DUKE ENERGY OHIO EXHIBIT________

BEFORE

THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Complaint of Citizens Against Clear Cutting, *et al*.,	)	
	)	
Complainants,	)	
v.	)	Case No. 17-2344-EL-CSS
	)	
Duke Energy Ohio, Inc.,	)	
	)	
Respondent.	)	

DIRECT TESTIMONY OF

JOHN W. GOODFELLOW

ON BEHALF OF

DUKE ENERGY OHIO, INC.

October 26, 2018

TABLE OF CONTENTS

PAGE

I. INTRODUCTION AND PURPOSE.

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is John W. Goodfellow, and my business address is PO Box 132, Marine on St Croix, MN 55047.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am employed by BioCompliance Consulting, Inc., as Principal Consultant.

Q. PLEASE BRIEFLY SUMMARIZE YOUR EDUCATIONAL BACKGROUND AND PROFESSIONAL EXPERIENCE.

A. I received a Bachelor of Science in Environmental Resources Management from SUNY College of Environmental Science & Forestry, and a Bachelor of Science in Forestry from Syracuse University. I have worked in the utility industry for 40 years; having held positions of responsibility for vegetation management, T&D operations, maintenance, engineering, and construction at three electric & gas utilities including New York State Electric & Gas, Wisconsin Public Service, and Puget Sound Energy. I currently manage an active portfolio of research projects related to utility vegetation management including work involving high voltage and mechanical testing of individual trees, characterizing risks that trees pose to overhead electrical conductors, and the practice of Integrated Vegetation Management (IVM). I was directly involved with high voltage testing that established an empirical basis of the Minimum Vegetation Clearance Distances between trees and transmission conductors established in NERC FAC-003.4. I am an active participant in the development of industry standards and best management practices as related to utility vegetation management. I worked directly with the National Arbor Day Foundation in creating that organization's "TreeLine USA" program which recognizes utilities for excellence in maintenance and construction activities in the urban forest. I also worked to create the "Right of Way Steward" accreditation program which recognizes excellence in the practice of IVM on the North American high voltage power grid. I am also a member of the International Society of Arboriculture (ISA), the Utility Arborist Association (UAA), Society of American Foresters, and the Institute of Electrical and Electronic Engineers, Power and Energy Society (IEEE, PES).

Q. PLEASE SUMMARIZE YOUR INVOLVEMENT IN THIS MATTER.

A. I've been retained by Duke Energy Ohio as a testifying expert in this matter. My role is to provide the Public Utilities Commission of Ohio (Commission) with information based on my experience that will help it render an informed decision.

Q. HAVE YOU PREVIOUSLY TESTIFIED BEFORE THE PUBLIC UTILITIES COMMISSION OF OHIO?

A. No.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THESE PROCEEDINGS?

A. The purpose of my testimony is to provide information pertaining to the risk of tree-initiated electrical faults on overhead transmission systems, describe relevant industry standards, discuss contemporary vegetation management practices, and explain why I believe that Duke Energy Ohio's vegetation management program is consistent with industry standards, best management practices and contemporary vegetation management programs in the utility industry. Specifically, I will speak to the manner in which trees pose risks to overhead transmission lines, describe the relevant industry standards and practices, and discuss why repeated pruning of trees within a transmission line corridor is inconsistent with industry practice.

II. <u>TREE-RELATED RISK TO TRANSMISSION LINES.</u>

Q. PLEASE DESCRIBE THE WAY IN WHICH TREES CAN HAVE AN IMPACT ON OVERHEAD ELECTRIC TRANSMISSION LINES.

A. There are two modes of failure on the transmission system attributed to trees. The mechanical mode of failure describes damage to utility infrastructure due to tree and branch strikes. The electrical mode of failure describes circumstances where the tree provides a short circuit fault pathway. This can occur either by direct contact between a tree and an energized conductor or by an air gap flash-across. The contact can be created by either movement of the tree, or movement of the conductor.

Q. ARE RISKS ASSOCIATED WITH EACH MODE OF FAILURE THE SAME?

A. Risk is a combination of the likelihood of an adverse event occurring and the consequences of that event. The mechanical mode of failure considers the likelihood of physical damage to conductors and supporting structures due to the structural failure of a tree or branch resulting in a strike. The electrical mode of failure considers the likelihood of an electrical short circuit caused by tree or branch close to or in direct contact with energized conductors. This may occur because of tree growth, branch deflection, or conductor sag or deflection. It may also be the result of tree or branch failure that doesn’t strike with enough force to damage infrastructure. In other words, there is a wide range of causes with the potential to result in the electrical mode of failure. The consequences of both the mechanical and electrical modes of failure that result in a tree-caused fault (short circuit) include an interruption, and outages to customers. Consequences associated with the mechanical mode of failure also include the direct cost to the utility to respond to, restore service, and repair the damaged equipment.

Q. PLEASE DESCRIBE THE CONSEQUENCES OF TREE-INITIATED FAULTS IN GREATER DETAIL.

A. As previously described, one of the consequences of tree strikes is physical (mechanical) damage to the transmission system infrastructure, which results in a direct cost of repair to the utility. However other consequences can be much more severe. Electrical short circuit faults on the transmission system result in a discharge of very large quantities of energy. For example, the amount of fault current that could flow during a tree-initiated fault between an energized conductor and earth on circuit 3881 and the other transmission lines at issue in this case is estimated at 11,599A, with an electric power equivalent of 2772 MVA. This is similar to the amount of power demand of a mid-sized city. If concentrated in one location, this amount of fault current can be very destructive, and threaten public safety. A fault due to a tree providing a pathway between two energized phases (conductors) has the potential to yield forty percent more power. The subsequent loss of electrical supply to vital services can also have an adverse effect on public safety.

Q. PLEASE DESCRIBE THE ELECTRICAL MODE OF FAILURE IN GREATER DETAIL.

A. A key point is that the electrical mode of failure is not associated with physical damage to transmission infrastructure. A short circuit fault pathway from an energized conductor through the tree to ground can be created in several ways, not all of which require physical tree to conductor contact. The position of transmission conductors is not static. They can be horizontally displaced due to wind, and vertically displaced due to sag under high electric load and in periods of hot weather. The dynamic nature of transmission conductor positions is also a function of span length, and the position within a span of wire. In other words, the conductors can move into contact with the tree. Similarly, trees can move into contact with energized conductors by deflection and by growth. It is also important to recognize that tree-initiated faults on high-voltage transmission lines do not require physical contact between an energized conductor and the tree. The likelihood of an air gap flash across between conductor and tree has been well documented.

Q. PLEASE DESCRIBE AIR GAP FLASH ACROSS FAULTS.

A. There is no coating of insulation on the wires (conductors) that that run between the transmission towers. The system relies on the dielectric strength of air and physical separation from areas of unequal electrical potential (voltage). There is an electrical field gradient between an energized conductor and earth. Objects such as trees distort the electrical field. Recent testing at the Electric Power Research Institute’s (EPRI) high-voltage lab in Lenox, Massachusetts revealed that tree size and shape have a direct influence on the likelihood of a flashover across the air gap between tree and conductor. The electric field gradient above flat ground is a uniform gradient. When an object such as a tree is encountered the field is distorted, bending around the object. A tree crown is composed of leaves, wood and water, with the majority of the volume often being simply air space. While not a solid object, it has sufficient electrical permittivity to distort the field. Electrical permittivity is a measure of how an electric field affects, and is affected by, a dielectric medium or object such as a tree, and relates to a material's ability to influence the shape of the electric field distribution. In other words the tree elevates and compresses the electrical field gradient. When the gradient becomes too high the dielectic strength of air breaks down and an arc is propagated across the gap. The result is a low impedance/high current fault from energized conductor, down the fault pathway provided by the tree, to earth.

Q. HOW DO UTILITIES MANAGE TREE RELATED RISKS ON TRANSMISSION SYSTEMS?

A. Vegetation management practices on transmission rights of way typically involve the elimination of tall growing trees, in favor of lower growing plant communities and landscapes. ANSI A300 Part 7 defines standard practices for Integrated Vegetation Management on electric transmission line rights of way.

III. RELEVANT INDUSTRY STANDARDS AND PRACTICES.

Q. WHAT STANDARDS APPLY TO UTILITY VEGETATION MANAGEMENT?

A. The American National Standards Institute (ANSI) publishes "*A300 -American National Standard for Tree Care Operations – Trees, Shrubs, and Other Woody Plant Management – Standard Practices*". There are two parts to this standard that are relevant to matters being considered in this proceeding; *Part 7 Integrated Vegetation Management a. Utility Rights-of way* and *Part 9 Tree Risk Assessment a. Tree Structure Assessment.*

Q. WHAT ARE ANSI STANDARDS?

A. ANSI establishes a formal process for creation of industry consensus standards and publishes the resulting standards. The Tree Care Industry Association (TCIA) is the accredited Standards Developing Organization (SDO). ANSI A300 was developed by a committee that included a wide range of stakeholders and included direct involvement of the utility industry.

Q. HOW DOES ANSI A300 PART 7 - INTEGRATED VEGETATION MANAGEMENT APPLY?

A. ANSI A300 Part 7 is the standard for Integrated Vegetation Management (IVM) which provides guidance on managing plant communities where compatible and incompatible vegetation is identified, tolerance levels and action thresholds are considered, and control methods are selected in order to achieve management objectives for a site. This standard and companion *Best Management Practice*, published by the International Society of Arboriculture, establishes the state-of-the-art vegetation management practices for electric transmission rights of way.

Q. PLEASE DESCRIBE THE CONCEPT OF COMPATIBLE AND INCOMPATIBLE VEGETATION IN MORE DETAIL.

A. The concept of compatible and incompatible plants is a core concept of IVM, which focuses on active management intended to establish plant communities and landscapes that are compatible with the primary purpose and use of the right of way. Compatible species include a wide variety of herbaceous and woody plants that at maturity would not pose a risk to overhead transmission conductors. In contrast, incompatible plants include species that have the potential to grow into close proximity to conductors. By this definition most species of tree are incompatible with overhead transmission lines.

Q. WHY IS RECOGNITION OF COMPATIBLE AND INCOMPATIBLE PLANTS AN IMPORTANT ASPECT OF IVM?

A. IVM is an active and efficient management system intended to establish sustainable conditions on transmission system rights of way. This is accomplished by actively managing the rights of way for the establishment of compatible vegetation that reduces risk, rather than simply attempting to control incompatible trees from growing into close proximity with energized conductors. IVM is efficient in that it results in the establishment of relatively stable plant communities and landscapes that reduce the amount of future work required to maintain and sustain transmission system rights of way.

Q. PLEASE DESCRIBE WIRE AND BORDER ZONES IN MORE DETAIL.

A. Most utilities have adopted a practice that separates a transmission corridor into zones based on the location of transmission conductors. The "wire zone" is directly below and extends some distance beyond the overhead conductors depending on the voltage of that particular transmission line. The border zone is that area beyond the wire zone to the edge of the cleared corridor. The IVM objective in the wire zone is to establish low growing vegetation which is predominantly herbaceous and may include species of compatible shrubs.

Compatible vegetation in the border zone typically includes additional taller growing species that mature at heights that would not pose a risk to transmission conductors. Duke Energy Ohio's vegetation management plan defines compatible species in the wire zone as those plants with mature height not more than seven feet, and not more than 15 feet in the border zone.

Q. IS DUKE ENERGY OHIO'S VEGETATION MANAGEMENT PLAN AND PRACTICES ON ITS TRANSMISSION LINES CONSISTENT WITH CONTEMPORARY IVM PRACTICE?

A. Yes, I have reviewed Duke Energy Ohio's transmission vegetation management plan and reviewed work that has been completed on circuit 3881 and the other transmission lines at issue in this case, and believe that both the plan and the work that has been completed are consistent with industry standards and practices. The reclamation work that's being performed is consistent with ongoing efforts across the industry to reestablish clearances on critical transmission circuits, post the Northeast Blackout. Once the transmission line corridor has been reestablished, future IVM practices will focus on establishing and enhancing the development of compatible plant communities in both the wire and border zones. Future work will also require continued vigilance to eliminate incompatible trees within the right of way.

Q. HOW DOES ANSI A300 PART 9 - TREE RISK ASSESSMENT APPLY?

A. ANSI A300 Part 9 is the standard used by utilities to assess risks to the overhead transmission and distribution systems posed by trees. The risk assessment process codified in this standard considers both the likelihood of a tree initiated event, and the consequence of that event. These concepts were used to describe tree-related risks described earlier in my testimony.

Q. PLEASE DESCRIBE ANSI A300 PART 9 IN THE CONTEXT OF IVM AND THIS PROJECT.

A. As previously described, trees and transmission conductors can come into proximity and/or contact with each other in a number of ways. The position of both trees and conductors is not static. Both can change in response to weather conditions and other factors. This insight serves to inform delineation of the wire and border zones. Trees can also grow into close proximity to transmission conductors. Recognition of height growth characteristics of trees serves to inform the species list for compatible and incompatible plants. The adverse consequences of tree-initiated incidents on the transmission system are considered in establishing tolerance levels and action thresholds which determine when vegetation management activities are carried out.

IV. REMOVAL OF TREES IN PROXIMITY TO TRANSMISSION LINES.

Q. WHY NOT SIMPLY CONTINUE TO PRUNE THESE TREES?

A. As previously described, trees growing underneath transmission conductors are incompatible with the primary use of the site. IVM has been previously described as a system for establishing sustainable, compatible plant communities beneath transmission conductors. In addition, continued height reduction pruning of trees growing beneath energized transmission conductors creates elevated risk to the facilities and to public safety. It should also be noted that vegetation management practices on transmission rights of way are different than work on the distribution system, where trees in proximity to distribution conductors are routinely maintained by line clearance pruning.

Q. PLEASE DESCRIBE HOW REPEATED PRUNING TREES BENEATH TRANSMISSION CONDUCTORS CREATES ADDITIONAL RISKS.

A. Duke Energy Ohio has determined a risk tolerance for vegetation less than seven feet tall in the wire zone. Mature trees being pruned (a.k.a. "topped") for clearance from overhead conductors are obviously significantly taller than seven feet above ground. As such they represent greater risk than Duke Energy Ohio has determined to be acceptable. They also create risk due to uncertainty and due to their crown forms.

Q. PLEASE DESCRIBE RISK-RELATED UNCERTAINTY ASSOCIATED WITH TREES DIRECTLY BENEATH TRANSMISSION CONDUCTORS.

A. Trees respond to pruning with an exaggerated flush of regrowth. Stem elongation rates can be twice that of normal rates of growth. The regrowth response can be varied and continue for two growing seasons following height reduction pruning. Most of the clearance achieved at the time of pruning is lost quickly. As a result, excessive height reduction pruning may be necessary to achieve adequate clearances at the time of pruning and call into question the aesthetic and/or biological viability of the tree as an element of the landscape.

Q. PLEASE DESCRIBE THE RISK ASSOCIATED WITH THE CROWN FORM OF TREES BENEATH TRANSMISSION CONDUCTORS.

A. As previously mentioned, recent testing by EPRI demonstrated that trees with broad flat tops growing directly below high voltage conductors create the weakest air gap for a potential flashover incident. This condition is most often associated with trees that are being maintained by repeated crown reduction pruning. As a result, line clearance pruning of trees directly under transmission conductors may unintentionally increase potential exposure to a flashover between a transmission line and the tree.

Q. BASED UPON YOUR KNOWLEDGE AND EXPERIENCE, IS THE DUKE ENERGY OHIO TRANSMISSION RIGHT OF WAY IVM PROGRAM CONSISTENT WITH INDUSTRY BEST PRACTICES AND SAFE AND RELIABLE UTILITY SERVICE?

A. Yes. Duke Energy's application of IVM is consistent with the relevant industry Standards, BMP's, and contemporary practices in the industry.

V. CONCLUSION.

Q. DOES THIS CONCLUDE YOUR PRE-FILED DIRECT TESTIMONY?

A. Yes.