Literature Search on Infrastructure Hardening
Compiled by FPSC Staff

This list is being updated as staff learns of other industry, technical, and academic studies, reports and news articles related to hardening of the electric utility infrastructure. Inclusion of a source on this list does not constitute an endorsement by staff nor does it mean that staff has fully reviewed the document.

I. Assessment of Nature and Causes of Storm Related Damages

I. A. Transmission Lines and Poles

I. A. 1)
Title of Report/Study/Article: *Utah Holiday 2003 Storm Inquiry*
Author: Pacificorp in consultation with the Division of Public Utilities and Committee of Consumer Service
Publication Date: May 13, 2004
Summary: Report on December 2003 storm prepared for the Utah Public Service Commission includes 28 recommendations. One conclusion was that 90% of the outages were caused by tree contact with power lines. Further, a tree trimming consultant hired as part of the storm inquiry found that 90% of the outages caused by trees were non-preventable. For example, damage was to distribution lines in customer's back yard. About 15% of tree-related outages were associated with high-voltage distribution lines and outages could have been prevent3d had the trees been trimmed to the company's existing standards. Recommendations 1-9: Initiatives to prevent or mitigate technology deficiencies that impacted the outage management system. Recommendations 10-17: Address number of downed secondary and service lines caused by fallen trees. Recommendations 18-25: Policy changes to improve the effectiveness of company's emergency operating plans. Recommendations 26-28: Initiatives to reinforce compliance with existing maintenance and correction policies for transmission and distribution assets.

I. A. 2)
Title of Report/Study/Article: *Pole Overloading: A Case for Joint Action*
Author: New Stratagem Consulting, Presented at 2nd Joint Wire and Pole Usage Conference
Publication Date: July 18, 2005
Summary: Poles are physically overloaded with electric, cable, telephone and fiber conductors, streetlights etc… As a result, poles are stressed and may bend and ultimately fail (break.) Pole overloading (in excess of NESC standards) has developed slowly over decades. There are few comprehensive surveys of overloading. An average of 5% of poles may be overloaded. Visual inspections and databases of pole attachments could help. A remediation plan, timetable and budget should be developed to correct existing problems.

I.A. 3)
Title of Report/Study/Article: Structural Reliability-Based Design of Utility Poles and the National Electrical Safety Code

Author: Nelson Bingel, Habib Dagher, Ronald Randle, Ronald Wofe, Lawrence Slavin, Michael Voda, and Jerry Wong
Publication Date: 2002
Summary: A manual developed by the American Society of Civil Engineers to determine appropriate strength and loading factors based upon objective reliability criteria. The manual provides a methodology for the proper determination of structural strength, preferably expressed as the 5% Lower Exclusion Limit, as well as appropriate strength factors to be applied to these values. In addition, through a calibration process, load factors have been determined to be applied to the ASCE 7 "50-year" extreme wind and combined ice and wind storms that will result in "equivalence" with the present NESC. Thus, the SRBD procedures will result in similar pole designs, on-the-average across the country, but with local variations, depending upon specific geographic location, number and type attachments. The recommendations are reflected in change proposals under consideration by the NESC Committee for incorporation into the upcoming 2007 Edition of the NESC.

I. A. 4)
Title of Report/Study/Article: The Need for NESC Loading & Strength Revision
Author: Richard F. Alchinger, PE, American Iron and Steel Institute
Publication Date: unknown
Summary: The National Electric Safety Code (NESC) has provided a means for establishing minimum loading and strength for transmission and distribution lines and structures since the early 1900's to the present. This paper recommends revisions to National Electric Safety Code to provide consistency and reliability for support structures design for the manufacture of both wood and steel poles.

I. A. 5)
Title of Report/Study/Article: Utility Storm Restoration Response – A Study for the Edison Electric Institute
Author: Brad Johnson, Independent Energy Advisor
Publication Date: January 2004
Summary: The report measures storm restoration performance of individual utility companies, includes survey results and two storm restoration case studies. The report finds that utilities have improved their ability to quickly repair significant damage done by major storms. They are deploying workers more efficiently, power is being restored more quickly and the overall duration of storm outages is decreasing. However, lack of data in a consistent format prevented measurement of performance at a nationwide or industry-wide level.

I. A. 6)
Title of Report/Study/Article: *February 2003 Ice Storm Assessment*, Kentucky Utilities Company Report to the Kentucky Public Service Commission
Author: Kentucky Utilities Company
Publication Date: May 15, 2003
Summary: This report is a critical review and self-assessment of emergency response activities undertaken by the Kentucky Utilities Company. The company identified four issues it will address to improve operations. 1) Addition of a Spanish speaking person in the call center. 2)

Education of customers regarding their responsibilities to repair customer-owned portions of electric service. 3) A "best available" computerized outage management system is needed. 4) An individual is needed to be dedicated specifically to meet the needs of governmental groups.

I. A. 7)
Title of Report/Study/Article: *Inspection Techniques for Detecting Latent Damage to Existing Overhead Transmission Lines from Previous Ice and Wind Storms*
Author: The Canadian Electricity Association Technologies , CEATI
Publication Date: 2004
Summary: The report recommends using checklists to customize the inspection of transmission line components to reduce the number of subsequent transmission line structure and component failures resulting from undetected latent damage. (From abstract, report available for purchase.)

I. B. Distribution Lines and Poles

I. B. 1)
Title of Report/Study/Article: *The Wood Pole 2005: Design Considerations, Service Benefits, and Economic Reward*
Author: W. Richard Lovelace, Hi-Line Engineering, LLC
Publication Date: 2005
Summary: The report concludes that with over 130 million wood poles in service and millions of new wood poles installed each year, treated wood is the electric utilities' material of choice for transmission and distribution lines. It further concluded that proper line design, pole selection and installation are the keys to the successful use of the wood pole. The reported touched on four important areas in material selection for power line construction which are: Basic Impulse Insulation Level, Raptor Protection, Installation, and Duty Cycle. In each of these areas, wood poles evaluated very favorably. Despite intense promotion by alternative materials and developments in engineered products, it still seems that now and for years to come, treated wood remains the best all around product for most utility applications. It is raptor friendly, easy to install, naturally insulating, and has a long duty cycle.

I. B. 2)
Title of Report/Study/Article: *Working Load Comparisons of Wood and Thin Walled Steel Poles Under NESC Grade C Line Construction*
Author: North American Wood Pole Coalition
Publication Date: None shown.
Summary: The report concludes that wood poles have a significantly higher "Working Load" than thin walled steel poles for a given pole class under the National Electric Safety Code (NESC) when designing line construction to NESC's Grade C standards. This construction is commonly used for distribution lines. Under NESC Grade C construction standards, in order to achieve "equivalency" with wood pole working loads, thin walled steel poles would either have to be 3 or more pole classes larger or have span lengths reduced to the point that approximately

80 percent more steel poles would be required per mile than wood poles of the same class. The report included tables to calculate the "Allowable Transverse Load on Conductors." This is typically the limiting factor in determining the required Pole Class for a given load design. As shown in these tables, wood poles and thin walled steel poles have identical allowable loads for a given pole class under NESC Grade B construction. However, under NESC Grade C construction, the "Allowable Transverse Load on Conductors" is not identical. This situation creates a significant difference between the use of wood and steel poles in NESC Grade C applications.

I. B. 3)
Title of Report/Study/Article: *Steel Pole Pilot Program Sets New Standard at Arizona Public Service Company*
Author: Duane Oliver, Construction Supervisor, Arizona Public Service Company, Northwest Division.
Publication Date: None shown.
Summary: The report choreographed the switching from wood to steel poles for Arizona Public Service Company service area. Some key conclusions stated in the report: Linemen adjusted well to the change in pole material from wood to steel; Steel offered substantial benefits such as when a steel pole is damaged, it may not require immediate repair, thus eliminating off-hours work and overtime; Steel poles can be pre-drilled to a utility's specifications by the manufacture; Steel poles are at least 30 percent lighter; Steel poles come from the manufacturer installed with a grounding plate saving both labor and equipment needed to install grounding rod on most installations. The report further concluded that steel poles longevity is greater than wood (except Cedar poles which are hard to get and as much or more than steel poles) which makes them cost-effective in the long run.

I. B. 4)
Title of Report/Study/Article: *Utilities Make Tradeoffs When Selecting Pole Types*
Author: Andy Stewart, EDM International, Inc.
Publication Date: June 1, 2003
Summary: The report addressed the particular advantages of four different materials for pole design which were; Wood, Light-duty steel, Fiberglass and Spun concrete. Typically, the advantages for each type were as follows: Wood-Cost, availability, workability; Light-duty steel-Service life, know strength, engineered product; Fiberglass-Service life, lightweight; Spun concrete-Service life durable. The report mentioned several other categories that should be evaluated as well before selecting which type of material that should be used in pole design. These are: Characteristics and Capabilities; Handling and Installation; Design Issues; Durability and Maintenance; Environmental Characteristics; Initial and Life-Cycle Costs.

I. B. 5)
Title of Report/Study/Article: Reliability of Poles, University of Maine
Author: Dr. H.J. Dagher, P.E., Director, Advanced Structures and Composites Laboratory, University of Maine
Summary: The presentation addressed the particular advantages of steel distribution poles. An American Society of Civil Engineers Committee on Pole Reliability-Based-Design (RBD) was formed consisting of Producers (steel, wood, concrete, and Fiberglass poles), University faculty, and Utility engineers. The purpose of the Committee was to write a pre-Standard on RBD of Transmission and Distribution pole structures The RBD will evaluate the following: Pole probability of failure, Design that will have consistent target reliability; Develop multiple partial safety factors rather than one safety factor; Develop partial safety factors depending on load and strength statistics.

I. B. 6)
Title of Report/Study/Article: *Annual Power Pole Integrity Program, Inspection of Florida Power & Light and Progress Energy*

Author: Florida Public Service Commission Electric Safety Group
Publication Date: May 2005
Summary: In the spring of 2005, the Commission's Electric Safety group conducted a physical inspection on a sample of utility poles. The goal of the inspection sample was to identify any power poles that might be rotted, damaged or otherwise structurally compromised and needing repair or replacement. This first investigation focused on areas served by Florida's two largest power companies, Florida Power and Light and Progress Energy–Florida. Twenty-three counties were included in the sample of Florida Power and Light's service area with 600 poles documented as physically inspected. Out of these 600 documented pole inspections, five poles were found with minor to moderate surface damage and one with apparent significant structural damage. No poles were identified with any significant visible rot. 16 counties were included in the sample of Progress Energy's territory with 553 poles documented as physically inspected. Out of these 553 documented pole inspections, no poles were identified with any visible rot or significant structural damage.

I. B. 7)
Title of Report/Study/Article: *Preliminary Review of Vegetation Management, Lightning Protection, and Pole Inspection at Florida Power & Light Company*
Author: Florida Public Service Commission Division of Competitive Markets and Enforcement, Bureau of Regulatory Review.
Publication Date: July 2005
Summary: The report addressed the efforts made by Florida Power & Light to maintain and improve distribution and transmission service reliability during the period 1999-2004. Staff found that FPL's vegetation-related outages increased during the period and remained above the 1999 level in 2004. FPL vegetation-related system average interruption duration index, customer average interruption duration index, and system average interruption frequency index also increased during the period. The number of total distribution line miles FPL trimmed decreased in 2000-2001, but increased during 2002-2004. Staff's review of FPL's lightening protection efforts during the period revealed that FPL has adequately addressed lightning protection. Staff found that FPL may not be completing sufficient numbers of formal specific pole inspections throughout its territory to identify the condition of deteriorated poles in a timely manner. Staff also found that FPL has not procedurally documented a cycle completion period for formal specific pole inspections in order to ensure all distribution poles have been inspected and their condition documented.

I. B. 8)
Title of Report/Study/Article: *Preliminary Review of Vegetation Management, Lightning Protection, and Pole Inspection at Progress Energy Florida*
Author: Florida Public Service Commission
Publication Date: July 2005
Summary: The report addressed the efforts made by Progress Energy Florida to maintain and improve distribution and transmission service reliability during the period 1999-2004. Progress experienced an increase in overall vegetation-caused interruptions during the review period. Along with an increase in outages, the number of customer interruptions due to vegetation outages has increased. Staff notes that the number of miles of feeder lines trimmed has declined during the same period. Progress Energy's number of interruptions caused by lightning declined

during the review period. The company has decreased the impact of lightning-related outages, as can be seen in the 2001 through 2004 lighting reliability results. The company has not experienced a large number of interruptions related to pole failure during the review period. The company has procedures and guidelines for conducting both distribution and transmission pole and facility inspections. While the company has conducted inspections during the review period, staff notes the company has not maintained its inspection schedule as outlined by management.

I.C. Substations and Transformers

I. C. 1)
Title of Report/Study/Article: *Analytical Methodology for Analyzing Aging Substation, Transmission and Grid Assets, Project P112.004* (Power Delivery Asset Management, 2006 Portfolio, pages 10-12)
Author: Electric Power Research Institute
Publication Date: 2006
Summary: This project provides a rational basis for selecting repair or replacement options for aging substation, transmission, and grid assets by balancing the risks of equipment failure and reliability deterioration against the costs of continued maintenance or capital replacement and the benefits of newer technologies. The products enable users to generate business cases for investments, project capital and O&M budget requirements, evaluate reliability impacts and risks, and focus scarce manpower and investment resources on high-value solutions. The decision framework takes a lifecycle costing approach that enables corporate financial managers and regulators to assess the multi-year reliability and financial impacts of maintaining specific classes of power delivery infrastructure assets. Case studies using the tools developed in this project have documented a 25%–35% savings (on a present value basis) for optimal policies compared to run-to-failure, as well as a smoothing of financial impacts.

I. C. 2)
Title of Report/Study/Article: *Substations, Projects PS37A-H*
Author: Electric Power Research Institute
Publication Date: 2006
Summary: Three projects within EPRI's Substation Program appear relevant. (1) *PS37A, Transformer Life Management.* Addresses management of the aging population of power transformers and load tap changers (LTC) from the aspect of diagnostics, monitoring, and on-line condition assessment. It also includes the development of guidelines and training in conducting transformer design reviews and developing specifications. (2) *PS37B, Improve Overall Substation Maintenance Management.* The primary focus of this project set is on research efforts to enable better use of optimized maintenance techniques that can help management address maintenance issues. The overall strategy is to develop an integrated set of tools that will operate on companywide real-time and historical data to support continuous risk and performance assessment. (3) *PS37H, Improved Substation Siting, Inspection, and Insulation.* Delivers knowledge and tools to assist Substation staff, save costs and improve reliability in three high-cost areas: the initial siting of substations, the insulation of substations, and the inspection of substations.

I. C. 3)
Title of Report/Study/Article: *Distribution Asset Analysis Suite Offers Transformer Load Management, Capacity Planning,*
Author: *Transmission & Distribution World*
Publication Date: December 21, 2005
Summary: This article from the publication *Transmission & Distribution World* describes commercially available tools for managing industry distribution systems. The Itron Distribution Asset Analysis Suite contains four asset load management and capacity planning tools for energy distribution systems. These tools combine actual customer usage and billing data with SCADA-based substation information and weather data to increase the resolution and accuracy of loading data throughout the distribution system, and result in more effective asset management decisions and practices. According to the article, through use of these tools, Xcel Energy in Denver now has the capability to predict which distribution transformers are likely to fail in extreme weather.

I. C. 4)
Title of Report/Study/Article: *Electric Distribution, Multi-Year Research, Development, Demonstration, and Deployment Technology Roadmap Plan: 2005-2009*
Author: Office of Electric Transmission and Distribution, U.S. Department of Energy
Publication Date: December 2004
Summary: This document will be used by the DOE's Office of Electric Transmission and Distribution to help formulate its Distribution R&D budget and set priorities on investments based on the recommended activities. The implementation will be carried out through the Electric Distribution Transformation Program, and the GridWise and GridWorks Initiatives. One activity of interest is "Enhancing the Value of Aging Infrastructure" (page 29), which deals with equipment such as underground cables, wood poles, transformers and circuit breakers, workforce effectiveness, and right-of-way vegetation management. However, these activities will not be completed until 2009. Regarding distribution substations and transformers, the goal is to develop a test bed for evaluating technologies for increased capacity, evaluate increased capacity technologies and evaluated diagnostics technologies. A related area within DOE, is a new program called GridWorks. The GridWorks program is designed to improve the reliability of the electric system through the modernization of key grid components: cables and conductors, substations and protective systems, and power electronics. The GridWorks program has a multi-year plan based on consultation with representatives of the electric utility industry, power system equipment manufacturers, other Federal and State agencies, universities, and national laboratories. The program will identify technical barriers to grid modernization and includes near-term activities to incrementally improve existing power systems and accelerate their introduction into the marketplace. It also includes long-term activities to develop new technologies, tools, and techniques to support the modernization of the electric grid.

I. C. 5)
Title of Report/Study/Article: *Critical Power*
Author: Digital Power Group
Publication Date: August 2003
Summary: This white paper is focused on hardening and protecting the power grid through the ability to isolate faults and split the grid into smaller autonomous islands. According to paper,

from the perspective of the most critical loads, the restoration of power begins at the bottom, with on-site power instantly cutting in to maintain the functionality of the command and control systems that are essential in coordinating the step-by-step restoration of the grid as a whole. Though the hardening of the grid does certainly begin at the top tier, in the generation and transmission facilities, much of modern grid's resilience is attributable to the simple fact that "interties" knit local or regional grids into a highly interconnected whole. In this way, any individual end user may receive power from many widely dispersed power plants (This architecture also increases everyone's vulnerability to far away problems.) Very large end users rely on similar "intertie" strategies – one-tier lower down in the grid – to help secure their specific critical-power needs. Substations, deeper in the network and closer to critical loads, can also serve as sites for deployment of distributed generating equipment. With the addition of its own generating capacity, the substation is a "sub" no longer – it becomes a full-fledged "mini-station." According to the report, opportunities for deploying new generation at this level of the grid – either permanently or when emergencies arise – are expanding, although still greatly under deployed. To complement the hardware, monitoring and maintenance play a key role in maintaining power reliability. Sensor and software driven predictive failure analysis will become an essential component of next-generation reliability-centered maintenance.

I.D. Maintenance Practices

I. D. 1)
Title of Report/Study/Article: *The Neglected Option For Avoiding Electric System Storm Damage & Restoration Costs – Managing Tree Exposure*
Author: Siegfried Guggenmoos, Ecological Solutions Inc. http://www.Ecosync.com
Publication Date: 2005
Summary: Undergrounding is not a feasible approach to avoiding future storm damage because of the high costs. Utilities do not advocate greater tree to conductor clearances due to fear of public opposition despite the fact that it would substantially reduce future storm damage. However, maintaining the status quo causes the continued rebuilding of the overhead electric system, further studies of undergrounding that yield the predictable conclusion that it is neither affordable nor feasible. The report states that it is possible, through a proper program of tree risk management, to substantially reduce future storm damage. The report states an avoidance of 50% of the currently experienced storm damage is within the realm of possibility.

I. D. 2)
Title of Report/Study/Article: *Operations Audit of Electric and Gas Transmission and Distribution of NorthWestern Energy – Montana*
Author: Liberty Consulting Group
Publication Date: July 2, 2004
Summary: The audit of NorthWestern Energy – Montana (NWE-M) found that with regard to transmission system inspection and maintenance, the number of electric transmission system outages caused by defective system hardware and relay scheme problems was a concern. Also, that vegetation management practices could be improved. The report recommended that NWE-M put its transmission lines on a time-based tree trimming cycle, based on tree types, terrain, and voltage, supplemented by an annual inspection program to identify hot spots. It also

recommended that NWE-M develop formalized substation equipment maintenance and testing programs based on system priorities such as equipment voltage and where the equipment is on the system. Regarding transmission pole maintenance, though the company's current inspection program had identified many bad (4-rated) poles, it did not have a 4-rated pole replacement timetable. For example, though it had 957 known "bad" poles on its system, it was not able to report the number of bad poles replaced in 2002 or 2003. It was recommended that the company develop methods for identifying schedules for replaying poles based on safety concerns as well as criticality.

I. D. 3)
Title of Report/Study/Article: *Decision Applications Division, 2005 Progress Report*
Author: Energy and Infrastructure Analysis Group, Los Alamos National Laboratory
Publication Date: March 2005
Summary: Analyzes electric networks to identify transmission and subtransmission lines that are critical for power transfer and subtransmission system configuration – availability of generation units for local system demand and voltage stability. (Pages 27 and 28)

I. D. 4)
Title of Report/Study/Article: *Decision Applications Division, 2005 Progress Report*
Author: Infrastructure and Emergency Planning Division, Los Alamos National Laboratory
Publication Date: March 2005
Summary: A computer model was developed to map hurricane utility impacts (page 47.) The Interdependent Energy Infrastructure Simulation System (IEISS) allows researchers to identify critical components and vulnerabilities in coupled infrastructure systems to (1) assess how future investments in the systems might affect quality of service; (2) perform integrated cost-benefit studies; (3) evaluate the effects of regulatory policies; and (4) aid in decision-making during crises. News release mentions a potential collaborative effort with Florida Power & Light to help prepare their planners and responders for next year's hurricane season.

II. Potential Mitigation Techniques

Construction and Management Practices

II. A. 1)
Title of Report/Study/Article: Maintenance a Key Issue**,** *South Florida Sun-Sentinal*
Author: Hank Sarkis
Publication Date: November 14, 2005
Summary: A former Florida Power & Light engineer provides his view of improvements that could be made to the power distribution system in Broward County to improve the ability of FPL facilities to withstand storm events. Among the issues identified are the failure of new poles, rotten lateral and service poles, tree-trimming along distribution lines in the public right-of-way. Undergrounding facilities is not the answer. He recommends a comprehensive joint FPL/BellSouth audit to identify compromised poles, and suggests that cities work with utilities to ensure adequate clearance for power lines.

II. Potential Mitigation Techniques

B. Engineering or Meteorological Studies

II. B. 1)
Title of Report/Study/Article: *The Wind Effects Committee*(http://www.seiwec.net/)
Author: Structural Engineering Institute, American Society of Civil Engineers
Publication Date: N/A
Summary: The Wind Effects Committee (WEC) is a technical committee of the Structural Engineering Institute (SEI), which is a semi-autonomous institute of the American Society of Civil Engineers (ASCE). Among the committee's goals is to enlighten the engineering profession on the subject of wind forces on structures, and the response of structures to those wind forces.

II. B. 2)
Title of Report/Study/Article: Assessment and Restoration of Major System Damage
Author: CYME International
Publication Date:
Summary: A power engineering T & D company, advanced analysis tools for transmission, distribution and industrial power systems. A program called MARS is used by CenterPoint Energy in Houston, Texas and Hydro-Quebec in Canada to help them manage restoration following major events such as hurricanes and ice storms. MARS 1) Automates "Best Practice" damage restoration methods; (2) Plans circuit switching, provides fastest restoration; (3) Provides overview of damages for news media (with estimated restoration date for each area); (4) Creates switching orders and maps, which guides the isolation of damages, and the transfer of priority customers to working circuits; (5) Prioritizes work for daily crew assignment with instructions on connecting loads after work is completed. These instructions may include rearrangements as restoration progresses.

II. B. 3)
Title of Report/Study/Article: Hurricane and Extreme Storm Impact Studies
Author: U. S. Geological Survey, Coastal & Marine Geology Program
Publication Date: 2005
Summary: The USGS Coastal and Marine Geology Program investigates the extent and causes of coastal impacts of hurricanes and extreme storms. The overall objective is to improve the capability to predict coastal change that results from severe tropical storms. Such a capability will facilitate locating buildings and infrastructure away from coastal change hazards

II. B. 4)
Title of Report/Study/Article: Hurricane Research Center
Author: Florida International University
Publication Date: N/A
Summary: The International Hurricane Research Center is a multidisciplinary center focused on the mitigation of hurricane damage to people, their property, and the built and natural

environments. To adequately assess these diverse yet inherently related topics the Center is comprised of four research laboratories:

II. Potential Mitigation Techniques

C. Undergrounding of Facilities

II. C. 1)
Title of Report/Study/Article: Lenox Underground Transmission Lab Operational, Pressurization Project Delivering First Results
Author: Electric Power Research Institute (EPRI)
Publication Date: December 7, 2005
Summary: EPRI developed an Underground Transmission Laboratory in Lenox, Massachusetts that provides a platform for full-scale testing of transmission cable.

II. C. 2)
Title of Report/Study/Article: Project Opportunity: Advanced Underground Transmission Construction
Author: Electric Power Research Institute (EPRI)
Publication Date: November 18, 2005
Summary: Utilities are invited to join a project opportunity to develop advanced and simplified technologies to greatly reduce the cost and increase the speed of underground transmission facility construction. The project will explore alternatives in three areas: develop a suitable manhole design to reduce the number of manholes on parallel cable circuits, evaluate reinforcing steel designs, and develop advanced technologies for underground facility construction.

II. C. 3)
Title of Report/Study/Article: *A Review of Electric Utility Undergrounding Policies and Practices*
Author: Navigant Consulting
Publication Date: March 8, 2005
Summary: A report for the Long Island Power Authority – updates earlier studies and surveys the current state of the industry on the issue undergrounding electric distribution systems. Over 90% of the annual number of customer interruptions on LIPA's the distribution system occur on distribution primary and secondary overhead construction. Interruptions on LIPA's transmission system account for less than 2% of the annual number of customer interruptions. Undergrounding existing lines would greatly increase both utility costs and customer rates. Utilities have adopted a variety of programs for undergrounding lines such as: California's "Rule 20" plan to finance undergrounding projects with utility rate money, combined rate funds and local tax proceeds through neighborhood special assessment districts, or private funds. The report stated that targeting certain portions of especially vulnerable overhead distribution system for undergrounding is an approach used by some utilities.

II. C. 4)

Title of Report/Study/Article: *Reducing Windstorm Damage to Property and Electrical Utilities*
Author: Oregon Emergency Management and the Federal Emergency Management Agency
Publication Date: July 2002
Summary: Hazard Mitigation Survey Team Report for the Severe Windstorm in Western Oregon. Mitigation strategies recommended included: improved communication and coordination; education and outreach; vegetation management; and engineering, construction and compliance.

II. C. 5)
Title of Report/Study/Article: *Out of Sight, Out of Mind?*
Author: Brad Johnson, Independent Energy Advisor
Publication Date: January 2004
Summary: A study prepared for the Edison Electric Institute on the cost and benefits of undergrounding overhead power lines. Burying overhead power lines costs about 10 times what it costs to install overhead power lines. When compared to overhead power systems, underground power systems tend to have fewer power outages, but the duration of these outages tends to be much longer.

II. C. 6)
Title of Report/Study/Article: *The High Price of Aesthetics*
Author: Brad Johnson
Publication Date: May/June 2004
Summary: Reliability benefits associated with burying existing overhead systems are uncertain and in most instances do not justify the high price tag.

II. C. 7)
Title of Report/Study/Article: *The Feasibility of Placing Electric Distribution Facilities Underground*
Author: Public Staff, North Carolina Utilities Commission
Publication Date: November 2003
Summary: Report of the Public Staff to the North Carolina Natural Disaster Preparedness Task Force. The Public Staff recommended that each of the utilities (1) identify the overhead facilities in each region it serves that repeatedly experience reliability problems based on measures such as the number of outages or number of customer-hours out of service; (2) determine whether conversion to underground is a cost-effective option for improving reliability of those facilities, and, if so, (3) develop a plan for converting those facilities to underground in an orderly and efficient manner, taking into account the outage histories and the impact on service reliability.

II. C. 8)
Title of Report/Study/Article: *Placement of Utility Distribution Lines Underground*
Author: Virginia State Corporation Commission
Publication Date: January 7, 2005
Summary: A report to the Governor and the General Assembly of Virginia. Based on research and analysis and input from interested parties, the wholesale relocation of the currently existing overhead utility distribution lines and placement of all new utility distribution lines underground

is probably not reasonable. The economic effects of such an effort on sate and local governments or utilities, and ultimately consumers, would be significant.

II. C. 9)
Title of Report/Study/Article: *Task Force to Study Moving Overhead Utility Lines Underground, Final Report*
Author: Task Force
Publication Date: December 30, 2003
Summary: Report to the Governor of Maryland. The report found that while undergrounding may be desirable for aesthetic or public policy reasons, the impact on reliability is unclear and the costs are substantial.

II. C. 10)
Title of Report/Study/Article: *A Citizen's Initiative: Evaluating the Benefits of Underground Utility Distribution, Final Report*
Author: Suresh K. Khator, Ph.D., P.E., George C. Moore, P.E., Vinit G. Dixit, University of South Florida College of Engineering
Publication Date: July 31, 1999
Summary: Report submitted to Florida Department of Community Affairs. The report analyzes the cost-benefits associated with converting the overhead distribution system on Davis Island, Florida to underground. The report concluded that it would be cost-effective to do so if the expected increase in real estate values were considered. According to the report, lower external, operation and maintenance costs, and increased real estate values offset the higher construction cost for underground.

II. C. 11)
Title of Report/Study/Article: *Undergrounding Public Utility Lines*
Author: Pamela Martin, Researcher, Legislative Reference Bureau, State Capitol, Honolulu, Hawaii
Publication Date: December 1999
Summary: A report by the Legislative Reference Bureau to the Hawaii State Legislature. The report highlights the need to develop the measurement of intangibles; create independent review throughout the process in order to reduce built-in bias; establish clearer communication lines between consumers and PUC operations; promote quality consumer participation in the process; encourage settlement through alternative dispute resolution; and provide for safety through the establishment of a one-call system.

II. C. 12)
Title of Report/Study/Article: *Putting Cables Underground*
Author: Putting Cables Underground Working Group for the Commonwealth of Australia
Publication Date: November 24, 1998
Summary: Estimated total cost of putting existing overhead electricity and telecommunications cables underground in urban and suburban Australia is about $23.37 billion, or an average of $5,516 per household. A number of innovative ideas were identified which could potentially reduce the cost of putting cables underground by up to 20 percent in the first year and up to 35 percent over five years.

II. C. 13)
Title of Report/Study/Article: *Overview of the Potential for Undergrounding the Electricity Networks in Europe, Prepared for the DG TREN/European Commission*
Author: ICF Consulting Ltd.
Publication Date: February 28, 2003
Summary: The report assesses the potential for undergrounding electricity networks in the Member States of the European Untion, Norway and Switzerland. It reviews technical and economic factors, benefits of undergrounding, new technology, electric and magnetic fields, cost benefit analysis of additional interconnection, impact of undergrounding on cost of electricity, and political and regulatory factors.

II. C. 14)
Title of Report/Study/Article: *After Hurricanes, A Renewed Interest in Underground Power Lines*
Author: Scripps Howard News Service
Publication Date: December 5, 2005
Summary: Rep. Clay Shaw says he is drafting legislation that would allow power companies to immediately write off the costs of burying lines, rather than depreciating the costs over 15 years as currently permitted under federal policies. However, the Edison Electric Institute says burying lines is just not cost-effective as it can be 10 times more per mile to install.

II. C. 15)
Title of Report/Study/Article: Funding Utility Relocation
Author: Scenic America
Publication Date: Unknown
Summary: Provides several sources of funding from federal, state, and local agencies, in addition to special assessments to help pay for utility relocation.

II. C. 16)
Title of Report/Study/Article: Kailua Undergrounding Project gets a big boost from new HECO Cost Sharing Policy
Author: Don Bremner, Kailua Vision Group
Publication Date: December 8, 2000
Summary: Hawaiian Electric Company, Inc. converts existing overhead lines to underground lines as part of a community or government-initiated underground project, subject to PUC approval, and will cost-share up to one-third of the costs to underground distribution lines of 25kV and below.

II. C. 17)
Title of Report/Study/Article: *Preliminary Analysis of Placing Investor-Owned Electric Utility Transmission and Distribution Facilities Underground in Florida*
Author: Florida Public Service Commission
Publication Date: March 2005
Summary: Using estimates from the previous 1991 Commission study on undergrounding and escalating them for inflation, it would cost approximately **$51.8 billion** to underground the

existing transmission lines of the five electric investor-owned utilities. Assuming conversion and cost recovery over a ten-year period, the impact for such an undertaking, on a kWh basis, for all customers combined for these utilities would be an increase in rates of approximately 49.7% with the increased rates continued for the ten-year period. The estimated cost to place existing overhead distribution lines and feeders underground for the five investor-owned electric utilities is $94.5 billion. This conversion cost estimate is primarily based on cost estimates from the previous 1991 Commission study escalated for inflation. Assuming conversion and cost recovery over a ten-year period, if the $94.5 billion estimated cost of undergrounding distribution feeders and subdivisions is spread over all rate payers for the combined IOUs, the impact on rates, on a kWh basis, would be an increase of 81.1% with the increased rates continued for the ten year period. If the costs are spread over only residential customers, the increase would be 141.5% with the increased rates continued over the ten year period. These rate impacts are with reference to all customer costs, including base rates and fuel. It is emphasized that the estimated costs developed in this document to underground overhead transmission and distribution lines include only utility costs. No customer costs or other external costs were considered.

II. C. 18)
Title of Report/Study/Article: *FPSC Order No. 23126-A,* Docket No. 890833-EU, Investigation into the cost-effectiveness of undergrounding electric utility lines.
Author: Florida Public Service Commission
Publication Date: July 16, 1990
Summary:

II. C. 19)
Title of Report/Study/Article: *Report on Cost-Effectiveness of Underground Electric Distribution Facilities*
Author: Florida Public Service Commission
Publication Date: December 1991
Summary: Three volumes plus report to Florida Legislature

II. C. 20)
Title of Report/Study/Article: *FPSC Order No. PSC-92-0975-FOF-EU,* Adoption of Rule 25-6.0115, F.A.C., Underground Electric Facility Costs, and Withdrawal of Amendments to Rule 25-6.078, F.A.C., Schedule of Charges
Author: Florida Public Service Commission
Publication Date: September 10, 1992
Summary:

II. Potential Mitigation Techniques

D. Hardening the Electric Utility Infrastructure

II. D. 1)

Title of Report/Study/Article: FPL Weighs Storm Plans, Budgets: FPL May Pay Part of the Costs of Burying Lines, is Increasing Tree-Trimming Budgets and is Examining Its Whole System
Author: Miami Herald
Publication Date: December 19, 2005
Summary: Florida Power & Light is reanalyzing its attitude toward underground lines and is increasing its tree-trimming budget by 20 percent. FPL will consider whether meeting the National Electric Safety Standards is enough or if another standard should be considered and what it the cost

II. D. 2)
Title of Report/Study/Article: *After the Disaster: Utility Restoration Cost Recovery*
Author: Bradley W. Johnson, ACN Energy Ventures LLC
Publication Date: February 2005
Summary: Outlines steps electric utilities and state regulators should consider in establishing concrete, stable mechanisms to plan for and mitigate the massive cost of rebuilding electric systems following a major weather event.

II. D. 3)
Title of Report/Study/Article: *The 3 R's of Critical Energy Networks: Reliability, Robustness and Resiliency*
Author: Richard Larson, David Marks, Munther Dahleh and Marija Ilic for the MIT Energy Research Council
Publication Date: October 30, 2005
Summary: A research proposal to (1) develop system models with sufficient fidelity to identify weaknesses in energy networks as well as potential for cascading failures; (2) design and analyze new methods for improving infrastructure, taking into account the interactions with legacy systems; (3) improve real-time monitoring and control of energy networks; (4) develop new technologies for transmitting and storing energy; (5) determine how economic and regulatory incentives can be used to direct investment for improving the network infrastructure; and (6) to reduce needed network capacity by decreasing peak energy demands via incentives and technologies for time-shifting the demand to off-peak hours.

II. D. 4)
Title of Report/Study/Article: An Approach To Action For The Electricity Sector
Author: Working Group Forum on Critical Infrastructure Protection, North American Electric Reliability Council
Publication Date: Version 1.0, June 2001
Summary: A working group proposal for the North American Electric Reliability Council (NERC) and the U.S. and Canadian members of the electricity sector to take an active voluntary role in the full range of Critical Infrastructure Protection (CIP) activities for the electricity sector.

II. D. 5)
Title of Report/Study/Article: *Katrina Poses Extreme Challenges for Power Engineers*
Author: Greg Hill - Today's Engineer online
Publication Date: September 2005

Summary: Electric power engineers discuss how to make electrical transmission and distribution systems more robust and resilient to storms.

II. D. 6)
Title of Report/Study/Article: *Windstorm Impact Reduction Act – Public Law 108-360*
Author: U.S. Congress
Publication Date: October 25, 2004, reauthorized January 2005
Summary: Federal legislation establishes a National Windstorm Impact Reduction Program. Program objective is achievement of major measurable reductions in losses of life and property from windstorms. Objective to be achieved through coordinated Federal effort, in cooperation with other levels of government, academia, and the private sector, aimed at improving the understanding of windstorms and their impacts and developing and encouraging implementation of cost-effective mitigation measures to reduce those impacts. Interagency Working Group to give Congress an implementation plan for achieving the Program objectives within 1 year. Office of Science and Technology Policy shall establish a National Advisory Committee on Windstorm Impact Reduction.

III. Safety Standards

A. National

III. A. 1)
Title of Report/Study/Article: National Electric Safety Code (NESC)
http://standards.ieee.org/nesc/
Author:
Publication Date:
Summary: The National Electrical Safety Code (NESC®) sets the ground rules for practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines and associated equipment. The NESC contains the basic provisions that are considered necessary for the safety of employees and the public under the specified conditions.

III. A. 2)
Title of Report/Study/Article: National Institute of Standards and Technology, Electronics and Electrical Engineering Laboratory
Author:
Publication Date:
Summary: Provides the fundamental basis for all electrical measurements in the United States. In consultation with industry, tailors research and calibration programs to meet critical measurement needs for the manufacture and operation of electrical and electronic systems, including semiconductor, magnetic, radio frequency, microwave, optical, optoelectronic, and superconducting equipment; flat-panel displays; electronic instrumentation; and electrical power apparatus and systems.

B. State

III. B. 1)
Title of Report/Study/Article: Order Instituting Safety Standards
Author: New York Public Service Commission
Publication Date: January 5, 2005
Summary: Order issued by New York Public Service Commission in the Proceeding on Motion of the Commission to Examine the Safety of Electric Transmission and Distribution Systems.