EYP/ research

Natural Disasters, Hospitals and Emergency Generators: A natural progression to complete energy resiliency

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/ Executive Summary

Energy management is one of the most critical components of life safety and a factor that affects patients, staff, and the local community. The entire facility depends on electrical and thermal energy to function optimally, and emergency power management must be resilient so that the facility can operate 24 hours a day, 365 days a year, despite storms or natural disasters. Therefore, just as most hospital departments employ systems to stay up to date with technology and medical procedures, they also need to plan for resiliency. Each facility faces unique challenges and must develop its own road map, but all facilities can benefit from taking some essential steps to improve hospital resilience and safety.

When our internal research team started to scrutinize the energy component of life safety, its complexity quickly became apparent. Our initial goal was to develop a case study comparing two hospitals, analyzing their respective costs and efficiencies. When we realized how multi-faceted the energy question was, however, we modified our strategy to include a methodology for creating and implementing a resiliency road map to help hospitals determine how to harden the existing infrastructure and prepare for future infrastructure improvements.

Our investigative analysis yielded lessons in resiliency that have broad applications. The most critical discovery is that a facilities generation system that is continuously operated is more reliable than one that is utilized only during maintenance exercises. During normal operation, continuous generation can provide low cost electrical and thermal feeds. During natural disasters, it then becomes a valuable asset that can effectively respond to increased pressures associated with disaster relief. Evidence supporting continuous operation was gathered from historical accounts of facilities that fared well during major storms that devastated the East Coast and the Gulf Coast.

Since several accounts suggested that natural gas generators, CHP systems, and fuel cells were more resilient than diesel generators, we developed a case study assessing the proposed model path to analyze an East Coast facility. The initial financial analysis supported the application of alternative generation systems. To assist facilities with the transition to alternative sources, we also developed a process diagram with a resiliency measuring system. This metric can be used to assess a facility's current resiliency and highlight the additional components needed to advance it to a higher level of resiliency. The methodology is generic enough to address current and future technology developments.

The first step of the proposed model path identified weaknesses in the existing infrastructure of the case study facility. These findings, along with an interview and the resiliency metric, were then analyzed together to uncover opportunities for improvement. The overall strategy for improving resiliency is diversify both technology and generation sources. Ultimately, the most resilient facility will have the capacity to go off-grid and run autonomously. To achieve that goal without negatively impacting the environment, our recommendations identify immediate solutions and identify future opportunities for increasing resiliency by steering development towards cleaner fuels.

Our report presents alternative generation systems along with their respective payback periods, which range from one to ten years. In our case study facility, a natural gas generator with CHP capabilities pays for itself in 3.5 years. If the system is limited to electrical output only, then the payback period rises to 5.28 years. However, there are also opportunities to participate in PPAs with minimal upfront costs, making the payback virtually immediate. With our analysis of alternative options in hand, a hospital can then decide which direction to take. We also developed a longterm plan for the case study facility with recommendations for addressing resiliency for the next ten years. We anticipate that the proposed model path, with the proposed methodology, can be utilized on a yearly basis by critical facilities to assess their course towards improving their resiliency status.

/ Introduction

Although emergency power requirements are critical to medical facilities, the current standard of care is inadequate for current and future demands. Medical facilities require continuous uninterrupted power with or without assistance from the utility-grid. Also, it is critical that the emergency generation is resilient and dependable. For the most part, this requirement has been inadequately addressed with large diesel generators and fuel tanks. It is the default system that is used and operated by a majority of hospitals. Unfortunately, history has shown that the default system for emergency generation and diesel generators is not as dependable or as resilient as needed. During normal operations, hospitals face constant pressure simply maintaining the generators. History also shows that facilities face significant challenges with generation during natural disasters. By analyzing the existing standard of care, it is evident that there are opportunities for improvement, which include increasing resiliency, reducing operational expenditures, and improving the overall value of emergency power generation.

Currently, the standard of care does not address the rising demands associated with climate change. Growing environmental concerns, and their associated challenges with disaster relief, dictate that a path towards renewable energy is critical. With the advancements in alternative energy technologies and energy storage systems, it is necessary to analyze the benefits of shifting away from diesel generators and investigate the benefits of other energy generation systems. This is a critical step towards improving a facilities resiliency. Alternatives to diesel fuel can be addressed by hospitals since diesel generators are handled directly by the facility.

Cleaner power production by one facility can directly improve emissions on two fronts. Power that is produced by one hospital can offset emissions from the utility and the generator. Furthermore, a facility's ability to generate electricity can bolster the community by providing dependable power. The advancements made by medical facilities that can operate autonomously after outages can serve as a guide for transitioning towards cleaner fuels and ultimately clean renewables. This type of analysis is critical in the development of complete energy resiliency. Investigating alternate systems that address climate change demands can pave the way towards energy independence.

The following investigative analysis, model path, and case study aims to serve as a guide for design professionals, hospitals and facilities and as a road map towards improving energy resiliency and reducing both costs and emissions. The guide reviews the current standard of care and proposes improvements that can be applied with current technology. The various issues that are driving change are discussed and analyzed alongside an existing facility to form a case study. This analysis sets up the platform for prescribing how facilities can leverage current and future technologies. It is anticipated that this guide will be applicable to new and existing facilities for analyzing future expenditures associated with infrastructure improvements. By extension, the methodology may be applicable to other critical facilities as well.

/ Existing Standard of Care

Hospital operations for disaster preparation requires extensive planning and training. All operational aspects affecting patient safety are critical. Emergency generation systems are of prime importance since the medical staff is dependent on them. To properly meet the demand, these systems require continuous maintenance, staffing, and testing year round. Governing agencies, such as the Center for Medicare and Medicaid Services (CMS), and codes such as the NFPA 110, maintain detailed instructions that outline proper maintenance requirements. Along with having the proper facilities staff, there are also consultants and businesses dedicated solely to servicing emergency generators. To understand the level of care expected, we refer to the NFPA's maintenance schedule which provides a detailed matrix of the suggested procedures and their associated frequency. There are approximately 71 components that need to be either inspected, checked, changed, cleaned or tested, with approximately 21 of those components needing to be addressed on a weekly basis. As noted in one of the trade articles, "most maintenance is preventive in nature and consists of the following operations: General inspection, Lubrication service, Cooling system service, Fuel system service, Servicing and testing starting batteries, and Regular engine exercise" (Kovach, 2013). Preventative maintenance also requires regular exercise:

> " *An engine needs to be exercised at monthly intervals, and preferably weekly intervals, to maintain its healthy condition. This should be done at the manufacturer's recommended operating temperature — which can only be achieved by running it under recommended loads (usually 30% to 50% of designed capacity). If this is not possible, and if additional building loads cannot be periodically transferred to each Level 1 and Level 2 Emergency Power Supply or generator, a load bank procedure is probably the only option" (Chisholm, 2014).*

If the engines are not maintained properly, issues such as wet stacking, water contamination, fuel dilution, carbon deposit formation, and oil dilution can occur. If the generators cannot be tested at the recommended loads, additional costs are incurred to artificially load the generators; "load banks can be rented from a generator service company...[and]...procedures for connecting a portable load should be well thought out to mitigate problems in case of a failure of the normal/electric utility source during a load bank exercise" (Chisholm, 2014).

Whenever there is a switch in power, special care has to be applied in order to make the transition as seamless as possible, as minimal interruption of patient care is essential. These preventative maintenance procedures, and those previously mentioned, prepare the facility for emergency generation that is exclusively dedicated to disaster relief. Currently, continuous on-going maintenance of the generators is the cornerstone of natural disaster preparation for facilities.

Continuous on-going preventative maintenance has standard costs. Inherently so, these costs are predictable and cyclical. These costs are budgeted without question due to their critical nature. As extensive and meticulous as these maintenance procedures are, they are treated as stand-by systems. As a result, the associated expenditures are underutilized since the majority of their operational hours are incurred during maintenance exercises.

Since the expenditures are ongoing and cyclical, it behooves facilities to seek methods to maximize their usage. One method that has been utilized is Demand Side Response (DSR) generation. Although not available in all regions, its application can be financially beneficial to both hospitals and utility companies.

> *Demand Side Response (DSR) has the potential to make money for organizations, as well as support the System Operator as the generation mix changes. There is an opportunity to increase the use of existing technologies in order to manage demand. Company-owned standby generators are a rarely used resource; their maintenance schedule often accounts for a majority of their running hours" (Daniels, L.A., Potter, B.A., Coker, P.J., 2013).*

This exemplifies that there is a need to utilize stand-by generators for more than just emergency generation. Utility companies will compensate the hospitals to produce power during peak usage hours. As a result, consumption and demand charges can be reduced or eliminated during peak usage. The level of compensation for reducing the load on the grid via DSR varies per region. If a DSR program is not available, and air quality requirements allow it, the facility can develop their own load shedding program. The facility can take the initiative to reduce consumption and reap similar savings when the grid is most stressed. Whether the facility participates with a utility company or independently, it is evident that hospitals can benefit from actively increasing generator usage, instead of having them sit idle.

While the financial benefits of increasing generator usage are straightforward, the associated resiliency benefits of onsite generation are highly significant yet subtle. By using the generators to produce usable power, confidence in the systems improves for both the facility's generation and the utility's dependability. This reliability is created by the intertwined relationship. DSR programs rely on the "hospital to go off the grid for stabilization purposes if the grid is in danger of an outage" (Hampson, Bourgeois, Dillingham & Panzarella, 2013). A temporary and advantageous trade-off can be leveraged in times of peak demand. However, if needed, these benefits can be leveraged for longer durations, specifically during extended outages. Therefore, it can be assumed that if the facility can provide dependable power, then the utility company can also rely on the hospital's generation capabilities. To emphasize this further, if the hospital can increase operational usage beyond DSR programs, the benefits can be compounded. If the facility has the capability to run their generators continuously with a combined heat and power system (CHP), the systems reliability surpasses the current standard of care.

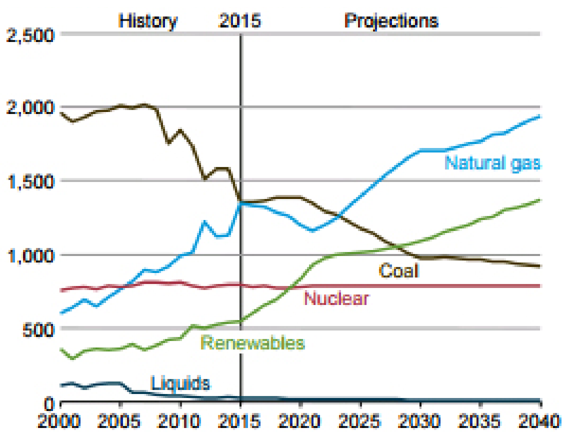
> *In general, a CHP system that runs consistently throughout the year is more reliable in an emergency than a backup generator system that only runs during emergencies. Because it is relied upon daily for needed energy services, a CHP system is also more likely to be properly maintained, operated by trained staff, and to have a steady supply of fuel" (Hampson, Bourgeois, Dillingham & Panzarella, 2013).*

The increased usage of on-site generation provides opportunities to identify operational risks, identify mechanical risks, and identify solutions during non-emergency periods. If the system proves to be constantly reliable throughout the year, it is likely that it will perform optimally during a smaller disaster period. Increasing generator usage directly increases dependability and resiliency.

Unfortunately, diesel generators have prohibitive properties that restrict facilities from realizing the potential benefits of continuous on-site generation. During normal operations, if air quality requirements allow, diesel generators are limited to demand-side response. During natural disaster operations, they are limited by fuel limits due to refueling challenges. During post disaster operations they face transportation and resource allocation challenges. Increasing their usage for continuous generation would also require that they meet Tier 4 emissions standards. They would need to adhere to stricter air quality standards set by the EPA: "Recent changes in laws and regulations, including the U.S. Environmental Protection Agency's (EPA) Clean Power Plan (CPP) [1], which requires states to reduce carbon dioxide (CO2) emissions from existing fossil fuel generators, and an extension of tax credits for wind and solar energy. Together with lower natural gas prices, these changes significantly affect the projected electricity generation fuel mix" (U.S. Energy Information Administration, 2016). Clean air regulations favor renewables.

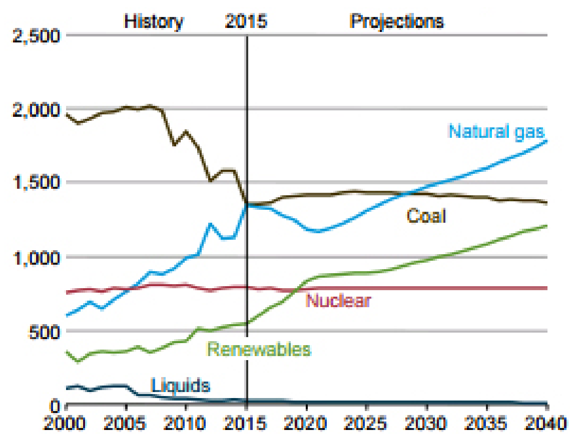
Clean Power Plan accelerates shift from coal to natural gas and renewables.

Figure MT-28. Net electricity generation by fuel in the Reference case, 2000-2040 (billion kilowatt hours)



With no Clean Power Plan (CPP), coal-fired generation shows little change from 2015 level.

Figure MT-29. Net electricity generation by fuel in the No CCP case, 2000-2040 (billion kilowatt hours)



*Source: The Annual Energy Outlook 2016, U.S. Energy Information Administration

The majority of hospitals will face these types of growing regulatory restrictions since the standard of care prescribes diesel backup generators. Therefore, the return on operational expenditures associated with the facility's generators is restricted. It is limited in its financial capabilities, generation capabilities and in its reliability. Attaining a higher level of resiliency is hindered by the challenges posed by the standard of care. The following section elaborates on these challenges and identifies the various drivers that are signaling a need to explore alternatives to the standard of care.

/ Issues that Drive Changes to the Standard of Care

Growing concerns associated with climate change have influenced many states and countries to actively strategize to reduce emissions. Timing is of the essence, “the insidious mathematics of carbon accumulation show that lost time creates essentially irreversible damage, and the carbon we emit now creates further damage every year for well over a thousand years. The only way to deal with this imperative is to pursue strategies that deliver large tons of emissions reductions, early” (Harvey, 2016). Some states and countries are instituting various political commitments to reduce emissions. On a global scale, the United Nations is aiming to “bring all nations into a common cause to undertake ambitious efforts to combat climate change” (UN). It is the “most ambitious climate change agreement in history” (Somanader, 2016). Somander further explains that not acting quickly will push climate concerns towards the tipping point in which runaway consequences will create irreparable results. Without early action, “the effects of climate change are themselves non-linear as weather extremes become the norm...and it becomes clear that climate action in the next 15 years is crucial” (Harvey, 2016). An urgency is evident, and regulatory commitments are spearheading change. Regulations aimed at reducing greenhouse gas emissions will directly affect how facilities can operate their generators. With the growing concerns associated with air quality, the use of cleaner fuels is being favored.

> “ *New York’s Clean Energy Standard is structured to fight climate change, reduce air pollution, and ensure a diverse and reliable energy supply. The Clean Energy Standard requires 50 percent of New York’s electricity to come from renewable energy sources by 2030.” (U.S. Deployment Programs, 2017)*

The effects of climate change and its impact on resiliency have been also noted by LEED, the organization for Leadership in Energy & Environmental Design. It is the green building certification program that recognizes best-in-class building strategies and practices. Some of the pilot credits that were recently accepted by the organization addresses the growing issues with climate change.

> “ *Credit IPpc98 – Assessment and Planning for Resilience*
> *This credit encourages designers, planners and building owners or operators to assess and then plan for a wide range of natural disasters or disturbances as well as consider longer-term trends affecting building performance such as changing climate conditions.”(Wilson, 2015)*

These new resiliency credits incentivize building owners to address the growing challenges associated with extreme weather.

Growing issues with disaster relief are being exacerbated by an aging infrastructure. The existing power grid is deteriorating, and it cannot keep pace with growing electrical demands. It is facing performance demands that are much higher than for what it was designed. It is struggling to meet the demands of a continuously evolving electronics age. Medical facilities are increasingly growing their reliance on electronics, and their dependency on them is critical to operations. The majority of their systems depend on reliable, high quality, electricity. The disparity between current demands and the aging infrastructure is creating a dangerous situation.

> *This digitization trend is accelerating just as the nation's electric transmission and distribution systems are rapidly approaching their limits. Investments in these systems have not kept pace with their depreciation. According to a recent press report, "Engineering experts now believe the nation is entering a period that could be marked by a dramatic increase in localized power outages unless considerably more is spent on replacing old and deteriorated lines." This same report notes that utilities have been using equipment far beyond its intended life in order to keep costs down, and often equipment is run until it fails rather than replaced at the end of its intended life" (Felder,2007).*

> *These limitations, and more, were exposed in the aftermath of Superstorm Sandy. Superstorm Sandy caused outages for over 8.1 million people from Virginia to Maine, and as far west as Michigan. This storm proved that the northeast power grid was neither reliable nor resilient enough to stand up to extreme weather" (FCHEA, 2015).*

With increased extreme weather events and an aging infrastructure, the impact of natural disasters will increase in severity, duration, and frequency. As a result, disaster planning, along with emergency generation, disaster mitigation, and post disaster stresses will need to meet the increased demands. Determining the types of growing challenges that facilities will face can be analyzed by reviewing past accounts. Historically, post disaster accounts show that there is always an influx of community pressure during and after natural disasters. Facilities typically have difficulty maintaining additional support. One such account took place in 2013.

> *As a massive tornado destroyed the upper floor of Moore Medical Center (MMC) ... 300 people were huddled on the hospital's ground floor—and about half of them were community members who had sought shelter in the building.... MMC is "not designated as a public shelter... but frankly, we exist to care for the people in our local community," .... After the storm had passed, many residents had either become homeless or were unable to reach home over damaged roads. For those people, Moore-area hospitals continued to serve as temporary lodging. (Advisory Board, 2013)*

Similar accounts are described by the Department of Health and Human Services that addressed findings and recommendations in response to Superstorm Sandy. They found that "Hospitals that sheltered in place served several functions during the storm, including receiving patients from other health care facilities and providing care to the public.... During hospital site visits, administrators described how hospitals also served as shelters for people in the community (with and without medical needs) given that the hospitals were often the only buildings nearby with electricity" (Levinson, 2014). Levinson highlights the challenges associated with handling this surge of needs. Although many visitors did not qualify for hospital admission, they consumed a large portion of their available resources. Additionally, "In some communities, hospitals also became "neighborhood sanctuary(s)"...[overall there was a] "costly challenge of feeding the community and giving away large quantities of supplies during and in the immediate aftermath of the storm, purchased at full retail prices rather than wholesale prices, at the same time it was losing revenue on canceled elective surgeries and outpatient services" (Levinson, 2014). To compound the situation, the stresses associated with additional pressure presented "a range of interrelated problems from infrastructure breakdowns, such as electrical and communication failures, to community collaboration issues over resources, such as fuel, transportation, hospital beds, and public shelters" (Levinson, 2014). Out of 174 hospitals that were surveyed, 89 percent of them faced these obstacles. With increased climate changes, properly mitigating these types of challenges are critical to both the hospital and the local community.

The ever present challenge with supporting the hospital's generation and the local community means that the generators need to be run at higher loads for longer periods of time. This poses a financial and environmental issue for diesel generators. When you analyze them financially, they are the most expensive method to produce power with conventional means. Reciprocating engines that are fueled with diesel cost on average $246.5/MWh, while natural gas engines cost on average $84.5/MWh. Coal falls in between diesel and natural gas at about $107/MWh. The costs of energy from wind and solar have been decreasing rapidly. In the past six years, the costs have decreased 82% (Lazard, 2015). Without getting into detail, there are several alternative generation technologies that are cost-competitive with conventional generation technologies (Lazard, 2015). When you analyze the environmental impacts of running diesel generators, it is evident that they are much higher than other alternatives:

"Table 4 shows a range of emissions from diesel generators, and Table 5 shows nitrogen oxide (NOx) and particulate matter of 10 microns (Pm10) for some alternatives to diesel generators. Note that pollutant emissions from diesel generators are much higher than the alternatives."

Table 4: Ranges of Pollutant Emissions from Diesel Generators

Pollutant	Low Range (lb/MWh)	High Range (lb/MWh)
NOx	5.9	17.1
PM	0.74	3
CO_2	1482	1700
CO	7.6	30
VOC	0.73	2
SO_2	0.3	0.5

Table 5: Emissions of NOx and PM10 for Some Alternatives to Standby Diesel Generators

Alternative	NOx (ib/MWh)	PM10 (lb/MWh)
Lean Burn IC Engine	3	0.4
Small Gas Turbine	1.1	0.2
Microturbine	1	0.09
Rich Burn IC Engine w/Catalyst	0.6	0.4
Combined Cycle Gas Generator	0.06	0.04
Phosphoric Acid Fuel Cell	0.03	0
Solid Oxide Fuel Cell	0.01	0

> *Fuel cells are very clean and quiet, although they depend on either large onsite fuel storage tanks or reliable supplies and transportation of offsite fuel. They can be powered by natural gas or hydrogen. When powered by hydrogen that is produced in a carbon-neutral manner, fuel cells emit only nitrogen oxide (NOx) at levels that are barely detectable. Natural gas and hydrogen fuel cells do not emit sulfur dioxide (SO2). Micro turbines are lighter and quieter than diesel generators, almost as clean as fuel cells when fueled by natural gas, but are slightly less cost competitive than diesel generators. Like diesel generators, but not like fuel cells, micro turbines use combustion to produce electricity. In some cases, solar power could be an alternative option (Felder, 2007).*

One of the biggest factors is that diesel generators impact the ozone significantly. During "hot summer days, power systems in the Northeast experience close-to-capacity demand... [and] pressure on the electricity grid" develops (Friedlander, 2015). In order to relieve this burden, "industrial and commercial entities with diesel backup generators can fire them up" (Friedlander, 2015). These are known as demand response programs, and their purpose is to assist with electricity costs and relieve pressure on the grid. However, "analyzing data from the demand response programs from power system operators to commercial entities with generators, ...[it was] found that the emissions from diesel backup generators (called "behind-the-meter" generators in the power industry) very likely contribute to exceedingly high ozone concentrations in the Northeast region and account for a substantial amount of total nitrogen oxide emissions from electricity generation. The emission rates from existing diesel backup generators are similar to, or even exceed those from, the highest emitting natural gas-fired generators" (Friedlander, 2015). This problem will only continue to get worse, "as the climate changes, peak demand for electric power becomes more frequent" (Friedlander, 2015). The much needed additional hours of operation will create conflict. As air quality requirements become more restrictive, their operational hours will continue to face growing regulatory restrictions.

Historical accounts, associated with reliability issues with stand-by generators, show that there are inherent risks that are propagated by the standard of care. Maintaining a backup generation system for years on end, to only be utilized sparingly, brings about a series of risks associated with human error. Some of the most noteworthy storms that brought this issue to light were Katrina (2005) and Sandy (2011). The type of failures associated with diesel generators are staggering. Simple things such as bad fuel, bad filters or old batteries proved to be catastrophic. "When standby generators fail to start or perform as designed, it is usually due to faulty maintenance procedures or neglect" (Kovach, 2013).

Because there are several components and systems associated with proper maintenance, the potential for human error grows rapidly. The proper way to maintain a diesel generator is closely tied to the service it receives. Proper maintenance comes down to constant attention on a daily basis: "In fact, the top three reasons standby generators fail to automatically start or run are: (1) The generator START switch was left in the OFF position instead of AUTO. (2)Starting batteries were dead or insufficiently charged. (3) The fuel filter was clogged due to old or contaminated fuel" (Kovach, 2013). The top failures originate from simple careless mistakes. On the other hand, the historical accounts that showcase systems have fared well during major storms indicate that the majority of these systems differ from the standard of care. In particular, there is strong support for back-up systems that continuously run. Even the most well maintained stand-by generators are unreliable.

> *Although diesel generators are a mature technology, their performance and environmental emissions continue to improve. Nevertheless, diesel generators fail regularly. Experience from both the Federal Aviation Administration (FAA), which uses backup diesel generators for control towers, and the nuclear power industry, which uses them for power for critical safety systems when there is loss of offsite power, is not reassuring. Mills and Huber summarize the experience with reliability of diesel generators: Some of the most pampered, carefully maintained backup diesel*

generators in the world reside at nuclear power plants. Yet about one percent of all nuclear-plant diesels fail to start when required, and fully 15 percent of the units will fail if run for 24 hours. The operators and regulators of nuclear power plants are well aware of these limitations, and most nuclear plants have three separate, independent emergency power systems for just that reason. Because they are much less well maintained, diesel generators at hospitals and many other sites have failure rates 10 times higher. The May 2000 FAA report (noted earlier) identified failure rates in some of their diesel-generator-based systems at air traffic control centers that approached the grid's failure rates. More importantly, the same study showed a doubling in the past decade of the mean-time-to-repair for standby power systems" (Felder 2007).

Although the report is a few years old and references some figures that may be more than 10 years old, the issues are still relevant and continue to present themselves. Just recently, the same issues were brought to light during Hurricane Matthew (2016).

Hurricane Matthew (2016) resurfaced problems associated with stand-by diesel generators. Among them, two in particular are noteworthy and interrelated; generator performance and community support. The North Carolina Regional Medical Center was faced with mitigating pressures created by troublesome generators along with unprecedented needs from the local community. These two stresses continuously fed off each other. During the hurricane, the North Carolina Regional Medical Center struggled with both challenges: "throughout Hurricane Matthew and its aftermath…[the] center faced failing generators and an influx of people looking for shelter and impassable roads that kept staff and supplies from easily getting to the hospital" (Willets, 2016). Despite proper emergency preparation and stocking up on resources, the true test was unprecedented; "Nearly all of it was in the emergency plan, it just had never been tested to this magnitude," said David Sumner, Vice President of Corporate Services and Chief Strategy Officer". The reserves were quickly strained since they did not "anticipate the total impact of the hurricane itself" (Willets, 2016). At certain points, the existing generators were being overloaded, "the generators typically run for no more than 12 hours at a time" (Willets, 2016). The thick black smoke that emanated as a result, prompted rumors that the hospital was on fire. One of the most trying moments came when the hospital realized they needed to prepare to be without power and learned that the water system could be down for a month or longer. "In an emergency, every hospital is an island. This has been reflected vividly over the past few years, between regional power outages, hurricanes, floods and tsunamis… no matter how outside forces may challenge the hospital's very existence, let alone its ability to remain in operation… the role of the hospital emergency power system stretches far beyond a simple system planning decision" (Mouer and Chisholm, 2010). Although some pressure was expected, the resulting influx was far more shocking than anticipated; "there were just people everywhere…they were sitting everywhere…I couldn't understand why they were here, and I realized they had nowhere to go. The power was out. They needed to be able to secure power for their phones so they could communicate or for their health care devices" (Willets, 2016). Extensive damage to power lines forced Robeson residents to do without electricity for a week and "for them this was a beacon amid the darkness." Due to the lessons learned, going forward officials said that future plans would address preparation for more than 72 hours of isolation.

"

We learned a lot through this process," Anderson said. "We learned the absolute value of email and the internet for communication. We learned the value of water and what you lose when you don't have water. I think we already knew the value of power and electricity, but when you put all those together, you realize that you're kind of left on an island in and of yourself, and you have to be self-sufficient" (Willets, 2016).

> “*The American power grid is incredibly extensive and interconnected, which inherently increases the threat of outages caused by downed power lines. In the event of a loss of power, many industries utilize diesel back-up generators to provide critical power until grid power is restored. However, fuel to power these generators can run out during longer outages, or the diesel generators malfunction, rendering them useless” (FCHEA, 2015).*

The isolation that hospitals face in post disaster recovery demand certain requirements in regards to emergency power preparedness. Historical accounts such as this highlight an additional level of preparedness that is missing from the standard of care. Due to the uncertain nature of natural disasters, on-site generation needs to have the flexibility to run for uncertain periods of time. Unfortunately, current methods for addressing emergency power generation are prescribed to function under a limited set of parameters.

Currently, the standard of care dictates that a “standby system” is sufficient. It forces operations to design procedures that operate around fixed limits. Natural disasters are not entirely predictable or restricted to a set of constraints. Therefore, the standard of care undermines the facility’s ability to be flexible and run autonomously. It demands the need to connect back to the main power as soon as the on-site resources are consumed. If emergency power generation can be robust enough so that the facility can island itself and run continuously, the hospital can adapt to changing conditions as needed. If a facility has the capability to run autonomously, without fuel limits, it would eliminate the dilemma on whether to compromise the patient’s or the community’s’ needs.

The variety of drivers discussed indicate that there is a need for alternate means of emergency generation. The multitude of pressures are forcing facilities to take on a bigger responsibility in regards to meeting increased electrical demands. The following section elaborates on systems that can be utilized to assist with the facility’s electric and thermal demands.

/ Proposed New Model Path

Improving a facility's resiliency hinges on having a diversified power generation system. At the most fundamental level, a standby generator backs up the utility grid. Thus, there are two potential sources of power. It is also common for some facilities to have two backup systems that mirror each other. If one emergency system goes down, then the other one can maintain the same level of support. This is usually termed as an N+1 system. The proposed new model path supports the aforementioned principles and extends them to regular operations as well. If the facility can have diversified sources of normal power, it too is an improvement in resiliency. Since some alternative energy generation technologies are already cost competitive with conventional methods, it is worth analyzing their applicability for regular power generation. At the moment, there are some challenges associated with reliance on renewables for emergency generation, but eventually they too may be applicable to emergency generation. It is anticipated that as renewable technologies improve, their applicability will become more prominent. The ultimate goal is to have a facility that can run on its own micro grid.

> “ *After being hit hard by storms, some Northeast states are looking to micro grids as a way to boost resiliency and ensure ongoing power. A micro grid is a small-scale power grid that can operate independently or in conjunction with the area's main electrical grid. Micro grids can bolster the main power grid during peak demand periods, ensure service in the case of emergency outages, and often involve multiple energy sources, including renewable power" (Gangi & Curtin, 2016).*

Ideally, the most resilient facility would be one that can produce its own power -from various sources- with the least amount of emissions. Its applicability would allow facilities to operate autonomously. The journey between the current standard of care to this ultimate goal may take some time. The proposed model path proposes a method that can be utilized to strengthen a facilities resilient conditions and prepare for future improvements in technology. It can be thought of as a stepping stone towards complete autonomy. The proposed model paths looks at the process in three steps:

1) Analyze and identify weaknesses in the existing infrastructure
2) Identify opportunities for immediate infrastructure improvements
3) Analyze opportunities for future improvements

The intention is to address any issues that impede the resilient nature of a facility and prepare a path towards a continued effort in hardening the infrastructure. A major reason for the proposed model path originates from those issues previously mentioned. Some of the opportunities for improving weaknesses in the existing infrastructure are grounded in the standard of care and the industry culture.

Although jurisdictions have been accustomed to expect diesel generators as standard practice, the reasons may be misguided. In an article published in July 2016, Engineered Systems investigated why natural gas has been overlooked even though the code allows its use. In this article, Karr analyzes this disparity. When it comes to code enforcement, “There has been a misunderstanding among code enforcing jurisdictions that the fuel source for emergency generators must be onsite storage of sufficient quantity to serve these loads for the specified duration. This misunderstanding may have come about from a pushback from the Center for Medicare and Medicaid Services (CMS). Natural gas generators were being used, and the CMS stated the need to provide on-site fuel, or the site must provide a “Letter of Reliability” from the natural gas provider….The question comes up about whether the generators are required to have on-site fuel, which typically is diesel, or whether natural gas is an approved fuel for the emergency generators” (Karr 2016). Karr expands by clarifying that “natural gas is an approved fuel, all other codes (including NFPA and the NEC) specifically allow for natural gas generators where there is a “low probability of simultaneous failure of both the grid and natural gas.” More specifically, NFPA 99.6.4.1.1.7 states, “The generating equipment used shall be either reserved exclusively for such service or normally used for other purposes of peak demand control, internal voltage control, load relief for the external utility, or cogeneration.” (CHP is synonymous and is a rebranding of what the older generation of engineers calls cogeneration.)

NFPA 110.5.1, 5.1.1, bullet #3 specifically states “Natural or synthetic gas” as a fuel source shall be permitted to be used for the emergency power supply (EPS) (Karr 2016). She backs her observations further by pointing out that CMS, the organization which oversees these regulations, also addressed this misunderstanding. In 2009, they produced a presentation to clarify what they expected from this “letter of reliability” and that “they explicitly state that they never intended to not allow natural gas as a fuel source for backup generators.” (Karr 2016). CMS also recognizes the additional benefits that a natural gas generator can provide. This includes a variety of benefits that assist the facilities daily rather than just during emergencies. Examples included daily operating savings, capital costs savings, and continuous operation during an event (a very important point, noted the author). Overall, natural gas and CHP is a critical asset that “offers the opportunity to improve critical infrastructure resiliency, [by] mitigating the impacts of an emergency by keeping critical facilities running without any interruption in electric and thermal service” (Karr 2016).

Despite the support for alternative systems in the code, the established culture is a hindrance to the development of alternative systems. It is likely that the biggest barriers associated with breaking away from the standard of care may be technology lock-in. Therefore, making changes to the established standard of care is slow and difficult.

> “*Cowan and Hultén argue that technology lock-in may also prevent the development of competing technologies…. despite the availability of superior technologies, and that this may be a particular problem with respect to environmental protection. There is good reason to believe that this possibility exists with respect to backup power supplies because in many applications, the demand is required by governmental regulation written with a particular technology (diesel generators) in mind” (Felder 2007).*

In contrast to the established standard of care, there are a number of reports that support alternative systems. As mentioned earlier, the most frequently supported system is the natural gas CHP system. It is integral to supporting both electrical and thermal demands. Evidence-based support says that:

“Combined heat and power (CHP) offers the opportunity to improve CI resiliency, mitigating the impacts of an emergency by keeping critical facilities running without any interruption in electric or thermal service. If the electricity grid is impaired, a specially configured CHP system can continue to operate, ensuring an uninterrupted supply of power and heating or cooling to the host facility……. CHP systems provide regular benefits to their host facilities, rather than just during emergencies. Some advantages that CHP systems have over backup generators include:

- Backup generators are seldom used and are sometimes poorly maintained, so they can encounter problems during an actual emergency. Most CHP systems run daily and are typically better maintained.
- Backup generators typically rely on a finite supply of fuel on site, often only enough for a few hours or days, after which more fuel must be delivered if the grid outage continues. Many CHP systems have a permanent source of fuel on demand; for example, most natural gas infrastructure is underground and rarely impacted by severe weather events.
- Backup generators may take time to start up after grid failure and this lag time, even though it may be brief, can result in the shutdown of critical systems. In many cases, backup generators not permanently located on-site must be delivered to the sites where they are needed, leading to further delays in critical infrastructure recovery. CHP systems are the permanent and primary source of electricity for the site they serve, and if properly sized and configured, are not impacted by grid failure.
- Backup generators typically rely on reciprocating engines burning diesel fuel, a polluting method of generating electricity. CHP systems typically burn natural gas, a cleaner fuel, and achieve significantly greater efficiencies, lower fuel costs, and lower emissions.
- Backup generators only supply electricity; whereas, CHP systems supply thermal loads (heating, cooling, chilled water) as well as electricity to keep facilities operating as usual.

The majority of the reports highlight the benefits quoted above because “overall, a CHP system that runs every day and saves money continuously is more reliable in an emergency than a backup generator system that only runs during emergencies” (Hampson, Bourgeois, Dillingham & Panzarella, 2013). There are several technologies available for implementing CHP systems. These include natural gas generators, micro turbines, and fuel cells.

There is substantial literature that addresses the pros and the cons of each technology. For brevity purposes, there are just a few notes that need to be pointed out regarding the CHP technologies. The biggest barrier to entry is capital costs. Natural gas generators are the most accessible. Micro turbines and fuel cells rely on government incentives to make them viable investments.

> “ *Several states encourage the integration of fuel cell power generation to improve the resiliency of power generation, lessen the burden on the grid, and help meet emissions reduction goals. CALIFORNIA, CONNECTICUT, NEW JERSEY and NEW YORK have incentive programs focused on distributed generation and/or micro grids under which fuel cells are eligible. Thirty states include fuel cells among the eligible technologies under their Renewable Portfolio Standard (RPS). Thirty-seven distributed (onsite) generation technologies help to improve the resiliency of power production and lessen the burden on an aging electric grid. They also help states achieve RPS goals that lower the carbon intensity of grid resources. Several states have recently issued clean energy procurements to help meet their RPS and include fuel cells or hydrogen in the definition of a clean or alternative fuel. Others have clean energy programs that provide incentives for stationary fuel cell installations” (Gangi & Curtin, 2016).*

When considering which technology to use, an in depth investigation needs to take place in order to assess available credits and incentives. Currently, the political climate has shifted, and some of the tax incentives have not been renewed for micro turbines and fuel cells. However, incentives for solar and wind have been extended.

In the case study that follows, Natural Gas generators, micro turbines, fuel cells, solar, and wind capabilities were analyzed. Due to real estate restrictions, the solar and wind options are not feasible. For discussion purposes, the numbers are shared in order to show the potential capabilities. Micro turbines and fuel cells were also not feasible for the case study since they are dependent on incentives. Without the incentives, the simple pay-back period is too long.

When the technology is too expensive to incorporate, Power Purchase Agreements (PPA) can be investigated. PPA's are partnerships that allow one facility to benefit from lower energy costs by allowing another entity to maintain and operate the infrastructure. Another avenue for reducing capital costs is available in private/public partnerships.

> "*Property Assessed Clean Energy (PACE) programs can be used by local governments to finance renewable energy systems or energy efficiency improvements. Local governments finance the cost of the improvements and the property owner pays back the loan over 15-20 years through an additional tax assessment on their property tax bill. The property owner receives immediate benefits from energy improvements via a reduced electric bill. The PACE assessment and lien are tied to the property, not the owner, and are transferred to a new owner upon a sale of the property" (FCHEA, 2015).*

For the purposes of developing and testing the proposed model path, we interviewed a facility on the east coast. We interviewed a hospital that currently maintains several stand-by generators, and the facility confirmed facing pressures similar to those that have been discussed.

/ Case Study

The following is a proposed model path for bolstering a facility's resiliency. The path will be demonstrated in a case study format. In this case, the East Coast Hospital mentioned earlier will be utilized. There is also a process diagram in the appendix that will assist with understanding the proposed model path. The hospital's feedback, along with the proposed model path, go hand in hand. Therefore, it is encouraged to review the diagram before reading the case study findings.

Case Study Findings with Road Map

1) The interview

For anonymity reasons the hospital that was interviewed will be renamed to East Coast Hospital (ECH). ECH has implemented several layers of defense when it comes to resiliency. The power from the grid is flaky and they have added an additional power feed to mitigate the momentary outages that sometimes take place during natural disasters. They described issues with the quality of the electricity and the pricing structures. At one point the facility had to install capacitors to smoothen out the power supply. With the growing dependency on sensitive electronics. ECH also faced billing issues. The billing structure from the power grid places high transmission and demand charges. It is a premium to bring power to ECH's area. When comparing utilities, natural gas is more dependable and better priced. Constant attention has to be placed on fuel costs, as there is always a need to negotiate those costs. The facilities department expressed that they would prefer if utility costs were more consistent and predictable. ECH also mentioned that they used to participate in a lucrative DSR program but do not participate anymore, since it is not available. Although the facility has taken some steps beyond the standard of care, we were able to identify opportunities for increasing its resiliency.

Every city and state faces unique conditions. Therefore, an interview with the facilities department is the first step in analyzing opportunities for making a hospital more resilient. It is critical to understand each facility's specific challenges and resource availability; only then can applicable solutions be developed. For brevity purposes, the discussion topics of the Interview have been itemized as lists. Only the items that were utilized for the analysis will be discussed through the course of the case study.

Topics associated with current challenges

- Flaky Grid
- Quality of electricity from utility
- Constant Fuel Cost Negotiation
- Load Transferring is a Nuisance
- Generator testing at the peak of summer
- No DSR program
- Fines if generators tested on days with poor air quality
- High Water Table

Topics on Maintenance Expenditures

- Facility Staff
- Battery Bank Replacement Intervals
- Fuel Costs / Fuel Limits
- Monthly / Yearly Testing
- ATS replacement intervals
- Maintenance Contracts w/ 3rd parties
- Budgets

Wish List for Facilities

- Trending Reports
- DSR programs
- Budget Certainty
- Subsidies
- ROI (1year ideally)
- Higher Quality Electricity
- Fuel Diversification
- Predictive Maintenance
- Fuel Cells

2) Financial Analysis

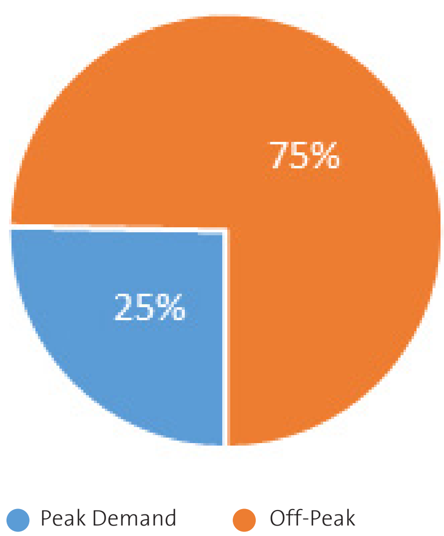
During the interview an emphasis should be placed on understanding the management systems, the staffing, and the utility costs that are associated with the mechanical and electrical systems. The purpose is to identify benchmarks and funding sources. Most facilities have very tight budgets and it may be difficult to have extra financing on hand. By identifying expenditures that are underutilized, the facility can leverage misappropriations and turn them into sources of funding. It is also beneficial to mark which expenses are fixed and which can be restructured. This investigative process will increase the number of sources for funding infrastructure improvements. As a result, misappropriations can be recovered and reused to make the facility more resilient.

During the financial analysis for ECH, the gas and the electric bills exposed a couple of underutilized expenditures. The electrical demand charges accounted for 15% to 40% of the monthly charges. These charges averaged out to 35% for the year. In the gas bills, 40% to 60% of the charges were demand charges. The demand charges get billed whether or not the utility is used. During one of the months analyzed in 2015, only 1800 CCF's were utilized, while the billed demand charges were for 6900 CCF's. These demand charges averaged out to 50% of costs for the year. The costs associated with the demand charges and those that were billed without utilization were noted down as funding sources that can be redirected. Note the highlighted costs. If needed, the department has access to additional funding for infrastructure improvements. However, that funding will be left untouched until the appropriated funds run out.

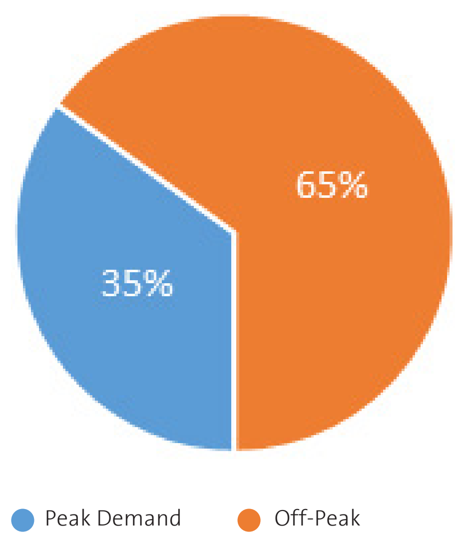
Electrical Consumption Benchmarks (2016)

Category	Consumption (KWH)	Cost
Total Yearly Peak Usage	8,437,800	$555,328
Total Yearly Off-Peak Usage	24,918,600	$1,031,587
Average Monthly Peak Usage	703,150	$46,277
Average Monthly Off-Peak Usage	2,076,550	$85,965
Average Daily Peak Usage	23,438	$1,542
Average Off-Peak Usage	69,218	$2,865

Consumption



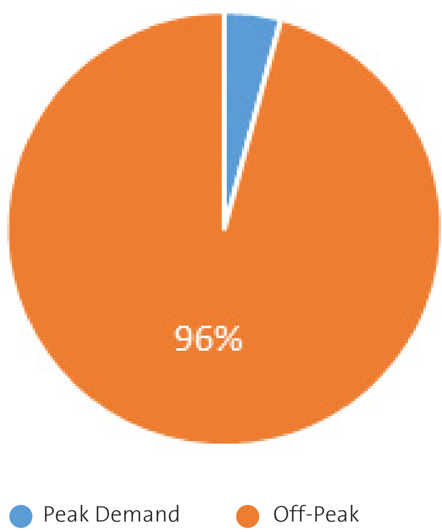
Expenditures



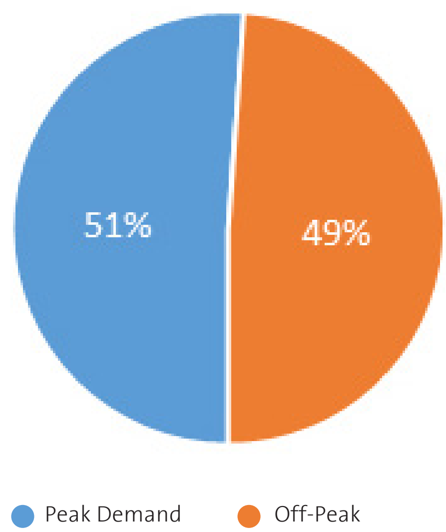
Gas Consumption Benchmarks (2016)

Category	Consumption (KWH)	Cost
Total Yearly Peak Usage (actual use)	75,500	$158,187
Billed Peak Usage (charged)	119,000	$249,328
Total Yearly Off-Peak Usage	1,715,500	$238,487
Average Monthly Peak Usage	6,292	$13,182
Average Monthly Off-Peak Usage	142,958	$19,873
Average Daily Peak Usage	210	$439
Average Off-Peak Usage	4,765	$662

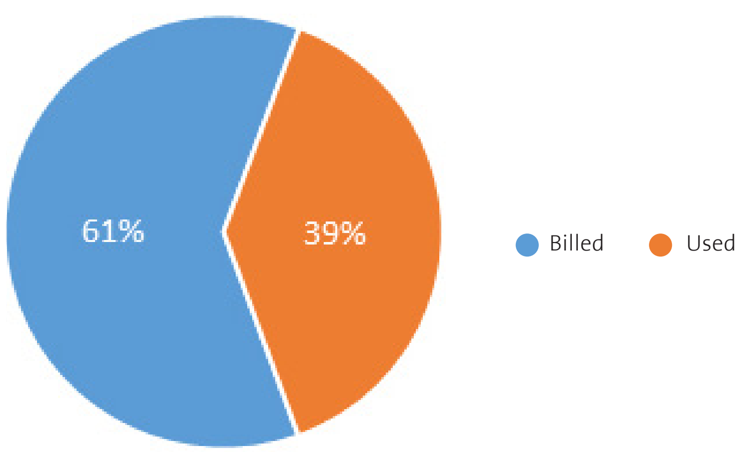
Consumption



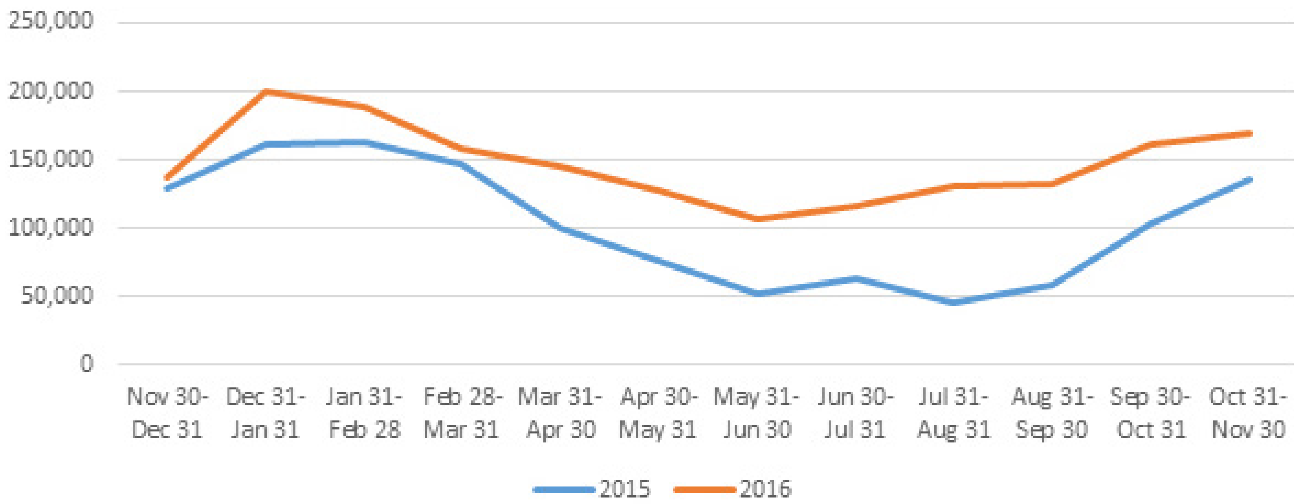
Expenditures



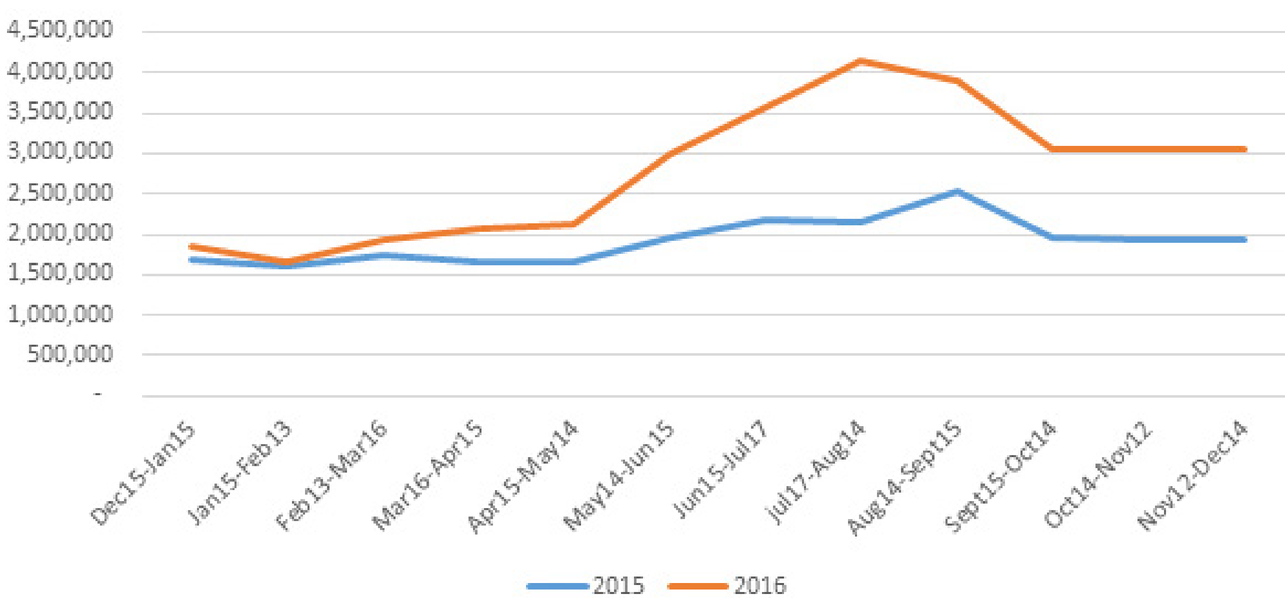
Billed Demand VS Utilized Demand



Gas Consumption (CCF)



Electrical Consumption (KWH)



3) Analyze the existing electrical utility feeds

After funding is identified, the analysis can move in two directions. The analysis can look for improvements associated with the utility feeds or improvements to the generation systems. If we find out that the financial analysis does not allow spending on the generation system, the focus would then need to be directed to the utility feeds. However, for thoroughness purposes, it is best to analyze all options. For ECH, we only discussed improving the electrical utility, since it was evident that the gas utility was very reliable. During our interview of the ECH facility, it became apparent that they had made provisions to combat the flaky grid by adding an additional feed. It's normal for facilities to have two feeds but this one installed a third feed. The ideal configuration is if all three of the feeds come from different substations, but the facility made it clear that it would be cost prohibitive to route the third feed to another station. The quoted costs were astronomical. Therefore, hardening the electrical utility further for ECH is out of the question.

If the option to harden the utility is available, the next step is to identify risks between the utility source and the utility feed. A third party would need to trace each feed from the hospital, step by step, all the way to the substation to identify vulnerabilities. Once identified, these remedies can be priced. If the costs associated with making these type of improvements are cost prohibitive, the process would need to start again from the beginning. With the additional information, it may become apparent that the funding should be spent on the generation system instead. In our case, the ECH facility's financial analysis suggests that spending the available funds on the generation system is more beneficiary.

4) Resource Availability

Once the consumption benchmarks and funding sources are identified, we need to extract the ones that can be redirected towards facility improvements, and then combine these items with any existing resources. In this case, the budget for ECH is composed of the expenses that were underutilized or lost in the previous year. Instead of wasting those expenses the next year, it makes more sense to utilize them ahead of time on assets to minimize future losses, ideally on assets that will provide a return on investment.

The onsite staff has been identified as a highly trained resource that can monitor and maintain future generation improvements. At the moment, there will not be any additional discount considerations for the on-site staff. However, it is worth noting that once the numbers are realized, there is a potential for additional savings. For financial analysis purposes, it is best to work with the most restrictive scenario first in order to be as resourceful as possible. Overall, the funding that is available is about $1.3 million. For this analysis, we will utilize $1 million to investigate what level of generation can be purchased. The remaining $300,000 can serve as contingency funds for unplanned overages.

Resources Availability

Category	Description
On Site Staff	4 personnel
Pre-Built Space for future CHP units	Pad space available at central plant
Direct access to improvement funds	$500,000
Redundant electrical feeds	3 feeds from 2 substations
Redirect Demand charges from Gas Utility	$249,328 (Yearly)
Redirect Demand Charges for Electric Utility	$555,328 (Yearly)
Contingency Budget	$2,000,000
Existing Diesel Generators	1 - 500 KW 1 - 350 KW 2 - 800 KW 2 - 2500 KW

5) CHP generation

When assessing the applicability of CHP systems, a reliable gas utility is necessary. The reliability of the gas system in the ECH region is evident when you analyze the utilities fuel mix. In the ECH region, the utility mix is composed primarily of nuclear and gas: 51.90% gas 30% nuclear. On the other hand, the national mix is primarily composed of coal and gas: 30.30% gas, 37.40% coal. Since the ECH region relies on natural gas for their electrical utility, it can be assumed that it is dependable. Once that is confirmed, the financial analysis for the varying CHP systems can be performed.

The available funding of $1 million will dictate the potential generation capabilities. Each technology will leverage different amounts of power and heat. The capabilities are determined by using Lazard's 2015 levelized energy analysis. The report provides a range of costs to capture the low and high end. For the case study, the average of the range is utilized; the same applies to the heat output. The average is used for calculating the potential output. The systems design will determine what percentage can be captured. As a control, one of the pricing sets was compared to a vendor's pricing on the East Coast. The pricing matched up rather closely.
In order to provide some room for error, the hours of generation and the number of days per year were reduced by a small factor. By using Lazard's unsubsidized capital costs, we were able to assess how big of a generation system could be purchased.

Purchasing power for electrical generation

Technology	Budget	Cap Cost ($/KW)	System Size (KW)	Hours of Daily Production	Daily Electrical Output (KWH)	Days (YR)	Yearly Electrical Output (KWH)
Natural Gas Engine	$1,000,000	$875	1143	23	26,286	360	9,462,857
Micro Turbines	$1,000,000	$2,600	385	23	8,846	360	3,184,615
Fuel Cell (Direct)	$1,000,000	$5,650	177	23	4,071	360	1,465,487
Fuel Cell (PPA)	n/a	n/a	460	23	10,580	360	3,808,800

Due to a lack of federal incentives in the coming year, only the natural gas engine technology can be assessed as a direct purchase system for ECH. The federal government's choice to not re-instate certain tax incentives is a bit unprecedented as it was anticipated that they would be renewed. However, due to the pressure from several states in support of renewables, it is foreseeable that in the future the incentives will be re-instated. If they are, the analysis should be performed again.

Despite the reduced funding from federal incentives, the option for Fuel Cells is still viable since there are companies that offer PPA agreements. For the ECH region, there are vendors that offer a guaranteed reduction in cost per KWH. It requires a 20-year contract without any upfront costs; the reduction in price will vary. Because the facility already receives a discounted rate, a lower rate may be difficult to negotiate. ECH's current combined rate, is at $.047/KWH. If the rate can actually be reduced by the Fuel Cell vendor, it is anticipated that they will save approximately $50,000 to $100,000 a year. For this financial analysis, a yearly savings of $75,000 will be utilized.

To determine the value of recoverable heat, the following formula - from "Assessing Value of CHP Systems" from the ASHRAE journal was used (Fisher, 2004).

Example

The calculations in *Equations 4* through *6* use sample data for a 1,000 kW gas turbine based CHP system producing steam for heating and chilled water from a 500 ton absorption chiller. The value of energy recovered for space heating or to produce hot water is approximately:

$$\overline{C}_{heat\ \&\ hot\ water} = \frac{7{,}820\ \text{Btu/kWh generated}}{1{,}000{,}000\ \text{Btu/Million Btu} \times 0.72} \times \$5/\text{Million Btu} = \$0.054/\text{kWh generated} \quad (4)$$

The demand side credit is determined from the following formula (Fisher, 2004).

Demand Charges

The algorithms presented are based on using the average cost of electricity including both the energy or "use" charge and demand charges. Demand charges could be used explicitly by defining the cost of electricity as in *Equation 8*.

$$\overline{C}_{electricity} = \overline{C}_e + \frac{C_{demand}}{H} \quad (8)$$

$\overline{C}_e$ = average electricity energy charge (\$/kWh) and
C_{demand} = annual electricity demand charges (\$/kW).

Equation 8 provides an explicit credit for demand charge savings from on-site generation. More savings could be achieved from reduced demand from substituting recovered heat powered absorption chillers for electric air conditioning or water chillers.

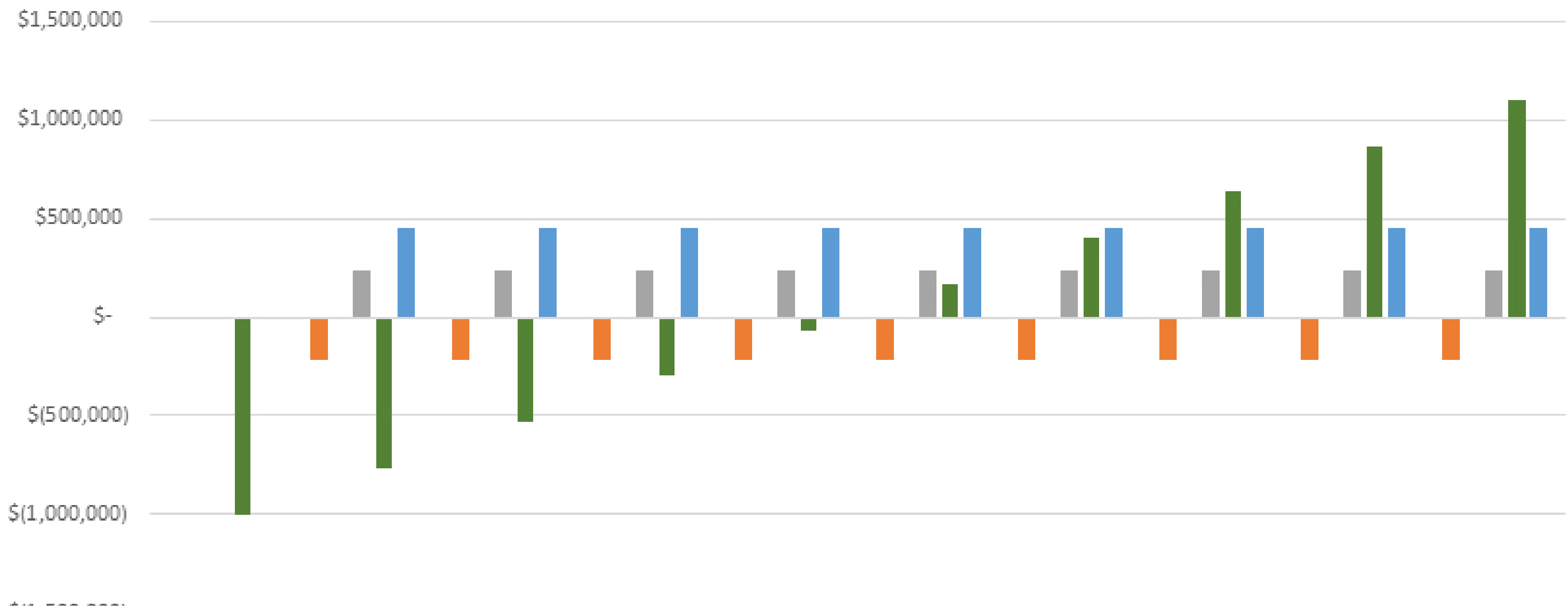
Yearly production with a $1M budget for capital costs

System	Potential Electricity Generated (KWH)	Yearly Demand Side Credit ($)	Value of recoverable heat ($)
CHP w/ Natural Gas Generator	9,462,857	$454,217.14	$614,429
CHP w/ Micro Turbines	3,184,615	$152,861.54	$175,486
CHP w/ Fuel Cells	1,465,487	$70,343.36	$48,663
CHP w/ Fuel Cells (PPA)	3,808,800	Combined savings of $75,000	

*capacities derived by using base figures from LCOE (Lazard, 2015)
* PPA savings derived from PPA agreement brochure

Simple Payback for generation only is 5.28 years with an ROI of 110% in a 10-year period.

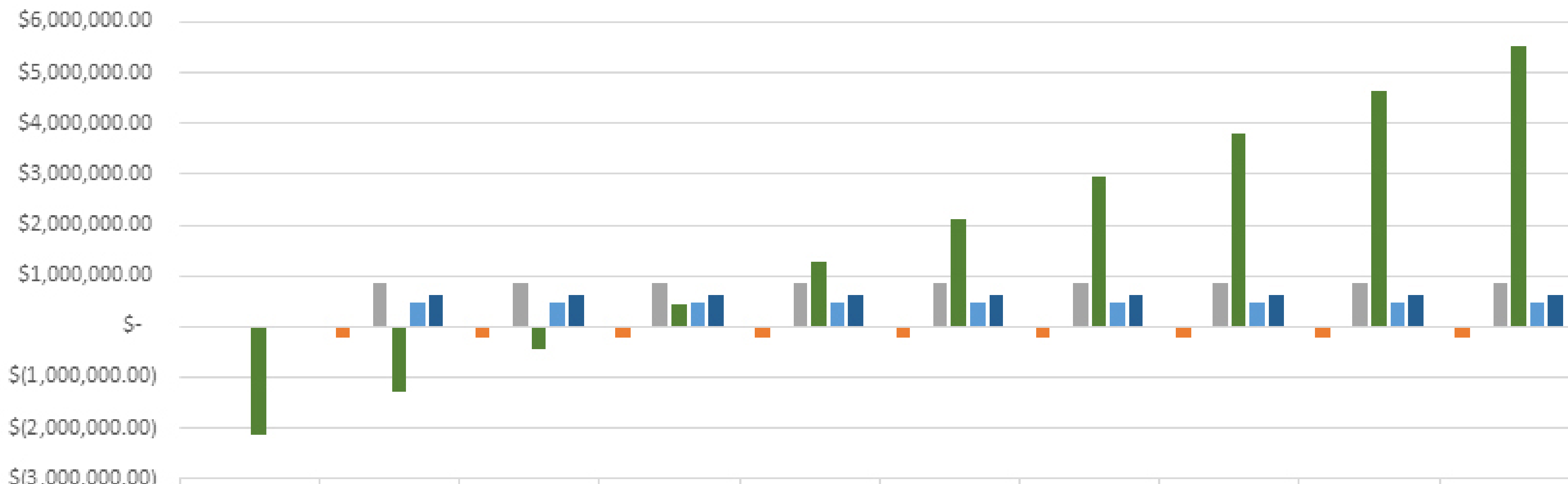
Natural Gas Generator w/o CHP



	1	2	3	4	5	6	7	8	9	10
Fuel Cost	$-	$(211,257)	$(211,257)	$(211,257)	$(211,257)	$(211,257)	$(211,257)	$(211,257)	$(211,257)	$(211,257)
O&M	$-	$(9,463)	$(9,463)	$(9,463)	$(9,463)	$(9,463)	$(9,463)	$(9,463)	$(9,463)	$(9,463)
Net Savings	$-	$233,497	$233,497	$233,497	$233,497	$233,497	$233,497	$233,497	$233,497	$233,497
ROI	$(1,000,000	$(766,503)	$(533,006)	$(299,509)	$(66,012)	$167,485	$400,982	$634,478	$867,975	$1,101,472
Demand Credits	$-	$454,217	$454,217	$454,217	$454,217	$454,217	$454,217	$454,217	$454,217	$454,217

The financial analysis for installing CHP components requires additional costs above the generation costs. The difference between the generation costs and the costs to include CHP is about $1,491/KW. If you apply the state incentives, the additional capital that is needed is $1.1 million. However, the payback period comes down significantly. The Simple Payback becomes 3.5 years, and the ROI over 10 years is 544%.

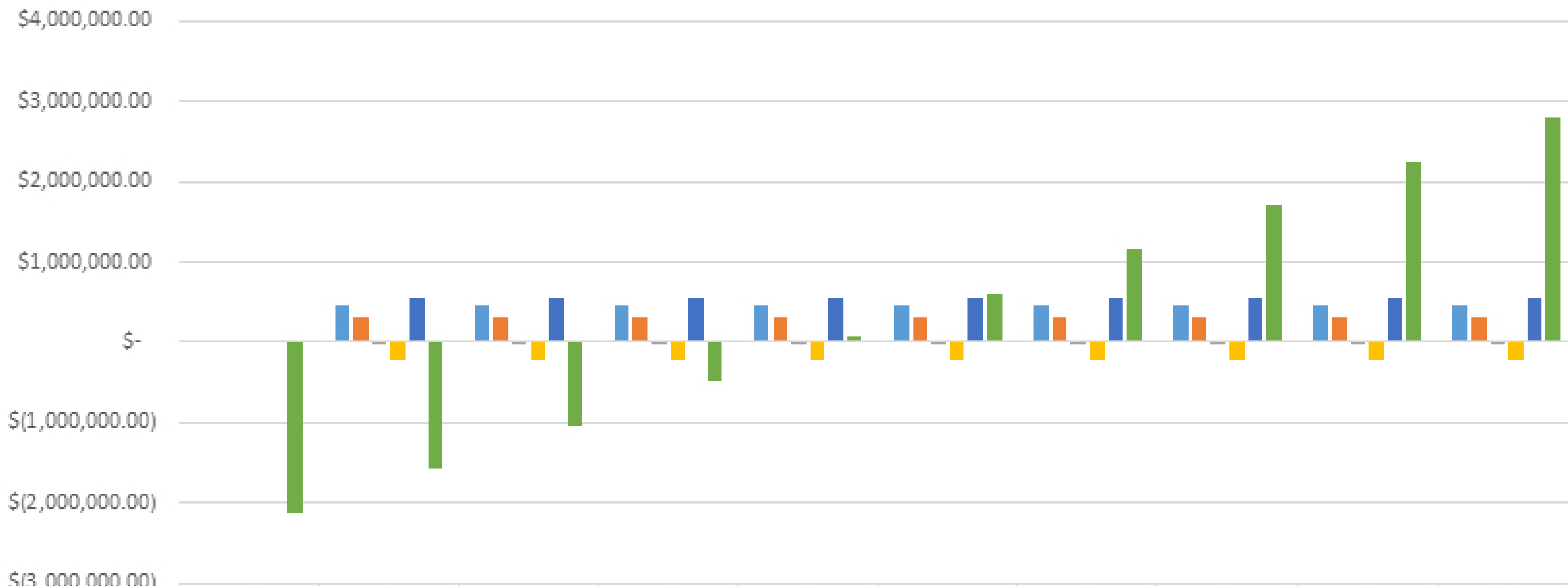
Natural Gas Generator with CHP



	1	2	3	4	5	6	7	8	9	10
Fuel Cost	$-	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3
O&M	$-	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)
Net Savings	$-	$847,925.49	$847,925.49	$847,925.49	$847,925.49	$847,925.49	$847,925.49	$847,925.49	$847,925.49	$847,925.49
ROI	$(2,125,750	$(1,277,824	$(429,899.0	$418,026.48	$1,265,951.	$2,113,877.	$2,961,802.	$3,809,728.	$4,657,653.	$5,505,579.
Demand Credits	$-	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14
CHP Value		$614,428.57	$614,428.57	$614,428.57	$614,428.57	$614,428.57	$614,428.57	$614,428.57	$614,428.57	$614,428.57

In order to include another level of conservativeness, the following model assumes that only half of the recoverable heat is redeemed. Simple payback is 4.9 years, and the ROI after 10 Years is 280%.

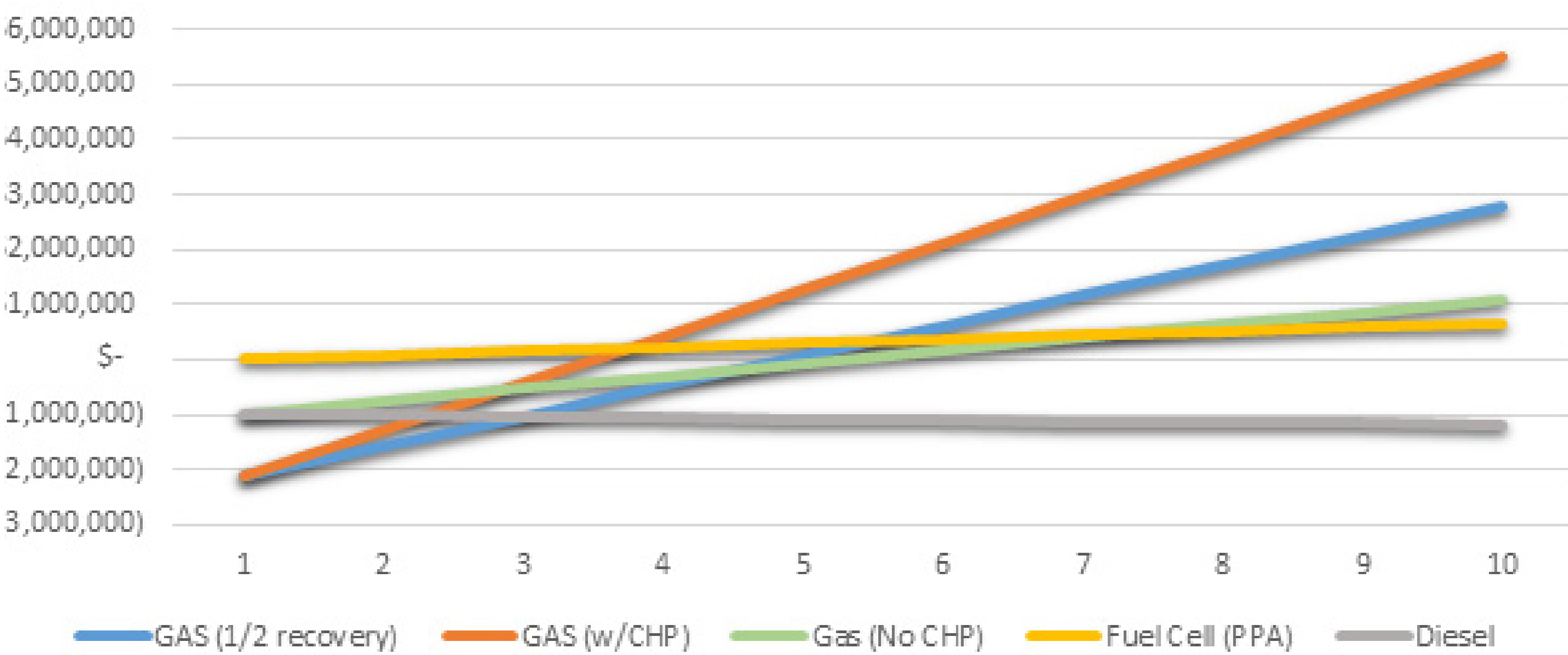
Natural Gas Generator with CHP (1/2 heat recovery)



	1	2	3	4	5	6	7	8	9	10
Demand Credits	$-	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14	$454,217.14
CHP Value	$-	$314,428.57	$314,428.57	$314,428.57	$314,428.57	$314,428.57	$314,428.57	$314,428.57	$314,428.57	$314,428.57
O&M	$-	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)	$(9,462.86)
Fuel Cost	$-	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3	$(211,257.3
Net Savings	$-	$547,925.49	$547,925.49	$547,925.49	$547,925.49	$547,925.49	$547,925.49	$547,925.49	$547,925.49	$547,925.49
ROI	$(2,125,750	$(1,577,824	$(1,029,899	$(481,973.5	$65,951.97	$613,877.46	$1,161,802.	$1,709,728.	$2,257,653.	$2,805,579.

Comparison between the feasible options:

ROI Comparison among applicable technologies



In order to include another level of conservativeness, the following model assumes that only half of the recoverable heat is redeemed. Simple payback is 4.9 years, and the ROI after 10 Years is 280%.

Natural Gas Generator with CHP (1/2 heat recovery)
6) Diversification of energy with Renewables

Although renewable energy systems (RE) may not be applicable at all locations, as the technologies continue to improve in efficiency, there may be a point in the future where their integration may be more predominant. Currently, one of the challenges associated with wind and solar is related to real state limits. Most urban environments have limited amounts of usable real estate for energy generation. By monitoring their development, facilities can prepare in anticipation of their integration. However, each site is unique. If the ECH facility happened to have access to extended tracks of land, there may have been an opportunity to utilize wind or solar. In such a case, a wind and solar analysis would play an important role in calculating generation. For the

Yearly production with $1 million budget for capital costs

Technology	Budget	Cap Cost ($/KW)	System Size (KW)	Hours of Daily Production	Daily Electrical Output (KWH)	Days (YR)	Yearly Electrical Output (KWH)
Solar Roof Top	$1,000,000	$3,175	315	6	1,890	360	680,315
Solar Thin Film	$1,000,000	$1,600	625	6	3,750	360	1,350,000
Wind	$1,000,000	$1,475	678	12	8,136	360	2,928,814

Yearly production with $1 million budget and the associated maintenance costs.

System	Electricity (KWH)	Fixed O&M
Solar- Roof Top	680,315	$5,354.33
Solar- Thin Film	1,350,000	$7,500.00
Wind	292,8814	$25,084.75

*figures calculated without consideration of real estate limits
*Assumption 1- Solar power is only available 6 hours per day.
*Assumption 2- Wind power is only available 12 hours per day.

purposes of this study, conservative assumptions have been made. The figures noted are only intended to show purchasing power if that were the case. Solar and wind power is not feasible at the moment for the ECH facility.

In regards to renewables, we will use the levelized costs to estimate the potential production capabilities without regard to real estate and space demands.

7) Resolution

The resiliency scale, along with the financial analysis, should be utilized together to determine how to distribute the identified funding. The goal is to slowly build up the on-site generation system so that eventually it can serve as a micro grid that can island itself. See the appendix for the graphic labeled “Levels of resiliency.” The scale dictates the varying degrees of resiliency from 0 to 5; Level 0 being the most susceptible to natural disasters, and Level 05 being the most resilient. It should be used as a milestone indicator. Because each facility faces unique circumstances, only the facilities management team can determine how aggressively they need to pursue the higher levels of resiliency.

The facility should first identify where they fall on the scale and use the proposed model path to make progress towards the next level. The final decision on which investment to pursue falls on the facilities department.

The case study analysis suggests that it would be most beneficial to pursue the installation of a natural gas generator with CHP capabilities. By doing so, ECH can make the best use of the available resources and attain the next level of resiliency. Based on the levels of resiliency, it would bump the facility to a Level 2. There is also an opportunity to add fuel cell generation. If the fuel cell vendor and the facility can come to terms on a good PPA agreement, an additional leg of continous generation can be implemented. At no cost to the facility, they have an opportunity to bolster their onsite generation with redundancy and diversification.

The proposed model path suggests that the ECH facility should repurpose the underutilized resources to attain the next level of resiliency with the natural gas generator option. Due to the political climate, and without the fuel cell vendor negotiations, that is the recommended direction. One million dollars can be pulled from the contingency budget to cover the CHP installation. From the $1.3 million budget of underutilized expenditures, $1 million should be spent on the natural gas genset and the remainder on items that will optimize its usage. For example, an energy control module may be one of the first items. Although this item was not discussed in the case study, at some point, a control module that will allow the development of a smart grid system would be beneficial. Not only would it monitor and control the systems, but it could also assist with identifying the most efficient method of integrating them together. For the next ten years, the following milestones are most appropriate for the ECH facility based on the proposed model path. The milestones should be reviewed on a yearly basis and become an integral part of yearly planning and budgeting exercises. The suggested path marks a moderate approach. Each facility will need to assess how aggressively they can pursue increased levels of resiliency. Some may be in dire need to pursue a Level 05 status, while others may be comfortable with a Level 03. In either case, assuring that the proper infrastructure is in place to meet current/future challenges is critical to the facility and the community it serves.

- **2017 Attain Level 02 resiliency status**
  Analyze the natural gas utility feed for vulnerabilities.
  Investigate PPA options with Fuel Cell vendors.
  Attain quotes to proceed with natural gas genset with CHP.
  Install natural gas genset with CHP.

- **2018-2021 Monitor and fine tune the generation systems**
  On a yearly basis, perform a resiliency analysis.
  In anticipation of future opportunities, prepare necessary systems.
  Monitor energy storage systems and renewable technologies.
  Proceed with Level 03 status as soon it becomes feasible.

- **2022 Pursue level 03 resiliency status**
  It is anticipated that the natural gas genset payback date falls around the year 2022.
  Therefore, actively pursuing a Level 03 resiliency status is recommended next.
  Continue to perform a resiliency analysis on a yearly basis.
  Monitor energy storage technologies and renewable technologies

- **2023 Attain level 03 resiliency status**
  Continue to perform .a resiliency analysis on a yearly basis.
  Monitor energy storage technologies and renewable technologies.

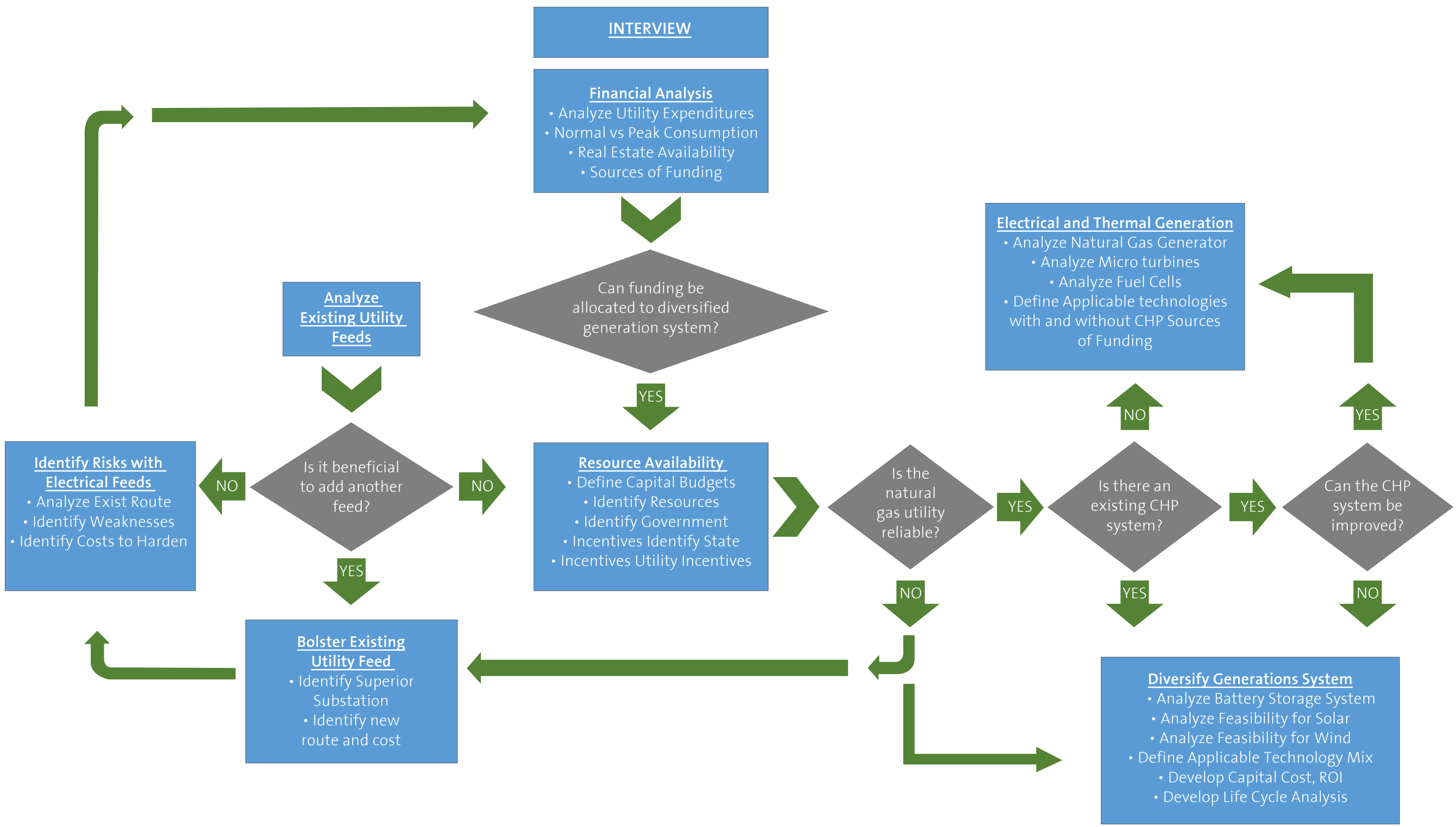
- **2025- 2027 Pursue Level 04 resiliency status**
  Continue to perform a resiliency analysis on a yearly basis.
  Monitor energy storage technologies and renewable technologies.

The case study also suggests that there is an opportunity to bump the facility to a resiliency Level of 03. If a good PPA agreement can be made with a fuel cell vendor, then the available funding can be used to explore battery bank options. It would provide the infrastructure needed towards fortifying off-grid capabilities, which is another step closer towards developing its islanding capabilities. During the financial analysis, it became evident that the CHP system could benefit from a battery bank. It can assist the facility with generating power during off-peak hours in order to be utilized during high-demand periods. In the future, when other forms of generation are added or when renewables such as wind and solar can be plugged in, the transition can be seamless. Therefore, in order to transition the facility to a Level 03, an additional financial analysis is needed. Currently, this is out of the scope of this case study since it does not explore energy storage. An additional study would determine the feasibility incorporating a battery bank.

/ Levels of Resiliency for Critical Facilities

LEVEL	STANDARD UTILITIES		ALTERNATIVE ENERGY GENERATION SYSTEMS				
0	Base Utility Feeds	+	No On-site Generation				
1	Fortified Feeds	+	Stand by Generation				
2	Multiple Fortified Feeds	+	Continuous On-Site Generation				
3	Multiple Fortified Feeds	+	Diversified Generation with Redundancy	CHP Generation	Energy Storage		
4	Multiple Fortified Feeds	+		Micro Grid	Island Capability	Energy Storage	
5	Multiple Fortified Feeds	+		Micro Grid	Island Capability	Energy Storage	Renewables

/ Resiliency Road Map for Critical Facilities for Assessing Infrastructure Improvements



/ References

Hampson, A., Bourgeois, T., Dillingham, G., & Panzarella, I. (2013). Combined heat and power: Enabling resilient energy infrastructure for critical facilities. Oak Ridge, TN: Oak Ridge National Laboratory. Retrieved from http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf

Willets, Sarah (2016, November). Hurricane Matthew put N.C., Regional Medical Center to Test. THE ROBESONIAN. Retrieved from http://www.govtech.com/em/disaster/storm-put-SeHealth-to-test.html#

Kovach, David (2013, October). Implementing a standby generator maintenance program for diesel engines. Electrical Construction and Maintenance. Retrieved from http://ecmweb.com/ops-amp-maintenance/implementing-standby-generator-maintenance-program-diesel-engines

Pentland, William (2013, April). Backup Generators Are the Bad and Ugly of Decentralized Energy. Forbes. Retrieved from http://www.forbes.com/sites/williampentland/2013/04/15/backup-generators-are-the-bad-and-ugly-of-decentralized-energy/#63b9b1335107

Chisholm, Dan (2014, March). Running without load. Emergency Power Supply Systems. Retrieved from http://ecmweb.com/blog/running-without-load

U.S. Energy Information Administration (EIA). (2016). The Annual Energy Outlook 2016. Retrieved from http://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf

Chisholm, Dan (2014, April). Testing generators with a portable bank. Emergency Power Supply Systems. Retrieved from http://ecmweb.com/blog/testing-generators-portable-load-bank

Daniels, L.A., Potter, B.A., Coker, P.J. (2013). Financial Implications for Companies Running Standby Generators in Support of the Smart Grid. 4th Annual TSBE EngD Conference Proceedings, University of Reading. Retrieved from https://www.reading.ac.uk/web/files/tsbe/Daniels_TSBE_Conference_Paper_2013.pdf

Harvey, Hal (2016, April). Climate: How to win. Energy Innovation.org. Retrieved from http://energyinnovation.org/wp-content/uploads/2016/04/Climate_HowToWin-final.pdf

U.S. Deployment programs (2017). Fuel Cell Energy. Retrieved from http://www.fuelcellenergy.com/applications/financial-incentives/u-s-incentives

Felder, Frank A. (2007, December). New performance based standards for standby power: Reexamining policies to address changing power needs. Clean Energy Group. Retrieved from http://www.cleanegroup.org/wp-content/uploads/New-Performance-based-Standards-for-Standby-Power.pdf

Mouer, Christopher L., Chisholm, Dan (2010, January). Island of stability: Power system overcomes unique vulnerabilities. Health Facilities Management Magazine. Retrieved from http://www.hfmmagazine.com/articles/983?dcrPath=%2Ftemplatedata%2FHF_Common%2FNewsArticle%2Fdata%2FHFM%2FMagazine%2F2010%2FJan%2F1001HFM_FEA_Infrastructure

Fuel Cell and Hydrogen Energy Association (FCHEA) (2015, February). Enhancing the role of Fuel Cells for Northeast Grid Resiliency. Retrieved from https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/54e5e838e4b00 72e73714e4b/1424353336299/Northeast-Resiliency-White-Paper-February-2015.pdf

Somanader, Tanya (2016, September). President Obama: The United States enters the Paris Agreement. [Web Log] The White House. Retrieved from https://www.whitehouse.gov/blog/2016/09/03/president-obama-united-states-formally-enters-paris-agreement

Advisory Board (2013, May). Why residents flock to hospitals during emergencies. Retrieved from https://www.advisory.com/daily-briefing/2013/05/30/why-residents-flock-to-hospitals-during-emergencies

Levinson, Daniel R. (2014, September). Hospital emergency preparedness and response during Superstorm Sandy. Department of Health and Human Services. Retrieved from https://oig.hhs.gov/oei/reports/oei-06-13-00260.pdf

Lazard (2015, November). Lazard's levelized cost of energy analysis- Version 9.0. Retrieved from https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/

Friedlander, Blaine (2015, January). Generators that relieve power grid worsen ozone pollution. Cornell Chronicle. Retrieved from http://news.cornell.edu/stories/2015/01/generators-relieve-grid-worsen-ozone-pollution

Gangi, Jennifer, & Curtin, Sandra (2016, November). State of the States: Fuel Cells in America 2016 7th Edition Fuel Cell Technologies Office. U.S. Department of Energy. Retrieved from https://energy.gov/sites/prod/files/2016/11/f34/fcto_state_of_states_2016.pdf

Karr, Marcia (2016, July). Emergency Generators in health care: Diesel or Natural Gas. Engineered Systems. Retrieved from http://www.esmagazine.com/articles/97817-emergency-generators-in-health-care-diesel-or-natural-gas?v=preview

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