# Fuel Cell Distributed Generation: Cost, Value, and Market Potential

Connecticut Center for Advanced Technology
Joel M. Rinebold
Paul Aresta
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**Abstract**

This paper identifies the economic drivers and potential market factors for the use of high efficiency fuel cell distributed generation (DG) in Connecticut. The use of fuel cells for DG sized from 200 kW to 20 MW is assessed for cost, value, and market acceptance. The analysis addresses hard tangible values for consumer electricity, grid power, and thermal energy from a combined heat and power (CHP) application. This analysis also addresses consumer value for reliability and public value for environmental performance.

**The Historic Grid Model**

In the US, centralized electric power generation began in the early 1880s. The provision of power from utilities to consumers was reinforced in 1932 with the Public Utility Holding Act that provided utilities with an obligation to serve as a monopoly service provider in exchange for public regulation of electric power as public goods. At that time, technology efficiency and scale favored centralized baseload generation connected to consumers with transmission and distribution lines. However, with the Energy Policy Act of 1992, independent Non-Utility Generators were given access to the grid. Further, several states including Connecticut (Public Act 98-28 (1998)) began the process to restructure electric utilities by separating transmission and distribution from power generation and allowing independent competitive power companies equal access to the grid for sale of power to consumers and wholesale markets. With these regulatory changes and with advancements in technology, DG became economically viable especially when including the value of consumer reliability and reduction of costs associated with transmission and distribution.

These relatively recent regulatory changes that require competitive access to the grid now provide an opportunity for independent power producers to compete in wholesale and retail consumer markets. Moreover, consumers may produce electricity for their own needs and also sell surplus supplies to other consumers on the grid. The direct engagement of electric power generation by consumers does not diminish the need for the grid, but rather reinforces the public value of the grid necessary to balance a large and diverse supply of energy resources with consumer loads. With this competitive market, new and different energy resources, such as fuel cells, solar and wind technology, demand response, CHP, and energy storage have become available as both grid and consumer resources.

**Clean Distributed Energy and Market Potential**

*Loads and Resources:*

The awareness of the economic and reliability benefits of fuel cell technology as an advanced DG resource has grown and the cost of fuel cell technology has fallen leading to steady growth in the fuel cell manufacturing industry, which includes large and small original equipment manufacturers (OEMs) and supply chain companies located across the country. Stationary fuel cells are now providing stable power and thermal energy around the world at public and private facilities, including wastewater treatment works, food and beverage manufacturing plants, office buildings, telecommunication hubs, data centers, retail stores, universities, hospitals, hotels, government facilities, and other applications. On the utility side of the meter, large-scale fuel cell systems are being deployed to support the electric grid where transmission is constrained and/or where increased reliability is sought. Fuel cell systems are also being used to provide clean 24/7 power generation to complement the increasing deployment of intermittent solar and wind resources to support grid reliability.

Combined retail sales of electricity in Connecticut (2016), amounted to approximately 29 million megawatt-hours (MWh) for the residential, industrial, transportation and commercial sectors with over 36 million MWh of net generation.[1] Connecticut's load growth is projected to grow at a compound annual growth rate of 1.19 percent over the next ten years. In addition, retirements of older, less efficient generation facilities may put additional pressure on the electric grid. To meet this current and projected demand for generation capacity, Connecticut's residents rely on in-state centralized resources, local DG on consumer sites, and imports of power.[2]

Policy to support the deployment of renewable energy DG has been recognized by the State of Connecticut Department of Energy and Environmental Protection (DEEP) with recent energy procurements. In the 2018 Connecticut Comprehensive Energy Strategy, DEEP recognized the importance of expanding clean energy resources and the value that DG plays in the diversity of the electric system. In addition, DEEP has seen the benefit of utilizing competitive procurements to drive down the cost of clean energy resources for ratepayers and has proposed restructuring net energy billing as the best way to meet Connecticut's carbon reduction goals, and make DG pricing more equitable and transparent. DEEP evaluated six scenarios to determine what approach would provide the most cost effective results to support the growth of DG from 2020 to 2030 while also mitigating cost exposure to electric ratepayers. After evaluating the six scenarios, DEEP recommended an annual investment of $35 million for clean DG, which is the amount projected to best help Connecticut meet its energy and environmental goals, while also mitigating major cost exposure to ratepayers.[3]

In review of past decisions, DEEP has procured over 400 megawatts (MW) of small scale renewable energy and energy efficiency resources as well as over 400 MW of large-scale renewable energy projects, 90 MW of which will be located in Connecticut.[4] While the 90 MW (11.25 percent) of projects being procured in the state is of high value, Connecticut has lost an opportunity for increased local reliability, local construction jobs, and reinforcement of the local grid resulting from out of state development. Further, the lack of selection of fuel cells within the DEEP procurements has resulted in a substantial adverse impact to local fuel cell businesses and the state's economy. For every dollar of revenue generated by the hydrogen fuel cell industry through the manufacture and provision of fuel cell technology to meet load, an additional $.84 of revenue is generated by other Connecticut businesses[5]. Using this conservative industry economic multiplier of 1.84, the economic activity potentially produced by 310 MW of energy sources procured by DEEP but located outside of Connecticut, would have resulted in $1.24 billion of direct revenue and an additional $1.04 billion in indirect and induced revenue that could have been added to the state's economy[6].

*Reliability:*

The driver for DG can be internalized as insurance to maintain productivity without loss of business functions, products, data, and critical services. These functions can be identified as necessary services and could include: manufacturing facilities that can't withstand the loss of a production setup even for short durations; firms, which rely on data that if lost or corrupted would damage business opportunities;

[1] EIA, Connecticut Electricity Profile 2016; Table 1. 2016 Summary statistics (Connecticut), Release Date: January 25, 2018.
[2] This does not diminish the value of conservation and load management to reduce loads and minimize the need for new capacity.
[3] 2018 Connecticut Comprehensive Energy Strategy; Distributed Generation Cost Analysis.
[4] 2018 Connecticut Comprehensive Energy Strategy, p. 4.
[5] Final Report, Fuel cell Economic Development Plan, Hydrogen Roadmap, CT Department of Economic and Community Development, CCAT, 2008. Assumes a conservative industry revenue economic multiplier of 1.84.
[6] Based on an installed cost of $4000/installed KW.

and mission critical functions that include everything from health related services to banking, fuel supply, communications, and food/water supply.

In the U.S. the estimated annual cost of weather related storm outages is between $18 billion and $33 billion per year, with weather related outages in some years costing the economy between $40 billion and $75 billion. Connecticut was significantly impacted by: Tropical Storm Irene in 2011, which curtailed power to 800,000 customers; an October 2011 snow storm, which resulted in a record setting 880,000 customer outages; and Superstorm Sandy in 2012 that left over 626,000 customers without power.

The federal government recognized the value of investment in power technology to increase the resilience and reliability of the grid, and in 2013 helped secure $4.5 billion for investments in smart grid technologies through the Recovery Act. At the time, the Executive Office of the President further proclaimed "Developing a smarter, more resilient electric grid is one step that can be taken now to ensure the welfare of the millions of current and future Americans who depend on the grid for reliable power".[7] Recent legislation in Connecticut has supplemented these federal efforts with provisions and funding to support community "microgrids" that have internal power generation and the ability to "island" during grid outages. Several states have or are considering initiatives that include increased use of performance and engineering standards, improved planning, hardening of infrastructure, increased communications and collaboration, additional response training, and the use of microgrids and other emerging technologies to mitigate impact(s) on the energy grid infrastructure.

Fuel cells have been selected as the power supply in some microgrid projects to provide clean, Class I renewable energy to the microgrid.[8] Fuel cells operating as DG have a proven reliability record and can operate synchronous with grid resources with a capacity factor exceeded 95 percent[9]. These microgrid applications provide an opportunity for fuel cells to provide energy to the grid for grid customers and disconnect / island to provide power directly to defined users in the event of a widespread grid failure. Operation of a baseload dispatchable fuel cell in both synchronous mode during normal operation and non-synchronous mode during grid outage provides power resiliency, which is of high value during storm, cyber-attack, and other outage related events. The value proposition involves full baseload use of the fuel cell to provide power during normal operations thus contributing to energy needs rather than standing idle until needed as an emergency generator. This baseload operation contributes to energy supply capacity, voltage support, and frequency regulation in manner that also provides a positive daily cash flow for fiscal stability.

The notion of DG for energy reliability with procurement of energy resources has been further identified and recognized by the Connecticut General Assembly with Public Acts 13-303, 15-107, 15-113, and most recently with 17-144, An Act Promoting the Use of Fuel Cells for Electric Distribution System Benefits and Reliability and Amending Various Energy Related Programs and Requirements. Public Act 17-144, now being executed this year, authorizes the electric distribution companies (EDCs) to present a plan to the Connecticut Public Utilities Regulatory Authority (PURA) for deployment of up to 30 MW of grid enhancing fuel cells, and authorizes DEEP to procure energy from fuel cells, biomass anaerobic digestion, and offshore wind to enhance reliability of the grid. Execution of Public Act 17-144 includes a DEEP Request for Proposals ("RFP") to solicit offers for offshore wind, fuel cell, and anaerobic digestion

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[7] Economic Benefits of Increasing Electric Grid Resilience to Weather Related Outages, Executive Office of the President, August 2013.

[8] During the widespread grid outages experienced during the 2012 Hurricane Sandy event, all 23 fuel cell systems in the affected area remained in operation. In 2013, the City of Hartford was awarded a microgrid grant to connect mission critical facilities together as a microgrid with fuel cell technology selected to provide power for the microgrid.

[9] EPA, Catalog of CHP Technologies, Full Report, September 2017; Table 1-3. Comparison of CHP Technology Sizing, Cost, and Performance Parameters.

generation.[10] The proposals submitted in response to the RFP include four anaerobic digester projects in Connecticut with a combined capacity of over 4 MW; three offshore wind proposals with a combined capacity of over 590 MW; and 18 fuel cell projects in Connecticut with a combined capacity of over 230 MW.[11] On face value, the General Assembly is to be commended for identifying the values of both DG and fuel cells to provide power to end users and the grid. While the wind proposals are proposed to be located offshore of Massachusetts, the fuel cell and anaerobic digesters would be baseload facilities located in Connecticut and able to contribute to local reliability, job creation, and in the case of the fuel cell proposals, local manufacturing.

*Environmental Value:*

Connecticut and several other states have recognized the advantages of hydrogen and fuel cell technology in providing energy with reduced emissions, improved air quality, and favorable siting. These states have established policies to promote the adoption of hydrogen and fuel cell technologies and/or initiated collaborative efforts to accelerate adoption. Currently, Connecticut and 10 other states and Puerto Rico recognize fuel cells as a Class I renewable energy source for compliance with renewable portfolio standards (RPS) or alternative RPS requirements; another 17 states recognize fuel cells operating on renewable fuel as eligible to comply with their respective state's RPS. Also, several states including Connecticut have adopted formal "Roadmaps" to identify market drivers and incentives for preferred development of fuel cells.

Although it is understood that all commercial energy technology options must meet regulatory requirements, some states and energy consumers place a premium on zero and ultra-low emission energy generation technology. This external driver appears to be growing with preference by some states and consumers to support health and environmental causes, climate control, or corporate responsibility. Indeed, some states and municipalities have engaged in campaigns for carbon reduction and climate control; companies have considered high performance buildings with LEED construction[12]; and some health related businesses target clean energy technology for energy supply to protect campus air resources.

The manufacturers of fuel cell technology in Connecticut meet the challenge to provide power generation below regulatory standards for air emissions. As shown in Table 1, Doosan's PureCell® Fuel Cell System and FuelCell Energy's fuel cell systems are ultra-low emissions electricity generators that operate through an ultra-clean electrochemical reaction without combustion. Regulatory approval has been streamlined by Section 22a-174-42 of the Regulations of Connecticut State Agencies (RCSA) that governs air emissions from new DG which exempts fuel cells from air permitting requirements. Furthermore, these fuel cells systems are certified by the California Air Resources Board (CARB) to meet the Distributed Generation Certification Regulation 2007 Fossil Fuel Emissions Standards.

**Table 1: Anticipated Emissions for Fuel Cell Technology for Large Stationary Power Applications[13]**

| Emissions | CO2e | NOx | SOx | CO | PM |
|---|---|---|---|---|---|
| unit emissions rate *lbs/MWh* | 980 to 998 (less with heat recovery) | 0.01 | negligible | 0.02 | negligible |

[10] Notice of Request for Proposals from Private Developers for Clean Energy, January 31, 2018; Pursuant to Section 8 of Public Act 13-303, An Act Concerning Connecticut's Clean Energy Goals, as amended by Section 10 of Public Act 17-144, An Act Promoting the Use of Fuel Cells for Electric Distribution System Benefits and Reliability.
[11] DEEP Energy Filings; Procurement of Clean Energy and Renewable Resources Pursuant to Public Acts 13-303, 15-107 and 17-144; "Proposals"; April 18, 2018.
[12] Installation of a fuel cell can provide 4 to 6 points for LEED Certification.
[13] Doosan Fuel Cell America, PureCell Model 400 and FuelCell Energy, SureSource 1500 data sheets, April 17, 2018.

It is expected that some other states and consumers will follow this lead and encourage replacement of older generation facilities with newer, cleaner advanced fuel cell DG technology that can reduce emissions and improve air resources. The Northeast States for Coordinated Air Use Management (NESCAUM)[14] has supported Connecticut's planning efforts including the 2018 Connecticut Comprehensive Energy Strategy, which encourages the development and use of clean DG.

With low emissions, high density power, and a high capacity factor, fuel cells provide clean power and compact siting to meet grid and consumer loads. Siting is generally simple without sacrifice of large land areas and view sheds, or impact on ecological resources. In Connecticut, the ease for the siting of fuel cells has been formally recognized and provided a streamlined siting process through the Connecticut Siting Council (Connecticut General Statutes Section 16-50k).

*Industry Economic Profile:*

The economic value of the hydrogen and fuel cell industry has grown and is expected to continue to grow in global manufacturing markets. Research and Markets[15] reports that the global fuel cell market is poised to grow at a compound annual growth rate (CAGR) of 15.4 percent over the next decade to reach approximately $12.5 billion by 2025. In the Northeast, the hydrogen and fuel cell supply chain has a significant bearing on the region's economy, contributing over $1.4 billion in revenue and investment annually; more than 6,620 direct, indirect and induced jobs; and labor income of approximately $615 million in 2016/2017. This clean energy cluster provides an opportunity for the Northeast region to more fully utilize its research and development capabilities, manufacturing base, and financial markets to make the region a global showcase for advanced technology and clean energy business development. While this regional hydrogen fuel cell industry has exhibited some recent declines in OEMs and direct jobs primarily from a decline of the OEMs in Connecticut, the industry is moving from research to manufacturing, and appears to be on a positive trajectory with growth in supply chain members, total revenue and investment, total jobs, and total labor income. Overall, the hydrogen and fuel cell Northeast cluster is growing and will still have a substantial impact on the region's economy, as shown below:

**Table 2: Economic Impact of the Hydrogen and Fuel Cell Industry in the Northeast US[16]**

| | **Northeast Cluster Economic Data 2011** | **Northeast Cluster Economic Data 2016/2017** |
|---|---|---|
| **OEMs** | 30 | 26 |
| **Supply Chain Members** | 1,091 | 1,200+ |
| **Direct Jobs** | 2,135 | 1,940 |
| **Total Rev & Investment ($M)[1]** | $1,179 | $1,412 |
| **Total Jobs[17]** | 5,770 | 6,620 |
| **Total Labor Income ($M)[1]** | $449 | $615 |

[14] NESCAUM is a nonprofit association of air quality agencies in the Northeast that consists of the air directors from the New England states, New York, and New Jersey. NESCAUM provides scientific, technical, analytical, and policy support to administer the air quality environmental programs required under the Clean Air Act and other federal legislation.
[15] 2002 – 2018 Research and Markets.
[16] 2017 Economic Impact of the Northeastern Hydrogen Energy and Fuel Cell Industry, September 2017. Includes all the states in New England, New York, and New Jersey.
[17] Includes direct, indirect, and induced impacts.

*Local and Project Level Value:*

As discussed above, over 230 MW of fuel cell capacity has been proposed in response to the recent solicitation for clean resources by DEEP. On a project level, fuel cell power plants provide sales tax, property tax and local capital investment, and job creation unmatched by any other Class I resource. Further, the fuel cell industry is the only Class I resource that has a strong OEM presence and manufacturing supply chain in the region, with the cluster hub in Connecticut.

By example, the manufacture and installation of 50 MW of fuel cell power plants, in Connecticut provides:

- In-state capital investment of approximately $200 million;[18]
- Approximately $45 million in local property tax revenue over 10 years;[19]
- Approximately $5 million of investment in local electrical and gas infrastructure; and[20]
- Approximately 400 direct manufacturing jobs and an additional 800 indirect and induced jobs in Connecticut.[21]

While the Connecticut hydrogen fuel cell industry supply chain has recently declined primarily due to a decline of the OEMs in Connecticut, the industry still provides approximately $601 million in revenue and investment and over $31 million in state and local tax revenue to Connecticut (2016).[22] The reasons for the decline of the OEMs in Connecticut are not fully understood; however, some of the factors include competition from foreign OEMs, uncertainty of incentives and supporting policy to deploy fuel cells as Class I renewable DG and grid resources, and the high cost of doing business in Connecticut. With a long term commitment of investment, incentives, and supporting policy, it is expected that the hydrogen and fuel cell OEMs in Connecticut can rebound and again provide a lead for economic growth in the region and nation, and be recognized as the global manufacturing hub for the industry.

*Cost Comparison:*

The weighted average cost of Connecticut's Low Emission Renewable Energy Credit (LREC) program in 2016, which was primarily occupied by fuel cells, is approximately 77 percent less than the weighted average cost of Connecticut's Zero Emission Renewable Energy Credits (ZREC), which was primarily occupied by solar and wind projects. As shown in Table 3 below, this trend for lower cost LREC bids has been documented since the first year of the LREC / ZREC program in 2012 and is projected to continue into 2019. As shown in Table 4 below, this trend is expected to continue through 2030 and suggests that the overall costs of fuel cell technology (capital and operating) as a baseload unit (24/7) are less than the costs for wind and solar technologies that operate on an intermittent basis.

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[18] Based on an installed cost of $4000 per kW.
[19] Based on a $200 million investment*.30 mill rate* 75 percent assessed value = $4.5 million/year*10 years.
[20] Based on ten installations at $500,000 per project for gas and electric infrastructure.
[21] Indirect and induced impacts based on an industry employment multiplier of 3.0; 2015 Economic Impact of the Northeastern Hydrogen Energy and Fuel Cell Industry, January 2016.
[22] 2018 Hydrogen Fuel Cell Development Plan, Connecticut, NEESC, 2018.

**Table 3: Actual and Estimated LREC/ZREC Weighted Average Cost (Years 1-7)**[23]

| | Year 1 (2012) | Year 2 (2013) | Year 3 (2014) | Year 4 (2015) | Year 5 (2016) | Year 6 (Projection) (2018) | Year 7 (Projection) (2019) |
|---|---|---|---|---|---|---|---|
| LREC Prices ($/REC) | 66.86 | 53.05 | 56.15 | 50.46 | 42.57 | 41.33 | 41.33 |
| ZREC Prices ($/REC) | 133.23 | 95.36 | 71.59 | 67.57 | 75.53 | 73.34 | 73.34 |

**Table 4: Projected LREC/ZREC Prices – Average of All Sizes ($/REC) through 2030**[24]

| Projected LREC/ZREC Prices – Average of All Sizes ($/REC) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** |
| ZREC Prices | 73.15 | 84.29 | 82.42 | 83.39 | 80.61 | 74.67 | 69.75 | 64.92 | 58.22 | 50.11 |
| LREC Prices | 35.12 | 40.47 | 39.57 | 40.03 | 38.70 | 35.85 | 33.49 | 31.17 | 27.95 | 24.06 |

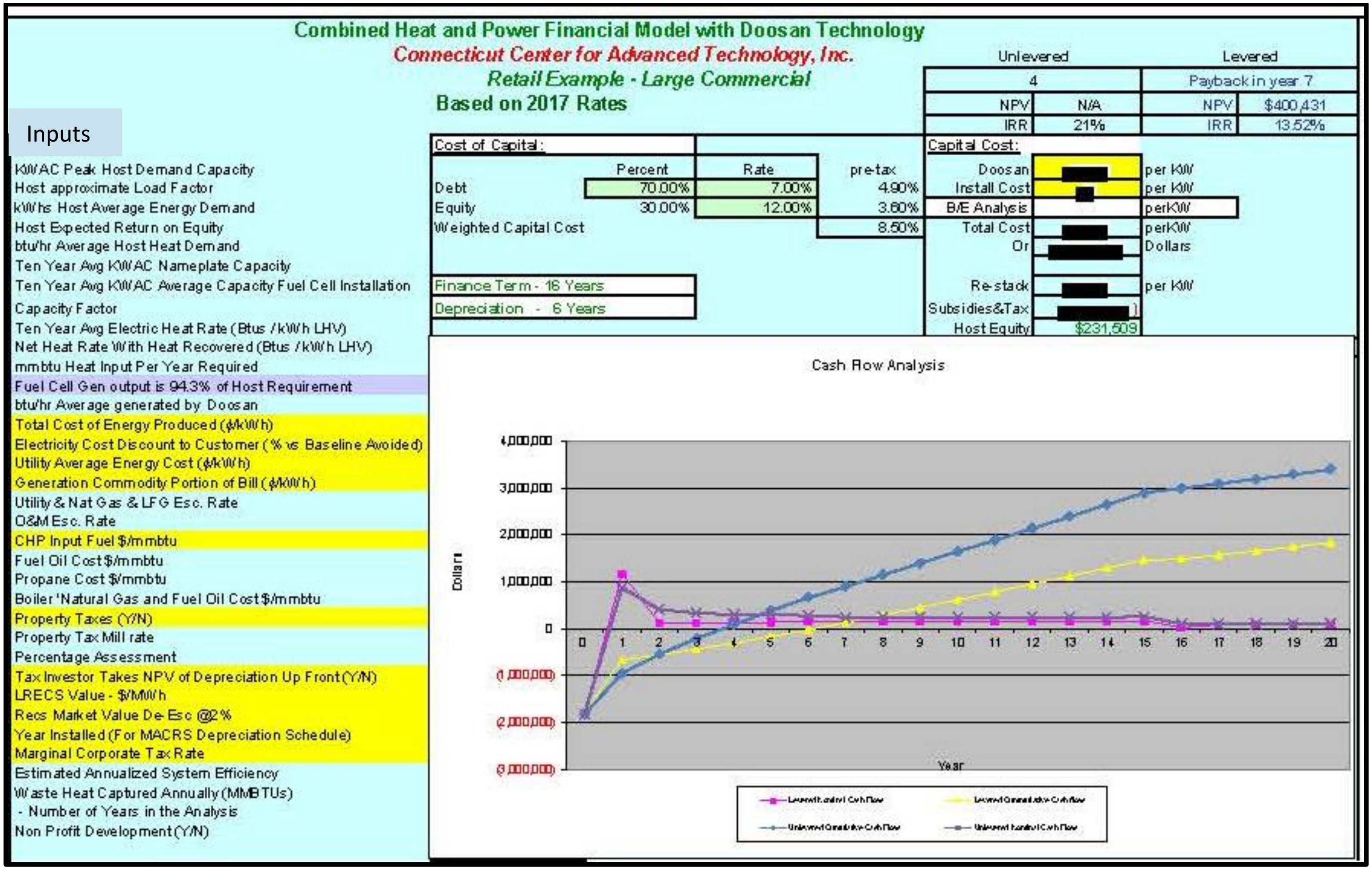
These confirmed and projected prices demonstrate the value of fuel cells to meet Connecticut's Class I RPS. The value to the ratepayers is substantially greater because fuel cells have a high capacity factor (95 percent) compared to wind and solar technologies with average capacity factors of 40 percent and 14 percent, respectively. Furthermore, fuel cell technology does not require additional generation, batteries, or other energy storage technologies to meet demand, unlike intermittent renewable sources.

*Market Acceptance:*

It is assumed that the driving factor for market acceptance of fuel cell DG power is availability, reliability, and cost relative to other alternatives including grid power. Cost is assumed to be a net cost after inclusion of all values for capital investment, operation and maintenance, and reliable performance to provide power for critical energy intensive activities. As an example, a cash flow analysis for a Doosan PureCell®400 (460 KW) is presented below in Figure 1. The capital investment, operation and maintenance costs, financing, and available incentives including RECs and LRECs, Federal Investment Tax Credit, and accelerated depreciation have all been accounted in the model presented below. In this cash flow proforma, a payback is achieved within 4 to 7 years depending on financing. This hypothetical model shows financial viability while also providing low emission energy, and perhaps most importantly from an economic standpoint, industry and tax revenues with job retention of a global manufacturing industry.

[23] 2018 Connecticut Comprehensive Energy Strategy; Distributed Generation Cost Analysis, Table 9, p. 8.
[24] 2018 Connecticut Comprehensive Energy Strategy; Distributed Generation Cost Analysis, Table 11, p. 9.

**Figure 1: Hypothetical Fuel Cell Cash Flow Analysis 460 kW**[25]



## Conclusion

Fuel cell DG technology provides a significant opportunity for Connecticut to increase use of cleaner energy directly at consumer and grid sites; increase energy reliability for the grid and consumers; and create opportunities for job creation and economic development associated with a world class industry poised to grow. When compared to other Class I renewable sources, fuel cells have lower costs for consumer energy, have a high capacity factor and reliability that negates the need for redundant backup power or energy storage, and can be located at or near grid and consumer loads with ease of siting and without significant adverse environmental impact. This technology also provides an opportunity for Connecticut to more fully utilize its intermittent renewable energy industry at consumer sites. Further, the Connecticut OEM industry has an opportunity to compete in the global market for the manufacture and deployment of advanced clean energy technology, which will bring dividends back to Connecticut in the form of jobs, revenues, corporate investments, in addition to clean and reliable energy. With these opportunities readily assessable, Connecticut can best continue combined implementation of existing policies to enhance energy reliability, environmental protection, and economic development through support of fuel cell DG.