NYSERDA Smart Grid Evaluation Case Study:
Micatu's Real-Time Voltage Sensors

Final

Prepared for:

NYSERDA

Albany, NY

Marsha Walton, Ph.D.
Project Manager

Prepared by:

Industrial Economics, Inc

Cambridge, MA

Daniel Kaufman
[Principal]

NYSERDA Contract #[104541] July 8, 2020

Notice

NYSERDA Smart Grid Program Case Study:
Micatu's Real-Time Voltage Sensors

Key Results

- $6 million awarded by NYSERDA
- Pilot project with Con Edison demonstrated a new application of Micatu's sensor
- Distribution contract signed with global distribution company Eaton
- Employment growth from 18 to 60 employees expected in 2020
    - Multiplier effect of 78 additional jobs in the New York State economy
    - $19.5 million in total value added to the New York State economy
- Potential CO_2e benefits of a utility-scale installation at a large New York utility:
    - Over 75,000 metric tons of CO_2e emissions avoided annually; 1.5 million metric tons of CO_2e emissions avoided over 20 years
    - $3.8 million in environmental damages avoided annually; $68.5 million in damages avoided over 20 years
- Increased safety for electric utility line workers

1. Introduction

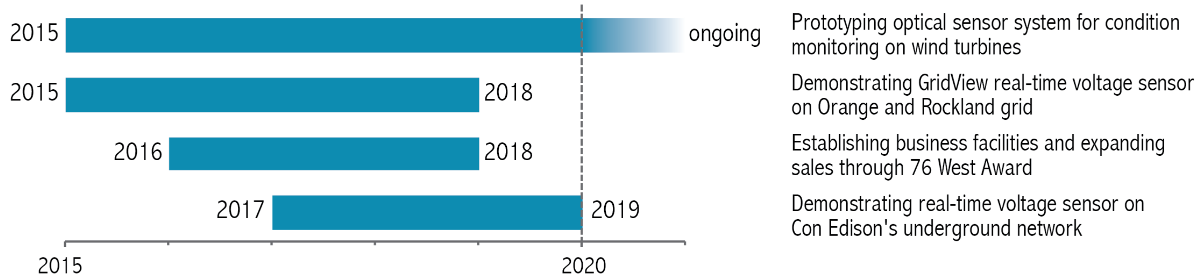
NYSERDA's Smart Grid program promotes modernization of New York State's electric grid by funding research and technology development projects that can be implemented at the utility scale. Through these projects, the program aims to:

- Increase grid efficiency by encouraging real-time data collection and management;
- Reduce costs associated with integrating renewable energy sources; and
- Improve the ability of the grid to predict, withstand and recover from power outages.

Examples of smart grid technologies include remote sensing devices for monitoring grid conditions in real-time, tools enabling two-way communication between a utility's operations center and various points on the grid; and automated controls for optimizing grid performance. These technologies and devices are relatively new and are evolving quickly.

Beginning in 2015, NYSERDA's Smart Grid program provided a series of awards to Micatu, Inc., through a competitive solicitation process that, in more recent years, was funded by the Clean Energy Fund (CEF). Micatu is an engineering product development firm that focuses on developing technologies to monitor power conditions on electricity lines. Micatu was founded in 2011 and is located in Horseheads, NY. Micatu received approximately $6 million in NYSERDA funding across four project awards (Exhibit 1). These awards supported the development and demonstration of a real-time voltage sensor that allows grid operators to monitor and manage electricity flows more safely, reliably and precisely.

Exhibit 1. NYSERDA Awards to Micatu



> "76West helped us get in front of academics and venture capital firms; it helped us get our name known."
>
> -Micatu

In particular, Micatu was awarded the $1 million Grand Prize for the inaugural 76West Clean Energy Competition, which provides financial and business development support to clean energy technology companies creating jobs in the Southern Tier region of New York State.[1] As a result of NYSERDA's funding, Micatu was able to grow its business and now sells the sensor developed through these awards under two names: GridView (for direct sensor sales through Micatu) and GridAdvisor Insight (for sensor sales through the global distribution company Eaton, a global power management and technology company that sells products in more than 175 countries).[2,3] Three of the four NYSERDA-funded projects, including the 76West award, are completed and one technology development project that monitors conditions on wind turbines is ongoing.

This case study summarizes the key benefits that resulted or are expected to result from NYSERDA's projects with Micatu, including business development, economic benefits, avoided CO_2 emissions, and increased safety. The information for this case study was collected through interviews with Micatu and two New York utilities (Orange and Rockland and Con Edison), review of Micatu's project materials, and research conducted by one of NYSERDA's independent evaluation consultants, Industrial Economics.

2. Overview of Micatu's Sensor and Pilot Projects

Micatu's sensor uses fiber optics to measure current and voltage in real time and eliminates the need for conventional current and voltage transformers. Utility operators depend on current and voltage measurements to ensure that the grid is operating as efficiently as possible while providing customers with high-quality power. Fluctuations in current and voltage can be caused by many factors, such as equipment failures, a misalignment between energy supply and demand, or weather. Because of the potential for unexpected fluctuations, in the absence of real-time data, utilities must generate "extra" electricity to ensure that fluctuations do not reduce power quality below the level required by their customers. Real-time monitoring of current and

[1] 76West Award information: https://www.nyserda.ny.gov/All%20Programs/Programs/76west
[2] Micatu product page: https://micatu.com/products/
[3] Eaton product page: https://www.eaton.com/us/en-us/catalog/utility-and-grid-solutions/gridadvisor-optical-sensor.technical.html

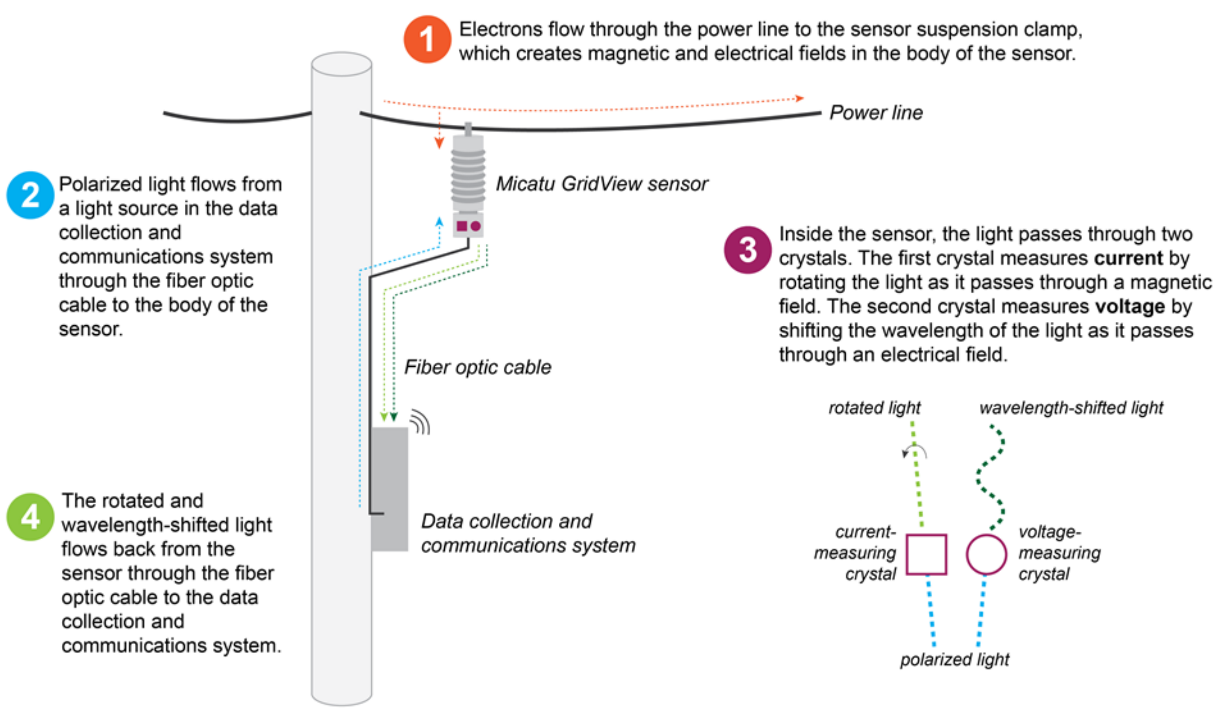
voltage – like that provided by Micatu's sensor – allows utilities to more closely match electricity supply to demand, thereby avoiding unnecessary generation and improving overall grid efficiency. By improving grid efficiency, sensors like those provided by Micatu can reduce a utility's operating expenses, equipment costs, unnecessary electricity generation and associated CO_2 and other greenhouse gas emissions.

> "It's not necessarily obvious on a single basis why the traditional transformers are not cost effective. But when… multiplied by a thousand poles across the system, and all the linemen required to maintain it, you can see how many dollars in O&M are in play that can be saved by using sensors."
>
> \- Orange and Rockland

An additional benefit of Micatu's sensor is increased safety for electric utility line workers. Because Micatu's sensor uses fiber optics (i.e., light) instead of voltage and current transformers to measure power flow, there are no conductive materials to put technicians at risk of electrocution.

Micatu's sensor is also designed to be easy for utilities to install. Unlike traditional transformers, Micatu's sensor is compact and lightweight and is designed to be hung directly on power lines. The sensor is compatible with existing utility monitoring and metering systems and does not require specialized software. Exhibit 2 illustrates the operation of Micatu's sensor.

Exhibit 2. Operation of Micatu's GridView Sensor



Source: IEc, based on interviews with Micatu and Orange and Rockland Utilities and Micatu project documents.

Micatu currently has pilot projects with five of the seven large utilities in New York State. Two of these pilot projects – one with Orange and Rockland (the utility farthest along with piloting Micatu's sensor) and one with Con Edison – are funded by NYSERDA. This case study focuses on these two pilot projects because they are the most mature and have been active long enough to have benefits to report at the time of the case study.

The pilot with Orange and Rockland Utilities allowed Micatu to analyze the sensor's performance under real-world conditions at the pilot site over multiple years and refine the technology accordingly, and then share the pilot's results with utilities across New York State. Orange and Rockland cited the experience gained from its Micatu pilot as instrumental in helping to determine the sensor technology that was most appropriate for its service territory.

> "We happen to have this test site which no one else has, so we can provide everyone else with data. This [NYSERDA-funded pilot project] was good money, and any further projects regarding experiments with sensing are definitely worth their dollars."
>
> -Orange and Rockland

Orange and Rockland ultimately decided not to adopt Micatu's sensor due to concerns about power quality monitoring precision, but noted that Micatu's sensor is preferable to competing technologies in other ways and would be ideal for applications where sensing is difficult or impossible with conventional technologies. Micatu continues to refine its sensor to improve its performance through ongoing pilot projects, including Orange and Rockland's pilot. Although Orange and Rockland ultimately decided not to select Micatu's sensor, the utility confirmed that it intends to keep Micatu's sensors installed at the pilot site and will continue to provide performance data to Micatu, as well as to the other New York State utilities. As Micatu continues to refine its sensor's performance and demonstrate its use in utility pilot-scale installations, other utilities in New York State and beyond may be inspired to establish (or expand upon existing) pilot projects.

> "Optical sensors have been useful for contact voltage sensing. There are a number of applications we see in this regard."
>
> -Con Edison

The NYSERDA-funded pilot project with Con Edison demonstrated a new application for Micatu's sensor and thereby helped Micatu expand its potential market. Con Edison installed Micatu's sensor (on a pilot scale) on its underground distribution network where the sensor must be able to withstand submersion in occasional flood waters.[4] Because of challenges like flooding and space constraints, traditional current and voltage transformers cannot be installed on underground networks. Micatu's sensor allows utilities to add sensing capabilities in underground locations not previously possible with existing sensor technologies. The pilot project with Con Edison is ongoing, and the sensor's potential underground application is advertised on Eaton's website.

The benefits of the sensors will be realized when a utility adopts the sensors at scale across its service territory. For example, environmental benefits would result from improved monitoring and response to conditions at the grid level, better matching of electricity supply and customer demand, and avoiding unnecessary electricity generation and associated emissions. Because utilities are still in the process of evaluating and potentially adopting the sensors at scale, this case study discusses the potential benefits in terms of a hypothetical installation across a utility's

---

[4] Oshetski, Michael, Paul Stergiou, Serena Lee, and Ryan Rausch. Con Edison Pilots Micatu's Submersible Optical-Sensor Platform to Enhance Grid Visibility. ENSC Magazine, Vol. 1, Ed. 2. Fall 2018. (19)

service territory to illustrate the magnitude of potential benefits. The following sections discuss the potential impacts if Micatu's sensor were to be adopted on a utility-wide scale.

3. Environmental Benefits

Micatu's sensor provides environmental benefits in two ways. First, by enabling real-time voltage monitoring, the sensor can help utilities more efficiently meet New York State's ambitious renewable energy strategy (see text box). Due to their intermittent nature, renewable energy resources such as solar and wind tend to produce more fluctuations in power quality than fossil fuel-based sources, making real-time monitoring and control increasingly important at higher levels of renewable penetration.

Climate Leadership and Community Protection Act

Introduced in 2019, New York State's Climate Leadership and Community Protection Act (CLCPA) is a comprehensive energy strategy for New York State that lays out a path to carbon neutrality to make the energy system cleaner, more resilient, and more affordable, while committing to environmental justice, benefiting disadvantaged communities, and ensuring a just transition to zero carbon electricity. The programs and initiatives directed by CLCPA are designed to help the state achieve an ambitious set of goals including:

- 85% reduction in greenhouse gas emissions from 1990 levels by 2050
- 70% of electricity generation from renewable sources by 2030 and 100% zero-carbon electricity by 2040

Second, in addition to supporting the transition to clean energy, Micatu's sensor can reduce emissions by improving grid efficiency. Improving efficiency means that the utility does not need to generate as much "surplus" electricity to ensure sufficient voltage is available to meet customer demand in real time, thereby avoiding economic costs and carbon emissions associated with unnecessary generation. A large utility like Con Edison which installs 13,000 sensors could avoid approximately 75,000 metric tons of CO_2e annually, or 1.5 million metric tons over the lifetime of the sensor.[5] Each sensor is estimated to avoid 5.71 metric tons of CO_2e annually.[6]

> How are emissions reductions valued?
>
> Reductions in CO_2 emissions are valued using the social cost of carbon (SCC). The SCC is a measure of the value (in dollars) of the long-term societal damages resulting from emitting one ton of CO_2 in a given year; these damages include impacts to human health, agricultural productivity, and property damage, among others.
>
> Social cost of carbon estimates are developed by the U.S. Government's Interagency Working Group on the Social Cost of Greenhouse Gases (Interagency Working Group), which released an initial report in 2010 and an update in 2016.
>
> The Interagency Working Group indicates that the social cost of carbon should increase over time (over and above the effects of inflation) due to accelerating climate impacts and anticipated economic growth, which will make future impacts of carbon emissions more costly.
>
> For more information, see https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html.

Reductions in CO_2 emissions were valued using the social cost of carbon (SCC) – a measure of the value of the long-term societal damages resulting from emitting one ton of CO_2 in a given year (see text box). SCC is the standard method for valuing CO_2 emissions when the objective is to value societal benefits or costs associated with changes in CO_2 emissions. The U.S. Government Interagency Working Group on the Social Cost of Greenhouse Gases (Interagency Working Group) for 2019 estimated the SCC to be \$50.55 per ton of CO_2 as their central estimate (using a 3% discount rate), and \$75.21 per ton for 2019 as a higher estimate (using a 2.5% discount rate), both expressed in 2019\$.[7] The SCC values escalate over time; the corresponding values in 2038 are \$71.51 (central estimate, 3% discount rate) and \$101.11 (2.5% discount rate). This case study uses the central SCC estimates for the years 2019-2038 in the calculations, but presents the higher estimate for sensitivity analysis.[8]

---

[5] CO_2e is a common unit of measure for describing the global warming potential of different greenhouse gases. In New York State, average grid CO_2 emissions are 485.12 lbs-CO_2/MWh while average grid CO_2e emissions are slightly higher at 485.92 lbs-CO_2e/MWh. This conversion factor was used to convert CO_2 to CO_2e.

[6] Analysis conducted by Industrial Economics based on information provided by Micatu.

[7] U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. August 2016. https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

[8] The difference between the central estimate and higher estimate reflect the choice of social discount rate (3% and 2.5%, respectively). As explained in the Intergovernmental Working Group's (IWG's) report: "Based on the review of the literature, the IWG chose discount rates that reflect reasonable judgements under both prescriptive and descriptive approaches to intergenerational discounting. As discussed in the 2010 TSD [Technical Support Document], in light of disagreement in the literature on the appropriate discount rate to use in this context and uncertainty about how rates may change over time, the IWG selected three certainty-equivalent constant discount

To estimate the potential scale of benefits for utilities of different sizes, this case study scales the benefits by estimating the number of sensors that would be required to cover utility service territories of different sizes. The number of sensors installed depends on the number of distribution feeders. Typically, between three and nine sensors are installed per distribution feeder; this case study uses an average value of six. Using available information[9] on the number of distribution feeders at New York State utilities of different sizes, this case study estimates that a utility-scale installation could avoid between 8,600 metric tons of CO_2e for a smaller utility with 250 distribution feeders and over 75,000 metric tons of CO_2e for a large utility with 2,200 distribution feeders annually, or between $0.4 million and $3.8 million in societal damages in 2019, using the central SCC estimate. Over 20 years, a utility-scale installation could avoid between 171,000 metric tons of CO_2e for a small utility and 1.5 million metric tons of CO_2e for a large utility, or between $7.8 million and $68.5 million in CO_2e damages (Exhibit 3). (For illustrative purposes, Exhibit 3 also shows the higher SCC estimate using the 2.5% discount rate.) Although these are rough benchmarks that do not reflect specific investments, this case study shows that the potential societal benefit of Micatu's sensors installed on a utility-wide scale is significant. As described above, efficiency and environmental benefits will only be realized when sensors are installed across a broad enough service area to enable real-time grid management.

Exhibit 3. Potential Societal Benefits of Utility-Scale Replications

Benchmark Scenario	**Example Utilities**	**Dist. Feeders**	**Avg. No. of Sensors**	**Estimated CO_2e Reductions (metric tons)**		**Estimated Annual Reduction in CO_2e Damages ($ millions)**			
						Central Est.		**Higher Est.**	
				2019	**20 Years**	**2019**	**20 Years**	**2019**	**20 Years**
Small	Orange and Rockland	250	1,500	8,560	171,203	0.4	7.8	0.6	11.9
Medium	Long Island Power Authority	1,000	6,000	34,241	684,810	1.7	31.1	2.6	47.4
Large	Con Edison	2,200	13,200	75,329	1,506,582	3.8	68.5	5.7	104.3

Source: Social cost of carbon values used for the analysis are from the August 2016 Technical Support Document of the U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases.

4. Safety Benefits

Improved safety for utility workers is another potential benefit of Micatu's sensors. Because the sensor uses fiber optics (i.e., light) instead of voltage and current transformers to measure power flow, there are no conductive materials to put electric utility line workers at risk of electrocution. The number of injuries and fatalities that could be avoided by using an optical sensor like

rates to span a plausible range: 2.5, 3, and 5 percent per year." (Technical Support Document - Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis, p. 19, https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf) This case study uses the central (3%) SCC as the primary estimate because it is the central estimate recommended by the IWG and is used by New York State. The higher (2.5%) estimate is shown for illustrative purposes, and reflects the IWG's prediction that the cost of carbon will increase in the future. New York State policy does not use the 5% discount rate for SCC.

[9] Please see the appendix to this case study for the sources of these estimates.

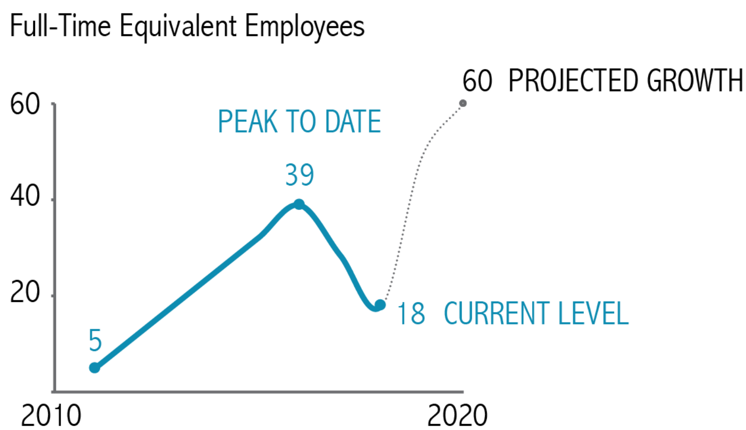
Micatu's instead of voltage and current transformers is unknowable; however, avoiding even a single serious injury or fatality would be a significant benefit.

5. Business Development and Economic Growth

The largest expansion in Micatu's business is associated with its recent distribution contract with Eaton. Although neither the financial value nor expected sensor sales negotiated through the contract have been shared publicly, Micatu intends to triple its workforce in the next year to meet expected demand. The goal of the contract is to enable Micatu to sell sensors to utilities outside of New York State, including internationally. Eaton currently has 96,000 employees and sells products in more than 175 countries, which represents a significant expansion for Micatu's potential sales.[10] Micatu plans to continue focusing on sales to New York State utilities while using its distribution contract with Eaton as a means of expanding to other locations.

Since Micatu's launch in 2011, the company grew from five to 39 full-time equivalent employees (FTEs) at its peak in 2016. Over the last three years, employment dropped to its current level of 18, as a result of a reduction in orders. Because Micatu recently signed several large-volume sales contracts, including the exclusive distribution contract with Eaton, Micatu planned to ramp up beginning in late 2019 and anticipates growing to 60 full-time equivalent employees in 2020 (Exhibit 4).

Exhibit 4. Growth in Employment at Micatu



[10] Eaton. Eaton expands smart grid portfolio with new optical sensor platform to help global utilities advance intelligent power and grid modernization. April 17, 2018. https://www.eaton.com/us/en-us/company/news-insights/news-releases/2018/eaton-expands-smart-grid-portfolio-with-new-optical-sensor-platf.html

The IMPLAN model was used to analyze the regional economic impacts that would result from 20, 40, and 60 full-time jobs at Micatu (Exhibit 5 on the following page).[11]

Regional Economic Analysis Using IMPLAN

The IMPLAN model is a standard input-output model that is used to analyze the multiplier effects associated with a change in demand within one or more sectors of the economy. IMPLAN uses data from several federal agencies to model the linkages and spending patterns between different industries in the U.S. economy. IMPLAN measures economic impacts using four metrics:

- **Employment:** The mix of full-time and part-time "job-years" (one job-year refers to one job for one year) that result from the employment demand created by a project. For this analysis, IMPLAN's job units were converted to full-time equivalents (FTEs) using sector-specific conversion factors developed by IMPLAN.
- **Labor Income:** All wages, benefits, and proprietor income generated as part of the project-related employment demand.
- **Value Added:** The total value of all production, minus the costs of any intermediate outputs (i.e., Gross Domestic Product).
- **Output:** The total value of all production, including the costs of intermediate and final outputs. Labor Income and Value Added are components of Output.

For each metric, IMPLAN breaks out direct, indirect, and induced effects:

- **Direct Effects:** Production changes or expenditures that directly result from an activity or policy. In this analysis, the direct effects are associated with 20, 40, and 60 FTEs at Micatu.
- **Indirect Effects:** The "ripple" effects resulting from changes in the output of industries that supply goods and services to those industries that are directly affected.
- **Induced Effects:** Changes in household consumption arising from changes in employment and associated income that result from direct and indirect effects.

As shown in Exhibit 5(a), 20 direct jobs at Micatu is associated with approximately $6.5 million in total value added, including $3.0 million in direct effects, $2.0 million in indirect effects, and $1.6 million in induced effects. In this context, "indirect" effects are the "ripple effects" resulting from changes in the output of industries that supply goods and services to those industries that are directly affected. "Induced" effects are changes in household consumption arising from changes in employment and associated income that result from direct and indirect effects.

Regional economic impacts are higher when modeling 40 direct jobs (Exhibit 5b) and higher still with 60 direct jobs (Exhibit 5c). If Micatu meets its forecast of 60 direct full-time employees in 2020, this would correspond to approximately $19.5 million in total value added, including $8.9 million in direct effects, $5.9 million in indirect effects, and $4.8 million in induced effects.

IMPLAN also estimates downstream changes in employment. As shown in Exhibit 5(a), the economic activity associated with 20 direct full-time jobs is estimated by IMPLAN to increase New York State employment by an additional 26 FTE jobs (including 12.7 indirect jobs and 13.5

[11] Micatu reported that it has spent all of NYSERDA's award money in New York State.

induced jobs). Similarly, the economic activity associated with 40 direct full-time jobs corresponds to an additional 52 FTE jobs (25.4 indirect and 27 induced), as shown in Exhibit 5(b). As shown in Exhibit 5(c), 60 direct full-time jobs corresponds to over 78 additional FTE jobs (38 indirect and 40.5 induced). This suggests a multiplier effect of 2.3.[12]

Exhibit 5(a). Regional Economic Impacts – Modeled with 20 Jobs

Impact Type	Employment (FTEs)	Labor Income	Value Added	Output
Direct Effect	20.0	$2,246,615	$2,976,324	$8,119,166
Indirect Effect	12.7	$1,254,564	$1,953,511	$3,232,287
Induced Effect	13.5	$887,507	$1,586,734	$2,436,351
Total Effect	**46.2**	**$4,388,686**	**$6,516,570**	**$13,787,804**

Exhibit 5(b). Regional Economic Impacts – Modeled with 40 Jobs

Impact Type	Employment (FTEs)	Labor Income	Value Added	Output
Direct Effect	40.0	$4,493,230	$5,952,649	$16,238,333
Indirect Effect	25.4	$2,509,128	$3,907,022	$6,464,574
Induced Effect	27.0	$1,775,013	$3,173,468	$4,872,701
Total Effect	**92.4**	**$8,777,371**	**$13,033,139**	**$27,575,608**

Exhibit 5(c). Regional Economic Impacts – Modeled with 60 Jobs

Impact Type	Employment (FTEs)	Labor Income	Value Added	Output
Direct Effect	60.0	$6,739,845	$8,928,973	$24,357,499
Indirect Effect	38.0	$3,763,692	$5,860,534	$9,696,860
Induced Effect	40.5	$2,662,520	$4,760,202	$7,309,052
Total Effect	**138.6**	**$13,166,057**	**$19,549,709**	**$41,363,412**

Source: Industrial Economics analysis using IMPLAN.

Micatu directly attributes much of its growth to the introductions NYSERDA facilitated to New York utilities and other business partners. Because of the connections facilitated by NYSERDA, Micatu was able to accelerate its timeline for piloting projects with New York State utilities. Micatu noted that it would have been challenging to establish pilot projects with these utilities without the introductions that NYSERDA provided. As noted above, five of the seven major utilities in New York State are currently piloting Micatu's sensor.

> "NYSERDA has relationships with utilities throughout New York State, so we can speak to who we need to speak to… Those contacts are priceless."
>
> -Micatu

[12] 2.3 = (138.6 total jobs / 60.0 direct jobs)

6. Conclusion

This case study identified key benefits from NYSERDA's project funding for Micatu, including business development, economic benefits, potential avoided CO_2 emissions, and improved safety for electric utility line workers. NYSERDA's support enabled Micatu to pilot the sensor with utilities across New York State, allowing Micatu to further refine its sensor and develop a new application for the sensor. With NYSERDA's support, Micatu has grown and expanded its business, selling its sensors directly in New York State and through the global distribution company Eaton. The company's growth provides significant economic impacts for the New York State economy, particularly in the Southern Tier where Micatu's Horseheads facility is located. The estimated economic benefits and carbon reductions that could result from utilities adopting Micatu's sensor across their service territories are substantial.

7. Sources

Eaton. Eaton expands smart grid portfolio with new optical sensor platform to help global utilities advance intelligent power and grid modernization. April 17, 2018. https://www.eaton.com/us/en-us/company/news-insights/news-releases/2018/eaton-expands-smart-grid-portfolio-with-new-optical-sensor-platf.html

Laglenne, JP, Brandon Peifer, Angelo Regan, and Lou Colangelo. July 18, 2018. Next-Gen Sensors for the Modern Grid. T&D World. https://www.tdworld.com/digital-innovations/next-gen-sensors-modern-grid

Long Island Power Authority. Long Island Smart Energy Corridor, Final Report, submitted to U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, National Energy Technology Laboratory. DOE Award Number DE-OE0000220. April 27, 2015. https://www.smartgrid.gov/files/DE-OE0000220-Final-Report-04-27-15.pdf.

Moran, Molly J. and Carlos Monje. U.S. Department of Transportation. Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses – 2016 Adjustment. August 8, 2016. https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20a%20Statistical%20Life%20Guidance.pdf

New York State Department of Public Service. List of Electric Substations Feeding Distribution System. Utility: National Grid. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B3F86059C-C872-415C-BA34-BCF6D20A831F%7D

NYSERDA and Micatu project background documents.

Orange & Rockland. Initial Distributed System Implementation Plan. Orange and Rockland Utilities, Inc. Case No. 14-M-0101. June 30, 2016. http://nyssmartgrid.com/wp-content/uploads/OR-DSIP-Report.pdf.

Oshetski, Michael, Paul Stergiou, Serena Lee, and Ryan Rausch. Con Edison Pilots Micatu's Submersible Optical-Sensor Platform to Enhance Grid Visibility. ENSC Magazine, Vol. 1, Ed. 2. Fall 2018. (19)

Personal communication with Con Edison. November 1, 2019.

Personal communication with Micatu. September 3, 2019.

Personal communication with Orange and Rockland. October 3, 2019.

Reilly, Griffin. Consolidated Edison Company of New York, Inc. Electric Grid Hardening and Resiliency Initiatives. April 17, 2015. https://www.bnl.gov/rsgworkshop/files/talks/Reilly.pdf

U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. August 2016. https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

Appendix: Detailed Methodology

Environmental Benefits

Reductions in CO_2 emissions were valued using the social cost of carbon values calculated by the Interagency Working Group on Social Cost of Greenhouse Gases.[13] For each year, the Interagency Working Group estimates the social cost of carbon using three discount rates: 2.5%, 3% (central estimate), and 5% per year. This case study uses the central estimate, which has been adopted by New York State, and also shows the 2.5% estimate for illustrative purposes. The Interagency Working Group presents all values in 2007 dollars. These values were converted to 2019 dollars using the price deflators used with the Federal Reserve Economic Data (FRED) Consumer Price Index.[14] The analysis calculated the present value of the 20-year reduction in CO_2 emissions.[15]

Although benefits are only realized when sensors are installed across a broad service area, a per-sensor value was estimated to help benchmark the scale of potential benefits. It was assumed that an average of six sensors[16] are installed for each of Con Edison's 2,194 distribution feeders,[17] and that approximately 13,000 sensors would be required to cover Con Edison's entire service territory. A large utility like Con Edison could avoid approximately 75,000 metric tons of CO_2 annually, with each sensor avoiding 5.7 metric tons of CO_2 (75,000 metric tons divided by 13,000 sensors). To benchmark the scale of potential benefits in territories of different sizes, the number of distribution feeders for a small utility was used (Orange and Rockland: 220 feeders[18]) as well as the number of feeders for a medium-sized utility (LIPA: 903 feeders[19]). The analysis then applied the 5.7 metric tons of CO_2 per sensor to estimate the emissions reductions in a small and medium-sized service territory if they were to adopt Micatu's sensors across their service territories. The environmental damages value of the avoided CO_2 emissions was estimated using the SCC dollar value per metric ton of CO_2 and the approach described above. CO_2 figures were converted to CO_2e using a conversion factor of 485.12 lbs-CO_2/MWh to 485.92 lbs-CO_2e/MWh.

---

[13] U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. August 2016. https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

[14] Federal Reserve Economic Data (FRED) Consumer Price Index. https://fred.stlouisfed.org/series/CPIAUCSL.

[15] The New York State Department of Public Service (DPS) advises that if the societal value of avoided CO_2 emissions is being summed together with the value of avoided electricity costs, it is important not to "double count" the projected Regional Greenhouse Gas Initiative (RGGI) compliance costs that are included in wholesale electricity price forecasts. This issue is not applicable to the Micatu case study because CO_2 reductions were not summed with avoided electricity costs.

[16] According to Micatu, between three and nine sensors are typically installed per distribution feeder. For estimation purposes, the analysis uses the midpoint of this range.

[17] Reilly, Griffin. Consolidated Edison Company of New York, Inc. Electric Grid Hardening and Resiliency Initiatives. April 17, 2015. https://www.bnl.gov/rsgworkshop/files/talks/Reilly.pdf

[18] Orange & Rockland. Initial Distributed System Implementation Plan. Orange and Rockland Utilities, Inc. Case No. 14-M-0101. June 30, 2016. http://nyssmartgrid.com/wp-content/uploads/OR-DSIP-Report.pdf.

[19] Long Island Power Authority. Long Island Smart Energy Corridor, Final Report, submitted to U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, National Energy Technology Laboratory. DOE Award Number DE-OE0000220. April 27, 2015. https://www.smartgrid.gov/files/DE-OE0000220-Final-Report-04-27-15.pdf.

Regional Economic Analysis Using IMPLAN

A regional economic analysis was conducted using the input-output model IMPLAN. IMPLAN analyzes the multiplier effects associated with a change in demand within one or more sectors of the economy, for a specific geographic region. IMPLAN uses data from several federal agencies to model the linkages and spending patterns between different industries in the U.S. economy. These relationships are geographic-specific and sector-specific, with the sectors organized based on the North American Industry Classification System (NAICS).

IMPLAN measures economic impacts using four metrics:

- **Employment:** IMPLAN's employment data are reported in units of "jobs," which reflect an annual average mix of full-time and part-time job-years.[20] For this analysis, the Evaluation Team converted from IMPLAN's jobs units to full-time equivalents (FTEs) using sector-specific conversion factors developed by IMPLAN.
- **Labor Income:** All wages, benefits, and proprietor income generated as part of the project-related employment demand.
- **Value Added:** The total value of all production, minus the costs of any intermediate outputs (i.e., Gross Domestic Product).
- **Output:** The total value of all production, including the costs of intermediate and final outputs. Labor Income and Value Added are components of Output.

For each metric, IMPLAN breaks out direct, indirect, and induced effects:

- **Direct Effects:** Production changes or expenditures that directly result from an activity or policy. In this analysis, the direct effects are associated with 20, 40, and 60 FTEs at Micatu.
- **Indirect Effects:** The "ripple" effects resulting from changes in the output of industries that supply goods and services to those industries that are directly affected.
- **Induced Effects:** Changes in household consumption arising from changes in employment and associated income that result from direct and indirect effects.

The IMPLAN model was run for 20, 40, and 60 direct FTEs (estimating employment numbers at Micatu at different points in time) in the "electricity and signal testing instruments manufacturing" sector, NAICS 334515. For this analysis, the "IMPLAN Pro" version of the IMPLAN model was used, and a study area region consisting of New York State specified using the 2016 IMPLAN data set.

---

[20] For IMPLAN, one "job" lasting 12 months is equivalent to two jobs lasting six months each, or three jobs lasting four months each, and so on. A job can be either full-time or part-time. The IMPLAN definition matches that used by Bureau of Economic Analysis Regional Economic Accounts data and Bureau of Labor Statistics Census of Employment and Wages data. More information about IMPLAN's employment metric is available at https://implanhelp.zendesk.com/hc/en-us/articles/115009510967-Employment-FAQ.