State of Rhode Island Public Utilities Commission

Proceeding to Establish a Pilot Metering Program for Municipal-Owned Streetlights

Docket No. 4513

Pre-Filed Testimony of

CIMCON Lighting

September 12, 2018

Contents

Q. Please state your name and business address.

William A. White III. 35 Crosby Drive, Bedford MA.

Q. By whom are you employed and in what capacity?

I am employed by CIMCON Lighting as Director of Emerging Technology.

Q. Please describe your educational background and training.

I have a Bachelor of Science Degree in Computer Science from Northeastern University in Boston, a Master of Science in Systems Architecture from Cesames Institut (Paris), and an MBA jointly awarded by New York University Stern School, London School of Economics, and L'École des Hautes Études Commerciales (Paris).

Q. Please describe your professional experience.

My career has centered around precision measurement and precision machine control. I have seven patents awarded and several more pending or in preparation.

My early career was in the defense business at Honeywell Electro-Optics Center in Lexington MA, writing machine control and measurement software. These systems included precision laser fabrication of cryogenically-cooled parts for infrared-guided weapons systems, high-speed precision resistor measurement and trim systems, complete precision measurement systems for wafer-level semiconductor testing, imaging and signal processing, and several other types of electro-mechanical control and measurement systems. I spent nine years in Honeywell's defense business.

I continued my career in the industrial automation industry at Modicon (now part of Schneider Electric), designing control systems used in many different applications, such as pharmaceutical production and bioreactor control, physical security, mining, water and wastewater, food & beverage processing, automobile manufacturing, etc. I spent 13 years in this industry, finishing at the top of the engineering ranks. Most electricians recognize Schneider Electric through their Square D brand of power distribution products.

From Schneider Electric I joined utility service company Doble Engineering, which provides precision test equipment to the utility industry for testing grid apparatus such as transformers, circuit breakers, and rotating machinery. This instrumentation provided precision stimuli to out-of-service substation apparatus, and collected equally precise measurements, as part of utilities' asset condition monitoring programs. Doble also provides onsite test services for those utilities that do not have the skill set on their staff. As Director of Engineering I led a 40-person team of engineers and support staff, including analog and digital electrical engineers, power system engineers, mechanical engineers, embedded software engineers, and PC application developers. Doble's customer list includes the 400 largest electrical utilities in the US, as well as in Latin America, India, and the

Philippines, and commercial customers with large electrical plant such as aluminum smelters. I spent 5 years in the utility service industry at Doble Engineering.

Following Doble I joined startup AirSprite Technologies, designing industrial wireless product for chemical plants and oil refineries. As Director of Product Engineering I was responsible for the entire package deployed in the field, most particularly the design for operation in explosive atmospheres and the related agency approvals. AirSprite Technologies expired during the financial crisis of 2008.

I rejoined Schneider Electric in a relatively new division developing and deploying environmental controls. As measured by unit shipments, much of this business is in typical office comfort-control applications, but specialized applications represent a disproportionate amount of revenue. These specialized applications, such as biocontainment facilities and pharmaceutical processing, often require precision environments, government-reportable records traceability, and conformance to regulations such as the Food and Drug Administration's 21 CFR 11 and the related pharmaceutical industry "GAMP 5" standard. Also, environmental controls in data centers are critical to the continued operation of the internet, including banking, communication utilities, and other mission-critical systems; data centers must meet standards set by the Uptime Institute. As Director of Technology Partnerships, I worked with industry majors such as Cisco and Autodesk to bring complete and integrated control solutions to market, including power distribution, granular metering, aggregation of small loads, active device management for energy savings and cost allocation purposes, and communications for distributed for controls and apparatus. I spent 6 years in that industry.

Most recently I joined CIMCON Lighting as Director of Emerging Technologies. In this role I evaluate new technologies for suitability in a streetlight-centric intelligent network system. I purposefully evolve those technologies for usefulness and compatibility with "life on the pole", and I incorporate those developments into our R&D plan for deployment into field-ready smart city applications. I have been with CIMCON since May 2017.

Q. What is the purpose of your testimony in this docket?

CIMCON's streetlight controller nodes were selected to be part of RIPUC's integrated circuit metering pilot project, the results of which were published in Nation Grid's Streetlight Metering Pilot Final Report. I represent CIMCON's stakeholder interest in that project and have a duty to ensure that our product performance is reported accurately to our potential customers, the cities and towns of Rhode Island, and to the general public, including public records such as this docket.

The pilot project report concluded that node metering is "*reasonable in metering the energy consumption*", but goes on to lists tests that "failed", although they were performed outside the limits prescribed by ANSI C12.20, outside the limits of the product data sheet, and outside the limits of the utility's commitment to power provision. The test procedure has merely discovered limits beyond which products do not operate, which is not sufficient to declare that they fail to meet actual requirements.

An effort such as this metering pilot should rather 1) determine whether node metering provides reliable metering under expected conditions, and 2) quantify any reduction in billing error enabled by the introduction of node metering. As part of that, the test plan might reasonably verify that products meet their own specifications, meet the applicable standard ANSI C12.20, and operate within the voltage and frequency range provided by the utility. Testing beyond that amounts to out-of-warranty operation of the product.

The report contains several classes of errors of reasoning and fact, which I detail in the Appendix and discuss in the narrative.

I will identify actual sources of uncertainty that result in differences between billed energy and energy consumed. I will quantify those uncertainties and estimate their worst-case cost. I will demonstrate that there are several sources of uncertainty that are not addressed in the report. These uncertainties can be mitigated by node metering.

Q. In sum, what is your expert assessment of the final metering pilot report?

In this testimony, when I refer to a page in the National Grid's Streetlight Metering Pilot Final Report, I refer you also to the corresponding rebuttal contained in the Appendix to this testimony. Also, for convenience I use an assumed electricity price of $0.25 per kilowatt-hour[1], which is high, perhaps twice as high as some ratepayers are paying. Reduce any dollar calculations below accordingly.

It is gratifying to see, on Page 87 of the report and elsewhere, the utility concluding that

> "*when properly specified, manufactured, and operated, the nodes' performance was reasonable in metering the energy consumption of the designated loads or street lights as compared with the existing unmetered analytical calculation*"

Node metering is a great step forward for smart cities and we are happy that NGRID agrees that node metering accuracy is reasonable.

At the heart of activity was the evaluation of streetlight controller nodes for metered energy measurements, determining the nodes suitability as an accurate meter using ANSI C12.20 as the meter accuracy standard, and quantifying the costs and benefits of implementation. NGRID's report makes various claims that lead the reader to the

[1] In January 2015, the highest rates offered (commercial variable or industrial) were nearly 21 cents. The same category today is 11 to 14 cents, varying by month. See http://www.ripuc.org/utilityinfo/electric/narrelecschedule3a.html

false conclusion that CIMCON's metering does not meet ANSI C12.20, and therefore its use in a system of energy management and billing is not advisable. Those claims are thoroughly refutable, as detailed in the appendix. Among the false claims are:

- Misstatements of CIMCON product specifications on report page 24, Table 1, and see "page 24" notes in the Appendix to this testimony.
- Claiming operational failure that occurred following abuse of the product. See page 33 and thereafter in the report, and "page 33" notes in the Appendix.
- Testing outside the product ratings. See ANSI C12.20-2010 Section 5.5.4.5.2: "NOTE—Test all conditions within the operating ranges of the meter."
- Misidentification of passing units as failures, page 42.
- Misidentification of untested units as failures, page 48.
- Misattribution of text and charts. No doubt a simple error, but sloppy work leading to false claims, on page 43.

Integration with billing systems was never seriously addressed, and eventually dropped entirely as a project deliverable. Despite the large reduction in scope, the project ran well over budget. The utility failed to assess or even identify potential changes in business process for integrating node meters and simply assumed that each streetlight must appear separately in the billing system. Aggregation of data from a streetlight fleet is something that CIMCON specializes in and could have contributed to that part of the solution.

The focus on meter accuracy to the exclusion of all other sources of billing error causes the report to miss its target entirely. As I detail below, billing error (in dollars) cannot be determined from meter accuracy tests because there are sources of uncertainty aside from the meter.

Separating signal from noise, the report concludes that node metering is a reasonable alternative for accurately measuring energy use to meet the needs of the utility and the community. The plain language of the report says so. Node metering also offers flexibility for the community that is not available in a fixed-price and fixed-schedule arrangement, and node metering avoids the large errors inherent in the S-05 tariff[2].

Q. What information is missing from the report?

I would have expected an analysis of billing errors that are embedded in the current process, and a comparison of that with the more accurate measurement enabled by node metering.

There is a potential for large errors built in to the population model embedded in the tariff; those errors are realized if the deployed fleet does not match the model. Node metering eliminates this class of error.

[2] See S-05 tariff at https://www.nationalgridus.com/media/pdfs/billing-payments/tariffs/ri/s05_ripuc-2190.pdf

There are also large errors inherent in the tariff bucketing approach, unless special care is taken to deploy luminaires rated in the middle of each tariff bucket. Node metering also eliminates this class of error.

Another source of billing error deriving from fixed tariffs are fixed schedules; when determining tariff rates, assumptions are made about burn duration which are then fixed into a permanent schedule; the assumptions become operating constraints and the cost of those constraints are never measured. These schedules are unlikely to match exactly the need for light, and in fact the schedules must light during many times when light is not required just to be sure there is light when it is needed. A smart lighting system with node metering provides several features that address these problems: 1) flexible scheduling 2) light-sensitive operation using the built-in photocell, 2) responsive lighting / motion detection to reduce usage when not needed, and 4) accurate metering for energy accounting and measuring the impact of changes.

If photocells are used, there is an additional mismatch between the photocell's control behavior and the assumed schedule in the tariff's billing model. This mismatch results in 2 additional uncertainties; 1) photocell operation will be affected by the weather (overcast or sunny at the shoulders of the day), and 2) there will be variability from one photocell to another. Fifteen minutes weather-related difference in a 12-hour schedule results in 30 minutes of uncertainty in each 24 hours, or just over 2%.

Photocells are a price-driven product. Accuracy and resolution are generally not quoted as part of the specification. It is reasonable to think that photocells provide an additional 2% or more of uncertainty.

Streetlight controls prevent both uncertainties (photocell variability and photocell sensitivity to weather) from appearing as dollar errors in the bill.

Billing errors embedded in tariffs are unmeasurable today except via laborious manual processes. Because of the size and likelihood of errors due to model mismatch, tariff bucketing, and non-optimal scheduling, a node metering approach will always be more accurate than legacy practice. The report should say so clearly.

Defective lights, such as dayburners or failed luminaires, are not accounted for. Either of these failure conditions immediately sever the fixed tariff rate from reality, while node metering will provide an almost instant alert and maintain accurate energy measurement during the failure.

No aspect of billing process was addressed. It should have been possible to propose a method of meter aggregation to adapt to the shortcomings of the legacy billing process. It is an obvious approach, and given the reduction in project scope and related increase in project cost, it should have been possible to demonstrate the possibility. Lighting control systems already have the information and can deliver it via secure web services.

An opportunity was missed to identify the many indirect and/or non-economic benefits of node metering. It seems clear that RIPUC was interested in the potential for incremental societal improvement by the deployment of granular metering and control of streetlights. Such improvements are of several kinds, 1) energy savings realized through active management of the light, 2) quality-of-life improvements, by adaptive lighting, installation of additional equipment (air quality monitor, hyperlocal weather, traffic counter, public safety cameras, and other "smart city" applications), 3) operational efficiencies of the type successfully deployed by Georgia Power and Florida Power & Light, and 4) future improvements invented or deployed after the metered technology platform becomes available.

The report did not assess any non-tariff-related economic benefits in the analysis, such as cost reductions enabled by fine-grained control (e.g., motion-sensitive lighting, time-of-day tariffs), or new revenue-generating opportunities such as digital signage or powering of telecom small cells, or information about the patterns of use of civil infrastructure such as travel routes in congested districts. These would further positively affect the economic viability of granular metering.

Quality-of-life improvements enabled by adaptive lighting are also not addressed, such as deep-dimming responsive lighting, lower light pollution, and multiple service schedules depending on the neighborhood. Cambridge MA, for example, decided on at least 11 separate lighting schedule regions, based on feedback from the community, and can tailor the lighting schedule even more closely as experience is gained. Recent reports from England indicate that, in some cases, reducing nighttime light reduces crime by reducing the number of attractive places to congregate. Without granular control, these types of inquiries are not possible except at great expense.

The report incorporates perceptions of non-benefit unsupported by evidence. An example suffices to illustrate this behavior. RIPUC directed that the cost of adapting the utility's billing system should be assessed as part of the project. The utility explicitly declined to make that cost assessment, but then goes on to claim that the cost is too high and therefore a fixed tariff is more cost-efficient. Either the cost has been assessed, or it has not been. Even the cost of assessing the cost is unknown.

Such a cost assessment would include an examination of more than one proposed billing method and whether each mode of billing is reasonable in the context of thousands of small loads, considering that the smart lighting control system has all the aggregated energy data already.

That cost assessment would consider the 20% and 33% errors that are built into tariff S-05; these errors are detailed in the appendix.

Also consider that such small-load aggregation is already being done in other contexts. Demand-reduction schemes aggregate load measurements from many consumers (refrigerated warehouses for example) and, those consumers can agree to curtail their usage (for a fee) on request from the utility. Cisco's EnergyWise offer aggregates usage from many different office devices (phones, printers etc); these devices can be automatically turned on/off on a schedule or via motion detection, badge swipe etc. In a large office complex with 25,000 phones, aggregation provides a powerful tool for cost reduction. The same logic is even more powerfully at work in the streetlight fleet, where the loads are numerous and higher than office equipment loads.

A reasonableness test for billing proposals has not been reached because NGRID has successfully avoided addressing the question altogether, and avoided the need to make any specific proposal or inquiry. They have assessed only meters, and not the billing results. There is no test of billing accuracy in the report, only meter accuracy.

The accuracy of the integrated circuit meters has been well characterized and any remaining meter uncertainty can be extinguished with a meter accuracy tariff that includes utility profit margin.

Q. What is your own analysis of potential errors in the billing process?

There are several sources of uncertainty in the current process, and each of these contributes to dollar errors on the bill. Some of these are:

- Mismatch between the deployed fleet and the population model used to determine tariff rates.
- Mismatch between the individual luminaires and the breakpoints in the tariff buckets.
- Mismatch between tariff-based schedules and the desired luminaire behavior.
- Lack of live data concerning dayburners and burnouts.
- Variability in photocell timing with varying daylight.
- Variability in inherent performance of photocells.
- Meter accuracy

The tariff model assumes a certain distribution of luminaires in the fleet, and places the luminaires into wattage groups that are billed identically. The actual deployment may not match the modeled distribution, which directly results in dollar errors on the bill.

Accurately determining the cost for this uncertainty requires an inventory of the fleet. While the inventory can be estimated using purchasing history, a true inventory process is laborious and therefore is often done on a sampling basis. It is important to note here that node metering can eliminate the need for manual inventory and can also provide full data on the fleet rather than sampling.

As with billing errors inherent in the tariff model, estimating the cost of errors built into each tariff bucket depends on the details of the fleet.

It is possible to identify the edge cases. For example, a 100-watt luminaire will be put in a tariff bucket with an attributed usage of 120 watts, nearly 20% billable error. This is because the entire load is considered, not just the luminaire rating, so the LED driver consumption as well as any consumption from a photocell or controller is also added to the nameplate load[3], pushing it into the next higher bucket.

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[3] From S-05*: "LED Nominal Wattage includes the total device system wattage (LED array, driver, and control) and applicable adjustments."*

The following table indicates the maximum billing error in each tariff bucket:

Luminaire Wattage Min	Luminaire Wattage Max	Billed wattage	Max overcharge	Max undercharge
0.1	20	10	9900.00%	50.00%
20.1	40	30	49.25%	25.00%
40.1	60	50	24.69%	16.67%
60.1	100	80	33.11%	20.00%
100.1	140	120	19.88%	14.29%
140.1	220	180	28.48%	18.18%
220.1	300	260	18.13%	13.33%

Note that the percentage of overcharge is higher than the percentage of undercharge, even with the same absolute error. For example, a 25-watt load will get charged as a 40-watt load, or 60% more than actually used. The same 15-watt absolute error, running a 55-watt load in the same tariff bucket, results in just 37.5% undercharge.

It is possible to estimate the percentage of luminaires that will operate with less than 2% billing error using the fixed tariffs. Let us consider luminaires from 20 to 300 watts, a total spread of 280 watts. Unless special care is taken to order luminaires that will minimize tariff bucketing error, we assume that the available market of luminaires is uniformly distributed in this range. The luminaires that will operate within 2% of tariff are 10 watts +-2%, 50 +-2%, 80 +-2%, 120 +-2%, 180 +-2%, 260 +-2%. These ranges account for 29.2 watts out of 280 watts in the range, or 10.43%. Put another way, 89.57% of luminaires will have billing errors of more than 2% due to errors built into the tariff buckets. The following table illustrates the percentage of the tariff bucket that is within 2% of the tariffed cost.

Bill Wattage	2% low end	2% high end	Spread	Bucket spread	% of bucket within 2%	% of bucket outside 2%
10	9.8	10.2	0.4	19.9	2.01%	97.99%
30	29.4	30.6	1.2	19.9	6.03%	93.97%
50	49	51	2	19.9	10.05%	89.95%
80	78.4	81.6	3.2	39.9	8.02%	91.98%
120	117.6	122.4	4.8	39.9	12.03%	87.97%
180	176.4	183.6	7.2	79.9	9.01%	90.99%
260	254.8	265.2	10.4	79.9	13.02%	86.98%
		Total spread	29.2			

It is clear from the table that, unless special care is taken to purchase luminaires tailored to the tariff, approximately ninety percent of luminaires will be billed with more than 2% billing error. Node metering eliminates this class of error.

There is a potential for large errors built in to the population model embedded in the tariff; those errors are realized if the deployed fleet does not match the model. Node metering eliminates this class of error.

Another source of billing error deriving from fixed tariffs are fixed schedules; when determining tariff rates, assumptions are made about burn duration which are then fixed into a permanent schedule; the assumptions become operating constraints and the cost of those constraints are never measured. These schedules are unlikely to match exactly the need for light, and in fact the schedules must light during many times when light is not required just to be sure there is light when it is needed. A smart lighting system with node metering provides several features that address these problems: 1) flexible scheduling 2) light-sensitive operation using the built-in photocell, 2) responsive lighting / motion detection to reduce usage when not needed, and 4) accurate metering for energy accounting and measuring the impact of changes.

If photocells are used, there is an additional mismatch between the photocell's control behavior and the assumed schedule in the tariff's billing model. This mismatch results in 2 additional uncertainties; 1) photocell operation will be affected by the weather (overcast or sunny at the shoulders of the day), and 2) there will be variability from one photocell to another. Fifteen minutes weather-related difference in a 12-hour schedule results in 30 minutes of uncertainty in each 24 hours, or just over 2%.

Photocells are a price-driven product. Accuracy and resolution are generally not quoted as part of the specification. It is reasonable to think that photocell performance will vary from unit to unit and provide an additional 2% or more of uncertainty.

Streetlight controls prevent both uncertainties (photocell variability and photocell sensitivity to weather) from appearing as dollar errors in the bill.

It is possible and desirable to quantify these uncertainties. The largest streetlight in Rhode Island's municipal fleet is 145 watts. At 25 cents per kilowatt-hour, with a 145-watt light burning 12 hours, a 2% error results in

0.145 kw * 12 hours * 30 days = 52.2 kwh per month actual usage

2% error = 52.2 * 0.02 = 1.04 kwh worst-case 1-month meter error

1.04 kwh * $0.25/kwh = $0.26 worst-case cost of meter error, per month

A meter accuracy tariff of 30 cents in this scenario would provide more than 13% profit margin on simultaneous worst-case meter error and worst-case load. Should actual meter error be better than worst case, the utility's profit margin increases. Note that, in general, this error may favor the utility or the customer. If the meter is perfectly accurate, or if meter error favors the utility, the meter accuracy tariff is pure profit. If meter errors average out to zero across the fleet, then the meter accuracy tariff is pure profit. If the load is less than 145 watts, the utility profit margin increases.

A more typical 70-watt luminaire on a 2% meter presents even less monthly risk:

0.070 kw * 12 hours * 30 days = 25.2 kwh per month actual usage

2% error = 25.2 * 0.02 = 0.50 kwh worst-case 1-month meter error

0.50 kwh * $0.25/kwh = $0.126 worst case cost of meter error, per month.

Under these circumstances, a meter accuracy tariff of 15 cents would provide 16% profit margin under maximum deployed load and worst case meter accuracy.

According to information received, the average wattage of the 16, 945 lights installed in the well-lit city of Providence is 106.4 for nameplate wattage, 75.05 for full operating wattage (at dawn and dusk), and dimmed 50% for six hours per night. The risk of significant dollar billing errors introduced by node metering is clearly low under these circumstances,. The inherent error in the fixed tariff is much larger and will almost certainly result in dollar errors on the bill.

Q. What are your concerns about the report?

A review of Docket 4513 and its predecessor Docket 4442 shows that this issue has been brewing since at least 2013. While other utilities (including those referenced by NGRID in the report) have successfully evaluated intelligent streetlight controls and their associated integrated circuit meters, and incorporated them into their business processes, NGRID has avoided doing so by serial failure to grapple with the issue.

Furthermore, the cover letter and abstract of the report contain assertions that are not supported by evidence in the body of the report. For example, "*using the* *unmetered calculation method for billing remains a less expensive way to achieve similar results*".

No assessment of cost was made for changes to billing practices; when this cost is assumed to be zero (as it is in the fixed-tariff case) then that zero-cost proposal has an obvious advantage over any proposal with even minimal cost. And yet the reader is left to wonder whether any alternatives at all were considered, and what that minimal cost might be that would affect the utility's judgment. The reader is left without the means to judge for herself.

The "*similar results*" referred to are the utility's own model of energy consumption. Clearly, if ratepayers use lighting exactly as predicted by the utility model, there is no need for any meter at all, whether utility-owned or customer-owned. But the fact is that ratepayers do not desire to use energy exactly as predicted, and furthermore, have no opportunity to assess costs and benefits of changes in usage and adapt lighting proactively for the benefit of the lighted and the ratepayers.

The unmetered calculation is not used for billing as claimed. Each luminaire is assigned to a tariff bucket based on nameplate wattage, plus LED driver and node wattage. The buckets I examined contain errors of ~20% and ~33%. The calculation is not used for billing. The midpoint of the assigned bucket is used. The S-05 tariff is simply inaccurate.

Q. What are your concerns about the testing protocols that were followed?

To be use meter accuracy tests as controlling elements in decision-making, several things are required.

A clear standard should be available for each aspect of the evaluation. I believe ANSI C12.20 is the standard for metering accuracy chosen for this initiative, which specifies that tests should be done within the specifications of the devices tested. There are many cases, detailed in the appendix, where devices were subject to out-of-specification conditions, and were claimed to have failed. That process is not what is prescribed in ANSI C12.20. In some cases the product was subject to abuse, by being operated and tested at nearly 90% above its ratings. It can hardly be claimed that products failed to meet their specifications under these circumstances.

There is no clear standard for the accuracy of the tariff. After all, it is also the electricity bill that needs to be accurate, and not only the meter. As noted elsewhere in this rebuttal, there are built-in errors of 20% and more built in to the 100 watt and 150 watt S-05 tariffs.

Q. What other issues did you identify in the report that are of concern?

The use of anecdotes as evidence is particularly troubling. A technical report such as this should focus on methods and measurements, and then conclusions should be drawn from those. Comments of the kind "somebody else said they had some trouble" do not inform the reader or help to evaluate the measurements that were actually made as part of the project.

Conclusions are presented in the cover letter ("*general conclusion reached … is that the network lighting controls did not meet … ANSI C12.20*") that are unsupported by the measurements and serve only to bias the reader before she even begins reading the report. These conclusions are apparently so infirm that they are not repeated in the report abstract. Indeed, the report abstract states that "*integrated circuit meter technology* […] *generally performed adequately enough to provide reasonable energy consumption measurement values*". The abstract does note that describing the products as "revenue grade" is "*not completely accurate*", implying that it is at least partially accurate, but it is difficult to discover what the utility found acceptable and therefore actionable.

Q. Are any other utilities using these devices for billing purposes.?

Yes. Not mentioned in the report is PG&E, who today sells CIMCON metering technology as part of their SmartPole Meter offer. Cimcon has more than 400,000 nodes deployed. The information and control they provide results in a variety of economic and non-economic benefits, including accurate accounting for energy, ensuring quality of service and rapid repair notifications, reducing maintenance survey time and cost, active management of energy use to reduce waste, reducing light pollution, and actively aiding pedestrians and drivers.

Also as noted in the report, San Diego Gas and Electric has used data from the meters to validate "*pre-determined billing metrics*". In San Diego, as here, the outcome regarding billing was predetermined, but at the end it was the node meter that provided validation for the predetermined approach. As here, no further flexibility or efficiency is allowed by the fixed-tariff arrangement.

Also as noted in the report, Florida Power & Light is using meter data to streamline maintenance. While not directly related to billing, FPL clearly sees economic value in having the node meter data. According to the report, FPL specifically rely on the voltage, current, and wattage readings from the node meters.

CIMCON has deployed a total of more than 400,000 metered streetlight nodes, including 40,000 in the City of Chicago, 40,000 in Halifax Nova Scotia, 15,000 in Worcester Massachusetts, and 40,000 in Jamaica.

Q. What are your conclusions?

Street lights are a golden goose for utilities and there is little incentive to change. Fixed tariffs must account for documented costs at the time of tariff inception, with profit margin built-in. Any errors built into the assumptions at tariff inception will never be discovered. Any cost reductions after inception accrue to the utility. The fixed tariff applies whether the light is operable or not. Municipalities have little incentive or ability to alter street lighting schedules and thereby save money or improve quality of life. Utilities have little incentive to upgrade or actively control street lighting while the income is stable.

The result is a system of sub-optimal stasis, in which captive buyers have limited scope for escaping their captivity. Evolutionary approaches that might improve efficiency with simple solutions (such as aggregating small loads outside the current billing system) are not addressed while red herrings are introduced (*"network service provider's head-end software proved challenging", "exposure and awareness of important considerations and specification criteria to be addressed by consumers"*).

In a sad future, when the time comes to address billing issues, another study (and years of delay) will be required. And by then integrated circuit metering technology will have evolved, requiring a new round of meter validation, imposing years of opportunity cost on municipalities in the form of savings never realized.

Q. What action do you propose?

It is clear from the data that node metering technology is viable. Variability in integrated circuit meters will be addressed in the normal course of business through normal quality control practices. This initiative should proceed assuming that meters provide good data because they are certified to ANSI C12.20 by an independent certifying agency.

At its core, aggregating meter values is just addition. Summing the results of many meters is already done today by the lighting control system. The lighting control system should be treated a single meter (or several, but not hundreds) within the current billing business process.

CIMCON has certified its nodes to ANSI C12.20. Certificates from a certifying agency should be given appropriate deference. That does not mean that the utility should simply accept whatever data the nodes produce; the quality of any batch of deliverables can certainly be challenged using a small test sample. It does mean that node metering is accurate enough for deployment and should be deployed for the benefit of the community.

RIPUC should recognize that node metering is not only "good enough" but is much more accurate than the current system of unconfirmed estimates.

RIPUC should recognize that there is a "lost opportunity" cost, in addition to the cost assessment for changes to billing practice. Eventually, node-level granular metering will be common, but the community loses the benefits between today (indeed, since 2013) and "eventually".

Two opportunities suffice to make the argument. First, motion-sensitive lighting allows reduced light pollution and reduces energy cost while being responsive to the public who are actively are using the light. Second, time-sensitive billing is an important load-leveling initiative across the power generation, transmission, and distribution industries, and streetlights are no different. Streetlights are a perfect place for municipalities to reduce energy cost, by taking advantage of low nighttime pricing, an option not otherwise available. Ratepayers should not need to wait for the utility to lead the way when it is so clearly against the utility's interest in this case.

It is not necessary that those opportunities provide a business case for investment by the utility. It is enough that they show the utility is not allowing municipalities to make full use of the asset in the right of way. Neither does the utility make full use of the right-of-way. Ratepayers are disadvantaged by that failure.

CIMCON will review our calibration method, and if feasible, will implement a multipoint calibration scheme with piecewise linear interpolation. That will allow our system to more closely approach the theoretical performance of the embedded integrated circuit meter. The use of small, distributed and varying loads has increased; the use of small, distributed meters is an obvious response, and CIMCON intends to be at the forefront of that industrial change.

CIMCON will review the anecdotes and anomalies reported and take corrective action as evidence indicates.

Cimcon will review performance at 96 volts, and make changes as required.

Appendix – rebuttal points

Cover letter

Reciting the utility's understanding of the RIPUC order:

(1) meter accuracy

(2) integration of meters with National Grid's billing system

(3) a comparison of metered rates to unmetered rates

(4) cost allocation.

The report itself does not cover these points congruently. Point 2 (billing integration) was abandoned at the request of the utility. That makes it impossible to make a comparison between metered and unmetered rates (Point 3) due to the non-recurring costs associated with changes in business processes.

Which further makes it impossible to perform cost allocation (Point 4).

I believe that leaves only Point 1 (meter accuracy) as the actual investment requested by RIPUC and addressable by the utility as part of the project budget. As a vendor participant in the project, CIMCON would not expect NGRID to evaluate us on criteria outside of the scope of the directive.

So, in term of congruency with the original directive, 3 out of 4 points were missed. Oddly, the reason for abandoning Point 2 was the high cost of performing a study to estimate one-time costs, when the essence of Point 2 was to provide exactly that one-time cost estimate. If a study to do an estimate is too much work, even though it is central to the analysis, then the problem is not well understood by the utility, and that knowledge gap should be filled by another entity.

It is also odd that the large reduction in scope has led to running over budget.

A reader might reasonably conclude that the utility is not best positioned to assess and judge the economic benefits of granular metering. Certainly, the utility has not done so despite directive, budget and opportunity.

Further, several extraneous qualitative points are introduced as if important. In industry this is known as FUD (creating Fear, Uncertainty, and Doubt).

Secondhand stories are introduced as evidence, using words like "*dismal*" (for anomalies not well-understood or well-measured) and "*reasonable*" (for things that were, in fact, clear indications of success). Such rhetoric is out of place in a technical and economic assessment.

So again, in relation to congruency with the original directive, anecdotes unrelated to Point 1 are introduced, while Points 2, 3, and 4 are wished away.

My recommendation, in reading the remainder of the report, is to consider only those issues related to the original directive Point 1, meter accuracy. It is the only part of the directive that has been addressed with any rigor.

The report claims that

> *"ANSI industry accepted protocols must be available to qualify … integrated circuit meters"*

ANSI C12.20 is the standard in question and has been applied to integrated circuit meters. After this report was released, CIMCON meters were tested by a certifying agency, which confirmed that CIMCON's design meets ANSI C12.20 as tested.

In the NGRID pilot, lab testing was not done by a certified testing lab. TESCO is a fine organization, but they are not a certifying agency, nor do they claim to be. Their claim regarding metering is at http://www.tesco-advent.com/service-meter-lab.html:

> "TESCO Meter Lab Services offer utilities the opportunity to investigate specific issues related their meters and/or metering department. These investigations often result in lab equipment, which TESCO will then install at our customer's facility. "

Abstract page 1:

Project scope expanded by NG to include (outside original scope):

> *Network communication operational performance*

> *Data transmission accuracy*

While these might conceivably affect the accuracy of integrated circuit meters (for example, if they cannot communicate their readings), the communication testing performed does not reveal any such defect.

> *The conclusions represent a commentary on the present state of the various technologies associated with the networked integrated circuit metering application, the business transitions occurring within the outdoor lighting market segment, and the various external forces conflicting with the utility-oriented outdoor lighting business paradigm.*

Clearly, conclusions and commentary about "*business transitions*" and "*forces conflicting with the utility-oriented … business paradigm*" are out of scope. An examination of these issues would necessarily go beyond the skill set and budget required by the plain language of the directive.

Likewise, "*commentary on the present state of various technologies*" does not constitute evidence that these technologies meet (or not) the requirements of RIPUC or the accuracy and precision requirements of the public utility.

Abstract page 2:

> *[…] industry standards are needed to establish accepted testing protocols to support the utility industry's required definition of revenue grade metering […]*

Industry standard ANSI C12.20 exists for this very purpose. CIMCON's devices have been tested by a certifying lab and shown to meet the ANSI C12.20 specifications when the devices are used according to instructions.

> *Many concerns became apparent when meter data information received from the variable operating schedule testing in the laboratory Meter Farm application presented meter read data inconsistencies, timing anomalies, and inexplicable and random data gaps.*

Such "*read data inconsistencies, timing anomalies, and […] data gaps*" do not provide evidence that CIMCON devices meet (or not) the required precision and accuracy for a metering application. Also, these seem to be precisely three concerns, or perhaps only one, but certainly not "*[m]any*".

The smart streetlight network is built on a resilient mesh of connections between nodes, with multiple paths possible between and endpoint node and a cloud-based aggregator. This design is intended to function in the presence of interference; that interference might well cause such temporary disruptions on communications.

The utility has not claimed that CIMCON meters are less precise or less accurate because of these temporary interferences, nor did they make any effort to determine whether the interferences were caused by the test setup itself. Such interferences might appear to be "*inexplicable and random*", but of course physics is at work here and such interferences are caused by physical phenomena. The lack of investigation into communications anomalies (an investigation which is indeed out of scope) does not render those anomalies "*inexplicable*" any more than they can be attributed to fairies or unicorns. It's science.

As part of any node deployment project, a site survey is performed to characterize the radio environment as it affects the deployed nodes. The site survey might be performed before or after node deployment. It is often the case that some nodes have higher rates of message loss than others due to site-specific conditions, such as crowded radio spectrum, interference with line-of-sight such as trees, weather etc. These are normal variations and are addressed in the field when they occur.

Lost messages are not uncommon, are already incorporated into the design of the resilient mesh network, are a small percentage of traffic, and <u>no data is lost</u> because the meter readings are sent again in subsequent messages. For a meter reading that is billed monthly this has proved adequate. Readings seconds or minutes apart would allow time-sensitive billing.

Page 10

> *On October 23, 2014, National Grid […] created a plan to (i) evaluate the meter manufacturer's laboratory test results; (ii) confirm the claims of the meter manufacturers through testing by National Grid in a controlled environment using sample sizes of each meter to provide a statistically significant result; (iii) evaluate the technical and communication capabilities of each meter; and (iv) select successful meter candidates for field testing with communications in a sample selected to provide statistically significant results.*

While points (i) and (ii) are clearly within scope, there are no specifications for evaluating and approving point (iii), the "*technical and communication capabilities of each meter*". This seems to be a catch-all for features which the utility prefers to deprecate regardless of their applicability to metering accuracy.

Also, in this section it is noted that "*municipalities expressed an interest in using aggregated street light node meter readings for the purpose of utility billing for the electric energy consumed, which was not an option at the time*". In Cimcon's case, the data was already available from the lighting control system, at the time of the test, and is available today through standard, secure web services. Using aggregated data was certainly an option, but the utility chose not to take it. If I were to engage in long-term delaying tactics, that is what I would do – ignore the available data and obfuscate instead.

Page 12

Beginning on page 12, there is an outline of the testing plan, interspersed with qualitative commentary about results that were obtained when the tests were performed.

Noted in section "*1.1 Bench Testing*" is that

> *The scope of several defined testing protocols was expanded to increase or decrease the various critical test criteria in an effort to observe the integrated circuit metrology performance when exposed to certain extreme circumstances. The benefits of the expanded application included the exposure and awareness of important considerations and specification criteria to be addressed by consumers at the time of network lighting control system procurement.*

While integrated circuit metrology performance is clearly within scope, providing "*exposure and awareness of important considerations and specification criteria to be addressed by consumers at the time of network lighting control system procurement*" is clearly out of scope. The PUC has not directed this activity as part of Docket 4513, nor is it clear even today what those "*important considerations and specification* *criteria*" are or how they might be evidenced. The PUC has not asked for help in selecting or purchasing a lighting control system.

I recommend ignoring portions of the report that are outside the scope of "metering accuracy" since these out-of-scope issues were not addressed with any rigor.

Page 14

Noted in section "*1.2 Meter Farm Testing*" is that "*Additional testing was performed to assess actual lower consumption characterization of various LED luminaires based on a linear dimming output/power profile*".

Such nonlinearity of LED devices does not affect the correctness of the meter reading from the node.

There is no expectation that a curve plotting the 0-10 volt dimming signal vs. LED power consumption should be perfectly linear, or linear within some tolerance, or even that such linearity is desirable or that nonlinearity is problematic.

Linearity testing of LED devices serves to drive up the project cost without providing forward progress on the project goals, which center around billing errors and not around the LED device.

Inclusion of this type of extraneous test result, here and elsewhere in the report, distracts the reader and instills false doubt about quality of node metering in general, while not actually delivering useful information to RIPUC about meter accuracy.

Also noted here are an unspecified "*variety of meter data reporting concerns*", with no further detail, again occupying the reader and injecting false doubt while providing no actual information as to metering performance.

Page 13

Noted in section "*1.4 Information System Integration*" is that IS integration was immediately identified as a project activity to be jettisoned as having "*larger and more diverse scope … than originally anticipated".*

The utility approach to the billing problem shows no inclination to innovate. If a fleet of streetlights were to provide their own meters, then (according to the utility) each of these meters must be incorporated individually into the utility IS system. Furthermore, because of the utility limitations on the number of meters per location, a large number of new accounts would require creation (and individual billing) to support the new meters. It is not surprising that costs will quickly become unreasonable.

According to the report, a typical deployment of 10,000 streetlight controllers would require 10,000 new meters to appear in the utility IS system. Even consolidating meters into fewer bills would results in hundreds of new bills in many deployments. It is not surprising that this approach is not found to be cost-effective. To a systems engineer like myself, with analogous experience in several industries, this solution seems absurd.

I suggest that this approach is rooted in 19th-century electrical practices. The 21st century offers additional options. Aggregation of many small-load meters could simplify the "many meter" problem greatly. Such aggregation could be done by the lighting control system, requiring just 1 new meter to appear in the utility system of record. See above the discussion of aggregated demand reduction, and aggregated office equipment management, for examples where this approach is already applied successfully.

Page 14

Section "*1.5 Comparative Billing Analysis*" notes that "*Upon completion of the […] meter test results, calculation of unmetered energy consumption was performed"* and these results were used as the baseline for comparison of measured vs. estimated.

This section does not report any "*Billing Analysis*" and does not actually analyze any billing. An examination of billing would identify sources of error in the S-5 tariff and estimate their effect on billing, not merely check the meter readings. As noted elsewhere, a ~20% overcharge is built in to the S-05 tariff for every 100-watt and 150-watt luminaire in the field. A 60-watt luminaire is overcharged by ~33%.

While CIMCON is confident that the utility's calculated results are reasonably accurate, we also note that creating accurate estimates by calculation is quite easy after one has collected reams of actual measurements to test the estimation model against. The estimate becomes even more accurate when the lighting end user is not permitted to deviate from the modeled behavior.

In contrast, creating estimates from first principles eventually requires comparison to the real world, in the form of actual measurements.

Given the case that the utility's estimates were created **after** numerous actual measurements were taken, it would be quite surprising for the utility to provide estimates that differed significantly from CIMCON's measurements.

Also, given that the utility's modeling remains proprietary, it would be surprising for the utility's model to produce a number significantly different from an actual meter reading, which would bring obvious questions as to the nature of the divergence.

Finally, the utility's vigorous investigation of metering accuracy is not matched by a vigorous inquiry as to the accuracy of the resulting electric bill. As noted elsewhere, the electric bill for luminaires bill may contain dollar errors of 20% to 33%, and perhaps more, due to tariff bucketing and billing higher than actual wattage.

Page 15

Section "*2.1 Pilot Program Justification*" indicates, as only a bureaucrat can, that "*third-party stakeholders opined that the proposed unmetered billing tariff did not insufficiently provide an accurate representation of the consumed energy relative to the use of new LED luminaire technology*".

The odd construction "*did not insufficiently provide"* we assume means "did sufficiently provide".

We are to understand here that an unnamed third party believes that the unmetered tariff is sufficient. Unquantified hearsay from a third party, filtered through the utility, is not evidence that CIMCON's meter meets (or not) ANSI C12.20.

Also in this section, the utility notes "*concerns regarding the inability to manage the proposed street light meter reads from customers using the current meter billing functions within all related information systems*". Of course, using the current meter billing functions was foreseen as an issue, and that is why the IS integration issue was originally in the order.

The utility chose to avoid this issue and then claim their system can't handle it, rather than look for solutions.

Further in this section, the utility notes that "*two unmetered annual operating schedules*" were used for evaluation against the vendor meters. Not included in this evaluation are the cost of changing these schedules in the current manual system vs. a system of automated controls. Also not included are the costs of creating separate schedules for different subsets of the streetlight fleet, in the current manual system vs. a system of automated controls. Also, not included are the lost savings opportunities provided by lighting controls, such as motion-sensitive operation, which also help to reduce light pollution. Also, not included are quality-of-life improvements provided by lighting controls such as adaptive and responsive lighting. Also not included are the "*unmetered annual operating schedules*" themselves, leaving the reader to wonder whether those schedules correspond to the behavior desired today or in future. The schedules provided in the report cover only a single 12-hour period with no seasonal or annual component.

Also in this section, the utility claims that PUC ordered the utility to "*ascertain factual information regarding the accuracy and performance reliability […] for energy consumption metering*". Several places in the report describe communication anomalies, but nowhere are these anomalies claimed to affect metering accuracy or performance for billing purposes.

Page 16

Section "*2.2 Network Technology Status*" indicates a "*lack of approved industry testing and performance standards in addition to the proprietary nature of the system communication configuration*".

On this point, first, it is not necessary to have an industry standard for network testing practices as a prerequisite to approving an energy meter.

Second, the proprietary nature of the radio protocol is the utility's own choice. The utility specifically and intentionally chose a proprietary radio system. Non-proprietary systems could have been chosen, for example, the many non-proprietary systems based on IEEE 802.15.4, including those offered by CIMCON.

In any case, I believe that CIMCON did provide a Zigbee-based solution. Zigbee is not proprietary.

This section goes on further to decry "*inherent technology limitations caused by the lack of device interoperability due to the use of proprietary systems*". Again, the choice of using proprietary systems was intentional on the part of the utility.

While the utility "*made significant efforts to determine and create project partnerships that would allow for the collaboration of multiple product vendors*", that served only to further drive up project cost while making no headway towards evaluating integrated circuit meter accuracy. A project to form a collaborative that serves the business purpose of the utility may certainly be justified in the utility's business judgement, but is not justified by the directive that initiated this project. Such a collaborative is not necessarily in the interest of the vendors or the municipalities, which is perhaps why these efforts failed.

Page 17

Section "<u>3.2. Testing Vendor Selection</u>" notes that TESCO has been chosen to perform the test. TESCO is a reputable firm, but it is not a certifying agency for ANSI C12.20. After the issuance of the final report, CIMCON commissioned an independent certifying agency (ERDA) to test its metering technology to ANSI C12.20. Certificates are available upon request.

The report positions TESCO's results as a certification of CIMCON's nonconformance with ANSI C12.20. CIMCON is prepared to challenge that conclusion and have evidence in hand from a certifying agency.

Page 19-21

Section "*4.1.1.3. Alternate Utility Experiences*" provides several summaries from third parties, as restated by NGRID.

The report notes that Florida Power & Light has 95,000 nodes deployed. The report claims that FPL "*did not use the nodes' metering capabilities"* but then goes to claim that FPL's work management system "*automatically dispatches service personnel and generates service tickets based on abnormal voltage, current, or wattage readings as reported by the nodes*".

They cannot have it both ways. The reader wonders where NGRID think the abnormal voltage, current, and wattage readings are coming from, if not from the meter in the node.

Presumably the lights were already metered somewhere and no stakeholders (including FPL) required more granular metering, or billing changes.

FPL is in fact a great success story for lighting controls, reducing the maintenance burden for the utility and for the ratepayers. Meters embedded in the nodes were essential to this success. Anecdotes regarding an unspecified number of nodes (out of 95,000) failing do not obscure this success.

The report notes that San Diego Gas and Electric had "*started testing nodes with real loads",* and *"expressed observations that at low dimming levels, the power factor and total harmonic distortion of the luminaires tested began to produce significant negative results*". It would be important to know how low is "*low*" and whether that is a realistic dimming level. Actual human behavior would be unlikely to produce dimming requests of 1% or 2.5%; in my experience most people choose percentages that are round numbers, and nobody chooses to dim their lights to 1% or 6%. A low-level threshold is easily implementable within the current product capabilities if these nonlinearities are shown to be a real risk to billing accuracy.

The report goes on to say the "*[t]he metering validation only assured the use of the reported energy consumption meter values*" and that "*San Diego Gas and Electric used the meter values*". It seems that San Diego Gas and Electric provides another success story for node metering.

The report notes that Georgia Power "*performed prequalification testing*" but "*did not include any manufacturers selected for the* [NGRID] *Pilot*". Results were "*fairly accurate"* (GP quote) "*up to 10 amps"* (NGRID quote).

It is important to note that CIMCON product is not rated for 10 amps at 120 volts. It is surprising to this reader that project time was spent testing product outside its design range, and then using that data to disqualify the tested product. That fact the performance was "*somewhat dismal*" at 15 amps only serves to underline this point.

While "*Georgia Power expressed additional concerns regarding the use of the wireless communications network*", these problems seem not serious enough to document in any detail.

Likewise, while there were claimed "*excessive time requirements to observe the final test results*", the reader is left to wonder what the limit of excessibility is, and whether "*excessive time*" in a live-testing lab environment is equivalent to machine time for a device in the field that is billed monthly, and whether that kind of anecdote should be a controlling factor in acceptance of integrated circuit metering in this project.

Page 22

Section "*4.1.1.5. Test Parameters*" claims that "*requirements were modified to* […] *conform the test parameters more closely to the vendor's stated node specifications*". That fact that CIMCON's product was tested and 10 amps and at 15 amps indicates that the utility's requirements-modification process contained substantial defects, generating lots of labor that produced no useful information. Not only was CIMCON's product tested outside of its design envelope, the high-current end of CIMCON's product was not tested at all, where it would be most accurate. The utility promises a voltage minimum of 114 volts (see https://www.nationalgridus.com/media/pronet/constr_esb750.pdf), which at CIMCON's specified limit of 960 watts would be just under 8.5 amps.

Section "*4.1.1.6. Test Duration*" notes that the resolution of meters will vary, while their accuracy must remain within specification, and that test time is affected by resolution. While the test-time metric may be important in a lab setting, it does not affect the practical use of the integrated circuit meter, the accuracy of its readings, or its usefulness for municipal purposes including adaptive lighting and paying for actual usage.

Page 23

Section "*4.1.1.7. Load Current*" notes that "*advertised current limit of each node tested was approximately 10A*". This is not correct. CIMCON's iSLC 3100 data sheet notes a limit of 960 watts. With a DC load at 120 volts, 960 watts would result in 8 amps of current. To stay within the specification, 10 amps would need to be supplied at 96 volts maximum. As noted above, NGRID advertises 114 volts minimum at the point of service under normal conditions.

This section further notes that a

> "*secondary justification for the 10A Full Load current rating was that National Grid believed that the nodes can and will be used in the future to meter more than just LED luminaires, including for a wide range of pole-mounted ancillary equipment*"

CIMCON concurs that a wide variety of equipment will be pole-mounted in future, and that energy used by that equipment must be paid for. Testing 8-amp devices at 10 amps is not a useful exercise towards that future.

Most LED fixtures use much less than 8 amps, leaving plenty of headroom for additional devices. For example, the largest LED floodlight in Rhode Island's municipal fleet draws just 1.39 amps. Additionally, it might well be that, in a future of finely metered energy, those ancillary devices will usefully require their own, separate meter. In any case, those ancillary devices are not the problem of the utility, as long as the energy is paid for.

CIMCON's performance specification is misstated in this section:

> "*The advertised current limit of each node tested was approximately 10A, based on vendor specifications stating a power rating of 1,800 volt-amperes (VA)*"

CIMCON's data sheet indicates 1560 VA. The reader is left to wonder what nodes were actually tested.

Section "*4.1.1.9. Network Lighting Control Vendor Input*" is perhaps most problematic. This section of the report purports to summarize the key performance promises of each of the submitted test nodes. The nodes are not identified by manufacturer. CIMCON does not offer nodes that match any of the devices in Table 1 on Page 24. The reader is left to wonder what devices were actually tested.

CIMCON's iSLC 3100 has an operating temperature limit of -40 F to + 158 F, which would indicate that CIMCON is either Vendor C or Vendor D. However, the voltages supported by these vendors are 90-320 VAC and 105-305 VAC, respectively. That does not describe CIMCON's iSLC 3100.

Vendors A and B both support voltages of 85-264 VAC as standard, which does match CIMCON's iSLC 3100. However, the claimed support of 1200 watts, temperature limit of -22 F, and maximum switching capacity of 15 amps do not match CIMCON's iSLC 3100.

Also noted in this section is that "*Vendors A through C did not believe that their nodes would hold tolerance at the*" 15 amp level. Testing at this level seems not a good use of project budget given that, even if the units pass at 15 amps, three of the four the manufacturers would likely consider that an out-of-warranty usage of the product. CIMCON would not offer to extend the warranty on an 8 amp product for 10 amp or 15 amps usage without a rigorous technical review and necessary adaptations. Also, asking vendors what they "*believe*" is interesting but not evidence that their product meets (or not) the specifications on the vendor's product data sheet or the requirements of ANSI C12.20.

Page 25

Section "4.1.2. Final Test Specification" notes that

> "*The final bench test specification [… a]dded tests for full load amperage at 15A*"

This, despite the fact mentioned above that this current level is outside the specifications of CIMCON and believed to be outside of the operating range of three of the four vendors.

This section further notes that

> "*Added tests for expanded voltage testing at +/- 15% rated voltage and +/- 20% rated voltage. This requirement was requested by National Grid as a check to address voltage variance ranges that may exist at locations where the nodes could be installed.*"

ANSI C12.20 specifies testing at 90% of the lowest rated voltage and 110% of the highest rated voltage. Failures at +-15% and +-20% are not indicative of failing ANSI C12.20. See the topic of FUD raised above.

Those "rated voltages" are voltage of the devices, not mains voltage.

It appears that the utility means +-20% of nominal mains voltage.

No ANSI C12.20 pass/fail decision should be made on the +-15% or +-20% mains variation tests, unless it also falls within the +-10% ANSI C12.20 test with respect to the rated voltage of the device. That is my understanding of the standard and the utility's intent.

Page 28

Section "*4.1.4.1. Service Provider 1 Communication Method*" describes a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 29

Section "*4.1.4.2. Service Provider 2 Communication Method*" describes a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 30

Section "*4.1.6.2. Data / Results*" encourages the reader to "*Reference Attachment 2 (Final Bench Test Specification Plan) for a detailed explanation of test conditions and individual test methods*". This reader would certainly like to do so, but the attachment is not actually attached, nor was it submitted separately as part of the docket. This makes it difficult to identify whether there are other factors, other than testing outside the design envelope, that might influence the results and lead to faulty decision-making.

Page 31

Test 4.5.1 (no load) passed.

Page 32

Test 4.5.2, (10 milliamp test). This test produces the expected results. CIMCON imposes a "Current Creep Limit" cutoff, below which we assume is noise and assume the true current to be zero. In this case the limit is calculated to be 30 mA. This test should be considered passing for several reasons.

First, the node works as designed; small currents are ignored as a noise rejection feature. It would be surprising to get any other result.

Second, the limit is imposed in software and can be changed or removed.

Third, 10 milliamps is not a reasonable setting for a luminaire. It is around 1% of full scale, perhaps much less, depending on the luminaire. Human behavior will tend to set dimming on a "one to ten" scale, perhaps with half-steps in the mid range. This behavior can be codified if the 10 ma error is considered to be serious.

A 10 ma continuous error at 120 volts amounts to 0.864 kilowatt-hour, or 21.6 cents.

Page 33

Section "*Test 4.5.3.1 – Load Performance – Full Load*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 34

Section "*Test 4.5.3.2 – Load Performance – Light Load*"

Because we do not know which vendor is CIMCON, and indeed Table 1 of the report does not describe any CIMCON product, it is difficult to respond to this test data. However only Vendor C raises any concerns, with 50% of Vendor C units operating outside of the acceptable error band. Vendor A and B both have 90% of units within the error band, and Vendor D 100%. With this small sample size is it not possible to confidently make generalizations about fleet performance.

Page 35

Section "*Test 4.5.4 – Power Factor Variation*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 36

Section "*Test 4.6.1.2 – Voltage Variation – Full Load (-10%)*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 37

Section "*Test 4.6.1.3 – Voltage Variation – Full Load (+10%)*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 38

Section "*Test 4.6.1.5 – Voltage Variation – Light Load (-10%)*" is difficult to reconcile with known facts. CIMCON offered two lots of nodes with the same metering technology in both lots. We would expect to see similar performance from both lots, but Vendor B and Vendor D are most similar on this chart. Vendor D offers the infrared output, so we know that is not CIMCON. As above, knowing the test setup and which nodes are CIMCON will help in understanding the data collected.

Page 39

Section "*Test 4.6.1.6 – Voltage Variation – Light Load (+10%)*" describes all but one node passing for Vendors A and D. Without knowing which nodes are CIMCON, it is difficult to investigate the nature of the single outlier. In any case the graph shows the outlier for Vendor A to be at -1.2% error, which seems to be within the claimed 2%.

Page 40

Section "*4.1.6.2.4. Frequency Variation Tests*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 41

Section "*Test 4.6.2.2 – Frequency Variation – Full Load (+2%)*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 120 volts results in 1200 watts of load, 25% above CIMCON's 960 watt rating.

Page 42

Section "*Test 4.6.2.2 – Frequency Variation – Light Load (-2%)*" contains an error. The text describes 3 of 4 nodes passing for Vendor A. All the markers for Vendor A (2%) are within 1.5%, and yet one is claimed to have failed.

Page 43

This page is an error. Section "*Test 4.6.2.2 – Frequency Variation – Light Load (+2%)*" refers to Graph 13. Graph 13 is a scatter plot labeled "*Test # 4.6.3 (a) – Custom Test – Voltage – Full Load (+15%) – ANSI C12.20 Test N/A*". There is no correspondence between the text and the chart.

One Vendor B unit failed, apparently after repeated testing at 10 amps. The report later details testing at 10 amps and 144 volts, 50% above CIMCON's rating, and no further failures were noted.

Page 44

Section "*Test 4.6.3 (a) – Custom Test – Voltage – Full Load (+15%)*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 138 volts results in 1380 watts of load, 44% above CIMCON's rating.

The claim is made here that "*Vendors A through C failed to meet their stated specifications on any of the four nodes tested*". This statement is not correct, assuming that CIMCON is Vendor A, B, or C. CIMCON does not claim to support a 10 amp load at 138 volts.

Page 45

Section "*Test 4.6.3 (b) – Custom Test – Voltage – Full Load (+20%)*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 144 volts results in 1440 watts of load, above CIMCON's rating.

The claim is made here that "*Vendors A through C failed to meet their stated specifications on any of the four nodes tested*". This statement is not correct, assuming that CIMCON is Vendor A, B, or C. CIMCON does not claim to support a 10 amp load at 144 volts.

Page 46

Section "*Test 4.6.3 (c) – Custom Test – Voltage – Full Load (-15%)*" is a 10 amp test. This test is not valid for CIMCON meter accuracy testing. The 10 amp load at 102 volts results in 1020 watts of load, above CIMCON's rating.

The claim is made here that "*Vendors A through C failed to meet their stated specifications on any of the four nodes tested*". This statement is not correct, assuming that CIMCON is Vendor A, B, or C. CIMCON does not claim to support a 10 amp load at 102 volts.

Page 47

Section "*Test 4.6.3 (d) – Custom Test – Voltage – Full Load (-20%)*" is a 10 amp test at 96 volts, which should draw 960 watts, right at the top of CIMCON's limit. Vendors A, B, and C failed, and Vendor D failed 1 out of 4.

The fact that three units were successful within 0.5% at the low end of voltage variation indicates that the technology can be successful. It appears from the graph that an additional unit was within 1% and four more within 2%. They are considered failures because they don't meet their own spec, but otherwise conform to the 1% and 2% accuracy classes.

If a 2% accuracy is considered acceptable for the small load of a streetlight controller, then in fact 8 units passed, That is further evidence that the technology can be usefully applied.

The small load of a streetlight brings noise into the previously clear economic signals provided by tariffs. The cost of lighting has dropped dramatically and continues to drop. The quality of light has also improved at the same rapid pace.

Much of NGRID's text focuses on uncertainties, but here are just two:

1. What is the fixed "streetlight service fee" that will account for the meter uncertainty? My calculations indicate this uncertainty is small and will affect

the bill by just pennies even in the worst case. It is possible to charge a higher fee for lower-accuracy units, and build profit margin into that fee.

2. What is the process for aggregating many small metered loads outside of the legacy billing system? I propose that it can be ANSI C12.20. The node meters today produce a digital reading and digital readings are acceptable to the utility. It is straightforward to create software to collect and aggregate data from several meters; streetlight control systems do this today. The aggregator can provide data for each of the individual meters that it monitors. The aggregator can also provide summary statistics for the purpose of billing.

The aggregator provides digital readings and can be tested as any other digital meter.

The aggregator already exists, in the form of streetlight control systems. It is a straightforward project to set up a lab version of lighting control, add a small fleet of lights just as was done in this pilot, and test the output of the control system as inputs are permuted.

This might have been usefully done in place of testing the linearity of LED drivers, which seems out of scope. It would also have made great progress towards solving the billing question.

Page 48

Section "*Test 4.6.4 (a) – Custom Test Load (15A)*" is a 15 amp test. This test is not valid for CIMCON meter accuracy testing. The 15 amp load at 120 volts results in 1800 watts of load, 87.5% more than CIMCON's rating.

The claim is made here that "*Vendors A through C failed to meet their stated specifications on any of the four nodes tested*". This statement is not correct if CIMCON is Vendor A, B, or C. CIMCON does not claim to support a 15 amp load at 120 volts.

Furthermore, the report claims both that "*Vendor B could not be tested because of time constraints*" and that "*Vendors A through C failed*". Vendor B seems to get the short end, counting 4 untested Vendor B units as failures.

Page 49

Section "*Test 4.6.4 (b) – Custom Test Load (0.5A)*" is a 15 amp test. If CIMCON is Vendor C or D, this section is not correct. CIMCON does not claim to support 15 amps at 120 volts. CIMCON cannot be considered failing to meet its specifications under those test conditions. That is 1800 watts, 87.5% more than CIMCON's rating.

Page 50

Section "*4.1.6.2.7. Customer Tests – Parasitic Load*" notes first that "all nodes passed".

Section "*4.1.7. Observations*" notes that two nodes ceased operating, but there is no information about which Vendor. It is not clear if these are in addition to the one reported earlier. Or if there are 2 in total. I suggest this claim should be discounted as not actionable. The nodes should be returned to the Vendor for forensics.

This section notes that it takes "*a few minutes any of the nodes to come back online after even a brief (less than 10 seconds) power outage*" and this "*may become an issue*". CIMCON nodes do not store energy for continued long-term operation, but just enough for a short period of urgent power-down activity. The time to join a network after power up is not dependent on the amount of time the power was out. I am certain that the utility already has many devices with these characteristics. The network formation time of a few minutes is normal. Network formation time does not affect the accuracy of the node meter.

Page 51

I encourage the reader to deprecate qualitative comments on this page not relevant to meter accuracy. Such factors as user-friendliness for lab technicians is not at issue in the directive.

One Vendor A defect is partially noted, that a start reading for one test was lower than the final reading of the previous test. The report claims that was "*possibly during power cycles*" and that "*could be significant over long periods of time*".

Since we do not know what the readings are, we are unable to agree that the difference could be significant over any given period of time. Assuming that the power fails daily in this utility's service area, and one 10 watt-hour meter tick has gone missing each and every time, in the course of 30 days the uncompensated energy use would be (10 watt-hours * 30 days / month) = 0.3 kilowatt-hours.

At 25 cents per kilowatt-hour, that is approximately 7.5 cents per month, and then only if the power fails every day. It will be a long time indeed before this measurement error appears on the accounts.

Later in the report (page 88) additional detail about this error is provided, indicating that error amounts to a few thousandths of a kilowatt-hour (perhaps just 0.009 kwh), not nearly the 0.3 kilowatt-hour used in the worst-case calculation above.

Also noted in this section is that "*Vendor A explained to National Grid*" its 8.5 amp calibration and low-current measurement cutoff. In the same paragraph it is noted that "*Only Vendor D took the opportunity to provide feedback to National Grid*". The reader is left to wonder why the explanation provided by Vendor A is not considered "*feedback*" and why the clarifications provided by Vendor A are not reflected elsewhere in the report.

Page 52

Beginning at Section "*4.2. Meter Farm Testing (Stage 1-Phase1)*" the testing process is described in summary. The detail is to be found in attachments., for example "*Attachment 6 (Photocell Node Meter Farm Testing – Project 8594)*" is specifically referred to. That attachment seems to be not actually attached, which make it difficult to discuss this section in detail.

Presumably this test setup produced the result expected by the utility.

Page 56

Section "*4.2.5. Test Results and Analysis*" subsection "*4.2.5.1. Laboratory Conditions*" notes that "*The temperature was not regulated, but typically varied between 70ºF and 80ºF*." This is outside the limits prescribed in ANSI C12.20 section "5.5.1 Test Conditions".

Page 59

Section "*4.2.5.2.3. Communication Integrity Test Results – Service Provider 1*" states that "*There were occasions, however, on Vendor A nodes, where the accumulated Watt-hours prior to the shutoff were greater than after the power was turned back on to the nodes. An example of this condition can be observed in Attachment 10 (Meter Farm Testing Data Final Report)*".

However, it seems that the attachments have been redacted, making it impossible to assess this claim. As calculated elsewhere in this appendix, a 1-tick error during daily power failure could result in approximately 7.5 cents worth of lost energy. That amount could certainly be embedded in a token service fee for meter uncertainty. Ones hopes that the utility would address the daily power failures in this scenario, rather than a lost meter tick due to daily power failures.

The possibility that the meter is correct should also not be discounted. The instantaneous effects of uncontrolled connection and disconnection have not been analyzed. It is conceivable that a small amount of energy capacitively stored within the node or the luminaire is transferred "wrong way" across the meter during these uncontrolled connects and disconnects. If the meter had just crossed one tick, the energy could be enough to turn it back. Without having access to the data, there is no opportunity to rule out 1-tick rounding or counter-currents as an explanation for this observation.

The reader can infer that this error is the same as the "*few thousandths of a watt-hour*" error previously described. At 25 cents per kilowatt-hour, each thousandth of a watt-hour is worth 25 micro-cents. A 10 thousandths watt-hour error would need to occur 20,000 times to amount to 0.5 cents, rounding up to a billable penny. That seems unlikely on its face and that rate of error was not experienced during testing.

Page 60-64

Page 60-64 describe tests that all passed or were not performed. Numerous attachments are referred to in this section. These attachments seem to have been redacted from the final report.

Page 63 – Section "*4.2.5.2.6. Communication Integrity Test Results – Service Provider 2*"; see notes for page 59 regarding uncontrolled connection and disconnection. Attachments supporting this section were redacted.

Page 65

Section "*4.2.5.2.7. Variable Schedule Analysis – Both Service Provider Networks*" provides information about the testing of nodes in simulated schedules. Two charts are shown with the same data, differing only on the x-axis tick marks and a half-hour incongruity at the chart boundary. It is not clear what the second chart is intended to show that the first chart does not show. Both charts show a schedule with lights on for 12 hours per day, with 3 levels of dimming in addition to 100% and 0%, and no other variability.

It appears that all 4 vendors showed occasional missed messages, and also 3 out of 4 vendors showed "*100% dimming power [...] did not always stay at 100%*". While interesting, these observations are not actionable. It is not clear how this "*not always stay*[ing]" phenomena manifested itself. Did the light go out? Dim? Did the measurement dip?

Given that these anomalies are shared by multiple Vendors, it is conceivable that the anomalies are introduced by the test environment or by a misconfigured option.

This section commonly reports occasional "node reports X power when expected Y". That would seem to be the instantaneous power reading from the meter, not the accumulated energy reading. Given the data from other tests, it does not seem that instantaneous power readings affect the measurement of energy usage. We should not discount the possibility that at least some of the instantaneous readings, which may seem anomalous at first, are correct and reflect the true behavior of the LED/driver/node/grid/lab equipment dynamic system.

A key feature of resilient mesh networks is that their messages are stateless, in that they do not depend on previous messages or affect subsequent messages. The meter accuracy tests do not show any effect from radio anomalies.

The anomalies were easily identified during testing, and discounted.

Page 77

Section "*4.2.5.2.8 LED Luminaire (0-10V Driver) Power Consumption – Dimming Rate Characterization*" illustrates that a perfectly linear dimming signal into an LED driver does not produce perfectly linear power consumption. The 16 graphs show that, no matter how much you test it, you will get the same result.

That is interesting but not relevant to meter accuracy. It would be easy enough to make a multipoint calibration to linearize what is by its nature a nonlinear physical process, but it is not very useful or profitable. The 0-10V dimming signal is exactly that: it is a signal. It is not a calibration constant and it is not not used in any measurement.

Page 81

Section "*4.2.6. Observations*" notes that a third-party, Michael Poplawski, concurs that the nonlinearity previously described is normal. It must be concluded that all tests related to linearity of power consumption and dimming signal should be considered to have passed, although they seem not part of ANSI C12.20, nor part of CIMCON's specification.

This section reports an anomalous reading. which seems to be the same as previously reported and addressed above. The reader should not understand that reported phenomena are common simply because the same event is reported multiple times in the report.

Page 83

Section "*5.2.7. Test Equipment Deployment and Validation*" provides a qualitative description of schedule-based testing, and assures the reader that supporting data will be found in "*Attachment 13 (RIDOTFrenchtown Road Park & Ride – Proposed*

Test Operating Schedule) and *Attachment 14 (Frenchtown Road Park & Ride – Working Schedule)*", however these attachments seem to be unavailable for review.

Section "*6. Billing System Integration (Stage 2-Phase 1)*" claims to provide justification for not performing the billing integration study, however, the details are claimed to be in attachments that seem not to be part of the docket.

Page 84

Section "*7.2. Unmetered Calculation Methodology*" provides the elementary calculation for energy use. It is noted here that the calculation does not account for day burners, outages, or convenience outlets. Not mentioned is that municipalities may not desire that schedule, or may desire to adapt schedules it over time, without requiring a government hearing or a utility service fee for each change.

No matter the accuracy of the calculation, large errors are introduced when luminaires are bucketed into discrete billing categories.

There is significant measurement error built into tariff S-05. For example, the error band for 100 watt fixtures is 120 watts +-16.67%, when LED driver and node dissipation is included, as it must be. The tariff for a 100 watt LED fixture is likely to be at least 15% higher than its nameplate wattage would justify. A 150 watt luminaire will be billed at 20% higher than its nameplate wattage.

Page 87

Section "7.4. Field Testing Observations" states that

> "*when properly specified, manufactured, and operated, the nodes' performance was reasonable in metering the energy consumption of the designated loads or street lights as compared with the existing unmetered analytical calculation*".

This would seem the be a declaration that node metering has been shown to be successful.

This section goes on further to say that "*the unmetered calculation methodology cannot account for inoperative lights*", a feature and benefit provided by node metering.

This section also notes that "*National Grid generally observed the existing National Grid standard revenue grade metered usage data to be noticeably higher than the calculated unmetered value or the exported XML usage values obtained by the nodes*" but goes on to note that is because the NGRID meter was measuring things that were not passing through the node meter. At the end, field test data from four sites was discarded.

Page 89-90

This chart contains much nonsense. The previous section notes that four data set were discarded, and yet they are presented here as evidence. It seems that only the Park & Ride site produced quality data.

The charts in this section label vendors as Vendor X, Y, and Z. It is difficult to understand whether these correspond to Vendor A, B, C, and D etc as previously used in the report. However, it is clear that the nodes perform much more accurately than the error band in the S-05 tariff schedule.

Page 92

Section "*8. National Grid Opinions and Recommendations*" introduces red herrings to distract from the successful performance of node metering during the pilot.

The installation of devices, such as cabinet heaters in electrical panels, does not affect the utility of node metering for streetlights. The fact that NGRID discovered these ancillary devices only by accident indicates that the current system has holes, and addressing those holes is outside the scope of streetlight controls.

The user-friendliness of the software is not a controlling factor as to whether node-level metering is viable technology.

The claim is made that "*using the unmetered calculation method for billing remains a less expensive way to achieve similar results*" to node-based metering. However, no costs assessment was ever made as part of the project, so this conclusion is not supported by the evidence presented.

Furthermore, such a conclusion will depend on the definition of "*similar results*". Node metering and lighting control software allows fine-grained and adaptive control. A fixed schedule and a fixed tariff cannot offer similar results to adaptive lighting.

Indeed, the report states clearly here that the "*billing system can be expanded to accommodate a limited increase in the number of unmetered schedules*" but that would "*pose[] a serious concern related to the affirmative application of the schedules by the operator*". Those are strong constraints imposed by the legacy system of fixed schedules and fixed costs, not at all "*similar results*" to what municipalities would get with an adaptive control system.

NGRID naturally recommends further testing, but the purpose of this docket is to implement the Municipal Streetlights Investment Act. The Act specifies that controls may be used. The report demonstrates that node metering is viable and accurate enough for billing purposes. Rhode Island should move forward with deployment of proven technology for the benefit of the public. Investigations of DALI, further linearity testing of LED drivers etc, are not useful in this context.

Signed

William A. White III

August 26, 2018