Smart City
REV Demonstration Project
City of Schenectady, New York
Case 14-M-0101

Quarterly Report – Q2 2021

July 30, 2021

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1.0 Executive Summary

Niagara Mohawk Power Corporation d/b/a National Grid ("National Grid" or the "Company") has partnered with the City of Schenectady ("Schenectady" or the "City") to demonstrate a smart city solution. Using the Company's outdoor lighting infrastructure as a platform for advanced outdoor lighting services, the Company and the City are deploying smart city technologies and testing the business models that will animate the advanced outdoor lighting and smart city markets (the "Project").

The Project is intended to identify innovative smart city solutions that will help the City expand the breadth and efficiency of services it provides to residents. This approach aligns with the Company's efforts to test, scale, and deploy clean energy solutions in line with the Reforming the Energy Vision ("REV") objectives, the State's clean energy agenda, including the Climate Leadership and Community Protection Act ("CLCPA"), and National Grid's own clean energy ambitions. Specifically, the partnership between the Company and the City will test whether the Company's outdoor lighting infrastructure can facilitate the adoption of smart city technologies by deploying approximately 4,275 efficient light-emitting diodes ("LED") outdoor lighting fixtures, network lighting control ("NLC") nodes, and smart city technologies. The upgrades will effectively turn Schenectady into a smart city, more capable of saving energy, efficiently providing municipal services, and opening the door to further innovation.

During the second quarter of 2021, the Company advanced several aspects of the Project, including:

- Completed preliminary Phase 1 technology evaluation
- Concluded the lighting study lead by Rensselaer Polytechnic Institute ("RPI")
- Issued 21 licenses to the City for public Wi-Fi attachment and established service connection
- Finalized LED conversion design and procured LED material for construction
- Tested 3 Ubicquia® NLC samples against the current draft of the American National Standards Institute ("ANSI") C136.50 standards
- Progressed Vodafone® and Quantela® integrations with Phase 1 data platforms
- Conducted field surveys of 475 proposed Phase 2 smart city sensor locations

Finally, the Project team held a pre-construction training with Ubicquia® to provide a hands-on demonstration of recommended installation procedures and requirements.

2.0 Highlights Since Implementation Plan Filing

Sections 2.1 and 2.2 below provide detailed descriptions of the major activities completed in the last quarter, as well as the challenges, lessons learned, and risk mitigation strategies from this work. The updated Project work plan is attached as Appendix A, and a summary Project one-pager describing key Project highlights is attached as Appendix B.

2.1 Major Task Activities

The Company worked on nine significant tasks during the second quarter of 2021. First, the Company and the City conducted a preliminary Phase 1 technology evaluation that considered a variety of capabilities provided by the installed technologies. The evaluation was performed by key Project members based on user experience and knowledge of each technology solution, and assessed capabilities using a simple 0 – 5 grading scale, with zero meaning a capability was not available, and five meaning the technology met requirements and surpassed expectations for a particular capability. Appendix C provides the detailed scoring results of the preliminary Phase 1 technology solutions evaluation, and Table 1, below, provides a summary of the results.

Table 1. The sum of average preliminary scores for technology solutions deployed in Phase 1 Zones A and B.

Technology Type	**Zone A**	**Zone B**
Streetlight NLC	56	66
Network	12.5	16.0
Smart City Sensor	32.0	36.3
Sum of Average Points	101	119

It is important to highlight that the two technology solutions are different and do not deliver the same capabilities. The Project team understands that additional capabilities may be enabled in the future through software updates, which could result in a higher score. With Phase 2 consisting of a single technology solution, all three technology solutions will be evaluated in the Project's final report after Project closure. The preliminary scores in Appendix C are the opinions of key Project members based on experience to date. The purpose of this analysis is to capture the experiences and feedbacks of key Project members after a full year of operations.

Second, in partnership with RPI Lighting Research Center, the Project team concluded the streetlight dimming study. The study recommended that dimming streetlights to 30 percent output (or 70 percent dimmed) has little impact on residents' acceptability or perception of the streetlights between the hours of 11:00 PM and 5:00 AM. This suggests the City could capture incremental energy savings during off-peak pedestrian and traffic hours at night without limiting streetlight effectiveness or safety. By dimming streetlights, the City could further reduce energy use and related carbon emissions beyond the reductions resulting from converting to LEDs alone. Notwithstanding the potential benefits from nighttime dimming, some areas are not appropriate for such dimming. For example, for areas with security cameras, high traffic corridors, frequent accident intersections, evening venues, and high vegetation areas, the study suggests an output level of 100 percent (not dimmed) to 70 percent (30 percent dimmed). This suggests the City should determine streetlight classification for all streetlights based on the local parameters to determine the appropriate incremental dimming. This could be labor intensive; however, it is likely a one-time effort that could produce benefits associated with reduced streetlight output during off-peak hours. The full streetlight dimming study can be found in Appendix D of this report.

Third, the Company's third-party attachment group issued 21 licenses to the City to attach public Wi-Fi access points and leveraged the existing streetlight to provide power. The Company established the electric service connection by connecting the PowerTap® device provided by the City to the streetlight ANSI C136.41 7-pin receptacle. The Company will evaluate this proof of concept to determine whether it is a practical approach for municipalities to expand public Wi-Fi and whether streetlights as a convenience outlet for cities should be expanded.

Fourth, the Company finalized Phase 2 LED conversion design and procured streetlight materials needed for Phase 2. For the upcoming LED conversion in Zones C, D, and E, the remaining roadway streetlights in the City will use LED streetlights with 3K color temperature by Acuity®. The Company anticipates the streetlights will be delivered in July 2021, and will later be transferred to a staging site before construction begins.

Fifth, the Company's meter labs evaluated three engineering validation test ("EVT") samples provided by Ubicquia®. The EVT samples were delayed because of a delay in production samples due to the global semiconductor shortage. Upon testing the EVT samples with the tools available at National Grid, all three NLCs exceeded the allowable deviation during test number 3, which is the effect of variation of power. This information was shared with Ubicquia® immediately. Ubicquia® informed the Company that it also observed this deficiency in a parallel test and the condition will be corrected before production.

Sixth, the Company and the City continued to work with Vodafone® and Quantela® in separate engagements to tailor their software platforms to scope. Both platforms encountered integration issues with Zone A and Zone B solutions during the quarter. However, the majority of the development process is complete. The Project team anticipates the two platforms to be operational in early Q3 2021, enabling the City to gather insights and actionable intelligence from the smart city data collected to improve the quality of life for its residents.

Seventh, the Company completed field clearance audits for 475 proposed streetlight locations using the completed design drawing which was included in the Q1 2021 report. The field audit approved 314 locations to have adequate clearance, identified 82 locations where the City's firewire can be removed to avoid extensive make-ready, and identified 50 locations where minor make-ready is needed. In addition, 29 locations were considered unsuitable for UbiHub AI® installation, requiring the City to identify new locations for field audit because of extensive make-ready costs. Towards the end of Q2 2021, the Company designed the 50 locations requiring minor make-ready work, scheduled to be completed in July 2021, prior to Phase 2 construction. The Company will work closely with the City in July 2021 to identify and field-audit additional locations to complete planning for all 475 UbiHub AI®.

Eighth, the Company restored services to five streetlight outages and three smart city device outages. These outages were notified by the NLC platforms and vendor support teams, allowing the Company to plan outage restoration and combine work nearby. The Project continues to see a reduction of smart city sensor and NLC failures that require the Company to replace failed equipment. This suggests that future deployments should consider a commissioning period during the first operational year to replace pre-mature device failures in the field after installation. The Company procured a maintenance contract with Ubicquia® during Phase 2 technology procurement stage to reduce the risk of product replacements due to premature failures during the first operational year.

Finally, the Company hosted a pre-construction installer's training at a National Grid facility in Schenectady. The training, given by Ubicquia®, allowed National Grid and the installation contractor to understand installation best practices, identify potential installation issues, and find installation efficiencies. During the training, the Company identified an issue where the UbiHub AI® bracket may not fit smaller diameter streetlight arms. After surfacing this potential issue, Ubicquia® will provide bracket inserts for the installation contractor to avoid improper fitting.

As communicated in the Q1 2021 report, the global shortage of semiconductor computer chips continues to cause manufacturing delays for technologies planned for Phase 2 in Q2 2021. Recently, Ubicquia® informed National Grid about service disruptions and daily load limits of shipping couriers related to COVID 19 for shipments originating from Asia. This is causing NLC and UbiHub AI® delay by an additional month, which pushes the start of construction of remaining zones from early July 2021 to mid-August 2021. The installation contractor has agreed to provide additional installation crews, totaling three crews, in an effort to reduce the construction duration and make up for the lost time related to material delays. The updates are included as part of the revised work plan included in Appendix A. Also, the Company provides a further description of general Project milestones below:

Anticipated Start /End Date	**Adjusted Start/End Date**	**Checkpoint/ Milestone**	**Status**	
October 2018 to December 2018		Install LED (Proof-of-Concept Stage; Max. 20 Fixtures)	Completed	
October 2018 to June 2019	October 2018 to June 2020	Install LED & NLC Nodes (Zones A & B; Approx. 2,250 Fixtures) Compare vendor solutions	Completed	
October 2019 to June 2020	October 2019 to October 2020	National Grid Install Smart City Sensor Nodes (Zones A & B)	Completed	
October 2018 to March 2019	October 2018 to October 2019	National Grid Implement Multi-Purpose IoT Mesh Network	Completed	
January 2020 to March 2021	January 2020 to April 2021	City Install Smart City Device Attachments to Smart City Sensor Nodes (All Zones)	Completed	
July 2019 to June 2021	January 2020 to December 2021	LED and NLC Node Steady State (Evaluate operational capabilities)	On Track	

Anticipated Start /End Date	Adjusted Start/End Date	Checkpoint/ Milestone	Status	
September 2019 to October 2020	September 2019 to June 2021	National Grid Install IoT Mesh Network Sensors and Meters (Gas ERTs; Temperature Sensors; Environmental Sensors; Etc.)	On Track	
July 2021 to August 2021	August 2021 to September 2021	Install LED and NLC Nodes (Zones C, D, & E; Approx. 2,000 fixtures)	Delayed Start	
July 2021 to August 2021	August 2021 to September 2021	National Grid Install Smart City Sensor Nodes (Zones C, D, & E)	Delayed Start	
January 2019 to June 2020	June 2021 to December 2021	Explore potential Third-Parties Sensors (Smart-Home Devices; Electric Vehicle ("EV") Chargers; Water Leak Sensors; Water Shutoff Valves; Water Meters; Vacant-Home Sensors; Parking Management Sensors; Etc.)	On Track	
November 2020 to June 2021	October 2021 to March 2022	Steady State Review and Evaluations	On Track	

2.2 Successes, Challenges, Changes, and Lessons Learned

Below is a high-level description of lessons learned which the Company is using to inform its ongoing work and future smart city deployments:[1]

1. Because smart city technologies are non-traditional attachments to utility infrastructure, technology providers must provide product specification drawings and mounting methods for the Company to ensure code compliance before installation.
2. Once the utility provides installation guidelines, a field survey must be conducted at the proposed location to ensure existing conditions can safely accommodate the installation. The NESC H238B-2 requirement for the Current® by GE Digital Infrastructure node added complexity to the Project. However, this important lesson learned is a testament to the Company's strong business culture through safety-by-design principles.
3. After starting to deploy street lights with NLC nodes, the Company and the City recognized the potential benefits offered through the technology. The lighting platform provides the City with greater control, convenience, and the potential to unlock additional energy savings through platform capabilities.

[1] Item number 22 and beyond are new lessons learned during the quarter.

4. Some smart city technologies are manufactured abroad, resulting in longer product lead times. This has created approximately three months of delays due to manufacturing and overseas transport. The Company used this lead time to conduct additional due diligence and prepare for the installation process.
5. Depending on the advanced network lighting solution, the installation needs to follow the optimal deployment scheme for the technology. Whether it is a point-to-many-points solution, cellular, or mesh technology, the deployment scheme should involve close communication and guidance with the manufacturer. This allows the technology to function as desired from the start.
6. Currently, there is no approved national metering accuracy standard for NLC nodes. While ANSI standard C136.50 is being developed, the Company believes ANSI standard C12.20 is a reasonable proxy to test NLC nodes for the Project. Additional time will be needed for lab testing of NLC nodes to incorporate the components of both ANSI standards.
7. The initial observations of the Project have identified a variety of NLC technology benefits that provide opportunities for utilities to enhance outdoor lighting services and provide operating efficiencies.
8. Continued involvement in the ANSI C136.50 NLC industry committee will build on the Company's meter testing experience for preliminary tests. The knowledge gained will enable the Company to formulate business models for various technology applications to provide customers with alternate service options and rate structures.
9. NLC metering accuracy specifications and industry-accepted testing requirements are needed before NLC meter data can be used for billing purposes. In addition, the integration of NLC meter data into the Company's billing system may require system upgrades.
10. The multipurpose mesh technology installed in Zone A has experienced numerous endpoint connectivity issues since installation in Q4 2019. The vendor group has reached out to Cisco® for support and to conduct a root cause analysis.
11. The Project has seen several replacements of both NLCs and smart city technologies due to product defects or premature failures. Failed pieces of equipment are being returned to the vendors for further diagnosis and investigation. Furthermore, vendors should provide spares to reduce lead times required for field replacements. The Company is taking this learning into the Phase 2 deployment and will explore options to minimize return trip expenses.
12. During the September 30th storm that impacted Schenectady County and the broader capital region, both smart city solutions deployed in Zone A and B required manual intervention to ensure functionality is restored after a power outage.
13. Technologies deployed in Zone B can also be used to enhance public safety. The data collected by the smart city technologies and accessed by City officials can help respond to dangerous incidents or circumstances and promote public safety. Toward realizing this benefit, the City will expand access to more staff members and provide additional internal training.
14. The cost of 4G LTE is decreasing, improving the cost-effectiveness of cellular networks for smart city technologies requiring high bandwidth for connectivity. Cat-M1 is an increasingly popular low-cost, low-power connectivity option for IoT devices. The Project will deploy lighting controllers operating on a cellular provided Cat-M1 for connectivity.
15. LoRaWAN® is also becoming an increasingly popular low-power IoT network connectivity option. The Project received a LoRaWAN® gateway from Phase 1 vendor partner Presidio®. The Company and the City will explore demonstration opportunities during Phase 2.

16. Several electric service-related issues (*e.g.*, voltage and neutral) or premature NLC device failures (*e.g.*, communication module and internal relay) can lead to the NLC losing network connectivity. Once NLCs are offline, a truck-roll is required for further troubleshooting and repair.
17. The third-party attachment process involving co-owned utility poles requires attachers to submit individual applications to the owners. The application process can involve establishing new agreements, which can introduce delays in the attachment process.
18. Based on the current draft of the ANSI C136.50 standard, the Company can perform six of the 11 test parameters with the testing equipment available at National Grid. Additional ANSI C136.50 tests can be attempted by the Company; however, it would require additional time and resources to complete. With the limited testing equipment at National Grid and the national standard for NLC energy metering still in development, the Company plans to cease lab testing in Q2 2021.
19. NLCs and smart city sensors rely on semiconductors to compute and communicate. The global shortage of semiconductors created supply chain disruptions and product manufacturing delays of smart city technologies.
20. Cybersecurity is an evolving threat requiring ongoing monitoring, control, and response. Smart City IoT devices have complex architectures and could vary across device types and use-cases. Having cybersecurity plans in smart city deployments could identify cyber-vulnerabilities and allow for a quick response when situations arise. Utilities have dedicated cybersecurity groups that are versed in protecting utility systems and critical infrastructure. Practices and security standards can be applied to smart city deployments to promote a more secure digital ecosystem.
21. Similar to hardware, software platforms may eventually reach end-of-life. Smart City is an emerging market; therefore, there will be market entrants and exits as the market matures.
22. The reduction in NLC replacements and smart city repairs suggest future deployments should consider a commissioning period during the first operational year to replace pre-mature device failures in the field after installation.
23. The lighting study suggests most streetlights can dim to 30 percent of light output during pedestrian and vehicle off-peak hours, between 11:00 PM and 5:00 AM.
24. The PowerTap® device placement is before the NLC. Therefore, the NLC cannot measure the ancillary load. For low-powered, always-on third-party devices, the PowerTap® device could be an alternative to establishing a new service connection from the secondary distribution lines.
25. NLC lab tests at National Grid meter labs show incremental technology improvements in parallel to the development of a nationally recognized standard for NLC revenue-grade metering (ANSI C136.50).
26. The global semiconductor chip shortage impacts NLC and smart city sensor manufacturing. Furthermore, disruptions in the global shipping courier services due to COVID 19 increases material transit time. As a result of multiple delays due to COVID 19, Phase 2 construction has been pushed from early April 2021 to mid-August 2021.

The table below highlights the successes, challenges, and lessons learned in Q2 2021 and identifies the corresponding adjustment to the Phase 1 deployment and Phase 2 startup schedules:

Success, Issue, or Change	Strategies to Resolve	Resulting Change to Project Scope/ Timeline	Lessons Learned
The Company observed a reduction of NLC and smart city technology replacements during Q2 2021.	N/A	N/A	The reduction in NLC replacements and smart city repairs suggest future deployments should consider a commissioning period during the first operational year to reduce the need for replacing replace pre-mature device failures in the field after installation.
The lighting study conducted by RPI suggests streetlights can dim to 30% of the total output.	N/A	N/A	The lighting study suggests most streetlights can dim to 30% of light output during pedestrian and vehicle off-peak hours, between 11:00 PM and 5:00 AM.
The Company issued 21 licenses to the City to attach public Wi-Fi access points using a PowerTap® device. The Project team was led to believe NLC could also meter ancillary loads.	The Company will continue to evaluate whether streetlights can serve as a convenience outlet and an advantageous offering for municipalities. The City will be billed under an unmetered electric rate for power consumption.	N/A	The PowerTap® device placement is before the NLC. Therefore, the NLC cannot measure the ancillary load. For low-powered, always-on third-party devices, the PowerTap® device could be an alternative to establishing a new service connection from the secondary distribution lines.
EVT samples provided by Ubicquia® failed test number 3, which is the effect of variation of power.	Perform lab testing of 10 production Ubicell UG® in Q3 against the six tests National Grid can perform using the testing tools available at the meter lab.	Extend NLC meter lab testing into Q3 2021.	NLC lab tests at National Grid meter labs show incremental technology improvements in parallel to the development of a nationally recognized standard for NLC revenue-grade metering (ANSI C136.50).

Success, Issue, or Change	Strategies to Resolve	Resulting Change to Project Scope/ Timeline	Lessons Learned
Global semiconductor chip shortage and disruption in shipping courier services related to COVID 19 continues to delay the Project.	The Company adjusted the Project timeline to account for the material delay. The Project team holds weekly meetings with Ubicquia® to manage Project impacts. The Company also requested additional installation contractors to minimize potential construction delays.	Pushes the start of construction of remaining zones from early-July 2021 to mid-August 2021	The global semiconductor chip shortage impacts NLC and smart city sensor manufacturing. Furthermore, disruptions in the global shipping courier services due to COVID 19 increases material transit time. Because of the combined delays due to COVID 19, Phase 2 construction has been pushed from early April 2021 to mid-August 2021.

2.3 Stakeholder Engagement and Knowledge Sharing

The Company and the City are planning a media engagement in late July in efforts of engaging and notifying the public of upcoming Phase 2 activities.

3.0 Next Quarter Forecast

Although construction is pushed to August 2021 for the remaining Project zones, the delay provides additional time to find alternate poles for locations with expensive make-ready costs estimates. Furthermore, the Company will adopt an agile approach to continually assess COVID-19 related risks and adjust Project timelines as needed. In the third quarter of 2021, the Company expects to perform the following tasks:

1. Complete field clearance audit and minimize potential make-ready costs.
2. Lab test Ubicell UG® and conclude lab testing of all three NLCs deployed on the Project.
3. Complete remaining Vodafone® and Quantela® integration activities.
4. Complete material staging after material delivery.
5. Complete make ready work before Phase 2 construction.
6. Begin and progress toward completion of Phase 2 construction.
7. Perform cybersecurity penetration testing of Phase 2 solution.

4.0 Work Plan and Budget Review

4.1 Updated Work Plan

The Company updated the work plan outlined in the Project Implementation Plan to reflect changes in the status and ongoing workstreams. Given the complexities encountered on the Project, the Company updated the work plan to capture the following components:

1. Extend Phase 2 construction start of remaining zones from July 2021 to August 2021.
2. Extend Ubicell UG® meter lab testing into July 2021
3. Delay Phase 3 start into October 2021

The updated work plan is included in Appendix A.

4.2 Current Budget

Project Task	Quarter Actual Spend	Project Total Spend to Date	Project Budget	Remaining Balance
CapEx				
CapEx Total	$114,340	$4,598,456	$6,510,000	$1,911,544
OpEx				
City Payment		-$56,112		
OpEx Total	$8,265	$284,501	$1,075,000	$790,499
Project Total	**$122,605**	**$4,882,957**	**$7,585,000**	**$2,702,043**

5.0 Quarterly Report Template

Quarterly Report Template	
Milestones:	
Project Milestones Accomplished:	1. Issued 21 licenses for the City to attach public Wi-Fi access points
Next Quarter Project Milestones:	1. Complete field clearance audit and minimize potential make-ready costs 2. Lab test Ubicell UG® and conclude lab testing of all three NLCs deployed on the Project 3. Complete remaining Vodafone® and Quantela® integration activities. 4. Complete material staging after material delivery 5. Complete make ready work prior to Phase 2 construction 6. Begin and progress toward completion of Phase 2 construction 7. Perform cybersecurity penetration testing of Phase 2 solution
Tasks/Timeline:	
Completed Project Tasks Since Last Quarterly Report:	1. Concluded the lighting dimming study with RPI 2. Completed pre-construction contractor training 3. Phase 1 technology evaluation by the Company and the City 4. Procured Phase 2 LED material 5. Tested 3 EVT samples against ANSI C136.50 6. Progressed Vodafone® and Quantela platform integration toward completion
Changes or Impacts to Schedule Since Last Quarterly Report:	1. Extend Phase 2 construction start of remaining zones from Early-July 2021 to mid-August 2021. 2. Extend Ubicell UG® meter lab testing into July 2021 3. Delay Phase 3 start into October 2021
Lessons Learned:	Please refer to section 2.2 Challenges, Changes, and Lessons Learned above.
Work Stream Coordination:	Coordination occurring among the Company's electric and gas functions, procurement, communications, marketing, customer organization, energy efficiency, grid & network communications, metering and billing, grid modernization, AMI, and IT groups for engineering design, review, and deployment.
Risks:	
Identified Risks:	COVID 19 can potentially delay product supply chain and field construction activities.

Quarterly Report Template	
Risk Mitigation Plan:	Work with Phase 2 suppliers and the installation contractor to ensure resources are aligned. Weekly meetings will allow parties to communicate potential delays and issues.
Finance:	
Total Spend to Date:	$4,882,957
Target Budget Spend:	$5,014,789
Actual Incremental Spend:	$ 0
Variance:	$131,831
In-Kind and Grant Support (Specifically for REV Demo):	Estimated $150,000 from Phase 1 vendors. Estimated $156,000 from Ubicquia® for Phase 2. Vodafone® in-kind sponsorship of its V-SmartX.
Additional Notes:	

Appendix A – Updated Work Plan

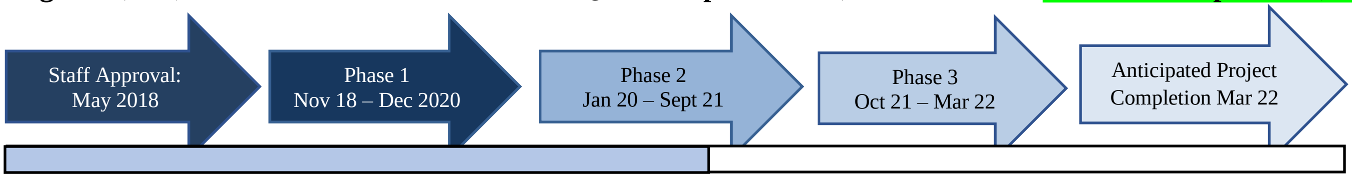
	Smart City - Implementation Plan																		
			Timing		CY21												CY21		
		Activities	Adjusted Start	Adjusted End	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22
Phase 1	1.00	**NG install LED Proof of concept**																	
	1.10	Install LED Max 20, 3k vs 4k																	
	2.00	**NLC & LED Installation Phase 1**																	
	2.10	Develop survey, release survey, analyze	Jan-2019	Apr-2019															
	2.20	Finalize results and provide survey to City	Apr-2019	Apr-2019															
	2.2.1	*Milestone City Decision Point*	Apr-2019	Apr-2019															
	2.2.2	*City signs City Agreement and SOW*	Apr-2019	May-2019															
	2.30	Plan, Design, Procure, Legal	Oct-2018	Jun-2019															
	2.40	NG install LED and NLC Nodes Zones A and B; install and co	Oct-2018	Dec-2019															
	2.4.1	*Sign Contract*	May-2019	May-2019															
	2.4.2	*Vendor Kickoff Meetings with the City*	Jul-2019	Jul-2019															
	2.50	Complete Field Installation LED and NLC	Jul-2019	Jun-2020															
	2.60	Evaluate	Jul-2019	Sep-2020															
	2.70	Lab test meters and NLC	Aug-2019	Dec-2020															
	2.80	NLC Troubleshooting																	
	2.90	Cost Recovery A & B	Jul-2019	Sep-2020															
	3.00	**Smart City Sensor Phase 1**																	
	3.20	Plan, Design, Procure, Legal	Oct-2018	Jun-2019															
	3.30	Pilot Test Install 20 max	Jul-2019	Jul-2019															
	3.3.1	*Request Permission from City to proceed*	Jul-2019	Jul-2019															
	3.40	Zone A & B Field install	Aug-2019	Aug-2020															
	3.50	Smart City Sensor Troubleshooting																	
	4.00	**Multipurpose network Phase 1**																	
	4.10	Plan, Design, Procure, Legal	Oct-2018	Aug-2019															
	4.20	*Network Test ******	Jul-2019	Aug-2019															
	4.30	Network Field Installation	Oct-2019	Oct-2019															
	4.40	NG install Iot Mesh network, Sensor, and Meters	Dec-2019	Jan-2019															
	5.00	**Energy and attachment as a service Phase 1**																	
	5.10	Scoping	Oct-2018	Dec-2018															
	5.20	Assist the City for 3rd party or City owned attachements	Oct-2018	Sep-2020															
	5.30	Cost Recovery	Jul-2020	Dec-2020															
	5.40	Decision to procure Phase 2 technologies	Jun-2020	Jun-2020															
Phase 2	6.00	**NLC & LED Installation Phase 2**																	
	6.10	Plan, Design, Procure, Legal	Feb-2020	Mar-2021															
	6.20	Field Installation LED and NLC Zones C,D,E	Aug-2021	Sep-2021															
	6.30	Cost Recovery All Zones	Oct-2021	Mar-2022															
	6.40	Steady State	Oct-2021	Mar-2022															
	6.50	Energy Calculations and credit; Penetration testing; final eval report	Oct-2021	Mar-2022															
	7.00	**Smart City Sensor Phase 2**																	
	7.10	Plan, Design, Procure, Legal	Feb-2002	Mar-2021															
	7.1.1	Solution Planning UbiHub AI	Jan-2021	Feb-2021															
	7.1.2	Field Survey for clearence	Mar-2021	Apr-2021															
	7.1.3	EVT lab test	Jun-2021	Jun-2021															
	7.1.4	In-person training with Contractors	Jun-2021	Jun-2021															
	7.20	Continue Lab Test and Test Ubicell UG	Apr-2021	Jul-2021															
	7.2.1	Product delivery	Jul-2021	Jul-2021															
	7.20	Zone C,D,E field install Smart City Technologies	Aug-2021	Sep-2021															
	7.30	Cost Recovery for smart city sensor node	Oct-2021	Mar-2022															
	8.00	**City or Third Party Sensor Install**																	
	8.10	City Smart City Device Attachement to Smart-City Sensor N	Jan-2020	Dec-2020															
	8.20	City Planning and Procurement	Oct-2020	Feb-2021															
	8.30	City Field Installation	Mar-2021	Apr-2021															
	8.40	City Data, Software, Platform Integration	Mar-2021	Apr-2021															
	9.00	**Multipurpose network Phase 2**																	
	9.10	Explore LoRaWAN with the City	Jan-2021	Mar-2022															
	9.2	Explore City-WiFi Densification	Jan-2021	Mar-2022															
Phase 3	10.00	**Smart City Sensor Phase 3**																	
	10.10	**Steady State**	Oct-2021	Dec-2021															
	10.20	Review and refine as needed Final Eval report	Oct-2021	Dec-2021															
	11.00	**Multipurpose network Phase 3**																	
	11.10	Steady State	Oct-2021	Dec-2021															
	11.20	Company Owned Devices and sensors	Oct-2021	Dec-2021															
	11.30	Third party owned devices and sensors	Oct-2021	Dec-2021															
	11.40	Cost recovery	Oct-2021	Dec-2021															

Keys
- Current Timeline
- Abandoned
- New Changes
- Decision/critical

Appendix B – Summary One Pager

nationalgrid **Smart City Schenectady REV Demo** **Q2 2021** **Overall Status (Active)**

Project Start Date: 05/24/2018 **Project End Date:** 3/30/2022
Budget: $7,585,000 **Current Quarter Spend:** $112,605 **Cumulative Spend**: $4,882,957



Project Summary: The Project is designed to test whether the Company's outdoor lighting infrastructure can serve as a platform for advanced services through the deployment of a multipurpose IoT network to enable smart-city technologies and to develop viable business models to animate the advanced outdoor lighting and smart city markets.

Cumulative Lessons Learned		
The Customer	**Market Partners**	**Utility Operations**
• Cities want more than smart lighting alone. The City of Schenectady intends to improve public services, increase public safety, and find ways to save money in the process. • The City and the Company understand the need to continue to engage with stakeholders as the Project progress. • Conversion to smart LED street lights with NLC nodes provides greater control, convenience, and opportunity for additional GHG savings that help meet clean energy and CLCPA goals. • Protecting citizen privacy and practicing cybersecurity are core towards a successful smart city deployment. • Installation costs are high. However, deployment cost reductions can be achieved by combining smart city installation with LED upgrades.	• The definition of a Smart City is different for each city. Technology solutions must be customized to meet the needs of the city. • Standardization and market advancements would improve network interoperability between smart-city devices. • New and disruptive smart-city technologies are emerging in the market. • The cost of smart lighting and IoT connectivity is decreasing. • The third-party attachment application process for co-owned utility poles can involve establishing new legal agreements with each pole owner. • Once ANSI C136.50 is adopted and published, NLC manufacturers would need to certify products through independent laboratories.	• Building a smart city entails a complex deployment of diverse smart technologies. Utility involvement consolidates smart cities into a packaged solution to manage complex deployments and provide long-term service. • Adequate time is needed to fully ensure the solution meets standards compliance and cybersecurity requirements. Initial field surveys are also required to ensure NESC code compliance and clearances. • NLC nodes offer a range of customer benefits and provide opportunities to enhance outdoor lighting services. • NLC standards and requirements would need to be adopted by the PSC, including the development of new processes and procedures for witness testing.

Application of lessons learned: The Company is taking the learning gathered to inform its ongoing work and applying smart city attachment experience for other municipal applications.

Issues Identified: Ongoing COVID-19 pandemic may impact product supply chain and deployment schedules.

Solutions Identified: Work with Phase 2 suppliers and the installation contractor to ensure resources are aligned. Weekly meetings will allow parties to communicate potential delays and issues.

Recent Milestones/Targets Met: Completed City attachment of public Wi-Fi using streetlights for power. Completed streetlight dimming study with RPI.

Upcoming Milestones/Target: Conclude meter lab testing; Conclude Vodafone® and Quantela® integrations; Complete material staging after material delivery; Complete field clearance survey; Complete make ready work prior to Phase 2 construction; Begin and progress toward completion of Phase 2 construction; Perform cybersecurity penetration testing.

Appendix C – Detailed Scoring of Phase 1 Technology Solutions

	Requirement	Technology Capability	Importance Average	NG Zone A Average	NG Zone B Average	Importance Average	City Zone A Average	City Zone B Average
Streetlight NLCs	Functionality	Scheduling, fault detection, asset grouping	5	5.0	5.0	5	3.0	4.0
		GPS Functionality and Accuracy	5	3.0	5.0	5	3.0	4.0
		Photocell has override for "overcast conditions"	4	4.0	4.0	3	3.0	3.0
		Easy-to-use-User Interface	5	3.5	4.0	5	3.0	5.0
		Map-based asset tracking and grouping	5	4.5	4.5	5	5.0	5.0
		Interoperability with existing analytics platforms	3	3.0	3.0	4	4.0	5.0
		ANSI 7-Pin connector for LED Dimming	5	5.0	5.0	5	5.0	5.0
		ANSI C12.20 traceability or C136.50	5	0.5	3.5	5	5.0	5.0
		Last Gasp health reporting	4	3.5	0.0	3	3.0	0.0
		15-minute meter readings	4	2.0	5.0	4	1.0	5.0
		MDMS ready	3	3.0	3.0	4	3.0	3.0
		Allow Asset data to be added	5	5.0	5.0	5	5.0	5.0
	Reliability	10 year minimum Warranty	5	3.5	5.0	5	1.0	5.0
		Mean Time Failure	5	2.0	4.5	5	2.0	4.0
		Fault Detection	5	4.0	4.0	5	5.0	5.0
		Surge protection	5	5.0	4.0	5	5.0	5.0
			Total	57	65	Total	56.0	68.0

	Requirement	Technology Capability	Importance Average	NG Zone A Average	NG Zone B Average	Importance Average	City Zone A Average	City Zone B Average
Network	Functionality	Smart Sensor backhaul CG-Mesh vs LTE	5	3.0	3.5	5	2.0	5.0
		NLC Gateway Scalability	3	3.0	3.5	3	3.0	4.0
		NLC Endpoint Network Scalability	3	4.0	3.0	2	5.0	4.0
		NLC Latency - CG Mesh vs 6LowPAN	5	3.0	4.0	5	2.0	5.0
			Total	13.0	14.0	Total	12.0	18.0

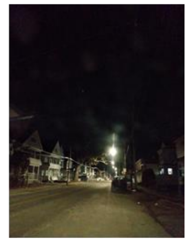
Technology Type	Zone A	Zone B
Streetlight NLC	56	66
Network	12.5	16.0
Smart City Sensor	32.0	36.3
Total	101	119

	Requirement	Technology Capability	Importance Average	NG Zone A Average	NG Zone B Average	Importance Average	City Zone A Average	City Zone B Average
Smart City Sensor and use cases	Product Cost	Hardware cost	4	4.0	3.0	4	2.0	4.0
		Software cost	4	4.0	2.5	4	3.0	4.0
	Smart City use cases	Easy to use interface (user interface)	5	4.0	4.0	5	3.0	4.0
		Data Accuracy	5	2.0	4.0	5	3.0	4.0
		Pedestrian Counting	3	3.5	3.5	4	1.0	4.0
		Vehicle counting	3	3.5	3.5	4	2.0	4.0
		Environmental monitoring	3	3.0	2.0	4	2.0	4.0
		Public safety	3	2.0	5.0	5	1.0	4.0
		Gunshot	3	4.0	1.0	3	2.0	2.0
		Glass and Alarm (Threshold)	3	0.5	1.0	3	2.0	2.0
		Aggression	3	3.0	1.0	3	2.0	2.0
		Road temp Monitoring	3	4.5	1.0	4	3.0	3.0
			Total	38.0	31.5	Total	26.0	41.0

A score of 0 means the capability is not available or insufficient evidence; a score of 1 means the capability is below basic requirement; a score of 2 means the capability meets basic requirement with deficiencies; a score of 3 means it meets all requirements; a score of 4 means it meets requirements with additional capabilities; and a score of 5 means it meets requirements and surpasses expectations.

Appendix D
Adaptive Street Lighting Study by RPI

Evaluation of Adaptive Street Lighting Protocols in Schenectady, NY

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Lighting Research Center, Rensselaer Polytechnic Institute

Project Sponsor: National Grid

Project Partner: City of Schenectady

Final Report: May 28, 2021

BACKGROUND

Street lighting serves multiple purposes, including assisting with traffic and pedestrian safety and in reinforcing a sense of safety among pedestrians at night (Rea et al., 2009). With the advent of light emitting diode (LED) technology using solid state sources, street lighting throughout the U.S. has begun a transformation from primarily high pressure sodium (HPS) light sources to LED systems.

In general. LED street lighting systems offer increased efficacy resulting in lower energy costs (Bullough et al., 2015) as well as the potential for reduced maintenance costs. LED street lighting systems, because of the “white” color appearance of the illumination they produce, also tend to result in streets and sidewalks that appear brighter and safer (Rea et al., 2017) than the “yellowish” illumination from HPS lighting systems, even when they are producing the same light level. Further, LED lighting systems can be dimmed relatively easily compared to HPS lights, and many municipalities and transportation agencies are considering adaptive lighting approaches in which light levels might be reduced during hours of low activity, which will further save energy and reduce light pollution.

This report documents activities undertaken by the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute to assist National Grid, working with the City of Schenectady, to identify and evaluate approaches to adaptive lighting in the Mont Pleasant district of the city. This district includes both commercial areas (along Crane Street) and residential areas (along Pleasant, Webster and Congress Streets). Figure 1 shows a map of the general area under study.

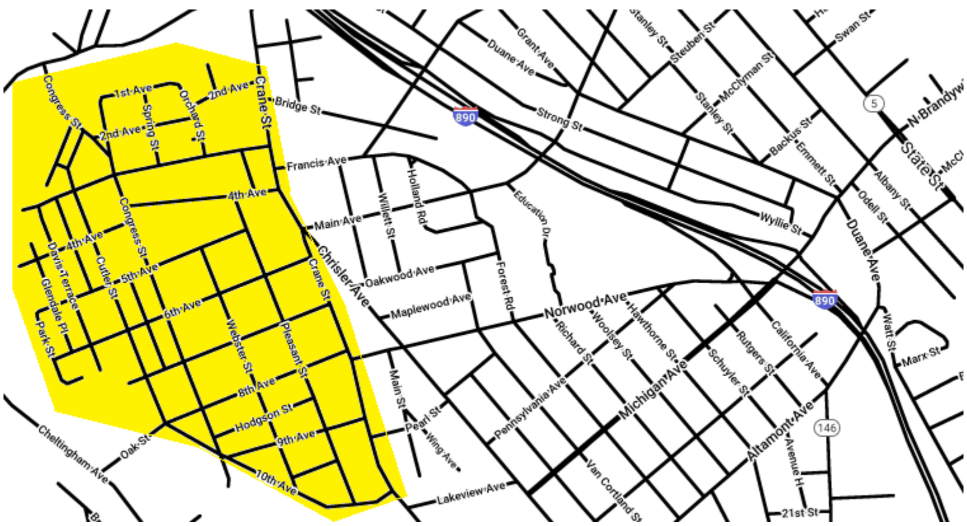

Figure 1. Shaded area shows the Mont Pleasant area of Schenectady, NY.

OBJECTIVE

The objective of the present project is to assess the lighting conditions in the Mont Pleasant district following the installation of LED streetlights, to assess patterns of traffic and pedestrian use during nighttime hours, and to identify dimming control profiles that would provide adequate illumination throughout the night in the commercial and residential areas of the district.

LED LIGHTING CONDITIONS

In order to identify the existing lighting conditions following the installation of LED street lighting in the Mont Pleasant district of Schenectady, two approaches were taken. First, photometric simulations of the light levels along different sections of Crane Street (in the commercial area), Pleasant Street (in the residential area) and 5th Avenue (in the residential area) were performed, using the Visual Roadway Tool (Acuity Brands) and photometric data for the GE Evolve luminaires used in these areas. Full light output (100%, no dimming) was assumed for all lighting calculations. Second, spot measurements of illuminance were made in several locations to verify the accuracy of the photometric simulations.

Commercial Area

The assumed roadway geometry for Crane Street was a two-lane road with, 20 ft lane widths including both traffic and parking. Sidewalks that were 6 ft in width were also assumed. For the lighting geometry, a mounting height of 28 with a 2 ft pole setback and a 10 ft mast arm length was used. A pole spacing of 100 ft pole along each side of the road was assumed based on observations made using Google Maps. South of the intersection with Main Avenue the lighting configuration consisted of poles along a single side of the street; north of Main avenue the configuration was two-sided and staggered. Based on discussions with National Grid the LED luminaire was a GE Evolve 122 W (ERLH, Type II distribution). A light loss factor of 0.8 was assumed for this and for all subsequent calculations.

For the one-sided configuration, the assumed lighting conditions resulted in the following light levels:

- Average illuminance (street): 25.4 lux, maximum 35.3 lux, minimum 19.6 lux
- Average illuminance (sidewalks): 12 lux

For the two-sided configuration, the following light levels were calculated:

- Average illuminance (street): 50.7 lux, maximum 70.6 lux, minimum 39.1 lux
- Average illuminance (sidewalks): 24 lux

For comparison, spot measurements (performed on the night of July 16, 2020) of the illuminance along the roadway in the section with a one-sided layout configuration ranged between 20 and 25 lux, which is consistent with the calculated values for this layout.

Residential Area

Two LED luminaires were used in the residential areas. Along some streets (such as Pleasant Street), 31 W GE Evolve (ERL1, Type III distribution) luminaires were installed, and along others (such as 5th Avenue), 71 W Evolve (ERL1, Type III distribution) luminaires were used. For Pleasant Street, a roadway geometry consisting of a two-lane road with, 12 ft lane widths and sidewalks that were 6 ft was assumed. The lighting geometry consisted of the 31 W luminaires with a 28 ft mounting height on a pole set back 2 ft from the road edge, and with a 6 ft mast arm length. The poles were assumed to be spaced 150 ft apart along one side of the street. The resulting light levels that were calculated were as follows:

- Average illuminance (street): 5.2 lux, maximum 11.6 lux, minimum 2.6 lux
- Average illuminance (sidewalks): 4 lux

It should be noted that in practice the illuminance would be affected by the presence of trees in the residential areas. For example along Pleasant Avenue, there were fewer trees between 6th and 7th Avenues, but more trees between 7th and 8th Avenues. The lighting calculations presented here assume no blockage of the light by trees, so actual light levels in areas with trees could be expected to be lower. As discussed below, when trees are present in residential areas, the output of low-wattage luminaires should not be reduced in order to maintain light levels for safe passage through the area.

For 5th Avenue, the assumed roadway geometry consisted of a two-lane street with 12 ft lane widths, and a sidewalk 6 ft in width. The 71 W luminaires were assumed to be mounted on poles 28 ft above the ground, with poles set back 2 ft from the street edge, and on mast arms that were 6 ft in length. The poles were located along a single side of the street and spaced 100 ft apart. The resulting light levels were calculated as follows:

- Average illuminance (street): 15.8 lux, maximum 27.4 lux, minimum 10.8 lux
- Average illuminance (sidewalks): 11.9 lux

In comparison, illuminances measured (during the evening of July 16, 2020) along Pleasant Street identified a maximum luminance of 12 lux under the streetlights, and an illuminance of 2 lux in the darker areas between poles. When trees were present the illuminance between poles could drop to under 1 lux. Overall these observations are consistent with the calculated light levels in the residential area.

TRAFFIC AND PEDESTRIAN OBSERVATIONS

In order to devise possible criteria for reducing street lighting levels based on use patterns of traffic and pedestrians, it is necessary to understand what those use patterns are.

Commercial Area

The LED street lighting system installed by National Grid in the City of Schenectady includes sensors and cameras that can record and count pedestrians and vehicles in various locations including several in the Mont Pleasant district. Data from these sensors are recorded and stored via an online interface for subsequent retrieval and analysis through different platforms. One platform revealed minimum traffic volumes occurring between 11:00 p.m. (2300) and midnight (0000), increasing steadily through the 6:00 a.m. hour. This differed from previously published observations of nighttime traffic (Bullough and Rea, 2011; Bullough et al., 2015), which showed minimum volumes between 3:00 and 4:00 a.m., and was considered to be in error. A different platform revealed traffic volume profiles that were more similar to that expected, and data for the commercial area along Crane Street are shown in Figure 2 for the period of July 11-16, 2020 (occasionally, data for certain hourly intervals were missing as is the case in Figure 2).

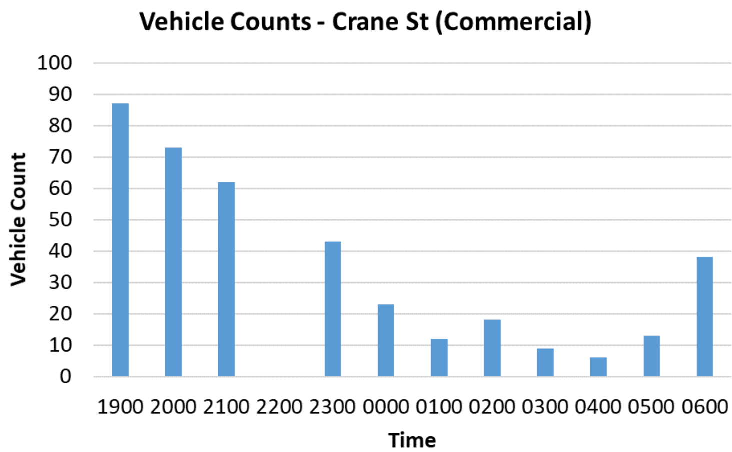

Figure 2. Nighttime vehicle traffic data (in one direction) for Crane Street, binned by hourly interval, based on recorded sensor data.

In order to verify that the profile in Figure 2 was representative, in-person counts of traffic volume were conducted (on the night of September 23, 2020) for a portion of the night, and data gathered by the New York State Department of Transportation (NYSDOT) were consulted (the most recent available data were for October 26, 2015). Along the upper portion of Crane Street, Figure 3 shows the hourly traffic patterns based on both subsequent data collection efforts.

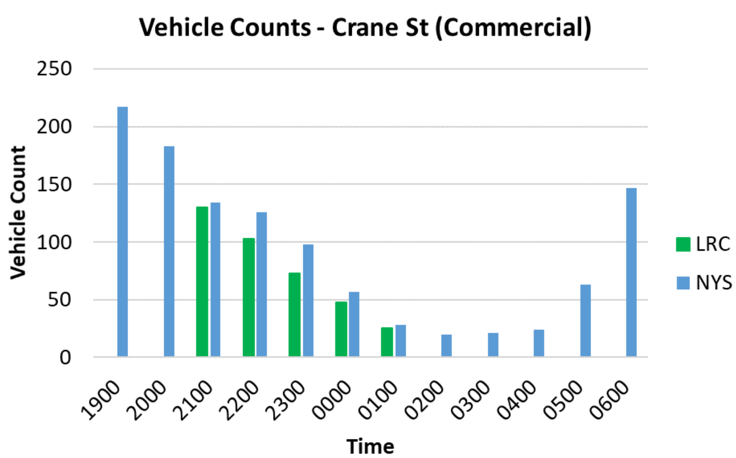

Figure 3. In-person (LRC) traffic count (in one direction) observations (green) and NYSDOT reported traffic volume data (blue) for a portion of upper Crane Street.

Both subsequent data sets were more consistent with each other and with the latter sensor-based set of data in Figure 2, although the hourly traffic volume values differ in magnitude. Most likely this is because the location of the vehicle traffic sensor was closer to lower Crane Street, south of its intersection with Chrisler Avenue, where many vehicles enter or leave Crane Street.

Pedestrian counts along Crane Street as assessed with the sensor data were much lower, making temporal patterns more difficult to assess. Nonetheless, except for upper Crane Street, the sensor recordings reported an average of fewer than 10 pedestrians per hour during all hours of the night. For upper Crane Street, pedestrian traffic did not fall below 10 pedestrians per hour until after 11:00 p.m.

This level of hourly pedestrian traffic is used by the Illuminating Engineering Society (IES, 2014) to identify times when street lighting levels might be reduced to account for lower activity patterns. During the time in-person traffic volume observations were made, pedestrian traffic between 9:00 p.m. and 2:00 a.m. were also made; pedestrian traffic averaged 33 pedestrians/hour until 12:00 midnight, after which 4 pedestrians/hour were observed between midnight and 1:00 a.m. and the same number in the subsequent hour.

Residential Area
Vehicle traffic counts along Pleasant Street in the residential area were generally much lower than along Crane Street, so temporal patterns were more difficult to assess. Nonetheless, neither vehicle counts nor pedestrian counts ever exceeded 10/hour for any of the nighttime hours during which data were collected.

Basis for Adaptive Lighting Criteria
Because different streets in different parts of the city are likely to have different absolute levels of activity during the night, it is suggested that two criteria be considered for reducing light levels from street lighting at certain times of the night. One is based on identifying hours during which the traffic volume is less than 50% of the peak traffic volume that occurs between the hours of 7:00 p.m. and 6:59 a.m. Another is based on identifying hours during which the traffic volume is lower than 10 vehicles/hour (in a single traveling direction) as an absolute criterion. Light level reductions could be considered when ***either*** of these criteria (traffic volume less than 50% of peak ***or*** fewer than 10 vehicles/hour) are met.

In addition, a criterion based on pedestrian traffic is also recommended. Based on IES (2014) recommended practices, an absolute criterion of 10 pedestrians/hour (on one side of the road) could be used to identify times of the night when street lighting levels could be reduced. Given the large drop in pedestrian traffic that occurs after 11:00 p.m., it is suggested that street lighting not be dimmed before 11:00 p.m. even if vehicle or pedestrian traffic levels would suggest otherwise.

Given these criteria, street lights along Crane Street in the commercial district could be dimmed from 11:00 p.m. until the 5:00 a.m. hour. Street lights in the residential area could also be dimmed during these hours, based on the observations and recordings of traffic and pedestrian use volumes.

IDENTIFYING APPROPRIATE DIMMING LEVELS

In order to identify appropriate dimming levels, an approach to gauge residents' impressions of different light levels was used, based on a short survey offered to residents in the Mont Pleasant district of Schenectady. The light levels in Mont Pleasant were dimming during eight nights (March 8-11 and March 15-18, 2021), for two nights at each of four output levels: 100% (not dimmed), 70%, 50% and 30%. Residents were asked to go outside and view the lighting during each of the four dimming periods and answer several questions about their impressions of the lighting. The average responses to four of the questions are shown in Figure 4.

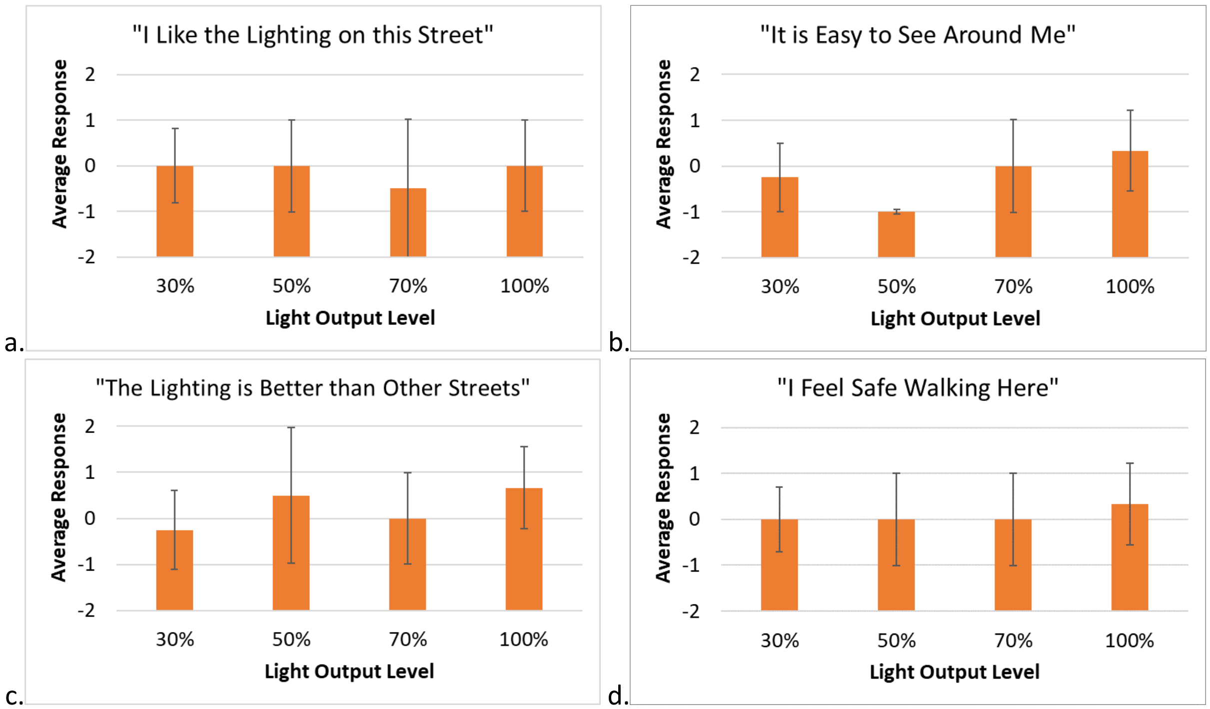

Figure 4. Average responses (+/- standard error of the mean) to four questions given in the survey questionnaire.

In general, there were no strong trends among any of the questions and the mean responses. Some respondents only answered questions for some of the conditions, and when only the responses of people who answered for all four lighting levels were considered, the trends did not differ. Accordingly these limited responses, given the large error bars and often non-monotonic answers, do not suggest there was much perceived different among the light levels from 30% to 100% output.

Photometric measurements of the light levels and photographic recordings of the street scenes were performed during one of the nights for each light level (on March 8, March 10, March 15 and March 17, 2021) in order to confirm that the lighting levels were indeed adjusted as planned between 30% and 100% output. Figure 5 shows measured light levels in three representative locations in the commercial and residential areas; the levels show a very close relationship between the intended output level and the relative level compared to the full output condition (defined as 100% for each location).

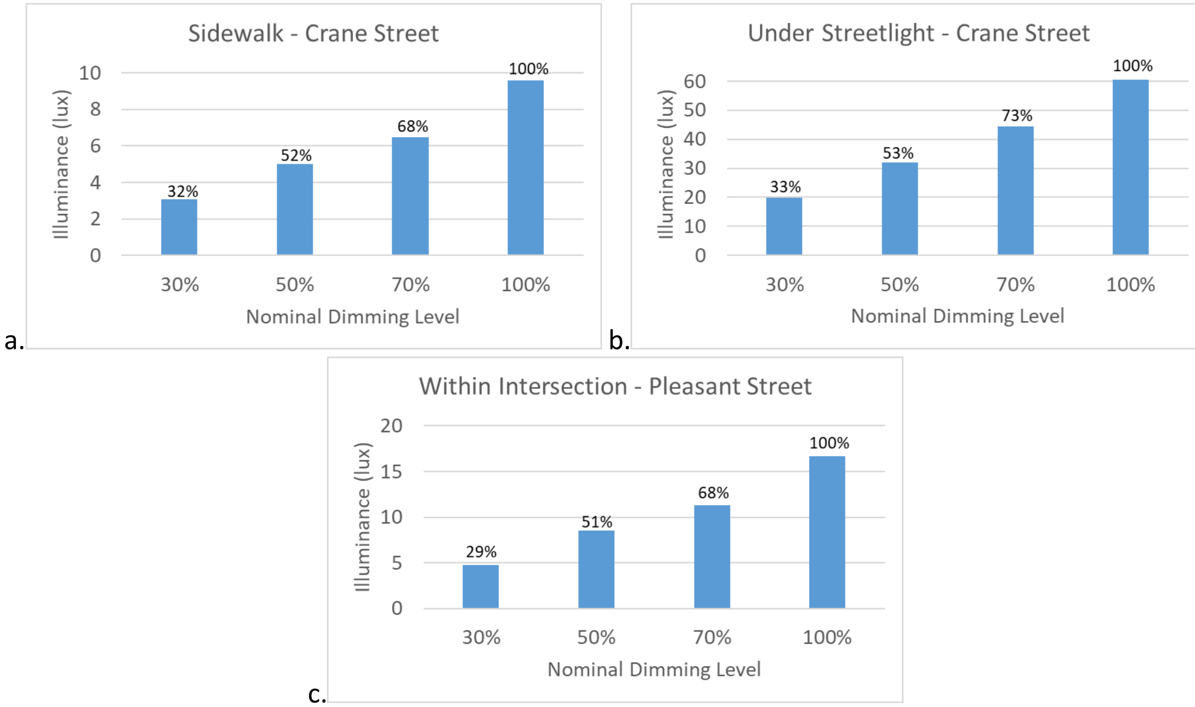

Figure 5. Measured light levels at three representative locations during the dimming evaluation test.

Figure 6 shows photographs of upper and lower Crane Street and Pleasant Street taken during the photometric measurement sessions. The aperture (ISO) setting on the mobile phone camera and the exposure time was manually set for each location in order to prevent the camera from adjusting any parameters in order to increase or decrease the brightness. The images in Figure 6 confirm visually that the light levels for each dimming level performed as expected.

One potential reason that residents might not have noticed that light levels for an output setting of 30% were substantially different from those for the 100% output setting is that in both commercial and residential areas, light from storefronts and residential porches and stairways could have made small contributions to the light levels on sidewalks. This ambient light could have offset the reduction from the street lighting, even though it would not have had a large impact on the light levels in the street itself. However, at night, vehicles will be using their headlights, and at speeds of 30 mph (corresponding to the speed limit in Schenectady), the Illuminating Engineering Society reports that vehicle headlights are the primary source of visibility for drivers along the street.

Figure 6. Photographs of three locations taken at each light output setting.

Because of the very limited responses to the survey questionnaire, further literature describing studies of adaptive outdoor lighting control was identified and reviewed. In one study of adaptive bi-level parking area lighting (Brons, 2019) at a community center in Seattle, WA, dimming levels similar to the ones used in the present field evaluation were compared: 100%, 70%, 50% and 26% output. Observers approached the lighted area and observed the lighting set to each output level. No differences in acceptability of the lighting were found among any of the output levels.

In another study that looked at bi-level dimming of LED street lighting (Rahman et al., 2013), levels that produced 62% and 38% of the original lighting system were compared in terms of satisfaction of the lighting by roadway users. At both levels (62% and 38% output), all of the users reported that the light level during their observation was “just right” rather than “too bright” or “too dim.”

A study of outdoor lighting at a college campus (Davis et al., 2015) was carried out in which LED luminaires were dimmed during periods of low activity to 20% of the full light output level. The researchers and property managers had been concerned that dimming the lighting to this level would be problematic, but users of the installation did not appear to have any issues with the reduced lighting and the campus received no complaints about the light levels or any reduction in visibility.

Together, these studies suggest that dimming to 30% light output as done in the present field demonstration is not likely to be noticed or judged as problematic by residents of an area. However, there still may be concerns with reducing light levels, related to the possible use of cameras that could record vehicle and pedestrian use in an area.

With regard to cameras, the minimum illumination specification for cameras used with outdoor lighting systems in Arlington, VA is 0.125 lux (Arlington, 2014). At typical pole spacings described earlier in this report, the 31 W LED lights would be expected to produce about 0.2 lux of illumination at the cameras, while the 71 W and 122 W lights would be expected to produce about 0.8 and 1 lux, respectively (this assumes an average ground reflectance of 0.1 corresponding to typical asphalt). Thus, an output level of 70% from the 31 W LED streetlights would be expected to yield an illumination level for the cameras of 0.14 lux, which still exceeds the minimum level of 0.125 lux recommended by Arlington (2014). Camera illumination under the higher-wattage streetlights would exceed 0.125 lux under all dimming levels investigated in this project (down to 30% output).

An analysis was performed to evaluate the light levels from Acuity Autobahn streetlights varying in wattage (31 W: ATBS, Type II distribution; 60 W: ATBS, Type II distribution; 94 W: ATBM, Type III distribution). These lights are being used in different locations of Schenectady. A comparison of the wattages, lumen output values, and average roadway/sidewalk illuminances for representative scenarios is shown below:

Scenario	Manufacturer and Model	Luminaire Wattage	Luminaire Light Output	Average Roadway Illuminance	Average Sidewalk Illuminance
Residential Street (low)	GE Evolve	31 W	3900 lm	5.2 lux	3.8 lux
	Acuity Autobahn	31 W	3629 lm	5.8 lux	3.6 lux
Residential Street (high)	GE Evolve	71 W	7800 lm	10.2 lux	7.7 lux
	Acuity Autobahn	60 W	6915 lm	10.4 lux	6.0 lux
Commercial Street	GE Evolve	122 W	13,400 lm	20.6 lux	9.9 lux
	Acuity Autobahn	94 W	12,065 lm	17.0 lux	10.4 lux

In general, differences in wattage, light output and average illuminances on the roadway and sidewalks between streetlights in the same overall wattage category are similar and average light levels are within ~5%-25% of each other for the same wattage category. Previously published work from the Lighting Research Center showed that in general, the light levels along the street from LED streetlights were proportional to their lumen output. It is suggested that a lumen output value of 4000 lm or lower be used as a threshold for deciding when a streetlight should only be dimmed to 70% output rather than 30% output as part of an adaptive lighting strategy.

SUMMARY AND CONCLUSIONS

Based on the findings of this project, the adaptive control system tested by National Grid in the Mont Pleasant district of Schenectady works as planned in terms of providing precise control over the illumination at specific times of the night. Based on the calculated and measured light levels and hourly levels of vehicle and pedestrian use, reducing light levels to 30% output would appear to have little impact on resident acceptability between the hours of 11:00 p.m. and 5:00 a.m.

In order to minimize disruptions associated with camera not being able to record activity under reduced light level, it may be considered to reduce the output from luminaires with wattages with a lumen output value of 4000 lumens or less (this corresponds to the 31 W GE Evolve or 31 W Acuity Autobahn luminaires) to a minimum output level of 70% rather than 30% in order to help reduce the likelihood that cameras will not be able to observe traffic or pedestrians. The municipality may also wish to use a higher output level under the following conditions:

- Reports of frequent accidents exist for specific locations
- Intersections with busy streets in residential neighborhoods
- The location is near a commonly used nighttime venue (e.g., school, church, community center)
- Trees and other vegetation block illumination from reaching the road and sidewalks (this may be a seasonal effect; when trees reduce light levels in residential areas, light output reductions below 70% should not be implemented)

Under any of these conditions it may be reasonable to avoid dimming altogether to ensure that light levels remain sufficient for visibility and for perceptions of safety.

ACKNOWLEDGMENTS

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