Critical Infrastructures
Virginia's Challenge for the New Millennium

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Abstract

Virginia now is the 12th-most populous state in the U.S. (2000 Census) and much of that growth has occurred in the past twenty years. Virginia's population has increased by 50 percent since 1970. Increasingly, the marginal impact of internet-based technology development in Virginia can be seen through both demographic and infrastructure measures. During 1998, the Commonwealth saw some $250 million of venture capital pumped into the area for high-tech investment, as well as some 650,000 miles (1.05 million km.) of fiber optic cable in place - more than any other state.

The Commonwealth's unprecedented growth has brought with it an equally unprecedented – and unanticipated - demand on physical and planning resources, at both the state and local level. At the state level, this demand is manifested in the call for higher levels of primary energy services, particularly electricity and natural gas, even as the Commonwealth attempts to deregulate these services, along with increased reliance on telecommunications. At the local level, issues such as right-of-way, growth-based traffic congestion and land use planning have moved to the forefront of the planning agenda.

The sectors cited above, along with environmental resources (air and water) and transportation, constitute the major pieces of the Commonwealth's critical infrastructures. In the past decades, individual components have evolved with minimal consideration for their interaction with other systems; this 'approach' has been sufficient to support the rapid expansion of high tech industry, particularly in Northern Virginia. However, in order for this development to continue, and for Virginia to maintain its attractiveness for new industry, it is now apparent that a holistic approach to infrastructure development is needed.

This paper outlines some of these issues, and seeks to identify initial steps to develop a holistic approach at the state level in Virginia. Selected issues will be pursued under the Critical Infrastructure Modeling and Assessment Program (CIMAP) being implemented by the Virginia Tech Center for Energy and the Global Environment (CEAGE) to assess critical infrastructures in Northern Virginia.

[NOTE: Information for this draft working paper has been derived from a variety of primary and secondary sources. Every attempt has been made to cite original sources. The author apologizes for any oversight in this regard. - MW]

Critical Infrastructures: The CIMAP Focus

The CIMAP approach is based on a working definition of critical as "indispensable, essential" or "being in or verging on a state of crisis or emergency", and principally addresses those weaknesses resulting primarily from a combination of inadequate planning and significant non-intentional failures.[1] This differs from other national and state-based programs, which focus primarily on intentional threats – including physical (attacks on power stations, communications, infrastructure corridors) and cyber-based (hacking and 'cyber-terrorism').

While intentional threats are, and should be, a serious concern for all states, the Commonwealth of Virginia has the responsibility and capacity to act in a proactive manner to anticipate non-intentional and planning-based concerns. The following sections of this paper outline a set of key issues that CIMAP will address; future papers will explore these and other topics in greater detail.

Electrical Power Generation

Although consumers in Virginia will be protected from rapid price increases over this period (with price caps until 2007, albeit allowing for fuel cost fluctuations), it is not clear what will transpire after that time. Virginia appears to be well positioned in the near term to meet the electricity demands posed by new industry. The problem thus appears to be not be one of total generation capability, but rather one of power quality, facility siting, environmental constraints, access to primary fuel sources or distribution points, and access to transmission lines. This also is compounded by high tech firms' need for increased power quality and accelerated construction deadlines.

In addition to servicing the growing needs of in-state businesses, Virginia now is seen as a preferred site for merchant power plants that market to out-of-state customers. The Federal Energy Policy Act of 1992 opened the national wholesale electricity market to competition by allowing the development of merchant plants, which were permitted comparable, non-discriminatory access to the transmission network. A supporting infrastructure – which Virginia appears to provide - is critical to merchant plant site selection. In particular, this would include locating in an area of convergence of natural gas pipelines (the primary fuel for new power plants), electrical transmission lines (or substations) and water resources.

In the words of Virginia Business (August 2001), Virginia is "strategically located near high-demand markets in the Northeast and Midwest, and criss-crossed with natural gas pipelines and critical high voltage lines . . . [and] . . could become a miniature Saudi Arabia of electrons, at least for power markets east of the Mississippi River." According to the publication, non-Virginia utilities planned to take advantage of Virginia's location and regulatory climate to build more than 20 natural gas-fired generating plants worth more than $3 billion, with most of their 6,000 or more megawatts of power to be shipped

[1] Definitions from *American Heritage College Dictionary, 3rd ed*.

out-of-state, while Dominion Virginia Power planned to expand its current generating capacity of 18,590 megawatts in the state by 8,500 megawatts.

It is not possible to forecast how much of the permitted generation capacity will ultimately be constructed. However, whether driven by utility or merchant plant construction, increased power generation will have an impact on key aspects of the Commonwealth's infrastructure, as outlined below:

Natural Gas Availability

As noted earlier, many analysts believe that Virginia will be a growth center for electricity generation, due to its access to natural gas pipelines and high voltage power transmission lines. According to a recent CIT Task Force study, if less than half of the proposed utility and merchant gas-fired power plant projects planned are implemented, the natural gas consumption in the Commonwealth could double.[2]

As the CIT study noted, the Average Usage Rate for the major pipelines that transport natural gas to and through Virginia has increased from 60 percent (1996) to 74 percent (1999), and the implication is that "although new pipeline capacity is being installed, the growth in natural gas use by Northeast Region consumers is increasing faster and new pipeline construction is not keeping up with the growth in demand."

However, there are several other factors that must be considered in evaluating the availability of sufficient natural gas to support development in Virginia. For example, significant increases in flows from the Midwest region to markets on the East and West Coasts have already occurred, and additional increases are projected through 2020. Of even greater significance, import capacity between the United States and Canada has increased by 15 percent since 1998, with the major addition being the Northern Border expansion through Montana into the Midwest. Overall, the larger picture for natural gas supply in the United States is favorable, as evidenced by the following quote:

> "Given the efficiencies that industry restructuring has brought to the U.S. natural gas market, the abundant technically recoverable domestic resource base, the growing availability of natural gas imports, the role of technology in making additional supplies available and reducing costs, and the continuing expansion of the U.S. pipeline grid, the natural gas industry is expected to be able to respond to the challenge of substantial increases in future demand. As long as the industry is confident that the demand will be there and that natural gas can be produced and delivered at prices that are competitive with those of other fuels, the needed investments in drilling, manpower, and pipeline infrastructure are expected to be made."[3]

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[2] Rahman, Saifur, and Bigger, John, "Improving Virginia's Attractiveness for High-Technology Industries," Task Force on Electric Power for Virginia's High Technology Industry, Alexandria Research Institute, Virginia Polytechnic Institute and State University, October 31, 2001.

[3] Issues in Focus, Report#:DOE/EIA-0383(2001)], December 22, 2000

At the macro scale, as a consequence of deregulation of both electricity and natural gas, it will be very difficult to predict natural gas sources and sinks for power generation, particularly with the growth of merchant power plants and an increased call for gas-based distributed generation to service the high-tech industry. In reality, the ability of natural gas to serve Virginia's needs may hinge on questions of a more local nature, in terms of environmental, technical and right-of-way concerns.

In New York, for example, Consolidated Edison has objected to the initial proposed route of the Millennium Pipeline, proposed by the Columbia Gas Transmission Company of Fairfax, Va. on a right of way carrying high-voltage transmission towers that, on a warm day, bring in about 40 percent of New York City and Westchester's electricity. In the view of Con Edison officials, the danger of an explosion was remote but potentially catastrophic to the power supply. As a result of this, along with other NIMBY objections, pipeline construction has been delayed for more than two years. This may well become a major issue in northern Virginia, where the bulk of high-tech industry is located, particularly if new industry attempts to acquire natural gas resources to sustain in-house distributed generation capability. In the past, facility designers and owners have not rated natural gas (not easily stored on-site) on a par as liquid fuel stored on the facility site; however, increasing familiarity with the fuel, supported by the emergence of technologies such as fuel cells - along with concerns over storing large quantities of fuel on site – may shift this balance point.

To the extent that natural gas distribution pipelines are required in built-up areas to support development, co-location along rights-of-way (e.g. highway, railroad, or power transmission lines) can minimize much of organized community response, but (as shown above) will raise concerns that rightfully focus on a 'weak' point in the Commonwealth's infrastructure. While there is no single best answer, it is quite certain that no acceptable answer will be found without the participation of all major stakeholders (including state and local interests) in the decision process. What will be needed during this process is guidance in methodologies designed to incorporate stakeholder concerns in a transparent and equitable manner.

Transmission Line Capability

As one of the steps toward deregulation, the Virginia State Corporation Commission recently announced that electricity generation would heretofore be separated from transmission and distribution at the division level – that is, utilities will not be able to sell off their generation resources; in addition, generation rates will be market-based, while transmission and distribution fees will continue to be regulated by the State. In this way, state regulators hope to avoid many of the problems encountered by such states as California.

However, an unanswered question - and potential problem – is how sufficient funds will be made available for upgrading the transmission systems, given that these may well be stressed beyond their current capabilities in the near term, particularly with the advent of interstate wholesale power sales by merchant power plants. One suggested approach is to apportion the cost of transmission upgrading – from the market-based side, or from anticipatory pricing based on expected use. The latter path appears to be extremely complex and probably unworkable in the near term.

Why is this an issue in Virginia? First of all, it is important to recognize that national transmission capacity is falling further and further behind the demand for power, according to consultant Eric Hirst, in a report for the D.C.-based Edison Electric Institute. The problem, according to the industry watchdog North American Electric Reliability Council, is that the existing network of high-power transmission lines was not constructed to handle the complexity and congestion of today's ever growing energy demands and changing markets. As EPRI has reported, the value of bulk power transactions in the U.S. has increased four-fold in just the last decade, and about one-half of all domestic generation is now sold over ever-increasing distances on the wholesale market before it is delivered to customers. In the view of many industry analysts, transmission grids are already strained, and could not support the 200,000 to 400,000 MW of new generating capacity without substantial upgrades and new transmission links. The transmission system now is at risk, and "the question is not whether, but when, the next major failure of the grid will occur," according the group's general counsel David Cook in a recent submittal to the U.S. Department of Energy.[4]

Even as the U.S. Department of Energy estimates that generating capacity in the United States alone will grow more than 20 percent over the next ten years, there is only a 4.2 percent increase in high-voltage transmission additions planned over that same period, and it is likely that only a portion of these will be completed.[5]

This concern also is reflected in a recent DOE Task Force report, which raises a question that directly speaks to the reliability of Virginia's infrastructure: "It is . . . apparent that the Nation's transmission grid will be used by many more (and more diverse) entities for a larger quantity and variety of transactions. With these changes comes a critical challenge: Will consumers of electricity be able to count on traditional levels of grid reliability?" In addition, we may rightfully add, will Virginia's high-tech consumers be able to assure the even higher levels required to support their operations?

One obvious answer is to embark on upgrading of the national electrical grid. Significant capital expansion of the nation's transmission grids would be required to meet continuing load growth through new generation, while supporting increasingly active regional wholesale power markets. However, there is no national consensus on the appropriate way to price transmission services in order to provide optimal incentives for both investment in transmission facilities and the demand for transmission services. Given the lack of consensus, according to DOE, it is "appropriate and desirable that a variety of approaches are being tested around the country". *(Maintaining Reliability in a Competitive U.S. Electricity Industry)*. Some of the proposed approaches include incentive rates for transmission investments, federal preemption of state and local siting laws,(36) and grants of authority to RTO'S to commission transmission facilities and pay for them through broad-based regional uplift charges.(37)

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[4] A Smarter Power Grid, by Peter Fairley, Technology Review, July/August 2001
[5] Ibid

Unfortunately, “this grand experiment is going on, but the result is that nobody's [utilities or merchant plants owners] investing now because it's far too uncertain," according to Lawrence Makovich of the Cambridge Energy Research Associates in Massachusetts. Utilities, for example, have little incentive to build new long-line transmission connections, for instance, particularly if that would make it easier for its customers to buyer cheaper power from competitors in neighboring states, according to Illinois Public Service Commissioner Terry Harvill. A recent FERC study supports this conclusion, noting that “when utilities control monopoly transmission facilities and also have power marketing interests, they have poor incentives to provide equal quality transmission service to their power marketing competitors.”[6] Compounding the lack of activity, a June 2001 NARUC study noted, is that “the environmental impacts from construction of new transmission facilities are also likely to be significant, and it is unlikely that major new transmission lines will escape citizen opposition in the siting process.”[7]

In the face of this deregulation-driven dilemma, what are the implications and recommendations for Virginia regulators and energy planners? While it appears that some new approaches, such as power electronics for switching high-voltage power flows, can partially address this problem, there is no clear-cut solution in the near term. The long-term solution involves a multi-faceted approach, including transmission line construction, improved power electronics, a more complete ability to model (and anticipate) power flows, increased demand-side management, and the promotion of distributed generation.

Distributed Generation

Confronted with sufficient electrical power supply but decreased reliability, particularly as Virginia moves further into a high tech world, the attainment of extremely stable and reliable electricity supply will be a primary consideration for high-tech industry. This is a far more stringent requirement than the historic “Three Nines” criterion, or 99.9 percent reliability. Some high-tech industries are even looking at nine nines reliability.

Traditionally, utilities have supplied electric power to industry, supplemented by Independent Power Producers (IPPs) and dedicated in-plant electricity generation. However, while the U.S. has the most reliable electricity system in the world with 99.9 percent reliability, "that's only good enough if you're running light bulbs and refrigerators," said EPRI's Wilhelm (Mark Wilhelm, vice president of EPRI). "Any industry that is computer chip-based needs 99.999999 percent reliability." At 99.9 percent, e-commerce and other IT systems are only assured of 8,751 hours of electricity supply per year out of a possible 8,760, Wilhelm added. "That's not good enough when even an interruption of one-third of a second can cause major problems or equipment damage."

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[6] State Of The Markets 2000: Measuring Performance in Energy Market Regulation, Federal Energy Regulatory Commission, March 2000

[7] Efficient Reliability: The Critical Role of Demand-Side Resources in Power Systems and Markets, The National Association of Regulatory Utility Commissioners, June 2001

The problem is that "(t)he power system that we have today was not designed for the measures of reliability that would support a silicon-based society," according to Karl Stahlkopf, vice president of EPRI, a Palo Alto, Calif.-based research and development company working to understand and develop new solutions for the nation's utilities. In his view, rebuilding it to do so would make it too expensive to support the economy power needed by the dominant 'dumb' appliances on the grid. Diesel-powered backup electricity, which cost two to three times as much as grid-based power, may be affordable for large companies but not always feasible for most smaller businesses, and also may be limited in time of use.

What may be 'good enough' is distributed power generation, which at a minimum involves locating the power source on-site or close to the end user. The greatest market for distributed power is premium power, a $7 to $10 billion-per-year market nationally, primarily for backup power systems; this should continue to be the case in the near term. In Virginia, with more than 4,300 high-tech firms, the role and potential of distributed power assumes great importance, both in maintaining the existing infrastructure and attracting new high-tech enterprises.[8]

There are two basic avenues that high-tech firms and other organizations with extremely reliable energy needs can pursue.[9] In order to satisfy reliability criteria, some firms may look to a combination of delivered electricity supplemented by in-house control, 'cleanup' and emergency backup. Others may seek to divorce themselves more distinctly from the grid, and rely primarily on premium in-house power with the capability of selling power back to the grid when it proves profitable. Still a third group could (in theory) locate in premium power 'park', essentially off-grid but with power provided by a captive generator. As stated in a recent article in Technology Review, "(m)anufacturers, banks, telecommunications providers — just about any company that depends on computers or digital equipment such as Web servers and routers—need premium power. And the only sure way to get it, energy experts agree, is to generate it yourself."[10] However, there appears to be some latitude in what 'yourself' actually means in terms of physical infrastructure.

What are the implications of distributed generation for Virginia's power and telecommunications infrastructure? From an overall power reliability standpoint, and individual distributed generation system could lessen the load on the transmission system, and thus increase system reliability. However, as more systems are developed with the capacity to effect power flows to the grid, some transmission system experts are concerned that the overall transmission system stability could be reduced. Power sales to the grid will be highly dependent on deregulated market prices, and it is impossible to say a priori what energy flows will result.

[8] Technology in Virginia's Regions, May 2000

[9] These include computers, communications equipment, and semiconductors manufacturing sectors.

[10] Power to the People, Technology Review, May 2001

For new companies proposing to rely on diesel backup systems, air quality regulations could affect either capital costs of construction, siting criteria, and any ability to sell power back to the grid, particularly if they choose to locate in or near ozone non-attainment areas. The growth of fuel cell technology for premium power will provide an environmentally acceptable alternative, and already has been employed in some high reliability facilities. For example, the First National Bank of Omaha recently installed a fuel-cell system with 'six 9s' reliability, which exceeds the reliability of the bank's computer system, citing the "critical difference over existing power arrangements that will substantially increase our computer uptime."[11]

Distributed power resources have the capacity to serve more than a specific end user. For some distributed facilities with sufficient generation capacity, power sold back to the grid also can reduce stress on regional transmission and distribution systems, and thereby increase overall system reliability. In a similar manner, these facilities might be employed when economic signals allow the owner-operator to sell power at a profit (although demand-side reduction programs may also be employed to the same end). However, in the case of diesel-based distributed power, this is subject to applicable air quality regulations.

Although distributed generation may represent a viable long-term strategy in Virginia, it still has significant barriers to overcome. According to a recent DOE study:[12]

- A variety of technical, business practice, and regulatory barriers discourage interconnection in the US domestic market.
- These barriers sometimes prevent distributed generation projects from being developed.
- The barriers exist for all distributed-generation technologies and in all regions of the country.

Water Resources

The availability and quality of water resources to support Virginia's economic development represents a largely overlooked aspect of the Commonwealth's infrastructure, but one that could have an increasingly significant impact on development. As an example, the total generating capacity of power plant projects announced, in the permitting process, or under construction is more than 19,000 MW, according to the CIT ARI/Task Force report. Of these, individual base load and intermediate load plants (as many as 21 plants) may require between 360,000 and 720,000 Gal/Day for each 100 MW of base and intermediate load capacity, assuming that they employ conventional cooling systems; peaking plants will require between 55,000 and 175,000 Gal/Day for each 100 MW of capacity.

[11] Fuel-Cell Power System Gets Real-World Test, by Ron Wilson, EE Times; see web site: http://www.eet.com/story/OEG19990604S0017)
[12] Making Connections: Case Studies of Interconnection Barriers and their Impact on Distributed Power Projects, NREL/SR-200-28053, Contract No. DE-AC36-99-GO10337, May 2000

Depending on their location, individual power plants – as well as water-consuming high-tech enterprises – could have significant impacts on local surface and/or ground water resources. A primary dictate for power plants is the ability to access both natural gas distribution systems and high-voltage power transmission lines; this would lead to siting either in northern or southwestern Virginia. Plants attempting to site in northern Virginia face the additional hurdle imposed by siting in or near ozone non-attainment areas (see section following), and well as relatively well-organized local opposition.

Even when these air quality and zoning requirements can be met, constraints imposed by both the supply and cost of water may have major impact on facility design and siting; this is the case in Loudoun County where a 1,400 MW, combined-cycle project proposed by Tractebel, Inc. was designed to utilize a dry-cooling system (at measurably greater construction cost).

The combination of factors cited above would argue for increased (merchant) power plant siting in southwestern Virginia, particularly in order to access out-of-state energy markets via high-transmission lines. For example, Jackson Ferry in Wythe County, which serves as the terminus of a 765-kilvolt AEP transmission line, is the locus for a planned 620-megawatt gas turbine merchant plant that Duke Energy North America intends to build, primarily to ship to midwest markets. However, relatively little is known about the surface water – ground water recharge characteristics of this area; according to the US Geological Survey State Office for Virginia, of the 320 monitoring wells in Virginia, fewer than 20 are located west of Interstate 95. Virginia currently manages ground water resources through a program regulating the withdrawals in certain areas called ground water management areas. However, the only two ground water management areas in the state are the Eastern Shore and eastern Virginia. Aquifers in the southwest part of the state are mainly fractured rock aquifers, and the ground water hydrology is significantly different from that of the eastern portion.

High technology firms, ranging from data centers to electronic component manufacturing facilities, also are large users of water, with extremely stringent requirements for reliability and supply. Water requirements can range from few hundred thousand gallons to as much as one million gallons per day for air conditioning (evaporative cooling, with minimal recycling), and as much as 7,000,000+ gallons per day (with 30 percent recycling) in the manufacturing process. In addition to their primary water supply, these systems employ on-site storage and, as a back-up source, on-site or nearby water wells are installed.

The State Water Control Board uses water withdrawal data to prepare water supply plans, to delineate surface water management areas and other reports for the management of the water resources of the Commonwealth. The data are available to local governments and private interests to assist them in their own water supply planning. However, based in part on the CIT ARI/Task Force study, the Virginia State Corporation Commission (SCC) recently proposed revised filing requirements strengthen the water portion for all facilities seeking to construct and operate electric generating facilities in Virginia.[13] This is a step forward in recognition of the potential impacts that could arise from large-scale withdrawals, but the requirements point to the need for a larger-scale systematic analysis of the Commonwealth's water resources at the sub-state level.

Air Resources

The relationship between development and air quality resources in Virginia is rather complex, in that a series of laws and regulations are in place to govern the specific air quality impacts. As the Congressional Research Service noted, "(e)xcept for CO_2, the regulatory regimen of the Clean Air Act provides authorities for controlling the potential increase in emissions -- assuming they are effectively implemented. Existing controls "cap" SO_2 emissions in the 48 contiguous states and the District of Columbia, and there is no reason to question the effectiveness of the cap in the future, regardless of the changes underway in the utility industry."[14]

However, problems arise in attempting to determine the impacts of NOx emissions from both in-state and out-of-state power plant development on Virginia's ozone non-attainment areas. According to the CRS, "(h)ow this regional, state-implemented process would be affected by restructuring is not certain."

Construction of merchant power plants in Virginia to service out-of-state customers will be governed by appropriate state and Federal regulations, but they raise another fundamental development issue: What is Virginia's response to appropriation of in-state airshed resources to service out-of-state demand? Based on the number of power plants already permitted, the projected development of merchant power plants in Virginia could use up the available airshed capability in attainment areas, making it more difficult and expensive for other, Virginia-based, industry to locate in these areas. This could in essence limit Virginia's economic growth, including the development of high-tech industry utilizing distributed generation to meet premium power needs.

Chapter 302 of the most recent 14 December SCC Order mentioned above also recognizes the weakness in earlier filing requirements, and proposes a (relatively) ambitious program for assessing air quality impacts of significant combustion-related power generation (excluding distributed generation) both within the Commonwealth and in other areas affected by in-state power generation. This is a necessary step in clarifying air quality issues in Virginia, and the CIMAP Program will coordinate with relevant SCC staff work groups.

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[13] State Corporation Commission, Order Adopting Rules and Prescribing Additional Notice, Case No. PUE010313, December 14, 2001.

[14] 98-615: Electricity Restructuring: The Implications for Air Quality, by Larry Parker and John Blodgett, Environment and Natural Resources Policy Division. Congressional Research Service, Updated July 14, 2000.