MICROGRIDS

INSOURCING MORE RELIABLE ENERGY RESOURCES TO CONNECTICUT TOWNS AND CITIES

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PREPARED FOR THE CONNECTICUT DISTRIBUTED ENERGY SOLUTIONS SUMMIT

FIRST DRAFT FOR DISCUSSION PURPOSES ONLY

Contents

EXECUTIVE SUMMARY

Over the past eight years, many Connecticut municipal officials have developed a strong motivation to insource energy to their communities by developing peer-to-peer distributed energy networks known as microgrids. Their motivations stem from a desire to supplement the existing utility company grid to increase reliability and also to lower costs and environmental footprints. They envision that local microgrids will be collectively owned and run by energy users in Energy Improvement Districts (EID's) enabled by State law in 2007 or, alternatively, as Connecticut Electrical Cooperatives enabled in 1971.

Microgrid architecture integrates demand from neighboring energy users and in-sources power supply with an optimized mix of on-site technologies, thereby reducing demand and enhancing local generation. Demand-side investments in a microgrid might include building control and demand response systems or the installation of more efficient end-use equipment. Supply-side investments in the 2 to 20 MW range might include engines or turbines for combined heat and power plus renewable energy such as fuel cells, waste-to-energy systems or building-integrated solar and wind systems.

While several towns and cities have established EID's, a number of issues have prevented the establishment of the State's first community microgrid. Chief among these are: 1) a need for technology to interconnect microgrids safely to the utility company distribution grid; and 2) a need to balance microgrid benefits between microgrid users, other energy users and utility company shareholders. On March 6th, therefore, a number of microgrid stakeholders will gather at Trinity College for the Connecticut Distributed Energy Solutions Summit. Stakeholders will include municipal officials, EID Board members, and large private energy users. State energy regulators, legislators, and utility company officials will also participate in the Summit along with companies that design, finance, build, own and operate microgrids.

In the wake of widespread outages during Hurricane Irene and last year's early-season snow storm, the Solutions Summit answers the calls of the Governor and some members of the State Senate for an expansion of distributed energy throughout Connecticut. The purpose of this paper is describe the depth of municipal interest in installing microgrids and to frame some of the issues that have retarded development of microgrids so that they may be addressed at the Summit.

While the Solutions Summit will consider what can be learned from the few distributed generation and municipally-owned distribution systems that performed well during the storms, a review of utility company performance in restoring power will be left to others. Performance during the storms may have differed considerably both between the State's two investor-owned utility companies and also between the investor-owned utilities and several municipally-owned utilities.[1] Therefore, any utility company may correctly claim that all or part of its grid performs reliably compared to national standards. Despite this, Connecticut municipal leaders on those more reliable parts of the grid will still have compelling reasons to insource power with microgrids to lower costs and environmental footprints.

Looking forward, recent innovations in technology, regulation and finance now make distributed energy microgrids a technically viable, legal, and cost effective alternative to traditional utility system upgrades. Remarkably, Connecticut-based companies have often conceived, financed and implemented these innovations in states other than Connecticut. Consequently, the Solutions Summit will seek to develop pragmatic technical, legal and financial road maps for the development of microgrids in-state. It will also consider some specific microgrid pilot projects that provide win-win-win benefits for microgrid customers, other energy users, and utility company shareholders.

This remainder of this paper considers the strong motivations of municipal leaders for microgrids and the impediments that have retarded the adoption of microgrids. It suggests a pathway for microgrid pilot projects and frames the following issues for consideration at the Summit:

Technical Issues

- Can existing distributed energy systems that could not run during the storms be retrofitted such that they can run safely and continuously during power outages in the future?

- What is the role in a microgrid of utility grid power, each type of Class 1 renewable resource, and Class 3 combined heat and power resources and how can they be optimally dispatched and controlled?

- Can a city-center microgrid be safely interconnected with a medium voltage utility distribution grid?

- What types of pilot projects are technically optimal?

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[1] See reports by Witt Associates and the so-called Two Storm Report on www.distributedenergysolutionssummit.com for an independent review of utility performance.

Regulatory Issues:

- What legal personality should a microgrid take? Energy Improvement District? Municipal Power Entity? Electrical Cooperative? How do these solutions compare with calls for a State Power Authority?

- Can a microgrid legally distribute energy within a utility company franchise area, especially where wires cross public rights of way?

- As distributed energy results in a more decentralized power network and a change in the traditional utility business model, what lessons from the governance of decentralized telecommunications networks and the internet can be useful for the governance of microgrids?

- What types of pilot projects are legally optimal?

Financing Issues

- What is the best way to fund the early stage microgrid designs necessary to secure project financing? What lessons can be learned from proposals for public-private infrastructure banks that would provide such funding?

- Are there solutions that could help energy users avoid having their commitments to buy power from a microgrid recorded as a liability on their books? In this context, is there a role for the State to pre-buy power or for the utility company to rate-base microgrids?

- What types of projects have the best opportunity of being financed? How could a group of microgrid users, an EID or a municipality develop a Request for Proposal ("RFP") for designing, building and operating a microgrid? What type of RFP would elicit responses with the best opportunity of financing?

A SUMMARY OF THE DEMAND AND VISION FOR MICROGRIDS BY CONNECTICUT TOWNS AND CITIES

Connecticut towns and cities are among the most motivated and proactive communities in the country for insourcing energy with microgrids.

While Connecticut communities pay among the highest rates for power in the continental United States, many of them also suffer from periodic, acute power outages and continuous, chronic power quality problems. On-going power outages due to Hurricane Irene and an early-season snow storm in 2011 have demonstrated a variable performance in terms of restoring power. Most parts of Connecticut's highly-centralized utility grid did not recover in a timely way. However, the recovery performance of other parts of the grid was exemplary. Facing the prediction by a State panel of experts that a Category 3 hurricane could result in month-long outages, many municipal leaders in Connecticut are now motivated to take a direct role in solving reliability problems. They are looking first to those few areas of the Grid that tend to perform well during outages.

Whatever the level of reliability, the typical Connecticut town or city imports most of its energy supply from interstate electric grids and natural gas pipelines. A large amount of cash flow leaves the communities to pay for energy and very few in-city residents are employed to provide it. Meanwhile, electric service imported by Connecticut's towns and cities is among the most expensive in the country. Therefore, Connecticut's municipal leaders also want to take a more direct role in lowering energy costs than they have in the past.

Finally, many of Connecticut's municipal leaders have observed that a commitment to lower environmental footprints for the community's energy use is coincident with better health and economic well-being. Therefore, thee also want to take a more direct role in finding greener technologies for their community's energy use.

Many state and municipal leaders have been convinced that the few Connecticut distribution systems that are publically owned generate power at much lower rates while also having a dramatically better performance record in restoring power during outages. They increasingly consider, therefore, that more of Connecticut's electric power grid should be collectively-owned and governed by its users in distributed energy microgrids. From a legislative point of view, these municipal motivations spawned the Energy Improvement District law in 2007 and even a vote by the State Assembly to form a state power authority.

Connecticut towns and cities have been frustrated that innovations in microgrid regulation, technology and financing conceived of by Connecticut law makers, companies and energy improvement districts are being implemented to develop microgrids in other states that compete with Connecticut economically.

Besides leading the nation in passing laws and providing financial incentives for microgrids, the State hosts offices for some of the world's best microgrid technology companies, such as General Electric, Fuel Cell Energy, Burns & McDonnell, van Zelm Engineers and United Technologies. Also, the Energy Improvement District concept first created and enacted by Connecticut legislators has been adopted by a number of other states. It has been frustrating for municipal leaders to learn, therefore, that while several states that compete with Connecticut have seen their first microgrid projects, no working community microgrid has ever been installed in-state.

One of the most sophisticated fuel cell projects is being installed to provide clean reliable power to trading floors at the new World Trade Center ("WTC") that will compete against those in Connecticut. Last year, UBS nearly moved the largest trading floor in the world from Stamford to the WTC. Connecticut-based engineers are implementing path- breaking microgrid projects in New York, the District of Columbia, California and Maryland.

Meanwhile, grid expansion plans being filed with the State do not call for a higher percentage of local generation in the future and instead propose increasingly higher costs for modernizing the centralized grid system. By contrast, Consolidated Edison of New York has committed to 800 MWs of customer-owned distributed energy before 2030 and has launched an initiative known at the 3G System of the Future to work with developers and customers on microgrid interconnection technologies and best sites for microgrid pilot projects. Similarly, seven utility companies that are members of the Edison Electric Institute ("EEI") have formed a working group to consider new utility business models that accommodate customer-owned distributed generation. To quote the mission statement of the EEI group "the marriage of smart grid (SG) technologies with distributed energy resources (DER) has the potential to change fundamentally traditional utility operating paradigms, and the utility business. This has become more pressing as public policy encourages the development of DER owned by customers and third parties. We think it is vital, therefore, to understand the implications of these new technologies and policies."

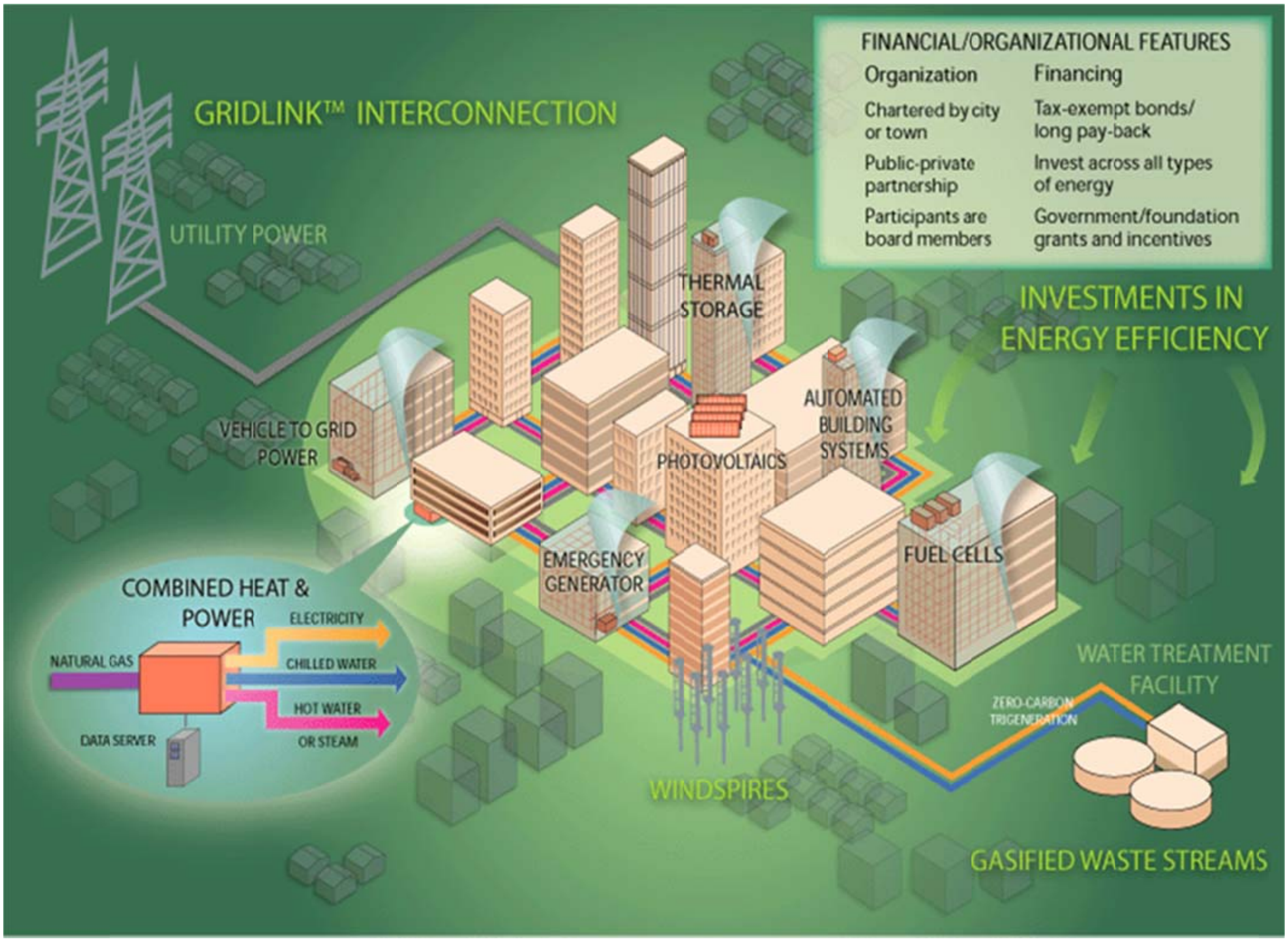
By not developing local microgrids, many of Connecticut's towns and cities also believe that they are losing opportunities to earn income from contributing to the stability of New England's transmission network. For example, the operator of the transmission grid, the New England Independent System Operator, provides incentives to communities that best manage power use and generation during times of peak power demand.

Studies of microgrid technology and project finance have encouraged Connecticut towns and cities to continue pursuing microgrids.

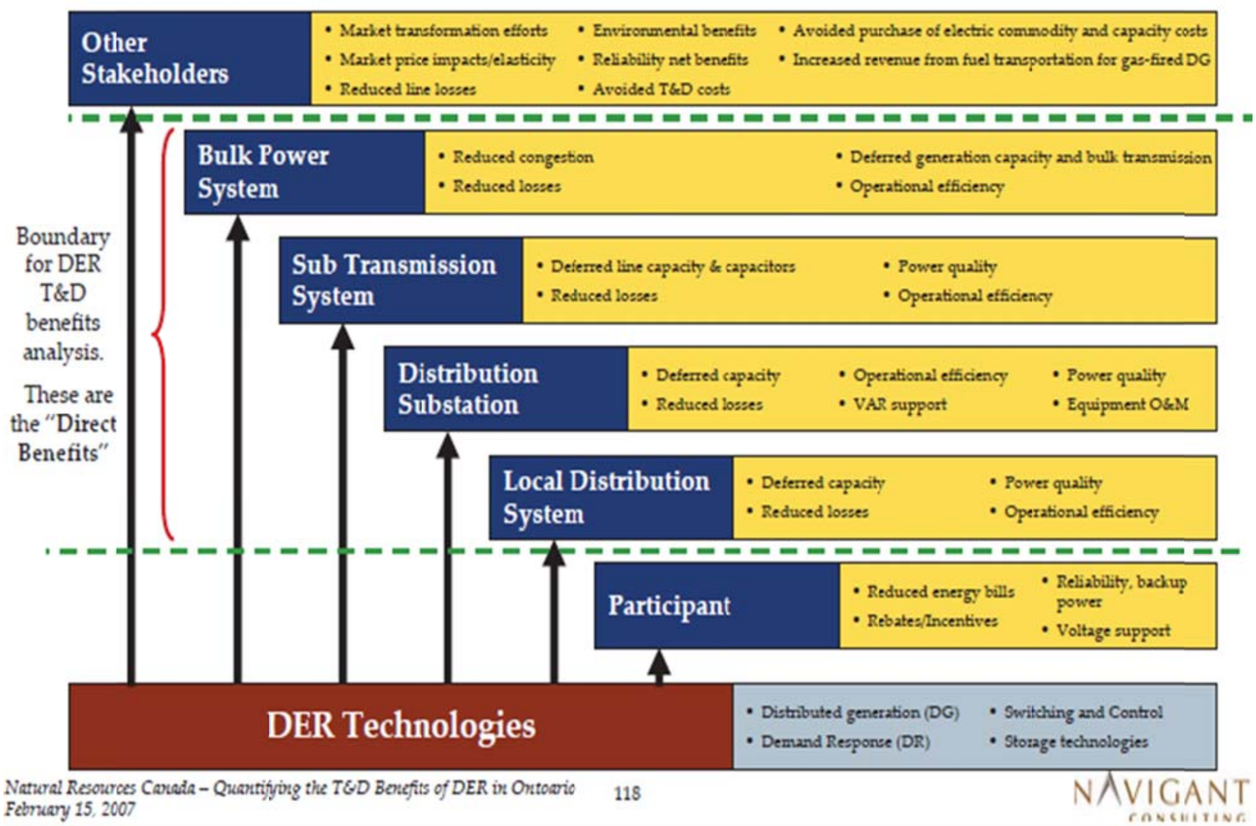
Recent studies of technology and project finance suggest that communities could now in-source some of the electric power they now import from the grid by installing microgrids that supplement and interconnect with the existing utility-company distribution network. Much like the network that serves the internet, energy users now imagine that they could govern microgrids as an economic commons and, thereby, better control their energy and environmental destiny.

Fuels that are now imported from gas pipelines could also be insourced. To achieve cleaner power, microgrids can use locally-available renewable fuels instead – intermittent geothermal, solar, wind and hydrogen resources can cover normal loads. To meet peak power demands, community waste streams can be gasified to fire up microgrids together with pipeline natural gas. Recycling waste heat from power generation and reducing reliance on transmission and distribution networks both increase energy efficiency for all microgrid users. As compared to grid power, therefore, a microgrid can dramatically reduce NOx, SO^2 and CO^2 emissions that contribute to asthma, acid rain and climate change, respectively.

To achieve more affordable power, microgrids typically exceed 80 percent fuel-use efficiencies versus an average of below 40 percent for grid power. By simply recapturing the cash flows now paid to import power and redirecting them to finance fuel-efficient microgrids, communities believe that they can attract private developers to fully fund the design, installation and operation of a microgrid. Once private developers and banks have recouped their investment by selling energy – typically within 10 years – ownership of the microgrid could transfer to the community and its energy users. In addition, communities can attract so-called smart grid companies that can more readily plug-and-play new technologies, such as electric vehicles, on a microgrid. The vision of microgrid potential is illustrated in the graphic below.


FINANCIAL/ORGANIZATIONAL FEATURES
Organization
Financing
Chartered by city or town
Tax-exempt bonds/ long pay-back
Public-private partnership
Invest across all types of energy
Participants are board members
Government/foundation grants and incentives
GRIDLINK™ INTERCONNECTION
UTILITY POWER
THERMAL STORAGE
INVESTMENTS IN ENERGY EFFICIENCY
AUTOMATED BUILDING SYSTEMS
VEHICLE TO GRID POWER
PHOTOVOLTAICS
EMERGENCY GENERATOR
FUEL CELLS
COMBINED HEAT & POWER
ELECTRICITY
NATURAL GAS
CHILLED WATER
HOT WATER OR STEAM
DATA SERVER
WATER TREATMENT FACILITY
ZERO-CARBON TRIGENERATION
WINDSPIRES
GASIFIED WASTE STREAMS

At first blush the substitution of locally-governed microgrids for imported grid power would seem like a losing proposition for Connecticut's investor-owned utility shareholders. Also, removing revenues paid by a small cluster of energy users in a microgrid would seem to leave non-microgrid rate payers in the community and state paying more. However, studies in many other states, such as the one illustrated below, have suggested that distributed energy microgrids would benefit all energy stakeholders such that Connecticut communities are been optimistic that could forge a win-win-win business model for microgrid users, other energy users and utility company shareholders.



Microgrids Can Balance Thermal Use Better than Single Facility Combined Heat and Power Systems and Result in Much Better Fuel-Use Efficiencies

The generation of electricity creates heat that can be captured to make thermal energy in the form of steam or hot and chilled water which, in turn, can be used to provide space heat, air conditioning and hot water or steam services. Capturing waste heat for useful applications can push the efficiency of the conversion of energy to over 80%, far beyond the current average in the United States or in Connecticut's utility service territories. Systems providing electricity, heating and cooling services are known as combined heat and power, or "CHP".

If one energy user installs a CHP system that is large enough to cover the electrical demands of its facility, then the possibility exists that the system will generate more thermal energy than can be used to meet total heating and/or cooling demands during times of peak electrical demand.

The sharing of thermal energy within defined urban districts is commonplace in the United States and in other industrial countries, which allows for significant savings in energy and maintenance costs as well as reductions in harmful air emissions to those who participate in them. For example, Hartford has a district heating system. Therefore, a microgrid design for one facility may serve the heating and/or cooling demands of neighboring energy users. This has the potential to create a source of revenue for the microgrid while also meeting the goal of community involvement by providing critical and life-sustaining services to neighboring organizations and individuals.

In many locations recycling the heat produced by local generation elevates the economic and environmental efficiency of the microgrid. In a few other locations, however, thermal loads may be relatively small, or the cost of laying pipes to distribute hot or chilled water may not be worth the investment. In that situation, microgrids can still harvest the heat, and use it to produce additional electricity. For larger microgrids (at least 10 megawatts), the recycled heat from gas turbines can produce steam, which can then used in a turbine to produce electricity. This approach is a miniature version of new, highly efficient "combined-cycle" natural gas plants, but sized at the smaller community scale. More recently, smaller microgrids (2 to 10 megawatts) can use a technology called Organic Rankine Cycle (ORC) to convert recycled heat into electricity. For example, Connecticut's United Technologies provides affordable ORC systems that effectively increase the efficiency of a natural gas engine by almost 20%. Proposals currently before both the U.S. Congress and the Connecticut PURA will enable ORC to share in the incentives received by other zero-emissions energy generation technologies. The result of adding ORC is a clean, highly-efficient package for community-scale electric-only microgrids, with a bit of leftover heat available for hot water or similar uses.

There are economically viable means whereby communities can insource fuels by converting local waste streams into microgrid feed stocks

A new source of fuel for microgrids is local biomass gas. New relatively clean technologies for gasifying wood and other organic materials, biodigesting human waste, and using plasma arcs to gasify medical and solid wastes suggests that instead of paying tipping fees for disposal, communities will now look to turn waste streams into microgrid feed stocks. The avoided tipping fees, which can be particularly high for specialty refuse such as medical waste, will tend to drive down both the carbon footprint and the net cost of microgrids.

Decentralized Microgrids Respond Better to Cyber Security than Centralized Utility Grids

Congress has also entrusted a Federal definition of smart grid standards to the Federal Energy Regulatory Commission ("FREC") which has delegated the work to the National Institute of Standards and the Electric Power Research Institute. One key concern has been the extent to which a more digital smart grid could increase exposure to cyber-attacks. Microgrids have been emerging as a solution by which critical infrastructure could become more secure against cyber-attacks. It is much more difficult to cyber-attack multiple microgrids and it is much easier to "fire-wall" a microgrid than to protect the entire utility grid.

There are Financing Options for Designing, Building, Owning, Operating Microgrids in Exchange for Agreements to Purchase Power

Alternative energy development companies are in the business of designing, building, owning, operating and transferring ("DBOOT") CHP microgrids for energy users. Typically, they will fully finance microgrids by raising funds for a Microgrid Project Finance Company. The Microgrid Project Finance Company will be a master limited partnership to secure the debt and equity financing needed to design and own the microgrid. Alternative energy development companies usually contribute the equity investment necessary to complete the design of community microgrids and thereby act as the General Partner of the master limited partnership. Under this approach communities would pay no capital costs towards the development of the Microgrid.

A significant benefit of a DBOOT approach is that the Microgrid Project Finance Company can earn significant tax credits not available to communities that are non-tax paying entities. Businesses within the community can be offered an option play a role as investment partners in the master limited partnership and, thereby, earn Federal tax credits.

Under the DBOOT approach, energy users in a community would enter into an "Energy Services Agreement" ("ESA") with the Microgrid Project Finance Company to pay charges for electric, heating and cooling services. The ESA can have a term of up to 20 years and allows the master limited partnership that financed the microgrid to recover capital costs and expenditures relating to the construction of the Microgrid. After payback to the Microgrid Project Finance Company, sole ownership of the asset could transfer and vest to the community in its entirety.

The Microgrid Project Finance Company would guarantee that the ESA service charges would be set at no higher than the same rates that the energy user would have paid if the Microgrid had not been implemented. This would guarantee that energy users in the community never pay more than the utility grid rates, but it does not limit the possibility that they will pay less; at the end of each year, an audit of actual costs would be conducted and any savings would be shared among the Microgrid Project Finance Company and the community's energy users. The lower the percentage of savings shared with the community, the faster the complete transfer of the microgrid to the community would occur. Therefore, a community may select between cash flow savings as articulated above or a faster transfer of the microgrid asset to their ownership.

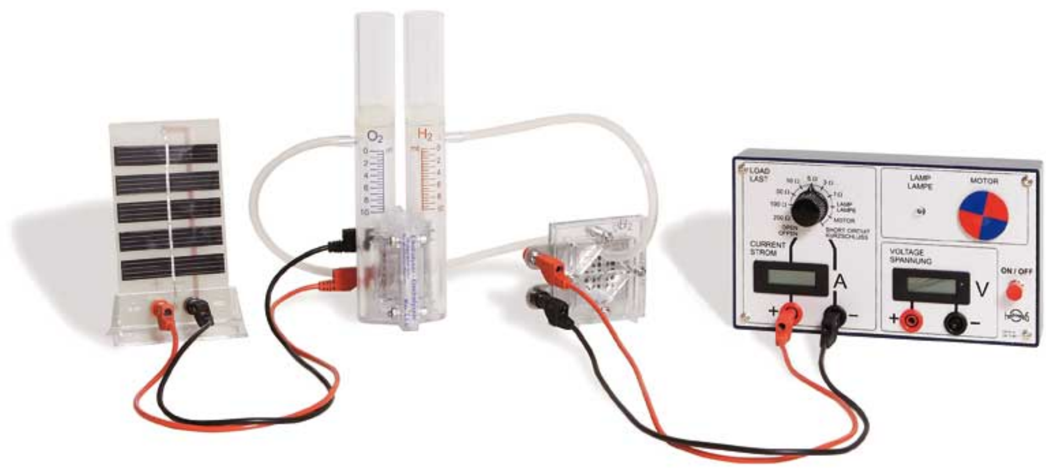
Microgrids Could Provide Connecticut Towns and Cities with Additional Educational and Employment Opportunities

Community microgrids can enable community-based learning and attract R&D facilities as follows:

Introductory Science: Communities are recognizing the importance of making students more aware of energy and the way it impacts their lives, their communities and the planet as a whole. There would be an opportunity to make microgrids a learning resource for high schools and community colleges. For example, it is expected that fuel cells will be installed in multiple microgrids in Connecticut. A desk top fuel cell learning kit and curriculum to be used for in schools is available (see attached photos) and could be used in conjunction with data from the full-scale fuel cell in a microgrid to provide learning opportunities. The course has curricular materials for both chemistry and physics experiments and can be adapted for local middle and high schools. Because Connecticut leads the world in fuel cell manufacturing, its schools should be encouraging more study of this technology.

Advanced R&D Opportunities: Community microgrids can provide two types of advanced educational opportunities. First, the microgrid will be generating data from its meters and measurement devices that will enable primary research and enhance opportunities for publication of results. Second, the microgrid can serve to plug-and-play new technologies. For instance, Nissan and other electric car manufacturers have expressed interest in plugging a fleet of cars to give and take power from micrograds. Similarly, Caterpillar has expressed interest in plugging in new engines and turbines that they can test at variable speeds within a microgrid.

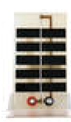
Energy Extension Service: Finally, there could be an extension service whereby outside energy users and workers could be educated at the State's private and public universities. For example, Trinity College is considering a service whereby Connecticut towns and cities that cannot afford an energy manager can send their engineers, attorneys and financial managers to learn about technical, regulatory and financial best practices for developing microgrids that use local renewable energy resources. An extension service could also provide training to electricians and technicians in how to assemble microgrid components and how to operate a microgrid.



Components

The components of the Dr FuelCell® Science Kit can be used in various ways for instruction.

Solar panel



The 5-cell photovoltaic module is used for experiments in solar energy and for generating electric energy for the hydrogen generator. The practical base facilitates alignment to the light source.

Fuel Cell

The fuel cell generates electrical energy from hydrogen and oxygen. It is based on PEM technology, which is the most widespread technology used in the development of fuel cell applications, e.g. for motor vehicles or stationary power supply systems.

Take-apart fuel cell

The take-apart fuel cell makes it possible to examine the functions and the design of a fuel cell in detail. A plug -in resistor, an electrode with reduced catalyst quantity and an air panel for air instead of oxygen operation enable in-depth experiments.

Electrolyzer

The electrolyzer separates water into hydrogen and oxygen. It is operated with distilled water and requires no caustic solutions or acids. The integrated graduated hydrogen storage cylinders visualize the classic hydrogen separation experiment, as in the Hoffmann apparatus.

Load measurement box

The convenient and compact load measurement box is used for recording data during experiments. Integrated consumers, such as a motor, a lamp and 7 selectable resistors, enable numerous experiments, e.g. recording characteristic curves, or current and voltage.

Methanol fuel cell

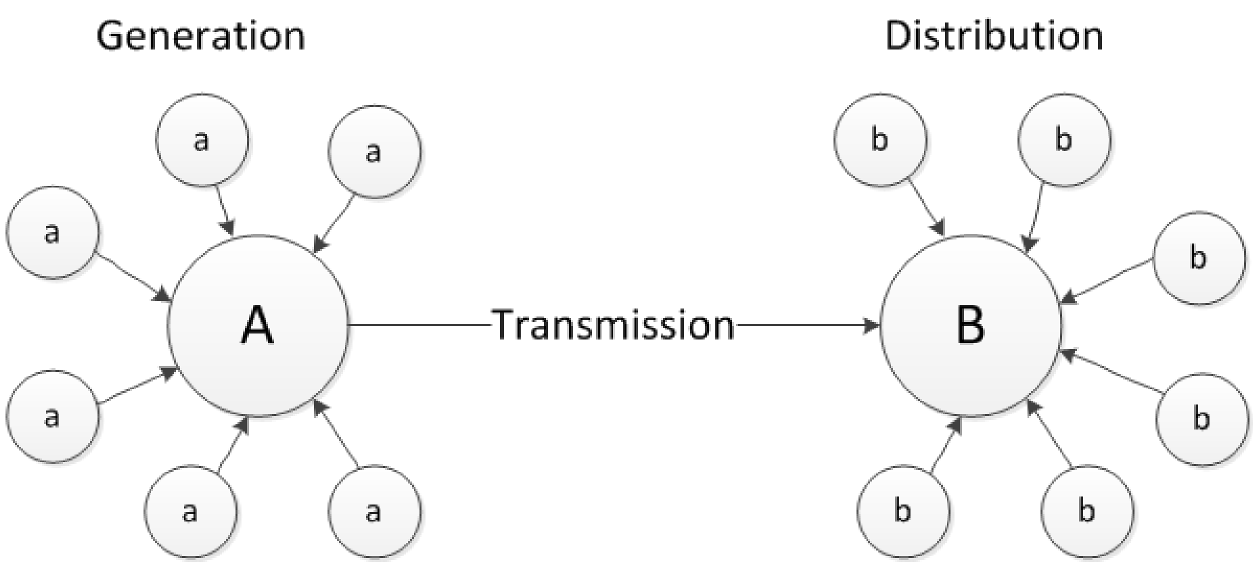
The methanol fuel cell uses methanol instead of hydrogen to generate electrical energy. This makes it possible to conduct more extensive experiments. The package includes storage cylinders for storage of the methanol solutions.

THE DIFFICULTIES OF INTERCONNECTING MICROGRIDS WITH THE UTILITY DISTRIBUTION SYSTEM

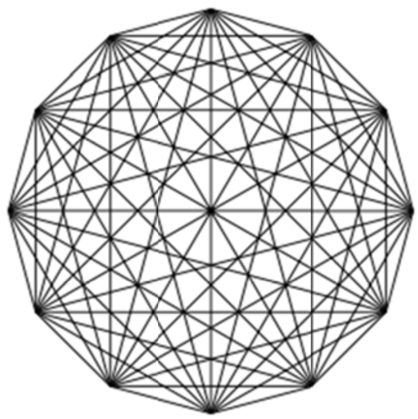
Distributed generation cannot interconnect to medium voltage utility distribution system in the same way that telecommunications devices and computers plug-and-play with telephone exchanges and the internet or large merchant generators and even some microgrids interconnect to high-voltage transmission grids.

Whether considering a telecommunications, computing or electrical network, there are differences in the degree of centralization. The most centralized topology is called a star network where all links go through the same node. On the other hand, a so-called mesh network is much more decentralized because each node is connected directly to every other node.

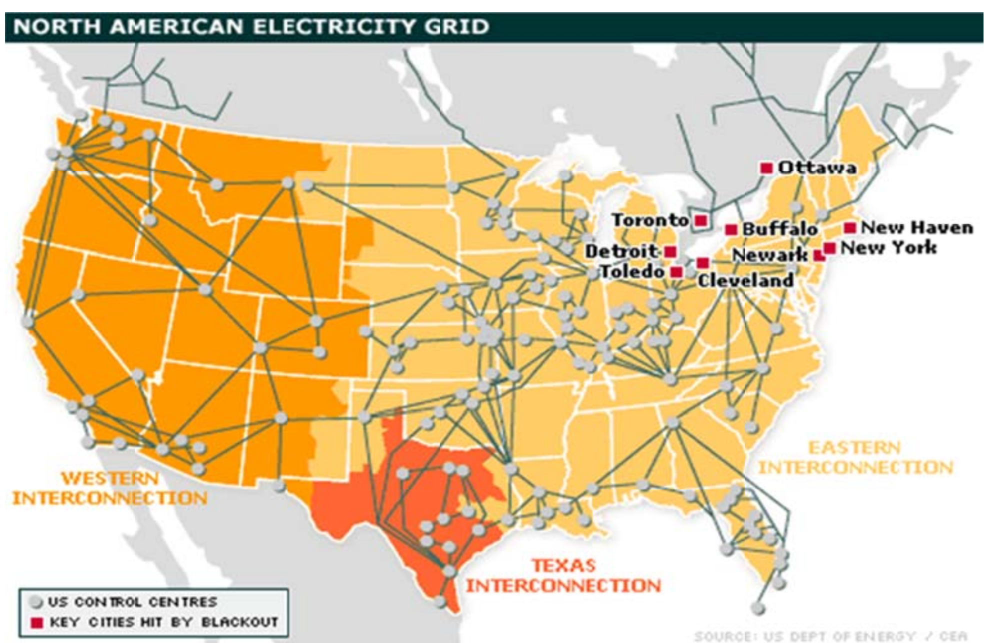
The diagram below is a simplified illustration of the initial electric network that served US cities in the 1920s. Notice that all exchanges between each object in this network go through two star networks with the central nodes, A and B. The small "a" nodes represent electric generating facilities. The line from A to B represents high-voltage transmission wires. The B node includes a step-down transformer and a substation and the small "b" nodes are individual end users of electricity. This is too simple a representation of the current US electrical network because starting in 1927 the generation and transmission topologies were no longer purely a star network as shall be seen shortly.



Modern telecommunications and computing systems typically organize as a mesh network as illustrated in the figure below. A mesh network can be designed using a routing technique that allows for continuous connections and reconfiguration around broken or blocked paths, using self-healing algorithms. The self-healing capability enables a routing-based network to operate when one node breaks down or a connection goes bad. As a result, the network is typically quite reliable, as there is often more than one path between a source and a destination in the network. Most telecommunications and computing networks are self-healing mesh networks.



Starting in 1927, the North American electric generation and transmission networks began to be engineered more as a mesh network, resulting in the nationwide system shown below. Note that this illustration also illustrates a case where self-healing algorithms ran out of pathways during the power outage of August 2003.



Therefore, in the North American transmission system, electricity can use multiple paths to travel from one location to another. Furthermore, electricity can flow two ways in transmission systems. This structure allows high-voltage transmission systems to accommodate generation sources from multiple locations. On the other hand, medium voltage distribution systems still resemble star structures that radiate outward from substations to end users and transmit electricity only one-way. Known as a "radial" and “loop” networks, this topology is used in 80% of all distribution systems worldwide and 99% of distribution systems in the U.S.

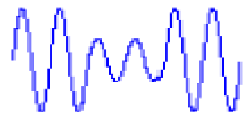
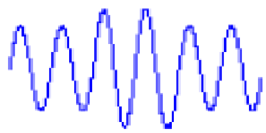
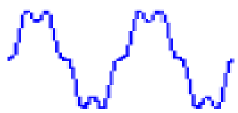
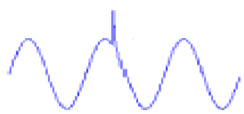
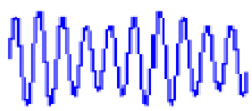
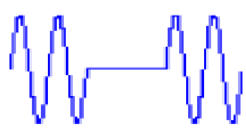
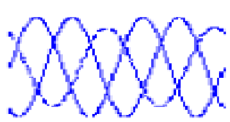
Such topological differences between the transmission and distribution systems are part of the reason why interconnections between merchant plants to the transmission grid appear technically easier than the interconnections between smaller-scale distributed generators and the distribution grid. Distribution utilities have a legitimate concern about maintaining system stability when too much of power enters the system below the substation level (the “penetration depth” issue), and about the fault current contribution of a microgrid to their grid, especially the extent to which microgrid fault currents could electrocute line workers during a grid outage or damage substations.

Consequently, most states have prudently and correctly restricted the interconnection of a large amount of distributed generation to utility distribution grids, such that when the utility grid experiences an outage, the microgrid must shut down also. This greatly reduces the reliability benefit of microgrids for the customer and curtails their adoption to address security and reliability needs of critical infrastructure.

Synchronizing microgrids in a high-voltage transmission network is complex and expensive and proposals to rebuild distribution network to do so are not realistic

On the high voltage transmission networks, engineers have successfully installed two large synchronized microgrids in New York City and a 50 MW microgrid to serve the US Food and Drug Administration in White Oak, Maryland, each of which has demonstrated the ability to operate during grid outages. Reportedly, the University of Connecticut also has a microgrid interconnected at high-voltage that seems to have remained operating during last year’s storm-related power outages. Whereas a microgrid that can produce power at below grid rates will generally cost less than $5,000 per KW to build, synchronized microgrids interconnected at high voltage have cost at least 40 percent more. These microgrids also required lengthy and expensive interconnection applications to the grid utility companies. Finally, these microgrids do not have the ability to add new modules without completing new interconnection applications.

Many proposals for re-architecting distribution grids to behave more like transmission networks for controlling and dispatching distributed generators do not seem realistic. The chart below shows all of the distribution system disturbances that may now lead to disconnections and that would have to be accounted for in a distribution grid that could control and dispatch distributed generation.

Disturbance		Origin	Consequences
Voltage sag undervoltage 2.2		Short circuits in the network grid passing or on another radial. Start up of large motors	Disconnection of sensitive loads Fail functions.
Voltage swell Overvoltages 2.3		Earth fault on another phase Shut down of large loads Lightning strike on network structure Incorrect setting in substations	Ageing of insolation Disconnection of equipment May harm equipment with inadequate design margins
Harmonic distortion 5.2-5.3		Nonlinear loads Resonance-phenomena Transformer saturation Notches	Extended heating . Fail function of electronic equipment
Transients 1.1-1.2		Lightning strike Switching event	Insulation failure Reduced lifetime of transformers, motors etc.
Voltage-fluctuations/ flicker 6.0		Arc furnaces Sawmill, crushing mill Welding Wind turbines Start up of large motors	Ageing of insulation Fail functions Flicker
Short duration interruptions 2.1		Direct short circuit Disconnection False tripping Load shedding	Disconnection Disconnection
Unbalanced 4.0		One phase loads Weak connections in the network	Voltage quality for overloaded phase Overload and noise from 3-phase equipment

Non-synchronous microgrid technologies adopted by the Stamford Energy Improvement District and approved by Connecticut Light & Power seem to hold promise for microgrids that can easily meet with utility company approval, add distributed generation modules without the need for new interconnection applications, and generate power at costs below utility grid rates

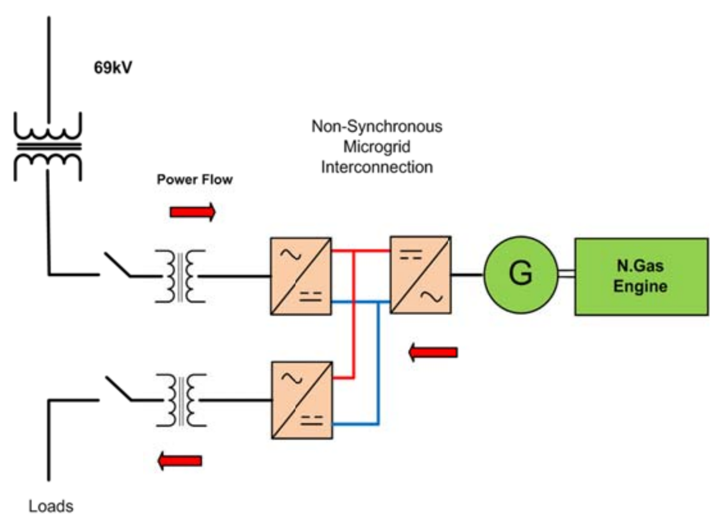
Having confronted all the limitations of interconnecting and synchronizing a microgrid with the utility distribution system, the Stamford Energy Improvement District decided to propose a new technology called GridLink that uses AC to DC to AC power inverters based on recent innovations in power electronics. GridLink technology opens up the feasibility of non-synchronized microgrids that are much more affordable to build and operate. Note that

Connecticut Light & Power approved the approach for a microgrid to serve the Stamford Government Center proposed by the Stamford Energy Improvement District. The utility distribution grid will see a non-synchronous microgrid not as generation, but as a simple resistive load. Adding the microgrid therefore appears to the utility in the same way that it sees a building control system, i.e., as a reduction in load. As such, distributed generation modules can be added to a non-synchronous microgrid without the need for new interconnection applications. In addition to CL&P, three other utilities have approved non-synchronous microgrid architectures and the utility company trade association for Edison Electric Institute expressed its interest in the Stamford EID's work as follows:

> *"The marriage of smart grid (SG) technologies with distributed energy resources (DER) has the potential to change fundamentally traditional utility operating paradigms, and the utility business. This has become more pressing as public policy encourages the development of DER owned by customers and third parties. We think it is vital, therefore, to understand the implications of these new technologies and policies. We have identified your project work in Stamford as among the cutting-edge demonstrations in this area. We believe your perspectives and experience can contribute significantly to building a knowledge base about pilots that demonstrate the integration and interoperability of multiple types of DER at multiple levels and establish frameworks for stakeholder collaboration and participation by new market players. Of particular interest to EEI are your innovative governance structure with Energy Improvement Districts and the "GridLink" technology that enables a safe connection between a microgrid and a traditional grid. These innovations represent significant sustainable economic development assets."* EEI, May 6, 2011

Non-Synchronous microgrids can insulate the utility grid from both local generation and local loads.

As illustrated here, a non-synchronous microgrid takes over the service to a customer's loads, integrating local power sources while still keeping them fully connected to their utility feeds. Once the GridLink technology is cut-and-spliced into the distribution line, no power ever flows directly from the utility grid to the loads. Utility feeds are treated equally with any local sources of power, and flow through the microgrid's inverters before connecting to customer loads.



A non-synchronous microgrid approach means no impact on utility systems and a true plug-and-play "interconnect anywhere" approach. Furthermore, a non-synchronous microgrid will stay up, regardless of disturbances or black-outs on the utility grid. Whether the on-site resources are cogeneration, waste-to-energy, large-scale solar, or any other local resource that provides cost, environmental, or reliability benefits to an end-user, non-synchronous microgrids enable utility integration without any operational restrictions.

Other benefits of non-synchronous microgrids are as follows:

- Once a microgrid is in place, additional local power resources can be added, without any impact on the utility interconnection.
- The same power electronics that provide a non-synchronous utility inter-connection, also provide important power quality improvements, essentially functioning as a whole-building or even whole-campus UPS system.
- Microgrids using GridLink can supply "ancillary services" to the utilities such as dynamic VAR, power factor correction, voltage support, and frequency regulation to help them stabilize their local distribution grids.
- Siting microgrids at the spots on the grid with the highest marginal cost of increasing power supply can cut losses to utility shareholders and ratepayers. That is, the utility will avoid providing power at rates that on the margin at some locations will be higher than their allowed rate under their duty to serve.

CONSIDERING UTILITY COMPANY BUSINESS MODELS TO BETTER ENCOURAGE MICROGRIDS[2]

From a business model point of view, the utility grid should be considered as an evolving bundle of property rights that, due to technological advances, have been gradually transferring from utility monopolies to non-utility stakeholders

A property rights regime regulates relations among users of a resource by allocating certain rights and duties with respect to access and use of the resource. Technological innovations tend to cause changes in property rights regimes over time. Some years ago, for example, advances in wireless communications technologies have caused a change in the property rights regime over access to and management of bandwidth. The Federal Government used to allocate bandwidth with exclusive-use licenses but now bandwidth tends to be managed collectively by its users as a common pooled resource. This change in property rights unleashed new applications of wireless technologies such as cordless phones and wireless home networks.

Similar changes in property rights regimes have been unfolding in the US electric industry. For example, technological trends between the early-1900s until the mid-1970s justified the concept of natural monopoly in the generation, transmission, and distribution of electricity. Since 1978, however, a number of federal and state laws and regulations have diluted the rights of natural monopolies to regulate access to the grid and invited new non-utility players and organizations to take a stake in electricity production and high-voltage transmission. By contrast, the technological impediments to interconnecting and synchronizing distributed generation at medium voltage have meant that the rights to access and manage the distribution grid in most areas has remained within the exclusive service territory of local utility monopolies. They should: it comes down to a safety issue where no one would argue about utility control, especially when it comes to protecting the lives of line wokers.

Now, there have been advances in microgrid technologies for safely interconnecting microgrids to the utility distribution networks. As noted above, these innovations have coincided with concerns about the reliability, cost and environmental footprint of centralized utility grids. Many analysts now believe that this portends a change of business model for utility distribution companies that resembles similar changes when decentralized telecommunications and computing technologies emerged.

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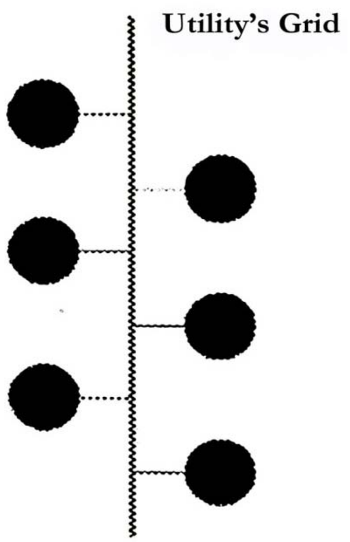
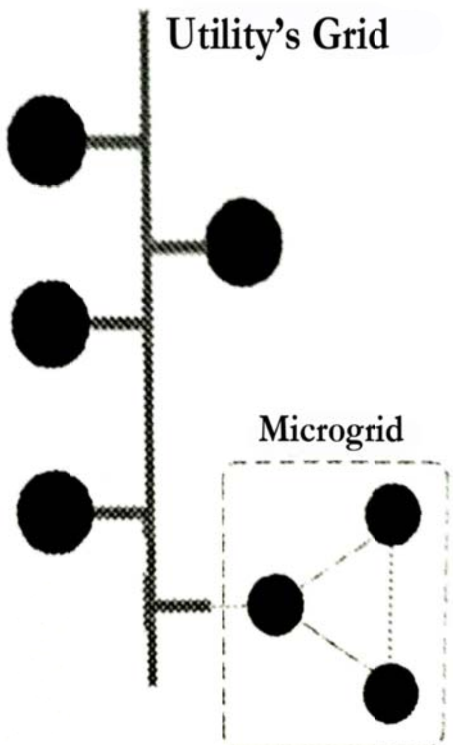
[2] Note that this section excerpts from research done at the University of California Santa Cruz and is used with permission of the authors. See the full Santa Cruz research report at www.distributedenergysolutionsummit.com.

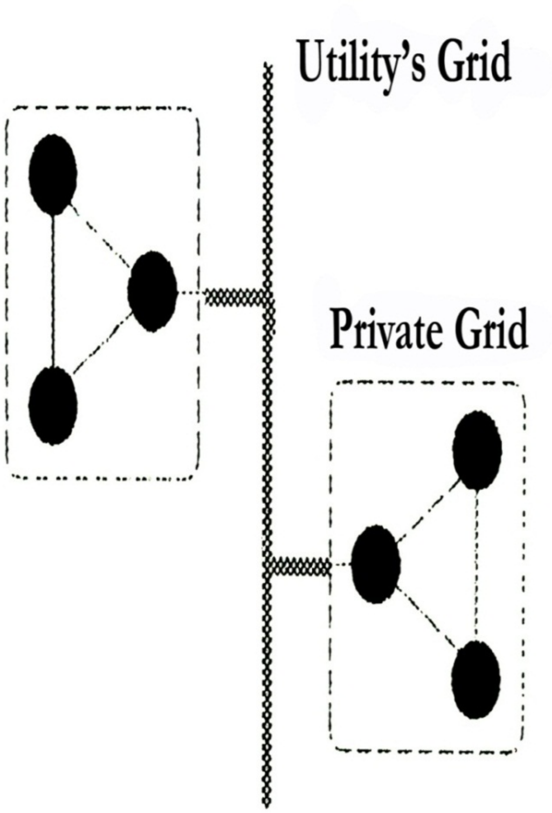
Some past and possible future changes in property rights regimes for electric power service have been considered with illustrations below:



The diagram to the left illustrates the connection of independently owned generators at the transmission level. In 1978, PURPA opened the way for privately owned and managed generation. Likewise, in many areas such as Connecticut, FERC Order 2000 and state-level deregulation resulted in non-utility ownership of generation and transmission that is owned by the utilities but with rights of access and use governed by a Independent Regional Transmission Operator. Note that in Connecticut utility shareholders were provided stranded asset compensation for the change in property regime and still earn a rate of return on transmission assets that are on the utility's rate base but independently governed by regional transmission operators.



Note that in some areas, microgrids have been interconnected to the transmission system. While some of the more published examples such as the large microgrid serving University of California San Diego have gone down for many hours during grid outages, others such the microgrid serving the US FDA labs at White Oak, Maryland have synchronized. In Connecticut, the microgrid serving the UCONN Storr's campus is reportedly connected at high voltage and appears to have provided power during last year's storm-related outages. Due to complexity and cost of synchronizing with the utility grid, these types of microgrid cannot usually provide power at below utility grid rates.



The emergence of technologies such as non-synchronous microgrids may open the way for privately owned and managed microgrids with seamless interconnection to the utility distribution grid. Legally, the right to private microgrid networks has been established by state laws or court rulings in New York, California, New Jersey and Pennsylvania.

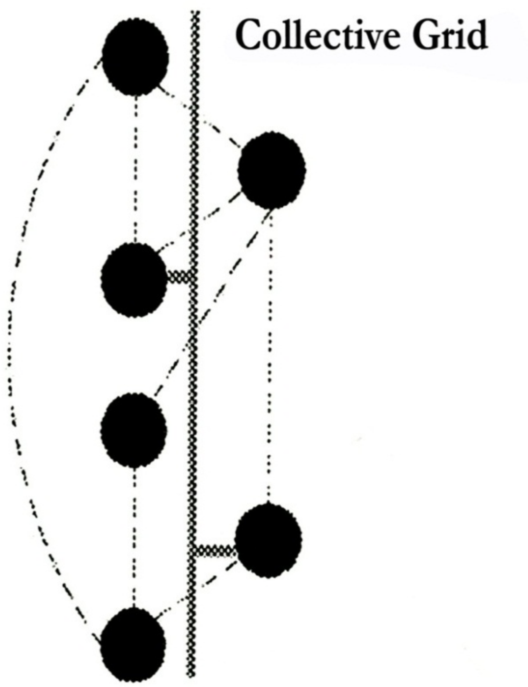
In Connecticut, Chapter 597 of the State Statutes, entitled the Electric Cooperative Act and passed in 1971, may be seen below. It appears to enable a group of energy users to organize as a cooperative and, with PURA approval, provides the cooperative the right, "to construct, maintain and operate electric transmission and distribution lines along, upon, under and across publicly owned lands and public thoroughfares, including, without limitation, all roads, highways, streets, alleys, bridges and causeways…"

Excerpts from Connecticut Electrical Cooperative Act

Sec. 33-218. Definitions. "Cooperative" means any corporation organized under this chapter or which becomes subject to this chapter in the manner hereinafter provided, and "person" means any natural person, firm, association, limited liability company, corporation, municipal corporation, municipal utility, business trust or partnership.

Sec. 33-219. Purposes. Exceptions. Utilization of cogeneration technology and renewable energy resources. (a) Cooperative, nonprofit, membership corporations may be organized under this chapter for the purpose of supplying electric energy and promoting and extending the use thereof to persons (1) in rural areas or in any portion thereof occupied by such persons and not receiving central station service, and (2) elsewhere except that the supplying of electric energy to franchise areas being supplied on October 1, 1971, with electric energy, or to areas supplied on said date by municipal utilities, shall be permitted only with the consent of the holder of the franchise or the municipal utility.

(b) Notwithstanding the provisions of subsection (a) of this section, cooperative, nonprofit, membership corporations may be organized under this chapter for the purpose of generating electric energy by means of cogeneration technology, renewable energy resources or both and supplying it to any member or supplying it to, purchasing it from or exchanging it with a public service company, electric supplier, as defined in section 16-1, municipal aggregator, as defined in said section, municipal utility or municipal electric energy cooperative, in accordance with an agreement with the company, electric supplier, electric aggregator, municipal utility or cooperative.



There have been future visions of a collectively- owned grid with microgrid-to-microgrid connections in a mesh network. In this more radical case, all rights of access and management formerly owned by regulated utility monopolies would become collectively owned property referred to in the literature as a common pooled resource. Although there is no precedent for common pooled resources in the electricity industry, this form of property regime closely resembles the internet, in which no single party owns the network. Interstingly, the utility trade association, Edison Electric Institute has launched a working group, entitled "The Energy Internet," with seven utility members to consider new utility business models as customer-owned generation becomes more common. Note that in some sense the municipal utility serving Wallingford, Connecticut may be seen as a collectively managed grid. Details are sketchy, but this grid appears to have restored power with 24 hours after the storm-related outages last year, and it also integrates a microgrid serving Bristol Meyers.

Most studies about the adoption of distributed energy and microgrids conclude that the best business model is one in which the incumbent utility companies have an ownership share of the microgrid

To be equitable and promote an efficient adoption of new business models, a new property rights regime that transfers rights of distribution grid access and management now held by a regulated monopoly to diverse non-utility microgrid stakeholders must compensate utility company shareholders that invested under the expectation of the old property rights regime. A number of studies have been performed to show that the most efficient way to do this is to enable utilities to own microgrids that are managed by their users. However, when the State has enacted laws to enable Connecticut utilities to own and rate base distributed generation, the utilities have not done so. Also, the State has encouraged the development of a least-cost integrated resource plan in which the utilities have proposed very little distributed generation as a substitute for more expensive distribution system upgrades. This is somewhat discouraging given that CL&P worked so effectively with the Stamford EID to approve a non-synchronous technology for safely interconnecting microgrids.

THE TECHNOLOGY ISSUES

Can existing distributed energy systems that could not run during the storms be retrofitted such that run safely and continuously during power outages in the future?

There is substantial anecdotal evidence that during various power outages over the last three years, a number of the State's larger existing distributed energy systems could not island within a reasonable time after grid power outages to keep their facilities working. The Summit should develop evidence about the extent to which distributed energy systems serving Bradley International Airport, Central Connecticut State College, Wesleyan College, Yale University, Fairfield University, and several hospitals and industrial facilities can provide continuous power to critical users after a grid outage. Engineering solution providers attending the summit will report on their solutions for islanding large distributed energy systems in other locations.

What is the role in a microgrid of utility grid power, each type of Class 1 renewable resource, and Class 3 combined heat and power resources and how can they be optimally dispatched and controlled?

The State has made a considerable investment what it calls class 1 renewable energy. In a microgrid, this would include fuel cells, building integrated solar and wind, and generation with gas or biomass from certain waste streams. The first three resources are much less useful for reliability either because they are intermittent or because they cannot efficiently follow peak loads. The use of waste gas or biomass that can follow loads has either met with community resistance or is unavailable due to long term contracts for shipping waste out of the community. Therefore, it is reasonable to assume that the core of any microgrid that can follow loads and provide a high-degree of reliability will be natural gas. Historically, however, certain locations have experienced gas shortages in the winter so it will be worth discussing the extent to which microgrids will be exposed to an unreliable gas network.

Can a city-center microgrid be safely interconnected with a medium voltage utility distribution grid?

As discussed above, the inability of distributed energy systems to interconnect and synchronize with the grid has been an impediment. The one solution accepted for use in Connecticut has not yet been implemented in a working microgrid. Engineers at the solutions summit should consider if there are other working alternatives and, if not, the extent of the risk in developing pilot projects that depend on non-synchronous interconnection.

What types of pilot projects are technically optimal?

In other states, distributed generation developers are working hand-in-hand with utility companies to identify spots on the utility distribution grid that are exposed to outages and/or have very high marginal costs for traditional distribution system upgrades when compared with the alternative of installing a microgrid. At the Summit, it will be important to discuss ways that optimal microgrid projects can be targeted with utility company information such that the State's integrated resource plan can become much more specific about the amount and location of distributed energy resources.

THE LEGAL ISSUES

What legal personality should a microgrid take? Energy Improvement District? Municipal Power Entity? Electrical Cooperative? How do these solutions compare with calls for a State Power Authority?

Officials of the Stamford and Bridgeport EID's will attend the Summit and provide information about their efforts to legally enable peer-to-peer microgrids. It will be important to explore the reasons why the utility companies did not take advantage of state laws that allowed them to own a large amount of distributed generation. The electrical cooperative law seems to have been largely ignored by microgrid proponents so it will be interesting to explore ways that it might be amended, especially in ways that develop win-win-win deals for cooperative members, non-member energy users and utility shareholders. With respect to a role for the State, the Delaware, Vermont and District of Columbia sustainable utility models will be considered.

Can a microgrid legally distribute energy within a utility company franchise area, especially where wires cross public rights of way?

The Summit will explore several of the arrangements in other states that have met with utility company approval.

As distributed energy results in a more decentralized power network and a change in the traditional utility business model, what lessons from the governance of decentralized telecommunications networks and the internet can be useful for the governance of microgrids?

When decentralized telecommunications and computing networks gained market penetration, the leading developers tended to find new and mutually beneficial working relationships with the incumbent telephone and mainframe companies. These examples will be explored at the Summit to see what lessons they can impart for the relationship between microgrid users, EIDs and the utility companies.

What types of pilot projects are legally optimal?

The extent to which microgrids can be developed on academic and commercial campus facilities should be addressed because these systems tend to avoid the issue of wires across public roadways within a utility franchise area. On the other hand, a legally sound approach for connecting energy users across roadways in a dispersed town center so they can better operate during power outages should be discussed given the State government's aspirations for this type of microgrid.

THE FINANCIAL ISSUES

What is the best way to fund the early stage microgrid designs necessary to secure project financing? What lessons can be learned from proposals for public-private infrastructure banks that would provide such funding?

The design work to determine if a microgrid is technologically feasible and economically financeable usually amounts to 8 to 12 percent of total microgrid project costs. This would amount to between $200 and $500 per megawatt. For a typical four megawatt town center microgrid, these early-stage costs could be between $800 thousand and $2 million.

Aside from a handful of developers willing to take the risks and some useful grants from the Connecticut Clean Energy Fund, there has not been an easy way to cover the pre-project financing design expenditures. An infrastructure bank proposal being implemented in New York State and a revolving loan fund will be considered. This may be the most useful application of the $300 million microgrid funding being proposed by the Connecticut Senate. A successful microgrid project in Connecticut should enjoy an internal rate of return of more than 15 percent. In comparison with the State's cost of money, a revolving loan fund should be able to charge a high enough rate to overcome the microgrids that do not prove feasible to build and/or finance.

Are there solutions that could help energy users avoid having their commitments to buy power from a microgrid recorded as a liability on their books? In this context, is there a role for the State to pre-buy power or for the utility company to rate-base microgrids?

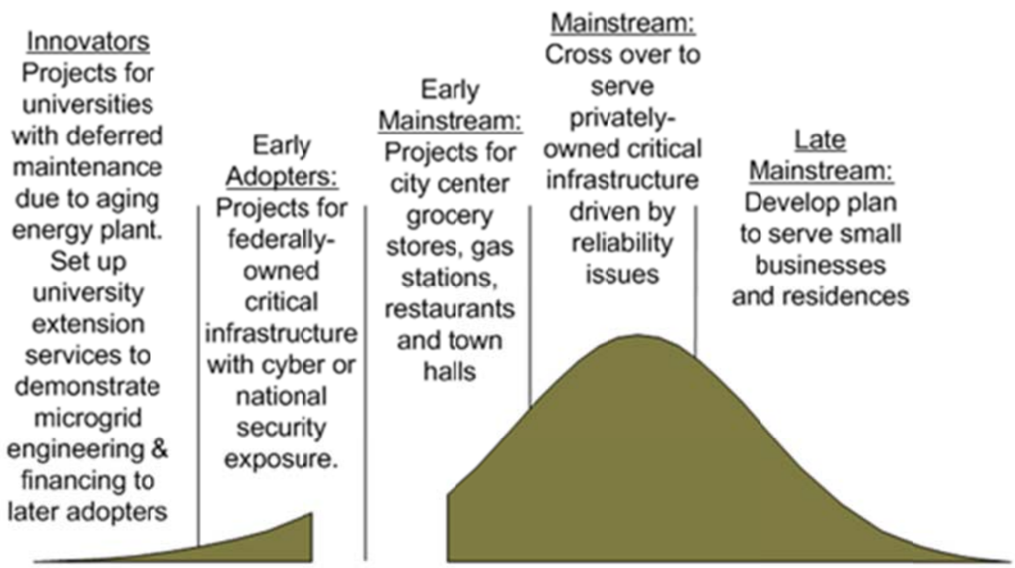
The Financial Accounting Standards Board is likely to enact new accounting rules whereby microgrid customers that commit to long-term purchased power agreements would have to include the discounted amount of those commitments as debt liabilities. That possibility will greatly curtail the amount of microgrid adoption. Therefore, the Summit will explore ways to structure microgrid financing to avoid this accounting treatment.

What types of projects have the best opportunity of being financed? How do a group of microgrid users, an EID or a municipality develop a Request for Proposal ("RFP") for designing, building and operating a microgrid? What type of RFP would elicit responses with the best opportunity of financing?

One of the difficulties of EIDs has been to develop requests for proposals of sufficient technical detail to elicit high quality offers from developers to design, finance, build and operate microgrids. Banks attending the Summit will provide some feedback on the types of microgrid projects that have the best chance of being privately financed. The role of utility or state pre-purchased power contracts for microgrid output will be considered as an alternative for microgrid project financing.

GETTING STARTED: A PATHWAY FOR PILOT PROJECTS

As seen in the graphic below, the broad-based adoption of microgrids envisioned by the Governor and State Senate will emerge more readily when some segments of early adopters demonstrate affordable and safe interconnection technology and prove out a mutually beneficial business model with the utility companies. These early adopters will have demand drivers in addition to reliability such as deferred maintenance, cyber and national security, and LEED/Green buildings.



Around the world, universities have consistently proven to be microgrid first adopters. In Connecticut, UCONN, Yale, Wesleyan, Central Connecticut State and Fairfield have a significant amount of distributed generation installed. The State could take a lead role by working with the US DOE Northeast Clean Energy Applications Center to issue a Request for Proposal for retrofitting one or more of the university systems that could not readily island to provide power during last year's storms.

For the next three market segments along the adoption curve – federally-owned critical infrastructure, town centers, and privately-owned critical infrastructure – there are indications that these types of energy users will adopt next but there are very few existing projects of this type installed in Connecticut.

For the Federal sector, poor energy reliability has frequently been mentioned in consideration of closing the Groton submarine base. Although there seems to have been little support at the base command level for a microgrid, it is likely that a proposal to Thomas Hicks, the US Navy Deputy Assistant Secretary of Energy would be worthwhile.

Again, working with the US DOE Northeast Clean Energy Applications Center, the Groton Municipal Utility would have the right to propose a sole source contract to develop a microgrid under the Federal Energy Management Program. Some of the solutions providers and banks participating in the Trinity Solutions Summit have perfected agreements whereby the Navy's commitment to buy power from a microgrid for the base would not be recorded by the US Office of Management and Budget on the Navy's budget. The US Coast Guard Academy might be another Federal location that would host a microgrid.

With respect to City Center projects, Bridgeport and Stamford with established EID boards would be ideal first locations. EIDs would provide substantial project financing capabilities in floating a bond to pre-buy power for the microgrids. Microgrid users could be organized as a Connecticut Electrical Cooperative to enable the construction and use of a distribution network. Similarly, with respect to privately-owned critical infrastructure, the Stamford EID would have a financing advantage and projects to serve the two large trading floors, the hospital or the re-development of the old Clairol plant would be possibilities for microgrid pilots. The Bridgeport EID also has several projects on the drawing board.