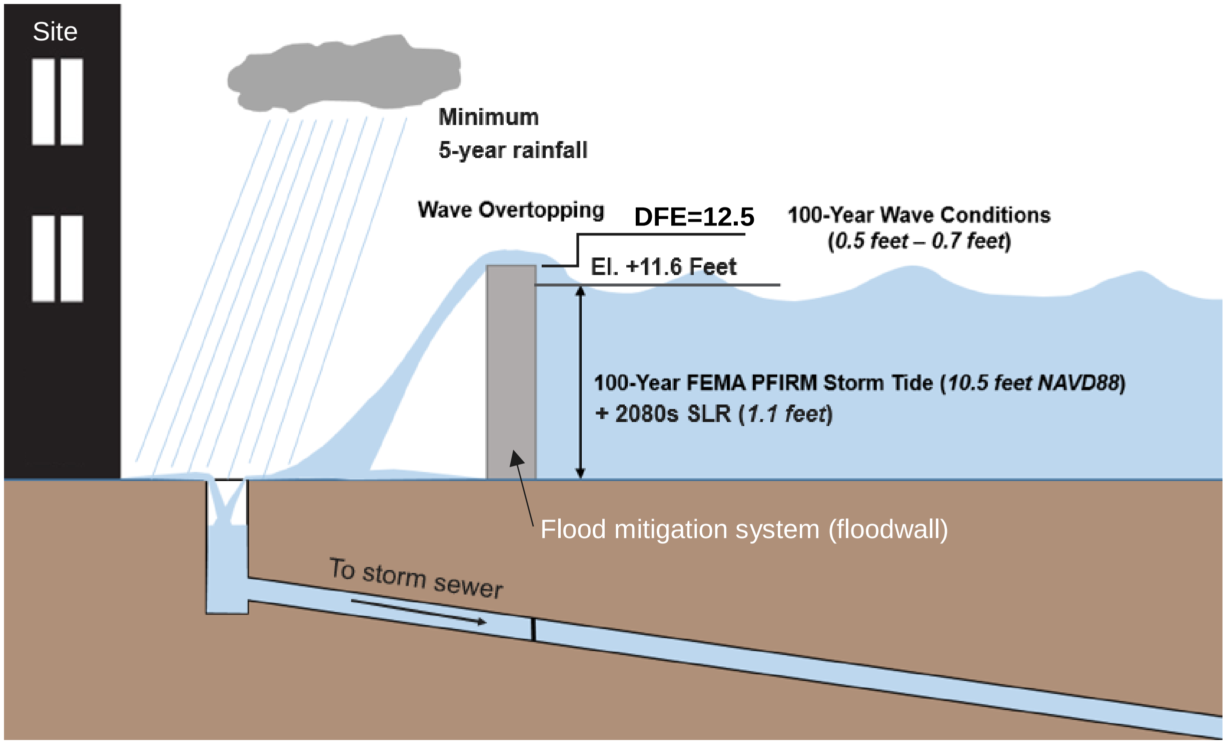

Figure 12 – Example of Design Flood Elevation elements. BFE is 10.5ft, SLR is 1.1ft, freeboard is 0.9ft and overtopping is expected from waves. A 5-yr event rainfall is coupled to the storm surge event to determine the total amount of catchment volume that will be needed inside the flood protection system.

Determination of DFE in Delaware Flowchart

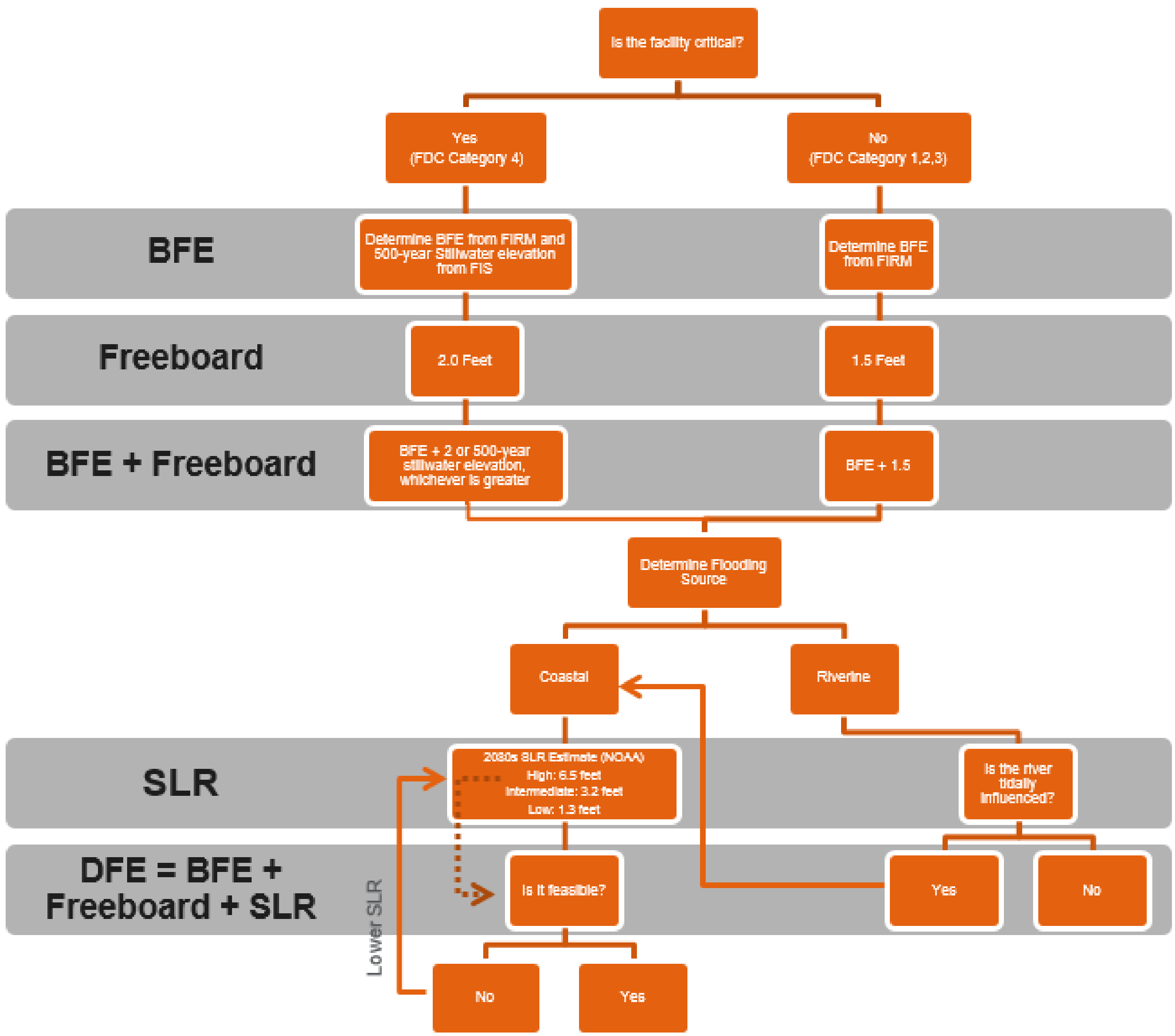

Figure 13 – Design Flood Elevation Flowchart

2.1.2.4 Flood Mitigation Alternatives

This section discusses the particular focus on the scale of the mitigation effort, whether an option is active or passive, and, if active, what level of human intervention is required for the flood-mitigation system to be successful before and during the event. Flood-mitigation options are typically considered passive or active, depending upon whether human intervention is required for successful protection during a flood event.

Active measures require proper warning time and human intervention to set up, lock down, or deploy the flood-mitigation system to be able to protect against a flood event. Some examples of active measures are temporary floodwalls (see Figure 14), vehicular flood gates, ingress/egress protection/gates within a permanent floodwall, retractable floodwalls, submersible doors, and relocation of emergency equipment.

Figure 14 – Temporary floodwall deployed at a hospital site

Passive measures require little or no warning times and little or no human intervention. The measures are already capable of withstanding an event as constructed. Some examples of passive measures are elevated structures/systems/assets (see Figure 15), relocation of structures/systems/assets, self-rising gates, submersible equipment, and drainage solutions.

Figure 15 – Boiler system on elevated structure

When considering mitigation options by scale, flood-mitigation examples include perimeter mitigation, structure mitigation, and system/asset mitigation.

Perimeter mitigation refers to deploying flood-mitigation systems that will isolate a site from runoff, tides, or wave action. The primary objective of perimeter mitigation involves mitigating the risk of flooding before it ever reaches the structure(s) being protected. Such systems include permanent floodwalls/levees (see Figure 16), temporary floodwalls, berms / fill solutions, and drainage solutions. These options may be integrated with green infrastructure to improve flood control, aesthetics, and environmental value.

Figure 16 – Example of permanent floodwall with green infrastructure

Structure mitigation consists of protecting only a specific building as opposed to a perimeter surrounding it or a campus. This can be achieved by dry floodproofing (reinforcing walls and sealing penetrations into the building to avoid water from coming into the site), wet floodproofing (allowing water to flow through the building while ensuring that no critical assets will be damaged), elevation of the building, relocating the structure or mitigation reconstruction (demolish and rebuild).

System/asset mitigation allows targeted mitigation to individual systems or assets critical to the performance of a structure. It is important to understand the potential cascading impacts of protecting individual assets. This can be achieved by elevating the assets, installing submersible assets, hardening in place (dry-floodproofing the room or around the asset).

2.1.2.5 Multi-Criteria Analysis

When researching and evaluating potential flood-mitigation options, many different factors (in addition to overall effectiveness) can be considered. By considering different factors, the stakeholders are guided toward selecting the highest-benefit option. The factors change depending on site specific and stakeholder requirements and priorities. The following are common factors to consider:

- Social. The project should be accepted by and benefit the community. Negative impacts to a particular portion of the population should be avoided. Political interests should also be observed since a local leader could aid in moving the project forward or create avenues for funding.
- Technical. This is related to feasibility. The level of protection of the project should be adequate and reliable, and the technical expertise required to carry out the project should be available so that the project can be constructed within an acceptable timeframe. The project should not result in additional problems for the site.
- Administrative. The project should be maintained properly throughout its lifespan, with sufficient resources and trained staff for the deployment of the flood protection system if required.
- Legal. Along with technical feasibility, the project must observe local, state and federal regulations of all Authorities Having Jurisdiction (AHJ). The permits and permissions required to proceed with a project need to be observed at early stages to avoid delays or violations.
- Economic. The potential benefits of the project should be balanced against its lifecycle cost. This is also referred to as Benefit Cost Analysis (BCA). This topic is not elaborated within this report; however, performing a BCA may be required for publicly funded projects. Potential funding sources for the project should be considered in this factor.
- Environmental. Considering the affects to the environment, both natural and built, often is required for obtaining construction permits from the AHJ. The need for performing extensive environmental studies for a potential flood-mitigation project might result in considering less intrusive alternatives.

Each one of the factors is assigned with a weight depending on the aspects that are prioritized by the stakeholders and on the project performance criteria. A score from 0 to 5 is then assigned to each factor under each alternative, 0 being the lowest score. The maximum weighted score is 5.0, and the option with the score closest to 5 should be selected. The first factors column offers the possibility of a “knock-out criterion” which if it is not met, the option is discarded without further consideration. The knock-out criterion might be for example: meeting the performance criteria, funding source, project timeline, or any other criterion that is essential for the stakeholders. A general explanation of each of the scoring criteria is offered next and an example is shown in Table 9.

Social Criteria

Minimal impacts to community: The highest score would be assigned to projects that do not visually or physically disrupt the surroundings. The lowest score would be assigned to solutions that may increase the impacts of flooding in neighboring areas.

Benefit of protection to community: A high score is given to solutions that offer benefits to the community, for example constructing a berm that will provide flood resiliency while creating a pleasant space for the community to use (e.g., a park or jogging trails). The lowest score would be assigned to a solution that changes the character of the community and provides no benefit to it. For example, a protection measure that isolates an asset from the community or blocks access, or changes the interaction with the community.

Technical Criteria

Feasibility: A higher score is given to solutions that can be implemented within the constraints of the site which may include property limits, structural challenges and other size constraints. A low score would be given to solutions that would require extensive retrofitting or technical challenges during construction.

Effectiveness: A higher score is given to solutions that mitigates the flood risk with a higher level of confidence and with a larger lifespan. A lower score is given to solutions that would require a second line of defense or that would need to be coupled with secondary systems (such as pumps) to prove effective.

Administrative Criteria

Ease of deployment: Passive solutions (i.e., require no human interaction for deployment) are scored higher, while solutions that require time for deployment and preparation prior to a storm event are scored lower. Self-rising gates and permanent solutions like floodwalls or elevating assets are examples of passive solutions.

Ease of storage: High-scored solutions will not require on-site storage while low-scored solutions will need to be stored at an assigned location when they are not being used.

Ease of Maintenance: A high score is granted to solutions that only need infrequent inspections, paintwork, lubrication, etc. A low score is given to intricate solutions that have different systems that need monitoring.

Building Accessibility: A high score is given to solutions that maintain access when deployed. A lower score is given to solutions that involve gates or perimeter barriers that must remain closed in preparation for a storm, and impede access.

Economic

Low Project Costs: The highest score is granted to the solution that not only has a lower cost, but that presents the most benefit for the stakeholders. A low score would reflect a contrasting value in the solution.

Lifecycle Costs: The highest score is granted to the solution that has a lower cost of operation and maintenance. If a solution needs constant maintenance or needs to be replaced regularly, in its entirety or its components, a lower score is granted.

Legal

Permitting Requirements: A high score is granted for solutions that stay within the property line and keep interaction with AHJ to a minimum. If the solution encroaches in state or city owned property, impacts several utilities, or blocks streets during construction, it will be granted a low score.

Minimizes time to obtain Permits: Projects that demonstrate technical feasibility and positive impacts to the community are likely to obtain permits from authorities faster, thus earning a higher score.

Environmental

Integration with community character: Higher scores would be assigned to solutions that seamlessly become part of the character of the community, the less noticeable the better, and if noticeable it should improve the area. A lower score would be assigned to solutions that contrast heavily with the surroundings and marginalizes the community.

<u>Minimize impact to natural environment:</u> Higher scores would be assigned to solutions that not only preserve the natural assets in the site but that might integrate improvements to the environment such as green infrastructure, erosion prevention or wetlands reclamation. Lower scores are assigned to solutions that have no positive environmental impact or involve non-mitigatable changes to the immediate natural environment.

		Multi-Criteria Analysis Factors																
		Knock-out Criteria		Social		Technical		Administrative				Economic		Legal		Environmental		
	WEIGHT			30%		20%		20%				10%		5%		15%		100%
	SITE IMAGE	Compliance to Performance Criteria	Minimal asthetic impacts	Minimal impacts to community	Benefit of project to community	Feasibility	Effectiveness	Ease of deployment	Ease of Storage	Ease of Maintenance	Building Accessibility	Low Project Costs	Life Cycle costs	Permitting Requirements	Minimizes Time to obtain permits	Integration with community character	Minimizes Impact to natural environment	SCORE
	WEIGHT			15%	15%	10%	10%	7.5%	2.5%	5.0%	5.0%	5.0%	5.0%	2.5%	2.5%	5.0%	10.0%	100%
Flood Mitigation Alternatives	Inflatable tubes	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	Sand bags	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	Sand Containers	1	1	4	4	5	3	2	4	4	1	4	4	5	4	5	1	3.48
	Floodwall	1	1	3	4	4	5	5	5	4	1	3	4	3	3	3	3	3.65
	Flood Planks	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	Self-closing barriers (rising)	1	1	4	4	4	4	5	5	3	4	4	3	3	4	4	4	3.98
	Manual closing barriers (sliding)	1	1	4	4	4	4	3	5	3	4	2	3	3	4	3	3	3.58
	Elevating assets	1	1	4	3	2	4	1	5	3	2	1	4	5	2	1	2	2.78

Table 9 – Multi-Criteria Analysis example

The weight factors in Table 9 should be seen as an example at this stage. Depending on the property usage, the anticipated investments or adaptation strategy, the percentage may change for the various criteria and show a different score. Social and technical considerations usually give the strongest direction to proposed strategies and thus should have a higher weight or percentage as administrative or legal considerations. For critical facilities, economic and legal criteria are usually ranked with a low percentage. For non-critical facilities such as commercial real estate, these percentages are usually higher.

2.2 Energy Assessments and Methodology

2.2.1 Assessments

2.2.1.1 Understanding Energy Efficiency

The two most familiar terms regarding energy are energy efficiency and energy conservation. Energy conservation and efficiency are both energy reduction techniques. Often these two terms are used interchangeably, but they have distinct meanings.

Energy efficiency is using technology that requires less energy to perform the same function. For example, using a compact fluorescent light bulb that requires less energy instead of using an incandescent bulb to produce the same amount of light is an example of energy efficiency.

Energy conservation refers to the reduction of energy consumption by using less of an energy service. Turning the lights off when leaving the room and recycling aluminium cans are both ways to conserve energy.

Energy conservation is a part of the concept of sustainability. Even though energy conservation reduces energy services, it can result in increased environmental quality, national security, personal financial security and higher savings. It is at the top of the sustainable energy hierarchy. It also lowers energy costs by preventing future resource depletion.

An energy conservation measure (ECM) is any type of project, activity, or technology implemented to reduce the consumption of energy in a facility. ECMs include both efficiency and conservation measures. The types of projects implemented can be in a variety of forms but usually are designed to reduce utility consumption: electricity and gas being the main two for industrial and commercial enterprises. The aim of an ECM should be to achieve a savings, reducing the amount of energy used by a process, technology or facility.

2.2.1.2 Understanding the Energy Assessment (Audit) Process

The most nationally recognized procedures for performing energy assessments or audits were developed by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). There are three basic ASHRAE energy audits, a Level I, Level II and Level III audit. The CMAP pilot project scope included a Level I audit, but definitions for all three levels are provided below.

The ASHRAE Level I audit or "walk-through audit" is the basic starting point for facility energy optimization. It consists of an initial review of the property's utility bills and a brief site survey of the facility, its systems and its modes of operation. The Level I audit is intended to be a quick assessment of the relative potential for energy and cost saving opportunities. The primary objective of the Level I audit is to identify and provide a savings and cost analysis of low-cost/no-cost measures. It may also provide a list of more capital-intensive improvements that merit further consideration, and an initial judgment of potential costs and savings. The Level I audit is intended to help the facility owner understand where the facility performs relative to its peers; establish a baseline for measuring improvements; decide whether further evaluation is warranted; and if so, where and how to focus that effort. The audit results in a brief summary report that details the findings.

The ASHRAE Level II audit provides the facility owner with a more detailed facility survey and energy analysis. A detailed fuel use analysis is performed and the facility is benchmarked to gauge overall performance. Energy consumption is broken out by end use such that facility owners and operators can easily understand which areas of operation may present the greatest opportunities. Utility rates are analysed to determine if there are rate change opportunities or if specific utility rate Demand Side Management (DSM) programs are available to the facility. All key facility representatives (owners, managers, operators and occupants) are interviewed to gain a thorough understanding of the operational characteristics of the facility, to explore potential problem areas, and to clarify financial and non-financial goals of the assessment. Once the detailed site assessment is completed, an energy model/facility simulation and engineering calculations are developed in order to create a detailed and cost-effective scope of work. The scope of work will include the cost and savings analysis of practical measures that meet the owner's economic criteria, along with a discussion of any changes to operation and maintenance procedures and health and safety recommendations. In addition to the energy model, the energy engineer will also generate an audit report that thoroughly documents facility conditions, operational characteristics, and proposed energy savings measures. It will also list any potential capital-intensive improvements that require more thorough data collection and engineering analysis (Level III Audit), and a preliminary judgment of potential costs and savings associated with those improvements.

The Level III energy audit is a highly instrumented and long-term study. The Level III audit involves collecting long term trend data using data logging devices and information fed from the facility's energy management or building management systems. These data are used to pinpoint operational opportunities, setpoint adjustments, sensor adjustment and calibration opportunities and other equipment-specific ECMs. The high-resolution data that is collected allows the energy engineer to perform calculations that can be used to very accurately predict energy and cost savings. The Level III audit is typically reserved for complex commercial and industrial facilities with very specific and accurate economic payback analysis requirements.

2.2.1.3 Understanding Current Energy Procurement Practices

The Delaware Office of Management and Budget/Division of Facilities Management (DFM) manages the procurement process of the State's deregulated energy supply contracts for electricity and natural gas. By aggregating its energy load with other public entities, Delaware is able to aggressively procure energy on the open market at attractive supply rates. The State's energy consultant assists the State in the aggregation and procurement process.

Delaware's current electricity supply contract is with Talen Energy, a Pennsylvania based company, and encompasses all State of Delaware accounts served by Delmarva Power. The contract contains the largest aggregation to date with 76 organizations state-wide and a total of nearly 1,800 separate electricity accounts. Both the DelDOT site and IRLSS site pay electric rates higher than the national average. It may be beneficial for these sites to look into other third party electric supply companies to reduce the electric utility rate.

Delaware's electricity supply contracts include renewable power, obtained through the purchase of regional and national renewable energy certificates (RECs) for wind, biomass and solar. The current contract with Talen Energy includes a 40% green power purchase, of which 37% is national RECs, and 3% is Delaware SRECs (solar renewable energy certificates). The use of clean, renewable energy was a pillar of former Governor Markell's Executive Order 18, and Delaware has steadily increased the amount of green power used at state facilities. Incorporating a larger percentage of renewable power would likely lead to higher utility rates, but would help fund future renewable power ventures within the state of Delaware.

The Delaware Public Service Commission (PSC) regulates the natural gas utilities, which include Delmarva Power and Chesapeake Utilities.

2.2.1.4 Understanding Energy Vulnerabilities to Climate Change and Extreme Weather

To fully understand climate change, it is important that the differences between climate and weather are understood. Climate and weather events may be differentiated by their wide range of spatial, temporal, and geographic contexts. According to the World Meteorological Organization, "At the simplest level the weather is what is happening to the atmosphere at any given time. Climate in a narrow sense is usually defined as the "average weather", or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time" (Intergovernmental Panel on Climate Change, 2012).

Climate change impacts the availability and reliability of electricity as it pertains to generation and transmission to end users. Increased ambient air temperatures reduce the efficiency of electrical generation and transmission, and lead to increased electrical demand. In addition, increasing temperatures can reduce the availability of water for cooling or the cooling efficiency of systems that utilize air or water as a heat transfer medium. Some important energy vulnerabilities are discussed below.

Electrical generation: Increases in ambient air temperatures across the United States reduce thermal efficiencies of electricity generation from nuclear, coal, natural gas, concentrating solar power (CSP), bioenergy, and geothermal facilities, which can reduce available capacity and increase fuel consumption by power plants. Higher temperatures reduce the current carrying capacity and decrease the transmission efficiency of electricity lines. Also, increases in ambient water can decrease the efficiency of methods that utilize water as a cooling medium. Power plants that use water from nearby sources, such as rivers, lakes, or the ocean, will have less heat carrying capacity if water temperatures rise due to increasing global temperatures.

Electrical transmission: Increasing temperatures reduce electrical transmission system efficiency and could reduce available transmission capacity. On average, approximately 7% of power is lost in transmission and distribution, and these losses increase as temperatures increase. Based on data supplied by the U.S. Energy Information Administration, transmission and distribution losses in Delaware in 2010 totaled 16.8%. As ambient temperatures increase, the current carrying capacity of electricity lines decreases. For example, a study in 2016 estimated that by mid-century (2040-2060), increases in ambient air temperatures may reduce electricity transmission/distribution efficiency by 1.9%-5.8% (Bartos, 2016). However, these capacity losses could be reduced by modifying future operating practices and system designs. The effects of high temperatures may be exacerbated when wind speeds are low or night time temperatures are high, preventing transmission lines from cooling. This is a particular concern because night time temperatures have been increasing at a faster rate than daytime temperatures, and they are projected to continue to increase in that manner.

Electrical Demand: Increasing temperatures will likely increase electricity demand for cooling and decrease fuel oil and natural gas demand for heating. Many factors can affect energy demand, including temperature and other weather conditions, population, economic conditions, energy prices, consumer behavior, conservation and efficiency programs, and the characteristics of energy-using equipment. While the effects of rising temperatures on overall energy demand are difficult to estimate, it is expected that where cooling (largely from electricity) accounts for the largest share of energy use in residential, commercial, and industrial facilities, such as in southern states, increases in cooling will exceed declines in heating (from a combination of natural gas, fuel oil, and electricity), with net energy use in facilities in such regions expected to increase. In contrast, for northern states, where energy demand for heating currently dominates, there could be a net reduction in energy demand. However, climate-induced switching from heating to cooling may contribute to increased primary energy demand even if site energy demand declines, since primary energy demand includes losses in generation, transmission, and distribution that are greater for cooling.

Population and Economic Growth: In general, the increased frequency of days with extreme heat is not the only factor contributing to peak demand. Increased population levels and economic growth will lead to increased electricity demand and could further increase the need for generation capacity. In contrast, technology advances such as improvements in air conditioning efficiency could help reduce the projected increases in electricity demand.

2.2.1.5 Understanding the Effects of Climate Change on Human Comfort

Human comfort within conditioned facility spaces is a perceived satisfaction or dissatisfaction with the thermal environment. Due to a difference of opinion from person to person, it is difficult, if not impossible, to satisfy the physiological and psychological desires of everyone. ASHRAE, in addition to providing industry-standard methods to performing energy audits as mentioned in Section 2.2.1.2, also provides industry-standard design criteria for heating, ventilation, air conditioning, and refrigeration equipment. According to ASHRAE Standard 55, there are six factors that affect the satisfaction of human comfort, including: metabolic rate, clothing insulation, air temperature, radiant temperature, air speed, and humidity (ASHRAE Standard 55).

ASHRAE defines dry-bulb temperature as the ambient air temperature measured by a thermometer exposed to the air but protected from moisture and contaminants. With specific reference to air temperature, ASHRAE recommends during the cooling season maintaining a maximum 20°F dry-bulb temperature difference between the outdoor temperature and ambient room temperature to maintain occupant comfort and safety when the outdoor temperature is above the design temperature. For example, if the outdoor temperature is 100°F (10°F above a design temperature of 90°F), the approximate ambient room temperature should be maintained around 80°F or above to remain within the ASHRAE-recommended maximum 20°F temperature differential. The notion of human comfort with respect to ambient air temperature is crucial when designing new heating, ventilation, and air conditioning (HVAC) systems. HVAC equipment is typically designed/sized based on ASHRAE 1% design conditions for a given location. This means that 1% of the total annual hours experience temperatures that are above the dry-bulb design temperature. Figure 17 contains an excerpt from the ASHRAE Fundamentals F14 Appendix (Design Conditions for Selected Locations), which provides design criteria for various weather station locations throughout the United States (ASHRAE Fundamentals). Using Figure 17 as an example, 1% of 8,760 annual hours is equivalent to approximately 88 hours. For Dover AFB, 88 hours of the year will see outdoor temperatures exceed the design temperature of 90°F and will be distributed across multiple days during the summer.

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB					
						0.4%		1%		2%	
				99.6%	99%	DB /	MCWB	DB /	MCWB	DB /	MCWB
Delaware											
DOVER AFB	39.133N	75.467W	28	14.7	18.7	92.5	75.7	90.0	74.8	87.3	74.0
NEW CASTLE AP	39.673N	75.601W	79	13.8	17.7	92.3	75.1	89.4	73.8	86.8	72.9

Figure 17 – ASHRAE Design Conditions for Delaware (ASHRAE Fundamentals)

In the above example, the HVAC equipment would be sized based on the design temperature of 90°F, with the understanding that 88 hours with temperatures greater than the design temperature are acceptable. During those 88 hours, humans would likely feel uncomfortable since the HVAC system cannot maintain the proper air temperature, but would still be able to function as usual. The exception to this would be critical facilities such as hospitals or nursing homes.

Due to the widely-accepted use of ASHRAE design conditions for HVAC design, and Delaware's 1% design temperature being approximately equal to 90°F, the climate projection data for days with temperatures above 90°F were exported and stored in tabular form for each station used in this study (Ensemble Means data tables were accessed through the Delaware Climate Projection Portal, described in Section 1.1). An example of the exported data for the Wilmington-New Castle weather station can be seen in Figure 18.

Annual Days with Max Temperatures>90F				
Ensemble Means of All Models				
Wilmington New Castle*: USW00013781, Delaware				
	Low Scenario		High Scenario	
Year	Min	Max	Min	Max
2030	21	92	15	64
2031	22	57	24	66
2032	6	64	2	65
2033	20	72	20	67
2034	15	62	12	71
2035	33	76	20	73
2036	17	86	21	76
2037	13	66	34	92
2038	24	91	13	86
2039	26	61	24	99
2040	21	83	19	94
2041	25	66	21	95
2042	22	71	8	86
2043	14	59	17	81
2044	14	74	37	81
2045	17	97	31	86

Figure 18 – Wilmington-New Castle days with maximum temperatures above 90°F

Based on the downloaded data, the number of days where the outdoor temperature is greater than 90°F is projected to increase. The number of days where the temperature is greater than 90°F for each weather station analyzed during this study are tabulated in Table 10 below, starting with the baseline year of 2016 and showing 10-year bins from 2020 to 2050. The minimum, average, and maximum days were calculated from the portal data. Despite the small geographic distance between the three weather stations, the values projected from the ATMOS downscaled climate projection data is an approximation, hence the variation in numbers between the three weather stations.

Year From	Year To	Wilmington-New Castle Weather Station			Dover AFB Weather Station			Lewes Weather Station		
		Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
2016	2016	4	29	53	2	30	62	3	30	57
2020	2029	13	37	66	11	39	72	17	42	73
2030	2039	16	47	81	13	49	89	20	52	86
2040	2049	15	53	92	11	54	100	19	58	97

Table 10 – Days with maximum temperatures greater than 90°F

Since the ASHRAE 1% design criterion for Delaware is approximately 90°F, analyzing projections of days with temperatures greater than 90°F showed the impacts of climate change on human comfort. With the increase in days with maximum temperatures greater than 90°F from Table 10, designing new HVAC systems will need to determine if during the lifespan of the new equipment, the new HVAC system can provide the necessary cooling to maintain occupant comfort. For example, if a new HVAC system is designed using current design criteria, then by 2030 the number of days where temperatures currently exceed 90°F will increase from approximately 30 days to nearly 50 days. Facilities will need to consider the projection of days with temperatures greater than 90°F when designing new HVAC systems.

2.2.2 Methodology

The methodologies for completing the energy assessment for all three sites followed the same process. The three methodologies that were utilized are as follows:

1. Climate change projection
2. Energy use projection
3. Energy cost projection

The climate change projection methodology develops projections of average CDD and average HDD calculated using data supplied by the Delaware Climate Projections Portal. This methodology can be applied to any site within the State of Delaware. For the purpose of this study, the climate change projections were only calculated out to the year 2045 due to the limitations of available data for energy utility cost projections provided by the NIST.

The energy use projection and energy cost projection methodologies were applied to specific sites: the State Police facility, DelDOT facility, and IRLSS site. The estimated projections were calculated using estimated existing energy utility data for 2015 and 2016.

2.2.2.1 Climate Change Projection Methodology

The climate change projection methodology utilized data compiled within the Delaware Climate Projections Portal. For the purposes of this study, data from the Wilmington-New Castle, Dover AFB, and Lewes weather stations were analyzed for the State Police facility, DelDOT facility, and IRLSS site, respectively. The State Police facility is characterized as a public order and safety facility, the DelDOT building is a mixed-use facility (shop and office), and the IRLSS site is a mixed-use site (gift shop and museum).

Alternatively, data presented within Chapter 4 of the Climate Change Impact Assessment provides state-wide estimates of percent changes in CDD and HDD during 20-year periods from the baseline range of years 1981 to 2010 (Hayhoe, 2014). The Impact Assessment's data sources are the same models used to develop the Delaware Climate Projections Portal, which were the Coupled Model Intercomparison Project version 5 (CMIP5) models. These models provide aggressive and conservative estimates using two methods: High Scenario and Low Scenario. The High Scenario is defined as representing fossil fuel-driven economic growth. As a result, the High Scenario carbon dioxide (CO_2) concentrations reach 1,000 parts per million (ppm) by year 2100. The Low Scenario is defined as representing a shift away from fossil fuel-driven growth toward clean energy technologies. As a result, the Low Scenario CO_2 concentrations reach 560 ppm by year 2100. Estimated results of the percent changes are shown in the Table 11. For any values in the table that present a range, the Impact Assessment defines first value as the estimate from the Low Scenario, and the second value as the estimate from the High Scenario. A single value is listed when the Low Scenario and High Scenario provided similar estimates.

Year Ranges	CDD Percent Increase	HDD Percent Increase
1981-2010	N/A	N/A
2020-2039	30%	-10%
2040-2059	35% (L) to 70% (H)	-20%
2080-2099	50% (L) to 130% (H)	-20% (L) to -40% (H)

Table 11 – Climate Change Impact Assessment CDD and HDD percent changes from the 1981-2010 baseline

This study utilized the Ensemble Means Mean Annual Cooling Degree-Days and the Ensemble Means Mean Annual Heating Degree-Days data along with supporting temperature data for each facility within a specific station that was closest to the facility to develop the climate change projections outlined in this study. Specifically, the supporting Ensemble Means Data tables for both CDD and HDD were exported and stored in tabular form for each station. An example of the exported data for the Wilmington-New Castle weather station can be seen in Figure 19.

Annual Mean Annual Cooling Degree-Days				
Ensemble Means of All Models				
Wilmington New Castle*: USW00013781, Delaware				
	Low Scenario		High Scenario	
Year	Min	Max	Min	Max
2020	1,150	1,758	1,163	1,880
2021	1,297	1,667	1,038	1,682
2022	1,164	1,849	1,074	1,674
2023	1,302	1,717	1,286	1,856
2024	1,138	1,807	1,332	1,857
2025	1,068	1,492	1,166	2,289
2026	1,238	1,643	1,182	1,951
2027	1,106	1,874	1,223	1,663
2028	1,301	1,753	1,264	2,030
2029	1,124	2,023	1,075	1,924
2030	1,138	2,299	1,367	1,869
2031	1,256	1,705	1,407	2,089
2032	1,210	1,867	1,179	2,100
2033	1,293	2,056	1,299	1,965
2034	1,073	1,994	1,216	2,181
2035	1,292	1,926	1,204	2,194
2036	1,118	2,252	1,340	2,134
2037	1,277	1,848	1,356	2,525
2038	1,278	2,317	1,324	2,269
2039	1,386	1,812	1,345	2,485
2040	1,124	2,126	1,231	2,476
2041	1,355	1,979	1,115	2,567
2042	1,355	2,051	1,058	2,128
2043	1,268	1,888	1,378	2,300
2044	1,284	2,215	1,342	2,692

Annual Mean Annual Heating Degree Days				
Ensemble Means of All Models				
Wilmington New Castle*: USW00013781, Delaware				
	Low Scenario		High Scenario	
Year	Min	Max	Min	Max
2020	3,604	4,976	4,069	5,223
2021	4,047	4,611	4,082	5,033
2022	3,536	5,200	4,330	4,952
2023	3,862	5,080	3,959	4,930
2024	4,250	5,162	3,971	4,604
2025	3,753	4,808	4,071	4,813
2026	3,707	4,647	3,688	5,259
2027	3,826	4,964	4,043	5,165
2028	3,545	4,828	3,827	5,120
2029	3,232	5,140	3,389	4,665
2030	3,585	5,183	3,852	5,079
2031	3,875	4,875	3,683	4,986
2032	3,538	5,424	3,945	5,141
2033	3,413	4,750	3,636	4,625
2034	3,812	5,196	3,747	5,034
2035	3,978	4,460	3,503	4,796
2036	3,608	5,283	3,461	4,632
2037	3,982	5,009	3,642	4,467
2038	3,367	4,860	3,659	4,831
2039	3,339	4,747	3,357	4,761
2040	3,015	4,764	3,700	4,528
2041	3,837	4,539	3,248	4,676
2042	3,326	4,547	3,058	4,509
2043	3,614	4,239	3,425	4,674
2044	3,913	4,391	3,190	4,343

Figure 19 – Example of Ensemble Means Mean Annual CDD and HDD for the Wilmington-New Castle weather station

Each data table was organized into 5-year bins from 2020 to the year 2045 to coincide with the energy utility cost projections. This study focused on showing the effects of changes in Mean CDD and Extreme CDD values. To develop the mean CDD data, all of the projected CDD data (the minimum and maximum values in both the Low Scenario and High Scenario) within each 5-year bin was averaged to estimate a single value. The minimum and maximum values in the Low Scenario and High Scenario were presented as the minimum and maximum estimations from the collective climate projection models as shown in Figure 19. Similarly, to develop the Extreme CDD values, the maximum projected CDD data within each 5-year bin was averaged. Each CDD value in each 5-year bin was compared to 2016's CDD value and the percent increase was calculated as shown in Table 12 and Table 13, where Wilmington-New Castle is used as the example.

MidPoint	Year From	Year To	Mean CDD	Percent Change from 2016
2016	2016	2016	1,411	0%
2022	2020	2024	1,485	5%
2027	2025	2029	1,520	8%
2032	2030	2034	1,628	15%
2037	2035	2039	1,734	23%
2042	2040	2044	1,747	24%

Table 12 – Mean CDD climate change projection bin data

MidPoint	Year From	Year To	Extreme CDD	Percent Change from 2016
2016	2016	2016	1,939	0%
2022	2020	2024	1,825	-6%
2027	2025	2029	2,034	5%
2032	2030	2034	2,145	11%
2037	2035	2039	2,354	21%
2042	2040	2044	2,433	25%

Table 13 – Extreme CDD climate change projection bin data

The same procedure and analysis was used for Wilmington-New Castle regarding the HDD as shown in Table 14 and Table 15, with the exception of the Extreme HDD being calculated by averaging the minimum projected HDD data within each 5-year bin. The results of this process are inversely similar to the results of the CDD analysis.

MidPoint	Year From	Year To	Mean HDD	Percent Change from 2016
2016	2016	2016	4,750	0%
2022	2020	2024	4,474	-6%
2027	2025	2029	4,324	-9%
2032	2030	2034	4,369	-8%
2037	2035	2039	4,187	-12%
2042	2040	2044	3,977	-16%

Table 14 – Mean HDD climate change projection bin data

MidPoint	Year From	Year To	Extreme HDD	Percent Change from 2016
2016	2016	2016	4,005	0%
2022	2020	2024	3,971	-1%
2027	2025	2029	3,232	-19%
2032	2030	2034	3,747	-6%
2037	2035	2039	3,339	-17%
2042	2040	2044	3,190	-20%

Table 15 – Extreme HDD climate change projection bin data

2.2.2.2 Estimated Energy Use Projection Methodology

The site-specific methodology expands upon the results of the climate change projection methodology to develop site specific data regarding the sites' cooling and heating energy use and energy cost variations. Due to the restriction of available utility data supplied by each site, three years of utility data could not be analyzed. To provide a consistent analysis of all three sites, only two years of utility data were analyzed. Estimated cooling and heating energy use were determined by analyzing the two-year energy use data supplied by each facility. This estimated cooling and heating energy use became the baseline energy use used in projecting future cooling and heating energy use to the year 2045.

Each site's 2016 energy use baseline was determined by analyzing energy use patterns during 2015 and 2016. Examples of establishing energy baselines for the State Police site can be found in Figure 20 and Figure 21. To establish an electric usage baseline, the "shoulder" months (months where there is minimal or no heating and cooling) are analyzed to estimate an average monthly electric consumption. Electricity usage during summer months (electric usage peaks) is typically attributed to space cooling, but peaks during winter months are more difficult to explain. Typically, winter month electric spikes can be attributed to electric-source space heating. For each site, the area between the summer electric usage and baseline energy usage for each summer month is the estimated space cooling usage. The process for estimating natural gas usage for space heating is similar to estimating the space cooling energy usage. In the case of natural gas usage, the summer natural gas usage can typically be attributed to domestic hot water generation and is labeled as the baseline. This implies that the rest of the natural gas usage during the year is used for space heating.

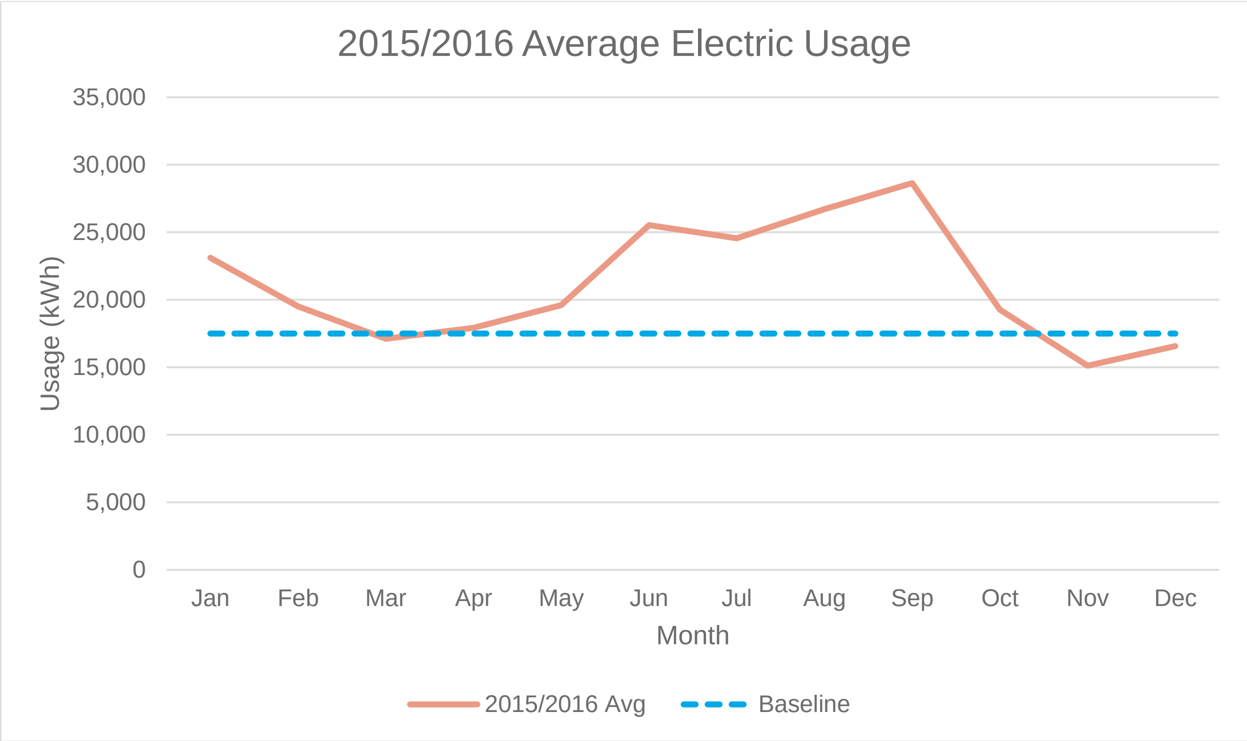

Figure 20 – Baseline electrical usage

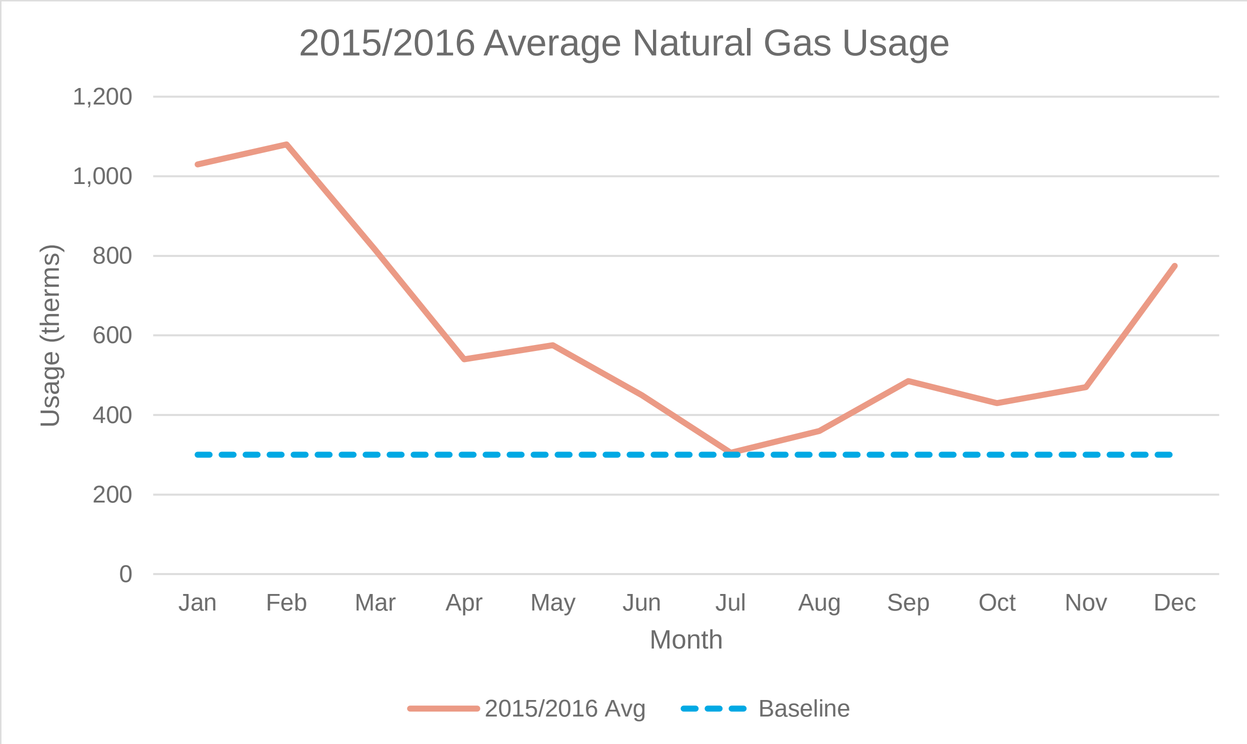

Figure 21 – Baseline natural gas usage

To better understand how a commercial facility's energy use compares to similar facilities, the U.S. Energy Information Administration (EIA) developed the Commercial Buildings Energy Consumption Survey

(CBECS). The CBECS collected building characteristic data from more than 6,700 commercial buildings in the United States that meet the criteria of being greater than 1,000 square feet and devote more than half of their floorspace to activity that is not residential, manufacturing, industrial, or agricultural (CBECS, 2012). Energy end uses are broken out by space heating, cooling, ventilation, water heating, lighting, cooking, refrigeration, office equipment, computing, and other. The survey further develops key determinants that influence energy use. Some of these key determinants include: building floorspace, principal building activity, climate, and weekly operating hours. These are just a few of the key determinants analyzed in the CBECS. The values presented by the CBECS is intended to be used as a measuring tool for facilities to analyze the attributes that drive commercial energy use and to help facilities compare energy use to facilities of similar size, age, geographic region, and principal activity. CBECS is not intended to be used to determine exact energy consumption, but it is a guideline to check if a building is within range of similar facilities.

A graph was developed for each site that attempts to estimate energy consumption by end use based on data collected during the site visit and benchmark breakdowns, as shown in **Error! Reference source not found.**. For two of the three sites analyzed, energy utilities include electricity (kWh) and natural gas (therms). In order to cumulatively analyze a building's energy consumption, electricity consumption and natural gas consumption are converted to the same units of energy: million British Thermal Units (MMBtus). The methods to converting both energy consumptions are shown in Equation 1 and Equation 2.

Equation 1 - Electricity consumption to MMBtu conversion

$$MMBtu_{elec} = \text{Electricity Consumption (kWh)} \times \frac{3{,}412\ Btu}{1\ kWh} \times \frac{1\ MMBtu}{1{,}000{,}000\ Btu}$$

Equation 2 - Natural gas consumption to MMBtu conversion

$$MMBtu_{nat.gas} = \text{Natural Gas Consumption (therms)} \times \frac{100{,}000\ Btu}{1\ therm} \times \frac{1\ MMBtu}{1{,}000{,}000\ Btu}$$

The estimated breakdowns by end use for each site were compared to a facility of similar principal activity in the CBECS to provide a measuring stick for site personnel, as shown in Table 16. The examples shown below are for the State Police building.

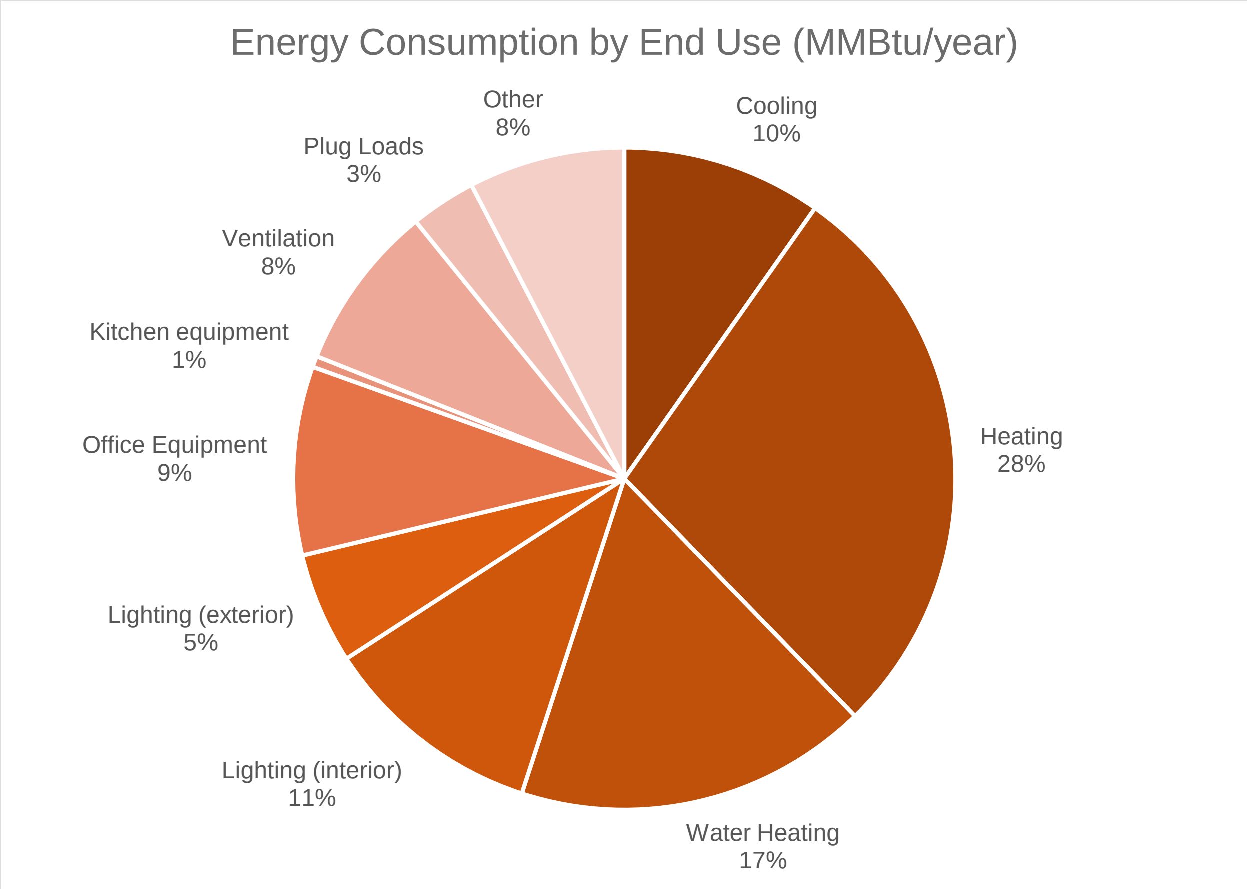

Figure 22 – Energy consumption by end use

End Use	State Police Consumption	CBECS Estimated Consumption
Cooling	10%	12%
Heating	28%	30%
Water Heating	17%	18%
Lighting	11%	12%
Office Equipment	9%	2%
Kitchen equipment	1%	4%
Ventilation	8%	4%
Plug Loads	3%	2%
Other	8%	6%

Table 16 – Comparison of the State Police energy consumption and CBECS data

Based on the estimated energy use baselines for electricity and natural gas, the space cooling and space heating energy usages can be estimated for 2016. In reference to the example shown in Table 12, the average estimated cooling energy use was estimated to be 35,500 kWh in 2015/2016. To project future space cooling and space heating energy use, the percent increase from each 5-year bin as calculated using the climate change projection methodology is compared to the 2015/2016 average space cooling and average space heating energy usages. The projected cooling and heating energy usages are estimated based on the mean CDD, extreme CDD, mean HDD, and extreme HDD. Using the State Police site as an example (Wilmington-New Castle weather station), the results of future cooling energy use projections are shown in Table 17 and Table 18. The results of projecting the future heating energy consumptions for this example are shown in Table 19 and Table 20.

Analysis of the three weather stations used in this study yielded an average mean CDD, average extreme CDD, average mean HDD, and average extreme HDD through 2045. Standard deviation calculations were performed for each temperature indicator mentioned above. Results of this analysis are shown in Table 21.

MidPoint	Year From	Year To	Mean CDD	Percent Increase from 2016	Projected Cooling Energy Use (kWh)
2016	2016	2016	1,411	0%	35,500
2022	2020	2024	1,485	5%	37,350
2027	2025	2029	1,520	8%	38,230
2032	2030	2034	1,628	15%	40,963
2037	2035	2039	1,734	23%	43,626
2042	2040	2044	1,747	24%	43,941

Table 17 – Results of projecting future mean cooling energy usage

MidPoint	Year From	Year To	Extreme CDD	Percent Increase from 2016	Projected Cooling Energy Use (kWh)
2016	2016	2016	1,939	0%	35,500
2022	2020	2024	1,825	-6%	33,407
2027	2025	2029	2,034	5%	37,231
2032	2030	2034	2,145	11%	39,269
2037	2035	2039	2,354	21%	43,107
2042	2040	2044	2,433	25%	44,538

Table 18 – Results of projecting future extreme cooling energy usage

MidPoint	Year From	Year To	Mean HDD	Percent Increase from 2016	Projected Heating Consumption (kWh)	Projected Heating Consumption (therms)
2016	2016	2016	4,750	0%	7,600	4,555
2022	2020	2024	4,474	-6%	7,158	4,290
2027	2025	2029	4,324	-9%	6,919	4,147
2032	2030	2034	4,369	-8%	6,990	4,190
2037	2035	2039	4,187	-12%	6,699	4,015
2042	2040	2044	3,977	-16%	6,363	3,814

Table 19 – Results of projecting future mean heating energy usage

MidPoint	Year From	Year To	Extreme HDD	Percent Increase from 2016	Projected Heating Consumption (kWh)	Projected Heating Consumption (therms)
2016	2016	2016	4,005	0%	7,600	4,555
2022	2020	2024	3,971	-1%	7,535	4,516
2027	2025	2029	3,232	-19%	6,133	3,676
2032	2030	2034	3,747	-6%	7,110	4,262
2037	2035	2039	3,339	-17%	6,336	3,798
2042	2040	2044	3,190	-20%	6,053	3,628

Table 20 – Results of projecting future extreme heating energy usage

Temperature Indicator	Average	Standard Deviation
Mean CDD	1,694	±162
Extreme CDD	2,287	±259
Mean HDD	4,061	±354
Extreme HDD	3,334	±381

Table 21 – CDD and HDD deviation from the average values through 2045

2.2.2.3 Estimated Energy Cost Projection Methodology

The baseline energy use costs were $.092/kWh for electricity and $0.936/therm for natural gas for the State Police example, which were based on average electric usage and natural gas usage utility costs over two years. The projections of future electric and natural gas use costs were estimated using data from the National Institute of Standards and Technology's (NIST): "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – 2015" report. The utility rate projections for electric and natural gas are for Census Region 3, which includes Delaware. The projections encompass complete years from 2016 to 2045.

NIST provides estimated fuel price escalation rates, but the rates do not include annual price inflation (NIST, 2015). To account for annual price inflation, it was estimated that there was an average 3.5% inflation increase per year. The final projected total cost of future energy use was calculated by multiplying the estimated future energy use as estimated from Table 17, Table 18, Table 19, and Table 20 above by the NIST-projected energy cost rate increases and annual price inflation increase. In addition, the estimated future energy costs are presented in constant base-date dollars. Again, using the State Police site (Wilmington-New Castle weather station) as an example, the results of projected energy costs for the State Police site for CDD and HDD can be found in Table 22, Table 23, Table 24, and Table 25.

MidPoint	Year From	Year To	Mean CDD	Percent Increase from 2016	Projected Cooling Energy Use (kWh)	Projected Electric Rate ($/kWh)	Projected Total Energy Cost ($)
2016	2016	2016	1,411	0%	35,500	$0.092	$3,266.00
2022	2020	2024	1,485	5%	37,350	$0.118	$4,399.29
2027	2025	2029	1,520	8%	38,230	$0.144	$5,498.38
2032	2030	2034	1,628	15%	40,963	$0.172	$7,063.27
2037	2035	2039	1,734	23%	43,626	$0.211	$9,215.14
2042	2040	2044	1,747	24%	43,941	$0.263	$11,572.73

Table 22 – Results of projecting future energy use costs for mean CDD

MidPoint	Year From	Year To	Extreme CDD	Percent Increase from 2016	Projected Cooling Energy Use (kWh)	Projected Electric Rate ($/kWh)	Projected Total Energy Cost ($)
2016	2016	2016	1,939	0%	35,500	$0.092	$3,266.00
2022	2020	2024	1,825	-6%	33,407	$0.118	$3,934.85
2027	2025	2029	2,034	5%	37,231	$0.144	$5,354.70
2032	2030	2034	2,145	11%	39,269	$0.172	$6,771.20
2037	2035	2039	2,354	21%	43,107	$0.211	$9,105.57
2042	2040	2044	2,433	25%	44,538	$0.263	$11,729.96

Table 23 – Results of projecting future energy use costs for extreme CDD

MidPoint	Year From	Year To	Mean HDD	Percent Increase from 2016	Projected Heating Consumption (kWh)	Projected Heating Consumption (therms)	Projected Electric Rate ($/kWh)	Projected Natural Gas Rate ($/therm)	Projected Total Cost ($)
2016	2016	2016	4,750	0%	7,600	4,555	$0.092	$0.936	$4,962.68
2022	2020	2024	4,474	-6%	7,158	4,290	$0.118	$1.222	$6,086.08
2027	2025	2029	4,324	-9%	6,919	4,147	$0.144	$1.542	$7,389.16
2032	2030	2034	4,369	-8%	6,990	4,190	$0.172	$1.878	$9,072.48
2037	2035	2039	4,187	-12%	6,699	4,015	$0.211	$2.427	$11,159.71
2042	2040	2044	3,977	-16%	6,363	3,814	$0.263	$3.239	$14,027.18

Table 24 – Results of projecting future energy use costs for mean HDD

Mid-Point	Year From	Year To	Extreme HDD	Percent Increase from 2016	Projected Heating Consumption (kWh)	Projected Heating Consumption (therms)	Projected Electric Rate ($/kWh)	Projected Natural Gas Rate ($/therm)	Projected Total Cost ($)
2016	2016	2016	4,005	0%	7,600	4,555	$0.092	$0.936	$4,962.68
2022	2020	2024	3,971	-1%	7,535	4,516	$0.118	$1.222	$6,406.63
2027	2025	2029	3,232	-19%	6,133	3,676	$0.144	$1.542	$6,549.88
2032	2030	2034	3,747	-6%	7,110	4,262	$0.172	$1.878	$9,228.40
2037	2035	2039	3,339	-17%	6,336	3,798	$0.211	$2.427	$10,554.93
2042	2040	2044	3,190	-20%	6,053	3,628	$0.263	$3.239	$13,345.13

Table 25 – Results of projecting future energy use costs for extreme HDD

Energy use and cost projections associated with climate change was estimated for the three sites evaluated as part of this study. However, the energy use and cost projection methodology can be applied to any site in Delaware utilizing data from the Delaware Climate Projections Portal, existing energy use data, and future energy cost factors.

3 CONCLUSIONS

The purpose of the pilot project was to proactively address the consequences of climate change to ensure reliable and uninterrupted services to its citizens in a cost-effective manner through identifying and implementing climate mitigation and energy efficiency measures in its public use and critical function facilities. Climate vulnerability assessments were conducted in three different facilities to identify strategies to improve resiliency focusing on SLR, increase in rainfall and increase in temperatures. To address these climate change impacts, site-specific flood risk assessments and energy audits were conducted for three sites and are detailed in Appendices A, B and C. The appendices provide flood risk information for each facility projected to the 2080s SLR, along with energy efficiency and resiliency improvements to the year 2045. The payback period for the energy improvements occurs before the risk from flooding poses a threat to business continuity in all of the assessed sites.

From the flood risk assessment standpoint, the flood risk methodology outlined above was successfully used to evaluate risk of flooding due to coastal storms and climate change projections reflected as SLR. The methodology is centered on ensuring that the site in question will be able serve the community during a flood event or withstand it with minimal impacts. To achieve this objective, vulnerable areas and critical site features were identified before determining the DFE. Mitigation strategies based on the DFE were developed for sites at risk, and those strategies were evaluated using the multi-criteria analysis. Table 26 below summarizes the findings for each of the sites.

Description	DelDOT	State Police	IRLSS
Design Flood Elevation (feet, NAVD88)	11	61	8.8 - 14
First Floor Elevation (feet, NAVD88)	28	127*	8
24hr,10yr rainfall depth (inches)	5.2	4.8	5.3

*Approximate grade elevation, no available first floor elevation data

Table 26 – Summary of flood risk findings

The table above shows that DelDOT and State Police sites are above the DFE; first floor elevations are at elevations +28 feet and +127 feet, respectively, while the DFEs are +11 feet and +61 feet respectively. Moreover, since the sites are at a higher elevation relative to the surroundings, rainfall runoff is unlikely to accumulate and cause flooding. Further hydrologic studies would be required to confirm this statement. The flood risk to these sites is minimal and no flood risk mitigation strategies are required. There are plans of potentially relocating the State Police Toop 6 facility which presents the opportunity to re-evaluate flood risk and implement stormwater management solutions. The DelDOT facility could implement diverse stormwater management solutions such as green infrastructure to reduce the runoff that the paved area where it sits directly contributes to the St. Jones River nearby. The IRLSS is at risk from flooding during a 100-year storm event when considering the SLR projections. Protecting this site in isolation might not be the right solution since it could become frequently inaccessible due to inundated roads. Further studies would be required to determine a new location for the IRLSS.

While this methodology is useful for determining if any given site is at risk of flooding, it is limited by the information obtained on the sites themselves. Further studies would be needed to understand geotechnical, structural and utility information on individual sites in order to follow the methodology to its fullest extent, and to pursue detailed design of flood-mitigation/resilience measures. Further improvement to this process would include updating SLR estimates with the most recent published data. Additionally, further studies could include conducting a hydrologic study that couples storm surge and intense rainfall events. This would provide insight on whether or not the flood risk is exacerbated by rain or if rainfall alone could be a source of flooding. Secondary improvements to this process would involve updating the multi-criteria analysis to reflect the priorities of individual stakeholders. With the understanding of the flood risk, vulnerabilities and potential solutions for a site, the next step would be starting the design phases to further develop the flood risk mitigation system.

From the energy assessment standpoint, the energy audit methodology was successful at analyzing existing systems and making recommendations for potential improvements to reduce energy usage, including lighting, HVAC, domestic hot water and emergency generator jacket heaters. The identified energy conservation measures (ECMs) and associated costs, energy savings, and CO_2 reductions results are presented below in Table 27 and Table 28.

The Energy Conservation Measures (ECMs) were broken down into two categories as follows:

1. ECMs where exact quantities and total costs and savings were known. The identified ECMs in this category and associated costs, energy savings, and CO_2 reductions results are presented below in Table 27.
2. ECMs where exact quantities and total costs and savings are not known. These are referred to as unit cost ECMs because all known quantities are not known, such as lighting fixtures. These identified ECMs and associated costs, energy savings, and CO_2 reductions results are presented on a unit cost basis below in Table 28. The total costs, energy savings, and CO_2 reductions can be calculated by multiplying the quantity of units (e.g. light fixtures, lamps, etc.) by the unit costs, energy savings, and CO_2 reductions.

CATEGORY ONE: TOTAL COST ECMS			
Description	Cost/Savings/Payback		
	DelDOT	State Police	IRLSS
Measure Costs ($)	$1,000	$1,000	$5,120
Estimated Annual Operating Savings ($)	$2,484	$956	$388
Simple Payback Period (Years)	6.0	1.0	13.2
Annual Electricity Savings (kWh)	23,432	10,386	3,526
Annual Natural Gas Savings (therms)	0	0	0
Total CO2e Reduction (lbs)	20,118	8,917	3,027

Table 27 – Total Cost Energy Opportunity Summary Table

CATEGORY TWO: UNIT COST ECMS			
Description	Cost/Savings/Payback		
	DelDOT	State Police	IRLSS
Unit Cost Measure Costs ($)	**$1,344**	**$846**	**$83**
LED Lighting	$894	$606	$83
Occupancy Sensors	$300	$240	-
DHW System	$150	-	-
Unit Cost Estimated Annual Operating Savings ($)	**$433**	**$430**	**$65**
LED Lighting	$241	$367	$65
Occupancy Sensors	$27	$63	-
DHW System	$166	-	-
Unit Cost Payback Period (Years)	**3.1**	**2.0**	**1.3**
LED Lighting	3.7	1.7	1.3
Occupancy Sensors	11.2	3.8	-
DHW System	0.9	-	-
Unit Cost Annual Electricity Savings (kWh)	**3,731**	**4,670**	**592**
LED Lighting	2,134	3,984	592
Occupancy Sensors	236	686	-
DHW System	1,361	-	-
Unit Cost Annual Natural Gas Savings (therms)	**51**	**0**	**0**
LED Lighting	0	0	0
Occupancy Sensors	0	0	-
DHW System	51	-	-
Unit Cost Total CO2e Reduction (lbs)	**3,796**	**4,010**	**508**
LED Lighting	1,832	3,421	508
Occupancy Sensors	203	589	-
DHW System	1,761	-	-

Table 28 – Unit Cost Energy Opportunity Summary Table

It can be noticed that the ECM payback periods are shorter than the SLR projections at which the IRLSS would be at risk from storm events and possibly relocated. With this information, stakeholders might conclude that implementing such ECMs would be a good investment. A similar statement can be made about the DelDOT facility because SLR might not pose a threat to facility operability. For the State Police Troop 6 facility, ECM payback periods should be considered relative to the anticipated life span of the building; if the facility is to be replaced, implementing the ECMs could be worthwhile depending on the replacement timeline.

More in-depth analysis of specific operations or equipment and metering/data logging are possible by performing an ASHRAE Level II audit. However, the methodology to estimate and project climate change and utility rates are dependent on the quality of the data and the assumptions made during the analysis period. The climate data supplied by the Delaware Climate Projections Portal includes information for fourteen weather stations spread throughout the state. The analysis performed for the CMAP project only analyzed three of the fourteen weather stations, including Dover Air Force Base, Wilmington-New Castle, and Lewes. Further improvement to this process would include performing additional analysis of projected climate change, energy use, and energy costs for the remaining eleven weather stations' climate data. A secondary improvement would be to distribute the fourteen weather stations into geographic zones covering the entirety of Delaware to allow facilities throughout the state to fall under a representative weather station. In reference to NIST's predictions of utility rate escalations, projected data after the year 2045 is not available, and the current predictions up through 2045 were based on the most recent projection data available.

The results of this study illustrate the importance of prioritizing energy efficiency to combat the effects of climate change. The relationship between energy use and climate change are directly proportional and cyclical—as the effects of climate change become more pronounced, energy usage increases to adapt to these changes. However, diversifying energy generation systems to include more renewable energy, implementing energy conservation measures, and improving overall energy efficiency in systems are methods to slow down the effects or reverse the effects of climate change.

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