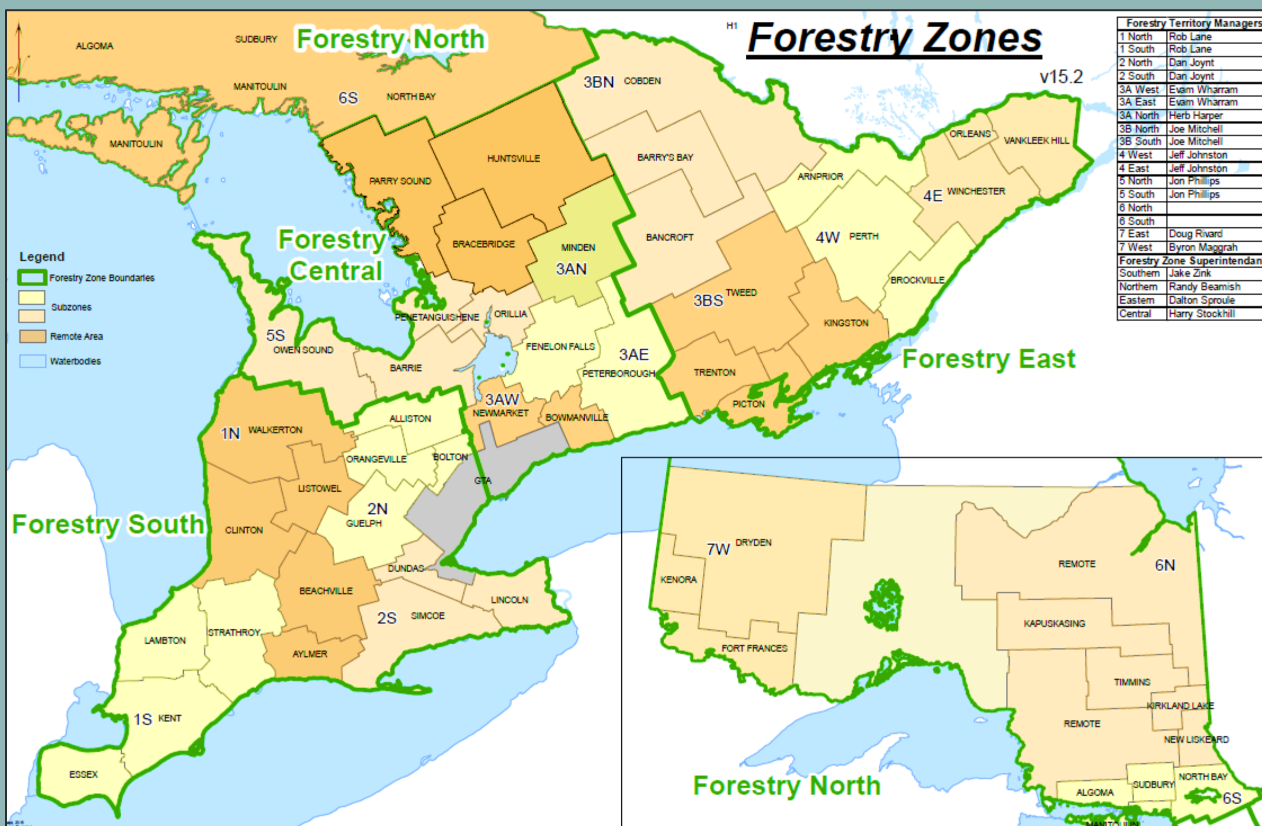
HYDRO ONE VEGETATION MANAGEMENT STUDY 2016



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Prepared by:
CN Utility Consulting, Inc
5930 Grand Ave
West Des Moines, IA 50266

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Disclaimer

The information collected through benchmark surveys and other data sources is offered as guidance to the readers of this report. How this data is interpreted is subject to many variables and potential biases. CNUC reviews benchmark data for errors and omissions and analysis is performed to advance positive recommendations and outcomes but makes no claims and does not take responsibility for interpretation or submitted survey information that is inaccurate or incomplete.

1 EXECUTIVE SUMMARY

1.1 STUDY PURPOSE

Hydro One was instructed by the Ontario Energy Board (OEB) in March 2015 to perform a trend analysis of the utility vegetation management (UVM) program. Specifically, the Ontario Energy Board (OEB) requested:

> • *A comprehensive trend analysis of the vegetation management program showing year over year comparisons in unit costs.*
> • *A best practices study, if undertaken, for vegetation management similar to the CN Utility study filed in EB-2009-0096.* (OEB, March 2015, p. 61)

In response, Hydro One contracted CN Utility Consulting (CNUC) to conduct a benchmark survey of North American UVM programs and perform trend analysis.

1.2 OVERVIEW OF THE HYDRO ONE SERVICE TERRITORY

Operating one of the largest North America distribution systems in vast remote and rural areas, dense forests and harsh winters, Hydro One maintains over 100,000 kilometres of rights-of-way (ROW) to keep trees away from powerlines. The service territory includes most of Ontario with the exception of the metropolitan areas around Lake Ontario and rural communities served by local distribution companies. The extreme northwestern region of the province (the Hudson Bay Lowlands) is also not included in the service territory.

Hydro One's geography presents several challenges to vegetation management. Although the majority of the powerlines are along roadways, one-third of the lines are off-road. These are rigorous to work and require special equipment, including heavy equipment, all-terrain vehicles, and boats. In addition, the system is large, sprawling and dense with vegetation as well as prone to ice-storms and wind events. In many areas the customers are scattered and separated by long distances. The number of customers per square kilometre is one of the lowest for all utilities compared and the number of trees managed per customer is one of the highest. On a cost per customer basis, these facts express the need for a highly efficient vegetation management program.

In general, electric systems start with high-voltage supply lines that divide and step-down into networks of lower voltage lines. For the Hydro One distribution system, the highest voltage lines are called M-Class feeders and are operated at 44,000 volts (44kV), 27,600 volts (27.6kV) and 25,000 volts (25kV) depending on the area. The rest of the network is comprised of F-Class feeders operated at lower voltages that consist of three-phase, two-phase, and single-phase lines. Of the 102,000 km of overhead line, 52,000 km are lower voltage feeders and two-phase and single-phase lines. The higher the voltage, the more customers are affected by an outage. M-Class feeders are a high priority for vegetation management. However, all overhead lines are managed to prevent vegetation encroachments. Although the higher voltage lines are more important to the system, vegetation needs to be managed for safety and reliable service, down to the lowest voltage.

There are three main forestry eco-zones within Hydro One's service area:

- The Boreal is mainly conifers
- The Great Lakes/St Lawrence Forest Zone is mixed conifer/deciduous forests
- The Deciduous Forests Zone has the greatest diversity of tree species

Hydro One's distribution system is divided into four forestry management regions: North, South, Central and East. The Central and East Regions have similar dense forestry conditions and require the greatest amount of vegetation management on the system. The North Region has dense forests, is mostly conifer, and has the least amount of line. In contrast, the South has scattered forests, is predominately agricultural, and has the most kilometres of line.

Expansive and large forests, harsh winters, frequent storms, and rugged and remote ROWs with long travel distances are realities that characterize forestry management for Hydro One.

1.3 Progress and Performance of Hydro one's Vegetation Management Program

Over the period of this study, 2011-2015, Hydro One increased their efforts to reduce the number of trees managed on their system. However, when the number of trees managed is almost eight million, it takes more than five years to experience a significant reduction in the workload. Since work is performed infrequently, a cycle of 9.5 years on average, it is difficult to make progress as trees are growing faster than they are managed. Until the backlog of work and the cycle length are reduced, Hydro One needs to continue to improve progress.

Hydro One has maintained the high level of efficiency that was discovered in the 2009 study. More trees are managed per hour than most peer utilities. In spite of all their challenges, Hydro One has fewer outages per kilometre of line than most peer companies. Even though the conditions are rugged and sometimes harsh, Hydro One has an excellent safety record in comparison to peers. Overall, Hydro One ranks high for performance in safety, reliability, and productivity.

Hydro One's costs per unit of work are very high in comparison to peers. Although many of Hydro One's costs are fixed costs, such as wages, benefits, equipment depreciation and overhead costs, there are some opportunities to decrease spending. Hydro One has been diligent at finding ways to improve efficiency and to lower labour costs. Continued efforts to employ new technologies, automation, mechanization, routing and scheduling, and outsourcing more of the labour will result in lower overall costs.

Hydro One's record shows a serious effort to reduce production costs and improve performance and progress. They have shown measurable headway in their performance over time. However, this progress has not been sufficient to effectively decrease the total workload.

Although most of the peer group has lower costs than Hydro One, it is not always due to better performance than Hydro One. This is because fixed costs are higher. Some companies do show that cost per unit can be lower. In fact, one company maintains their system three times during the same time period that Hydro One maintains their system once and the cost for three cycles is still less than Hydro One's single cycle. (See p. 39 for more details)

1.4 Best Management Practices

The following examples of vegetation best management practices (BMP) are based on industry standards and current industry practices.[1]

1.4.1 Best Management Practice Strategies

1. Perform consistent, compliant, and cost-effective ROW corridor management to maintain clearances between conductors and vegetation using industry-approved practices targeted to ensure reliable electric service, environmental quality, customer satisfaction, and safety for workers and the public.
2. Provide sufficient funding and resources to measurably achieve UVM program objectives. "A stable and consistently funded circuit pruning program minimizes the risks of public and worker electrocution as well as wild fire events and is a utility best practice (National Grid 2015)."
3. Build greater safety awareness and education for anyone who enters a ROW zone for any reason and measure success by using leading performance indicators, such as safe ROW environment metrics, safe work place metrics, and program features.
4. Define, measure, and audit the barrier space between conductors and vegetation.
5. Establish a cycle of inspection and maintenance that is sufficiently flexible to address a variety of vegetation management conditions but regular enough to anticipate conflicts before they occur.

1.4.2 Best Management Practice Tactics and Key Measures

1. Maintain 50-75% of distribution ROWs using industry-approved herbicides.
2. Cultivate and measure positive customer involvement with UVM.
3. Automate the UVM Program. See 4.3.2 for details
    a. Improve routing, deployment and management of crews through telematics technology and scheduling.
    b. Use predictive analytics and modeling to improve performance and achieve best management practices.
4. Perform detailed outage investigations by forestry personnel and model data to promote understanding of tree conditions and failure modes.
5. Convert the majority of distribution ROW to low-growing shrubs and herbaceous plants.
6. Assess ROW edge trees routinely for risk and replace hazardous trees with appropriate vegetation.
7. Improve adjacent off-ROW vegetation to ensure desired percent of tree cover to provide appropriate benefits and protections. Trees provide vital ecosystem services and having the right trees adjacent to powerlines requires appropriate planting and maintenance strategies.
8. Establish common goals and maintain action-based relationships with various provincial and community forestry units that foster a reduction in necessary line clearing activities: Align various vegetation management activities in province of Ontario

[1] Industry practices were derived from the benchmark survey conducted for this project and a literature review

9. Develop wood utilization programs as an organizing principle for sustainable harvesting and recycling of off-ROW trees before they become hazards. Trees provide many products and utility clearing can be a source of raw materials for wood products.
10. Develop land use programs such as food crops, pollinator habitats, recreational, emergency access, transportation, and other various land uses that are appropriate and beneficial for distribution ROWs.

1.5 Peer Group Criteria and Selection

The study included five Canadian companies, Hydro One and its four regions, and thirty-one US utilities for a total of forty-one companies. Based on selection criteria, four Canadian companies and twenty-three US companies were used in peer group comparisons. The remaining nine companies were used only in general industry comparisons. Peer companies were selected on the basis of geographic region, tree density, customer density and territory demographics, and whether the utility was a peer in the 2009 Hydro One Study.

All companies in the peer group have UVM programs aligned with the objective to deliver safe and reliable electricity. They have formal vegetation management programs, are directed by an employee of the utility, and operate year-round. Practices include aerial hand-pruning and tree removal with bucket trucks and climbing arborists, mechanical pruning and clearing with heavy equipment, and the application of herbicides to prevent stump sprouting and to terminate small trees and whips.

See Appendix C for further details on Peer Selection

1.6 Benchmarking and Year-over-Year Trending Metrics

For this project commonly collected performance and progress metrics were analyzed. In general, benchmarking are comparisons between Hydro One and the peer companies. Year-over-year trends (time-studies) for Hydro One and its regions were compared to the peer-average trends. System kilometres are the total number of overhead (OH) right of way kilometres in the distribution system. Managed kilometres are the number of overhead (OH) lines managed on an annual basis.

1.6.1 Unit Costs

Unit costs provides a basis for comparison and year-over-year analysis

1. **Cost per system kilometre:** Normalizes costs differences caused by variable cycle lengths
2. **Cost per managed kilometre**: Measures cost-efficiency and ability to control fixed costs
3. **Cost per tree:** Measures cost-efficiency and workload prioritizations

1.6.2 Labour Hours Expended

Labour Hours (LH) expended normalizes differences in fixed costs

1. **Labour Hours per system kilometre:** Normalizes LH differences caused by variable cycle lengths
2. **Labour Hours per managed kilometre:** Measures work-efficiency and workload reduction
3. **Labour Hours per tree:** Measures work-efficiency and workload prioritizations

1.6.3 Workload and Performance

Measuring workload is a baseline for improving performance

1. **Tree Density and Ingrowth:** Reductions indicate workload management improvements. Increases occur when the cycle of management is long. Disturbance from mowing and manual cutting can influence density of ingrowth especially in the absence of herbicide controls and long cycles.
2. **Tree Risk Assessment and Extent of Implementation:** Measures off-ROW risk reduction efforts
3. **Percent of System Kilometres Managed Annually:** Measures improvements on management cycles and enables industry comparisons

1.6.4 *Cost Efficiency*

Measures control over fixed costs

1. **Personnel Costs and Labour Mix**: Changes in labour costs were analyzed and compared to peers
2. **Equipment Costs and Usage:** Fleet management, usage rates and right-sizing were analyzed

1.6.5 *Reliability*

Measures the effect of UVM on electric reliability (See Appendix B for discussion on appropriate use of reliability metrics)

1. **Tree related outages per system kilometre:** Effective measure of UVM reliability performance
2. **IEEE Tree-Related Reliability Metrics:** SAIDI, SAIFI are customer density biased
3. **Storm Impact Prevention and Response:** Measures the impact of UVM on storm resiliency
    - **Major Event Day (MED) outages:** Changes indicate performance of UVM program
    - **Non-MED outages:** Helps to distinguish between asset improvement need vs UVM

1.6.6 *Safety*

Safety and reliability are ranked the most important UVM objectives by utility companies. Safety has a lack of leading indicator metrics. Accident incident rates are unevenly reported and are lagging indicators.

1. **Annual OSHA Incident Rates:** Rate of recordable accidents reported per 100 workers
2. **Annual Lost-Time Incident Severity Rate:** Rate of lost days per 100 workers
3. **Employee Turnover Rates:** High severity rates correlates well with employee turnover rate in this study and across industries

1.7 Key Findings

Each finding is followed by a section number where detailed discussion can be found.

1.7.1 *Unit Cost*

Hydro One reports high unit costs compared to the peer group. The high costs are due to heavy workloads associated with long cycle lengths, higher cost of labor and equipment, and better reporting of overhead costs by Hydro One as a result of having an in-house vegetation management program. (4.1).

1.7.1.1 System Unit Cost

UVM costs are increasing across the industry. Hydro One's costs, in contrast, are remaining relatively steady with a decrease in 2015. (4.1.2)

1.7.1.2 Managed Unit Cost
Hydro One's cost per managed kilometre and per managed tree was high compared to the peer group, but the percent increase in cost from 2011-2015 was not as high as the peer average increase for both units. This statement also holds true when comparing 2011-2015 averages to 2006-2008 averages (2009 study). (4.1.3)

1.7.2 Labour Efficiency
As shown in the 2009 study for the OEB, Hydro One continues to perform UVM at or below the average for number of labour hours expended per managed kilometre of overhead line. The result is a decade of efficient UVM performance. See Section (4.2)

1.7.2.1 Labour Hours per System Kilometre
All of the Hydro One regions performed better than the peer average in this measurement. Rather than demonstrating work-efficiency, this metric is an indicator that Hydro One is under-resourcing their program and more work needs to be done. This is true because tree density, the number of trees managed per kilometre, is increasing and Hydro One has not been able to decrease the length of its cycle. (4.2.1)

1.7.2.2 Labour Hour per Managed Unit
Hydro One outperforms the peer group with low labour hours per tree and is close to the average for labour hours per kilometre for 2011 - 2015. (4.2.2)

- **Labour hours per managed km:** In spite of increasing tree densities and long cycle lengths, Hydro One's tree crews have been able to stay close to the peer average of labour hours per managed kilometre for 2011-2015. (4.2.2.1 - 4.2.2.2)
- **Labour hours per tree:** Hydro One's labour hours per tree has stayed relatively constant from 2006 – 2015, while the peer group has increased by 60%. (4.2.3)

1.7.3 Tree Density, Ingrowth and Tree Risk Controls
Tree density has increased on Hydro One service territory over the last decade. This increase is the result of a program on a long cycle, which increases in-growth, workload, and off-ROW risk. (4.2.4)

Insufficient management controls include:

- Herbicide control of ROW in-growth
- Tree risk assessment for off-ROW edge trees
- Removal and pruning of hazardous off-ROW trees

(4.2.5 - 4.3.1)

1.7.4 Work Planning (4.3)
1.7.4.1 Automation
Hydro One has a comprehensive work planning program, and it performs well especially in regards to customer communication and the sheer size of the territory. However, it is insufficient in the areas of

technological innovation and automation of data collection, data analysis, work management, auditing and predictive modeling. Hydro One has initiated digital automation to the UVM program, but, like its peers, is challenged by transitions, knowledge transfers and change management that accompany new technologies. For detailed discussion see 4.3.1-4.3.2

1.7.4.2 Customer Service

Hydro One provides better customer service and communication than the industry at large. For detailed discussion see Sections 4.3.3 – 4.3.5.

1.7.5 Equipment and Personnel (4.4)

1.7.5.1 Equipment

- Hydro One's utilization rate of their equipment is lower than their peers.
- Hydro One has a continuous improvement program for the efficient use of equipment through logistics and mechanization.

(4.4.1)

1.7.5.2 Personnel (4.4.2)

- Hydro One's labour burden for in-house employees is double the cost of Hiring Hall employees and is more than three times the average of the peers' contractor charge-out rates.
- Hydro One employees on average have more than double the years of experience of peer contractor employees.
- The increase in UVM cost is not a matter of efficiency or increased workload; rather it is a result of increases in cost per labour hour, including wages, benefits, equipment, fuel expenses, and other overhead and administrative costs.

(4.1.4 and 4.4.2)

1.7.6 Reliability (4.5 and Appendix B)

- Hydro One is well below the peer group average for tree-related outages per system kilometre and this measurement has been improving since 2003 (See Appendix J analysis). This metric is preferred for measuring the performance of UVM over the standard reliability metrics because it is more closely related to the system workload and it more appropriately measures the performance on downstream facilities.
- Hydro One compares unfavorably with peers in the area of the standard reliability metrics, SAIDI and SAIFI. These metrics are biased when applied to Hydro One where there are no high customer density areas on a very large service territory. Low customer density, as well as six other factors common to Hydro One, is known to negatively impact reliability metrics. (4.5.1-4.5.2)

1.7.6.1 Storms are Hydro One's Greatest Challenge

- Hydro One's outage per system kilometre metric is an achievement given the length of management cycles, high tree densities, system size, and the propensity for storms in the South, Central, and East Regions.
- A high percent of outages, especially during storms are caused by trees on the Hydro One system.

(4.5.1-4.5.4 and Appendices B, E, and J)

1.7.7 *Safety as a Priority (4.6)*

- Hydro One is distinguished from the peer group by having a more experienced and stable workforce that is in-house and is more directly connected to safety monitoring and initiatives promoted within the company.
- Hydro One's lost-time safety incident severity annual rate (SR) for 2013-15 is 7.90 lost days/100 FTE compared to the peer group average of 31.36. Compared to the industry-wide fatalities over the past three years and the peer group's incident SR, Hydro One shows clear evidence of a more successful record of tree worker safety.
- Hydro One's safety incident average rate for 2013-15 is 3.90 incidents/100 FTE compared to the peer group average of 2.46. It should be noted that there are problems with accident under-reporting and OSHA has instituted a new rule effective in 2017 to improve accident reporting.

(4.6.1 & 4.6.2)

1.7.8 *2022 Model Cost Projections*

Four models with varying degrees of risk and workloads are proposed by CNUC with projections of cost out to 2022. The initial 2017 costs are Current Risk Model A, $150.2 million; Moderate Risk Model B, $166.5 million; Lowest Risk Model C, $174.9 M; and Best Management Practice Model D, $192.9 M. It is expected that SAIDI and SAIFI will improve under all three models. Under Model A outages per kilometre will likely increase and public and worker safety risks will increase. With Model B the number of outages per kilometre will probably not increase but reductions are likely to be minimal. The workload will improve at a slow pace. Model C would be the most likely model to secure some reductions to the workload, to long-term cost, and to safety risk. Model D would move Hydro One towards a cycle closer to best management practices in the industry and secure significant reductions to the workload. These predictions assume resource cost will be reduced by employing Hiring Hall or contracted labour for all work on one and two-phase lines and it does not account for improvements from innovations and new technology. The recommended labour mix, employing contracted labour for only lower risk activities, would increase all modeled estimates by approximately 10 – 15%.
The assumptions behind these models are discussed in Section 4.8 and in Appendix D.

1.8 Recommendations: Improvements, Best management practices and Innovation

The following are recommendations in the order of importance:

*ST means Short-Term and indicates a onetime change; LT means Long-Term and will require continuous improvement or will take many years to implement. When both LT and ST are indicated, periodic improvements will be needed to update a short-term improvement

1. **Bring the whole distribution system to a four to eight-year flexible cycle that is trued up each year to ensure backlogs do not creep back into the schedule. This will enable a more effective herbicide program, better off-ROW tree risk management, and reduce workload over the long term.** (LT)* See Sections 4.1 - 4.3, 4.6, 4.8

   a. **Reduce the current backlog over the next decade through innovations, automation and changes in labour mix** (LT)* See Recommendations 2, 3, 4, 6, and 9 (below), Section 4.1 (intro)
2. **Improve through innovation the mechanization and automation of the UVM program. This will improve understanding of the workload and it will enable more effective work planning and cost/resource predictions.** See Sections 4.3, 4.4
   a. **Improve data analytics and predictive modeling through automated data collection of key UVM activities.** (ST, LT)* See Sections 4.3.1, 4.3.2
   b. **Use technology such as LiDAR to improve measurements, condition assessments, and accuracy of data collection.** (ST,LT)* See Sections 4.3.2
   c. **Increase ROW clearing capacity and safety through innovations in mechanical equipment and routing technology** (ST,LT)* See Sections 1.4.2 and 4.4.1
   d. **Improve customer knowledge, communication, and involvement by merging UVM data with the customer service system**. (ST)* See Sections 4.3.3 - 4.3.5
3. **Improve productivity and control costs by utilizing higher percent of Hiring Hall and contract workers to perform lower safety and liability risk activities such as work planning, herbicide applications, and brush-clearing. This will lower unit costs.** (LT)* See Section 4.4.2
4. **Strategically increase herbicide usage for cost-effective results. This will ensure ROWs stay clear between shorter cycles of management and lower the long term cost** (LT)* See Sections 4.1.3, 4.2.5, 4.2.7, and 4.3.1
5. **Develop a vegetation management outage investigation protocol that expands on the current cause codes and utilizes UVM personnel. This will improve capability to predict tree failure modes and guide future tree risk mitigations.** (ST)(LT)* See Section 4.5.3
6. **Synchronize the annual asset inspections with the UVM work planning program to quantify system vegetation conditions based on performance metrics for maintaining air space around conductors**. **This will improve workload understanding and provide annual performance metrics for system conditions.** (ST)* See Section 4.3.1
7. **Improve and increase the Tree Risk Assessment Program to reduce outages caused by off-ROW trees. This will, with the help of lessons learned through outage investigations, improve reliability by reducing outages caused by trees or branches falling into overhead lines.** (LT)* See Sections 4.3.1, 4.5.3, 4.7 and Appendices F and G
8. **Identify fixed cost increases and overheads allocated to UVM to ensure cost effects of changes to the program are portrayed accurately. This will enable a better understanding of improvements to production and other cost reduction measures.** (ST)* See Sections 4.1 (4.1.1, 4.1.3, 4.1.4) and 5
9. **Improve equipment and personnel utilization**. **This will lower unit costs by improving efficiency and optimizing equipment availability.** (LT)* See Section 4.4 (4.4.1, 4.4.2)

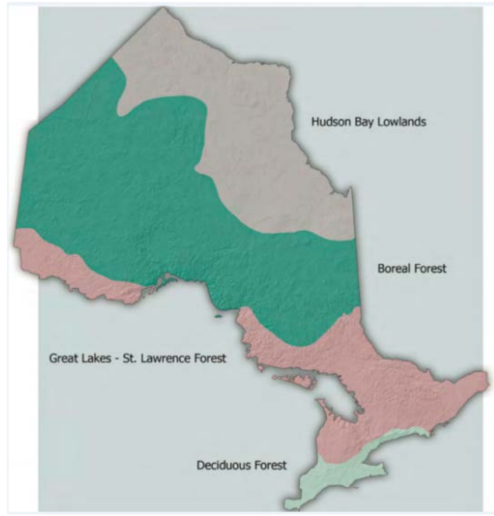
1.9 Conclusion

Hydro One has established over the last decade the capacity for safely managing dense vegetation on one of the largest service territories of the peer comparators. This accomplishment is highlighted above and is noteworthy considering the long cycles of management and financial constraints. Hydro One has achieved a below average number of outages per kilometre, but has high SAIDI and SAIFI. Budgetary constraints on UVM resources, insufficient innovation, incomplete digital automation of work management, and a long cycle have limited Hydro One's ability to convert ROWs to compatible plant communities. This has resulted in high costs of mechanical and manual intervention throughout the system. However, Hydro One has demonstrated improvements in numerous areas such as increased usage of herbicides, mechanization, and automation of planning and work management processes. To expand and sustain these efforts, longer-range goals for improving the management of the 52,000 kilometres of single and two-phase lines should be studied. Without this effort, the probability that outage numbers will increase should be expected. While the IEEE reliability metrics may show improvement under the current scheduling, they should not be viewed as a definitive performance metric for UVM. A minimum percent of tree-related outages should be investigated by arborists using root-cause analysis. Reliability is the center of UVM performance and there is a plethora of reliability data to gauge it. In the discipline of quality management, too much reliance on a single set of data can be misleading and the UVM program currently relies heavily on IEEE reliability metrics. Conversely, Hydro One's low accident severity rate and low employee turnover rate are evidence of a successful program, but the dataset is limited and is composed of lagging indicators. Equally important UVM objectives, such as safety, compliance to regulations, environmental quality, and customer satisfaction should be measured through improved data collection and included as key performance indicators, both leading and lagging.

2 Introduction

2.1 Study Background

Hydro One was instructed by the Ontario Energy Board (OEB) in March 2015 to perform a study similar to the *Hydro One 2009 - Vegetation Management Benchmark Study*, which analyzed Hydro One's relative efficiency. Central to the current project is a distribution utility vegetation management (UVM) survey conducted by CN Utility Consulting (CNUC) in February, March and April of 2016 with Hydro One and 35 electric utility companies throughout North America. The following statements by the OEB and the Ontario Auditor General have influenced this project:



Map 1: Forest Regions of Ontario

> *The OEB also directs Hydro One to present in its next rates application a comprehensive trend analysis of its vegetation management program showing year-over-year comparisons in unit costs. Further, the OEB encourages Hydro One to explore best practices in vegetation management with other distributors and transmitters, similar to the CN Utility Study filed with the OEB in the EB-2009-0096 proceeding, and file any resulting study in its next rates application.* (OEB, March 2015)
>
> *Explore best practices in vegetation management, considering changes in labour mix and innovation opportunities, as well as conduct a trend analysis of the vegetation management program showing year-over-year variations in unit costs.* (Office of the Auditor General of Ontario, 2015)

2.2 Benchmark Study Purpose and Limitations

This report is for the purpose of determining the level of efficiency that Hydro One has achieved in carrying out its mission to manage vegetation that impairs or potentially could impair the reliable and safe operation of their expansive distribution system, which serves over 1.3 million customers and requires management of over 7 million trees. The efficiency level is determined by comparing the productivity, costs, and measurements of reliability and safety for each Hydro One business unit (region) and Hydro One with a group of peer utilities across North America. Analysis includes longitudinal studies of the different metrics, particularly for Hydro One. Given the peer group level of efficiency, the question can be asked whether enough work is being performed by Hydro One to meet a standard of care. Regulations, policies and behaviors that establish a performance standard include the various decisions made by the utility and the regulator, the normative behavior of the industry at large, and the industry consensus standards that are applied to UVM. These are the gauges to determine whether the efficiency of Hydro One's performance is sufficient to manage the UVM workload and whether it meets a best management practice criteria.

2.3 Goals and Objectives of the Benchmarking Study

Based on the five obstacles to success in business enterprise (Deming, 1984), this project:

- Looks for inconsistencies, especially in the UVM planning process
- Evaluates whether long-term goals are receiving adequate attention
- Reviews the performance evaluation system with a focus on whether some metrics are relied on too heavily because the data are the easiest to obtain
- Looks at whether the customer is driving the quality of the program
- Examines the safety and liability risks and whether they are managed adequately

It is hoped that some changes can be implemented that will streamline processes and ease burdens. For utilities to succeed in the 21st century, they will have to create a new philosophy for UVM by envisioning it in a new framework that customers will appreciate. With the customer on board, improvements can move forward with leadership inspired to empower an advanced culture of positive and freely-exchanged knowledge, whether it is for productivity, technology, safety, reliability, customer service or the environment.

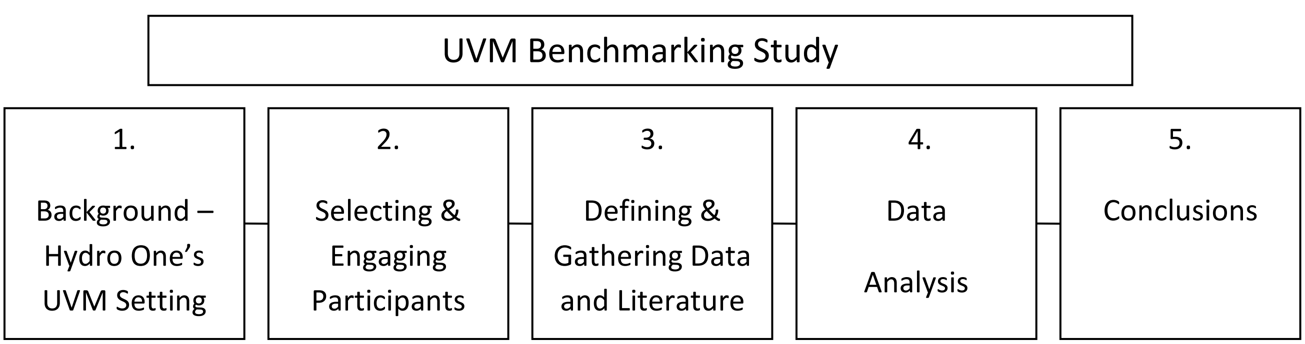
2.4 The Benchmark Report Team

CNUC was selected as an independent third-party consulting team to execute Hydro One's 2016 Vegetation Management Benchmarking Study. CNUC has extensive experience in both Utility Vegetation Management (UVM) and in benchmarking. This combination of expertise is unique in North America and is evidenced by experiences and achievements that CNUC brings as a consulting team.

Details about CNUC's project team can be found in Appendix A of this report.

3 Benchmark Study Framework

3.1 Benchmark Study Data Collection and Analysis Methodology

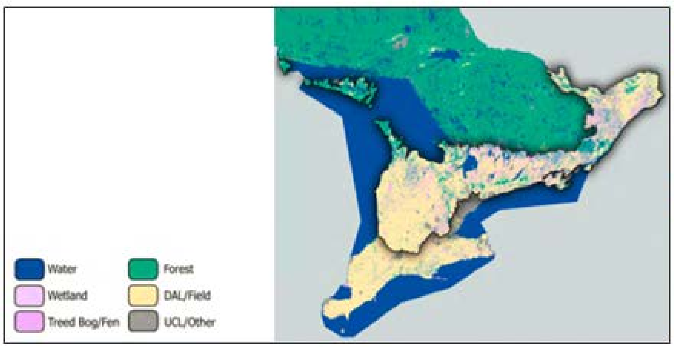


See Appendix I: Benchmark Study Process Chart for details

See Appendix D: Statistical Methodology and Model Development for details on analysis

3.2 Forests in Ontario

The South is mostly agriculture and has a small percent of deciduous forests scattered throughout. The East and South and Central are predominantly privately owned. Parts of the East and Central Regions, however, are heavily forested with large conifer, deciduous and mixed forests. The concentration of forested areas, particularly conifer, is the greatest in the North in the boreal forest. The land north of Lake Superior and Lake Huron/Georgian Bay is another ecoregion within the North Region that also contains many mixed and deciduous forests. It is in the East and Central where the density of customers is greater than the North but there are heavy and scattered forests. The Central incurs more tree-related reliability issues than the other regions, having many settlements in forested areas. The East is not far behind, but has more agricultural areas that reduce the tree populations in some areas and risks of tree-related outages.



Map 2 Urban Agriculture and Dense Forests

Map 3 Hydro One Regions Map

By comparing the yellow and green areas in Map 2 with the Hydro One regional boundaries in Map 3, one can see that about fifty percent of the Central and East Regions are densely forested. The North region (only partly shown in Map 2) is practically all dense forests. The East and Central regions also have significant areas that are agriculture, wetlands, scattered forests and many populated areas.

Forestry and customer demographics play a key role in UVM program implementation and performance results. The North Region is the largest area but only contains 18% of the system kilometres and 14% of the customers. The North Region is heavily forested and has the highest percent of kilometres (29%) that have limited or difficult access. The North region of Hydro One is roughly 512,600 km^2 with 190,000 customers. This vast area contains only 18,000 km of line. The South region has the largest number of distribution lines at 32,000 km and Central and East regions are roughly equal at 26,000 km.

3.3 Hydro One's UVM Environment and System Attributes

Peer Stats: Customers per Square Km			
Sample Size	27	Q3	74.5
Average	57.1	Min	0.9
Q1	11.0	Max	293.9
Median	27.5	SD	71.3
Hydro One Networks			
Hydro One	2.1	HO Central	8.8
HO North	0.4	HO East	8.7
HO South	9.2		

Peer Stats: Customers per OH System Km			
Sample Size	27	Q3	42.2
Average	37.7	Min	6.7
Q1	21.2	Max	141.1
Median	28.9	SD	27.7
Hydro One Networks			
Hydro One	13	HO Central	14.3
HO North	10.6	HO East	15.3
HO South	11.3		

Table 1: Customers per Square Kilometre and Customers per Distribution Overhead System Kilometre

With the exception of one other North American company, Hydro One has the lowest average customer density by land area. Even the South Region, the most densely populated of the four Hydro One regions, has only 9.2 customers per square kilometre (km^2) (Table 1, above left). *This is six times less dense than the average of the peer group*. Of the twenty-seven companies in the peer group, only three have fewer customers per overhead (OH) system kilometre than the East region, which has 15.3 customers per km, the highest of Hydro One's four regions (See Table 1, above right). Hydro One manages forty-one percent of the electric distribution equipment in Ontario, while it only serves twenty-five percent of the customers (OEB, 2015). All Hydro One Regions are in quartile 1 (Q1) for lowest customer density per km of line.

Customer density is important when analyzing the cost to the customer and reliability. In 2011-2015 each Hydro One customer spent on average $99.36 for UVM. Although this is above the average ($35.13 in 2015) for utilities in their peer group, it is important to note some extenuating circumstances that contribute to higher cost for Hydro One customers:

- Hydro One manages 76 trees per system km compared to the average for the peer group at 68 trees per km.
- Hydro One has nearly the lowest number of customers per km^2 and per km of line; therefore it has fewer customers to pay for the cost of UVM.
- On Hydro One's system there are significantly greater distances between customers than peer companies. Low customer density contributes to higher logistical costs for maintenance and longer response times for emergencies.
- Low customer density increases the difficulty of prioritizing work to achieve consistent reliability performance improvements uniformly across the system.
- Low customer density reduces the reliability improvement impact of any single UVM effort
- Wages are higher for Hydro One than for most of the peers.
- Hydro One's service territory has a higher than average number of storms, especially in winter, that damage the distribution system on a regular basis.
- Vegetation management is performed infrequently (9.5 year intervals).
- 30% of Hydro One's system is difficult to access because of terrain, lack of roads, water and other access issues. In the North and East regions, 75% of off-road locations are difficult to access.
- With the exception of the South Region, Hydro One has one of the coldest minimum average winter temperatures in the peer group, making winter time work challenging and sometimes less cost-effective. Lake-effect snow accumulations and snow that persists for much of the winter makes forestry work difficult to perform in some areas. Additionally, the window for applying herbicides is limited.

3.4 Selection of Peer Utilities

The study had a total of forty-one companies, including six Canadian companies as well as Hydro One's four regions. Twenty-seven peers were selected to be comparators to Hydro One and are referred to as the peer group. The peer group includes four Canadian companies and twenty-three US companies. In some comparisons, non-peer companies are included. The response sample size of each question is noted with each graph and if the non-peer group is included it is noted under the graph title. Peer companies were selected on the basis of geographic region, tree density, customer density and territory demographics, and whether the utility was a peer in the 2009 Hydro One Study.

All companies in the peer group have UVM programs aligned with the objective to deliver safe and reliable electricity. They have formal vegetation management programs, are directed by an employee of the utility, and operate year-round. Practices include aerial hand-pruning and tree removal with bucket trucks and climbing arborists, mechanical pruning and clearing with heavy equipment, and the application of herbicides to prevent stump sprouting and to terminate small trees and whips.

See Appendix C for further details on Peer Selection

3.5 Differences between 2009 study and 2016 study

- In 2009 CNUC distributed the survey only to companies who were deemed to be potential peers. In 2016 companies were invited to participate regardless of their peer potential and the peer group was selected after preliminary analysis of several factors, which resulted in a larger peer group sample size (14 peers in 2009 vs. 27 in 2016).
- Non-peer companies were included in the analysis for some industry-wide comparisons in 2016, whereas in 2009 all of non-peer data was discarded.
- Survey questions were changed, revised and clarified. The scope of the survey was expanded to ensure coverage of target areas and to include some topics not covered in the past.
- More intensive literature review was performed on laws and regulations, reliability and climate impacts on UVM.
- More correlational and predictive analysis was used to draw conclusions. A future UVM cost model for Hydro One was developed.

4 Findings and Discussion

4.1 Unit Cost Introduction

Cost is relative to production, efficiency, labour and equipment management, program stability, sufficiency, and risk acceptance. Cost is a measurement that incorporates many variables when making comparisons. It represents regional and local economics, monetary exchange rates, union membership costs and wage agreements, taxation differences, and the scope and interval of work. It is difficult to always know what is included in cost. Differences may be arbitrary, based on perceptions of valuation and where overhead costs are assigned. Cost comparisons in this report shouldn't be taken necessarily as a measure of efficiency or productivity but rather a measure of cost variables.

Annual cost is usually understood as an annual input that can positively or negatively influence future annual inputs. Variations in annual cost over the long-term are influenced by the frequency of maintenance. A stable annual UVM cost is achieved by having an optimum interval of maintenance that comports with the workload. The workload is determined by ingrowth, the annual accumulations of growth on existing trees, and the desired reductions in risk associated with off-ROW tree and branch failure.

UVM workload is managed through vegetation clearing activities and logistics. If the interval of maintenance is too short, then long-term logistical cost will increase unnecessarily. If the interval of maintenance is too long, then risk will rise above the acceptable level and annual vegetation-clearing cost will increase. If quality of work and duration of vegetation clearances aren't specified and audited, then financial constraints on a UVM program can result in a longer cycle of routine maintenance. At some point, as the cycle length increases, it will become more and more difficult or impossible to maintain acceptable risk including safety, reliability, adequate storm response, and fire protection. At some point when a long cycle is getting longer, a workload barrier is formed in which it will take extraordinary short-term measures to achieve even minor reductions to cycle length, and improvements to reliability and efficiency. Achieving a stable, consistent and desirable cycle length with maximum cost efficiencies is a long-term project. *In Hydro One's case it will take at least a decade of accelerated and highly productive UVM to reduce the cycle of management by two to four years.*

4.1.1 *Routine UVM Maintenance Cost per System Kilometre*

Long-term cost comparisons with the peer group are made by normalizing the cycle lengths and comparing the annual cost per kilometre. The term for this is **cost per system kilometre** and it compares what companies spend annually on UVM relative to the size of their system:

Routine UVM Cost per system kilometre = Annual Routine UVM expenditures ÷ Number of OH kilometres in the system

Cost per system kilometre compares what companies spend per kilometre regardless of the frequency of management. Hydro One spends more per system kilometre than the average of the peer group. This is because its annual clearing costs are significantly higher than the entire peer group. Hydro One's long cycle length is driving up the annual unit cost increment. However, there are more variables that affect cost and Hydro One would still spend more per system kilometre than their peers if the cycle was shortened.

In combination with other variables, such as tree density, labour burden, or overhead/administrative costs, system kilometre cost is a way to compare productivity costs. The following graph (Figure 1 below) compares Hydro One's system km cost with its peers.

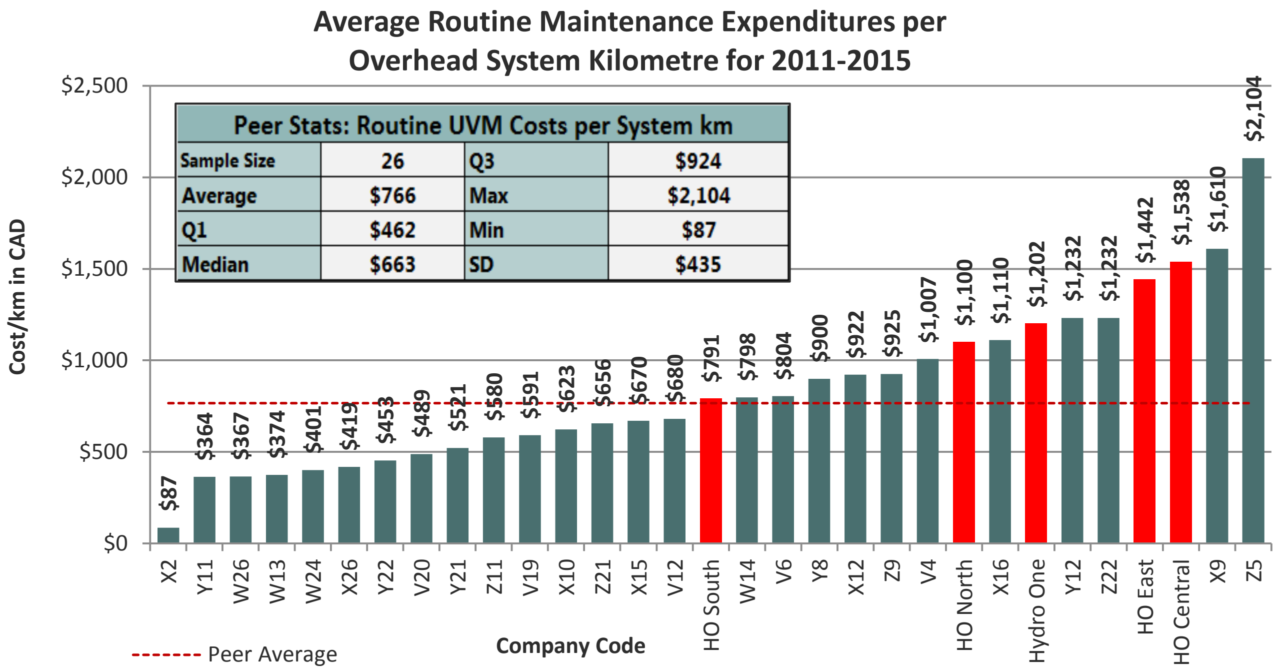


FIGURE 1: ROUTINE MAINTENANCE COSTS PER SYSTEM KILOMETRE

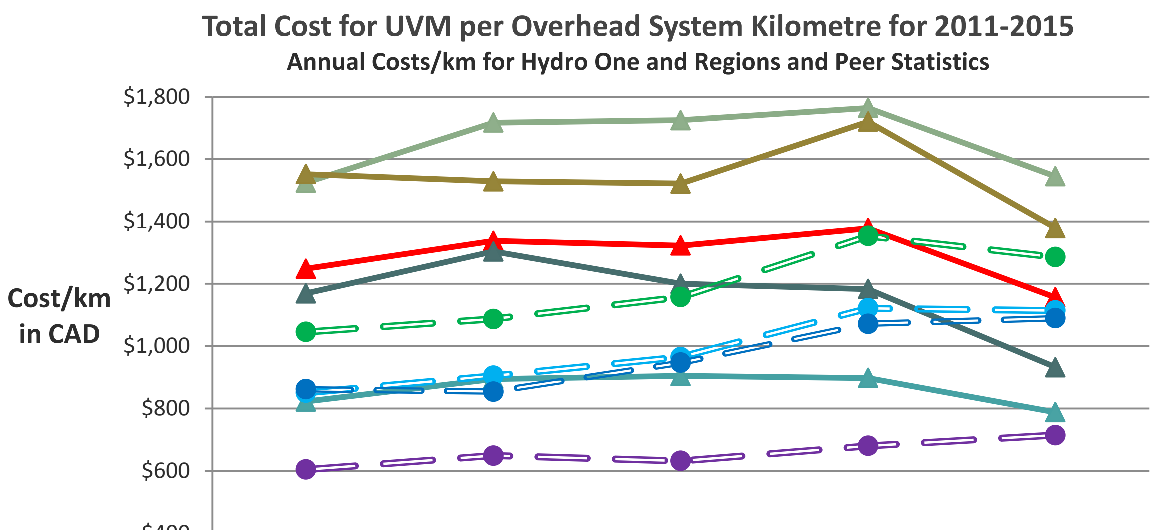
Hydro One is in quartile four for average cost per system km for routine maintenance 2011-2015. Hydro One is paying a high rate per km of UVM and the cost must be spread over one of the lowest number of customers per km. This makes the cost evaluation problematic and sensitive. Routine maintenance system kilometre costs at Hydro One are one standard deviation *above* the peer average.

In 2006-2008 Hydro One's routine system kilometre costs were also much higher than the peer average and it was attributed to significantly higher wages and benefits than the peer group. The current study finds that higher routine system kilometre cost is still a matter of hourly costs but is not solely a matter of higher wages and benefits. In fact, the cost of UVM per labour hour has increased significantly since 2011, while the number of labour hours actually decreased after 2012. System kilometre cost increases were due to hourly cost escalations which include administrative and equipment costs as well as labour burden. Hourly cost increases are discussed further in 4.1.4 below.

The peer group has a consistent ratio between labour burden and basic wage rates (about *17:10* for line clearance personnel). This ratio is much larger for Hydro One (about *29:10* for line clearance personnel). Hydro One UVM personnel are company employees who earn a higher wage than contract workers employed by peer companies. Furthermore, Hydro One includes significant administrative costs in their total UVM spend, whereas the peer companies outsource UVM and do not include administrative costs other than the personnel costs for the UVM department. Hydro One UVM hourly costs increased between 2011 and 2015 by $14 for line clearing, $18 for Brush Clearing and $25 for work planning. These increases represent fixed costs unrelated to efficiency and productivity and only a part of the increases are due to increases in wages and benefits. These increases are discussed further in the following sections.

4.1.2 Total UVM Cost per System Kilometre Year over Year

Another cost per system kilometre that can be compared is the total cost for UVM, which includes routine, reactive and storm costs. From 2011 to 2014, Hydro One increased the UVM expenditures by $130/system kilometre. In 2015, the cost per system kilometre was scaled back by $221/system kilometre. This reduction was achieved by modifying the work scope and schedule, which resulted in a $22.5 million budget decrease, only $3 million above the average spend in 2006-2008. In contrast, the peer group average system kilometre cost *increased* by $272/km from 2011 to 2014, more than double the increase of Hydro One during this time period. In 2015 Hydro One's system kilometre cost was only $42 above the peer average. Figure 2, below, highlights this fluctuation dynamic between Hydro One and the peer group. Hydro One's cost is split between high cost per system km in the East and Central Regions and low cost per system kilometre in the North and South Regions.



	2011	2012	2013	2014	2015
HO Central	$1,525	$1,717	$1,725	$1,764	$1,544
HO East	$1,552	$1,528	$1,521	$1,720	$1,379
Hydro One	$1,248	$1,338	$1,323	$1,378	$1,157
HO North	$1,170	$1,304	$1,200	$1,183	$932
HO South	$822	$895	$904	$898	$788
Peer Average	$850	$905	$965	$1,122	$1,115
Peer Q1	$604	$649	$632	$680	$714
Peer Median	$862	$854	$947	$1,072	$1,090
Peer Q3	$1,046	$1,087	$1,157	$1,354	$1,286

Figure 2: Year over Year System Kilometre Cost Comparisons

4.1.3 Routine Cost per Managed Kilometre

4.1.3.1 Average Cost 2011-2015 Comparisons

Another ratio for comparing cost is calculating the cost per managed kilometre. Managed kilometre is different from system kilometre. System kilometres are the number of overhead (OH) kilometres in the distribution system. Managed kilometres are the number of OH lines managed on an annual basis. The high cost for Hydro One vegetation management is apparent when measured by the cost of a managed kilometre (Figure 3, below). The routine average cost per managed km in the Central Region is nearly double that of the South Region and over four times the cost of the peer average. These costs are the result of:

- The accumulated biomass and heavy workload after a long interval between maintenance cycles. The management of in-growth after a long cycle is more expensive than treating a converted ROW on a short cycle with herbicides to prevent ingrowth.
- A higher cost of labour and equipment compared to the peer group, nearly all of which outsource UVM program implementation. A qualified line clearance arborist at Hydro One earns $5/hour more than the highest paid peer company contract arborist. The labour burden is $55 more. For the peers the average labour burden is 1.7 times greater than base wage. For Hydro One the labour burden is 3.0 times greater than the wage for field personnel, except for trainees (2.6 times) and temporary employees (1.6 times), which is closer to the contract crews. Hydro One's labour burden is loaded with associated UVM costs such as equipment and indirect administrative costs. The peer group labour burden is lower because wages and benefit costs are lower, but also because administrative/overhead costs are lower or they are not fully reported.
- Hydro One reports administrative/overhead costs better than their peers, since they are completely in-house. The peer group does not report indirect costs on the UVM program. They only report the direct costs to run the UVM department plus the cost of the contractor.

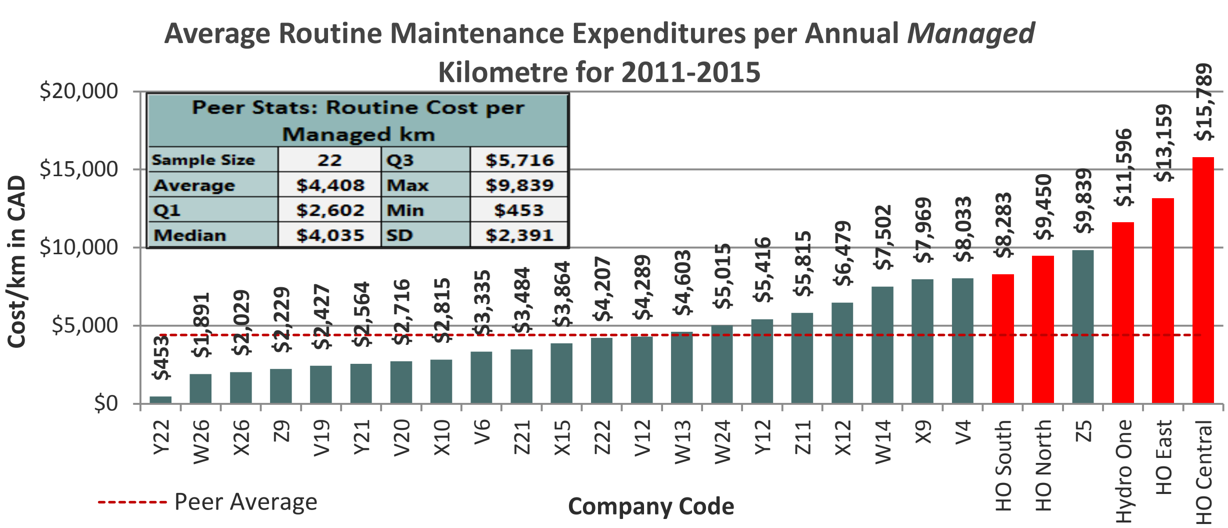
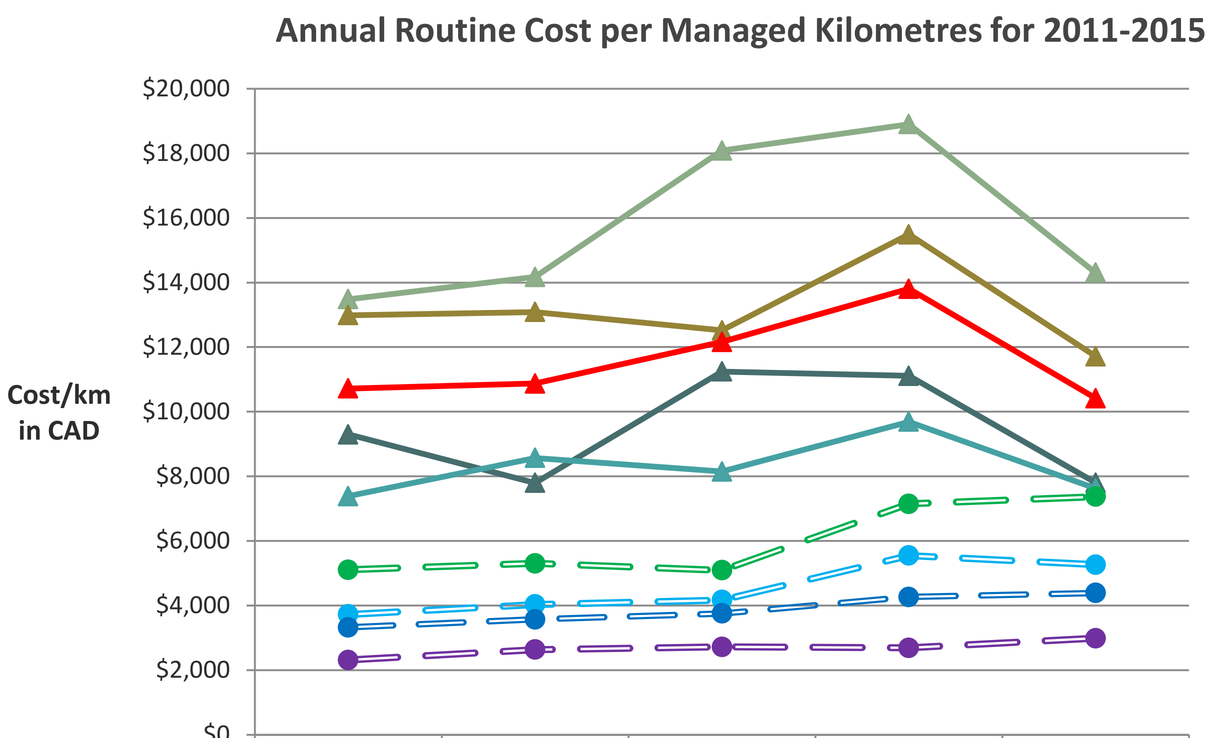


Figure 3: Routine Maintenance per Managed Kilometre

4.1.3.2 Longitudinal Cost per Managed Kilometre

Hydro One's 2011-2015 average cost per managed kilometre was a 22% increase over its average cost in 2006-2008 compared to a 25% increase for the peer group. Hydro One's 2015 cost per managed kilometre was only 13% over its 2006-2008 average compared to the 49% increase for the peer group. Also, Hydro One significantly reduced the cost per managed kilometre in 2015 over 2014 by 25% compared to the peer group average which was reduced by only 5% (See Figure 4, below). This reduction in cost was a result of targeting the 2015 schedule on M-Class feeders which are managed on a shorter cycle 6-8 years. The cost reduction in 2015 illustrates the cost savings possible when work is performed on-cycle and on a shorter cycle than in the past. It does not, however, show the cost reductions that could be achieved through herbicide use which requires a shorter cycle length to be effective.



	2011	2012	2013	2014	2015
HO Central	$13,483	$14,172	$18,084	$18,901	$14,303
HO East	$12,986	$13,087	$12,515	$15,487	$11,717
Hydro One	$10,721	$10,875	$12,163	$13,807	$10,417
HO North	$9,297	$7,795	$11,245	$11,112	$7,800
HO South	$7,388	$8,568	$8,150	$9,688	$7,624
Peer Average	$3,725	$4,034	$4,169	$5,547	$5,265
Peer Q1	$2,311	$2,633	$2,719	$2,688	$2,986
Peer Median	$3,326	$3,573	$3,756	$4,265	$4,391
Peer Q3	$5,107	$5,307	$5,092	$7,148	$7,370

Figure 4: Annual Routine Cost per Managed Kilometres for 2011-2015

4.1.4 HYDRO ONE UVM COST INCREASES ARE DUE TO RATES MORE THAN PRODUCTION

Total cost increases over time at Hydro One can be explained in part by variations in the number of trees treated per km or the amount of brush treated. Much of the cost increase is independent of tree densities or numbers of kilometres completed. It is the annual cost per unit of labour that has increased steadily since 2011 by nearly $20/hour (Figure 5, below). The number of labor hours increased in 2012 but decreased each year 2013-2015. The largest decrease was in 2015. The UVM cost increase is not a matter of efficiency or increased workload. It is due to increases in wages, benefits, equipment, fuel expenses, and other overhead and administrative costs. By reviewing Figure 5, the extent of the annual labour burden increase from 2011-2015 can be seen, irrespective of labour hours expended. In mid-2014 the labour pool was reduced by a large percent. When Hydro One was questioned about the increase in cost per labour hour, the following explanations were provided:

- $9 million cost centre administration costs
- $4.5M health and safety costs
- $1.5M BASC Costs
- $0.2M Central tools
- $0.35M shared services
- Wage increases
- Changes in the mix of full time employees and temporary hiring hall employees.
- Other labour burden increases

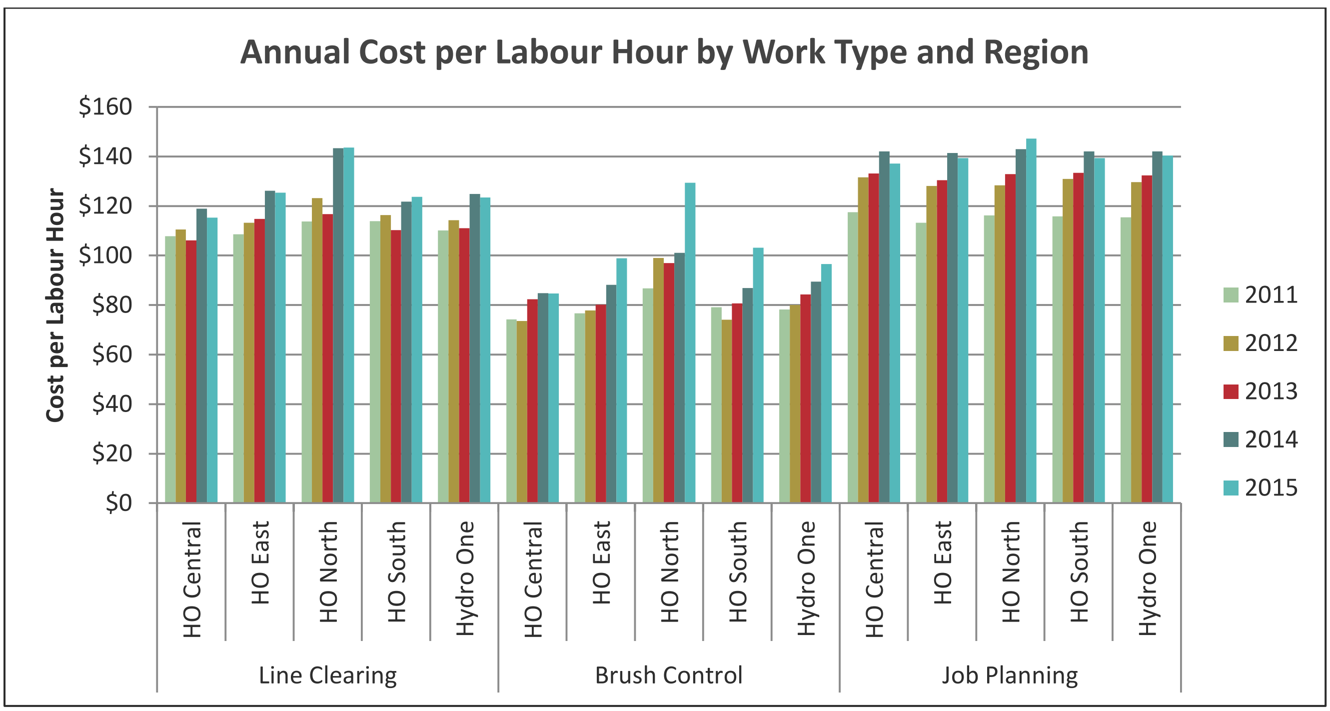


FIGURE 5: HYDRO ONE ANNUAL COST PER LABOUR HOUR BY WORK TYPE AND REGION

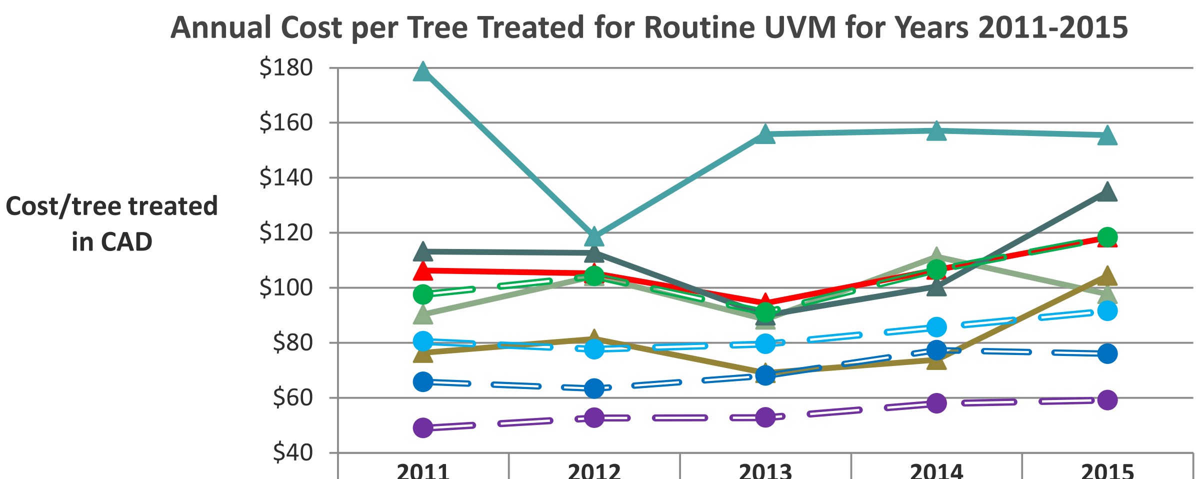
The increases in hourly costs should be separated from the variations in productivity costs. The peer group typically reports less than 1% of costs related to administration or overhead compared to Hydro

One whose administrative costs are closer to 8%. This is a significant difference. The peer group may not report all in-house costs associated with the UVM department.

4.1.5 *Cost Per Tree Treated*

Trees treated are the same as managed trees and include both prunes and removals. Hydro One has maintained an above average cost (third quartile) per tree treated (Figure 6, below). This ratio is moderate in comparison to the cost per managed kilometre, which is high for Hydro One due to high tree density. The average cost per tree increased by $11 for the peer group and $12 for Hydro One over the five years. For Hydro One the rise in cost per tree represented increases in fixed cost rather than changes in work scope or productivity. In contrast, the peer group's cost increase was due to a greater emphasis on off-ROW tree risk, mitigating emerald ash borer (EAB), and hardening distribution systems against more frequent and intense storms, all of which require more off-ROW removals of larger trees. The average labour hours per tree did increase for the peer group by 9%. Labour efficiency is analyzed in section 4.2.

Hydro One's average cost per tree treated in 2011-2015 increased by only 3% over the 2006-2008 average compared to the peer group which rose by 97%.



	2011	2012	2013	2014	2015
Hydro One Central	$90.37	$104.22	$88.51	$111.31	$97.74
Hydro One North	$76.37	$81.39	$69.07	$73.85	$104.43
Hydro One	$106.26	$105.28	$94.47	$106.55	$118.33
Hydro One East	$113.18	$112.76	$90.01	$100.55	$135.03
Hydro One South	$178.76	$118.66	$155.89	$157.11	$155.48
Peer Average	$80.51	$77.68	$79.58	$85.62	$91.54
Peer Q1	$48.96	$52.69	$52.84	$57.94	$59.14
Peer Median	$65.82	$63.34	$68.07	$77.29	$76.01
Peer Q3	$97.58	$104.22	$91.07	$106.55	$118.33

Figure 6: Year over year Changes in Cost per Tree Treated

4.1.6 COST AND TREES PER CUSTOMER

"The OEB notes that the 2011-2012 CN Utility Benchmarking analysis showed that Hydro One had the highest vegetation management cost per customer relative to its peers. This benchmarking comparison emphasizes the need for Hydro One to provide detailed and thorough evidence substantiating its spending requirements and how it intends to continuously improve in this activity (OEB, March 2015)." Figure 7, Annual UVM Cost per Customer, below, confirms Hydro One's high relative cost that was discovered in 2012. This measurement is an average. It does not account for the variations in electric usage which affects cost per customer, but it does show that a Hydro One customer has a measureable stake in the performance of the UVM program, and that there may be a customer expectation that costs should be closer to that of peers.

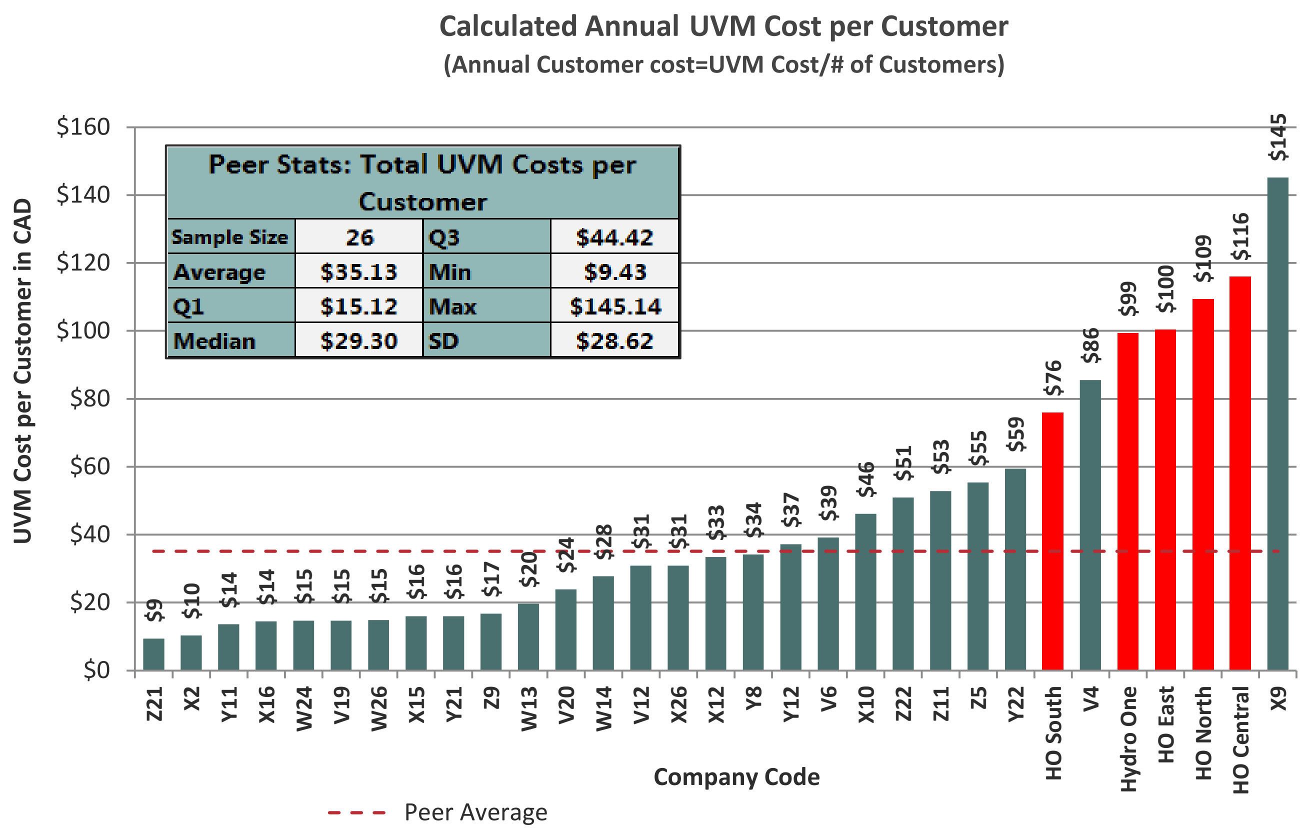
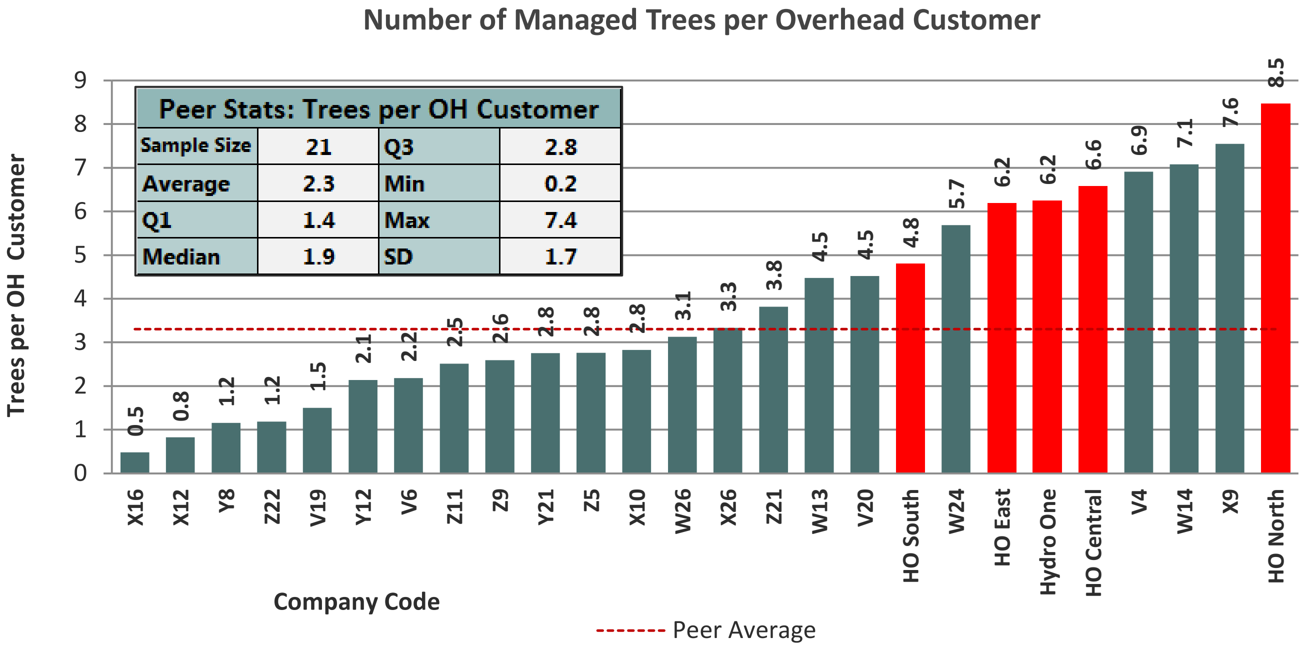


FIGURE 7: ANNUAL UVM COST PER CUSTOMER



Peer Stats: Trees per OH Customer			
Sample Size	21	Q3	2.8
Average	2.3	Min	0.2
Q1	1.4	Max	7.4
Median	1.9	SD	1.7

Figure 8: Number of Managed Trees per OH Customer

Another way to compare the customer's cost is to compare the workload per customer. The average number of trees per customer is calculated by dividing the total number of trees managed by the total number of customers. Since residential customers make up 90% of the total customer base, the calculations for trees per customer in Figure 8 (above) should be close the actual average (unlike the cost per customer, which is weighted to the industrial and commercial customers). There are wide variations of trees from one property to the next, but each Hydro One customer on average have 6.2 trees that must be managed compared to the peer and non-peer group average of 2.3. This is a cost factor that helps to explain a higher cost for Hydro One in terms of total cost and cost per customer.

4.2 Labour Efficiency

Another way to compare companies is to focus on the time units required to perform UVM. This is a more universal measurement (hours) for comparing the relative efforts of each company in the peer group. Hydro One compared favorably with the peer group in the 2009 study and again in the current study.

4.2.1 Routine Labour Hours per System Kilometre

When routine labour hours per system km are compared, a different picture of relative efficiency emerges in comparison to cost (Figure 9, below). Hydro One's labour hours per system km is nearly one standard deviation *below* the average. This could indicate the work is being performed as or more efficiently than the majority of companies in the comparison group. All of the Hydro One regions performed better than the peer average labour hours per system kilometre. However, rather than demonstrating work-efficiency, this metric is an indicator that Hydro One is under-resourcing their program and more work needs to be done. This is true because tree density, the number of trees managed per kilometre, is increasing and Hydro One has not been able to decrease the length of its cycle.

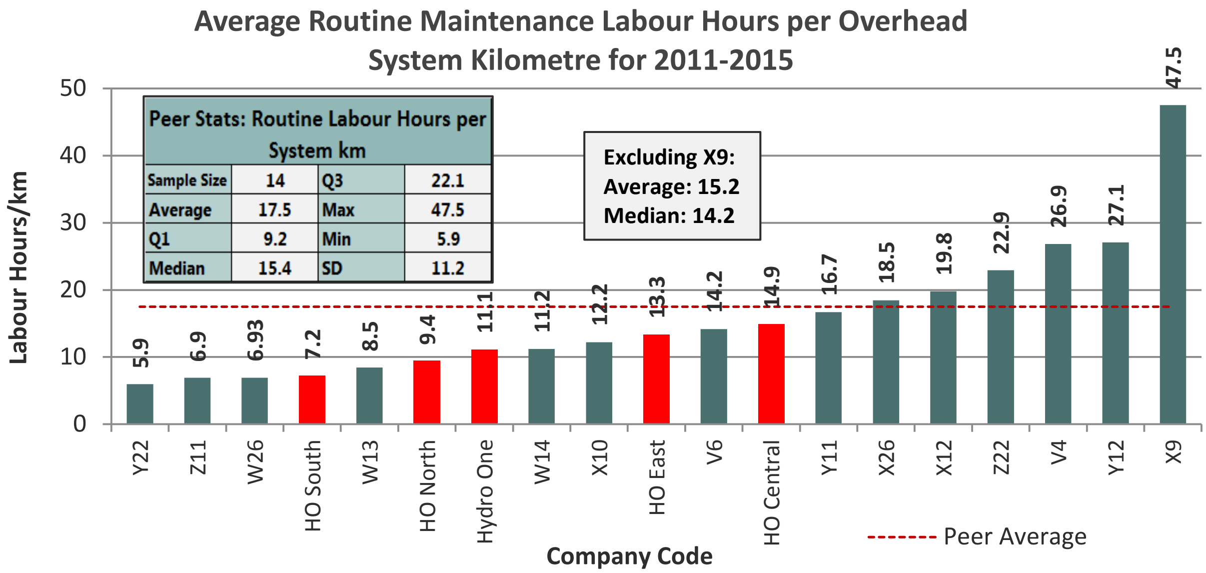


FIGURE 9: ROUTINE MAINTENANCE LABOUR HOURS PER SYSTEM KILOMETRE

4.2.2 LABOUR HOURS PER MANAGED KILOMETRES

4.2.2.1 Establishing Work Efficiency

The following discussion will establish that Hydro One has an efficient workforce relative to the peers. Figure 10, below more accurately depicts Hydro One's performance in labour hours per managed kilometre (LH/managed km) in comparison to peers by including tree density and cycle length for each company. Hydro One, W13 and W14 show similar measurements for all three metrics. All three have high tree densities, long cycle lengths and similar labour hours per kilometre. (**Gray bars = labour hours per km**; **Blue dots = trees per km**; **Green squares = calculated cycle length**). W13 and W14 have better ROW access than Hydro One regions with the exception of Hydro One South. This comparison with three different metrics lined up together shows how Hydro One compares evenly with other companies. Given a fourth metric, ROW accessibility, Hydro One compares more favorably with W13 and W14 because of the greater amount of access issues challenging the work at Hydro One.

The other companies with high tree densities, V4 and X9, expend significantly more labour hrs/managed km than Hydro One. Although their systems are on a shorter cycle than Hydro One, both V4 and X9 are under recent regulatory mandates that require increases in vegetation management. The remaining companies in Figure 9 have lower tree densities and shorter cycle lengths than Hydro One.

Work efficiency is reinforced by the higher tree density found on much of Hydro One's system. Hydro One also has a significant number of access issues to their system and it is typically in a state of heavy growth after nine to ten growing seasons. In conclusion, although Hydro One is close to the average for LH/km, they are in fact working UVM at a higher rate of efficiency in comparison to the peer group.

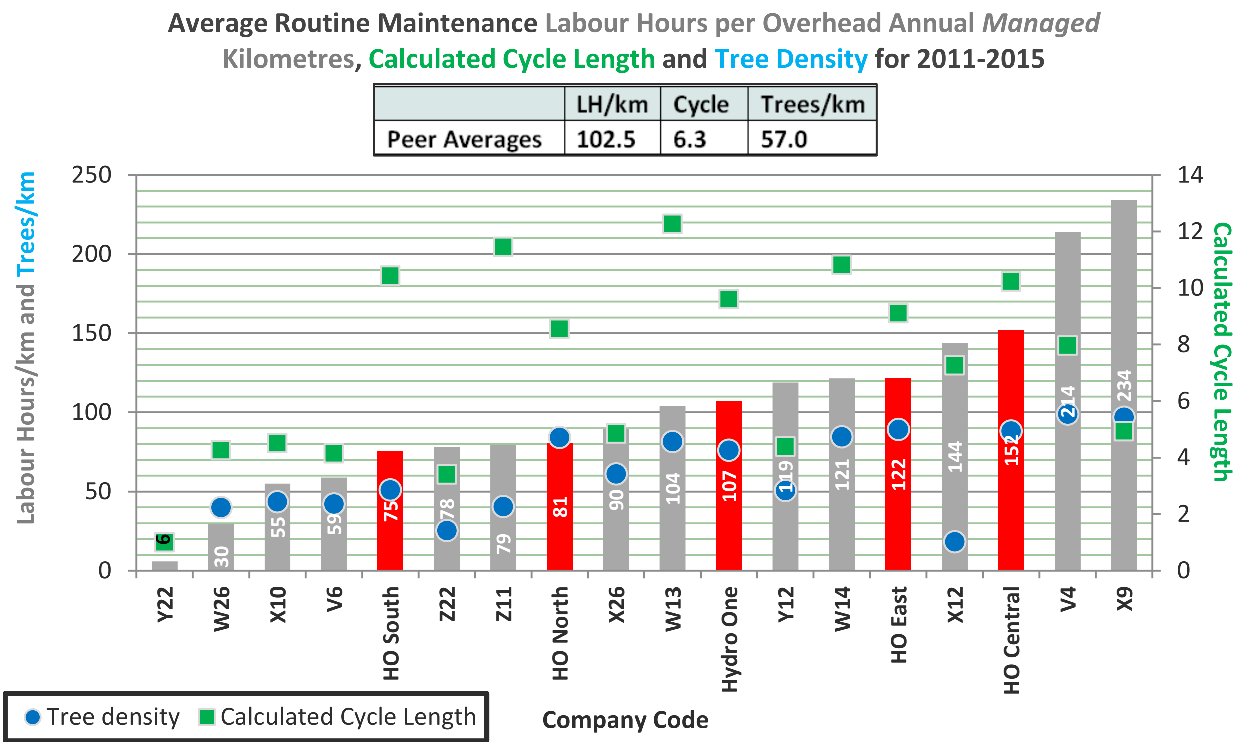


Figure 10: Routine Maintenance LH/Managed km, Cycle Length, and Tree Density

4.2.2.2 Tree Density and Managed Labour Hours

Figure 10, above is also a visual representation of the relationship between tree density and labour hours. In fact, there is a good correlation ($R= 0.66656$, $p < 0.005$) between tree density and labour hours for the peer group. As is expected, labour hrs/managed km increase as tree density increases. Hydro One's managed tree population has been enlarging for many years as a result of a long cycle length. Hydro One has had to work more efficiently to meet this rising demand. Hydro One's policy is to clear the ROW thoroughly in hopes of reducing outages, reactive work, and future workloads. When applied to circuits that have not been managed for many years (more than eight years), it is difficult to maintain efficiency. In order to sustain efficiency and reliability, in 2015 Hydro One modified the schedule to achieve shorter cycle lengths on M-Class feeders. At the same time, fewer kilometres of single phase and two-phase were worked. The change in labour hours per managed kilometre in 2015 can be seen in Figure 11 (below). This is evidence that shorter cycles will result in lower tree densities and less work and longer cycles will result in higher tree densities and more work.

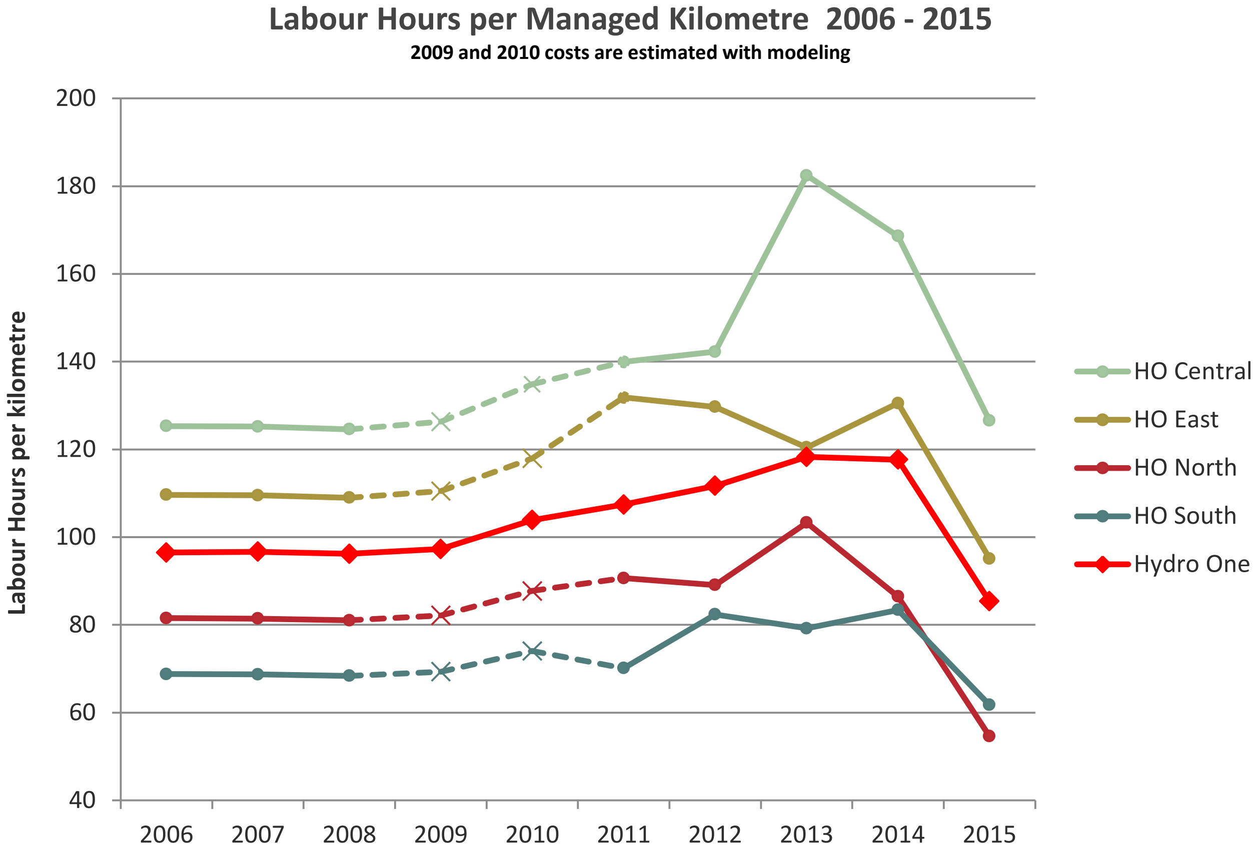
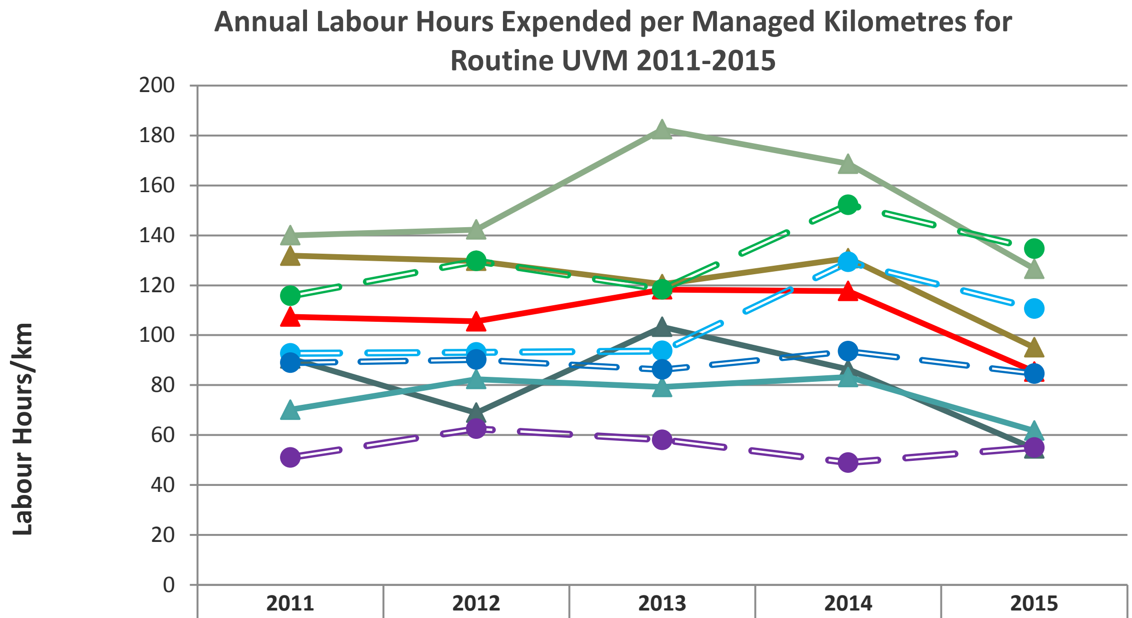


FIGURE 11: HYDRO ONE LABOUR HOURS PER MANAGED KILOMETRE 2006-2015

The following graph (Figure 12) is the same as the one above but it is limited to the labour hours per managed km of 2011-2015. The peer group average, median and 1st and 3rd quartiles are also represented. The peer average surpassed Hydro One in 2014 when both were at the highest number of labour hours per managed kilometre over the five years. It is easy to see in this graph that tree densities of the East and Central Regions are driving the annual labour hr/managed km output for the whole company. The North is managing a similar tree density with a much smaller labour output per km.

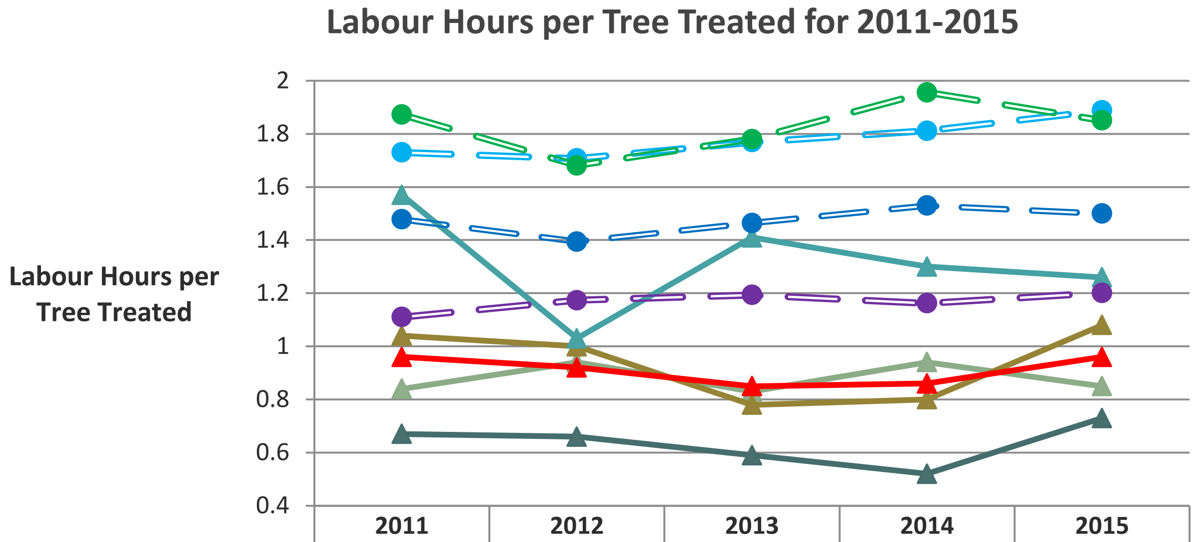


	2011	2012	2013	2014	2015
HO Central	139.96	142.26	182.41	168.63	126.56
HO East	131.83	129.68	120.43	130.79	95.09
Hydro One	107.42	105.52	118.30	117.67	85.40
HO North	90.66	68.91	103.29	86.30	54.60
HO South	70.14	82.38	79.23	83.26	61.74
Peer Average	92.7	93.1	93.7	129.3	110.7
Peer Q1	51.0	62.5	58.1	49.0	55.0
Peer Median	88.9	90.2	86.2	93.6	84.7
Peer Q3	115.8	129.7	118.3	152.2	134.6

Figure 12: Annual Labour Hours Expended per Managed Kilometres for Routine UVM 2011-2015

4.2.3 Labour Hours per Tree Treated

In contrast to the cost per tree treated, Hydro One's labour hours per tree treated are near the best-in-class (see Figure 13, below). In fact, the North Region is best-in-class all five years. If tree density was not so high, Hydro One could also be best-in-class at labour hours per kilometre. The South, which has the lowest labour hours per managed kilometre and per system kilometre of Hydro One's four regions, has the highest labour hours per tree. As previously mentioned, this is due to a longer growing season, a greater number of large trees, greater species diversity, and lower tree density. These conditions require moving personnel and equipment more frequently. The tree density in the North, Central and East Regions should be reduced to a level closer to the South Region, where possible.



	2011	2012	2013	2014	2015
Hydro One Central	0.84	0.94	0.83	0.94	0.85
Hydro One East	1.04	1	0.78	0.8	1.08
Hydro One	0.96	0.92	0.85	0.86	0.96
Hydro One North	0.67	0.66	0.59	0.52	0.73
Hydro One South	1.57	1.03	1.41	1.3	1.26
Peer Average	1.73	1.71	1.77	1.81	1.89
Peer Q1	1.11	1.17	1.19	1.16	1.20
Peer Median	1.48	1.39	1.46	1.53	1.50
Peer Q3	1.87	1.68	1.78	1.96	1.85

Figure 13: Year over Year Labour Hours per Tree Treated for 2011-2015

4.2.4 Tree Density is a Function of Cycle Length

In general, tree density is a natural phenomenon of the environment. For the purposes of UVM and this study, tree density is the average number of trees treated per kilometre each year. Consequently, tree density is not an independent variable. For example, although forested areas tend to have higher tree density than agricultural areas, tree density for UVM is still a function of management. Less management allows tree density to become a function of the environment. Consequently, companies with long UVM cycles (less management) tend to have higher tree densities (Figure 14 below). When Hydro One changed the UVM scheduling in 2015 and began focusing on M-Class, the tree density decreased because these lines have been managed more frequently. Hydro One's data shows that other non-M-Class backlogged circuits have greater tree density.

In Figure 14 the cluster of companies that have shorter cycles (left side of scatter plot) follow the correlation between tree density and cycle length more closely, because tree density increases with minor increases in cycle length. Companies with long cycle lengths correlate less well and the points are more scattered across both cycle length and tree density. The probable reason for this is that when the management cycle is long, environmental conditions begin to influence tree density more and changes in cycle length have a weaker relationship with changes in tree density. In other words, the shorter cycle UVM programs are lined up with a steep slope of tree density against the cycle length axis, whereas the long cycle companies are spread out and tree density is less oriented to the length of the cycle. Only one company in the long cycle group has less tree density than the short cycle group. Since Hydro One's cycle is already long, there is not as much change in tree density if the cycle is extended by another year or two. New trees, re-sprouted stumps, and increased growth from existing trees have already saturated the space.

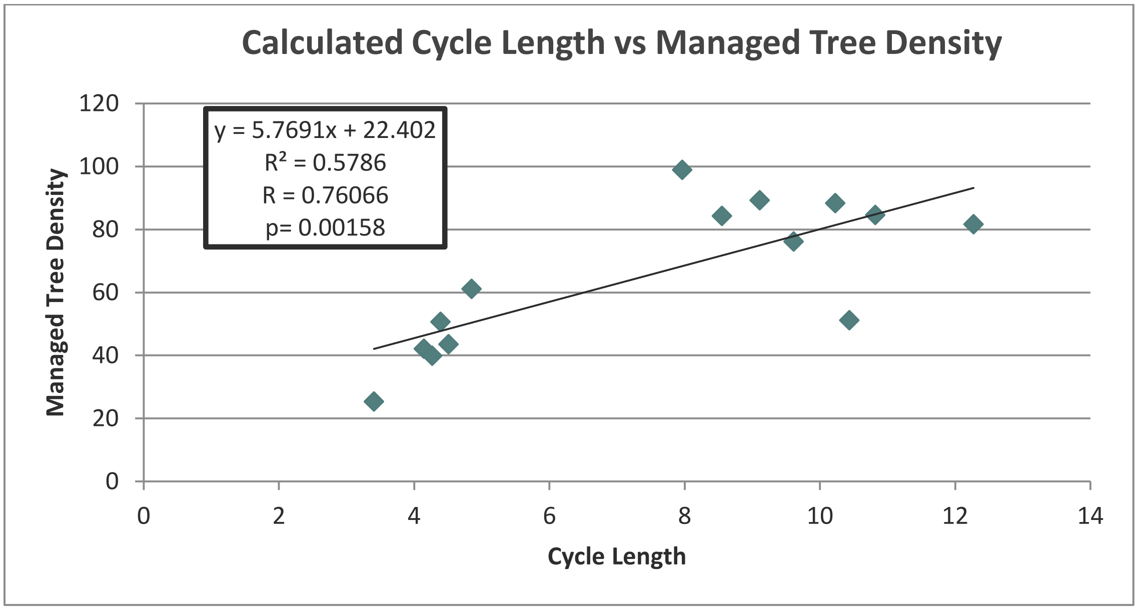


FIGURE 14: TREE DENSITY IS A FUNCTION OF CYCLE LENGTH

The measuring and definition of tree density is also changing. Traditionally, tree density has been defined as the number of trees managed for UVM. Some companies have come to recognize that off-ROW trees cause many, if not the majority of reliability risks. A few companies have begun collecting data that expands the scope of their management to off-ROW risk trees. If this trend continues, the measurements of tree density will be higher than in the past for reasons other than long cycle lengths. Like Hydro One, the field of peer companies has not established a best management practice that balances cost, cycle length and tree density. This is evident in the wide range of tree densities matched to a wide range of cycle lengths and labour outputs.

4.2.5 TREE DENSITY CONTROLS

The conditions on parts of the Hydro One system at the time of maintenance are a considerable challenge to workers faced with multitudes of trees that are in contact or nearly contacting conductors and with trees that are overhanging conductors that must be roped down or pruned one small piece at a time. Tree workers are also faced with ROWs that are overgrown with dense invasive plant growth. Utility companies have a certain amount of control over tree density:

- If on-ROW trees are removed;
- If ROWs are treated with herbicides frequently enough to prevent ingrowth

- If off-ROW trees are removed where possible according to tree-risk assessment

Another term for controlling tree density is "controlling in-growth" and this control is natural for a maturing UVM program. Programs on long cycles such as Hydro One may *not* be controlling in-growth. Such programs are accumulating biomass in the ROW faster than it is managed. Several years can pass in this condition if there is not a programmatic effort to limit how many tree are encroaching conductors. This long cycle approach increases safety and reliability risks, but by applying selective tree work and having a well trained workforce as well as making other technical improvements to the distribution system, reliability metrics can improve in spite of increasing in-growth, at least in the short-term (See Appendix B).

The path to a shorter cycle is blocked by high costs to reclaim ROWs and the added cost in subsequent years of reworking ROWs with herbicides to get a stable plant conversion established. Figure 11 (p. 27) shows the increased effort to reclaim ROWs, particularly in the Central Region, where labour hours per km went from 124 in 2008 to 140 in 2011 to 182 in 2013. The effort to reclaim ROWs will result in vigorous regrowth without a follow-up herbicide program.

4.2.6 Regional Costs Indicate Varied Forestry Conditions and Management Challenges

The following are a few facts that illustrate the varied conditions in the Hydro One regions for the years 2011-2015:

- The Central, East and North Regions have similar tree densities, which are approximately 1.7 times greater than the South
- The South has nearly one-third of Hydro One's line kilometres
- The cost per tree treated in the South is 30% higher than in the Central Region
- The need to improve forestry conditions is the greatest in Central Region, followed by the East
- The Central Region's reliability performance is the worst of the four regions, having the highest number of outages/km
- North is removing over 70% of the trees managed

The above facts indicate Hydro One UVM program needs varied approaches in order to reduce and control the workload. For example, the South needs to devise strategies to reduce cost per tree treated. This could be accomplished with specialized equipment, pruning practices, scheduling and routing. The East and the Central need to decrease the tree density. This might be accomplished by educating customers, tree risk assessment to identify higher risk trees, and similar tactics recommended for the South could be used. The North, and where applicable in the other three regions, could reduce tree density by applying herbicides on a shorter cycle than the line-clearing cycle. Each region needs a customized approach to reducing the workload.

4.2.7 Integrated Vegetation Management (IVM)

Integration Vegetation Management or IVM's ". . . ultimate goal is to maintain a desirable plant community with available tools, emphasizing biological and ecological control (Miller, 2014)." Using IVM to make planning decisions, Hydro One should endeavor to convert ROWs to more appropriate plant communities. Initially, it is recommended treat a higher percent of distribution kilometres with industry-approved herbicides or other land management applications that effectively reduce or eliminate mechanical-cutting. Treating 50 – 75% of ROWs is recommended, although this amount may vary depending on property owner acceptance.

IVM is considered the most universal of Best Management Practices by system foresters, vegetation managers, academic research, the Environmental Protection Agency, and many other environmental groups. It has been championed by the *ROW Stewardship Accreditation Program* and is the chosen methodology of many in the arboricultural, forestry, and landscape industries. It is also known as integrated pest management (IPM). IVM advocates a rational approach to managing vegetation that is environmentally beneficial, cost-effective and meets the approval of various stakeholders, such as property owners, regulators and other involved parties. A key component in current IVM methodology is the use of approved herbicides to control inappropriate plant species early, before more invasive and expensive manual and mechanical methods are necessary. This means the vegetation must be treated when it is small brush and before it reaches the smallest class size of tree. This is not possible when the cycle of management is too long. IVM also encourages conversion of the ROW to appropriate low growing plant communities. IVM is a best management practice for achieving safety, reliability and customer satisfaction objectives of UVM while reducing the workload and environmental impacts. In general, IVM prevents substantial in-growth in a cyclical management program.

One of the primary tools advocated in IVM is the use of herbicides to prevent ingrowth. Table 2 (below) provides the percent of distribution kilometres that are treated with herbicides by utility companies. IVM is one of the most effective tools for managing vegetation, but it is the most inconsistently applied tool. In a six-year study, EPRI determined herbicide control could reduce stem counts of trees in the ROW by 70% compared to manual cutting methods which increased stem counts and mowing which didn't significantly reduce stem counts. (EPRI 2000)

Peer Group Herbicide Use					
Sample: 21	**GENERAL (Foliar, Basal)**	**STUMP**		**GENERAL**	**STUMP**
Hydro One	**14%**	**7%**	**Q3**	75%	98%
Average	35%	66%	**Max**	100%	99%
Q1	9%	21%	**Min**	0%	0%
Median	20%	93%			

Table 2: Herbicide Use

The Ontario Pesticide Act is designed to provide safety to the applicator, the public and the environment. However, it is used as a constraint by many who do not understand its benefits and who are more comfortable with traditional mechanical controls or favor the absence of control. Consequently, Hydro One compares poorly with many of the peer group in the percent of distribution system managed with herbicides through IVM. Only about 14% of the Hydro One system is managed with general herbicide methods such as foliar or basal treatments. Only 7% of stumps are treated. A more widespread use of herbicides would be necessary for Hydro One to reduce the cost, equipment, and human resources currently required to provide management of distribution ROWs. Once a succession of appropriate stable plant communities is allowed to populate ROWs, the volume of needed herbicide applications would decrease. This is the ultimate goal of IVM- stable plant communities in the ROW that suppress ingrowth of incompatible tree species. Estimates for an IVM cost benefit ratio over traditional manual and mechanical treated ROW are 3:1 or better (Finley Engineering 2010).

Hydro One's best effort to utilize herbicides is in the North Region, where 22% of the managed kilometres are treated with herbicide. Although this is a higher percent than the other Hydro One regions, it is not nearly enough to be cost-effective. If a decade passes before the ROWs are treated again, they will need to be fully cleared before herbicides can be reapplied, which is not cost-effective. The Central Region is the furthest from ROW conversion to appropriate and stable plant communities. Only 6% of Central ROW kilometres are treated with herbicides. For much of Hydro One, applying herbicides is not cost-effective because the interval between applications is so long that the ROW must be re-cleared. Hydro One currently is increasing their use of herbicides.

4.3 Work Planning, Customer Notification and Scheduling

4.3.1 Work Planning and Cycle Length

The following (Figure 14) is a representation of the consequence of not being on cycle as cited by survey respondents. Overwhelmingly, UVM managers believe that getting behind in the maintenance schedule has negative effects on cost, reliability, and safety.

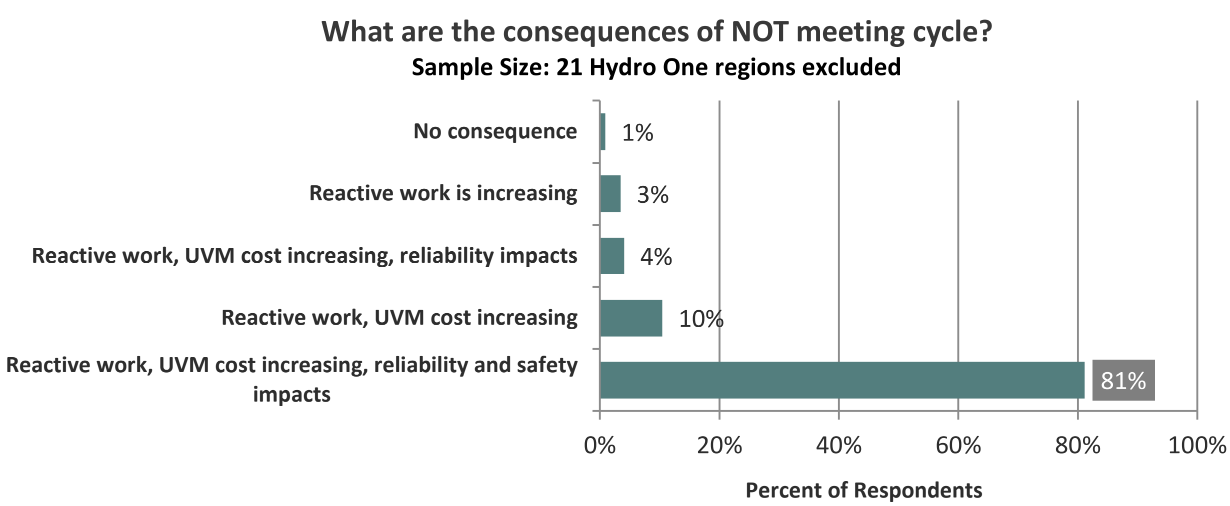


Figure 15: Consequences of NOT Meeting UVM Cycle Targets

The following are recommended practices for work planning at Hydro One. Included are some features that would enhance Hydro One's cyclical management of distribution corridors:

- **Cyclical survey of vegetation:** Document beneficial and unwanted vegetation conditions on the ROW. Hydro One only documents offending vegetation. 17% of system is inspected each year by non-vegetation management personnel trained to recognize the most obvious vegetation issues. Approximately 12% of the system is inspected by a qualified vegetation management pre-inspection planner. The 17% may overlap with the 12%. These inspection programs could be strategically synchronized to better capture tree risk that is out of reach of the routine program and to audit the success of the program. Improve, consolidate, and synchronize the current required asset inspections and the UVM work-planning inspections to add value and economies of scale to the planning program. Workload documentation should be more thorough at the circuit level to improve cost-planning, productivity, and quality management.
- **Cyclical survey of specific tree hazards off-ROW (Tree Risk Assessment) followed by prescribed work:** Hydro One has a formal Tree Risk Assessment Program that is a part of the pre-inspection program. The funding for this program is a small percent of the routine maintenance. It could be a more integral part of the UVM program if the responsibility was more clearly defined regarding trees off-ROW.
- **Management interval that is flexible based on actual conditions in the field and regular enough to prevent vegetation encroachment:** The M-Class and three-phase feeders are on a target for 4-8 years. The rest of the system should be managed similarly (See Table 3, below).
- **Establish performance metrics for maintaining air space around conductors**. Employ innovative data collection and leading performance indicators, such as safe ROW environment metrics, safe work place metrics, tree-risk assessment data, advanced outage investigation documentation, and other program features. These metrics will enhance and build greater safety awareness and education for anyone who enters and performs activities in a ROW zone for any reason.
- **Quality-driven IVM program that ensures ROWs are populated with beneficial plants and kept clear of inappropriate vegetation with a minimum of cutting, chemical application and soil disturbance:** Hydro One cannot cost-effectively apply herbicides until the cycle of UVM including herbicide applications is a shorter interval. The six-year cycle for M-Class and three-phase are sufficiently short if the herbicide applications are timed properly (Table 3).
- **Involvement of significant stakeholders, such as electric customers, regulators, governing jurisdictions, property owners, land agencies, media and the public:** Under equitable conditions the burden of liability risk would not be 100% on the utility company as they do not own the trees. Some stakeholder actions, such as property owners who are opposed to vegetation management, constrain the utility from performing UVM at standard industry levels. The pre-planners and utility foresters should be trained in customer communications and regulatory matters in order to build a future where carefully crafted incentives shift some of the financial and legal responsibility for trees away from the utility and toward property owners and local jurisdictions.

- **Database documentation of activities and favorable outcomes:** Hydro One has electronic data capture. Data transfers from paper to electronic and across various electronic formats should be streamlined so there is a seamless automation.
- **Use of innovation and technology to enhance effectiveness and efficiency of UVM program to achieve stated measureable objectives for reliability, safety, customer satisfaction and environmental quality:** Hydro One has a continuing commitment to innovation. More emphasis should be placed on R&D.

Variable Cycle Statistics [Peers plus Hydro One Networks]								
Cycle Type	General Target	General Actual	Urban & Suburban Target	Urban & Suburban Actual	Rural Target	Rural Actual	Remote Target	Remote Actual
Sample	25	25	11	11	11	11	8	8
Average	4.6	5.3	3.6	4.5	5.0	6.4	4.9	6.6
Q1	4.0	4.0	3.0	4.0	4.0	5.5	4.0	6.0
Median	4.0	5.0	4.0	4.0	4.0	6.0	4.5	6.5
Q3	5.0	6.0	4.0	4.5	6.0	7.0	6.0	7.3
Max	8.0	10.0	6.0	9.5	10.0	11.5	8.0	9.5
Min	1.0	1.0	1.0	2.0	1.0	3.0	2.0	3.0
STDEV	1.7	2.0	1.4	2.0	2.5	2.5	1.8	1.9

Table 3: Variable UVM Cycle Statistics

In Table 3 (above), target cycles and actual cycles are listed for demographic divisions. Descriptive statistics of the responses are given, including standard deviation from the norm. This table illustrates how the majority of the distribution UVM industry operates behind schedule, and has for many decades. The yellow highlighted numbers are recommended cycle lengths for Hydro One based on what is realistic for the average company and given the fact that a majority of Hydro One' system is rural or remote and that the North, Central and East Regions have harsher climates than most of the peers in this study. The variation in cycle lengths could be applied to the different regions or as needed to reduce risk. Similar cycle lengths have been cited by personnel at Hydro One during interviews about ideal cycle lengths.

Can a company, that is on schedule, has a proactive reliability program to reduce the risk of tree failures, and has a history of top-tier reliability, be spending less than Hydro One on a per km basis? A simple comparison of cost per system km shows the difference. One company (Y8) that is at the minimum cycle length (one-year inspection cycle and a three-to-four-year maintenance cycle) spends $900/system km for routine maintenance while Hydro One Central spends $1,538 per system km and is on a 9.5-year cycle (Figure 1, p.17). In other words, it is costing the Central Region almost twice as much to manage a km of line one time as it costs Y8[2] to manage a km of line three times. Even for the complete Hydro One system it cost more to manage it once than it does for Y8 to manage its system 3-4 times. Y8 inspects

[2] Y8 did not supply their labour hours which would have provided a more normalized comparison

their entire system once every year and only manages what is necessary. Hydro One Central may be clearing the full width of the ROW, but since the interval of maintenance is so long the workload stays the same. With a more frequent management, the workload (cost) could be reduced because vegetation is managed at a smaller stage of growth. This is not to say a three to four-year interval would be cost-effective for Hydro One, but it does establish that a more frequent interval could be more efficient. Inspecting the system more frequently than it is maintained also ensures a quality of management and increases the ability to discover hazardous trees.

4.3.2 *Work Planning Automation*

Survey participants were asked to name three technologies they have introduced into their program. The most frequently mentioned technology was software for planning, work management, and mapping. This technology adoption is not immediate or without challenges. Planning UVM work is less standardized than line clearance maintenance work, so software automation projects are unique and emergent. Only about 27% of companies have comprehensive work planning over 100% of their distribution system. Another 15% are formally planning at least 50% of the system. 36% of companies are conducting less formal summary planning over their entire system. The variations in data collection present challenges to adding value with electronic systems.

Hydro One conducts comprehensive work planning over 100% of their distribution system. There are 48 notifiers and five work planners. Although every tree is not documented and evaluated for treatment, tree-counts are estimated through samples and all customers are notified. Herbicide treatments require a signed permit. Although Hydro One has introduced custom software to the UVM program, there are still many challenges to effectively improving the efficiency of the program with data.

Hydro One administers the UVM program using several formats. Most of Hydro One's UVM administrative activities are done partly on paper, with the exception of the workload inventory database. Mapping is electronic but crews do not have access to it. Many activities are done in multiple formats such as paper, Microsoft office products, and various types of in-house or vendor software. Activities such as crew dispatch or work plans are done purely on paper. Time sheets are done on paper and in-house enterprise software. Production is on paper, on excel, and on in-house custom software. Invoices are on paper and electronic.

UVM administration and documentation activities performed in multiple formats are likely to have extra layers of data input and opportunities for error. Much of modern life is conducted electronically and increasingly outmoded paper formats are reviewed and verified less than in the past, making them more dysfunctional than when they were the primary transaction format. Paper today presents fewer opportunities to create summaries, because most calculations are currently performed in databases. Therefore, paper information has to be input to the database before calculations can be made. A best management practice (BMP) is to fully automate administration and documentation of the UVM program with the least amount of data input repetition and maximum integration within the UVM department and across other departments and stakeholders.

The following are work planning automation statistics with 33 companies providing data:

- 42% of companies reported that they use more than one format to collect work planning data.
- 55% use one format
- 18% use paper *only*
- 54% use paper
- 36% use paper with another format such as excel or a proprietary software
- 21% use excel, word or pdf only
- 9% use in-house software only
- <1% use vendor software only

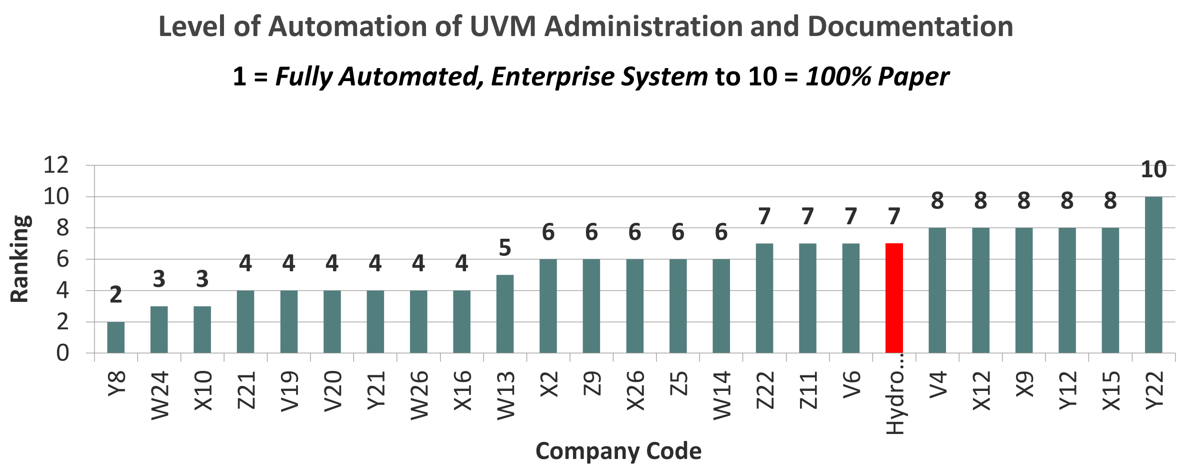


Figure 16: Level of Automation of UVM Administration and Documentation

A rough scoring was devised to compare Hydro One with other utilities based on how well each company has adopted electronic processes and how far they have progressed through transitions that require multiple formats. Figure 16 (above) shows the scores for each company. A fully automated and integrated UVM system would receive a score of one and a system that still performs all administrative and documentation activities on paper received a score of ten. No company received a one and only one company was scored at ten. The majority of companies is attempting to transition away from paper and has been since the last time a similar survey question was posed in 2009. The progress can be seen in how much paper has been transitioning to electronic processes, but it is more difficult to see how efficient the various electronic systems are performing, particularly in transition with multiple formats in use. Full transition to the field crew level is likely to take a few more years for many companies.

Automation should continue to be pursued and improved on all fronts. For example, the following work management activities would benefit from automation:

- Electronically documented measurements and assessments of ROW conditions
- Professional prescriptions
- Electronic work order transmission to crews
- Crew electronic time keeper submitted back with verification that work plan was completed with any modifications
- Documentation of production

- Records automatically generated for audits, payroll, invoicing, data analysis, and financial planning.
- Monthly and quarterly reports tracking progress and exceptions to plans
- Statistical process control calculator to determine weekly production that is two and three standard deviations above norm with investigative follow-up and corrective action when appropriate
- Data collected from the above activities can be used to develop predictive models

The use of remote sensing such as LiDAR to quantify and accurately measure vegetation conditions will improve Hydro One's ability to model appropriate, economical, safe, environmentally beneficial, climate-change aware UVM programs that help deliver optimum electric reliability.

4.3.3 *Customers and UVM*

Hydro One reported their "Customers are becoming more aware of their trees and more environmentally conscious, while not very aware of the hazards of powerlines and trees." The path to a rational and sustainable distribution ROW management begins with customers, who need to take some responsibility for their vegetation encroachments and their vegetation-caused damages to the infrastructures they depend on. This is no easy task since the ROW crosses over or is at the edge of customer property. If the utility is willing to manage the problem, then the customer should be willing to accept cost-effective management or plan to pay for management that is customized for their purposes. A rule such as this exists in Illinois where communities that require costlier UVM practices than what the utility prescribes have to pay the difference. Is reliability and the customer a *Catch-22* or an opportunity to know your customer? Most companies don't know much about their customers and rely on field workers to be good representatives for the company. Data on the customer is not impactful to decision making and policy. An improved UVM program would do a better job of understanding and educating the customer.

4.3.4 *Company Customer Service*

Hydro One is more customer service oriented compared to the peer and non-peer group. Hydro One personnel:

- negotiate with customers on work specifications
- negotiate with customers who refuse work
- get permission to remove trees
- notify every customer of impending work
- respond to focus groups
- get permission access property
- get permission to apply herbicides
- respond to complaints
- call property owners who don't live on the property

Hydro One does most of these customer service activities using multiple resources, including notifiers and other supervisory personnel. Although many companies provide these services, not as many do it at multiple levels and often the core of customer communication is conducted by the same people who are cutting the trees.

4.3.5 *HOW WELL ARE UVM DEPARTMENTS CONNECTED TO THE UTILITY CUSTOMER SERVICE EQUATION?*

The key to knowing the customer from a planning perspective is dependent on the data collected and how that data is leveraged in future customer services. 58% of companies, including Hydro One, keep a record on customers who respond to notifications. 92% of companies said they think there is 'a disconnect' between industry standards and what customers/property owners and local agencies require when UVM is performed on their properties. Hydro One has a customer refusal tab in their Tech notification software (*Forestry Application Production*), where information about customer refusals is captured. Figure 17 (below) illustrates the lack of knowledge about customers that may be at the root of why there is a disconnect between customers and the industry standards. Only 5% of companies store vegetation data on the customer service system (CSS) and less than half of UVM departments and/or UVM planners/notifiers can access the CSS database. As one survey respondent commented, one of the most important factors for UVM efficiency is customer relations.

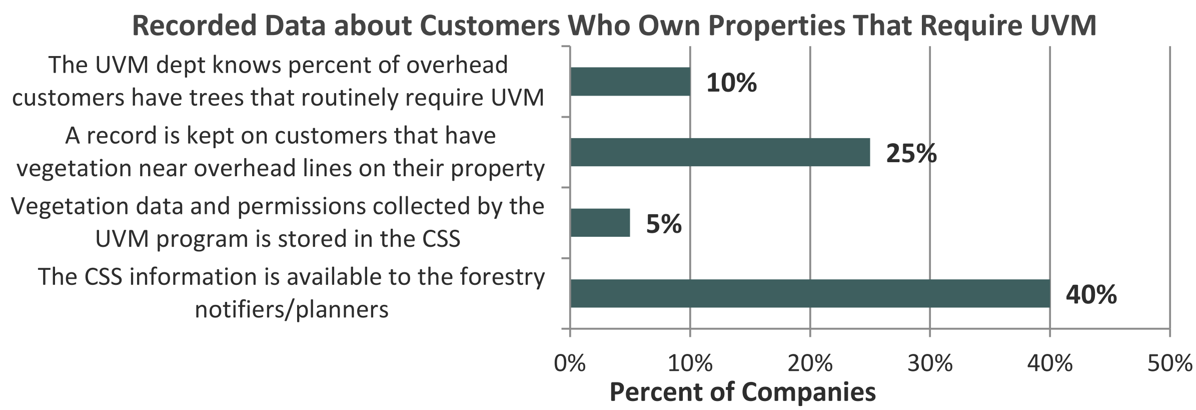


FIGURE 17: KNOWLEDGE ABOUT CUSTOMERS WHO OWN PROPERTY WHERE UVM IS REQUIRED

4.4 EQUIPMENT AND PERSONNEL

4.4.1 *EQUIPMENT*

Hydro One named three items that are key to the efficiency of their UVM program:

- Logistics
- Labour Rates
- Mechanization

Two of these: logistics and mechanization, involve equipment. One is for transportation and the other is equipment for performing work. Under logistics a subcategory of utilization could be included that maximizes the efficiency related to having the right equipment and people in the right place at the right time. Hydro One expects each local area to develop strategies based on local geographical knowledge. Beyond the prioritization of circuits, there isn't a company-wide approach for scheduling crews or pooling resources. Hydro One is developing GIS telematics to monitor crew locations, manage fleet maintenance and enhance emergency response. This technology could be used to improve routing of crews to minimize drive times and fuel consumption. This is an area of technology R&D that should be coordinated centrally to ensure high level planning prioritization feeds into routing optimization and to ensure storm response is enabled to decrease the current high number of MED SAIDI minutes.

To economize fuel and travel time, crews meet at temporary work headquarters that are remote from the local operations centres. Training is conducted on inclement days and in the winter to ensure blue sky days are utilized. Hazard trees are managed at the same time that routine work is performed to eliminate duplicate trips. Hydro One spends on average 6.4% (of routine + reactive work) on travel intensive reactive work to correct emergency system problems. This is lower than the peer average of 8.8% reactive expenditures. 40% of customer calls are resolved without a crew site visit. The UVM department only receives 15,000 calls per year out of the 2M customer calls made annually to the Hydro One call center. If this ratio were to increase, the productive utilization of labour and equipment would decrease. Customer satisfaction is important to the level of efficiency for a UVM program.

Hydro One made the following statement in the 2013 rate proceeding: "Equipment utilization averages have increased from approximately 65 percent in 2001 to approximately 80 percent in 2012. The 2012 average equipment rate is $21.38 per hour; this is established by averaging total annual fleet equipment costs over total annual fleet utilization hours." (EB-2013-0416 Exhib. C1 Tab 4, 2013) Hydro One reported in the benchmark survey that on average equipment is utilized 63% of the time. On average 60% of Hydro One employees are stood-off for at least three months of the year, which idles equipment. The savings in lost productivity due to weather extremes and short days and the winter wear on equipment may offset some of the utilization losses. Hydro One depreciates equipment at standard rates, which are based on year around utilization and this may prolong the time it takes to fully depreciate equipment. The excess pool enables equipment to be replaced when taken out of service for repairs and it enables quicker deployment to locations where the equipment is needed. The forestry department meets with the fleet department to decide the future equipment needs and which pieces to sell and replace. *This process could be incentivized to maximize utilization and optimize the life-cycle of useful equipment, while replenishing and rightsizing the fleet for maximum productivity, safety and environmental quality.*

The peer and non-peer groups did not report equipment utilization percent except for one company that reported 95%. Most companies (83%) said they rely on their contractor to have serviceable equipment. 22% of 36 companies reported they require contractor equipment to be not older than five years on average. 66% of companies said their contractors' trucks are tracked with GPS locators (Telematics). 36% of companies said crews are allowed to add workers whose equipment is being repaired.

Although an argument can be made for lack of utilization of equipment throughout some periods of the year, having a consistent and adequate budget to accomplish clearly established objectives is a more effective way to ensure a fleet is optimized and rightsized than simply penalizing a department for underutilizing equipment purchased when funds were more available. The increases in cost of equipment accounted for only a small percent of the increase in expenditures for UVM over the 5 years. Mechanization and new technology is necessary for forestry services as its importance grows.

Improvements can be made by focusing more resources in the North during the warmer months of the year and shifting resources to the South Region during the coldest months of the year. Productivity could be improved and labor costs reduced by increasing the deployment of crews when working conditions are optimal and discontinuing deployments during the harshest weeks/months of the year. Forestry staff deployment strategies and technology should also be tailored and coordinated to improve preparedness and restoration response to reduce outage durations.

Customers are becoming more aware of the value of their trees. Provided the right messages they will become more aware of the efforts and effective forestry practices required to have power system corridors crossing through many forests.

4.4.2 *Personnel*

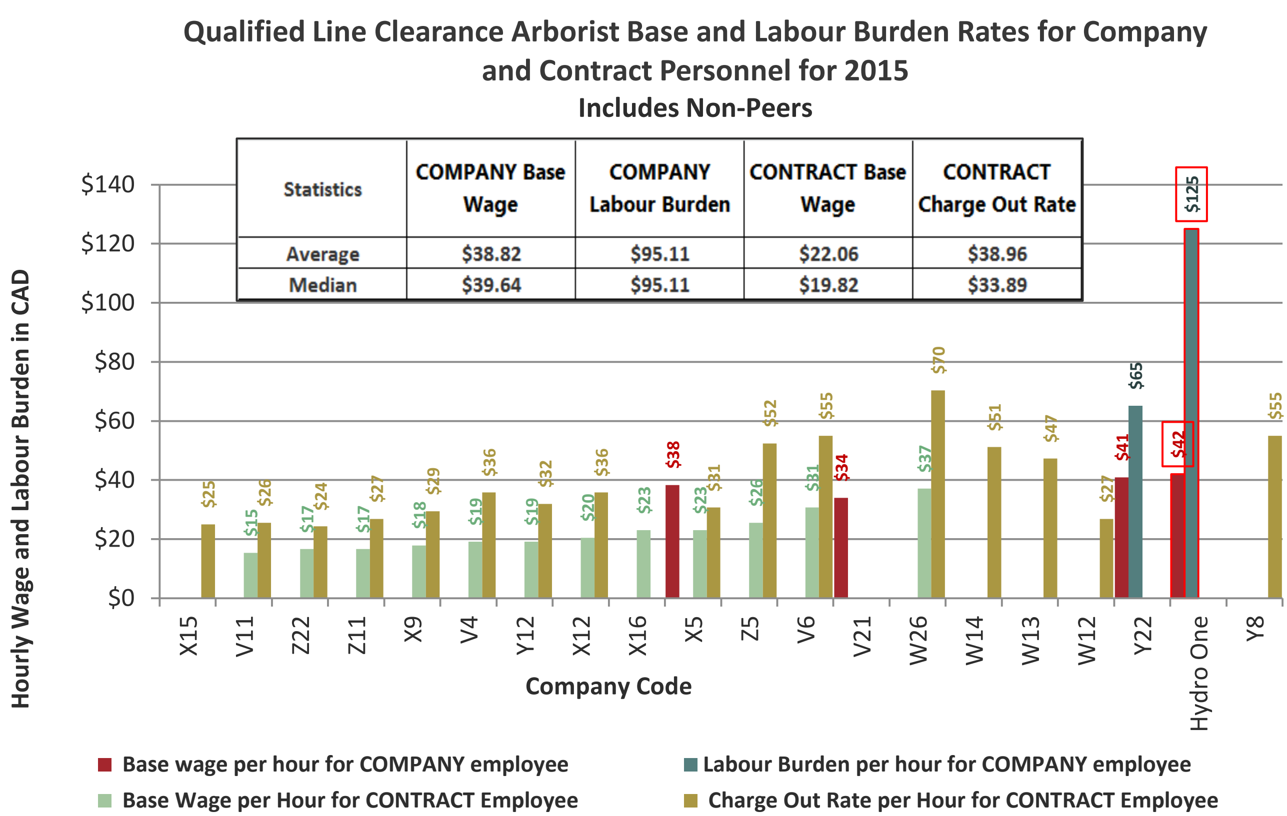


Figure 18: Line Clearance Arborists Base Wages and Labour Burden Comparison

The primary driver for the cost of UVM at Hydro One is the cost of labour. The base wages for Hydro One are in the fourth quartile (Figure 18 above) and they are about 1.9 times higher than the average of the peer group contract labour. The $125 charge-out rate for a Hydro One crew leader or qualified line clearance arborist combined with $67 for an apprentice is also about 1.9 times higher than the cost of a two-person aerial lift contract crew including typical line clearance equipment.

There are large differences between labour burden rates for in-house arborists, Hiring Hall line-clearance workers and contractors (Figure 18, above). Changes in the labour mix could improve productivity and control costs. These improvements can be made by utilizing a higher percent of Hiring Hall and contract workers to perform lower safety and lower liability risk activities such as work planning, herbicide applications, and brush-clearing. To maintain current level of lower safety risk, the more experienced and highly-trained in-house arborists who perform line-clearing activities should not be replaced with less experienced and less trained workers common to contractors and the Hiring Hall.

The turnover rate at Hydro One is at 5% compared to 32% for the peers. The table below shows the result of low turnover rates. For example, on average, Hydro arborists have 20 years of experience compared to 6.5 years for peer group companies that contract out line clearance activities (See Highlighted cells in Table 4, below). Since these are averages per company, it is evident some peer group contractors employ more people with minimal experience.

Number of Years Line Clearance Employees Have Been Working at the Utility					
Average, Max, and Min Exclude Hydro One		Peer Average	Hydro One	Peer Max	Peer
Supervisor	Company	13	25	24	5
	Contract	11.7		25	5
General Foreman	Company	5	15		
	Contract	10		18	5
Crew Leader	Company	5	20		
	Contract	8.7		20	3
Arborist	Company	8.75	20	15	5
	Contract	6.5		15	4
Arborist Trainee	Company	1.75	4	3	1
	Contract	3.1		7	1
Other Field Personnel	Company	3	15		
	Contract	5.5		15	1

TABLE 4: EMPLOYEE TENURE COMPARISONS

4.5 RELIABILITY PERFORMANCE

As a measure of performance, reliability metrics have been developed to help utilities prioritize work to provide optimum improvements to the expansive and aging overhead electrical grids that matured many decades ago and are now in various stages of renewal, rebuild and replacement. The metrics commonly known as the IEEE 1366 methodology have provided a way to triage complex systems that are vulnerable to dozens of minor and major interrupting events each year. It is not uncommon for large utilities to experience in excess of 10,000 outages every year, but most utilities have reduced the frequency that feeder lines fail and they have reduced the number of affected customers by inserting loops and breaks to isolate interruptions down to the fewest possible number of customers. Much of this effort has been the answer to storm events that are increasing in frequency and intensity. However, these efforts, while mitigating impacts, do not reduce the vegetation management workload. If anything they have allowed utilities to postpone UVM and to reallocate funds to other efforts that are more successful at improving the reliability metrics. Appendix B offers more details about the impact of IEEE 1366 reliability metrics on UVM programs.

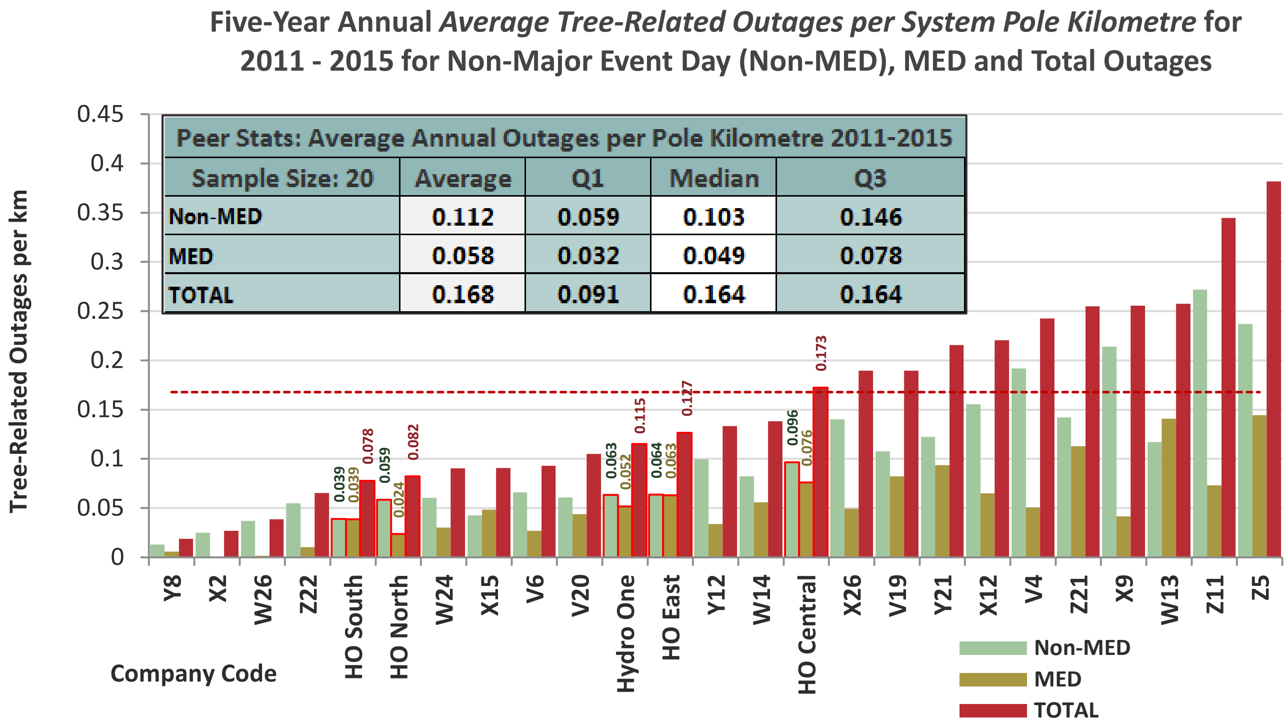
A majority, 54%, of companies, are using SAIFI (System Average Interruption Frequency Index) as a measure of performance in their UVM programs. Other indexes are used to a lesser extent. Recently, over the past decade, regulators started requiring utilities to report reliability metrics as a way to measure the performance of regulated utilities. 83% of utilities in the CNUC survey are reporting SAIFI to their regulator. Of particular interest to UVM are the separation of customer interruptions into Major Event Days (MED) and Non-MED. The threshold for MED is T_{MED} which is calculated with the Beta Method equation which involves the average of MED over a five-year period. Not all companies use this method, including Hydro One, who uses 10% of customers interrupted as the threshold for a MED. The following variables have a negative influence on reliability metrics and(Pacific Economics Group 2010) are all very common to Hydro One:

- **Weather**— South, East and Central regions are in path of common storm tracks in all seasons
- **Vegetation density**— 76 trees per km, which is above the peer average, nearly highest number of trees per customer (6 trees/customer)
- **Low percent of underground**—94% overhead
- **Low customer density**—lowest in peer group
- **Difficult terrain** –20-30% off road and 55% of off road is difficult to access
- **Industrial and Commercial Customer Influence** – Lowest percent of commercial and industrial customers in peer-group. Larger commercial and industrial commercial customers will pay a premium for better reliability and thus improve reliability of the system
- **Age of network**—high percent is beyond replacement age

This section provides comparisons of reliability metrics with peer groups, but any reliance on these comparisons should bear in mind the disadvantage that Hydro One has in regards to reliability metrics and that reliability metrics are a lagging indicator for performance in vegetation management, which is less cost effective to address after trees have encroached conductors and are causing more outages.

4.5.1 *Tree-Related Outages per System Kilometre*

The following graph, Figure 19, below, shows a less common reliability measurement that is more appropriate to UVM, although it is still a lagging indicator: outages per kilometre.



Peer Stats: Average Annual Outages per Pole Kilometre 2011-2015				
Sample Size: 20	Average	Q1	Median	Q3
Non-MED	0.112	0.059	0.103	0.146
MED	0.058	0.032	0.049	0.078
TOTAL	0.168	0.091	0.164	0.164

Figure 19: Tree-Related Outages per System Kilometre

This measurement indicates Hydro One is doing a better than average job of reducing the risk of trees causing outages across the Hydro One System. This Figure is analyzed and discussed further in Appendix E.

4.5.2 *IEEE Reliability Metrics for Tree-Related Outages*

The measurements for tree-related SAIDI (Figure 20 and Figure 21) and SAIFI are not as reassuring. Hydro One is in the fourth quartile in both non-MED SAIFI and SAIDI. Hydro One has improved from 2.9 hours (174 minutes) in 2003 to 2.3 hours (138 minutes) in 2015 for Non-Major Event Day (Non-MED) tree-related System Average Interruption Duration Index (SAIDI). This improvement has remained relatively steady since 2008 with a 2009-2015 average of 2.1 hours (126 minutes). In spite of improvements Hydro One still compares unfavorably with peers in the area of standard reliability metrics. Hydro One's 126 minute SAIDI average is more than twice as high as the peer average of 50 minutes for 2011 -2015.

Hydro One is currently scheduling UVM work to improve tree-related SAIDI and SAIFI. However, the prioritization of workload to accomplish reliability metrics improvement will not necessarily improve total UVM performance. See Appendix B for in-depth analysis of relationships between reliability metrics and UVM.

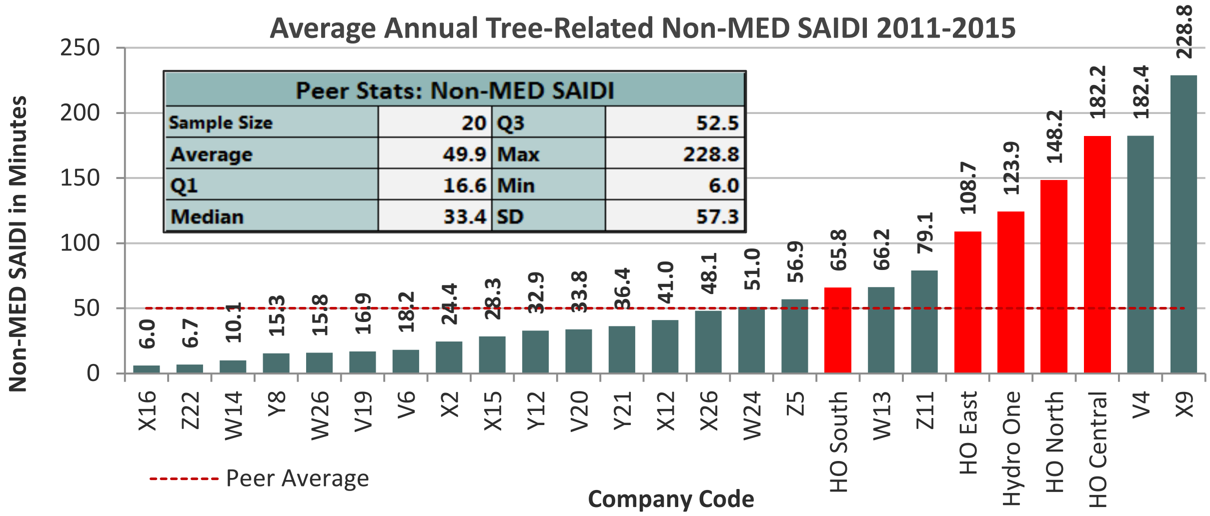


Figure 20: Tree-Related Non-MED SAIDI

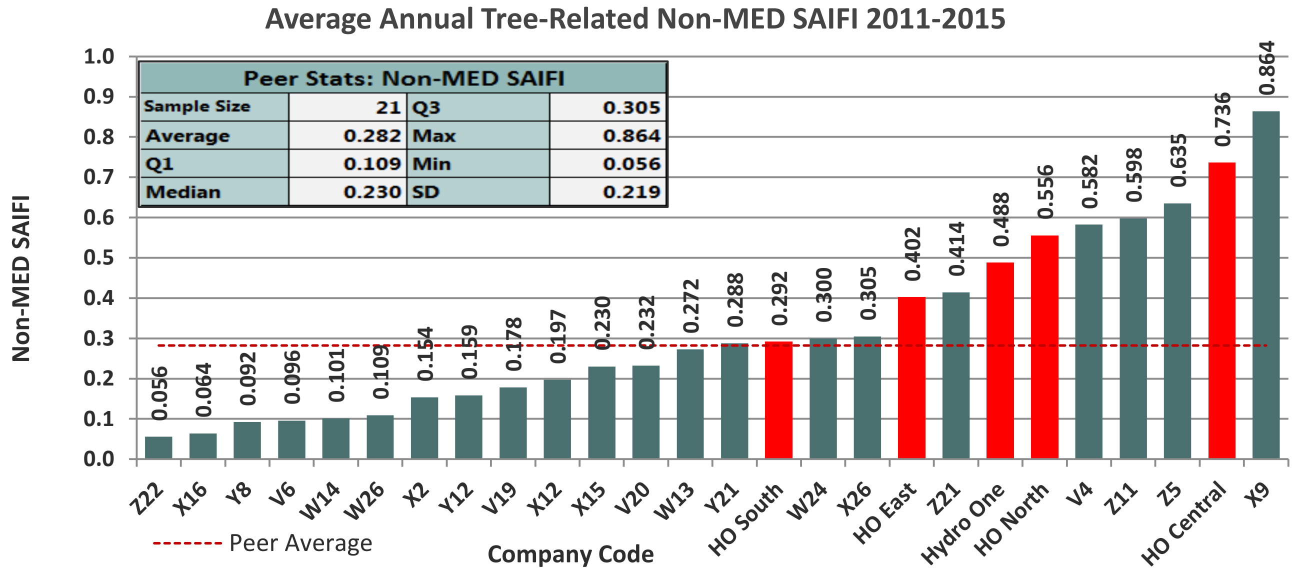


Figure 21: Tree-Related Non-MED SAIFI

There are other metrics that can be used as indicators of the reliability performance of a UVM program. For example, utility companies were asked whether they record what percent of trees are in contact. Few companies could produce this data. Trees in contact and trees overhanging conductors are condition-based metrics. Most companies estimate these measurements, but a few utilities record locations where trees are in contact or overhanging the conductors to better understand their workload and to measure the performance of the cyclical clearing work. This data also provides information about the growth characteristics associated with species, time of year pruning, local site differences and ecoregions, failure modes etc. Tree condition data can be correlated with reliability data to better understand proximity influences on reliability, particularly during ice and wind events. Lidar has been introduced most recently to provide tree condition data on distribution systems. Unmanned Aircraft Systems (UAS) hold promise for collecting Lidar data on distribution networks which have many times more kilometres than linear transmission, where Lidar measurement data has been collected with helicopters for nearly a decade.

The following graph (Figure 22) shows how important it is to recognize that vegetation management could be the leading edge in any program that seeks to reduce the reliability risk during storms. This is especially dramatic when comparing with the percent of Non-MED outages that are tree-related -- a dramatically lower percent of total outages (Figure 23 below). These are five-year averages and clearly the Central Region has a significant influence on both metrics. The effect of each region can be seen in the next section with longitudinal measurements (Section 4.4.3). The most striking finding in this is how vegetation becomes so much more relevant to reliability when there is a major event day. It suggests that better strategies should be developed for UVM resiliency against storms.

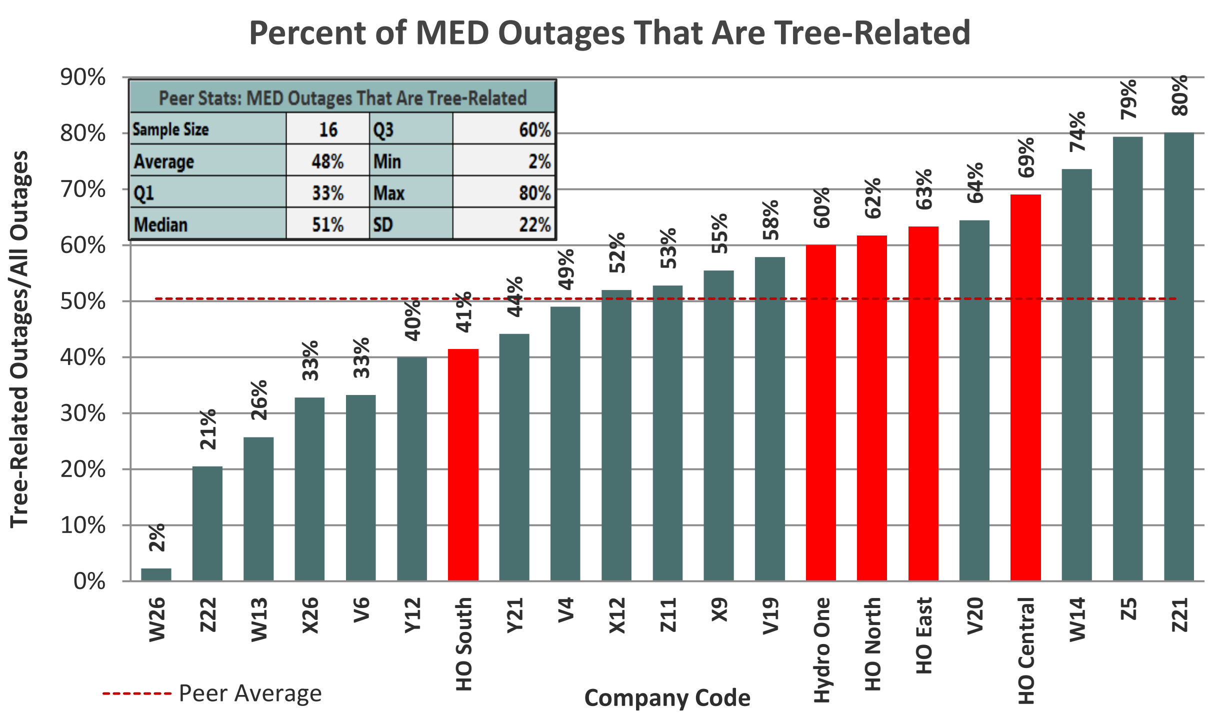


Figure 22: Percent of MED Outages That Are Tree-Related

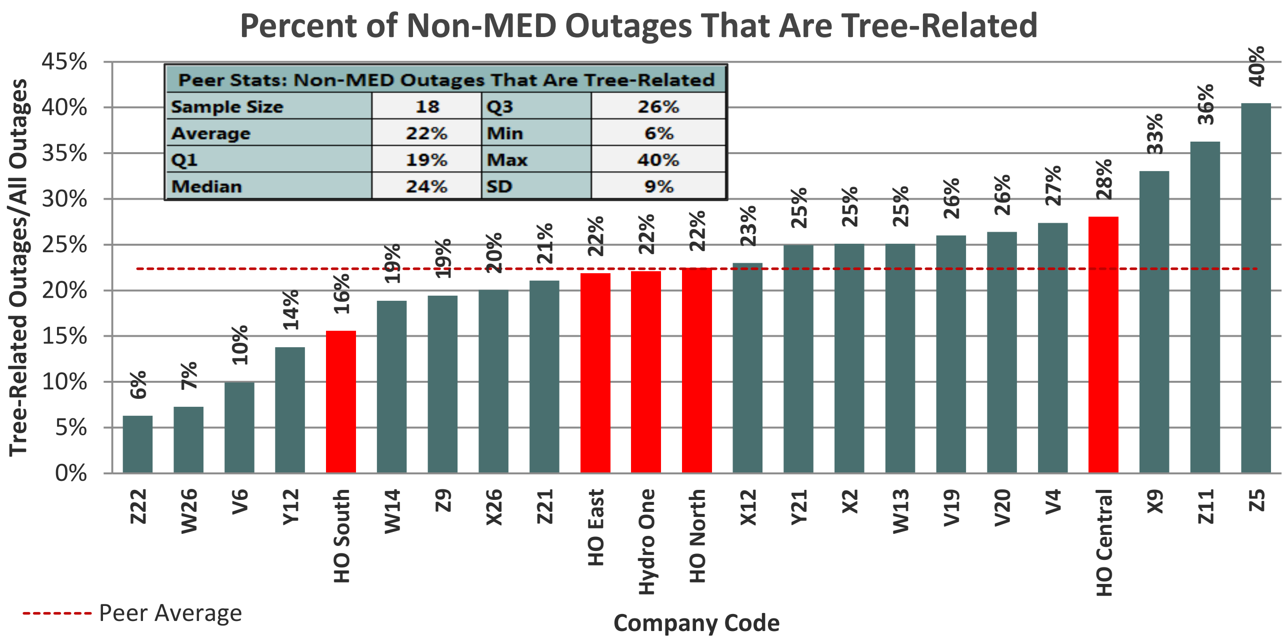


FIGURE 23: PERCENT OF NON-MED OUTAGES THAT ARE TREE-RELATED

4.5.3 *INDUSTRY AND LONGITUDINAL COMPARISONS*

Figure 24 (below) shows that the ratio of Non-MED tree-related outages to company outages has remained relatively static from 2011 to 2015. Although Hydro One and the peer average are similar performances in this metric, the Hydro One regions are not very consistent, with the exception of the South Region which has done well to keep the company at the average. Central is consistently a poor performer in regards to reliability and it would do well to fully evaluate its strategy for vegetation management.

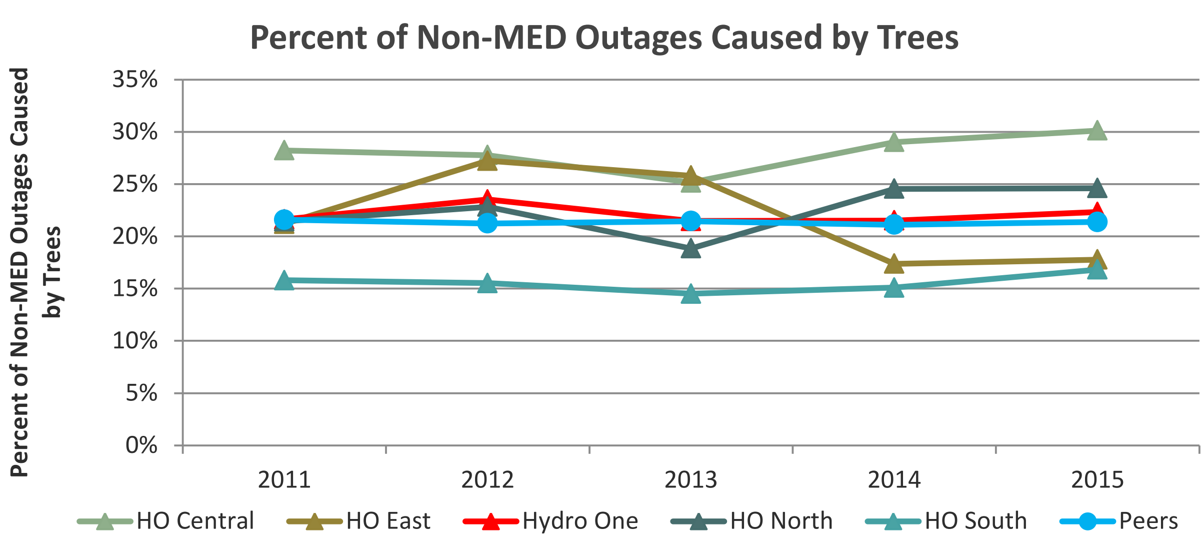


FIGURE 24: PERCENT OF NON-MED OUTAGES CAUSED BY TREES ON THE HYDRO ONE SERVICE TERRITORY 2011-2015

The percent of MED outages caused by trees (Figure 25 below) has also remained constant at Hydro One. It is an indicator that when a storm blows through the majority of restoration will involve distribution facilities damaged and interrupted by trees. In this measurement the peer group on average is improving from 51% down to 40% --an 11% improvement over the five-year period. Hydro One stayed much higher than the peer group at 64% of MED outages caused by trees. Central region has not been able to improve over the five years and nearly 70% of MED outages in the Central region are caused by trees. None of the regions are below the 2015 level of the peer group. Although Hydro One has a below average percent of outages per km caused by trees and the Non-MED tree-related outages are close to the peer average, MED tree-related outages are a high percent of the total and they are not improving. Major Event Day (MED) outages have dominated the worst years of Hydro One's tree-related outages, which escalated to as many as 17,200 in 2006 and 2013. In years with low MED outages, Hydro One has not been able to drop below 8,000 outages. Since Hydro One does not compare favorably with peers in either MED or Non-MED reliability metrics SAIDI and SAIFI, but has below average outages per km compared to peers, it will need to adjust its program to build more resiliency to storms while keeping the raw number of outages per km from increasing.

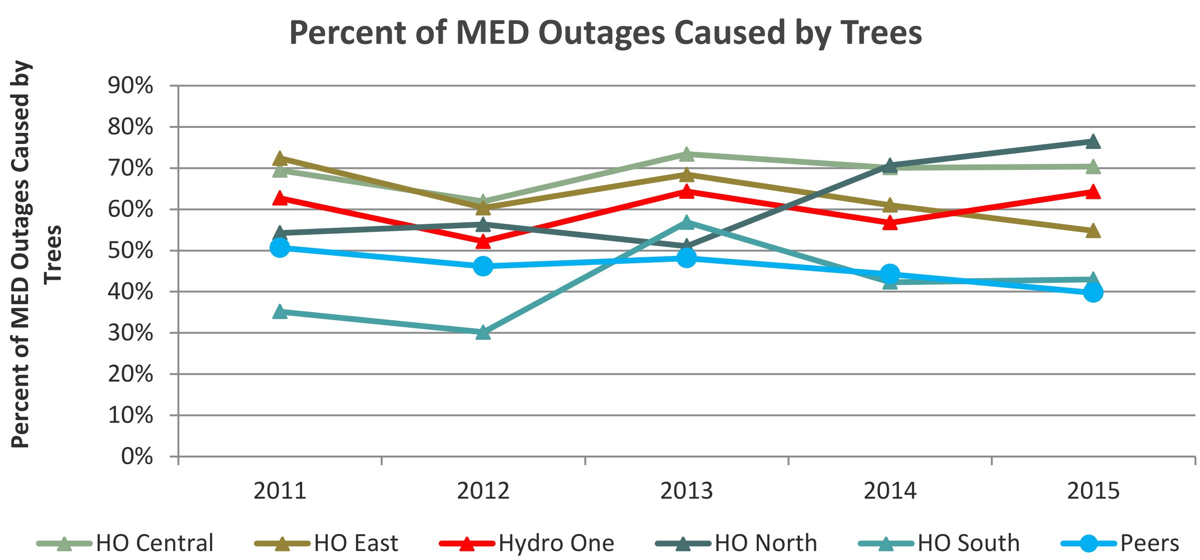


FIGURE 25: PERCENT OF MED OUTAGES CAUSED BY TREES ON THE HYDRO ONE SERVICE TERRITORY 2011-2015

Although Hydro One compares favorably using the metric of outages per kilometre, it will have to make improvements in reliability performance for the foreseeable future. First and foremost, the *UVM department* should be investigating tree-caused outages. Hydro One is the only utility in the survey where the vegetation management department does not investigate tree-related outages. It is also unknown how many tree-related outages are categorized as unknown or weather-related.

Outage investigations should be performed by trained forestry personnel and should be stored in a database. Areas of data capture and database development should include species, age, size, site conditions, tree failure modes beyond whole tree, branch and growth, measurements of ROW, whether tree is on or off ROW, description and condition of adjacent vegetation, investigation and analysis of external causes such as local weather and wind information. This program could be piloted on a stratified random selection of outages to limit costs and accentuate the focus on both high priority feeder outages and the variety of outage settings found on infrequently managed single and two-phase lines. A modeling program based on the outage investigation database will help identify tree failures before they happen and this will be more effective than removing all suspected trees in and off the ROW. The models should be used to improve the tree risk assessment program.

4.5.4 Reliability Improvement Targets

Hydro One was asked to explain the poor relative reliability performance in Central Region and they supplied the following response:

- The Central Region is covered by heavy tree density.
- Most of operation centers in the Central Region have radial distribution lines, which means lack of alternate feeding and switching capability compared to other regions
- The Central Region is in the path of normal storms that goes through Ontario
- Other design, planning, protection, and control issues

Given the metrics provided are accurate; Hydro One should focus on resiliency improvements to the Central Region where reliability issues are more prevalent.

4.6 Safety as a Priority

For the purposes of this report safety is evaluated as a performance metric and as elements of program design. Hydro One's performance in the field is compared with the peer group and the industry at large. Hydro One's UVM program is also compared to peers for how well safety risks are minimized to the public and line clearance workers.

4.6.1 Safety Performance

In general Hydro One's performance over the past five years falls short of the perfect incident rate (0 accidents) recorded in 2008 when CNUC performed a benchmark survey. However, some indicators suggest Hydro One's program is less likely to incur lost time accidents than other programs. Hydro One maintained a low accident severity rate and zero fatalities. Hydro One has one of the lowest employee turnover rates of the peer group. An extensive training program also is evidence that Hydro One reduces the risk of accidents occurring. Several studies have found that accidents increase proportionally to employee turnover and disproportionally to employee tenure: "[T]he weight of research evidence seems to overwhelmingly show a relationship between job tenure and accidents (Burt, 2015)." A high percent of incidents involves employees in their first year and many leave the line clearance industry because they perceive it to be too unsafe.

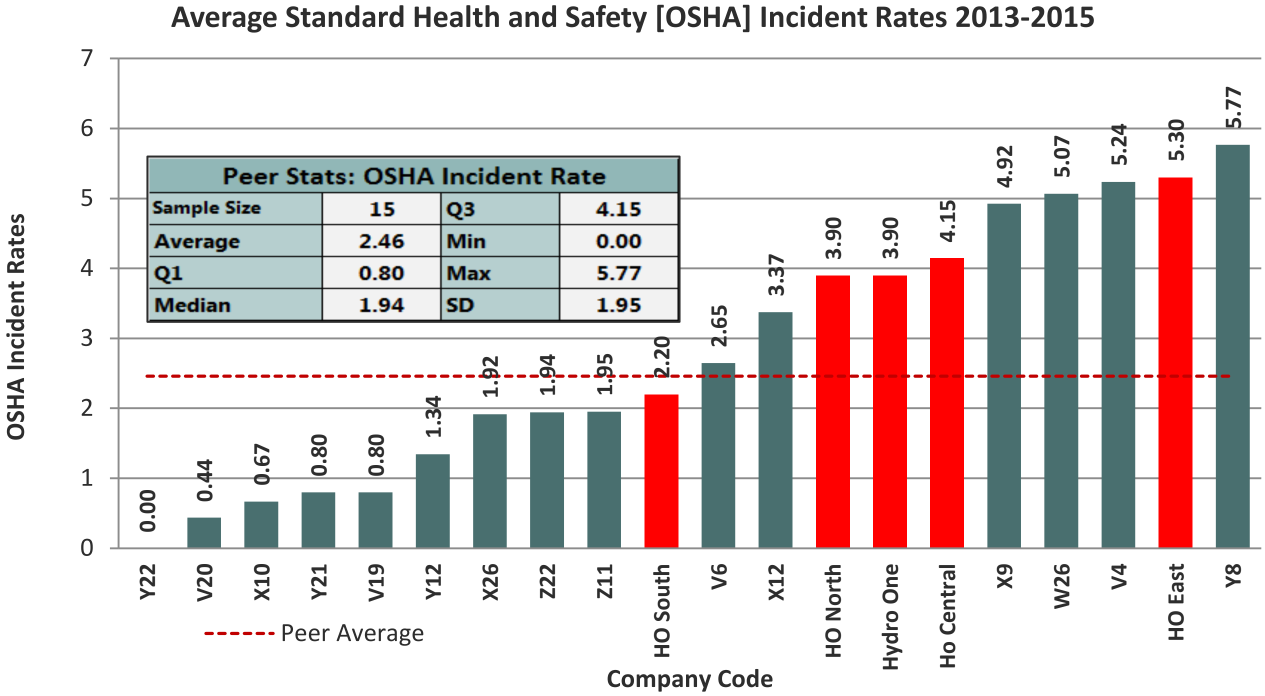


Figure 26: OSHA Incident Rate Comparisons 2013-2015

Hydro One has succeeded in minimizing the turnover rate and this can be associated with the zero accident frequency and severity rates that were reported in the 2009 study for the OEB. The current survey found the average turnover rate for the peer group is 32% for line clearance personnel compared to Hydro One which is 5%. Hydro One's incident rate was 3.90 incidents/100 FTE for 2013-15 (East region reported 5.30 incidents/100 FTE) (Figure 26 above). The average for the peer group was 2.46 incidents/100 FTE. However, recent statements and actions by OSHA in the US indicate incident rates may not be accurate for the tree care industry, which includes line clearance. Beginning in November 2016, new rules apply to incident reporting that are designed to improve accuracy of reporting. Accident Severity Rates were not reported by many survey participants. Of the nine peer companies who did report, the average severity rate 2013-2015 was 31.36 lost days/100 FTE (Figure 26 below). If companies reported rates for multiple contractors the worst rate was used for this comparison. Hydro One's severity rate was 7.9 lost days/100 FTE average for 2013-2015. It should be noted that regression analysis of employee turnover rate and incident severity rate for these nine companies showed a high correlation ($R^2 = 0.643$, $R = 0.802$, $p < 0.001$). This finding is also supported by multi industry studies which have found high correlations between accident rates and employee tenure.

Combined, the Hydro One incident rate and severity rate indicate some need for improvement at achieving the benchmark for limiting injury accidents. However, the low severity rate at Hydro One indicates there is still a high level of safety on the job. The accident frequency rate for the South region is below the average for the peer group and North Region is above average and is at the low-end of the third quartile. More problematic for Hydro One is the Central Region accident frequency and severity rates. The Central Region severity rate, 21.6 lost days/100 FTE, is below the peer average, 31.36 lost days/100 FTE, but it is still an indicator that safe work improvements are needed. The incident rate for

Central Region is at the upper end of the third quartile and the East Region, which is the second highest on the chart. Why has there been an increase in the incident rate over the period of this study,

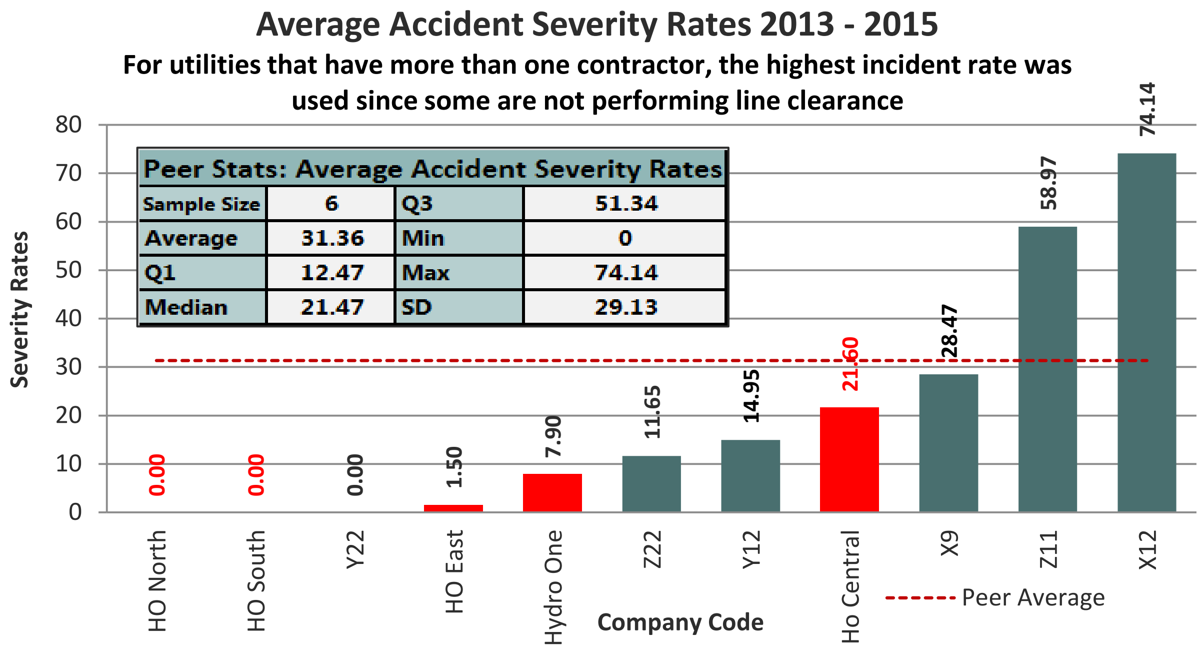


FIGURE 27: AVERAGE ACCIDENT SEVERITY RATES 2013-2015

particularly for the East and Central Regions? First, there has been greater reliance on temporary employees and a decreased reliance on in-house trained personnel. However, the safety data is not comprehensive or conclusive. Second, Hydro One stepped up the effort to decrease the cycle length through greater numbers of inexperienced employees and higher expectations for production, particularly in the Central and East regions. Fluctuating budgets changes the employee count and increases potential for some employees not to consider the employment permanent, which may have a negative influence on the safety culture. Higher stress levels with employees who are required to move around the province to maintain M and F class feeders on a more frequent basis. Increases in the number of backlogged kilometers worked each year that are past the target cycle length. Worker safety is affected by program changes. We recognize program improvements designed to improve safety in the work place, but we are not always cognizant of the unintended consequences of program changes that affect safety.

Hydro One is required to report the number of serious electrical incidents that occur on their system each year. An average of six per year was reported to the OEB for 2010-2014. Although the survey requested information related to vegetation and electrical contacts, only two peer companies could provide information. One company stated 0 incidents occurred over the past five years. Another stated no more than one to two per year and that these incidents are usually the fault of the victim, not the result of poor maintenance or system defects. Hydro One could not state whether contacts involving vegetation occurred on their system. 67% of peer companies report the rate of occurrence is unknown. 71% of companies, like Hydro One, do provide many public service announcements that discourage removing trees or branches near powerlines. 19% of companies provide electrical hazards awareness training to non-line clearance arborists. Hydro One did not report they provide this service. Another 19% said they do not frequently and/or effectively communicate safety concerns of trees and powerlines. Hydro One was not in this group.

Many companies in the survey consider safety to be the business of their contractors and a few said they supplement the contractor's programs with company-initiated safety training. Hydro One has 40-50 hours of safety training for their employees, which is more training hours than any participant in the survey reported for in-house or contractor employees.

92% of peer utilities plus Hydro One reported that they track safety metrics. The following are metrics tracked:

- All companies: Accidents, contractor-caused outages, vehicle incidents, and non-reportable incidents are included in their statistics
- Six companies: Web-based program that contractors use to enter incidents and calculate safety statistics
- Most companies: have quarterly meetings and contractors submit accident logs
- Two companies: Utilize near-miss reports.

Three companies in the survey (Hydro One, one peer, and one non-peer) had more extensive monitoring. These include frequent safety audits, internal safety specialists, and frequent departmental safety meetings. Hydro One is distinguished by having an in-house workforce that is more directly connected to safety monitoring and initiatives promoted within the company.

4.6.2 UVM Program Safety

The most important safety monitoring metrics and arguably a best management practice for documenting a successful program are leading indicators that measure safety in performance. Documented completion of specific task-oriented and performance-based training programs are an example of a leading indicator. Other examples could be certification and continuing education units through a third-party administered safety training program; new employee apprenticeship programs that audit the trainers and ensure new employees receive consistently adequate hands-on training and documented proficiency measurements; ongoing hazards and skills training that is specific for the work that the employee performs and appropriate training provided when an employee changes job duties.

Other leading indicator safety metrics are policies that specify the activities of the UVM program. Based on the responses of the peer group and a few of the non-peer group, there is a direct and positive relationship between UVM program policies regarding clearances between vegetation and conductors and the safety of the public and utility arborists.

Is a tree in contact with a powerline a safety issue? The following language is from Ontario Infrastructure Health and Safety Association (IHSA) of which a Hydro One employee was a board member at the time of this publication.

> ***The Line Clearing Operations Safe Practice Guide*** *(Infrastructure Health and Safety Association 2008)*
> *Should a limb still attached to a tree be found in contact with a conductor energized above 750V:*
> - *the tree should not be climbed directly from the ground*
> - *clearing should be done using live line equipment from the ground, from an aerial device or portable non-conductive ladder*
> - *the circuit should be isolated and de-energized prior to limb removal*

From a safety and economic perspective, preventing trees from being in contact with conductors should be a best management practice. The alternative is that trees *could* be climbed by a line clearance worker or someone else, when it is in contact, that a utility tree worker's electrical hazard exposure is increased by trees in contact, and that to follow proper protocols by de-energizing the line would be more expensive.

The topic of maintaining clearances is discussed in several places in this report with compelling arguments for why it is important, but there is probably no data that is as compelling as the 90% of survey respondents reporting that they believe a required airspace around conductors would be a *significant* improvement to the safety of the distribution system. A third of these UVM experts, who collectively manage a significant percent of the kms of distribution lines in North America, stated they have a requirement for airspace and it has improved worker safety significantly. A smaller percent, but a solid majority, 64%, of respondents said that clearance duration requirements play a role in over-all program safety. Multiple commenters stated that longer cycle lengths increase the probability of an incident.

4.7 Recommendations for Measuring and Determining a Risk Acceptance Level

In the future, it is recommended that a standard of care be documented that provides the acceptable level of risk reduction from vegetation conflicts with powerlines. It is also recommended that customers be notified of what responsibilities they have relative to the risk reduction. Some metrics should be introduced that measure the performance of UVM in achieving objectives. The following are suggestions for metrics, analysis, data collection, and databases:

- Create a tree-related outage database and analyze types of tree failure and weather conditions to support annual reliability report.
- Set a target percent limit for trees in contact found during annual audit inspections with corrective action measures.
- Create a customer vegetation transaction record that defines workload per customer.
- Keep a record of customers who refuse standard UVM work for pruning, removing trees or applying herbicides.

- Use a statistical process control calculator to continuously monitor km productivity with corrective action plans for work that falls outside of two standard deviations.
- Have a target percent reduction of tree density measured for each km (or by circuit) over each cycle of management with a corrective action plan if density is increasing.
- Create an annual reliability report for tree-related outages delineated by outage risk. Metrics such as tree-related SAIDI and SAIFI that are biased to customer densities should be evaluated cautiously because Hydro One's system has very a low customer density, which biases IEEE reliability metrics, and reliability performance is also related to other measures. Outage data statistics could include at-risk customers, heavy load circuits, outages on circuits with a long duration response time, time since last UVM maintenance for each tree-related outage, frequency and interval averages for outages by circuit. The report should be scored as 'improved' or 'not improved' over previous year(s) based on a variety of metrics.
- Publish an annual report of innovation and initiatives which is effective at bringing stakeholders and customers into partnership with UVM objectives. There should be a net reduction of tree density involved plus an enhanced environmental quality and a customer satisfaction metric.
- Document the Tree Risk Assessment Program that targets hazardous trees at the edges and beyond the ROW with target outage reductions by circuit and voltage class.

4.8 2022 Model Cost Projections

See Appendix D: Statistical Methodology and Model Development - Projections of Unit Costs for Hydro One for details on model development

Three different budget projections were developed based on levels of risk.

- **Risk Model A:** This model is at the *highest risk* level. It is a model built on the current scheduling methodology, which targets M-Class feeders and three-phase (3Ø) lines. This methodology will get the high priority lines on schedule, but the single and double phase will fall farther behind resulting to a 14.9 year cycle on average for this part of the distribution system.
- **Risk Model B:** This model is a *moderate risk model*. This model expands the Risk Model A by continuing the backlog and cyclical work on the M-Class and 3Ø lines, but will also increase the work on the single-phase and double-phase lines to keep this part of the system closer to the 9.5 year (on average) cycle.
- **Risk Model C:** This model carries the *least risk* and produces a more storm resilient system. It gets all of circuits on target cycles by obtaining an eight-year cycle (ten in the North region) for single and double-phase circuits.
- **BMP Model D:** This model produces a more storm resilient system with greater returns. It gets all of circuits on target cycles by obtaining a six-year average cycle for single and double-phase circuits.

4.8.1.1 Budget Projections for Each Model

MODEL	Risk Model A Highest Risk Model		Risk Model B Mid-Risk Model		Risk Model C Lowest Risk Model		Model D BMP Model	
	Annual Cost Projections	Annual Kilometres Completed	Annual Cost Projections	Annual Kilometres Completed	Annual Cost Projections	Annual Kilometres Completed	Annual Cost Projections	Annual Kilometres Completed
2017	$150,217,259	12,000	$166,458,286	13,973	$174,912,181	15,000	$192,914,780	17,167
2018	$152,725,887	12,000	$169,238,140	13,973	$177,833,215	15,000	$196,136,456	17,167
2019	$155,276,410	12,000	$172,064,417	13,973	$180,803,029	15,000	$199,411,935	17,167
2020	$157,869,526	12,000	$174,937,892	13,973	$183,822,440	15,000	$202,742,115	17,167
2021	$160,505,947	12,000	$177,859,355	13,973	$186,892,275	15,000	$206,127,908	17,167
2022	$163,186,396	12,000	$180,829,606	13,973	$190,013,376	15,000	$209,570,244	17,167

TABLE 5: BUDGET PROJECTIONS THROUGH 2023 FOR RISK MODELS A, B, C, AND D

Note: All four models were developed using exclusively Hiring Hall or contract labour for single and double-phase work. It is recommended that the lower safety risk work (planning, brush, and herbicide) be performed by contracted labour and that the higher safety risk work continue to be performed by in-house crews. *The costs for Risk Models B-D would increase by between 10% - 15% with the suggested labour mix.*

5 CONCLUSIONS

Hydro One's routine maintenance costs measured by system kilometre are one standard deviation *above* the peer average. Hydro One's expended labour hours per system km is nearly one standard deviation *below* the peer average. This differential is the result of the following factors (the first three explain the cost deviation and the last three explain the labour efficiency):

- The accumulated biomass and heavy workload after a long interval between maintenance cycles.
- A higher cost of labour and equipment compared to the peer group, all of which outsource UVM program implementation, with the exception of one other company.
- Hydro One reports overhead/administrative costs better than their peers, since they are completely in-house. The peer group does not report indirect costs on the UVM program. Comparators only report the direct costs to run the UVM department plus the cost of the contractor.
- Hydro One management organizes work and crews perform ROW maintenance more efficiently than the majority of the peer companies.
- Hydro One's long cycle of maintenance has resulted in fewer labour inputs per system kilometre than shorter cycle programs.

- The historical practice of clearing the full width of the ROW, a shorter growing season in 50-75% of the system, and a third of the system is in agricultural areas where tree density is low are all factors that contribute to a more labour efficient management.

The result of Hydro One's UVM program is 32% fewer outages per kilometre than the average of the peer group. Hydro One did not report a history of fires caused by powerline contacts, electrocution accidents involving trees and power lines, or other incidents related to the close proximity of powerlines and trees. The absence of such incidents and the employee safety record are testaments to the success of their program.

Despite the positive results of Hydro One's UVM program, there are areas that are in need of improvements, because:

- Some aspects of the program are not sustainable over the long-term
- Risk is increasing on parts of the system, and
- The environment and the customer are driving UVM programs to a higher level of performance than the past.

The positive outlook is that 50% of the system is targeted for a consistent schedule (4-8 year cycle) of maintenance that includes the highest priority and largest load kilometers on the system, M-Class and non-M-class feeders. Over the next six years all of the backlog of work for this half of system will be brought up to date. This requires 8,500 kilometres of M-Class and non-M-class feeders to be managed each year.

The areas that are in need of improvement are the other half of the system, which is composed of single and two-phase lateral primaries and associated secondary lines that feed residential and commercial customers. Under the current plan only 3,500 kilometres of these lines will be managed each year for the next six years. This will put the second half of the system further behind and the annual increment of work will be the equivalent of a 15-year cycle of management. This is a rational approach to cope with a reduced budget. Although greater efficiencies can improve the execution of the program, it will not be enough to offset the reductions in program expenditures. Additionally, the new schedule will increase the risk of outages occurring on the single and two-phase lines.

The highest priority recommendation from this study is that Hydro One should strive to bring all of its system to a 4-8 year flexible cycle that is trued up each year to ensure backlogs do not creep back into the schedule. The current plan to prioritize the M-Class and feeder system is appropriate if sufficient attention can be given to the rest of the system. This may require greater expenditures in the future and an increase in the number of lower cost hiring hall or contract personnel. In the short-term, the single and two-phase system should be worked on an eight to nine-year cycle of management instead of a 15 year cycle. This would require increasing the annual increment from 3,500 to approximately 6,000 kilometres. The program could be ramped up 500 kilometres each of the six years after which additional resources can be reassigned from the M-Class and feeders. These will be managed under a six-year IVM cycle and require fewer resources to keep cleared.

6 LIST OF APPENDICES

Appendix A: CNUC Team Qualifications and Experience

Appendix B: Study of Reliability Metrics' Influence on UVM Programs

Appendix C: Peer Selection

Appendix D: Statistical Methodology and Model Development

Appendix E: Climate Change and Storms

Appendix F: Tree Risk Assessment Analysis

Appendix G: Tree Risk Assessment Survey Results

Appendix H: Distribution Survey Results

Appendix I: Benchmark Study Process Chart

Appendix J: Longitudinal and Comparative Analysis of Hydro One Data

7 ACRONYMS AND GLOSSARY

7.1 ACRONYMS

22/04: Ontario Regulation for Electrical Distribution Safety

ATV: All-Terrain Vehicle

BMP: Best Management Practices

CAD: Canadian Dollars

CAIDI: Customer Average Interruption Duration Index

CNUC: CN Utility Consulting

DBH: Diameter Breast Height

FERC: Federal Energy Regulatory Commission

FTE: Full-time employees

IEEE: Institute of Electrical and Electronics Engineers

IEEE-1366: IEEE Electrical System Reliability Indices (e.g. SAIDI, SAIFI, CAIDI, etc.)

IPM: Integrated Pest Management

IVM: Integrated Vegetation Management

km: Kilometre

km^2: Square kilometre(s)

M: Million

MED: Major Event Days

NERC: National American Electric Reliability Corporation

Non-MED: Non-Major Event Days

O&M: Operation and Maintenance

OEB: Ontario Energy Board

OH: Overhead

PIM: Performance Incentive Mechanism

PPE: Personal Protective Equipment

R&D: Research and Development

ROW: Right-of-Way, Rights-of-Way, Right-of-Ways

SAIDI: System Average Interruption Duration Index

SAIFI: System Average Interruption Frequency Index

T_{MED}: Major Event Day Threshold

TRA: Tree Risk Assessment

UG: Underground

USD: United States Dollars

UVM: Utility Vegetation Management

7.2 GLOSSARY

Barriered: "Barriered" means separated by clearances, burial, separations, spacings, insulation, fences, railings, enclosures, structures and other physical barriers, signage, markers or any combination of the above (OEB, 2004)

Cause code: Code for reporting the initiating condition for electrical interruption

CAIDI: Customer Average Interruption Duration Index

$$\text{CAIDI} = \frac{sum\ of\ all\ customer\ interruption\ durations}{total\ number\ of\ customer\ interruptions} = \frac{SAIDI}{SAIFI}$$

DBH: Diameter Breast Height as a measurement of the size of a tree

FAC-003: Electric Transmission Vegetation Management Regulation in North America

F-Class: 27.5 kV, three-phase feeders

In-growth: The volume of new trees growing into the minimum dbh size class during the measurement period [cycle]

IVM: A systematic integrated approach to managing vegetation, which includes controlling vegetation in the ROW by removal of inappropriate species, discouraging re-growth or in-growth, and planting and maintaining of appropriate tree species

OSHA RECORDABLE INCIDENT RATE (IR): a mathematical calculation that describes the number of employees per 100 full-time employees that have been involved in a recordable injury or illness.

$$\text{OSHA RECORDABLE INCIDENT RATE} = \frac{Number\ of\ OSHA\ Recordable\ Cases\ x\ 200{,}000}{Number\ of\ Employee\ Labour\ Hours\ Worked}$$

M-Class: 44kV feeders, sub-transmission

Managed kilometres: The number of overhead (OH) lines managed on an annual basis.

Trees treated: The same as trees managed and includes both trees pruned and trees removed

SAIDI: System Average Interruption Duration Index

SAIDI= $\frac{sum\ of\ all\ customer\ interruption\ durations}{total\ number\ of\ customers\ served}$

SAIFI: System Average Interruption Frequency Index

SAIFI= $\frac{sum\ of\ all\ customer\ interruptions}{total\ number\ of\ customers\ served}$

System kilometres: The number of overhead (OH) kilometres in the distribution system.

Tree Density: Tree density = Average number of trees managed per kilometre each year.

Work Planning: Same as Pre-Planning

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APPENDIX A: CNUC TEAM QUALIFICATIONS AND EXPERIENCE

PROJECT TEAM MEMBERS:

William Porter, Project Lead and Chief Consultant

Nina Cohn, Data Analyst

Both project team members participated in the Hydro One 2009 UVM benchmark project

WILLIAM PORTER, PROJECT LEAD AND CHIEF CONSULTANT

- Director of Research, Development and Industry Intelligence (RDII) at CN Utility Consulting, Inc. (CNUC)
  - CNUC consults internationally with utility companies, vendors, lawmakers and regulators on all issues related to utility vegetation management (UVM)
- With more than 25 years of experience in the utility vegetation management (UVM) industry, Porter has direct knowledge of all aspects of UVM work
- Directed program and compliance reviews and special projects
- Performed analysis on a wide range of UVM metrics
- Principal author of the 2010 *CN Utility Consulting Utility Vegetation Management Benchmark and Industry Intelligence*
- Often presents on UVM benchmarking and LIDAR projects and other industry topics in the U.S. and abroad.
- Continuously monitors and evaluates legal and regulatory changes, as well as issues and trends related to UVM around the world.
- Led a research project for the Centre for Energy Advancement through Technological Innovation (CEATI) on *Data Analytics and Modeling Tools Applied to UVM Programs.*
- Serving on a task group to revise the ANSI Standard Z133, the *American National Standard for Arboricultural Operations – Safety Requirements*.
- Provides support to legal cases for CN Utility Consulting, tracks legal cases involving UVM in the U.S. and has participated in several legal cases as a witness.
- Has 15 years of line clearance experience, starting as a ground-person and advancing to supervising crews for 11 of those years. He was employed for Davey Tree and Wright Tree Service in Colorado and Iowa for most of these years, as well as supervising storm restoration throughout the US.

EDUCATION AND TRAINING

Education

Attended arboricultural and utility vegetation management seminars over the last 22 years

2003	General Foreman's School, Wright Tree Service
1997	Davey Institute of Tree Sciences
1976-1986	Post Graduate Studies at University of Illinois and University of Colorado
1975	Bachelor's Degree, University of Illinois, Urbana, Illinois

Certifications

1997-2009	Certified Pesticide Applicator
2006	Certified Proctor of ISA Certification Exams

2003	ISA Certified Utility Specialist
1996	ISA Certified Arborist
	International Society of Arboriculture: Certification # MW-0620AU

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1. Porter, W. (2016, June). *The Measure of UVM*. Transmission & Distribution World: Vegetation Management Supplement, pp. 14 – 19. http://tdworld.com/td-world-magazine/2016-03-31-0

2. Porter, W. (2015, May/Jun). *Regulatory Changes to Utility Vegetation Management in the US*. Utility Arborist Newsline, 6(3), pp.24-28.

3. Porter, W. H., & Cohn, N. L. (2014, October). *A Study of Data Analytics and Modeling Applied to Utility Vegetation Management Programs*. Montreal, Quebec, Canada: CEATI International, Inc.

4. Porter, W. (2014, June). *Higher Expectations Drive UVM Mandates*. Transmission & Distribution World: Utility Vegetation Management, 14-16 (104-106). http://tdworld.com/june-2014#104

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NINA COHN, DATA ANALYST

- Nina Cohn, Senior Analyst for CN Utility Consulting, provides data and statistical analysis for reports.
- Cohn earned degrees in Mathematics and Sciences with work experience in entomology research, biochemistry research, and mathematics instruction.
- She taught Mathematics for over 14 years at Community Colleges in Denver, Colorado and Des Moines, Iowa.
- Cohn began working in the utility vegetation management field in 2009 by analyzing benchmark data for the publication, *"CN Utility Consulting Utility Vegetation Management Benchmark and Industry Intelligence."*
- The current benchmark report, *2011-2012 Cumulative Distribution CN Utility Consulting Benchmark Survey Report,* is co-authored by Nina Cohn and William Porter.
- Her statistical analysis has also been utilized in a Canadian rate case, consulting projects, numerous utility vegetation management (UVM) program reviews, and reports conducted for CNUC.
- Cohn co-authored a 2014 research project for the Centre for Energy Advancement through Technological Innovation (CEATI) on *Data Analytics and Modeling Tools Applied to UVM Programs.*
- Cohn's background in the math and sciences lends a distinctive skill-set to the UVM industry.

EDUCATION AND TRAINING

- University of Illinois, 1975
  Bachelor of Science in Physiological Psychology, Minor in Chemistry

- University of Colorado at Denver,1987
  Mathematics Degree and Teacher Certification in Mathematics and Sciences

PARTIAL LIST OF PUBLICATIONS

1. *Fluidity of LM cell membranes with modified lipid compositions as determined with 1,6-diphenyl-1,3,5-hexatriene.* Reid Gilmore, Nina Cohn, Michael Glaser. *Biochemistry*, 1979, 18 (6), pp 1042–1049.
2. *Rotational relaxation times of 1,6-diphenyl-1,3,5-hexatriene in phospholipids isolated from LM cell membranes. Effects of phospholipid polar head-group and fatty acid composition.* Reid Gilmore, Nina Cohn, Michael Glaser *Biochemistry*, **1979,** *18* (6), pp 1050–1056.
3. Acknowledged in several articles in *Biochemistry, Journal of Biological Chemistry,* as well as articles in Entomology and Physiological Psychology.
4. CNUC. (2010). *Utility Vegetation Management Benchmark & Industry Intelligence.* Des Moines: CN Utility Consulting.

5. CNUC (2014) *2011-2012 Cumulative Distribution CN Utility Consulting Benchmark Survey Report.* Des Moines: CN Utility Consulting.

Utility Vegetation Project Portfolio (Partial List)

William Porter was the Lead on all these projects. All Projects Included a Written Report.

1. Hydro One
   - Performed benchmark analysis for *Hydro One 2009 - Vegetation Management Benchmarking Study.* Retrieved from http://www.hydroone.com/RegulatoryAffairs/Documents/EB-2009-0096/Exhibit%20A/A-15-02_Attachment_1.pdf
2. United Illuminating
   - Sorted and cleaned LIDAR data supplied by LIDAR acquisition company to make field ready. These sorts were done to desired clearances and rights-of-way (ROW) widths
   - Developed methods to determine how many trees were represented and to eliminate duplicate LIDAR information
   - Developed methods to input data into field software to aid inspectors in organizing field work
3. Connexus Energy
   - Organized and analyzed data supplied by Connexus to answer specific questions posed by the utility
   - Analysis proved crucial to presenting a business case to increase the UVM budget
4. Reports for Internal and External Stakeholders
   - Produced numerous statistical reports on specific topics for utilities and for use by CNUC personnel
5. The Centre for Energy Advancement through Technological Innovation (CEATI)
   - Co-author and co-researcher of *A Study of Data Analytics and Modeling Tools Applied to UVM Programs,* a research project funded by CEATI (William Porter primary author)
   - Performed a Literature Review for the research project
   - Helped develop a survey for the project
   - Analyzed the data collected from the survey
   - Developed a template for UVM managers to aid in the incorporation of data analytics into UVM programs
6. Greencoat Capital
   - Benchmark Study of LiDAR use in North America and the United Kingdom
   - Helped develop a survey for the project.
   - Analyzed the data collected from the survey.
   - Performed market research.
   - Co-authored final report (William Porter primary author)
7. Ameren Illinois (AIC) Project One
   - Benchmark Study of UVM programs in North America
   - Helped develop a survey for the project.
   - Analyzed the data collected from the survey.
   - Secondary author of final reports (William Porter primary author)
8. Ameren Illinois (AIC) Project Two
   - Researched and analyzed data for three white papers for AIC's UVM program
   - Modeled return on investment and capitalization of UVM program enhancements
   - Secondary author of final reports (William Porter primary author

Appendix B: A Study of Reliability Metrics' Influence on UVM Programs

A decade ago, utility vegetation management (UVM) subject matter experts were encouraging utility executives to realign their UVM programs for measureable reliability benefits. It was suggested this realignment would result in lower costs and bring UVM out of the industrial age and into the technological realities of modern business management. The most significant and clearest measure of reliability improvement has been with extra high voltage transmission, because the internationally mandated FAC-003 standard has spurred utilities to achieve specific results. FAC-003 affected transmission lines, which account for about 3% of the total miles of overhead power lines in the US, but what about the other 97% of miles of overhead T&D electric lines in the US?

Although the bright light of business models, including economies of scale and process management, has been shined into the voids of UVM performance, there is no consensus that the industry has given birth to the golden age of utility arboriculture. Young arborists, some freshly trained on UVM, are still put to daily task to work around lethal conductors engulfed in vegetation. Utility arborists, scolded by the public for being butchers, continue to wonder why the industry does things the way it does them. Every year, a few go to work and never return. Many more tree workers lose their lives or are injured because they made contact with electrical energy, often not knowing the wires were there.

Studies conducted to evaluate how UVM has conformed to reliability data revealed several interesting findings:

- Reliability improvement is correlated with increases in customer density .
- Reliability-centered maintenance (RCM) applied to UVM may shift focus away from other objectives, such as safety, fires, environment and the customer.
- When UVM programs are prioritized to improve reliability metrics, long-term UVM workloads are likely to increase
- An increase in tree-related outages can occur at the same time reliability is improving.

The need to apply computer-enabled technology to UVM has coincided with the adoption of IEEE-1366. The Interruption Cost Estimate (ICE) calculator designed by the Department of Energy (DOE) reinforces the nexus between data-driven UVM and a burgeoning growth of reliability data. It would be imprudent to discourage actions that prevent outages that affect large electric loads. However, it is also important to recognize that the priorities of electric system reliability are not the only motivation for performing UVM. The consequences of applying electric system reliability metrics to UVM should be fully vetted. Is it okay that RCM encourages UVM policies that increase the frequency that outages occur? Improvements for relative reliability and improvements for absolute reliability are two separate outcomes that both require adequate planning and resources to achieve.

The following discussion demonstrates the theory, the logic, and the empirical evidence that the industry should be supporting UVM beyond the current reliability-centered maintenance (RCM).

Theory:
In *theory*, UVM programs operate upon a set of objectives that are established to support a mission and vision for a utility company. These objectives are collectively the driver and benchmark upon which the program is measured and implemented in a continuous spiral of improvements. Objectives provide the theoretical framework behind UVM. Without such a framework UVM would be reactions to system failures and liability. The cost alone of reactive UVM has driven UVM programs to become more preventative. To be preventative one must have a plan based on a theory of objectives, strategies and results.

Logic:
Once the theory behind UVM is established, then logical steps are taken to achieve the framework of objectives. Theory may be the the lodestar, but logic is the navigation system and it has to adjust to stay on course. For example, a UVM program must show a return on investment, but what logic gets you there? UVM has sought cost-effective ways to manage high risk, but in order to maximize return on investment, it has bypassed managing smaller risks and made compromises and adjustments. This strategy has allowed UVM departments to show success by using IEEE reliability metrics. Managers can report success if the system average interruption duration index (SAIDI) and the system average interruption frequency index (SAIFI) are reduced. For upper management, this provides a reduced cost burden achieved through reliability improvements.

Unfortunately, the marriage of UVM risk and reliability metrics has also meant performance for other objectives and risks could be reduced, ignored or transferred away from UVM departments. Worker safety liability has been shifted to contractors. Reliability performance shows UVM is performing what is reasonable and shields utilities from public liabilities. State regulatory compliance validates this idea by requiring reliability metrics. Other objectives like fire prevention, environmental quality, and customer service have become weak objectives.

Regardless of relative ranking, each objective should have key performance indicators. Strategies and tactics should be formulated to support measureable achievements and improvements. Some objectives, such as reliability and safety, may be more important, but a program ought to be balanced. A single objective, such as reliability, should not be the only characteristic of quality service. For example, UVM, from a customer perspective, is an inconvenient intrusion onto private property where vegetation is negatively altered in order to complete an electric system correction. Asset corrections protect equipment and ensure reliability, which is misconstrued as the primary if not only element of customer service. Why shouldn't UVM be a customer service activity in which the customer perceives they are receiving a benefit to their property or vegetation and their community? Perhaps we have come to accept adversarial relationships with rate-paying customers.

Empirical Evidence:
While logic is necessary to navigate, we need empirical evidence - an analysis of readings from our instrument cluster - to support and measure the performance of our logic. The following four sets of data are readings from the current era of UVM, and they suggest that there is a need to change our theoretic lodestar or reevaluate the logic used to navigate our UVM programs.

1. **Reliability is a UVM problem, but Reliability-Centered Maintenance is an asset management strategy**

   Reliability-centered maintenance (RCM) from an asset perspective is designed to address the vast majority of failure modes that are likely to occur during normal operating conditions. RCM is integral to the life-cycle of assets, which includes constructing, maintaining, extending, and finally replacing. Since abnormal conditions are usually an "event" such as weather, IEEE devised a statistical method to exclude certain outages in reliability performance metrics.

   The IEEE- 1366 2012 defines a Major Event as one *"that exceeds reasonable design and or operational limits of the electric power system. A Major Event includes at least one Major Event Day (MED)."* A T-MED is a calculated threshold for excluding outages in reliability metrics. It provides a limit beyond which a utility should not be expected to perform within expected reliability parameters.

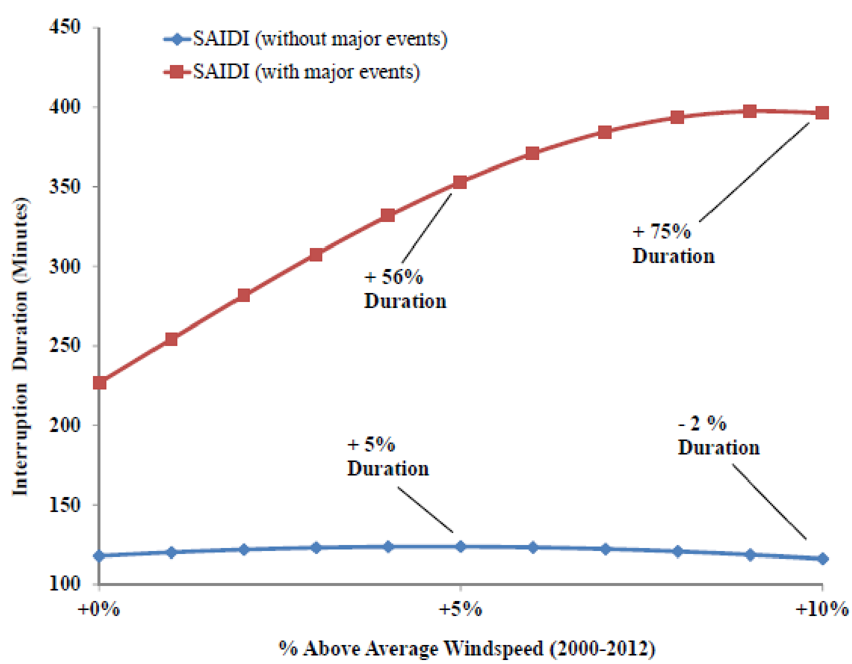


Figure 28: Above-average wind speed and duration of interruptions (SAIDI) (Larsen, 2015)

Berkeley National Laboratory (BNL) has performed cumulative statistical research on utility reliability data collected over the past thirteen years. Some specific variables are associated with measureable improvement in SAIDI and SAIFI. T&D expenditures, percent of underground, hot weather, and increases in customer density were found to correlate with lower SAIDI and SAIFI. Other variables such as wind are associated with increases in SAIDI and SAIFI (Larsen, 2015). Although the BNL research does not differentiate wind-caused outages between tree and equipment failures, CN Utility Consulting (CNUC) benchmark surveys have found at least 43% of outages during major event days (MED) are tree-related (CNUC, 2015). Wind-event data were studied at BNL, including and excluding MED. If MED are included, a 10% increase in average annual wind speed is correlated with a 75% increase in SAIDI. In contrast, if MEDs are excluded, a 10% increase in average annual wind speed is correlated with only a 2% increase in SAIDI (Larsen, 2015) (See Figure 1). This data analysis is significant to UVM since the majority of tree-related outages are caused by wind and other loading events. Without actionable knowledge of the life-cycle of trees and their failure modes and without a reliability system designed around the effective management of right-of-way (ROW) land and nearby trees, RCM is not likely to address tree-related reliability nearly as well as it can guide asset management.

2. Reliability Performance is not measured the same from one company to the next

The CNUC benchmark surveys found that 88% of responding companies track tree-related SAIFI, SAIDI and CAIDI, and 74% of companies are using this information to make planning and resourcing decisions for the UVM department (CNUC, 2014). Additionally, 59% of companies have not strictly used the IEEE-1366 guidelines for separating major event days (MED) from non-MED (CNUC, 2014). In fact, the 1366-2012 revisions left the door open for companies to adopt their own specific definition of a catastrophic storm. Some companies may have to comply with a state commission definition. Differences in MED definitions and thresholds may effectively increase or decrease the number of events which become MEDs and subsequently influence the threshold for determining MED. When one major event is excluded, the average used to determine the T-MED is also lowered, which causes additional events to be classified as major. Consequently, the measurement of reliability performance is inconsistent and possibly misleading, because SAIFI and SAIDI numbers vary significantly depending on whether outage events are included or excluded.

3. Reliability is worsening, according to SAIDI

Despite the reported improvements to non-MED SAIDI, the most current research into reliability data indicates that distribution system SAIDI measurements are worsening by 10% annually over the 13-year period of study (Larsen, 2015). In recent years, major storm events have become a critical reliability issue, and tree-related outages are the chief contributor. A comparison of the ratios of tree-related to system SAIFI revealed Non-MED tree-related SAIFI was, on average, 24% of system non-MED SAIFI. In contrast, MED tree-related SAIFI was 43% of the system MED SAIFI (CNUC, 2015). This difference underscores the significance of the SAIFI amplitude that vegetation causes during MEDs compared to other distribution system failure modes.

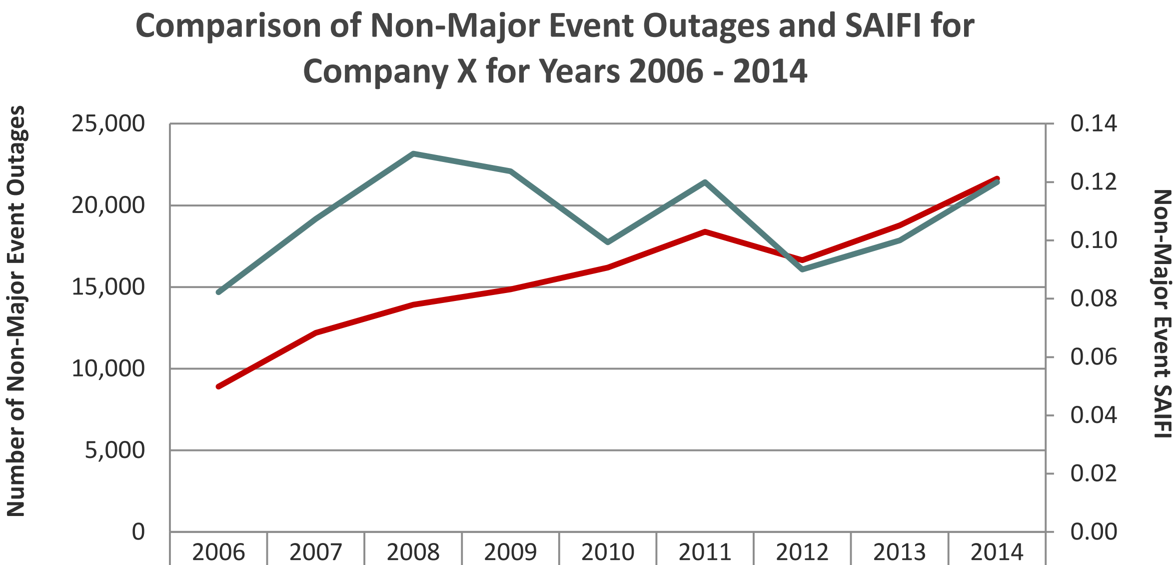
The risk factor for MEDs is greater for UVM than it is for equipment failure in the absence of tree damage. The Larsen study, which has many interesting findings, also found a 10% decrease in precipitation is correlated with a 3% increase in SAIFI (Larsen, 2015). It has been thought that drought conditions may contribute to tree-related outages.

4. **A Case Study**

The following is a comparison study between SAIFI, SAIDI, and tree-related outages per pole mile between three companies (X, Y and Z). The UVM programs for these utilities represent a reliability-centered maintenance program (Company X), a compliance-based program (Company Y) and a company (Company Z) that had favorable reliability performance but was dissatisfied with its UVM program. All three companies were excellent performers based on SAIDI and SAIFI. Company Z initiated the study with CNUC by asking the question, “How is it possible that we achieve best-in-class reliability when we know the UVM program is not meeting best management practices?”

By comparing the metrics from the three companies within a field of other companies, CN Utility Consulting (CNUC) found several revealing facts that demonstrate the limitations for using reliability metrics as a measure of the standard of care for UVM.

Company X almost doubled the number of tree-related outages on its distribution system in five years (2008-2012) and still showed significant improvements in SAIFI (31%) for the same years (See Figure2, below). By focusing UVM efforts on high customer density feeder lines while deferring maintenance on single-phase lines with lower customer density, X was able to report almost best-in-class metrics in 2012. An increase in SAIFI in 2011 could have been an anomalous year given the return to dropping SAIFI values in 2012. Subsequent years, 2013 and 2014, suggest something else is happening. Potentially, there is an upper limit of tree-related outages at which point SAIFI will also increase (2012-2014 in Figure 2).



	2006	2007	2008	2009	2010	2011	2012	2013	2014
Outages	8,906	12,194	13,918	14,865	16,197	18,379	16,636	18,774	21,633
SAIFI	0.08	0.11	0.13	0.12	0.10	0.12	0.09	0.1	0.12

Figure 29: SAIFI improves whilevegetation-related outages increase

Another interesting aspect of the reliability metrics occurs when SAIFI increases faster than SAIDI, then customer average interruption duration index (CAIDI) will actually improve, in spite of an overall worsening of the other metrics. This is another example of how reliability metrics may be misleading. A company could show exemplary reliability - in comparison to industry averages - by only focusing on non-major events, even while vegetation-related SAIDI, SAIFI and outages are increasing.

Outstanding reliability is a product of interpreting statistics and focusing on the bigger picture of utility reliability, which include other failure modes such as equipment failure and generic categories such as non-major weather events. If asset improvements are made – such as replacing equipment, adding isolating fuses, monitoring with sensors and making equipment more resistant to weather, vegetation, and animals – then reliability will improve and vegetation appears to be under better control. In reality, it is the asset that is improved, not the vegetation management.

In a comparison of reliability indices for the three companies of interest (X, Y, and Z), all three utilities show excellent metrics when compared with the UVM industry in general (See Figures 3 and 4, below). If the graphs only included peer utilities (companies with similar key characteristics), all three companies are best-in-class among their comparators. These two figures also show that X and Z, RCM companies, compare well with Y, the compliance-based program. Of note, a majority of the other companies that are in the first quartile have cycle-mandated programs (regulatory-based programs).

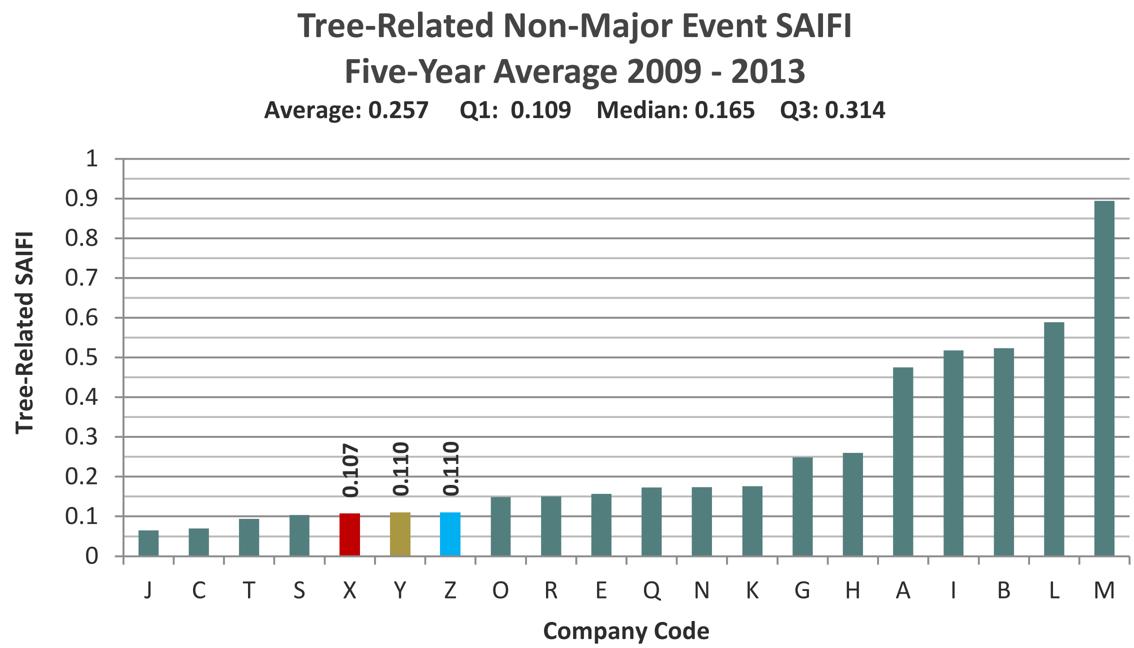


Figure 30: Utilities X, Y, and Z have different UVM strategies but similar SAIFI

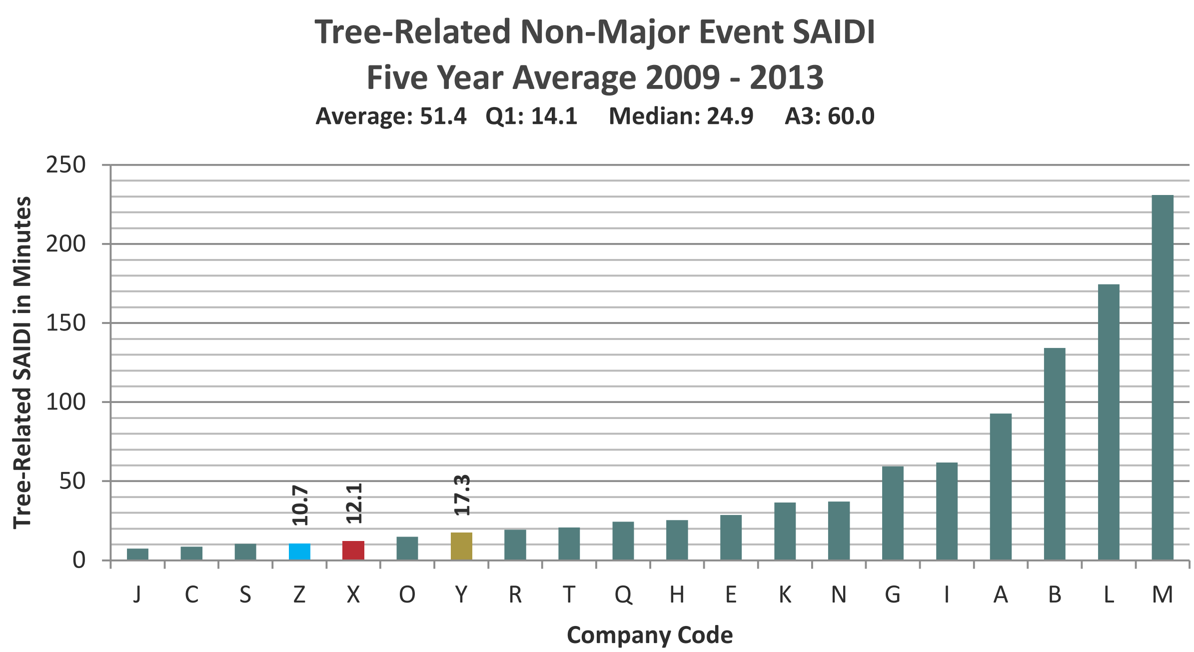


Figure 31: Company Y has a slightly higher SAIDI byt program is focused on the bigger picture

As noted above in Figure 2, company X is able to achieve a high reliability performance as measured by SAIFI, while the absolute number of outages has increased 143% over a nine-year period. Company Z knew that there was something misleading about their best-in-class tree-related reliability metrics, because the increases in the percent of trees in contact with powerlines and the increases in the percent of reactive maintenance were not represented by these measurements.

What was unclear to company Z was the relative value of SAIFI and SAIDI. In other words, IEEE metrics are customer-density dependent and UVM is tree-density dependent. When comparing companies X, Y and Z with peers using an absolute rate (outages per mile), a different picture emerges (Figure 5, below). Company Y, which is focused on regulatory mandates, achieves similar SAIDI/SAIFI but much better outage prevention performance that the RCM utility, X, while meeting other objectives as well. These objectives include public and worker safety, fire risk reduction, and environmental quality. As figure 5 shows, this inclusive strategy also results in best-in-class reliability when measured as an absolute rate.

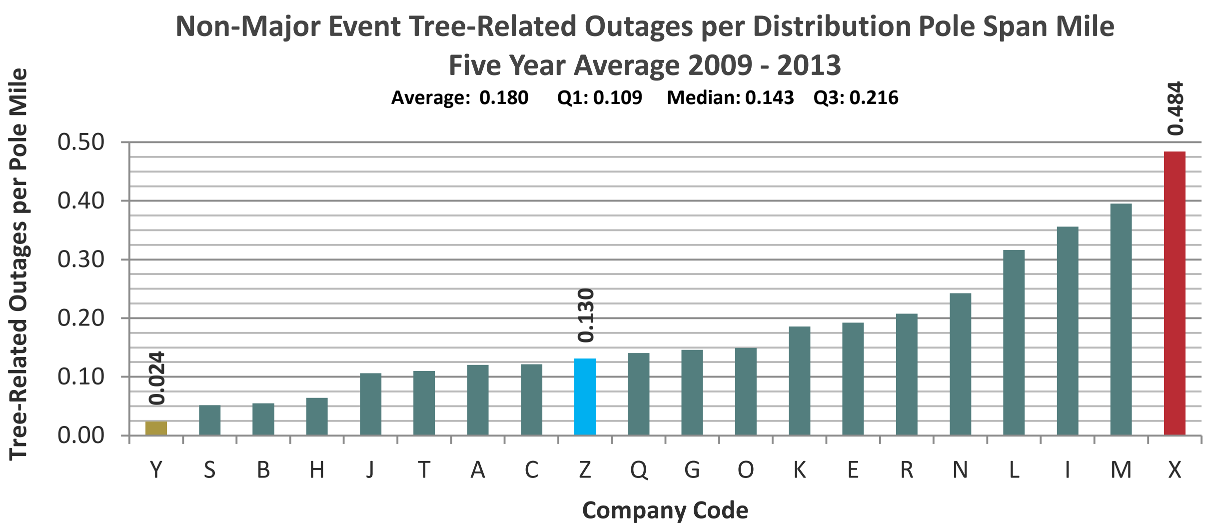


Figure 32: Absolute Reliability Rates

Conclusion:

Reliability is a major objective, especially as we enter into an era when climate changes are a significant threat to utility operations. However, effective vegetation management is not a direct response to conditions that negatively impact reliability. The reliability metrics that currently guide vegetation management do not measure or recognize the full extent of the UVM workload or forestry conditions. It is not the incremental tree growth that impacts reliability but rather the accumulative growth which leads to branch and tree failure. Nonetheless, it is still growth that UVM must control in order to prevent interruptions. This growth component must be managed in a cost-effective way and UVM must be performed to satisfy other objectives besides reliability. The use of reliability metrics as a measurement of UVM efficacy is pressuring utilities to practice reliability-measured UVM rather than sustainable

UVM that adheres to principles of forestry and urban arboriculture. All vegetation near power-lines must be managed at some point, regardless of its impact on reliability. Delaying maintenance to serve improvements to reliability metrics compromises all of the objectives and creates a greater long-term risk. This research was performed to demonstrate the shortcomings of reliability-centered maintenance and offer some alternatives to steer UVM in the direction of a more balanced approach that includes multiple objectives.

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APPENDIX C: PEER SELECTION

In 2009 CN Utility Consulting (CNUC) conducted a Distribution Vegetation Management Benchmark Survey for Hydro One and performed a comparative analysis of program efficiencies with utilities that had been selected as peers. The current study is a continuation of this analysis.

The selection of peer utilities in 2009 was based on the following criteria:

- Vegetation Cover and Density
- Weather Considerations
- Distribution System Characteristics (i.e. Customer Density, Size of Service Territory, Percent of Overhead (OH) Lines and Off-Road Lines)

The current peer selection expanded upon the 2009 criteria. There are several departures in the 2016 study design that allowed CNUC to select peers based on a larger set of criteria and to limit bias. These departures were:

- The survey was distributed to utilities that wanted to participate regardless of whether they were perceived as a possible peer to Hydro One.
- Comparative analysis of system characteristics and vegetation cover was performed on all survey participants before selecting peers.

Once the preliminary analysis was done, CNUC gave weights to the importance of each characteristic. These weights were assigned partly on regression analysis and correlational studies. The order of importance is as follows:

1. Peer in the 2009 study
2. Geographic location and proximity to Hydro One
3. Tree density and managed tree characteristics
4. Customer Density (i.e. Customers per sq km, customers per system km, customers per OH km and OH customers per OH km, Urban versus Remote)

Peer in 2009:

2009 peers were automatically selected as peers to give the current study continuity to the previous study. A majority of the 2009 peer utilities are represented in the current study.

Geographic location and proximity to Hydro One:
Utilities in Northern United States as well as Canada had similarities to Hydro One in several areas. Canadian companies not only had geographical proximity to Hydro One, they had comparable regulatory oversights that may vary from US utilities. Canadian utilities were given greater scrutiny for this reason. Most of the survey participants that are Canadian companies were chosen as peers, although not all. Northern US, excluding the Northern Great Plains utilities, has comparable climate and tree populations.

Tree density and managed tree characteristics:
Tree density and tree characteristics are of major importance, since it is really trees that are managed by the UVM department, not kilometres of line. A kilometre of line that is heavily treed will require more work than one with few trees. The tree species make-up will also affect the amount of time required for management.

Customer density:
Customer density was the last factor that was used for peer selection. Customer density was viewed from several perspectives, since each viewpoint gave insights into comparability of different utilities.

Customer density was calculated as followed:

- *Customer density by land area*: customers per square kilometre
- *Customer density per system circuit kilometre*: customers per overhead (OH) and underground (UG) distribution system circuit kilometre
- *Customer per pole kilometre*: Customer per OH distribution system kilometre
- *Service Territory Descriptions*: Percent of Urban, Suburban, Rural and Remote

This selection process allowed a larger sample set than the 2009 study and afforded the different territories comparators that had similar characteristics. It also eliminated some assumptions about comparability of UVM programs.

APPENDIX D: STATISTICAL METHODOLOGY AND MODEL DEVELOPMENT

UNIT CONVERSION

NUMERICAL DATA

All numerical data was converted to metric if necessary. Survey participants stated the units they used and appropriate conversions and calculations were done.

FINANCIAL DATA

United States dollars (USD) were converted to Canadian dollars (CAD).

- Statistics on financial graphs that used five-year averages or year-over-year trends were converted using the average of the annual exchange rates for years 2011 – 2015. This rate is: 0.9343524 (USD to CAD). This method was selected to smooth out the anomalous variation in the exchange rate.
- Statistics that only used only 2015 financial information (e.g. wages) employed the 2015 exchange rate (0.782992)

NORMALIZATION

Data was normalized by:

1. Filtering by peer group selection
2. Dividing by distribution system overhead (OH) kilometres
3. Dividing by annual managed kilometres
4. Dividing by number of electric customers
5. Focus on labour hours expended as a proxy for cost
6. Using percents
7. Selective comparisons of peer group

Given the complexity of the utility vegetation management (UVM) industry, calculations using weighted adjustments were not employed since they would mostly likely introduce bias. If there had been only one or two variables affecting differences between UVM programs, it would have been an appropriate approach. Multivariate analysis proved one factor could not be selected for weighted adjustment over another. Therefore, root-cause analysis was used to explain variability.

EXPLORATORY DATA ANALYSIS

Comparative investigation was based on an exploratory data analysis (EDA) approach. Simply put, the key data was summarized visually and by descriptive statistics before hypotheses were formulated.

REGRESSION AND MULTIVARIATE ANALYSIS

The relationship between UVM program cost and productivity components was explored using graphical visualization and by regression analysis. For example, tree density (trees/managed km), cycle length, and cost per managed kilometre were charted on one graph using the secondary axis to view all three variables simultaneously.

Regression analysis was done with some of the variables to see if relationships exist between factors. When more than two variables were being explored, multivariate analysis was done. Analysis was performed using JMP software, which is an exploratory statistical software. JMP allowed the researchers to perform a variety of tests and provided best fit analysis.

This exploration was done to build hypotheses about efficiencies, especially when identifying best management practices (BMP).

PROJECTIONS OF UNIT COSTS FOR HYDRO ONE

Hydro One is unique in three major ways with regard to the peer group:

- Line clearance, brush control, and job planning is performed by in-house crews using company-owned equipment
- The UVM program costs include administrative costs that other utilities do not include
- Hydro One employs seasonal workers that are hired from the Hiring Hall at lower labour burden rates

These differences make it difficult to use information from peer utilities to estimate costs for the model. Therefore, all projections were made using Hydro One's past spending records as a basis for setting cost estimates.

Hydro One experienced a major funding cut in 2014. This compelled them to change their UVM program in terms of equipment utilization, scheduling, and labour mix. Therefore, historical data of costs and production took a sharp turn beginning in 2014. Long-term cost modeling had to be based on the current budget, which has a larger cost per labour hour, but total expenditures are similar to pre-2011. This decision was determined through consultations with Hydro One UVM strategists.

Variables that affect the predictions:

- Fixed Variable Cycle Lengths

- Number of kilometres managed annually
- Annual Inflation
- Tree Density
- Cost per Labour Hour
- Employee Resource Mix (Hiring Hall vs FTE)

Three models were built:

1. **Risk Model A:** This model is at the highest risk level. It is a model built on the current scheduling methodology, which targets M-Class feeders and three-phase (3Ø) lines. 8,500 km of 3Ø (~one-sixth of the 3Ø system) will be done annually, including approximately 7,083 km of backlog work. Only 3,500 km of single-phase (1Ø) and double-phase (2Ø) will be done annually on a case-by-case basis and will be performed by Hiring Hall employees. There are 52,000 kilometres in this category and this will put this part of the distribution system on a 14.9 year cycle. 1Ø, 2Ø scheduling will be triggered by reliability problems. This scheduling methodology will take approximately six-years to get all the M-Class and the 3Ø feeders on the desired target variable cycles (four, six, and eight-year dependent on reliability considerations). This approach will get the high priority lines on schedule, but the single and double phase will fall farther behind.
2. **Risk Model B:** This model is a mid-risk model. This model expands the Risk Model A by continuing the backlog and cyclical work on the M-Class and 3Ø lines, but will also increase the work on the single-phase and double-phase lines to keep this part of the system closer to the 9.5 year (on average) cycle. This will increase the number of km for 1,2Ø lines to 5,473 km/year (13,973 total km managed annually). This increased work on the 1Ø will be done by Hiring Hall or contracted labor.
3. **Risk Model C:** This model carries the least risk and produces a more storm resilient system. It gets all of circuits on target cycles by obtaining an eight-year cycle (ten in the North region) for single and double-phase circuits. This requires that 6,500 km (1,2Ø) and 8,500 km (3Ø) be managed annually for the next six-years, a total of 15,000 km a year. The single and double –phase circuits will again be performed by Hiring Hall or contracted labor.
4. **BMP Model D:** This model produces a more storm resilient system with greater returns. It gets all of circuits on target cycles by obtaining a six-year average cycle for single and double-phase circuits. This requires that 8,687 km (1,2Ø) and 8,500 km (3Ø) be managed annually for the next six-years, a total of 15,000 km a year. The single and double –phase circuits will again be performed by Hiring Hall or contracted labor.

Once these models have cycled through the six-years, it is anticipated that the cost of maintenance on the scheduled work will decrease due to improved forestry conditions. Anticipated cost savings in each model:

- **Risk Model A** will see improvements only for the M-Class and 3Ø. At the same time, the single-phase will have accumulated a greater workload. This model will possibly see little to no improvements in the cost of maintenance due to half the system falling into greater arrears. In fact, it may make the work on the single-phase circuits more expensive and time-consuming. The time and money saved on the three-phase system will need to be funneled into the single-phase work after six-years.

- **Risk Model B** will see improvements only for the M-Class and 3Ø, but the single-phase system will have maintained its present conditions. This should produce reduced costs and labour hours for work done on the 3Ø. This will allow concentration on the single-phase. Once again, the time and money saved on the three-phase system will need to be funneled into the single-phase work.
- **Risk Model C** will see improvements on all circuits in the system and there should be a reduction in costs. These savings will not only come from reduction in workload, but also from increased storm resilience and a decrease in reactive work. It will take many years beyond the six year time-frame to establish an appropriate plant community and ROW conditions and to realize cost-savings.
- **BMP Model D** will see improvements on all circuits in the system and there should be a reduction in costs. These savings will not only come from reduction in workload, increased storm resiliency, and a decrease in reactive work. There will also be a reduction in the need for line clearance personnel and an increase in the herbicide and planning personnel. This change in labour mix will also be a cost-savings. It will take many years beyond the six year time-frame to establish an appropriate plant community and ROW conditions and to realize cost-savings. The long-term gains for this model will be greater than Risk Model C, since cycle lengths will be closer to best management practices.

The following elements and assumptions were built into all models:

- Units completed for Line Clearing, Brush Control, and Job Planning were equalized to account for the large differentials experienced in 2014 and 2015.
- 2015 costs were projected to be the best indicator of labour burden rates for the future by Hydro One. These unit rates were adjusted to include equal units completed for all three work types.
- The South's 2015 costs per managed km were thought to be a target for a system in control by Hydro One. The cost per kilometre was adjusted to include equal units completed for all three work types. Since all the regions in the Hydro One territory vary in terms of what will be required once on schedule, it is possible that this may need to be adjusted after several years of data has been collected on the new scheduling and work-force implementation.
- The M-Class feeders are mostly in control. It was assumed that the rest of the three-phase and F-Class feeders would get on schedule by 2022-2023
- East's costs per km were used to represent costs when circuits are in arrears or backlogged. Although the Central region has higher costs, the East was chosen to be a better estimate to account for regional differences. . Since all the regions in the Hydro One territory vary in terms

of what will be required to address backlog, it is possible that this may need to be adjusted after several years of data has been collected on the new scheduling and work-force implementation.

- An annual inflation rate of 1.67% - calculated from the current ten-year average for Canada.
- Hiring Hall/Apprentice and FTE mix is unpredictable at present. An approximation of the effect this mix will have on costs was established in the following way. Since, on average, the labor burden for hiring hall/apprentice personnel runs about 59% of a FTE, this ratio was used to model costs on the single and two-phase circuits. Presently, Hydro One will dedicate the use of hiring hall employees to the single and two-phase work. Since this mix has not been established and will change due to attrition, all calculations using this variable are subject to variation.
- An average of approximately $10M was added on each year to the projected costs. This represented the difference between routine maintenance and total cost of UVM. This includes reactive and administrative cost and was calculated using the five-year average from 2011-2015.

Model Set-ups

Risk Model A: 8,500 kilometres were set for the M-Class and 3Ø, and the single and double-phase lines were set at 3,500 km. 1,417 km of M-Class/3Ø will be circuits already on cycle and it will be predicted that UVM costs (Planning, Brush and Line Clearance) could be approximated by the 2015 cost for the South Region. The rest of the 3Ø will uses an equalized 2015 rate for Hydro One East, since the brush control and job planning were decreased in 2015.

Risk Model B: 8,500 kilometres completed were set for the M-Class and 3Ø, and the single and double-phase lines were set at 5,473 km. The same costing rates were used for projections as Risk Model A.

Risk Model C: 8,500 kilometres completed were set for the M-Class and 3Ø, and the single and double-phase lines were set at 6,500 km. The same costing rates were used for projections as Risk Model A.

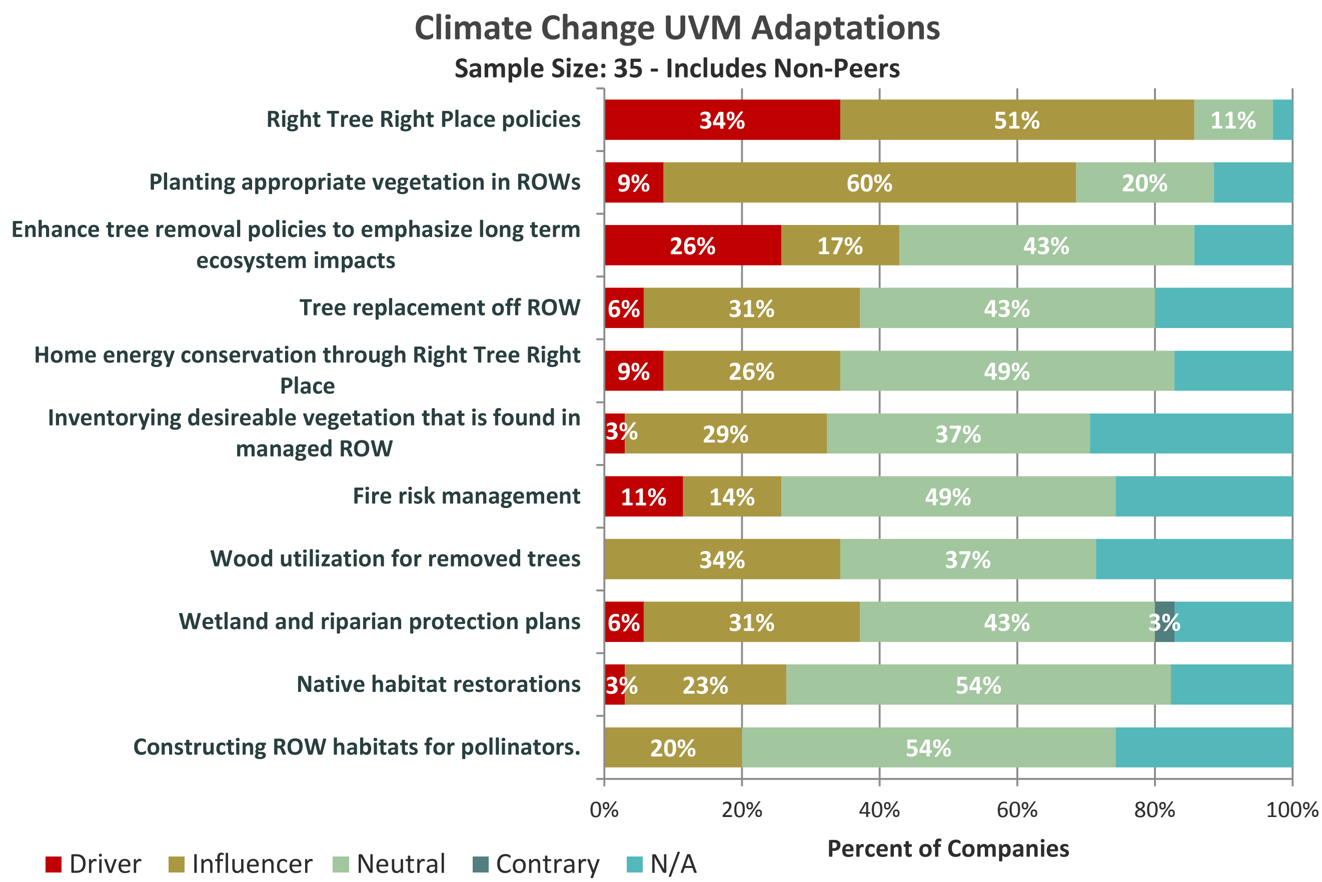
Model D: 8,500 kilometres completed were set for the M-Class and 3Ø, and the single and double-phase lines were set at 8,667 km. The same costing rates were used for projections as Risk Model A.

APPENDIX E: CLIMATE CHANGE AND STORMS

INTRODUCTION

This appendix addresses *Climate Change and Storms.* Of importance is not only the current storm severity but the impact on vegetation conditions due to climate change. A proactive approach to utility vegetation management (UVM) will most likely result in a long-term savings and mitigation of heightened risk from climate change.

Climate change adaptation will have its most aggressive opportunities in cycling trees out of the system before they become hazardous and entering trees into the system early enough to provide a sustainable canopy. UVM has to make this their mission in order to integrate with more global forestry efforts.



Graph 1: Climate Change Adaptation

Graph 1 (above) provides an analysis of how UVM policies are aligned with climate adaptive behavior. This is not an exhaustive listing of how UVM policy is or can adapt to climate change.

The models for climate change in Ontario indicate there may be significant increases in temperatures with the number of high temperature days (>30°C) doubling by 2050. Consider what this means to UVM at Hydro One. 2016-2050 is roughly 3.5 cycles of UVM for Hydro One. Heat waves are predicted to increase from the current "moderate/possible" (0-2.5 days) to "often" (1-5 days). The number of winter cold waves (≥ 3 days of <-10°C) will decrease from occasional to remote. Heavy rain days (>50mm/24hr) in southern Ontario are expected to increase from "moderate/possible" to "often." Summertime precipitation is predicted to decrease by as much as 10-25% by 2050 in southern ON. The predictions for beyond 2050 escalate (CIMA 2014). Will the UVM department be able to respond effectively to a much different future, when it is challenged by the present growth conditions?

Adaptation to climate change could be a positive influence on UVM programs efficacy, efficiency and knowledge of the evolving conditions. Opportunities for the forestry and utility industries have already been manifested in a multitude of ways. Utilities have decreased their use of coal and other fossil fuels in favor of cleaner and ultimately cheap sources of energy such as wind and solar. Regulators are discovering ways to keep utilities successful while generating and distributing less electricity. End-users are getting more benefits while using less energy. Western Canadian timber companies have already salvaged the majority of useable lost timber from the Mountain Pine Beetle (MPB) devastation. These are winning, "no-regrets" adaptations that are helping to solve a problem. UVM could follow a similar pattern, by strategically planning for a future in which fewer resources will be needed to bring solutions for adapting to climate changes and improving electric reliability.

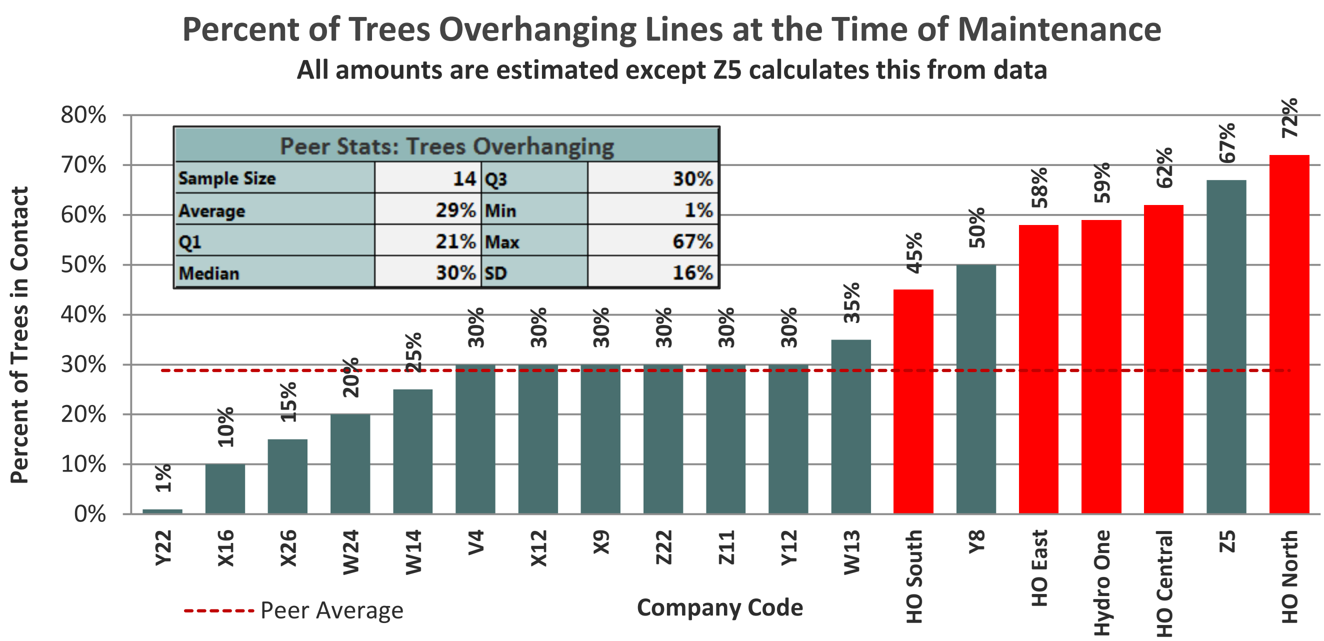
STORMS

CLIMATE CHANGE AND THE UVM RESPONSE TO STORMS

Reliability is the number one UVM objective for Hydro One. This is because Hydro One has been in the fourth quartile for system average interruption duration index (SAIDI) in peer performance comparisons for many years. Storms are a tree problem. Strategies for reducing damages that occur from storms are a priority for Hydro One's UVM programs, because customers have come to expect electricity to be highly resilient to storms. Customers, the public, the media, elected officials, and regulators will judge utilities when major storms interrupt power for prolonged periods. Climate change has begun to cause catastrophic storms to happen more frequently and with greater intensity than in the past. Major storms have been happening ever since the first overhead system was built. In many ways storms already represent climate change because they are never the normal and they have always set new records. Distribution grids typically sustain heavy damage and require resources many times the size of the routine workforce that are brought in from long distances to work incredible hours in often dangerous conditions of unstable trees and broken equipment. Unfortunately for

UVM programs, the history of violent storms bringing down trees has not inspired society to want the utility to scientifically and effectively manage for reductions in damage. Perhaps for a short time, customers want to give up a tree to protect their part of a circuit, but soon the major event is historical and the risk of losing power again is not as important as the tree.

A realistic equation between tree benefits and cost-effective utility forestry strategies and best management practices has to become a part of the future environmental zeitgeist of the larger society that Hydro One serves. Not until overhead electrical equipment is afforded an appropriate space without vegetation will Hydro One be able to effectively manage the risk of failing trees during storms, particularly storms in the 21st century of climate change. Hydro One's *estimated* percent of managed vegetation that overhangs conductors is higher than nearly all of its peer group (Graph 2 below).



Graph 2: Percent of Trees Overhanging Lines at the Time of Maintenance

Without effectively managing to achieve a low percent of overhanging trees, particularly susceptible species, storm risk will remain dangerously high. This situation is likely to collide fatefully with the catastrophic storms predicted for the coming decades.

Proactive initiatives to increase system resiliency are happening at several utilities. Hydro Quebec, Manitoba Hydro, Consolidated Edison, Connecticut Light and Power, PSEG, FPL, and Entergy are a few utilities that have experienced multiple events over the last few years that have inspired them to respond to perceived impacts of climate change (CIMA 2014). They have implemented programs to harden their distribution systems against more frequent and more intense storms. Hydro Quebec has ramped up its efforts with a special pruning program in areas that are prone to freezing rain over 25mm. Identifying and removing hazardous trees is a key component to hardening a system.

The benchmark survey performed for this project probed whether UVM departments have linked their efforts to climate change prevention/adaptation policies and strategies adopted by the generation and grid operators they serve. The survey and literature review shows that while UVM departments are aware that climate change is already affecting their programs, there aren't strategies for adapting beyond meeting the current urgencies. 85% of companies view Right-Tree Right-Place policies as a driver or influencer to their program (see Graph 1, p.85), but it is unclear whether such policies and initiatives are being applied in a strategic response to climate change or if programs passively apply it because it would effectively reduce workloads. Right-tree right-place is the ultimate solution to UVM and many other urban forestry problems and it has been trending since the term was coined in the 1940's. However, unless it is applied more faithfully, right-tree right-place becomes little more than a wish and any place a tree grows is the right place. In the past we managed forests with fire to regenerate new forests and provide new food for wildlife. It is in a similar spirit of stewardship and benefits that a utility should maintain networks to provide reliable modern "fire" that powers our homes, cities and towns. 43% of companies who responded to the survey are adopting more assertive climate change adaptation by enhancing their UVM program tree removal policies to emphasize long-term ecosystem benefits (Graph 1). This is an alignment of UVM objectives, such as reliability, with more global forestry urgencies.

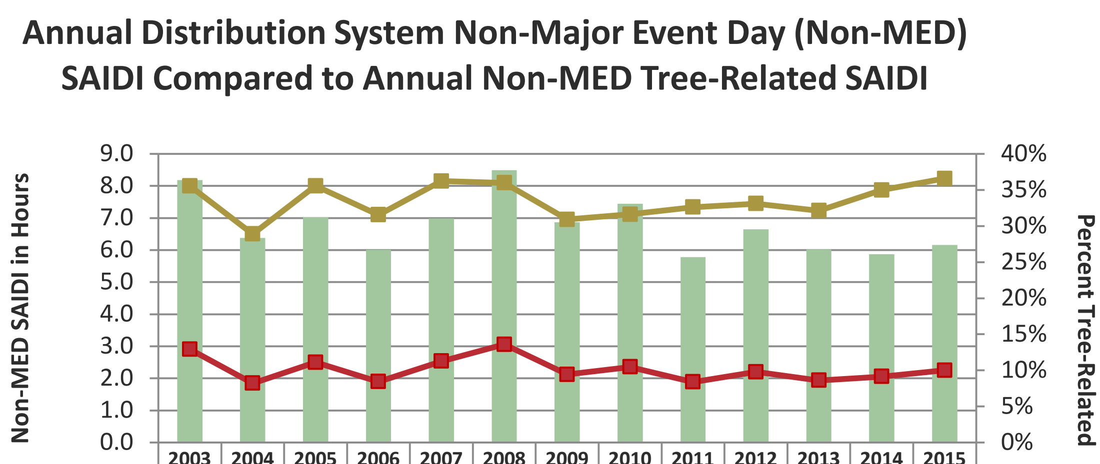
STORMS AND THE RELIABILITY

Out of the last thirteen years, Hydro One finished ten of them with greater than 60% of Major Event Day (MED) outages caused by trees (Graph 4, p.90). This poor performance during storms is a great challenge. When climate change effects intersect with long-term poor reliability performance, there is likely to be a catastrophic outcome.

Hydro One has had numerous ice storms and wind events that have resulted in a high number of outages. While lightning strikes and tornadoes may happen less frequently than in parts of the US, Hydro One faces many logistical challenges in managing storms that other companies in the study are better suited to handle. These challenges are evident in reliability data over the past decade. A few facts emerge when you look at the reliability (SAIDI) of the Hydro One Networks on Non-MEDs (Graph 3, p.89):

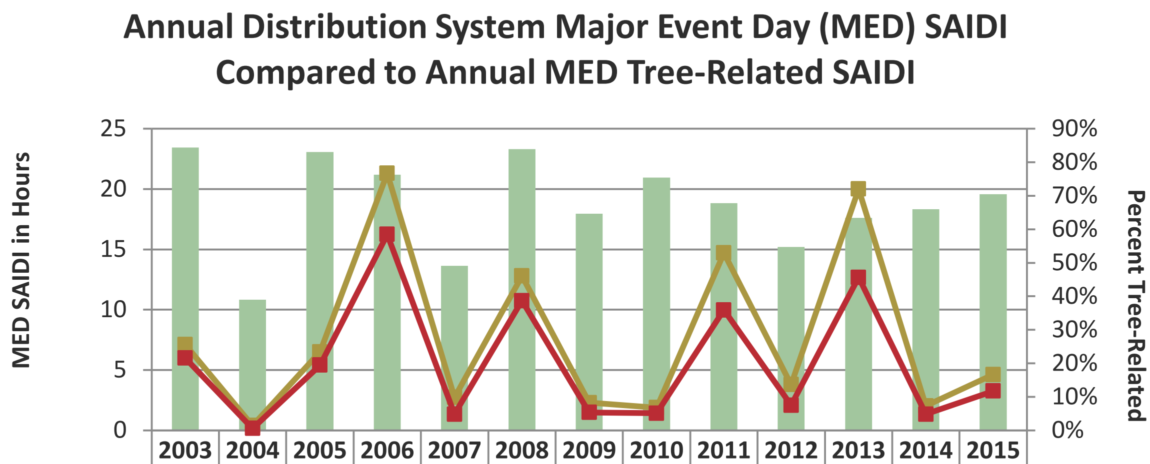
- Tree-related Non-MED SAIDI has improved for Hydro One since 2008. The improvement since 2003 is less significant.

- Other (non tree-related) causes of non-MED failure have been increasing steadily since 2009 so that SAIDI has increased nearly an hour during the last 6 years while tree-related SAIDI has remained relatively steady since 2009.
- *2011 through 2015 was the lowest five- year period of non-MED tree-related SAIDI for the last thirteen years*.
- Non-MED tree-related SAIDI has ranged between 26-38% of the company non-MED SAIDI for the last thirteen years.
- Non-MED SAIDI is probably a higher priority for asset improvements since on average more than two-thirds of it is not tree-related.
- The percent of SAIDI that is caused by trees during non-major event days (non-MED) is average in comparison to peers (see reliability section in main report).
- The contrast between non-MED performance and MED performance is striking and emphasizes the need for making the system more resilient (See Graph 4,below).



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Tree-Related	36%	28%	31%	27%	31%	38%	31%	33%	26%	30%	27%	26%	27%
Total Non-MED	8.0	6.5	8.0	7.1	8.2	8.1	7.0	7.1	7.3	7.5	7.2	7.9	8.2
Tree-Related	2.9	1.8	2.5	1.9	2.5	3.1	2.1	2.4	1.9	2.2	1.9	2.1	2.3

Graph 3: Hydro One Time Study of Non-MED SAIDI from 2003 – 2015

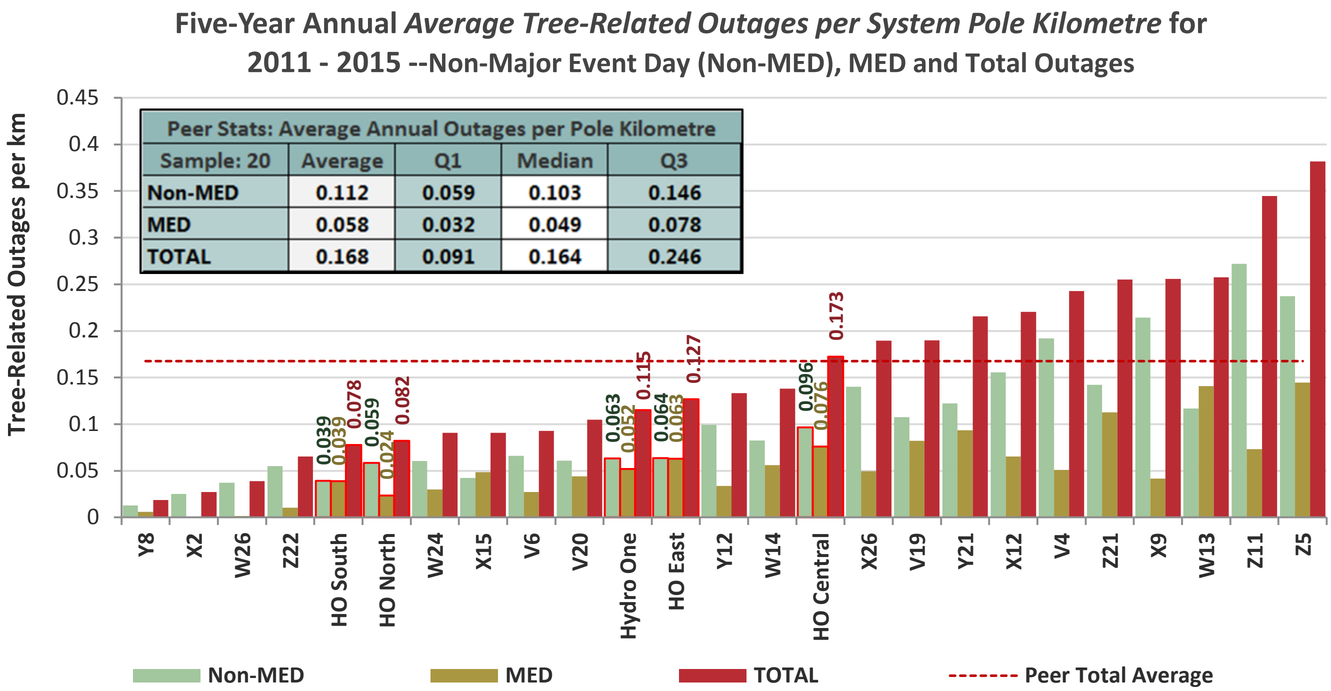


	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Tree-Related	84%	39%	83%	76%	49%	84%	65%	75%	68%	55%	63%	66%	70%
Total MED	7.1	0.4	6.5	21.3	2.7	12.8	2.3	1.9	14.7	3.8	20.0	2.0	4.6
Tree-Related	6.0	0.2	5.4	16.2	1.3	10.7	1.5	1.4	10.0	2.1	12.7	1.3	3.3

Graph 4: Hydro One Time Study of MED SAIDI from 2003 – 2015

MED SAIDI is a different puzzle and trees are the culprit for the majority of cases. MED tree-related SAIDI was 70% of total MED SAIDI in 2015 (See Graph 4, above). The significant fact to recognize with these measurements is how much the ratio of tree related outages to asset failure increases during storms. A Department of Energy (DOE) study has noted that SAIDI is increasing throughout the US particularly when measured with major events. Even a slight increase in average annual wind speed of 10% correlates with a 75% increase in SAIDI (Larsen et al, 2015). The 2014 CNUC distribution benchmark survey found tree-related SAIFI accounted for more than 43% of total SAIFI during MED compared with 24% during non-MED. What this tells us is that UVM will have much greater success if it can reduce the outages that happen during major event days. It is the duration of interruptions during major events that have caught the attention of the public, the media and high level officials (White House 2013).

Hydro One performs relatively well when total outages are measured per kilometre of overhead line (See Graph 5, below). With the exception of the Central region, the five-year average of *total* outages per kilometre is below the average of their peers. The South and the North are in the first quartile. The whole company, performing at 0.115 outages per kilometre, is well below the average of 0.168. The ratio of Non-MED to MED outages is on average about 2:1 for the peer companies. However, for Hydro One East and South it is 1:1, Central is 5:4, and North is 5:2. With the exception of North, the ratio of MED to Non-MED outages is significantly less than peer companies. Since 2003, the majority of storm outages have been caused by trees nearly every year (See Graph 4, above).



Peer Stats: Average Annual Outages per Pole Kilometre				
Sample: 20	Average	Q1	Median	Q3
Non-MED	0.112	0.059	0.103	0.146
MED	0.058	0.032	0.049	0.078
TOTAL	0.168	0.091	0.164	0.246

Graph 5: Hydro One Comparison with Peers for Non-MED, MED and Total SAIDI 2011 - 2015

Hydro One's relative performance with outages in MED or Non-MED may be somewhat related to methodology in determining the MED, which does not follow the 2.5 Beta Method described in IEEE-1366. However, Hydro One's methodology would tend to keep small scale storm impacts in the Non-MED category because the bar is set sufficiently high for MED—10% of customers are disrupted. Most companies are able to remove catastrophic storms from the metric so that their Non-MED isn't an unrealistically low bar and if a company has no big storms the bar is automatically set at a level to allocate a fair proportion of outages to MED. Additionally, this data is smoothed by averaging over five years. In other words, storm events are frequently severe enough that 40% of Hydro One outages are MED. Hydro One Central is in the high end of the third quartile in peer comparisons of outages per km during storms, East is in the third quartile, and the company as a whole is close to the median (Graph 5 above). *Central and East should make storm resiliency a priority*.

Hydro One and all of its stakeholders would like to see an improvement in the reliability of the system, especially when storms blow through. A definite trend emerges for MED tree-related SAIDI (Graph 4, p.90). The data since 2003 has shown that storms have been worse every second or third year since 2003. The cause is unknown to CNUC, but it is worth noting from a planning perspective. The percent of SAIDI during storms attributable to tree failures is most interesting. From an engineering perspective, the asset failure causes are mostly happening during non-MED and could be solved with system upgrades and other condition-based refurbishments. Equipment failures that happen during storms may be the same failures that happen on non-MED days and the same maintenance processes will solve both reliability issues. The hardening of the system during storms is predominantly a single issue - trees. These are ostensibly not the same issues that are happening during non-MED outages, although a consistently applied improvement in routine maintenance would result in a substantial improvement to MED SAIDI. From a UVM perspective, if the right trees could be removed, then the system would be more resilient during storms, which is when it needs the most improvement (See Appendices F & G Tree Risk Assessment).

Typically on most systems the events that cause the greatest damage are wind events. A map of wind events from the Ontario Ministry of Community Safety and Correctional Services, Hazard Identification Risk Assessment (Figure 1, below) illustrates the relative potential for storms in the four Hydro One Regions. The South has the highest potential, but it has the lowest tree density and lowest number of outages per km. The Central has the second highest risk and it has high tree density and the highest number of outages per mile. The East has the second highest number of outages per km, but it has only a moderate risk of wind events. The North has the least risk in regards to wind events. Similar maps are included for tornadoes and freezing rain. The highest concentration of the most severe tornadoes are in the South (Figure 2, below). The East has the second highest risk for tornadoes and also has the highest risk for freezing rain (Figure 3, p.94). The South has the third highest risk for tornadoes and the southern part of the North region is fourth.

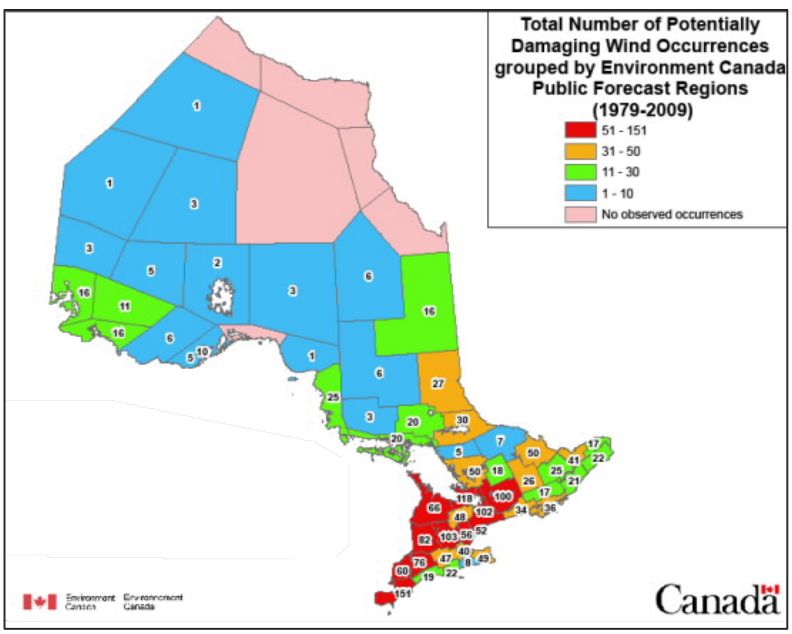


Figure 33: Historical Cumulative Number of Damaging Wind Events 1979-2009 (Hazard Identification Risk Assessment)

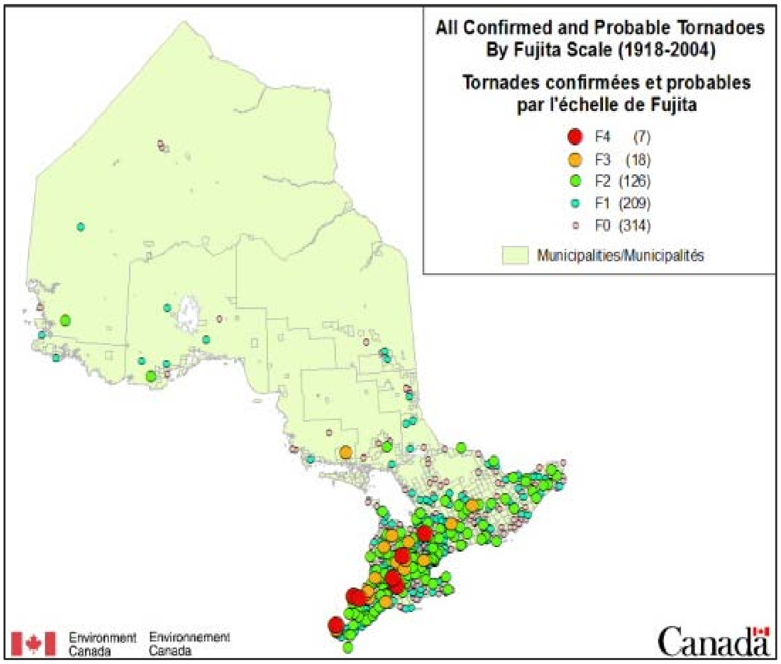


Figure 34: Total Tornado Occurrence in Ontario 1979-2004

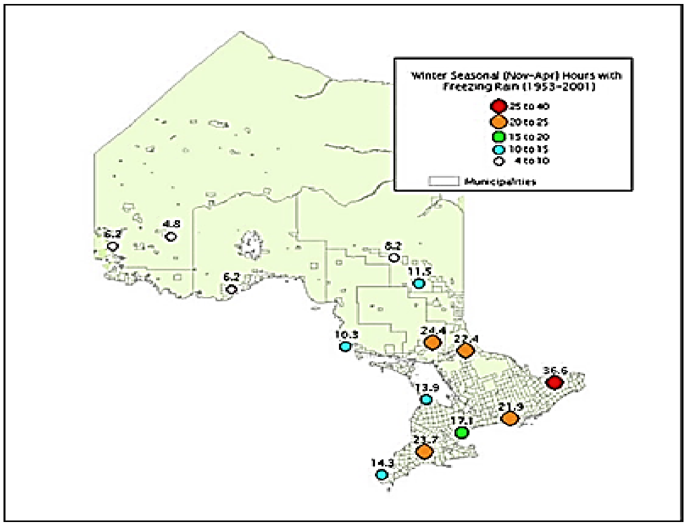
Wind damage has been cited as the largest cause of destruction to forested areas in Europe:

> *Tree species and average tree or stand dimensions, especially height, have been found to be the most important factors controlling [wind] storm damage in the forests typical of central Europe* (Hanewinkel 2013).

Tree defect, which is sometimes difficult to assess, is the most common attribute that an arborist in the US uses to determine the risk of failure. The collection of articles entitled Living with Storm Damage to Forests (Gardiner 2013) suggests there is an attribute elevating wind damage risk - tree heights - that can more easily be evaluated at the stand level instead of individual tree assessments. Other important factors affecting wind damage noted in this study were:

- Types of trees: Conifers are more susceptible than hardwoods
- Waterlogged soils with restricted rooting
- Acidic soils
- High final tree height and high target diameters are key factors for determining risk
- Early thinning at low heights increases diameter and reduces wind risk
- Slopes and valleys exposed to prevailing wind
- Thinning at latest stages of forest rotation increases wind throw risk
- New edges on a upwind side of stands increase wind damage risk
- Trees with highest taper are most wind resistant
- Thinning on exposed sites increases wind risk

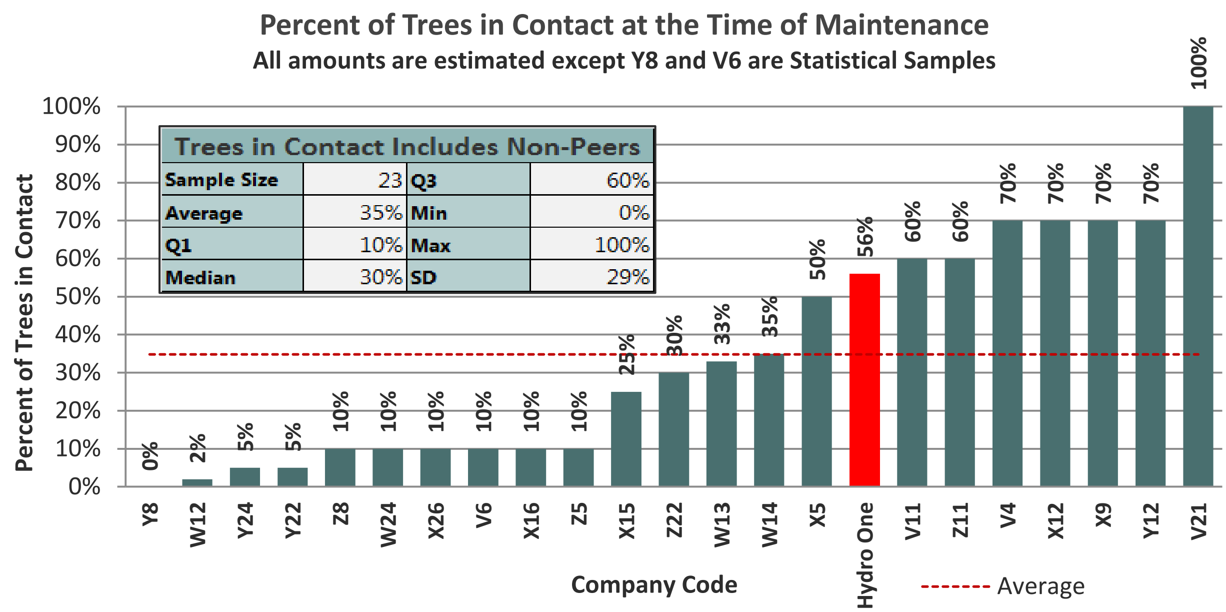
(Hanewinkel 2013)



Freezing rain is a frequent hazard in Ontario. Northern and Central Ontario experience the greatest number of days per year with freezing precipitation (Figure 5) with an average of over 17 days per year. Southern Ontario has fewer days per year with an average of just over 11 days. In Ontario, the most severe ice storms/freezing rain events usually occur from November to March with approximately one half occurring between the last two weeks of December and the first two weeks of January. In general, these have lasted between 12 hours and 1-2 days (Environment Canada, 2009). Freezing rain can be a small scale or a large scale hazard, depending on the size of the storm system.

Figure 35: **Average number of hours per year with freezing rain, based on data form 1953-2001**

Ice storms are not an uncommon occurrence in Ontario and, as noted by the Ministry of Community Safety and Correction, from 17-36 hours of freezing rain can occur annually in Hydro One's South and East regions and the southern part of the North region. Ice storm risk is increased by a considerable margin when trees are overhanging or in close proximity to conductors. The ice brings the branches into the conductors. Until ice-covered, broken, and permanently-bent branches are removed, the power cannot be restored. This is repeated for *every* tree that has not been managed for clearance from conductors. Unlike wind, there is less chance that trees from a further distance will be blown over into the conductor. Managing a system for permanent clearances is the greatest defense against ice storms, which are a frequent cause of disruption on parts of the Hydro One system. A similar case can be made for protection against heavy snows on conifer trees. When the percent of trees overhanging (Graph 2, p.87) and the percent of trees in contact (Graph 6, below) on the Hydro One system is considered, it is not surprising that wind, ice and snow events cause many MED outages for Hydro One.



Graph 6: Percent of Trees in Contact at the Time of Maintenance

STORM CASE STUDY

In 2014 after Nova Scotia Power (NSP) experienced the aftermath of Post-Tropical Storm Arthur, the company entered into an investigative and rule-making proceeding with the Nova Scotia (NS) Utility and Review Board (UARB or "Board"). The jurisdictions of various stakeholders regarding vegetation management and storm hardening were the primary concern of the Board. Like Hydro One, the issue of vegetation management must be handled with stakeholder consultation. Organizations, such as the transportation authority, the union of NS Municipalities and Wood Lot associations, are included in the proceedings. A consulting company was hired to study NSP's preparations and response to the hurricane. The following activities have resulted from the proceeding:

- Improve the capability for weather forecasts on a local level
- Reclaim overgrown distribution ROW including widening of the ROW
- Prioritize three-phase feeders
- Execute multi-year performance evaluation for worst-performing circuits
- Widen ROW of sub-transmission lines (69kV)

Comments from intervenors regarding vegetation management were generally aligned with the independent recommendations, which were nearly all made into policy at NSP. Most of the letters from the public stated NSP should do more vegetation management (UARB 2014).

"*More than 90% of the power outages caused by Post-Tropical Storm Arthur were due to trees contacting lines and other equipment"* (NSPower 2014). In 2015, NSP filed with UARB a follow-up report in which they stated, "*There is approximately 10,875 km of distribution right-of-way remaining to reclaim throughout the province and at the current budget for vegetation management it is estimated to take approximately 32 years (at $3M per year) to get the program to a sustainable level"* (NSPower 2015 p. 18).

For Nova Scotia Power the measure of progress is the percent of ROW kilometres that are classified as sustainable with integrated vegetation management (IVM). NSP has begun widening the sub-transmission corridors and has submitted a plan for widening the remaining 40% of the distribution line kilometres at a cost of $8,500 per km (NS Power 2016). This plan should effectively bring the NSP distribution system to an optimum level of cost efficient management and reduced reliability and safety risk.

One of the issues that was reviewed at length after Post-Tropical Storm Arthur was the weather forecasting capabilities. This is an area of technology that is developing rapidly and many companies are now setting up local weather reporting systems to enable preparations and responses to impending storms. This will enable the utility's response to be more finely tuned to the timing, intensity and actual damages from a storm. These hyper-local forecasts can inform load planning as well as "ensure utilities know what weather will affect a specific point of their service area up to the minute and throughout the entire day, up to 72 hours in advance. They also can determine if high winds or rain will hit a portion of their service area, while other areas will be hit with ice and snow. This allows utilities to plan for outages before they happen and understand where their pain points will be" (Schneider Electric 2015).

CONCLUSION

The human-built world will have to adapt to changes that will not always be predictable. For an electric distribution company, it makes sense to take a "no regrets" approach (Figure 4, below) to protecting the grid against more frequent and more intense weather events. The win-win outcome will be to have a more reliable and safe system regardless of climate change and a more environmentally adaptable, safe and reliable system.

POTENTIAL REGULATORY SOLUTIONS FOR CLIMATE CHANGE ADAPTATION

Common Regulatory Commission Functions	Potential Enabling Roles for Adaptation
Determine the revenue requirement and utility rates	Guidance on eligibility of adaptation-related investments for rate reimbursement; Structure utility rates to enable demand responsiveness (Ex: dynamic pricing)
Set service quality standards and consumer protection requirements	**Require robust storm plans and conduct evaluations and drills.**
Oversee the financial responsibilities of the utility, including reviewing and approving capital investments and long-term planning	**Examine adaptation-related investment and require long-term planning take climate change impacts into account.**
Review and approve comprehensive supply resource plans	Require that resource plans are tested against future scenarios that include climate change projections and uncertainties; Provide opportunities for collaborative decision making.
Approve the entry of competitive retailers into the state's market	Allow microgrids and ESCOs to operate in utility service territory to provide customers with energy management options

Figure 36 : Potential Regulatory Solutions for Climate Change Adaptation (Higbee 2013)

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Appendix F: Tree Risk Assessment - A Best Management Practice

A Tree Risk Assessment (TRA) standard, ANSI A300 Part 9, has provided a framework for utilities to develop formal TRA programs. In a survey performed in February and March 2016 for Hydro One and the Utility Arborist Association TRA Best Management Practice (BMP) Working Group, 40 utility companies throughout North America gave their opinions and facts on their programs relative to tree risk and hazardous trees. The data from this survey is intended to help determine current practices and what would fairly represent a BMP for publication. This discussion will pose some questions and potential directions for a Best Management Practice as the basis for evaluating Hydro One's current practices. The cornerstones for determining tree risk are inspection, measurement, and record keeping. Some key practices include site and tree inspections, remote sensing, customer education, and data analysis.

An important aspect when making vegetation management decisions is understanding specific hazards in the context of populations of trees. An inspector looking for suspect trees rarely encounters a tree that is ready to fail. Instead, a decision to remove a tree may need to be based on a classification list that comports with a system-wide effort to reduce risk over the entire population of trees. It is different for an arborist about to commence work, who must inspect the tree for hazards as a matter of safe practice. If the tree has some hazards that the arborist considers a compromise to his or her safety, then a decision might be made to adjust the method of working the tree, including a recommendation that the tree be removed. Removal may be recommended if the tree cannot be worked safely, and so that the tree isn't left as a safety risk for the public, the property owners or future arborists assigned to work on the tree. The arborist decision process is valid, because it is vital to weigh out the probability of safety factors that are part of the exigent realities of working in the trees. However, these trees are typically expensive and risky to work on and it is unfair to arborists to expect such conditions to be the normal life-cycle of trees they work on. A better scenario involves deciding to remove trees before they become hazardous. Hence, there are significant benefits to be derived from a formal Tree Risk Assessment program.

There are also social and economic reasons for developing a formal process. The final decision to remove a tree may require assessments based on the probabilities for how many trees will be selected for removal versus how much resource is available to remove the trees. These are calculations that cannot be easily made, even by a trained, experienced inspector, armed with precision measurements and techniques for detecting signs that a tree should be removed.

Removing trees is a product-based event with a dramatic and permanent outcome; i.e. there is no longer a tree standing, there is substantial debris, and there are agreements and communications to make it happen. For these reasons, the process for permitting the removal of a tree, the time it takes to remove, particularly large trees (hazard trees are frequently mature trees), and the challenges related to debris disposal have made tree removals an expensive, onerous business for utilities. Waiting until trees become hazardous before removing them may be the most expensive mistake utilities have made over the last century. The following testimony highlights this assessment:

> *"The fact is that many of our outages that are caused by trees are actually from trees that are outside of our right-of-way. Limbs fall on our equipment or trees fall down: This is just a fact. If you look at our distribution system, the three largest causes of interruptions, in order, are tree contact, tree contact and tree contact. That's a fact."* (Hydro One recorded testimony 2016 Legislature)

There are few incentives for removing large trees adjacent to ROWs beyond a fear the tree is about to fail any minute. Even with the knowledge that a tree may be unsafe, it is unclear whose responsibility sits with a bad tree. In fact, only 11% of utility respondents to the Tree Risk Assessment survey stated their company has a clear idea of where their responsibility for risk ends and the property owner's begins. Consequently, a standard of practice for the utility industry is likely to be somewhat of a lowest common denominator, such as the arborist performing a job site analysis decides the tree is dangerous and the *only* way to work it is to cut it down. Otherwise, leave the tree standing until there is a more definitive assessment that the tree is going to fail. And then maybe the property owner will step up and take responsibility. Many trees are worked by arborists who have doubts about their structural integrity, but the external pressures for them to perform to a standard of productivity in spite of their doubts has led to a culture of risk-taking behavior. A standard or best management practice for evaluating tree risk could alleviate some of the danger of trees failing into high voltage distribution lines. In fact, this is occurring on regulated (FAC-003/NERC) transmission corridors and some distribution and sub-transmission corridors. The TRA survey identified the percent of companies that frequently inspect their lines:

- 18% of companies inspect 100% of their single-phase line annually
- 26% inspect 100% of their multi-phase primary lines annually
- 63% inspect 100% of their non-FAC-003 regulated lines annually
- 100% inspect 100% of their FAC-003 regulated lines annually

Of the companies that have separate TRA programs (17), 65% (11 companies) also have pre-inspection programs. Of the remaining six companies who have a separate TRA program, 83%

do inspections at the time of maintenance (one did not answer this question). These statistics indicate it is probable that formal TRA programs are better implemented as a subset of pre-inspections than added to the highly-focused and risk-intensive activities of aerial arborists. The skill levels of inspection and assessment and capabilities to analyze data are the current limits on how successful a TRA program can effectively pay for itself. Successive inspections and the use of historical data, as well as the growing database of outage root-cause analysis, will bring regular improvements to TRA. The TRA process is likely to remove some trees that in reality would not have failed in the near term. For utility purposes this is not as efficient as cutting down a tree that would have caused a significant amount of service disruption, damage, and customer dissonance. Nevertheless, benefits are derived because the tree does not have to be removed in the future and, since the tree is not fully decadent, it may have value as a wood product. Renewal of trees adjacent to the ROW offers an opportunity for changing the culture of land management to one that is more harmonious with infrastructure. Laura Cooke from Hydro One made the following statement about Hydro One's efforts:

> *Something else that we like to do is we like to work with communities to beautify a section on a right of way after we've done the work. We understand that in some communities, the rights of way and the greenery along the rights of way are the only green space some communities have, so they really, really want to protect that space. What we try to do is manage our obligations to reliability and manage our obligations to the community by trying to do some beautification work following some aggressive tree trimming.* (Hydro One recorded testimony 2016 Legislative Standing Committee)

Since inspections on distribution ROW for the majority of companies, 54-58%, is performed by the crew at the time of maintenance, there is little opportunity to fully engage the customer or plan a ROW conversion that is beneficial to both the customer and the utility. For the 43% of companies that do engage in a pre-inspection process, the most common way utilities make improvements on the properties they impact is to plant a new tree or shrub in an appropriate place. A few companies have begun offering to plant trees that provide energy conservation. Research from the University of Guelph indicates significant value to maintaining a high percent of canopy for human comfort levels to prevent heat islanding (Graham 2012). The peak load needs of summer heat waves are mitigated by tree canopy, thereby relating tree canopy to energy efficiency. It is expected that summer time heat waves in southern Ontario will increase as the effects of climate change intensify. Customer service via utility forestry services may be directly influenced by the nexus of energy, environment and conservation. It is apparent the utilities cannot operate forestry programs without integrating with the larger environmental concerns.

In general, a formal inspection program is a prerequisite for a TRA program. Arborists performing tree work could be expected to implement a formal TRA program, but there are many challenges to manage and it could result in cost escalations in areas where tree removals are indiscriminant or do not bring any reductions in tree-related outages and equipment damages. Utility reaction has been to limit the number of removals and allow only the smallest class trees to be selected without approval from forestry management. There are some questions to consider:

- Should a tree risk assessment program go beyond the effort of trying to find the trees that are imminently in danger of failing?
- Should aerial arborists who are charged with production expectations make decisions whether to remove trees that are not imminently hazardous but carry long-term financial and safety risks that could be mitigated?
- Should a utility have some level of understanding about the inventory of trees that are tall enough to strike distribution lines and have the risk for failure?
- Will the costs of measuring, collecting and analyzing data plus the additional work of removing trees bring a return on investment?

While these questions have been presented, they are exceedingly difficult to quantitatively answer. Studies have shown that deferring maintenance escalates cost and increases safety hazards. The North American UVM standard for transmission (FAC-003), California requirements for permanent airspace around conductors including managing hazardous trees, and a few states and provinces that have initiated reliability performance expectations have compelled utilities to manage hazardous trees. Beyond these regulations, there are few incentives for utilities to spend funds on removing anything other than the most obvious hazardous trees and the smallest class trees (in-growth).

The Auditor General for Ontario has noted the following concerning Hydro One's UVM program:

> *Hydro One's cycle for clearing vegetation (forestry) under, around and above distribution lines is more than twice as long as that of comparable utilities. Because trees are not trimmed back as often, Hydro One experiences more outages caused by fallen trees or tree limbs. We noted that line breaks caused by trees were the main cause of distribution outages from 2010 to 2014, responsible for 31% of all outages.*
>
> (Auditor General 2015)

One could argue that a few select removals on high- priority feeder lines could improve the reliability performance. On the other hand, this type of effort would divert resources from the already escalating problem of ROWs spiraling out of control with growth into the lines. This strategy has been tried and what has been learned is that it does improve reliability if select trees are removed.

While the survey has many measurements to consider and the UAA is in the process of designing a best management practice for the industry, a phased in approach with flexibility is appropriate for Hydro One to begin addressing the reliability, safety, cost, and customer service problems caused by a preponderance of off-ROW tree -related outages. The design of a TRA program could involve discussions with regulators and a public discourse to arrive at consensus of what a long-term approach would look like and where responsibilities and funding would be assigned. A TRA program should begin with baseline expectations for on-ROW management to ensure the effectiveness of the practice is not compromised by on-ROW growth and that the program is efficiently administered. Otherwise, the TRA program would not be a best management practice.

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Appendix G: Tree Risk Assessment Best Management Practices Survey Results

TABLE OF CONTENTS

INTRODUCTION

The following report represents the results of the *Tree Risk Assessment Best Management Practices Survey* deployed in March 2016. This report will be used by Utility Arborist Association (UAA) to develop a Utility Best Management Practice (BMP) for Tree Risk Assessment (TRA).

Work is currently underway to develop a Tree Risk Assessment (TRA) Best Management Practice (BMP) specific to the utility industry. The BMP will follow the general format and use the risk assessment constructs included in the current ISA TRA BMP (2012). The utility-specific BMP needs to reflect current practices within the industry and provide useful guidance on contemporary best management practices. The results of this survey will help guide development of the new BMP.

How to Navigate the Report

- The Table of Contents (previous page) has links to each graph and table
- All questions (as written in the survey) are given after the survey question number.
- Graphs and comment tables are shown after each question to report on the survey results.
- Responses to the questions are in brackets on comment tables. In other words, if the respondent answered, “Yes”, [Yes] will appear after their comment. This will be true for most comment tables in this report.
- Each participating utility has been given a unique code (Company Code)

CONFIDENTIAL PARTICIPANT INFORMATION

Question 1: Confidential Information. Results not available for publication

COMPANY AND UVM PROGRAM INFORMATION

All questions as written in the survey are given after the survey question number. Graphs and comment tables are shown after each question to report on the survey results.

Responses to the questions are in brackets on comment tables. In other words, if the respondent answered, "Yes", [Yes] will appear after their comment. This will be true for most comment tables in this report.

Question 1: Please indicate the *Region* in which the majority of your T&D system is located. Note: Map included in survey to locate region in which the utility operates.

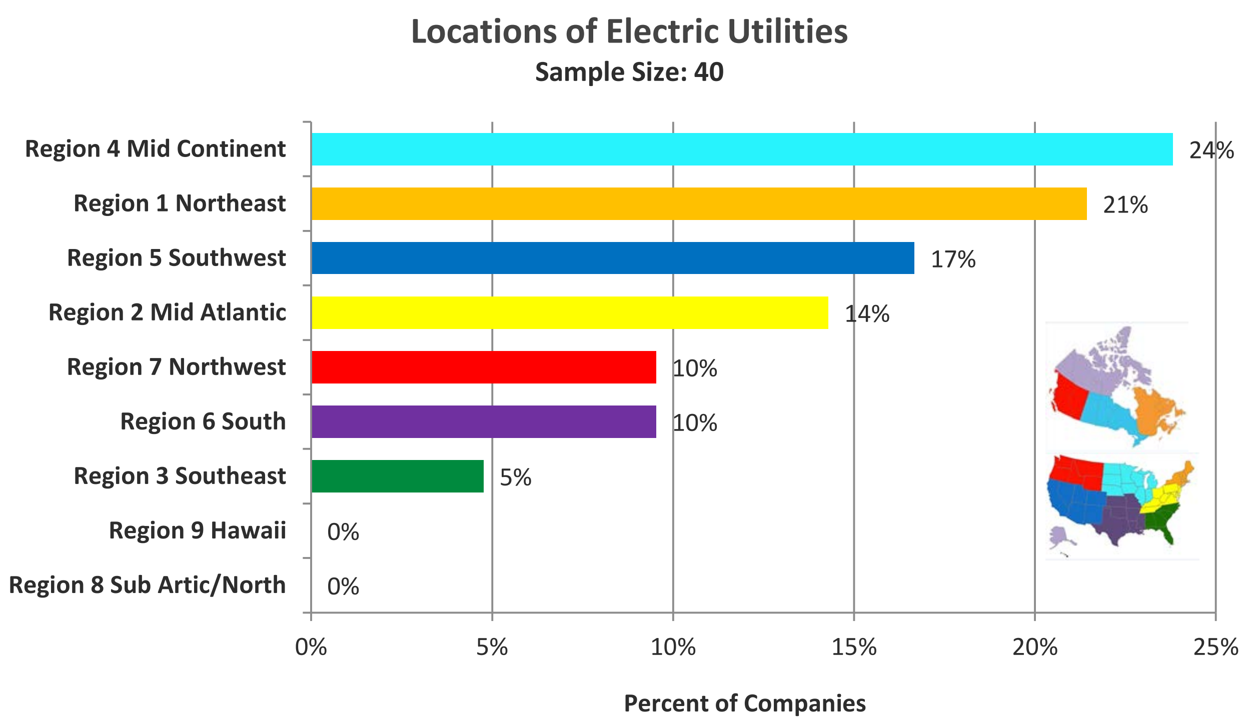


Figure 37: Locations of Electric Utilities

Three participants operated in more than one region and these additional regions are included in the above graph.

Question 2: Please select from your following choices to describe your company type

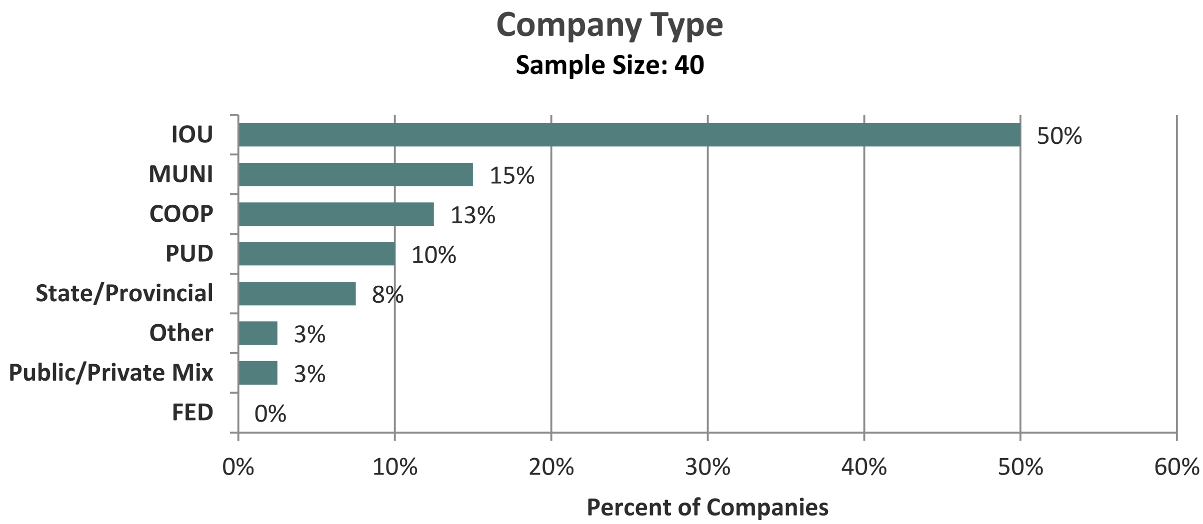


Figure 38: Company Type

Legend:

IOU: Investor Owned Utility

MUNI: Municipal Utility

COOP: Rural Electric Cooperative

PUD: Public Utility District

State/Provincial: State or Provincial Run Utility

FED: Federal Utility

Public/Private Mix: Quasi-Public and Privately Owned Utility

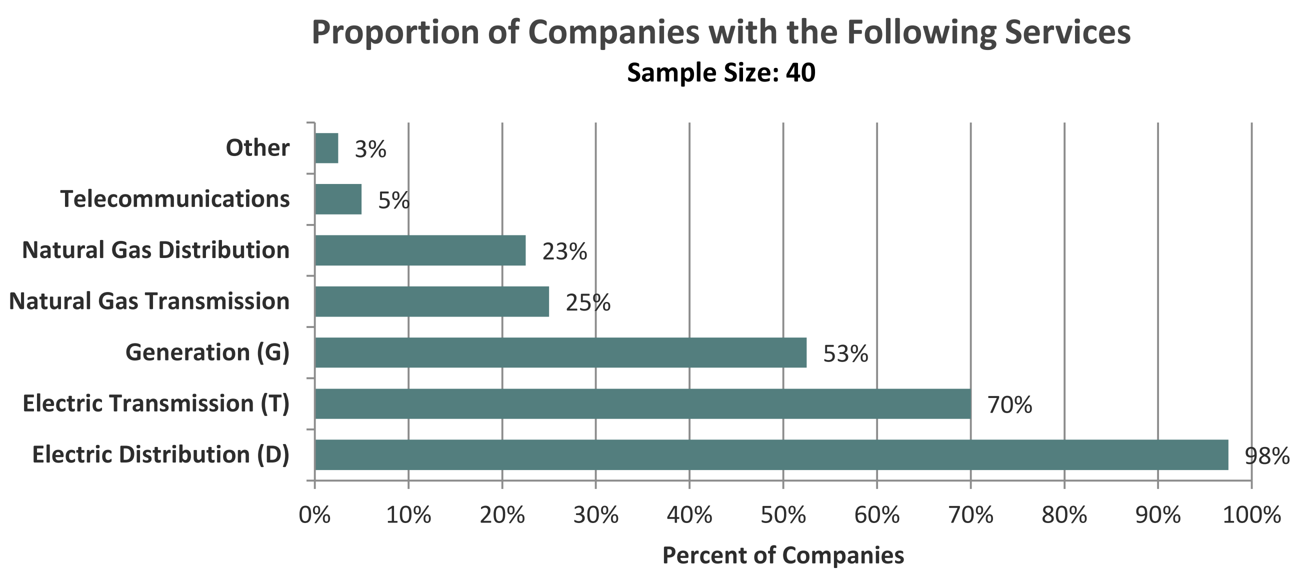


Figure 39: Proportion of Companies with the Following Services

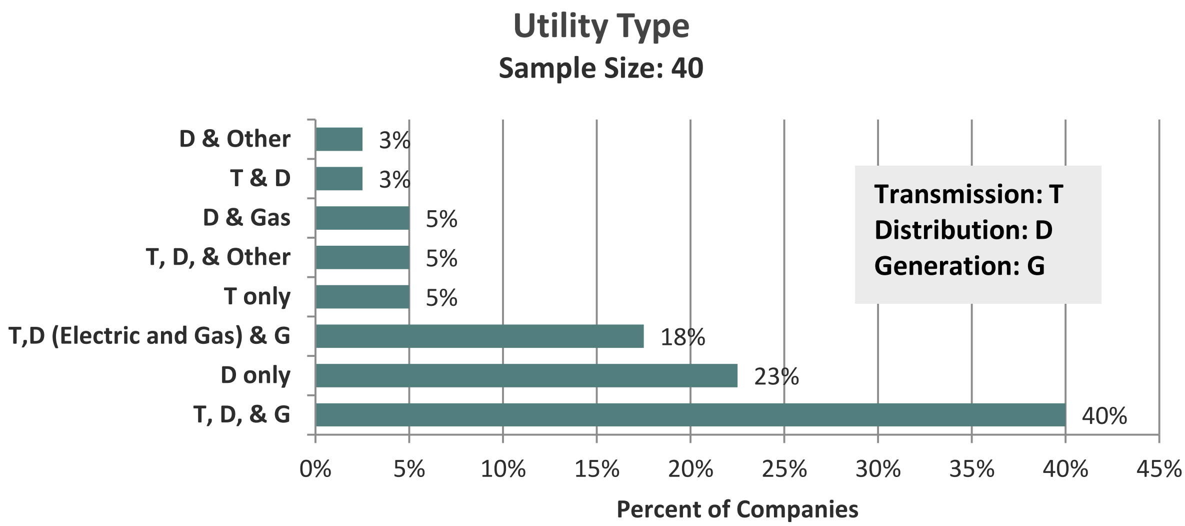


Figure 40: Utility Type

Question 3: How many circuit miles of overhead line in each line type are included on your overhead system within this region?

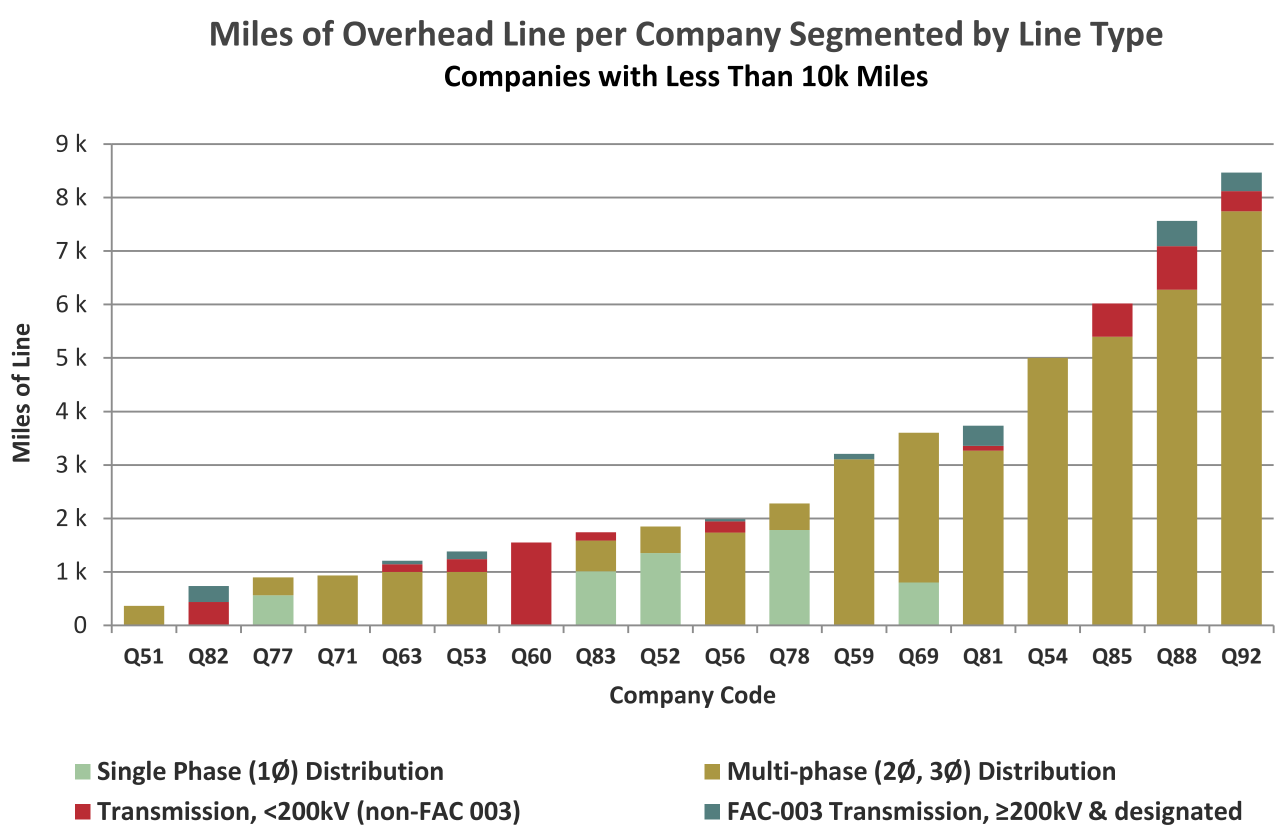


Figure 41: Miles of Overhead Line per Company Segmented by Line Type Companies with Less Than 10k Miles

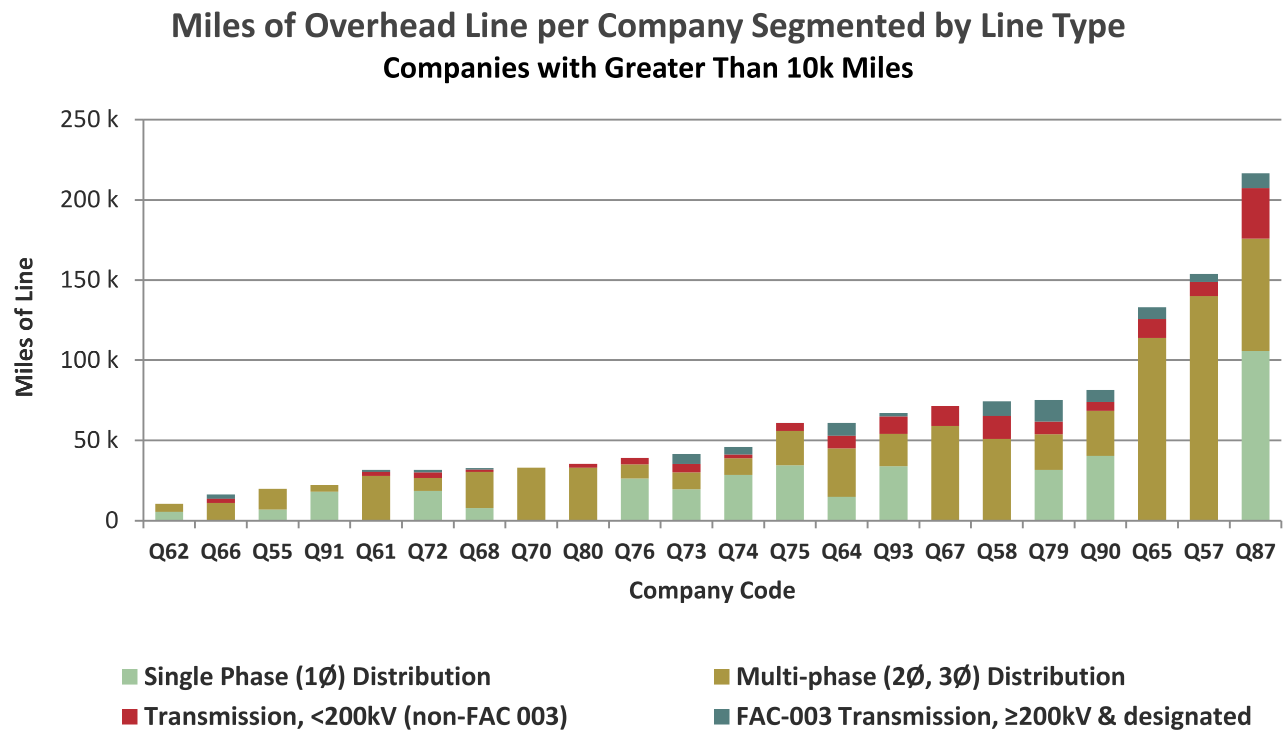
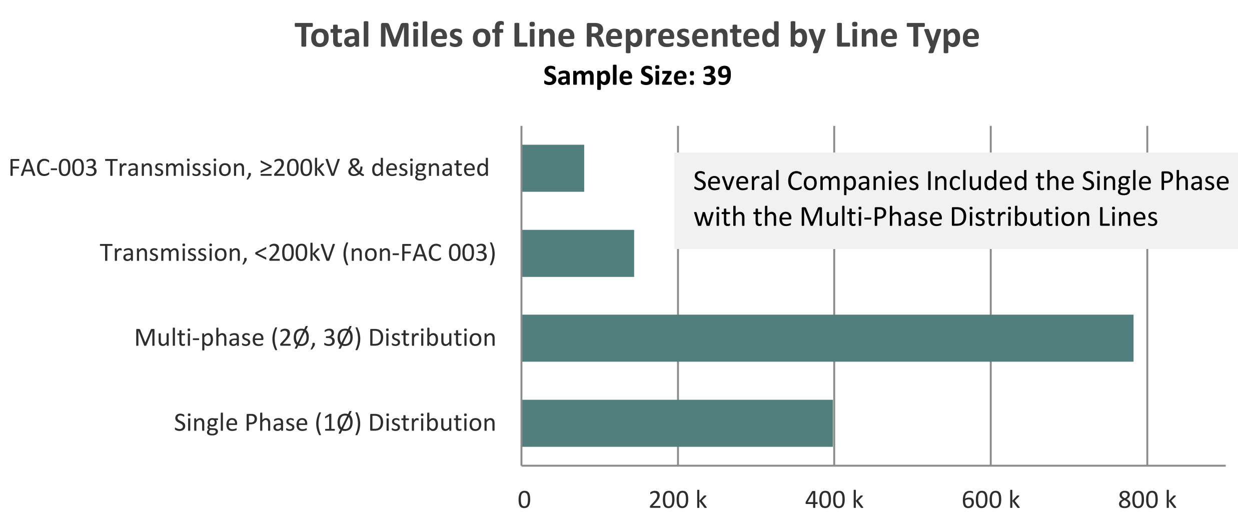


Figure 42: Miles of Overhead Line per Company Segmented by Line Type Companies with Greater Than 10k Miles



	Single Phase (1Ø) Distribution	Multi-phase (2Ø, 3Ø) Distribution	Transmission, <200kV (non-FAC 003)	FAC-003 Transmission, ≥200kV & designated
Miles of Line	398,254	782,276	144,207	80,208

Figure 43: Total Miles of Line Represented by Line Type

Question 4: Do you have a formal Tree Risk Assessment (TRA) program separate from routine maintenance for assessing and managing tree risk involving potentially hazardous trees? Comment on the nature of your Tree Risk Assessment program.

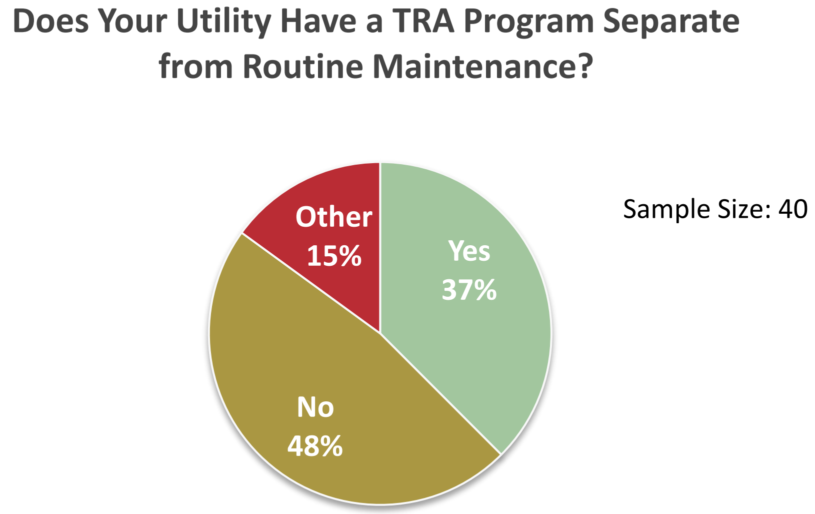


Figure 44: Does Your Utility Have a TRA Program Separate from Routine Maintenance?

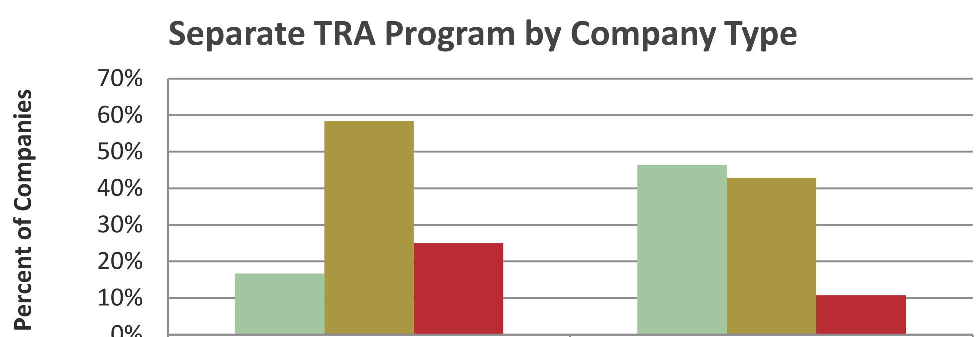
Responses to the questions are in brackets on comment tables. In other words, if the respondent answered, "Yes", [Yes] will appear after their comment. This will be true for all comment tables in this report.

TRA Program Descriptions
We have a mid-cycle vegetation patrol for obvious hazard trees [Other]
TRA is conducted as a critical component of routine maintenance [Other]
Yes for mountains of Colorado, focusing on trees killed by Mountain Pine Beetle and other insects in the 'epidemic area'. Otherwise hazard trees are mitigated as part of routine cycle maintenance in all other areas. [Other]
Distribution: Public Safety and Reliability Program addresses live trees with identified failure patterns. 2nd Patrol Program addresses dead or dying trees due to drought, beetle kill. Transmission: [Yes]
Aerial and Ground patrols [Yes]
For our Distribution program [Yes]
We have one of our [ ] foresters [are] train in hazard tree id and dedicate one day per week to looking for hazard trees. [Other]
Trees of a hazardous nature, posing either from limb, branch or tree position or state or decline, or positioning (leaning) are identified during foot patrol of transmission. [No]
We have a hazard tree program on both distribution and transmission systems. [Yes]
Level 2 risk assessment as part of prescriptive work planning [No]
While routine work is being completed, a trained job planner identifies hazard trees/limbs and these are removed at that time. [Other]

TRA Program Descriptions - continued
First we arrange our line in consideration of their outage number per kilometre (poor performing circuit). We patrol the worst fifth (20%) of these lines to detect 10 to 15 trees per km that show imminent risk of failure and we cut 40,000 trees per year. We detect and cut another 10,000 trees per year when patrolling line in the pruning and brush cutting cycle (15% of system about 17,500 Km/per year). We try to obtain owner authorization to cut all of those trees in respect of legal exigence. [Yes]
We complete an annual ground-based patrol and four aerial patrols of which Tree Risk is incorporated. [Yes]
Tree Risk Assessment Protocol built specifically for us based on ANSI Part 9 and TRAQ but modified for utility. [Yes]
Trees may exhibit potential threats to the facilities due to disease, damage, physical location, growth characteristics or environmental problems. Where these trees exist, the utility considers them high priority risks that need to be addressed and remediated. [No]
We have a program but it is very basic. Any dead, dying or significantly leaning trees are identified. We make a filed decision to remove or trim. This is only for our NERC/FERC facilities [Other]
The TRA is completed within the Asset Defect Program. [Yes]
Select potential hazard tree for removals [Yes]
Potential Danger trees identified during routine maintenance of circuits. Have utilized Intern to do Danger tree inventory on distribution. [Yes]
EHTM - Enhanced Hazard Tree Mitigation ranks circuits based upon customer count, miles of three phase bare wire, Tree exposure, & three year average for Customer Impacted per tree event and total customers impacted. Review Intensity is very robust from station breaker to 1st protection device. Intensity of review is reduced as progress moves beyond each protection device further out on a circuit. Customer count from protection device to end also dictates level of review. [Yes]

Comment Table 1: TRA Programs Descriptions

The following graph integrates the answers from Questions 3, 4, and 5.



	Distribution Only Companies: Sample 12	Distribution & Transmission and Transmission Only Companies: Sample 28
Have Separate TRA Program	17%	46%
Do NOT Have Separate TRA Program	58%	43%
Other	25%	11%

Figure 45: Separate TRA Program by Company Type

Question 5: Is your Tree Risk Assessment program modeled after Level 1 Tree Risk Assessment practices as described in ANSI A300 Part 9 and the current ISA TRA BMP?

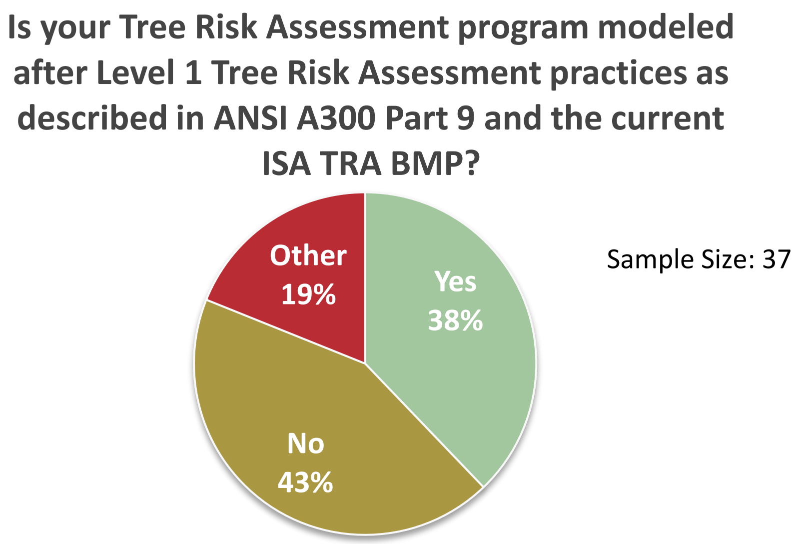


Figure 46: Is your Tree Risk Assessment program modeled after Level 1 Tree Risk Assessment in ANSI A300?

TRA Program Practices in Relation to ANSI A300 Part 9
We employ professional arborists who have qualifications such as college degrees in forestry, ISA arborist certified, utility arborist certified, and/or hold State tree expert certifications plus have on the job experience. Current vegetation management specifications require identification, evaluation and mitigation of trees as described in a Level 1 TRA. Today our current specifications do not reference ANSI A300 Part 9. [Yes]
[Province] has the "[Province] Reliability Standard" which is modeled from the NERC Standards. [Other]
Ours is based on the UAA Utility Best Management Practices Tree Risk Assessment and Abatement for Fire Prone States and Provinces in the Western Region of North America [Other]
To my knowledge our program is not modeled after others, but our guy, [ ], is using principals learned from a week long certification class attended last year. [Other]
Overhead inspection of 33% of the plant each year to identify hazards and high priority actions. [No]
Developed in-house [Other]
ANSIA300 part 9 is unknown here in [Province]. [No]
We use the same terminology for Level 1, visual and limited visual assessment. [Yes]
1. Visual Assessment While performing work on a circuit, contract crews shall conduct a visual assessment to identify trees with imminent and/or probable likelihood of failure inside and outside the right-of-way. The tree should be viewed from some distance away, if possible, to consider crown shape and surroundings. Any tree identified to be a potential imminent threat to a utility line shall be reported to the responsible forester. [Yes]
[Utility]'s Level 1 would be the most intense review including a 360 survey of each tree. This is from the station breaker to the first protection device or beyond depending on calculated customers served on the specific circuit. *** A [Utility] level 3 would equate to a level 1 per ANSI A300

Comment Table 2: TRA Program Practices in Relation to ANSI A300 Part 9

Question 6: Does your company have specified and formally documented procedures to elevate the level of inspection intensity of a tree or site from Level 1 to Level 2 and/ or Level 3?

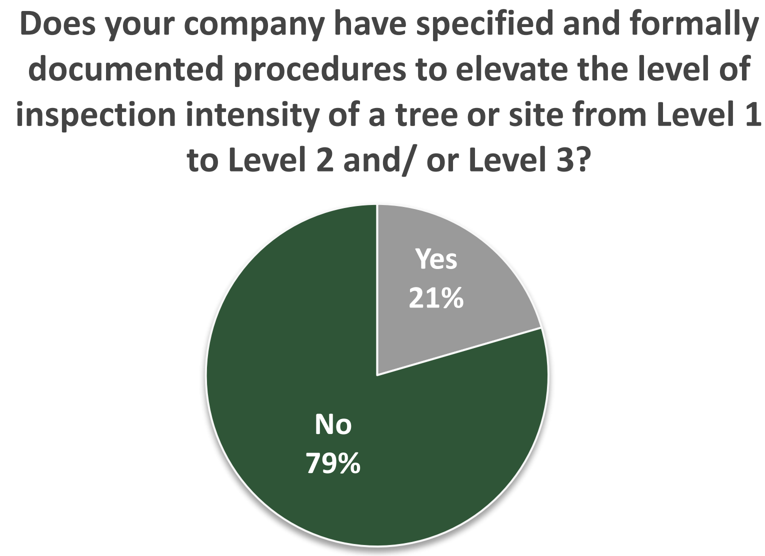


Figure 47: Does your company have procedures to elevate the level of inspection intensity?

TRA Level of Inspection Intensity
Due to the small size of our area, we inspect and complete any work identified in the same year. [No]
If hazard trees are identified in a level one assessment, inspectors are expected to look farther into the issue. [No]
Trees posing an imminent threat are reported immediately and removal is governed by timeline. Formalized program to manage trees of risk. [Yes]
We have developed inboard criteria. [Yes]
We state that we only elevate to Level 2 (we don't have the means for level 3). We have defined required action/assessment based on defect levels. [Yes]
Only to Level 2. Program is conservative and will take any trees that are a threat without the need of a Level 3 evaluation. [Level] 2. Ground Evaluation: If a Hazard Tree is identified during the visual assessment, a 360° ground evaluation shall be required. The evaluations should include an inspection of: * Tree crown * Trunk * Trunk flare * Above-ground roots * Site conditions around the tree in relation to targets. The Contractor shall report risk and mitigation options to the responsible utility forester. [Yes]
Our level 2 is a Moderate Inspection Intensity and is conducted beyond the first protection device out to a calculated customer service point or pre-determined number of customers served. Level 3 is an Imminent Risk Inspection. Again, a calculated customer service point determines the intensity of tree inspection. [Yes]

Comment Table 3: TRA Level of Inspection Intensity

Question 7: Do you use a Visual Tree Assessment (VTA) checklist or risk evaluation form that is intended to assign a numeric score to tree related risk?

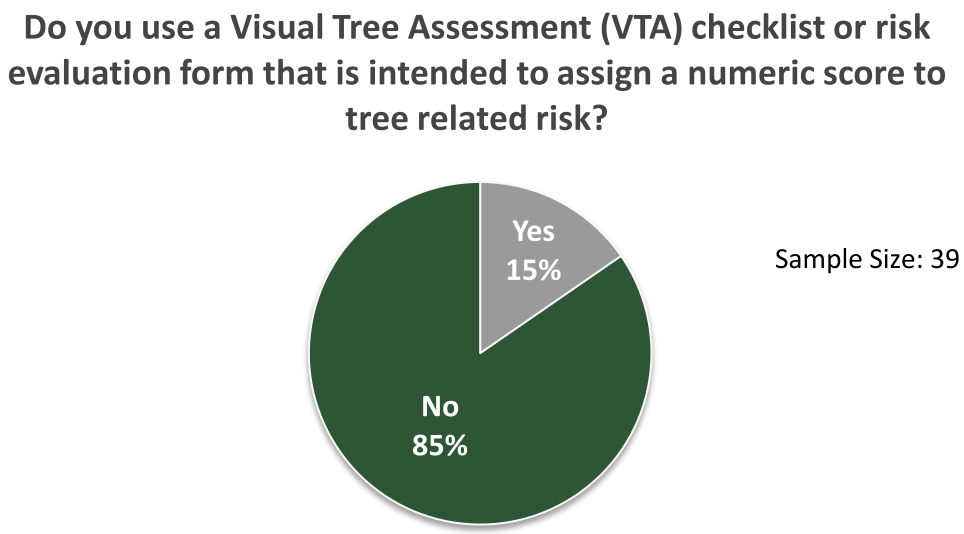


Figure 48: Do you use a Visual Tree Assessment (VTA) checklist intended to assign a numeric score to tree related risk?

Risk Evaluation Descriptions
Derived internally and incorporates circuit information and customer counts, site specific weather patterns, and common failure patterns derived from internal outage investigations. [Yes]
Some of us had the formation and we integrated the principle in our process. [Yes]
We do use a form, but it does not assign a numeric value. It leads you to an action based on a matrix. [No]
Numeric score is just prioritization depending on tree assessment and site conditions (voltage, type of construction etc.) [Yes]

Comment Table 4: Risk Evaluation Descriptions

Question 8: Which best describes the type of vegetation inspection(s) conducted on your system? Please enter an estimated percent (%) of total line miles inspected for each line type. *NOTE: Each graph for Question 8 is arranged by percent of lines inspected annually with the most on the right.*

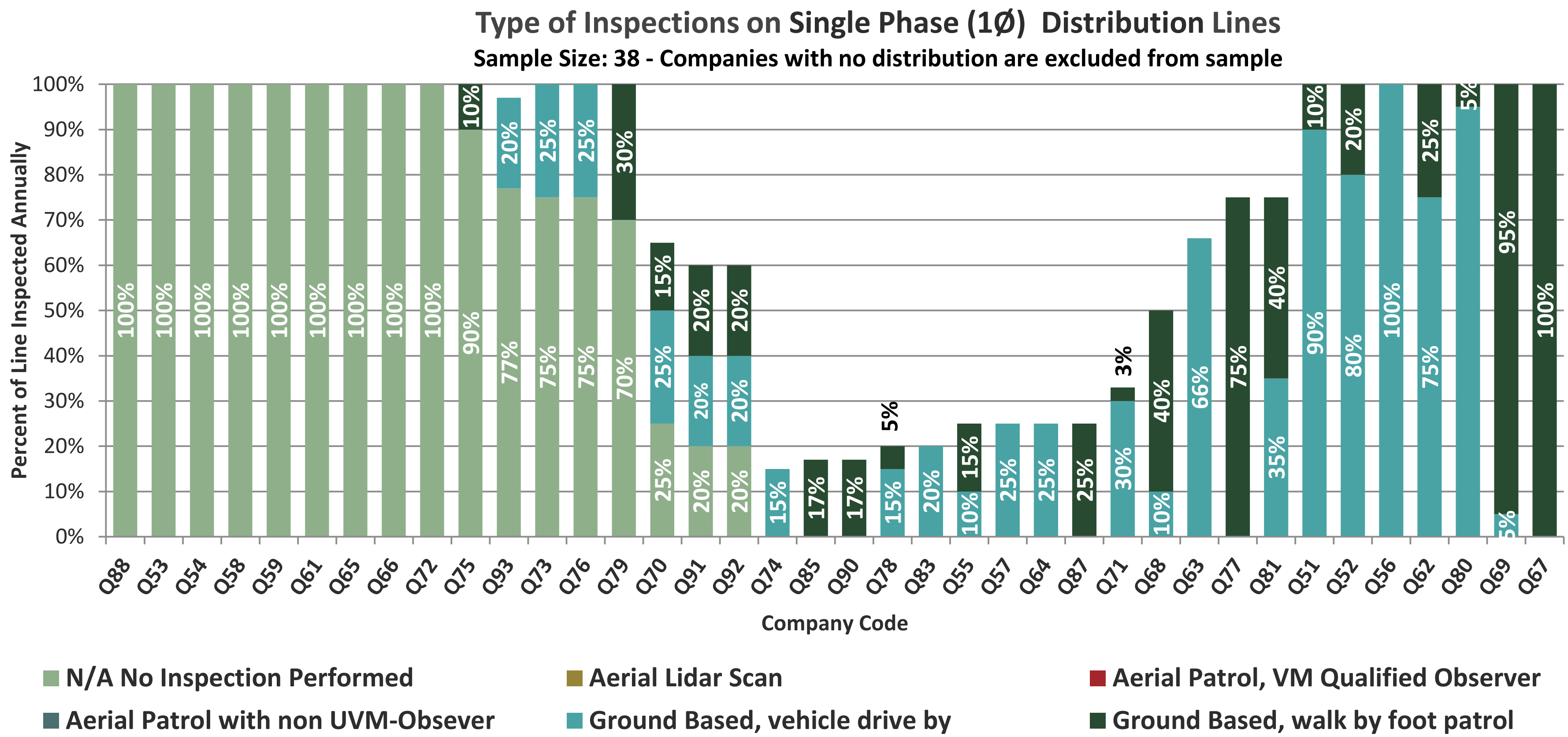


Figure 49: Types of Inspections Performed on Single Phase Distribution Annually

Statistics on Annual Inspection for Single Phase Distribution Lines:

- 18% Inspect 100% of the Single Phase Lines Annually
- 24% Do Not Inspect Any of The Single Phase Lines

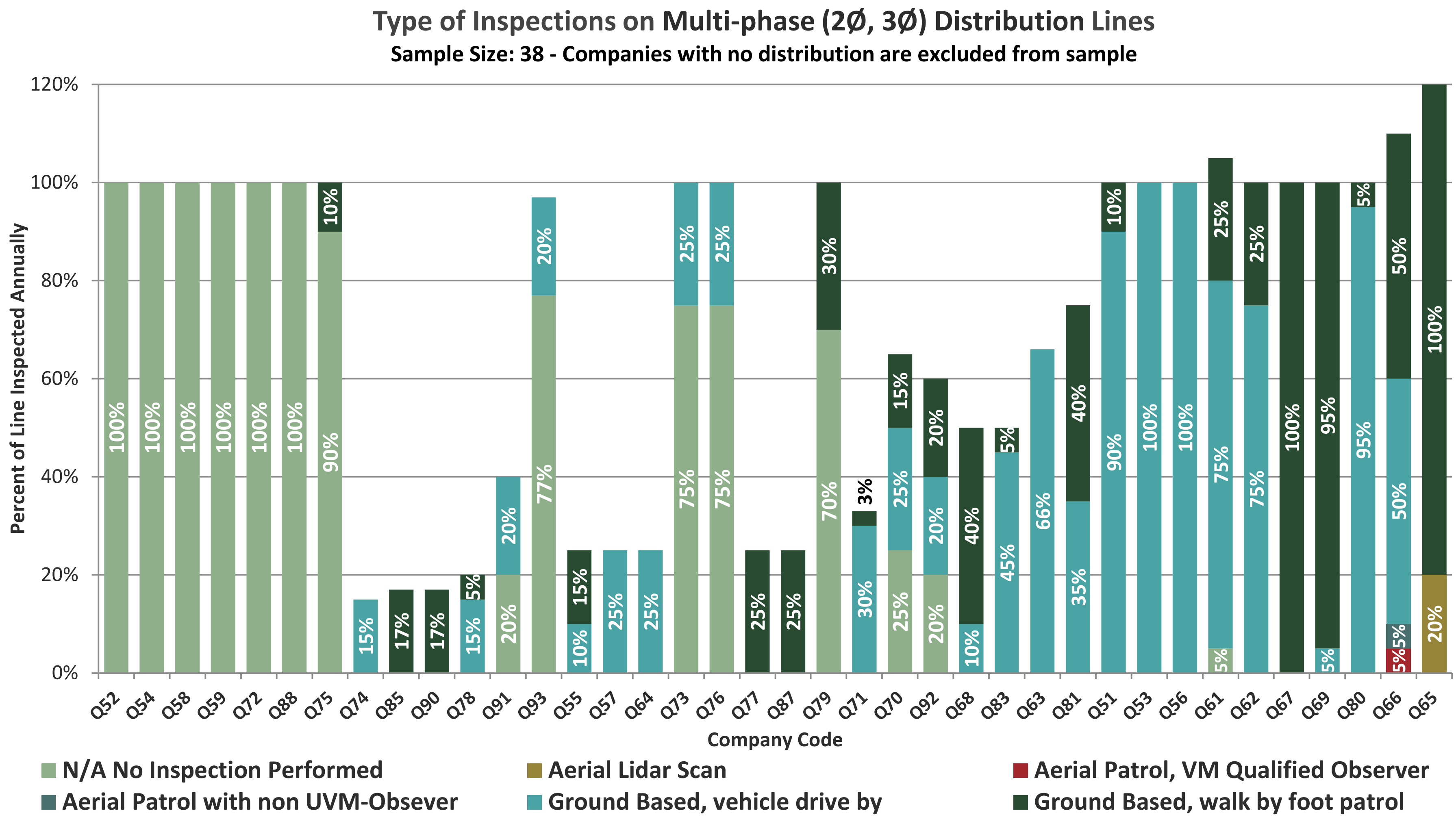


Figure 50: Types of Inspections Performed on Multi Phase Distribution Annually

Statistics on Annual Inspection for Multi-Phase Distribution Lines:

- 26% Inspect 100% of the Multi-Phase Lines Annually
- 16% Do Not Inspect Any of The Multi-Phase Lines

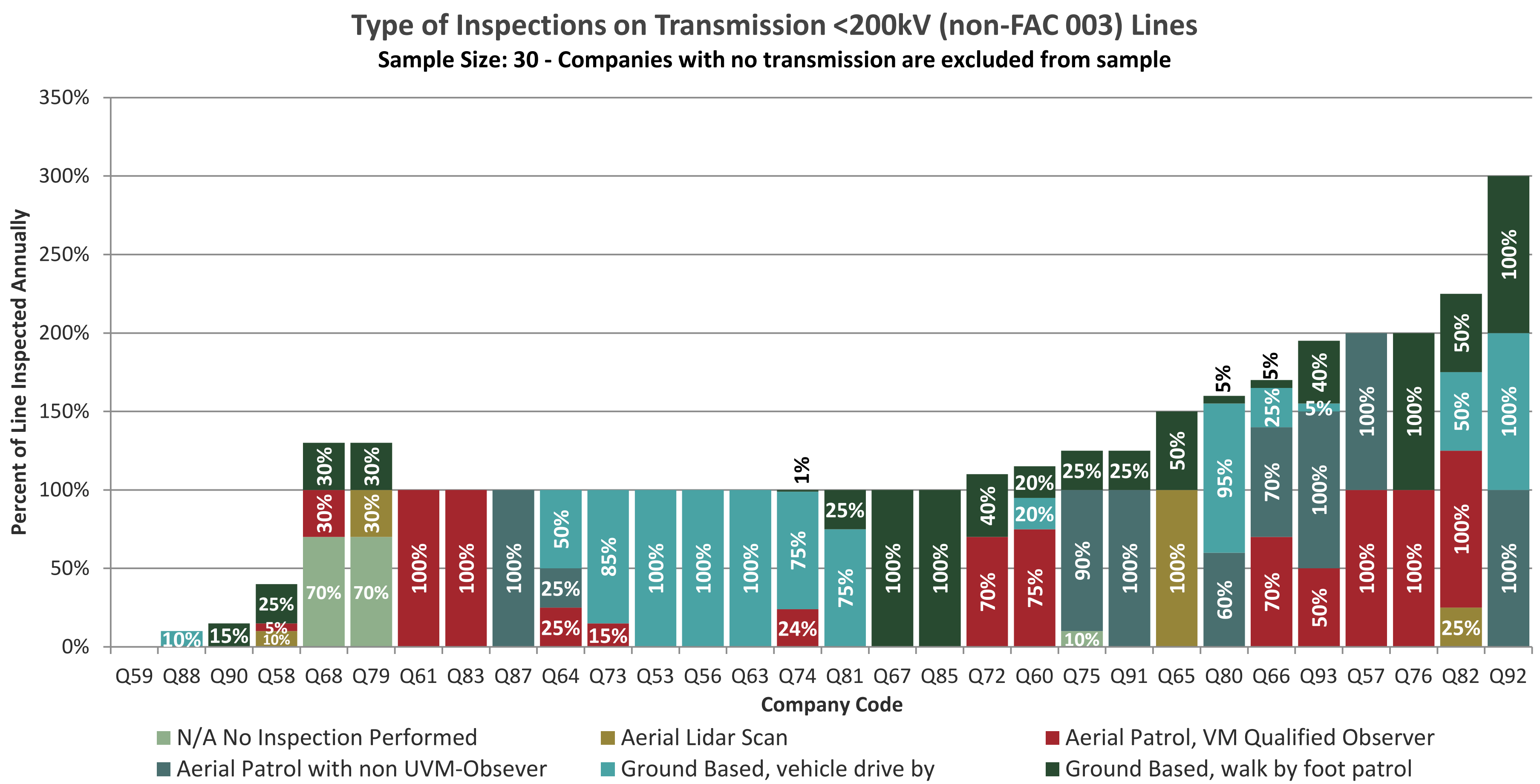


Figure 51: Types of Inspections Performed on Non-FAC-003 Regulated Transmission Lines Annually

Statistics on Annual Inspection for Non-FAC-003 Regulated Transmission Lines:

- 63% Inspect 100% of the Non-FAC-003 Regulated Transmission Lines Annually
- 3% Do Not Inspect Any of The Non-FAC-003 Regulated Transmission Lines

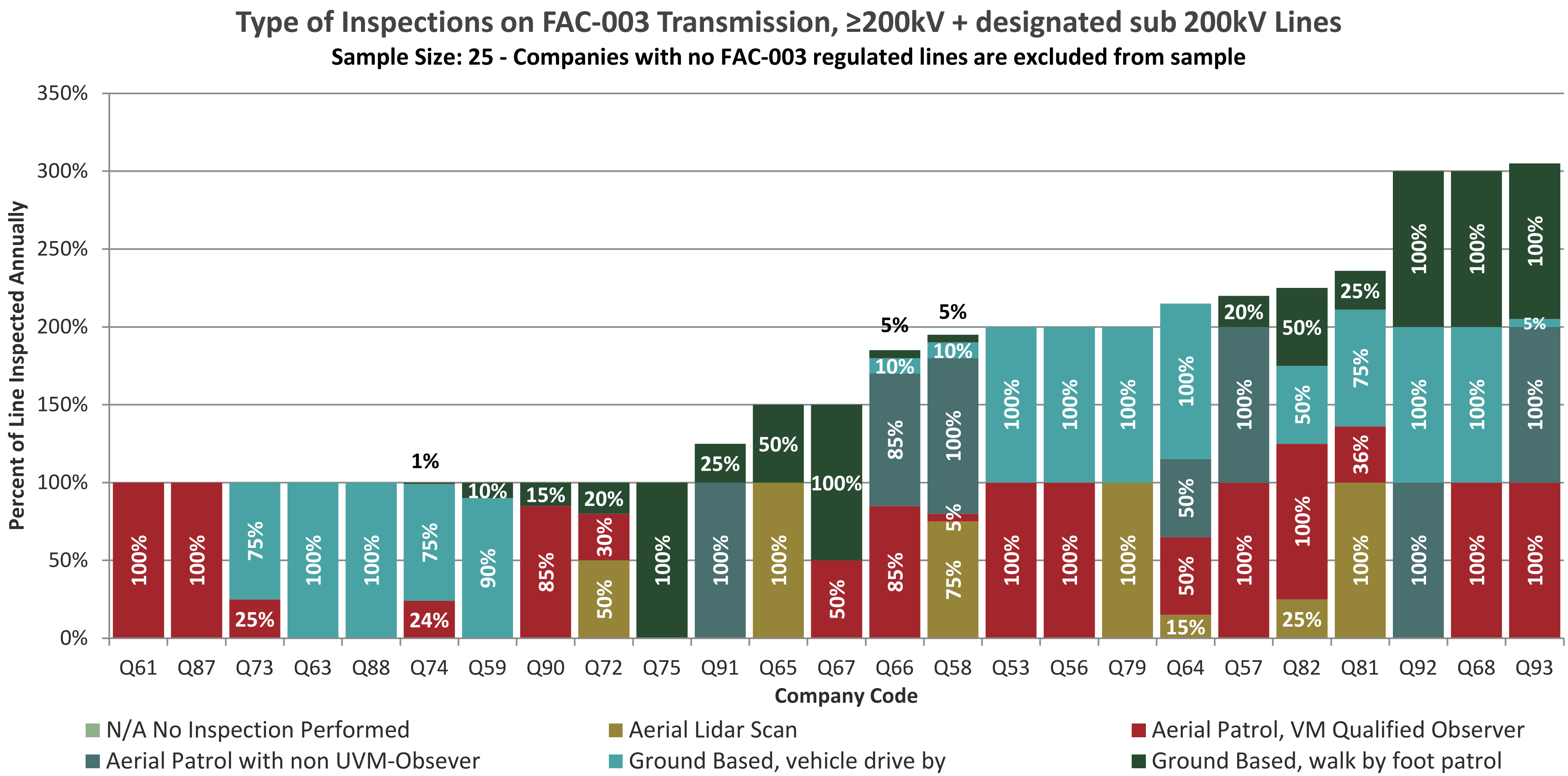


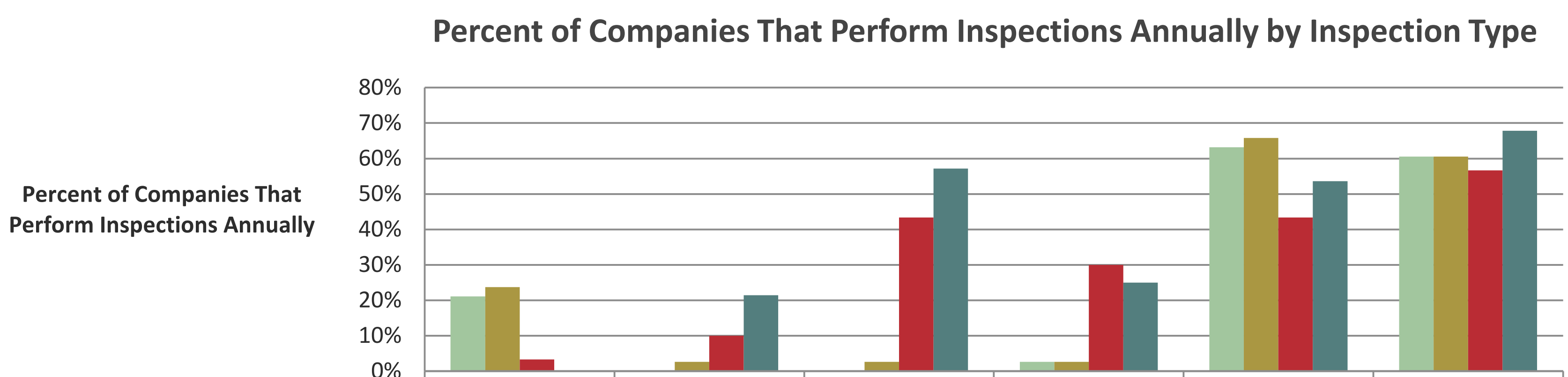
Figure 52: Types of Inspections Performed on FAC-003 Regulated Transmission Lines Annually

Statistics on Annual Inspection for FAC-003 Regulated Transmission Lines:

- 100% Inspect 100% of the FAC-003 Regulated Transmission Lines Annually
- 60% Use Multiple Methods of Inspection for Some of the FAC-003 Regulated Transmission lines

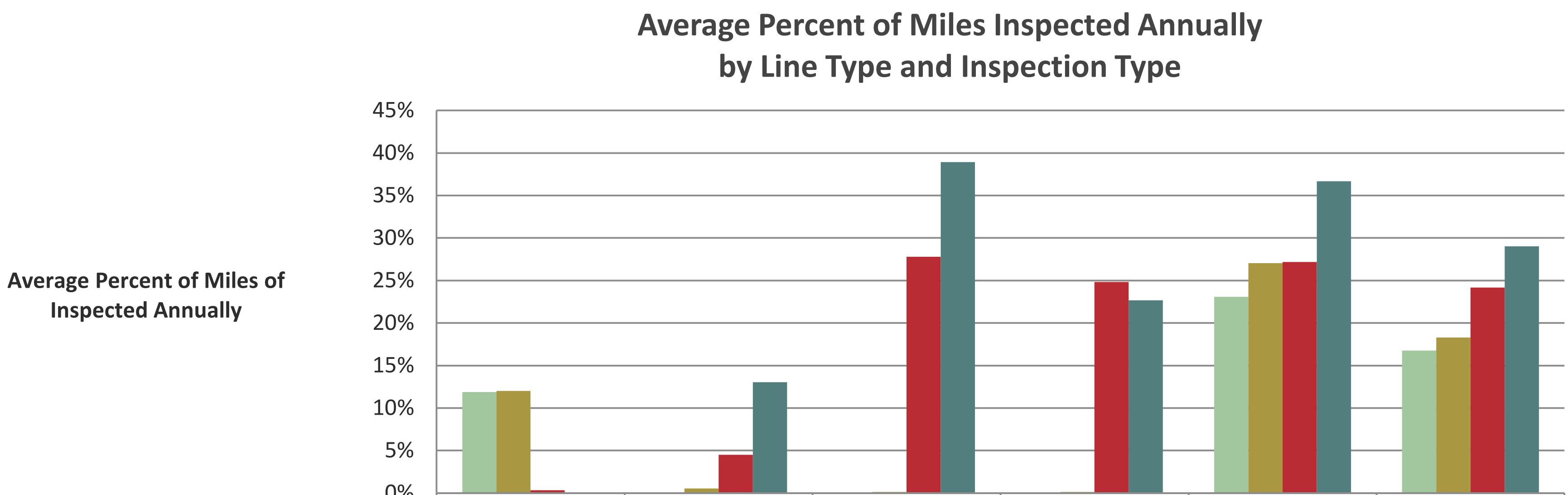
Comments on Types of Inspections
All distribution are patrolled (either vehicle or foot if private property) based on feeder classification. Urban is trimmed every 4 years, rural every 6 with each inspection at mid-point
fixed wing monthly on all BES by non UVM-observer
Some of the foot patrols are followed by aerial patrol.
100% of lines above 200kV are inspected annually
Line patrol for hardware and trees 5-year cycle
LiDAR is once every 5th year.
We patrol all 230kV facilities twice a year, should be 200% in the 230kv category
In 2015 we captured Lidar on all FAC 003-3 lines in one Jurisdiction including pending 115kV IROL circuits. To date it is not an annual inspection tool

Comment Table 5: Comments on Types of Inspections



	No Inspection Performed	Aerial Lidar Scan	Aerial Patrol, VM Qualified Observer	Aerial Patrol with non UVM-Obsever	Ground Based, vehicle drive by	Ground Based, walk by foot patrol
1Ø Distribution (Sample 38)	21%	0%	0%	3%	63%	61%
2Ø, 3Ø Distribution (Sample 38)	24%	3%	3%	3%	66%	61%
Transmission, non-FAC 003 (Sample 30)	3%	10%	43%	30%	43%	57%
FAC-003 Transmission (Sample 28)	0%	21%	57%	25%	54%	68%

Figure 53: Percent of Miles Inspected by Line and Inspection Type



	No Inspection Performed	Aerial Lidar Scan	Aerial Patrol, VM Qualified Observer	Aerial Patrol with non UVM-Obsever	Ground Based, vehicle drive by	Ground Based, walk by foot patrol
1Ø Distribution (Sample 38)	12%	0%	0%	0%	23%	17%
2Ø, 3Ø Distribution (Sample 38)	12%	1%	0%	0%	27%	18%
Transmission, non-FAC 003 (Sample 30)	0%	5%	28%	25%	27%	24%
FAC-003 Transmission (Sample 28)	0%	13%	39%	23%	37%	29%

Figure 54: Average Percent of Miles Inspected Annually by Line Type and Inspection Type

Question 9: Which best describe the intended frequency of vegetation inspections completed as part of a deliberate inspection program (rather than informal, incidental inspection). Check all that apply

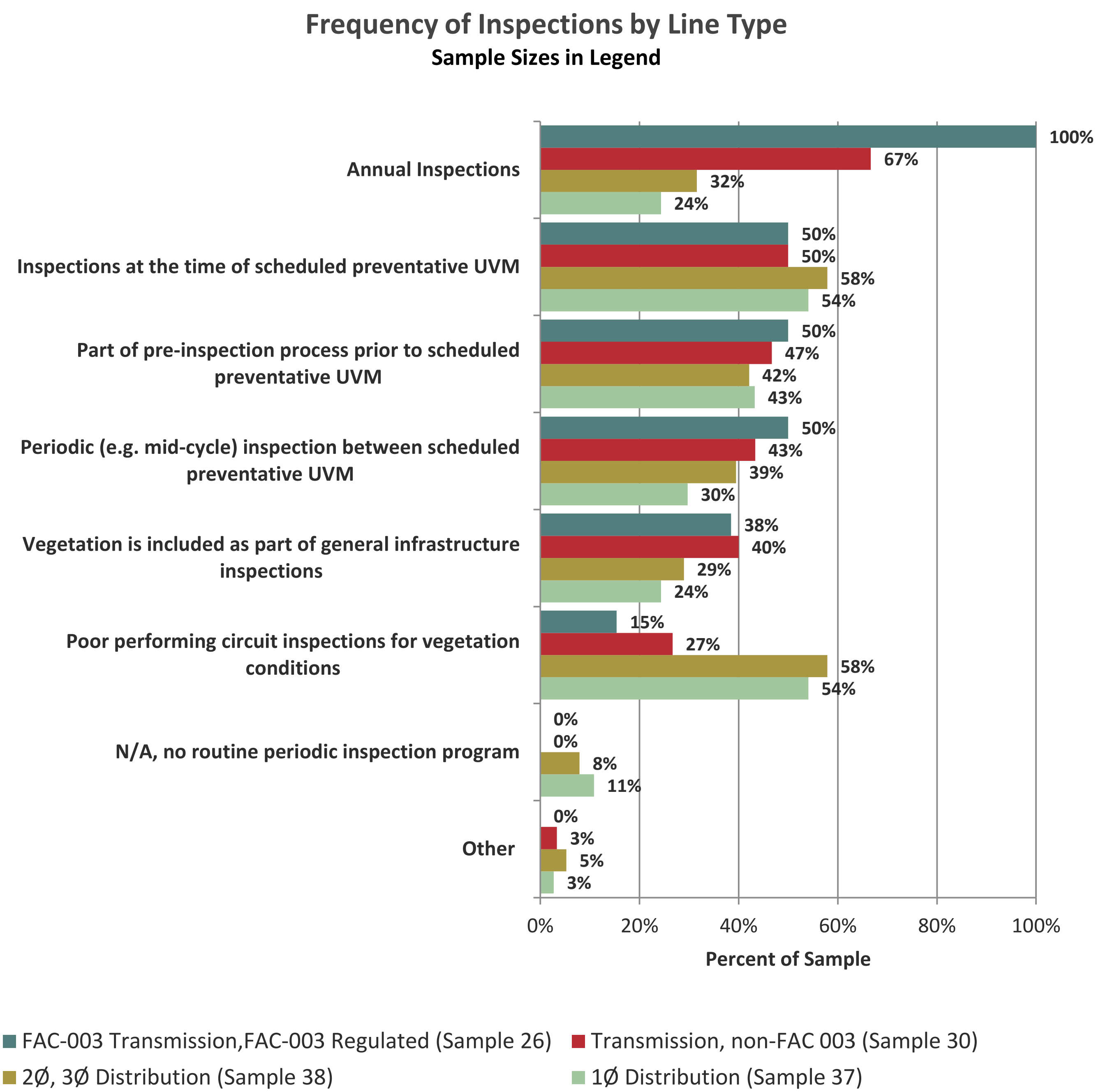


Figure 55: Frequency of Inspections by Line Type

Comments on Frequency of Inspections
For maintenance trimming, typically have a planner do a pre-inspection, crews perform inspections at time of trimming, and General Foreman does a post-trimming quality assessment.
DISTRIBUTION: random inspections by operations personnel for circuits of interest. Level 1 inspections by veg management of circuits experiencing significant general reliability issues or increased customer complaints.
Quarterly aerial patrols with qualified VM personnel of all 200kV and greater transmission corridors.
We added "Post Storm" inspections to our program a couple years. We usually find more risk trees per mile immediately after a major storm event. [Other]
We consider anytime that we are out looking at circuits that we are on inspection/ patrol
Line patrol 5-year cycle
100% post audit for all NERC VM control activities, and 7 to 8% post audit for everything else.
We patrol our 40 miles of 138kV and selected priority 69kV (tie line) facilities.

Comment Table 6: Comments on Frequency of Inspections

Question 10: Which best describes the qualifications of personnel who regularly perform Tree Risk Assessments (TRA)? If more than one category of Assessment Personnel is involved for a line type, please indicate the percent (%) of line miles inspected by each.

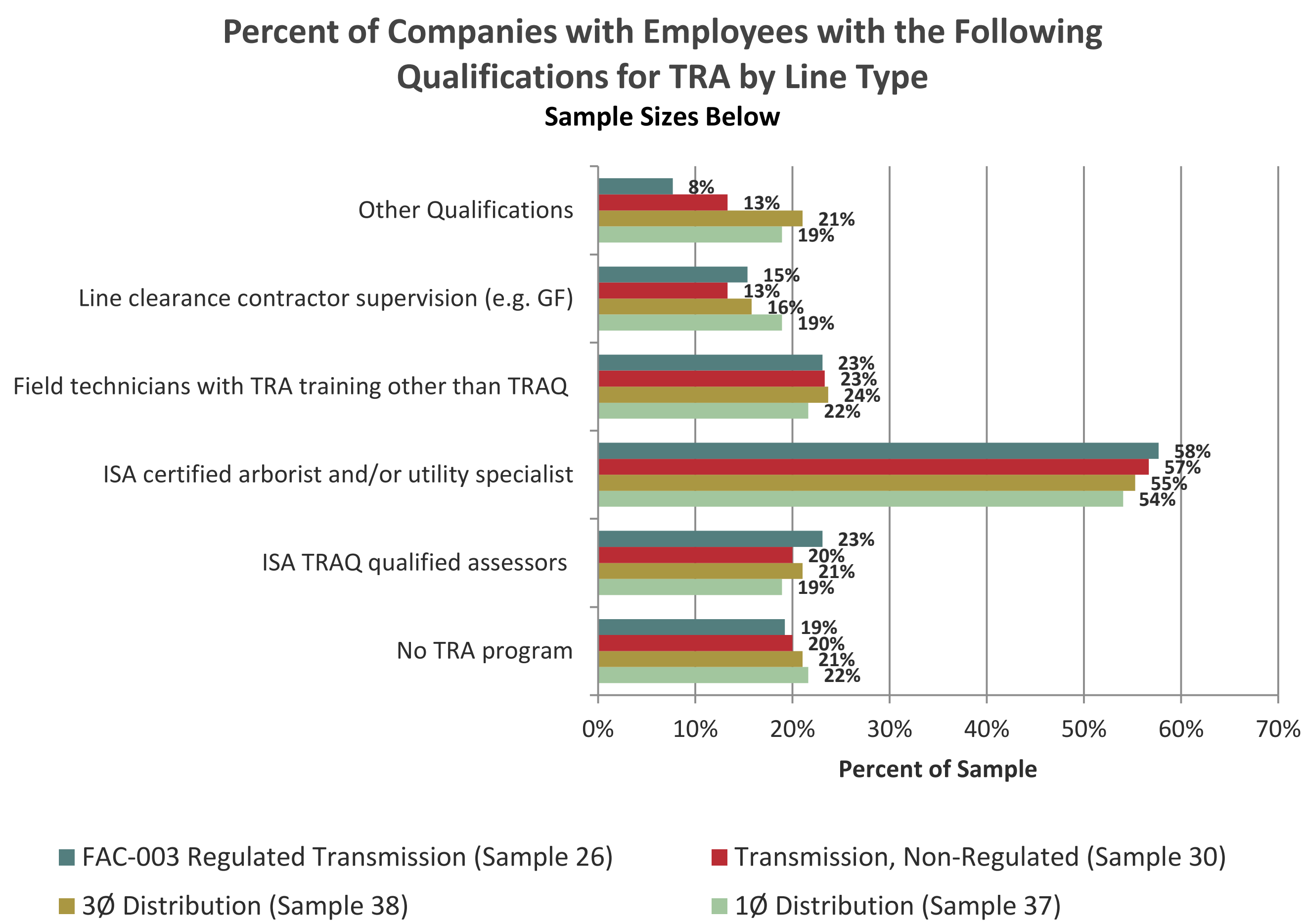


Figure 56: Percent of Companies with Employees with the Following Qualifications for TRA by Line Type

Other Qualifications for Inspectors
Our contract foresters have additional TRA training programs through their parent employer.
Internal risk tree assessment protocol training
Other qualifications are degreed foresters.
We do not have a separate TRA program, but we do have trained planners evaluating and looking for high risk whole tree failures and co-dominate branching during our VM cycle
It's an internal equivalent
We do not currently perform TRA.
Power Lineman
Forestry Technicians
Line clearance contractor supervision is also ISA certified arborists.
UVM contractor personnel with general working knowledge of obvious hazards; administered by dedicated utility forester.
Powerline Technician that is also a Safety Codes Officer

Comment Table 7: Other Qualifications for Inspectors

TRA Inspection Qualifications for 1Ø Distribution

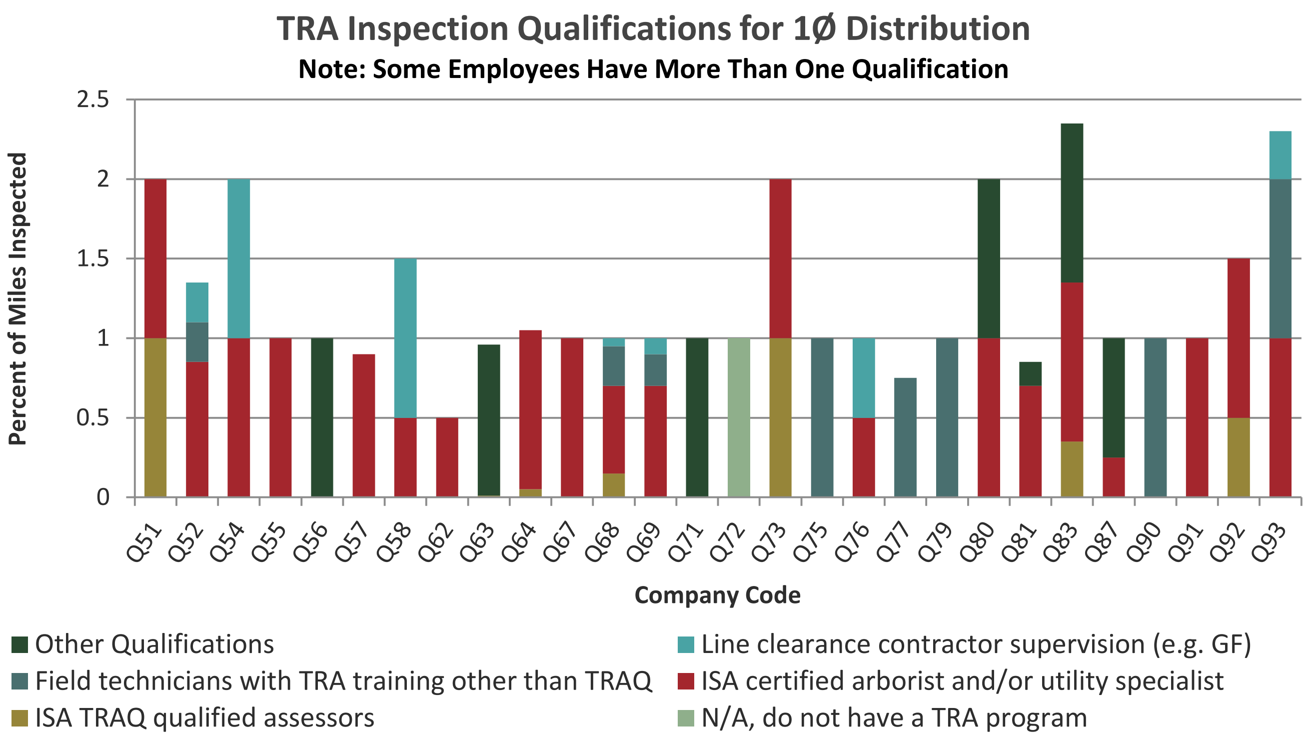


Figure 57: TRA Inspection Qualifications for 1Ø Distribution

Percent of Miles Inspected By Personnel with Given Qualifications For 1Ø Distribution						
Statistics	**No TRA program**	**ISA TRAQ qualified assessors**	**ISA certified arborist and/or utility specialist**	**Field technicians with TRA training other than TRAQ**	**Line clearance contractor supervision**	**Other Qualifications**
Sample Size	1	7	20	8	7	7
Average	100%	44%	82%	68%	46%	84%
Median	100%	35%	100%	88%	30%	100%
Q1	100%	10%	66%	25%	18%	85%
Q3	100%	10%	66%	25%	18%	85%
Max	100%	100%	100%	100%	100%	100%
Min	100%	1%	25%	20%	5%	15%

Statistics Table 1: Percent of miles inspected by personnel with given qualifications for 1Ø Distribution

TRA Inspection Qualifications for 3Ø Distribution

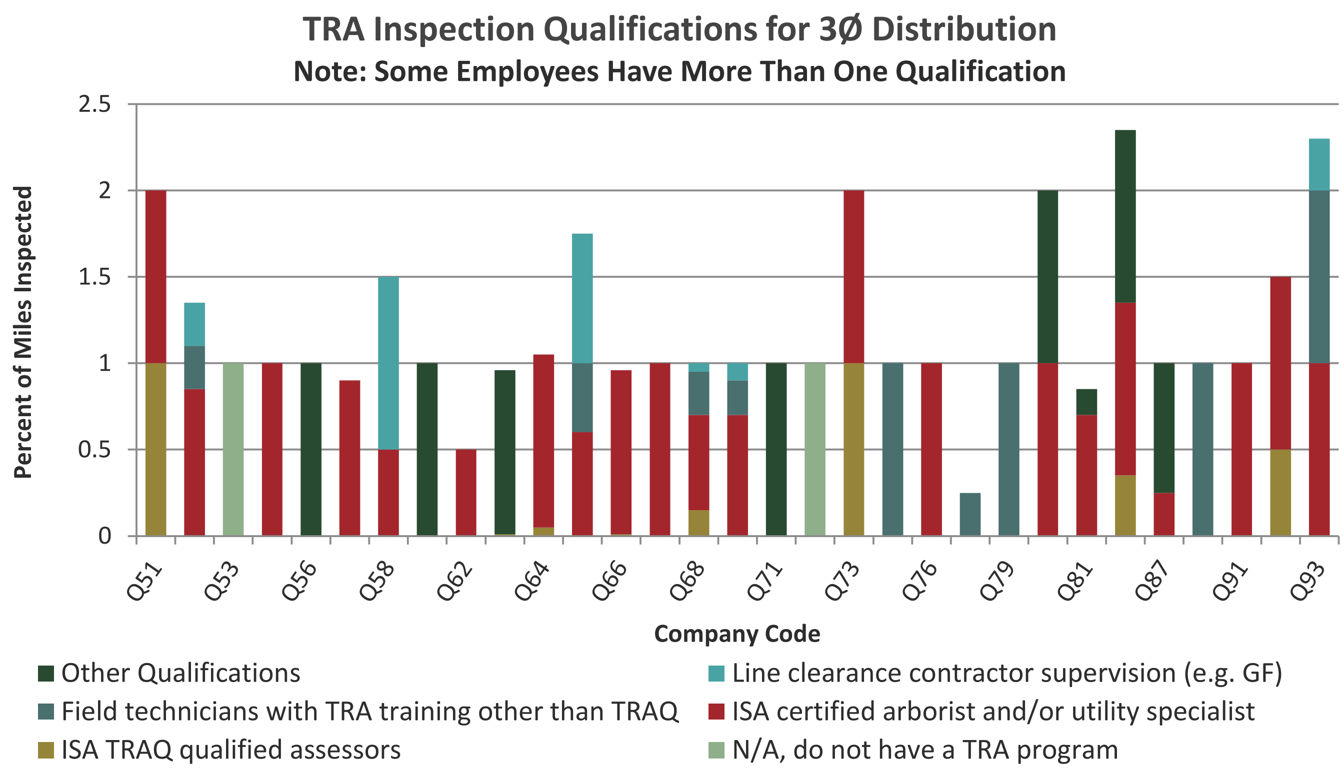


Figure 58: TRA Inspection Qualifications for 3Ø Distribution

Percent of Miles Inspected By Personnel with Given Qualifications For 3Ø Distribution						
Statistics	No TRA program	ISA TRAQ qualified assessors	ISA certified arborist and/or utility specialist	Field technicians with TRA training other than TRAQ	Line clearance contractor supervision	Other Qualifications
Sample Size	2	8	21	9	6	8
Average	100%	38%	83%	59%	41%	86%
Median	100%	25%	100%	40%	28%	100%
Q1	100%	4%	70%	25%	14%	90%
Q3	100%	4%	70%	25%	14%	90%
Max	100%	100%	100%	100%	100%	100%
Min	100%	1%	25%	20%	5%	15%

Statistics Table 2: Percent of miles inspected by personnel with given qualifications for 3Ø Distribution

TRA Inspection Qualifications for Non-FAC-003 Regulated Transmission

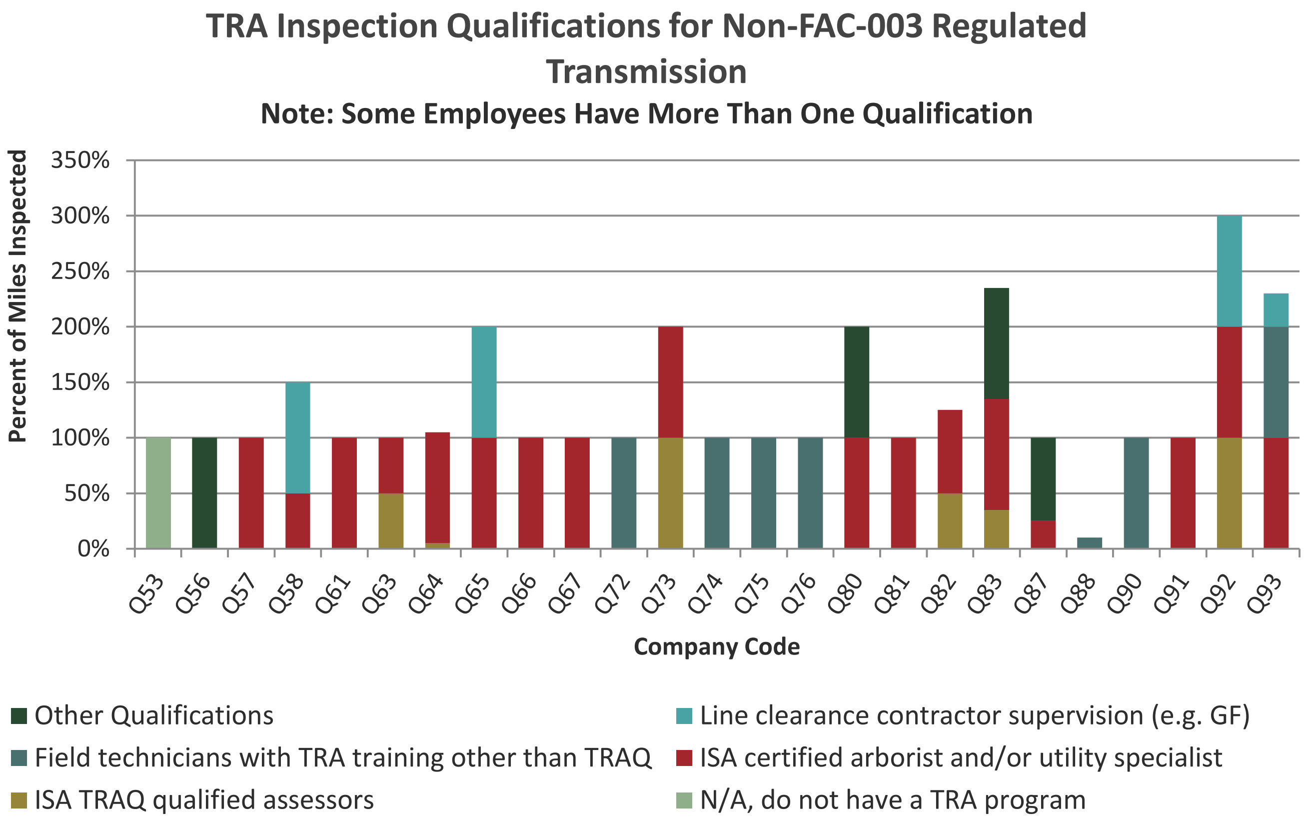


Figure 59: TRA Inspection Qualifications for Non-FAC-003 Regulated Transmission

Percent of Miles Inspected By Personnel with Given Qualifications for Non-FAC-003 Regulated Transmission						
Statistics	No TRA program	ISA TRAQ qualified assessors	ISA certified arborist and/or utility specialist	Field technicians with TRA training other than TRAQ	Line clearance contractor supervision	Other Qualifications
Sample Size	1	6	16	6	3	4
Average	100%	57%	88%	87%	83%	94%
Median	100%	50%	100%	100%	100%	100%
Q1	100%	39%	100%	100%	83%	94%
Q3	100%	39%	100%	100%	83%	94%
Max	100%	100%	100%	100%	100%	100%
Min	100%	5%	25%	10%	30%	75%

Statistics Table 3: Percent of Miles Inspected By Personnel with Given Qualifications for Non-FAC-003 Regulated Transmission

TRA Inspection Qualifications for FAC-003 Regulated Transmission

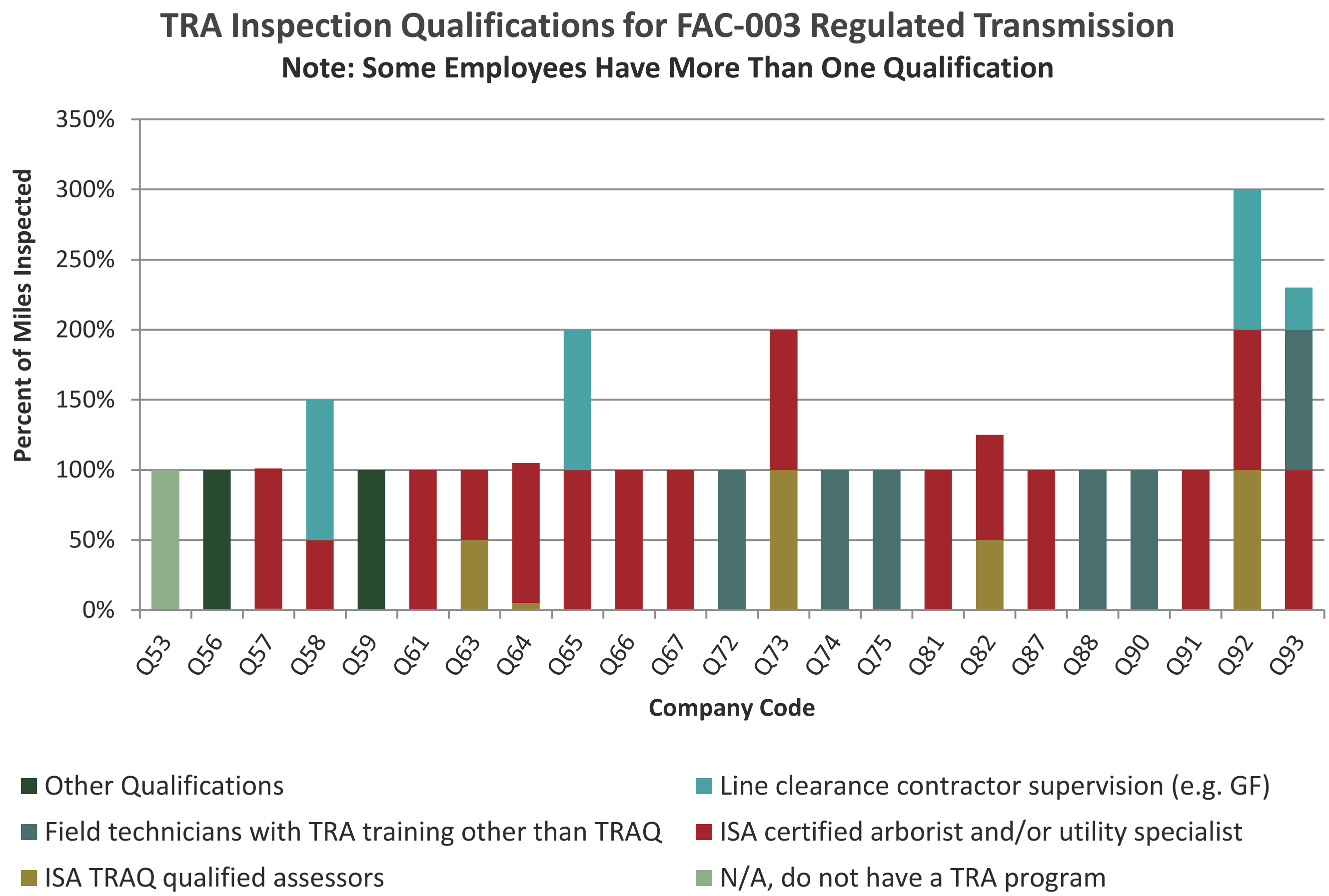


Figure 60: TRA Inspection Qualifications for FAC-003 Regulated Transmission

Percent of Miles Inspected By Personnel with Given Qualifications for FAC-003 Regulated Transmission						
Statistics	No TRA program	ISA TRAQ qualified assessors	ISA certified arborist and/or utility specialist	Field technicians with TRA training other than TRAQ	Line clearance contractor supervision	Other Qualifications
Sample Size	1	6	15	6	1	6
Average	100%	51%	92%	100%	100%	51%
Median	100%	50%	100%	100%	100%	50%
Q1	100%	16%	100%	100%	100%	16%
Q3	100%	16%	100%	100%	100%	16%
Max	100%	100%	100%	100%	100%	100%
Min	100%	1%	50%	100%	100%	1%

Statistics Table 4: Percent of Miles Inspected By Personnel with Given Qualifications for FAC-003 Regulated Transmission

Question 11: Do you have formal specifications that codify requirements for Tree Risk Assessment?

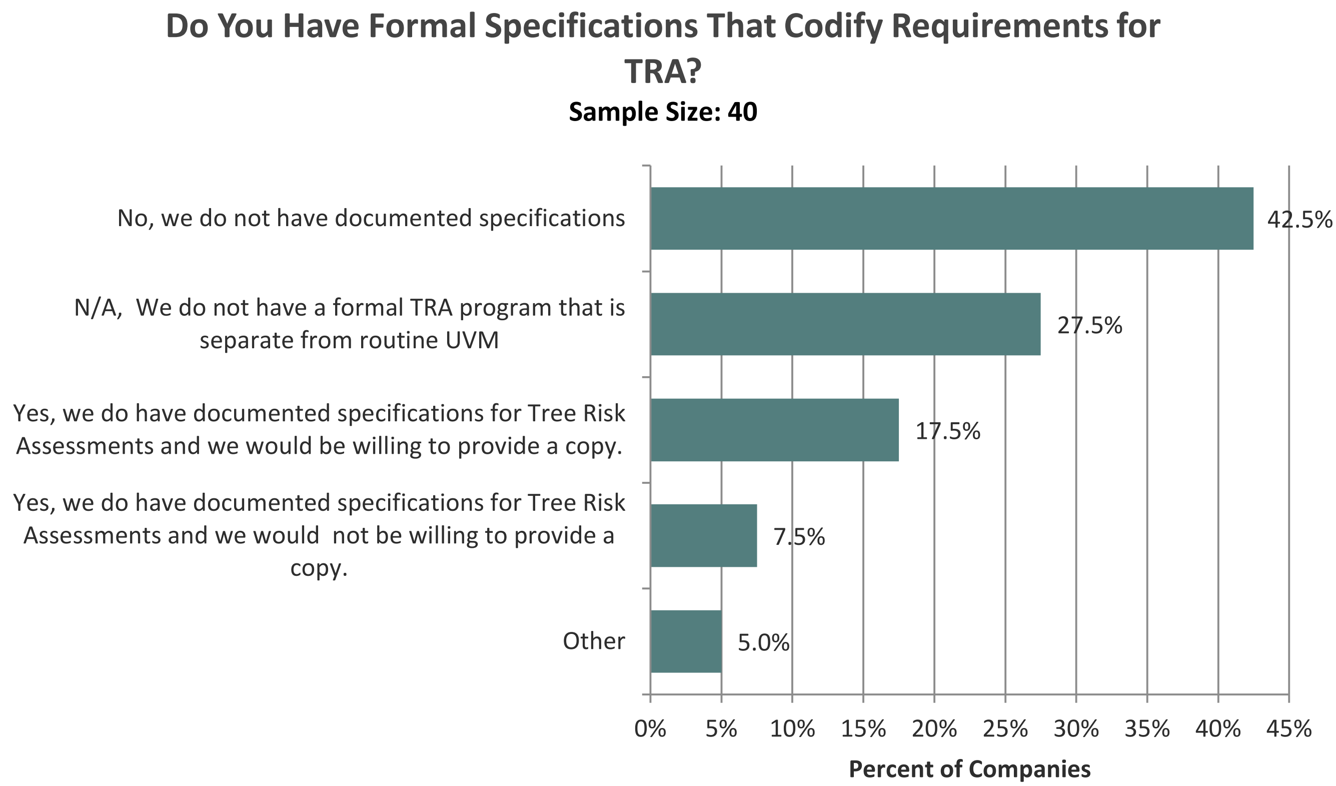


Figure 61: Do You Have Formal Specifications That Codify Requirements for TRA?

Formal Specification for TRA Comments
We have a general approach on risk vs target (voltage/facilities). For example a tree with slight risk for a single phase line would not be acceptable risk for sub-T radial feed [Other]
Experience and common sense is our guide! [N/A, No]
We do not have a formal TRA program that is separate routine UVM [N/A, No]
I would need approval from the vendor who helped us develop the material, as it is copyrighted. [Yes, will provide copy]
Specifications are specific to FAC-003 applicable lines. [Yes, will *not* provide copy]
As [we] gather more data we expect to craft specs. [N/A, No]
Most of TRA program is routine UVM, we are currently doing inspections and collecting danger tree inventory on Distribution. Transmission is done during annual and mid-cycle inspections [Other]
We craft our specs ourselves and we do inform our personnel. And our spécifications are in French. [Yes, will provide copy]
We have a section in our Vegetation Management Guidelines Book that refers to hazard tree expectations (section 2.2). [Yes, will provide copy]

Comment Table 8: Formal Specification for TRA Comments

Question 12: Do you provide or require training for Tree Risk Assessment assessors?

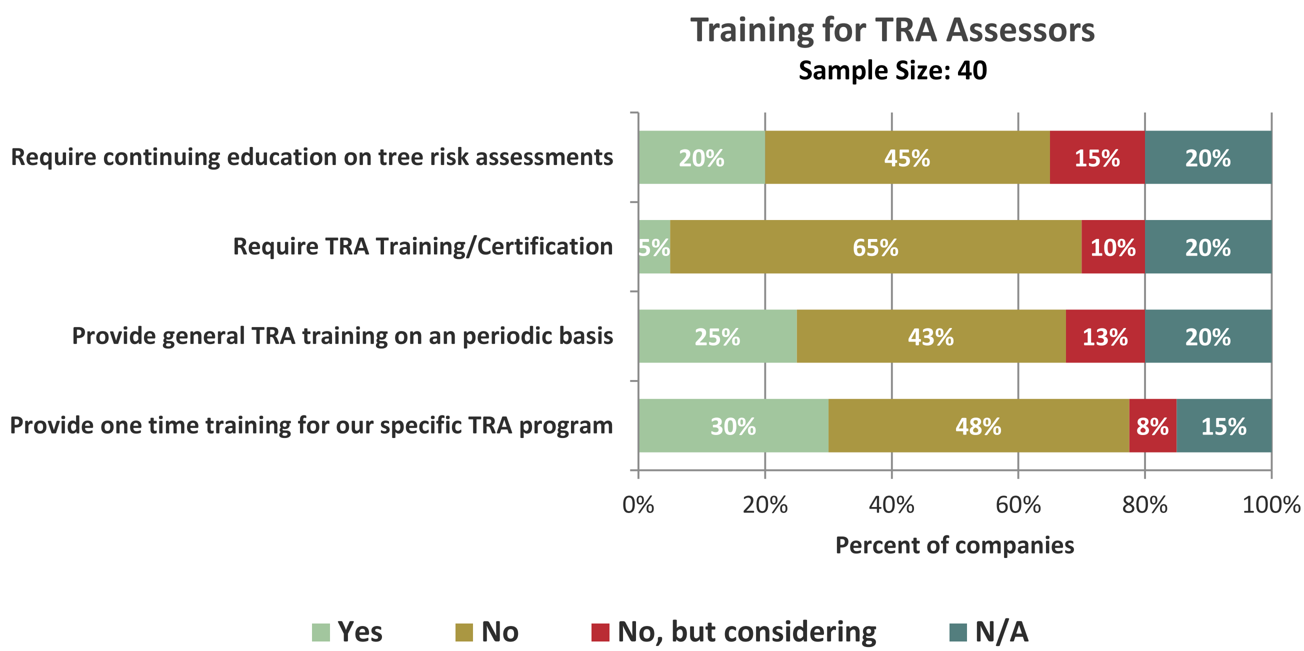


Figure 62: Training for TRA Assessors

Other Training Scenarios
Annual training along with specification review
Transmission specialist with an understanding of the Clearance requirements in the Alberta Reliability Standard.
Distribution: Review general expectations with available UVM contractor inspectors to identify trees that are obviously hazardous (i.e. dead trees, leaning, etc.); Transmission: Utilize experienced internal utility transmission foresters to perform aerial inspections, with subsequent follow-up ground assessments by contractor personnel if needed.
Contractor lead trainings
The ISA TRA requirement of re-testing and no CEUs is ridiculous. I will not be re-certifying when my certification expires.
[Inspection contractor] volunteered to have one of their foresters trained, which has proven very valuable to our informal TRA program
Annual training as an aspect of general orientation
We provide our on specific training for determining hazard trees and profession judgement
MN tree inspector license and MN first pest detector
Annual training for anyone involved with FAC003-3

Comment Table 9: Other Training Scenarios

Question 13: Which best describes the normal/expected location (viewing position) from which routine ground-based Tree Risk Assessment is conducted? Please indicate the one Assessor Location which best describes what is done on each type of line.

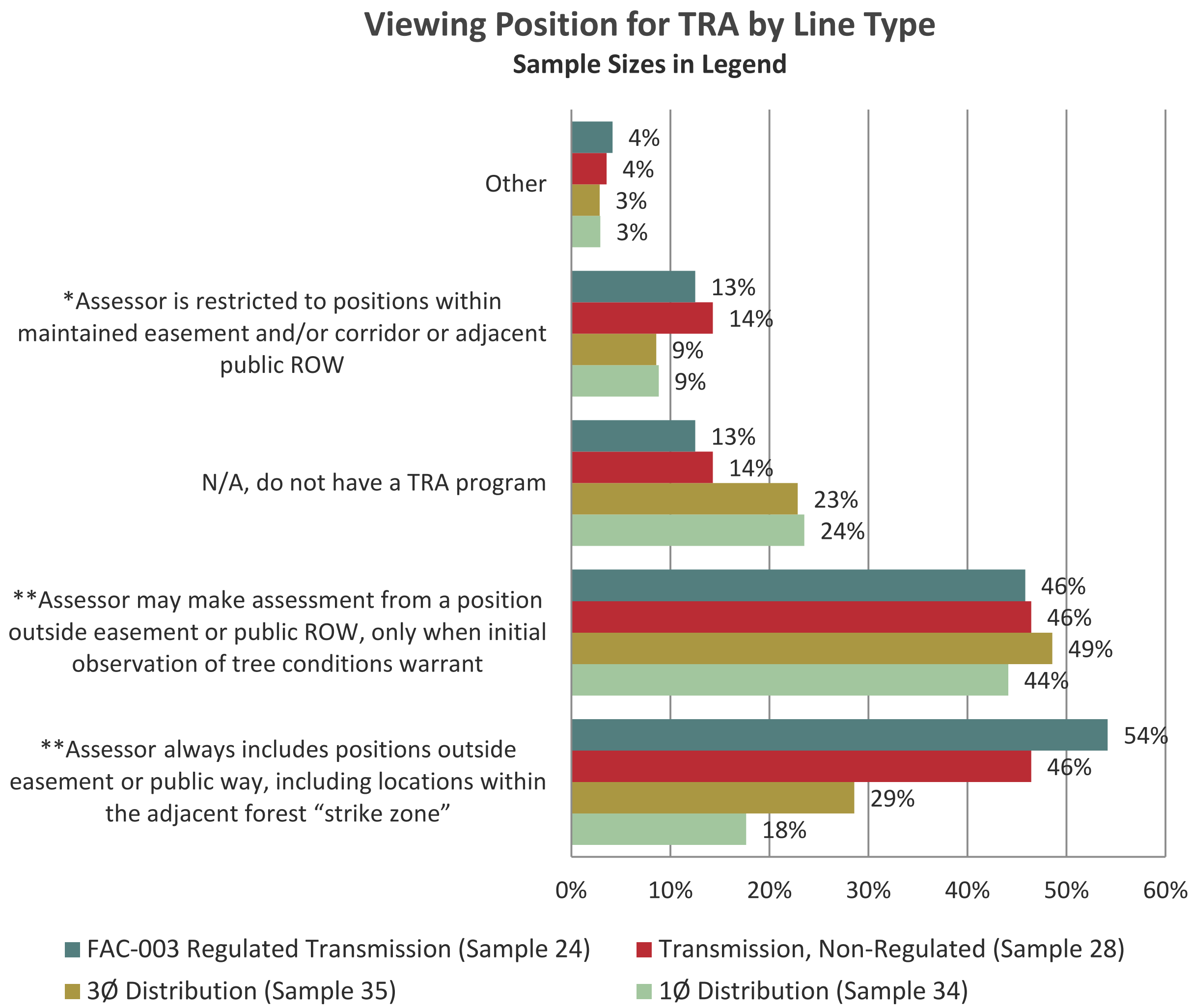


Figure 63: Viewing Position for TRA by Line Type

Three companies chose more than one response per multi-phase and transmission line types:

- *One company chose this response *and* the responses labeled ** and ***
- Two companies chose responses labeled ** and ***
- Therefore, these categories do not add to 100%

Comments

- We do not have any rule on observation positioning for our TRA program
- I don't understand what you're getting at with this question. We can inspect our lines from outside or inside the easement as needed and we do.

Question 14: Which approach best describes the primary area of focus for Tree Risk Assessment (TRA) on each of the four line types?

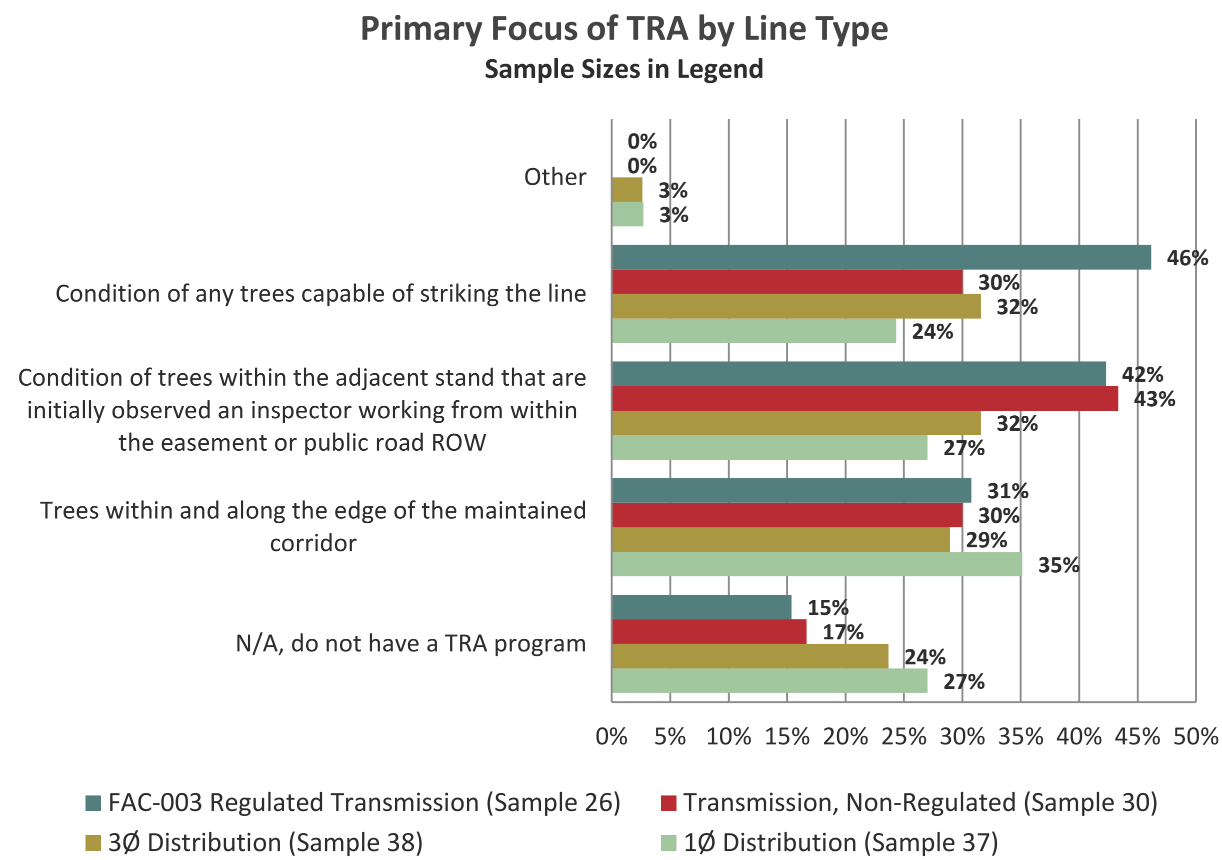


Figure 64: Primary Focus of TRA by Line Type

Other: Risk trees can be mitigated as far away from line as needed

Question 15: Please identify the types of rights you have to inspect and mitigate risks posed by Off ROW trees, by indicating the estimated percentage (% of total line miles) of Off ROW Rights for each line type.

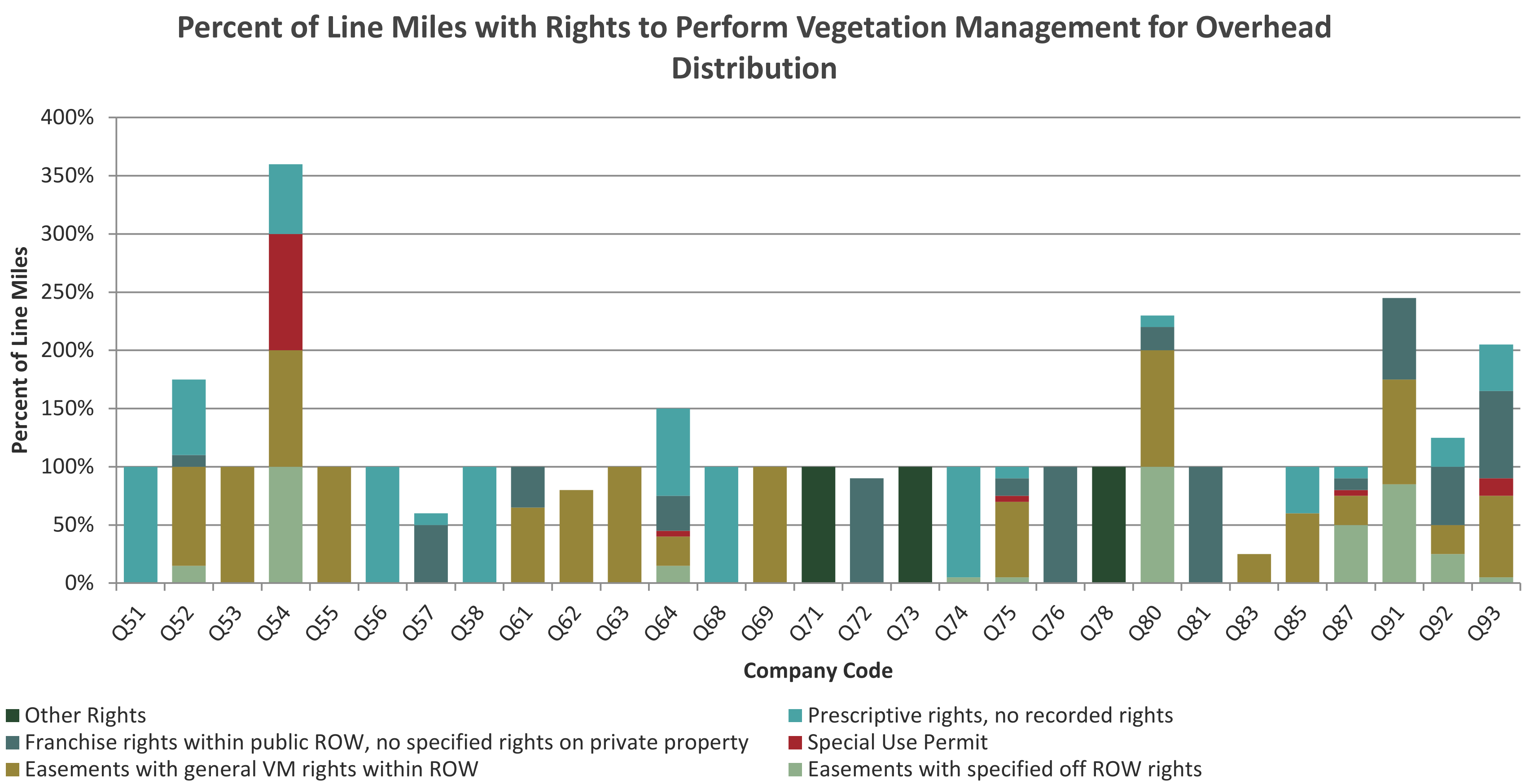


Figure 65: Percent of Line Miles with Rights to Perform Vegetation Management for Overhead Distribution

- **26% Reported 0% in all categories (Total Sample: 34)**

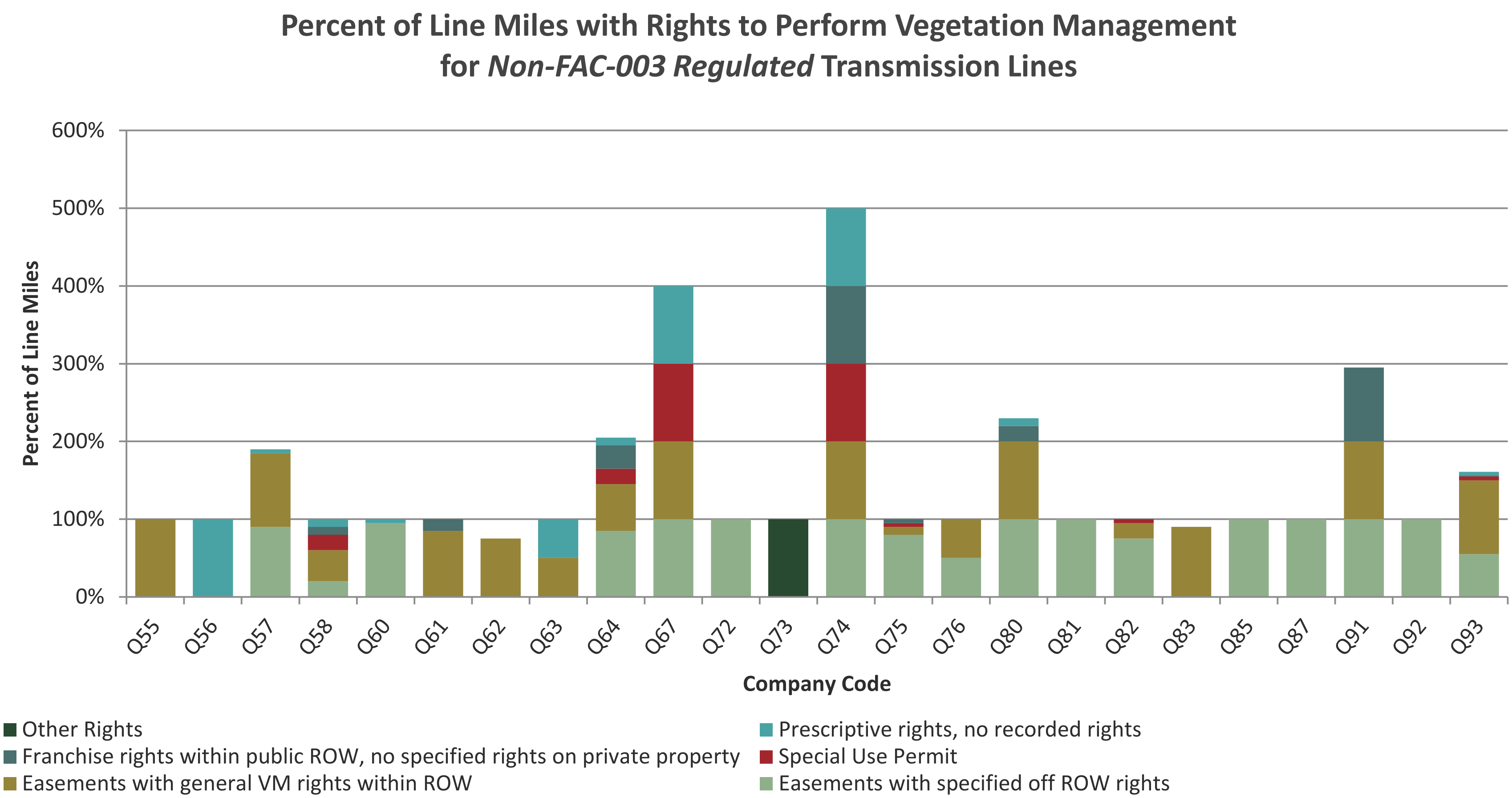


Figure 66: Percent of Line Miles with Rights to Perform Vegetation Management for *Non-FAC-003 Regulated* Transmission Lines

- **24% Reported 0% in all categories (Total Sample: 33)**

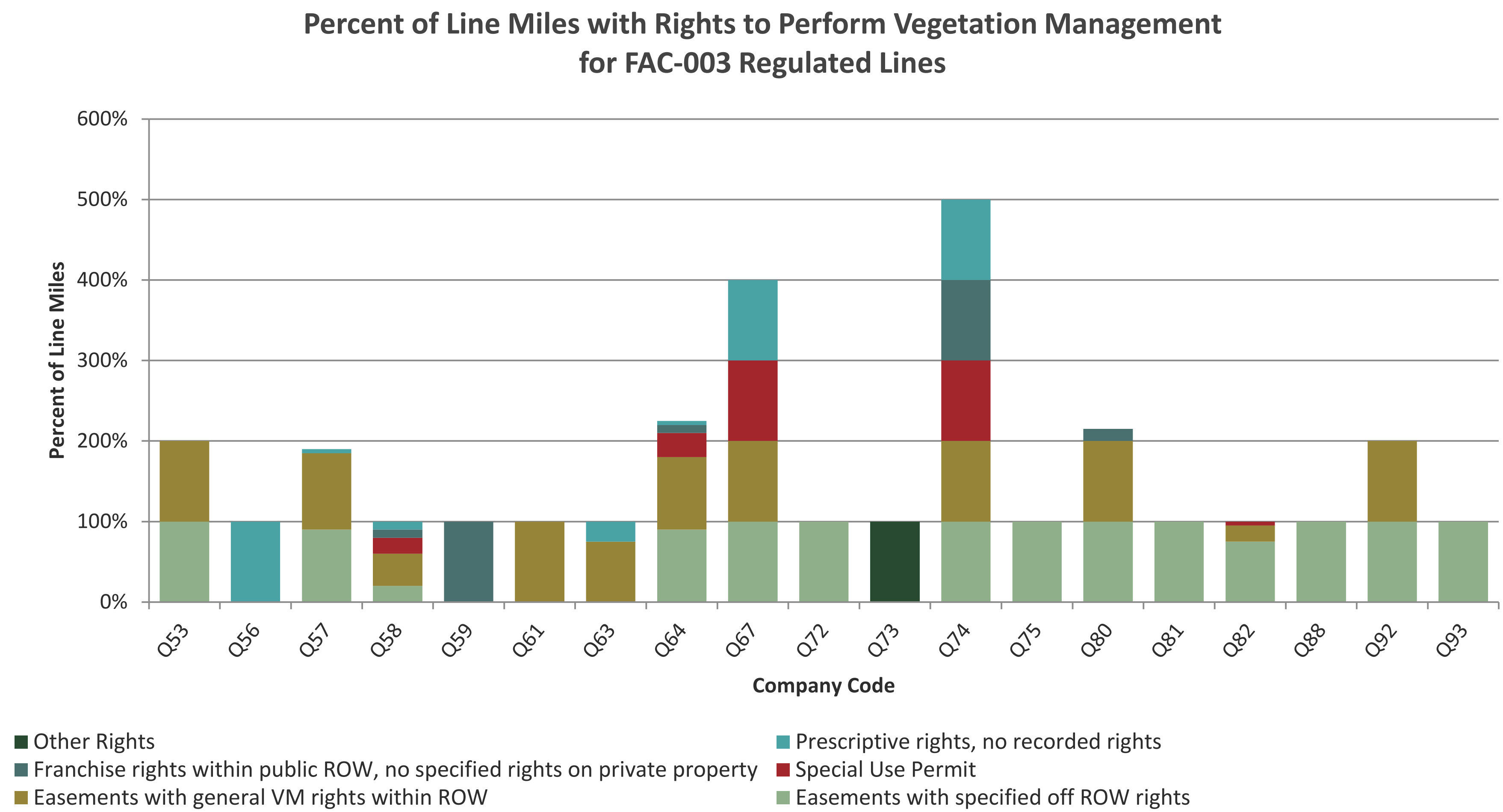


Figure 67: Percent of Line Miles with Rights to Perform Vegetation Management for FAC-003 Regulated Lines

- **34% Reported 0% in all categories (Total Sample: 29)**

Comments Rights on Off-ROW Trees
These are estimates [percent of miles]
We do not have any way to track this information by mileage.
Information not attainable.
We go wherever necessary.
Only cross country distribution line has easement rights but no off-ROW rights.
Under law, we have the authority to remove any vegetation that we deem hazardous to our electrical system
Prescriptive easement with general VM rights
We do not need right to inspect any trees; we need owner's authorization to cut risk trees.
Unknown, really a poor question. Rights or not, if we identify a tree that is a problem we will find a way to purchase the tree, work with the customer, etc. Really do not have all these easement rights categorized in this way.
We do not keep records of this as it relates to line miles.

Comment Table 10: Rights on Off-ROW Tree

Question 16: Are there any regulatory requirements in your service territory that specifically address the need to conduct periodic inspections of vegetation conditions? If so, please cite Regulatory agencies and titles of requirements in the comments box.

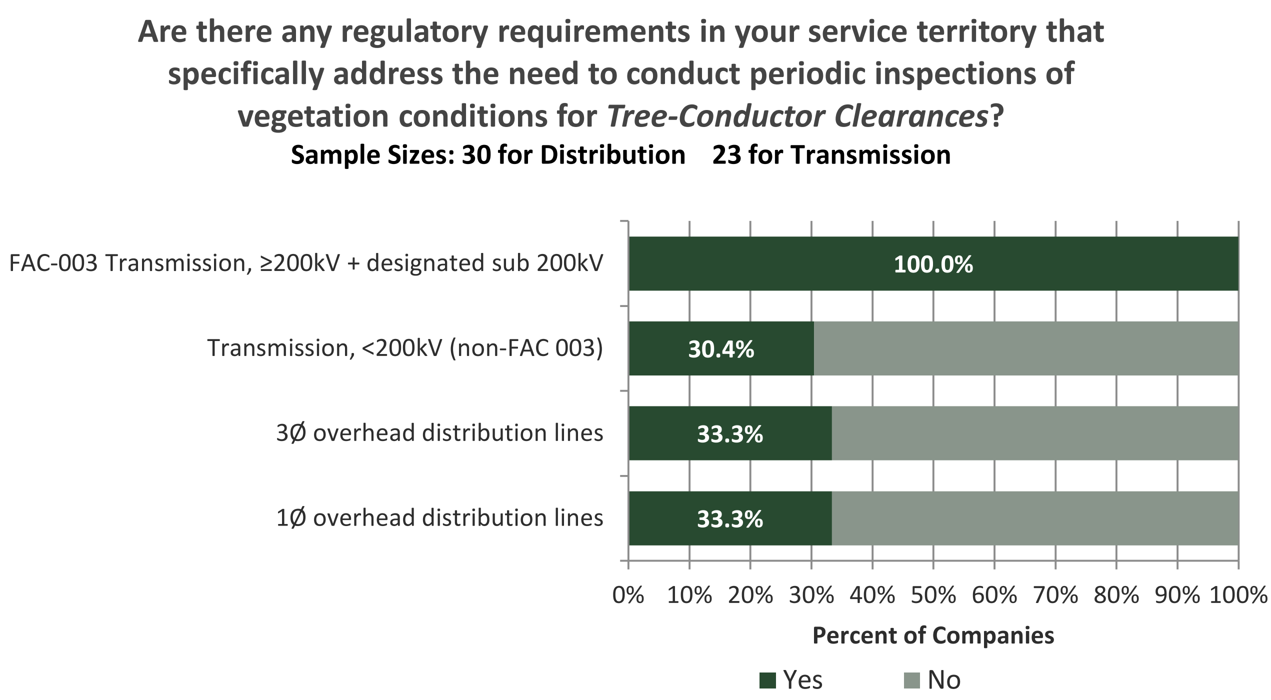


Figure 68: Regulation Requirements for Tree-Conductor Clearances

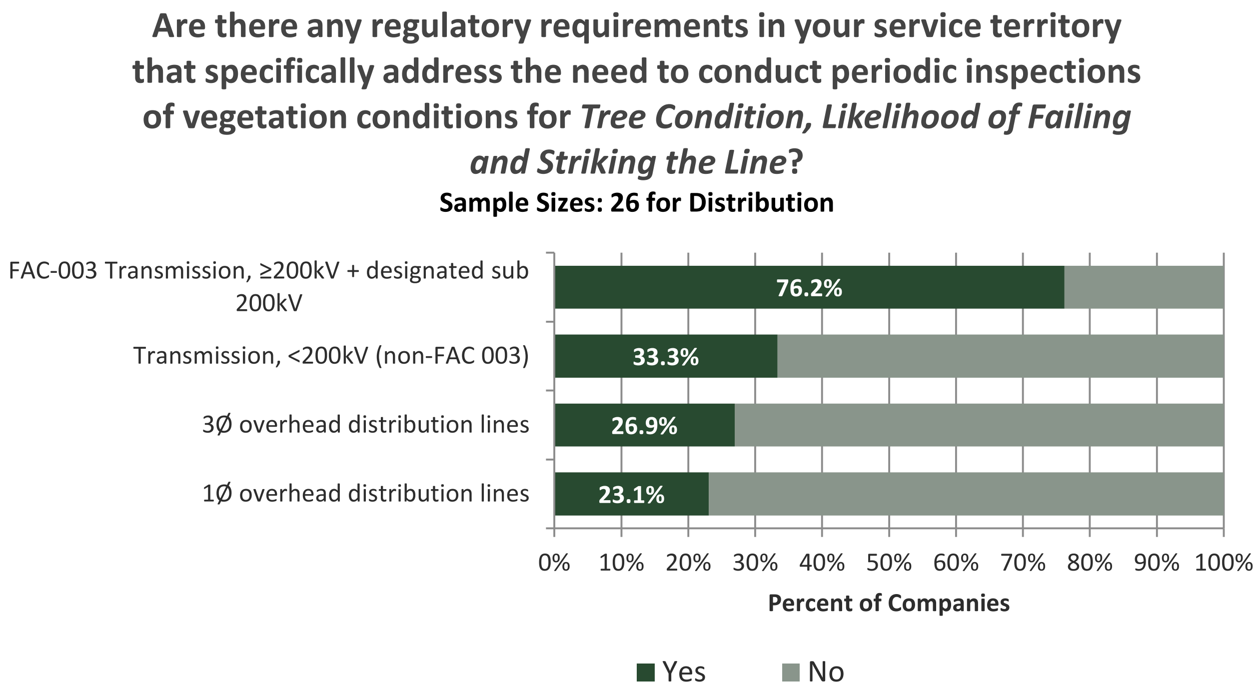


Figure 69: Regulation Requirements for Tree Condition, Likelihood of Failing and Striking the Line

Identify Regulatory Agencies and Titles of Regulations
CPUC NERC
General clearances are contained within PSC rule 4 CSR 240-23 along with all investor own filing of specific clearances for each programs.
New Jersey Administrative Code - 14:5 various Maryland RM43
FAC-003 on NERC lines ***(Cited 8 times as only regulation)***
Alberta Reliability Standard Alberta Utilities Commission
CA GO 95 R35 and PRC 4293 in addition to NERC standards for Transmission
FAC-003 WECC
California Public Utility Commission [CPUC], General Order #95 Rule #35, PRC 4292, and PRC 4293.
only NESC 218
ICC
Ontario Energy Board- Maintain historical practices- inspect 33% of the plant annually.
Manitoba Hydro Distribution Standards / Tree Trimming Clearance and Brush Clearing NERC/FERC
FERC, CT PURA, MA DPU, NH DPUC
NH PUC 3017.10
Régie de l'énergie du Québec
California Public Resource Codes 4292 and 4293
State of New York Public Service Commission, CASE 04-E-0822 Order Requiring Enhanced Transmission Right-of-Way Management Practices By Electric Utilities

Comment Table 11: Identify Regulatory Agencies and Titles of Regulations

Question 17: Do you have different standards or policies for tree risk assessment inspection in areas of potentially elevated risk (e.g. fire prone areas).

Sample Size: 40
Yes 27.5%
No 72.5%

Description of TRA in Areas of Elevated Risk
Extra patrols and clearance is required in [California Department of Forestry] CDF areas [Yes]
Fire [Yes]
Yes, our Mountain Pine Beetle program (this is a general program title which includes hazard trees created by insects other than MPB too) in Colorado. [Yes]
Area very small [No]
Emerald Ash Borer affected areas. Ash trees that shows any degree of decline caused by the Emerald Ash Borer is removed as a hazard tree. [Yes]
No different standards; however, have focused inspections on areas that have historically experienced higher mortality rates during enhanced drought conditions or elevated bark beetle infestations. This may increase the frequency of inspections for those specific areas. [No]
We inspect California Resource areas annually [Yes]
Conducting Redundant patrols in high fire risk areas [Yes]
More aggressive vegetation clearances and proactive tree removals where permitted to mitigate risk in high fire locations. [Yes]
We inspect fire prone or recent fire areas yearly until not needed. [Yes]
We have standards for hazard tree removal that define a process for "worst performing" circuits [Yes]
Higher focus on Backbones (un-fused portion of circuit) [Yes]
No, other than what is required for [inspections]. [No]
We have different standards of tree risk assessment for those circuits that meet our Storm Resiliency Program qualification [Yes]
If we ever did this it would be after the fact/event, after the fire in a specific area, after the storm, etc. [No]
Not a large fire risk [No]

Comment Table 12: Description of TRA in Areas of Elevated Risk

Question 18: Are there any regulatory requirements in your service territory that specifically address the risk of power-line-initiated wildfire, such as tree risk assessment?

Sample Size: 40
Yes 22.5%
No 77.5%

If yes, please cite regulatory agency and requirement title(s).
G.O. #95 and [California Department of Forestry] CDF High fire threat areas [Yes]
State [Yes]
Not applicable to our utility [Yes]
California Public Service Commission [Yes]
CA GO 95 R35 and PRC 4293 specify minimum clearance requirements and mitigation of potentially hazardous trees. [Yes]
California Public Utility Commission [CPUC], and PRC 4292 and PRC 4293. [Yes]
Wildfire Act [Yes]
Provincial Fire Smart Program - to negotiate with Manitoba Conservation [Yes]
Régie de l'énergie du Québec [No]
California Public Resource Codes 4292 and 4293 [Yes]

Comment Table 13: Regulatory Requirements in Service Territory That Address Powerline Initiated Wildfires

Question 19: Do you provide any training to staff specific to wildfires (e.g. prevention, limiting spread, evidence preservation)?

Sample Size: 40
Yes 25.0%
No 75.0%

Description of Fire Risk Training
Extreme dry conditions limit mowing work/all crews have fire extinguishers on vehicle and [are] trained. [Yes]
Monthly safety meeting [Yes]
Contractors conduct their own fire prevention training internally. [No]
Annual Fire Season Kickoff Meeting, training on prevention and practical exercises to familiarize with common tools such as fire rake, shovel, and water pack. [Yes]
Arizona Wildfire Academy [Yes]
General fire prevention and safe operating practices in high fire areas. [Yes]
Utility doesn't provide the training; we have Department of Natural Resources conduct periodic training. [Yes]
Contractors are required to provide annual training on fire prevention and response. [Yes]
Not really just for fire, but it is discussed. We annually review our Imminent threat process, this is general to all threats, but fire damaged tress, dead trees, wind throw trees, etc. [No]
Basic Fire awareness. [Yes]

Comment Table 14: Description of Fire Risk Training

Question 20: When evaluating trees for risk, do your Tree Risk Assessors document fire potential (e.g. fuel build up or the potential for tree wire contacts to occur, which could lead to wild land fire ignition)?

Sample Size: 40
Yes 5.0%
No 95.0%

If yes, could you briefly describe the assessment process?

- DNR & [utility] jointly generated form [Yes]
- Question may be N/A since we have no TRA program. [No]

The following graph compiles the information from questions 18 -21, which all relate to wildfire risk.

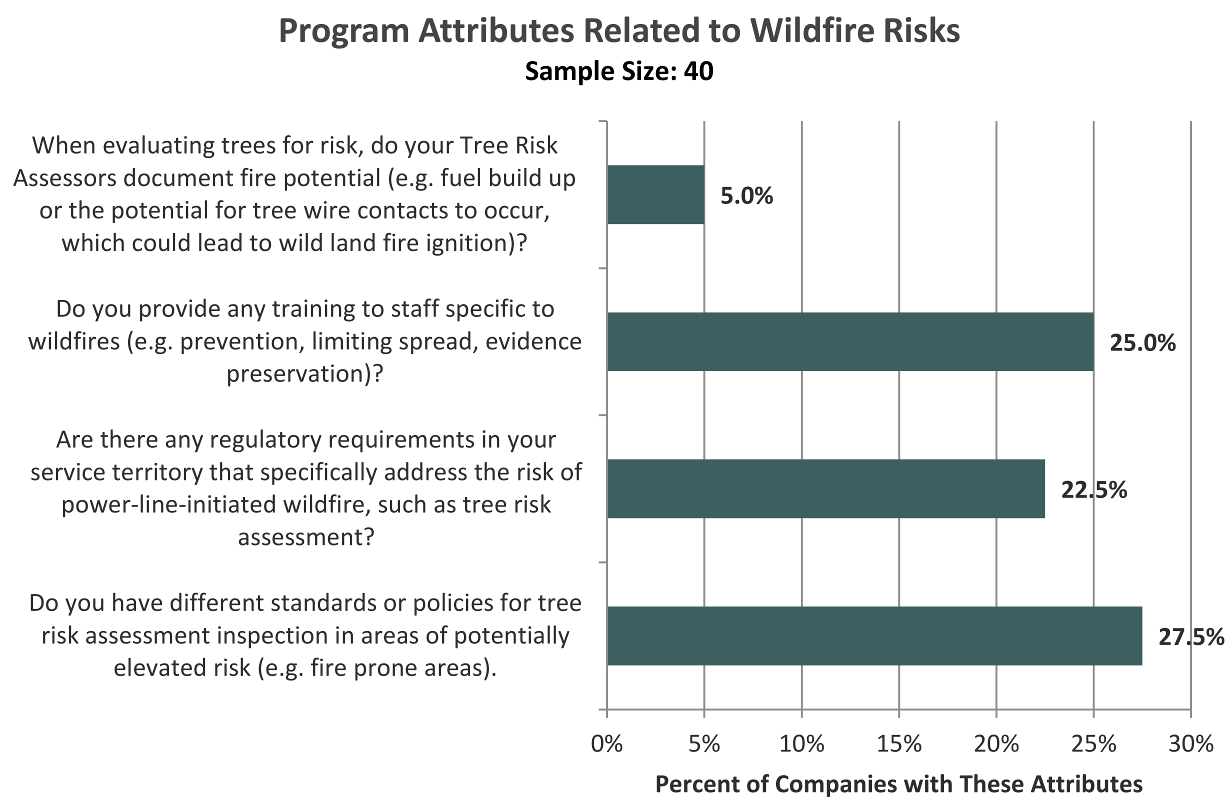


Figure 70: Program Attributes Related to Wildfire Risks

Question 21: Do your hazard tree inspectors pursue removal permits on large trees that appear to be in good health but could impact an important feeder line if they failed in a storm? If yes, how many such trees are removed each year? Choose all that apply

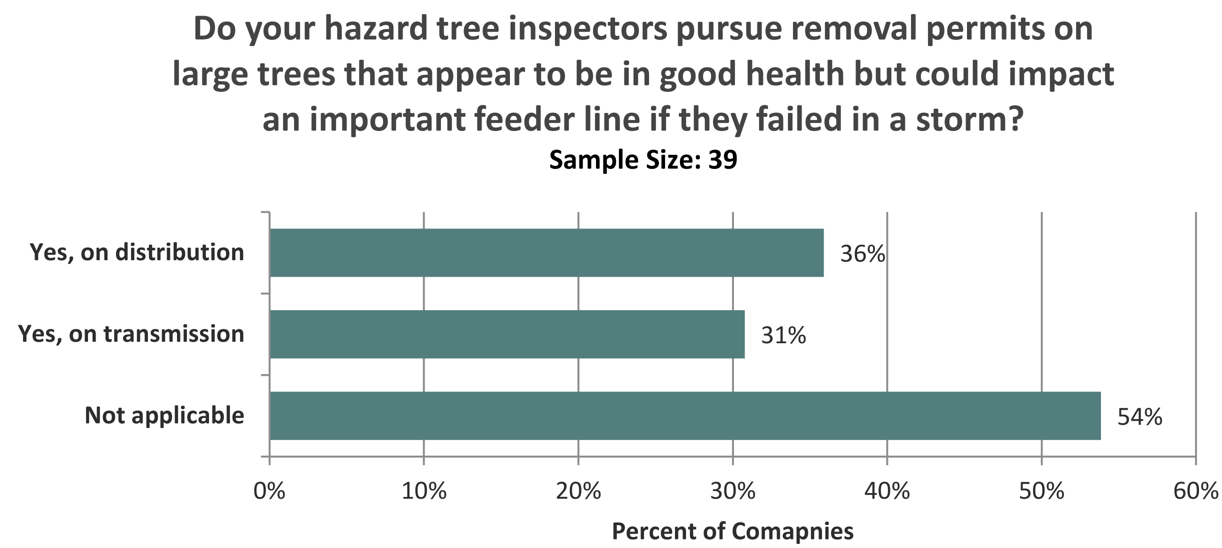


Figure 71: Pursue the Removal of Healthy Trees That Could Impact Important Feeder Lines

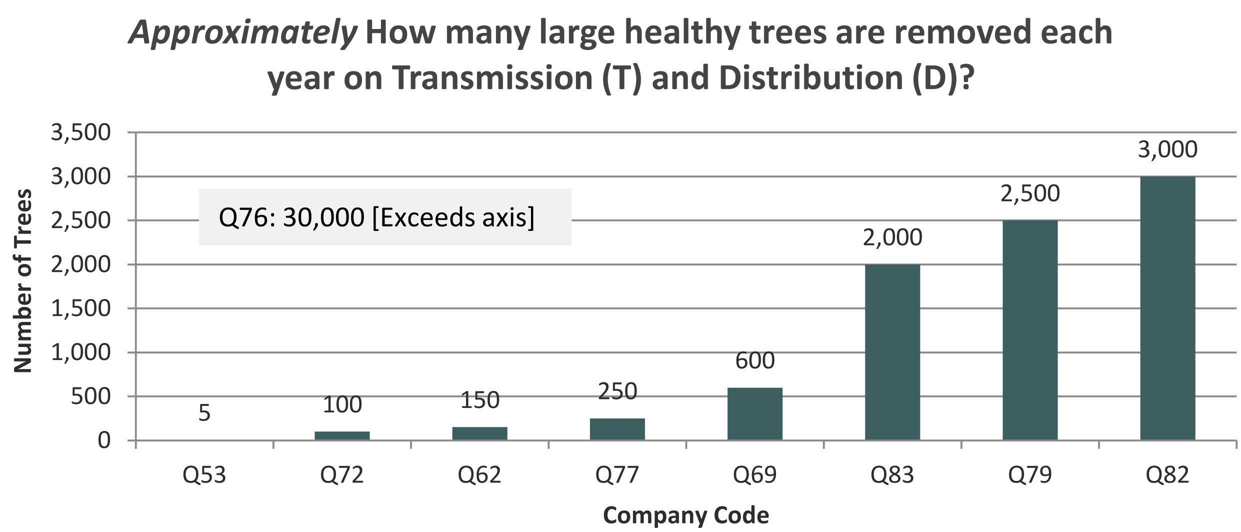


Figure 72: Number of Healthy Trees Removed per Utility

Approximately How many large healthy trees are removed each year on T and D?
Tree count does not distinguish between healthy vs hazard removals [Yes, on T & D]
If they are in good health, why would we take them down? [N/A]
Unknown [Yes, on T & D]
No on Dist. Pursue removals on Trans if on the easement (may or may not need a permit). Transmission off-ROW, if healthy, limited pursuit of removals. [Yes, on Transmission]
Starting with H[azard]&D[iseased] tree survey this year [N/A]
< 100 total; however, we capitalize widening activities on T&D annually. [Yes, on T & D]
5% of our 50 000 removals and it's recent [Yes, on Distribution]
On average 3000 [Yes, on Transmission]

Comment Table 15: Removal of Healthy Trees Comments

Question 22: When trees are assessed for risks, are targets other than powerlines considered (e.g. traffic, pedestrians, playgrounds, and backyards where children are present)?

Sample Size: 40
Yes 47.5%
No 52.5%
Other 0%

Are Other Targets than Powerlines Part of TRA?
NESC 218---we consider any tree on major highway crossings for removals. We consider any tree in school yard or backyard that is readily able to climb an issue. Any tree house within a tree in proximity to electrical wires would be an issue. [Yes]
While we are cognizant of such risks other than to our transmission lines, they do not factor into a decision to remove a tree that is not a threat to our lines. [No]
May observe/assess these risks during the course of normal work to identify any tree, healthy or hazardous, to determine if risk should be mitigated. [No]
We have a lot of internal discussion on how much responsibility lies with the property owner. We don't have an answer, but if we are unsure, we act to remove the tree at our ratepayer's expense. [Yes]
We take in to account the environment in order to prioritize when the work will be done. [Yes]
Public safety and reliability are our highest goals. [Yes]
We notify customers of potential risks from tree houses, playground equipment, etc. that are within minimum approach distances. [Yes]
Not officially part of the removal criteria but if they are a factor they can be used in discussing removal with the tree owner [No]
[We] got no TRA [No]
These factors may influence tree A versus tree B that are otherwise evaluated as a similar risk [Yes]
The potential hazards are articulated to the member [Yes]
We use those risk assessments to obtain owner authorization [Yes]
Public and employee safety [Yes]

Comment Table 16: Are Other Targets than Powerlines Part of TRA?

OPINIONS

Question 1: Please indicate whether you, strongly agree (SA); agree (A); have no opinion (No O); Disagree (D); or Strongly Disagree (SD), with the following statements:

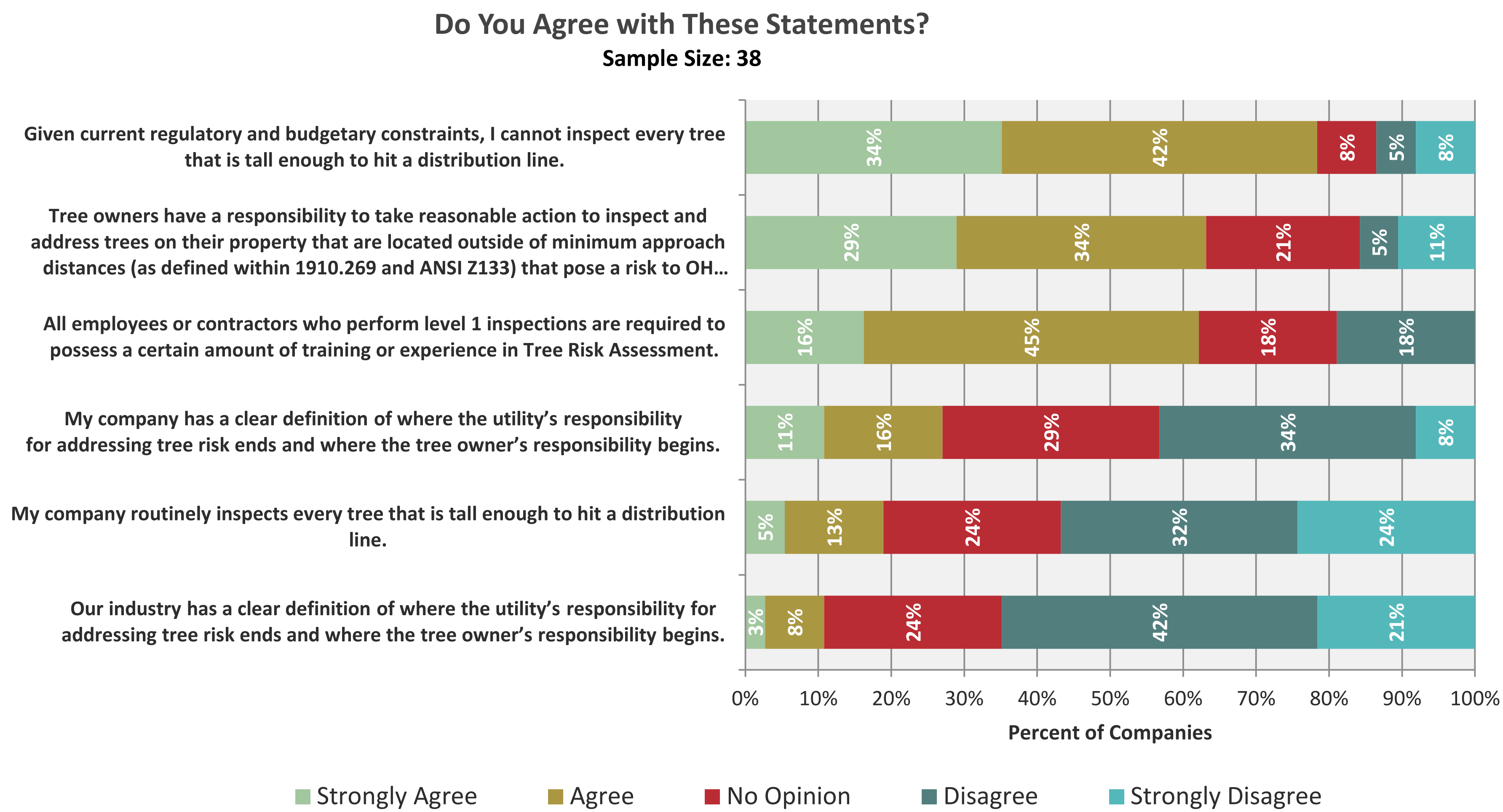


Figure 73: Do You Agree with These Statements?

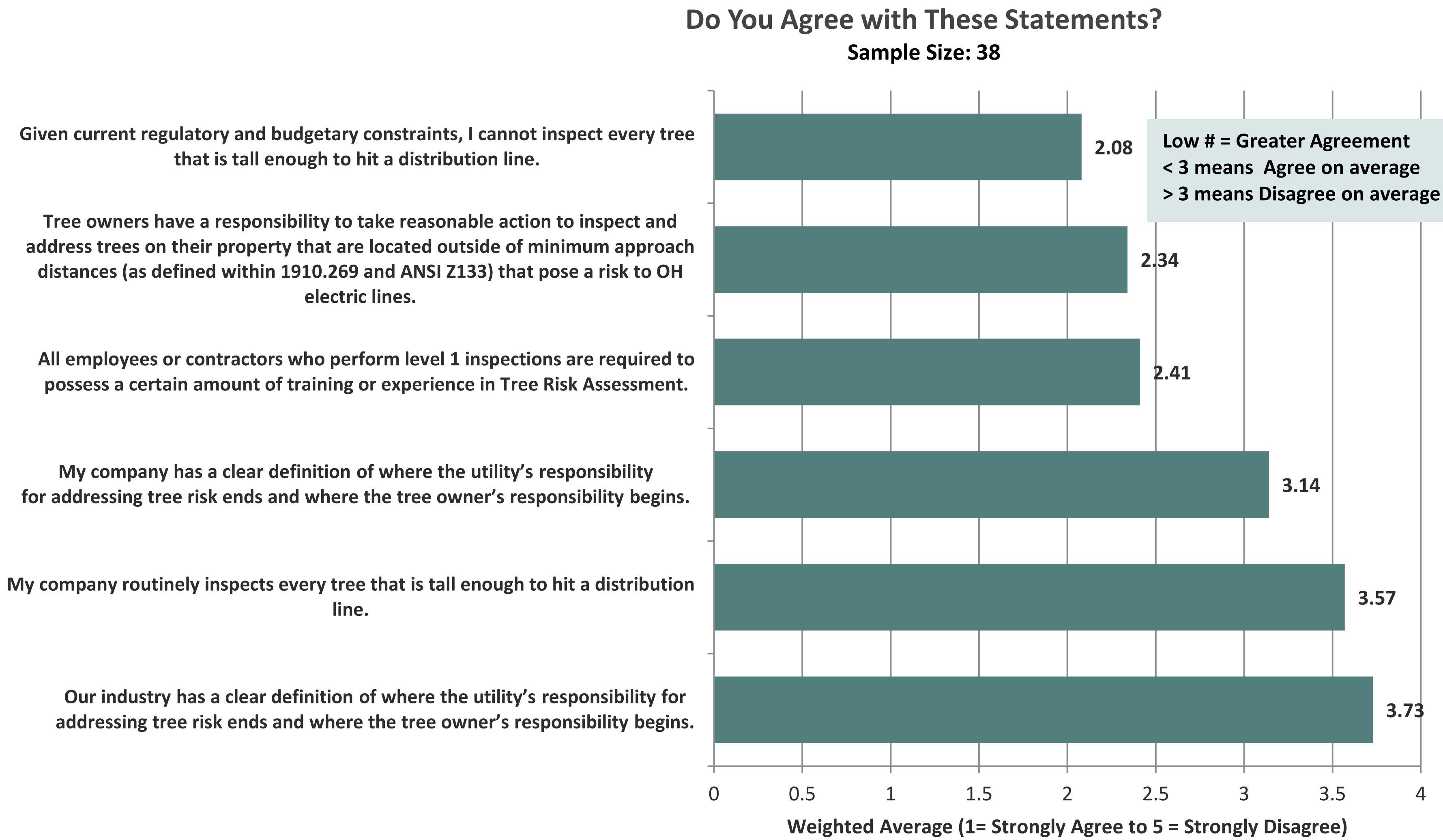


Figure 74: Do You Agree with These Statements? Analyzed with Weighted Averages

How is this Responsibility Established between the Utility and the Customer?
As a public utility we are all about customer service, but we will not remove stumps and [we] leave the wood for the customer whenever possible when removing trees. I would like to place the liability for the tree on the owner of the tree for refusals and danger trees.
Comes down to definition of inspection. Limited vantage point versus intense inspection.
The customer responsibility: it is on the service line from the last pole to the meter Panel and depending on the degree of hazard we may provide the service.
In my opinion, tree maintenance or mitigation responsibility and liability should shift significantly towards the property owner.
Municipal property is utility's responsibility, and private property is the responsibility of the property owner with the exception of easements (i.e. rear lot)
Owner has no responsibility
Distribution up to 14.4/24.9 kV out to 35 feet from centerline; 46 kV out to 80 feet from centerline; 138 kV and 345 kV out 40 feet from edge of cleared ROW
Tree risk assessment should be utility's responsibility, but addressing the risk should be owner's responsibility.
Again, this is a rather difficult question, funding, staffing, corporate value for this service are all factors.

Comment Table 17: How is this Responsibility Established between the Utility and the Customer?

Question 2: Do you have additional thoughts or opinions about a Best Management Practice for Tree Risk Assessment?

Additional Thoughts or Opinions

- Our company does not have an official TRA program in place. We assess risk trees while doing normal routine R.O.W. maintenance. We do offer incentives to property owners for removal of large trees on and off our ROW's that are a danger to our facilities. Our system arborist, (myself) has been certified in Tree Risk Assessment by the ISA for mitigating risk by tree's on and off our ROW.
- Tree risk assessment is an important part of conducting vegetation management to reduce tree related outages to utility facilities. A basic level of TRA should be required; however, [utility is] cautious about requiring high level of TRA on individual trees and on stands due to size of our utility, limited resources, limited qualified personnel etc.
- Due to our small size and limited vegetation, we do not have any additional comments.
- Our utility has chosen to widen distribution circuits to a new standard ROW width as well as 69kV. Trees of risk are removed on an individual basis on all rights-of-way no matter the voltage class.
- Dangerous road to go down as it introduces liability questions that have to be answered in court if something goes awry. Property law says property owner is responsible but development of a risk assessment standard can be used to say the utility has a duty of care beyond their easement rights with no formal permission to perform the work.

Appendix H: Distribution Survey Benchmark Results

INTRODUCTION

CN Utility Consulting conducted a benchmarking survey in January - April 2016. The participants included 36 companies (excluding Hydro One) and of this group 27 were selected as peers to Hydro One Networks. This peer group was used for making comparisons involving costs, reliability, and safety.

Peer companies were chosen to some degree by geographic proximity (see Appendix D for further details on how the peer group was selected). This proximity helps equalize variables that impact the functioning of a utility vegetation management (UVM) program such as tree species populations, economic factors, weather conditions, and regulatory oversight. Although all UVM departments and utilities are unique, benchmarking has value and all efforts have been made to normalize or analyze data to accommodate "fair" comparisons. "Company Profiles of Peer Companies," the first section in this appendix, highlights how the selected group varies on core elements. A list of companies that responded to the survey is shown in Table 1. In order to maintain confidentiality and anonymity, the peer group list will not be distinguished from this group.

List of Participating Utilities

Participating Utilities in the Hydro One Networks 2016 Benchmark Study	
AEP Texas	Liberty Utilities (New Hampshire)
Ameren Illinois Company	Lincoln Electric System
Appalachian Power Company	Manitoba Hydro
Arizona Public Service	Massachusetts Electric (National Grid)
Avista Utilities	Modesto Irrigation District
BC Hydro	Mount Pleasant Power System
City of Tallahassee	Narragansett Electric (RI) (National Grid)
Connexus Energy	Niagara Mohawk (National Grid)
Consumers Energy	Ohio Power Company
CoServ	Omaha Public Power District
Entergy Corporation	Pacific Gas and Electric
EPB (Electric Power Board)	Public Service of Oklahoma
EPCOR	Puget Sound Energy
Hydro Ottawa	Southern California Edison
Hydro-Québec	Southwestern Electric Power Company
Indiana Michigan Power	Tampa Electric (TECO)
Kansas City Power and Light (KCPL)	Turlock Irrigation District (TID)
Kentucky Power	Unitil

Table 6: Participating Companies

The data used to develop this appendix is important to the accuracy of the analysis in the report. In particular, the number of kilometres of overhead line is a key element of many of the calculations and models used for comparing utility vegetation management (UVM) programs. To ensure accuracy of elemental data, survey responses were verified with publically available sources, such as utility websites, legal dockets, the Energy Information Administration (EIA), Platts Directory of Electric Power Producers and Distributors, utility reports to regulatory entities, regulatory reports, and previous CN Utility Consulting (CNUC) survey responses. This process was used to "scrub" the data of erroneous data entry, missing data or misinterpretation of the question. Respondent communication was also a part of this data "cleansing."

Most graphs use data only from the peer group companies. *Data from **all** participants in the survey was used for information that is not regionally or workload dependent, such as what factors influence the utility vegetation management budget (UVM).* **Graphs that include non-peer companies will be indicated next to the sample size.**

Graphical Representation and Highlighting of Hydro One Networks

The graphs in this appendix highlight the data from Hydro One in the following ways:

- On graphs, Hydro one Networks' label is *Hydro One*.
- The South, East, Central and North region labels are *HO South, HO East, HO Central*, and *HO North*, respectively.
- A gray text box surrounding the data label indicates the group to which Hydro One belongs. This applies to bar graphs or pie charts.
- A red highlighted bar indicates Hydro One Networks and its regions for single column graphs, where individual utilities have their data represented with a bar or two variable stacked column graphs.
- Hydro One Networks and its regions are represented with a red outline for stacked or column cluster graphs, unless 'bright" colors can be used without losing clarity.
- All *Statistical Tables* in plot area of graphs are peer statistics and exclude Hydro One and its regions in the calculations.

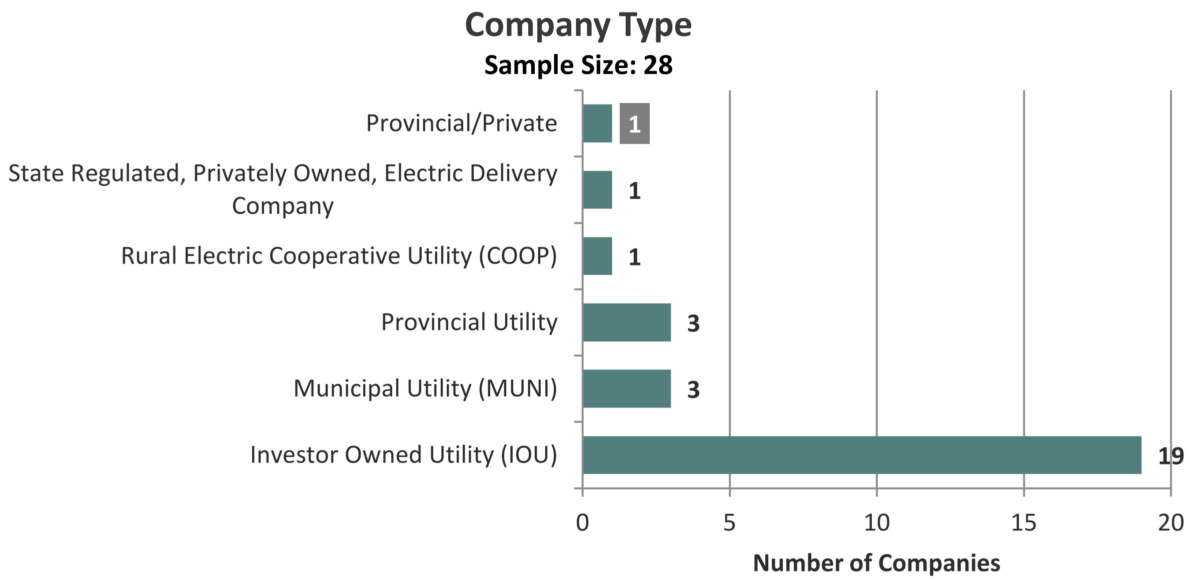
Graph and table numbers in this appendix vary from labels in the main report and other accompanying appendices.

Responses to the question are in brackets on comment tables. In other words, if the respondent answered, "Yes", [Yes] will appear after their comment. This will be true for most comment tables in this report.

COMPANY PROFILES OF PEER UTILTIES

The graphs in this section are comprised of general information about the peer group. They support the efficacy of the choice to include each utility in the target group for comparison with Hydro One.

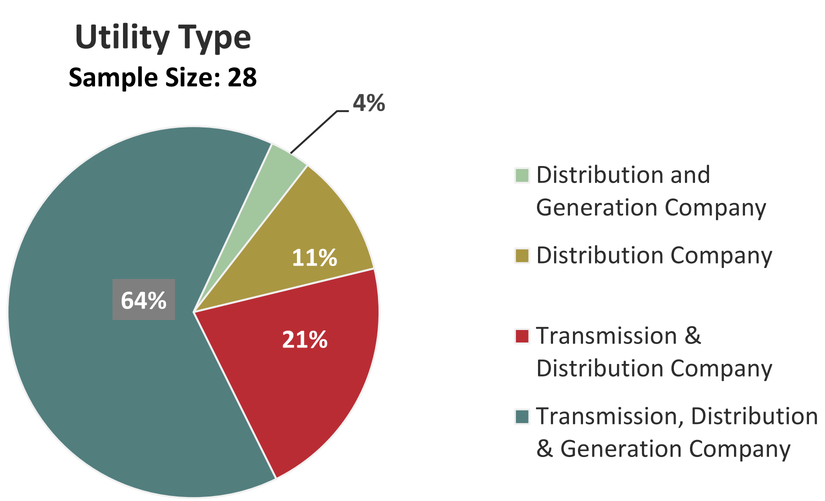
Company Type



Graph 7: Company Type

NOTE: Hydro One only counted as one company (not five) in graph above and below.

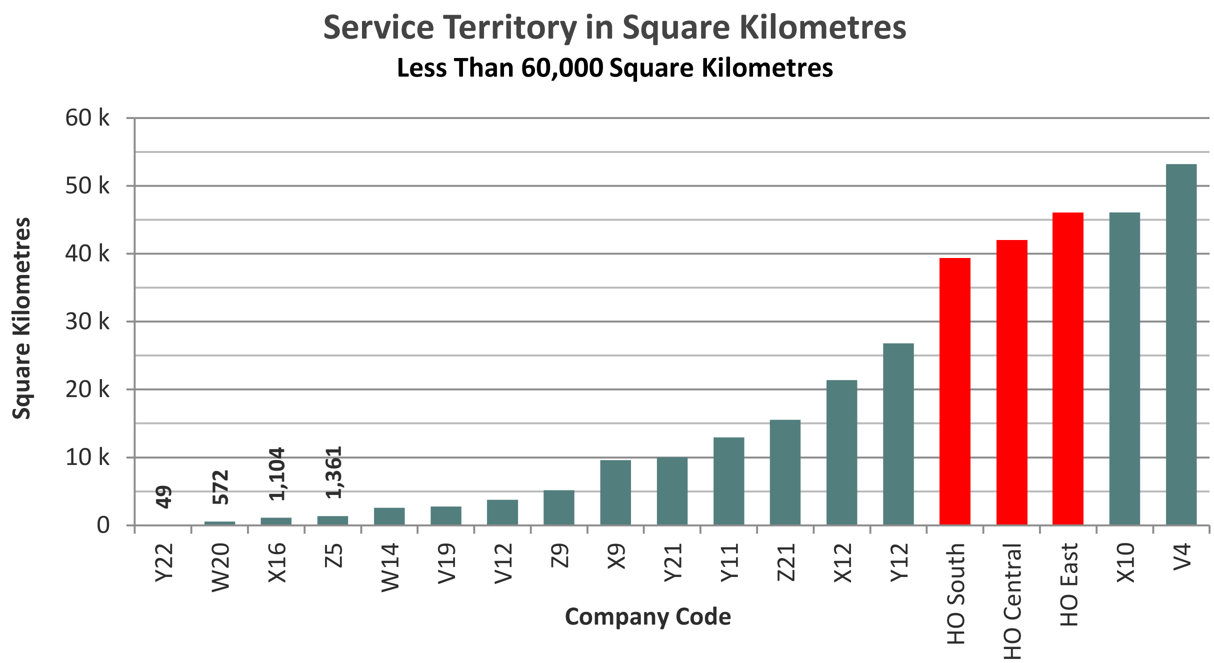
Utility Type



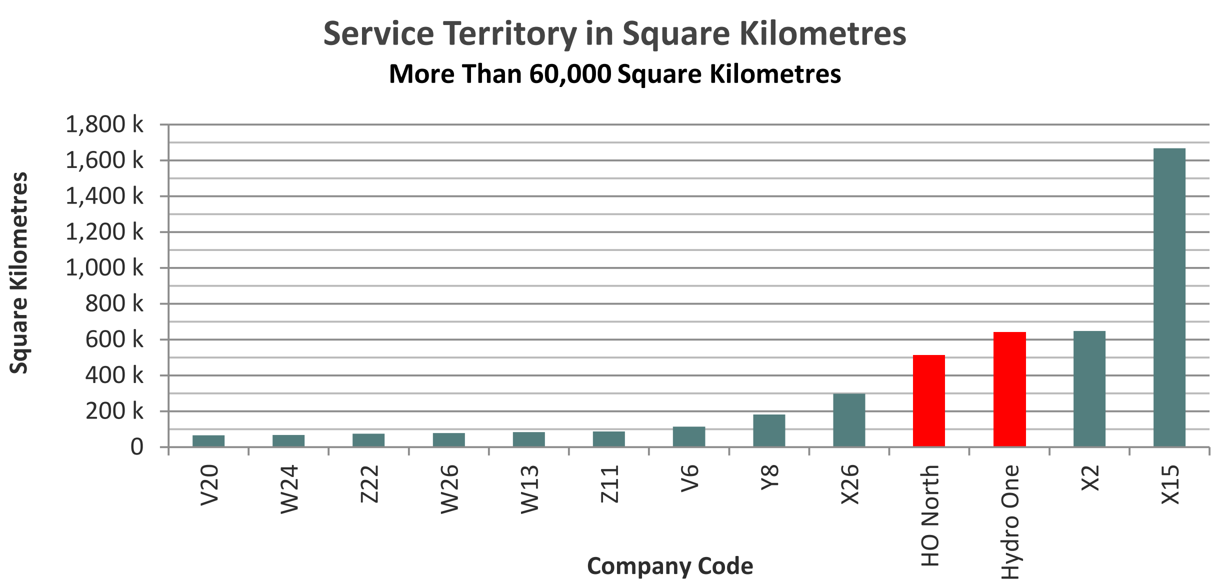
Graph 8: Utility Type

Service Territory in Square Kilometres (Land Area)

The peer group is shown on two graphs (*with different y-axis scales*), so that the range of service territory sizes can be distinguished.



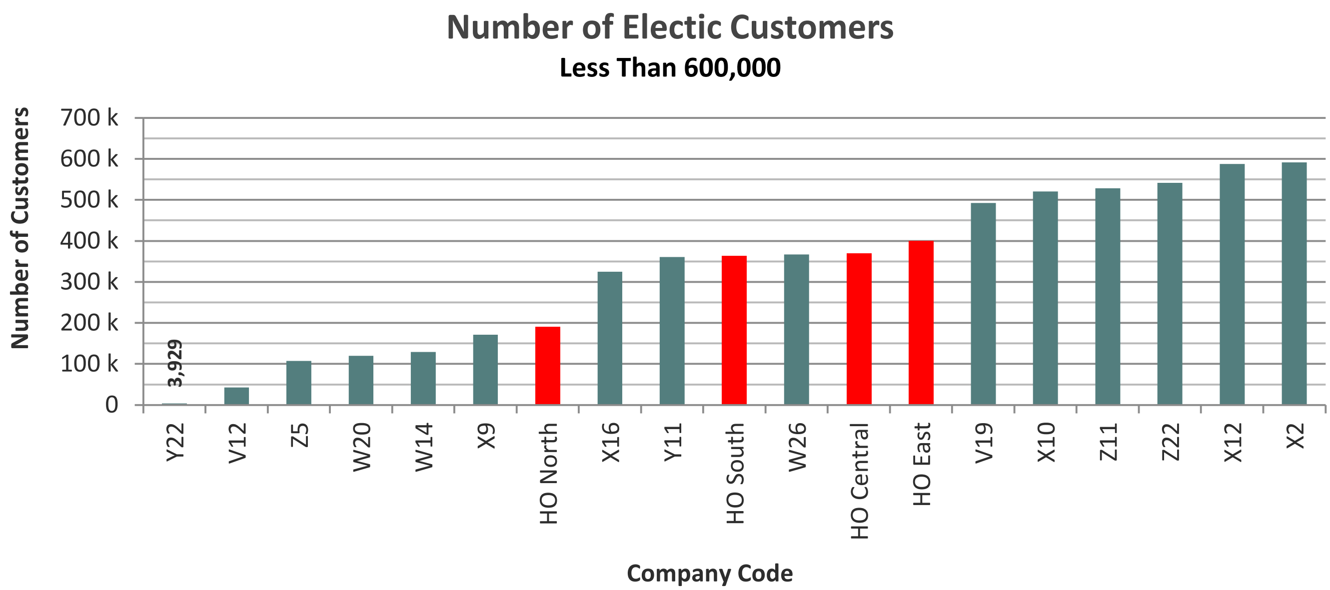
Graph 9: Service Territory in Square Kilometres – Companies with Less Than 60,000 Square Kilometres



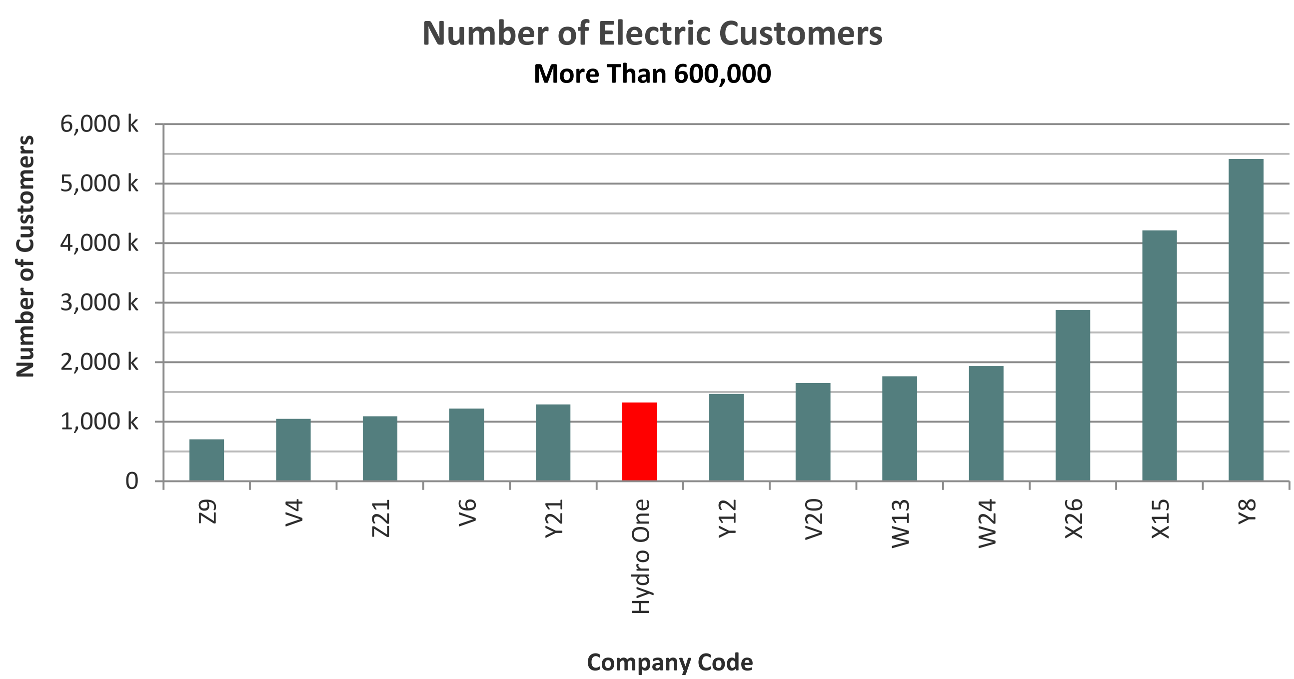
Graph 10: Service Territory in Square Kilometres – Companies with More Than 60,000 Square Kilometres

Number of Electric Customers

The peer group is shown on two graphs (*with different y-axis scales*), so that the range of customer count can be distinguished.

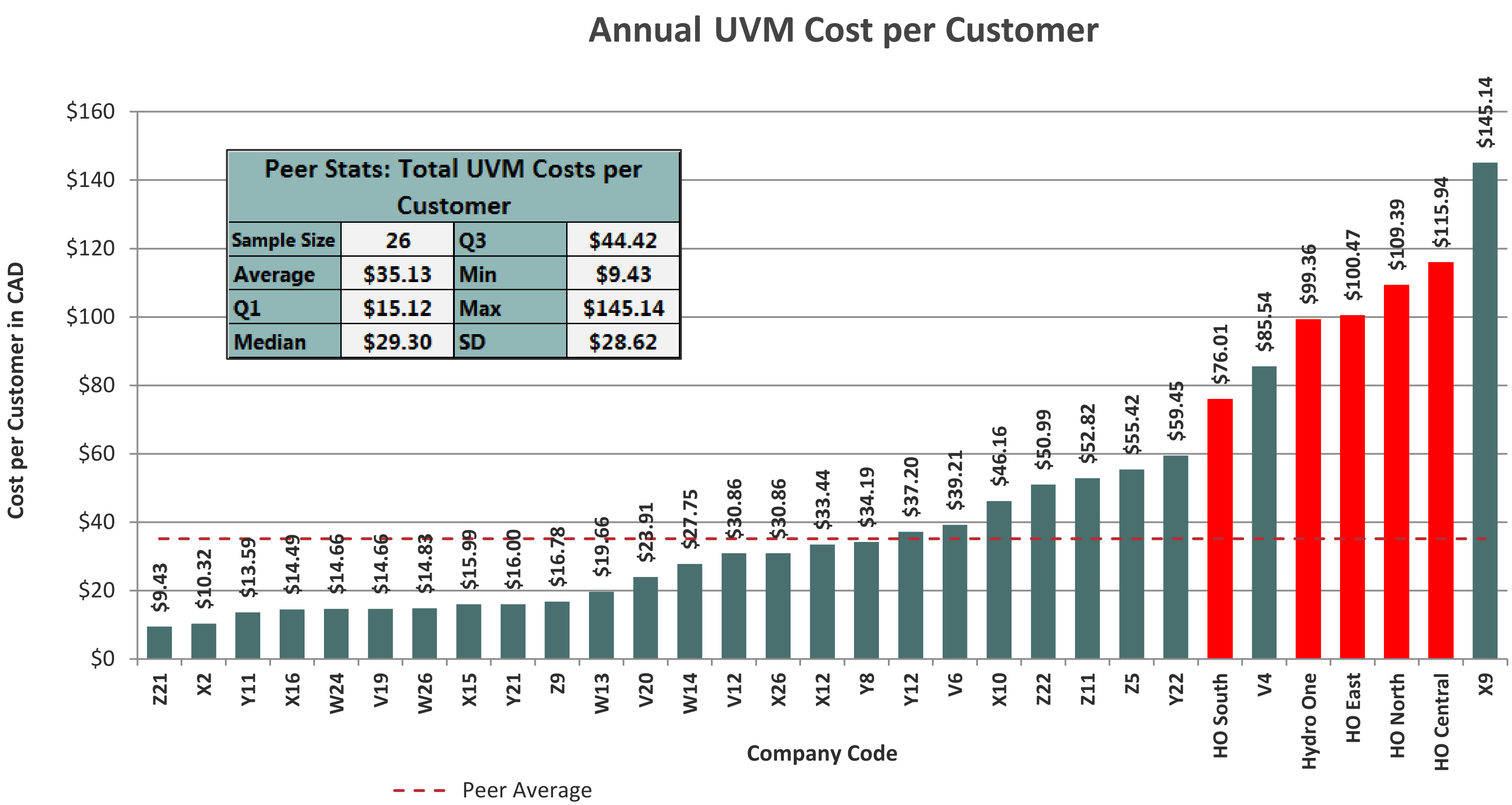


Graph 11: Number of Customers – Companies with Less Than 600,000



Graph 12: Number of Customers – Companies with More Than 600,000

Annual Cost per Customer



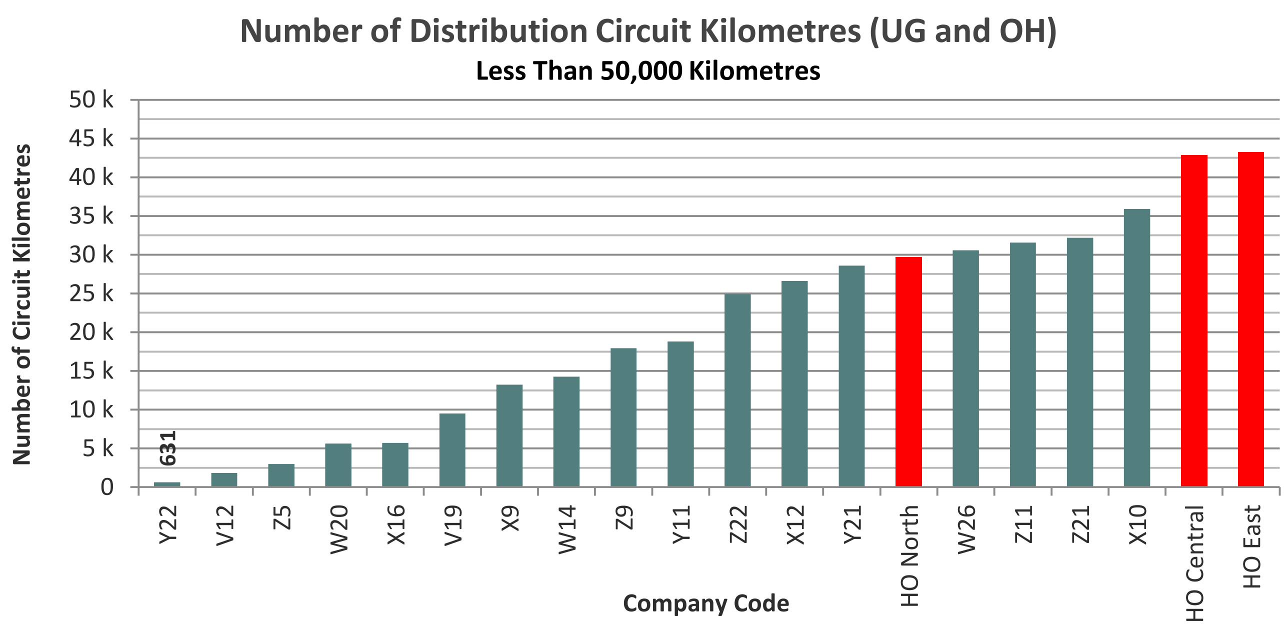
Graph 13: Annual UVM Cost per Customer

This rate was calculated by dividing Total Cost of UVM by number of electric customers, using 2015 numbers. Hydro One's UVM expenditures were an average of 2011-2015, since their 2015 total cost was significantly reduced from the previous years.

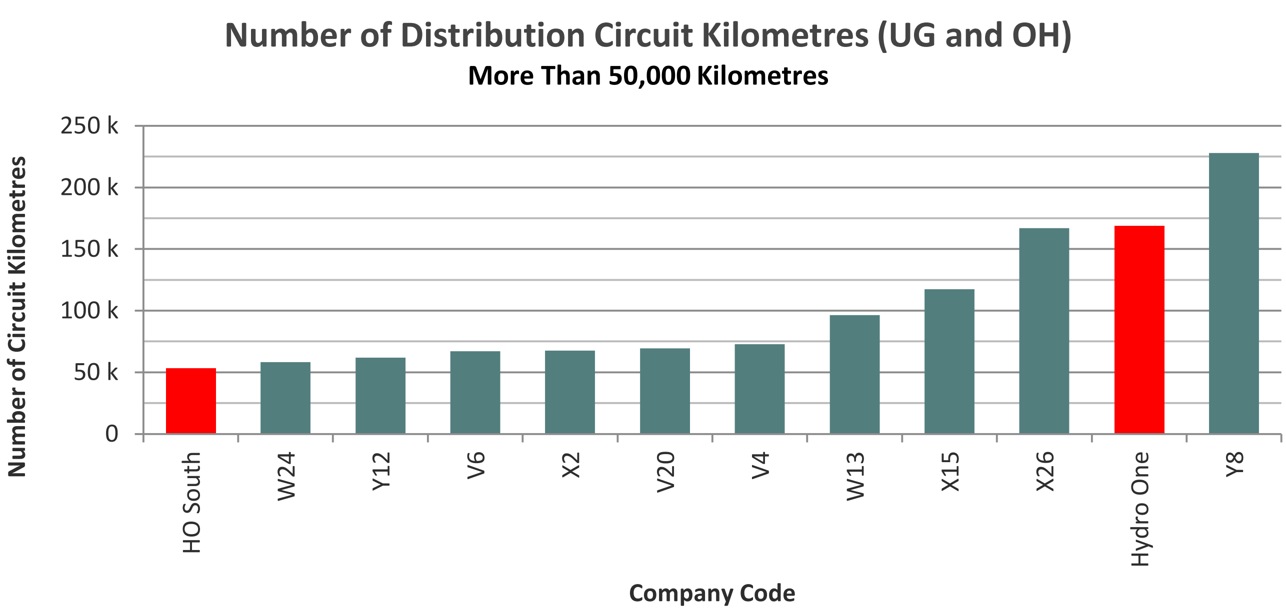
ELECTRIC DISTRIBUTION SYSTEM DESIGNS

Distribution System Circuit Kilometres

The peer group is shown on two graphs (*with different y-axis scales*), so that the range of circuit kilometres lengths can be distinguished. This includes all lines greater than 1kV and less than 60kV.



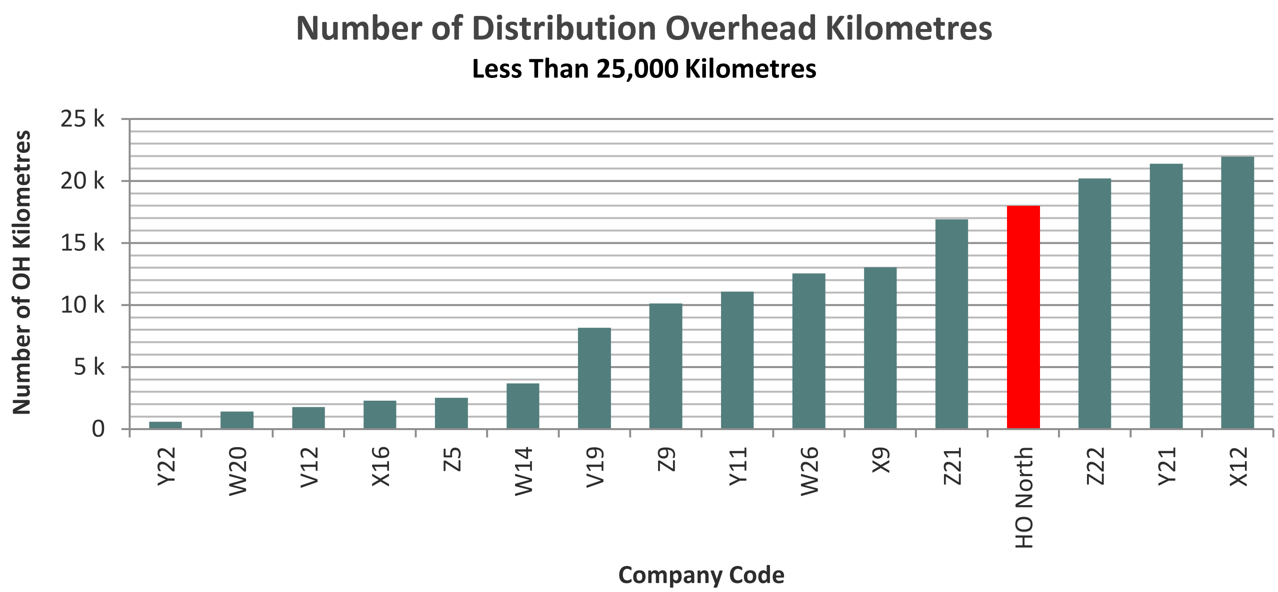
Graph 14: Number of Distribution Circuit Kilometres (UG and OH) – Companies with Less Than 50,000 Kilometres



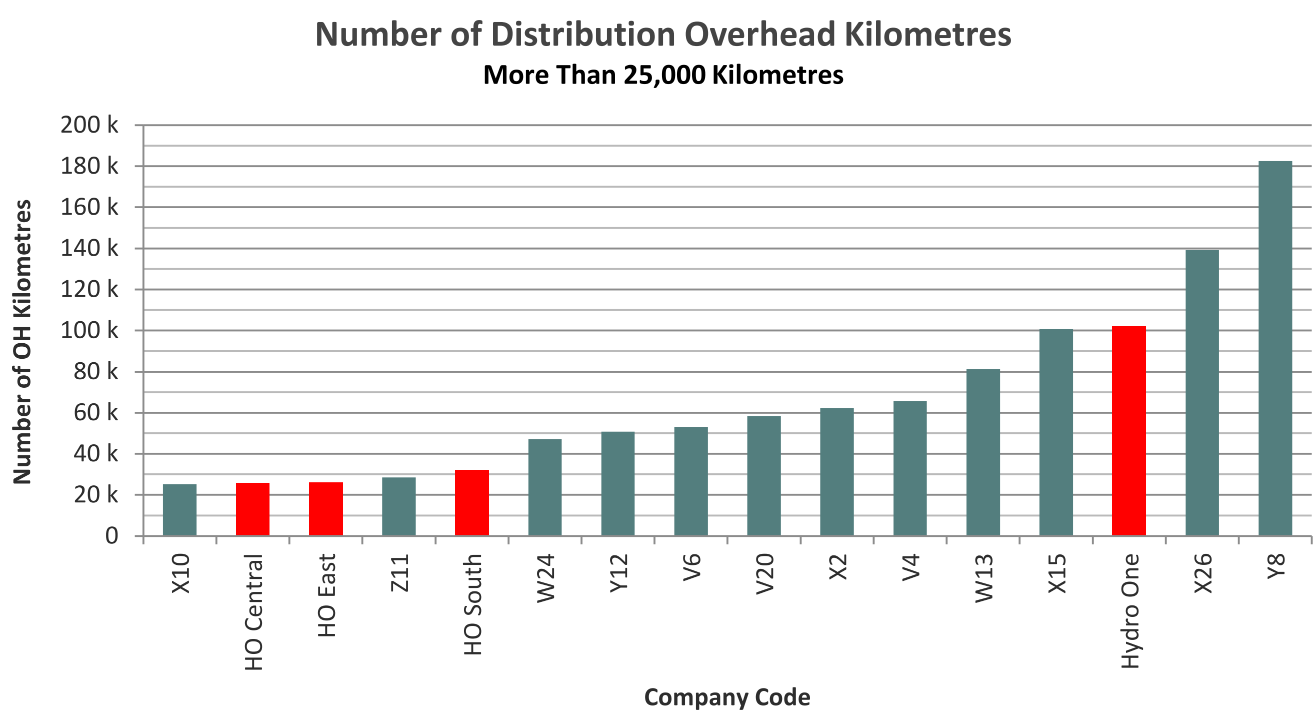
Graph 15: Number of Distribution Circuit Kilometres (UG and OH) – Companies with More Than 50,000 Kilometres

Distribution System Overhead Kilometres

The peer group is shown on two graphs (*with different y-axis scales*), so that the range of pole kilometres lengths can be distinguished. This includes all overhead pole kilometres greater than 1kV and less than 60kV.



Graph 16: Number of Distribution Overhead Kilometres – Companies with Less Than 25,000 Kilometres

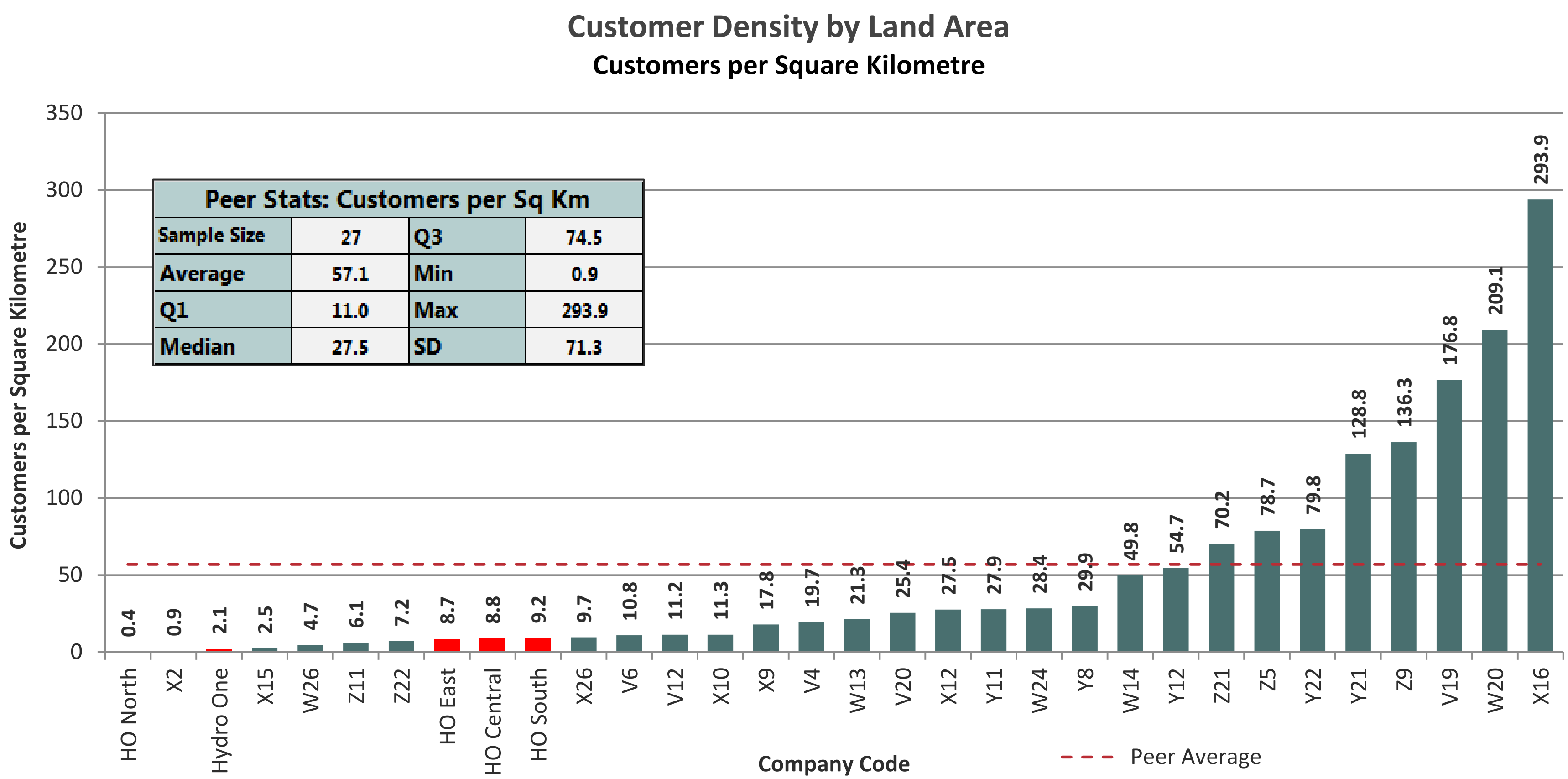


Graph 17: Number of Distribution Overhead Kilometres – Companies with More Than 25,000 Kilometres

COMPANY CHARACTERISTICS

Customer Density

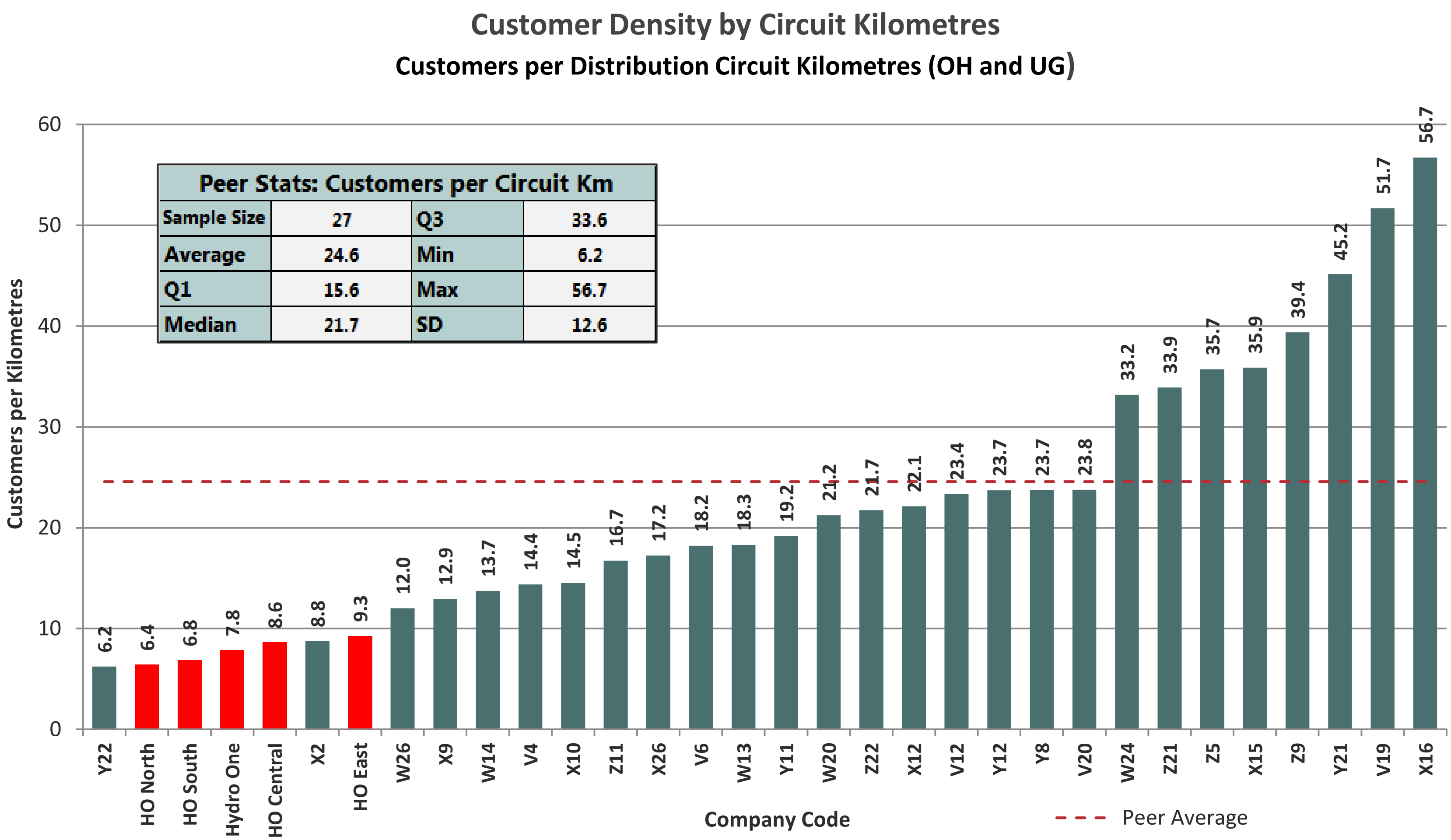
Electric Customers per Square Kilometre



Peer Stats: Customers per Sq Km			
Sample Size	27	Q3	74.5
Average	57.1	Min	0.9
Q1	11.0	Max	293.9
Median	27.5	SD	71.3

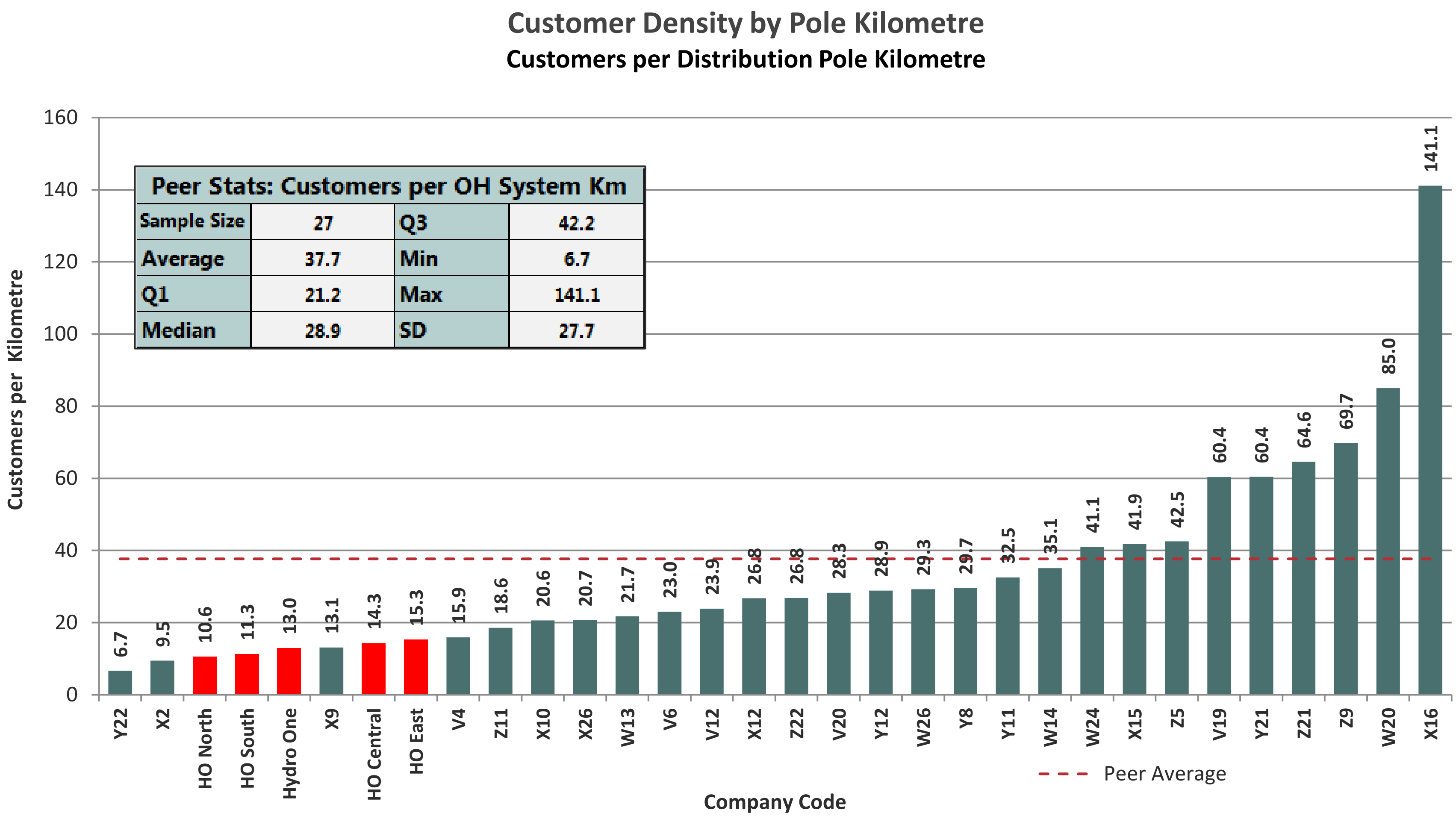
Graph 18: Customer Density by Land Area - Customers per Square Kilometre

Customers per Distribution Circuit Kilometres



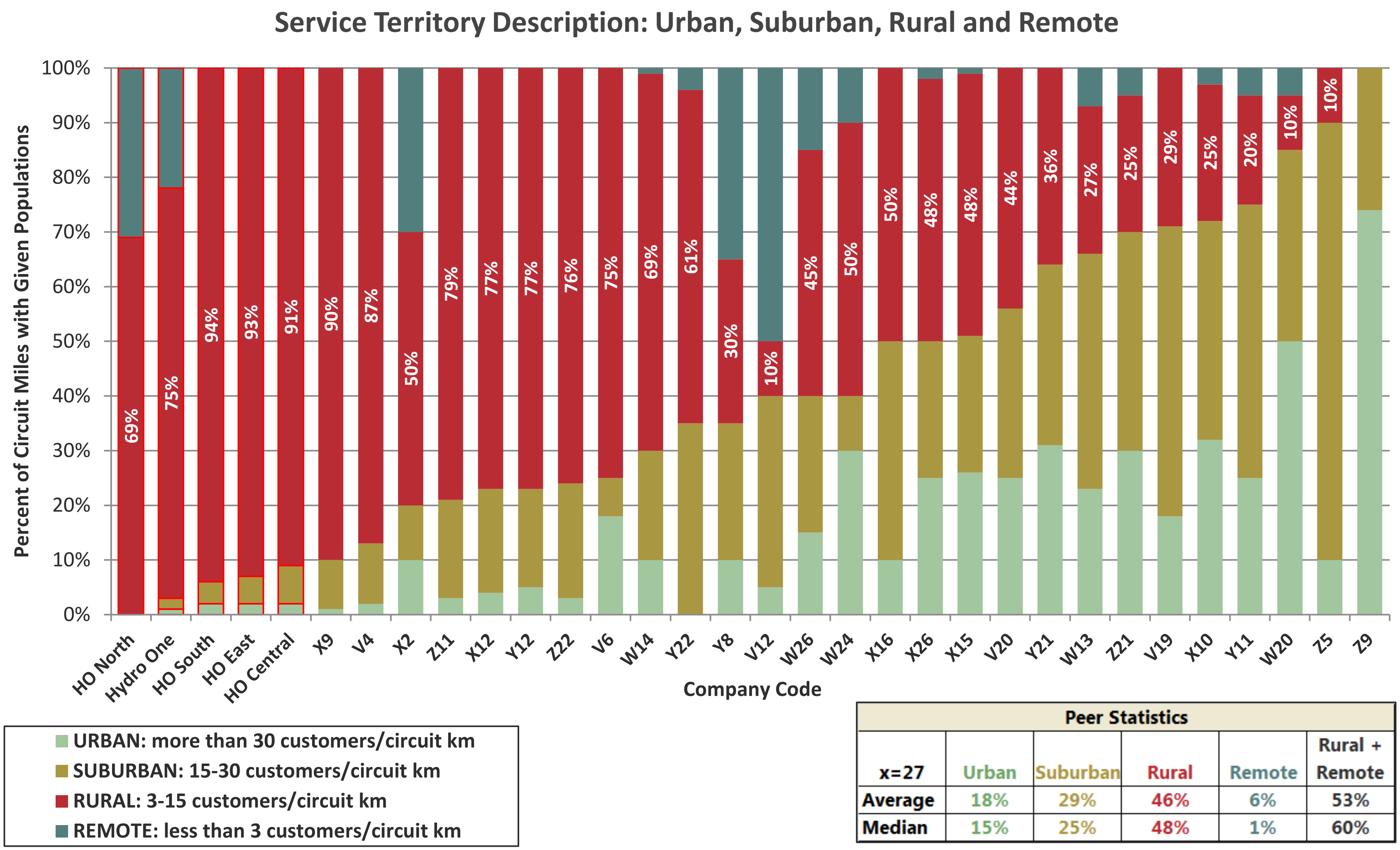
Graph 19: Customer Density by Circuit Kilometres - Customers per Distribution Circuit Kilometres (OH and UG)

Customers per Pole Kilometre



Graph 20: Customer Density by Pole Kilometre - Customers per Distribution Pole Kilometre

Service Territory Description by Customer Density

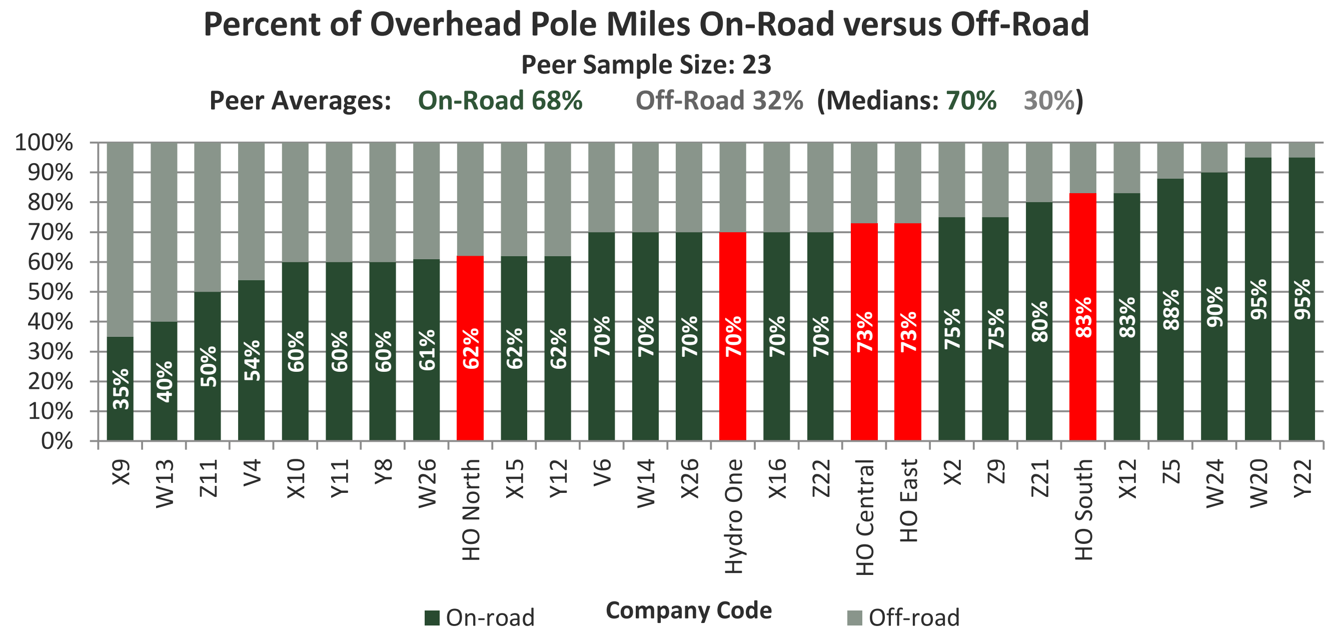


Peer Statistics					
x=27	Urban	Suburban	Rural	Remote	Rural + Remote
Average	18%	29%	46%	6%	53%
Median	15%	25%	48%	1%	60%

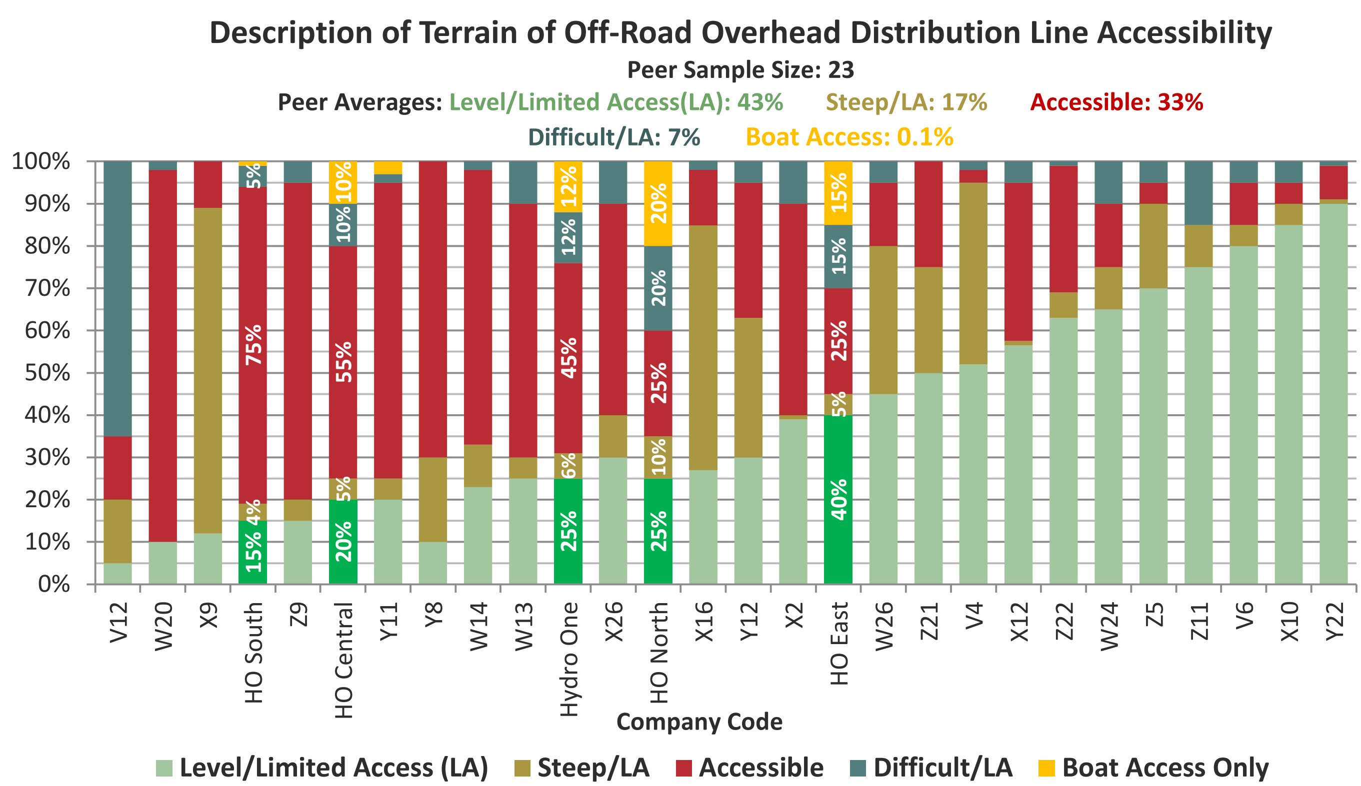
Graph 21: Service Territory Description: Urban, Suburban, Rural and Remote

Note: Graph sorted by combined rural and remote – largest to smallest; followed by urban – smallest to largest

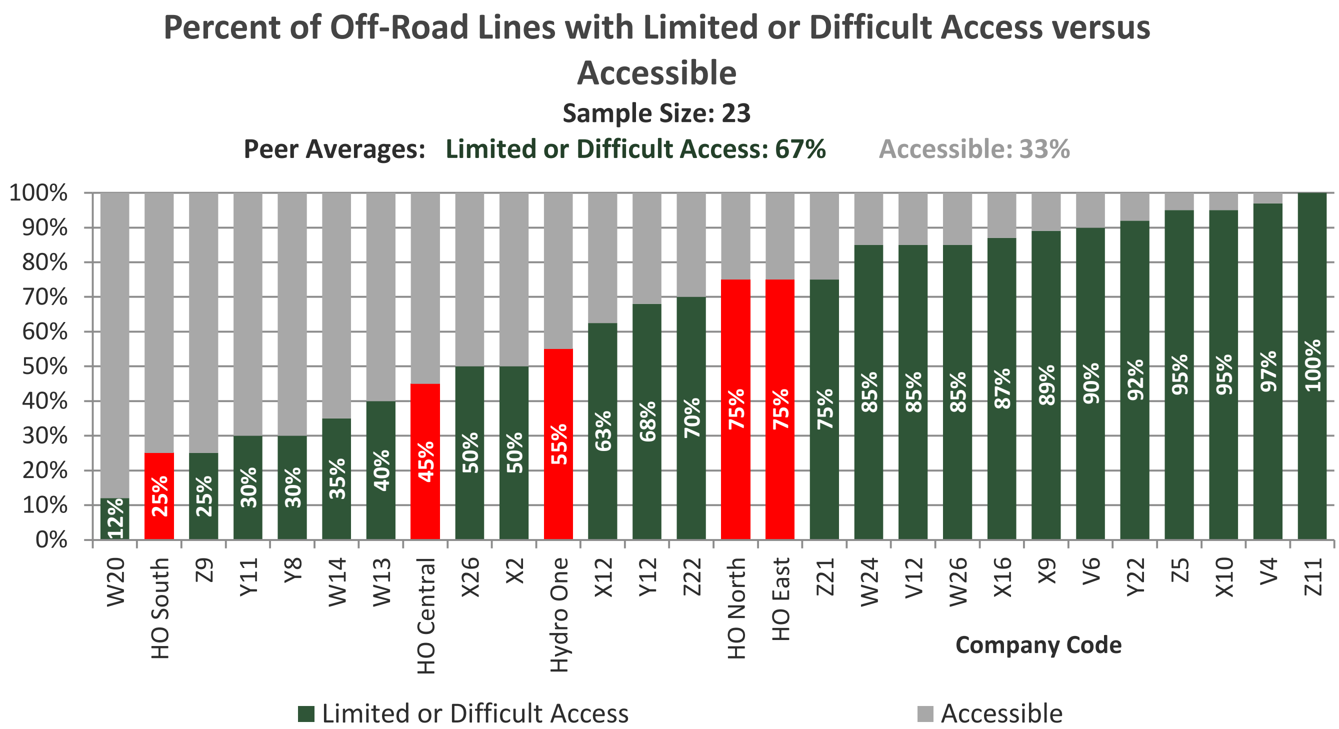
Accessibility



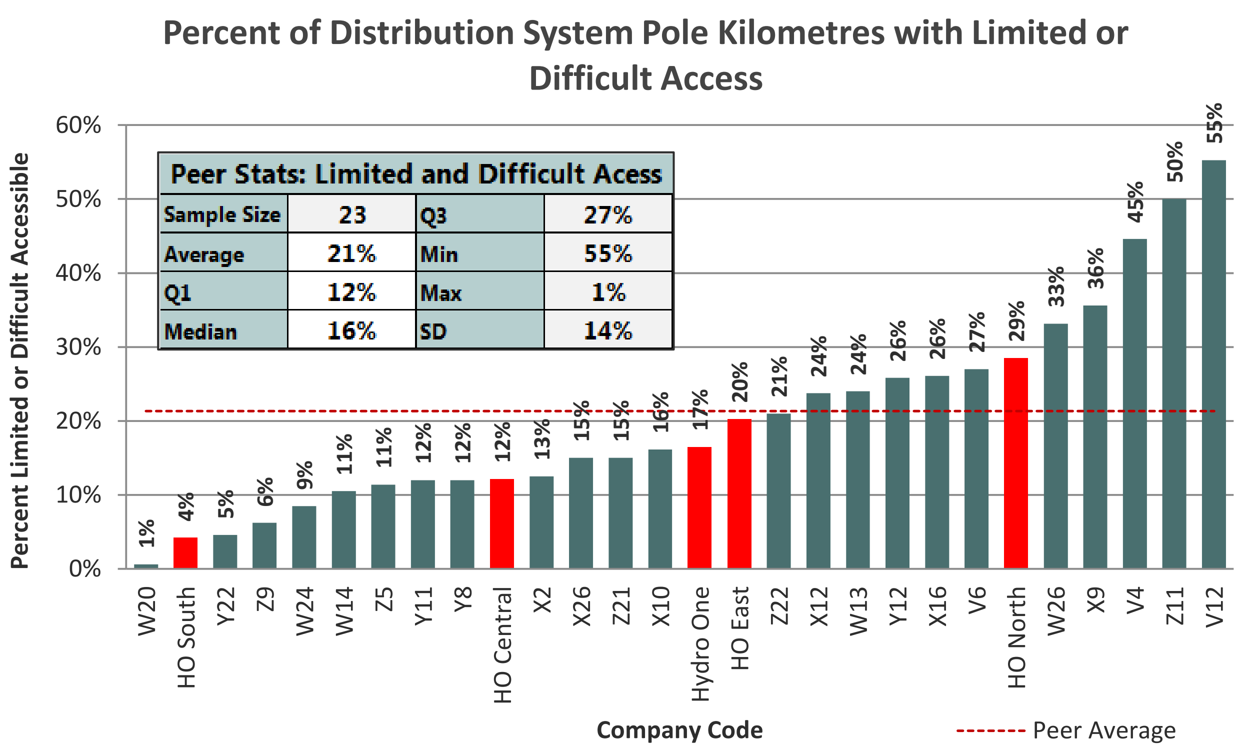
Graph 22: Percent of Overhead Pole Miles On-Road versus Off-Road



Graph 23: Description of Terrain of Off-Road Overhead Distribution Line Accessibility



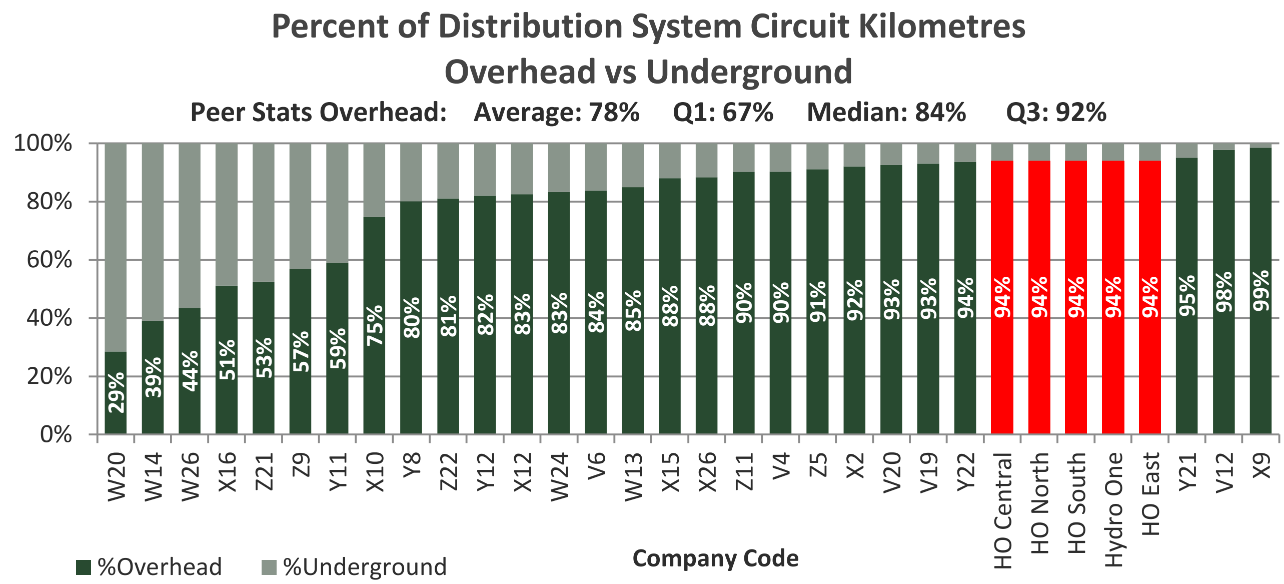
Graph 24: Percent of Off-Road Lines with Limited or Difficult Access versus Accessible



Peer Stats: Limited and Difficult Acess			
Sample Size	23	Q3	27%
Average	21%	Min	55%
Q1	12%	Max	1%
Median	16%	SD	14%

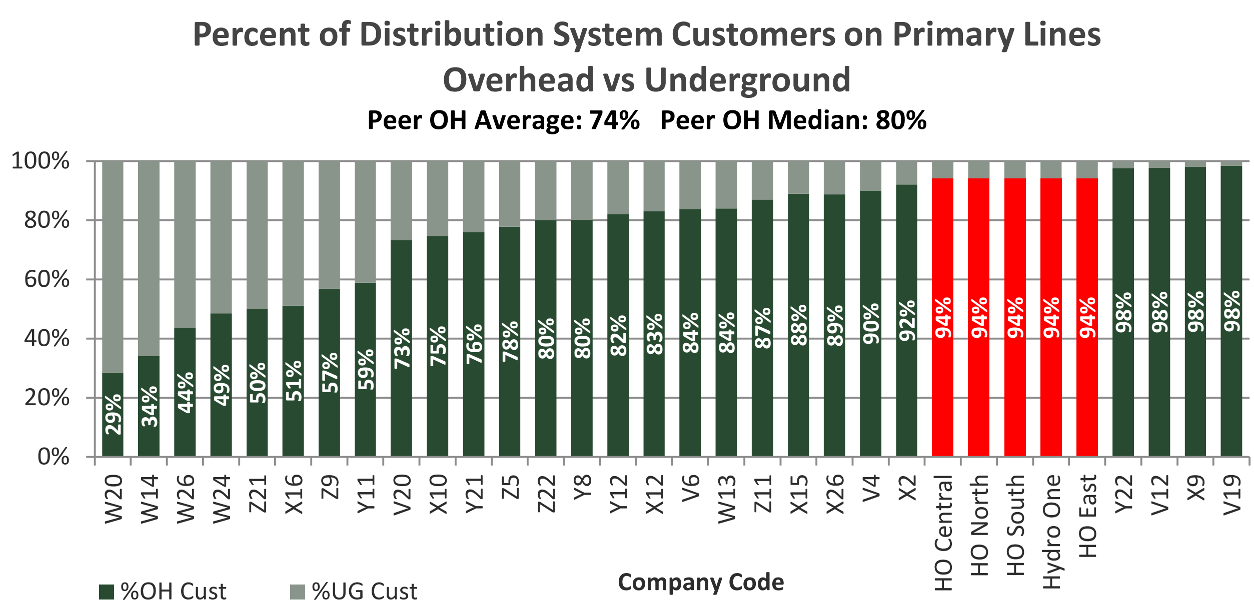
Graph 25: Percent of Distribution System Pole Kilometres with Limited or Difficult Access

Overhead versus Underground



Graph 26: Percent of Distribution System Circuit Kilometres Overhead vs Underground

NOTE: Customers on the distribution system that are on overhead primary lines versus underground primary lines follow a similar pattern for most of the peer group as the circuit kilometre breakdown.



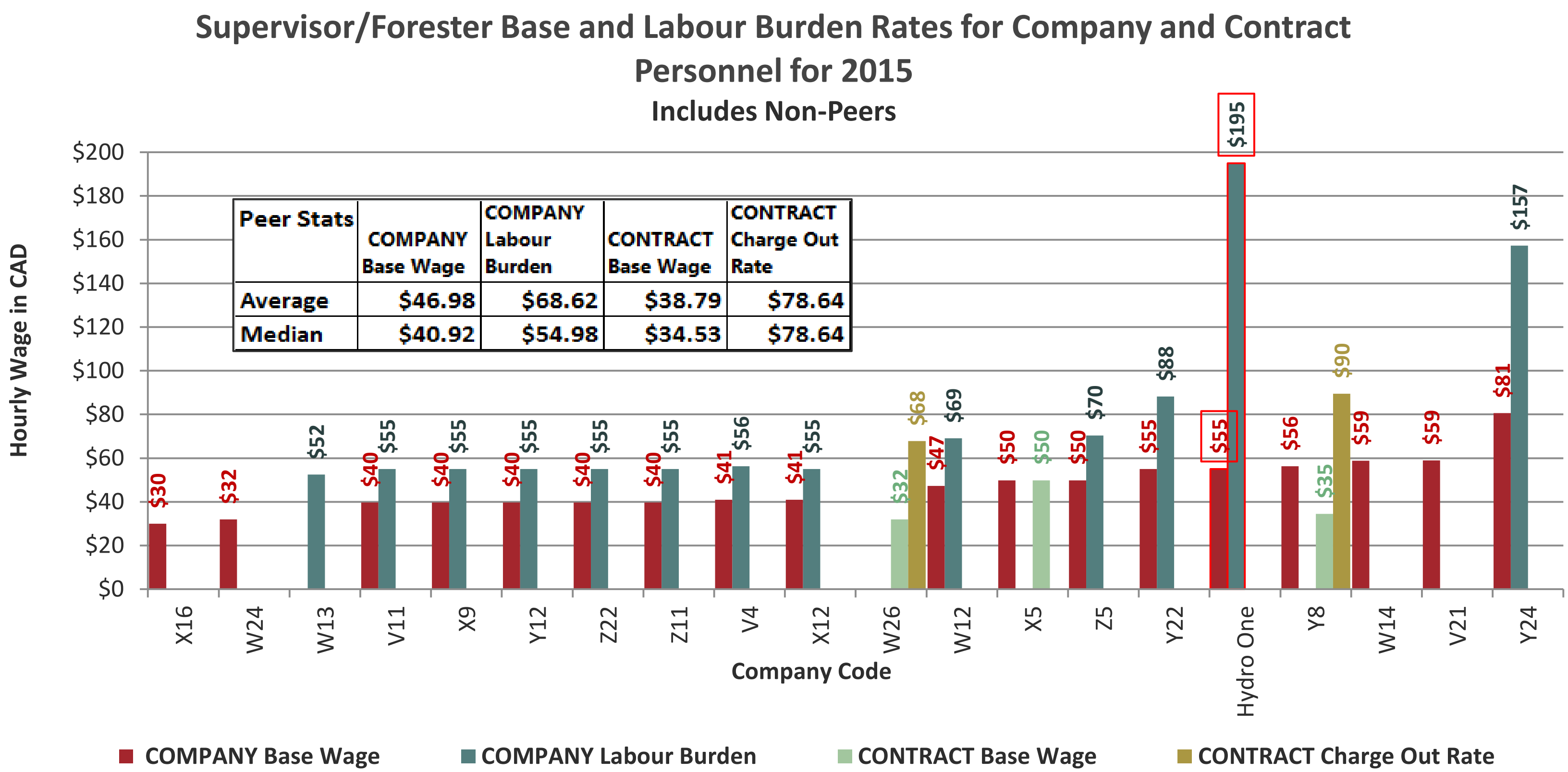
Graph 27: Percent of Distribution System Customers on Primary Lines Overhead vs Underground

WAGES AND MANAGEMENT RATIOS

Wages

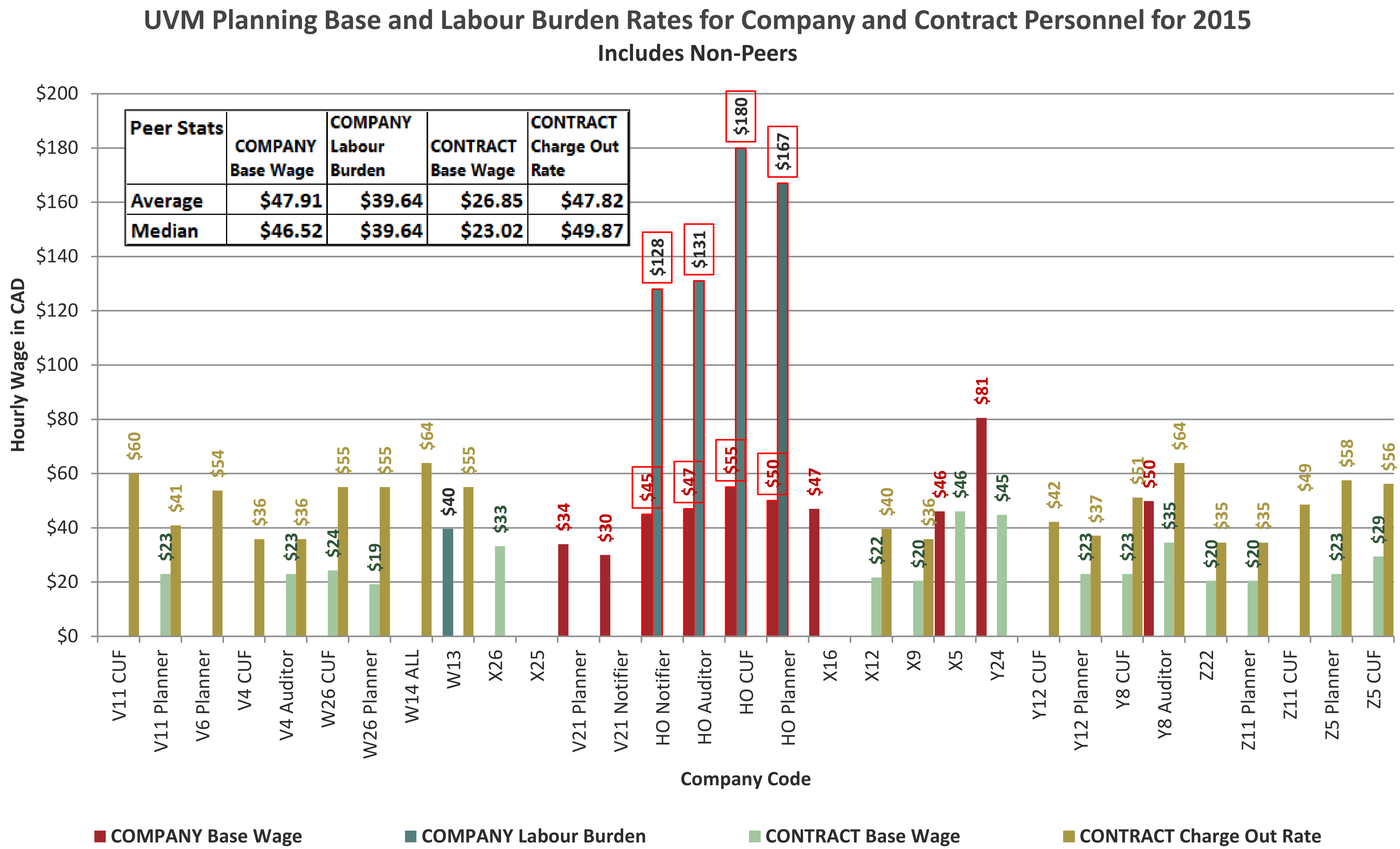
All the wage comparisons include Non-Peer Utilities and are in CAD using the 2015 annual exchange rate for USD to CAD, since this was the year for which the wages were given.

- Personnel Who Perform Work Planning and Quality Assurance



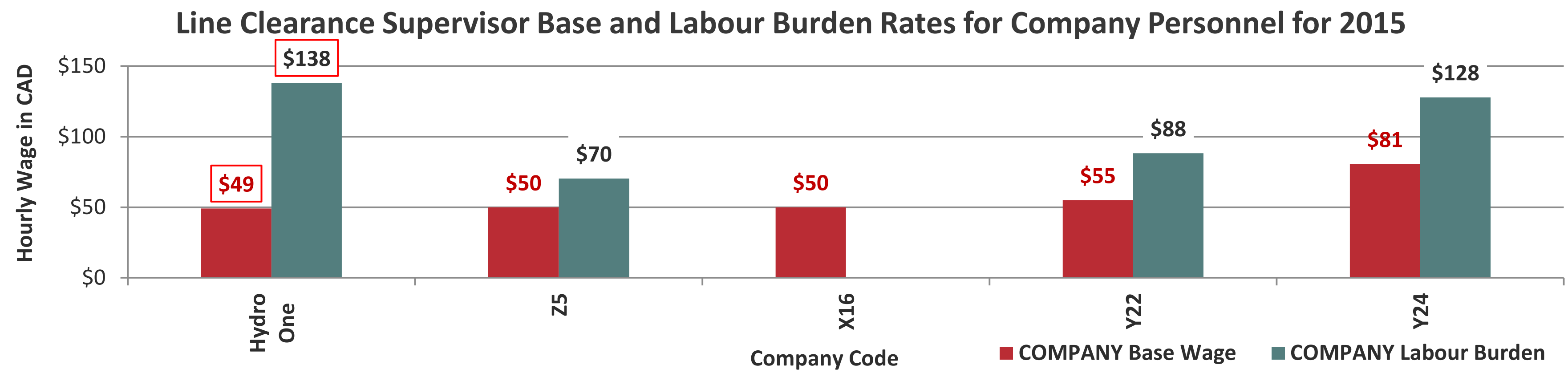
Peer Stats	COMPANY Base Wage	COMPANY Labour Burden	CONTRACT Base Wage	CONTRACT Charge Out Rate
Average	$46.98	$68.62	$38.79	$78.64
Median	$40.92	$54.98	$34.53	$78.64

Graph 28: Supervisor/Forester Base and Labour Burden Rates for Company and Contract Personnel

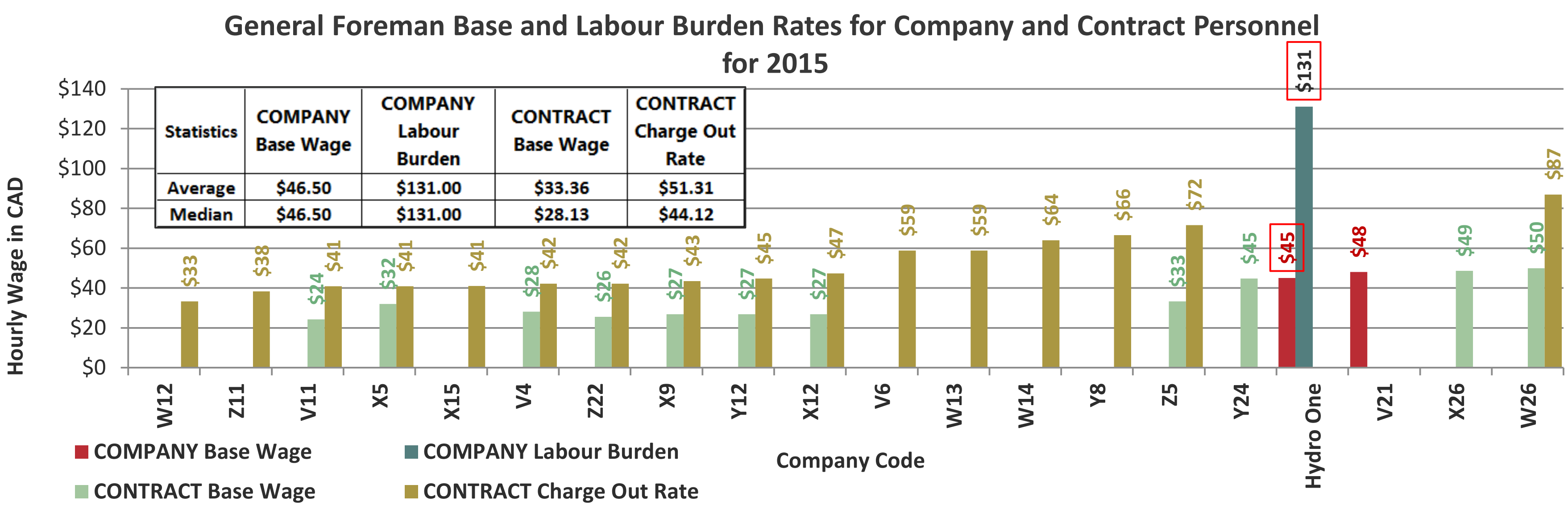


Graph 29: UVM Planning Base and Labour Burden Rates for Company and Contract Personnel for 2015

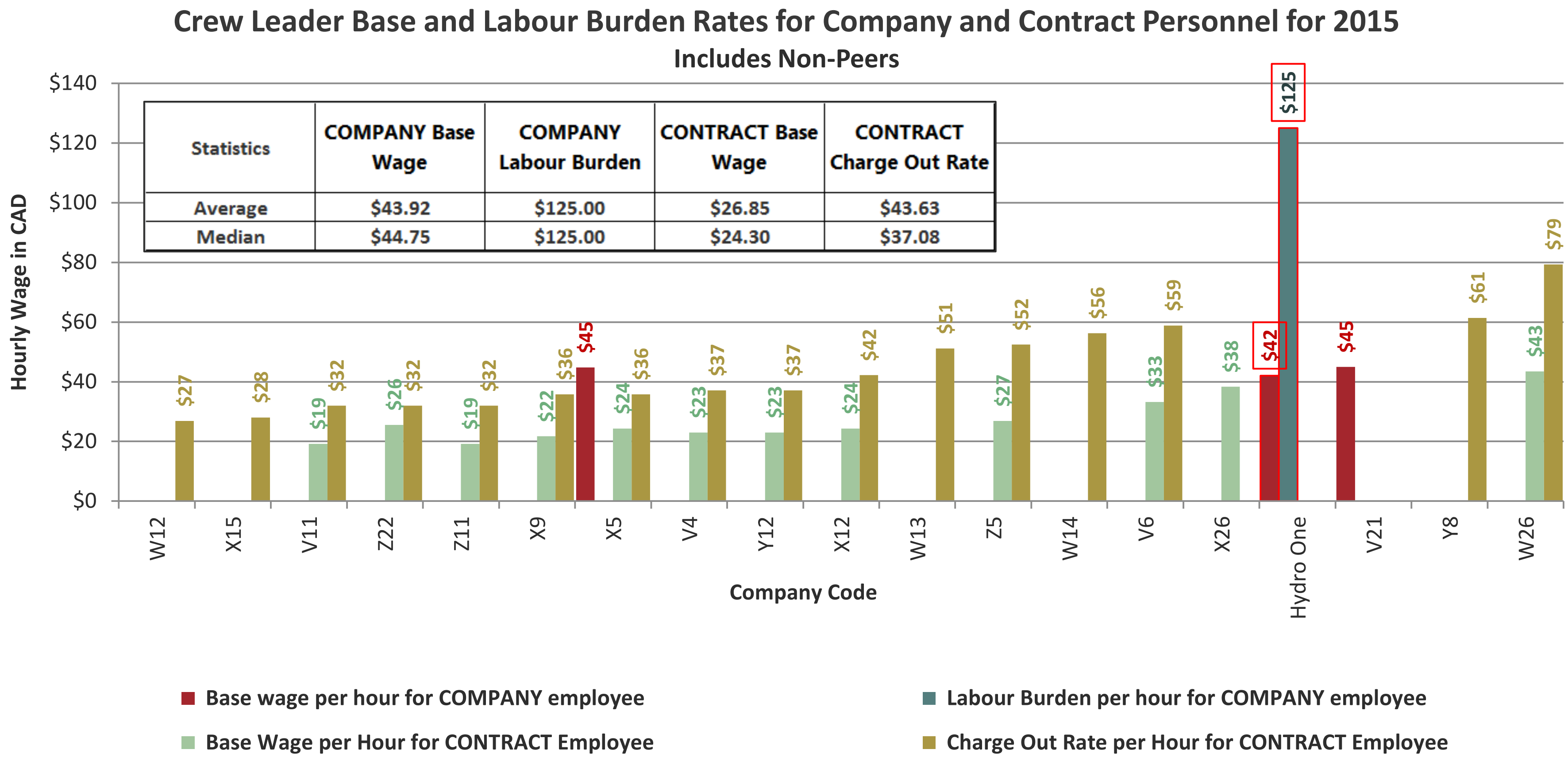
Line Clearance Supervisory Personnel



Graph 30: Line Clearance Supervisor Base and Labour Burden Rates for Company Personnel



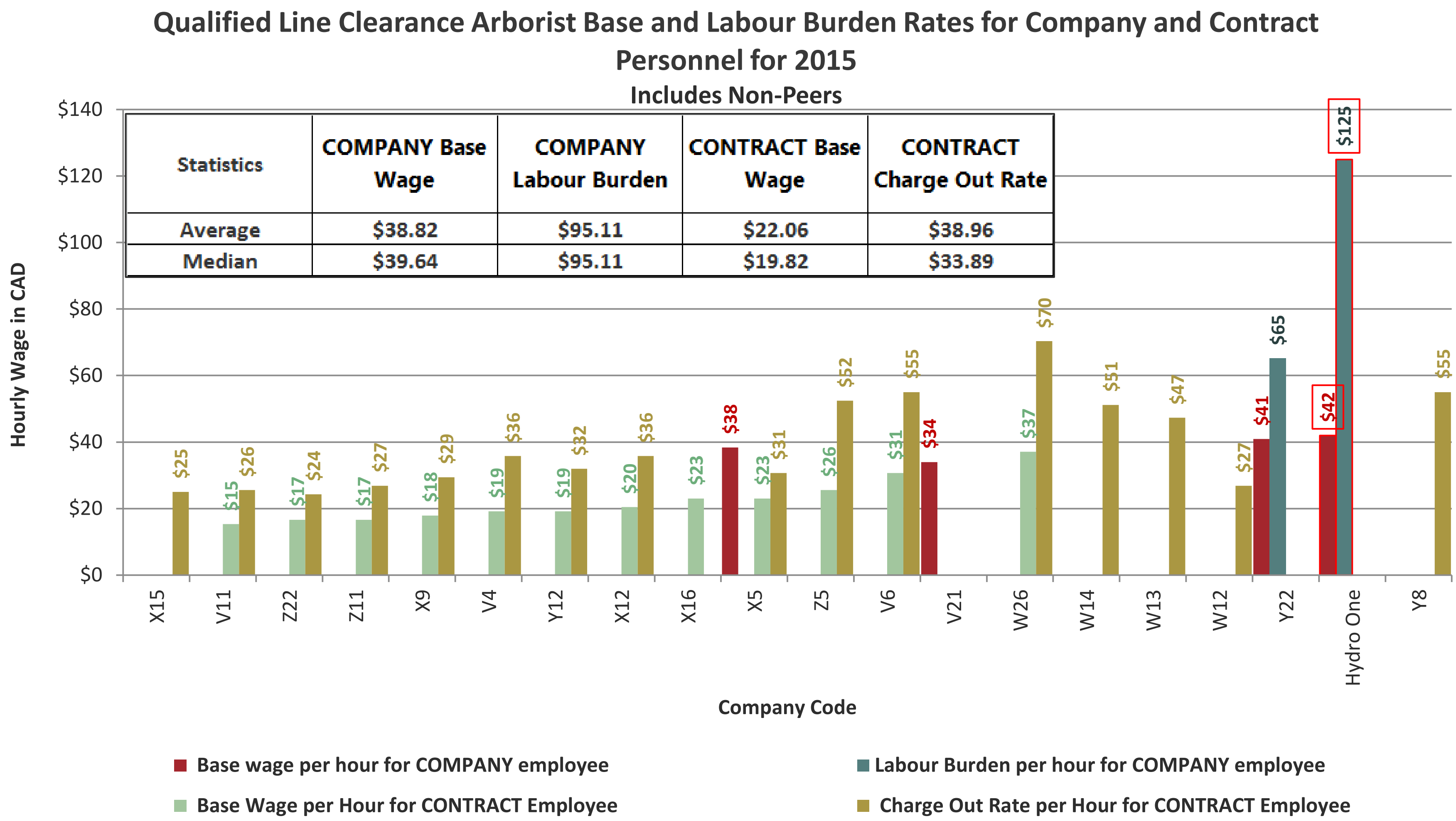
Graph 31: General Foreman Base and Labour Burden Rates for Company and Contract Personnel



Statistics	COMPANY Base Wage	COMPANY Labour Burden	CONTRACT Base Wage	CONTRACT Charge Out Rate
Average	$43.92	$125.00	$26.85	$43.63
Median	$44.75	$125.00	$24.30	$37.08

Graph 32: Crew Leader Base and Labour Burden Rates for Company and Contract Personnel

Line Clearance Field Personnel

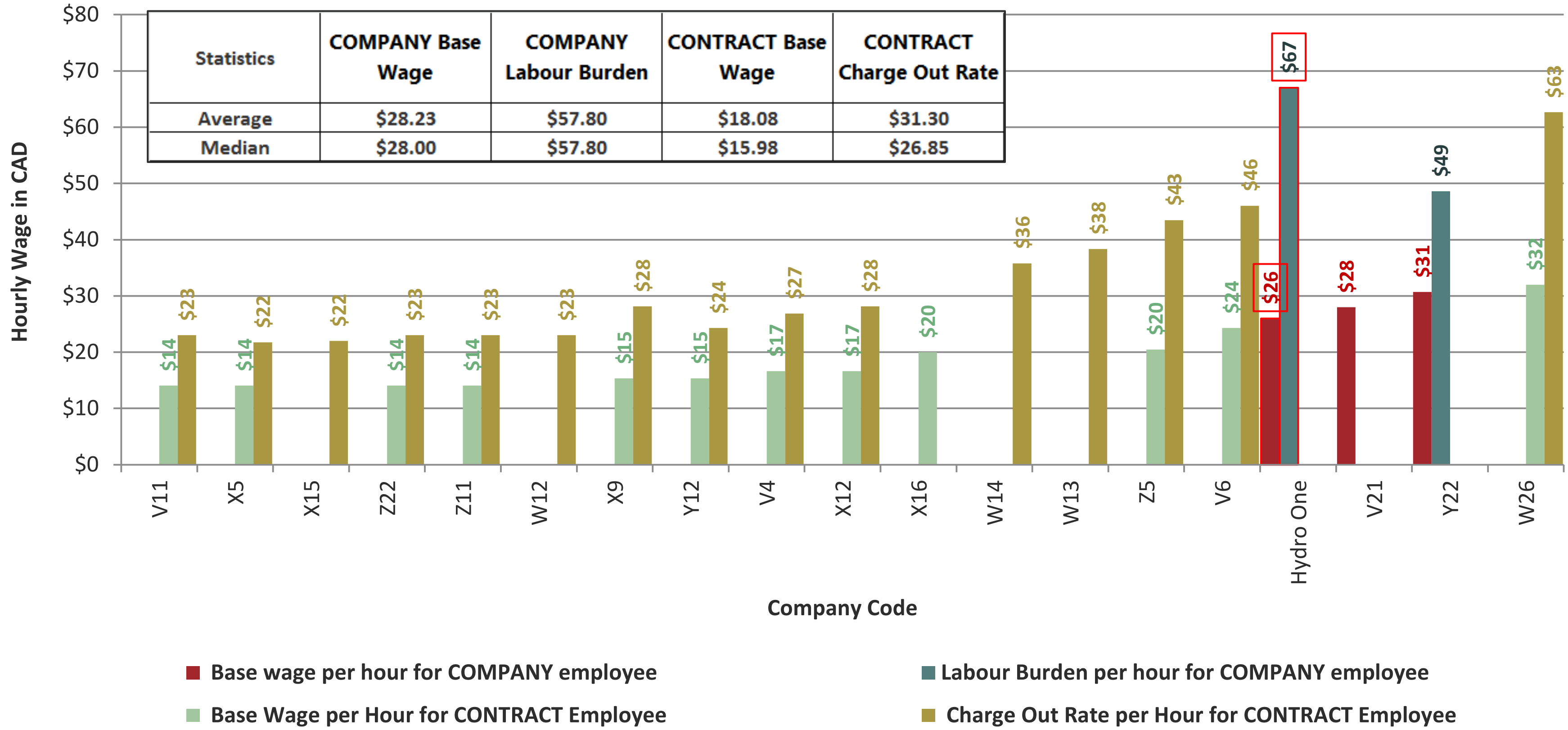


Statistics	COMPANY Base Wage	COMPANY Labour Burden	CONTRACT Base Wage	CONTRACT Charge Out Rate
Average	$38.82	$95.11	$22.06	$38.96
Median	$39.64	$95.11	$19.82	$33.89

Graph 33: Qualified Line Clearance Arborist Base and Labour Burden Rates for Company and Contract Personnel

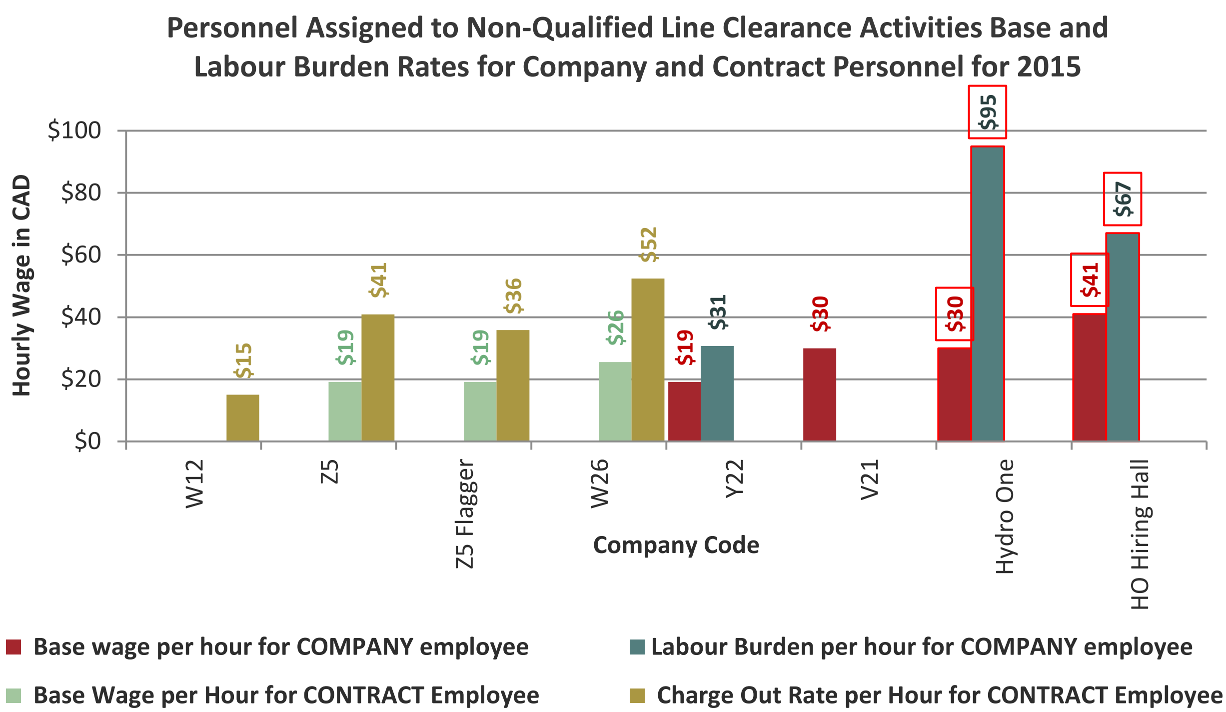
Qualified Line Clearance Arborist Trainee Base and Labour Burden Rates for Company and Contract Personnel for 2015

Includes Non-Peers



Statistics	COMPANY Base Wage	COMPANY Labour Burden	CONTRACT Base Wage	CONTRACT Charge Out Rate
Average	$28.23	$57.80	$18.08	$31.30
Median	$28.00	$57.80	$15.98	$26.85

Graph 34: Qualified Line Clearance Arborist Trainee Wages for Company and Contract Personnel



Graph 35: Non-Qualified Line Clearance Activities Base and Labour Burden Rates

Number of Years Line Clearance Employees Have Been Working at the Utility					
Average, Max and Min Exclude Hydro One		Average Number of Years on Job	Hydro One	Peer Max	Peer Min
Supervisor	Company	13	25	24	5
	Contract	11.7		25	5
General Foreman	Company	5	15		
	Contract	10		18	5
Crew Leader	Company	5	20		
	Contract	8.7		20	3
Arborist	Company	8.75	20	15	5
	Contract	6.5		15	4
Arborist Trainee	Company	1.75	4	3	1
	Contract	3.1		7	1
Other Field Personnel	Company	3	15		
	Contract	5.5		15	1

Table 7: Average Number of Years on the Job

The maximums in all the contract categories are from a utility that has sole-sourced their work to the same contractor for over twenty years.

Base Wages versus Labour Burden or Charge-Out Rates					
Average, Max and Min Exclude Hydro One		Average Difference between Hourly Base Wage and Labour Burden [Times Greater]	Hydro One	Peer Max	Peer Min
Supervisor/Forester	Company	1.6	3.6	2.0	1.3
	Contract	2.4		2.6	2.1
UVM Planning Personnel	Company	1.6	3.3	2.0	1.4
	Contract	2.4		2.6	2.1
Supervisor	Company	1.5	2.8	1.6	1.4
	Contract				
General Foreman	Company		2.9		
	Contract	1.7		2.2	1.3
Crew Leader	Company		3.0		
	Contract	1.7		2.0	1.3
Arborist	Company	1.6	3.0		
	Contract	1.7		2.1	1.5
Arborist Trainee	Company	1.6	2.6		
	Contract	1.7		2.1	1.5
Other Field Personnel	Company		3.2		
	Contract Hiring Hall [HO]	2.0	1.6	2.1	1.9

Table 8: Base Wages versus Labour Burden or Charge-Out Rates

Note: Some companies only have the Supervisor/ Forester as the planning personnel

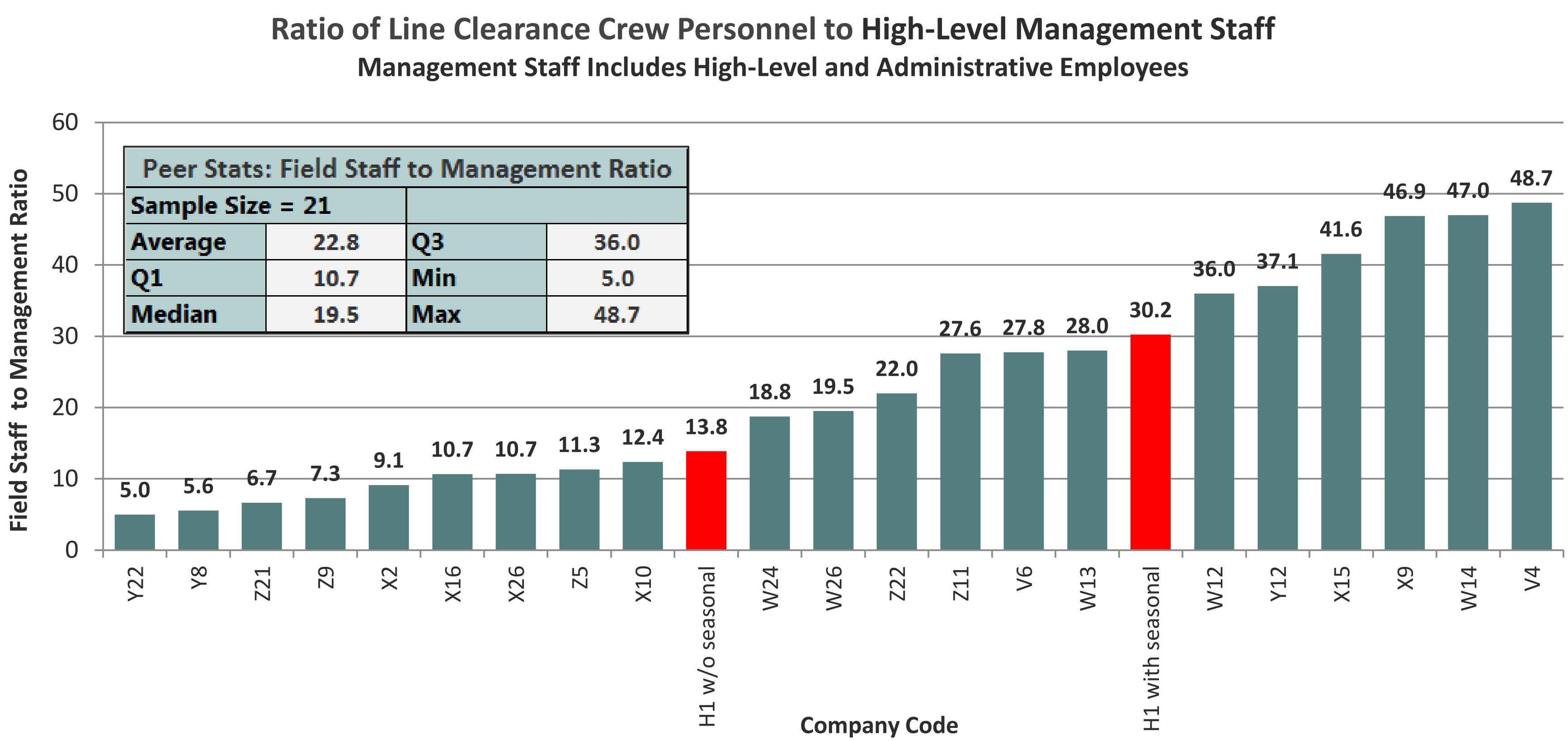
Management Staff to Line Clearance Crew Personnel Ratios

Utilities organize their UVM departments differently. Variations in position titles and duties, in-house to contract personnel ratios, and extent of work planning all impact the following study. It should also be noted that Hydro One is the only company in the peer group that uses temporary labour to any degree. As a result of these differences, Hydro One data are presented as an upper and lower range using the management staff reported and the number of full-time staff with and without seasonal labour.

Management Staff was separated into three categories:

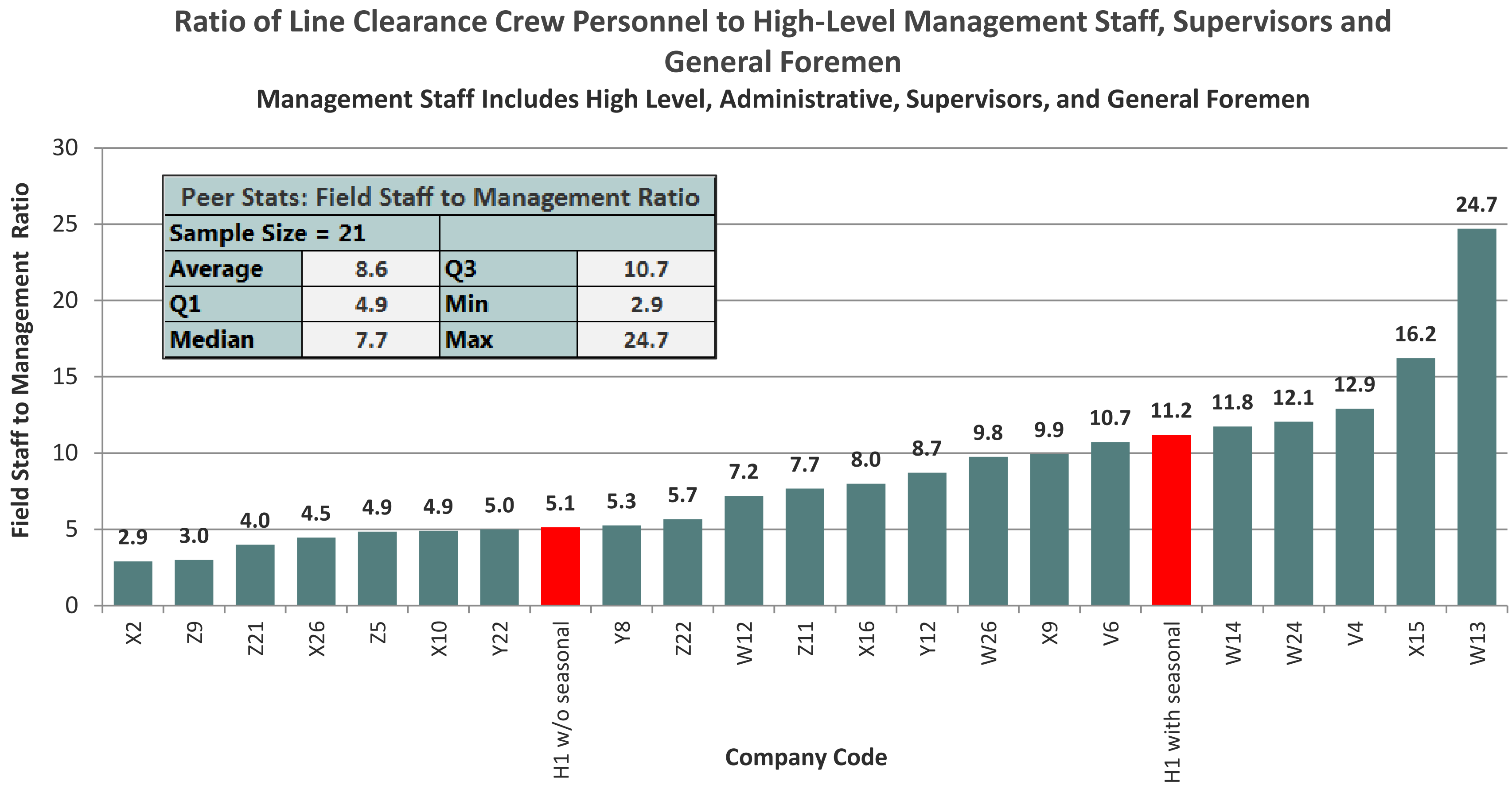
1. High-level and administrative
2. Line Clearance Supervisors and General Foremen
3. Work planning staff

Graphically, the above categories were grouped as follows: 1 only; 1 + 2; and 1 + 2 + 3



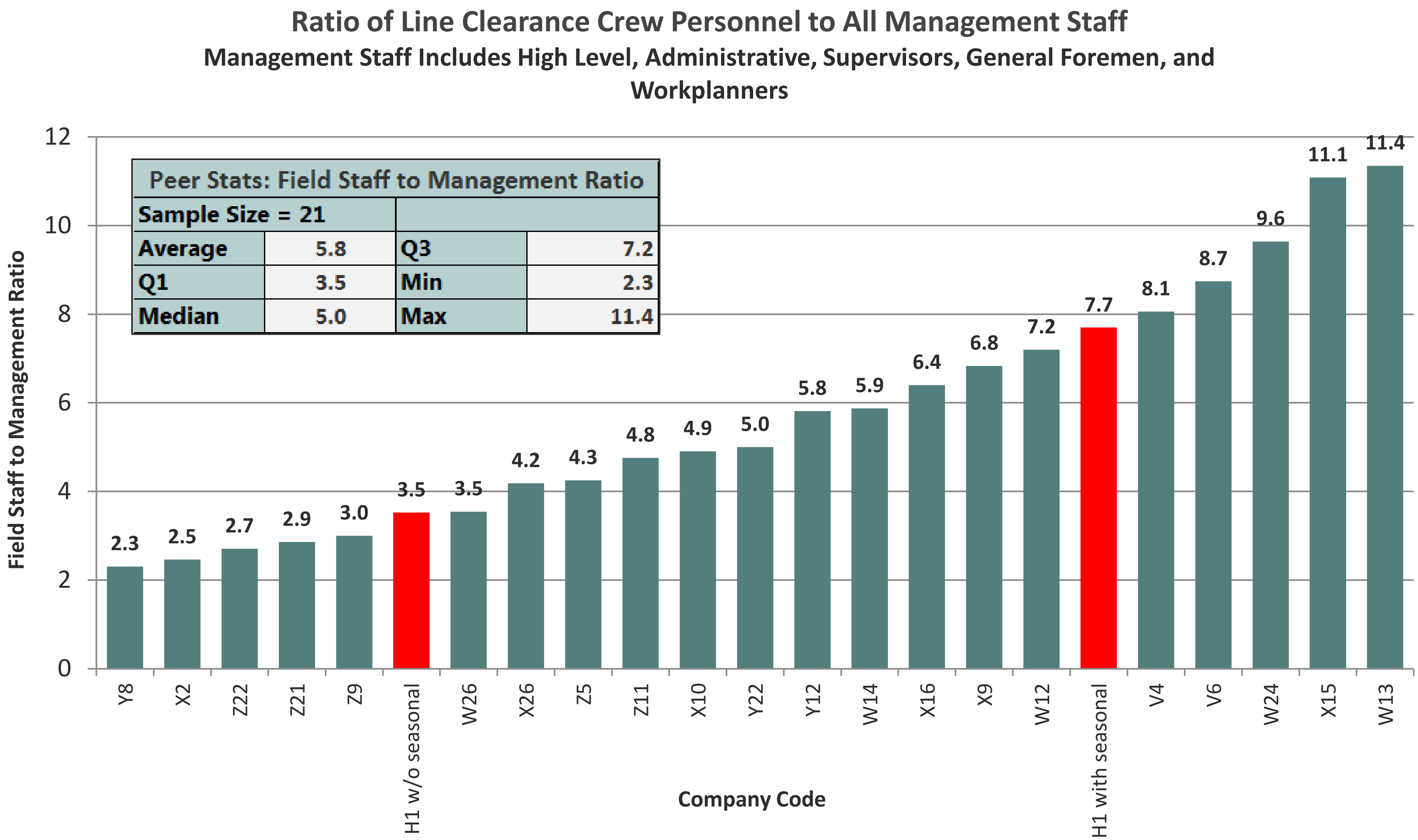
Peer Stats: Field Staff to Management Ratio			
Sample Size = 21			
Average	22.8	Q3	36.0
Q1	10.7	Min	5.0
Median	19.5	Max	48.7

Graph 36: Ratio of Line Clearance Crew Personnel to High-Level Management Staff



Peer Stats: Field Staff to Management Ratio			
Sample Size = 21			
Average	8.6	Q3	10.7
Q1	4.9	Min	2.9
Median	7.7	Max	24.7

Graph 37: Ratio of Line Clearance Crew Personnel to High-Level Management, Supervisors and General Foremen



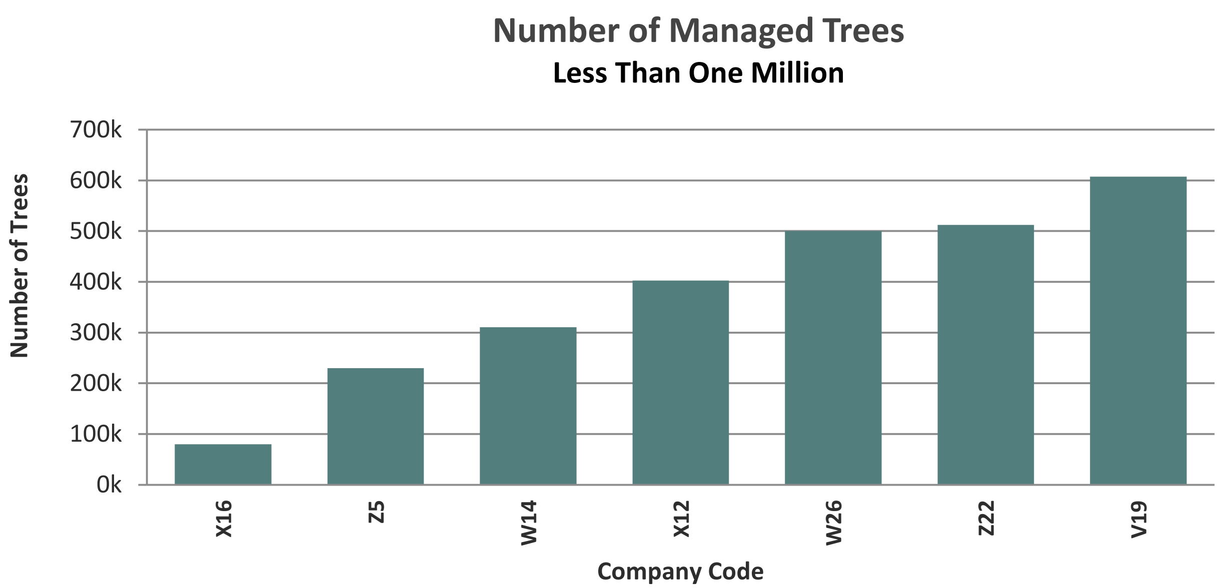
Peer Stats: Field Staff to Management Ratio			
Sample Size = 21			
Average	5.8	Q3	7.2
Q1	3.5	Min	2.3
Median	5.0	Max	11.4

Graph 38: Ratio of Line Clearance Crew Personnel to All Management Staff

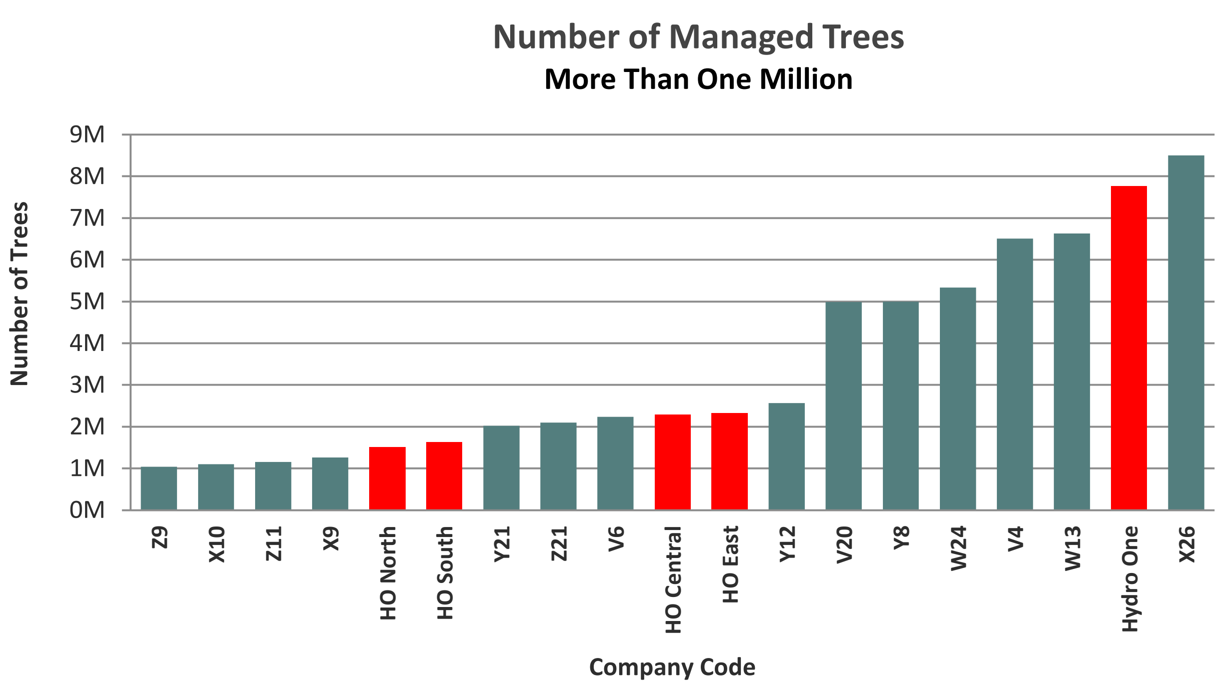
UTILITY VEGETATION MANAGEMENT WORKLOADS

Number of Managed Trees on Distribution System

The peer group is shown on two graphs (*with different y-axis scales*), so that the range of managed trees sizes can be distinguished.

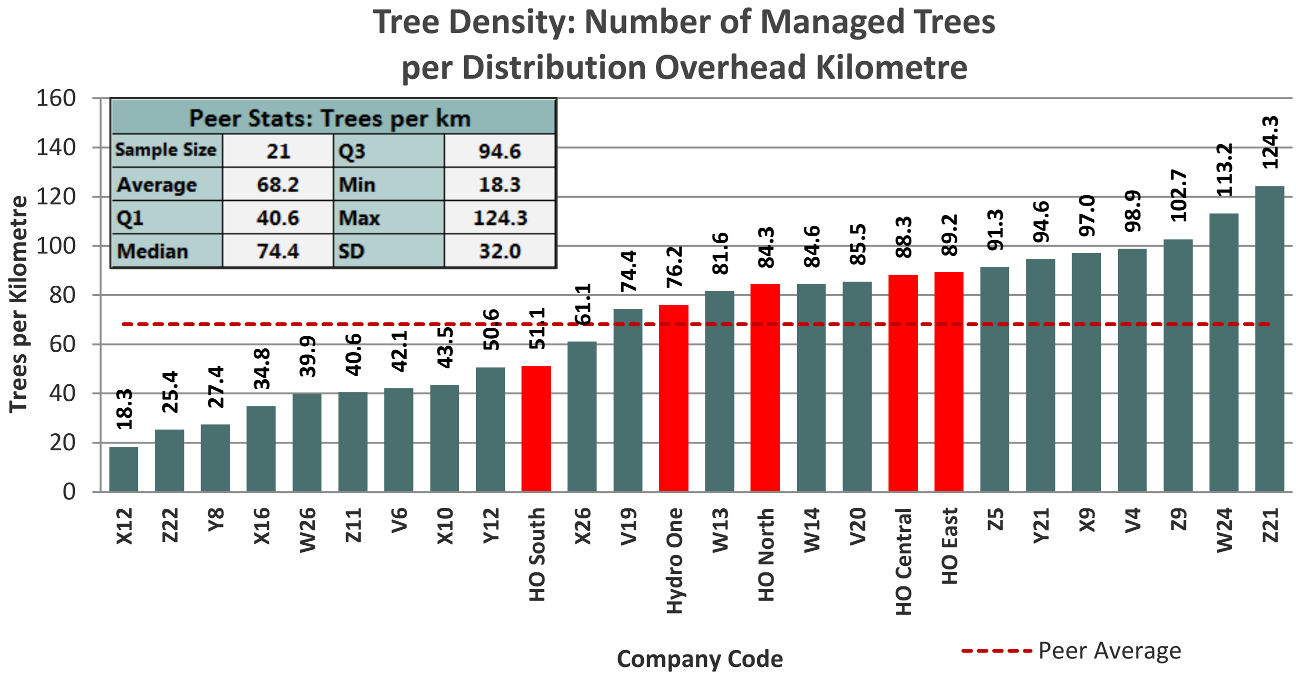


Graph 39: Number of Managed Trees – Companies with Less Than One Million

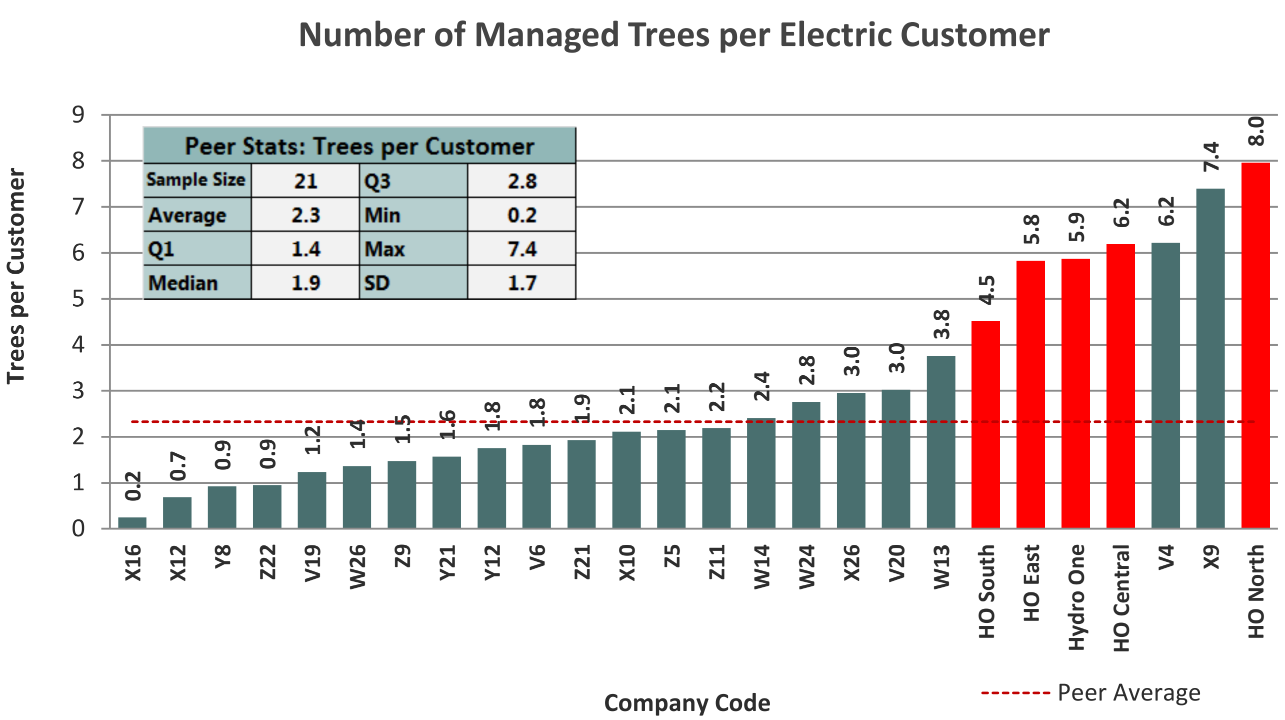


Graph 40: Number of Managed Trees – Companies with More Than One Million

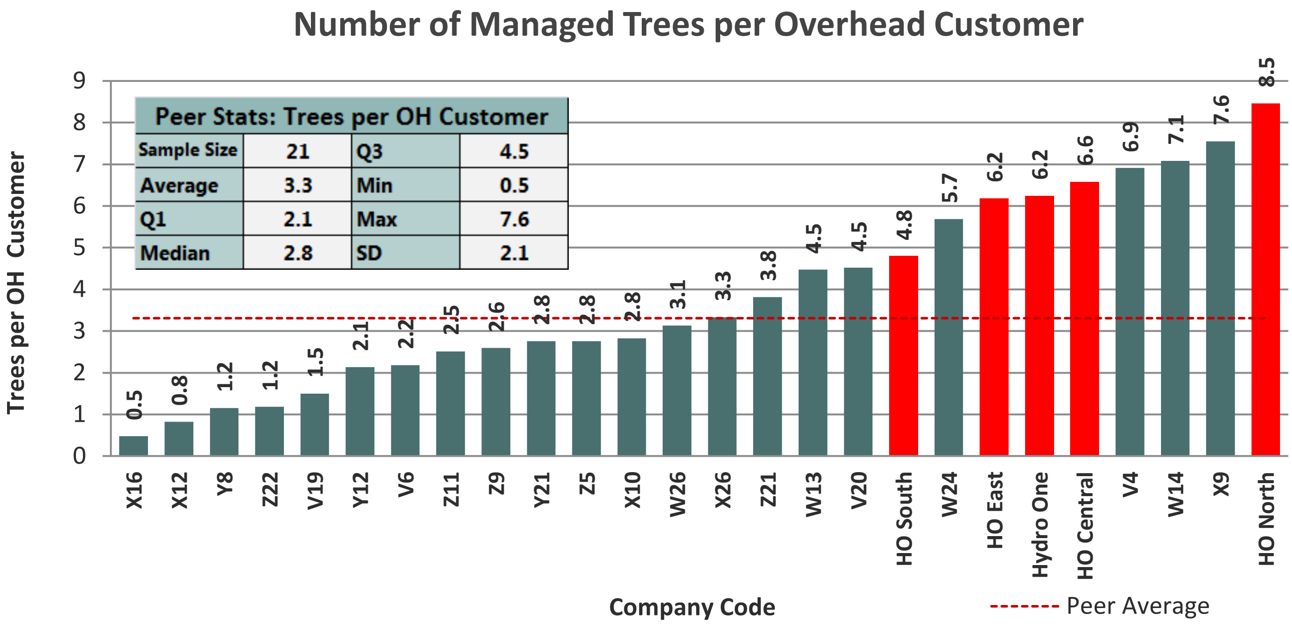
Tree Density



Graph 41: Tree Density: Number of Managed Trees per Distribution Overhead Kilometre

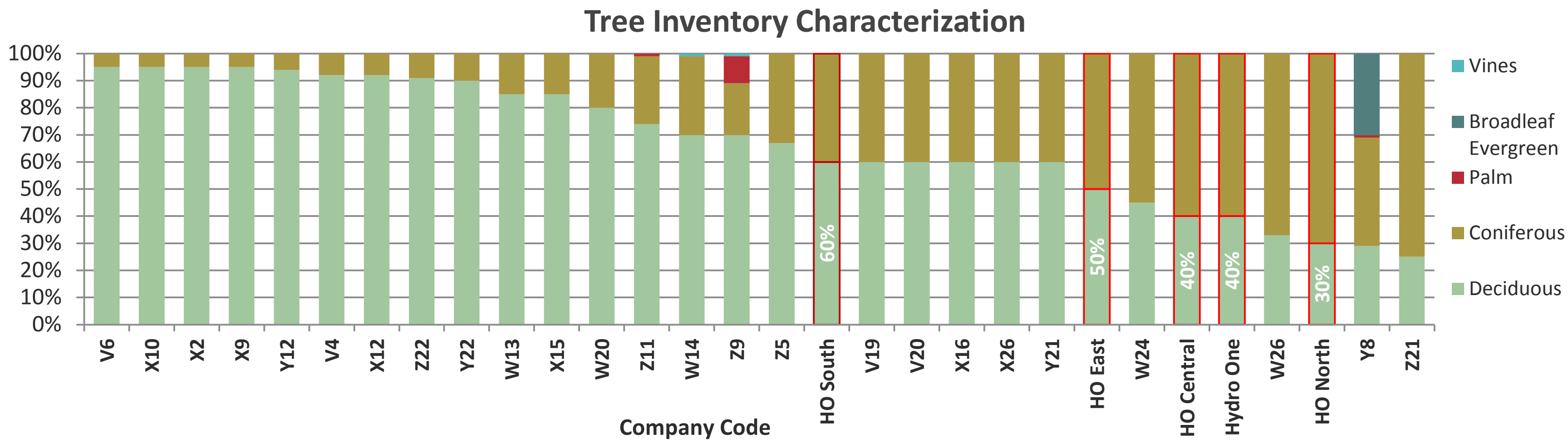


Graph 42: Managed Trees per Electric Customer

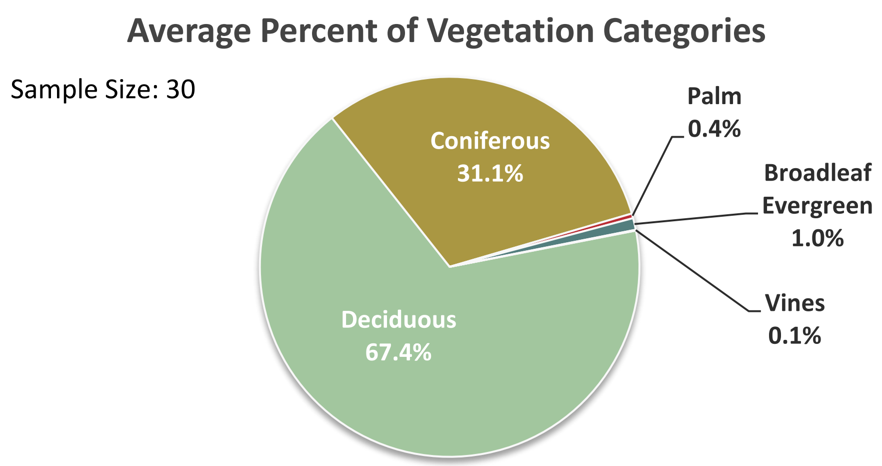


Graph 43: Managed Trees per Overhead Customer

Characterization of Managed Trees



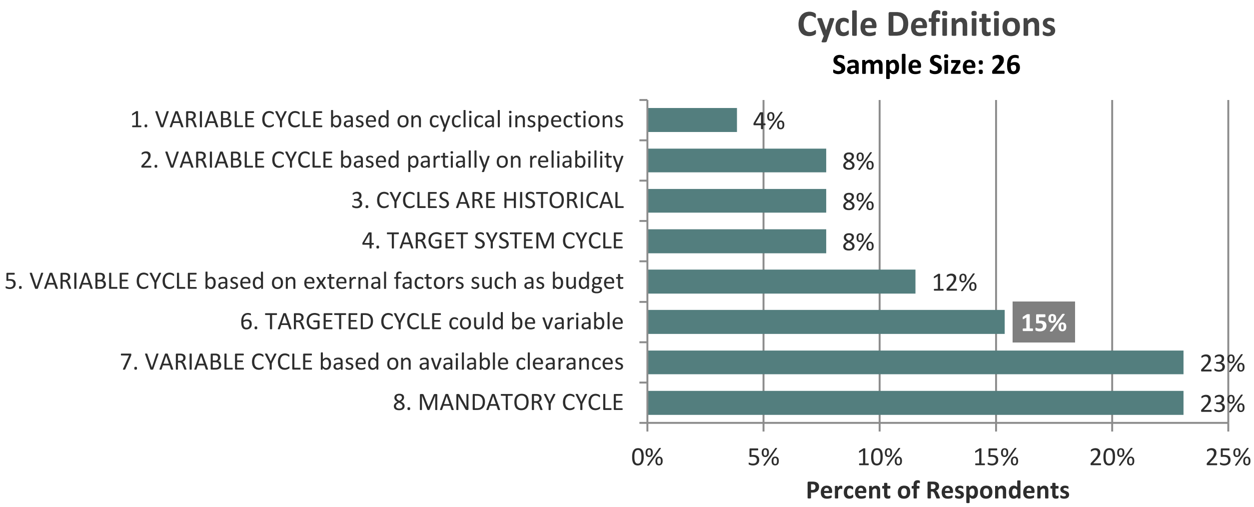
Graph 44: Tree Inventory Characterization



Graph 45: Average Percent of Vegetation Categories

CYCLES OF MANAGEMENT

Cycle Definitions



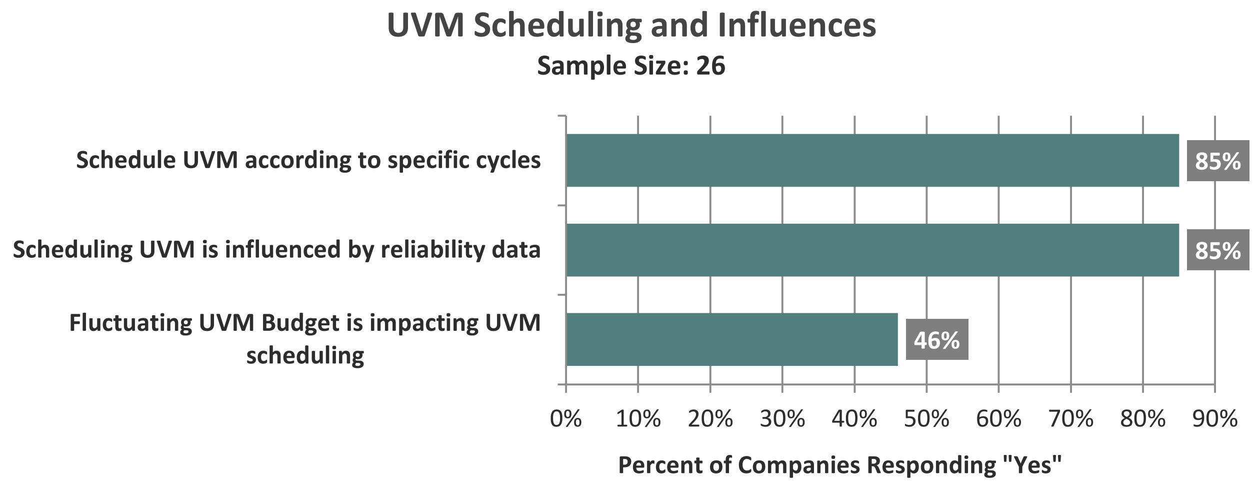
Legend: Complete Definitions
1. VARIABLE CYCLE based on cyclical inspections: A set SCHEDULE OF INSPECTIONS that determines which trees are in need of maintenance
2. VARIABLE CYCLE based partially on reliability
3. CYCLES ARE HISTORICAL: A measure of the time it takes to manage ALL of the trees, spans or miles in your distribution system ONE TIME
4. TARGET SYSTEM CYCLE: A SCHEDULE of maintenance applied to the entire distribution system
5. VARIABLE CYCLE based on external factors such as budget: The time between management of a SINGLE tree, span or mile in your distribution system
6. TARGETED CYCLE could be variable: PLANNED length between vegetation maintenance activities
7. VARIABLE CYCLE based on available clearances: A SCHEDULE based on the amount of clearance that can be realistically obtained as well as the expected growth rates of the trees on any given site
8. MANDATORY CYCLE: A PLANNED length of time that MUST be maintained between vegetation management activities
9. VARIABLE HISTORICAL CYCLES: The amount of time between SCHEDULED pruning operations

Graph 46: Percent of Companies with Given Cycle Definitions

Descriptions of Vegetation Maintenance Cycles
We run 4 and 6 year cycles on distribution. [7]
Working towards a cycle based on inspections [5]
Based on predictive model that forecasts tree related outages per mile of line and impact to SAIFI and SAIDI for the next 12 months [2]
Our UVM cycle is a four-year average (or effective) cycle. For example, we maintain 25% of our overhead UVM system miles annually. This is a reliability based, variable cycle. [2]
We are expected, by [State] Commerce Commission mandate, to perform full maintenance on each of our distribution circuits at least once every 48 months. We are also mandated to perform a mid-cycle patrol of every circuits the second year after full maintenance has taken place. [8]
Utility vegetation cycles are planned lengths of time attributed to every circuit of our system and are based on vegetation response to all factors influencing growth as well as customer density. These cycles should be maintained for each programmed interventions. [5]
Also agree that it is a planned length of time not only looking backwards, but forwards as well. But it is a measure of time to manage all trees, spans, or miles one time. [3]
Our tree program is driven by customer density and budget and reliability. 5-year cycle suburban 10-year cycle Rural [4]

Table 9: Descriptions of Vegetation Maintenance Cycles

Scheduling, Cycles, and Impacts



Graph 47: UVM Scheduling and Influences

Comments on Fluctuating UVM Budget
We set budgets according to the number of miles being maintained in a given year [No]
Due to program underfunding we are experiencing a backlog of work [Yes]
Depends upon the year and the budget. Over the years we have been successful in creating a more stable annual budget [No]
Yes and no. Maintaining 48-month compliance is first priority and we have been successful in achieving this despite budget fluctuations over the past few years. It affects us most in regard to how we approach the work. When resources are limited, we often have to just get by with the necessary clearance and move on. Often times we may not be able to address good removals (trees and brush), off - ROW trees/hazard tree conditions, overhang removal (beyond what our minimum specs require), etc. Essentially, we are not able to do the work that really improves reliability. Also, we sometimes are not able to do full maintenance on the isolated sub-t. We often have just been able to "hot spot" the sub-t. Limited resources also have an effect on fulfilling customer requests and reliability work. [Yes]
Our cycles are based on vegetation response to all factors influencing growth as well as customer density. These cycles should be maintained for each programmed interventions. They can be consider[ed] as objectives. Availability of resources impacted directly our scheduling. [Yes]
Beginning of 2014 we have a stable budget for the next 4-years [Yes]

Table 10: Comments on Fluctuating UVM Budget

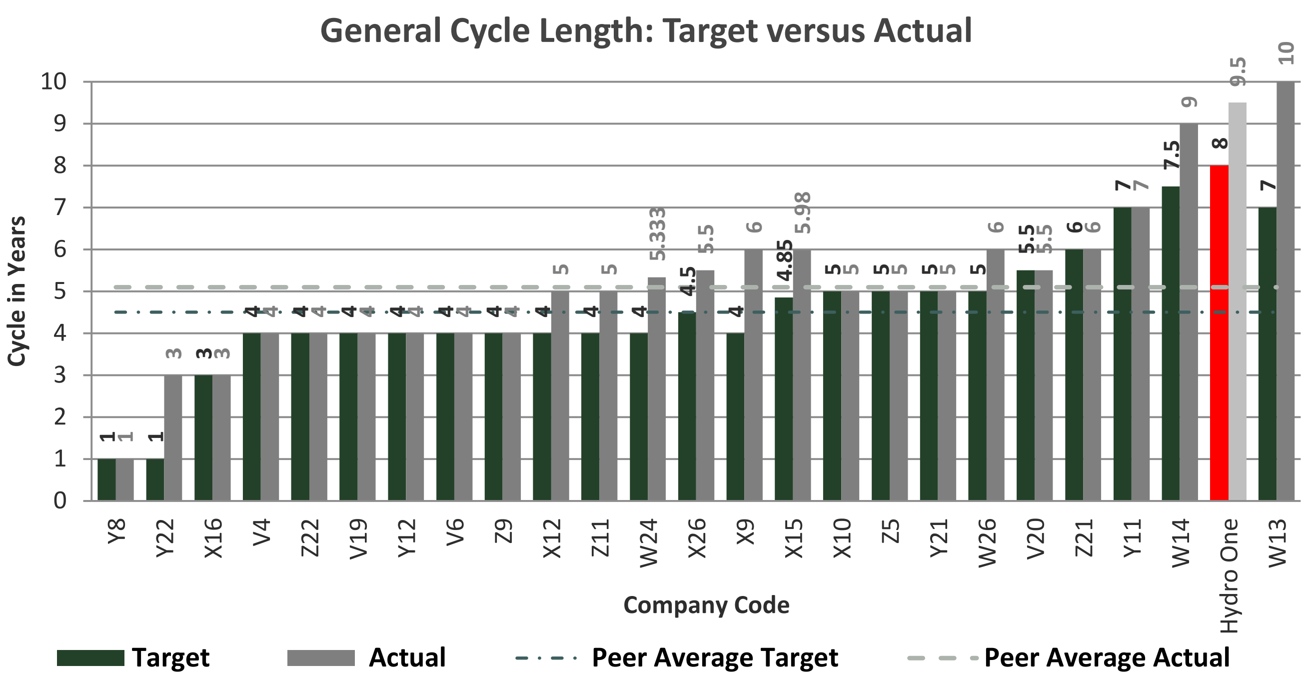
Explain How Reliability Measurements Influences Your UVM Scheduling
We schedule on a yearly basis and we'll often move circuits up in a given year to make sure the reliability benefits are realized as early as possible [Yes]
Priorities are based on targeting worst performing areas and/or feeders [Yes]
Previous 12 month vegetation coded outages have a great impact in the predictive model for forward 12 months [Yes]
[Enhanced Hazard Tree Mitigation] EHTM program is influenced by reliability [Yes - 3 companies]
Our routine operations are not influenced by this however we have a dedicated reliability program that incorporates this data to determine the SSDs that will be worked in a given year. [No]

Explain How Reliability Measurements Influences Your UVM Scheduling [Continued]
[Utility] Power Quality team tracks momentaries on poor performing circuits and will issue trim locations within circuit. [Yes]
Part of our rankings for determining EHTM circuits are based on reliability.
[Utility] utilizes the Davies Consulting Tree Trim Model (TTM), a sophisticated software program that projects a "Bang for Buck" approach, a balance of reliability and cost. [Yes]
Time between UVM activities may be in/decreased based on reliability. [Yes]
All circuits/feeders reliability is monitored throughout the year for vegetation outages. Circuits with poor performing reliability #'s are inspected and if it determined by the Forester/OC that the circuit is performing badly due to grow-in type vegetation outages, then the circuit will be added to the trim list for that coming year. This plays a role in the reliability metrics, but doesn't always effect scheduling. Scheduling the yearly trim plan is determined by the last trim year, distance of vegetation from conductor, and viewing outage data on that feeder. If the feeder is having a lot of grow-in outages it will be a good candidate for trim, where as a feeder that is performing badly from a SAIFI/SAIDI standpoint due to outside ROW Tree fall in's, the forester may not schedule that feeder to be trimmed but instead conduct a danger tree patrol or see if skylining certain parts of the feeder are feasible to alleviate the non-preventable outages. [Yes]
Poorly performing line segments are priority for line clearing [Yes - 6 companies]
Sometimes, but seldom. We may move a circuit up on the schedule (perform work before the circuit is actually due for full maintenance) if there are tree conditions present which warrant addressing, and may be causing reliability issues. In most cases, if there are issues, we will perform some hot-spotting to help alleviate problems before the next cycle trim is due. For worst performing circuits: On the vegetation side, I do not believe that we are actually REQUIRED to do anything. We do, however, take a closer look (through an inspection) at these circuits to see if there is any additional work (beyond what our program guidelines dictate) that could be done to improve reliability. We would look at possibly removing more overhang, removing "problem" trees, addressing off-ROW trees, etc. [Yes]
Reliability data is used as the driving force behind our composite risk index used to prioritize feeders for UVM treatments [Yes- Hydro One]
[Reliability data is used] for the tree removal program only. [Yes]
We do off-cycle trimming to mitigate urgent reliability issues. [No]
Annual work is prioritized in that year based on reliability ranking. Occasionally a cycle can be shortened (other(s) lengthened) to meet a reliability need. [Yes]
If we have a circuit that is having [outages] it will be given priority until reliability is successfully restored. [Yes]
If a section of line or circuit is experiencing an unacceptable amount of outages we will trim out area before the designated UVM cycle. (2013). The 10 worst performing circuits are reviewed and addressed on a yearly basis [Yes]

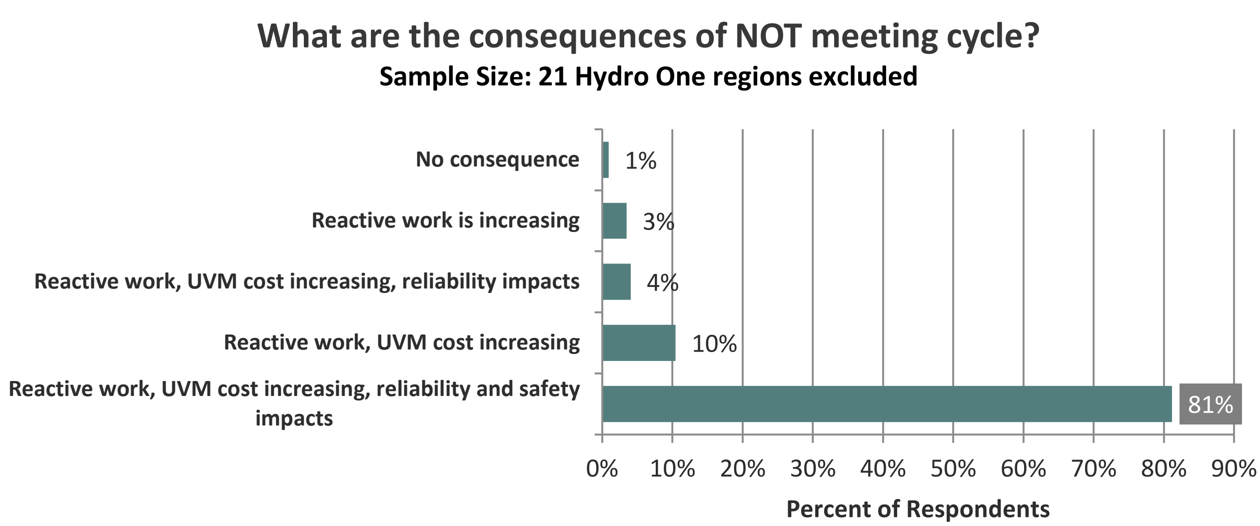
Table 11: Explain How Reliability Measurements Influences Your UVM Scheduling

Responses highlighted in tan prioritize poor or worst performing circuits.
Hydro One highlighted in rose.

General Cycle Lengths



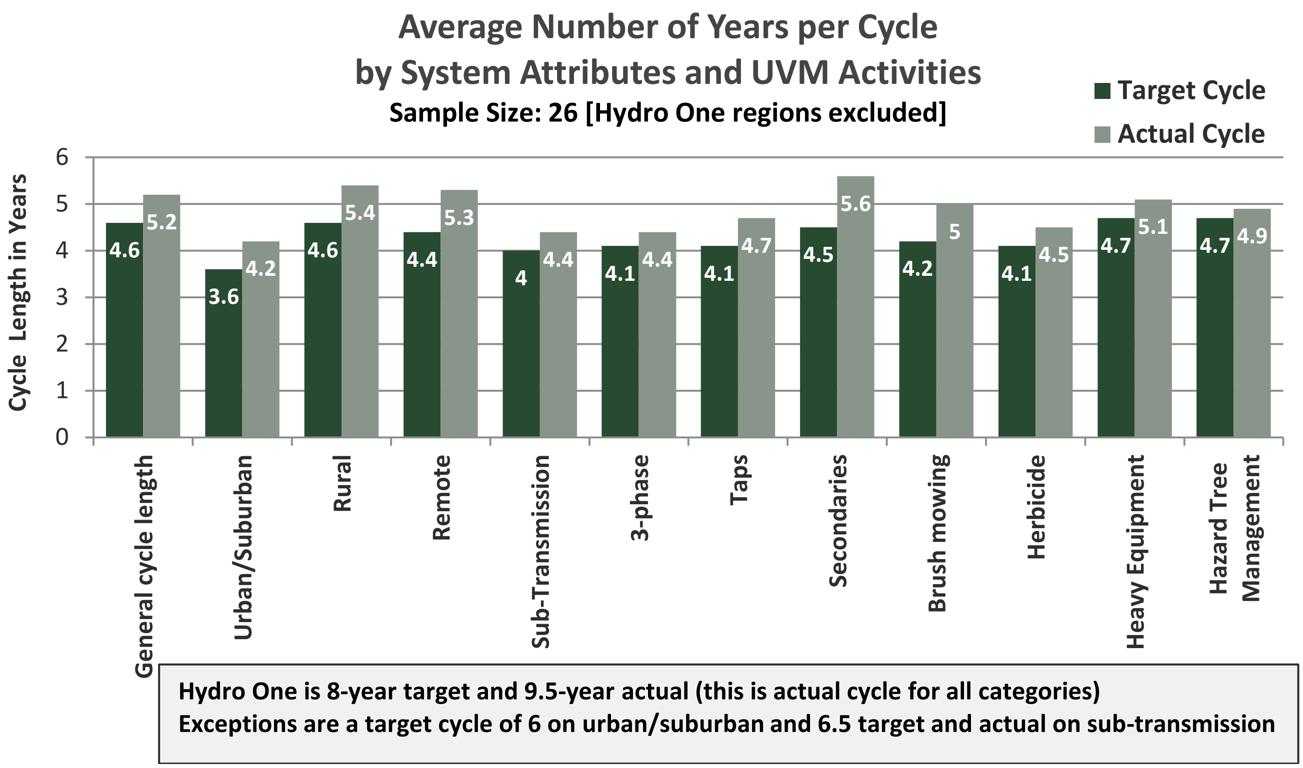
Graph 48: General Cycle Length: Target versus Actual



Graph 49: What are the consequences of NOT meeting cycle?

The graph (Graph 40) above is based on responses from the following twelve cycle categories: General, Urban/Suburban, Rural, Remote, Sub-Transmission, Three-phase, Taps, Secondaries, Brush mowing, Herbicide control, Heavy equipment work, and Hazardous tree management. The variation between the twelve categories was not significant, so all cycle types were averaged to derive the statistics in the graph.

Variable Cycles

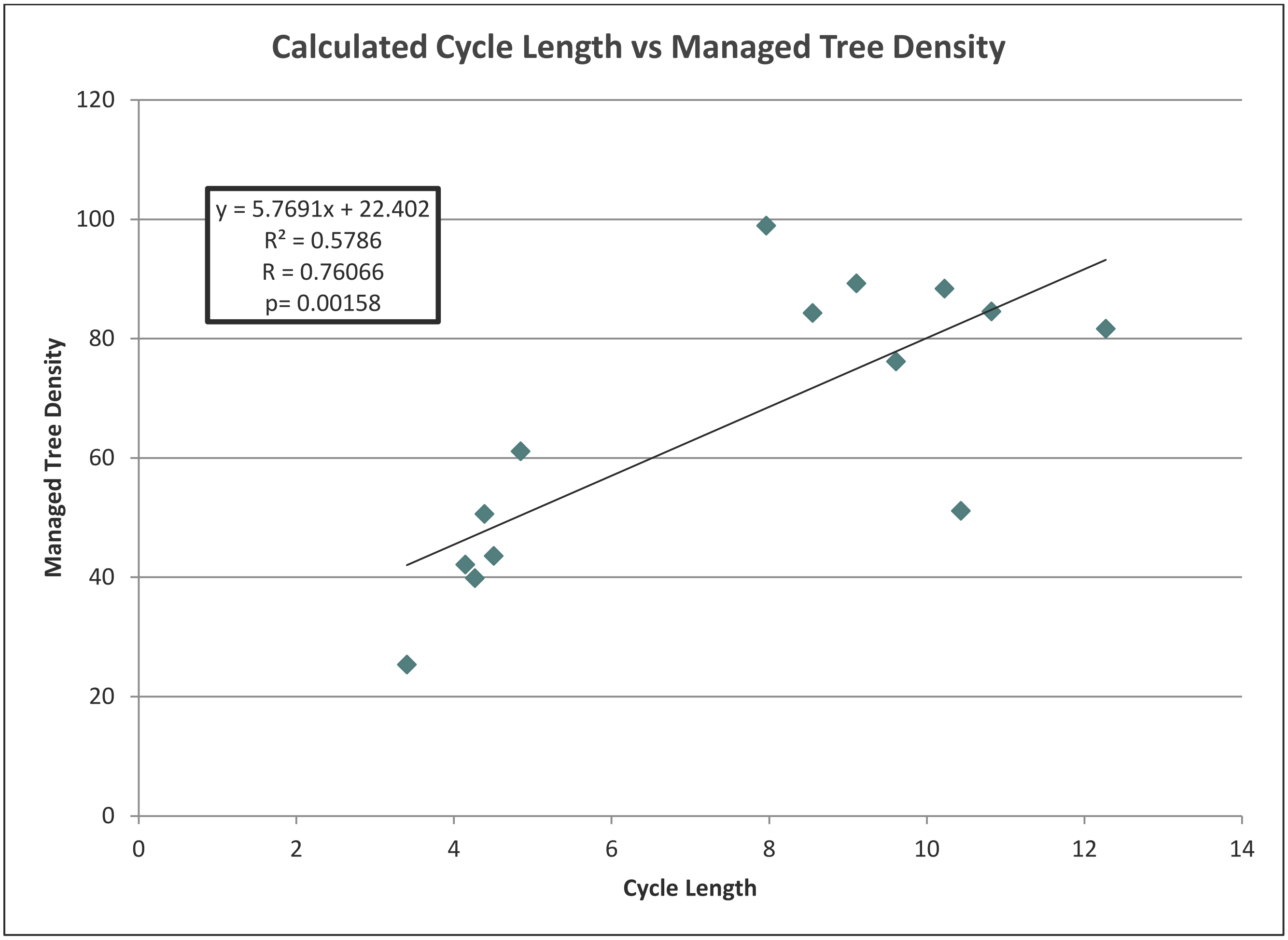


Graph 50: Average Number of Years per Cycle by System Attributes and UVM Activities

Variable Cycle Statistics [Peers plus Hydro One Networks]								
Cycle Type	General Target	General Actual	Urban & Suburban Target	Urban & Suburban Actual	Rural Target	Rural Actual	Remote Target	Remote Actual
Sample	25	25	11	11	11	11	8	8
Average	4.6	5.3	3.6	4.5	5.0	6.4	4.9	6.6
Q1	4.0	4.0	3.0	4.0	4.0	5.5	4.0	6.0
Median	4.0	5.0	4.0	4.0	4.0	6.0	4.5	6.5
Q3	5.0	6.0	4.0	4.5	6.0	7.0	6.0	7.3
Max	8.0	10.0	6.0	9.5	10.0	11.5	8.0	9.5
Min	1.0	1.0	1.0	2.0	1.0	3.0	2.0	3.0
STDEV	1.7	2.0	1.4	2.0	2.5	2.5	1.8	1.9

Statistics Table 5: Variable Cycle Statistics

Correlation between Cycle Length and Managed Tree Density

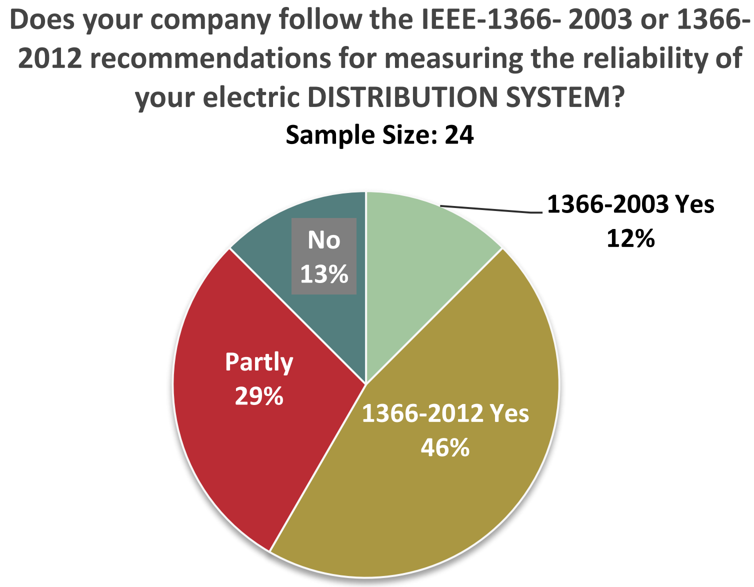


Graph 51: Calculated Cycle Length vs Managed Tree Density

R^2 = 0.5786 or 57.9% of the variance can be accounted for in the model. Simply, this indicates the strength of the model for prediction (This is adequately high)
R = 0.76066 is the correlation coefficient and it is an indication of the strength of the relationship (1 is perfect). This is a good correlation
p = 0.001582 or p-value loosely means 'how significant or repeatable is this result or model?' The smaller the p-value indicates that the probability that this model is a good predictor is high. In this case it is well below 1%

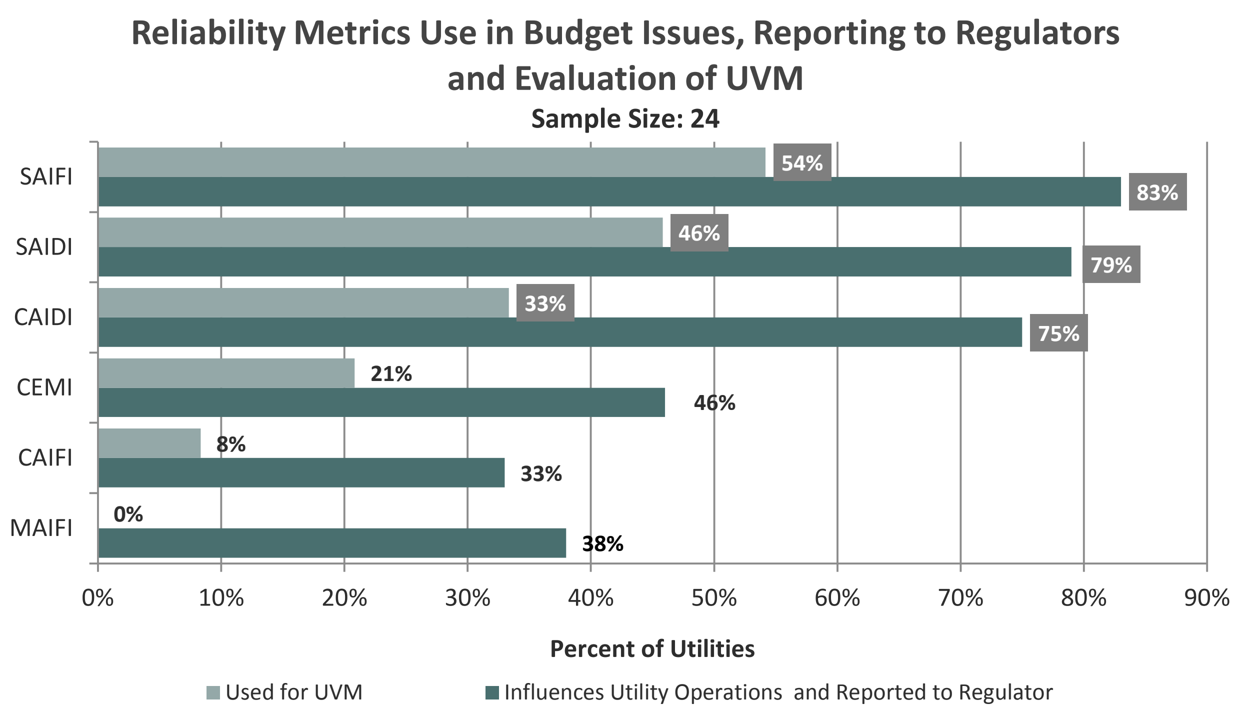
RELIABILITY

Calculating Reliability Metrics



Graph 52: IEEE 1366 Usage for Calculating Reliability Metrics

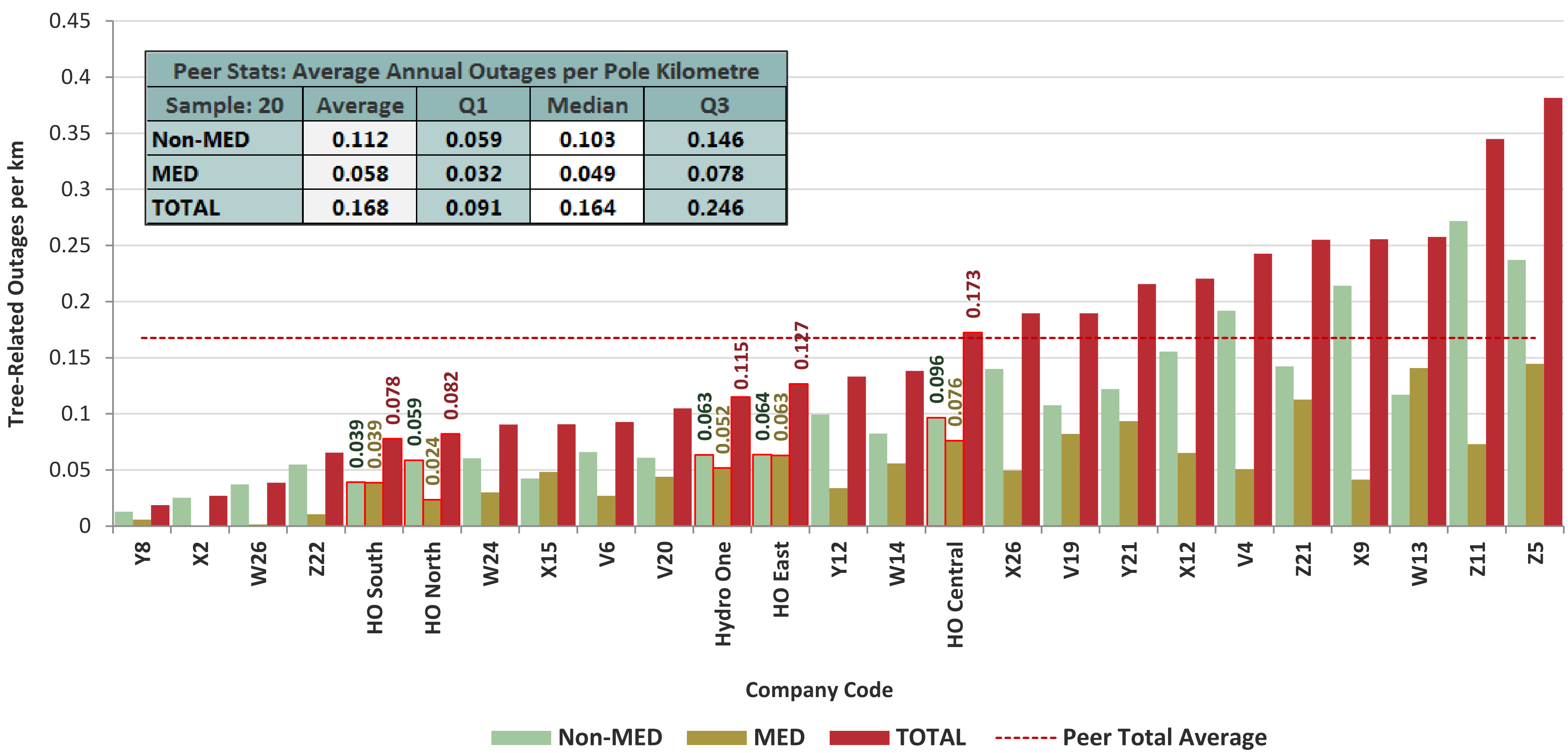
Reliability Metrics Used for Evaluating the UVM Program



Graph 53: Reliability Metrics Used for Utility Vegetation Management

Tree-Related Outages per Kilometre of Distribution Overhead Line

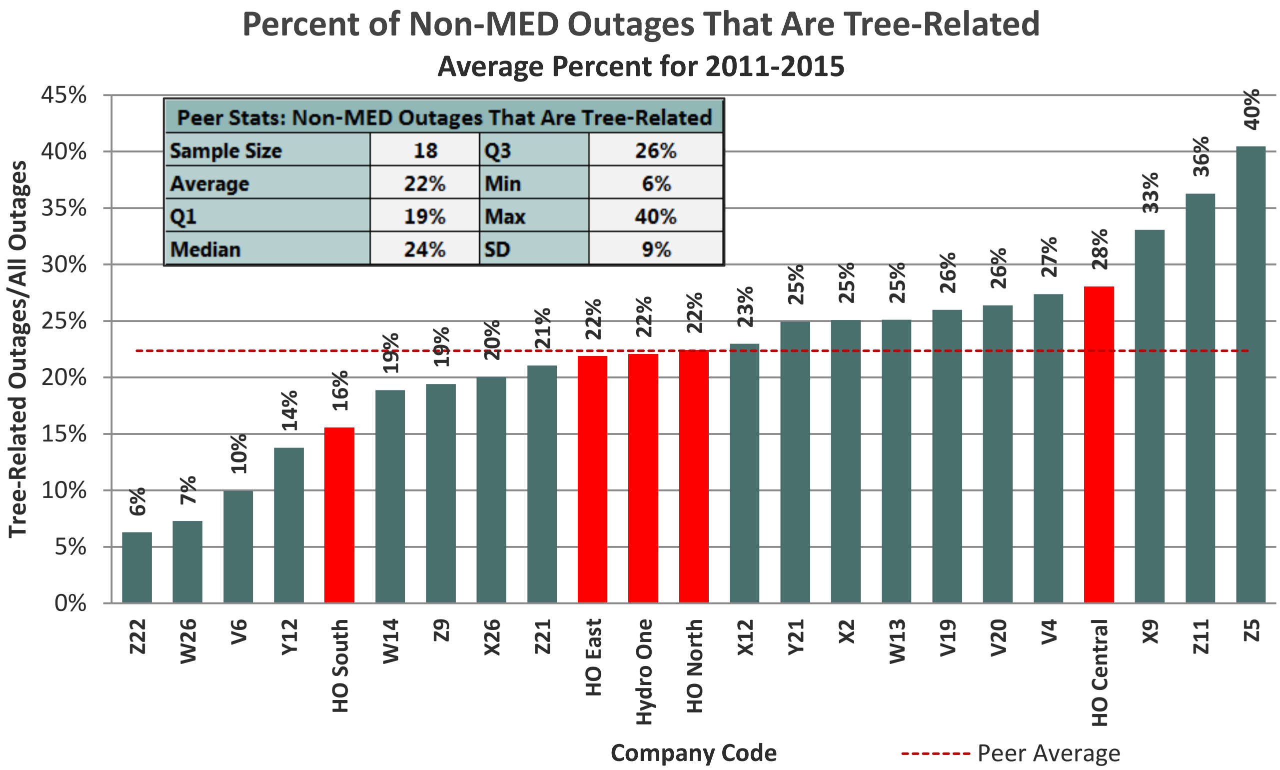
Five-Year Annual *Average Tree-Related Outages per System Pole Kilometre* for 2011 - 2015 for Non-Major Event Day (Non-MED), MED and Total Outages



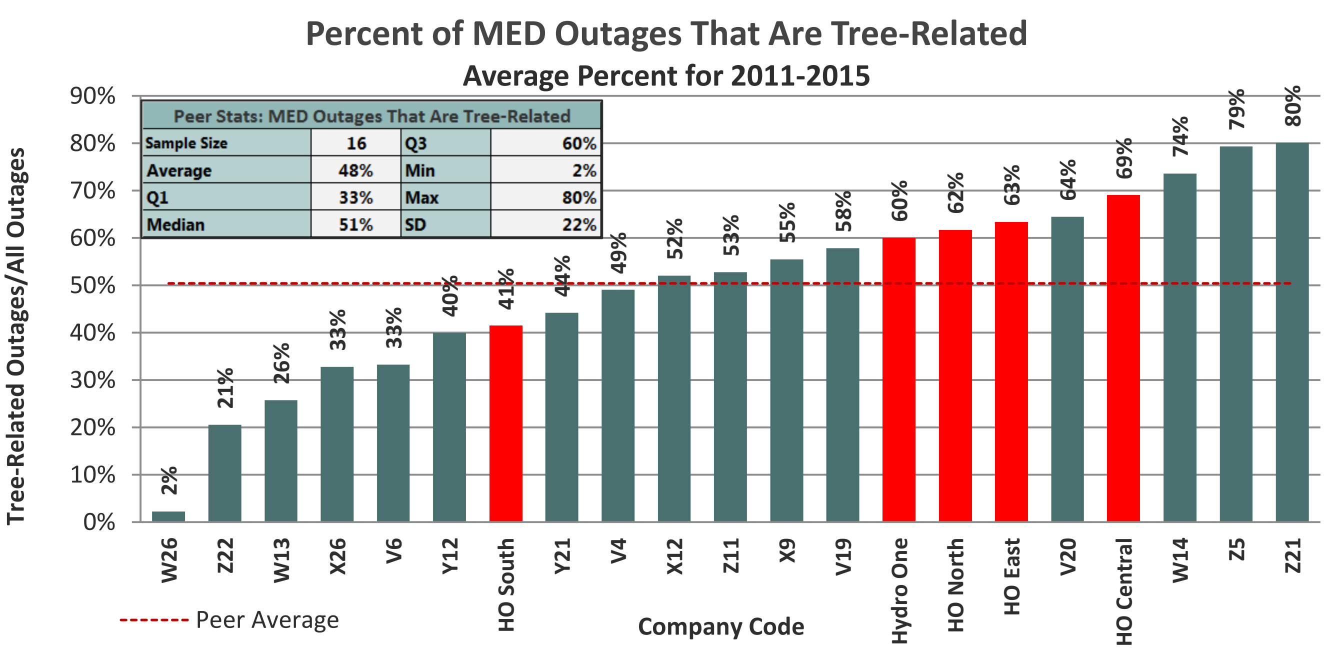
Peer Stats: Average Annual Outages per Pole Kilometre				
Sample: 20	Average	Q1	Median	Q3
Non-MED	0.112	0.059	0.103	0.146
MED	0.058	0.032	0.049	0.078
TOTAL	0.168	0.091	0.164	0.246

Graph 54: ***Average Tree-Related Outages per System Pole Kilometre*** **for Non-MED, MED and TOTAL Outages**

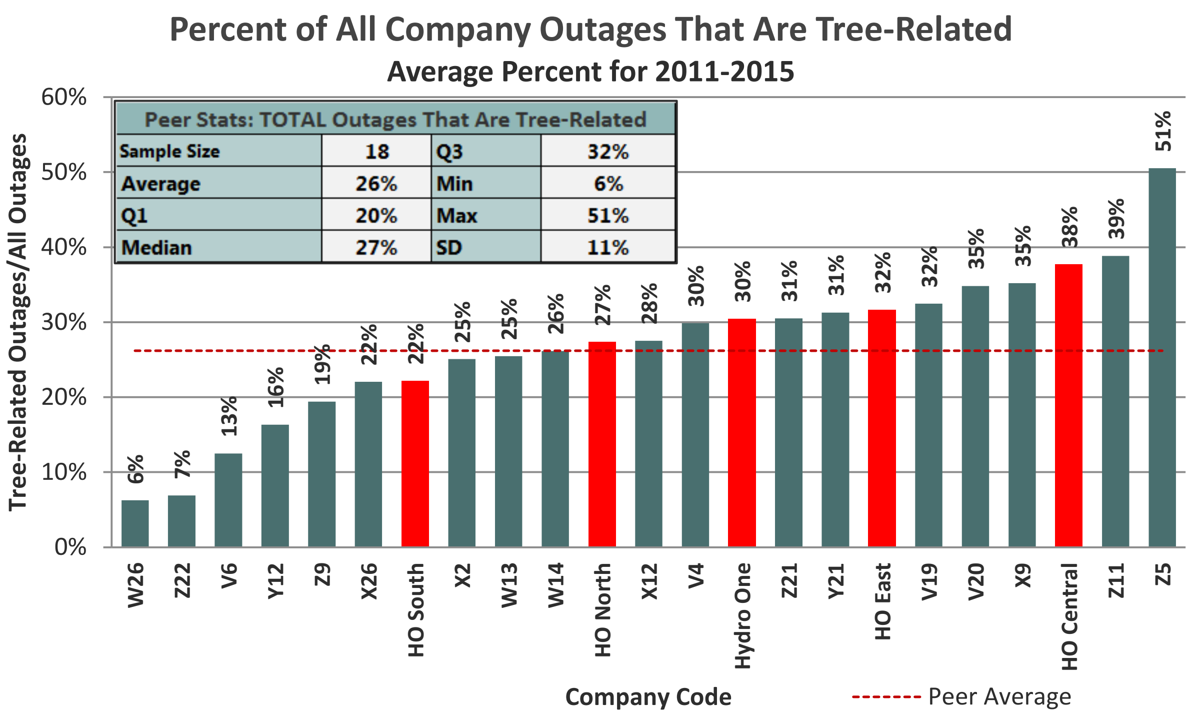
Percent of Outages That Are Tree-Related



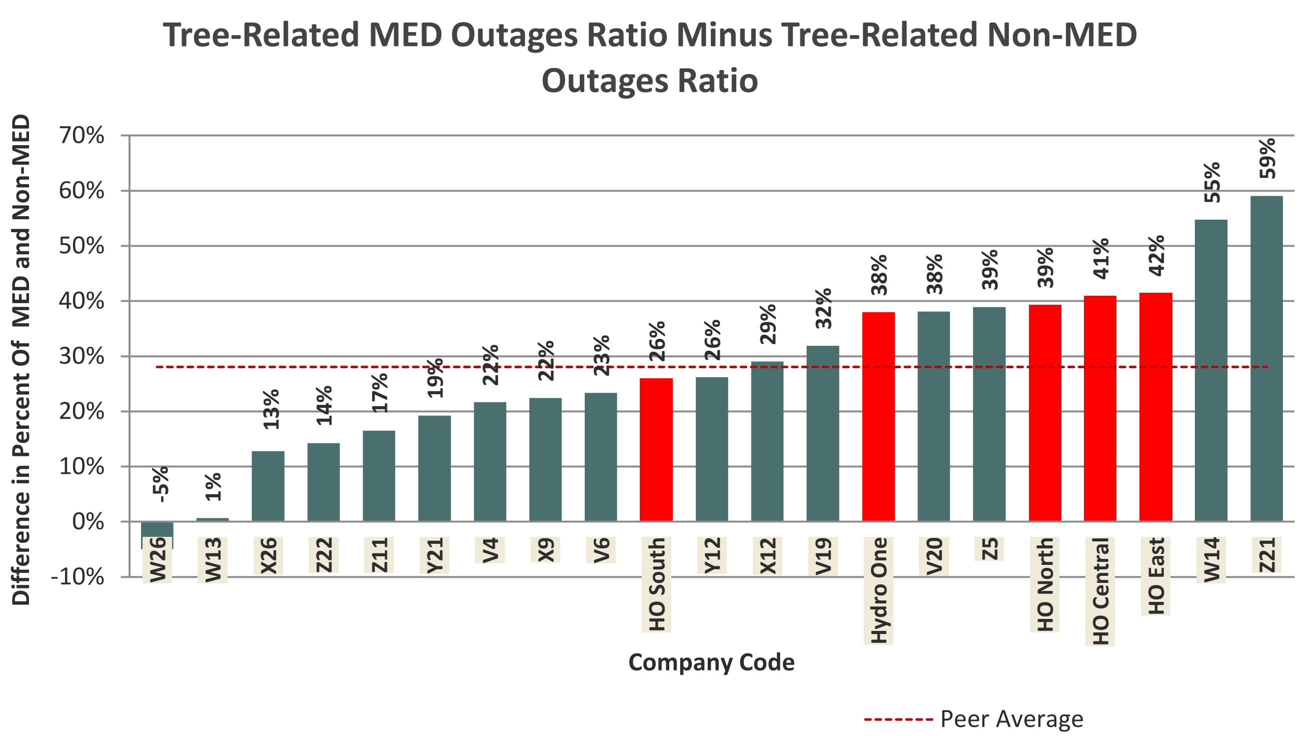
Graph 55: Percent of Non-MED Outages That Are Tree-Related



Graph 56: Percent of MED Outages That Are Tree-Related

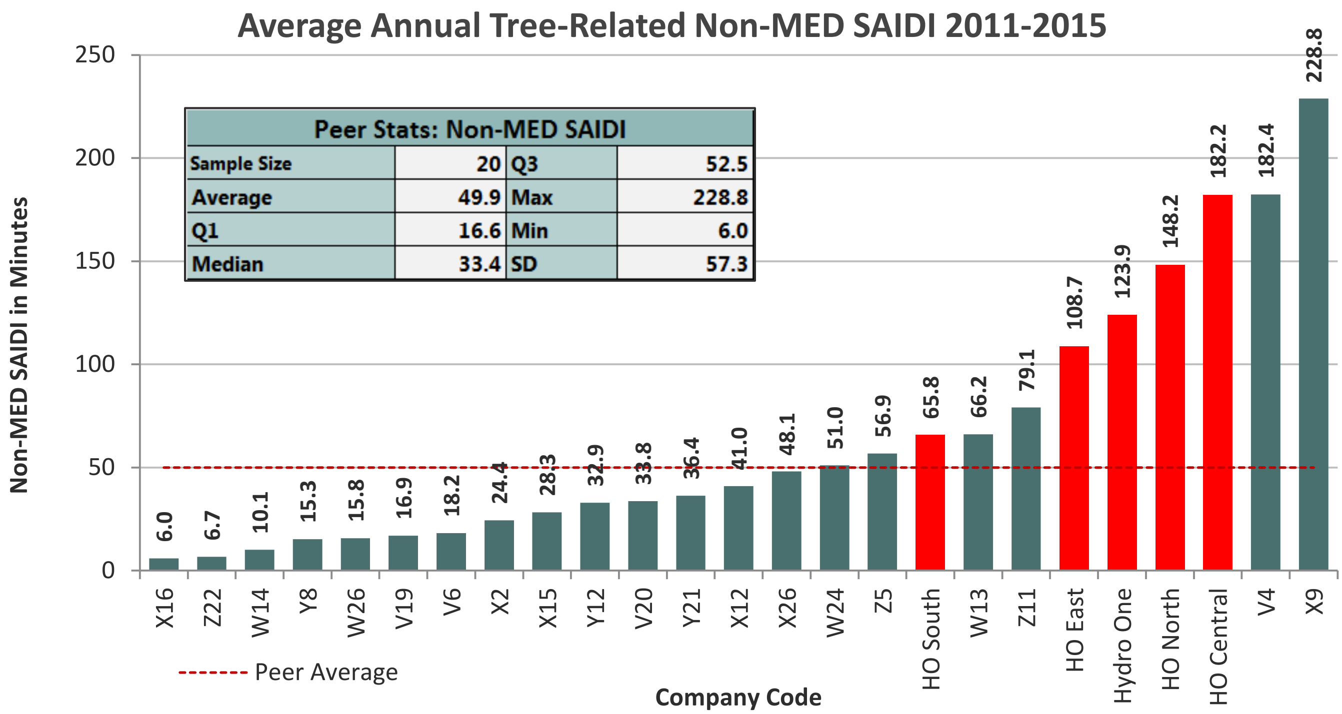


Graph 57: Percent of All Company Outages That Are Tree-Related

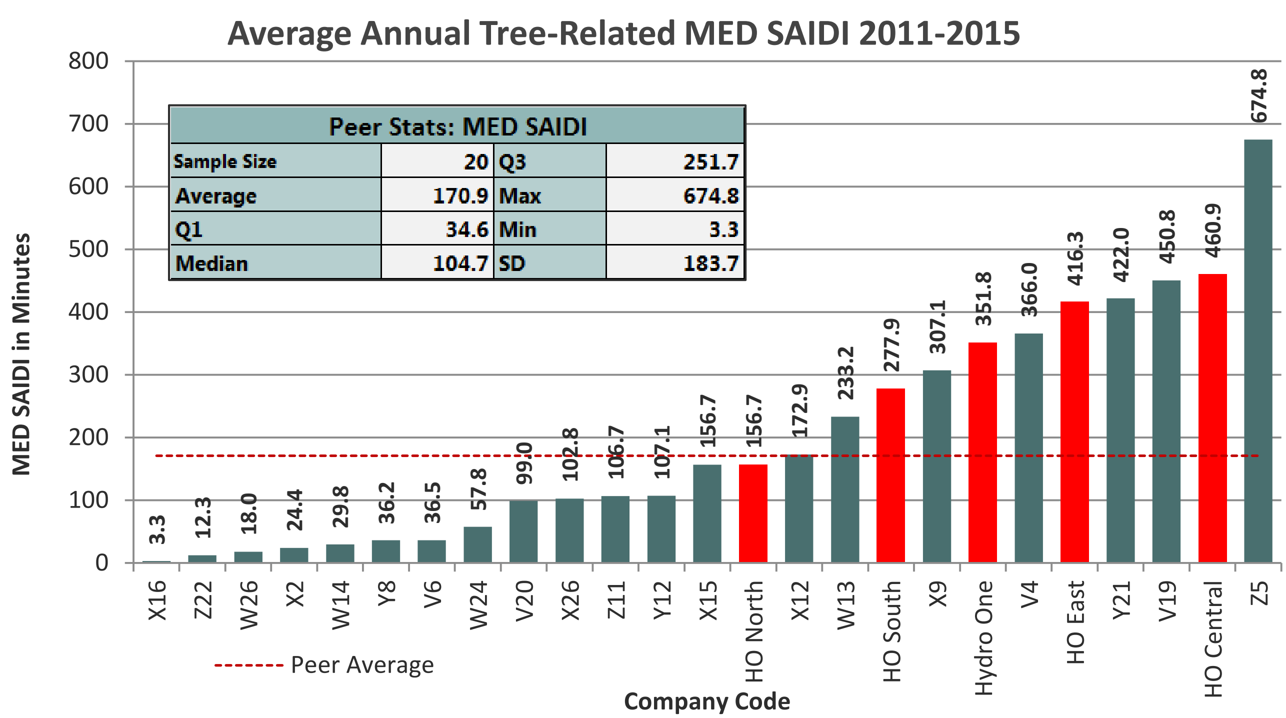


Graph 58: Tree-Related MED Outages Ratio minus Tree-Related Non-MED Outages Ratio

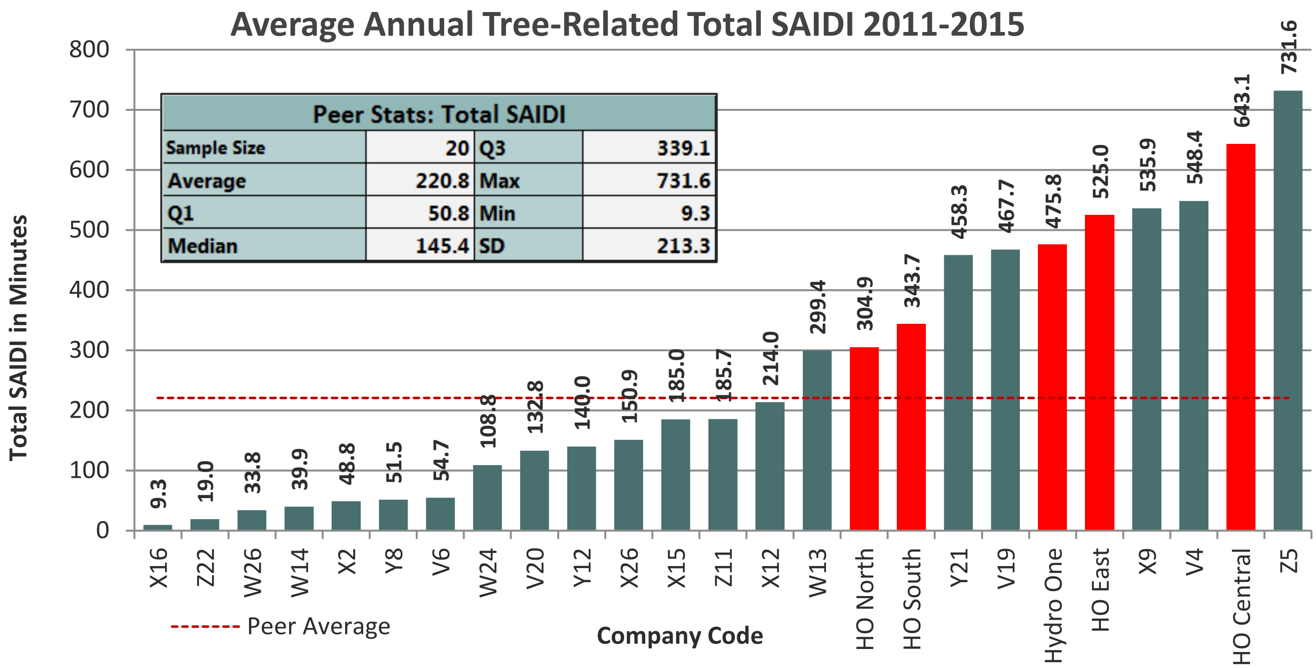
SAIDI Comparisons



Graph 59: Average Annual Tree-Related Non-MED SAIDI 2011-2015

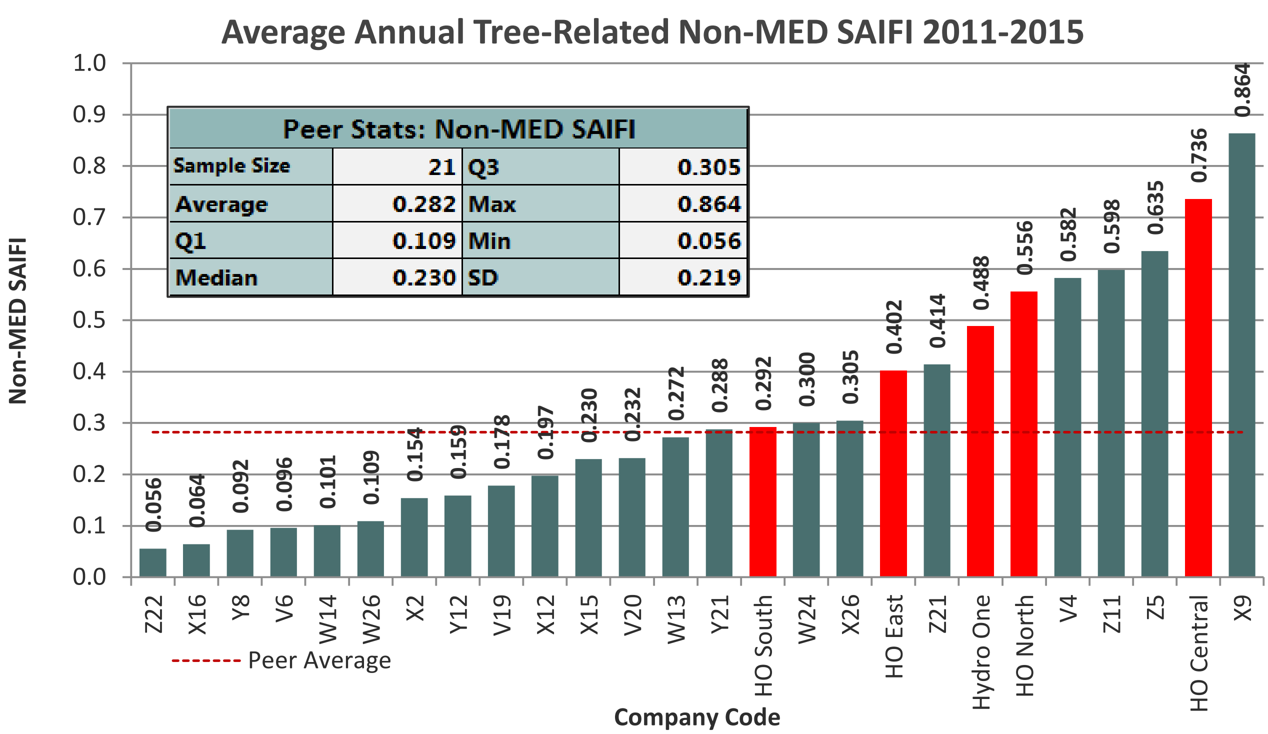


Graph 60: Average Annual Tree-Related MED SAIDI 2011-2015

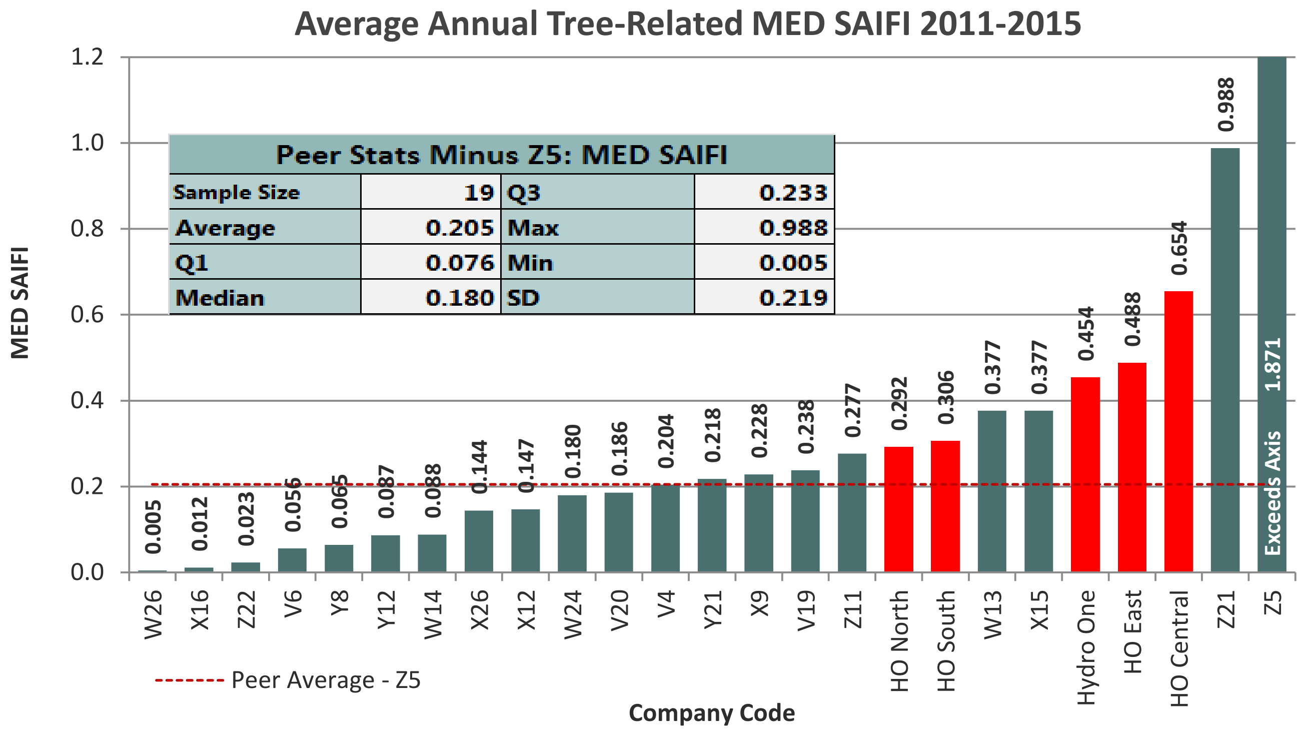


Graph 61: Average Annual Tree-Related Total SAIDI 2011-2015

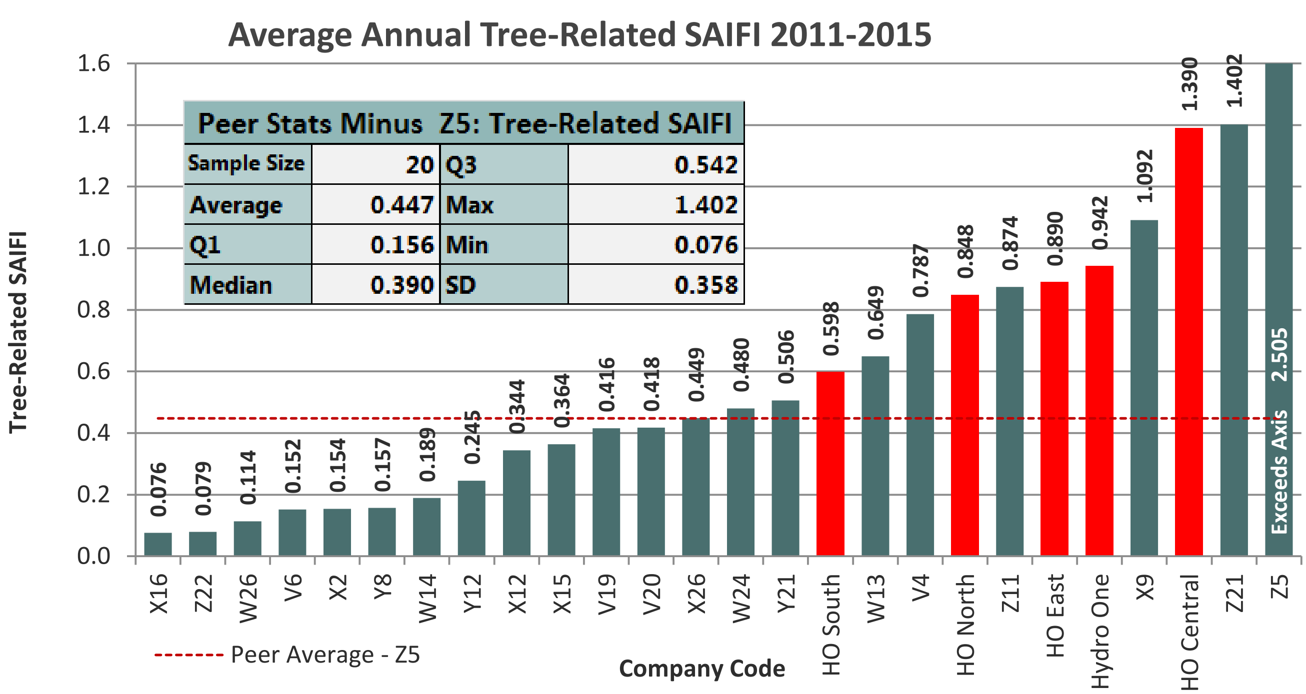
SAIFI Comparisons



Graph 62: Average Annual Tree-Related Non-MED SAIFI 2011-2015

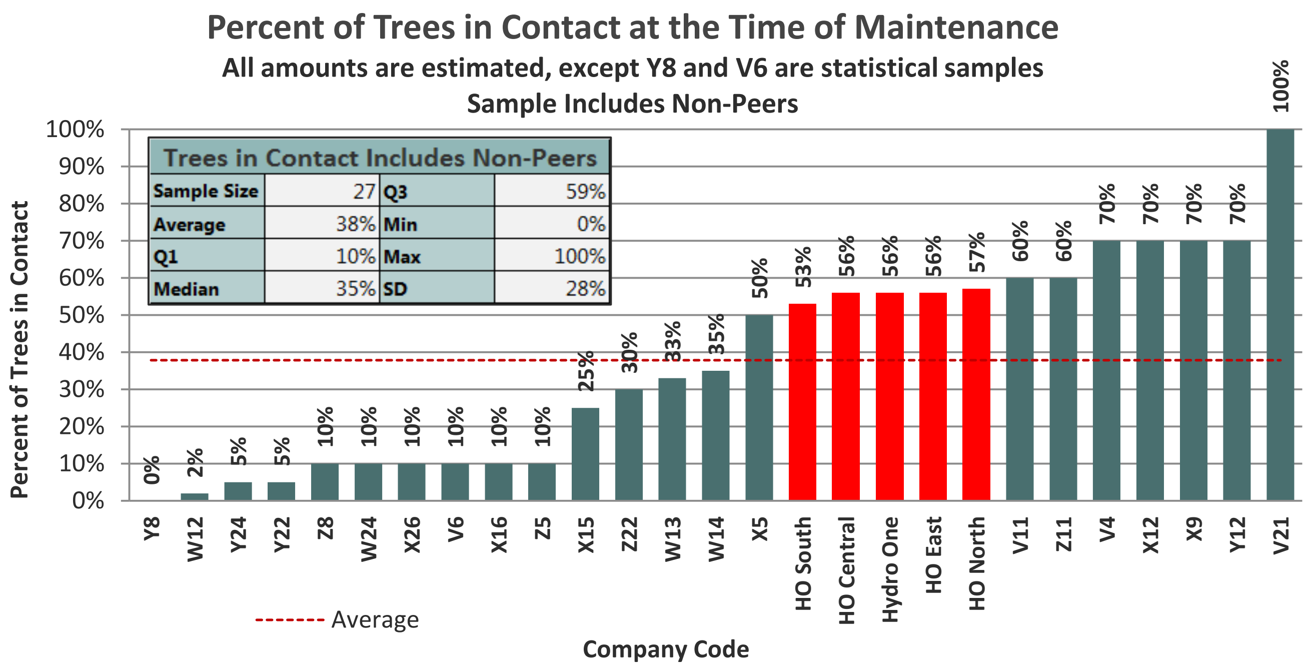


Graph 63: Average Annual Tree-Related MED SAIFI 2011-2015

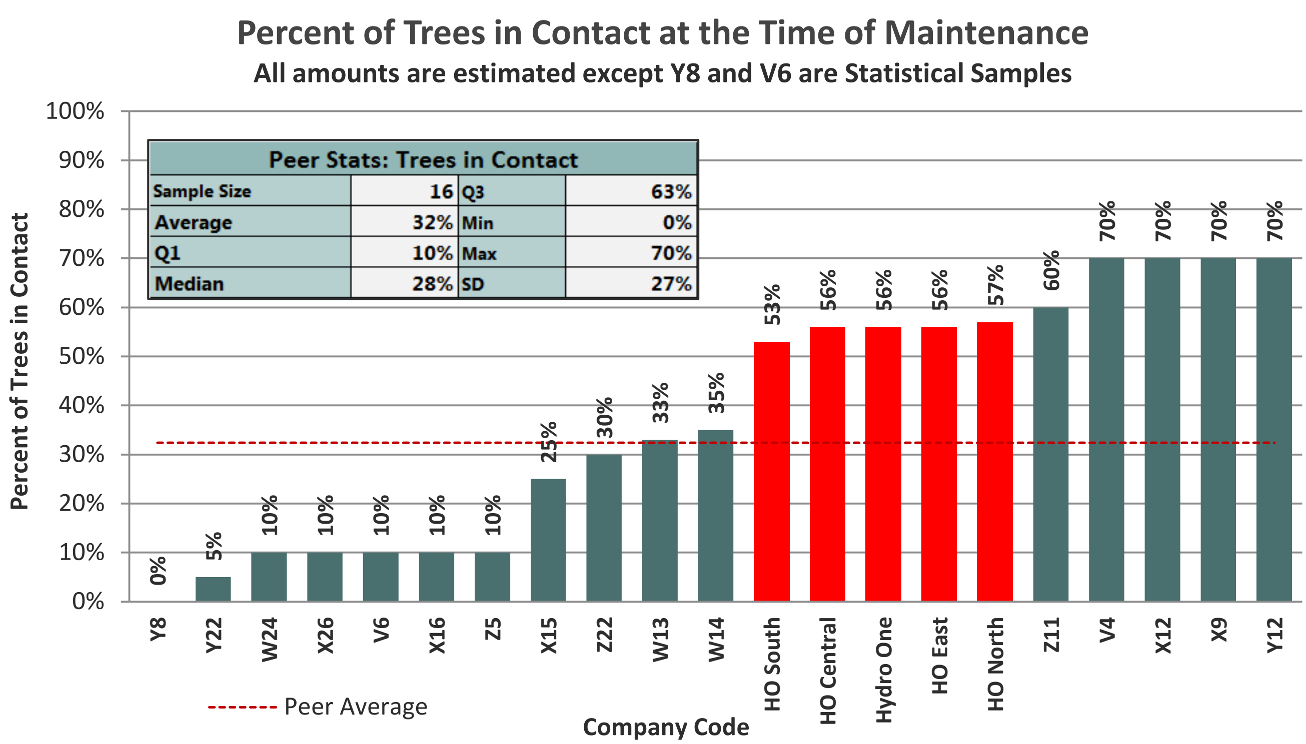


Graph 64: Average Annual Tree-Related SAIFI 2011-2015

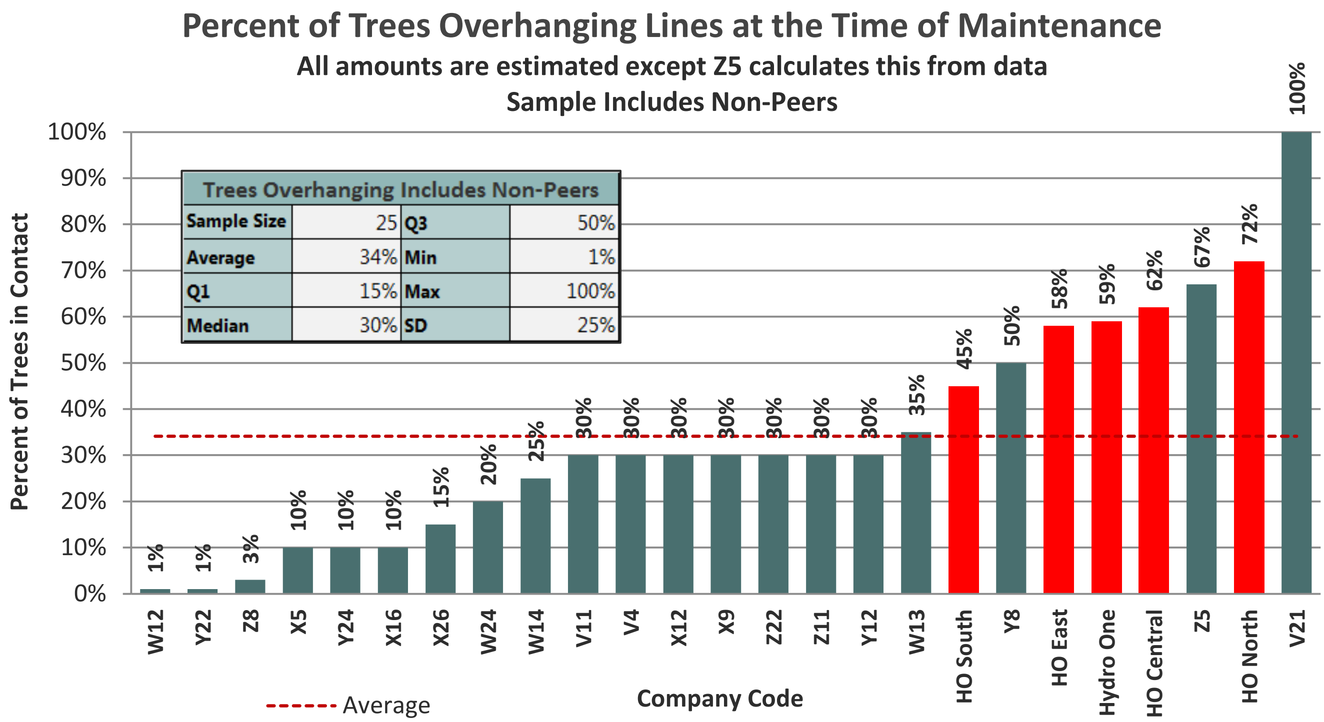
Vegetation Conditions at Time of Maintenance



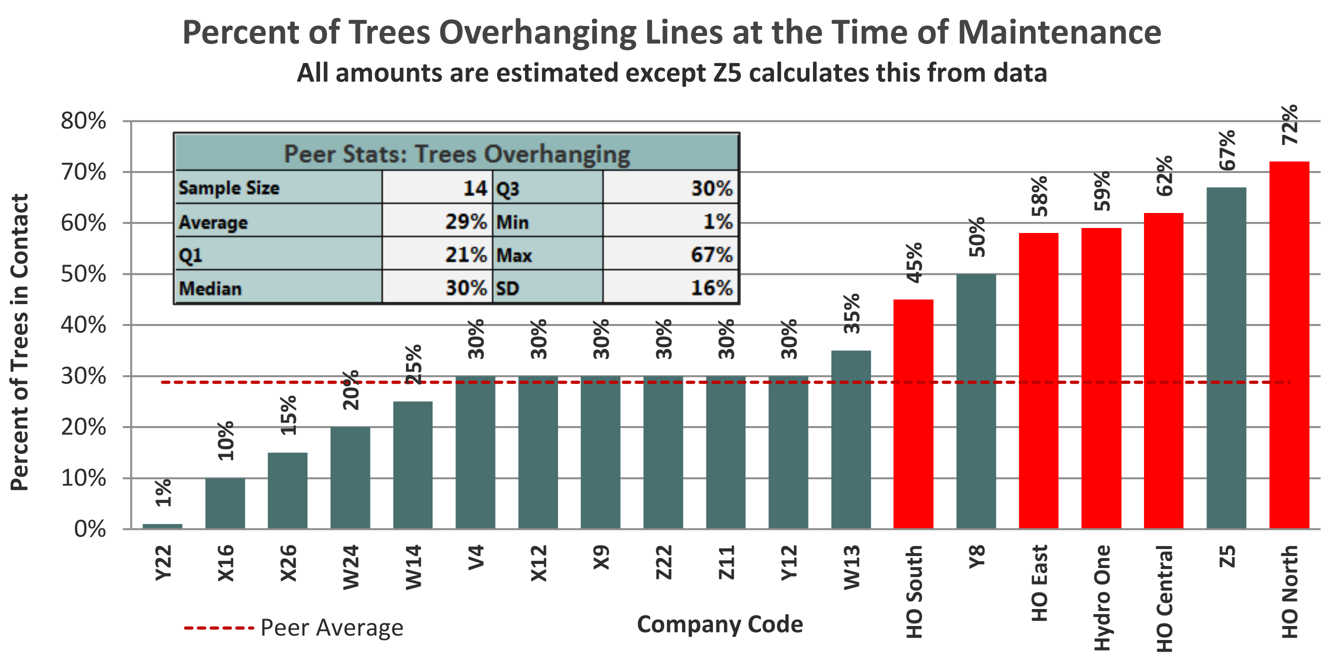
Graph 65: Percent of Trees in Contact at the Time of Maintenance – All respondents



Graph 66: Percent of Trees in Contact at the Time of Maintenance – Peers and Hydro One



Graph 67: Percent of Trees in Overhanging Lines at the Time of Maintenance – All Respondents

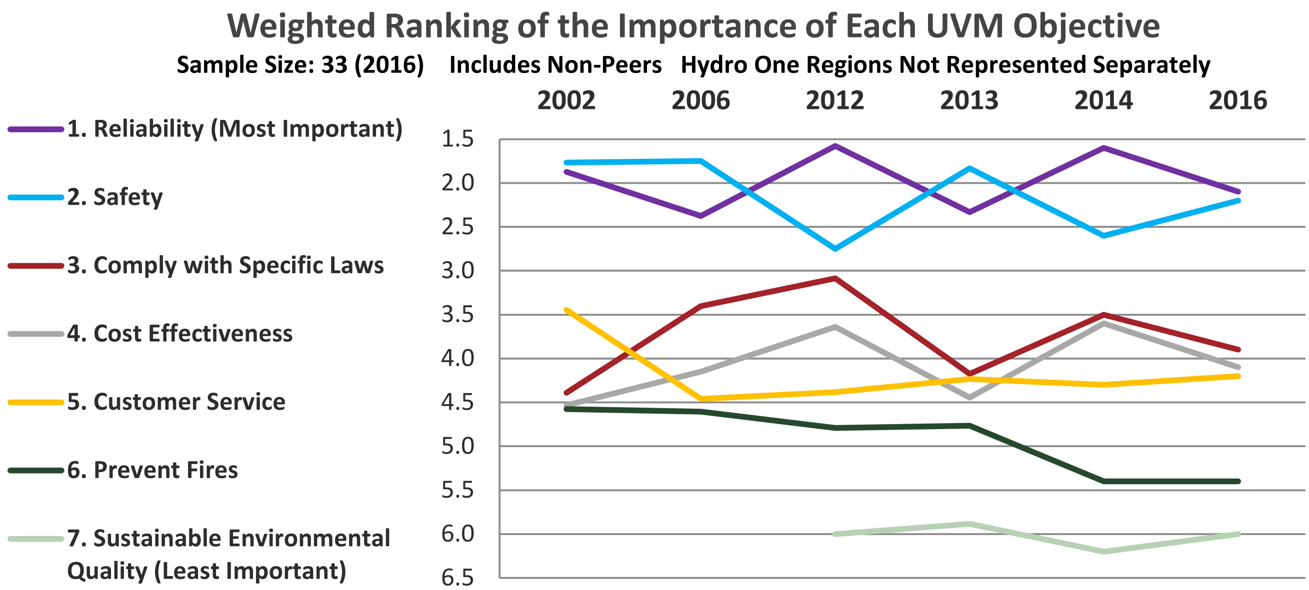


Graph 68: Percent of Trees in Overhanging Lines at the Time of Maintenance – Peers and Hydro One

UVM DRIVERS AND FUNDING

UVM Objectives

This graph was created from six different CNUC surveys given in 2002, 2006, 2009, 2014, and 2015 (the survey done for this project). The number of participants varied from year to year and the utilities were not the exact same set, although many participated in all five surveys. The order shown in the legend is the 2016 rankings.



Graph 69: Weighted Ranking of the Importance of Each UVM Objective

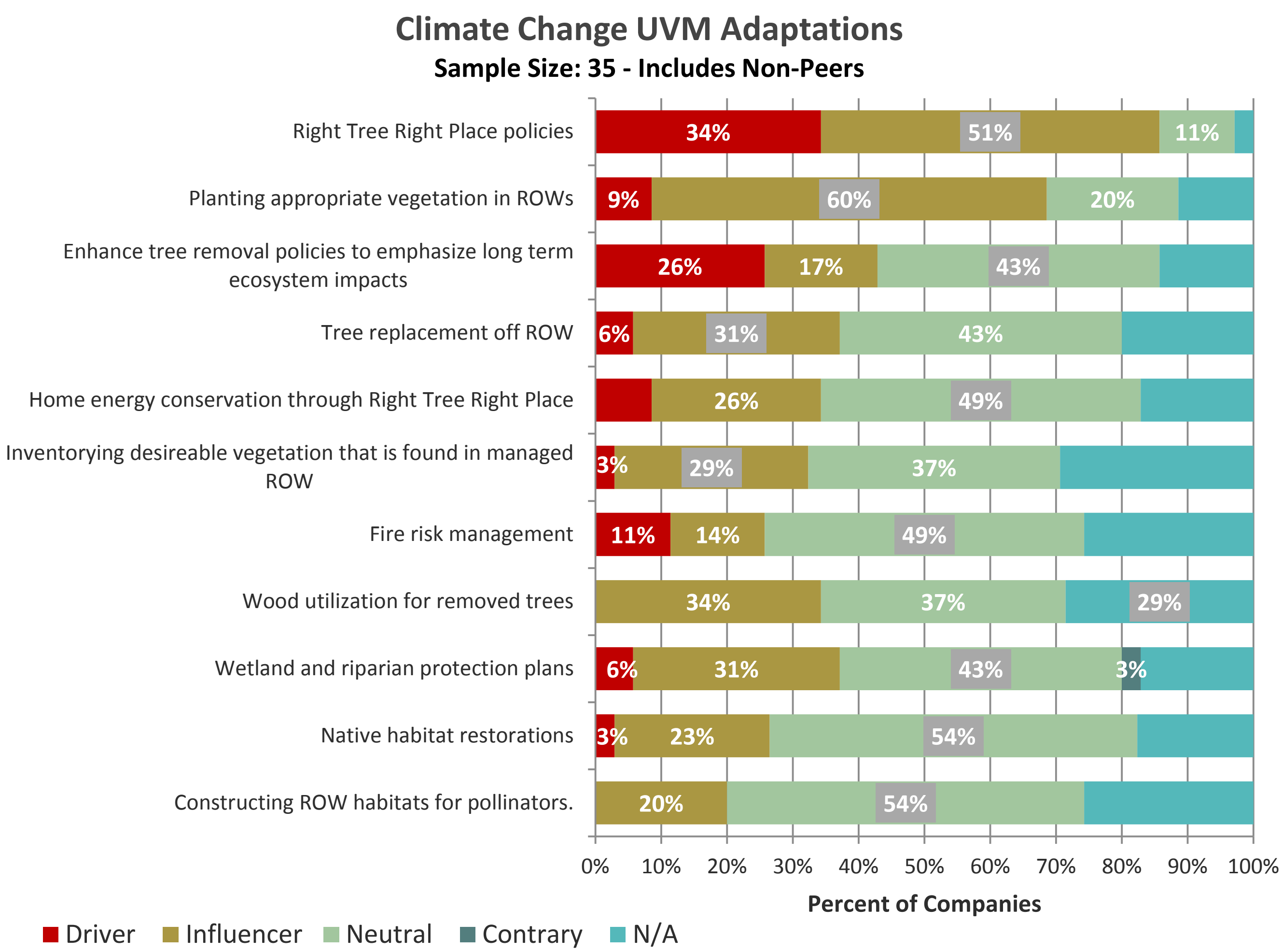
Hydro One's Rankings in order of importance were:

- Most Important: Reliability
- Cost-Effectiveness
- Customer Service
- Safety
- Sustainable Environmental Quality
- Comply with Specific Laws
- Least Important : Prevent Fires

Of note is the Hydro One's ranking for Safety (4th), which is significantly lower than the industry; Compliance - 6th compared to the industry ranking of 3rd; and Cost-Effectiveness, which is significantly higher than the industry. Although much of the industry ranks preventing fires a lower priority, several rank it is as the second most important. These utilities are located in areas of high fire danger. Locations with higher fire danger are changing as changes in climate impact forest health and composition. The fires in Alberta in May 2016 may be an indication that Hydro One should consider incorporating fire prevention into their UVM program.

UVM Programs Contributions to Ecosystem Sustainability

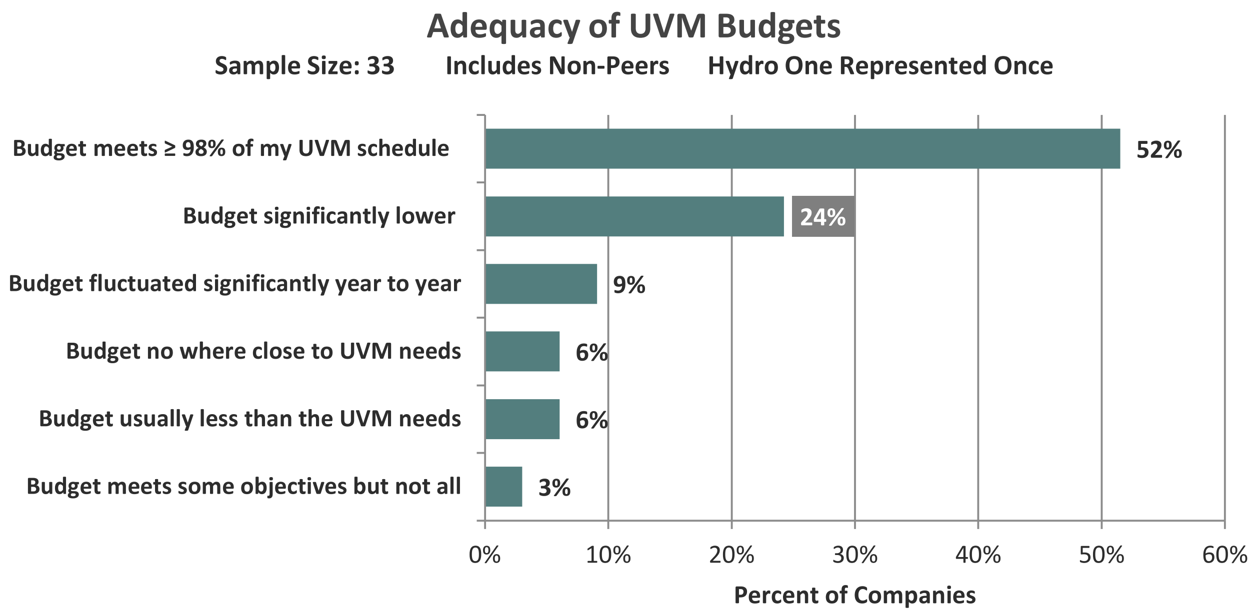
The following question was posed to UVM managers:
OBJECTIVE: To determine the extent that distribution UVM programs are contributing and adapting to carbon free initiatives and ecosystem benefits.
QUESTION: Evaluate whether the activities listed below are driving, influencing, neutral or contrary to your UVM program.



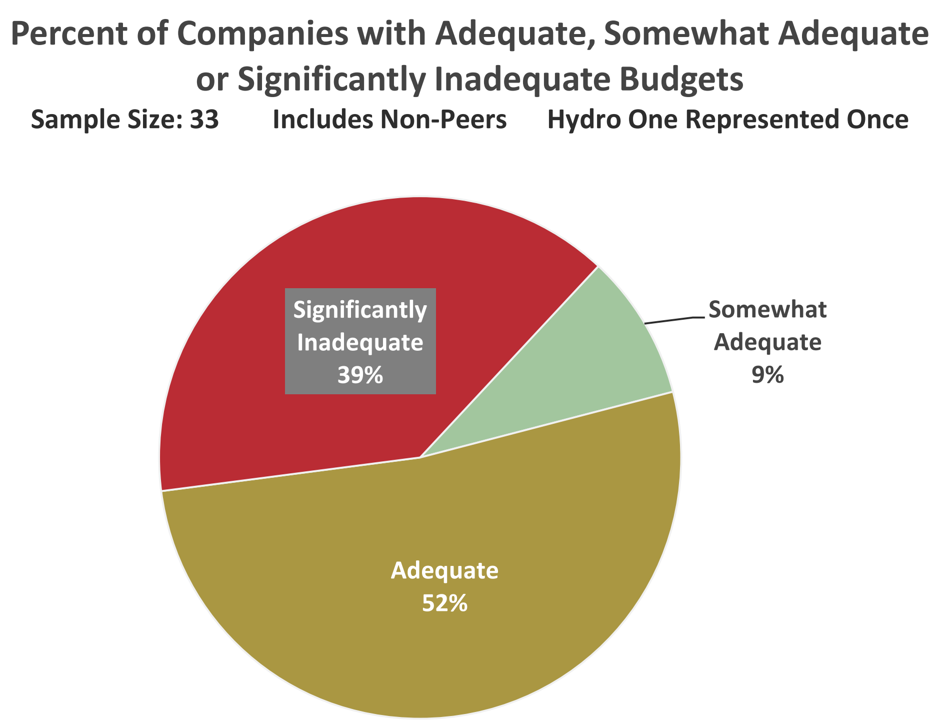
Graph 70: Climate Change UVM Adaptations

- One utility targets invasive species and this influences their UVM activities.

UVM Budget

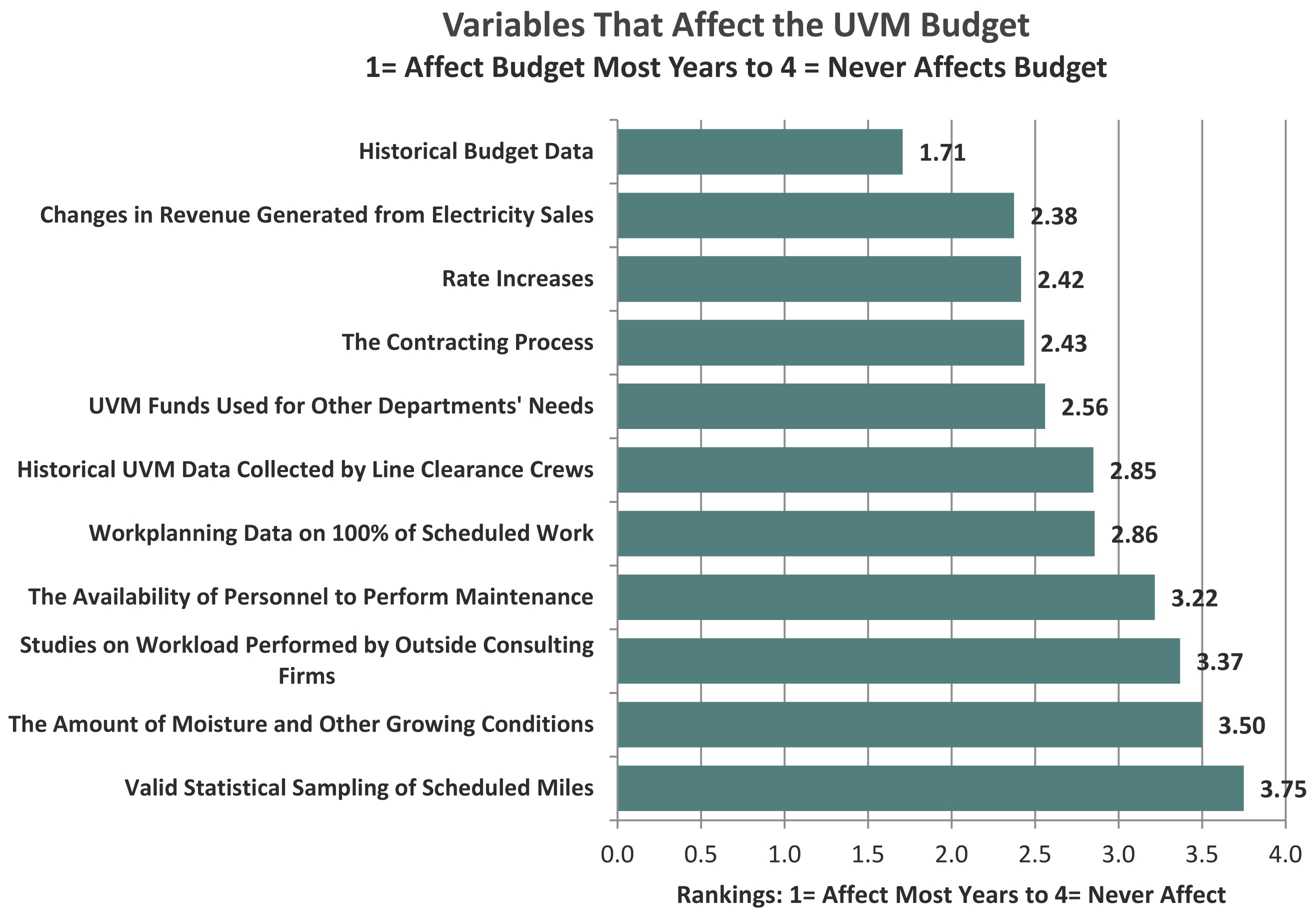


Graph 71: Adequacy of Budgets Meeting UVM Needs



Graph 72: Percent of Companies with Adequate, Somewhat Adequate or Significantly Inadequate Budgets

Variables That Influence UVM Budget



Graph 73: Variables That Affect the UVM Budget

Program Policies to Optimize Efficiency

These responses include **Non-Peer** utilities. 32 companies answered this question.
The survey asked:

> Do you have scheduling strategies or program policies that are designed to optimize efficiency and reduce non-productive costs resulting from transportation and related costs of the mobile work environment?

Included in this question were several sub-categories. A summary of responses follow.

What scheduling strategies are employed?

We ask [our contractor] to schedule work in the most efficient way possible. This is to their benefit as their contract is dependent on meeting quarterly production metrics
Planned feeder cycles, SAIDI, and routine patrols
An annual target for all compliance work is employed.
O&M program clearing work is coordinated with capital line work to maximize efficiency
Planning, inventory to plan maintenance schedule (3 similar responses)
Time of year (Seasons) coordinating work (maintenance and hazard tree programs)
Mainly try to put the right equipment in the right place at the right time. For example, get bucket trucks into farm fields before crops are planted.
Switched to Unit Price contract for planned maintenance work two years ago
Organized at a local level, no overall strategy [Hydro One]
Group circuits of a substation together in an annual plan (or group by local work area)
We try to concentrate all of efforts to a particular location and do all we can in that location until completed.

Table 12: Scheduling Strategies

What program features, such as cycle length, limit unplanned or reactive work?

Our cycle lengths are appropriate for our system, [the] grow[th] in outages are less than 10%. We have also had third party studies confirm that our cycle length is appropriate.
Two- year planned feeder cycles, targeting past outage areas
Cycle length does not affect unplanned/storm/reactive work. We are able to ramp up crews to meet unforeseen events along our powerline systems.
Relatively short and consistent cycle
Managing vegetation maintenance to a cycle (6 Companies)
Cycle length [and] increasing use of technology such as LiDAR.
Our mid-cycle program helps address issues that may result in unplanned work.
We have had to increase our Transmission pruning to stay compliant with NERC requirements and it had a negative impact on our routine pruning so I have implemented the use of topping machines and have been able to keep our regular crews on routine work.
Combine vegetation defect program with regular maintenance to avoid duplicate trips [Hydro One]
[Third party contractor] work inventory and prescriptions
Cycle length, mid-cycle review, Forestry driven reliability assessment work, Engineering driven reliability enhancement work

Table 13: Strategies to Limit Unplanned Work

Clearance and removal policies that limit future reactive work to optimize efficiency

We defer a lot of requested off cycle work, we mainly only do reactive work that really needs to be done.
We remove problem trees as much as possible
Aggressive removal of "cycle busters"
Maximize removals of trees inside and hazardous trees outside of the right-of-way
Aggressive removal policy (7 companies)
Data
Contractor incentives for reducing inventory
Remove if allowed
Remove trees vs just trim to eliminate future issues [Hydro One]
We attempt to clear 10-15' to all sides of the primary conductors to minimize growth into or close before the next cycle is due.
Corrective pruning and certain removals are performed on hourly T&M billing
Remove all dead, dying, defective branches in overhang (regardless of height)
We alter all scheduling for any and all tree removal near our facilities.

Table 14: Policies to Limit Future Work

Tree removal was the primary method to reduce future unplanned work. (53%)

Contract policies on travel time to optimize efficiency

Must be approved by [utility]
None. Our contracts are set up so that there are crews positioned in each respective district.
Contract crews locate pullouts within 15 minute drive of work locations (2 companies)
No charges for travel time.
No requirement - Unit Price contract

Table 15: Travel Time Policies

A vast majority (86%) of UVM departments do not have a policy for travel time.

Technology that monitors transportation to optimize efficiency

68% of the respondents (Hydro One is in this category) use a GPS-based monitoring system for tracking vehicle locations. One company mentioned having a two-way communication system included with their monitoring system.

Two responses that varied were:

- We are in the process of introducing a Work Force Management tool.
- [Contractor] uses Telogis to monitor crew travel and production.

Customer service activities and policies to optimize efficiency

Customer contact is handled by contractor representatives and by [utility] personnel to ensure 100% compliance and satisfaction.
Increased utilization of partnership with internal customer care department.
No debris clean-up after storms or damage from acts of nature, customer responsible for service
We try to do this ahead of time to minimize the impact on time.

Table 16: Customer service and policies

Parking locations for crews to optimize efficiency

This is always a challenge in our Urban areas
None. This is a contractor's responsibility. (2 companies)
At substation or farm or gas station within 15 min of work site (2 companies had 15 minute policies).
Various staging sites based on work plan (7 companies)
Yes we provide places for contractor trucks.
Encourage "show-up" locations close to circuit
Parking/staging locations are set up close to the work to minimize travel times. These are changed frequently to keep contractors close to the work. (3 companies)
Temporary work headquarters for jobs that are remote from the local operations centre. [Hydro One]
At local operating center for reactive work crews (none for bid work crews)

Table 17: Parking locations for crews

Lodging and per diem to optimize efficiency

Must be approved by [utility]
Only during storm work/emergent work
Only for peak workloads when utilizing out-of-state traveling resources
Per diem per designated distance from show-up as defined in contract (7 companies)
Very minimal; considered on a case-by case basis. Seldom utilized except in extreme circumstances.
Limited but union mandated when applicable
None (2 companies)

Table 18: Lodging and per diem

Large crews transported in one vehicle to optimize efficiency

On some jobs, yes
Organized at a local level, no overall policy [Hydro One]
Again, contractor's responsibility.

Table 19: Large crews transported in one vehicle

Training to optimize efficiency

We generally pay time for training, we ask [contractor] to cover the cost of conferences, etc.
Contractor provides training to all crews. We conduct an annual environmental sensitivity training for all contractor personnel.
Focus on winter and inclement weather days for crew training [Hydro One]
At least annual
Training is an ongoing process that we schedule around.
On the job

Table 20: Training

Other methods used to optimize efficiency

If conditions merit we may perform a mid-cycle maintenance cut (basically a planned and controlled hot spot cut)
Incentive/remedy program has increased productivity
Assigning contractors to specific geographic areas to reduce non-productive travel time
Smart phone with email, GPS, mapping for reactive work crews
Work is planned in advance; contractor is responsible for optimizing resources.

Table 21: Other optimizing methods

Compensating for Storm Disruptions

What adjustments to your schedule do you make to compensate for storm disruptions of the routine schedule?
None. If we have a storm the contractors try to add resources to get back on schedule. Not always successful. [8 companies similar responses including Hydro One]
Storms can be a big challenge; they interfere with getting maintenance work done. We will often have crews that are on storm standby go out and do maintenance work so they're not just sitting around.
Bump scheduled work as needed
Compliance tree crews are ramped up after a storm incident to be able to ensure compliance time-frame is on track.
Overtime based on length and severity of the storm (7 companies)
Depending on the severity of the storm and damage
Overtime may be authorized when significantly behind schedule. Work may be shifted from reliability to compliance pruning.
Adding crews, working overtime or both if possible.
We have been able to absorb storm costs without impacting the completion of our annual schedule
We can be flexible on the Target miles that contractors are to complete each quarter if they have worked numerous storm disruptions. In many cases we will not penalize them for being behind target on line mile production.
Circuit completion dates are reported as month/year, not an exact date. This means that you have until the last day of each month to complete a circuit. We schedule each of them to be completed by the 15th however to provide us with some breathing room in case of unforeseen circumstances. For instance, if a storm hit an area the last week of the month, and you had to take your crews of the circuit work to address the storm, you may not meet the end of the month deadline.
Increase Risk Tree assessments post storm to cover all affected areas -push out other maintenance work
Reactively adjust all scheduled activities
Bring in an extra crew or add Saturday work at straight time or OT, if necessary
Being an in house crew, routine UVM is restarted as soon as the disruption is resolved.
Our utility budgets an annual amount for storms
Add on additional crews if possible in order to meet our cycle goals

Table 22: Strategies for Storm Disruptions

Basically, companies use the following two strategies:

- Increase expenditures by adding overtime or extra crews to maintain schedule
- Keep target maintenance schedule flexible or readjust them

Elements of UVM Program That Optimize Efficiency

Name three things that are key to the efficiency of your UVM program:
1: Contractor continuity - [Contractor] has been here so long they know our system intimately. 2: We have several cycles' worth of cost data so we know how much each circuit should cost. 3: We run very low overheads (7.5%) so more funding goes towards tree trimming
Outage tracking, targeting tree type (faster growing to slower growing) and patrols
Accountability of the inventory personnel and tree crews, accurate work of such, and proper oversight and management of all contractors by [utility] personnel throughout the year.
100% audit of all vendor work, vendor flexibility in scheduling to maximize their productivity, incentives for exceptional on-time delivery of quality work.
Weather, Customer Relations, Equipment Reliability
1. Great contractor leaders and trained, dependable personnel; 2. Small, but excellent internal team; 3. Sufficient budget funds to pay for quality contract help
Mowing the brush/trimming rather than chipping in the rural area mainly. The 55' back yard-lift to reduce manual climbing. Mini skid for removing brush/trimming from back yards and having the clam truck pick up brush rather than chipping. Job planners talking members rather than VM tree crew. -herbicides play a huge role.
1) Field-verify any unknown ticket work prior to crew dispatch. 2) Cycle customized to each VM area. 3) Assess VM areas several months prior to making a scheduled cut to allow for re-prioritizing based on actual field conditions
Targeted RE (time per primary tree unit includes associated brush & secondary) with quarterly payment adjustments Use of mowers and side trimmers where ever possible Backyard buckets and "bigfoot" aerial lifts to increase accessibility
Safety, planning, proper equipment (7 companies)
Adequate funding, quality work audits, resourceful management.
Inventory, safety and square meter contract
Getting consistency in all aspects of the program such as planning, work layout and end product delivery. Effective contracting strategy. Contractors that are committed to supplying resource to our programs.
Consistent workload over a year (number of trees consistent over the year). Long-term contracts (5 years). Incentive for reducing the number of trees that need to be pruned compared to a baseline quantity at start of contract. (reward for removal vs prune)
electronic inventory/prescription, electronic time keeping and invoicing, Google Earth mapping and pictures of work
Budget, inspections of work, and crews regularly
Close communication with the contractor, good supervision and well thought out planning
Adequate funding, quality work audits, resourceful management. (2 companies)
Contractor performance, Staff inspection of the work performed, Management of staff, contractors and budget
Pre-notification Incentive/Remedy Program Consistent workforce

Continued next page
(1) Receiving funding to meet our target Trim cycle, (2) Adequate funding to our Danger Tree Program (3) Knowledge transfer from retirees to new hires.
Logistics, labour rates, mechanization [Hydro One]
Weather, Resources and Planning
1) Accurate estimation of the resources needed to complete the 48-month work. 2) The right contractor management folks in place to make sure the work is managed most effectively/efficiently. 3) Experienced work force in regard to the tree workers themselves.

Table 23: Three things that are key to the efficiency of your UVM program

New Technologies Used in UVM Program

What new technologies have you introduced to your UVM program?
Unfortunately we are not a technology forward company.
Use of SAIDI information and outage tracking
We introduced at the start of the year a new GIS tree inventory program utilizing handheld iPad units that enables the inventory patrolmen to digitally inventory the tree with GPS placement, updated inventory count, pertinent notes related to the site, and GIS mapping capability for QC work of the tree crews in real-time.
Mechanized hazard/danger tree removal, use of Hiring Hall crews, LiDAR trial [Hydro One]
Electronic work planning (7 companies)
GPS data collection for patrol inventory of vegetation
Electronic data (computer and GIS based work management systems.
LiDAR is being used for transmission inspection, and we are testing its use for distribution.
Trying to get away from Paper maps. We are attempting to email all maps to GF's in the field. Many of our Company Forester's can make updates to the map in the field and send directly to our contractors. All OC's have mobile offices in their trucks and we're looking at going to a tablet.
Pilot TGR program. Electronic timesheets and production trackers. New UVM software to be introduced possibly late in 2016.
Electronic inventory/prescription, electronic time keeping and invoicing, Google Earth mapping and pictures of work
Work management system, electronic invoicing, new equipment technology (new type of whole tree chipper, new type of mower, cranes. etc) herbicide application (plus starting TGR in 2016)
Lateral Pruning, Herbicide Treatment
1. Skid-steer with forestry cutter; 2. Mini back yard Jaraffe; 3. Organized herbicide program; 4. Clear, simple expectations
Inventory software - back yard lift 55'- Quick trim where possible

Table 24: New Technologies

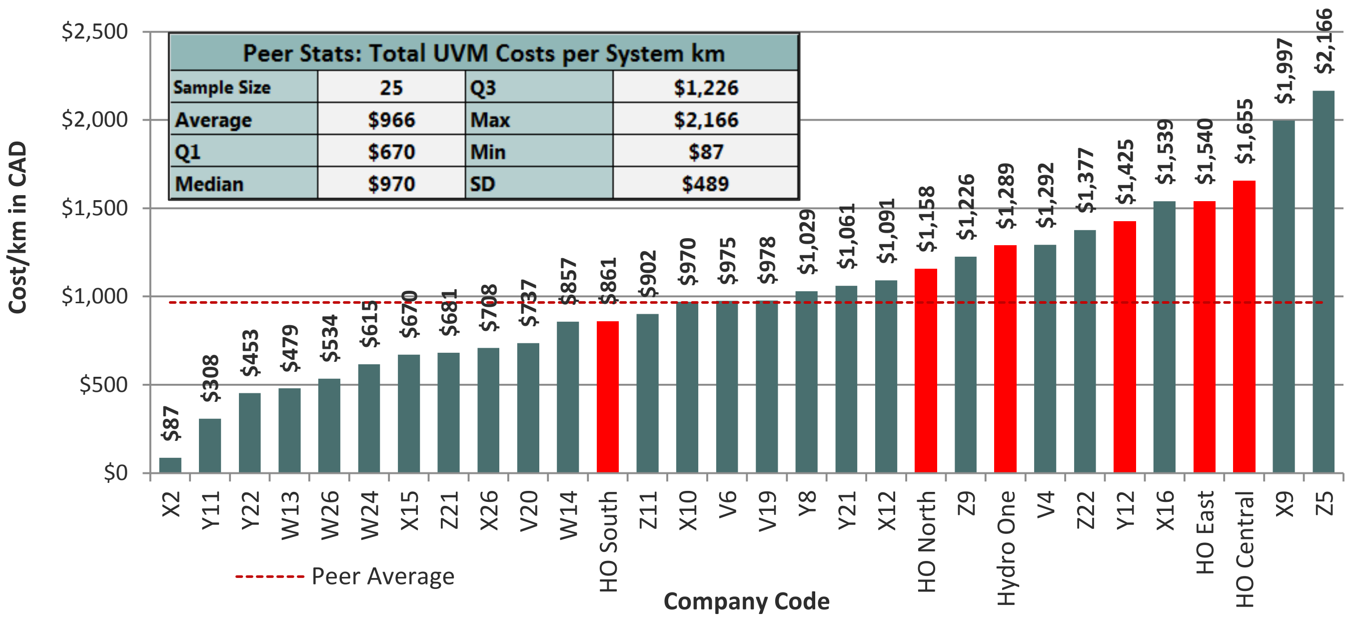
Predominate New Technologies in the order of times mentioned:

- Software for data collection, inventory, and work-planning, which may also include electronic mapping capabilities
- Mechanization and UVM equipment technologies
- LiDAR and remote sensing technologies
- Herbicide

FINANCIAL AND LABOUR HOUR COMPARISONS

UVM Expenditures

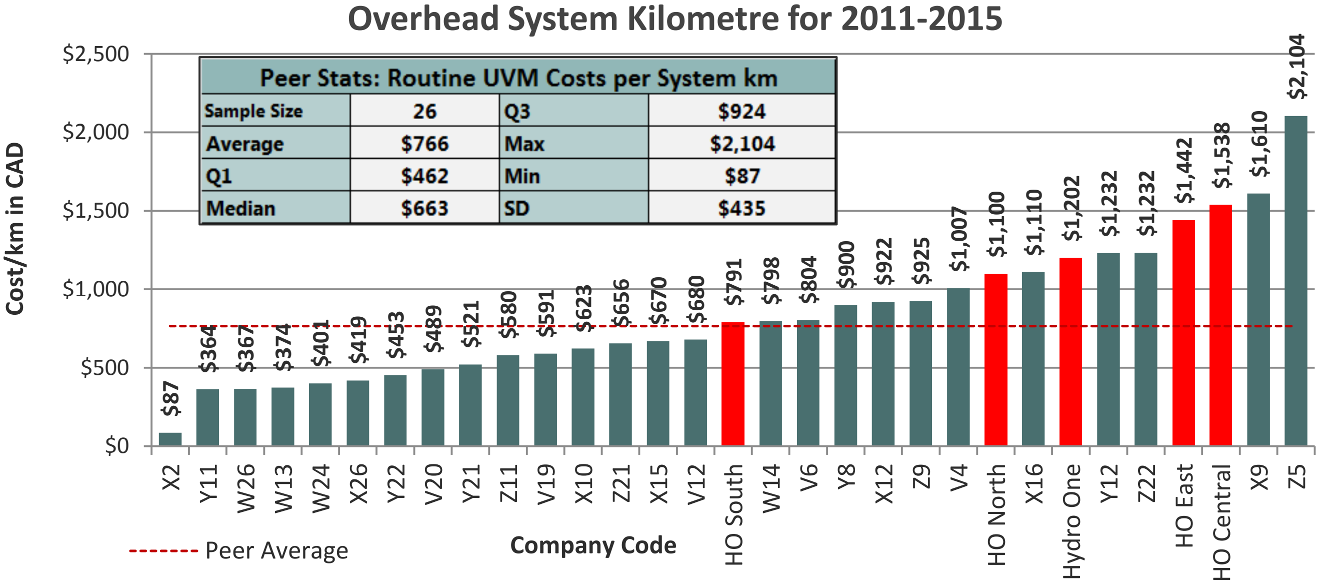
Average Total Cost for UVM per Overhead System Kilometre for 2011-2015
Total Cost Includes Routine, Reactive, Storm and New Construction Costs



Peer Stats: Total UVM Costs per System km			
Sample Size	25	Q3	$1,226
Average	$966	Max	$2,166
Q1	$670	Min	$87
Median	$970	SD	$489

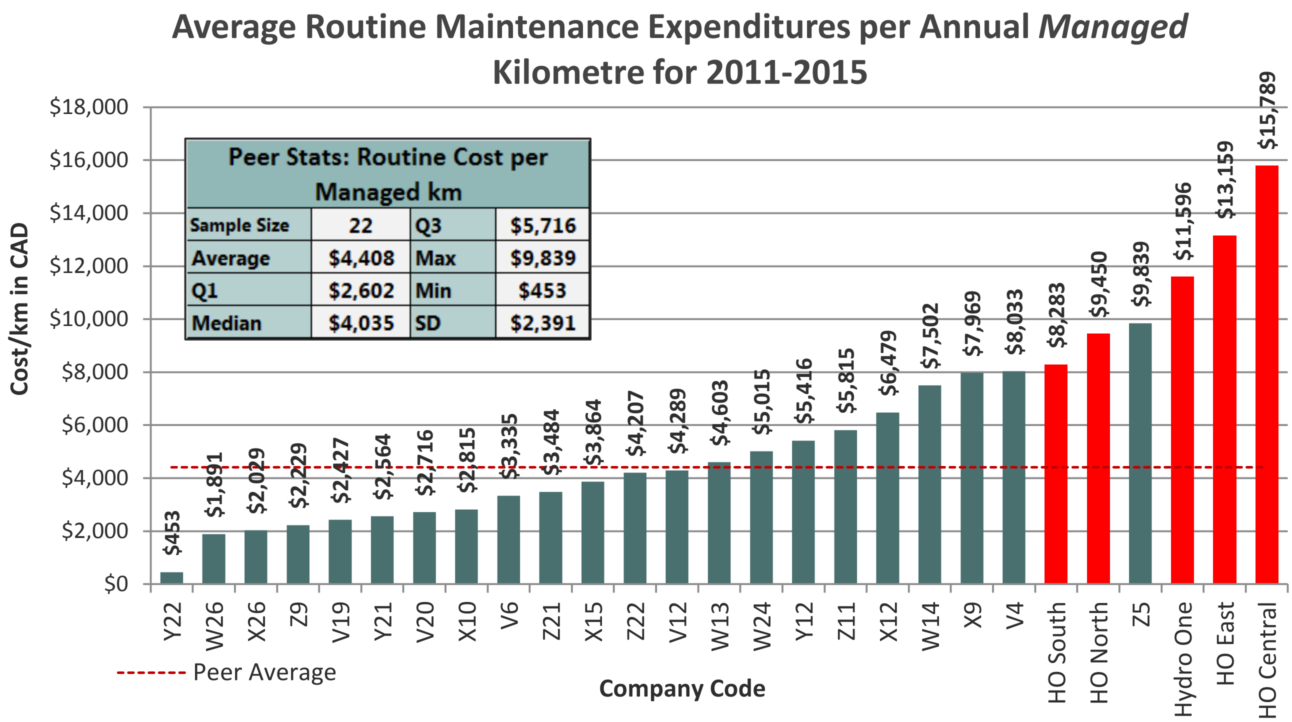
Graph 74: Average Total Cost for UVM per Overhead System Kilometre for 2011-2015

Average Routine Maintenance Expenditures per Overhead System Kilometre for 2011-2015

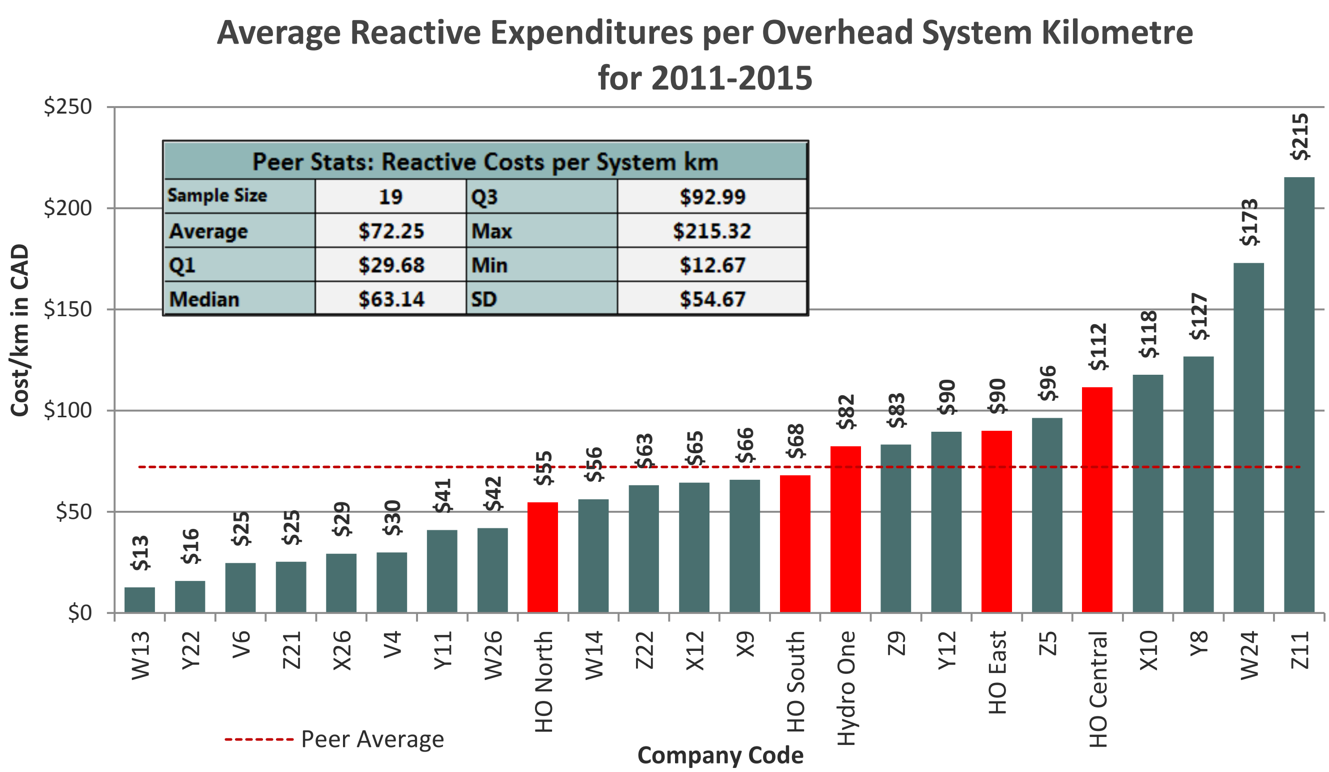


Peer Stats: Routine UVM Costs per System km			
Sample Size	26	Q3	$924
Average	$766	Max	$2,104
Q1	$462	Min	$87
Median	$663	SD	$435

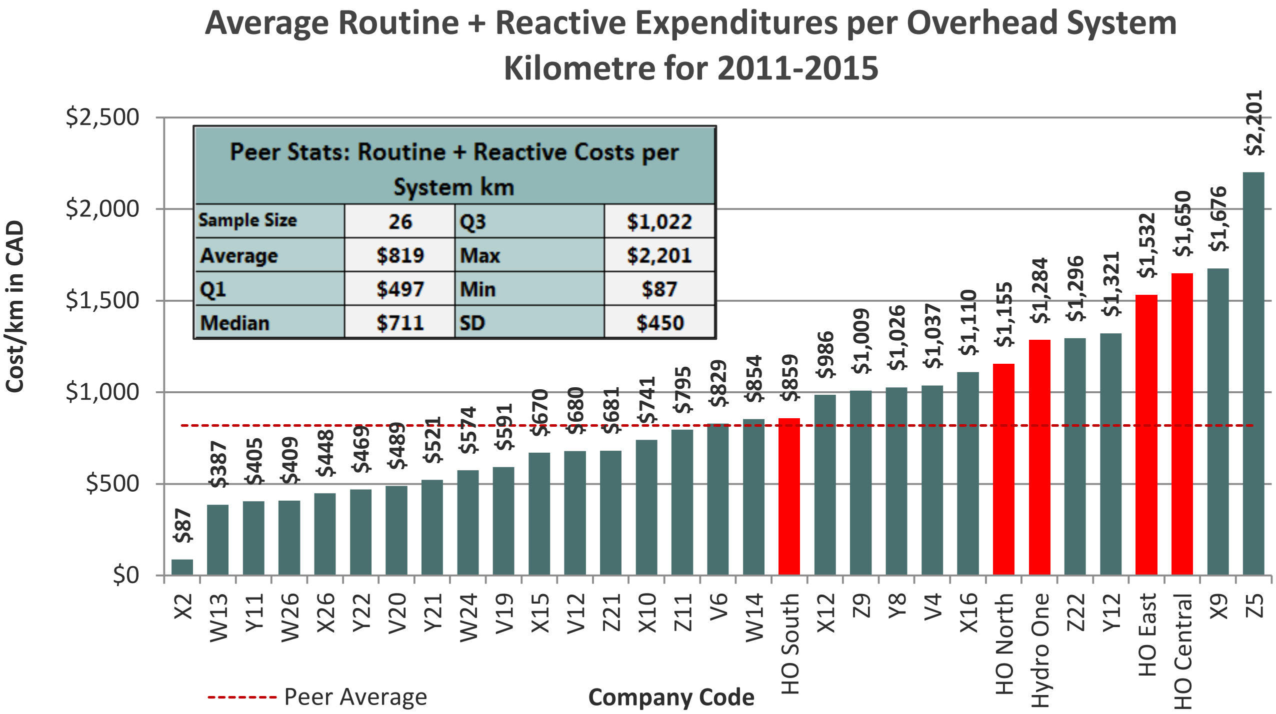
Graph 75: Average Routine Maintenance Expenditures per Overhead System Kilometre for 2011-2015



Graph 76: Average Routine Maintenance Expenditures per Annual *Managed* Kilometre for 2011-2015

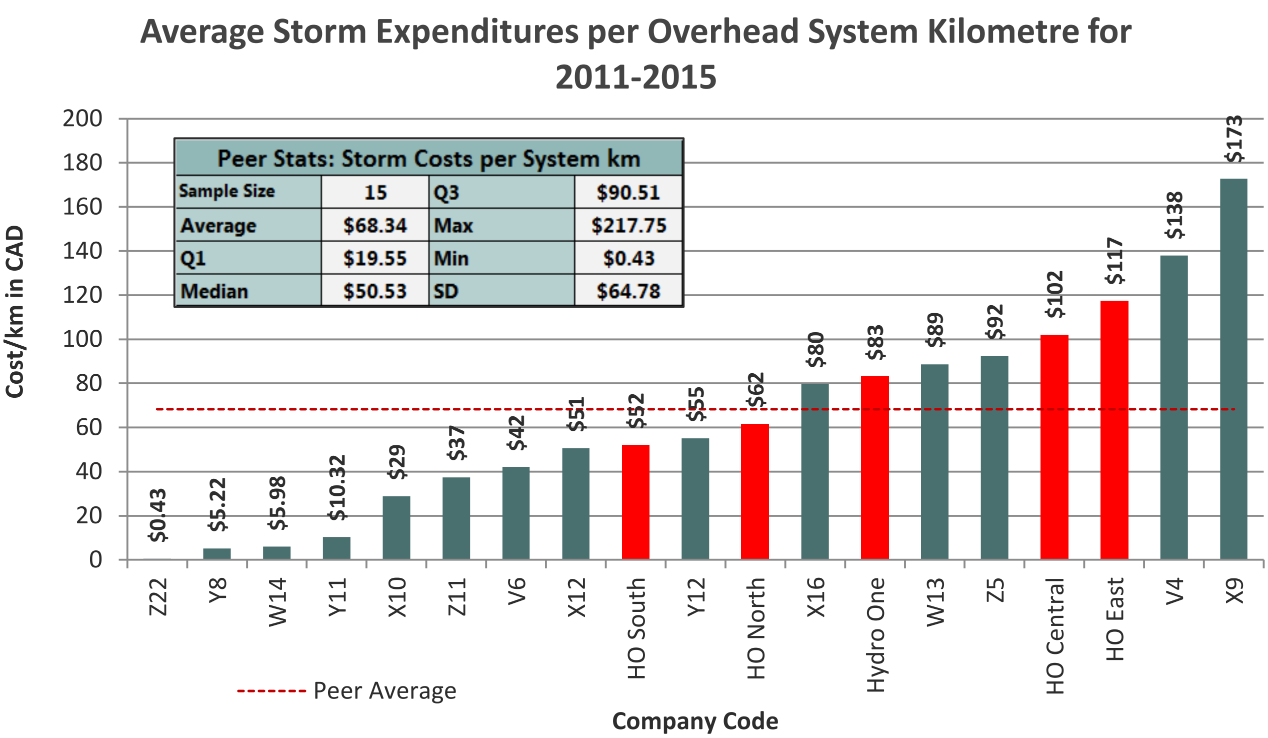


Graph 77: Average Reactive Expenditures per Overhead System Kilometre for 2011-2015



Peer Stats: Routine + Reactive Costs per System km			
Sample Size	26	Q3	$1,022
Average	$819	Max	$2,201
Q1	$497	Min	$87
Median	$711	SD	$450

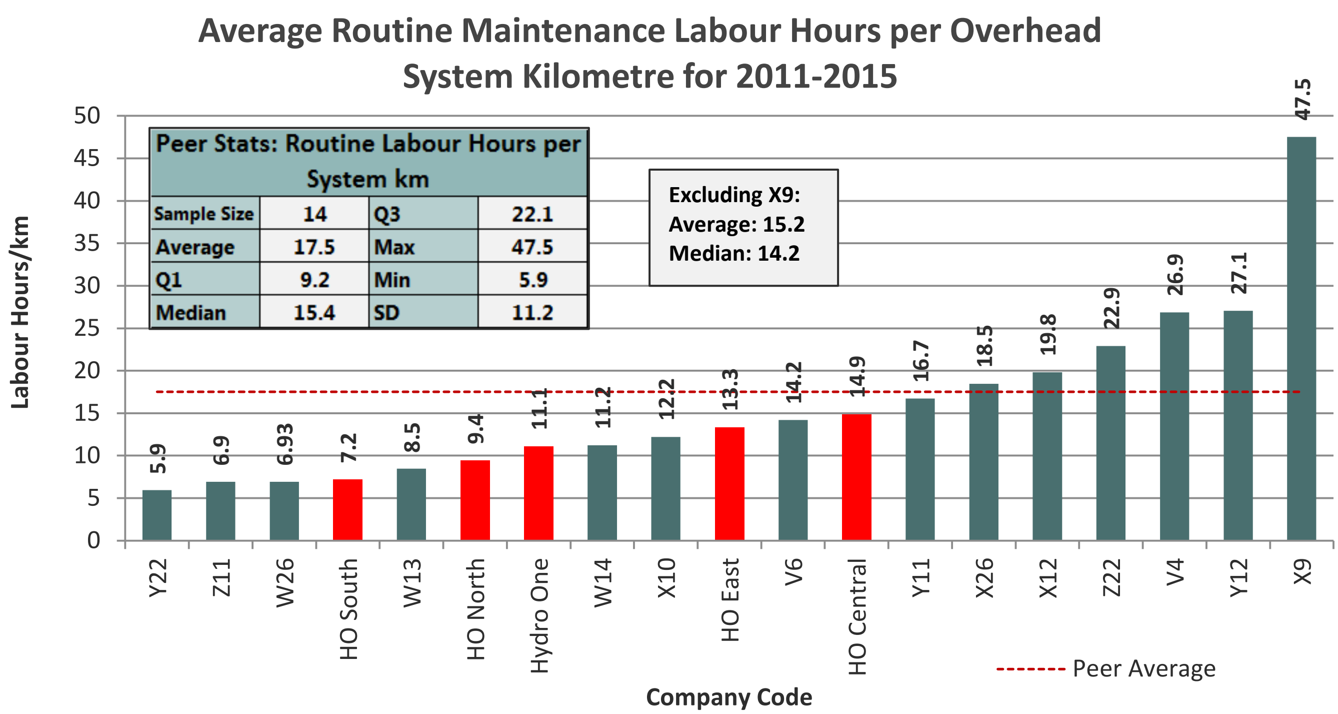
Graph 78: Average Routine + Reactive Expenditures per Overhead System Kilometre for 2011-2015



Peer Stats: Storm Costs per System km			
Sample Size	15	Q3	$90.51
Average	$68.34	Max	$217.75
Q1	$19.55	Min	$0.43
Median	$50.53	SD	$64.78

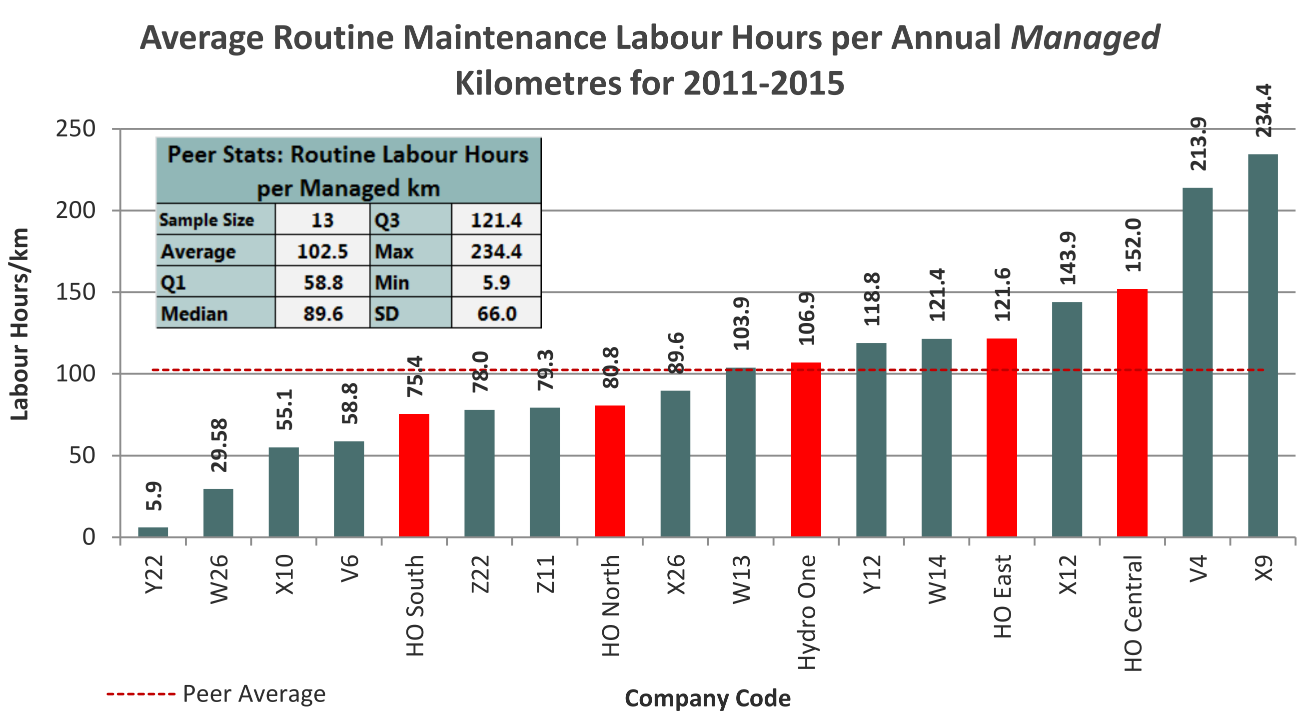
Graph 79: Average Storm Expenditures per Overhead System Kilometres for 2011-2015

Labour Hours Expended on UVM



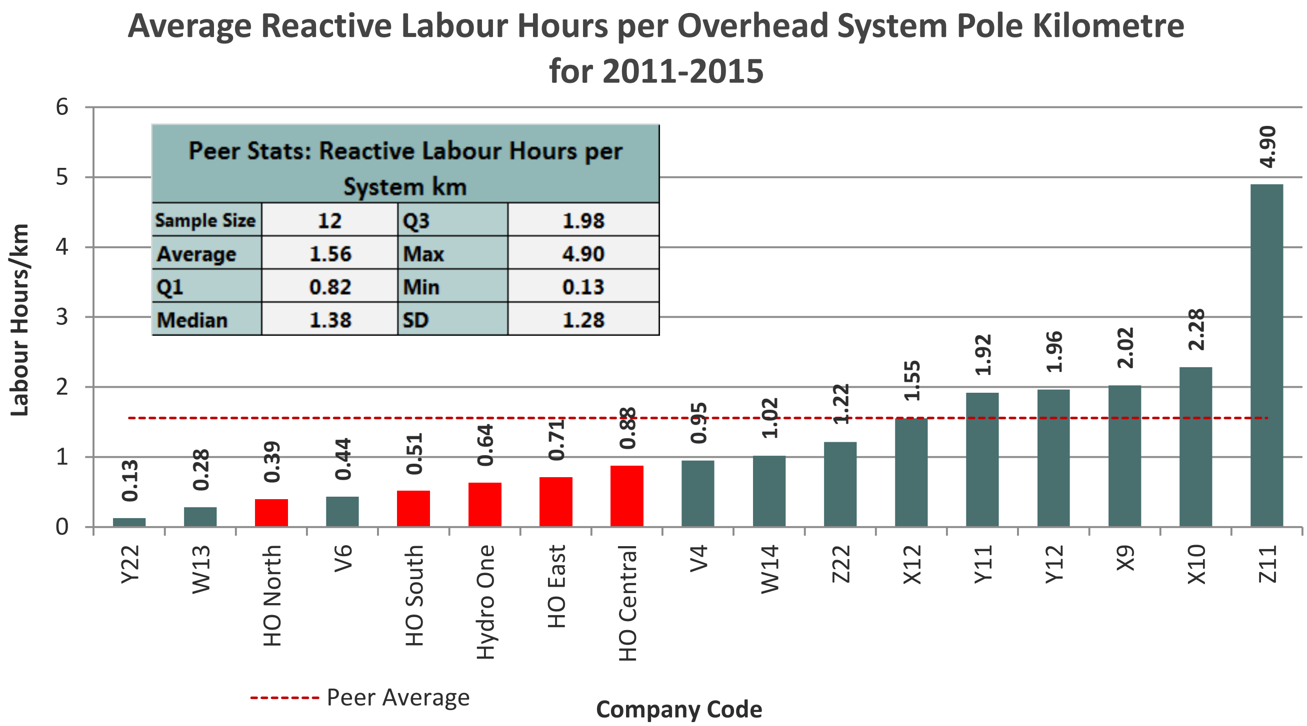
Peer Stats: Routine Labour Hours per System km			
Sample Size	14	Q3	22.1
Average	17.5	Max	47.5
Q1	9.2	Min	5.9
Median	15.4	SD	11.2

Graph 80: Average Routine Maintenance Labour Hours per Overhead Distribution System Kilometre for 2011-2015

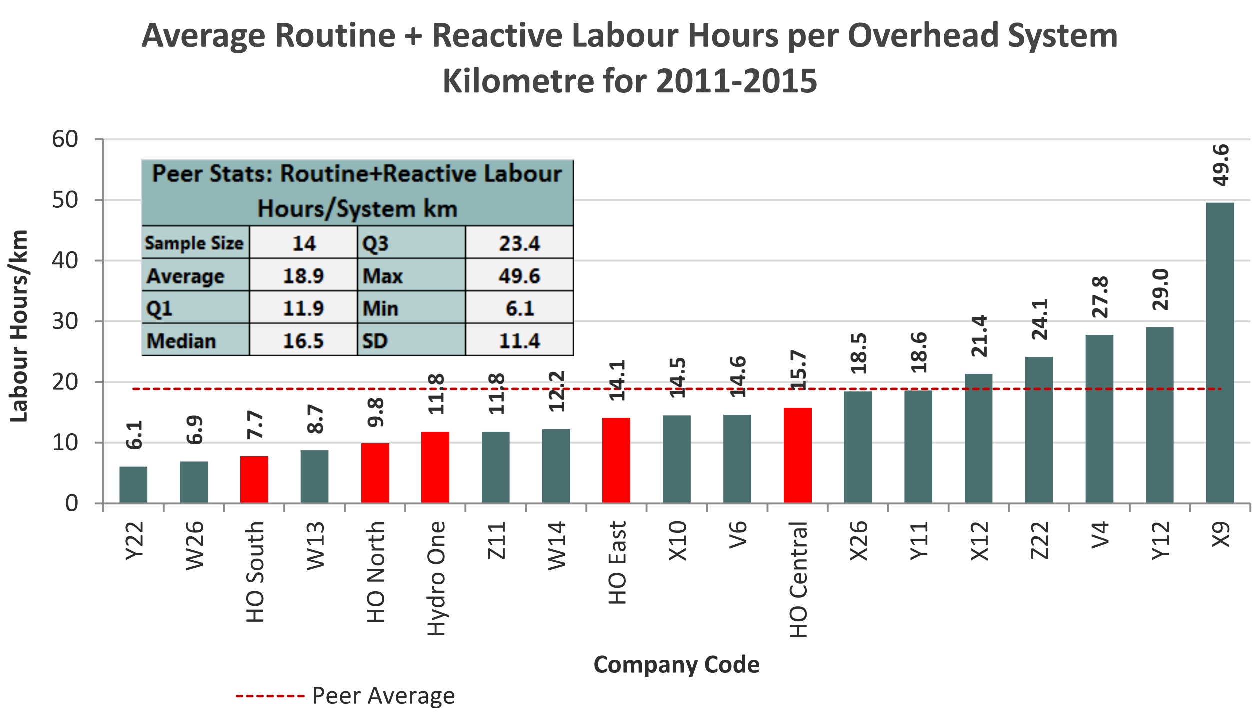


Peer Stats: Routine Labour Hours per Managed km			
Sample Size	13	Q3	121.4
Average	102.5	Max	234.4
Q1	58.8	Min	5.9
Median	89.6	SD	66.0

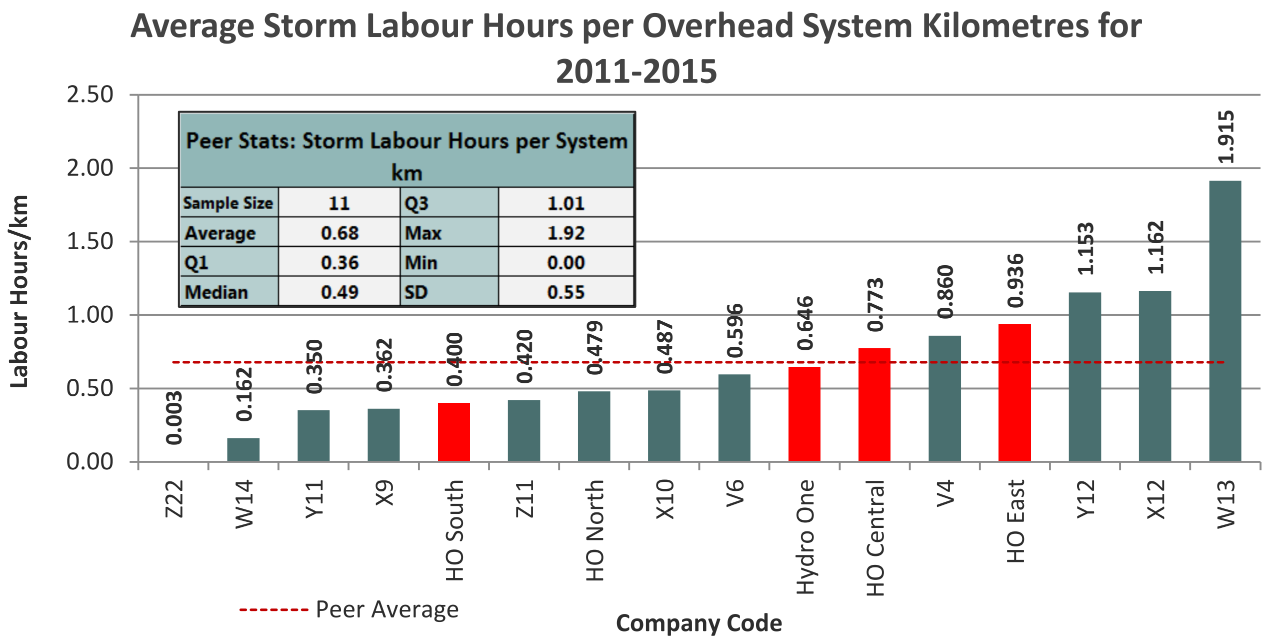
Graph 81: Average Routine Maintenance Labour Hours per Annual *Managed* Kilometres for 2011-2015



Graph 82: Average Reactive Labour Hours per Overhead System Kilometre for 2011-2015

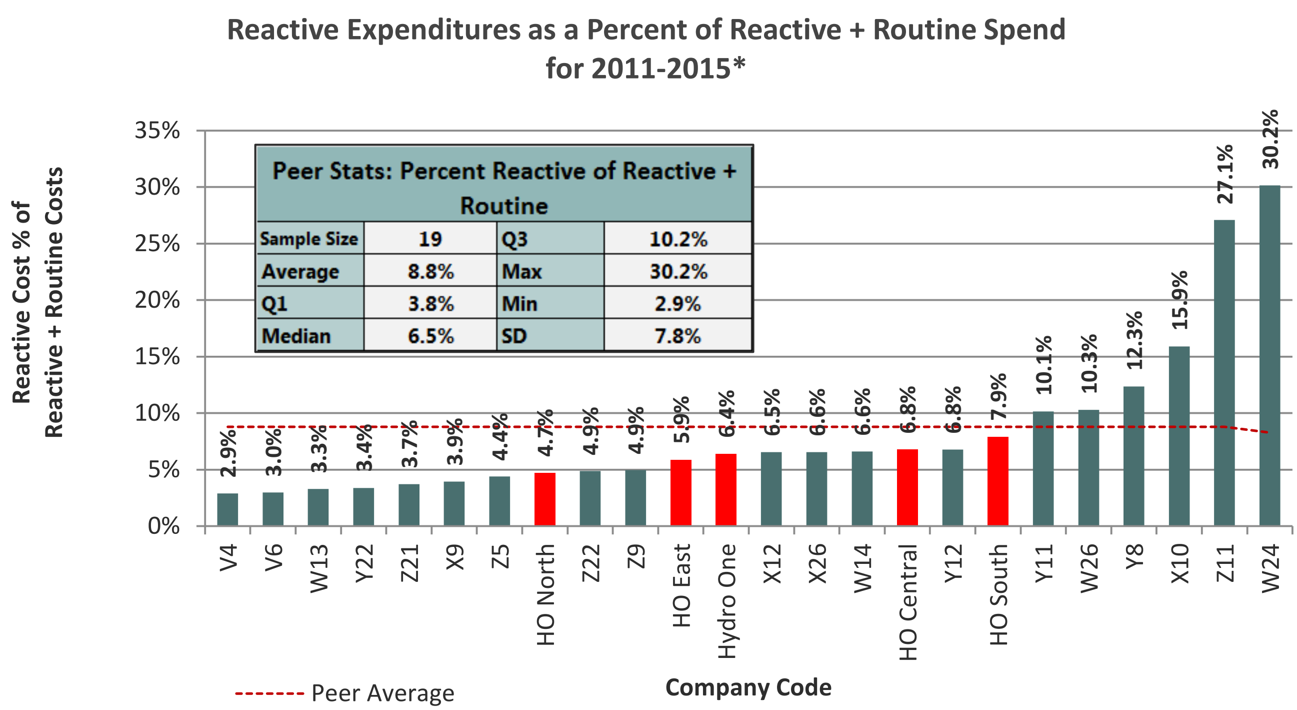


Graph 83: Average Routine + Reactive Labour Hours per Overhead System Kilometre for 2011-2015



Graph 84: Average Storm Labour Hours per Overhead System Kilometres for 2011-2015

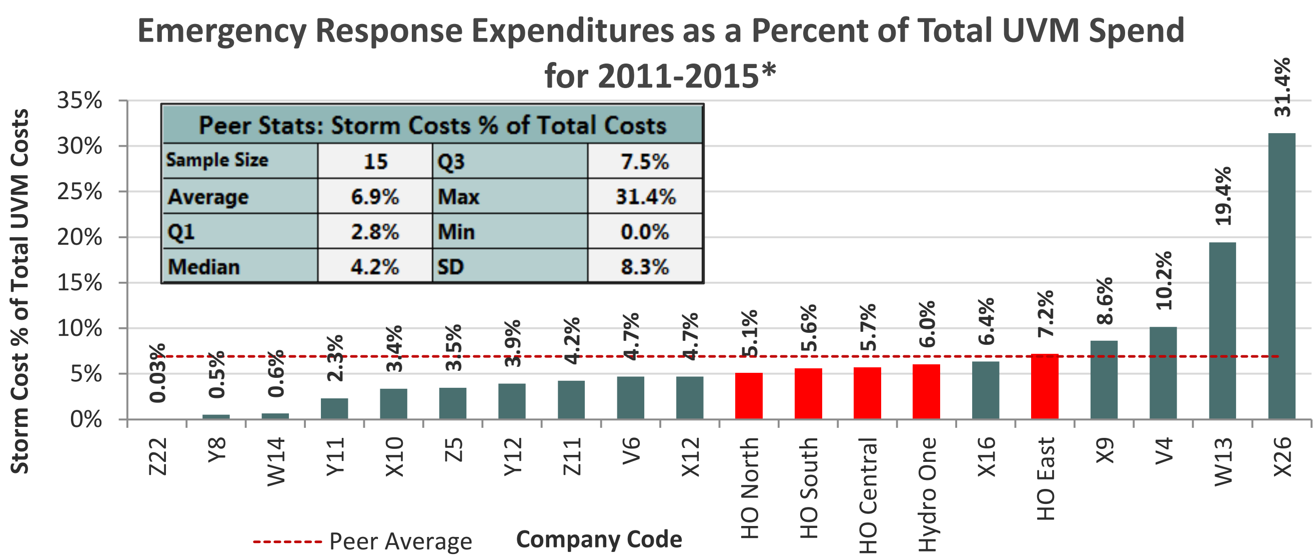
Reactive Work Expenditures as a Percent of Reactive and Routine Maintenance Costs



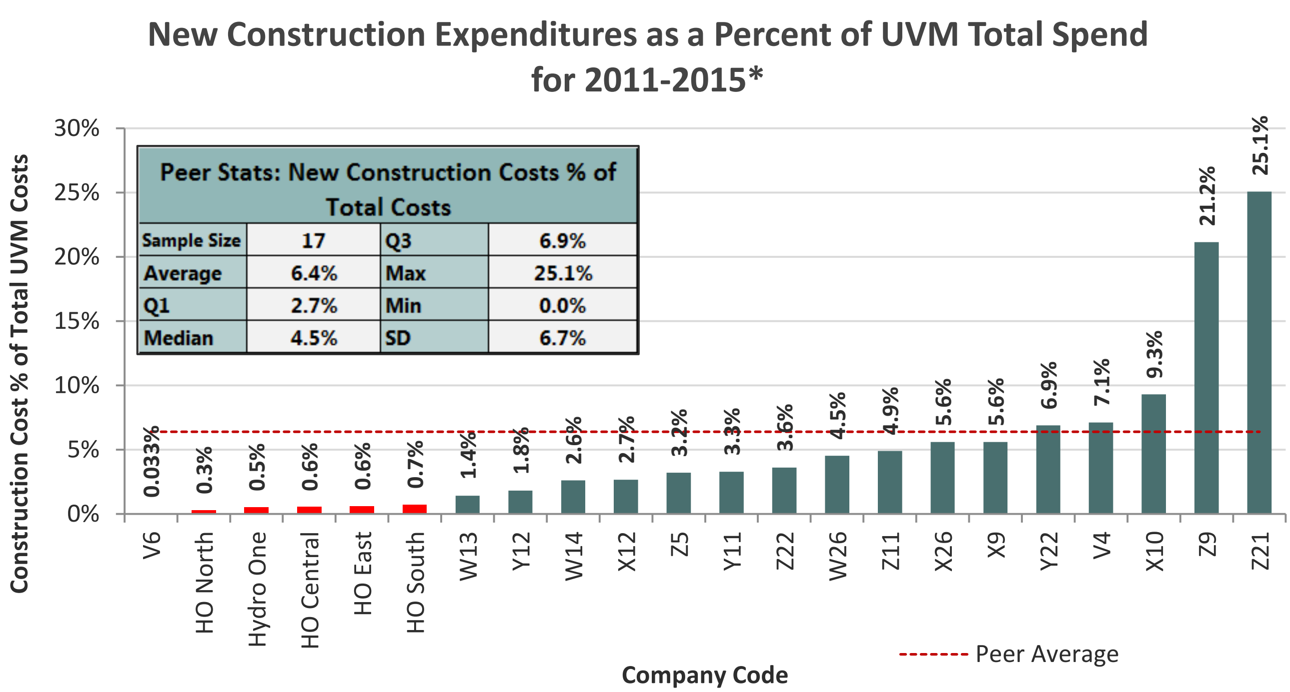
Graph 85: Reactive Expenditures as a Percent of Reactive + Routine Spend for 2011-2015

Percent of Total UVM Spend

*The following graphs were derived by adding the reported expenditures *for Routine Maintenance, Reactive, Emergency Response,* and *New Construction Work* costs to derive the "Total Spend." This "total" may vary from reported *Total UVM Expenditures* reported by the respondents due to the way costs are accounted for each utility. Some utilities included overheads, excluded storm and/or new construction since these expenses are not part of the UVM budget. Therefore, to equalize "Total Spend", CNUC added the costs of each work type.

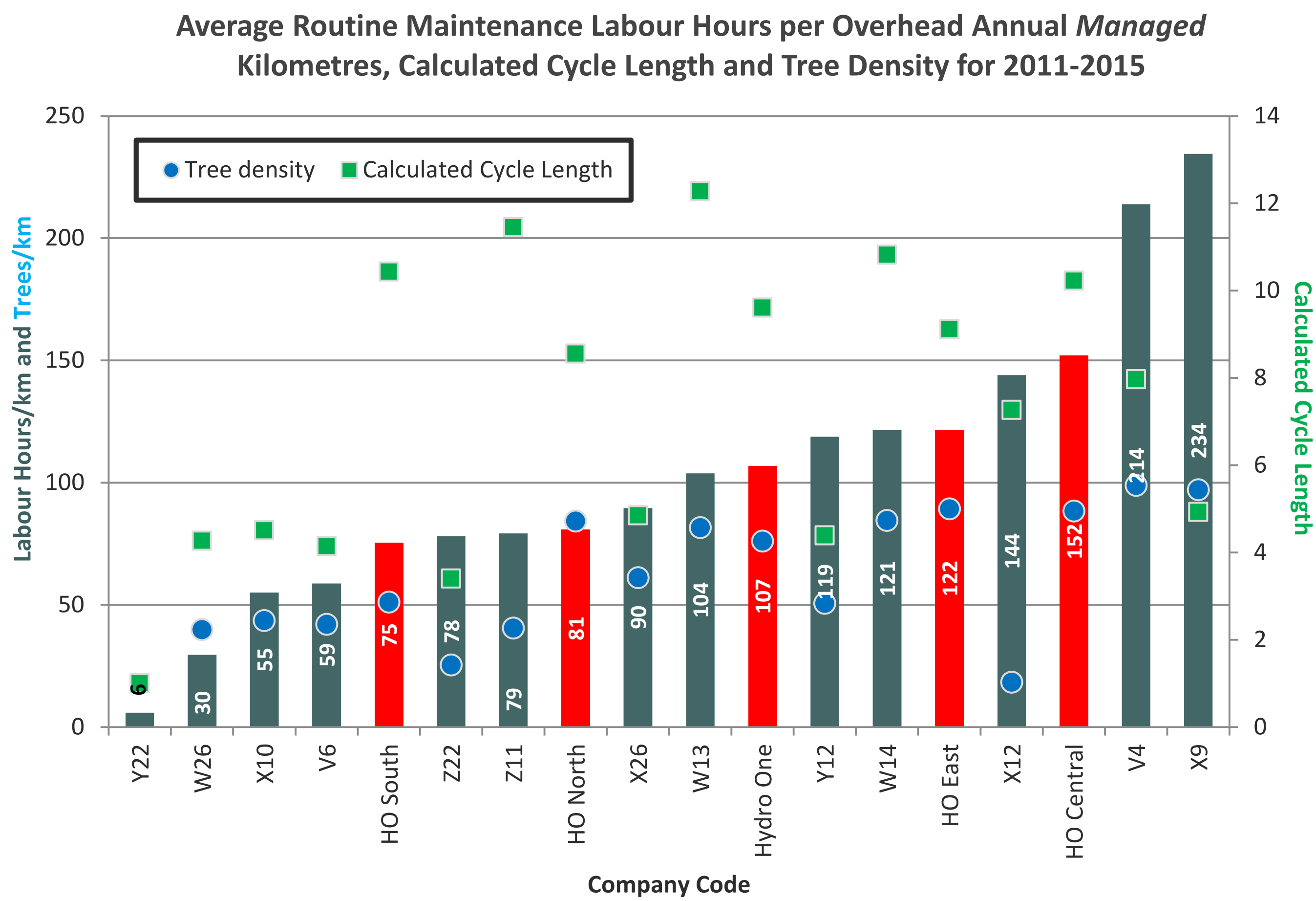


Graph 86: Emergency Response Expenditures as a Percent of Total UVM Spend for 2011-2015*



Graph 87: New Construction Expenditures as a Percent of UVM Total Spend for 2011-2015*

Labour Hours per Kilometre, Tree Density, and Cycle Length



Graph 88: Labour hours per Kilometre, Tree Density and Calculated Cycle Length*

A good correlation (0.7480) exists between tree density and actual cycle length ($p<0.002$). This analysis left-out X12, since this company has high calculated cycle length (143.9) with low tree density (18.3 trees/km). X12 is mitigating a tree mortality epidemic at present, which is affecting management scheduling. Although the reason for this correlation can only be guessed, CNUC believes that the longer cycles are allowing in-growth which produces a larger workload.

A good correlation (0.66656) exists between tree density and labour hours per km ($p<0.005$). This analysis left-out X12, since this company has high labour hour expenditure (143.9) with low tree density (18.3 trees/km). X12 is mitigating a tree mortality epidemic at present, increasing the current workload.

*Cycle length was calculated from information collected for 2011-2015 using the following calculation:

$$Calculated\ Cycle = Average\ \frac{Routine\ Labour\ Hours}{Annual\ Managed\ km} \div Average\ \frac{Routine\ Labour\ hours}{System\ km}$$

PRODUCTIVITY MEASURES

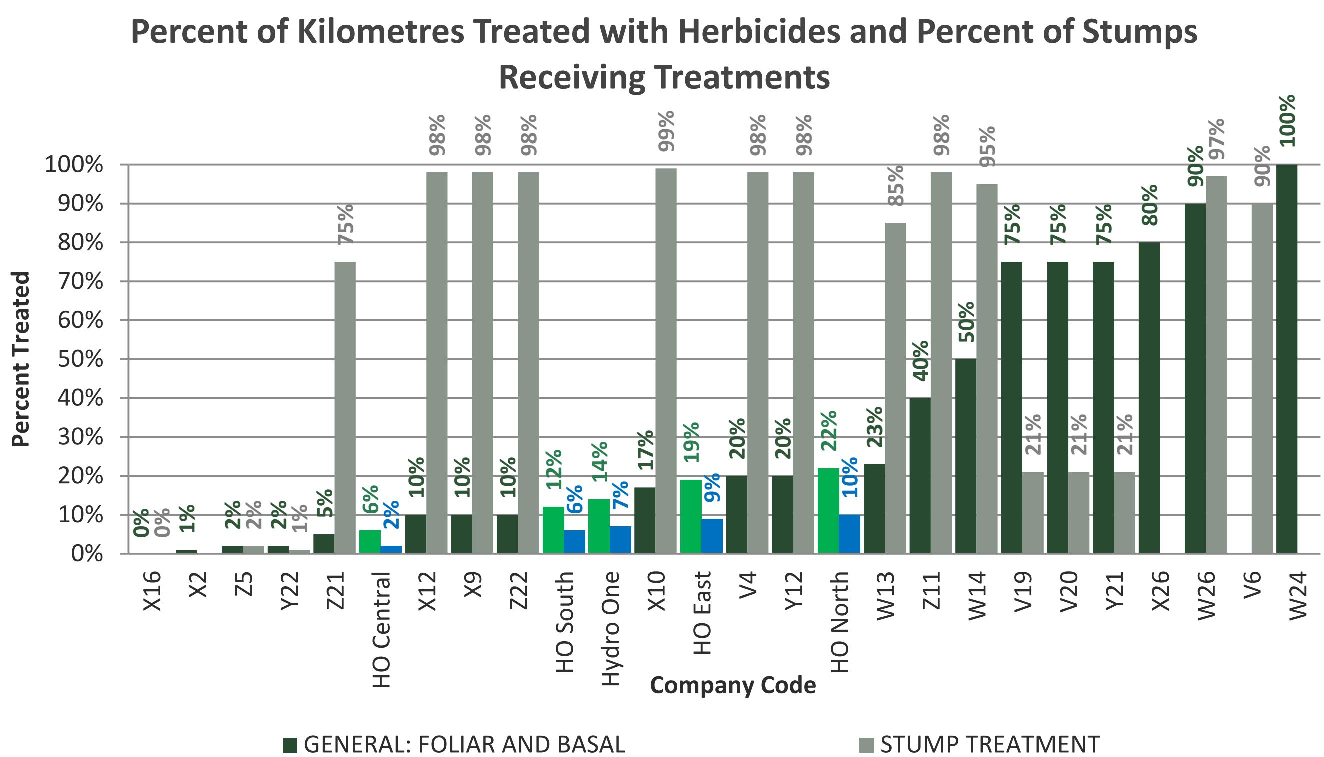
Herbicide Use

Participants were asked, “On average, what percent of the annual managed km (miles) of distribution ROW receive herbicide treatments to eliminate the in-growth incompatible species (excluding stump treatments on established trees)?” for GENERAL application methods (e.g. foliar, basal, etc.). They were also asked, “What percent of stumps from removed trees are treated with an herbicide to prevent re-sprouting?” for STUMP TREATMENTS.

Peer Group Statistics (Sample size: 21):

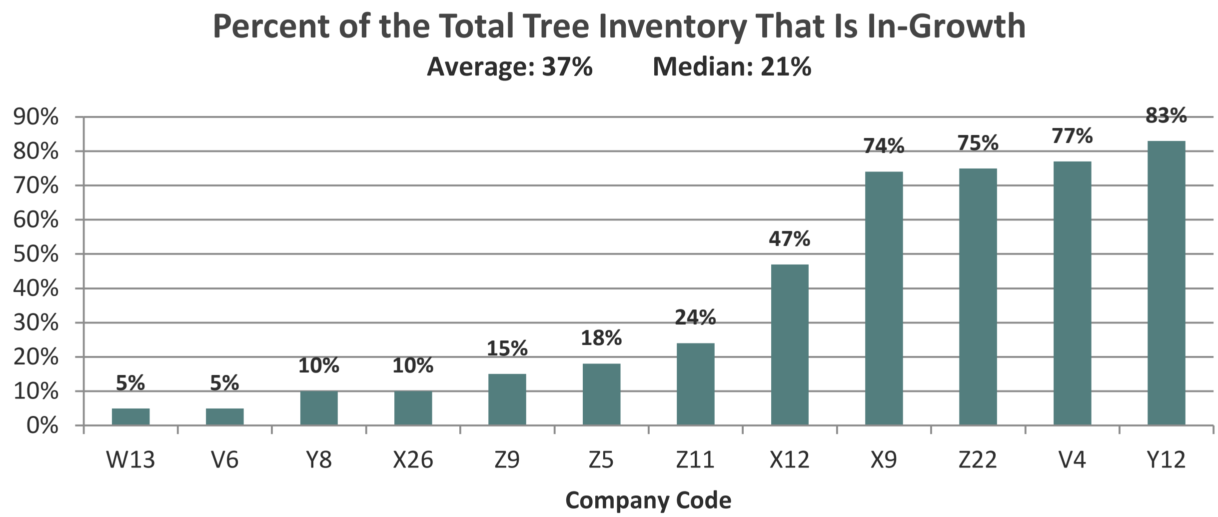
Herbicide Use					
	GENERAL	STUMP		GENERAL	STUMP
Average	35%	66%	**Q3**	75%	98%
Q1	9%	21%	**Max**	100%	99%
Median	20%	93%	**Min**	0%	0%

Statistics Table 6: Herbicide Use - Peer Group Statistics



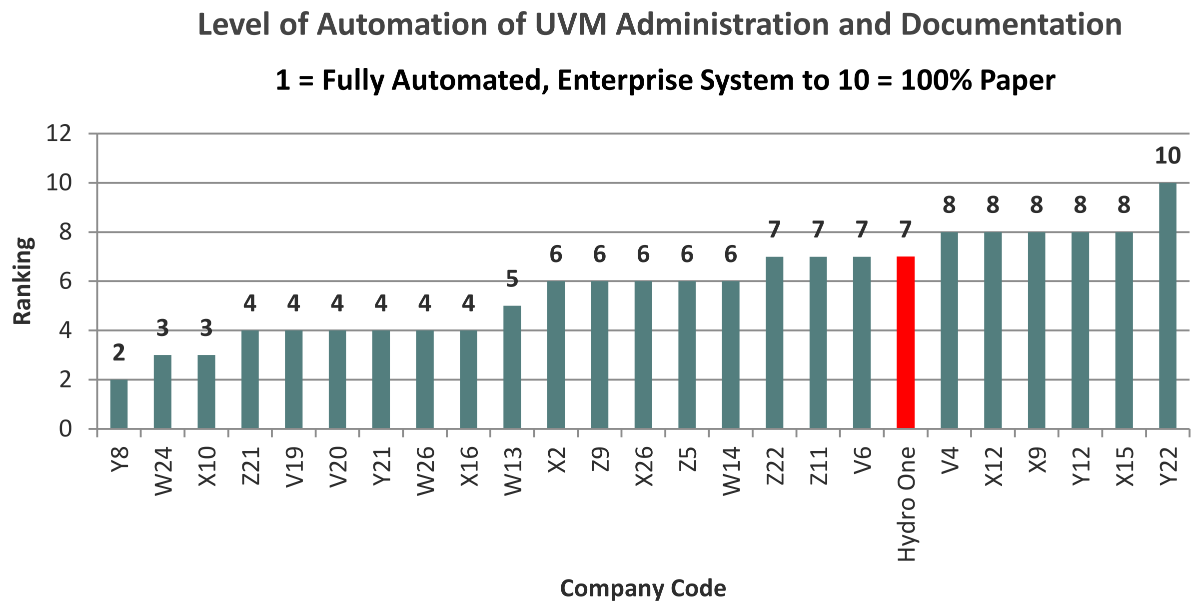
Graph 89: Percent of Kilometres Treated with Herbicides and Percent of Stumps Receiving Treatments

In-Growth Estimates



Graph 90: Percent of the Total Tree Inventory That Is In-Growth

WORK-PLANNING, PRE- INSPECTION AND AUTOMATION



Graph 91: Level of Automation of UVM Administration and Documentation

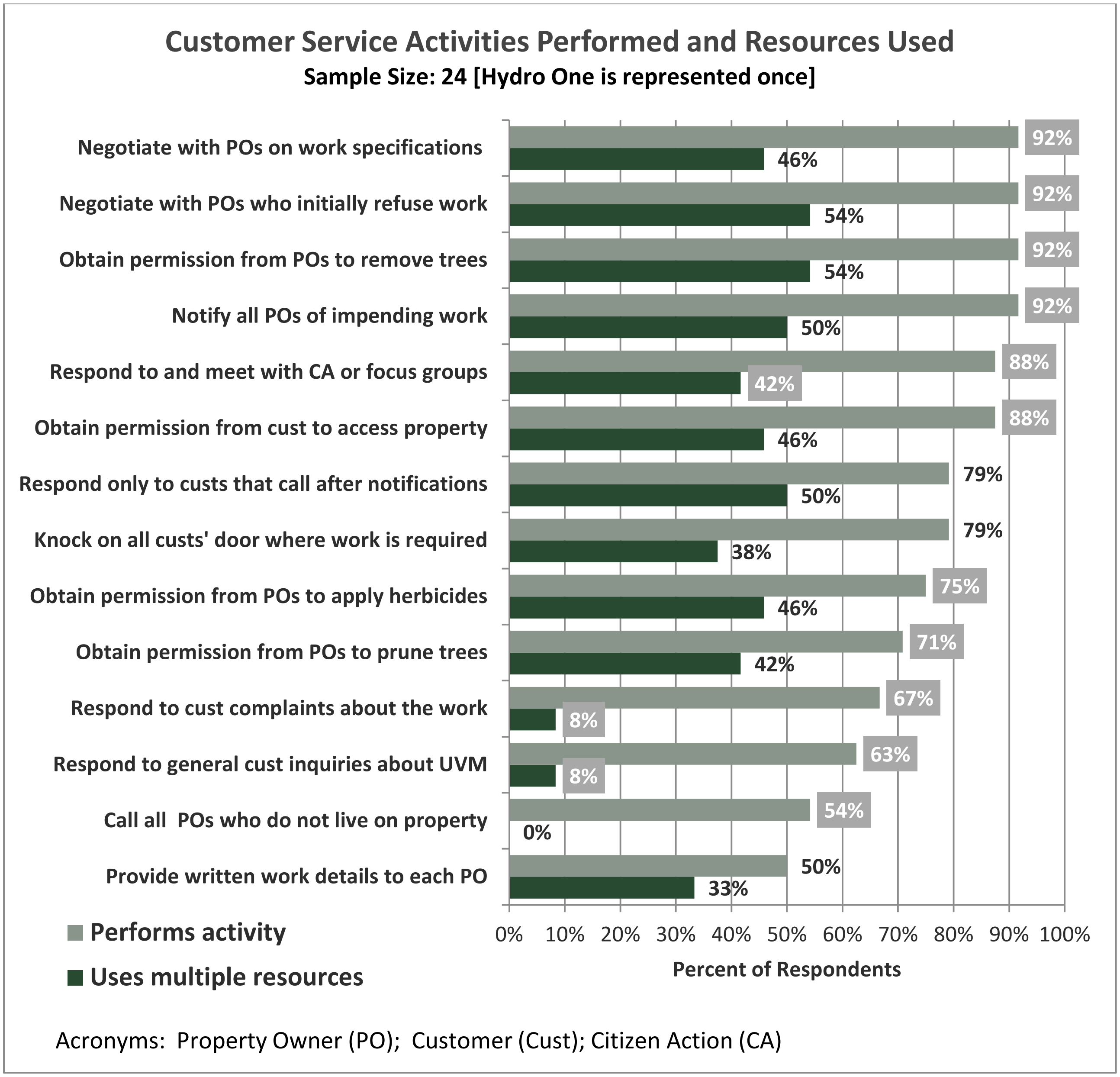
CUSTOMER SERVICE

Customer Service Activities Performed and Number of Resources Used

Survey Participants were asked the following question:

> If you have foresters, preplanners, workplanners, notifiers or auditors included in your distribution UVM program, choose from the following the types of customer communications that these individuals perform as parts of their routine work.

Resource choices were: Notifier, In-House Forester, Consulting Utility Forester (CUF), Line Clearance Planner, Automated Technology or Other. *NOTE: PO = Property Owners*



Graph 92: Customer Service Activities Performed and Resources Used

Customer Relations

Data Collection for Customers that Require UVM on their Property

Peer Utilities and Hydro One networks were asked, “Do you keep records on customers who respond to notification and refuse to allow the planned UVM work?”
Sample Size: 26
Yes 58% [Hydro One responded Yes]
No 42%
One participant said that a database was being developed.

Public Understanding of UVM

Peer Utilities and Hydro One networks were asked, “Do you think there is a "disconnect" (lack of understanding) between industry standards and what your customers/property owners and local agencies require you to do when performing UVM?”
Sample Size: 26
Yes 92% [Hydro One responded Yes]
No 8%

If yes, to what extent and what are the typical issues?
People in [state] love their trees and don't particularly care if we need to remove a tree for reliability or prune a tree to obtain clearance for an entire cycle.
Typically, the opinion of the customer is that we are doing too much work to the tree, or should be leaving the tree / brush alone altogether. Just take a little and come back more often.
General lack of knowledge of state and local guidelines (6 companies)
Only for difficult customers
Most of our customers don't realize there is a service guaranty/contract approved by [PUC] giving us the right to trim/remove trees.
Virtually all utilities operated a dual clearing standard; say 10 feet plus ANSI A-300. It is the ANSI A-300 portion which seems to always lead to misunderstanding.
Don't understand why the tree was trimmed in the manner it was- trimming is performed for clearance from the conductor, not aesthetics.
They do not always understand why we must trim certain trees as we do. Especially the u or v shape cuts made for trees directly under the line. This technique in their eyes is butchering a tree.
Public does not understand the wire-tree conflict issue
It doesn't really affect our operation in terms of getting things done, but the issue continues to be why we trim as much as we do and why we trim using the "natural" method of pruning to direct growth away from the lines.
There is a disconnect regarding the customers don't like the looks of industry standards pruning, but we don't do anything else. They don't "require" us to do something different.
Continued

Customer refusal tab in Tech notification software (Forestry Application Production) where the info about customer refusals is captured. [Hydro One]
It's getting better and better, but in general: Our pruning cycle is often perceived too long, and the result of the activity, too intense. We can also report that our various [customers] grant to trees a very different importance accordingly to their origin, or their culture. As an example: the urbans are more sensitive to the tree than the countryman; the English speaking are more sensitive than French speaking. And urban moved in the countryside wishes a quality of service [as] impeccable as in the city while keeping the forest character of his new environment. Quality of the electric service: the complaints of this nature are among the most numerous but the subject is not carried in the media. Quality of the work done: the aestheticism of the pruning is the object of less numerous complaints but more frequently carried in the media; Also [leaving] debris is the object of complaints.
Typically concerned customers do not want healthy trees pruned to our standards. They do not understand the impact on public safety and reliability when trees are not trimmed to standard. On the other hand when trees are in decline they think it is the Utilities' responsibility to remove the trees at 100% our cost.
Prune to customers often means how they would annually trim their bushes. They don't understand the magnitude of the work. They also don't understand that their small "tree" we call brush. Customers often don't understand how power [electricity] works and that their property's trees can potentially affect thousands of people's power.
Lack of education and public relations by not only the utilities but also by the government agencies themselves.

Table 25: Descriptions of Customer Understanding about UVM

SAFETY AS A PRIORITY

Tracking Safety Metrics

23 peers and Hydro One Networks answered the question, "Do you track safety metrics?

- 92% responded **"Yes"**
- 81% responded **"Yes"** for the industry-wide sample (31 companies)

24 companies (industry-wide sample) *described* how they track safety. The following is a summary of their remarks:

- All utilities monitored *worker* safety by tracking incidents (accidents) and some of the respondents included contractor-caused outages, vehicle incidents, and non-reportable incidents in their statistics.
- Six companies used a web-based program that contractors can access to enter incidents and calculate safety statistics.
- Several have quarterly meetings and have contractors submit logs.
- Two companies ask for near-miss reports.

Only three companies (one of them is Hydro One) had more extensive monitoring. Their comments follow:

- Weekly safety audit are required and tracked through the Supervisor safety and accountability program along with internal Safety specialists and ISN
- We have a safety department within our UVM that tracks incidents and non-compliances of not only our contractors but of our own department as well. Additionally, we conduct monthly safety meetings as an entire department and require annual training of all personnel.
- ***Hydro One- Forestry*** has a number of metrics to track safety of the UVM program. Key focus is reducing High Maximum Reasonable Potential for Harm type incidents and total recordable injuries among other things. The other safety metrics that are constantly monitored are reducing Preventive MVAs, Electrical contact, Musculoskeletal Disorder Injuries, slips, trips, falls, Contact with Sharp Objects, Fall from Heights & Stuck by Falling objects

Other Metrics Applied to Safety

When asked, "**Do you have other measurements that you utilize to measure safety achieved by your UVM program?**" 22 peers and Hydro One Networks responded:

- **43% Yes**
- **57% No**

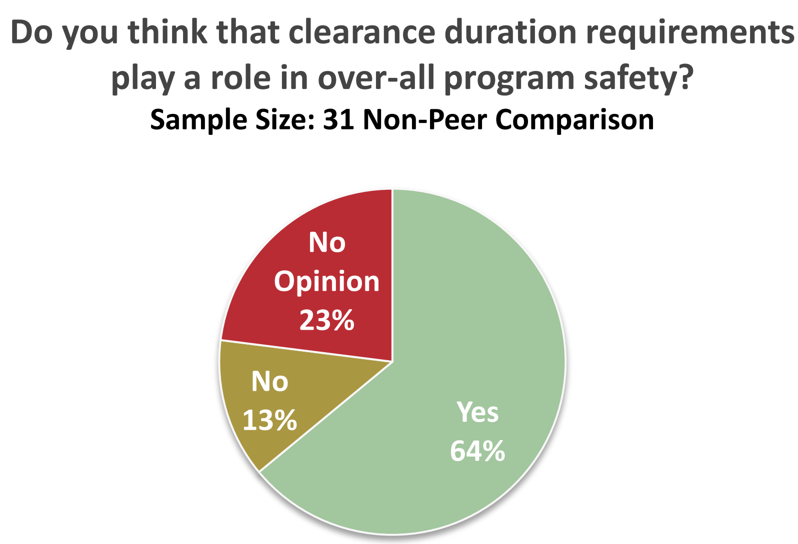
Once again, most of the monitoring was done on incident rate. See comments that follow.

Measuring Safety
We track Total Recordable Injuries per 200,000 hours worked. We also develop on an annual basis Forestry Health, Safety & Environment Initiatives – Prevent Struck by Injuries from lodged tree, Prevent fall from height, eliminate injuries from electrical contacts and off road MVA incidents. We are also meet OHSAS: 18001. [Yes – Hydro One Response]
Any quarter of the year with a lost time recordable injury or a crew caused outage removes that quarter from consideration for Performance Incentives (paid holidays) -Any year with 5 or more injuries or outages (combined) will require a meeting regarding safety process/procedures and an action plan to reduce these incidents [No]
Incident rate, severity rate, DART rate, at fault vehicle accidents [Yes]
We monitor each contractor's RAI [Requests for Additional Information] and have a review with each vendor quarterly to review their safety record and performance records. [Yes]
Track contractor hours, incidents, and TRIRs [Total Recordable Injury Rates] [Yes]

Table 26: Measuring Safety

Safety policies

Clearance Duration Policies and Safety



Graph 93: Clearance Duration Requirements

Comments on the relationship between clearance duration requirements follow.

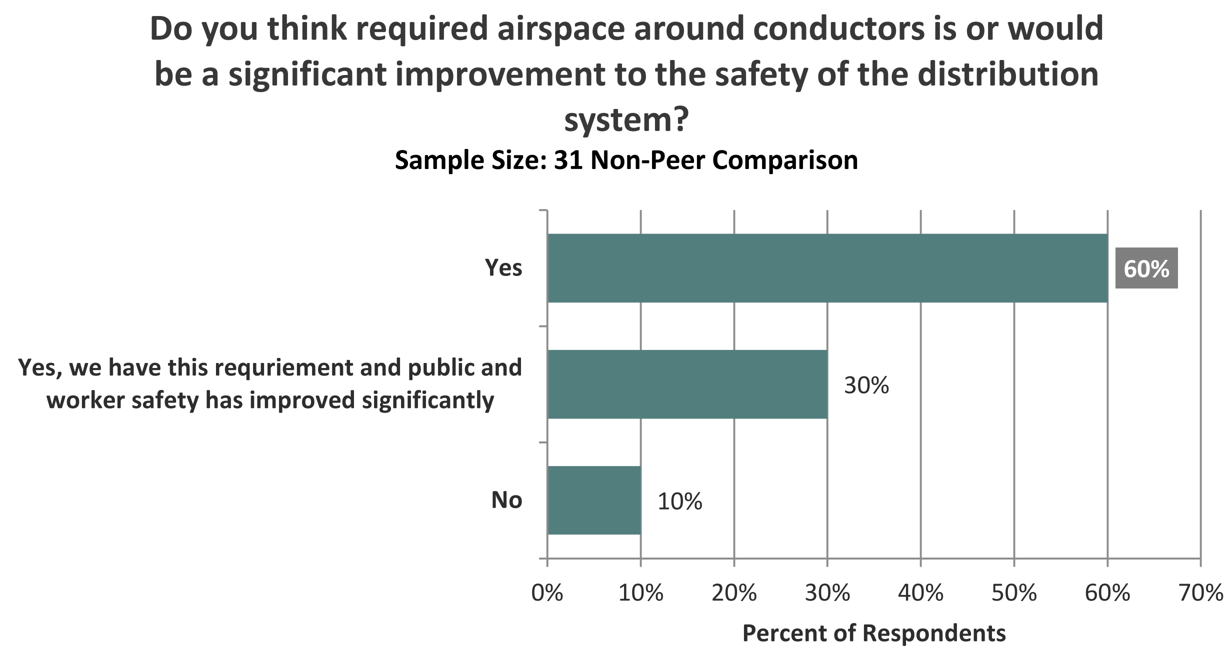
Clearance Duration Requirements and Safety
Longer cycles mean more tree/conductor contact and a higher chance of an incident [Yes]
Increased cycle length means increased exposure. [Yes]
Deferred vegetation maintenance becomes more difficult to deal with. I.E. increased encroachment to energized conductors [Yes]
I do believe that if the ROWs are not kept adequately clear, it can pose safety issues for those who have to work there. [Yes}
Not with our program. Even though we may be behind in cycles, the growth into primary conductors is not significant. The safety concerns (and potential outages) are elevated when it comes to open secondary lines, street light lines, and service drops. [Yes]
If clearance is poor, there is a safety issue with crews working around the wires. The more clearance around the wires at time of pruning, the more visible the wires, and the safer the program is. [Yes]
The farther we can keep our trimmers, vegetation and equipment away from energized lines, the safer all included are. common sense [No]
If safety practices are being thoroughly implemented, there should be no increase in accidents despite clearances. [No]

Table 27: Clearance Durations Requirements and Safety

Required Airspace between Trees and Conductors and Safety

Utilities were asked, **"Do you think required airspace around conductors is or would be a significant improvement to the safety of the distribution system?"**

90% of the industry-wide sample (31) agreed with this statement. See graph below (Each category is exclusive).

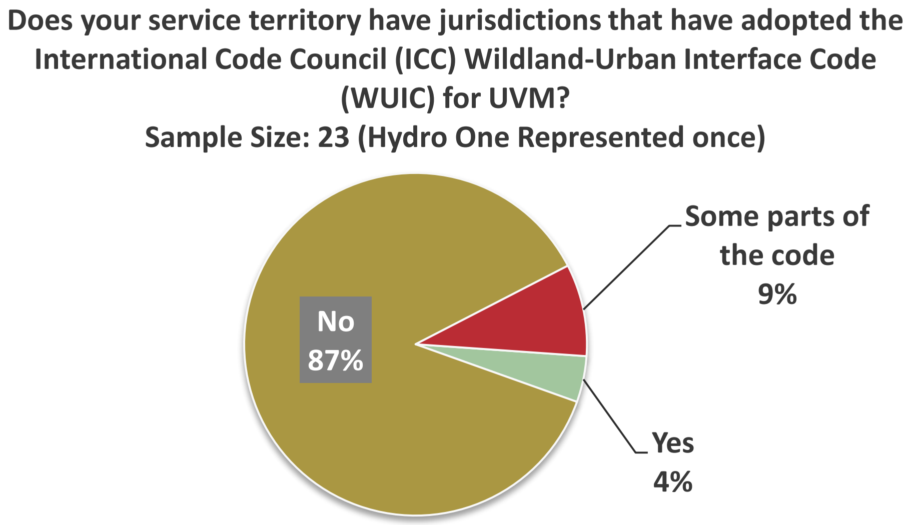


Graph 94: Required Airspace and Safety

Required Airspace and Safety Comments
Mandatory minimum clearances would likely triple our budget but our system would be safer [Yes]
There would be almost no change from what we do now [No]
We have no data to suggest that a required airspace would improve safety. It might increase production if there is less encroachment. There would be a significant increase in costs to achieve a required airspace [No]
I am not in favor of a required amount of clearance. I think clearances should be dependent on species, voltage, site conditions, etc. Maybe there could be a minimum required clearance. [Yes, with modifications]
Certainly couldn't hurt. [Yes]
IHSA requires 3' between conductors and trees to establish safe work areas for climbers. If the tree is within 3' the tree is a hazard. [Yes, Have requirement]
I'm leaning more towards the yes, but before I support it 100% it would be nice to see some research and results on the topic. [Yes]
I think anything coming from the ground, especially wet vegetation which can contact live high voltage conductors, produces a dangerous condition. [Yes]

Table 28: Comments on Required Airspace and Safety Comments

Wildfire-Urban Interface Code



Graph 95: Adoption of the ICC WUIC for UVM

Wildfire Incidents

It should be noted that when peers were asked about fire incidents attributed to fires started by conductor and tree conflicts, several reported none, but they also reported that they had no metrics to track this.

Peers were asked, "Have confirmed tree-wire contact-caused wildfires occurred in your distribution system in the last decade?"
35% Yes
65% No [Hydro One answered **No**]

Fire Incidents in Service Territory Due to Tree-Wire Conflicts
We may have 6-10 small fires per year [Yes]
I know of one small fire contained to the tree and surrounding hedges. [Yes]
No metrics to track wildfires occurring from tree-to-wire contact [No –Hydro One response]
Several small fires (< 2 acres) over the last decade 8 acre fire in 2013 100 (?) acre fire in 2006 No fires the last two years [Yes]
Don't have a firm count, but we know we have caused wildfires in the past. Our climate is not conducive for large wildfires (Our Humidity is high), but during periods of severe drought, this is monitored more closely. [Yes]
We don't have that statistic. Any wild fire resulting from a tree contact is usually a tree fallen (off corridor) tree. We had several of these as a result of the Mountain Pine Beetle epidemic. [Yes]
1. Less than 2 acre grass fire/no structure damage [Yes]

Table 29: Fire Incidents in Service Territory Due to Tree-Wire Conflicts

Safety Training

Safety Training Initiatives Undertaken in Last Three Years
[Contractor] has one of the most intensive safety programs in the country. We allow them to do what they think is needed for safety, we never have to ask them to do more.
100% vendor function
Lodged tree training, heavy equipment training, and Herbicide application training. Foresters receive 30-40 hours of new training annually. [Hydro One response]
Require all contractors to have own safety program, including tailboards and regular safety officer visits. Contract initiation meeting includes review of the program and expected reporting to MH
Contractor KPI impacted by safety numbers, increased safety audits by the utility, training days provided as needed.
Vendors provide basic training, all have different programs.
No information available
We use a 3rd Party company to carry out our Power Safe training. These courses are entry level courses in reviewing the requirements to work for our Utility and we have created some job specific modules that are mandatory for our contractors to take. To take all courses it is about $100 per year per contractor employee and the trainings take about 4-6 hours.
Safety training is handled by the contractors. We do conduct Safety Seminars annually with our contractor's management folks, which cover a variety of safety topics. There is also a steering committee composed of both Ameren and contract employees.
Vendors with a reported caused outage had to undergo company safety mitigation steps to become qualified as a line clearance vendor again, and continue work.

Table 30: Safety Training Initiatives Undertaken in Last Three Years

Public and Non-Utility or Utility-Contracted Tree-Worker Electric Incidents

Survey participants were posed the following question:
OBJECTIVE: To determine the utility's awareness of electrical contacts which occur outside of utility managed line clearance operations. As many as 15-20 on the job electrocutions occur each year in the US that involve non-line clearance tree and landscape workers. It is estimated that there are more that involve the home owners or non-employed tree workers.
QUESTION: Which of the following apply to your company?
Sample: 21 (20 peer utilities and Hydro One Networks)

- The utility provides many public service announcements that discourage pruning or removing trees near powerlines and the utility requires notification to perform or determine approved vegetation management : **71% [Applies to Hydro One]**
- A rate of occurrence is unknown for electrical contacts involving vegetation, powerlines and non-line clearance workers or members of the public: **67% [Applies to Hydro One]**
- The utility company provides electrical hazards awareness training to non-line clearance arborists in the service territory: **19%**

- The utility does not frequently and/or effectively communicate the safety concerns of trees and power lines: **19%**
- The utility is alerted anytime an electrical contact is reported by the media: **0%**
- A study of non-line clearance tree companies has been performed by the utility to determine the percent of tree workers who have had electrical contacts: **0%**

One utility commented: The utility is notified of incidents, but **UVM is not alerted** of all incidents that occur.

State the number of known electrical contacts involving vegetation that have occurred in the utility service territory over the past 5 years:

- One utility stated "**0"**
- I don't know how many electrical contacts we've had in the last 5 years, but we have them occasionally. Probably not more than 1 or 2 per year. They are almost [always] a result of error on the part of the person contacting the system and not a result of poor maintenance or system defects.
- The rest stated that they do not know or the information is not available

Conclusion:
Electrical contact incidents involving non-utility workers or the public is not measured or available to the UVM department.

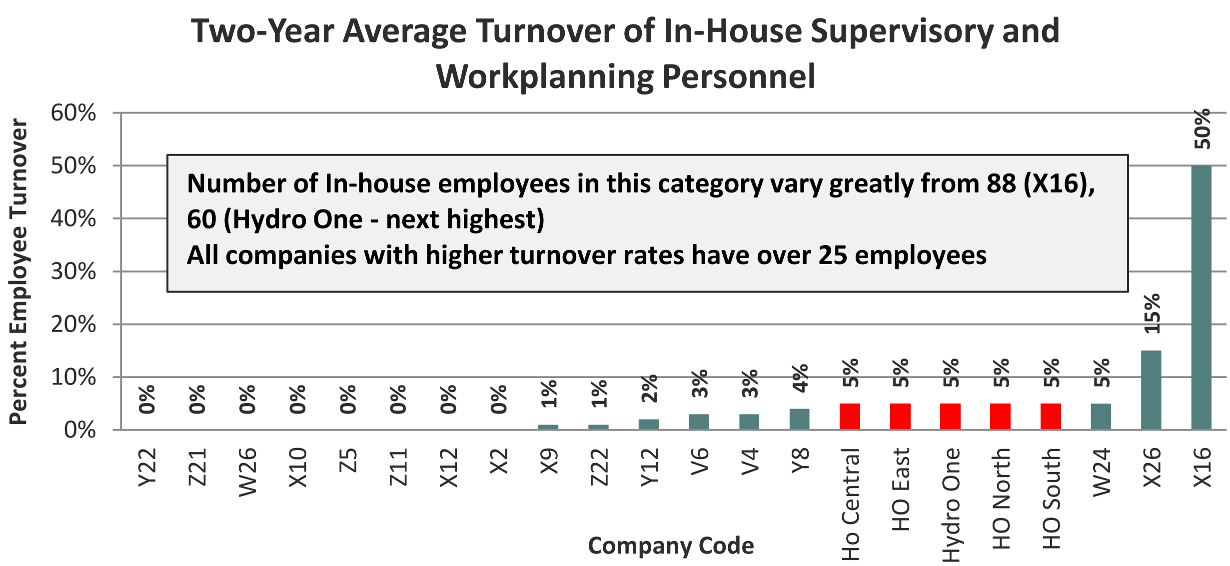
Safety Statistics

Employee Turnover

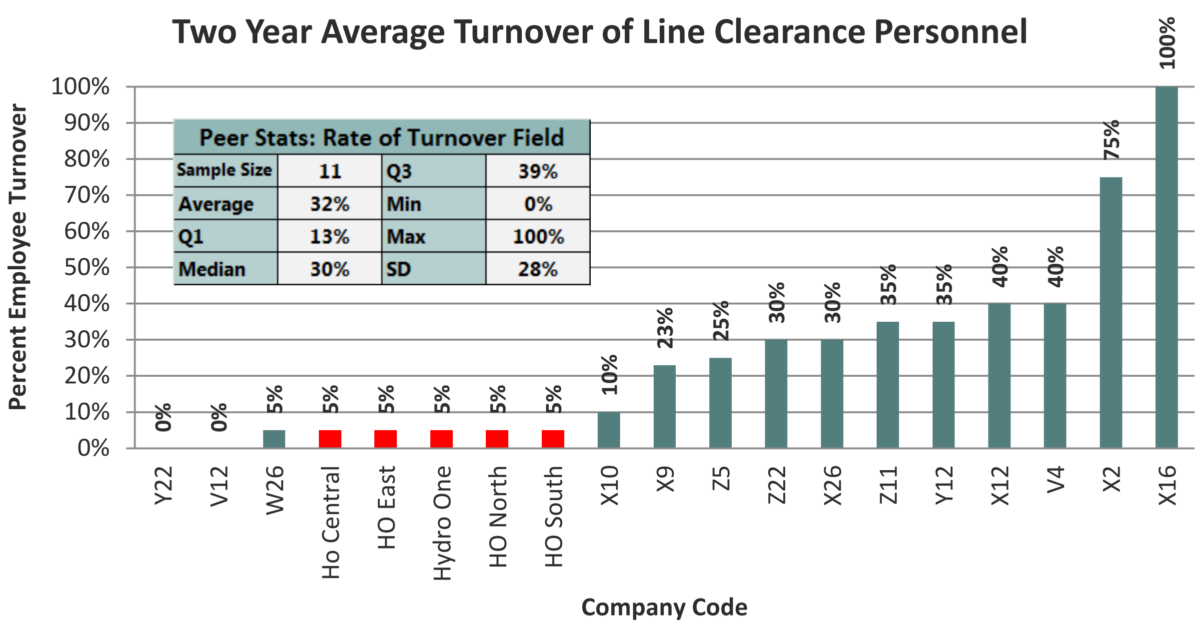
Since there is not a consistent way to measure safety in the UVM industry other than incidents, which are lagging indicators, CNUC looked at employee turnover as an gauge of a safety culture.
The following two quotes identify that employee turnover can be used as a safety measure:

> *While there are certainly more precise and scientific measures of safety culture, I believe that turnover rates provide the best quick, easy, and cheap "snapshot" of an organizations' culture. — Dave Weber, a former Safety and Environmental Manager and founder of Safety Awakenings*
>
> *When temporary workers have to be continually replaced, their impact on profitability includes: . . .*
>
> - ***Safety** (Bureau of Labor Statistics [shows a correlation between] accidents and safety violations increases proportionately to employee turnover) . . .*
> - ***Training . . .***
> - ***Productivity . . .***
>
> http://www.insourceperforms.com/news/employee-turnovers-impact-on-your-budget

Since Hydro One is the only utility in the survey (and there are very few in the industry as a whole) that performs UVM completely in-house, the turnover rates are divided into in-house (non-clearance activities) and contracted line-clearance personnel. The line-clearance employees are confronted with more safety issues than the non-clearance personnel of the UVM department, so the second graph is of greater significance to the discussion of safety.



Graph 96: Two-Year Average Turnover of In-House Supervisory and Work-planning Personnel

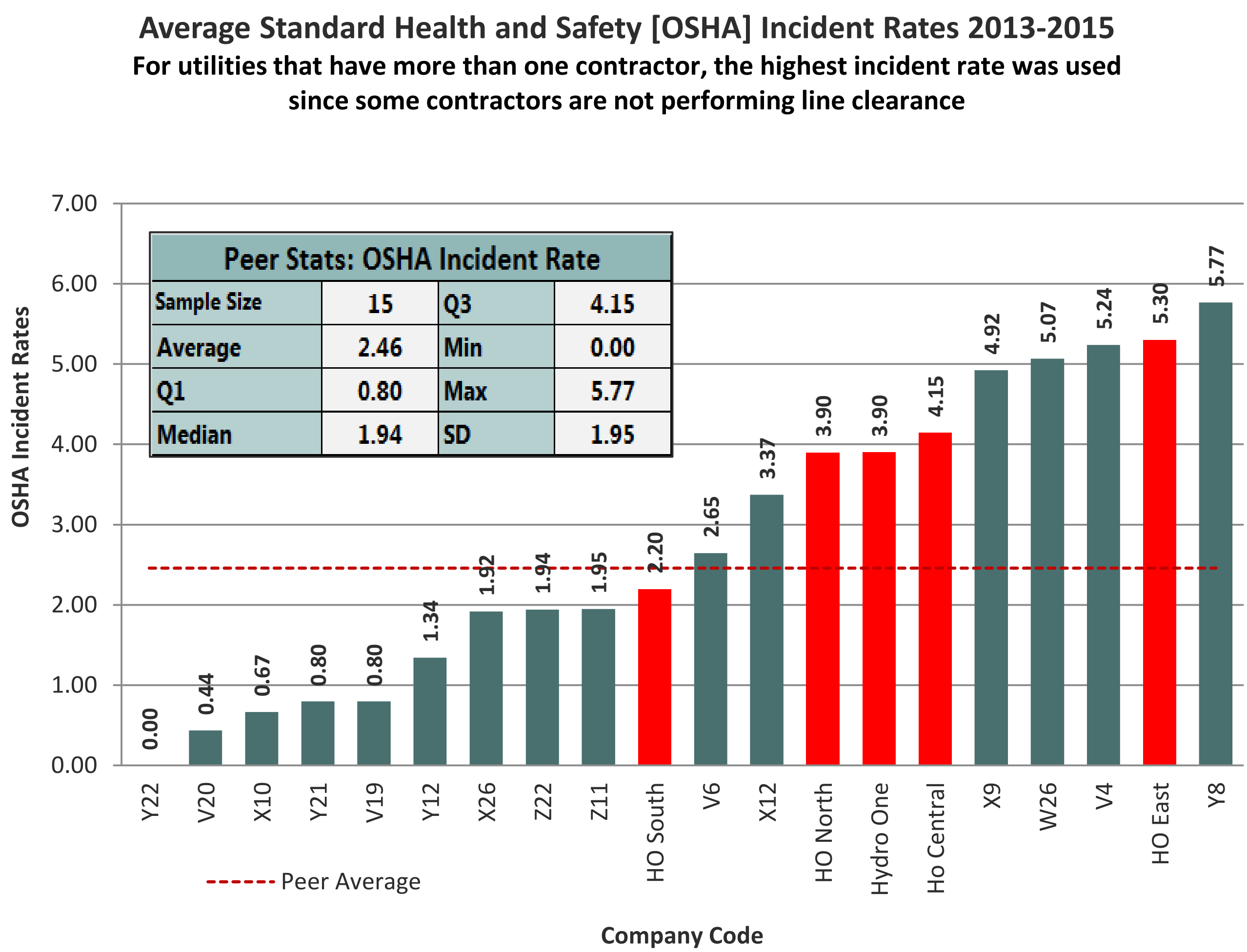


Graph 97: Two-Year Average Turnover of Line Clearance Personnel

Safety Statistics

Incident rates are shown in the next graph by company. Most of the statistics for this graph have been gathered by the contractors and reported to the utility. Since Hydro One is all in-house employees, the information is gathered by Hydro One.

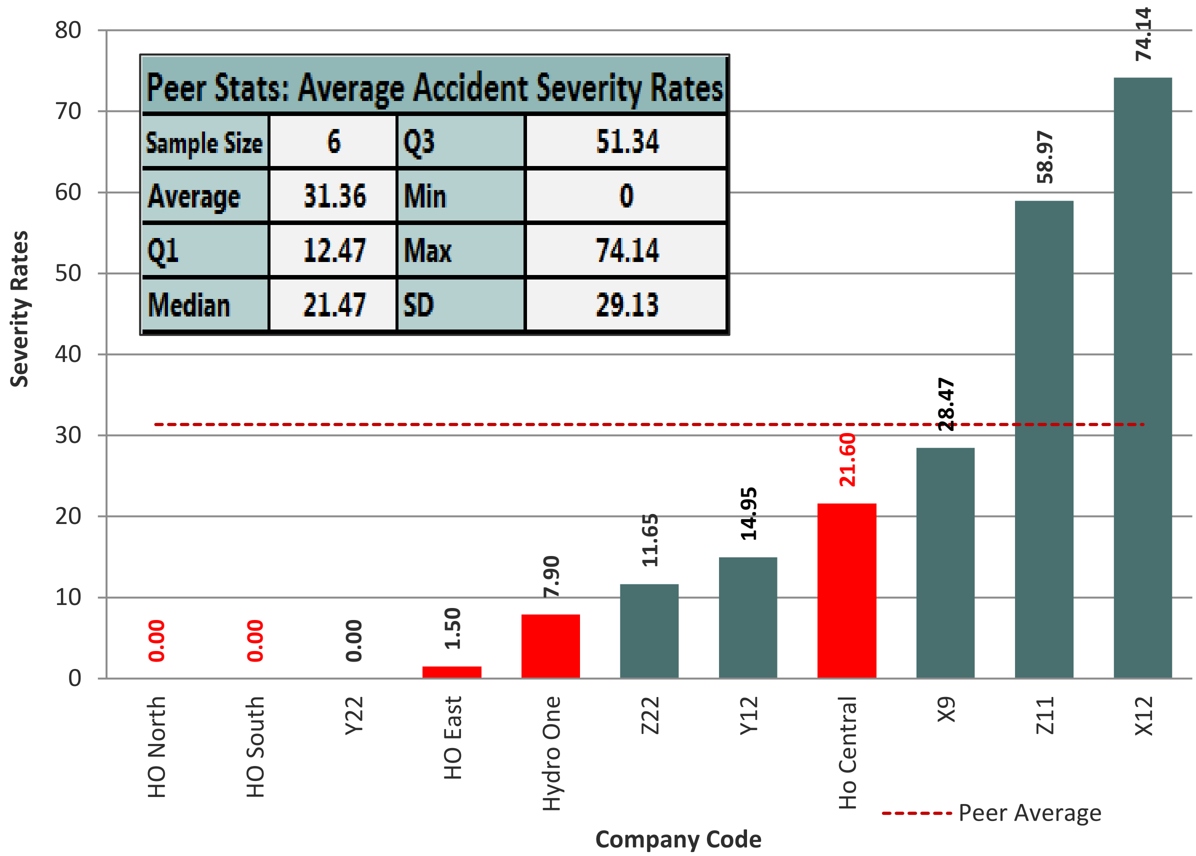
Incident rates vary from severity rates in that an incident may be reported, but very little work time is lost if the incident was not significant to the health of the worker. OSHA incident statistics are the most common form of reporting and only tells part of the story. Unfortunately, the severity rate was not reported by as many utilities, but the sample is adequate to derive some statistics.



Graph 98: Average Standard Health and Safety [OSHA] Incident Rates 2013-2015

Average Accident Severity Rates 2013 - 2015

For utilities that have more than one contractor, the highest incident rate was used since some are not performing line clearance

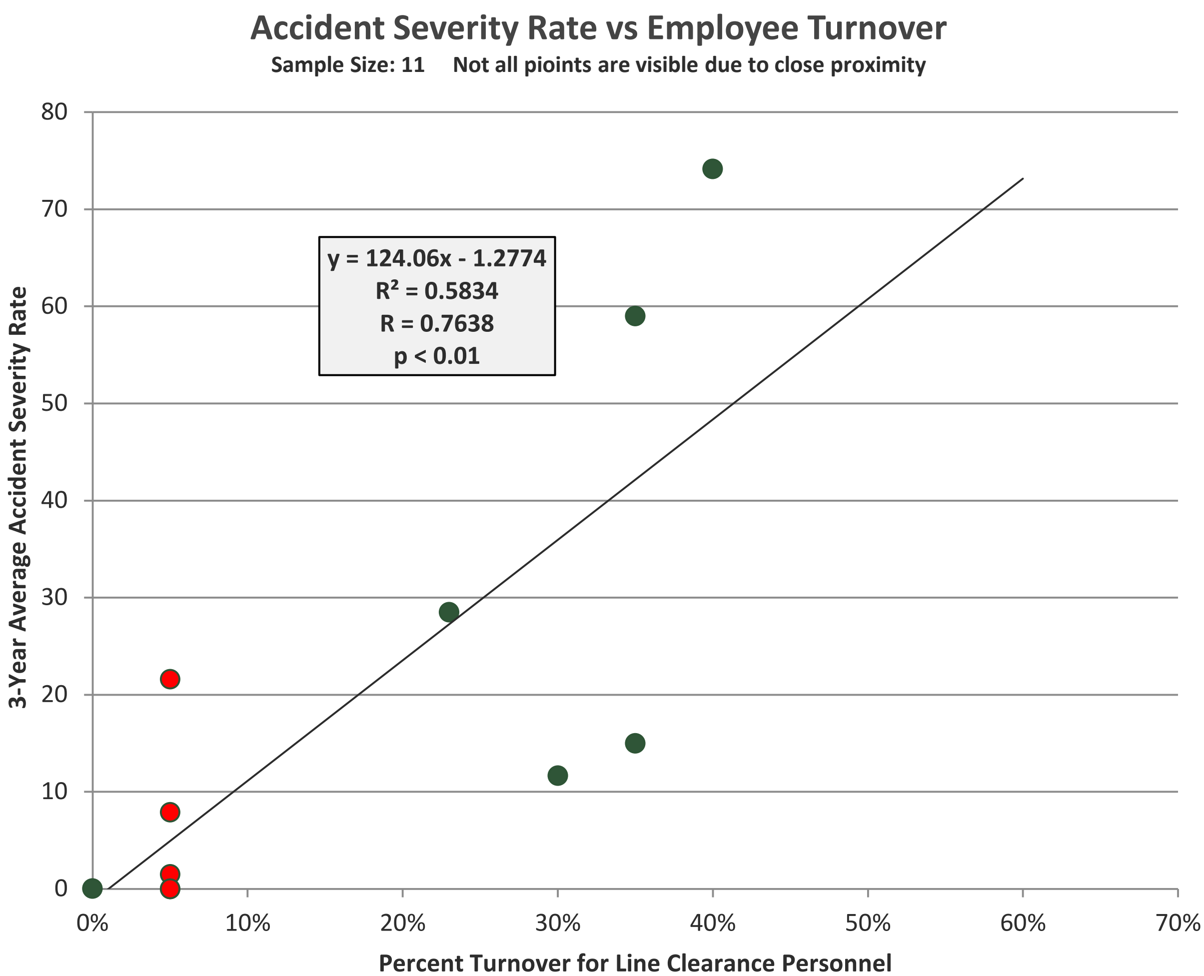


Peer Stats: Average Accident Severity Rates			
Sample Size	6	Q3	51.34
Average	31.36	Min	0
Q1	12.47	Max	74.14
Median	21.47	SD	29.13

Graph 99: Average Accident Severity Rates 2013-2015

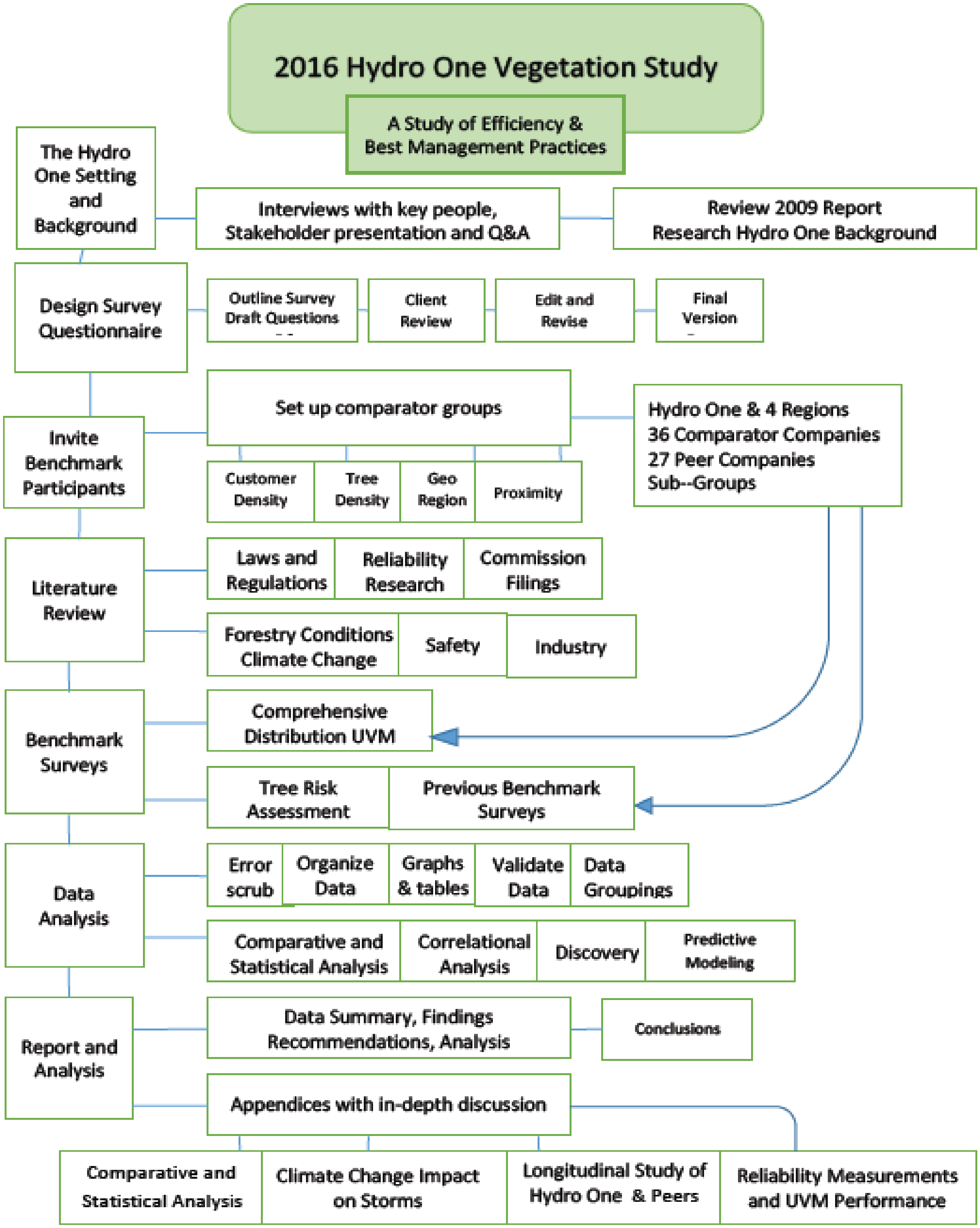
Correlation between Employee Turnover and Safety Severity Rate

A significant correlation can be drawn between employee turnover rates and incident severity rates. Hydro One is identified by red data points. Sample limited to companies that supplied turnover rates and incident severity rates.



Graph 100: Accident Severity Rate vs Employee Turnover

Appendix I: Benchmark Study Process Chart



Appendix J: Longitudinal and Comparative Analysis of Hydro One Regions Data and Peer Data

INTRODUCTION

All the graphical and tabular representations are derived from Hydro One and Peer data collected in the *2015 CNUC Distribution Benchmark Survey*. CNUC has included data from previous CNUC UVM benchmark surveys and from the CNUC *Hydro One 2009 -Vegetation Management Benchmark Study* that was submitted to the Ontario Energy Board in September 2009.

Regional studies of Hydro One's territory include 2009 data, which had separated Hydro One into three regions. The original regions were the South, the North and the East. The current study has four regions with the addition of the Central region. The Central region was created by taking a portion of each of the original three regions. CNUC has taken the percent of the electrical system removed from each of the original three regions to understand trends for the current four divisions. By proportioning regional data from 2009 to the current regional makeup, CNUC was able to compare information dating back to 2008 with a two year gap (2009 and 2010) in these comparisons.

Most of the graphs and tables in this appendix are longitudinal (over time). Some analysis for trends in the data has also been included in this appendix.

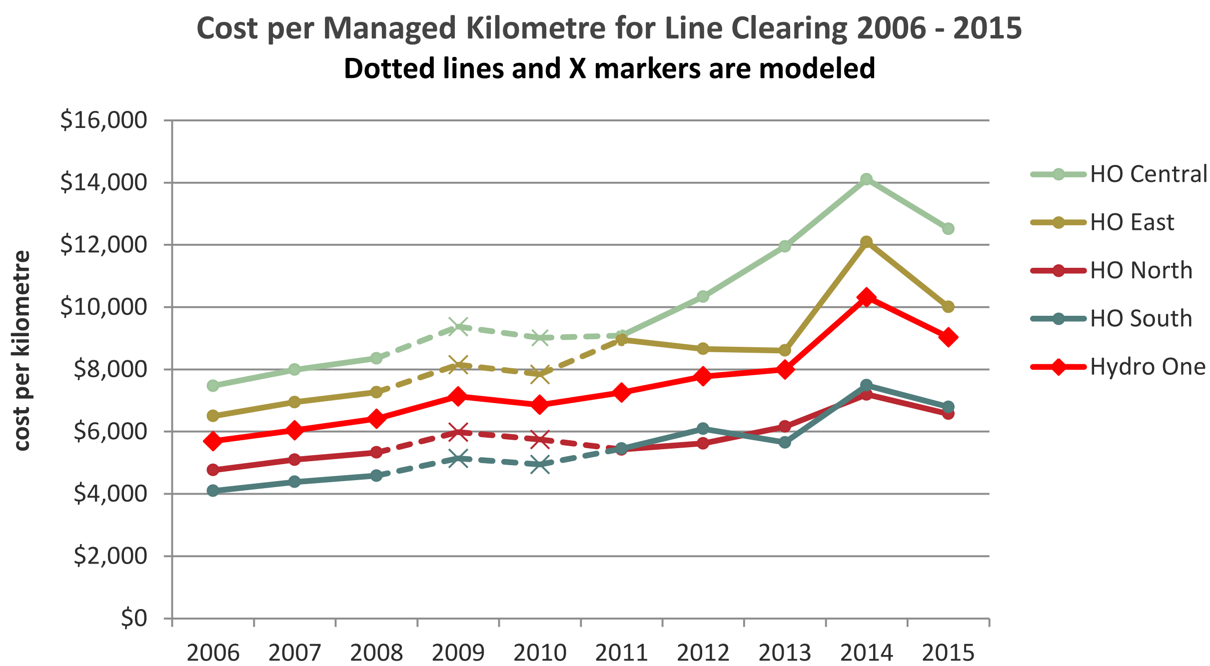
The following concepts are important for interpreting the graphical results:

- "Per System Kilometre"
- "Per Managed Kilometre"

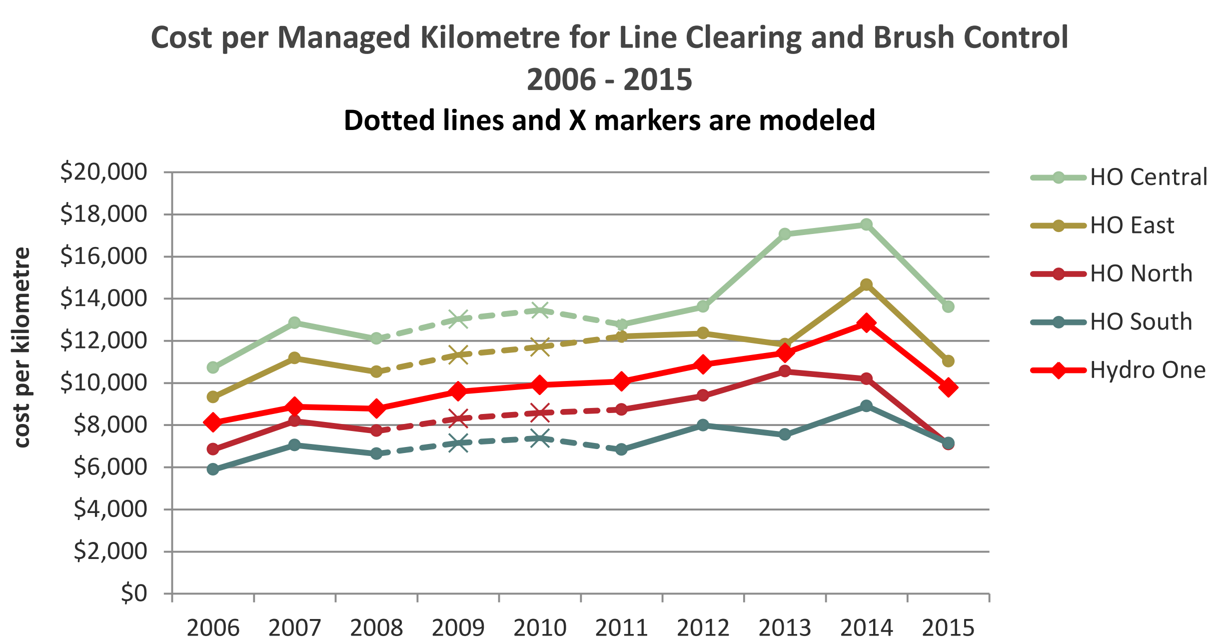
Graph and table numbers in this appendix vary from labels in the main report and other accompanying appendices.

HYDRO ONE REGIONAL FINANCIAL AND LABOR HOUR COMPARISONS

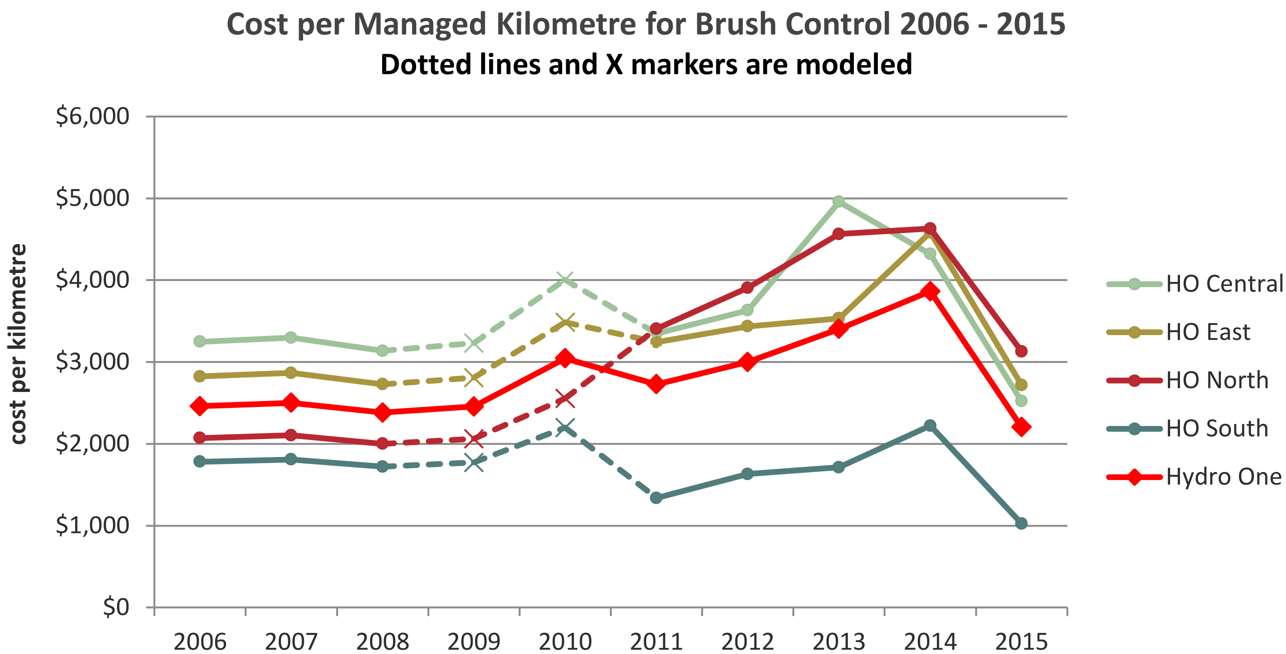
Hydro One UVM Expenditures



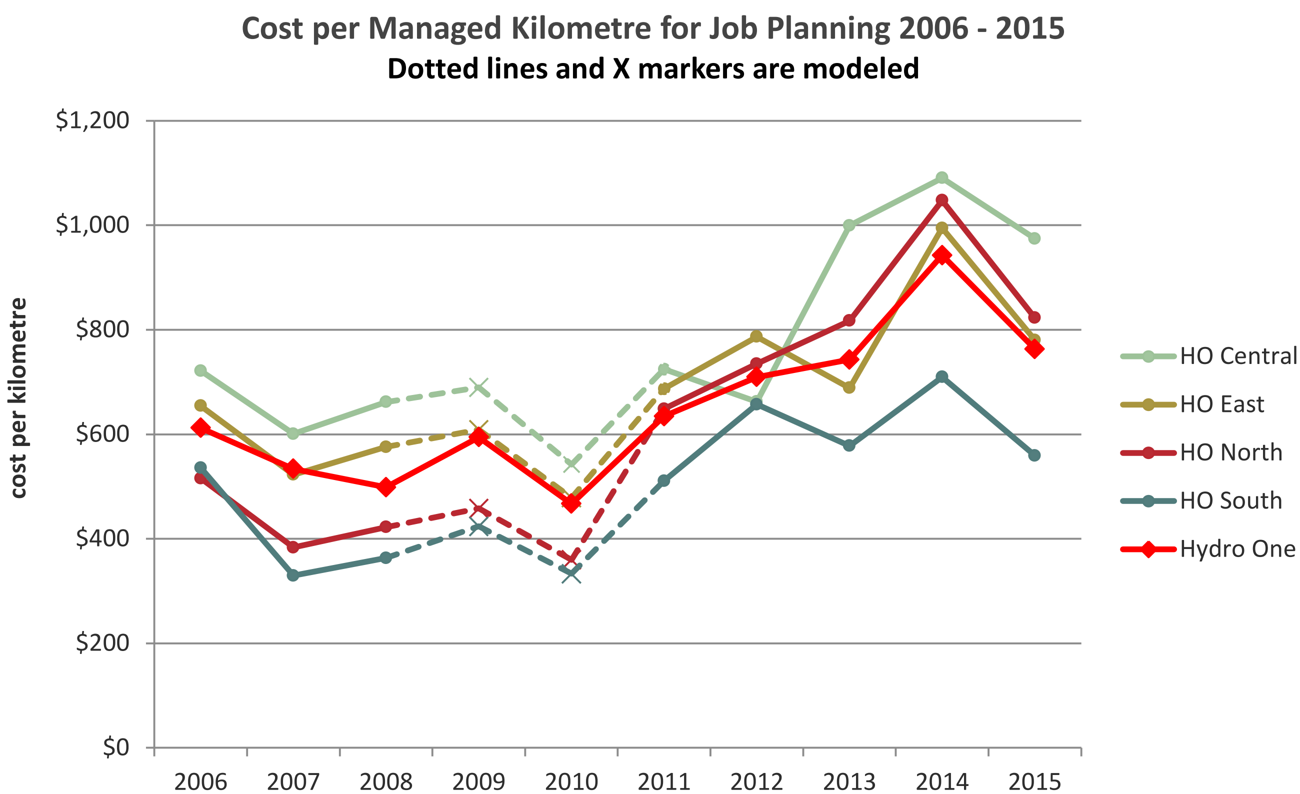
Graph 101: Cost per Managed Kilometre for Line Clearing 2006 – 2015



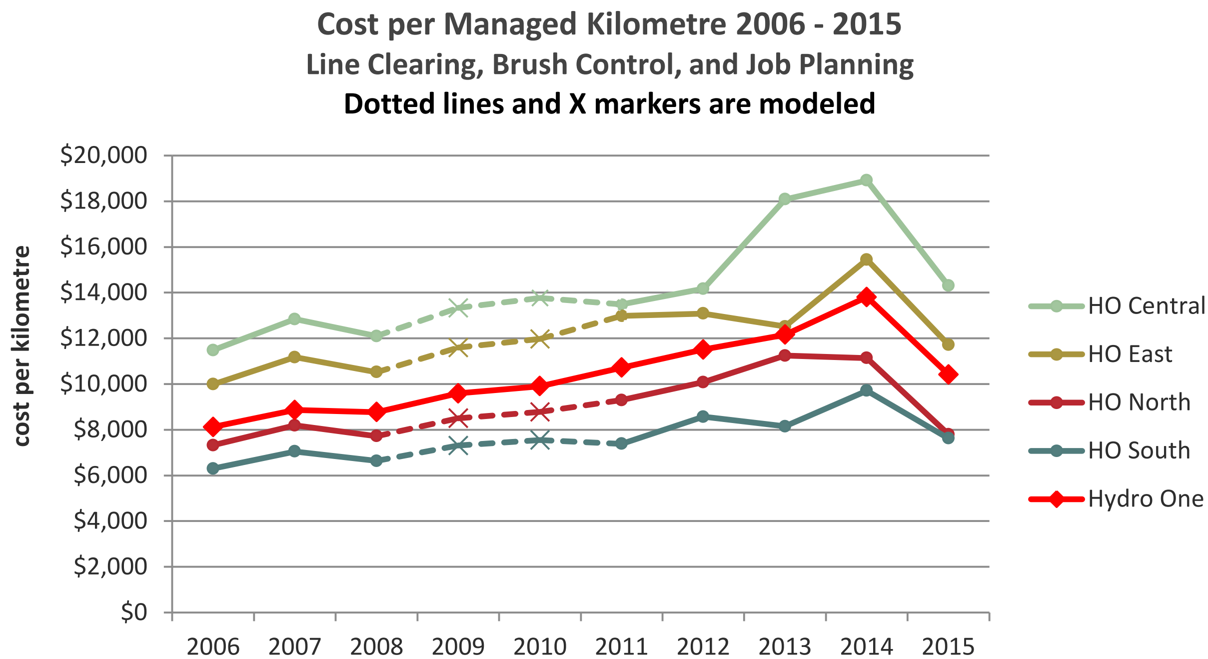
Graph 102: Cost per Managed Kilometre for Line Clearing and Brush Control 2006 - 2015



Graph 103: Cost per Managed Kilometre for Brush Control 2006 - 2015

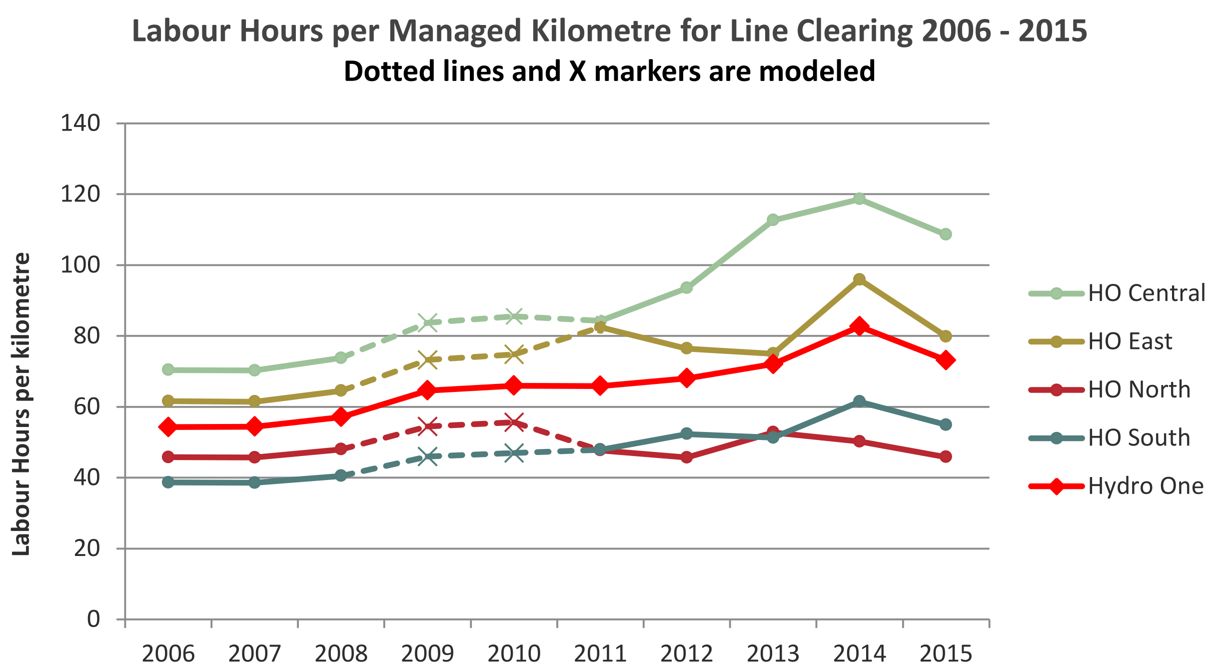


Graph 104: Cost per Managed Kilometre for Job Planning 2006 – 2015

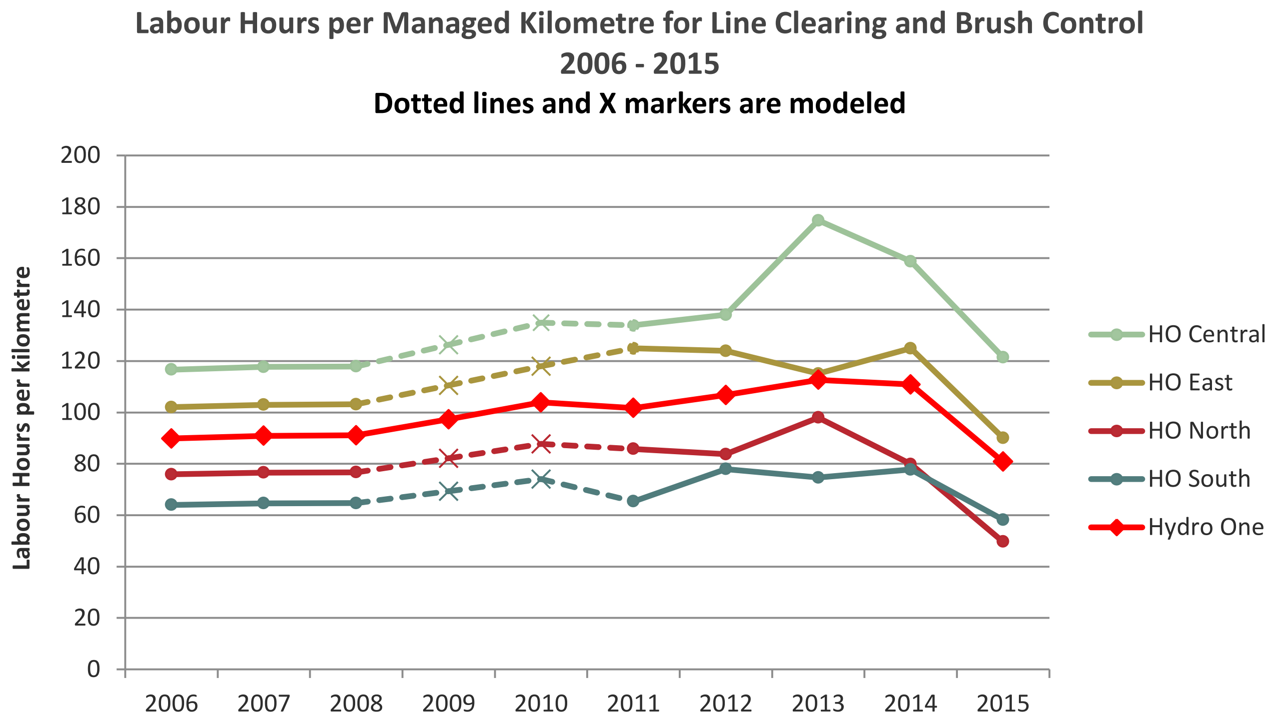


Graph 105: Cost per Managed Kilometre 2006 - 2015

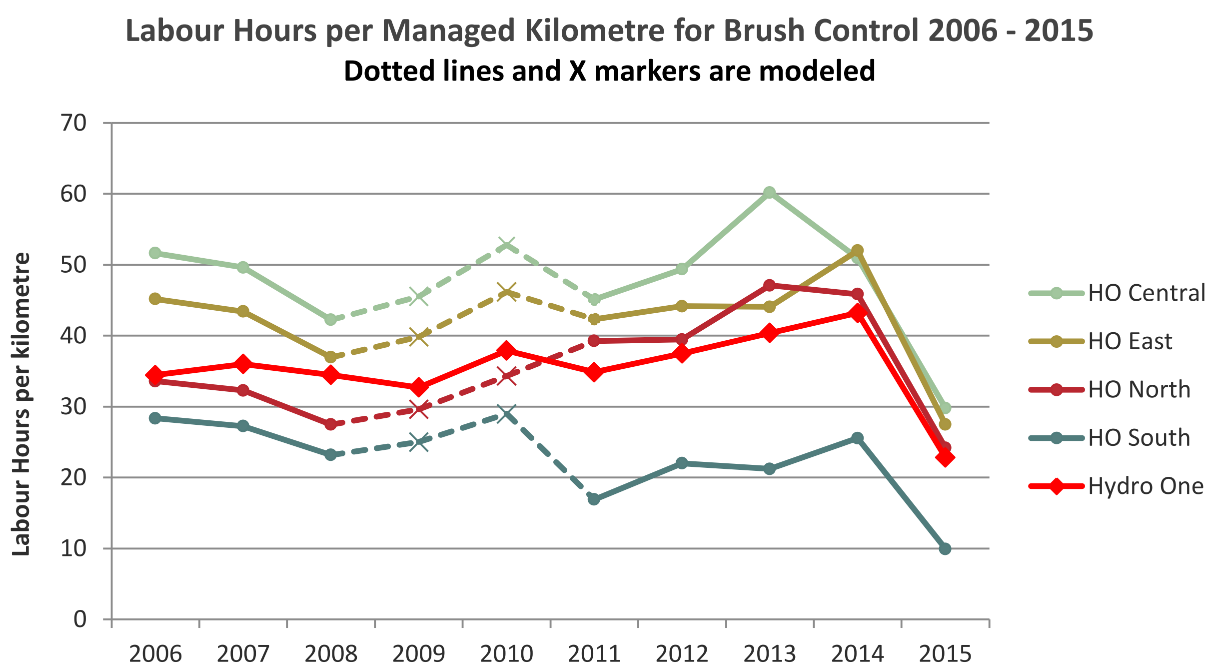
- *Hydro One UVM Labour Hours Expended*



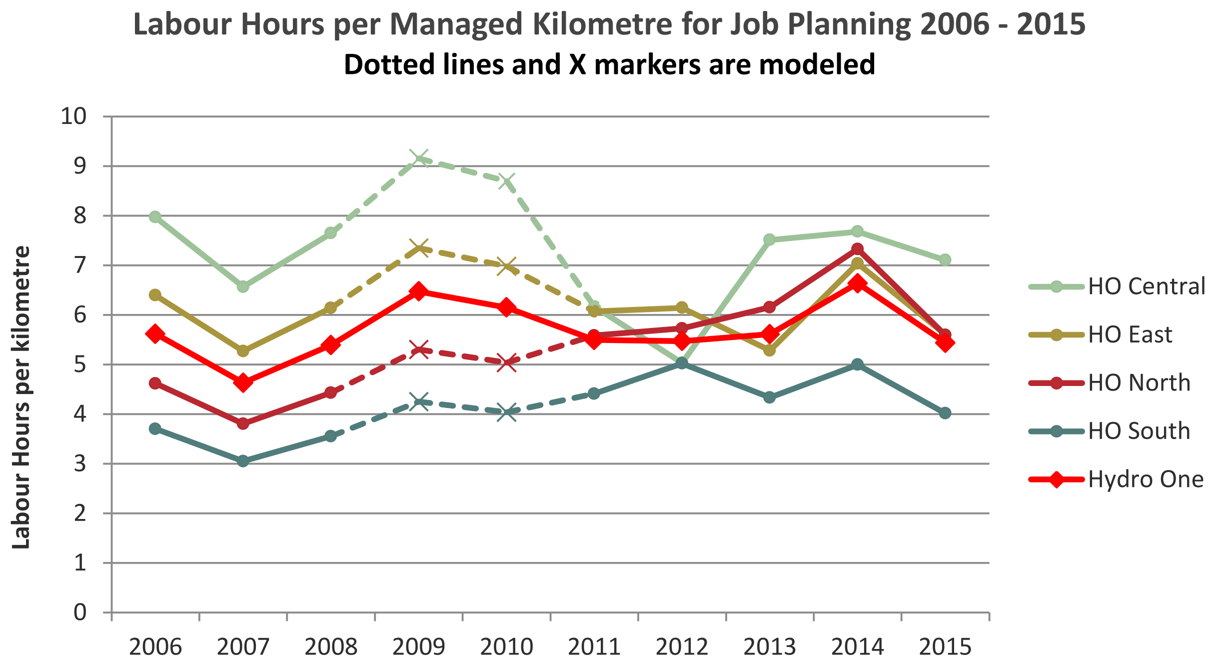
Graph 106: Labour Hours per Managed Kilometre for Line Clearing 2006 - 2015



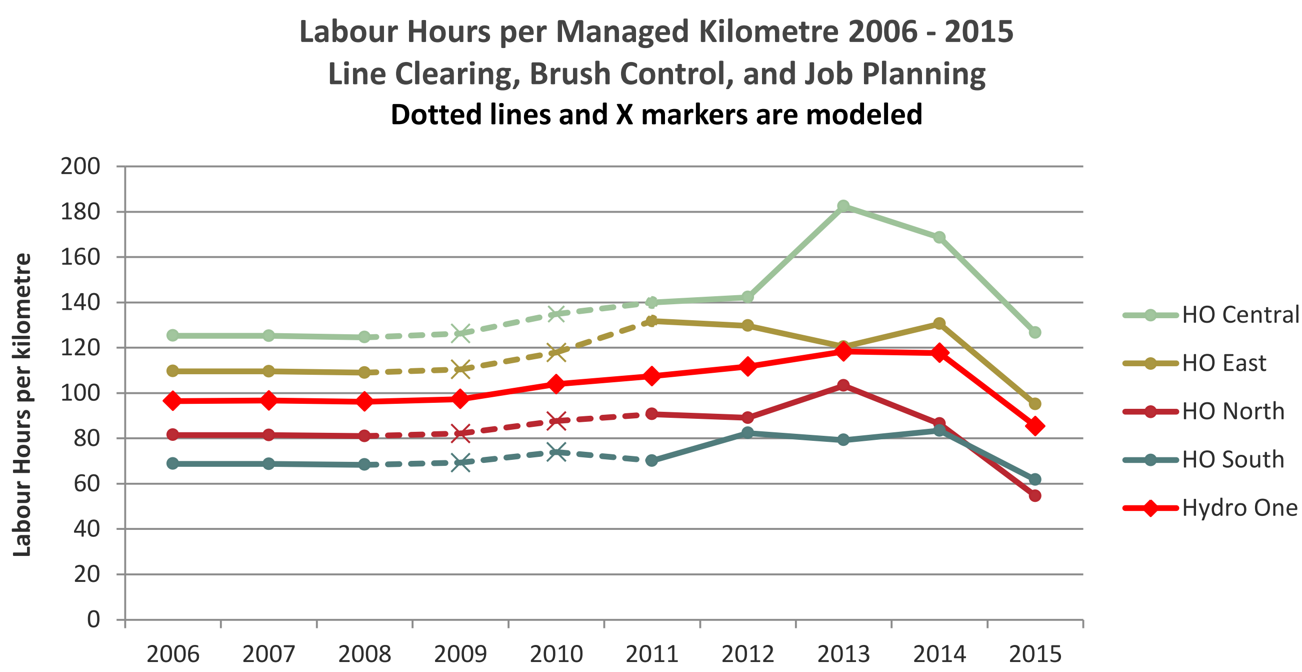
Graph 107: Labour Hours per Managed Kilometre for Line Clearing and Brush Control 2006 - 2015



Graph 108: Labour Hours per Managed Kilometre for Brush Control 2006 - 2015

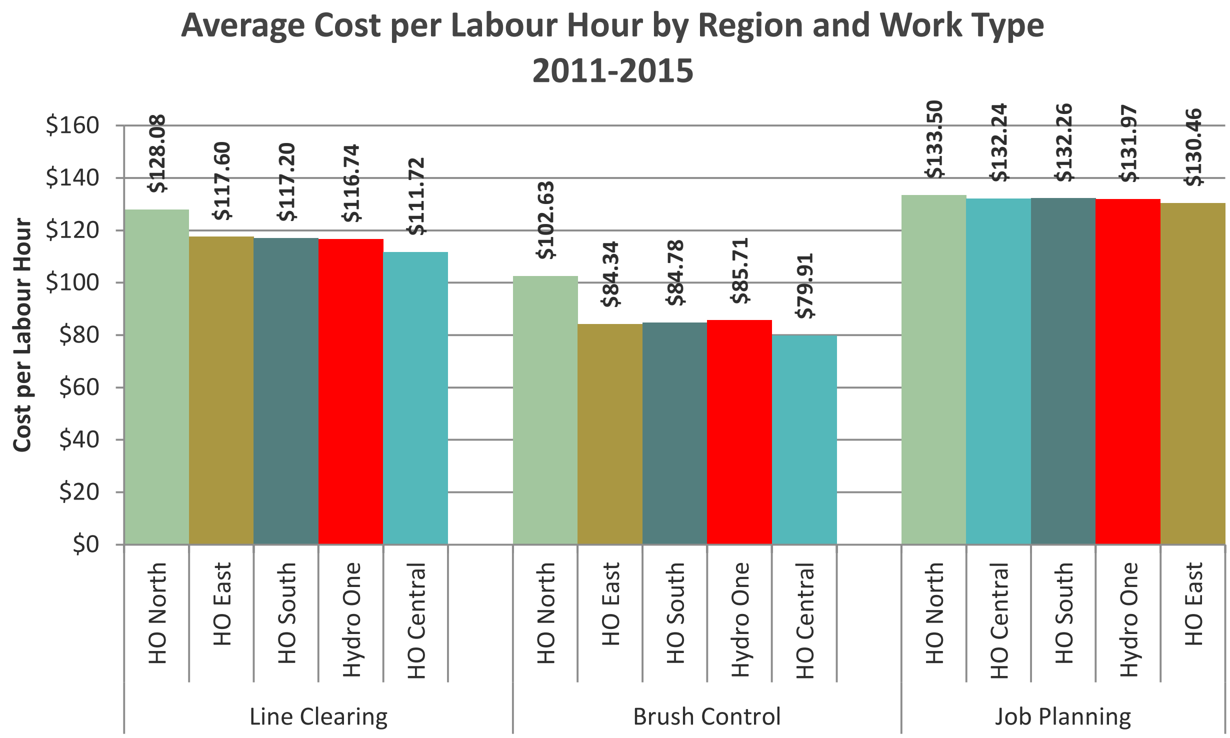


Graph 109: Labour Hours per Managed Kilometre for Job Planning 2006 – 2015

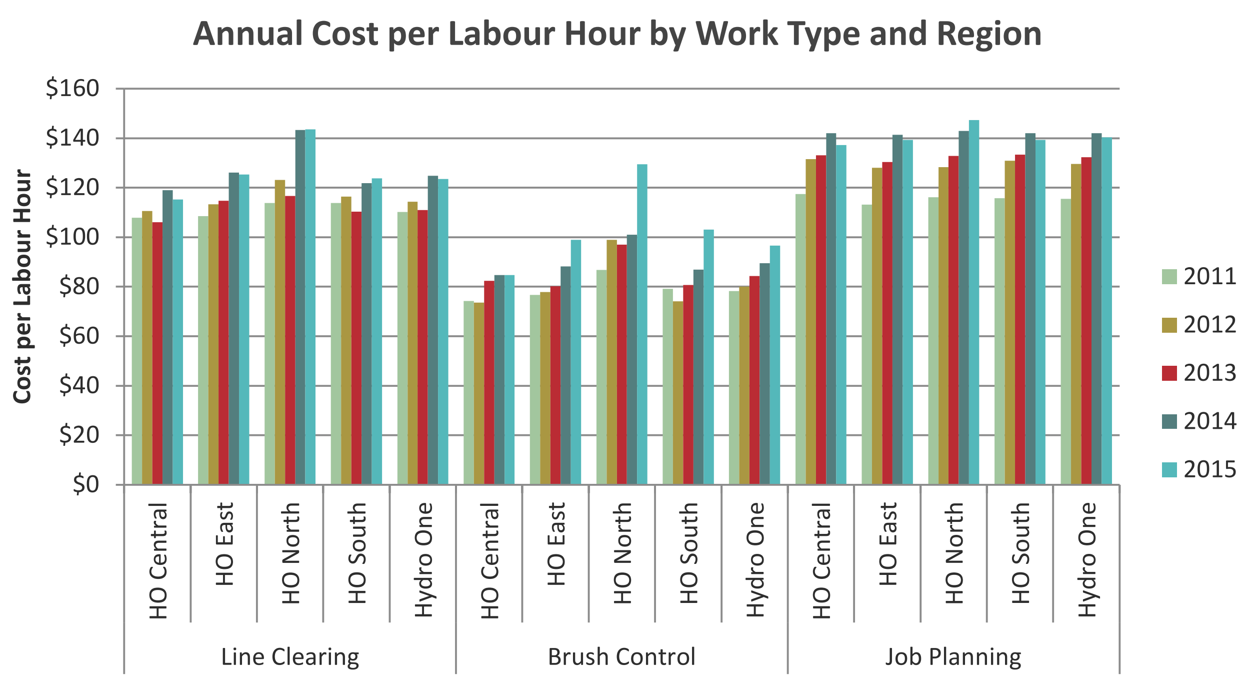


Graph 110: Labour Hours per Managed Kilometre

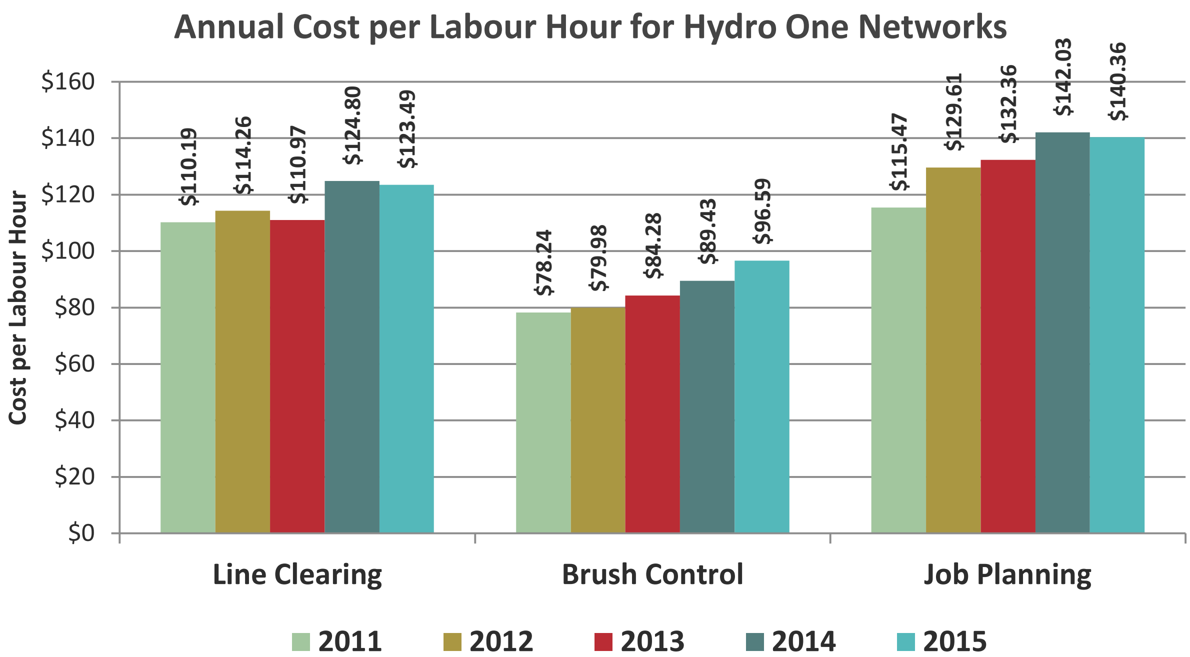
Hydro One Cost per Labour Hour



Graph 111: Average Cost per Labour Hour by Region and Work Type 2011-2015



Graph 112: Annual Cost per Labour Hour by Work Type and Region



Graph 113: Annual Cost per Labour Hour for Hydro One Networks

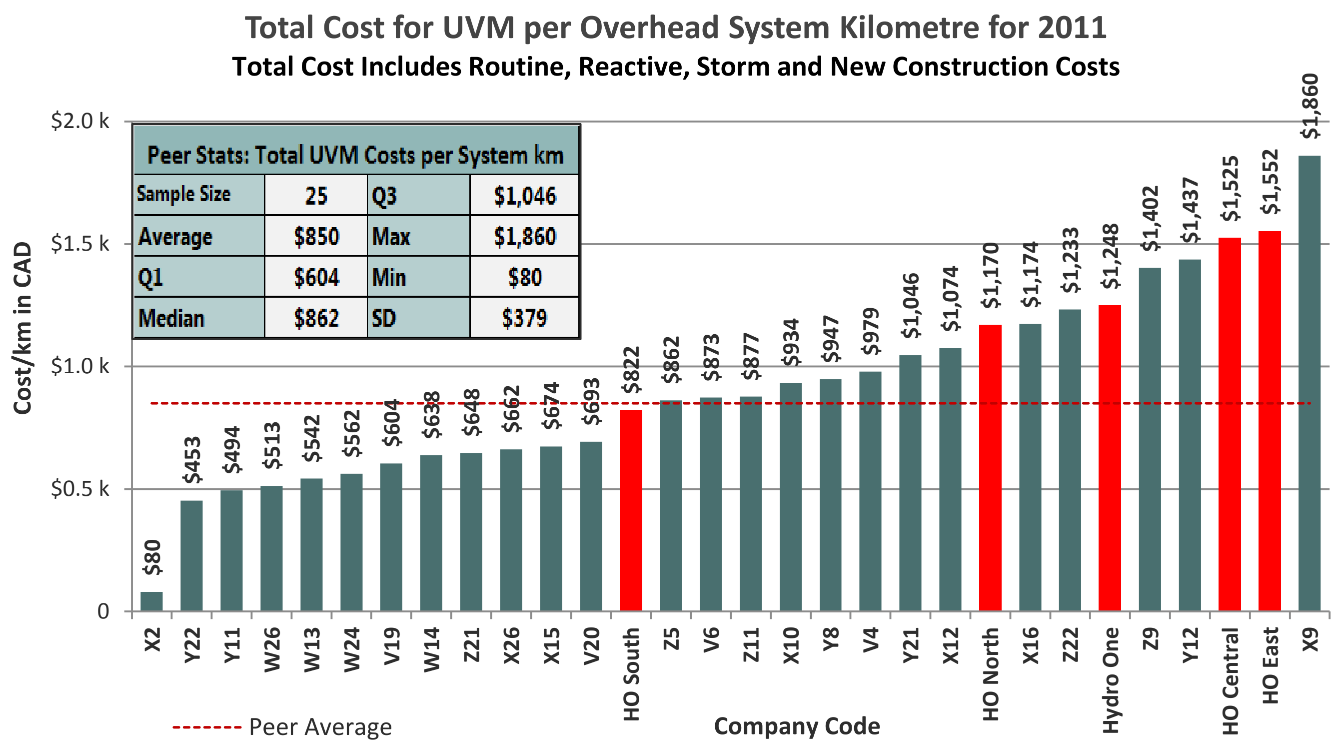
FINANCIAL AND LABOUR HOUR LONGITUDINAL COMPARISONS WITH PEER UTILITIES

UVM Expenditures 2011-2015

Total UVM Expenditures per Distribution Overhead System Kilometre

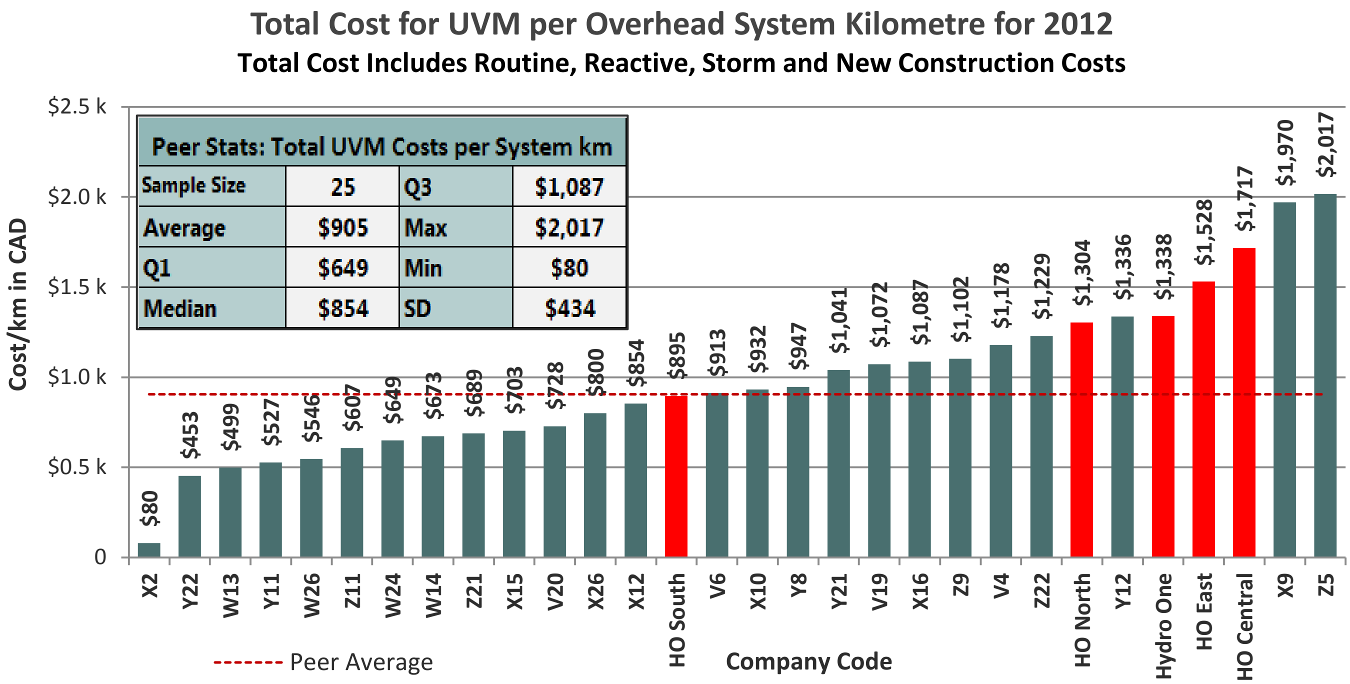
Yearly Total UVM Expenditures Comparisons per System Kilometre for Years 2011-2015

Total Cost Includes Routine, Reactive, Storm and New Construction Costs
It should be noted that not all companies capture their storm or new construction costs in this metric.

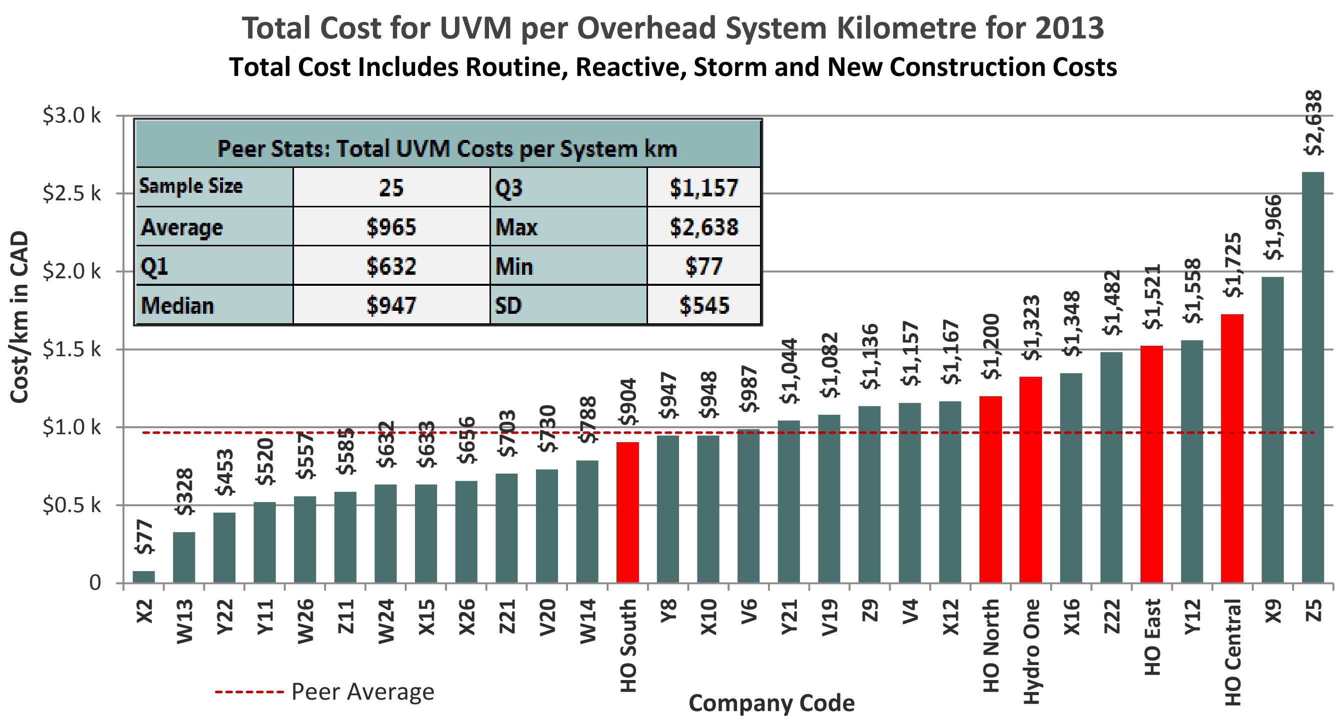


Peer Stats: Total UVM Costs per System km			
Sample Size	25	Q3	$1,046
Average	$850	Max	$1,860
Q1	$604	Min	$80
Median	$862	SD	$379

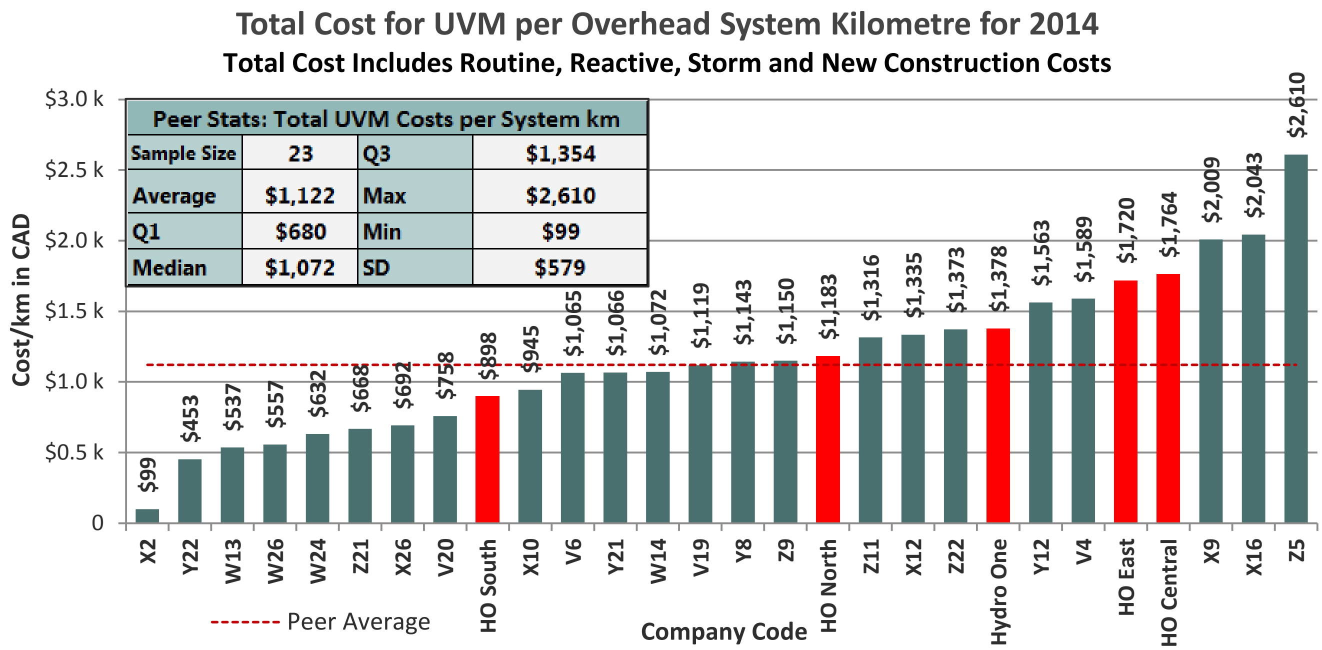
Graph 114: Peer Comparisons of Total Cost for UVM per Overhead System Kilometre for 2011



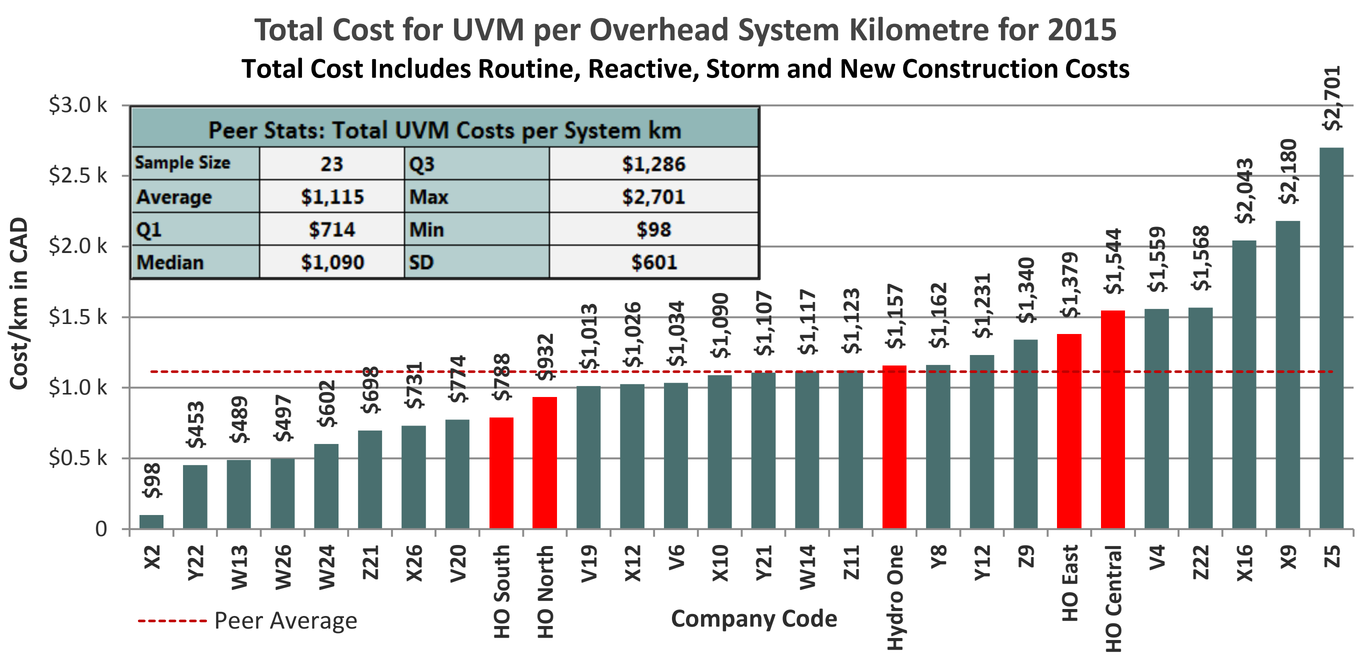
Graph 115: Peer Comparisons of Total Cost for UVM per Overhead System Kilometre for 2012



Graph 116: Peer Comparisons of Total Cost for UVM per Overhead System Kilometre for 2013

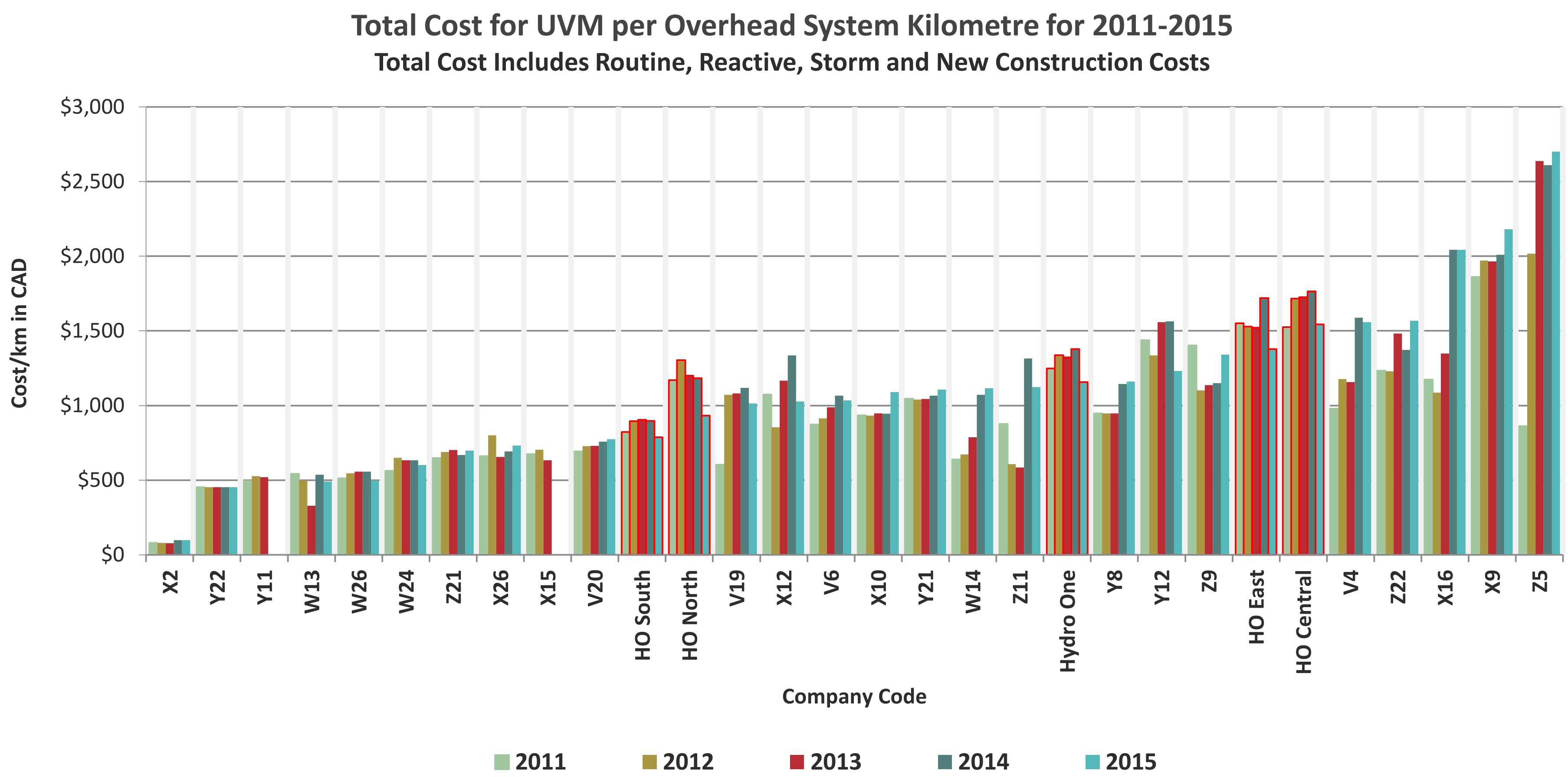


Graph 117: Peer Comparisons of Total Cost for UVM per Overhead System Kilometre for 2014

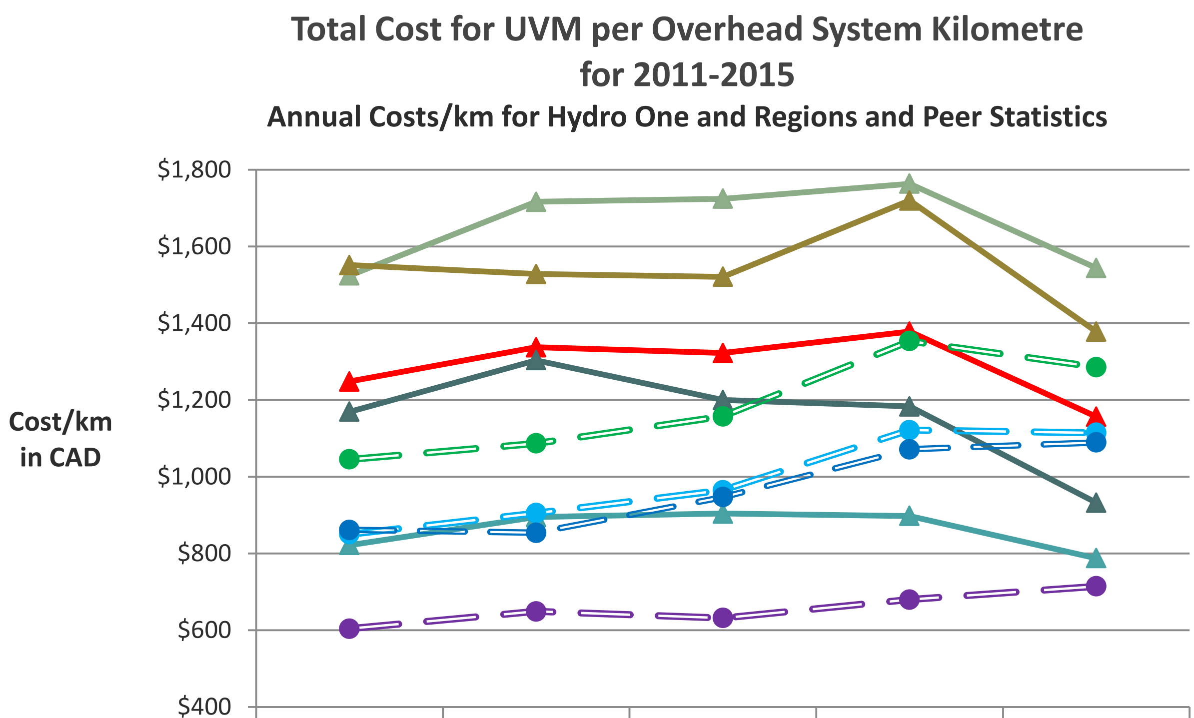


Graph 118: Peer Comparisons of Total Cost for UVM per Overhead System Kilometre for 2015

Total UVM Cost per Overhead System Kilometre Comparisons with Peers 2011-2015



Graph 119: Peer Comparisons of Total Cost for UVM per Overhead System Kilometre for 2011-205

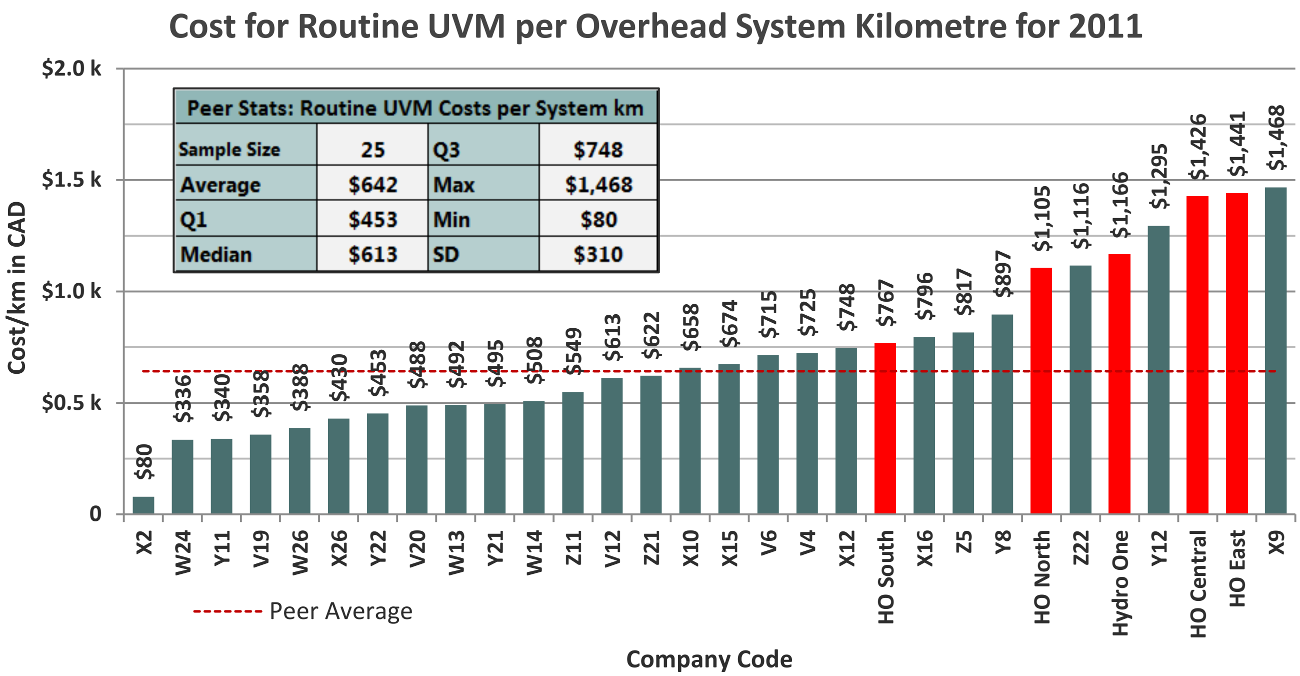


	2011	2012	2013	2014	2015
HO Central	$1,525	$1,717	$1,725	$1,764	$1,544
HO East	$1,552	$1,528	$1,521	$1,720	$1,379
Hydro One	$1,248	$1,338	$1,323	$1,378	$1,157
HO North	$1,170	$1,304	$1,200	$1,183	$932
HO South	$822	$895	$904	$898	$788
Peer Average	$850	$905	$965	$1,122	$1,115
Peer Q1	$604	$649	$632	$680	$714
Peer Median	$862	$854	$947	$1,072	$1,090
Peer Q3	$1,046	$1,087	$1,157	$1,354	$1,286

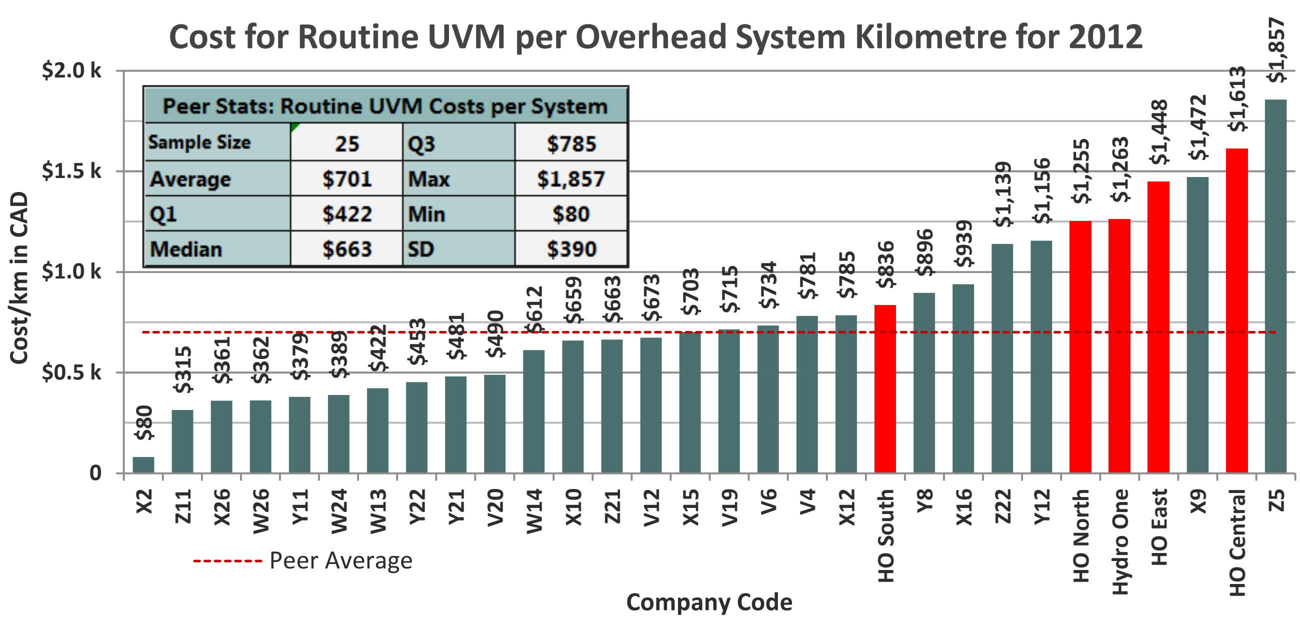
Graph 120: Annual Total UVM Cost per System Kilometre 2011-2015: Hydro One and Regions vs Peer Statistics

Routine Cost UVM Expenditures per System Kilometre

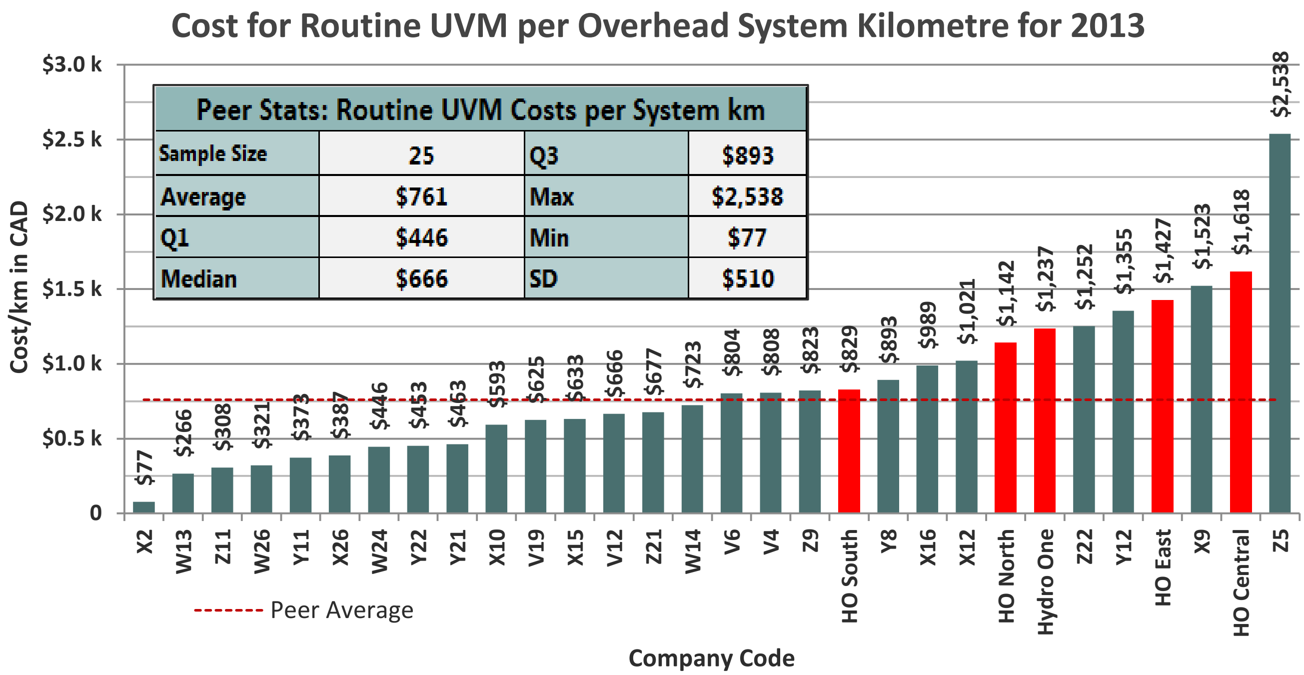
Yearly Routine UVM Expenditures Comparisons for Years 2011-2015



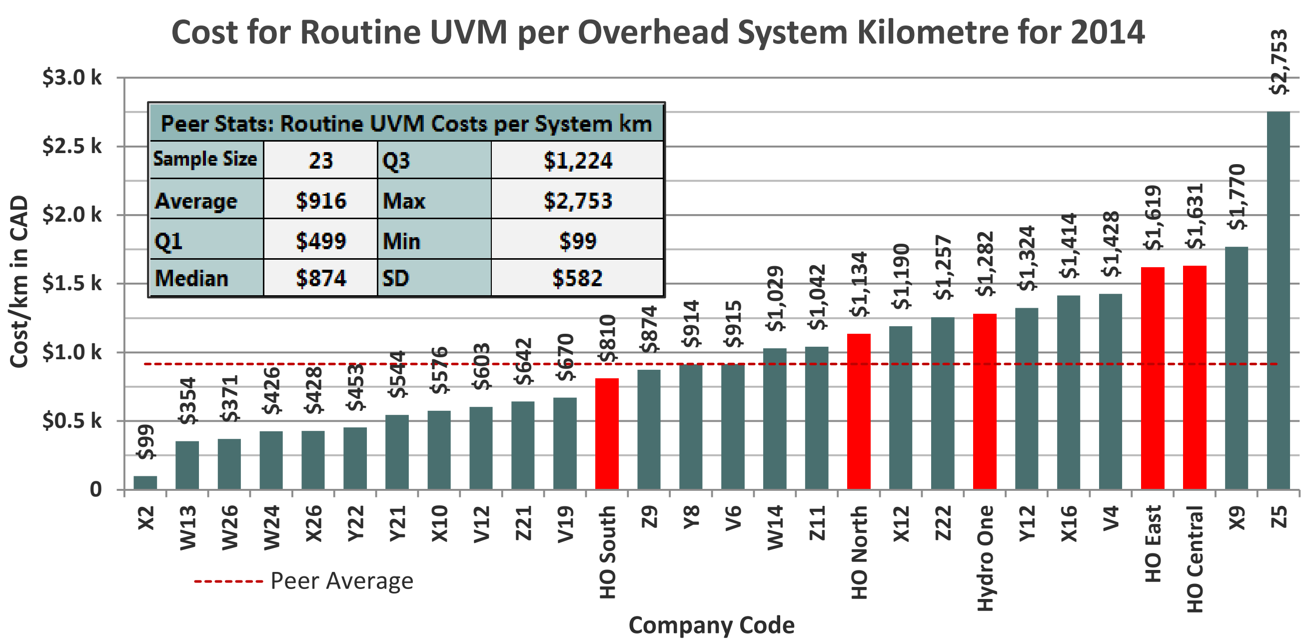
Graph 121: Peer Comparisons of Routine Cost for UVM per Overhead System Kilometre for 2011



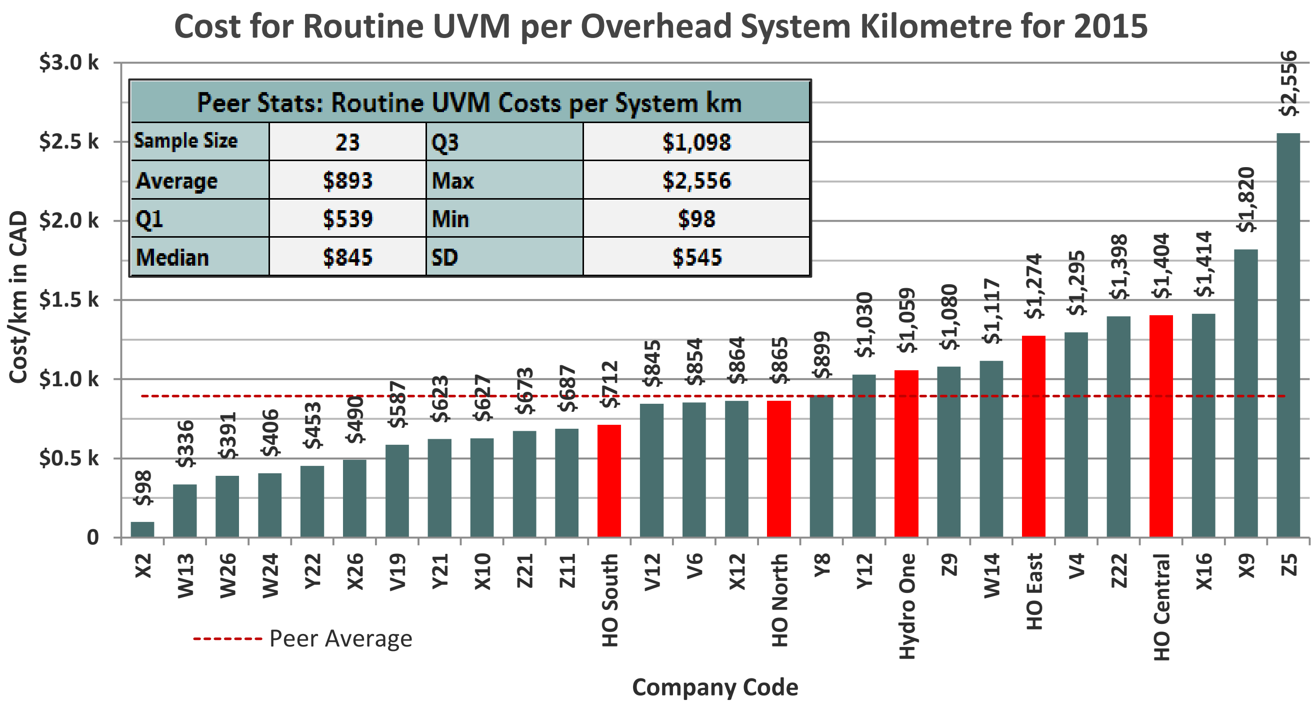
Graph 122: Peer Comparisons of Routine Cost for UVM per Overhead System Kilometre for 2012



Graph 123: Peer Comparisons of Routine Cost for UVM per Overhead System Kilometre for 2013

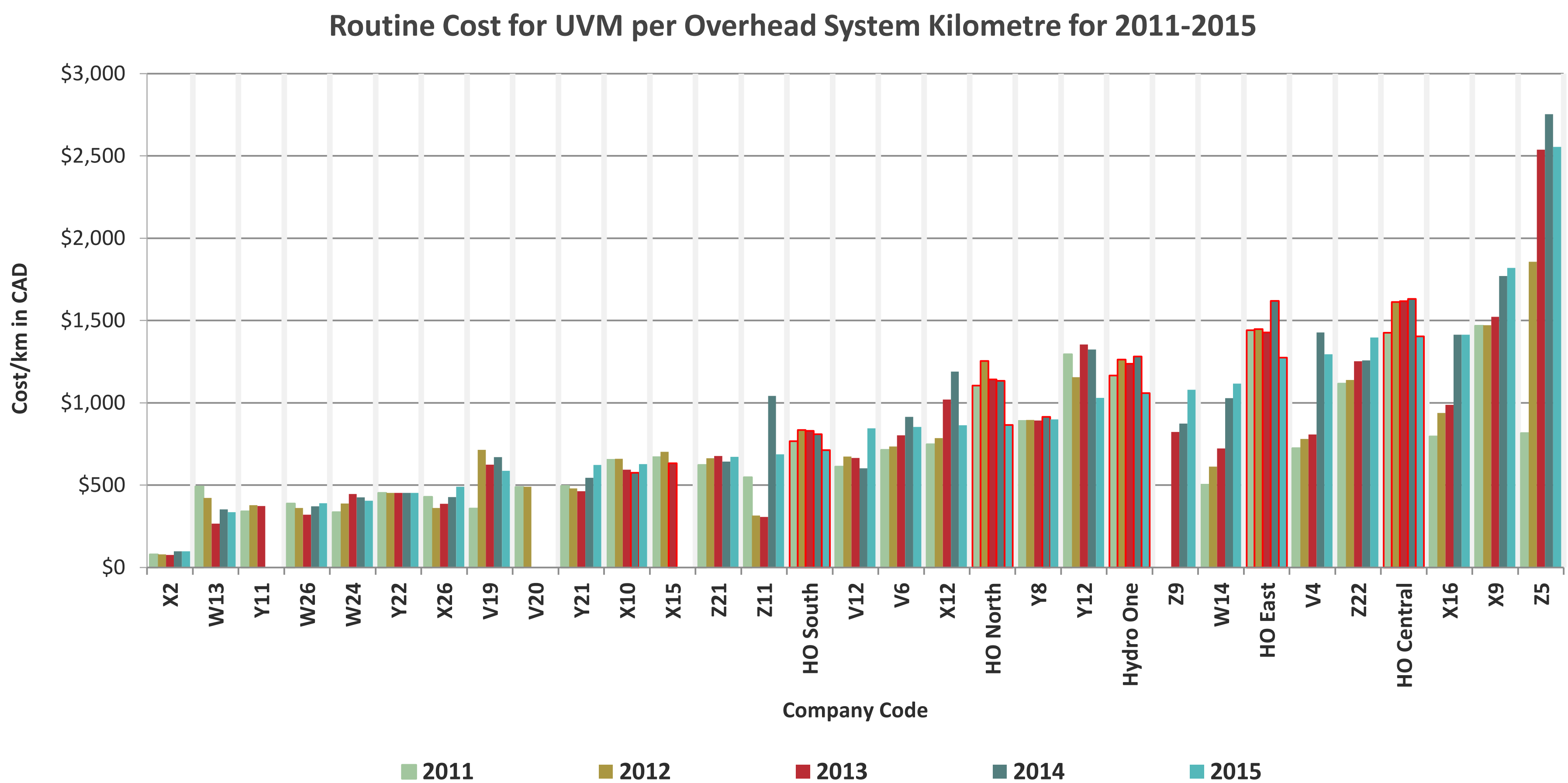


Graph 124: Peer Comparisons of Routine Cost for UVM per Overhead System Kilometre for 2014

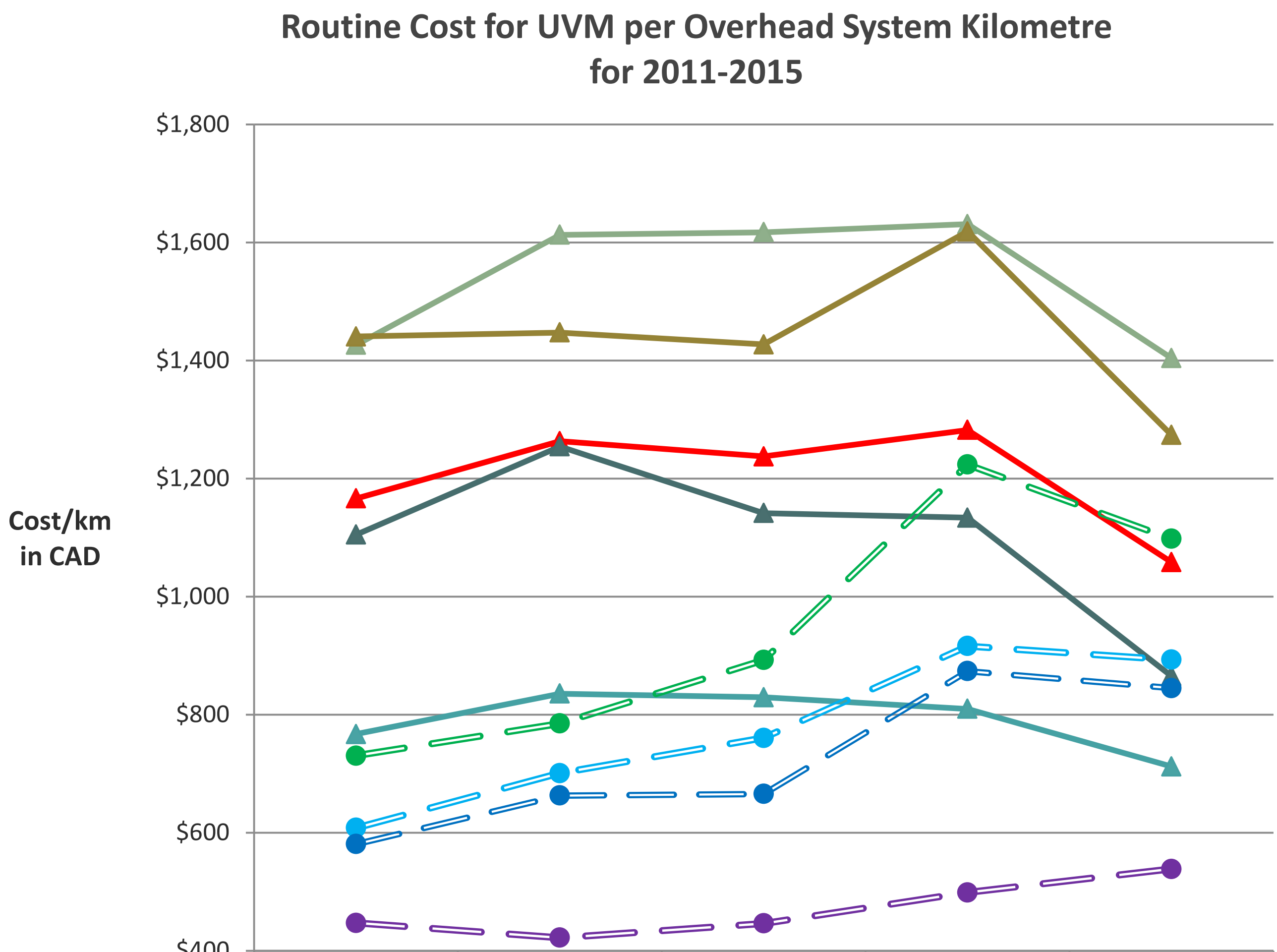


Graph 125: Peer Comparisons of Routine Cost for UVM per Overhead System Kilometre for 2015

Routine UVM Cost per System Kilometre Comparisons with Peers 2011-2015



Graph 126: Peer Comparisons of Routine Cost for UVM per Overhead System Kilometre for 2011-2015

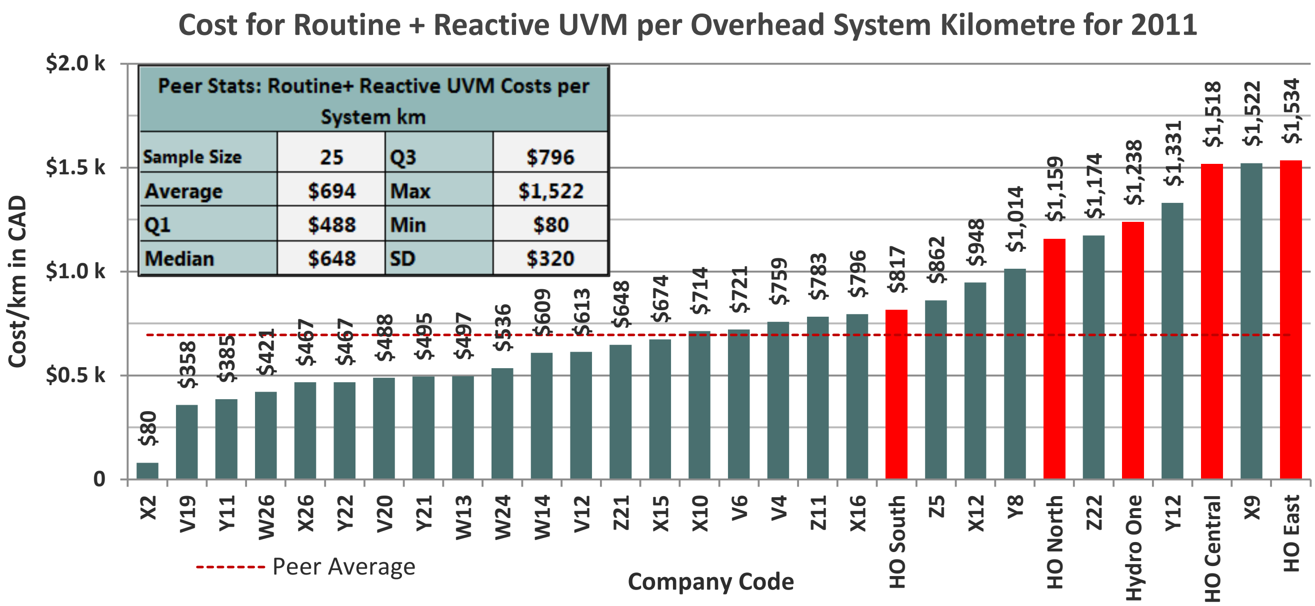


	2011	2012	2013	2014	2015
HO Central	$1,426	$1,613	$1,618	$1,631	$1,404
HO East	$1,441	$1,448	$1,427	$1,619	$1,274
Hydro One	$1,166	$1,263	$1,237	$1,282	$1,059
HO North	$1,105	$1,255	$1,142	$1,134	$865
HO South	$767	$836	$829	$810	$712
Peer Average	$608	$701	$761	$916	$893
Peer Q1	$447	$422	$446	$499	$539
Peer Median	$581	$663	$666	$874	$845
Peer Q3	$731	$785	$893	$1,224	$1,098

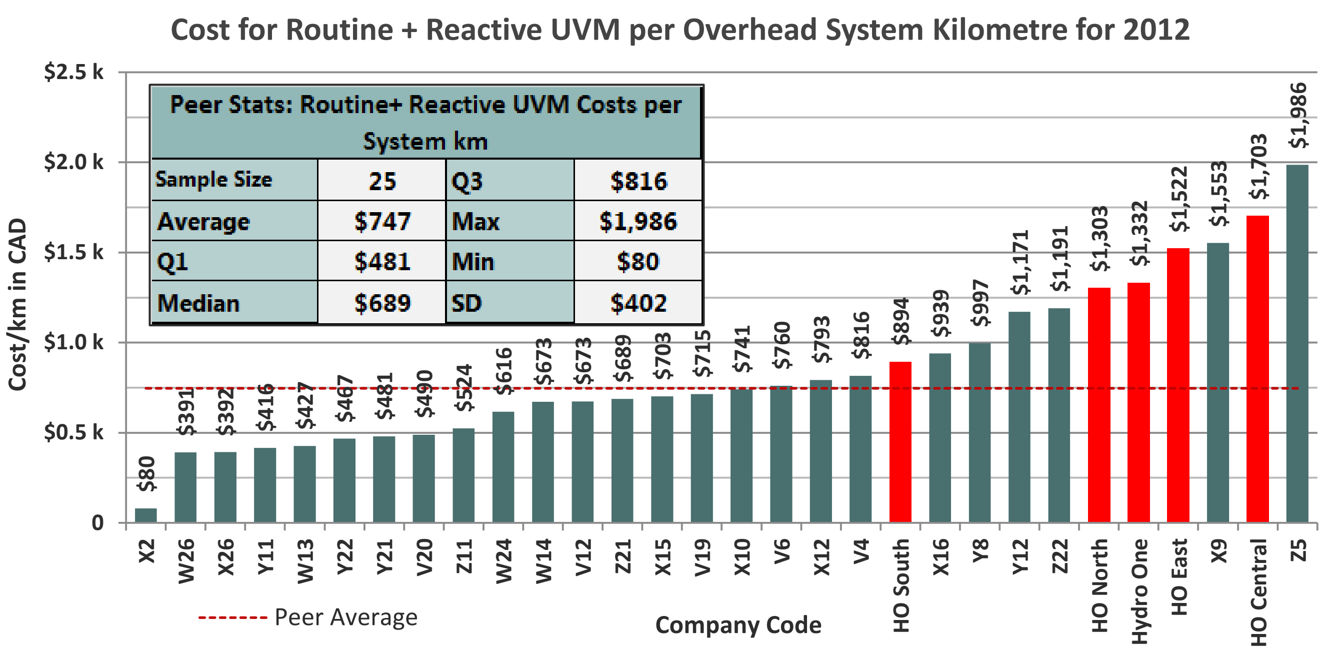
Graph 127: Annual Routine UVM Cost per System Kilometre 2011-2015: Hydro One and Regions vs Peer Statistics

Routine and Reactive UVM Expenditures per System Kilometre

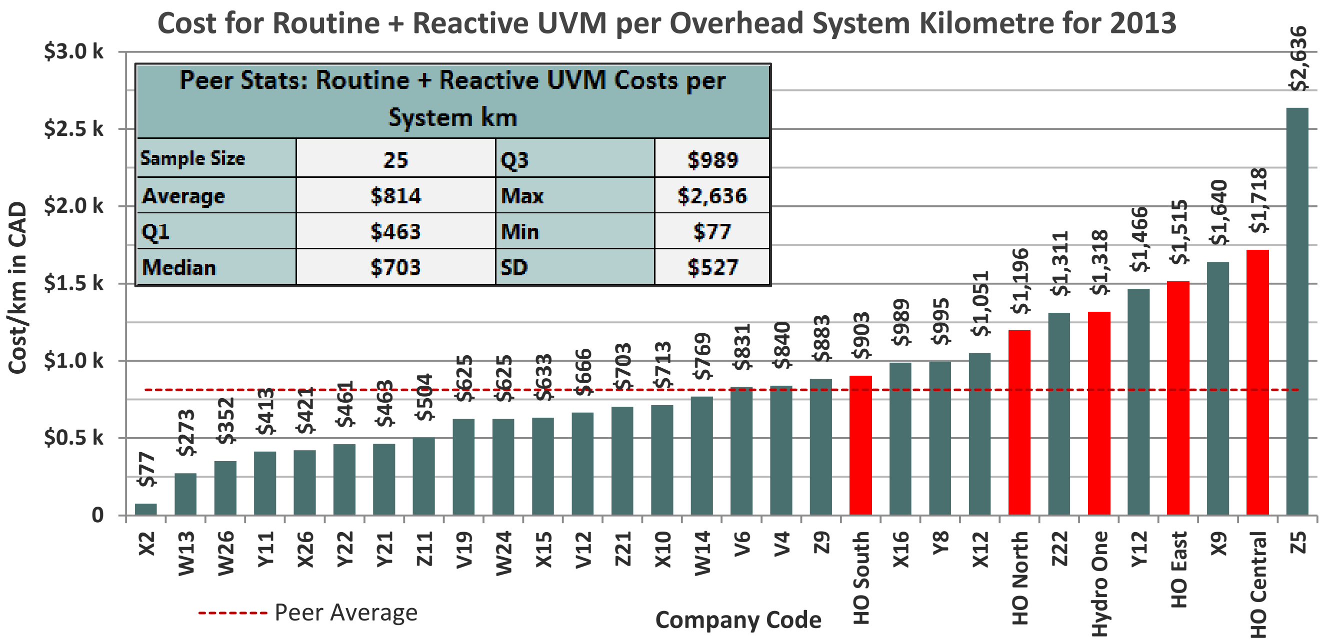
Yearly Routine UVM Expenditures per System Kilometre Comparisons for Years 2011-2015



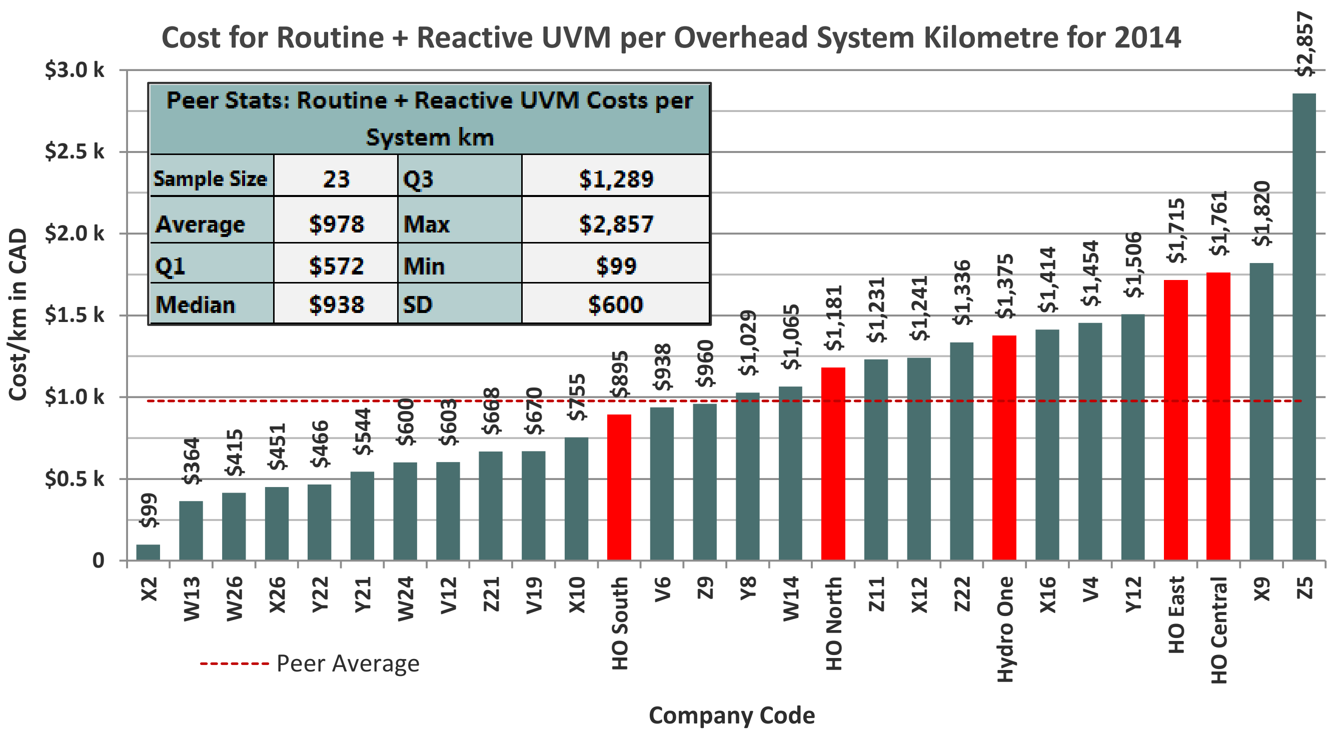
Graph 128: Peer Comparisons of Routine + Reactive Cost for UVM per Overhead System Kilometre for 2011



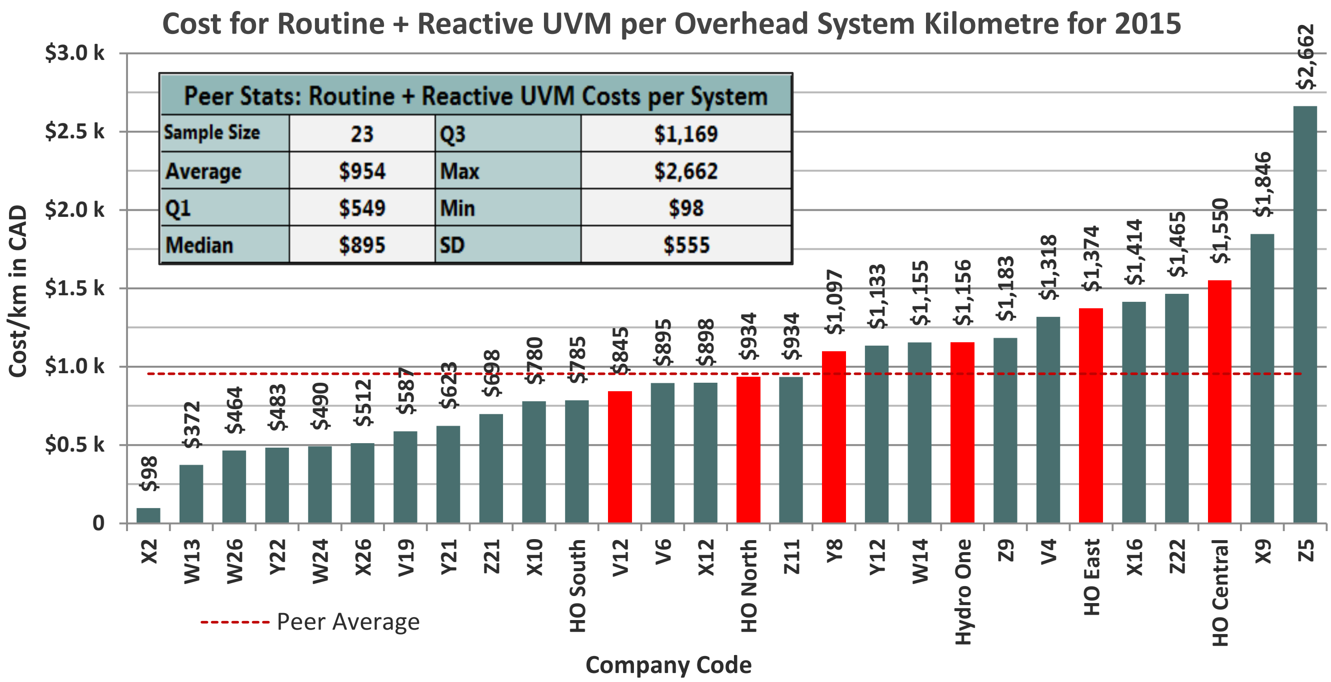
Graph 129: Peer Comparisons of Routine + Reactive Cost for UVM per Overhead System Kilometre for 2012



Graph 130: Peer Comparisons of Routine + Reactive Cost for UVM per Overhead System Kilometre for 2013



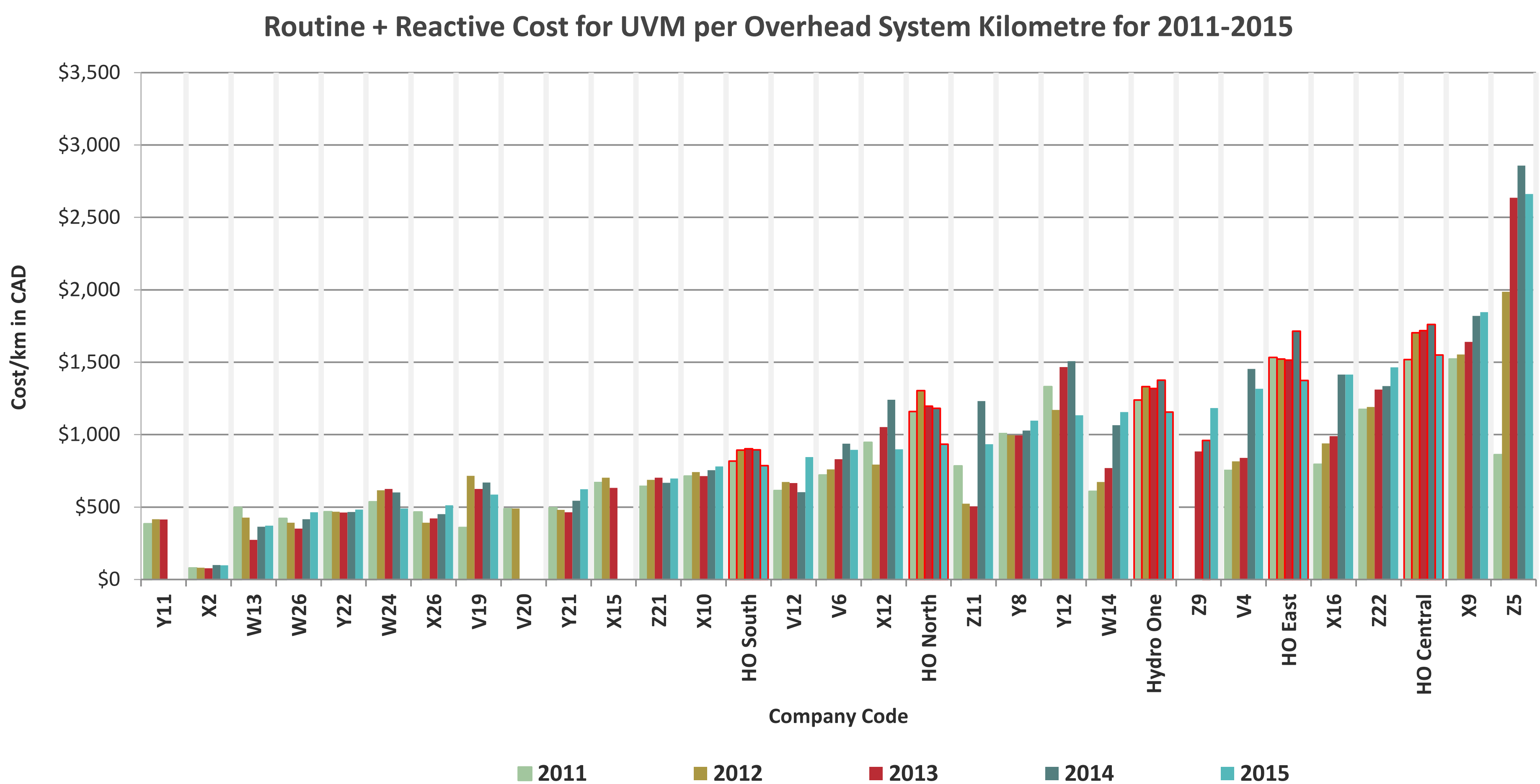
Graph 131: Peer Comparisons of Routine + Reactive Cost for UVM per Overhead System Kilometre for 2014



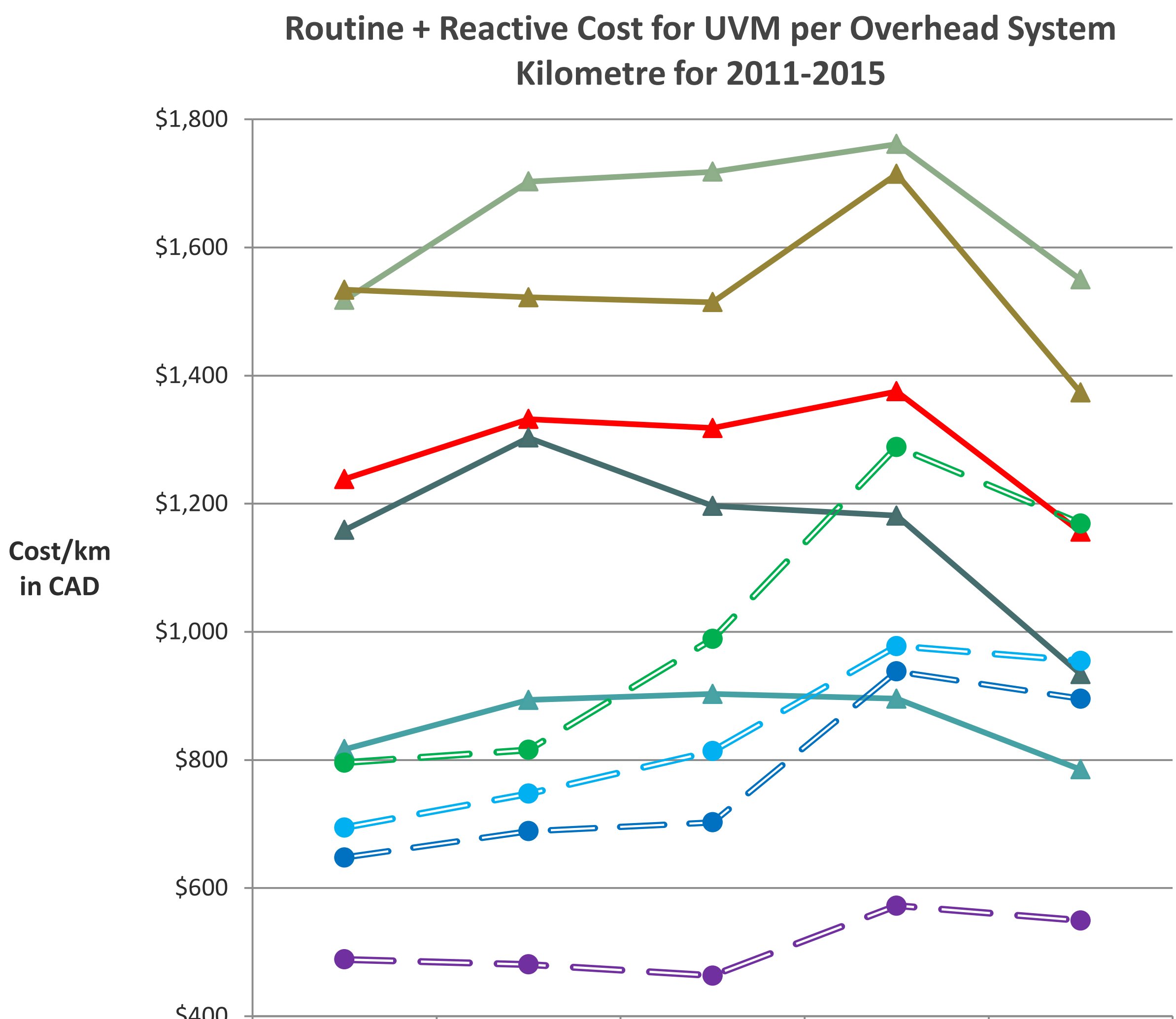
Peer Stats: Routine + Reactive UVM Costs per System			
Sample Size	23	Q3	$1,169
Average	$954	Max	$2,662
Q1	$549	Min	$98
Median	$895	SD	$555

Graph 132: Peer Comparisons of Routine + Reactive Cost for UVM per Overhead System Kilometre for 2015

Routine UVM Cost per System Kilometre Comparisons with Peers 2011-2015



Graph 133: Peer Comparisons of Routine + Reactive Cost for UVM per OH System Kilometre for 2011-2015

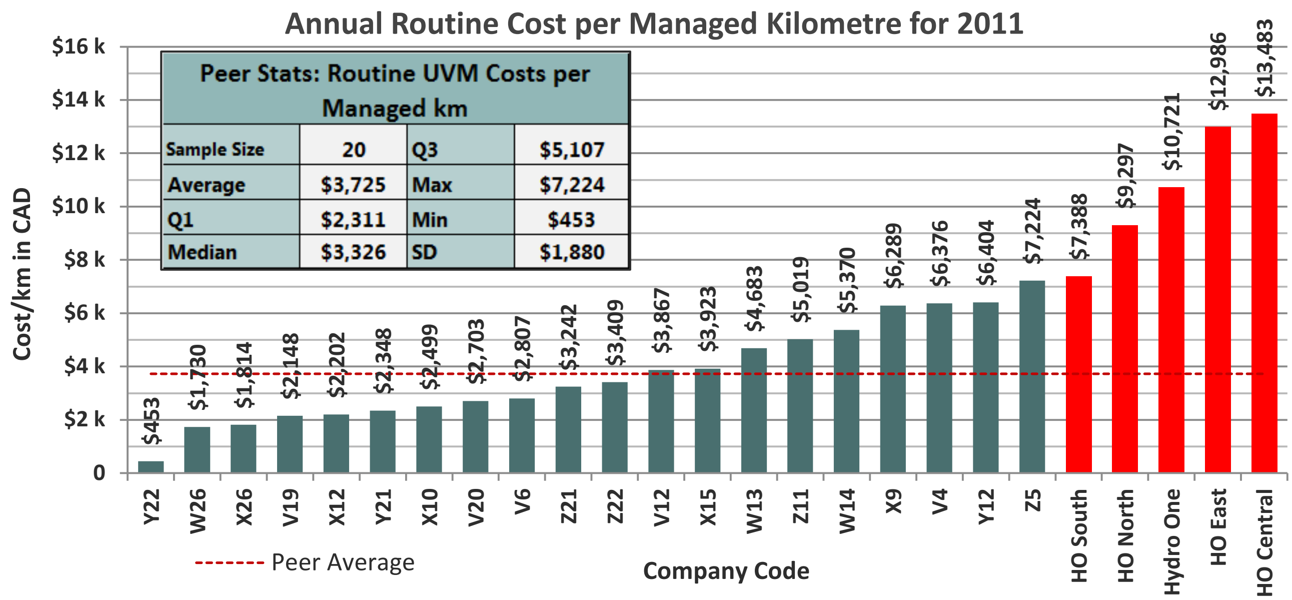


	2011	2012	2013	2014	2015
HO Central	$1,518	$1,703	$1,718	$1,761	$1,550
HO East	$1,534	$1,522	$1,515	$1,715	$1,374
Hydro One	$1,238	$1,332	$1,318	$1,375	$1,156
HO North	$1,159	$1,303	$1,196	$1,181	$934
HO South	$817	$894	$903	$895	$785
Peer Average	$694	$747	$814	$978	$954
Peer Q1	$488	$481	$463	$572	$549
Peer Median	$648	$689	$703	$938	$895
Peer Q3	$796	$816	$989	$1,289	$1,169

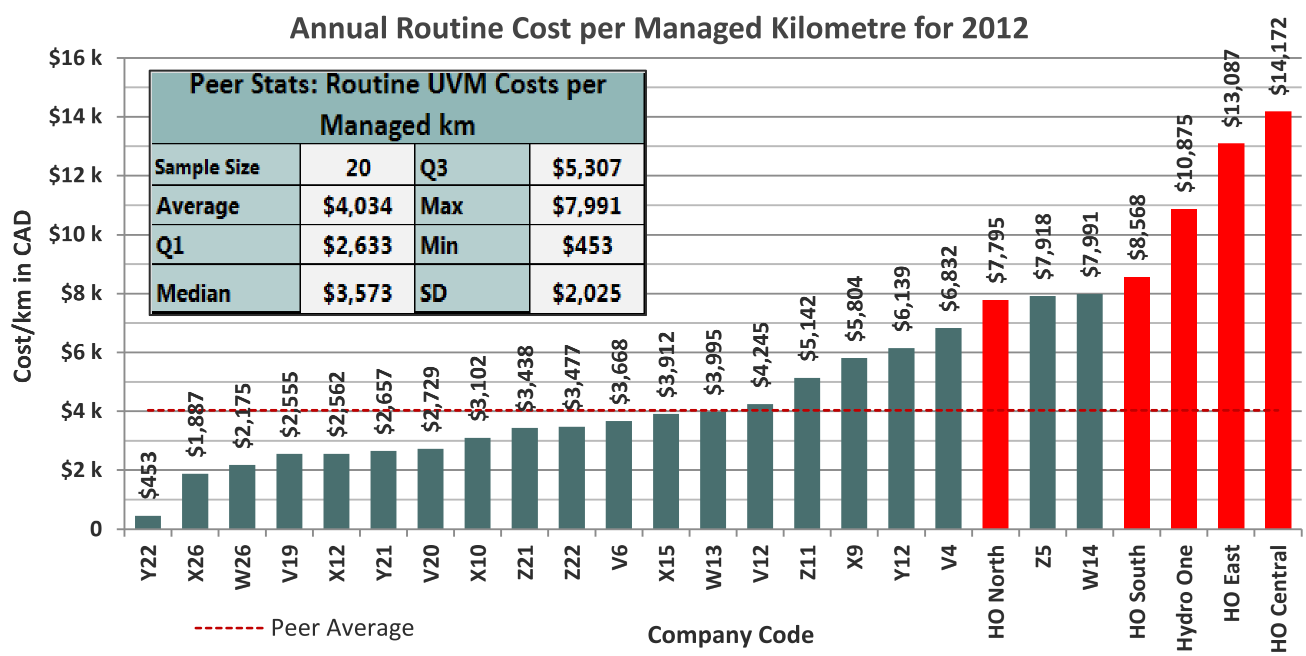
Graph 134: Statistical Comparison of Routine + Reactive UVM Cost per System Kilometre 2011-2015

Annual Routine Cost UVM Expenditures per Managed Kilometre

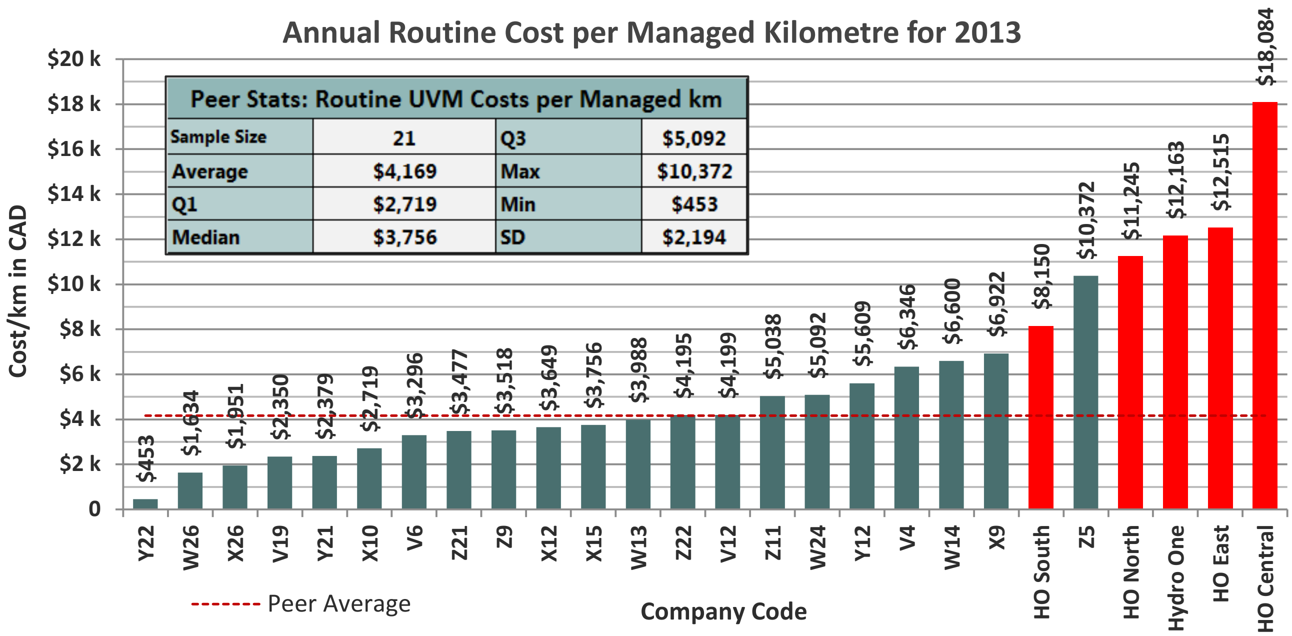
Yearly Routine UVM Expenditures per Managed Kilometre Comparisons for Years 2011-2015



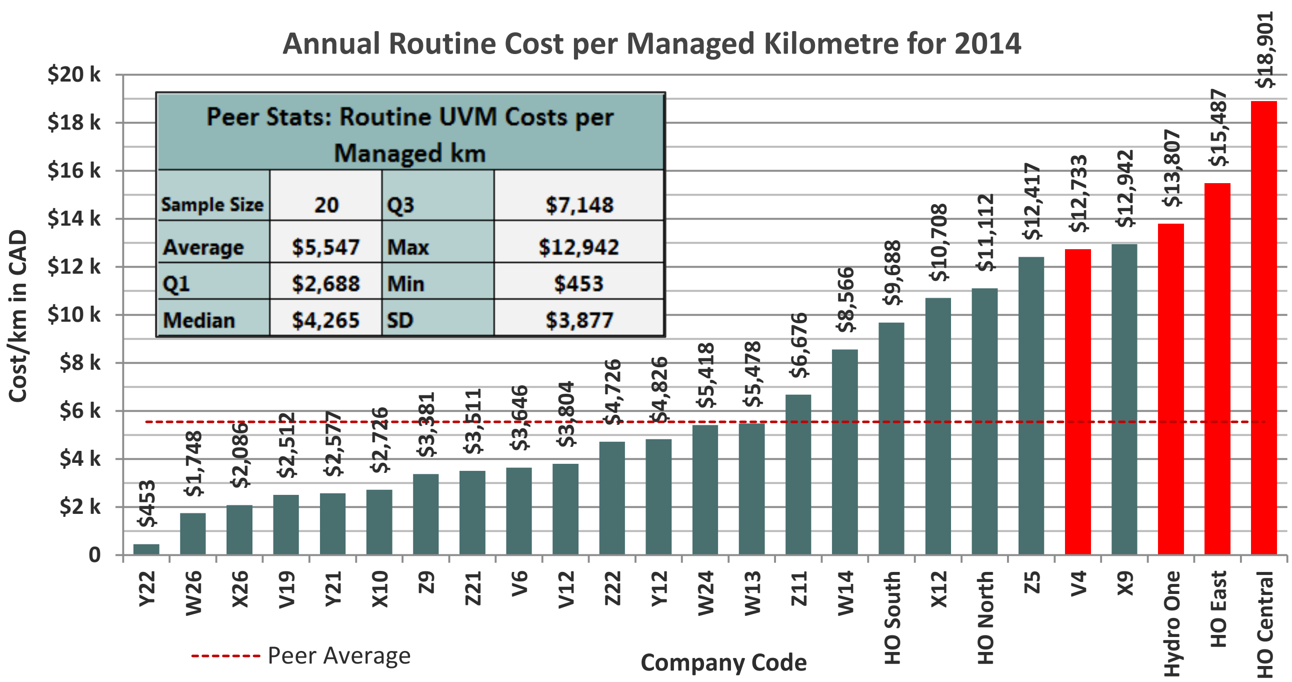
Graph 135: Peer Comparisons of Routine Cost per Managed Kilometre for 2011



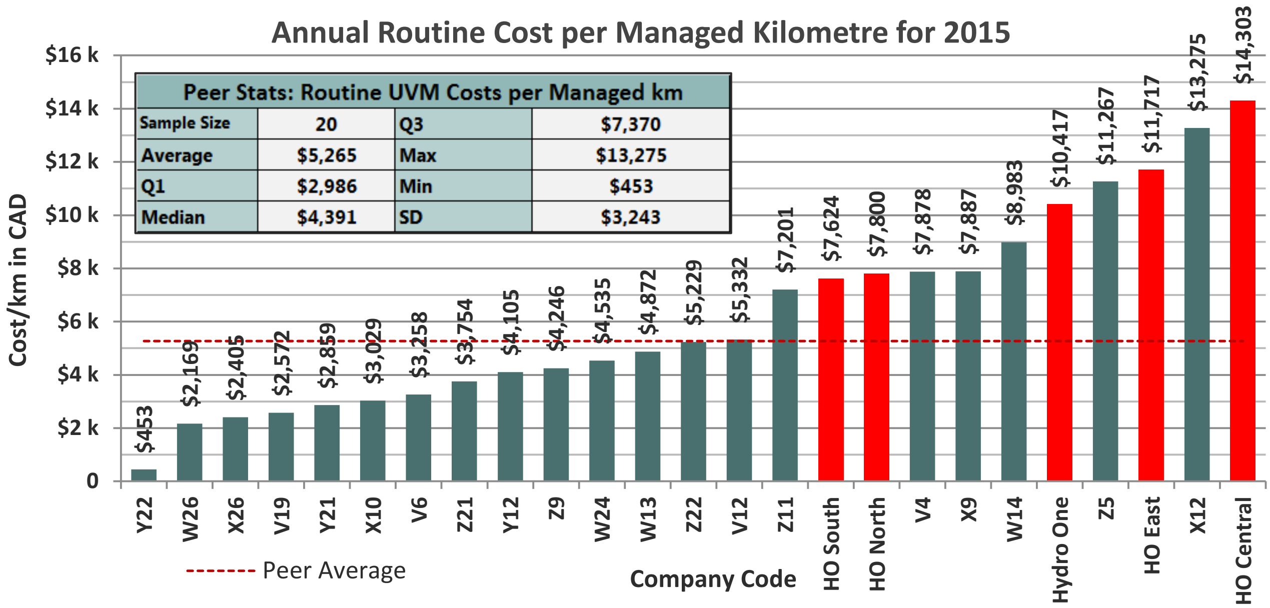
Graph 136: Peer Comparisons of Routine Cost per Managed Kilometre for 2012



Graph 137: Peer Comparisons of Routine Cost per Managed Kilometre for 2013

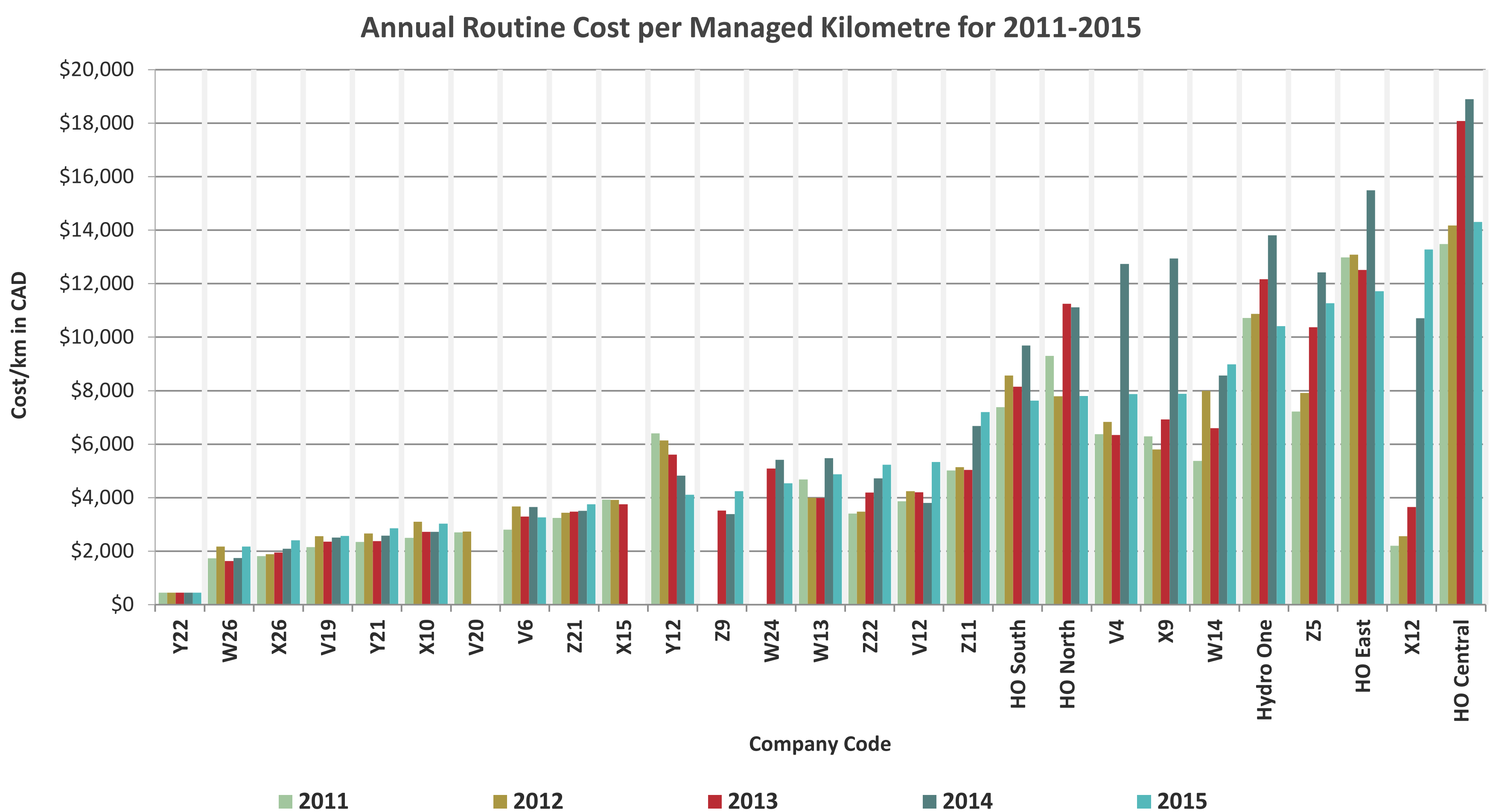


Graph 138: Peer Comparisons of Routine Cost per Managed Kilometre for 2014

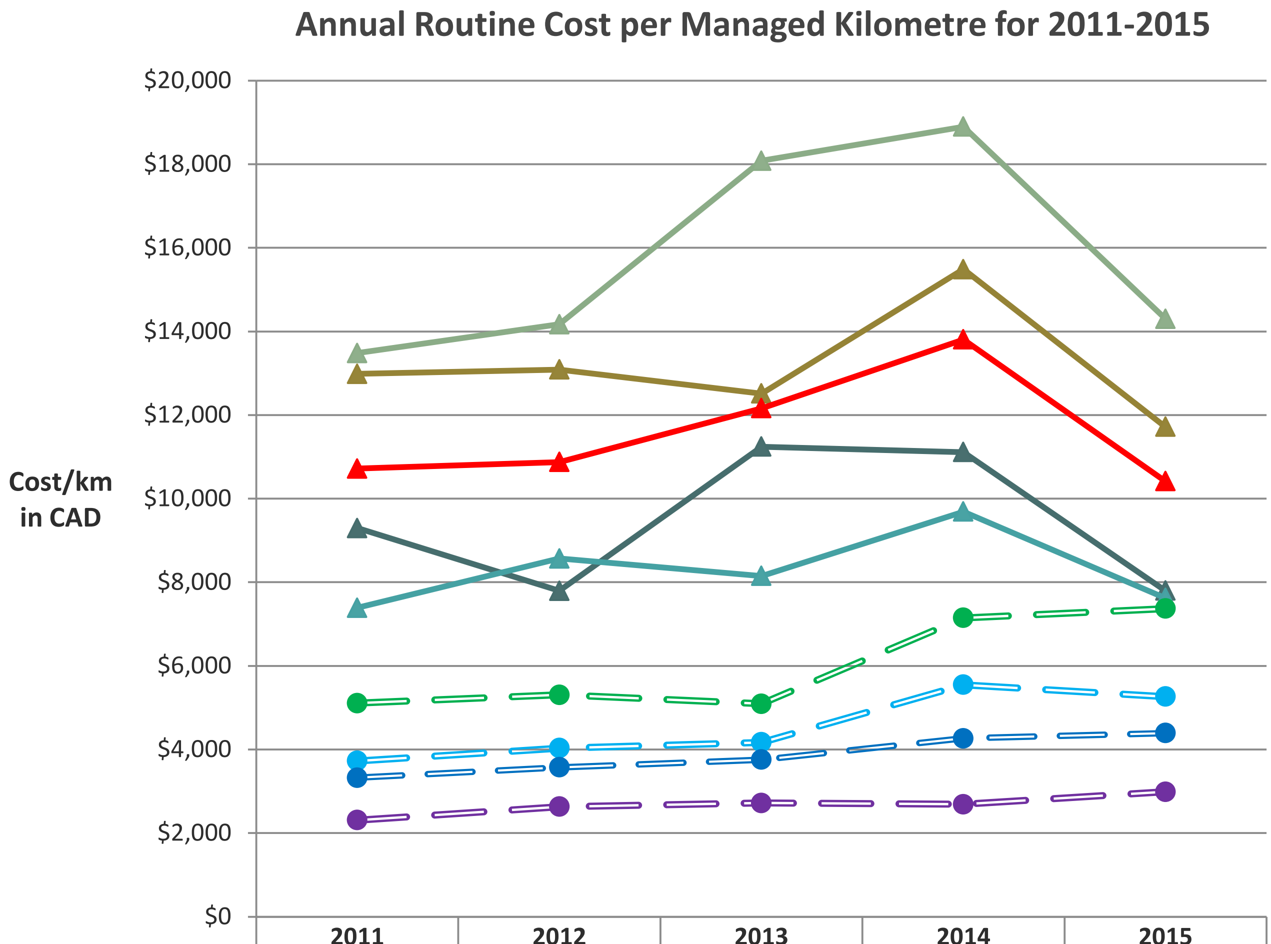


Graph 139: Peer Comparisons of Routine Cost per Managed Kilometre for 2015

Routine UVM Cost per Managed Kilometre Comparisons with Peers 2011-2015



Graph 140: Peer Comparisons of Routine Cost per Managed Kilometre for 2011-2015

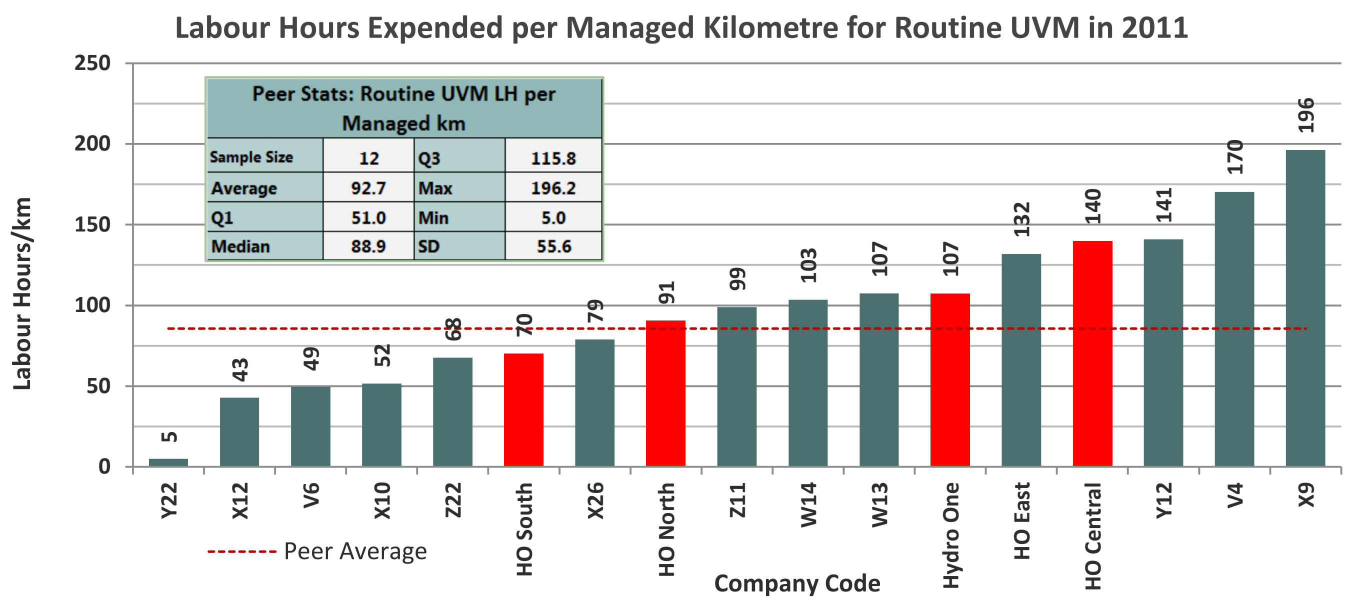


	2011	2012	2013	2014	2015
HO Central	$13,483	$14,172	$18,084	$18,901	$14,303
HO East	$12,986	$13,087	$12,515	$15,487	$11,717
Hydro One	$10,721	$10,875	$12,163	$13,807	$10,417
HO North	$9,297	$7,795	$11,245	$11,112	$7,800
HO South	$7,388	$8,568	$8,150	$9,688	$7,624
Peer Average	$3,725	$4,034	$4,169	$5,547	$5,265
Peer Q1	$2,311	$2,633	$2,719	$2,688	$2,986
Peer Median	$3,326	$3,573	$3,756	$4,265	$4,391
Peer Q3	$5,107	$5,307	$5,092	$7,148	$7,370

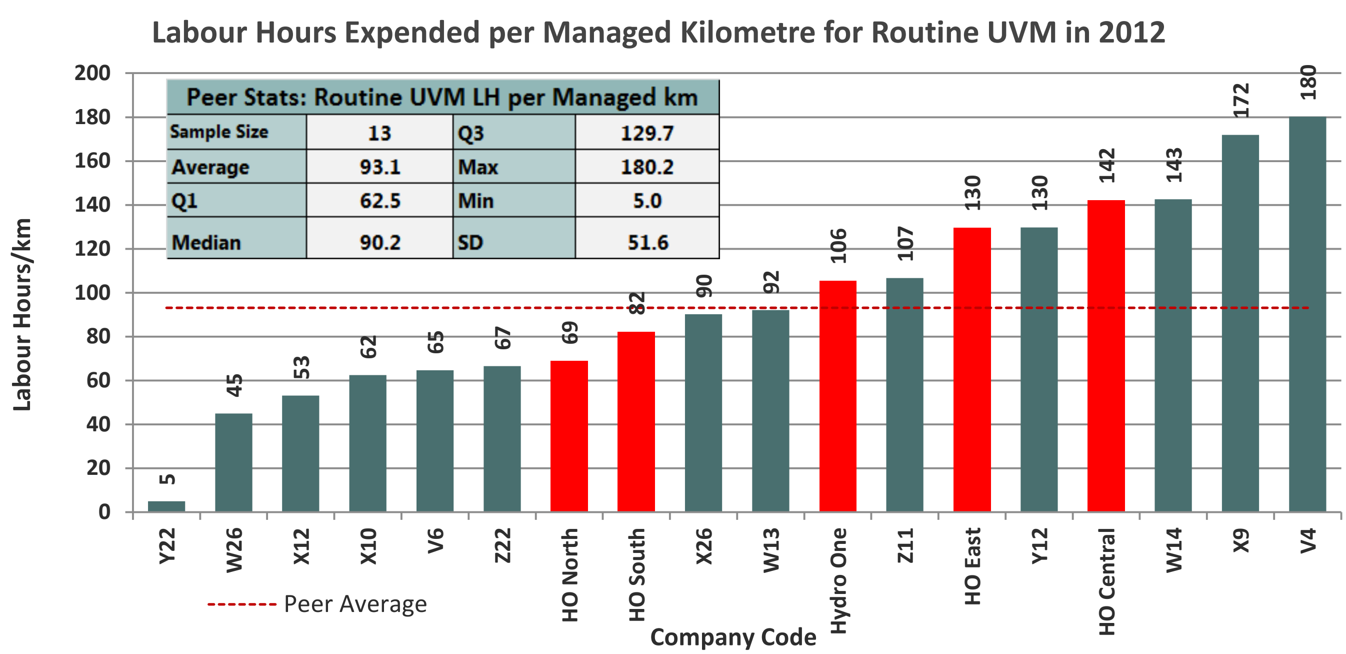
Graph 141: Statistical Comparison of Annual Routine UVM Cost per Managed Kilometre 2011-2015

Annual Routine UVM Labour Hours Expended per Managed Kilometre

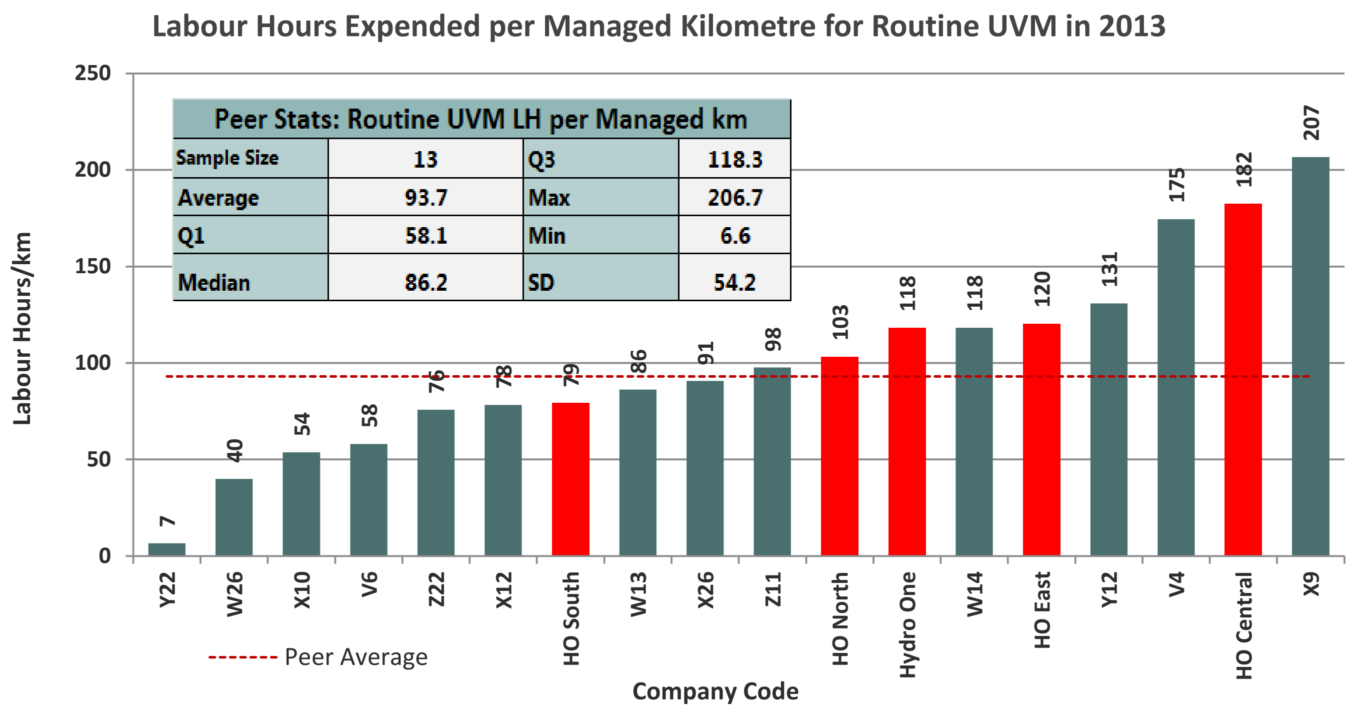
Yearly Routine UVM Labour Hours Expended per Managed Kilometre Comparisons for Years 2011-2015



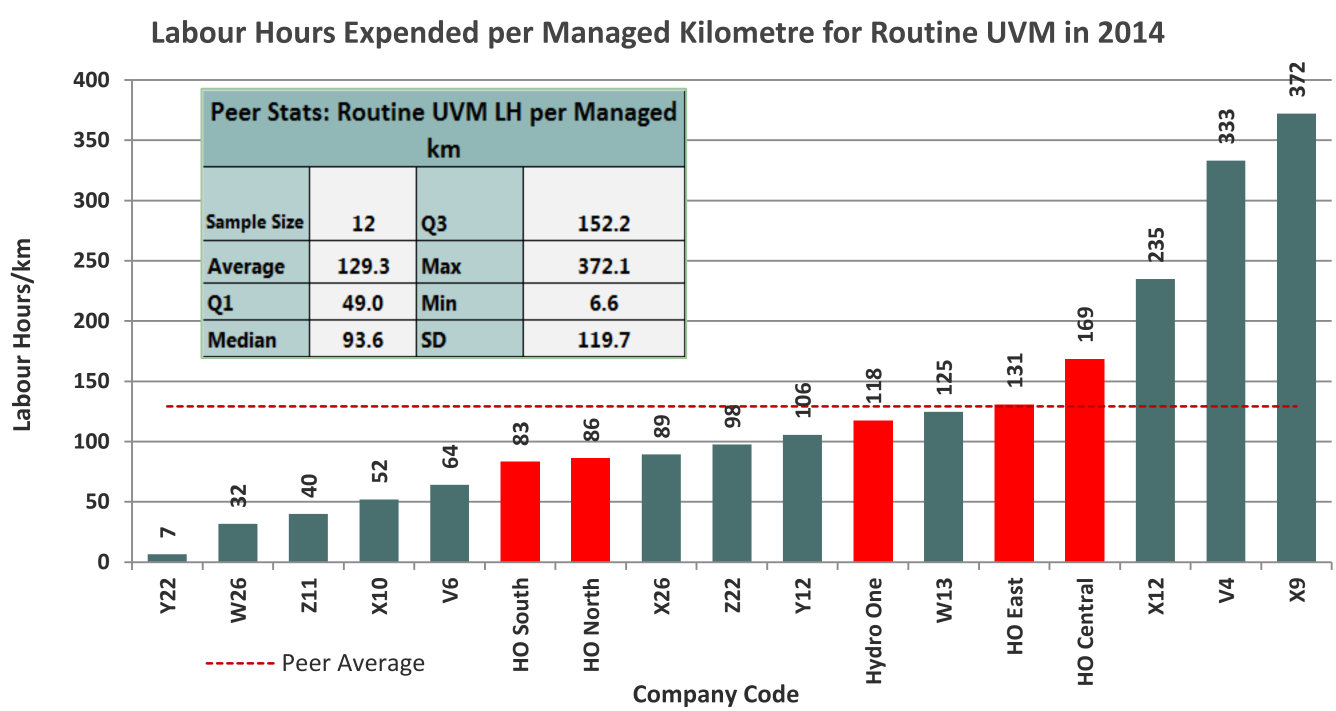
Graph 142: Peer Comparisons of Labour Hours Expended for Routine UVM per Managed Kilometre for 2011



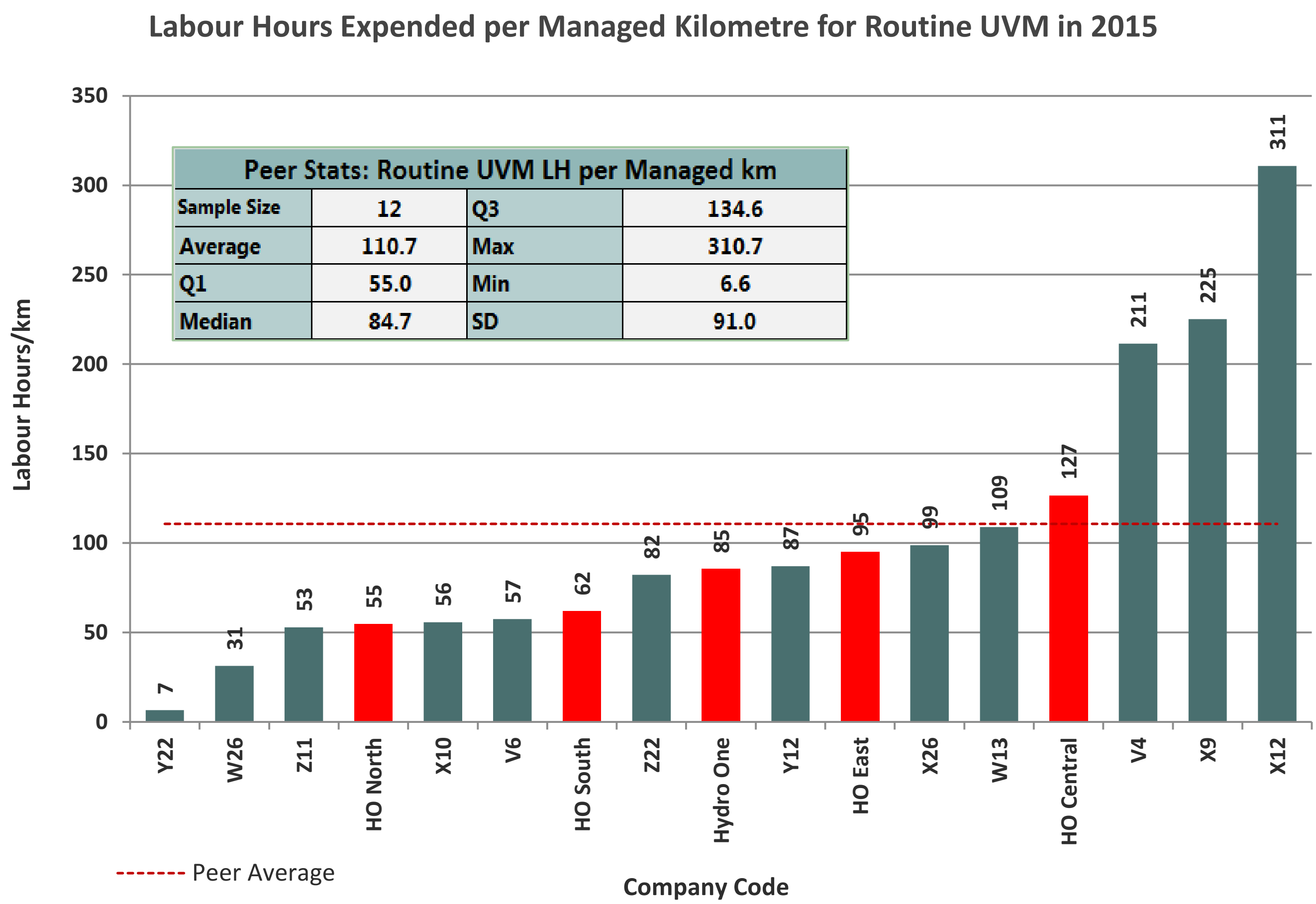
Graph 143: Peer Comparisons of Labour Hours Expended for Routine UVM per Managed Kilometre for 2012



Graph 144: Peer Comparisons of Labour Hours Expended for Routine UVM per Managed Kilometre for 2013

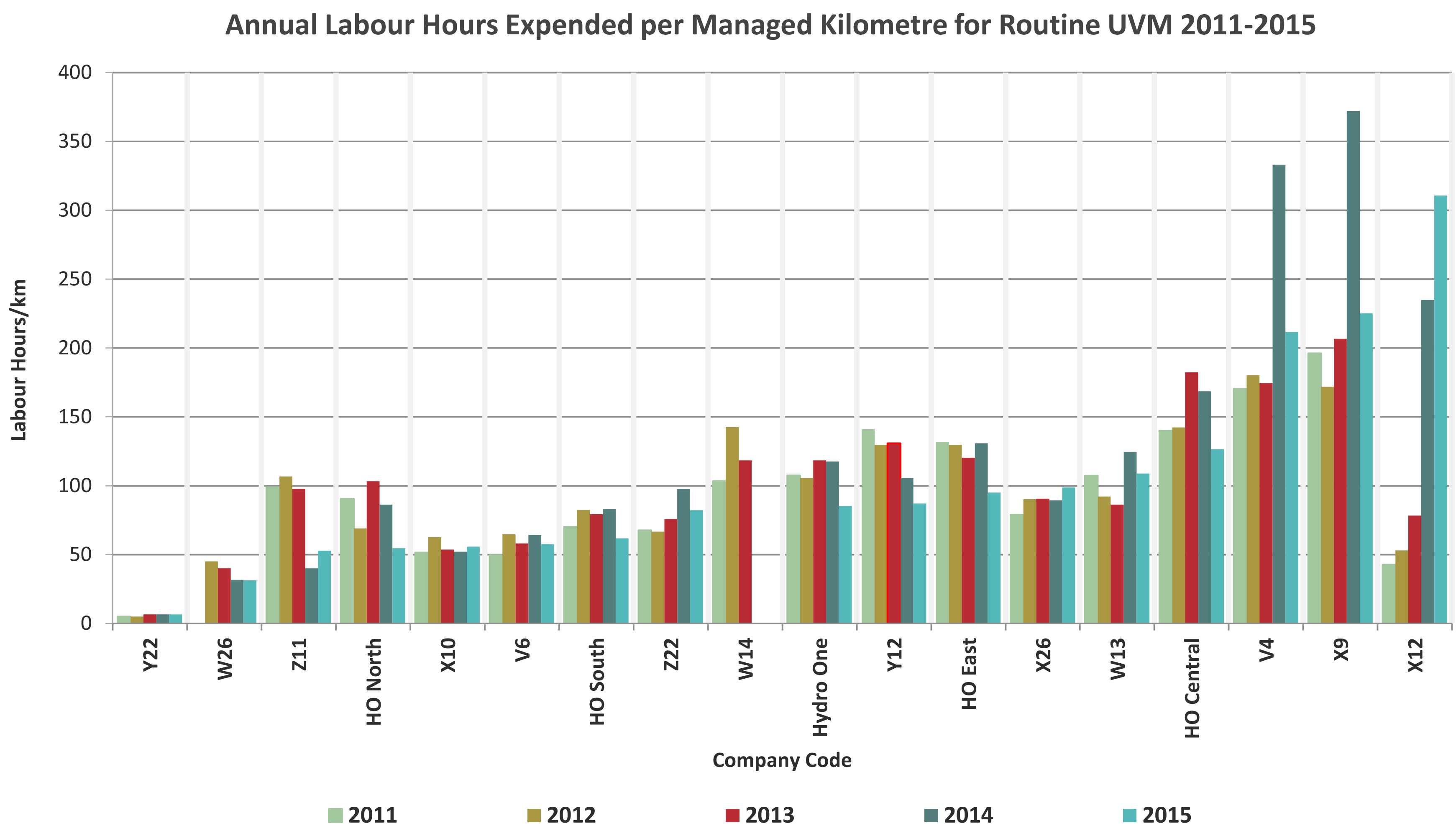


Graph 145: Peer Comparisons of Labour Hours Expended for Routine UVM per Managed Kilometre for 2014

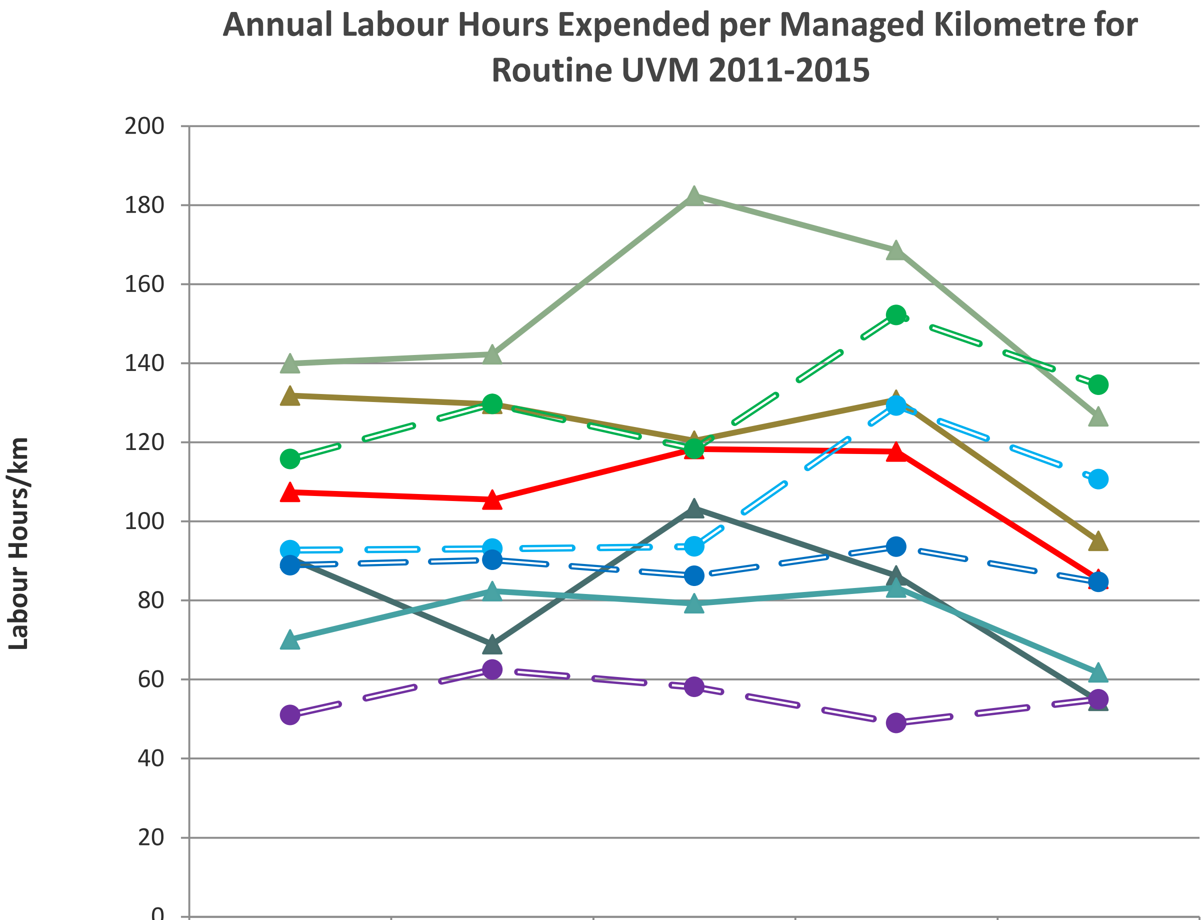


Graph 146: Peer Comparisons of Labour Hours Expended for Routine UVM per Managed Kilometre for 2015

Routine UVM Cost per Managed Kilometre Comparisons with Peers 2011-2015



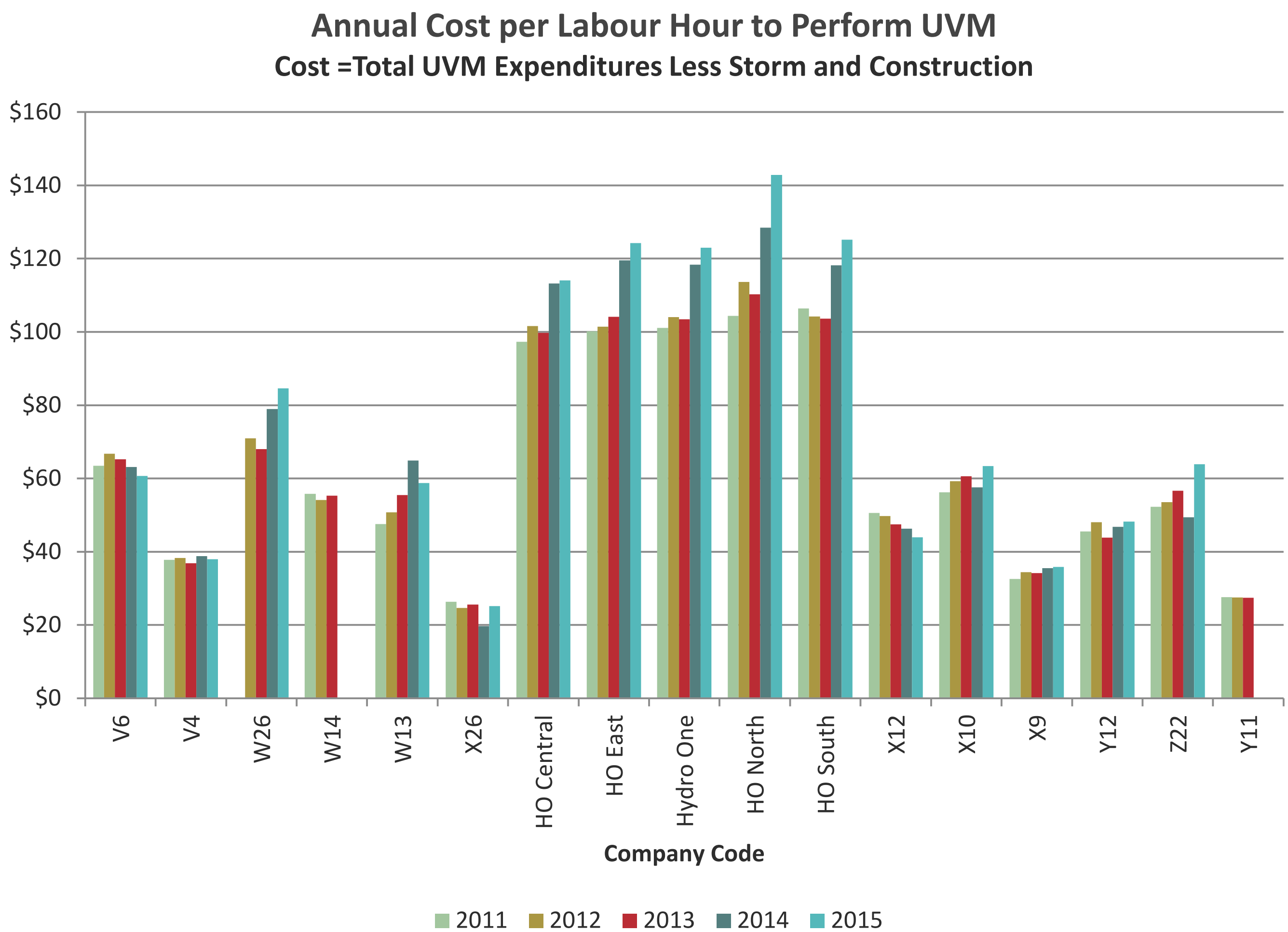
Graph 147: Peer Comparisons of Routine Labour Hours Expended per Managed Kilometre for 2011-2015



	2011	2012	2013	2014	2015
HO Central	139.96	142.26	182.41	168.63	126.56
HO East	131.83	129.68	120.43	130.79	95.09
Hydro One	107.42	105.52	118.30	117.67	85.40
HO North	90.66	68.91	103.29	86.30	54.60
HO South	70.14	82.38	79.23	83.26	61.74
Peer Average	92.7	93.1	93.7	129.3	110.7
Peer Q1	51.0	62.5	58.1	49.0	55.0
Peer Median	88.9	90.2	86.2	93.6	84.7
Peer Q3	115.8	129.7	118.3	152.2	134.6

Graph 148: Statistical Comparison of Annual Routine UVM Cost per Managed Kilometre 2011-2015

Longitudinal Study of Cost per Labour Hour for Peer Group



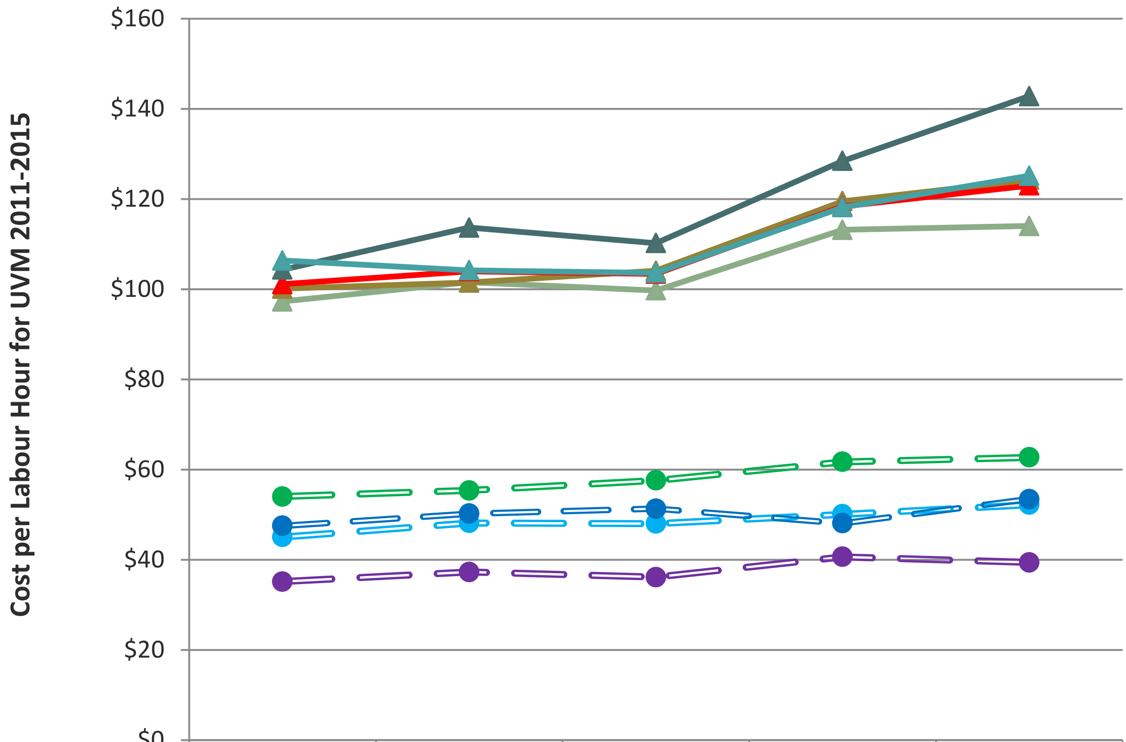
Graph 149: Annual Cost per Labour Hour to Perform UVM

This study was done to visualize the change the change in cost per labour hour over time and identify trends in the change. Companies like V6 are actually decreasing their cost per labour hour, while the majority is increasing.

Storm and New Construction were not included in this study for several reasons:

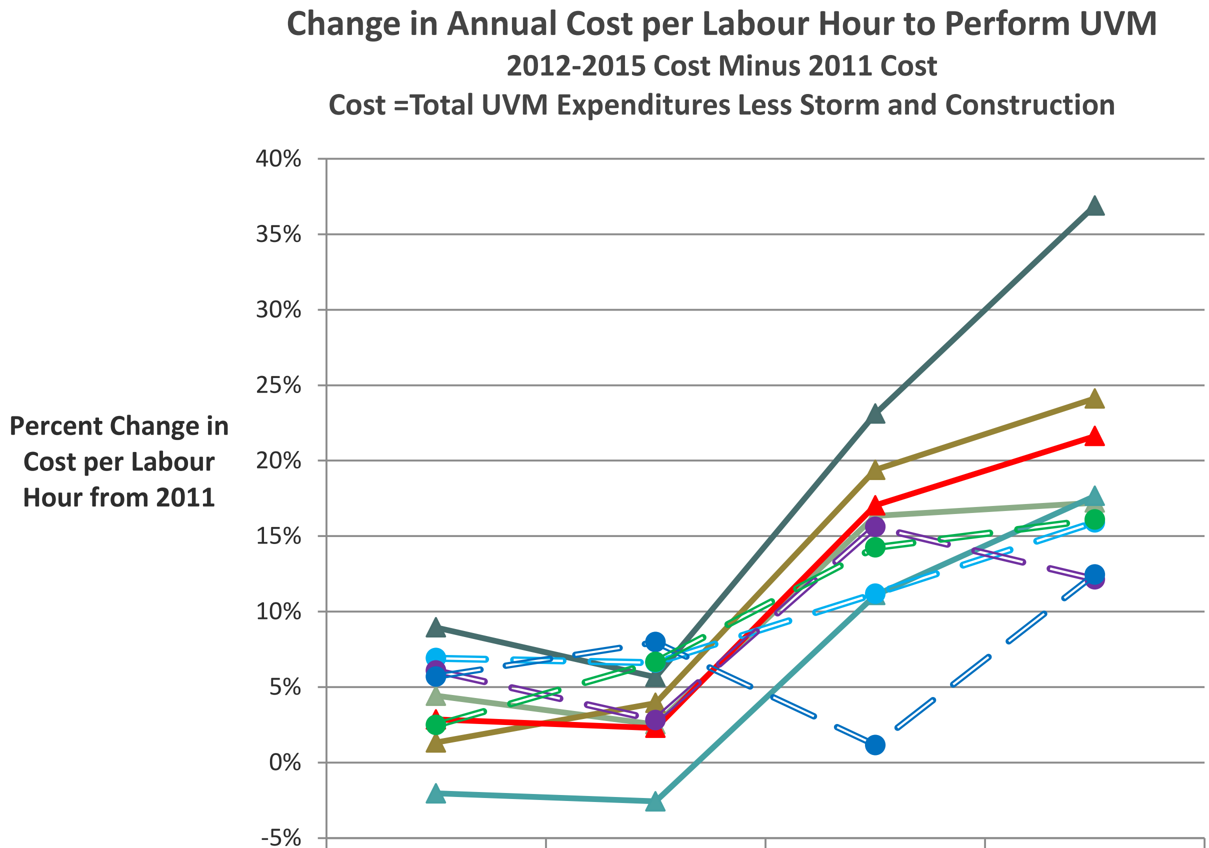
- Some utilities do not capture these costs
- Many companies capitalize these costs or they are paid for by different departments.

Annual Cost per Labour Hour to Perform UVM for 2011-2015
Cost =Total UVM Expenditures Less Storm and Construction



	2011	2012	2013	2014	2015
HO Central	$97.30	$101.60	$99.75	$113.20	$114.05
HO East	$100.13	$101.47	$104.09	$119.55	$124.28
Hydro One	$101.12	$104.00	$103.43	$118.34	$122.99
HO North	$104.34	$113.68	$110.25	$128.45	$142.83
HO South	$106.37	$104.19	$103.63	$118.17	$125.16
Peer Average	$45.07	$48.18	$48.05	$50.10	$52.24
Peer Q1	$35.18	$37.32	$36.17	$40.66	$39.45
Peer Median	$47.56	$50.27	$51.35	$48.11	$53.48
Peer Q3	$54.03	$55.37	$57.63	$61.73	$62.73

Graph 150: Annual Cost per Labour Hour Comparison of Hydro One and Regions to Peer Statistics



	2012	2013	2014	2015
HO Central	4%	3%	16%	17%
HO East	1%	4%	19%	24%
Hydro One	3%	2%	17%	22%
HO North	9%	6%	23%	37%
HO South	-2%	-3%	11%	18%
Peer Average	7%	7%	11%	16%
Peer Q1	6%	3%	16%	12%
Peer Median	6%	8%	1%	12%
Peer Q3	2%	7%	14%	16%

Graph 151: Change in Annual Cost per Labour Hour Comparison of Hydro One and Regions to Peer Statistics

LONGITUDINAL PRODUCTIVITY COMPARISONS

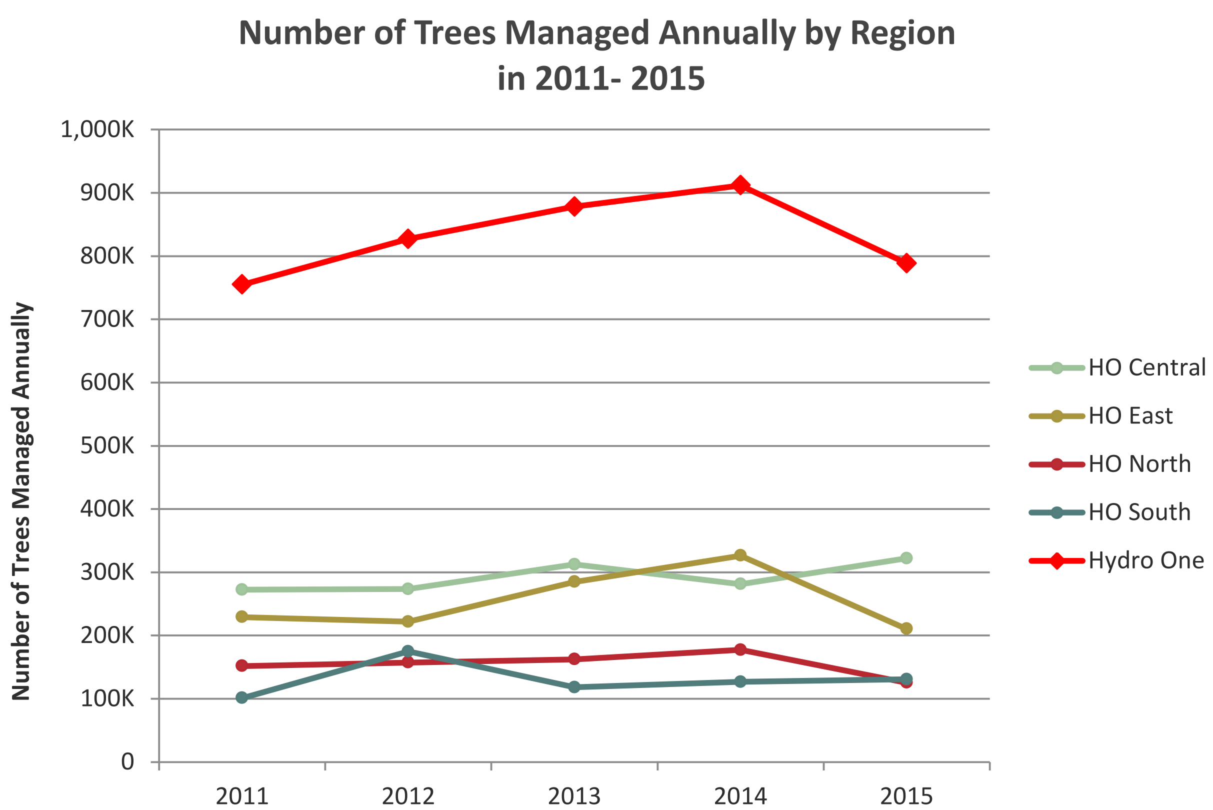
Productivity Comparisons between Hydro One Regions

Hydro One Regional Production Statistics

Five-Year Averages of Tree Production Statistics 2010-2015				
Regions	**Percent Pruned**	**Percent Removed**	**Cost per Tree Treated**	**Labour Hours per Tree Treated**
Hydro One Networks	**53%**	**47%**	**$106.18**	**0.91**
Hydro One Central	**62%**	**38%**	**$98.43**	**0.88**
Hydro One South	**61%**	**39%**	**$153.18**	**1.31**
Hydro One East	**54%**	**46%**	**$110.31**	**0.94**
Hydro One North	**27%**	**73%**	**$81.02**	**0.63**

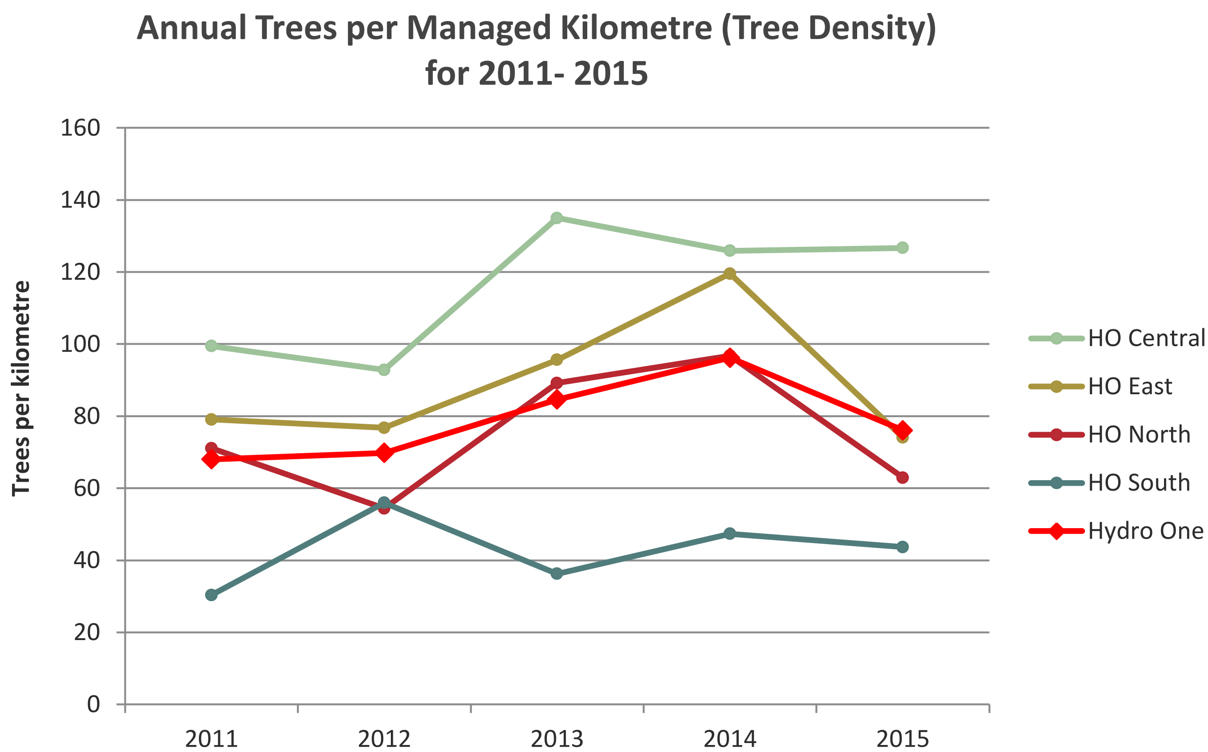
Table 31: Five-Year Averages of Tree Production Statistics 2010-2015

Trees Managed Annually in Hydro One Regions

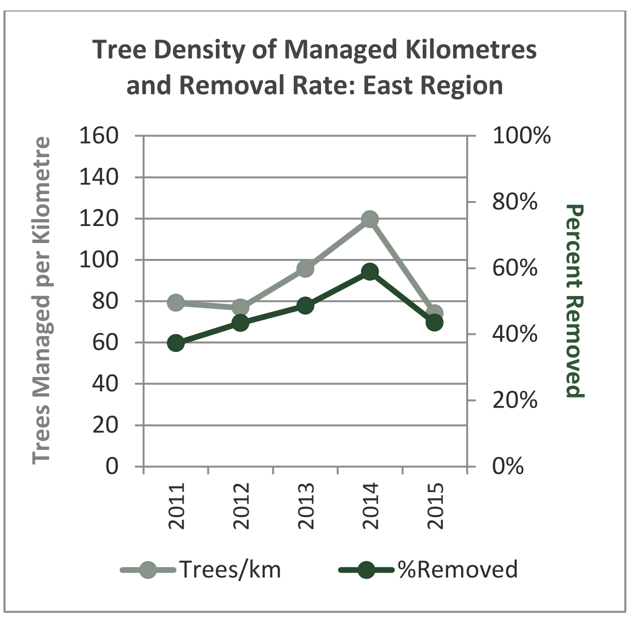


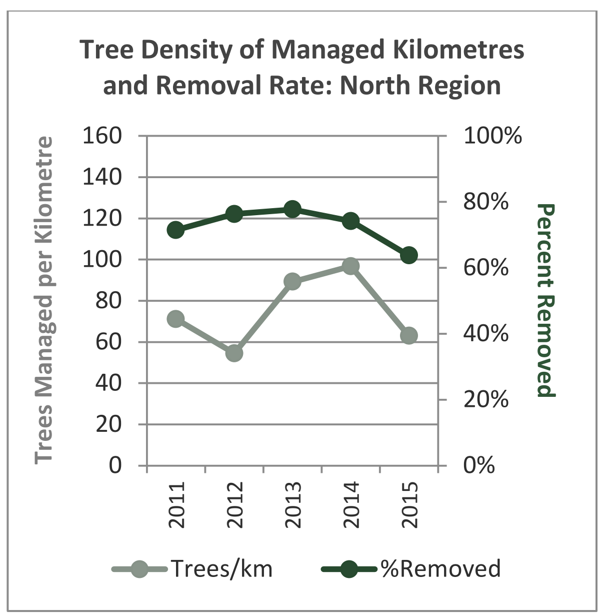
Graph 152: Number of Trees Managed Annually by Region in 2011- 2015

Managed Tree Density for Hydro One by Region

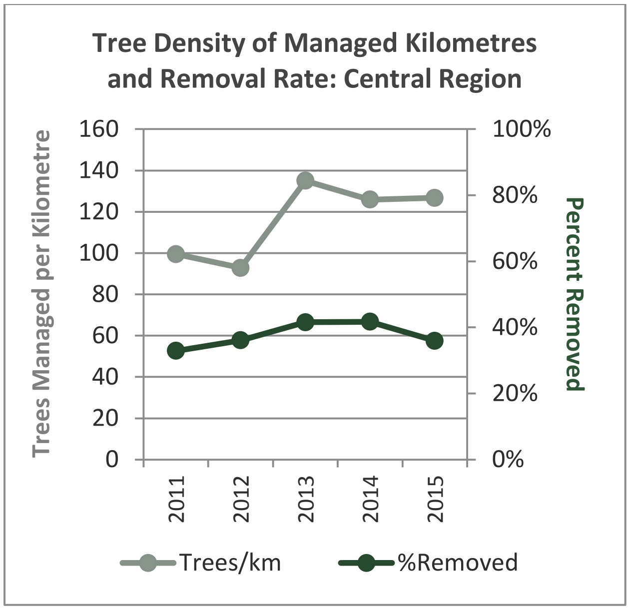


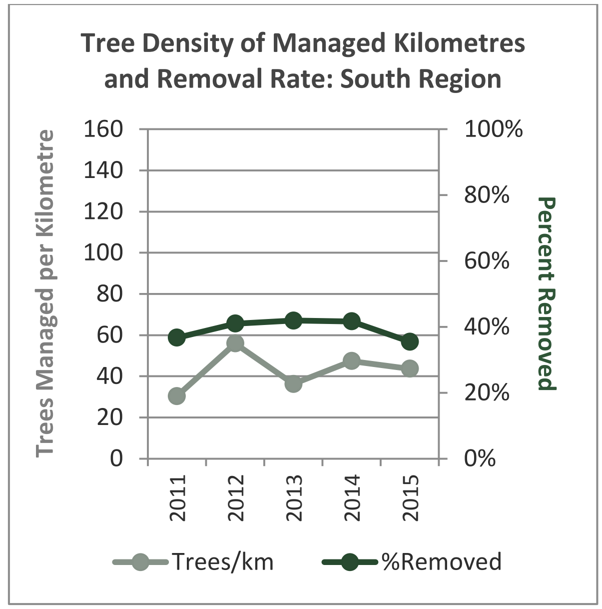
Graph 153: Annual Trees per Managed Kilometre (Tree Density) for 2011- 2015



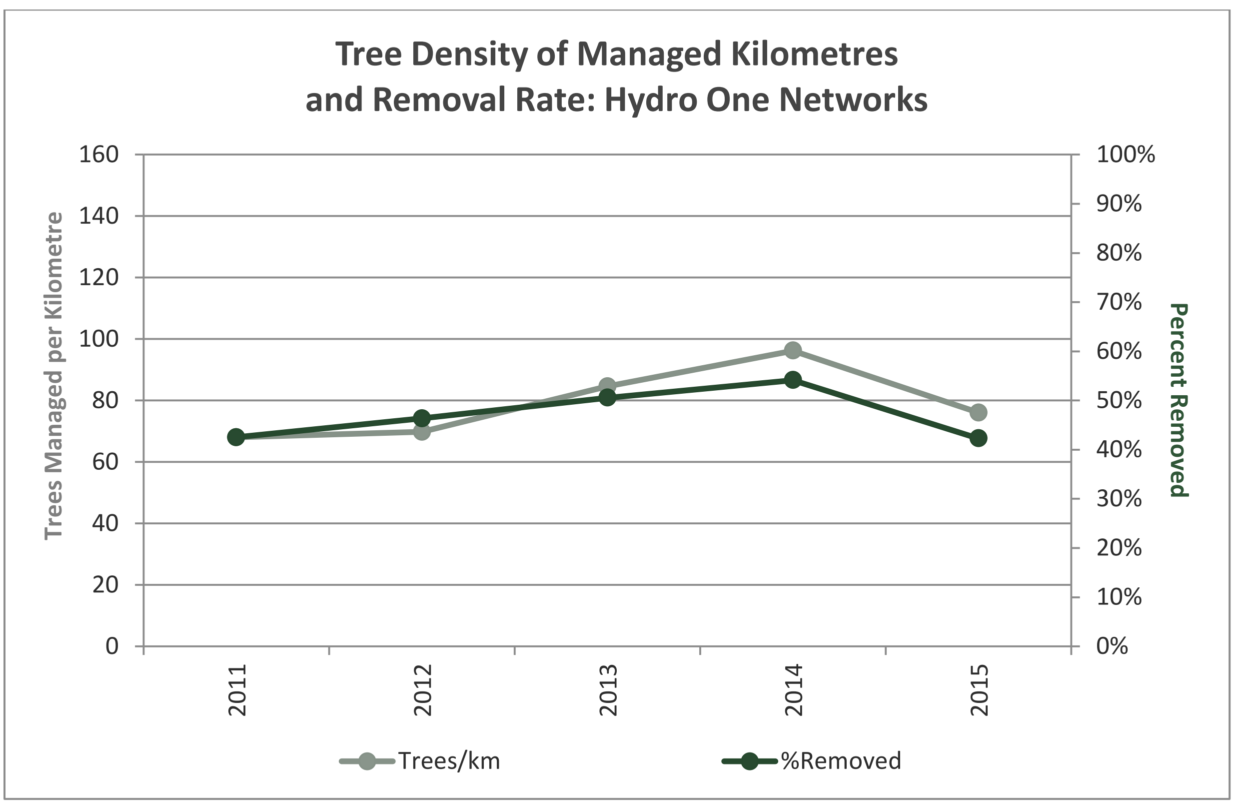


Graph 154: Tree Density of Managed Kilometres and Removal Rate: East Region and North Region





Graph 155: Tree Density of Managed Kilometres and Removal Rate: Central Region and South Region

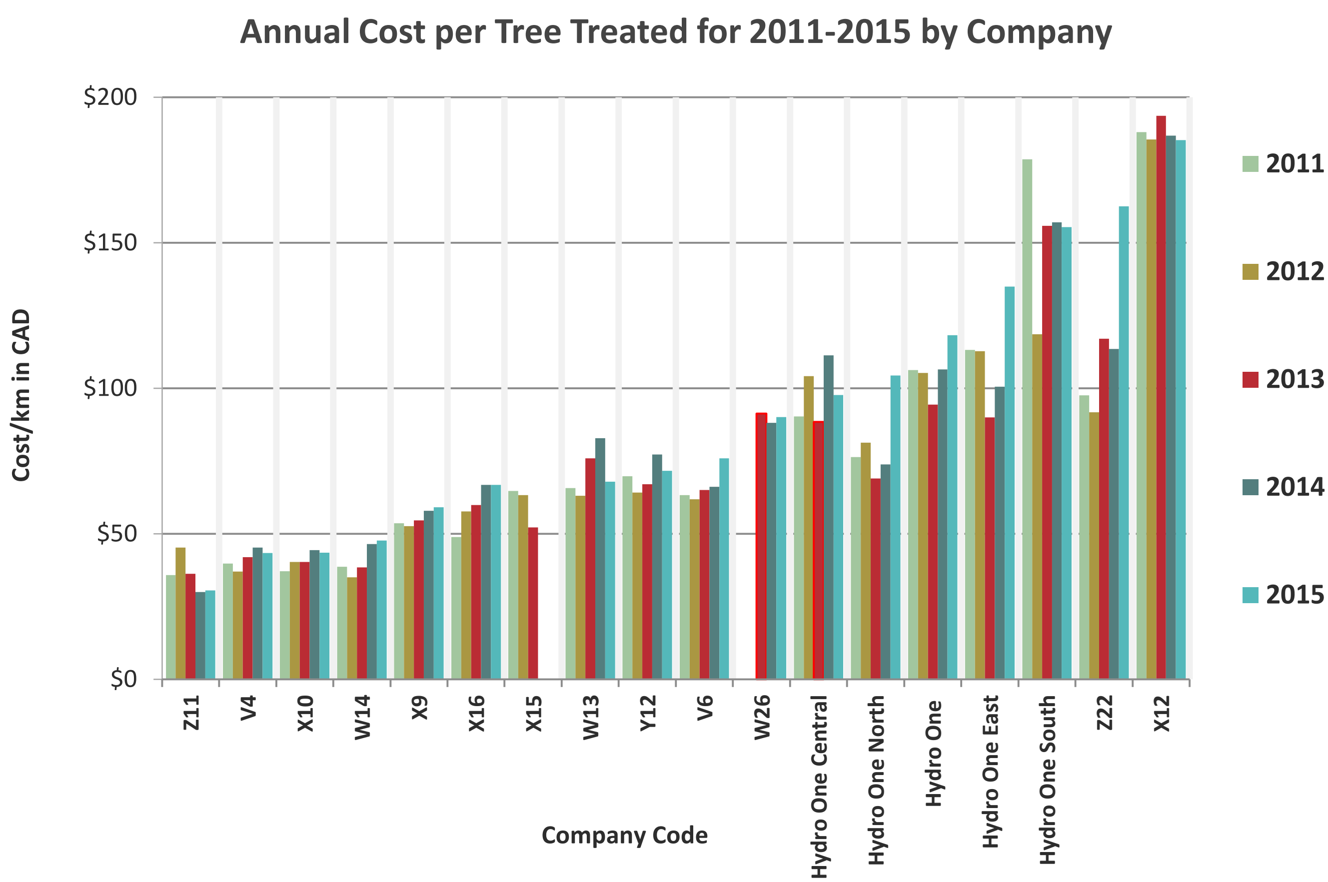


Graph 156: Tree Density of Managed Kilometres and Removal Rate: Hydro One Networks

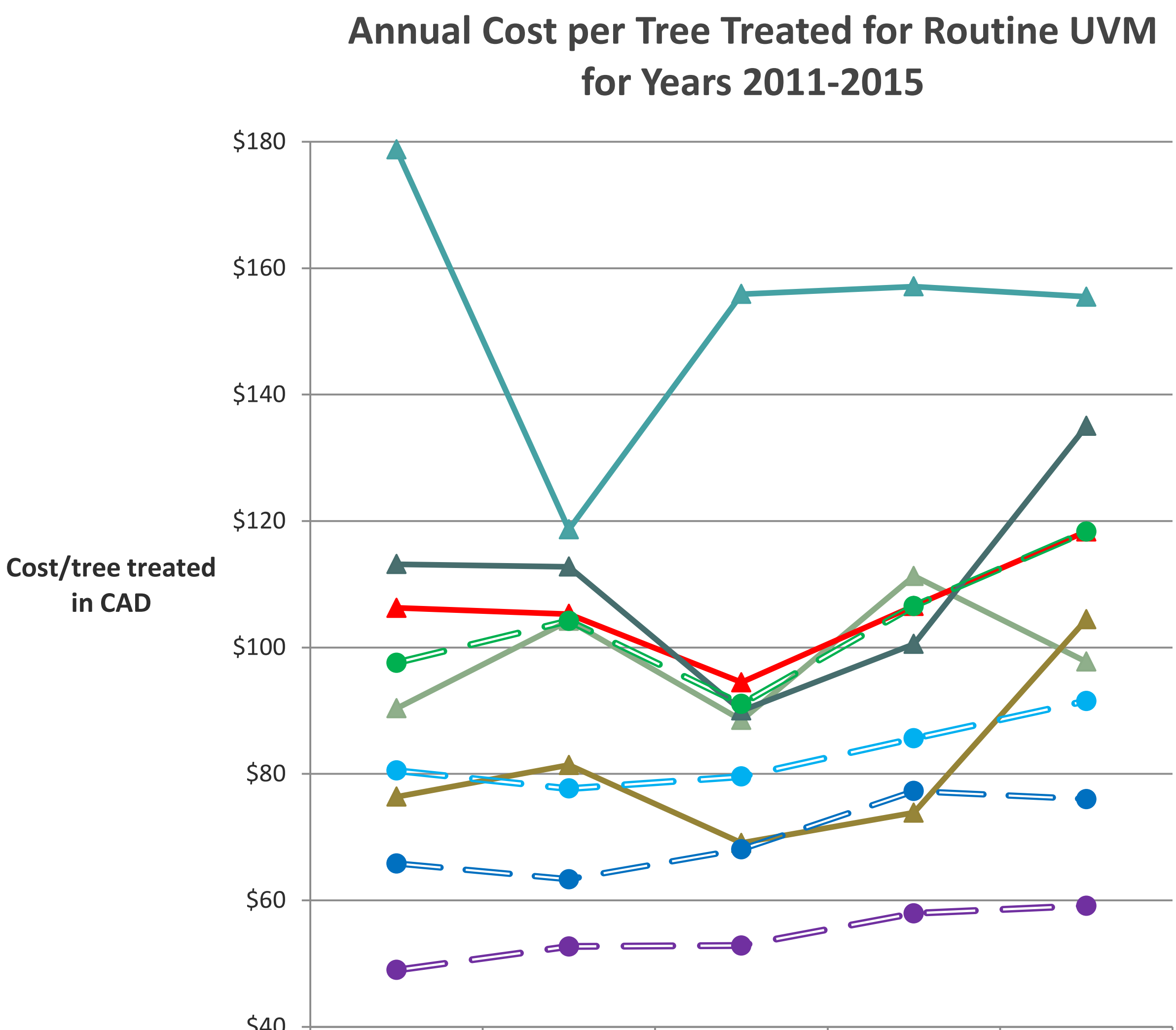
Year by Year Productivity Comparisons between Hydro One and Peers

Tree Treated is defined as trees either pruned or removed. Graphs with clustered bars representing years are sorted by 2015 ratios.

Cost per Tree Treated for Routine Maintenance 2011-2015



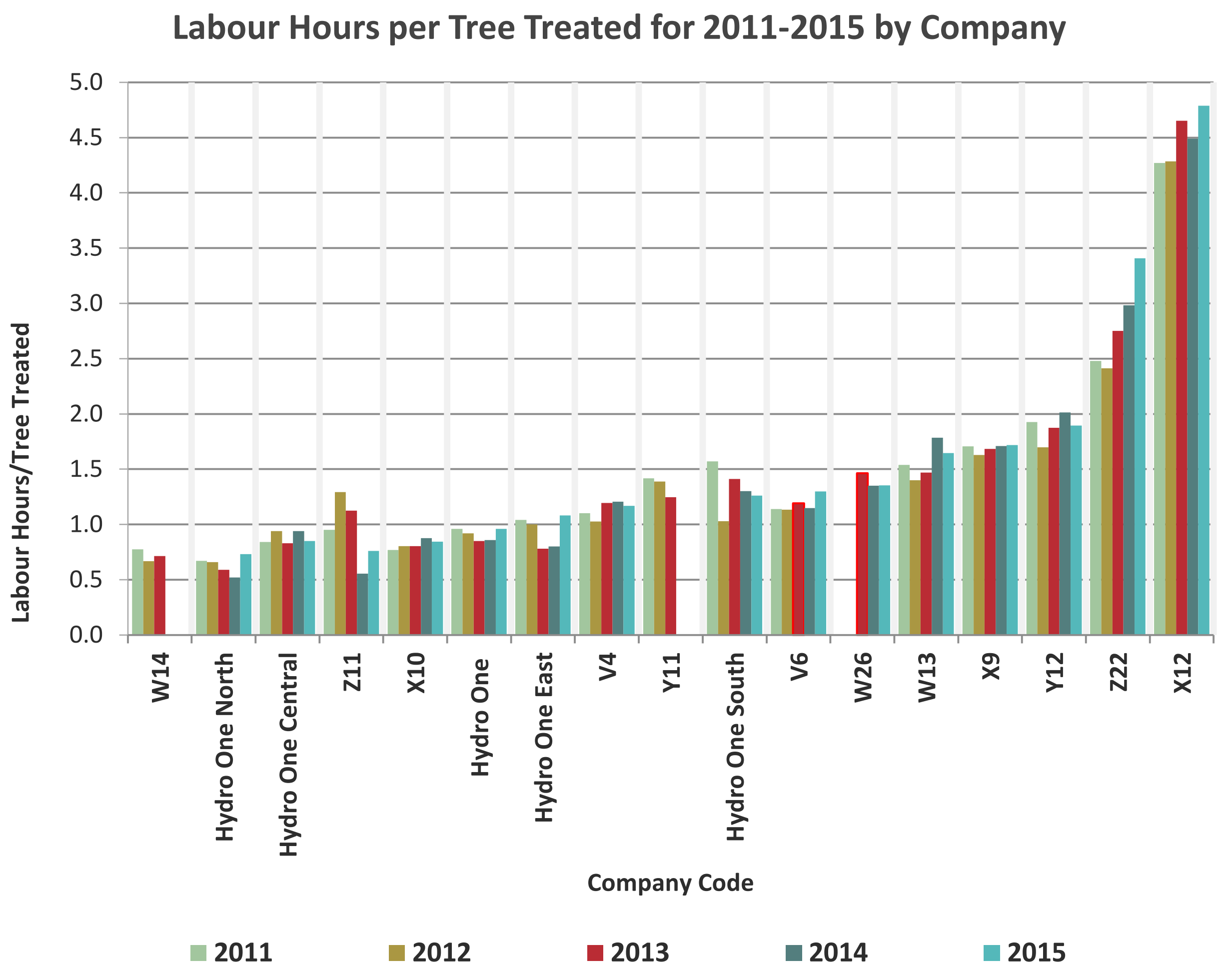
Graph 157: Annual Cost per Tree Treated for Years 2011-2015 by Company



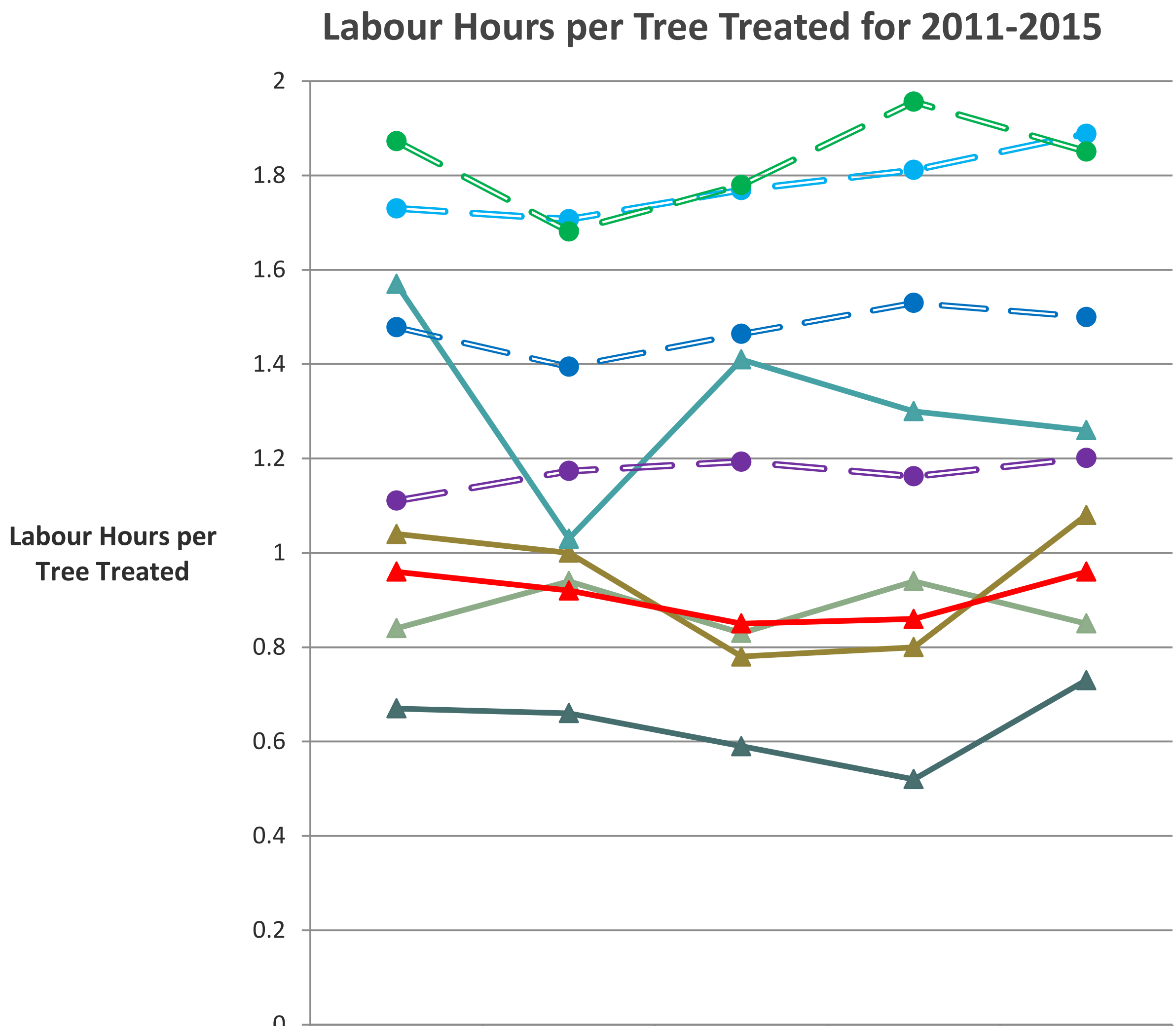
	2011	2012	2013	2014	2015
Hydro One Central	$90.37	$104.22	$88.51	$111.31	$97.74
Hydro One North	$76.37	$81.39	$69.07	$73.85	$104.43
Hydro One	$106.26	$105.28	$94.47	$106.55	$118.33
Hydro One East	$113.18	$112.76	$90.01	$100.55	$135.03
Hydro One South	$178.76	$118.66	$155.89	$157.11	$155.48
Peer Average	$80.51	$77.68	$79.58	$85.62	$91.54
Peer Q1	$48.96	$52.69	$52.84	$57.94	$59.14
Peer Median	$65.82	$63.34	$68.07	$77.29	$76.01
Peer Q3	$97.58	$104.22	$91.07	$106.55	$118.33

Graph 158: Statistical Comparison of Annual Cost per Tree Treated for Routine UVM for Years 2011-2015

Labour Hours per Tree Treated for Routine Maintenance 2011-2015



Graph 159: Annual Cost per Tree Treated for Years 2011-2015 by Company



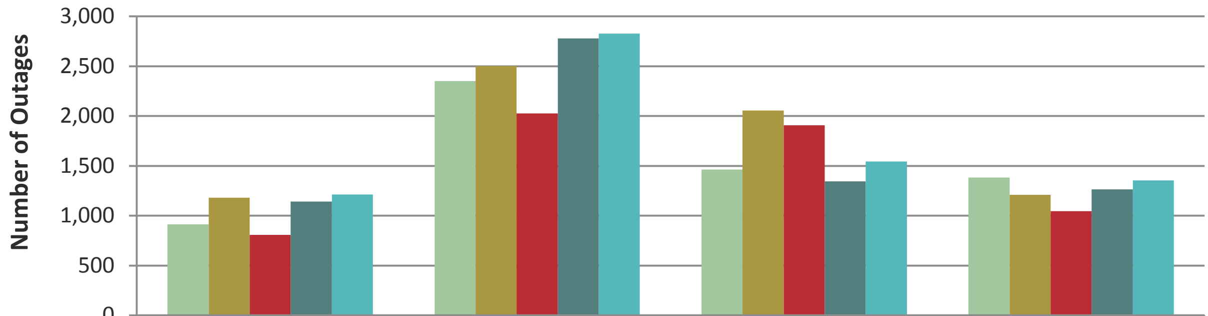
	2011	2012	2013	2014	2015
Hydro One Central	0.84	0.94	0.83	0.94	0.85
Hydro One East	1.04	1	0.78	0.8	1.08
Hydro One	0.96	0.92	0.85	0.86	0.96
Hydro One North	0.67	0.66	0.59	0.52	0.73
Hydro One South	1.57	1.03	1.41	1.3	1.26
Average	1.73	1.71	1.77	1.81	1.89
Q1	1.11	1.17	1.19	1.16	1.20
Median	1.48	1.39	1.46	1.53	1.50
Q3	1.87	1.68	1.78	1.96	1.85

Graph 160: Statistical Comparison of Annual Labour Hours/Tree Treated for Routine UVM for Years 2011-2015

HYDRO ONE RELIABILITY LONGITUDINAL ANALYSIS

Annual Number of Tree-Related Outages

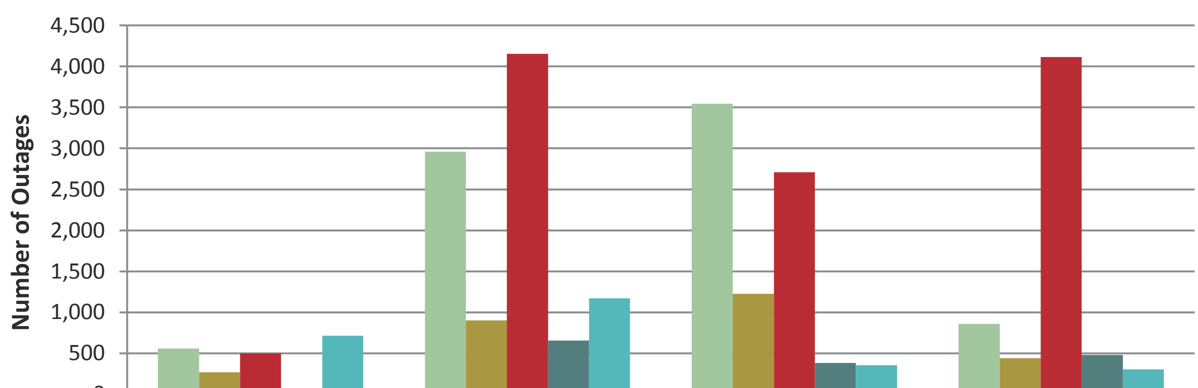
Annual Number of Non-MED Tree-Related Outages by Region



	HO North	HO Central	HO East	HO South
2011	913	2,351	1,462	1,382
2012	1,180	2,501	2,054	1,209
2013	808	2,026	1,907	1,046
2014	1,143	2,777	1,346	1,263
2015	1,212	2,828	1,543	1,354

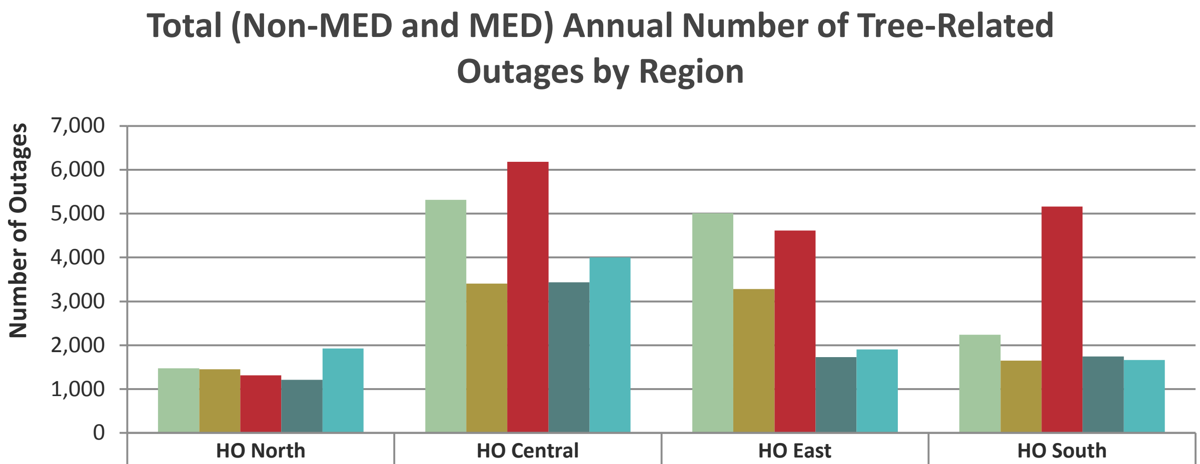
Graph 161: Annual Number of Non-MED Tree-Related Outages by Region

Annual Number of MED Tree-Related Outages by Region



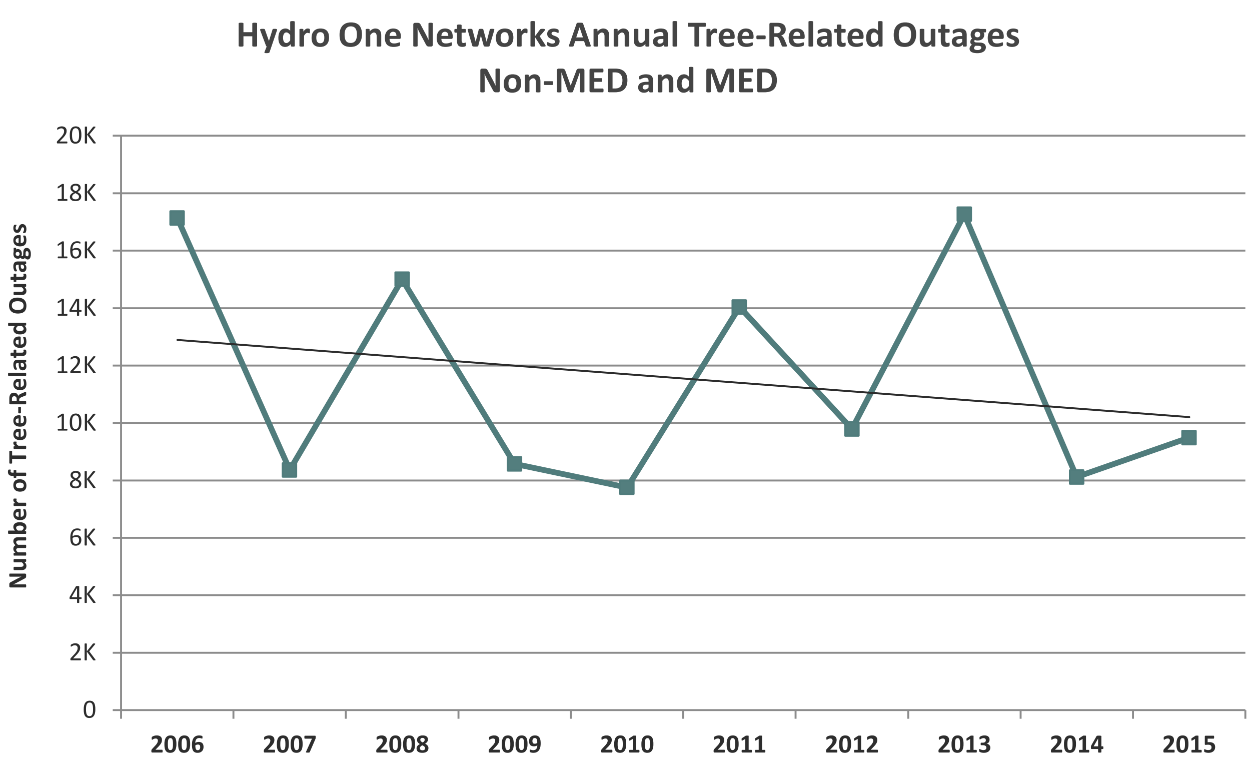
	HO North	HO Central	HO East	HO South
2011	561	2,959	3,546	860
2012	272	901	1,226	443
2013	502	4,152	2,709	4,113
2014	65	658	385	481
2015	715	1,172	358	307

Graph 162: Annual Number of MED Tree-Related Outages by Region



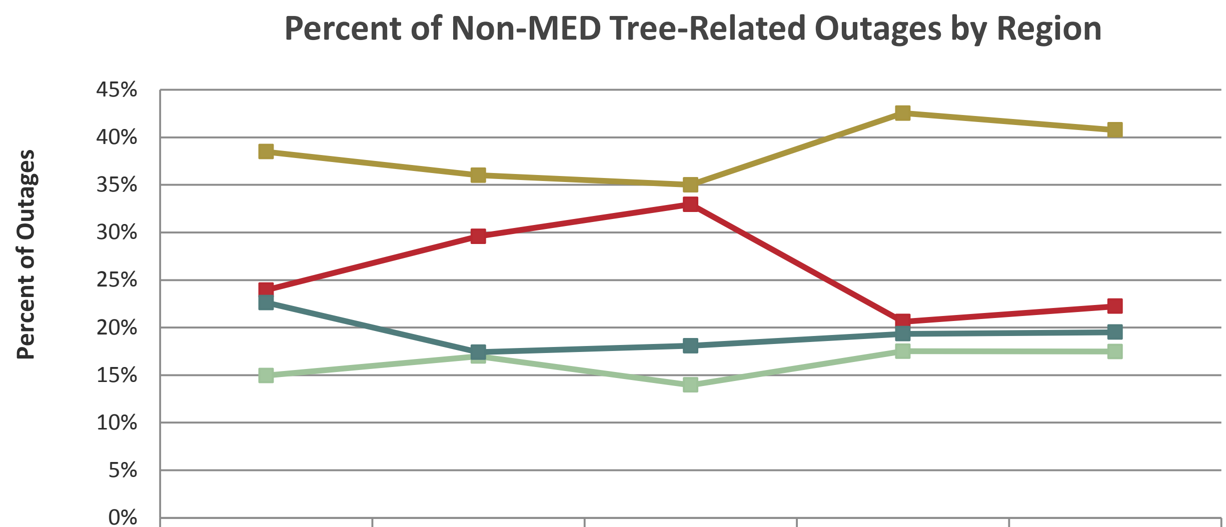
	HO North	HO Central	HO East	HO South
2011	1,474	5,310	5,008	2,242
2012	1,452	3,402	3,280	1,652
2013	1,310	6,178	4,616	5,159
2014	1,208	3,435	1,731	1,744
2015	1,927	4,000	1,901	1,661

Graph 163: Total Annual Number of Tree-Related Outages by Region



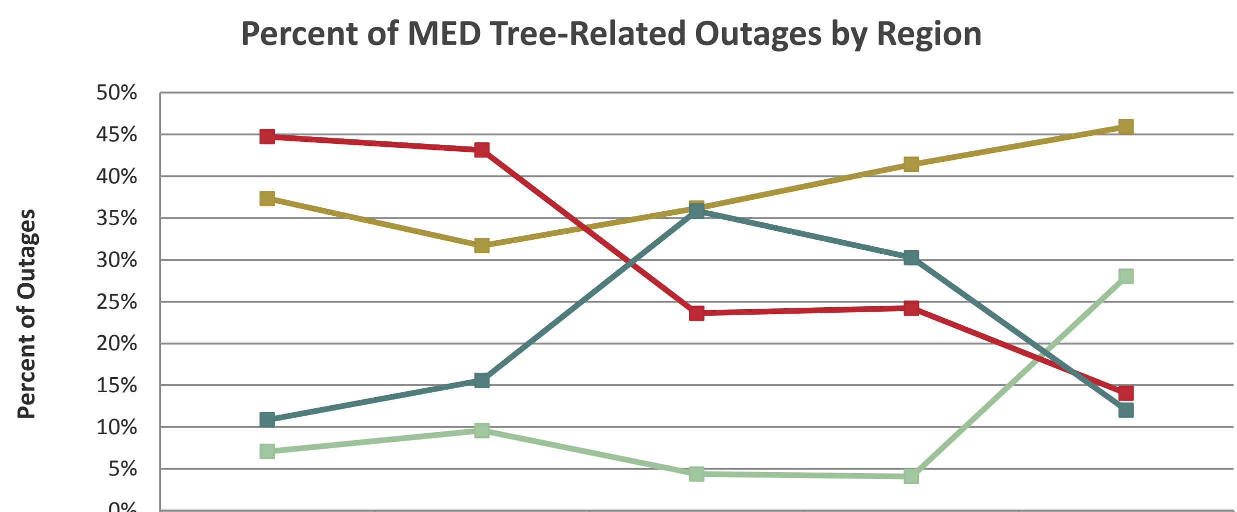
Graph 164: Hydro One Networks Annual Tree-Related Outages

Percent of Company Sustained Outages That Are Tree-Related



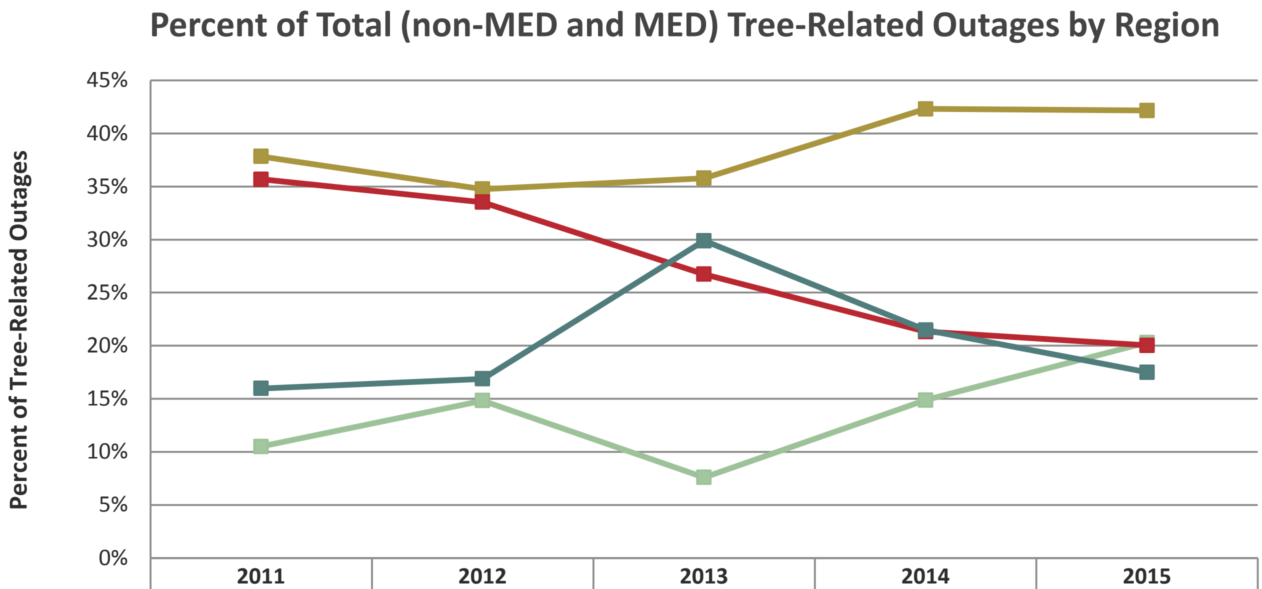
	2011	2012	2013	2014	2015
HO North	15%	17%	14%	18%	17%
HO Central	38%	36%	35%	43%	41%
HO East	24%	30%	33%	21%	22%
HO South	23%	17%	18%	19%	20%

Graph 165: Percent of Non-MED Tree-Related Outages by Region



	2011	2012	2013	2014	2015
HO North	7%	10%	4%	4%	28%
HO Central	37%	32%	36%	41%	46%
HO East	45%	43%	24%	24%	14%
HO South	11%	16%	36%	30%	12%

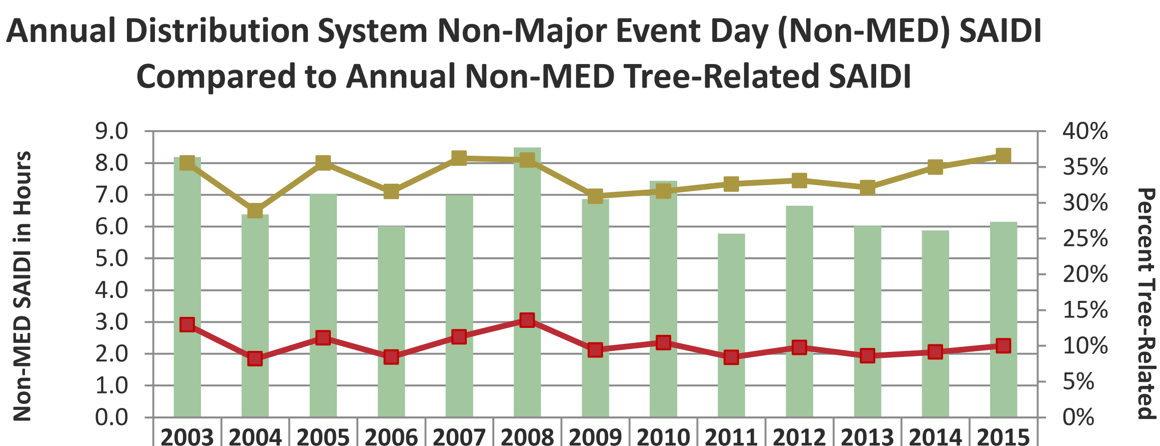
Graph 166: Percent of MED Tree-Related Outages by Region



	2011	2012	2013	2014	2015
HO North	11%	15%	8%	15%	20%
HO Central	38%	35%	36%	42%	42%
HO East	36%	34%	27%	21%	20%
HO South	16%	17%	30%	21%	18%

Graph 167: Percent of Total (non-MED and MED) Tree-Related Outages by Region

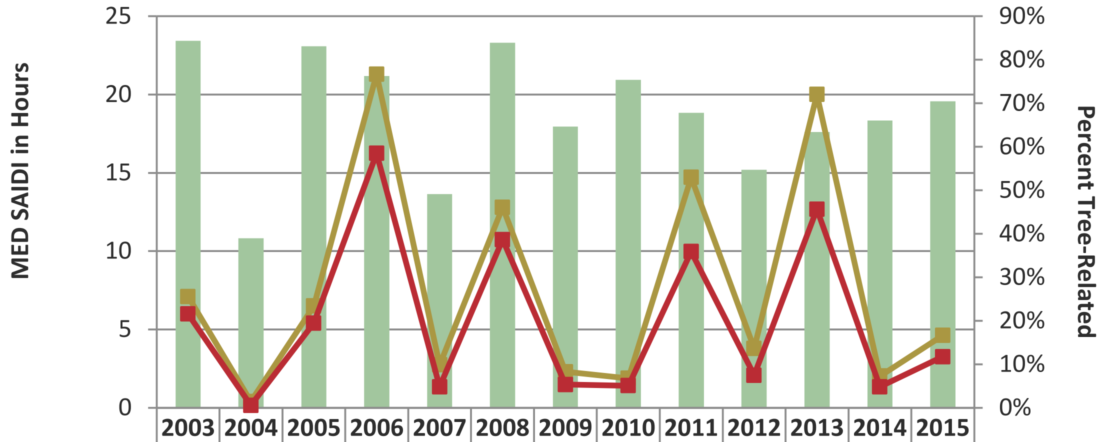
Total SAIDI versus Tree-Related SAIDI 2003 - 2015



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Tree-Related	36%	28%	31%	27%	31%	38%	31%	33%	26%	30%	27%	26%	27%
Total Non-MED	8.0	6.5	8.0	7.1	8.2	8.1	7.0	7.1	7.3	7.5	7.2	7.9	8.2
Tree-Related	2.9	1.8	2.5	1.9	2.5	3.1	2.1	2.4	1.9	2.2	1.9	2.1	2.3

Graph 168: Non-MED SAIDI – Total vs Tree-Related 2003 – 2015

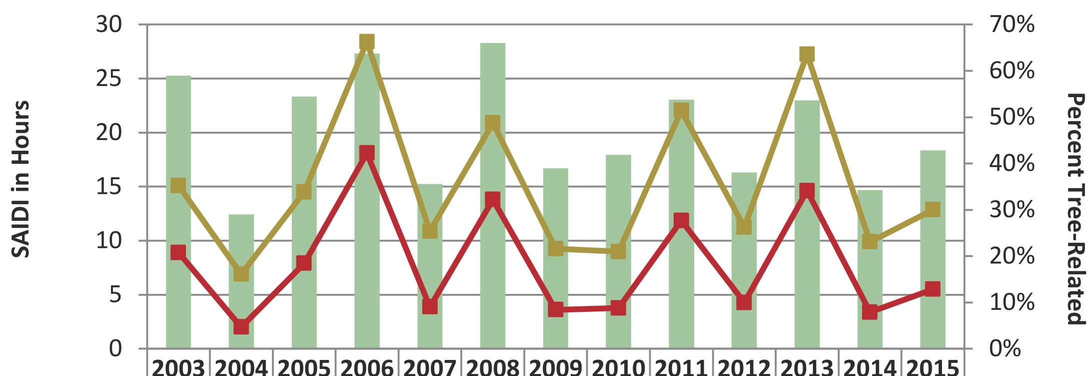
Annual Distribution System Major Event Day (MED) SAIDI Compared to Annual MED Tree-Related SAIDI



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Tree-Related	84%	39%	83%	76%	49%	84%	65%	75%	68%	55%	63%	66%	70%
Total MED	7.1	0.4	6.5	21.3	2.7	12.8	2.3	1.9	14.7	3.8	20.0	2.0	4.6
Tree-Related	6.0	0.2	5.4	16.2	1.3	10.7	1.5	1.4	10.0	2.1	12.7	1.3	3.3

Graph 169: MED SAIDI – Total vs Tree-Related 2003 – 2015

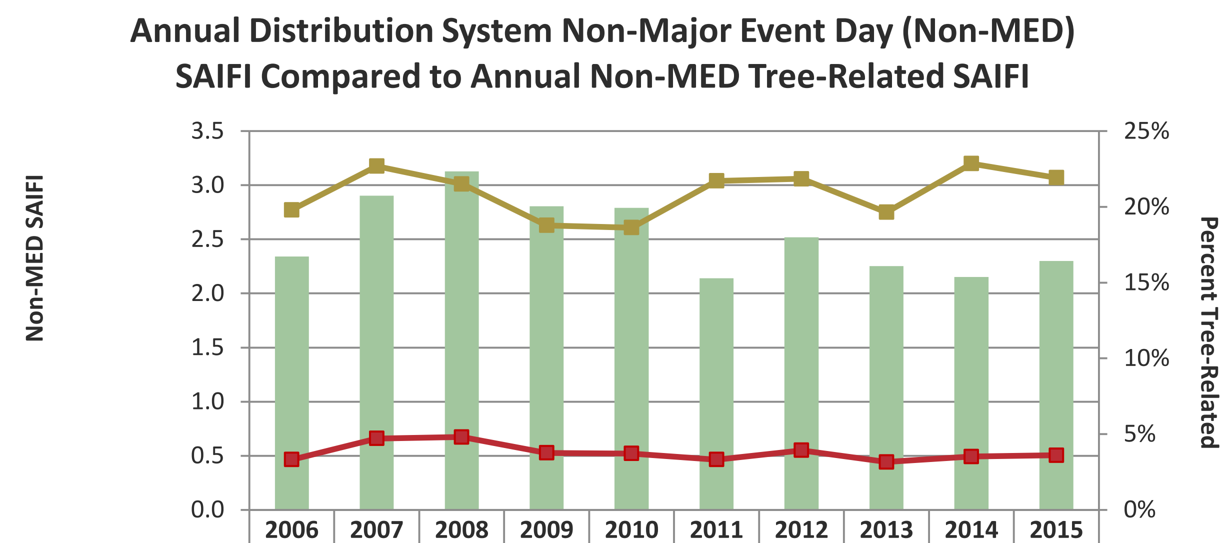
Annual Distribution System SAIDI Compared to Annual Tree-Related SAIDI



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Tree-Related	59%	29%	54%	64%	36%	66%	39%	42%	54%	38%	54%	34%	43%
Total	15.1	6.9	14.5	28.4	10.9	20.9	9.3	9.0	22.1	11.2	27.2	9.9	12.9
Tree-Related	8.9	2	7.9	18.1	3.9	13.8	3.6	3.8	11.9	4.3	14.6	3.4	5.5

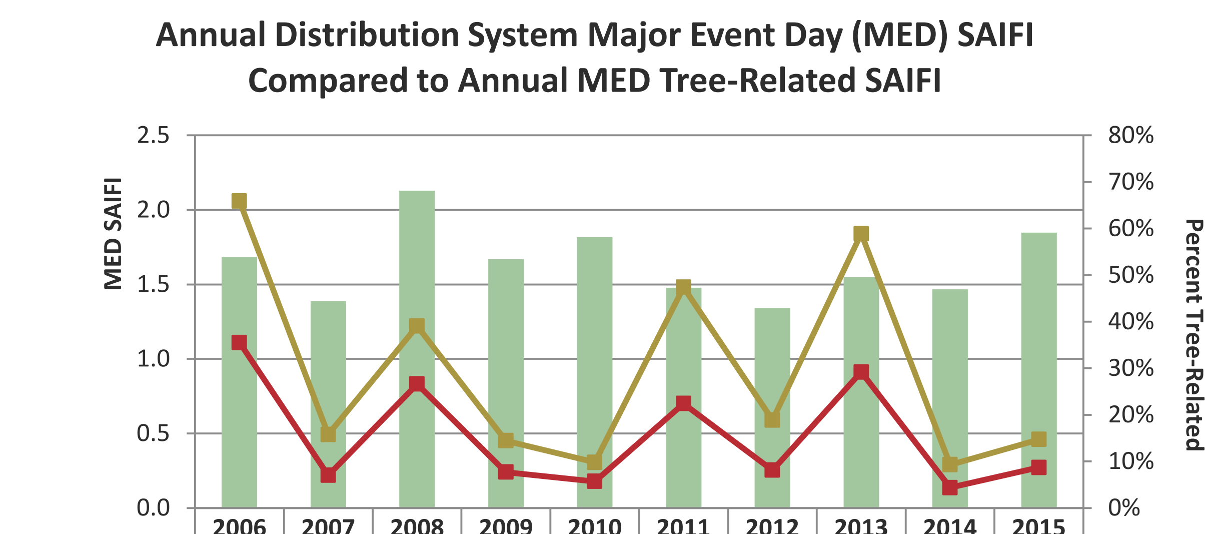
Graph 170: SAIDI – Total vs Tree-Related 2003 – 2015

Hydro One Networks Total SAIFI versus Tree-Related SAIFI 2006 - 2015



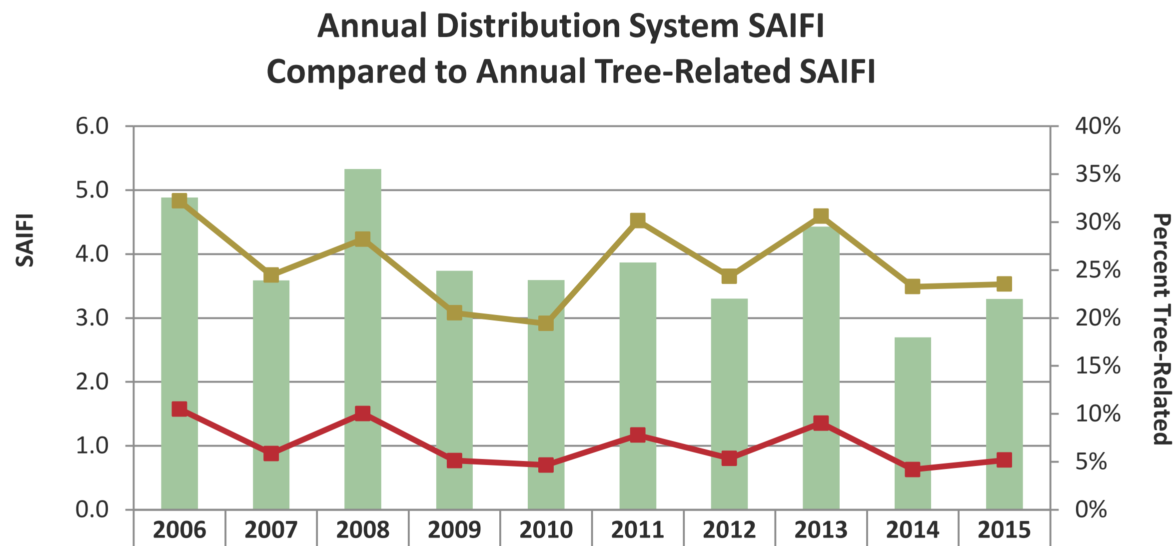
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Tree-Related	17%	21%	22%	20%	20%	15%	18%	16%	15%	16%
Total Non-MED	2.8	3.2	3.0	2.6	2.6	3.04	3.06	2.75	3.20	3.07
Tree-Related	0.5	0.7	0.7	0.5	0.5	0.46	0.55	0.44	0.49	0.50

Graph 171: Non-MED SAIFI – Total vs Tree-Related 2006 – 2015



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Tree%	54%	44%	68%	53%	58%	47%	43%	50%	47%	59%
Total MED	2.1	0.5	1.2	0.5	0.3	1.5	0.6	1.8	0.3	0.5
Tree	1.1	0.2	0.8	0.2	0.2	0.7	0.3	0.9	0.1	0.3

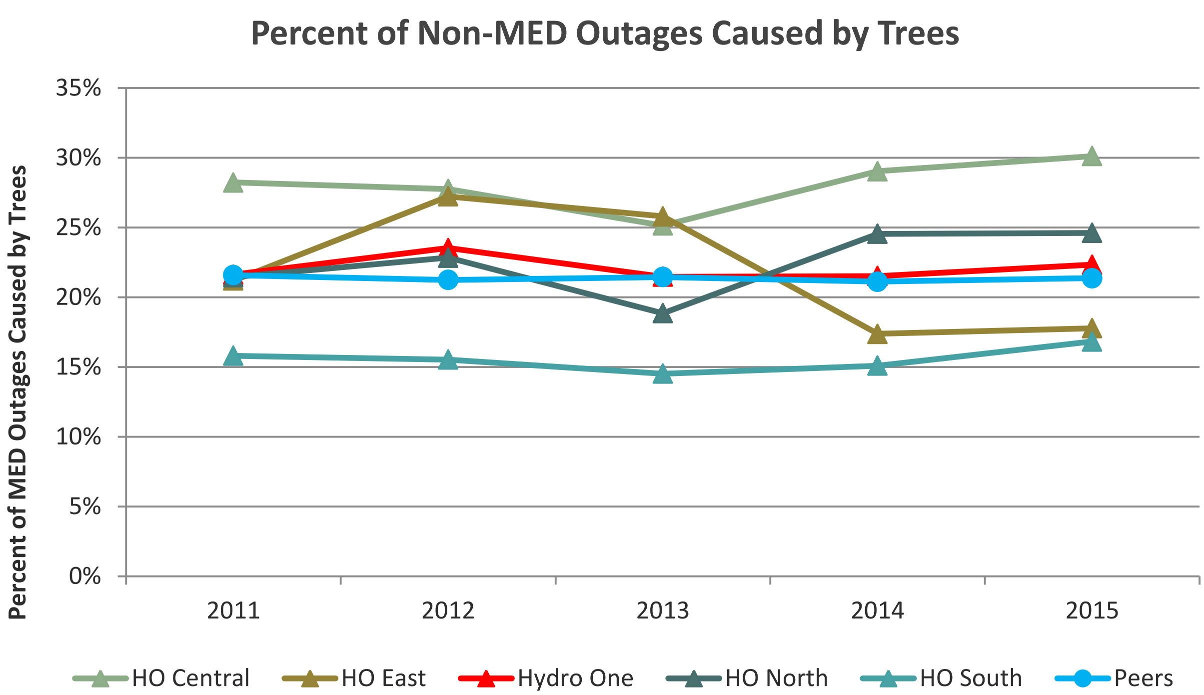
Graph 172: MED SAIFI – Total vs Tree-Related 2006 – 2015



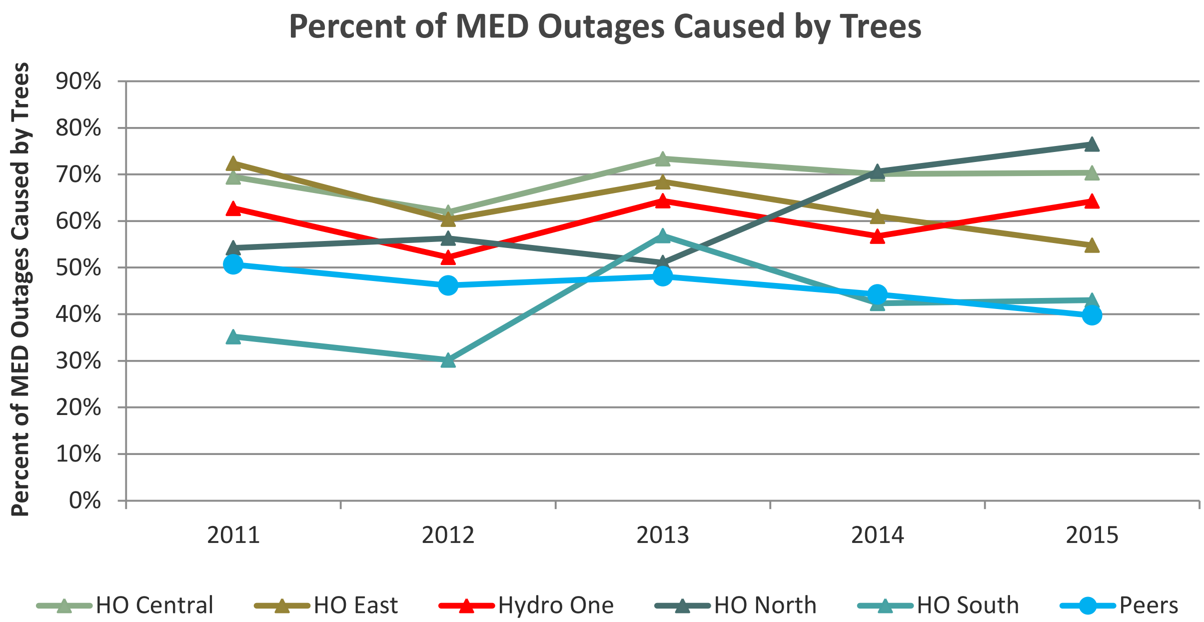
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Tree%	33%	24%	36%	25%	24%	26%	22%	30%	18%	22%
Total	4.8	3.7	4.2	3.1	2.9	4.5	3.7	4.6	3.5	3.5
Tree	1.6	0.9	1.5	0.8	0.7	1.2	0.8	1.4	0.6	0.8

Graph 173: SAIFI – Total vs Tree-Related 2003 – 2015

Outages Caused by Trees in Hydro One Regions



Graph 174: Percent of Non-MED Outages Caused by Trees



Graph 175: Percent of MED Outages Caused by Trees

FORM A

Proceeding:………………………

ACKNOWLEDGMENT OF EXPERT'S DUTY

1. My name is ....William Porter..........(*name)*. I live at .....Chicago..... (*city)*, in the .....Illinois..... (*province/state*) of .....USA..... .

2. I have been engaged by or on behalf of .....Hydro One..... (*name of party/parties)* to provide evidence in relation to the above-noted proceeding before the Ontario Energy Board.

3. I acknowledge that it is my duty to provide evidence in relation to this proceeding as follows:
   (a) to provide opinion evidence that is fair, objective and non-partisan;
   (b) to provide opinion evidence that is related only to matters that are within my area of expertise; and
   (c) to provide such additional assistance as the Board may reasonably require, to determine a matter in issue.

4. I acknowledge that the duty referred to above prevails over any obligation which I may owe to any party by whom or on whose behalf I am engaged.

Date .....23 February 2017.....

Signature

FORM A

Proceeding:.....EB-2017-0049.....

ACKNOWLEDGMENT OF EXPERT'S DUTY

1. My name is ....Nina Cohn.........(*name)*. I live at .....Chicago..... (*city)*, in the .....IL..... (*province/state*) of .....USA..... .

2. I have been engaged by or on behalf of .....Hydro One..... (*name of party/parties)* to provide evidence in relation to the above-noted proceeding before the Ontario Energy Board.

3. I acknowledge that it is my duty to provide evidence in relation to this proceeding as follows:

   (a) to provide opinion evidence that is fair, objective and non-partisan;

   (b) to provide opinion evidence that is related only to matters that are within my area of expertise; and

   (c) to provide such additional assistance as the Board may reasonably require, to determine a matter in issue.

4. I acknowledge that the duty referred to above prevails over any obligation which I may owe to any party by whom or on whose behalf I am engaged.

Date .....23 February 2017.....

Nina Cohn

Signature