COMMONWEALTH OF KENTUCKY
BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

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| ELECTONIC APPLICATION OF KENTUCKY UTILITIES COMPANY FOR AN ADJUSTMENT OF ITS ELECTRIC AND GAS RATES, A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY TO DEPLOY ADVANCED METERING INFRASTRUCTURE, APPROVAL OF CERTAIN REGULATORY AND ACCOUNTING TREATMENTS, AND ESTABLISHMENT OF A ONE-YEAR SURCREDIT | ) | CASE NO. 2020-00349 |

In the Matter of:

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| ELECTONIC APPLICATION OF LOUISVILLE GAS AND ELECTRIC COMPANY FOR AN ADJUSTMENT OF ITS ELECTRIC AND GAS RATES, A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY TO DEPLOY ADVANCED METERING INFRASTRUCTURE, APPROVAL OF CERTAIN REGULATORY AND ACCOUNTING TREATMENTS, AND ESTABLISHMENT OF A ONE-YEAR SURCREDIT | ) | CASE NO. 2020-00350 |

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# DIRECT TESTIMONY OF RICHARD BUNCH
# ON BEHALF OF
# LEXINGTON-FAYETTE URBAN COUNTY GOVERNMENT
# AND
# LOUISVILLE/JEFFERSON COUNTY METRO GOVERNMENT

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**March 5, 2021**

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## I. Introduction and Qualifications

**Q. Please state for the record your name, position, and business address.**

A. My name is Richard Bunch. I am a senior consultant with 5 Lakes Energy LLC, a consulting firm located at 220 MAC Avenue, Suite 218, East Lansing, MI 48823.

I am also Executive Director of Michigan Municipal Association for Utility Issues (MI-MAUI), a non-profit association that gives local governments in Michigan a collective voice and technical support in utility regulatory proceedings and in direct relationships with regulated utilities.

**Q. On whose behalf is this testimony being offered?**

A. I am testifying on behalf of Lexington-Fayette County Urban Government and Louisville/Jefferson County Metro Government.

**Q. What is 5 Lakes Energy, LLC?**

**A.** 5 Lakes Energy is a Michigan-based policy consulting firm dedicated to advancing policies and programs that promote clean energy and sound water policy for a resilient environment.

**Q. Please summarize your educational background.**

A. I hold a Master of Business Administration degree with Environmental Management Certificate from University of Washington Business School, and a bachelor's degree in political science from Yale University. My resumé is attached as Exhibit Bunch 1.

**Q. Please summarize your professional development coursework in the field of electric utility regulation.**

A. In June of 2019 I attended EUCI's Outdoor Street Lighting Conference: Best practices in streetlight design, strategy, deployment, and LEDs in Atlanta. In July of 2019 I attended EUCI's Electric Cost-of-Service - Essential Concepts for a Changing Industry Course in Chicago.

I have worked for more than five years in positions related to clean energy, primarily on behalf of local governments. A significant portion of that work has included analysis of Michigan utility rate and other cases and supporting local government participation in rate cases and other regulatory proceedings. From 2015-2017, I organized and led the Municipal Street Lighting Coalition, a group of 24 municipalities served by DTE Energy, which intervened in Cases U-17767 and U-18014 and participated in the Michigan Public Service Commission-ordered street lighting collaborative. I organized and supported intervention of several municipalities receiving street lighting services from Consumers Energy in cases U-20134 and U-20697 and served as an expert witness in both. I also served as an expert witness on production cost allocation in MPSC case U-20561, DTE general electric rate case. I currently am representing municipalities in a Michigan Public Service Commission-ordered technical conference addressing numerous Consumers Energy street lighting tariffs and practices, and application of the state's Service Quality and Reliability Standards to street lighting services. I am currently also representing municipalities in intervention to DTE Electric Voluntary Green Energy case U-20713 before the MPSC. I have submitted comments in several other dockets on behalf of MI-MAUI and have participated in various MI Power Grid working groups and the Electric Distribution Planning working group.

**Q. Have you testified before the Kentucky Public Service Commission?**

A. No.

**Q. What is the purpose of your testimony?**

**A**. I am testifying on behalf of Lexington-Fayette County Urban Government and Louisville/Jefferson County Metro Government regarding street lighting rates and tariffs.

**Q. Are you sponsoring any exhibits?**

A. Yes, I am sponsoring the following exhibits:

- Exhibit Bunch 1: resumé of Richard Bunch
- Exhibit Bunch 2: revised allocation of required revenue among KU and LG&E tariffs
- Exhibit Bunch 3: DTE Electric Company Community Lighting Outdoor Lighting Outage Cost 2009-2018.
- Exhibit Bunch 4: DTE Electric Company Community Lighting Outdoor Lighting Outage Duration 2007-2018
- Exhibit Bunch 5: excerpt from testimony of Robert Bellini, Director of Community Lighting, DTE Electric Company, in Michigan PSC case U-20561
- Exhibit Bunch 6: "Lamp Lighters and Sidewalk Smoothers: How Individual Residents Contribute to the Maintenance of the Urban Commons", Daniel T. O'Brien, American Journal of Community Psychology (2016) 58:391-409

## II. Street Lighting Is An Important Service and Cost of Local Governments that is also Central to Their Achievement of Various Policy Objectives

**Q: Why are local governments concerned about quality of street lighting services?**

**A:** Street lighting is among the most ubiquitous and visible services offered by local governments. Many residents and business owners feel an abiding personal interest in street lighting along their block and see the quality and reliability of street lighting as a barometer of the municipal government's overall effectiveness.

Street lighting also contributes strongly to place making, a key concern of economic and community development officials. A downtown business district with poorly designed or unreliable street lighting is unlikely to be perceived as a cheery and welcoming environment for shoppers, diners, strollers and others.

Street lighting contributes to traffic and pedestrian safety, bedrock responsibilities of local governments. The relationship between street lighting and crime prevention and enforcement is complex and poorly understood, but it clearly enhances perceived safety which may encourage more people to be out and about after dark.

**Q: Why are local governments concerned about the cost of street lighting services?**

**A:** Unless a municipality operates its own water treatment facilities, street lighting is likely to be its largest energy expenditure. In most municipalities, street lighting costs come out of the general operating budget. Money saved on street lighting can be re-allocated to higher-priority needs including police and fire protection or can be returned to taxpayers in the form of tax cuts.

**Q: Why are local governments concerned about energy used by streetlights?**

**A:** All local governments feel a keen responsibility to steward taxpayer dollars responsibly, and less energy used means less money spent.

In addition, a growing number of local governments have adopted energy-related policy goals, ranging from energy efficiency targets to carbon-reduction/climate goals. While many climate- and energy-related policy objectives involve difficult tradeoffs, switching to LED street lighting not only saves money and advances climate and energy goals, but also improves the quality of service.

**Q: What is the scope of your testimony in this proceeding?**

**A:** I address the cost, quality, and reliability of street, traffic and outdoor lighting services offered by the Companies. Broadly, I address three topics:

- The unreasonably high rates of return that the Companies charge to their lighting tariffs;
- The Companies' slow, costly and inequitable practices for converting their streetlight fleets to LED luminaires; and
- The Companies' poor performance keeping the lights on, identifying when they are off and fixing them quickly.

## III. The Companies' Rates of Return for Lighting Tariffs are Excessive, Unfair and Detrimental to Public Policy

**Q: Are the Companies' proposed rates of return for lighting tariffs fair to lighting customers?**

A: No. Please see my Exhibit Bunch 2 for a comparison of rates of return across the Companies' tariffs and rate impacts of a more equitable allocation of required revenue.[1]

KU proposes a 7.26% rate of return (ROR) averaged across all rates. For Lighting Rate LS/RLS, however, the Company proposes to maintain the current 12.32% ROR. LS/RLS customers collectively would pay $5,829,438 more under the Company's proposal than if they paid the average rate of return for all customers. Lighting Rate LE is proposed to continue paying 28.05% rate of return, and Lighting Rate TE would continue to pay 12.39%, both also far above the company-wide average

LG&E proposes a 7.18% overall rate of return. For Lighting Rate LS/RLS, the Company proposes to increase the current 9.74% rate of return to 12.0%. Lighting customers would pay $4,559,419 more at the Company's proposed rate of return than if they paid the average ROR. Lighting Rates LE and TE are proposed to remain at 31.88% and 15.01% ROR, respectively, also far above what the average customer would pay.

An equity adjustment to these rates is long overdue. It is unconscionable that lighting customers should perpetually pay sharply higher rates than customers in other rate groups. The Companies' proposed rates fail to acknowledge this inequity in any way, offering no

[1] Bunch Exhibit 2, based on data drawn from KU and LG&E COSS studies, "Summary Returns" worksheets.

equity adjustment and even increasing the main LG&E lighting rate even further above average ROR.

**Q: What changes should the Commission order to lighting rates of return?**

**A:** The Commission should order both Companies to charge company-average rates of return to all three of their lighting rates.

**Q: How should revenue requirements be re-allocated as result of this change?**

**A:** Reduced revenue requirements from the lighting tariffs should be re-allocated to tariffs proposed to pay less than company average, to create the same percent change in rates for each of them.

In the case of KU, the Residential, Time of Day Primary and Secondary, Retail Transmission and Fluctuating Loads rates would all absorb 0.48% increases in revenue. Despite these increases, each of these classes would remain well below KU's overall average ROR.[2]

In the case of LG&E, the residential tariff would absorb a 0.92% increase in revenue and would still pay well under half the ROR paid by the average LG&E customer class.

Imposing more equitable rates of return is not only a matter of fairness to municipal budgets, but also a question of fairness so that those who use the streetlights pay for them. Many individuals, beyond the citizens of a municipality, obtain benefits from the streetlights provided by the municipality. Street lighting is a public service that creates value to all ratepayers. Even ratepayers who live outside of Lexington and Louisville benefit from street lighting when they visit those cities.

[2] See Bunch Exhibit 3.

**Q: Why not re-allocate required revenue gradually, to avoid rate shock?**

**A:** The impact on the rates that would absorb the re-allocated revenue would be very small in percentage terms, so rate shock is not a concern.

There is a compelling, urgent need, however, to correct the rates of return being paid by lighting customers. Most of my testimony in this case focuses on the desire of local governments to expedite installation of LED luminaires as quickly as possible, foremost to reduce their costs but also to improve lighting quality and reliability. Charging excessive rates of return to lighting tariffs distorts the pricing signals that the Companies and their customers receive and may well slow the deployment of LEDs. For example, the Companies have provided an internal study comparing the Net Present Value of two LED conversion plans differentiated mostly by timeline.[3] The study concludes that the faster timeline has marginally higher NPV than the slower timeline, but the Companies are currently opting for the slower timeline because it's a close call and the slower scenario requires less near-term investment. I take issue with assumptions and conclusions of that study later in my testimony, but my point here is costs inflated by unreasonable rates of return imposed on lighting tariffs are proving to be highly consequential for the Companies' investment decisions today.

**Q: What action do you recommend the Commission take with respect to rates of return on the Companies' lighting rates?**

**A:** I recommend that the Commission set rates of return for the lighting rates equal to average rates of return for both companies. To make the changes revenue neutral for the

[3] Company witness Wolfe, attachment to response to LFUCG1-KU and -LGE question 5, pp. 75-80.

Companies, I further recommend that the Commission increase revenue requirements by equal percentages for all tariffs proposed to pay less than average rates of return.

## IV. The Companies' LED Luminaire Conversion Plans are Too Expensive, Too Slow and Inefficient

**Q: Do the Companies' standards and practices for LED conversion impose reasonable costs on customers?**

A: No. The Companies' standards and practices drive up customer costs unnecessarily and unreasonably. First, the Companies are exceeding manufacturer recommendations for LED luminaires that replace HID fixtures, which also incurs unjustified costs. Second, installing higher-wattage/lumen LED luminaires than recommended results in energy waste over the long lifetime of the LED luminaire, which drives up customer cost. Third, the Companies are employing inefficient methods for converting fixtures to LED, which drives up labor costs. Fourth, the Companies are assessing arbitrary and unnecessary conversion fees on customers who request expedited LED conversions. Fifth, the Companies' lighting tariffs are not consistent with principles of cost causation, a problem that will be more acute if the Company accelerates its pace of conversions under the plan I propose. Sixth, the Companies are paying too much for LED luminaires. Seventh, the Companies are not tracking capital and operating costs in sufficient detail, undermining accuracy of cost allocation and efficacy of asset management.

**Q: Do the Companies comply with manufacturer recommendations when choosing LED luminaires to replace HID fixtures?**

A: No. The Companies' default LED luminaires to replace the most common types of HID fixtures use significantly more energy, generate significantly more lumens and cost significantly more than the manufacturers' suggested conversions, but provide no purported benefit to customers.

Cobrahead fixtures are the most common installation type in most municipalities, and the High-Pressure Sodium 100w nominal (117w with ballast) is usually the most common cobrahead luminaire. The manufacturer recommends that 100w HPS cobrahead luminaires be replaced with 31-39w LED luminaires,[4] realizing 67%-74% energy use reduction.

However, for this common conversion, the Companies' standard LED replacement is a 71w LED luminaire[5] which uses about twice as much energy as the manufacturer's recommended models and realizes only about 39% energy use reduction compared to the HPS fixture it succeeds.

Similarly, the manufacturer's suggested conversion for a 200w HPS cobrahead fixture is a 71w-98w LED, but the Companies instead install a 122w LED,[6] again realizing significantly less energy use reduction than the manufacturer's recommended conversion would.

The Companies offer no justification for departing from the manufacturers' suggested HID conversions. "The Company does not have its own internally developed technical specifications or metrics to select LEDs ."7 There are no universal benefits to increasing

[4] Witness Wolfe, Attachment to Response to LFUCG-1 Question 5, p. 4-5 of 89.
[5] Witness Wolfe, Attachment to Response to LFUCG-1, Question 12b, spreadsheet row 13.
[6] Witness Wolfe, Attachment to Response to LFUCG-1 Questions 5 and 12b (Ibid).
[7] Witness Wolfe, Response to LFUCG-2, question 8a.

illumination above design specifications as presumably represented by the pre-existing HID fixture.

**Q: Does systematically replacing HID fixtures with higher-wattage LED luminaires than recommended by manufacturers create benefits for customers?**

A: No. Unless a site-specific lighting study shows that higher levels of illumination are indicated, increased lighting is as likely to create safety and nuisance problems as it is to improve roadway or public safety. The Companies have not indicated that they are seeking to create such benefits through their technical conversion standards, nor have they provided lighting studies showing how and where such benefits might be created.

It should never be assumed that increasing roadway illumination without careful, site-specific study would be a harmless measure that could only help. Excessive roadway illumination can create glare and contrast that make it harder for roadway users to quickly and accurately perform necessary visual tasks, resulting in decreased safety for motorists and pedestrians. Excessive illumination can also create nuisances including light pollution and light trespass. Likewise, peer-reviewed academic research has not demonstrated a clear and consistent link between increased lighting and crime reduction.

Roadway illumination should be increased only if current illumination levels are below IES (Illuminating Engineering Society) standards or careful study supports site-specific changes for public safety reasons. Indiscriminately increasing illumination costs money and is as likely to create problems as solve them.

**Q: Does replacing an HID fixture with a higher-wattage LED luminaire than recommended by manufacturers impose reasonable capital costs on customers?**

A: No.

LED purchase costs increase in relation to wattage/lumen output. The Companies spend $218.06 for the 122w LED described above, but if they used the 71w LED at the bottom of the manufacturer's suggested conversion range, they would spend only $167.23. [8] The difference in "Investment per Unit Total" between these two luminaires, once all material, labor and burden costs are added, is $62.62.[9]

**Q: Does replacing an HID fixture with a higher-wattage LED luminaire than recommended by manufacturers impose reasonable operating costs on customers?**

A: No. Installing a higher-wattage LED than standard practice forces the customer to use, and pay for, more electricity than is reasonable over the 25+-year expected service life of the luminaire.

KU's proposed energy rate for the LED tariff is $0.07178/kwh.[10] KU's standard conversion of 117w HPS to 71w LED instead of 39w (or less) LED forgoes at least 32w of energy savings compared to manufacturer recommendation, costing customers at least $9.19 in additional energy cost per year. If this level of forgone energy savings is typical across all streetlights in the KU fleet, once converted to 100% LED the City of Lexington's 31,000 streetlights would incur about $284,821 in excess energy cost per year, or more than $7.1 million over the projected 25-year service lives of those LEDs – assuming the retail cost of

[8] Witness Wolfe, Attachment to Response to LFUCG-1, question 118a, spreadsheet cells H17 and I17.
[9] Witness Wolfe, Attachment to Response to LFUCG-1, question 118a, spreadsheet cells H50 and I50.
[10] Company witness Seelye, KU Exhibit WSS-4, "KU LED Rates", spreadsheet cell K7.

electricity does not increase. Because LED luminaires have such long service lives it is critical to install the most energy-efficient luminaire that meets lighting design criteria.

LG&E's proposed energy rate for LEDs is $0.07293/kwh[11], slightly higher than KU's rate, meaning that forgone energy savings from conversions are even costlier to Louisville than Lexington.

Because streetlighting is typically the first or second largest energy use of municipal governments, the forgone energy efficiency gains represented by the Companies' luminaire conversion standards also significantly compromise the ability of municipal customers to achieve energy efficiency or climate/carbon reduction goals for well into the future.

**Q: Do the Companies' policies and methods for converting HID fixtures to LED luminaires impose reasonable costs on customers?**

A: No. The Companies are using inefficient LED conversion policies and practices that impose excessive and unjustified costs on customers.

**Q: How could the Companies convert HID fixtures to LED luminaires more efficiently?**

**A:** The most important step would be to stop routine servicing (e.g., re-lamping) of HID fixtures, rather than converting them to LED only when the entire fixture fails. Any service call to an HID fixture should result in LED conversion ("maintenance replacement"). Leaving an HID fixture in place when there is an opportunity to convert it wastes money and energy and externalizes other costs to the customer.

Maintenance replacement may command most of the Companies' field capacity for several years. Any remaining capacity should be dedicated to planned, group conversions to LED.

[11] Company witness Seelye, LG&E Exhibit WSS-4, "LG&E LED Rates", spreadsheet cell K7.

**Q: Does the Companies' practice of maintaining HID fixtures until they fail impose reasonable costs on customers?**

A: No. HID fixtures should not be maintained in any way. Re-lamping HID fixtures and replacing failed control nodes is a waste of time and money. The reason is that these maintenance visits are expensive and HID fixtures require re-lamping visits every five to eight years – much more frequent than LED maintenance visits. Rather than re-lamping or replacing the control node, the HID should simply be converted to an LED, which averts the inevitable subsequent service visit in five to eight years costing hundreds of dollars.

**Q: Does the Companies' policy of converting *all* HID fixtures to LED upon failure impose reasonable costs on customers?**

A: Not with the current tariff structure. The Companies state, "…76% of LKE's HID fixtures have a comparable LED fixture that is lower in cost."[12] Ipso facto, the other 24% of the Companies' fixtures do **not** have a comparable LED fixture that is *currently* lower in cost for the customer. Most customers don't want their costs to go up, even if they would get higher quality and more-reliable lighting in the bargain. It is not reasonable for the Company to flip a customer to a higher tariff payment against their will.

The solution to this problem is deceptively simple: charge customers the same for LEDs as for their HID equivalents. Below, I recommend that the Companies combine their LED and HID tariffs so that fixtures that produce the same amount of illumination pay the same tariff. However, if the Commission does not order the Companies to perform maintenance conversions on all HID fixtures *and* to adopt a unified street lighting tariff, then it should order the Companies to convert HIDs to more-expensive LEDs only with the customer's consent. Fortunately, by adopting more reasonable rates of return on lighting tariffs and

[12] Witness Wolfe, Attachment to Response to LFUCG-1, Question 5, p73 of 89, section C(f).

buying the right LEDs for each conversion, the Companies can greatly minimize or even eliminate these currently financially disadvantageous conversions.

**Q: How long would it take to convert the fleet to HID via maintenance conversions?**

**A:** About six years, and possibly faster. About one-sixth of HID lamps fail every year, and all those fixtures would be converted rather than re-lamped. Any other maintenance visit to an HID, whether luminaire-related or caused by wire, pole, mast arm or other assets serving an HID fixture, should likewise precipitate conversion. Any remaining labor capacity, as I will argue next, should be devoted to planned, group conversion projects. By year four, most fixtures should have already been converted, and while continuing to address outages, field crews should simply drive around replacing the few remaining HID fixtures proactively on sight, without waiting to receive a trouble report.

**Q: Why should the Companies also devote resources to proactively converting HID fixtures that have nothing wrong with them? Isn't that wasteful??**

A: It's not wasteful. After all, car owners aren't wise to continue driving a gas guzzler merely because it hasn't yet broken down. It's well understood that getting that car off the road as soon as possible has both private and social benefits.

In addition to the direct cost and efficiency arguments, the Companies should be mindful that reactive conversion of failed fixtures imposes avoidable outage costs on the customer and the community, whereas proactive conversions avert inevitable outages. As I will show below, outages likely last for a month or more, not the typical two or three days between a report being received and the Companies restoring service. Outages have important implicit costs that are externalized to the community by the Companies, and much more should be done to reduce those costs.

Proactive conversion, additionally, assures consistent lighting quality throughout an area rather than the constantly shifting patchwork of lighting created by one-off, reactive conversions. HPS fixtures have a noticeably different ("yellower") color temperature than LEDs, and vastly inferior color rendering performance. Differences between randomly alternating HID and LED lighting can be aesthetically annoying to community members and visually challenging for roadway users.

**Q: Aside from averting outages and providing consistent lighting quality, what direct cost advantages do planned, group conversion projects offer?**

**A:** Planned, group conversions offer various efficiencies compared to reactive conversions. Group conversions can be planned more carefully, work assignments can be made and materials staged in advance, and the amount of indirect labor time spent traveling between job sites and setting up anew at each site is drastically reduced when all the fixtures to be converted are adjacent to each other.

**Q: The Companies studied the costs of group versus maintenance conversions and concluded that group conversions are not clearly better. Why do you disagree?**

**A:** I don't disagree with the Companies' study. It concluded that a 6-year proactive, group LED conversion initiative would have $1,644,000 greater net present value (NPV) than a 25-year, reactive conversion timeline.[13] The study author further noted that his findings were likely conservative, stating, "I believe looking at conversion programs in this manner

[13] Witness Wolfe, Attachment to Response to LFUCG-1, question 5, p.75 of 89.

provides a favorable view of LEDs and that putting this into practice would reveal an even greater NPV cost of an LED conversion."[14]

Therefore, I agree with the study. Furthermore, once the Companies start charging a fair rate of return to lighting tariffs and start using the right LEDs to replace each HID wattage, the cost advantages will only grow.

**Q: Why aren't the Companies following the recommendation of their own cost study?**

**A:** When asked why they have not adopted the internal study's recommendation, the Companies responded, "The analysis makes a number of assumptions that set up an ideal environment for both plans and evaluates the initial capital investment over 50 years. These assumptions include perfect recovery by the Company, consistent cost of capital, does not include replacements of failed LED fixtures and does not consider the stranded asset costs incurred for removing ~270,000 fixtures in good working order from service."[15] This response does not explain clearly why the highlighted assumptions invalidate the study findings, since the assumptions apply to both conversion scenarios albeit to varying extents, which the Companies' response does not explore.

The Company goes on to explain, "In light of the Company's goal to make this base rate case the last base rate case it will file for a number of years . . . the initial capital outlay of ~$118 million over 6 years necessary for this plan does not represent a feasible investment at this time.[16] The only relevant capital-outlay figure for the Companies to consider is the *marginal* difference in the NPVs of the Capital Investments required under the two conversion

[14] Witness Wolfe, ibid.
[15] Witness Wolfe, Response to LFUCG-2, question 7c.
[16] Witness Wolfe, ibid.

scenarios, which is only about $21.6 million over the entire 50-year period of the internal study.[17]

In the bigger picture, however, it is not appropriate to evaluate a project based only on capital investment. The NPV analysis, using conservative assumptions, shows that the benefits created for customers over this 50-year period exceed these capital, and other costs. The Companies should respect its findings and implement its recommendation to adopt proactive, planned group conversion methods.

**Q: Does the Companies' comparison of labor costs for proactive, group LED conversions versus reactive conversions demonstrate, as claimed, that there is no net cost advantage to proactive conversion?**

A: No. The Companies' comparison of labor-unit costs comparing proactive conversions to maintenance conversions is flawed and incomplete.[18]

The study is flawed because it compares negotiated unit costs of maintenance conversions to actual costs of proactive conversions. Apples-to-apples analysis would either compare negotiated contractor unit costs for both methods of conversion, or actual costs for both methods of conversion.

The study is also flawed because it makes poorly justified assumptions about differences in labor requirements. Specifically, it assumes that proactive conversions require a two-person, two-vehicle crew, whereas reactive conversions for the very same fixtures require only a one-person crew. The Companies do not explain why a proactive conversion requires an additional crew member and vehicle for traffic control purposes, when replacing the exact same fixture reactively would require only one person in a bucket truck. The study also

[17] Witness, Wolfe, Attachment to response to LFUGG-1, question 5, p76 of 89, "Summary" sections.
[18] Witness Wolfe, Attachment to Response to LFUCG-1, question 5, pp.70-74.

states that the second vehicle is needed to carry materials for proactive conversions but fails to explain why more materials are needed if, as claimed, the reactive conversion approach can actually convert more fixtures per day and thus would require more materials to be on hand.

Finally, the study is incomplete because it considers only direct labor-unit costs. "These costs do not directly include any planning or administrative costs, but do include transit costs to and from the worksite. . . . These costs do not directly include the costs of staff who work to prepare project proposals to customers, engineering and design staff, staff who record lighting changes to assure correct billing, or corporate staff."[19] It is intuitively plausible that identification, reporting, tracking, diagnosing, planning response and fixing one-off fixture outages is likely to suffer from inefficiencies of scale compared to planned, group conversions; the scale of those cost differences is not intuitively obvious, however, and ought to be examined. Even if comprehensively considered, total labor costs should not be weighed in isolation from other capital and operating costs and benefits; the NPV study discussed above attempts this kind of comprehensive analysis and concludes that the costs of proactive, group conversions are more than justified over time by the financial benefits alone.

**Q: Are you recommending that the Companies convert HIDs to LEDs primarily through planned, group conversions or through maintenance conversion whenever HIDs require service visits?**

**A:** Primarily through reactive/maintenance conversions of HIDs fixtures whenever they require maintenance visits, with any additional conversion capacity dedicated to planned, group conversion projects.

[19]

Making service calls on HIDs as their lamps burn out and they develop other problems is unavoidable. The drumbeat of these service calls will likely account for most of the Companies' labor capacity for the next several years, and nearly all these calls should result in LED conversions. Any additional labor capacity, however, should be allocated to planned, group conversions to realize the labor productivity and lighting consistency benefits they offer and to avert fixture outages that necessitate reactive service calls.

**Q: Should the Companies continue to assess conversion fees to recover the net book value of HID fixtures that are retired prematurely from service?**

**A:** No. Shifting to near-universal maintenance conversions of HID fixtures, rather than customer-initiated conversions, changes assignment of causation for conversion costs. A customer does not cause maintenance conversion of an HID fixture when it fails, and therefore should not be held individually responsible for conversion costs.

**Q: If not through customer conversion fees, how should the Companies recover the net book value of luminaires that are retired early?**

**A:** They should create a regulatory asset to track the value of those assets and recover that value through tariffs charged for the new fixtures. This approach also allows the Companies to assess graduated stranded asset fees, which would be more equitable than the current system which assigns the same Net Book Value ("NBV") _ to every retired HID fixture. Just as the installed costs of LED luminaires varies 400% based on wattage and fixture style, so do the NBVs of HID fixtures vary widely. A 100-watt LED likely succeeded an HID fixture with greater value than a 50-watt LED did, and therefore should pay a higher stranded asset cost.

**Q: Won't customers still be "causing" some LED conversions, for which they should pay conversion fees?**

**A:** Conceivably, a customer might want to jump the queue and get their LEDs faster, or have them all converted at once for the sake of uniformity or to reduce traffic disruptions. Consumers Energy (Michigan) uses the maintenance conversion method I propose and has not experienced this kind of request from customers. The customers are happy to know that they will have LED fleets soon, and very happy not to be paying out of pocket for them.

The costs that would be recovered by such a fee are not clear, in any event. The stranded asset cost will be embedded in rates the customer will pay after conversion, as are the LED fixture costs.

Thus, even if the Commission does not order the Companies to convert HIDs in response to any maintenance event, it should end the assessment of conversion fees.

**Q: Do your recommendations have any implications for the Companies' rate designs?**

**A:** Yes. The Companies should no longer offer separate tariffs for HID and LED streetlights. Rather, the Company should offer a unified unmetered lighting tariff that is organized such that customers will pay the same for different kinds of streetlights that deliver equivalent amounts of illumination regardless of how much energy they use or cost to install.

**Q: Wouldn't charging customers the same amount for fixtures with different capital and operating costs violate the principle of cost causation?**

**A:** No. In fact, if the Company were to adopt my recommendation to convert all HID fixtures as soon as possible, then adopting a unified unmetered tariff would truly be the *only* way to uphold the principle of cost causation.

The key insight here is that when the Companies, rather than the customer, decide what lighting technology is installed at any given location at any given time, then the customer is not causing the cost differences between those choices. A customer whose burnt-out HID fixture is replaced automatically by the Companies, without any decision or up-front financial contribution from the customer, does not deserve to benefit from a reduced LED tariff any more than their neighbor "lucky" enough to have a still-functioning HID fixture deserves to continue paying more. Both customers should pay the same amount because they are receiving equivalent illumination service.

When the Companies decide what kind of lighting technology is installed and how much energy it uses, then to the customer lighting is nothing more than a service, and it is logical that they should pay only according to how much light their roadway receives.

Recall the HPS-LED conversion discussion above. In a unified unmetered tariff table, the 100w nominal (117w total) HPS cobrahead fixture would be listed in the same row, and pay the same tariff, as its manufacturer-recommended 31w-39w LED equivalent. Likewise, the 200w nominal (224 w total) HPS cobrahead fixture would be listed in the same row, and pay the same tariff, as the manufacturer's recommended 71-98w LED replacement.

Over time, as the proportion of LEDs represented in each row of the rate table steadily climbs, the blended HID-LED rate converges toward the LED cost. If it is judged necessary to recover stranded asset costs for prematurely retired HID fixtures, they can be added to the tariff on each line of the unified table rather than being separately and cumbersomely assessed as customer contributions.

The unified tariff also greatly simplifies and facilitates the Companies' task of converting their fleets to LEDs. Under the current two-tariff system, the Companies must take some amount of care to ensure that all customers receive a roughly equal stream of LED conversions over time. Spreading the LEDs around equally every year may cause operational headaches and inefficiencies, whereas if customers can be financially indifferent between HIDs and LEDs because they cost the same, then they will care much less about getting the LEDs as soon as possible and will not be jealous if their neighbor gets more LEDs in any given year.

**Q: Wouldn't transitioning to a unified tariff help some customers financially and hurt others?**

**A:** Possibly. It depends on how unevenly the current, small fleet of LEDs deployed by the Companies is distributed. Overall, the change should work out to be revenue-neutral.

A unified tariff establishes an average cost for HIDs and LEDs that are judged equivalent in illumination. Typically, the LED cost will go up a bit, and the HID price will drop a bit, when the unified rate is imposed. A customer with a higher-than-average proportion of LEDs installed, therefore, will see their total bill rise.

This scenario is of concern primarily if the customer has paid out-of-pocket for their LEDs and is expecting to receive a projected payback on investment. The Companies should certainly stop assessing these customers any ongoing monthly conversion fees. Some sort of bill credit might be discussed; however, it is almost indisputable that accelerated conversion of their remaining HID fixtures will more than offset any changes to rates on their existing LEDs. The reason is that they will now get many more LEDs fixtures much faster than they otherwise would have, and they will no longer have to pay a conversion fee to get them.

If the LED was installed by the Companies with no customer contribution, then the customer may be disappointed with the rate change but has no inalienable claim to future savings they may have anticipated.

This equity consideration underscores why it is important for the Companies to embrace this change quickly, before many more LEDs are installed.

**Q: Do you have any recommendations to improve cost allocation among the lighting rates?**

**A:** Yes. The Companies should create FERC 373 sub-accounts to track different kinds of lighting assets. Doing so can help allocate costs among different lighting types and assets and can help manage assets more efficiently.

For example, to calculate the LED conversion fee (for stranded asset cost recovery), the Companies had to bootstrap an estimate of how much of their FERC 373 rate base is luminaires and how much is poles and other assets. They made that estimate by comparing installed costs for poles and luminaires for new installs. However, with the advent of LEDs, which cost more than HID fixtures, the proportion of rate base representing luminaire costs is

likely growing. Thus, assessing current costs is not a reliable way to allocate past costs. Because the Companies continue to assess a pole fee for luminaires that are mounted on dedicated street lighting poles, having accurate cost data to determine that fee is important.

Similarly, the Companies should track fixtures and other assets associated with outage and other maintenance events. For this case, the Companies were unable to provide data describing what kind of assets were involved in outage events. To the extent that O&M costs need to be allocated accurately among different rates, tracking them more granularly will help. These data should also help the Companies to conduct preventive maintenance and to identify unreliable assets they should stop buying.

The Commission should order the Companies to create FERC 373 sub-accounts for different luminaire types (light source as well as fixture style), poles, overhead and underground wiring and mast arms. The Commission should also order the Companies to track O&M events and costs with greater specificity for cost allocation and quality management purposes.

If the Commission does not accept my recommendation to order the Companies to develop a unified tariff for HID and LED lights, then accurate cost allocation becomes even more important. LED lights have higher installed cost and lower O&M costs than HIDs, and these differences need to be tracked accurately to support cost allocation, particularly with the investment in LEDs set to surge in the coming years.

**Q: Do you have any other recommendations to improve the Companies' LED conversion programs?**

**A:** Yes. The Companies should periodically conduct RFP processes to source luminaires, a standard practice that is apparently not observed now: "The Company periodically evaluates products from different lighting manufacturers to select LEDs"[20] There is, notably, no suggestion that these evaluations include a competitive procurement process. Based on my knowledge of LED luminaire costs paid by peer utilities, gained from access to confidential case discovery data in recent Consumers Energy and DTE Electric (both Michigan) rate cases, the Companies are currently paying somewhat higher prices for LED luminaires than peer utilities. If, as anticipated, the Companies greatly increase their deployment of LEDs in the coming years, they should implement competitive procurement processes to make sure they are getting the best prices possible.

**Q: What are your recommendations for the Commission's orders with respect to LED streetlight conversions and rate design?**

A: The Commission may be reluctant to tell the Companies how to manage their streetlighting operations. Regardless of *how* the Companies manage streetlighting, the Commission should ensure that customers pay reasonable costs and receive good service. My discussion of streetlighting practices above is intended to demonstrate that the Companies have straightforward, logical, widely practiced alternative methods for managing streetlight conversions that would improve services and reduce costs. Whatever business decisions the Companies may make, the Commission should ensure that customer outcomes in terms of cost and service quality are up to industry standards. Specifically:

[20] Company witness Wolfe, Response to LFUCG-2 question 8b.

- The Commission should order the Companies to demonstrate that their HID-to-LED conversion standards do not impose greater cost on customers than manufacturer-recommended conversion standards;
- The Commission should order the Companies to demonstrate that their HID-to-LED conversion standards do not systematically result in increased roadway illumination and comply with IES roadway illumination standards;
- The Commission should order the Companies to convert HID fixtures to LED in response to any maintenance event, not only fixture failures;
- The Commission should disallow the Companies' proposed LED conversion fees and instead instruct the Companies to recover HID-fixture stranded asset costs through creation of a regulatory asset to be recovered through LED rates;
- The Commission should order the Companies to adopt unified, unmetered lighting tariffs that charge the same tariff for the same amount of light, regardless of light source, cost basis or energy use, but continuing to differentiate by installation and wiring type;
- The Commission should order the Companies to procure luminaires using competitive procurement processes; and
- The Commission should order the Companies to track capital and operating costs in greater detail, including creation of FERC 373 subaccounts, to aid in accurate cost allocation and strengthen procurement and asset management efforts.

## V. The Companies' Streetlight Outage Identification, Reporting, Tracking, Restoration and Compensation Practices are Deficient and Unfair to Customers

**Q: Please describe the Companies' performance with respect to streetlight outages?**

A: Customers are dissatisfied. The outage and restoration data the Companies report lacks detail and appears to be incomplete. The Companies' tariffs and lighting contracts establish little accountability for the Companies to provide reliable service.

**Q: What actions do you recommend the Commission take?**

**A:** The Commission should order the Companies to establish better systems and practices, with particular attention given to the use of networked lighting controls which are compatible with LED technology, to identify, report and resolve outages.

The Commission should order the Companies to provide detailed quarterly outage reports to customers.

The Commission should establish meaningful, enforceable tariff provisions that create accountability for the Companies to deliver reliable streetlighting service, refund customer costs for outages and provide for financial penalties for repeated or prolonged outages.

**Q: Why are customers dissatisfied?**

**A:** Customers report that outages are too frequent and too long. They also report that the Companies often erroneously report that service has been restored to a particular streetlight.

Customers feel that the Companies' systems and processes for identifying and reporting outages are ineffective and likely lead to many outages not being reported for extended periods.

**Q: Do the outage and restoration data reported by the Companies support these complaints?**

**A:** On the one hand, the Companies' outage frequencies and reported times to restoration compare well to that of peer utilities. On the other hand, the reported outage totals very likely understate the actual number of outages and the data provided are not detailed enough to support analysis and accountability. That is why one of my key recommendations is that the Companies be required to regularly report detailed outage and restoration data to customers.

**Q: Please describe the outage and restoration data reported by the Companies.**

A: KU reported an average of 19,728 outages per year for 2018-2020.[21] KU has 172,819 total fixtures.[22] Therefore, an average of 11.4% per year of KU's fixtures had reported outages during these years. The average time from reporting of outage to restoration of service was 2.96 days in 2019 and 2.01 days in 2020.[23]

LG&E reported an average of 11,892 outages for 2018-2020.[24] LG&E has 88,567 fixtures.[25] Therefore, on average of 13.4% of LG&E's fixtures had reported outages each year. The average time from reporting of outage to restoration of service was 3.3 days in 2019 and 2.82 days in 2020.[26]

**Q: Do these figures represent good reliability performance?**

A: The figures as reported compare well to peer utilities. For example, DTE Energy, which serves southeastern Michigan including the City of Detroit, owns and manages a similar

[21] Witness Wolfe, response to LFUCG1-KU, question 17.
[22] Witness Seelye, Attachment to Response to LFUCG2-KU, question 3. Spreadsheet cell B27.
[23] Witness Wolfe, response to LFUCG1-KU, question 18.
[24] Witness Wolfe, response to LFUCG1-Metro, question 17.
[25] Witness Seelye, Attachment to response LFUCG2-Metro, question 3, spreadsheet cell B26.
[26] Witness Wolfe, response to LFUCG1-Metro question 18.

number of streetlights as the Companies and reports reliability statistics along with its periodic rate cases.

For 2018, DTE reported 20,469 outages with a total street lighting fleet of 199,804 fixtures, for a total of 10.2% of fixtures experiencing reported outages.[27] DTE's average streetlight outage duration in 2018 was 3.52 days.[28] DTE's incidence of outages was marginally lower than the Companies', and its average outage duration was slightly longer. DTE's figures, at least superficially, are like those reported by the Companies.

**Q: Does this comparison to a peer utility cause you to discount the customers concerns you described above?**

**A:** Not at all. Rather, it causes me to discount the quality of the outage and restoration data the Companies have reported.

**Q: Why do you state that the Companies' reported outage figures likely understate the actual number of outages?**

A: Because the Companies' reported outage numbers don't add up to totals that comport with what we know about streetlight reliability and the reliability performance of peer utilities, **the Companies' reported outage figures likely understate the actual number of outages**.

The number of outages the Companies are reporting cannot even account for the number of lamps they should be replacing in HID fixtures every year, based on highly predictable lamp burnout rates. There are several other common outage causes that should drive the numbers up even further.

[27] Exhibit Bunch 3, DTE Electric Community Lighting Outdoor Lighting Outage Cost, Exhibit A25, Schedule 02 to testimony of DTE witness Robert Bellini, Michigan Public Service Commission case U20561.
[28] Exhibit Bunch 4, DTE Electric Community Lighting Outdoor Lighting Outage Cost, Exhibit A25, Schedule 01 to testimony of DTE witness Robert Bellini, Michigan Public Service Commission case U20561.

DTE Electric provides a useful streetlight reliability benchmark for the Companies only because they have similar fleet sizes. Below I describe how DTE has much more reliable lighting assets, preventive maintenance practices and different reporting standards than the Companies. It is simply not credible to suppose that the Companies have comparable streetlight reliability performance to DTE's.

**Q: How can you predict the number of lamp failures that should be observed? Isn't there a large amount of variability?**

A: HPS lamps from leading manufacturers are rated to last 24,000 hours, which is six years based on the number of annual burn hours in KU/LG&E territory. There is some variability but HPS technology is very mature and has been preferred by utilities because it has highly predictable performance. Some utilities, in fact, schedule group replacement of HPS lamps knowing with high confidence when they will start to burn out, a practice that averts most burnouts and realizes much higher labor productivity than responding to burnouts one at a time. Of course, to schedule HPS lamp replacement the Companies would have to keep track of when they install new lamps in each luminaire, an inventory practice they give no indication of observing.

Mercury vapor lamps also have a rated life of 24,000 hours. Mercury vapor lamp failures are more difficult to detect because they tend not to burn out, but to progressively dim ("lumen depreciation") over a long period of time. A mercury vapor lamp is considered to fail when its lumen output falls below 70% of original output. The Companies don't know how many mercury vapor fixtures remain in their fleets, but the numbers are presumably small because federal law has prohibited manufacture or import of mercury vapor ballasts since 2008 and most will have failed by now. Therefore I assume that almost all mercury vapor fixtures have

failed and been converted either to HPS or LED since 2008, and the few that remain experience lamp failures at about the same rate as HPS fixtures.

**Q: How many outages should be observed by the Companies in an average year?**

A: We should see a minimum of 46,600, and probably substantially more, HID outages per year. Instead, the Companies reported an average of 31,620 per year for 2018-2020. At least 1/3 of the expected number of outages are not showing up in the reported numbers.

**Q: How did you estimate the number of expected HID outages per year?**

**A:** First, I predicted the number of HID lamp burnouts that should occur each year. Then I increased that number by 50% to represent the usual ratio of other outage causes to lamp burnouts. It is important to note that I base this assumption on my knowledge of outage causes reported by other utilities; the Companies do not currently track outages by source of report or by cause.

As of November 2020, 4.93% of LG&E lights are LEDs.[29] Based on LG&E's total streetlight count of 88,567, this means that LG&E has 84,201 HID lights that need periodic re-lamping.

As of November 2020, 4.74% of KU lights are LEDs.[30] Based on KU's total streetlight count of 172,819, this means that KU has 164,627 HID lights that need periodic re-lamping.

The two Companies therefore have a total of 248,828 HID fixtures that require periodic re-lamping. If we generously assume that the average lamp lasts eight years – two years longer than its rated life – then a minimum of 31,103 HID fixtures per year should experience lamp burnout. If we further assume that other types of outage causes account for about half as

[29] Witness Wolfe, response to LFUCG1-Metro, question 8.
[30] Witness Wolfe, response to LFUCG1-KU, question 8.

many outages as lamp burnouts, then we should see another 15,552 other failures. In total, employing generous assumptions, we should see at least 46,655 outages per year between KU and LG&E. By this conservative estimation, the Companies should be identifying, fixing and reporting almost 50% more outages each year than they are.

If we instead assume that the average service life of an HPS lamp is its rated life of six years, we should observe more than 57,000 HID outages per year. This assumption is better justified because HPS lamps dim predictably over time. An HPS lamp that was been installed much more than six years ago may still be producing light, but it is very likely producing less than 70% of its original illumination. Technically, this lamp has burned out. It should not remain in service, but many do because members of the public can't be expected to recognize when lights are slightly too dim as opposed to completely burnt out.

These projections are also conservative because they disregard LED outages, which the Companies, say they do not track separately. LED luminaire outages are likely to be small in number because the Companies haven't yet installed many, plus, they are new and presumably less likely to malfunction. However, LED fixtures, as the Companies note in testimony, will still experience non-luminaire outages caused by other equipment including poles, wires and transformers as well as luminaire outages caused by natural events and human interference. However, in the interest of being conservative in my projections, I am not including any estimate of these outages.

**Q: What does benchmarking to a peer utility tell you about the Companies' reliability performance?**

A: As I summarized above, benchmarking to DTE suggests strongly that the Companies' data are incomplete.

First, although KU and DTE have similar streetlight fleet sizes, KU has much fewer LEDs installed than DTE. DTE had 72,000 LED luminaires installed by the end of 2018, leaving it with about 127,804 HID luminaires. Therefore DTE had about 23% fewer HID lamps than KU and from that difference alone should experience 23% fewer HID lamp burn-outs.

In addition, "DTE Electric currently re-lamps its HID luminaires on a periodic basis to ensure that their performance (light output) is maintained at an appropriate level to provide for the safety and security of its customers."[31] The effect of DTE's preventive re-lamping is to avert most HID lamp failures by replacing them before they can fail. The Companies do no preventive re-lamping, waiting instead for an outage report before servicing the fixture.

Third, like KU and LG&E, DTE practices annual patrol-and-fix of its streetlights. Unlike the Companies, however, DTE does not include patrol-and-fix outages in its reported totals.[32] The Companies do not generally track outages by reporting source, so we do not know how many of their outages were identified by patrol-and-fix. We are told that Lex311 accounted for an average of 1,158 streetlight complaints per year[33] – whereas HID lamp failures alone should cause 4,000-5,000 easily observable outages every year in a population of 31,000 total fixtures in the City of Lexington. I address this curious observation in greater depth below,

[31] Exhibit Bunch 5, excerpt from direct testimony of DTE witness Robert Bellini, Michigan Public Service Commission case U20561.
[32] Exhibit Bunch 3
[33] Witness Wolfe, response to KFUCG1-KU discovery question 17.

but note it here mainly to suggest that, if the Companies are getting very few outage reports from the public, then we can deduce most of those reports must originate from their own patrol-and-fix. Removing those incidents from the outage totals reported by the Companies would leave absurdly few outages, as compared to the numbers reported by DTE.

In sum, compared to DTE the Companies have many more HID fixtures, they do not practice preventive maintenance (scheduled HPS re-lamping) that averts many outages, and they count patrol-and-fix outages toward their totals. Considering these differences, the Companies should be reporting significantly more outages than DTE, but they are not. The numbers do not add up.

The overall point here, then, is that the Companies need to track and report outages with greater granularity, accuracy and transparency.

**Q: Still, don't the Companies' reported outage durations compare well?**

A: Not upon closer examination.

First, we can't arrive at credible conclusions when there are obvious signs that many outages aren't being reported.

Second, the Companies can report short average outage durations only because so many of the outages are identified and fixed right away through the patrol and fix practice. If these "zero duration" outages account for a plurality of those reported – and the numbers we have are consistent with that inference – then their instant resolution may mask much slower response to outages reported by the public or customers. DTE Electric reports slightly longer outage durations than the Companies, but the difference is likely ascribable to DTE not including "zero-day" patrol-and-fix outages from its averages.

Third, the Companies have not reported how long it takes them to restore service in response to outages reported by customers or the public, which would be the true apples-to-apples benchmark with DTE Energy. We are told, "In 2020, when repairs reported by LexCall 311 could be completed by component replacement (bulb and/or photovoltaic control replacement), the Company's average street light repair took 1.10 days." We are not told what proportion of repairs is represented by these easy fixes, nor how long the more challenging cases took to resolve. The Companies need to be tracking and reporting more difficult outages not only for accountability, but for prevention. The Companies should be buying more durable equipment and maintaining it to avert outages that are difficult to remedy; but the Companies cannot do any of this if they fail to track, and learn from, detailed outage information at all.

Fourth, focusing on the time between outage report and restoration of service is a red herring. We have abundant indicators, from data supplied in this case to academic research to outage-tracking data supplied by customers of other utilities, that the great majority of outage time occurs before the outage is ever reported. In short, it is apparent that most outages don't get reported for a long time, and the result is that the customer pays for a long time for lighting service that they unknowingly aren't receiving. Leasing equipment of dubious reliability to customers, then making the customer responsible for reporting problems they don't even have the ability to detect, is disingenuous. The fact that it is an expedient and long-established system does not excuse ineffectiveness; and the fact that there are better options makes it time to change.

**Q: Why do you contend that most outages occur long before they are reported?**

**A:** We have inferences we can make from data supplied in this case, academic research and analysis of data from customers of other utilities to support this assertion.

As noted above, the incidence of public outage reports using the LexCall 311 system is drastically below the number of outages we know must be occurring. If the public is not reporting most outages at all, it is logical to deduce that the outages they do report are not being reported promptly. If the Companies' patrol-and-fix practice visits each neighborhood only once per year, and public reporting is sluggish, it is entirely possible that some of the outages identified by patrol-and-fix started more than 11 months earlier.

Second, academic researchers have explored streetlight outage reporting by community members. A 2011 study of streetlight outage reporting using the City of Boston's 311 system found:

> The probability of a streetlight outage being reported increased at a decreasing rate over time. Nine percent of outages were reported by constituents within a week of the audit, 14% by the end of the second week, 22% by the end of the first month. After 5 months, 67% of streetlight outages had been reported by a constituent.[34]

In other words, one-third of outages had never been reported by community members fully five months after they were identified by audit.

More recently, the City of Ann Arbor, Michigan, found that the number of streetlight outages discovered by DTE during one of its snapshot "patrol-and-fix" initiatives was equal to the number of citizen-reported outages over a preceding 53-day period – suggesting that the

[34] Bunch Exhibit 6, "Lamp Lighters and Sidewalk Smoothers: How Individual Residents Contribute to the Maintenance of the Urban Commons", Daniel T. O'Brien, American Journal of Community Psychology 2016 (58), p.397.

average outage would have begun about 26.5 days before being reported by a community member. Adding on DTE's reported restoration time of about 3.5 days, we can estimate that actual outage time in Ann Arbor was closer to 30 days. There is no reason to suppose that reporting speed is better among KU and LG&E communities, given that the customers feel the reporting mechanisms are ineffective and not widely known.

While these data are not conclusive, it seems that reported outage time is merely the tip of the outage "iceberg". Not only should the Companies do a better job tracking, addressing and reporting outages once they are identified, but they should also do much more to shorten the amount of time it takes for outages to be identified after onset. There is nothing wrong with giving community members the opportunity to help the Companies monitor and maintain their own equipment but continuing to rely on that information channel when we know it works very badly and there are better alternatives is unacceptable.

**Q: How are the Companies' service restoration and outage credits deficient and unfair to customers?**

**A:** They are deficient because they do not exist. The only standard the Companies espouse related to outages is an expectation that they will investigate an outage within two days. There is no standard for actual restoration of service. Hypothetically, a light could remain out for a full year and the customer would not even be permitted to stop paying full price for it. Customers are contracting and paying for "Lighting Service," per the name of the tariff; if they do not receive the service they pay for, they should not have to pay. The Companies' tariffs and policies regarding restoration standards and bill credits are out of step with common practice among peer utilities and need to be revised.

**Q: What standards should apply to a streetlight outage?**

**A:** The usual outcome of an outage in an electrical distribution system is that the customer pays nothing for energy usage because their meter stops running. In addition, customers who suffer lengthy or repeated outages may be entitled to additional compensation for inconvenience and losses. The Companies observe none of these common-sense protections for their streetlight customers. There is no principled reason why an unmetered customer should continue to pay for service they are not receiving; there is simply the practical difficulty that in the absence of a meter, it's harder to tell when service stopped and re-started.

The obvious solution is to develop much more accurate and timely ways to discover and track streetlight outages. Below, I propose that the Companies should pin their reliability efforts on the installation of networked lighting controls, which can report precisely how much energy a luminaire is using – or not using – at frequent intervals. With this information in hand, subtracting outage hours from the standard 4,000 operating hours per year would be a straightforward process that might well be automated.

**Q: What alternatives to networked lighting controls might be considered that would be measurable, enforceable and workable for customers?**

**A:** In the absence of a networked solution, the Commission should impose standards for timely restoration and for bill credits that not only hold the Companies accountable for quick reaction to reported outages, but also establish powerful incentives to prevent outages altogether through use of reliable equipment, preventive maintenance and to identify outages quickly.

Without real-time measurement capability of luminaire operating status using networked technology, the only accurate way to know how many lights are operating, and thus how many lights a customer should be paying for, at any given time is through a sample audit. When the Companies conduct patrol-and-fix activities in a given area, that sample can be taken to represent the operating condition of all that customer's lights, and their entire bill should be adjusted accordingly until a subsequent sample updates the figure. The customer should be able to submit its own audit figures, subject to quality standards, that the Companies could either accept or challenge by conducting their own audit.

**Q: Why do you not propose a more standard bill-credits system based on reported outage durations?**

**A:** A standard bill-credits system based on reported outage durations is not workable for the customers, and if it is not workable, then it cannot establish accountability and an incentive for the Companies to deliver better service. Further, measuring outage durations and basing credits on reported time of outage does not begin to compensate the customer for their actual loss of service.

The foundational problem with most bill-credits systems for streetlight accounts is that the customer doesn't even have the information they need to make a claim. Outages are normally reported to the utility, not the customer. Even if the customer has the necessary data, either by getting it from the utility or developing its own tracking, the process for claiming credits has a forbidding cost-benefit ratio: it takes a lot of time and only nets a refund of, on average, around $0.50/light/night. There simply are not many public works directors who have the time to track outages (including checking on claimed restorations), document violations of standards and submit credit requests to net such a small amount of money.

Restoration standards and bill-credit processes that rely on significant investments of labor, compilation of hard-to-get data and small rewards will never change the status quo. If outages are hard to discover, then more effort should be made to prevent them; if they are hard to identify and track using human systems, then technology should be deployed to identify and track them. Next, I describe two paradigms for improving reliability performance that the Commission should prod the Companies to adopt.

**Q: What should the Companies do to reduce outages?**

**A:** Categorically, the Companies could improve reliability of their streetlight fleets through "Blocking and Tackling" or "Bells and Whistles." The two approaches are not mutually exclusive but both require investment that may need to be rationed.

**Q: Please describe better "Blocking and Tackling" to improve reliability.**

**A:** "Blocking and Tackling" connotes rigorous attention to fundamentals. Practices I ascribe to DTE Energy, above, are good starting points:

- Install more-reliable equipment – principally, LED luminaires.
- Perform preventive maintenance: service luminaires at specified intervals to replace components, clean them to maintain lumen output, clear away tree limbs and other vegetation, etc.
- Provide the public and customers with easy-to-access and -use reporting channels. Keep them informed about status of their "tickets". Use various public communications means to educate the public about reporting channels.
- Track outages by reporting source, asset type, diagnosed problem and time to resolution.

- Provide customers with regular, detailed reports on outage occurrences and durations including details on long-duration or repeated outages.

These measures aren't very fancy, but they can go a long way toward restoring communication and trust with customers, and may save money by preventing problems that precipitate scrambles.

**Q: Please describe the "Bells and Whistles" approach to streetlight reliability.**

**A:** "Bells and Whistles" connotes the use of newer information technology and systems to revolutionize all aspects of the Companies' reliability effort.

The central element in this approach is the use of networked lighting controls. "Bells and Whistles" hints at the various advanced lighting, information and communication functions that some streetlight systems have begun to integrate. Here, however, the immediate emphasis and justification for the use of networked controls is to improve reliability. With networked controls, each luminaire can frequently report its operating condition, even allowing operators to anticipate problems and effect repairs before an outage occurs. Networked controls report when a light stops working and when it goes back on, supporting precise billing, measurement of energy use and outage credits. Averted, and greatly abbreviated, outages alone justify the investment in controls for customers: remember that averting an outage likely saves 30 days, not two or three, of lost service when reporting delays are recognized.

Networked controls can also enable advanced lighting functions. For example, the amount of energy an LED luminaire is supplied can be adjusted as it ages to compensate for lumen depreciation and maintain constant illumination over its lifetime. Scheduled dimming – for

example, imperceptible dimming of up to 20%, very late at night when fewer people are out and sleeping people want less light shining in their windows – can save customers money and energy and extend the service lives of luminaires.

Networked controls can also support a variety of "smart city" information and communication functions, as well. I will not dwell on these capabilities here, other than to note that installing networking capacity now offers an option down the road to add smart city capabilities, as many observers expect cities will want to do before too long.

Although "Bells and Whistles" suggests cutting-edge, risky and maybe indulgent features, networked controls used to boost reliability in fact are proven, cost-effective and already widely in use. For example, Georgia Power and Florida Power & Light have installed networked controls on virtually their entire statewide lighting fleets.

Technology companies offer state-of-the-art networked controls and their operating systems for as little as $10/luminaire/year. The Companies, and customers, may be reluctant to add this amount to their tariffs, but it must be remembered that these systems can significantly reduce the frequency and cost of maintenance visits to luminaires, and can greatly enhance customer satisfaction by sharply reducing the incidence and duration of outages. The Companies state that the average service visit costs $155; if service visits to HIDs occur every six years on average, then the annual average cost per fixture is around $25. The ability to avert and shorten outages and save labor costs through better diagnostics is likely to claw back most, if not all, of the $10 annual networking cost per light.

**Q: Networked controls have intriguing possibilities, but what's the hurry if the Companies aren't sure of all the ways they might use them:**

**A:** Even if the ultimate use case for networked controls remains unclear today, the Companies should begin installing networked controls on all new luminaires merely to realize reliability benefits and to preserve the option value for other functions. The reason to act now is that the Companies plan to install significantly more LEDs in the coming years, which already have capability to support a wider range of network and lighting functions than are currently exploited. It makes no sense to install a "dumb" LED today only to make a costly service call in a few years for the sole purpose of retrofitting a networked control. The cost of that retrofit visit alone – several hundred dollars – claws back years of financial benefits that networked controls confer. This argument is like the LED conversion argument I made earlier – it is a waste of time and money to perform any kind of service, even re-lamping, on an HID luminaire. Doing so only triggers a subsequent re-lamping visit in about six years' time, incurring more marginal cost than the cost of installing a new LED today and leading to wasteful energy use in the intervening years.

Thus, I strongly recommend that the Companies quickly develop an initiative to install networked controls along with all new LED luminaires as their principal effort to improve reliability of their streetlight fleets. Certain aspects of the "blocking and tackling" reliability scenario should also be maintained or enhanced – for example, user-friendly Internet and mobile apps for community members to report outages. These methods, however, should be seen as supplementary to the use of information technology and systems to transform the basic premise of the Companies' approach to reliability, drastically improve performance and delight customers. The reason is that even excellent "blocking and tackling" fundamentals by

utility providers still allow outages to go unreported at length and put burdensome demands on customers to track, report and follow up if they wish to protect their interests.

**Q: Please summarize your recommendation to the Commission regarding streetlight reliability standards and practices.**

**A:** The Commission should order the Companies to establish better reliability systems and practices, with particular attention given to the use of networked lighting controls which are compatible with LED technology, to identify, report and resolve outages.

The Commission should order the Companies to provide detailed quarterly outage reports to customers.

The Commission should establish meaningful, enforceable tariff provisions that create accountability for the Companies to deliver reliable streetlighting service, emphasize prevention over restoration, refund customer costs for outages and provide for financial penalties for repeated or prolonged outages. If the Companies do not begin deployment of networked lighting controls that allow for real-time reporting of luminaire operating parameters, then the Commission should mandate that the Companies provide customers with bill credits based on periodic, statistically valid field audits of their lighting fleets.

**Q: Does this conclude your testimony?**

**A:** Yes**.**

# Exhibit Bunch-1

# RICHARD J. BUNCH

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Executive and organizational innovator with expertise in energy technology, finance, utilities and regulation. Leadership experience in academic, non-profit and public sectors. Broad topical and functional expertise in sustainable and socially responsible business and public policy. Demonstrated ability to recruit top performers and build strong teams.

## EXPERTISE

- Clean energy project evaluation, development and financing for local governments; utility tariffs and regulatory processes.
- Broad understanding of sustainability and clean energy issues that impact businesses through markets, technology and public policy.
- Integration of clean energy and sustainability into organizational strategy, management and culture through education, training and strategic planning.

## PROFESSIONAL EXPERIENCE

**5 Lakes Energy, Lansing, MI,** *Senior Consultant, May 2019-present*

**Michigan Municipal Association for Utility Issues**, Ann Arbor, MI
*Founder and Managing Director, 2017-present*
Providing collective, expert and focused representation for municipal governments in Michigan Public Service Commission proceedings and in dialog with regulated utilities.

**Southeast Michigan Regional Energy Office**, Ann Arbor, MI
*Executive Director, 2014-2017*
Directed coalition of southeast Michigan municipalities cooperating to identify, finance and implement clean energy projects.

**University of Michigan, Erb Institute for Global Sustainable Enterprise**
*Managing Director, 2008-2013*
Led world-leading sustainable enterprise program at top-10 business school.

**Aspen Institute Business and Society Program**, New York
*Senior Fellow, 2006-2008*
Launched new Corporate Social Responsibility business education program in China in partnership with Chinese business schools, accrediting agency and corporations

**Bainbridge Graduate Institute**, Bainbridge Island, WA
*Executive Director, 2003-2005*
Led administration, education, fundraising and communications of fast-growing, startup business school with world-first infusion of sustainability throughout MBA curriculum.

**World Resources Institute,** Washington, DC
*Director of Business Education, 1996-2003*
Developed, fundraised and directed international sustainable business education initiatives engaging universities, companies, governments and non-profit leaders.

**Washington Public Interest Research Group**, Seattle, Washington
*Executive Director, 1989-1992*

## EDUCATION

MBA with Environmental Management Certificate, University of Washington, 1995
BA in Political Science, Yale University, 1985

## TRAINING

EUCI Outdoor Street Lighting Conference, June 4-5, 2019, Atlanta.
EUCI Electric Cost-of-Service – Essential Concepts for a Changing Industry Course, July 15-1, 2019, Chicago.
EUCI Utility Green Tariffs: A to Z course, November 4-5, 2020, online.

## ENERGY-RELATED PROFESSIONAL ACCOMPLISHMENTS

- Expert Witness, MPSC case U-20697 (Consumers Energy electric rate case), municipal street lighting tariffs, 2020.
- Expert witness, MPSC case U-20561 (DTE Electric general rate case), production allocation, 2019
- Submitted comments, MPSC case U-20147, Electric Distribution Planning. Participated in stakeholder meetings.
- Submitted comments, MPSC case U-20629, electric reliability standards. Focused on municipal street lighting reliability standards.
- MPSC case U-20134 (Consumers Energy general electric rate case), organized and managed coalition of municipalities intervening to challenge street lighting tariffs.
- MPSC cases U-18014 and U-17767, DTE Electric general rate cases, organized and managed coalition of municipalities challenging street lighting tariffs.

## SELECTED RESEARCH AND PUBLICATIONS

"*Corporate Responsibility In a Transitioning Industry: An Automotive Supply Chain Perspective*", Automotive Industry Action Group, 2019. Co-author and researcher.
"*Expect the Unexpected: Building Business Value in a Changing World*", KMPG 2012. Erb Institute (University of Michigan) research team leader and contributor.
*Where Will They Lead? China 2008 MBA Student Attitudes about Business & Society*. The Aspen Institute, 2008.
"*Beyond Grey Pinstripes: Preparing MBAs for Social and Environmental Stewardship*," World Resources Institute and The Aspen Institute, 1998, 1999, 2001 and 2003. Creator, co-author.
Numerous academic, non-profit and public agency conference and meeting presentations and public testimony.

## SERVICE

Michigan Environmental Council Board of Directors, 2009-present. Treasurer, 2017-present. Lansing, MI.
Soulardarity Board of Directors and Secretary, 2018-present. Highland Park, MI.
Washington Public Interest Research Group Board of Directors, 1994-present
WashPIRG Foundation Board of Directors, 1994-present. Seattle, WA.
PIRGIM Education Foundation Board of Directors, 2015-present. Ann Arbor, MI.

# Exhibit Bunch-2

# See Excel File

# Exhibit Bunch-3

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Michigan Public Service Commission** | | | | | | | | | Case No.: | U-20561 |
| **DTE Electric Company** | | | | | | | | | Exhibit: | A-25 |
| **Community Lighting Outdoor Lighting Outage Cost** | | | | | | | | | Schedule: | O2 |
| **For the Years 2009 through 2018** | | | | | | | | | Witness: | R. A. Bellini |
| | | | | | | | | | Page: | 1 of 1 |
| | (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) |
| | **Year** | | | | | | | | | |
| | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| **Total Outgage Cost ($000)** | $ 9,318 | $ 8,640 | $ 6,244 | $ 5,363 | $ 4,728 | $ 4,719 | $ 5,083 | $ 5,383 | $ 4,566 | $ 5,238 |
| **Total Outage Events** | 19,796 | 19,463 | 19,116 | 17,797 | 16,977 | 16,810 | 18,501 | 18,568 | 20,099 | 20,469 |
| **Outage Cost Per Event** | $ 471 | $ 444 | $ 327 | $ 301 | $ 278 | $ 281 | $ 275 | $ 290 | $ 227 | $ 256 |
| **Total DTE-owned Assets** | 201,733 | 202,185 | 201,686 | 198,910 | 198,668 | 198,484 | 198,128 | 198,413 | 198,925 | 199,804 |
| **Outage Cost Per Asset** | $ 46.19 | $ 42.73 | $ 30.96 | $ 26.96 | $ 23.80 | $ 23.77 | $ 25.66 | $ 27.13 | $ 22.95 | $ 26.22 |

# Exhibit Bunch-4

**Michigan Public Service Commission**
**DTE Electric Company**
**Community Lighting Outdoor Lighting Outage Duration**
**For the Years 2007 through 2018**

Case No.: U-20561
Exhibit: A-25
Schedule: O1
Witness: R. A. Bellini
Page: 1 of 1

| | (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) | (k) | (l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Year | | | | | | |
| | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| **Average Days Duration** | 8.50 | 6.73 | 4.08 | 3.33 | 3.37 | 2.94 | 2.96 | 5.26 | 2.56 | 2.39 | 3.60 | 3.53 |
| **Standard Deviation** | 8.90 | 6.01 | 4.56 | 3.48 | 3.91 | 2.54 | 2.89 | 5.92 | 2.68 | 2.48 | 2.95 | 3.30 |
| **Long Duration Defects (> than 10 Days)** | | 3,765 | 1,400 | 746 | 882 | 350 | 526 | 2,425 | 371 | 182 | 801 | 415 |
| **Percent of Street Light Trouble Orders Completed in < 4 days** | | | | 70.10% | 69.88% | 73.88% | 74.68% | 57.06% | 81.28% | 81.11% | 67.10% | 63.88% |

* Average Outage Duration Cycle times are expressed in Days. Performance metrics do not include any patrol and fix activities nor any preventative maintenance activities such as Group Relamping; only reactive maintenance repairs are included. Outdoor Lighting Events include all underground fault repair times and 3rd party damage repairs. The total cycle time is measured from when the outage was first reported out to when repaired and operating again, and reflects all the outdoor area and streetlights owned and maintained by DTE Energy.

# Exhibit Bunch-5

**Q15. Does your historical O&M expense include any preventive maintenance expense for LED luminaires?**

A15. Yes. Prior to 2018, DTE Electric had not performed any preventive maintenance on LED luminaires. However, beginning in 2018, DTE implemented its LED washing and group relamping preventive maintenance program. The proposed known and measurable change for Account 596 for the forecast test period of May 2020 through April 2021 reflects the projected expense for washing and group relamping of LED luminaires during that period.

**Q16. Why has DTE Electric initiated a LED washing and group relamping preventive maintenance program?**

A16. DTE Electric currently re-lamps its HID luminaires on a periodic basis to ensure that their performance (light output) is maintained at an appropriate level to provide for the safety and security of its customers. Given the increasing saturation of LED luminaires in its lighting portfolio, DTE Electric was similarly concerned about the lighting performance of LED luminaires over time. Because of this concern, DTE Electric conducted two formal and separate LED light loss factor (LLF) studies, initially in 2015 and again in 2017, to determine how LED lumen output depreciated over time. The results of those studies identified the need to wash LEDs on a periodic basis to ensure that their lumen output remained at or above L70 (70% of the original design lumen output), the level at which the Lighting Industry has defined LED luminaire end of life and no longer provides acceptable light output to meet the lighting safety and security design requirements of its customers.

# Exhibit Bunch-6

Am J Community Psychol (2016) 58:391–409
DOI 10.1002/ajcp.12093

ORIGINAL ARTICLE

# Lamp Lighters and Sidewalk Smoothers: How Individual Residents Contribute to the Maintenance of the Urban Commons

**Daniel T. O'Brien**[1,2]

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**Abstract** Research on collective efficacy in urban neighborhoods has focused predominantly on whether a community can regulate local behavior and spaces and less on how they do so. This study pursues the latter question by examining the social regularities that create collective efficacy, measured as the behavioral composition of a neighborhood (i.e., the extent to which each individual contributes to a social regularity). This perspective is applied to the database of requests for non-emergency government services received by Boston, MA's 311 system in 2011 (>160,000 requests). The analysis categorized *custodians* who have used the system to combat physical disorder in the public space (e.g., requesting graffiti removal) into two groups—"typical custodians" who have made one or two requests in a year, and "exemplars" who have made three or more. A neighborhood's collective efficacy in reporting public issues was identified through audits of sidewalk quality and streetlight outages. Analyses revealed a collaborative model of maintenance in which typical and exemplar custodians were each necessary and non-substitutable. A second analysis found that the two types of custodian were associated with different contextual factors, articulating two different pathways from demographic and social characteristics to collective efficacy, suggesting implications for theory and practice.

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**Keywords** Collective efficacy · 311 Hotlines · Computational social science · Broken windows · Social regularities · "Big data"

## Introduction

A major challenge for any urban community is the maintenance and management of public spaces—what one might call the *urban commons*. This can entail the enforcement of social norms, for example, by breaking up fights, or efforts to counteract physical deterioration, like sweeping up litter. In either case, the implications for residents are substantial. Some of these benefits may be immediate and direct, like the reinforcement of healthier habits (e.g., refraining from cigarette smoking; Ahern, Galea, Hubbard & Syme, 2009) or the reduction in violence (Browning, 2002; Kawachi, Kennedy & Wilkinson, 1999; Sampson, Raudenbush & Earls, 1997). Others are more ambient, as living in a clean, safe environment can have diverse implications for physical, mental, and social health (e.g., Cagney & Browning, 2004; Mujahid et al., 2008; Wen, Hawkley & Cacioppo, 2006). Conversely, failures of maintenance can result in physical and social "disorder" elements that signal that a neighborhood is in disarray and vulnerable to any number of issues, potentially inviting further incivilities and crime, sowing a sense of fear, and discouraging civic behavior (O'Brien & Wilson, 2011; Ross, Mirowsky & Pribesh, 2001; Skogan, 1992; Wilson & Kelling, 1982).

Because the urban commons is a responsibility shared by the entire community, its maintenance is generally framed as a problem of collective efficacy, or the capacity to accomplish shared tasks (Bandura, 1985; Sampson et al., 1997). The concept of collective efficacy has been

important in the study of neighborhoods because it highlights the role of social processes in mediating the relationship between prominent demographic characteristics, like wealth or homeownership, and major outcomes, like crime, disorder, and public health (Sampson, Morenoff & Gannon-Rowley, 2002). The social processes of a neighborhood, however, must themselves be realized through the actions and interactions of individual residents, each exerting her own influence on the space or those that use it. Traditional work on collective efficacy obscures this additional level of detail by effectively aggregating all of those individual actions into a single metric (using the survey measure from Sampson et al., 1997). Furthermore, it focuses more on the perceived capacity for collective action than on the events in which collective efficacy is manifested. It is not possible from such study designs to answer questions about how this capacity is realized: Does the propensity to take action vary across residents? How do different types of actors contribute to neighborhood maintenance? What are the specific behavioral dynamics that make key demographic factors, like wealth and homeownership, so important?

An examination of how collective efficacy emerges from the actions of individuals must bridge these two levels of analysis. Here, I use social regularities to do so. Social regularities are patterns of behavior or interaction, often observable at the individual level, that shape and are shaped by a social setting (Seidman, 1988, 1990, 2012). I introduce a particular analytic approach to social regularities that emphasizes the *behavioral composition* of a community, that is, the embodiment of a social regularity in terms of each individual's propensity to contribute to it. Importantly, rather than aggregate all of the actions or individuals within a community into a single metric, the behavioral composition encompasses a full range of the different levels or forms of contribution to a social regularity that exist within the population. In turn, it provides the flexibility to develop and analyze measures that best capture the variations in a particular social regularity and its consequences.

This study applies the behavioral composition approach to the specific example of collective efficacy in the task of counteracting physical disorder. In doing so, I adopt the perspective that, although there might be social characteristics that endow a neighborhood with a generalized capacity for collective efficacy across tasks, a neighborhood has a characteristic level of collective efficacy for any specific task that might differ from this baseline (see Wickes, Hipp, Sargeant & Homel, 2013). In order to capture the dynamics of counteracting physical disorder, I utilize a novel data source arising from a recent innovation in urban policy. 311 systems (or 311, for short) provide residents with a set of convenient channels for requesting city services, often including a telephone hotline and associated web-based applications, with the primary goal of making city operations more responsive to community needs. This includes the facilitation of a collaborative model for the maintenance of the urban commons, in which residents identify and report deterioration or neglect in the public space, like streetlight outages, potholes, or graffiti, through their daily movements, and the city deploys the necessary expertise and equipment to address them. Depending on the size of the city, 311 might receive hundreds or even thousands of reports of public issues per day, each one capturing an instance of *custodianship* on the part of the reporter, that is, behavior that seeks to prevent or counteract physical disorder (O'Brien, 2015). Consequently, the resultant database is an extensive record of efforts by residents to maintain the city's spaces and infrastructure.

I leverage the 311 database from Boston, MA in two ways to articulate the role of the behavioral composition in the realization of collective efficacy in counteracting physical disorder. First, some 311 systems, Boston's included, provide a direct window into the behavioral composition by allowing (and even encouraging) each reporter to create a personal account that tracks her requests. For analytic purposes, each account acts as a sub-database that offers a detailed description of that individual's patterns in using 311, including how many requests she made, the types of issues, and their geographic distribution, directly capturing her contributions to the neighborhood through this medium. Based on previous research, I divide 311 users into two groups, each representing a distinct resource for the maintenance of the urban commons: "typical" custodians, who only sporadically take such action and do so over a narrow range nearby their homes; and "exemplars," who do so with greater regularity and geographic coverage. Second, I measure collective efficacy in neighborhood maintenance through audits identifying streetlight outages and broken sidewalks, two types of issues that are reported via 311. By cross-referencing these incidents with the 311 database, it is possible to identify if and when they were reported, thereby generating a neighborhood-level measure of efficacy across the city. By combining these two methodological techniques it is then possible to examine the relative importance of typical and exemplar custodians in the realization of collective efficacy in this case.

Before proceeding to the data, analyses, and their interpretation, the following three subsections further develop the rationale of the study. The first subsection summarizes the theoretical history of collective efficacy. The second discusses how social regularities and the behavioral composition might help us to understand how collective efficacy emerges from the actions and interactions of a

community. The third describes in greater detail the methodological plan and the main hypotheses.

## History and Measurement of Collective Efficacy

In the early 20th century, the Chicago School of urban sociology noted that dozens of undesirable conditions and outcomes clustered together across the urban landscape, appearing to be rampant in some neighborhoods and entirely absent in others. To explain this phenomenon, they posited that a critical component of a community's well-being was its social organization, that is, the relationships and norms shared by neighbors (Park, Burgess & McKenzie, 1968/1984; Shaw & McKay, 1942/1969). Where residents know each other and share values, they reasoned, the bonds of mutual trust will emerge, which can then be called upon to establish and enforce local social norms. Where they are lacking, the community will in turn lack the ability to enforce such expectations. Shaw and McKay (1942/1969) illustrated this concept with an extensive study of neighborhood rates of juvenile delinquency. They argued that, without supervision and socialization from the community, young peer groups would eventually mature into gangs, and their members would pursue increasingly problematic forms of delinquency and risky behavior. This same logic could be applied to the emergence of any sort of problem that might be managed by community interactions.

A long-standing challenge for research on social organization has been that of measurement. Shaw and McKay's (1942/1969) original work was criticized for either assuming that organization was equivalent to the demographic factors it was said to arise from, like poverty, or was inferred from the very outcomes it was meant to explain, like delinquency rates (see Bursik, 1988). That is to say, the proposed antecedents and consequences of social organization were measured, but the process itself was not. This difficulty was overcome by survey research that asked residents to describe the social ties and interactions of the community (Kasarda & Janowitz, 1974; Sampson & Groves, 1989). This was further extended by Sampson et al. (1997), who developed a survey scale for measuring *collective efficacy*, or the ability of a community to identify and achieve shared goals, which they argued was rooted in the social cohesion between neighbors and their consequent capacity for informal social control. This scale has been used widely, emerging as an important predictor of a diverse array of outcomes, from disorder to crime to health to youth socialization to collective action (e.g., Ahern & Galea, 2006; Bellair & Browning, 2010; Browning, 2002; Browning, Burrington, Leventhal & Brooks-Gunn, 2008; Cohen, Finch, Bower & Sastry, 2006; Kim, 2010; Maimon, Browning & Brooks-Gunn, 2010; Morenoff, Sampson & Raudenbush, 2001; O'Brien & Kauffman, 2013; Sampson, 2012).

Although Sampson et al.'s (1997) survey measure of collective efficacy has been effective in explaining cross-neighborhood variations in outcomes, work on the behavioral dynamics that actually generate collective efficacy has stagnated. This is because the survey measure is designed to translate residents' impressions of the neighborhood into a single, summarial metric of the level of collective efficacy, not to reveal the process by which collective efficacy emerges from the actions and interactions of the community. Even in a recent study by Wickes et al. (2013) that sought to extend the survey protocol to differentiate between multiple tasks, the result is still a series of measures of *whether* a community takes action or not rather than an articulation of *how* it does so. Furthermore, surveys of this sort measure the perceived ability of a neighborhood capacity for action, and do not actually capture the action itself, which has been shown to be a distinct construct (Matsueda & Drakulich, 2015). The question of how collective efficacy emerges requires a focus on the actions of individuals, and therefore a distinct methodological approach.

## The Social Regularities Underlying Collective Efficacy

Collective efficacy emerges from the discrete actions and interactions of community members, but it is dynamically responsive to local events and conditions in a way that the phrase "discrete actions and interactions" does not capture. In order to integrate these two levels of analysis, the one focused on the individual-level events and the other on a more general group-level capacity, we might turn to the concept of social regularities. Sarason (1972) originally argued for the importance of behavioral regularities for understanding social settings, as the patterns of action and interaction within a setting provide insights into its basic operation. Seidman (1988, 1990, 2012) recast the behavioral regularities of a social setting as social regularities, providing a logic for considering how these patterns of action shape and are shaped by social relations and norms, as well as other contextual factors. He described social regularities as the subset of social processes that are consistent or predictable at some level (i.e., are regular in their frequency), and underscored the primary importance of those that, like collective efficacy, influence both individual- and setting-level outcomes.

An emphasis on social regularities provides a frame for articulating the relationship between patterns of behavior and the realization of collective efficacy, as well as for examining the role contextual factors have in encouraging (or inhibiting) these behaviors. To begin, we must

consider the dynamic of a single instance of the regularity. For example, the maintenance of the urban commons comprises events that require the co-incidence of two things: a case of deterioration or denigration in a public space; and someone who moves to address it. A few analytic questions then follow. First, given the presence of a violation, what is the probability that the average community member will take action on it? This parallels most existing work on collective efficacy, referring to the generalized level of a social regularity across a population. A more nuanced question, although, would be how much this tendency varies across the members of the population. We might refer to this variation as the *behavioral composition* of the neighborhood, or the embodiment of a social regularity in terms of the propensity of each individual to contribute to it. From this, one might develop any of a range of measures describing this variation and in turn capture how the members of a community combine to create collective outcomes.

Quantifying and comparing the behavioral composition across neighborhoods, however, poses a methodological challenge. The optimal methodology would seemingly be systematic observation of public behavior (Raudenbush & Sampson, 1999), but one might spend hours in a neighborhood and only record a few qualifying cases. Even if such an approach could identify between-neighborhood differences in the propensity for action, this would be the observational equivalent of the single-survey scale measure of collective efficacy. It would likely be impossible to identify differences between residents, which would require observing the repeated reactions of each individual to multiple incivilities. In contrast, surveys focusing on the actions of individuals suffer from issues of validity, the largest being the need to pose the questions as responses to hypothetical situations (e.g., "If a crime occurred, would you…"; Slocum, Taylor, Brick & Esbensen, 2010; Steenbeek & Schutjens, 2014; Warner, 2007), or the potential effects of social desirability and recall bias (e.g., Wells, Schafer, Varano & Bynum, 2006). Last, although ethnographic work might be the most successful at uncovering these behavioral dynamics for a single neighborhood (Carr, 2005; Kefalas, 2003; Pattillo-McCoy, 2000), it cannot be extended to a broader quantitative scale.

311 presents a unique opportunity to study the social regularities underlying collective efficacy because it not only documents efforts by residents to counteract physical disorder in the public space but also tracks these behavioral patterns for thousands of registered users covering the entire city. Consequently, it is possible to quantify and compare the behavioral composition across neighborhoods. One might ask, though, whether it is an appropriate test case for understanding collective efficacy more generally. First, 311 reports do not carry the same gravity as the counteraction of social disorder or violent crime. Nonetheless, physical disorder has historically been a prominent feature of theories on urban decay, most notably as Wilson and Kelling's (1982) iconic "broken window," and there is extensive evidence of the deleterious impacts it can have on the well-being of residents (Cohen et al., 2000; Ross & Jang, 2000; Ross et al., 2001; Theall, Brett, Shirtcliff, Dunn & Drury, 2013). Second, being that the interaction of interest is not between multiple community members but between an individual and the space, it is unclear that these are "social" regularities. The spaces in question, however, are public, and the individual taking action shares it with the rest of the community. Furthermore, by requesting that government attend to an issue, the actor is actively benefitting the community, thereby shaping collective outcomes. Third, rather than a direct intervention, 311 reports have an indirect effect upon the neighborhood, mediated by a formal authority. Although less often discussed in the literature, this still reflects an important form of informal social control referred to as "public control," in which members of the community "secure public goods and services that are allocated by agencies located outside the neighborhood" (Bursik & Grasmick, 1993: 17) for enforcing local social norms. Of critical importance is that the act of enforcement originates with the actions of community members, and are directed to serve the community's needs. These arguments taken together, it stands to reason that 311 reports might reveal a model for action in collective efficacy that is then extensible to other forms of disorder or contexts.

## The Current Study: Patterns of Custodianship and Collective Efficacy

In order to design a study on the social regularities that underlie a particular form of collective efficacy, in this case the maintenance of public spaces through 311 reports, it is first necessary to: (a) describe in greater detail the specific behavior in question; (b) the methodology for operationalizing the behavioral composition of a neighborhood; (c) the methodology for objectively measuring collective efficacy in neighborhood maintenance; and (d) the analytic plan for analyzing how the components of the behavioral composition shape and are shaped by the local context. These are summarized in the following four subsections.

### *Custodianship as a Behavior*

A particular social regularity depends upon the profile of the behavior in question—how often individuals take

such action, where they are most likely to do so, and which factors motivate it. The behavior of interest here is custodianship, or efforts to prevent or counteract deterioration or denigration to the physical spaces of a neighborhood. Custodianship might manifest in direct actions, like sweeping up trash or fallen leaves, or, as in the case at hand, indirect actions like requesting city services to fix a pothole or streetlight outage.

It has been argued that custodianship is a manifestation of a basic human tendency for territoriality (O'Brien, 2015; O'Brien, Gordon & Baldwin-Philippi, 2014). Study on human territoriality originally grew out of work by biologists on how animals claim and defend spaces (e.g., Ardrey, 1966), but social and environmental psychologists have noted that humans exhibit "territorial" behaviors in a myriad of contexts, from classrooms to office spaces to the rooms of a house, that go beyond defense or exclusion to also include forms of beneficence and caretaking. This has led to an expanded definition of territoriality, spanning all attitudes, cognitions, and behaviors that arise from a sense of ownership of an object or space (Altman, 1970; Brown, 1987; Edney, 1974; Taylor, 1988). Key to this definition is an emphasis on psychological ownership, rather than the traditional legal definition of ownership, meaning that territoriality is motivated by a "feeling of possessiveness and of being psychologically tied to an object" (Pierce, Kostova & Dirks, 2001: 299; also see Brown, Lawrence & Robinson, 2005).

A subset of this work has documented the various forms that territoriality can take in urban neighborhoods. For example, Barbara Brown and colleagues (Brown & Werner, 1985; Werner, Peterson-Lewis & Brown, 1989) examined house decorations during the holidays as an expression of territoriality, and others have done the same with fences and "No Trespassing" signs (Caughy, O'Campo & Patterson, 2001). In keeping with the focus here, there is a consistent linkage between the territorial sentiments residents have for their home and neighborhood and the upkeep of their property and of the neighborhood as a whole (Brown, Perkins & Brown, 2004; Harris & Brown, 1996; Pitner, Yu & Brown, 2012). Research on 311 reports has produced additional evidence for the connection between territoriality and neighborhood upkeep. Consistent with a sense of psychological ownership, the average report references an issue that lies within mere feet of the reporter's house, and 79% of "custodians" reported public issues exclusively within two blocks of home (O'Brien, 2015). In addition, a survey of 311 users found that those expressing greater territorial motives were more likely to make such reports (O'Brien, Offenhuber, Baldwin-Philippi, Sands & Gordon, 2016; O'Brien et al., 2014).

Just as the bases for human territoriality are broader than the term might imply, there is a corresponding expansion in the contextual factors that drive it. Importantly, the distinction between psychological and legal ownership permits territoriality to extend from private items to shared ones, the latter rooted in collective psychological ownership (Pierce & Jussila, 2010). In this way, territoriality is closely related to an individual's sense of community, including relationships with neighbors as well as attachment to the space itself (McMillan & Chavis, 1986). Consistent with this interpretation, O'Brien, Gordon and Baldwin-Philippi (2014) found that an individual's level of territoriality was positively associated with their perceptions of social cohesion within the neighborhood and their attachment to place, and in turn mediated much of the relationship between these factors and levels of 311 reporting. This body of work not only provides a fuller perspective on custodianship but also further situates it as a consequential part of the social dynamics of an urban neighborhood.

### *Operationalizing the Behavioral Composition*

This study uses two main measures to operationalize the *behavioral composition*, or the embodiment and distribution of a particular behavior within the population. Previous work with 311 reports has found that custodianship varies considerably across individuals. Over a 15-month period, about 2.5% of Bostonians reported a public issue, only 10% of whom reported three or more (O'Brien, 2015). Additionally, this latter group tends to have a greater geographical range, reporting issues throughout the urban commons, whereas the majority of reporters do so only for issues in the spaces directly abutting their own property. This suggests two groups of custodians: "typical" custodians, who only sporadically take such action and over a narrow range nearby their homes; and "exemplars," who do so with greater regularity and geographic coverage. This is consistent with the well-established dynamic of civic organizations, which comprise both highly active community leaders and more occasional participants. The study tabulates typical and exemplar custodians for each neighborhood by leveraging two particular features of the database. First, user accounts provide the information necessary to quantify reporting frequency and to approximate home locations for tens of thousands of registered users. Second, 311 systems categorize requests into case types upon receipt based on the services required. Using these, I differentiate issues that are in the public domain from those that regard an individual's personal needs (e.g., general request, request for bulk item pick-up), thereby distinguishing custodians from users

who have not actually used the system for neighborhood maintenance.

### *Measuring Collective Efficacy in Neighborhood Maintenance*

I measure collective efficacy in the maintenance public space through two neighborhood audits, one documenting streetlight outages and the other broken sidewalks. Each issue identified in these audits is a natural experiment, testing a neighborhood's vigilance against deterioration. Because 311 reports include the date, location, and nature of the issue, it is possible to identify if and how quickly any issue identified in an audit was reported, creating objective measures of maintenance in a neighborhood.

### *Analytic Plan*

The main analysis will occur in two stages. Stage one will use the behavioral composition to predict collective efficacy in the maintenance of public space. Stage two will examine how contextual factors predict variations in the behavioral composition across neighborhoods, giving some insights on the sources of these social regularities. For stage one, the role of the behavioral composition in determining collective efficacy in the maintenance of the neighborhood might be described by one of four empirical models, two that assume that variation in neighborhood-level outcomes is determined primarily by the distribution of one behavioral type or the other, and two that describe situations in which both groups are critical to the collective outcome:

1. The *foundational actors* model posits that the actions of prominent individuals are central to the collective outcome, predicting that the distribution of exemplars would be most important to maintenance.
2. The *communitarian model* posits that the critical factor for collective outcomes is the overall volume of actors, thereby predicting that that the distribution of typical custodians would be most important to maintenance.
3. The *additive model* posits that members of the two groups make the same type of contribution to the collective outcome, differing only in the magnitude of their impact. Thus, a single exemplar and a set of typical custodians who generate the same quantity of activity would be interchangeable. This model would predict that the distribution of both exemplars and typical custodians have independent effects on maintenance.
4. The *collaborative model* posits that the two groups make qualitatively different contributions to the collective outcome, and therefore are not interchangeable but are both necessary. This model would specifically predict an interaction effect, in which neighborhoods high in both exemplars and typical custodians would be more effective at maintaining public spaces than neighborhoods high in only one.

The goal of stage one of the analysis will be to determine which of these four models best describes the process of neighborhood maintenance. Importantly, analyzing the efficacy in reporting exclusively in terms of the measured distribution of typical custodians and exemplars makes the assumption that the registered users of the 311 system are an unbiased representation of custodians across the city. There is, however, theoretical and empirical reason to believe that some minority groups—particularly immigrants—would be more likely to report anonymously, foregoing the creation of an account with the system. To account for this, the analysis controls for the ethnic composition of neighborhoods.

Stage two of the analysis will illustrate an additional value of the behavioral composition approach by examining the contextual factors that predict the distribution of typical and exemplar custodians across the city. This will focus on variables that are consistently associated with physical disorder, including demographic characteristics, like wealth and homeownership, and local social dynamics, as measured by Sampson et al.'s (1997) survey scale of collective efficacy. It is important to note that the latter measure is not included as an effort to validate the survey and observational measures against each other, but to understand how the generalized social context, including relationships and the strength of local norms, predicts the social regularities of residents in regard to the task of neighborhood maintenance. For example, a recent study found that social relationships between community members mediated the relationship between individual-level civic engagement and its translation into perceived collective efficacy (Collins, Neal & Neal, 2014). This analysis will offer additional nuance to our understanding of traditional correlates of physical disorder by illustrating how they might operate through a neighborhood's behavioral composition. In turn, it also provides a basis for understanding the mechanisms by which a policymaker or practitioner would most fruitfully intervene to alter local patterns of behavior. Of particular interest, it is possible that some factors are more associated with a higher representation of typical custodians and others with exemplars, suggesting multiple pathways from contextual factors to collective outcomes and therefore a more nuanced perspective on their relationship.

## Methods

The study utilizes three classes of data: (a) the 311 database from 2011; (b) two neighborhood audits conducted primarily in 2011; (c) survey-based measures of demographic and social conditions from 2009 and 2010. Although the latter are neighborhood-level metrics, the first two describe events or conditions at a specific address or street segment. As detailed in the following subsections these were converted into neighborhood-level descriptors, a process facilitated by a master geographical database that maps the addresses, intersections, and streets of Boston (drawn from the City's tax assessor and roads data) to the appropriate census geographies. This study utilizes census tracts ($N = 156$; from the 2005–2009 American Community Survey (ACS), the most recent geographies with measures of social conditions associated with them). The tract containing City Hall was excluded from analysis, because many reports without an address are attributed to that location by default.

### 311 Database

In 2011, Boston's 311 system received 164,489 requests for non-emergency government services via its three channels (hotline calls, Internet self-service portal, and smartphone application) that had a geographic reference. I limit to this period to be concurrent with the neighborhood audits (see below).

Each case record included the date of the request, the address or intersection where services were to be rendered, and the case type. Cases are categorized at the time of receipt into one of 178 standardized case types based on the services required. Of these, 59 case types referenced issues in the public space (e.g., streetlight outage, graffiti removal; complete list in Appendix A), thereby reflecting instances of custodianship. Other case types referenced personal needs rather than public concerns (e.g., general request, bulk item pickup).

All individuals who have registered with the 311 system have an anonymous ID code that is appended to each of their reports. There were 63,284 unique constituent users.[1] The ID code makes it possible to construct a database of users with variables describing each individual's pattern of reporting across time and space, including: (a) the total number of calls a user had made regarding public issues; and (b) an estimate of the user's home location, based on the locations at which she requested services.[2] Custodians were defined as any individual reporting one or more issues in the public space ($n = 28{,}024$ individuals, or 44% of all registered users; others only made requests for personal needs), accounting for 47% of all reports of public issues (the other 53% were reported by anonymous individuals or City employees). The number of public reports across users had a Poisson distribution, with 90% making two or fewer in a year. This dividing line is notable because it is where the distribution flattens and the tail begins, suggesting qualitatively different groups of individuals on each side (i.e., the "elbow test"). Additionally, the behavioral distinction between the two groups was not just about the frequency of reporting but also their geographic range of custodianship, and this cut-point created the greatest distinction in geographic range of reporting.[3] Based on this, the proceeding analysis divides custodians into two groups: *typical custodians*, who made two or fewer reports in a year; and *exemplars*, who made three or more in a year. Using estimated home locations, I tabulated the number of typical custodians and exemplars for each neighborhood.

### Neighborhood Audits

Actual issues in the public space were assessed through two separate audits. One identified streetlight outages in

[1] Users who made one or more reports as a department member at any time were removed because city employees differ from other constituents in their motivation for making reports. This excluded five individuals, a number that is low because for many employee-specific case types, user IDs were stripped before data sharing.

[2] Home location was estimated in one of two ways, depending on the geographic range of an individual's requests for service. If the individual reported cases over a range with diameter smaller than 0.5 miles (90% of users), location was defined as the centroid of all reports made, which was then attributed to the appropriate tract. Because of the small range, this estimate can be assumed to be reasonably precise. For those whose range had a diameter >0.5 miles, this precision was weaker. These individuals were attributed not to a centroid, but to the census tract from which they made the most calls. This was done using the entire period of the database (March 2010–June 2012) in order to make the greatest use of available information. This estimation technique was validated against a sample of 7433 users for whom home locations were known. Of these, 83% were attributed to the correct census tract. More importantly, the tract-level counts generated by this process correlated with actual counts at $r = .97$. There is reason to believe that this correlation is underestimated, as the subsample used in the validation had an above-average number of calls per person, creating estimates with greater error.

[3] Geographic range of reporting was estimated for those who had a home address on file as the furthest distance of a reported issue from the custodian's home (calculated using the Pythagorean equation, $\sqrt{(x_r - x_h)^2 + (y_r - y_h)^2}$, where the subscripts $r$ and $h$ indicate the location of the report and the home, respectively). Using three reports as a cut-point generated a greater distinction between groups in geographic range ($t = 11.2$, $p < .001$) than two reports ($t = 4.6$, $p < .001$) or four reports ($t = 10.6$, $p < .001$).

72 of Boston's 156 census tracts (46%) between June 1 and August 31, 2011. This sample covered about half of the city and was representative of its geographic and demographic diversity. In total, 244 streetlight outages were identified, distributed across 56 tracts; 16 tracts had no streetlight outages at the time of the audit (max = 11 outages). Each was attributed to the nearest address. More detail on this protocol is available in O'Brien, Sampson, and Winship (2015).

In the second audit, a consulting group hired by the City of Boston's Public Works Department assessed the quality of all of the city's sidewalks between November 2009 and April 2012, although primarily in 2011. For each continuous stretch of sidewalk running from intersection to intersection ($N$ = 27,388), assessors noted the proportion of panels that required replacement (i.e., cracked, broken), and subtracted this from the total, generating a 0–100 measure of *sidewalk quality* (100 = no panels requiring replacement).

Streetlight outages and sidewalks were cross-referenced with the 311 database to identify reports regarding them. For streetlight outages, this was defined as the earliest case of an outage reported on that street segment that was fixed by the city after the date an auditor noted the outage.[4] This was then used to create a series of dichotomous measures indicating whether the outage had been reported by a constituent within a certain time window (e.g., 1 month).[5] For sidewalks, all requests for repair were joined to the nearest sidewalk polygon from the same road, excluding those created by City employees. Of the 27,388 sidewalk polygons, 1168 generated requests for repair (4%; min = 1, max = 19).

### Demographic and Social Measures

Measures of demographic and social characteristics of neighborhoods were drawn from two other sources. First, the census' ACS (2005–2009 estimates) provided measures of *median income*, *homeownership*, and ethnic composition. Second, the Boston Neighborhood Survey (BNS), a random-digit dial telephone survey based on the methodology from Sampson et al. (1997) and administered in 2010 ($n$ = 1718), provided measures of collective efficacy. The scale measuring collective efficacy was first calculated for each individual respondent. Neighborhood-level measures were then calculated by fitting multilevel models that nested individuals within their tract and controlled for individual-level demographic characteristics (gender, age, ethnicity, and parental status). The Bayes residuals for the neighborhood-level model were then extracted as neighborhood measures adjusted for measurement and sampling error.

## Results

### Variation in Maintenance across Neighborhoods

The first step of the analysis was to use the neighborhood audits to measure collective efficacy in maintenance across the city. The probability of a streetlight outage being reported increased at a decreasing rate over time. Nine percent of outages were reported by constituents within a week of the audit, 14% by the end of the second week, 22% by the end of the first month. After 5 months, 67% of streetlight outages had been reported by a constituent. Of the city's 27,388 sidewalks, 1168 (4%) generated requests for repair, 730 (62%) of which generated more than one. Those with calls had lower sidewalk quality (SCI; $t_{\mathrm{df}\ =\ 27{,}386} = 3.79$, $p < .001$).

Hierarchical linear models were used to calculate neighborhood-level measures of the likelihood of reporting either an outage or broken sidewalk using (using HLM v. 6.06; Raudenbush, Bryk, Cheong, Congdon & du Toit, 2004). The models controlled for street-level characteristics that might influence reporting behavior—main vs. non-main streets, and the street's zoning (e.g., residential)[6]—in order to best evaluate whether significant variation existed across tracts for a given measure of reporting. For each audit, I compared multiple outcome measures of reporting in order to determine which best captured between-neighborhood differences. These measures were then retained for the subsequent analyses.

For streetlight outages, I compared time windows for reporting ranging from 1 week to 5 months after the audit. Variation across tracts was greatest for 2 months ($\chi^2_{df=53} = 80.80$, $p < .01$).[7] For sidewalks, most elicited

[4] This means a streetlight might have been reported before the audit but not been fixed until after.

[5] It was possible to distinguish whether a report was made by a constituent or a City employee, meaning a continuous measure of the time before reporting would not necessarily reflect the strength of constituent response. Instead, the dichotomous measures were created so that employee-reported outages could be considered not-reported until the date the employee report appeared. Thereafter they were omitted from the data, as it is not possible to know whether a constituent would have reported up to that point. For example, a streetlight outage reported 16 days later by a City employee takes the value "0" for the measure of being reported within 2 weeks, but would take no value (omitted) for the measure 1 month.

[6] For both streetlight outages and sidewalks, a dichotomous reporting variable was modeled as the outcome ("1" = eliciting a constituent report) using a logit link. For the sidewalks, a count of calls was also estimated, requiring a probit model. Tract-level measures were extracted as Bayes residuals from the models.

[7] There was also significant or nearly significant variation for the 1-month ($\chi^2_{df=54} = 78.39$, $p < .05$) and 2-week windows ($\chi^2_{df=54} = 68.61$, $p < .10$).

zero reports, leading to the comparison of two models, each controlling for sidewalk quality: a logit model predicting the likelihood of generating any requests; and a probit model predicting the number of requests across those with one or more. Tracts varied substantially in the likelihood of reporting a sidewalk ($\chi^2_{df=155} = 425.16$, $p < .001$), but not in the number of reports per sidewalk ($\chi^2_{df=152} = 179.58$, $p < .10$), making the former the preferable measure.[8]

## Behavioral Composition and the Production of Order

To explain cross-neighborhood differences in maintenance, we turn to the behavioral composition of neighborhoods, measured as the distribution of typical custodians and exemplars. In 2011, between 0.2% and 6% of a tract's adult population were registered 311 users who qualified as custodians ($M = 2.70\%$, $SD = 1.10\%$). About one in seven custodians qualified as exemplars (i.e., making three or more reports; 14%). Tracts had between 0 and 49 exemplars ($M = 11.41$, $SD = 7.60$). As percentages of the adult population, the two groups correlated highly ($r = .71$, $p$ values $<.001$), suggesting that they are not entirely independent.

In considering how the actors in a neighborhood collectively address streetlight outages, broken sidewalks, or other such problems, one must account for the spatial dynamics of reporting. Each of these issues requires that an individual be at that specific location, take note of the problem, and then make a report. Typical custodians tend to be custodial over narrow regions nearby their homes, and must combine to cover the broader neighborhood. Consequently, their overall value is best described in density per sq. mile. On the other hand, exemplars report issues over a multiblock radius and might take action on issues throughout the neighborhood. Thus, the raw count of exemplars would give the best approximation of their total coverage.

A second consideration is choosing the correct time window for measuring actors. Because sidewalk assessments were conducted primarily over the course of 2011, I limit to custodians in that year. The streetlight outages occurred within a more precise time window. For this reason, it seems appropriate to focus on reporter activity in the months just preceding the streetlight audits. Based on previous analyses of reliability, I utilize a 3-month time window (O'Brien et al., 2015). Because all measures of behavioral composition featured a positive skew, they were log-transformed before regression analysis.

I ran regression models to adjudicate between the four models that translate action to collective efficacy: foundational actors, communitarian, additive, and collaborative (for complete results of all models please see Appendix A). For sidewalks, separate regressions found that both a higher density of typical custodians and more exemplars predicted greater efficacy in reporting (typical reporters: $B = 0.47$, $p < .001$; exemplars: $B = 0.41$, $p < .001$). When entered together into a multiple regression, each independently predicted the likelihood of a report, explaining 30% of the overall variation, with typical users having a somewhat stronger effect (typical reporters: $B = 0.38$; exemplars: $B = 0.29$; both $p$ values $<.001$). This indicates contributions by both typical custodians and exemplars to maintenance.

To distinguish between the additive and collaborative models, that latter of which stipulates that both groups not only contribute but are independently necessary, an interaction effect between the two types of actors was introduced to the regression.[9] The interaction effect predicted an additional 1% of the variation ($B = 0.13$, $p < .05$; change in variance explained: $F = 3.88$, $p < .05$). This supported the collaborative model in that the combination of both a density of typical reporters and many exemplars best ensured that a report would be made (illustrated in Fig. 1a). For comparison, I ran two simpler models that did not differentiate between types of users, one with the total number of custodians as a lone predictor, and the other with custodians per square mile as a lone predictor. Although both were significant (total number: $B = 0.35$, $p < .001$; number per sq. mile: $B = 0.48$, $p < .001$), these models explained less variation than the full model with typical custodians, exemplars, and their interaction (ANOVA comparisons $p < .001$). This further justifies the division of custodians into two groups. See Appendix A for complete models.

The same analysis produced similar results for streetlight outages. A higher density of typical reporters ($B = 0.28$, $p < .05$) and more exemplars ($B = 0.30$, $p < .05$) in the 3 months preceding the outage audit predicted a greater likelihood of such a report being made. In a multiple regression the two were comparably strong predictors (typical custodians: $B = 0.26$; exemplars: $B = 0.23$; both $p$ values $<.10$; note that the lower level of significance in this model is owed to the smaller sample size, $N = 54$), explaining 14% of the variance. The addition of an interaction effect improved the model, again providing evidence for the collaborative model. It

[8] In addition, sidewalk quality did not significantly predict more reports for a sidewalk, suggesting it is a less effective measure for the purposes here ($B = 0.001$, $p = ns$, Odds Ratio = 1.001).

[9] To eliminate any shared variance between the interaction effect and the main effects, it was first regressed upon the two component variables, a process known as residual centering that is more effective than more traditional mean centering (Lance, 1988; Little, Bovaird & Widaman, 2006). The residual (i.e., the unique variance of the interaction factor) was then entered into the equation.

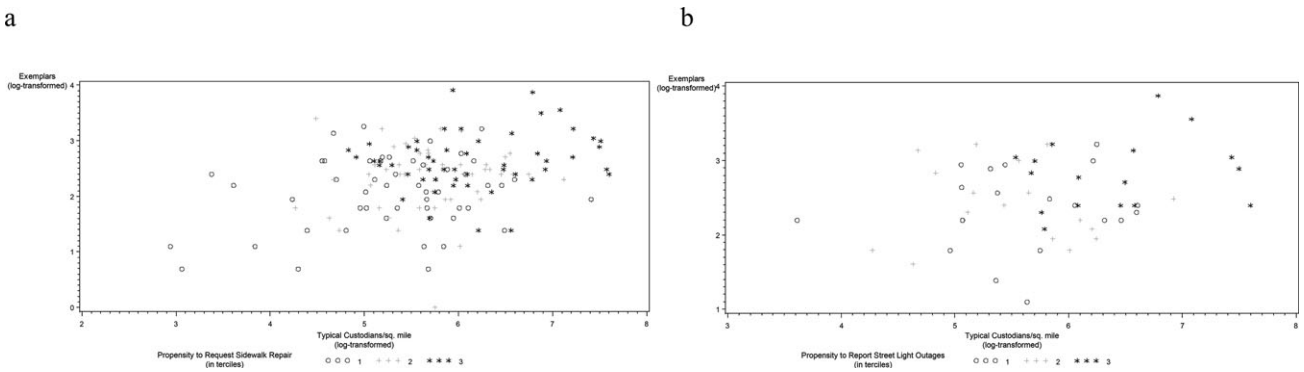


**Fig. 1** Scatter plots depicting the increased production of order where typical custodians are more dense and exemplars are more frequent, as measured by (a) requests for sidewalk paving and (b) reports of streetlight outages

increased the explained variance to 16%, although with the small sample size this was a non-significant change. It also made all predictors non-significant. Upon trimming the model, the interaction effect was the best single predictor ($B = 0.36$, $p < .01$). One can see in Fig. 1b, a pattern very similar to the analysis of reporting sidewalks; the likelihood that an issue was reported steadily increases with both more typical and exemplar reporters, but is highest in neighborhoods with both. Again, the two simpler models using total number of custodians and custodians per square mile as a lone predictor (total number: $B = 0.28$, $p < .05$; number per sq. mile: $B = 0.29$, $p < .05$) explained less variance than the more detailed model (ANOVA comparisons $p < .1$).

## Behavioral Composition and the Production of Order: Robustness Check

As noted above, this analysis makes the assumption that registered accounts, which generate about half of the reports of public issues, are an accurate estimation of the distribution of users across neighborhoods. Previous work, however, has found that users are less likely to register in regions with higher levels of disadvantage and immigrants (O'Brien, 2015), meaning these neighborhoods might be more effective in reporting issues than would be indicated by the representation of registered custodians in the 311 database. To check the robustness of the current findings the regression analyses were repeated, incorporating measures of median income, proportion Black, Hispanic, and immigrant (log-transformed when necessary).

These additions left the original results largely unchanged. For sidewalks, the parameters for the behavioral composition were nearly identical (typical custodians: $B = 0.38$, $p < .001$; exemplars: $B = 0.30$, $p < .001$; interaction: $B = 0.14$, $p < .05$). Of the new predictors, only Hispanic population marginally predicted greater reporting than accounted for by the three measures of the behavioral composition ($B = 0.16$, $p < .10$). For streetlight outages, the small sample size called for a stepwise regression. The four demographic variables were entered into the model first, none of which were significant predictors. The interaction was entered next as the strongest remaining predictor ($B = 0.31$, $p < .05$). The further introduction of either typical or exemplar custodians was non-significant, although they maintained their correlations with reporting when controlling for demographics (typical custodians: $B = 0.27$; exemplars: $B = 0.26$; both $p$ values $\leq .10$.)

## Context and the Behavioral Composition

With evidence for a collaborative model, in which typical custodians and exemplars each make distinct contributions to a neighborhood's efficacy in reporting public issues, I sought to identify which contextual factors most often associated with the level of disorder—median income, homeownership, and generalized collective efficacy—best predict the representation of each group. Because the two types of actors were so highly correlated across neighborhoods, I analyze two measures: the percentage of individuals acting as custodians in 2011; and the proportion of those individuals who were exemplars. This is done with regressions that also control for measures of ethnic composition (% Black, Hispanic, and Asian).

A greater proportion of a neighborhood's population reported a public issue where there was higher median income ($B = 0.34$, $p < .01$) and homeownership ($B = 0.26$, $p < .05$). Generalized collective efficacy was a non-significant predictor. The second model found that there was a higher proportion of exemplars where there was greater generalized collective efficacy ($B = 0.21$, $p < .05$) and a greater Asian population ($B = 0.30$, $p < .01$).[10] Unexpectedly, the proportion of exemplars

[10] To avoid spurious proportions it was necessary to exclude one tract with only two custodians (no other tract had fewer than five).

was also higher where there were fewer homeowners ($B = -0.29$, $p < .05$).

## Discussion

This study sought to elucidate how individual community members combine to realize collective efficacy in an urban neighborhood, focusing on the specific task of maintaining the urban commons. The 311 archive from Boston, MA offered a unique window into the microdynamics of the residents' efforts to counteract physical disorder in the public space, and made it possible to conduct two neighborhood audits that assessed a neighborhood's ability to effectively respond to instances of deterioration. In order to connect the discrete behaviors documented by the first dataset to the collective outcomes of the latter, the study focused on social regularities, or patterns of behavior within a social setting (Seidman, 1988, 1990, 2012). Specifically, I introduced an analytic frame for operationalizing social regularities known as the behavioral composition, or the embodiment of a social regularity in terms of each community member's tendency to contribute to it. Using this perspective, analysis of the neighborhood audits found that two different types of actors, typical custodians and exemplars, contributed independently to the maintenance of a neighborhood. There was evidence of what might be called a collaborative model, in which these two groups were not only equally valuable to neighborhood upkeep, but were essential and non-substitutable; an abundance of one could not compensate for a lack of the other.

Beyond permitting us to model how collective efficacy emerges from individual patterns of behavior, the focus on the behavioral composition enables an examination of how contextual factors operate through the social regularities of a neighborhood. Certain variables, including homeownership, wealth, and the social organization, have long been known to correlate with the level of physical disorder, and the analysis here was the first to demonstrate that these correlations might arise from different patterns of behavior. Median income's association with more typical custodians, but not exemplars, fits with a view of affluence as a force that enables and empowers individuals to take action when motivated to do so, but does not necessarily incentivize them to make a regular habit of reporting public issues (Black, 1976). In contrast, collective efficacy was only associated with a higher proportion of exemplars among a neighborhood's custodians, in keeping with the importance of social norms and a sense of community for motivating beneficial communitarian behavior. Last, homeownership had a curious effect in that it did predict more custodians but that *fewer* of these individuals would be exemplars. This might point not only to the value of property ownership supporting greater perceived ownership over a space but also its limitations in motivating custodianship that extends far beyond the boundaries of private property.

The remainder of this section explores the implications of these findings for two main areas. Theoretically, I explore more deeply how these two types of actor combine to realize the collective maintenance of the urban commons, and consider how attention to the behavioral composition of a neighborhood might be extended to other types of disorder. For practical implications, I turn to the source of data used here to evaluate how a focus on action might help municipalities to better administer 311 systems and allied programs that seek to engage residents in the activities surrounding neighborhood upkeep. Before proceeding, however, it is important to acknowledge a few limitations. First, these data capture a single type of action addressing a single type of task, and its extension to other situations should be done with full consideration of the particularities of reporting public issues to the government; for this reason, parts of the next section are undertaken as a thought exercise that even probes how this task might differ from other challenges of collective efficacy. Second, there is a need for care when interpreting administrative data like those generated by 311 because, by definition, they were not created for research purposes (Boyd & Crawford, 2011; Lazer, Kennedy, King & Vespignani, 2014; O'Brien et al., 2015). As noted, the dataset excludes those who have reported issues via 311 but did not create an account, and it is likely that these individuals are not evenly distributed across ethnic and socioeconomic groups. Although the analysis found the results to be robust to such demographic biases, this weakness might be probed further through future research. Last, one will note that the analysis using contextual conditions to predict the distribution of actors across neighborhoods suffered from the ecological fallacy. For example, it is possible that neighborhoods with more overall resources and homeowners have increased average custodianship across all residents, regardless of individual-level affluence or residential status. Nonetheless, the homeownership and collective efficacy findings are consistent with recent studies that were more capable of making individual-level conclusions (O'Brien, 2015; O'Brien et al., 2014).

### Theoretical Implications: The Behavioral Composition and Collective Efficacy

The behavioral composition provides a valuable tool for illustrating how the actions of individual community members lead to collective outcomes. Formally speaking, the behavioral composition is the distribution of different levels and forms of contribution to a particular social

regularity across all the members of a community, and it is up to the researcher to determine which descriptor or descriptors best capture it. The analysis here created a typology of actors based on volume of custodianship, but other options exist. One might focus on the mean level of activity, variance in activity levels, the maximum level of activity, or any other statistical feature of the behavioral composition, provided there is sufficient theoretical reason for doing so. A typology was useful to the current case as it showed that the challenge of maintaining the urban commons relied on a collaborative dynamic resembling that of traditional civic institutions and activism, which require both leaders and "foot soldiers" (Foster-Fishman, Collins & Pierce, 2013). We might then reasonably extend the same model, or variants thereof, to other challenges faced by a neighborhood. Before exploring this possibility, however, it is critical to move beyond analogies and ask how it is that these two different groups combine to maintain a neighborhood's spaces. To do so, let us look at the behaviors and conditions that characterize each.

Typical custodians report one to two issues per year, although a longer time course of these data suggests that many make only one call *ever* (O'Brien, 2016). Their distribution is strongly associated with both affluence and homeownership, the latter suggesting that homeownership may increase feelings of territoriality, which in turn would motivate greater custodianship (Fischel, 2005; O'Brien, 2012). The issues they report typically are on their street block of residence, demonstrating a geographically narrow sense of custodianship anchored by the home (O'Brien, 2015). Notably, although the actions of typical custodians are hyperlocal and inconsistent at the individual level, the number of typical custodians making reports in a neighborhood during any given month is remarkably stable across time (O'Brien et al., 2015). This suggests a latent tendency to take action that is distributed throughout the neighborhood at a level that is relatively low but sufficient to sustain a characteristic collective level of reporting. In contrast, exemplars are specific individuals who are actively vigilant, reporting issues with discernible regularity over a somewhat larger region. Given their greater representation in regions with higher generalized collective efficacy, one might argue that social relationships draw custodianship out from the "primary territory" surrounding one's home into the "secondary territory" shared by the community. How this activity is supported by social relationships might be further probed with network analyses of how exemplars are socially situated within the community (Neal & Christens, 2014).

When cast this way, it becomes clearer why a neighborhood might need both, as their distinct patterns of custodianship may lead each group to address issues that the other can or will not. Take the hypothetical example of two streetlight outages in a neighborhood, one on a traditional residential street, the other on an undeveloped street with empty lots. In the former, many residents might be motivated to take direct action—it very easily could be someone's only 311 report of the year. The latter case may lack typical custodians who claim the space as their own, meaning it would fall to an exemplar who is attentive to issues over the broader neighborhood. A neighborhood will regularly experience multiple issues of each type, meaning effective upkeep depends on both types of actor.

These insights provide the basis for considering how the behavioral composition might be a useful frame for understanding how a community responds to other issues in the urban commons, or any other task it might encounter. A diverse array of outcomes are attributed, in part, to a community's ability to manage and govern itself, but correlations across these tasks are certainly not perfect (Wickes et al., 2013). Attention to the different actions and interactions associated with each might help to disentangle and explicate these relationships in a way that neighborhood-level correlations alone would not. This might be demonstrated with the iconic example of monitoring peer groups in public. For the sake of illustration, let us begin with the assumption that the dichotomy of typical and exemplar custodians is relevant to this case, although this might not tell the full story, a point we will return to below. If adolescents are unruly in a public space, those living and working in adjacent homes and businesses, the analog of typical custodians, might respond to the disturbance and redirect the youths. There would also be those exemplars who are generally vigilant for such situations and take action whenever they see them. As with the case of a streetlight outage, these two groups would be likely to take action in overlapping but non-equivalent sets of situations, making them both necessary for the comprehensive management of the neighborhood.

Intervening with unruly adolescents, however, differs from reporting a streetlight outage in important ways that will likely have implications for the regularities that one might observe, as well as the supports or constraints for those regularities created by the context. Most apparently, social dynamics are a prominent component in the case of social disorder, both in terms of the immediate interaction and of the broader context of the neighborhood. Community members might see the adolescents as a more salient threat, raising the likelihood that any individual would care enough to take action. Conversely, they might be deterred by a concern that their efforts will be in vain; adolescents are much more likely to ignore adult admonitions than the department of public works is to ignore a work order. There are also cases in which an individual might choose not to take action precisely because she

knows the kids and would prefer to avoid conflict (Pattillo-McCoy, 2000). Understanding the behavioral composition in regard to this specific type of situation, then, might require attention to the social networks of the neighborhood, and how the individuals in question are embedded in them (Neal & Christens, 2014). This might in turn expand the typology of actors. For example, one could imagine the equivalent of "exemplars" separating into those willing to take action throughout the geographic extent of the neighborhood regardless of other variables, and those who take action over this broader geographical range but only when confronting adolescents that they know. Second, one might posit that the broader social organization will play a magnified, but qualitatively distinct, role in supporting action. Although strong integration into a community might provide an individual with normative motivations for 311 reports, individuals make such reports in isolation. In contrast, the relationships between neighbors act as the scaffolding that can either facilitate or inhibit an individual's ability to redirect people's behaviors in the public space, making the social organization a source of both motivation and empowerment. As such, the equivalent of "typical custodians" might be more sensitive to social variables than we saw in the current analysis. Last, this all further raises the question of collective action, and how multiple individuals coordinate their efforts to address either a single instance of individuals violating a norm or a more systemic pattern of social disorder (e.g., Cardazone, Sy, Chik & Corlew, 2014; Carr, 2005).

This thought experiment provides a model for how the behavioral composition might be applied to any of the many tasks and challenges that face a neighborhood. Who are the relevant actors? What are their patterns of behavior? How do they reinforce each other, and where do they play complementary roles? How do they mediate the role of contextual factors? The answers to these would illuminate any single case, but comparisons across them would have the potential to comprehensively illustrate the dynamics of collective efficacy.

## Practical Implications: 311 and the Coproduction of Order

311 and allied programs have been implemented in over 400 cities and towns in the United States, a rapidly growing popularity that is owed largely to two related trends in public policy. One is the increased usage of modern technology to improve municipal governance, a movement known as "civic tech" or "Gov 2.0" (Goldsmith & Crawford, 2014; O'Reilly, 2010). The second is the revived interest in *coproduction* programs, which actively involve constituents in the execution or enforcement of policy (Ostrom, 1996; Whitaker, 1980), of which 311 and certain other forms of civic tech are clear examples. A coproduction approach to neighborhood order is not an entirely new concept, however, as community policing programs have long sought to limit crime through the alignment of formal police activities and informal social control by residents (Greene, 2000). Analogously, while the expertise and equipment necessary for infrastructural maintenance sits with city operations, residents are better situated to identify issues in need of attention and thus act as "the eyes and ears of the city." In this manner, 311 facilitates a collaborative approach to the maintenance of the urban commons.

Although 311 has been touted as a demonstration of civic tech's potential for facilitating coproduction, it has not been without scrutiny. Some have argued that such programs could unintentionally create inequities, or, more likely, reinforce existing patterns of disadvantage across racial and socioeconomic groups (Clark, Brudney & Jang, 2013; Fountain, 2015; Levine & Gershenson, 2014). Most work on this topic to date has used the frame of civic engagement and disenfranchisement to discuss disparities in 311 usage. The most consistent finding has been that neighborhoods with a greater proportion of residents whose first language is not English utilize 311 less often, thereby receiving fewer services. A focus on the social regularities and behavioral composition of neighborhoods, however, would be more immediately actionable for practitioners and community leaders. Instead of focusing on *who* is not receiving these needed services, it places the emphasis on *how* these inequities arise: through the activities of typical and exemplar custodians.

In his call for an action science of social settings, Seidman (2012) argues that the interventions and programmatic innovations implemented by practitioners and policymakers are only effective insofar as they are able to adjust the social regularities of a particular setting. Often the goal is to reorient or newly establish patterns of interactions between multiple people, or between individuals and institutions, as in Christens, Inzeo and Faust's (2014) examination of which social regularities effectively promote empowerment in the context of community organizing. In the case of 311 usage, the emphasis is instead on interactions between individuals and the space, as each neighborhood requires both the latent concern for the urban commons that creates a high level of typical custodians, and the exemplary individuals who report issues throughout the neighborhood. Because each group is responsive to its own set of motivating factors, the lack of one or the other is its own unique problem calling for a particular strategy. For example, neighborhoods suffering from a lack of typical custodians might benefit from interventions that bolster individuals' identification with the space and encourage them to take pride in its upkeep. In contrast, interventions addressing a lack of exemplars

might do better targeting community leaders and organizations. Even if a municipality were unable to identify the distribution of types of custodians across the city, they could infer the needs of a certain population based on its demographic and social composition. These sorts of interventions would likely be more effective than more traditional outreach as they target not only the inequities themselves but also the underlying regularities that perpetuate them.

## Conclusion

The commons plays an essential role in the daily lives of urban residents. It is a shared space that relies on the collective efficacy of the community to maintain it. Little is known about the social regularities that underlie this maintenance, and how the efforts of individual residents in fact combine to address the issues facing their community. The 311 data facilitated such insights through their detailed documentation of everyday behaviors, and in conjunction with more traditional methodologies it was possible to uncover a model for how social regularities, measured as the behavioral composition of a community, translate into upkeep. This was merely a first step, as there remain many questions about where, when, and how custodians with different characteristics will take action. At the same time, it offers a potential model for analyzing others tasks and challenges that require collective efficacy, thereby opening up a new line of inquiry on an important subject regarding urban neighborhoods.

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The author declares no conflicts of interest in this research.

## Compliance with Ethical Standards

The research was conducted with the approval of the University's Institutional Review Board.

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# Appendix A

**Table A1** Case types that reflect an issue in the public space and counts from 3/2010 to 6/2012

| Case type | Count | Case type | Count |
|---|---|---|---|
| Abandoned bicycle | 71 | Park safety notifications | 2 |
| Abandoned building | 103 | Parking enforcement | 685 |
| Abandoned vehicles | 2233 | Parking meter repairs | 139 |
| Bridge maintenance | 29 | Parking on front/back yards (illegal parking) | 132 |
| Building inspection request | 822 | Parks general request | 106 |
| Catchbasin | 13 | Parks lighting issues | 5 |
| Construction debris | 101 | Pavement marking maintenance | 272 |
| Empty litter basket | 292 | Pick up dead animal | 1374 |
| Exceeding terms of permit | 68 | Pigeon infestation | 29 |
| Fire hydrant | 8 | PWD graffiti | 160 |
| General lighting request | 460 | Request for litter basket installation | 80 |
| Graffiti removal | 3893 | Request for pothole repair | 4603 |
| Highway maintenance | 3297 | Request for snow plowing | 7270 |
| Illegal auto body shop | 46 | Requests for street cleaning | 953 |
| Illegal dumping | 831 | Requests for traffic signal studies or reviews | 96 |
| Illegal occupancy | 263 | Roadway repair | 306 |
| Illegal posting of signs | 116 | Rodent activity | 1241 |
| Illegal rooming house | 177 | Sidewalk cover/manhole | 3 |
| Illegal use | 62 | Sidewalk repair | 1294 |
| Illegal vending | 32 | Sidewalk repair (make safe) | 2119 |
| Improper storage of trash (barrels) | 1745 | Sign repair | 1172 |
| Install new lighting | 25 | Snow removal | 2103 |
| Misc. snow complaint | 1407 | Streetlight knock downs | 476 |
| Missed trash/recycling/yard waste/bulk item | 6211 | Streetlight outages | 8127 |
| Missing sign | 671 | Traffic signal repair | 2585 |
| New sign, crosswalk or pavement marking | 976 | Trash on vacant lot | 121 |
| New tree requests | 831 | Tree emergencies | 3446 |
| Overflowing or un-kept dumpster | 149 | Tree maintenance requests | 3336 |
| Park improvement requests | 3 | Upgrade existing lighting | 15 |
| Park maintenance requests | 87 | | |

**Table A2** Parameter estimates from models using the relative prevalence of typical and exemplar custodians and demographic characteristics to predict a census tract's likelihood to report a broken sidewalk

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | | Model 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β |
| Typical Cutosidans/ mi$^2$ [a] | .21$^{***}$ [.14, .27] | .47 | — | — | .17$^{***}$ [.10, .25] | .38 | .17$^{***}$ [.11, .23] | .38 | — | — | — | — |
| Exemplars[a] | — | — | .24$^{***}$ [.15, .32] | .41 | .17$^{***}$ [.09, .25] | .29 | .17$^{***}$ [.09, .25] | .29 | — | — | — | — |
| Typicals $^{*}$ Exemplars | — | — | — | — | — | — | .05$^{*}$ [.0002, .10] | .13 | — | — | — | — |
| Total Custodians/ mi$^2$ | — | — | — | — | — | — | — | — | .22$^{***}$ [.15, .28] | .48 | — | — |
| Total Custodians | — | — | — | — | — | — | — | — | — | — | .20$^{***}$ [.12, .29] | .35 |
| % Immigrant | — | — | — | — | — | — | — | — | — | — | — | — |
| % Hispanic[a] | — | — | — | — | — | — | — | — | — | — | — | — |
| % Black[a] | — | — | — | — | — | — | — | — | — | — | — | — |
| Median Income | — | — | — | — | — | — | — | — | — | — | — | — |
| Adjusted $R^2$ | .21 | | .16 | | .29 | | .30 | | .22 | | .12 | |

$n$ = 155 census tracts.

*$p$ < .05, **$p$ < .01, ***$p$ < .001.

[a]Log-transformed to adjust for skew.

**Table A3** Parameter estimates from models using the relative prevalence of typical and exemplar custodians and demographic characteristics to predict a census tract's likelihood to report a street light outage

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | | Model 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β | β [95% CI] | Stand. β |
| Typical Cutosidans/ $mi^2$ [a,b] | .17* [.01, .34] | .28 | — | — | .14+ [−.03, .30] | .23 | — | — | — | — | — | — |
| Exemplars[a] | — | — | .27* [.03, .51] | .30 | .23+ [−.01, .47] | .26 | — | — | — | — | — | — |
| Typicals * Exemplars | — | — | — | — | — | — | .21** [.06, .36] | .36 | — | — | — | — |
| Total Custodians/ $mi^2$ | — | — | — | — | — | — | — | — | .17* [.01, .34] | .29 | — | — |
| Total Custodians | — | — | — | — | — | — | — | — | — | — | .26* [.01, .50] | .28 |
| % Immigrant | — | — | — | — | — | — | — | — | — | — | — | — |
| % Hispanic[a] | — | — | — | — | — | — | — | — | — | — | — | — |
| % Black[a] | — | — | — | — | — | — | — | — | — | — | — | — |
| Median Income | — | — | — | — | — | — | — | — | — | — | — | — |
| Adjusted $R^2$ | .08 | | .08 | | .11 | | .12 | | .06 | | .06 | |

$n$ = 53 census tracts with street light outages.

*$p$ < .05, **$p$ < .01, ***$p$ < .001.

[a]Log-transformed to adjust for skew.

[b]During the 3 months in advance of the street light outage audits.

## AFFIDAVIT

The undersigned, Richard Bunch, being duly sworn, deposes and says that he is a senior consultant of 5 Lakes Energy LLC, and is authorized to submit this testimony on behalf of Lexington-Fayette Urban County Government and Louisville/Jefferson County Metro Government in Case Nos. 2020-00349 and 2020-00350, and that the information contained in the testimony is true and accurate to the best of his knowledge, information and belief, after reasonable inquiry, and as to those matters that are based on information provided to him, he believes to be true and correct.

Richard Bunch, Affiant

## NOTARY CERTIFICATE

**STATE OF MICHIGAN**

**COUNTY OF** Washtenaw

Subscribed, acknowledged and sworn to before me by Richard Bunch on this 5th day of March 2021.

My commission expires: 1/25/2026.

RENA BASCH
Notary Public - State of Michigan
County of Washtenaw
My Commission Expires Jan 25, 2026
Acting in the County of Washtenaw

NOTARY PUBLIC