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INFRASTRUCTURE

Grid Resiliency From Electromagnetic Threats; the Infrastructure Plan Provides an Opportunity for Substantial Investment

- Given a confluence of events (the U.S. government's plans for a $1 trillion infrastructure investment and the geopolitical tensions currently being experienced as they relate to North Korea's nuclear program), we've examined the investment needs and opportunity for hardening of the United States electrical grid against Geomagnetic Disturbances (GMD) and Electromagnetic Pulse (EMP) events. What we found is that hardening against such attacks is possible, but will require significant leadership and coordination among federal agencies, state public utility commissions, grid operators and electric utilities.
- Reliable estimates of the total cost to ensure resiliency from electromagnetic pulse and geomagnetic events are wide-ranging. One offered to Congress from a special commission assembled to address this issue in 2004 recommended spending $10B to $20B (in 2004 USD) over a 20 year period, for a total investment ranging from $200B to $400B, but other estimates are as low as $10B to $30B. Given that solutions to achieve significant resiliency already exist and could be considered "shovel-ready", our view is that interested stakeholders should immediately press the political establishment to provide some level of funding for this endeavor. Given most utilities are likely to reduce rates to customers due to the recent lowering of the corporate federal tax rate from 35% to 21%, perhaps tax savings could be redeployed into the aforementioned resiliency investments. Other options could be special utility programs such as those used to address natural gas distribution pipe replacement for safety purposes, which have been successful in recent years.
- Grid reliability investment could easily be targeted to U.S.-based corporations, benefitting shareholders, workers, tax collections and the U.S. economy. The U.S. already possesses a handful of transformer manufacturers, and utilities/transmission operators and construction companies could substantially benefit. These would be highly skilled, high-paid jobs, the very type the current U.S. government administration is targeting to create more of. The benefits would be spread across the entire country, in both red and blue states, particularly those with dense population centers.
- Hardening will likely require a phased approach, based on 1) the natural replacement cycle of equipment, 2) focusing initially on protecting the largest, most important transformers, 3) investments in Regional Transmission Operators (RTO's) and Independent System Operators (ISO's), 4) communication hardening, and 5) generators and their "black-start" capability. Our report provides a brief overview of the grid, the threats to it, and partial potential investment opportunities for companies within (and a select group outside) our coverage universe focused in the Northeast and Mid-Atlantic regions.

REPORT OVERVIEW

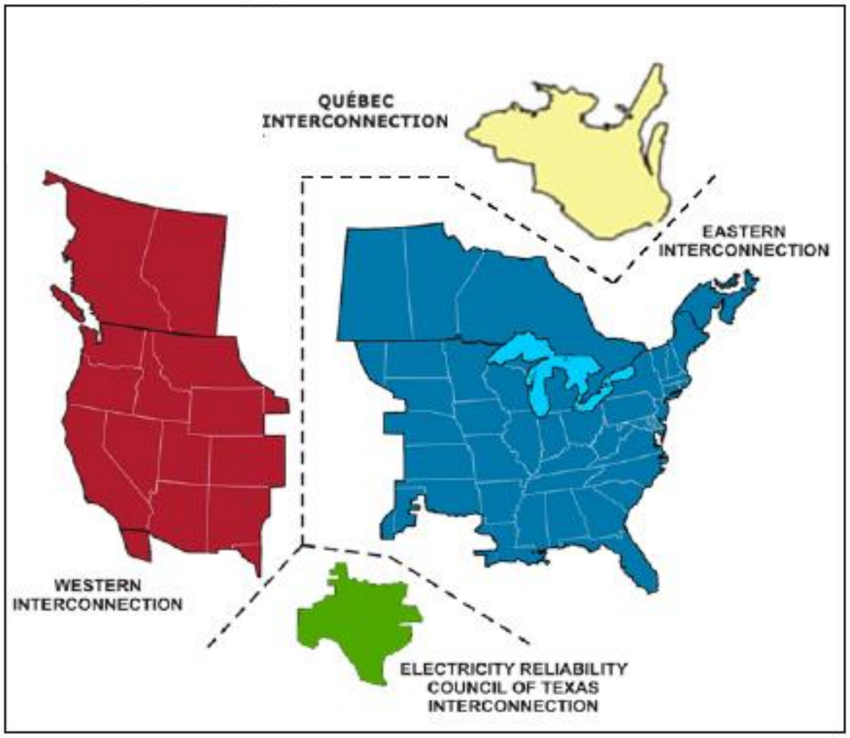
We see the potential for significant capital investment opportunities across the U.S./North American electrical grid. We believe a confluence of events, including a renewed focus by the U.S. government on infrastructure improvement (and commitment that could approach $1 trillion USD), the United States resolve to prevent the further spread of nuclear weapons across the world, and greater public awareness of electromagnetic threats could converge to create a real commitment to grid resilience and reliability beyond those already identified and receiving funding for (weather events and cyber-attacks). We also believe the FERC's recent rejection of the DOE's notice of proposed rulemaking (NOPR), which would have rewarded large-scale "black start" assets like coal-fired and nuclear generators with on-site fuel stockpiles could result in additional reliability focus (and pressures) on a grid increasingly reliant on markets where natural gas continues to take market share. While FERC has tasked the Independent System Operators (ISO's)/ Regional Transmission Operators (RTO's) to examine resiliency/reliability outside potential electromagnetic threats, the unintended consequence of the approach could result in more attention on transformer and digital protective relays (DPR) weaknesses. This topic has been broached at the federal level fairly recently; former Representative Henry Waxman (D-CA-33) introduced House Resolution 4298 (Grid Reliability and Infrastructure Defense Act) on 3/28/2014 that would have, among other things "directed FERC to order the Electric Reliability Organization (ERO) to submit reliability standards requiring owners or operators of large transformers to ensure their adequate availability to restore promptly the reliable operation of the bulk-power system in the event that any such transformer is destroyed or disabled as a result of a reasonably foreseeable physical or other attack or a geomagnetic storm event". Other bills during the 113th Congress were attempted (H.R. 2417 and S.2158) with similar goals; none became law.

We also note that should the investments we've outlined in this report become reality, it would provide high-paying jobs across the country and in some cases benefit "red" or "purple" states where many equipment suppliers are located, blue states where high population density demands more transmission/distribution infrastructure. Our purpose in this report is to 1) provide a brief overview of the electrical grid for background informational purposes and more importantly, the equipment specifically threatened, 2) identify the solutions and potential costs to rectify the problem, 3) identify the potential investment opportunity for companies within (and in some cases out of) our coverage universe, and 4) provide reinforcement to the opinion that no infrastructure at the civilian level is more important than the electrical grid, which provides the energy for such vital services as water/wastewater treatment, residential heating/cooling, medical facilities, national defense and transportation networks. Resilience against electromagnetic threats will ultimately depend upon the commitment to the endeavor; costs could range from $10B to protect only the most critical equipment to perhaps as high as $400B, which would take many years to complete, but could envelop regular equipment cycle upgrades.

THE GRID: A BRIEF OVERVIEW

The combined transmission and distribution network in North America (the United States, Canada and a small adjacent portion of Mexico) is known and commonly referred to as "the grid." Within the grid are four distinct power grids, known as interconnections. The Eastern Interconnection includes the eastern two-thirds of the continental United States and Canada from the Great Plains to the Eastern Seaboard. The Western Interconnection includes the western one-third of the continental United States, the Canadian provinces of Alberta and British Columbia, and a portion of Baja California Norte in Mexico. The Texas Interconnection comprises most of the State of Texas, and the Canadian province of Quebec is the fourth North American interconnection. The grid systems in Hawaii and Alaska are not connected to the grids in the lower 48 states. Exhibit #1 displays the four distinct power grids (interconnections).

Exhibit 1: North American Interconnection Map



Source: U.S. Department of Energy

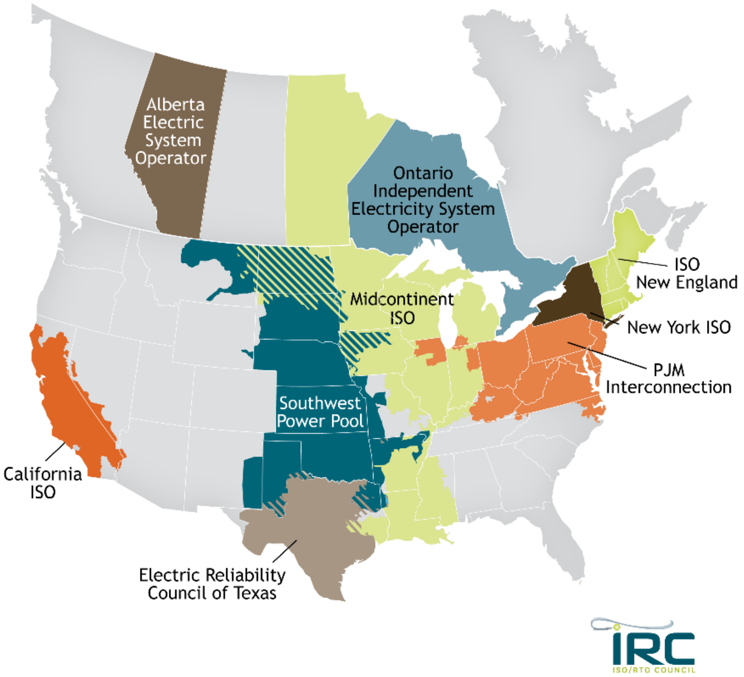
There are currently (7) Independent System Operators (ISO) within North America:

- CAISO – California ISO
- NYISO – New York ISO
- ERCOT – Electric Reliability Council of Texas; also a Regional Reliability Council
- MISO – Midcontinent Independent System Operator
- ISO-NE – ISO New England
- AESO – Alberta Electric System Operator
- IESO – Independent Electricity System Operator

There are currently (4) Regional Transmission Operators (RTO) within North America:

- PJM – PJM Interconnection
- MISO – Midcontinent Independent System Operator; also and RTO
- SPP – Southwest Power Pool; also a Regional Reliability Council
- ISONE – ISO New England; also an RTO

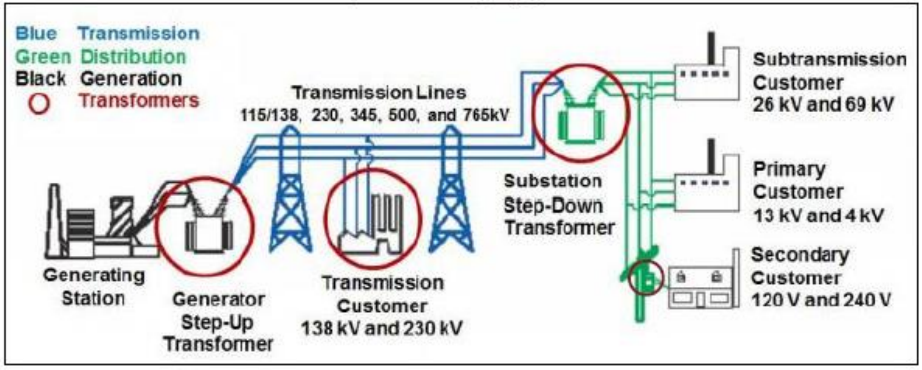
Exhibit 2: ISO/RTO Map



Source: ISO/RTO Council

The energy grid of the United States is comprised of generation, transmission and distribution that integrates 9,000+ electric generating units moving electricity across 200,000+ miles of high-voltage transmission lines rated at 230kV or greater. Generating stations use "step-up" transformers to increase voltage for transmission purposes; as electricity approaches its regional destination, substations use "step-down" transformers to decrease voltage, which is then distributed to end users such as industrial, commercial and residential end users. High voltage transformers comprise 3% of the total in transformer substations, but they carry 60-70% of the country's electricity. A basic diagram of how electricity is generated, transmitted and distributed is presented in Exhibit #3.

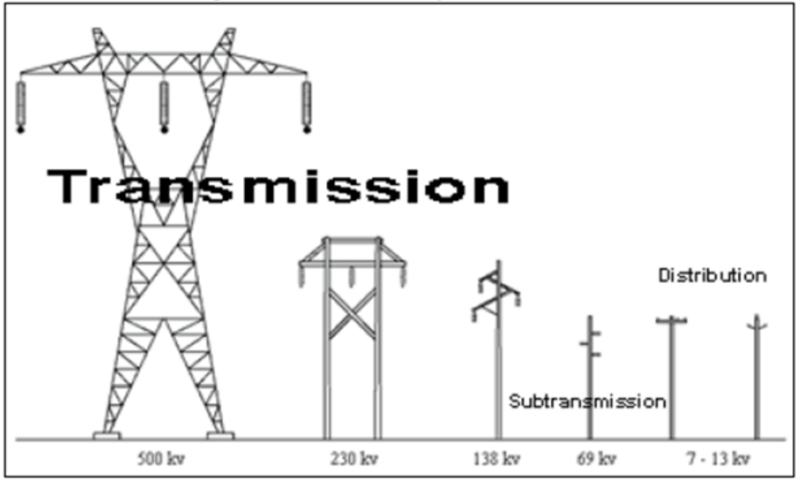
Exhibit 3: The Power Supply Chain



Sources: Federal Energy Regulatory Commission, U.S. Department of Energy

Transmission networks are defined as transmission lines that interconnect with each other that are separated from local distribution lines. Typical transmission lines operate at 765, 500, 345, 230, and 138 kV; the higher the voltage being transmitted, the larger the support structures and span lengths need to be, as shown in Exhibit #4.

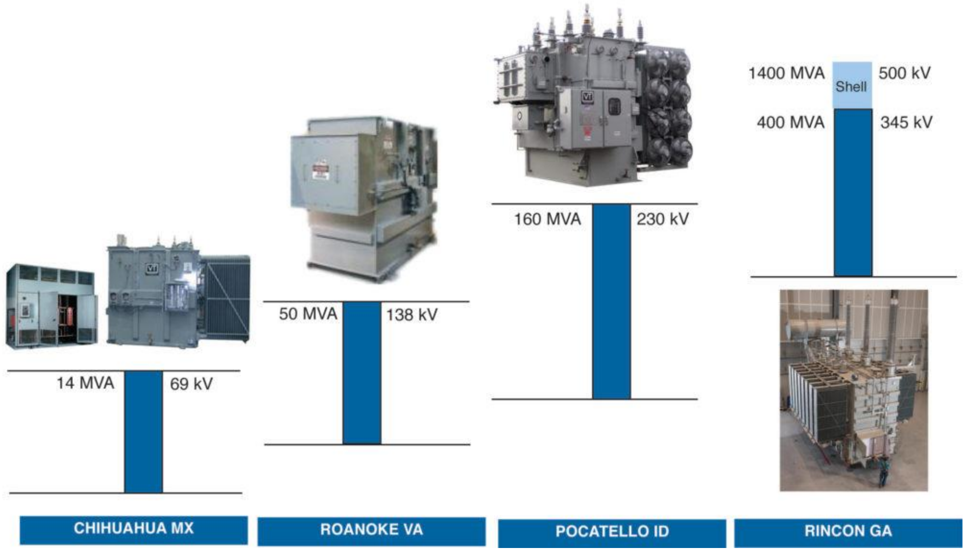
Exhibit 4: Transmission/Distribution Sizes (kV)



Source: U.S. Department of Labor, OSHA

Within the transmission/distribution system interface points are equipment and components. For our purposes in the discussion of protection of equipment deemed "critical" from electromagnetic damage, we focus only on transformers, Digital Protective Relays (DPR's) and control cables (Exhibits #5, #6 & #7).

Exhibit 5: Various Transformer Sizes



Source: Virginia Transformer

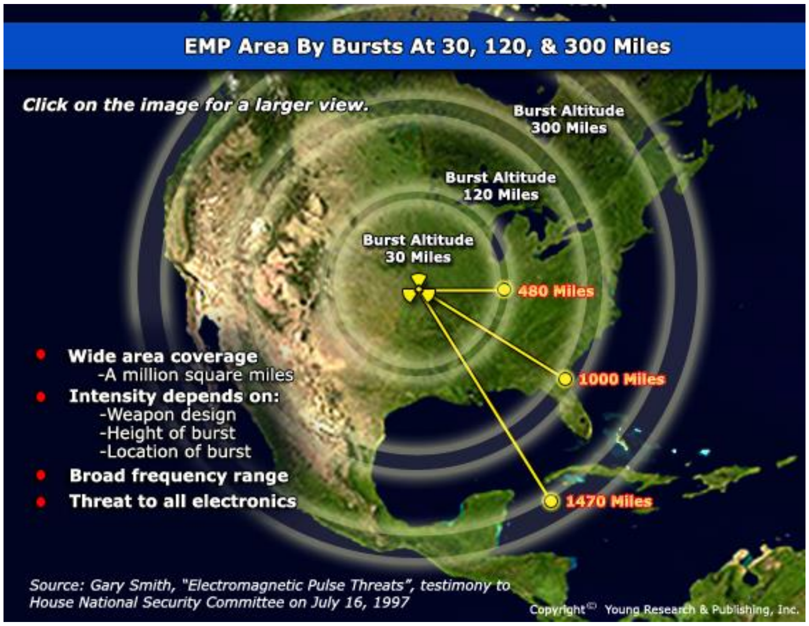
Exhibits 6 (Digital Protective Relay) and 7 (EMP Shielded Cable)

Sources: ABB, Aetna Insulated Wire

HOW DO ELECTROMAGNETIC EVENTS IMPACT GRID EQUIPMENT?

There are two specific grid threats we believe need to be addressed: intentional electromagnetic pulse (EMP) and geomagnetic disturbances (GMD) caused by solar flares. Recent geopolitical developments between North Korea and several other countries over its nuclear weapons program (and the threats those weapons pose) on a global basis has reignited the discussion over intentional electromagnetic threats. With respect to the North Korean situation, the focus is on the detonation of a nuclear warhead at high altitude that could send a HEMP (High-altitude Electromagnetic Pulse, or HEMP) into the North American airspace, causing catastrophic failure of critical electrical equipment (transformers and digital protective relays). The damage from a HEMP comes in 3 waves that can be spread across thousands of miles, referred to as E1, E2 and E3. "E1" has a duration of nano-seconds, but can damage many electronic components, from those found in vehicles with electronic fuel injection to computers and communication devices. The "E2" wave duration is slightly longer than E1, and resembles a lightning strike. The "E3" wave duration is longer, and has been proven in previous testing to damage large transmission equipment (transformers). Exhibit #8 illustrates how the altitude of a detonation can impact the range of effectiveness of an EMP.

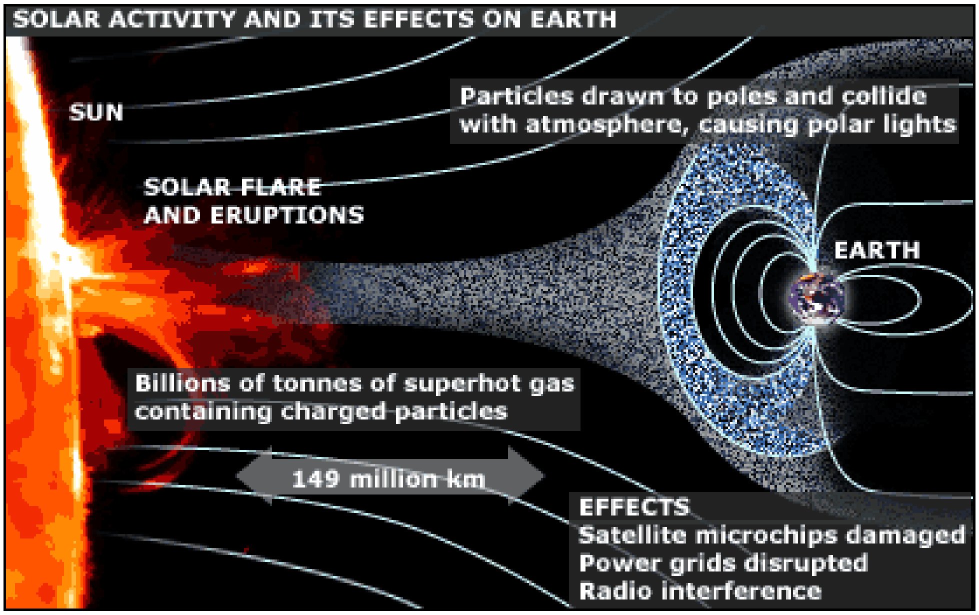
Exhibit 8: EMP Coverage by Burst Range, in Miles



Source: Young Research & Publishing, Inc.

Geomagnetic disturbances caused by solar flares can also inflict catastrophic damage on relays and transformers, and has does so. Examples include a severe geomagnetic storm caused by the sun's solar flare activity on March 13, 1989 that shut down Hydro-Quebec's electricity transmission system for 9 hours across Quebec, Canada. The aurora borealis that's typically only visible at the Earth's North and South Poles was visible as far south as Texas and Florida in the United States during that event. The most serious geomagnetic solar storm to hit the Earth is believed to have occurred on September 11th & 12th, 1859. Commonly referred to as the "Carrington Event" after the British astronomer that observed and recorded the event, the severity of the impact (if seen in modern day society) would likely disrupt and damage global electrical grids and electronics/communications. Reaction times are extremely limited; a solar flare's effect reaches Earth in approximately 8 minutes. The only known solution to prevent widespread disruption/damage would be a complete shutdown of electrical grids prior to the disturbance, which is highly unlikely. In the Quebec event in 1989, its speculated that the heavy rock formations upon which the transmission system is built upon provided some shielding and lessened the severity. Exhibit #9 displays the mechanics of how geomagnetic disturbances impact the Earth.

Exhibit 9: Geomagnetic Pathways/Impacts



Source: aviaton.stackexchange.com

WHAT STATE OF READINESS IS THE U.S. GRID IN TO WITHSTAND INTENTIONAL ELECTROMAGNETIC THREATS?

Put simply, it's not. Since the first atomic tests, the U.S. government (and the developed countries of the world) have been aware of the damaging impacts from electromagnetic pulses and geomagnetic disturbances. The U.S. military appears somewhat prepared; its E-4B fleet stationed at Offutt AFB, Nebraska (the Advanced Airborne Command Posts) are hardened to the point that they are expected to operate in the event of a nuclear-derived EMP event (the E-4B is built on a Boeing 747 platform; we believe it worthwhile to note that Boeing's Counter-electronic High Power Microwave Advanced Missile Project (CHAMP), in conjunction with the U.S. Air Force Research Laboratory (AFRL) Directed Energy Electorate, Kirtland Air Force Base, New Mexico has successfully tested flight-based weapons as far back as 2012 that produced EMP-like effects on electronics). The first studies related to HEMP impacts occurred on July 9, 1962 by the Atomic Energy Committee and the Nuclear Safety Agency of the Department of Defense of the United States of America (codenamed "Starfish Prime"). The extensive damage to the Johnson Attol, located in the Pacific Ocean is worthy of mentioning, given that it not only damaged electronic equipment, communications and overhead power lines, but disabled street lighting in the Hawaiian Islands.

The equipment in use in 1962 (in terms of complexity) was much simpler in design and operation than that in use today, which could make recovery from an event much more difficult. We count roughly 20 large entities in the United States studying this issue, including the following: Department of Homeland Security (DHS), EMP Commission of Congress, North American Electric Reliability Corp (NERC), Department of Energy (DOE), Department of Defense (DoD), Critical Infrastructure Partnership Advisory Council (CIPAC), Electric Infrastructure Security Council (EICS), U.S. Strategic Command (USSTRATCOM), Defense Threat Reduction Agency (DTRA), Defense Logistics Agency (DLA), Air Force Weapons Laboratory, Federal Bureau of Investigation (FBI), Sandia National Laboratories, Lawrence Livermore National Laboratories (LINL), Oak Ridge National Laboratory, Los Alamos National Laboratories, Federal Emergency Management Agency (FEMA), National Academy of Science, Federal Energy Regulatory Commission (FERC), Electric Power Research Institute (EPRI), National Aeronautics and Space Administration (NASA), and U.S. Northern Command, to name some (but not all) of researching participants on this topic. It seems fairly easy (to us) to understand why the grid has not been protected after 55 years of "research"; too many agencies without what we can determine to be a "clear leader" with a mandate to "get it done". Given the ultimate responsibility for the reliability of the grid rests with the FERC, we believe that regulatory body would be best suited to examine the options and provide guidance to implement a final solution (with assistance from the aforementioned agencies and state public utility commissions, as needed).

DO SOLUTIONS EXIST TO INSULATE THE U.S. GRID FROM HEMP (OR SIMILAR) EVENTS?

Solutions do exist to provide protection for critical infrastructure based in the United States/North America from intentional electromagnetic threats. Some solutions are rather simple, others require expensive, complex fixes. Starting with the E1 wave, equipment such as vehicular electronics, computers and cell phones not shielded can be rendered inoperable. Shielding for these types of equipment at the most simplistic level would be the use of "Faraday Shields" commonly referred to as "Faraday Cages". Faraday Shields can range in size from buildings to small boxes. The common element is that all interior spaces are shielded from damaging electromagnetic influences, which can be accomplished with grounding (insulation in these instances needs to be complete between the shielded surface (typically metallic) and interior electronic components). A simple metal box, completely sealed with foam insulation affixed to all interior surfaces is a most simplistic method of protecting electronic devices (the access point to the box must be sealed as well; common aluminum tape is one solution). In terms of utility-scale equipment, grounded metallic cages surrounding equipment can direct *some types* of electromagnetic energy around critical equipment and allow the energy to dissipate to ground. An example of a Faraday-shielded power facility is displayed in Exhibit #10.

Exhibit 10: Faraday Shielded Enclosure

Source: Wikipedia

Faraday shielding is among the easiest and most commonly suggested solutions to preventing GMD/EMP-related damage to equipment, regardless of what threat is being guarded against. Control centers for ISO/RTO's can be shielded by locating equipment to interior rooms with no windows and doors capable of sealing against threats. That said, ISO/RTO control centers (and DPR's and transformers) have another problem; cables entering these buildings/equipment act as a collector for EMP energy. At the DPR level, housing equipment within Faraday-type cabinets and ensuring EMP-resistant cabling (Exhibit #7) is used on all connections entering the cabinet from the exterior would provide significant protection for DPR and DPR-related equipment.

Our research indicates that among the equipment hardest (and most expensive) to replace, transformers present the greatest problem. Unlike DPR's and associated equipment (which provide an opportunity to store extra equipment on-site in Faraday-shielded containments), transformers have long lead times to manufacture, number in the tens of thousands, can be difficult to transport and site, and a complete failure of all transformers would take years to rectify, given spare transformers are expensive to maintain in a utility's inventory and what is limited manufacturing capability in the United States. Exhibit #11 displays a map included in the 2014 Department of Energy update detailing U.S. manufacturers.

Exhibit 11: North American Transformer Manufacturing Locations

Source: U.S. Department of Energy

SUMMARY/OPINION

The topics of protection against EMP and solar derived geomagnetic storms have been under study by multiple agencies, including some specifically created just for the aforementioned task for several decades. The "research" and expenditure of funds continues onward, and yet we weren't able to identify any specific substantial investments made into actual grid protection from these threats. A key reference material we utilized to gain basic technical knowledge of the issues (and solutions) necessary to protect the grid were found in a recent book published by Wiley & Sons in early 2017 titled "*Protection of Substation Critical Equipment Against Intentional Electromagnetic Threats*" written by Vladimir Gurevich. The author's background in electrical engineering is extensive, both in the private sector and academia. Basic preventive actions suggested by V. Gurevich (preventing the Geo-magnetically Induced Currents (GIC) from entering systems via overhead power lines (OPL) by using a series capacitance battery inserted into the OPL wires or by blocking the GIC from entering the neutral inputs in transformers by inserting capacitors into the neutral earth circuit in series, Faraday shielding around critical equipment and EMP-resistant cabling) have been known and detailed solutions for many years, and that work should begin immediately, starting with the 5,000 largest high-voltage transformers currently in service. We estimate the entire 5,000 could be outfitted with state-of-the-art, field-tested and proven technology such as SolidGround™ GIC/EMP neutral blockers for approximately $3.75B. Additional protection could then be added incrementally to the remaining ground-mounted transformers over a period of years.

With the United States considering a $1 trillion infrastructure plan, our view is that some of those funds should be directed to the electric utility industry to immediately begin hardening the grid against all electromagnetic threats, with a focus on the most expensive, critical (and difficult) component to replace, the largest transformers. Allocating funds just to the 5,000 largest transformers would represent less than 1% of the anticipated infrastructure spend; it would also dovetail nicely into the President's recently-released "National Security Strategy of the United States of America" on 12/18/17, which mentions "the vulnerability of U.S. critical infrastructure to cyber, physical, and electromagnetic attacks" as something that needs to be addressed.

In terms of the beneficiaries of a funded push toward grid resiliency against electromagnetic threats, electric utilities and transmission operators would need to spend additional CAPEX, which would increase rate base. Significant work, performed over many years, would be necessary to harden existing assets with significant useful life remaining. This could benefit electrical suppliers and contractors. The jobs required to complete these tasks are typically high wage, requiring post-secondary education. The total costs to harden the grid depends largely on the level of threat being protected against and what equipment is being hardened; for a HEMP-related event, Mr. Gurevich suggests equipment designed to block GIC in the neutral circuits of transformers can cost more than $300,000 (an example of this type of equipment provided by ABB costing $500K (plus $250K to install/commission) is shown in Exhibit #12.

Exhibit 12: GIC/EMP Protection Equipment

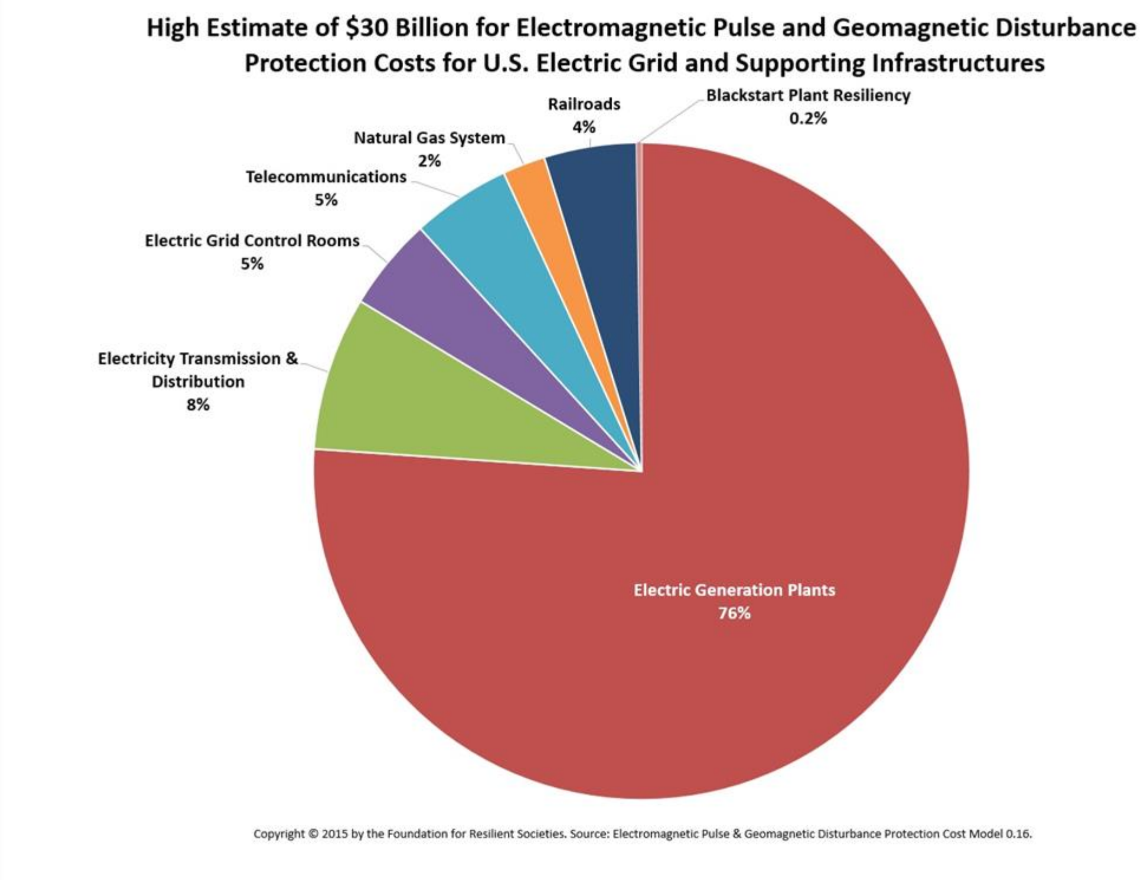
Source: ABB

Multiplying $750,000 by 50,000 or 70,000 ground-mounted transformers generates CAPEX costs of $37.5B to $52.5B and we note this estimate doesn't include costs necessary for the protection of DPR's by 1) Faraday shielding, most likely by locating equipment in specialized cabinets, 2) rewiring those relays with HEMP-resistant cable, or 3) the cost of locating critical spare parts at DPR and transformer locations in Faraday-shielded containers. Also not factored would be the cost of either procuring (and storing) specialized vehicles that would run after an event, or procurring the spare parts (and storing them in Faraday-shielded containers) so repair personnel can reach critical equipment in the field (vehicles made with electronics, typically those manufactured after 1985, would be susceptible to failure). One critical point we believe necessary to make is that naturally-occurring geomagnetic storms have a longer duration than EMP events, and pose (in our opinion) a greater threat to electrical grid stability given they are constantly damaging electrical equipment (a study by Zurich Insurance details several billion in losses each year from common low-level solar storms). Given the industry is experiencing billions of losses annually that exceeds the approximate cost to protect the largest 5,000 transformers, it would seem a logical course of action to protect this most critical of grid equipment (the savings from insurance claims alone should cover the protection equipment costs in either year 1 or year 2).

One other aspect we believe is worth mentioning is the potential legal liability utilities could face in a blackout scenario from GMD/EMP events. We've seen utilities come under pressure for lacking in natural disaster prepardedness (California for wildfires, Florida for hurricanes) given these are regularly occurring and forseeable natural events. While EMP's would likely not fall into that category, GMD's certainly would, and a severe disruption could result in substantial legal claims against utilities for a variety of reasons from all types of customers. The cost of some minimal investment by utilities could provide some level of protection against potential future litigation and financial liabilities.

Our research on official estimates of the total cost to protect the grid turned up several "opinions"; The Edison Electric Institute (an electric utility industry organization) states that cost estimates to protect the grid have not shown to be reliable or accurate http://www.eei.org/issuesandpolicy/cybersecurity/Documents/Electromagnetic%20Pulses%20%28EMPs%29%20-%20Myths%20vs.%20Facts.pdf. Perhaps the most extensive work done on the issue of assigning potential costs to grid reliability has been done by the Foundation for Resilent Societies http://www.resilientsocieties.org/research.html. They've produced both a high and low estimate; we display the high estimate ($30B) in Exhibit #13.

Exhibit 13: Resilient Societies High Estimate



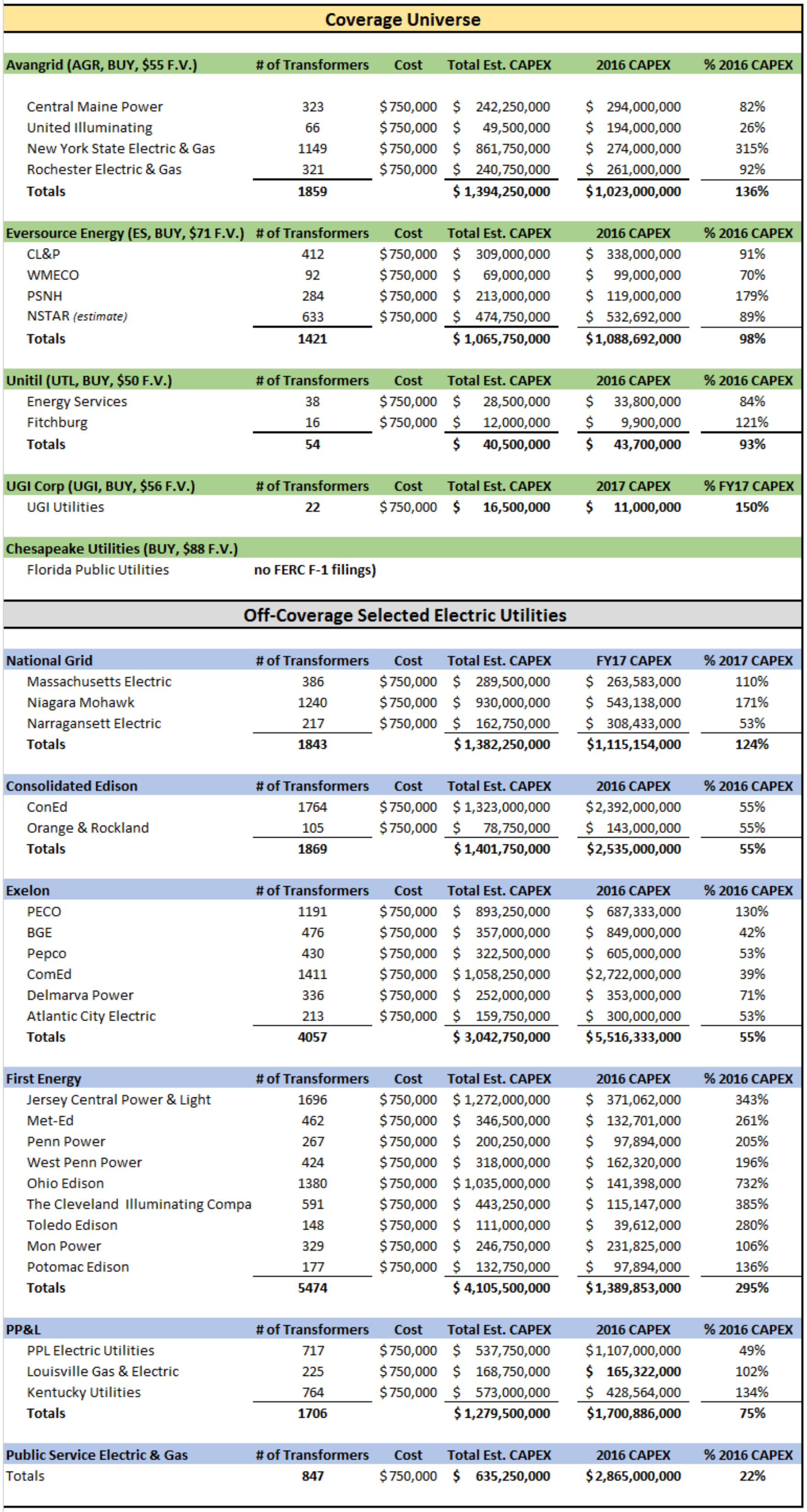
Source: Resilient Societies

The Resilient Societies estimate is available in excel format at the web site; we note that it incorporates into its forecasts only "several thousand" protected transformers; it appears to us that its estimates accepts some level of disruption within the grid among transmission/distribution equipment. We know that the number of sizable transformers within the grid is substantial; for selected utilities within the Mid-Atlantic/Northeast, it totals in excess of 18,000. The ultimate cost for grid protection depends upon how secure the society wants it to be.

Congress has moved to renew funding for The Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack as part of the National Defense Authorization Act. In a Bloomberg article dated 12/22/17 https://www.bloomberg.com/news/articles/2017-12-22/hardening-power-grids-for-nuclear-and-emp-attacks-by-north-korea, New Jersey Board of Public Utilities President Richard Mroz was quoted that the costs to prevent widespread failures would be "astronomical", and that placing transformers or substations in shielded cages would cost hundreds of millions of dollars, while the protection of critical assets just for the State of New Jersey could reach into the billions of dollars. Based on our research, President Mroz's estimates would appear to be conservative in terms of protecting transformers, but certainly correct in terms of overall costs for the State of New Jersey (we've compiled some estimates for utilities operating in New Jersey and the Northeast/Mid-Atlantic region later on in this report). In his book "A Nation Forsaken: EMP, the Escalating Threat of an American Catastrophe" author F. Michael Maloof, on page 79 indicates that the 2004 report presented to Congress from the aforementioned Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack as recommending spending $10B to $20B annually over 20 years ($200B to $400B, again in 2004 dollars). We reviewed the publicly-available documents from the Commission's work in 2004, and could not find the cost estimates mentioned, but again, based on our research into the topic, those figures (which were based on 2004 dollar purchasing power) could be fairly accurate if the United States decides to protect its entire grid from EMP/GIC events. If the costs are exceptionally high, perhaps a phased in approach (starting with the largest transformers) over many years under special programs such as those used to replace natural gas distribution pipe could be similarly utilized. Utilities also have a windfall from the recent reduction in U.S. income tax rates; perhaps that could be another avenue for covering costs associated with grid resiliency against GMD/EMP.

For companies within our coverage universe, **Eversource Energy (ES, BUY, $71 Fair Value estimate)** lists its transformers in its annual 10K report as totaling 538,032 (this includes the small transformers on utility poles). For our purposes, we're most interested in the ground-mounted transformers ranging in size from 69kV to 345kV, which we view as critical equipment and would be most likely to receive resiliency investment in the beginning of a comprehensive program. Based on FERC Form 1 filings, we estimate those transformers to total 1,421. Our estimated CAPEX just for transformer EMP/GIC resiliency is $1.1B; we note this estimate doesn't include the remaining small transformers on the utility poles, which we estimate to be approximately 537,000 (we believe hardening of those units could be done incrementally during routine normal maintenance and cycle replacement, as it occurs). Our estimate also doesn't include DPR protection, which is not calculable based on publicly available information we could find. We also note that transformer protection (at $750K per unit) represents 98% of last year's electric utility CAPEX, which would be a sizable investment for the company, but not so much that the company's state utility regulators should reject. We can envision a $1B - $2B total CAPEX opportunity for Eversource Energy; our remaining coverage universe (and a selected group of electric utilities that we do not cover) is displayed in Exhibit #14 (the tables use the estimated cost of ABB's SolidGround™ solution of $750K per transformer; Mr Gurevich offered a $300K per transformer cost assumption, but we were unable to determine if that estimate included transportation/installation costs). As we examined the data, we noted that transformer upgrades could provide a significant CAPEX lift for several utilities, including Eversource Energy, Avangrid, National Grid (not covered) and First Energy (not covered).

Exhibit 13: Coverage Universe CAPEX Estimates



Coverage Universe

Avangrid (AGR, BUY, $55 F.V.)	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
Central Maine Power	323	$750,000	$ 242,250,000	$ 294,000,000	82%
United Illuminating	66	$750,000	$ 49,500,000	$ 194,000,000	26%
New York State Electric & Gas	1149	$750,000	$ 861,750,000	$ 274,000,000	315%
Rochester Electric & Gas	321	$750,000	$ 240,750,000	$ 261,000,000	92%
Totals	**1859**		**$ 1,394,250,000**	**$1,023,000,000**	**136%**

Eversource Energy (ES, BUY, $71 F.V.)	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
CL&P	412	$750,000	$ 309,000,000	$ 338,000,000	91%
WMECO	92	$750,000	$ 69,000,000	$ 99,000,000	70%
PSNH	284	$750,000	$ 213,000,000	$ 119,000,000	179%
NSTAR *(estimate)*	633	$750,000	$ 474,750,000	$ 532,692,000	89%
Totals	**1421**		**$ 1,065,750,000**	**$1,088,692,000**	**98%**

Unitil (UTL, BUY, $50 F.V.)	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
Energy Services	38	$750,000	$ 28,500,000	$ 33,800,000	84%
Fitchburg	16	$750,000	$ 12,000,000	$ 9,900,000	121%
Totals	**54**		**$ 40,500,000**	**$ 43,700,000**	**93%**

UGI Corp (UGI, BUY, $56 F.V.)	# of Transformers	Cost	Total Est. CAPEX	2017 CAPEX	% FY17 CAPEX
UGI Utilities	**22**	$750,000	**$ 16,500,000**	**$ 11,000,000**	**150%**

Chesapeake Utilities (BUY, $88 F.V.)					
Florida Public Utilities	**no FERC F-1 filings)**				

Off-Coverage Selected Electric Utilities

National Grid	# of Transformers	Cost	Total Est. CAPEX	FY17 CAPEX	% 2017 CAPEX
Massachusetts Electric	386	$750,000	$ 289,500,000	$ 263,583,000	110%
Niagara Mohawk	1240	$750,000	$ 930,000,000	$ 543,138,000	171%
Narragansett Electric	217	$750,000	$ 162,750,000	$ 308,433,000	53%
Totals	**1843**		**$ 1,382,250,000**	**$1,115,154,000**	**124%**

Consolidated Edison	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
ConEd	1764	$750,000	$ 1,323,000,000	$2,392,000,000	55%
Orange & Rockland	105	$750,000	$ 78,750,000	$ 143,000,000	55%
Totals	**1869**		**$ 1,401,750,000**	**$2,535,000,000**	**55%**

Exelon	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
PECO	1191	$750,000	$ 893,250,000	$ 687,333,000	130%
BGE	476	$750,000	$ 357,000,000	$ 849,000,000	42%
Pepco	430	$750,000	$ 322,500,000	$ 605,000,000	53%
ComEd	1411	$750,000	$ 1,058,250,000	$2,722,000,000	39%
Delmarva Power	336	$750,000	$ 252,000,000	$ 353,000,000	71%
Atlantic City Electric	213	$750,000	$ 159,750,000	$ 300,000,000	53%
Totals	**4057**		**$ 3,042,750,000**	**$5,516,333,000**	**55%**

First Energy	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
Jersey Central Power & Light	1696	$750,000	$ 1,272,000,000	$ 371,062,000	343%
Met-Ed	462	$750,000	$ 346,500,000	$ 132,701,000	261%
Penn Power	267	$750,000	$ 200,250,000	$ 97,894,000	205%
West Penn Power	424	$750,000	$ 318,000,000	$ 162,320,000	196%
Ohio Edison	1380	$750,000	$ 1,035,000,000	$ 141,398,000	732%
The Cleveland Illuminating Compa	591	$750,000	$ 443,250,000	$ 115,147,000	385%
Toledo Edison	148	$750,000	$ 111,000,000	$ 39,612,000	280%
Mon Power	329	$750,000	$ 246,750,000	$ 231,825,000	106%
Potomac Edison	177	$750,000	$ 132,750,000	$ 97,894,000	136%
Totals	**5474**		**$ 4,105,500,000**	**$1,389,853,000**	**295%**

PP&L	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
PPL Electric Utilities	717	$750,000	$ 537,750,000	$1,107,000,000	49%
Louisville Gas & Electric	225	$750,000	$ 168,750,000	**$ 165,322,000**	102%
Kentucky Utilities	764	$750,000	$ 573,000,000	$ 428,564,000	134%
Totals	**1706**		**$ 1,279,500,000**	**$1,700,886,000**	**75%**

Public Service Electric & Gas	# of Transformers	Cost	Total Est. CAPEX	2016 CAPEX	% 2016 CAPEX
Totals	**847**	$750,000	**$ 635,250,000**	**$2,865,000,000**	**22%**

Sources: FERC F-1 filings, Company reports

Reference Sources:

1) Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse Attack, 2004
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3) Threat Posed by Electromagnetic Pulse (EMP) Attack – Committee on Armed Services House of Representatives: 110th Congress, Second Session, July 10, 2008
4) Large Power Transformers and the U.S. Electric Grid – Infrastructure Security and Energy Restoration Office of Electricity Delivery and Energy Reliability – U.S. Department of Energy, 2012
5) Maloof, F. Michael: A Nation Forsaken, EMP: the Escalating Threat of an American Catastrophe, Wind Books, 2013
6) Gurevich, Vladimir; Protection of Substation Critical Equipment Against Intentional Electromagnetic Threats, Wiley, 2017
7) Trump, Donald J: National Security Strategy of the United States of America; December 2017
8) EMPrimus; SolidGround™ GIC & EMP Neutral Blocker presentation, January 9, 2018

IMPORTANT DISCLOSURES

Research Analyst Certification

I, Michael Gaugler, the Primarily Responsible Analyst for this research report, hereby certify that all of the views expressed in this research report accurately reflect my personal views about any and all of the subject securities or issuers. No part of my compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views I expressed in this research report.

Chesapeake Utilities Corporation currently is, or during the past 12 months was, a Janney Montgomery Scott LLC client. Janney Montgomery Scott LLC, provided investment banking related services.

Unitil currently is, or during the past 12 months was, a Janney Montgomery Scott LLC client. Janney Montgomery Scott LLC, provided investment banking related services.

Janney Montgomery Scott LLC currently acts as a market-maker in the securities of Unitil.

Janney Montgomery Scott LLC managed or co-managed a public offering of securities for Chesapeake Utilities Corporation and Unitil in the past 12 months.

Janney Montgomery Scott LLC received compensation for investment banking services from Chesapeake Utilities Corporation in the past 12 months.

Janney Montgomery Scott LLC intends to seek or expects to receive compensation for investment banking services from Avangrid, Inc., Chesapeake Utilities Corporation, Eversource Energy, UGI Corporation and Unitil in the next three months.

The research analyst is compensated based on, in part, Janney Montgomery Scott's profitability, which includes its investment banking revenues.

Janney Montgomery Scott LLC ("Janney") Equity Research Disclosure Legend

Individual disclosures for the companies mentioned in this report can be obtained by accessing our Firm’s Disclosure Site

Disclosure Site

Definition of Ratings

BUY: Janney expects that the subject company will appreciate in value. Additionally, we expect that the subject company will outperform comparable companies within its sector.

NEUTRAL: Janney believes that the subject company is fairly valued and will perform in line with comparable companies within its sector. Investors may add to current positions on short-term weakness and sell on strength as the valuations or fundamentals become more or less attractive.

SELL: Janney expects that the subject company will likely decline in value and will underperform comparable companies within its sector.

Janney Montgomery Scott Ratings Distribution as of 12/31/17

			IB Serv./Past 12 Mos.*	
Rating	**Count**	**Percent**	**Count**	**Percent**
BUY [B]	111	48.05	31	27.93
NEUTRAL [N]	117	50.65	22	18.80
SELL [S]	3	1.30	0	0.00

*Percentages of each rating category where Janney has performed Investment Banking services over the past 12 months.

Other Disclosures

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