Shoreline Energy Advisors, LLC

# The Bridgeport City Hall Complex Microgrid
# Its' Development and Evolution

***Fred Fastiggi, DGCP***
***Shoreline Energy Advisors, LLC.***

## Project Background:

Early in 2013, the Connecticut Department of Energy and Environmental Protection (DEEP) initiated a pilot program to develop microgrids capable of providing continuous power to critical public facilities in the event of power outages affecting the existing utility grids operated by United Illuminating and Connecticut Light and Power. The program was developed in response to Governor Malloy's Two Storm Panel's recommendation regarding the use of microgrids as a method for minimizing the impact to critical infrastructure associated with emergencies, natural disasters, weather and other events which cause the larger electricity grid to lose power.

The program called for the development of microgrids that served multiple critical facilities that were capable of running continuously for a minimum of four weeks with their own generation resources. DEEP conducted a two-step project selection process to locate pilot projects which best achieved the goals of the program. The first step was a Project Feasibility Analysis where critical power-using entities submitted initial proposals for evaluation of their match to overall program objectives. After DEEP evaluation, those proposals judged as best fits were invited to submit more detailed proposals including requests for state funding of the non-generation (distribution wires, transformers, switch gear, transfer switches, controls, etc.) portions of the project.

Thirty-three projects were originally proposed during the project feasibility analysis phase and of these, twenty-seven were invited to submit formal proposals. Of the twenty-seven invitees, eighteen submitted detailed proposals and of these, nine were selected for a portion of the $18 million grant funding available from DEEP and the Federal government. Awarded grants ranged from a few hundred thousand to three million dollars.

The City of Bridgeport submitted two proposals with one, the "City Hall Complex" proposal, among the nine initially chosen by DEEP to receive grant funding. The City Hall Complex microgrid was designed to provide uninterruptible power to City Hall, Police Headquarters and a newly renovated Senior Center. The project was originally estimated to cost approximately $6 million in total, of which the DEEP grant would cover $2.975 million, leaving Bridgeport with a need to fund the $3.025 million balance to complete the project.

## Unique Characteristics of Microgrids and Uninterruptible Power:

Microgrids consist of electric generator set(s) located at one or more of the sites of users who will take power from the microgrid. They also consist of the electrical distribution infrastructure (wires, conduit, transfer switches, etc.) to distribute the electricity from the gen set(s) to multiple buildings and, interconnections with the local utility's distribution system (in this case, United Illuminating). The interconnection with the local utility allows the grid to both receive electricity from the utility system, and to export electricity from the microgrid system. In the case of a power outage, the microgrid needs to be capable of isolating itself from the utility distribution system, so that it can continue to generate electricity for the buildings served by the microgrid, without running the risk of exporting power to the utility system and injuring workers who may be working on its' repair. Once the utility system is re-energized from its outage, the microgrid needs to be able to re-synchronize with it.

The facilities served by the micro gird in the DEEP program were to be "critical facilities" which means the loss of their operation would cause a serious hardship on the public or on the population it serves. One key distinction between a microgrid and other types of distributed or emergency generation is that it needs to be able to run for extended periods of time (i.e. not just the few hours or days conventional emergency generators are designed for). The DEEP program required a minimum of four weeks run time without having to rely on utility service for back up or supplemental power.

The DEEP program also specified that the microgrid system must be able to service the critical facility peak loads on it at any time, day or night, winter or summer. This means that the microgrid needed sufficient generating capacity to supply all needed electric on a hot, humid weekday afternoon in July, as well as a mild, dry Sunday morning in early October.

A July or August requirement usually represents the "peak load" in that it is the peak capacity requirement needed to service the electrical load over the course of the year. The electrical generating capacity requirements (called "Load") in July may be many times the capacity required in October or April but since the DEEP program calls for service of critical loads at any time, the microgrid needs to have the capacity to service the loads whenever an outage occurs.

This capacity design requirement is very different from what is usually encountered when considering normal on-site generation of electricity (i.e. distributed generation or cogeneration if waste heat recovery is included). With a typical distributed generation project, the electrical generating capacity is sized to the "base load" as opposed to the "peak load". The base load is the minimum capacity requirement that is usually (i.e.: 85% if the time) needed to service a facility. The capacity requirement for a facility will exceed the base load very often but rarely will it be less. Most economically feasible cogeneration projects are sized for base load so that capital requirements are minimized and so that all of the generation runs at capacity as much as possible to get maximum efficiency and kilowatt hour (KWH) production from the system. The more KWH produced, the more the overall production is worth, and the faster the recovery of the capital invested in the project.

A typical weekday October or April electrical load is probably indicative of most base loads for the types of buildings included in the Bridgeport City Hall Complex microgrid however, if the microgrid was only sized to the base load, and an outage occurred in July, the microgrid would not have enough capacity to service the critical facilities on the grid. As such, the DEEP program, whose objective is electric resiliency and service to critical facilities whenever an outage occurs, by design, requires that a lot of generation capacity (i.e. the peak) be designed into the microgrid even though all the capacity may not run that often.

This required characteristic of needing "excess capacity" that may not run round-the-clock, the extra cost involved in "interconnecting" with the utility grid and having the ability to isolate from the utility grid and to run alone, made the type of microgrid desired by DEEP, very expensive to build.

The cost of generating electricity consists primarily of fuel cost, operations and maintenance cost, and capital recovery. When the high capital cost of a microgrid is factored into the cost of electricity, it is not surprising that the cost per kwh from this type of system is higher than if the system was only designed to service the base load.

Additionally, when comparing the cost of microgrid electric to the cost of electricity from the incumbent utility, the microgrid cost will be higher, probably much higher, unless it can be designed to utilize cogeneration, to take advantage of other sources of revenue from programs that address system operator and utility needs or environmental concerns or, to service other non-critical loads in non-outage situations, thereby increasing the revenues that can be derived from its operation.

**“Premium Power”- A Changing Paradigm**

The concept of “uninterruptible power” is not new and has been around for several decades however its application in the type of “critical” facilities included in the Bridgeport microgrid is a new and evolving trend. In the past, facilities like data centers that process credit card transactions, brokerage houses, etc., have used this type of generation because even a momentary lapse of electric to their computers would cost millions of dollars in lost transactions. Facilities such as hospitals, air traffic controllers, the military and other government operations had also been willing to invest in this type of “fail safe” power to make sure they were never out of service or that their applications involved with life or death situations were not interrupted.

In the past, critical power energy users thought nothing of paying forty or fifty cents per KWH or even in excess of a dollar per KWH, as long as power was available when needed. This type of power was often referred to as “premium power” because of the insurance provided by its failsafe nature, and because the investment required in multiple levels of generation, switch gear, etc., justified the payment of a “premium” above that of the cost for traditional utility electricity.

With ongoing budgetary constraints in the public sector, a major challenge with the Connecticut DEEP program, which was geared toward critical municipal or other public facilities, was building a project that met the objectives of their program, while providing electricity that was not significantly in excess of what the facility could expect to pay to their local utility or third-party supplier. The expectation that the customary “premium” for fail safe power would decrease significantly or disappear altogether, represent a paradigm shift that makes these projects difficult to develop successfully and to subsequently sell to elected officials. They require unusual ingenuity in engineering and resourcefulness and creativity in financial structuring.

**Evolution of City Hall Complex Microgrid Project:**

The City Hall Complex Microgrid project had its origins from action taken by Bridgeport’s Energy Improvement District (“EID”). EID’s are the result of Connecticut legislation that permits a municipality, through the action of its legislative body, to establish EID’s. Powers of the EID are numerous and include:

1. Developing and operating distributed generation plants
2. Establishing conservation programs
3. Development of a plan to finance these resources

Coming on the recent occurrence of three extended power outages in Bridgeport (Irene, an October snow storm and Sandy), the DEEP Microgrid program presented an opportunity to address the problem of loss of power at critical facilities for Bridgeport. The EID prepared the initial proposal, and once Bridgeport was selected for further consideration, it developed the detailed proposal that was submitted, resulting in the awarding of a $2.975 million grant. Much of the cost for preparing these proposals was covered by additional DEEP funding and was not included in the $2.975 million grant.

The DEEP program was the first of its kind in the United States and given its pioneering nature, was very well designed however, several key requirements of the program were to be clarified and revised as it evolved in in order to improve project viability and economics.   The initial Bridgeport project design evolved with these changes and in response to a critical late-stage decision to utilize a public/private partnership with third party ownership, as opposed to the city's initial plans for self-funding of the project.

Bridgeport was initially attracted to the Microgrid Program because of the resiliency it offered critical city buildings and was less concerned with the cost of attaining resiliency in the form of a higher cost per kwh.  It also initially intended to fund the balance of the capital requirement after the DEEP grant.  As often happens in the public sector, after the cost per kwh of production and the required capital cost were more definitively defined, the city determined that it still saw the project as worthwhile but could not pay the excess cost per kwh that microgrid electric would merit.  Also, the capital it had anticipated using to build the grid, was needed elsewhere.  The Mayor then directed the EID to find another party interested in financing the project with the caveat that cost of electric from the microgrid needed to be at, or below the cost of power currently available from United Illuminating.

Once this direction was received, the EID prepared a design-build specification for solicitation of proposals from likely developers of the project.  Several credible proposals were received, and a group led by two Branford Connecticut-based companies, OR&L Construction and Controlled Air (a mechanical engineering firm), along with a financial investor, Power Island from Jacksonville Florida (an experienced investor in energy projects) was selected to develop, design, construct, own and operate the project.  These members of the ownership team were supplemented by various Connecticut-based engineering resources including BL Companies (Environmental, Civil and Project Management) from Meridan and CH Electric (Electrical) of Waterbury,

With the selection of the OR&L Group as the third-party owner, Bridgeport's objectives simply became:

1. The implementation of a microgrid that met all the criteria of the DEEP program, while;
2. Offering power to its critical facilities included in the microgrid, at prices that were roughly comparable to what United Illuminating could offer.

**Some Positive Program Changes:**

As the program evolved, and perhaps in response to concerns of other entities who had received awards and decided to seek third party funding, the DEEP became more specific on certain requirements of its program, in doing so, making the projects easier to finance.  For example, initially the requirements suggested a heavy emphasis on a storable fuel backup with a preference for non-diesel alternatives.  This steered Bridgeport's initial design to natural gas as the everyday fuel with liquid propane backup.  Liquid propane is not only an expensive fuel but an alternative requiring both an expensive storage system and extensive land requirements for tank siting which added complexity and cost to the project.  Complicating this further, generator packages that are capable of burning both natural gas and propane fuel in the size required for Bridgeport's project were very limited in number, and because of this, Bridgeport initially settled on a micro turbine design which was not as efficient as natural gas reciprocating engine for the Bridgeport loads but did provide the natural gas/propane dual fuel capability that the design called for and which the DEEP seemed to prefer.

DEEP eventually indicated in their second phase of the program that natural gas fueled projects were acceptable as "uninterruptible" and that diesel was acceptable as a backup fuel but for no more than 25% of critical peak capacity.  DEEP also clarified the level of backup capacity (n+1) that was suitable for the project at

20% over peak. For many (including Bridgeport) who had built larger safety margins, and more exotic fuel mixes into their initial designs, this clarification of requirements helped decrease capital needs and improve project economics enabling them to attract third party investors.

**Revised Design of City Hall Complex Microgrid:**

The Bridgeport development team incorporated much of this new guidance from DEEP into a revised design to make it economically viable for a private investor. Because of the changes in the design from the original application, in the summer of 2014, the team resubmitted its revised design in response to DEEP's request to do so. DEEP needed to insure that the changes to design would not be viewed as so material as to make the Bridgeport proposal less attractive than competitive proposals submitted by others who did not receive a grant in the original solicitation. The team was asked to re-submit their original application based on the new design for evaluation by DEEP and its consultants and was notified in August of 2014 that its new design was acceptable and that the original grant in the amount of $2.975 million was re-confirmed.

The estimated annual electrical usage for the three buildings that are part of the Bridgeport microgrid was estimated at 2,550,000 KWH per year with a base load of around 185KW and a coincident peak critical load of 713KW. After extensive engineering and evaluation of hardware alternatives, the revised design to service the anticipated loads called for three (3) generator sets, burning natural gas, each with a gross capacity of 265KW or 795KW in total. The generator sets were to be sited at City Hall and interconnected with Police Headquarters, the Senior Center and the United Illuminating distribution service that currently services the buildings.

In an unrelated initiative, the City had also been planning for the replacement of the existing diesel backup generator at Police Headquarters which has reached the end of its useful life. Emergency generation for a public safety facility like Police Headquarters are generally designed with a storable fuel source on site in the extremely unlikely event that the flow of natural gas is interrupted. Given the utility and economy offered by tying the need for a new diesel generator into the microgrid initiative, it was decided to incorporate the new diesel generator into the microgrid project. The on-site generation design capacity for the microgrid then consisted of 795KW of natural gas fueled generation and approximately 250KW of diesel fueled generation.

The system was designed so that if the United Illumination grid lost power, the microgrid would disconnect from the grid and the diesel generator would come on line in a matter of seconds to first supply power to most critical emergency circuits such as those serving fire protection, safety and security needs. It would then supply one of the microgrid generators with the excitation needed to restart in isolation from the United Illuminating grid. The diesel and first microgrid generator would then sequentially take on additional loads and provide excitation to the remaining microgrid generators until the full load for the critical buildings were met. When the capacity of the microgrid generators became sufficient to satisfy the entire connected load for the buildings on the microgrid, the diesel generator would switch off and the microgrid generators would then be carrying the entire load, isolated from the United Illuminating grid.

Unfortunately, the capital investment required to implement the project grew to $7.475 million as more engineering was performed to firm up the design. The entry of a third-party owner to build, own, operate and maintain the project also added cost to the initial capital estimate. In order to make the project work economically for the investors and the city, new strategies that generated savings to the city or revenue to the investors that could be reflected in a lower electric price needed to be developed.

**Cogeneration:**

In the initial design, the project offered very few of the benefits of cogeneration such as lowering the costs of heating and domestic hot water production to Bridgeport. Cogeneration is a process whereby two or more forms of useful energy are produced from the combustion of one fuel source. To illustrate this concept, a simple example of a building that uses electricity but also has a boiler to provide heating is useful. Electricity for the building is purchased from someone who usually generates it by burning fuel (natural gas, fuel oil or coal) in a boiler to make steam that is routed to a steam turbine that turns a generator to make electricity. Hot water for heating the building is made by burning fuel in another boiler to make hot water. In this case, two sources of fuel are burned to make electric and hot water.

In a cogeneration system, only one source of fuel is used to make both electric and thermal energy (e.g. hot water). This is done by capturing the waste heat (hot exhaust gas or warm engine cooling fluids) from the fuel combustion, in a specialized type of boiler called a heat recovery boiler (or heat exchanger). The heat exchanger makes hot water or steam from the waste heat without having to burn additional fuel in a traditional boiler.

OR&L's initial design was only going to use the waste heat from the system to provide heating and domestic hot water to City Hall and Police Headquarters. With this low utilization of fuel and the high capital cost of a microgrid, the original base case had the microgrid producing electricity in the mid-twenty cent per KWH range which was very high in comparison to United Illuminating's expected price of $0.17 per KWH.

In order to bring the microgrid price for electric down, the EID in conjunction with OR&L looked at different alternatives that would lower the cost of electricity from the microgrid, but would also meet the requirements of the CT DEEP program, insuring qualification for the $2.975 million grant.

**Virtual Net Metering:**

The first change the group implemented was to apply for an allocation from the Connecticut PURA Virtual Net Metering program. Because the nature of microgrids are to have "fail safe" power as previously discussed, they have more capacity than would normally be designed into a self-generation system and unfortunately that capacity is often times idle. Virtual Net Metering ("VNM") is a practice whereby the production from a generating system, which is not used or needed over the course of a year at the facility(s) the generating system serves when it is generated (in our case City Hall, Police Headquarters and the Senior Center) can be allocated against the usage at other facilities. It differs from Net Metering which only allows excess production not used at a particular point in time at the site of the generation to be credited against future usage up to the annual total for that site. Virtual Net Metering extends this flexibility to sites other than the site where generation is located.

A credit for all, or a portion of what these "virtual" accounts would have paid to their host utility, is deducted from their cost. When this credit is allocated between the generator and the energy user, it results in a price equal to, or slightly less than, what these accounts would otherwise pay to the host utility. In other words with Virtual Net Metering, excess electric production from the microgrid, which the City of Bridgeport doesn't use at the Senior Center, Police Headquarters and City Hall, was to be applied against the electric needs of other Bridgeport facilities with the dollar credit from this production helping to defray the fixed costs of the installation. Since these non-microgrid customers are not "critical facilities" if an outage were to occur, the microgrid would simply cease supplying the "virtual" supply to these "non-critical" facilities and would not receive the credit, reverting to only serving the critical facilities it was designed to serve in an outage situation.

These types of interruptions are expected to be few and far between so the benefit of VNM in this type of project is that in a non-outage situation, the credit from the extra production to the "non-critical facilities" serves to help absorb the fixed cost of generating electricity such as capital recovery.

Connecticut's Virtual Net Metering program is additionally unique in that it allows power production to be allocated to what are termed "affiliated" accounts (accounts that are paid for by the same party who is generating the electricity) and "un-affiliated" accounts. A Bridgeport public school would be an example of an affiliated account that it is not on the microgrid but its electric cost is paid for by Bridgeport. The Bridgeport Holiday Inn is an example of an unaffiliated account in that it is not on the microgrid and its cost is paid for by the hotel owner, not Bridgeport.

After discussions with the Connecticut Public Utilities Regulatory Authority, DEEP and United Illuminating the project was given approval to use Virtual Net Metering which prior to this time had been intended only for use with photovoltaic (solar) projects. The microgrid was given a VNM allocation corresponding to a $379,680 credit to its annual costs of production. This credit was based on production of 3,154,930 additional KWHs above and beyond the use at City Hall, Police Headquarters and the Senior Center. After factoring the effect of higher KWH production against the fixed costs of the system, the use of VNM significantly improved the economics of the project. The revised base case for the microgrid with VNM, produced electricity at a projected cost slightly below $0.20 per kwh in comparison to expected United Illuminating costs of $0.17.

While this cost is still higher than United Illuminating's expected price, it has the benefit of being less volatile. The difference in microgrid cost versus United Illuminating cost is analogous to the difference in cost for firm gas service versus interruptible gas service, something we may be more familiar with. With firm gas service, a premium is paid for having natural gas service available without interruption. The microgrid premium is similar with the benefit of being available when electric service from United Illuminating is not available.

There were two other benefits in being able to use VNM, lower fuel costs and lower operations and maintenance costs per KWH of microgrid production. An engine running at higher and steady capacity uses less fuel per unit of production than when it is turned down to something less than capacity. Additionally, although total O&M costs in absolute dollars rise with higher volumes, the cost per KWH drops as the fixed aspects of these costs are spread over a larger production volume. Each of these benefits are accounted for in the sub-$0.20 cost per KWH when Virtual Net Metering is utilized.

Despite these favorable effects of Virtual Net Metering, microgrid power was still higher than the $0.17 cost for United Illuminating power and given the tight operating budgets the city was facing, the EID was asked to look at additional ways to defray the cost of generating microgrid power.

**Class III Renewable Energy Certificates**:

Many states including Connecticut have implemented a policy to assure that a portion of the electric that is sold there comes from renewable sources (solar, wind, hydro and other desirable forms of power generation that are renewable or more efficient that traditional generation). Each utility in Connecticut has a renewable portfolio standard (RPS) which prescribes the percent of its electric supply that must come from renewable resources each year. In the event the utility does not meet this RPS it must buy the right to renewable energy generated by others in the open market with the producer's renewable generation validated by Renewable Energy Certificates (REC's). Each MWH of renewable power generated creates one REC. The generator of the

REC is paid a price above and beyond its value as electricity for the REC and that premium can be a valuable economic benefit to generators of renewable or other qualifying generation.

Cogenerated electricity where the generator has an average efficiency (with efficiency defined as BTU's of useful energy out divided by BTU's of fuel into the cogeneration engines) of 50% or more, and which produces at least 20% of its energy output as thermal energy (when measured as BTU's of useful thermal energy out divided by BTU's of fuel into the cogeneration engines) and at least 20% of its energy output as electric energy, qualifies as a Class III Renewable and is entitled to market its produced MWH volume into the Class III REC market. At the time of project evaluation, the market for Class III REC's over the next three years was in the range of $225 to $275 per MWH. This revenue from Class III REC's equates to a credit to the cost of cogenerated electricity in the range of $0.0225 - $0.0275 per KWH.

The EID team determined that one avenue for getting closer to United Illuminating's cost of power was to qualify the microgrid as a source of Class III REC's but to do this it needed to find a use for more of the waste heat coming off the engines in order to meet the requirements of 50% overall efficiency with a minimum of 20% thermal / 20% electric output. In the base case the only use for waste heat from the microgrid operations was to use it to heat the Police Headquarters and City Hall in the winter and to make domestic hot water. Much of the microgrid's waste heat from the combustion activity was not being used to cogenerate thermal energy. In order to more fully utilize the waste heat and to get the efficiencies up, it was determined that Bridgeport needed to design several additional capabilities into the project which increased project revenue but also increased capital requirements.

**Increased Waste Energy Utilization Options to Increase Overall Efficiency:**

The microgrid was designed to have three engine/generator sets and heat exchangers to produce hot water for heating and domestic purposes sited at City Hall with distribution piping (supply and return) routed to Police Headquarters to provides its heat and hot water. In order to get a higher utilization of thermal energy in the non-heating season, an absorption chiller was added at City Hall which will provide chilled water for cooling to either City Hall or Police HQ. Absorption chillers run on heat, steam or hot water, as opposed to electricity, using a chemical process to convert the heat to colder temperatures to subsequently make chilled water that can be tied into a cold water cooling system. While the absorption chiller that is to be added to the microgrid will be located at City Hall, it will service both City Hall and Police HQ and as such the buildings needed to be interconnected with another two-pipe system (supply and return) between the two buildings. Utilizing an absorption chiller to offset cooling from an electrically driven chiller will reduce electric usage and the cost associated with it since the hot water that is being used to feed the absorption chiller is being made with free waste heat as opposed to electricity. There is a cost for installing the absorption chiller and interconnecting the two buildings with piping but it was partially offset by the savings from not running electric chillers.

The greater flexibility to generate hot water for Police HQ and City Hall and the addition of absorption chilling increased the efficiency of the microgrid and during certain months of the year it was close to 80% but at other times of the year, even with these improvements it could be as low as 37%. When the monthly seasonality was factored into the calculations, on average, these changes in themselves still had the annual system efficiency languishing at the 47% level, still not enough to get overall annual system efficiency to the 50% level to qualify for Class III REC's.

In order to pick up additional thermal load that would get the microgrid efficiency to the 50% level, after looking at many alternatives, it was determined that the best option was to further extend hot water piping between City Hall and a privately-owned building across from City Hall. This building was undergoing renovation into a mixed use with a health club, theatre, retail and residential units. It has an indoor pool in need of year round heating, additional needs for domestic hot water (lockers, etc.) and currently unfinished tenant space which can be fitted with water source heat pumps for heating and cooling. This building provided yet another outlet for the waste thermal energy from the microgrid. Interconnecting City Hall and this building added still more capital costs to the microgrid project but in doing so, the microgrid achieved the 50% overall annual efficiency and met the 20/20 thermal/electric requirements to qualify for Class III REC's. Adding the new building brought the annual efficiency to 54%. The resulting estimated $0.025per KWH REC credit to the cost of microgrid electric generation further decreased the cost to a level that was finally at parity, or slightly less than the cost of UI electric.

**Additional Economic Factors resulting from the Expanded Cogeneration / REC Initiative:**

Thermally interconnecting City Hall, Police HQ and the privately-owned mixed-use building, and the addition of the absorption chiller produce several benefits in addition to the critical Class III REC revenue estimated to be in excess of $100,000. Among these other benefits are savings to the City on electric costs of almost $61,000 per year from using absorption chilling versus electric chilling and revenues from the sale of hot water to the owner of the private building in a nominal amount. This additional microgrid revenue/savings of approximately $200,000 per year required an incremental capital investment of $1,346,000 above and beyond the base case investment of $7,475,000 for a total project investment of $8,821,000. This total investment of $8,821,000 also includes approximately $500,000 for investment in a new emergency generator at Police Headquarters which would have to be made with or without the microgrid but for purposes of convenience, and the fact that the emergency generator needs to be interconnected with the microgrid, as previously discussed, a decision was made to include it with the overall microgrid project

The cost of the emergency generator added around $0.0084 per KWH to the cost of microgrid power. The resulting cost per KWH for microgrid power was $0.1685 without the deferred investment in the emergency generator and $0.1765 with it included.

**Future Economic Enhancements:**

During the development of the Bridgeport microgrid nothing was allocated to its justification having to do with the emerging programs that are being made available from Independent System Operators or local utilities that allow owners of generation to participate in markets for demand reduction, ancillary services, NITs, etc. The reason for this was that New England was lagging other areas of the country such as New York and the PJM ISO and did not have programs in operation while the Bridgeport microgrid was being developed. It is anticipated that these programs will make their way into New England shortly at which time they should offer the opportunity to utilize microgrid generation assets. The value of these benefits would probably accrue to the owner of the generation portion of the microgrid project but the operating agreement specifies that any benefit will be split between both the owner and the city.

**Project Funding:**

The required capital for the project was sourced with the $2,975,000 grant from Connecticut DEEP, a $500,000 loan from the Connecticut Clean Energy Fund, a $4,146,000, 20-year commercial loan to the developers (not the city) and a $1,200,000 equity investment by OR&L and its development partners. The grant is in the name of Bridgeport while the loans and equity investment are all in the name of an OR&L special purpose subsidiary.

**Summary of Benefits and Cost of Microgrid Power:**

As designed and structured by the EID and OR&L, the City Hall Complex microgrid project offered the following benefits and features to Bridgeport:

1. A "fail safe" power supply for City Hall, Police Headquarters and the Senior Center, in the event of a power interruption due to weather, grid failure or other unanticipated events;
2. Base load and peak electric service at rates that are comparable to, or better than, anticipated United Illuminating and/or Third Party vendor options when the project is put into service (currently these costs per KWH are estimated at $0.1685 per KWH, which is slightly less than the expected delivered costs of power from United Illuminating at $0.17 per KWH when the project becomes operational);
3. A shield from future expected increases in UI Transmission and Distribution charges on both capacity and energy which are expected to increase at a rate that is much higher than the other components of electric power cost (fuel and O&M costs). The microgrid has a fixed capacity charge for twenty years and the difference between UI T&D and the microgrid capacity charges over the twenty-year term of the project is estimated conservatively at over $2 million.
4. The opportunity to potentially utilize the microgrid asset for future revenue opportunities in the New England ISO which may become available in the future for services like demand reduction, frequency regulation, black start, and other ancillary services which are becoming more frequent for Independent System Operators throughout the United States.
5. Savings on Bridgeport thermal energy such as hot water for heating or domestic purposes that can be made from waste heat as opposed to conventional boilers;
6. Savings on electric costs from using absorption chilling to partially offset chilling that is currently done with electric chillers;
7. Class III REC revenue which is a credit to overall microgrid cost of production;
8. Additional planned revenues from the sale of thermal energy to the neighboring privately owned building;
9. Installation of an approximately $100,000 of new energy efficiency measures related to lighting and HVAC controls in microgrid buildings at no capital cost to the City;
10. Savings in both energy usage and cost as a result of the implemented energy efficiency measures, and;
11. A reduction in greenhouse gases as a result of the higher efficiencies resulting from cogeneration (while annual efficiency from the system is approximately 54% there are months when the system yields efficiencies close to 80%) and implementation of energy efficiency measure.

**Another Complication – Change in Administration**

Complicating the development of the project further was a very late hurdle that emerged two years into the project at a time when contracts and financing were being finalized. The incumbent mayor who had been a strong proponent of the project was defeated in his bid for re-election, being unseated by an opponent who was supportive of the project but who was not as familiar with its history and placed much emphasis on the financial effects of contractual arrangements the city was committing itself to over the long term. Further complicating the initiative was the departure of the Deputy Director of Public Works who had been both the city's and EID's primary representative on the project. He left to take a new position outside of Bridgeport. The loss of his knowledge and institutional memory on the project severely impacted the speed with which to achieve approvals from the new administration. The microgrid was scheduled to start construction in the early fall of 2015 and to be completed by mid-year 2016. With the change in administration, the startup was significantly delayed. The transition to the newly elected mayor and his administration took place on December 1, 2015 after which he took time to deliberately and thoroughly review the project in its entirety despite it having previously attained the approval of the former mayor and then sitting council.

With a complex project like Bridgeport's microgrid, and with the long and winding history and evolution of its development, getting the new administration comfortable with the project added more time to the project's development schedule, compressing the time available to meet multiple expiration dates for critical components of the project such as lender commitments, the DEEP grant commitment, the interconnection agreement with UI and the qualification for Virtual Net Metering credits, all of which had their own sunset dates. The expiration of any one of these critical dates before the microgrid was operational, or before construction commenced in the case of the loan agreements, was capable of killing the project in its entirety.

The new administration finally gave its approval for the project in June of 2016 whereupon the OR&L team completed its financing arrangements, closed on its' construction loan, and began construction on the project. Construction of the project went relatively smoothly but the most challenging part of the final stages involved resolving details of arrangements with United Illuminating regarding interconnection, power transfer controls and re-finalizing the arrangements on virtual net metering. Finally, a ribbon cutting occurred and the project went commercial in March of 2018, almost five years from the date of its initial conception.

**Lessons Learned on Bridgeport Microgrid Development:**

The development of a microgrid is much more complicated than the development of traditional distributed generation or cogeneration projects and is not something that can follow existing process or precedent. Energy use and demand, site peculiarities and local regulatory programs and requirements each combine to require that these projects be individually developed with revenue, cost and contractual arrangements being customized to its own unique situation. They require extensive study, engineering and analysis and many trips back to the "drawing board" before a workable alternative emerges.

The Bridgeport City Hall microgrid is a particularly effective example of these challenges as it underwent several "near death" experiences. Meeting the ambitious goals of producing power at parity with the local utility's expected cost; Meeting the stringent requirements of the Connecticut DEEP's Microgrid program; Handling the challenges of dealing with the political risks and hurdles inherent in the public sector, and; Satisfying the financial needs of a private investor. Each added many layers of complication to the development of a project whose initial justification and attractiveness would appear to be indisputable.

***About the Author***

*Fred Fastiggi, Managing Director of Shoreline Energy Advisors, LLC. (www.shorelineenergyadvisors.com) was Bridgeport's co-developer and host site representative. He developed the initial concept for the microgrid and worked through the subsequent design changes and financial structuring of the project including advising during negotiations with the Connecticut Department of Energy and Environmental Protection, PURA, United Illuminating and OR&L (Bridgeport's Public-Private-Partner in this project). He was a long-term consultant to the city's Energy Improvement District. Fred has over twenty-five years of experience working in all phases of energy management, specializing in the development of distributed generation, cogeneration, renewable and district energy projects for industrial, commercial, utility, investor and public-sector clients. He is a Certified Energy Manager and is a Distributed Generation Certified Professional. Working from his office in Brielle, New Jersey, Fred can be reached at (732) 528-1639 or via email at fgfast@optonline.net or info@shorelineenergyadvisors.com.*