# Transmission Congestion in the Northeast United States and Its Role, Coupled with Natural Gas Availability in the Pace of Deployment of Distributed Generation

**A Report for the National Association of State Energy Officials**

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## Preface

Distributed generation can be an important resource for the electric transmission system, just as large scale generation is. This is especially the case where the transmission system is congested. "Congestion occurs when available, low-cost energy cannot be delivered to all loads because of limited transmission capabilities. When the least cost available energy cannot be delivered to load in a transmission-constrained area, higher cost units must be dispatched in this constrained area to meet that load. [1] The result is that the price of energy in the constrained area is higher than elsewhere because of the transmission limitations."[2]

Congestion does not happen all the time. Customer load and available generation must be in certain conditions for congestion to occur. Higher load, especially in the cities, is a usual precursor to congestion.

System operators manage congestion in real time. They can ramp down output from less expensive but remote generation, and turn on units near the load that are more expensive. They can also open or close circuits that take power lines out of service or back on line.

There are two basic ways to solve system congestion. One is to increase transmission capacity to allow remote generation to flow to the congested place. Existing transmission lines can be modified to carry more power, additional circuits can be placed in a right-of-way, or whole new transmission corridors can be created. The other is to reduce the demand on the transmission system and the pressure for power to flow over the existing transmission capacity. Lightening the load on the system can be accomplished with local generation, energy efficiency, or demand response.

[1] This is referred to as dispatching units out of economic merit order. Economic merit order is the order of all generator offers from lowest to highest cost. Congestion occurs when loadings on transmission facilities mean that the next unit in merit order cannot be used and that a higher cost unit must be used in its place.
[2] PJM State of the Market Report 2004, pg 36.

Devices like phase angle regulators (PAR) or flexible AC transmission systems (FACTS) can redirect power on the grid to alleviate congestion to a certain extent.[3] But these solutions are expensive and have technical limitations if growth outpaces their ability to prevent congestion. Superconducting systems are beginning to add to this quiver of solutions, but their application for congestion relief remains unclear.

Sometimes, the solution to congestion is less expensive than the cost of running more expensive generation, and in these cases, a utility or merchant investor should step in. The utility should certainly step in if the congestion leads to a power shortage and a reliability problem in the area. In some cases, however, the cost to solve congestion is much greater than the economic penalty. This illustrates that not all congestion needs a solution, and not all congestion is the same.

The Regulatory Assistance Project has worked for many years on electric system resource issues to assist state regulators and policymakers. This work includes developing policies to promote efficient deployment of distributed generation, and to promote efficient investment in the electric transmission system. This experience positioned RAP to create the DG Policy Analysis Tool software for NASEO and U.S. DOE as the centerpiece of this project and to write this report.[4]

While it is clear that distributed generation and other distributed resources are reliability resources and can address system congestion, efforts to solve congestion rarely feature these resources. Regulatory reform is underway in many states and regions to address this deficiency.

This brief report calls attention places in the Northeast U.S. where electric transmission congestion persists, and where distributed generation might contribute to congestion solutions.

## A. Transmission Congestion in the Northeast U.S.

The Northeast U.S. electric power grid has three system operators, ISO-New England, the New York ISO, and the PJM Interconnection.[5] Each of these is the reliability coordinator for their territory and each operates their system in real time, dispatching generation to balance constantly changing customer load based on a complex web of market rules.

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[3] A PAR on the west side of Lake Champlain controls power flows on a line from New York to Vermont. A FACTS device in operation near Burlington, Vermont, redirects power flows onto less congested transmission lines, and delayed the need for a transmission line upgrade for roughly ten years.

[4] This tool is available from the NASEO website, http://www.naseo.org, and the RAP website, http://www.raponline.org

[5] This report focuses only on the part of PJM that existed before its expansion west and south, what some call "Classic PJM." These are the Mid-Atlantic States of Maryland, Delaware, Pennsylvania and New Jersey, and the District of Columbia.

They are also responsible for transmission system planning, though in practice they take only a minimal role in any investment that ensues from their planning. Their stated goals include providing "signals" to others to invest appropriately. They operate under the jurisdiction of the Federal Energy Regulatory Commission. There are electrical connections between PJM and New York and between New York and New England. We will discuss these later.

In a perfect world, power from anywhere within these systems would be able to flow anywhere within each region. The most efficient use of resources, as defined by the daily bidding procedures supervised by the system operators and matching generation to load throughout the day, would occur.


**Figure 1: Three regional systems in the Northeast U.S. with transfer capacities noted. Source Remarks of Gordon van Welie to FERC, March 13, 2002.**

In fact, in each of the three regions there are limitations in power flows, or congestion. Generally, these conditions are caused by persistent load growth in the cities, while power generation is most easily accomplished in more rural places or where natural resources, like coal, are found. While this has always been the case, circumstances are coalescing to increase congestion and reliability concerns.

- Significant transmission built decades ago to accommodate large coal and nuclear generators are finally approaching or meeting their limits, at least during some hours. Many states have seen few transmission siting cases in recent years.

- Building new transmission can be expensive, and additional challenges come from environmental limits and conversion of countryside to suburban development and expansion of cities pressing in on right-of-way corridors. Transmission companies can be reluctant to start this process. Permitting or construction delays sometimes ensue.
- The ability to site natural gas fired generation in or near cities due to favorable air quality characteristics has reduced the frequency of congestion from what it would have been if the practice had persisted of building rural, large generating stations, which was typical in the 1970s and 80s. But increasing natural gas prices and a desire to maintain a diverse fuel supply indicate that the pace of natural gas generation construction near cities may slow in coming years.
- Demand side resource are under-utilized are not generally used to address congestion and reliability concerns.

**New England**

ISO-New England (ISO-NE) reports in its Regional Transmission Expansion report for 2004 several load pockets experiencing significant congestion.

Southwest Connecticut was forecasted to be short of capacity in 2004, with the problem getting more severe over time.[6] Congestion prevents resources from elsewhere in New England to fully supplement local resources, as is typically the case. This case is alarming because it has become a reliability concern, not just a case where more expensive generation must be run. Stated differently, even high cost resources in the area are insufficient to meet reliability standards. ISO-NE responded with an emergency solicitation for demand side resources for an interim period while a proposed transmission line was under siting review. Distributed generation was an eligible resource. Figure 2 shows that emergency actions, including acquiring demand resources, are necessary to maintaining reliability standards.

[6] This capacity shortage was compared to a summer peak demand for which there was a 90% probability that the peak would be at that level or below. For the purposes of reliability, this figure is more appropriate to use than a median forecasted figure. Added to this is required operating reserve. Emergency actions, including voltage reduction and rotating blackouts are still available in this scenario, but would be considered “last resort” options.

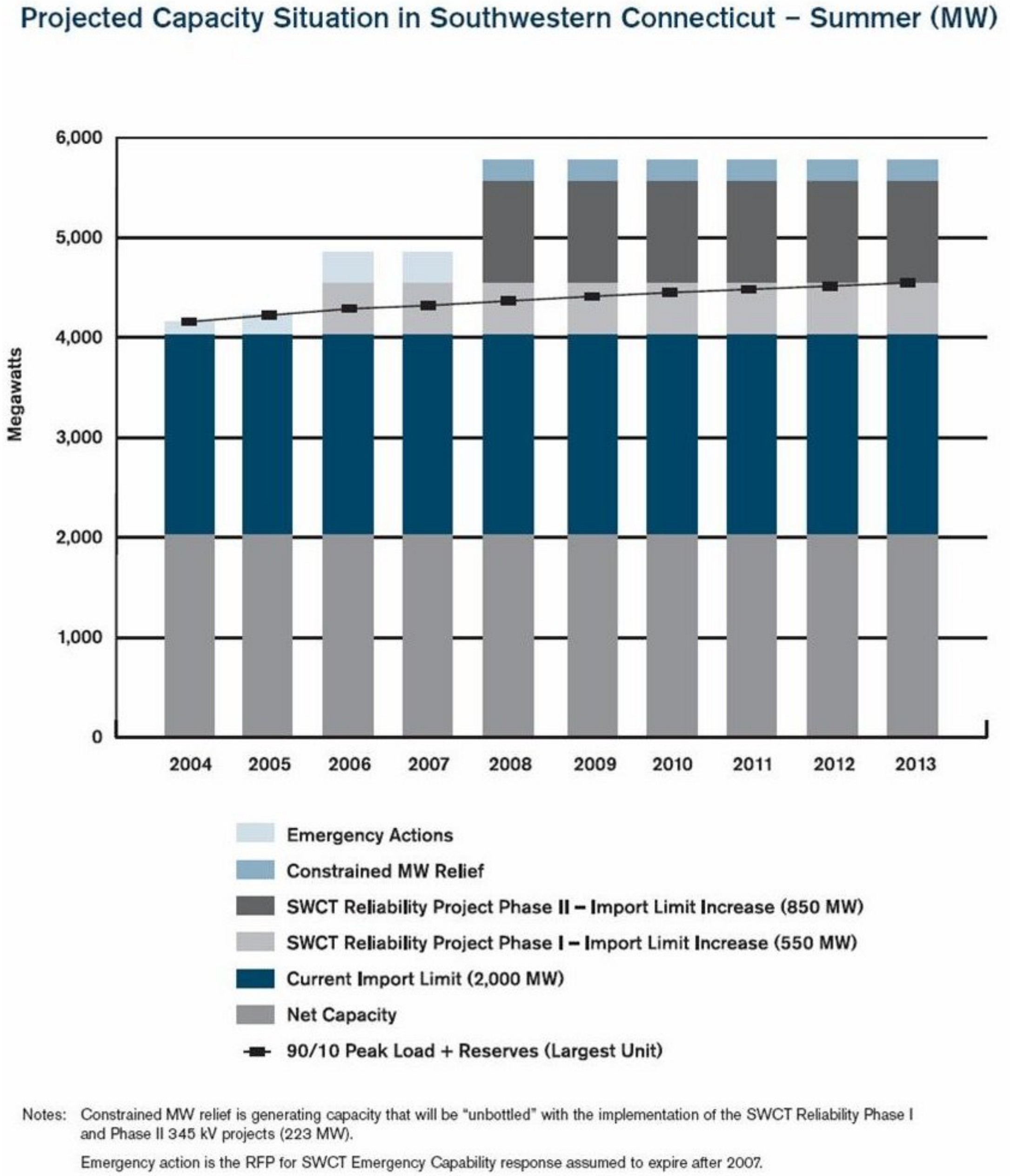


**Figure 2: A forecast from ISO-NE in 2004 showing that emergency actions, including demand resources, and new transmission lines, are needed to meet the 90/10 peak load forecast. Source: ISO-NE Regional transmission Expansion Plan 2004.**

Northeast Massachusetts and Boston suffers from several problems manifesting themselves as congestion and in other ways. While the Boston area has adequate operable capacity in the short term, there are:

- Limited access to regional supplies because of import restrictions into the Boston area (congestion);
- Dependency on over 1,300 MW of generation which has the possibility of retiring (which would increase congestion);
- Inability to import power into separate load pockets in Downtown Boston and the

North Shore (congestion);

- Vulnerability to outages possibly caused by fuel interruptions because about 45 percent of the generation in the Boston area is fueled by natural gas, a dependency that raises additional concerns;
- Reliance on up to 400 MW of emergency load shedding for the second contingency outage of a transmission facility.[7]

A recent study produced by the Center for Energy Efficiency and Renewable Energy at the University of Massachusetts examines the congestion in and around Boston, and explains how distributed generation can be a cost-effective way to mitigate costs flowing from this congestion.[8] Yet the discussion of reliability and congestion in Boston in RTEP 04 makes no mention of distributed generation among the various solutions discussed.

### Locational Marginal Prices

Locational Marginal Price is one of the key features of these three markets. LMP provides price signals for market transactions and economic signals indicating where investment in the bulk electric power system is needed — including the location of new generating units, expansion of transmission facilities, and participation in demand response programs. These elements are required in a well-functioning market to alleviate constraints, increase competition, and improve the system's ability to meet power demand. (adapted from NE-ISO RTEP 04 section 10.1) For New England, congestion adds to the LMP for Connecticut, and reduces it for Maine.

Congestion also occurs in Maine, but in a distinct way that offers no advantage to distributed resources there. In Maine, so much generation was built in response to the relatively recent introduction of natural gas from Nova Scotia that it cannot freely flow out of Maine through existing transmission lines. This generation is said to be "locked in." Transmission proposals to release this generation to the rest of the region are likely, though there is no way to know if or when they will come to fruition.[9]

While distributed generation was eligible for the solicitation for emergency resources in Southwest Connecticut, there is no process under more routine circumstances for distributed resources to compete to address transmission level concerns in New England.

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[7] RTEP 04

[8] Kosanovic, D., C. Beebe, **System Wide Economic Benefits of Distributed Generation in the New England Energy Market,** Center for Energy Efficiency and Renewable Energy University of Massachusetts, February 2005.

[9] The ISO-NE Regional System Plan 05 identifies $2-4 billion in transmission projects that appear to be needed in New England. The report does not focus on congestion, but project descriptions indicate that congestion relief would be one result in many cases.

## What Limits Flows on Power Lines?

Power lines are metal conductors generally suspended from power poles. Current flows through the lines pushed by a voltage applied from transformers at generating stations. Because of the nature of electricity, current is not a perfect way to transmit energy – some energy is lost to heat as atoms collide in the conductor. Depending on the thickness and choice of metal, a certain amount of current can flow through the conductor with minimal effects, with the air acting as a natural coolant. As the amount of current grows, the metal expands and weight of the conductor makes the sag between poles more pronounced. Lines that normally pass well over roads or other obstructions now risk sagging into traffic or structures. If sagging is not a problem, perhaps because the line is underground in an oil-cooled trough, the build-up of heat can cause a fire in a transformer or other catastrophic problems. Operators are familiar with the physical limits of the transmission lines and do not allow lines to operate past these limits.

There is one other category of line limit that can lead to congestion. While physical capacity may remain on a power line, operators may restrict flows on the line to lower levels. They do this because they must be prepared for a contingency, an event that would dramatically change power flows nearly instantly. Such an event, like a nuclear plant outage, or an outage on a heavily load power line, may redirect hundreds of MegaWatts to other power lines, and operators reserve transmission line capacity for such single contingencies. As a result, congestion may exist even if there is physical transmission capacity available to meet reliability standards. One way to reduce congestion is to improve operating procedures, if possible, so as to reserve less transmission capacity for contingencies and allow it to be used for normal operations.

### New York

The primary area of congestion in New York is into New York City, and also Long Island. Persistent demand growth outpaces the ability for generation to be built in a very sensitive urban landscape. Significant efforts by the state and its New York State Energy Research and Development Authority to deploy distributed resources in the metropolitan area have helped, though the concern remains significant.

More generally, there is significant congestion bringing power from western New York, where there is more generation, to the east, where there is more demand. Evidence for this is in higher locational marginal prices in zones F, G, H, I, J, K. in figure 3, and the demarcation line is known as the Central-East Interface. This is shown on figure 3, even on an average fall day. Some significant transmission projects added in the last 20 years have alleviated but not removed this congestion.

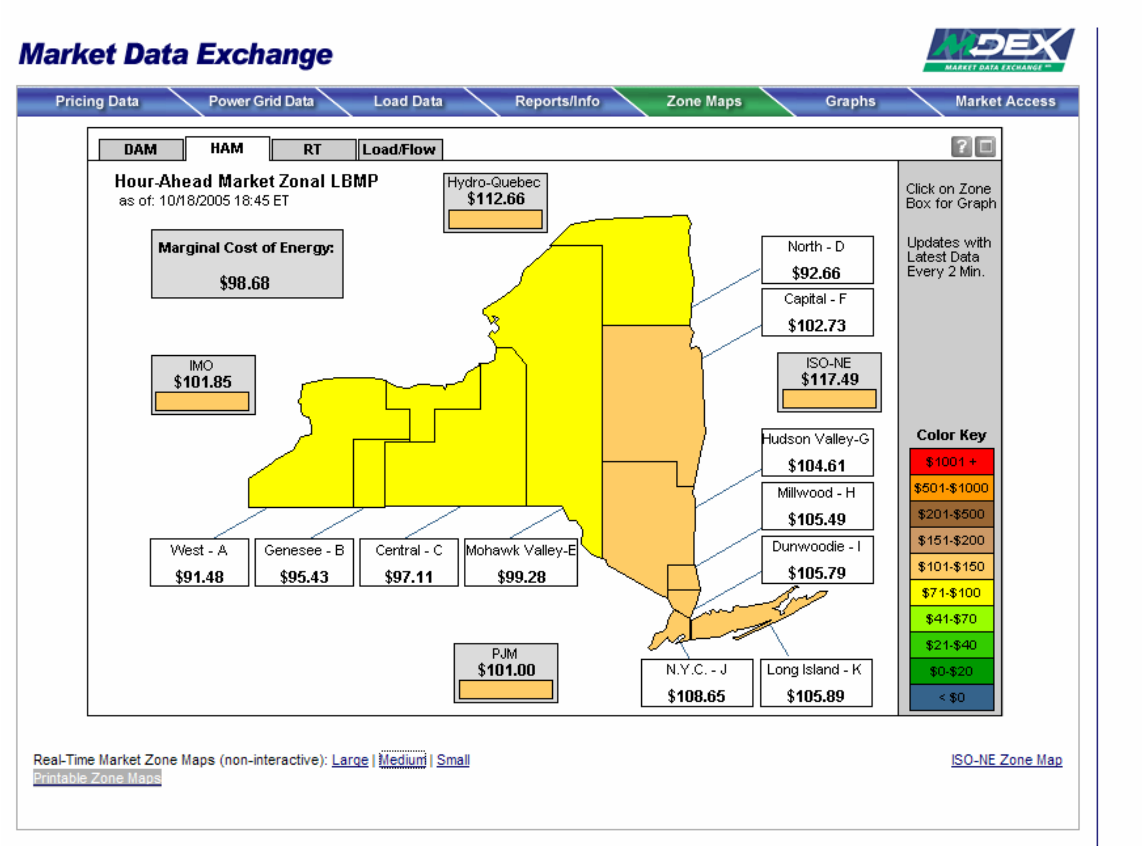


**Figure 3: This screen from the NYISO website shows the locational prices for the different zones in New York on a recent October day. The differences are modest compared to a hot summer day, when congestion is more pronounced.**

## PJM – Mid-Atlantic

Congestion is a significant issue in the PJM states and gets significant attention from PJM. Two figures illustrate the level of attention congestion is getting there.

In figure 4, facilities in the PJM region experiencing congestion are shown on a map. This map was used by PJM in a program called the Market Window. The idea of the market window goes like this. Congestion along with locational marginal prices creates a market opportunity for electric resources to secure higher prices in the congested area. If, however, there is no market response, PJM issues a solicitation for resources that will address the congestion over the course of one year. Eligible resources in this solicitation include distributed generation and demand response. One reason there might not be a market response is that once the fix is installed and congestion is mitigated, the benefit from a higher locational marginal price disappears! With the market window, solutions, including distributed generation, are able to directly mitigate transmission level congestion and receive committed revenues. The market window would open from time to time, as needed by PJM.

In PJM, the cost of congestion in terms of more expensive generation dispatched due to generation is calculated. In 2004, this amount was $808 million for the entirety of PJM, including the recently added territory to the west. However, the sale of firm transmission rights (FTRs) by PJM to market participants seeking to assure transmission paths for their product offset all but $16 million of this amount. FTRs act as a hedge for this purpose, so PJM characterizes the $16 million as the cost of “unhedgeable congestion.” From month to month, PJM reports significant volatility in positive and negative balances which nearly cancelled out at yearend, compared with annual revenue of $8.7 billion. This month to month volatility is due chiefly to varying levels of imports, different patterns of generation and weather.[10]

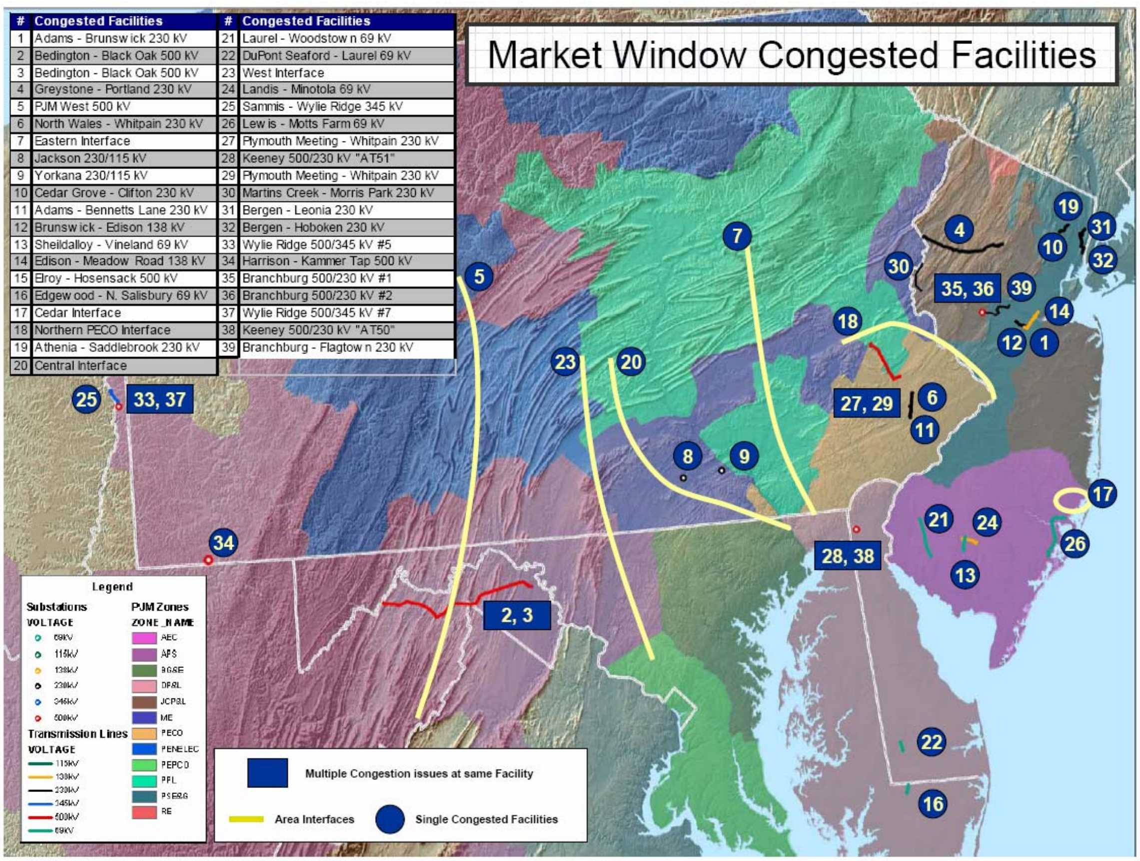


**Figure 4: Map of PJM Congestion http://www.pjm.com/planning/downloads/20040811-market-window-facilities.pdf (October 17, 2005)**

Figure 5 is a forecast analysis of the value of capacity in eastern PJM at three future time periods which was done to evaluate the value of generating capacity over time.

Both of these figures reinforce the fact that congestion is more significant in the easternmost part of PJM. This is due to an imbalance of generation in the west and load in the east. Figure 5 shows some other relationships. Congestion into New Jersey is very significant and becomes more pronounced as aging local generation retires. It also shows congestion being relieved if transmission is built. This indicates that the value DG in a

[10] PJM

load pocket is dramatically diminished by the construction of a power line, and illustrates that these two resource categories do compete.

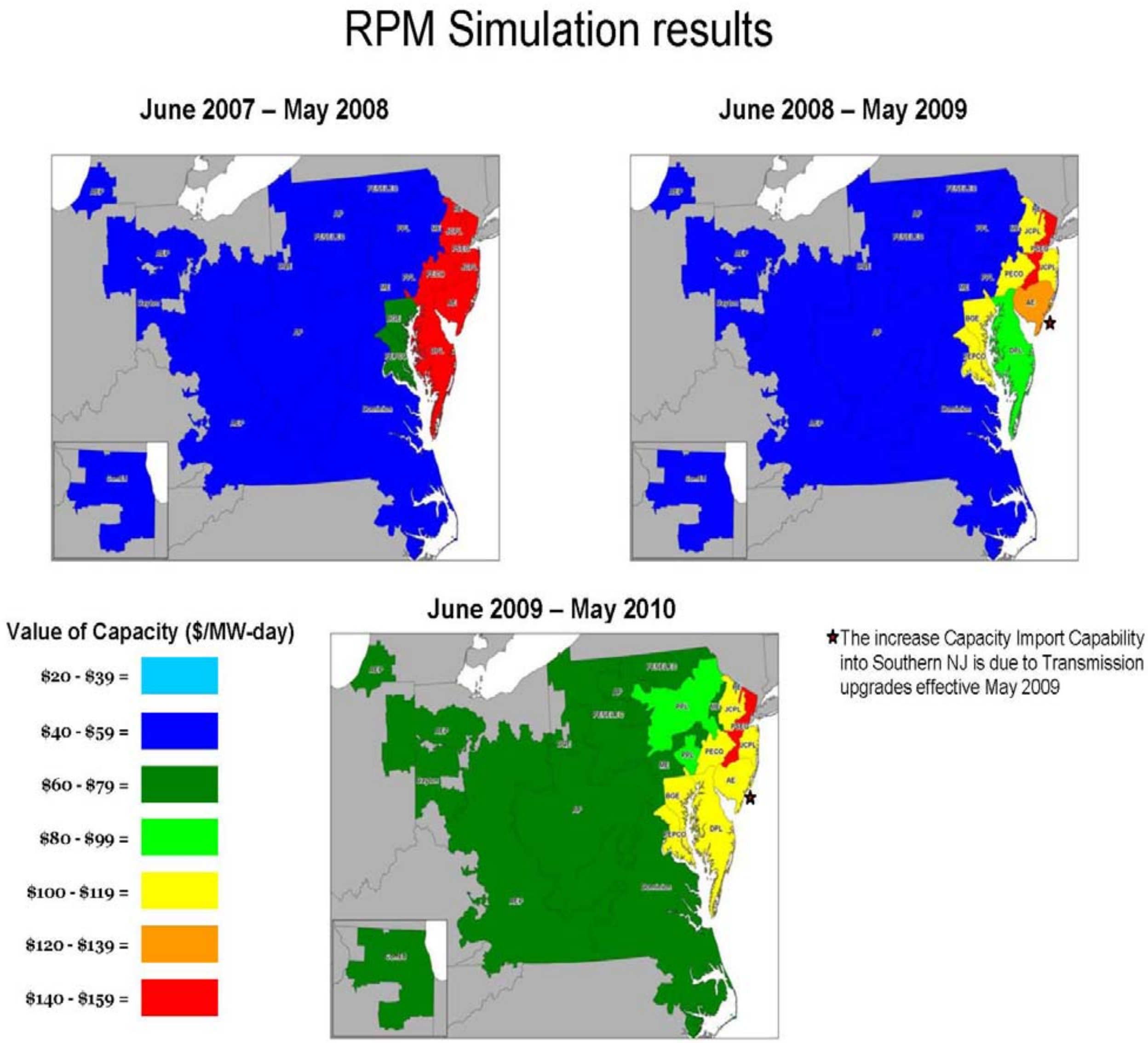


**Figure 5: Forecasted capacity values in PJM. Source: PJM**

<u>New Jersey</u>

As stated in the previous section, there is significant congestion in New Jersey, especially in moving power west to east toward the shore. The PJM 2004 State of the Market Report identifies the Public Service Electric and Gas system as having the highest incidence of congestion in the eastern PJM zone in 2004.[11] Growth in electric demand to support increased second home and tourist development at the shore coupled with the difficulty in siting new generation in an area which relies on avoiding industrialization lead to congestion of transmission feeders, especially in the summer. Pending retirements of

[11] PJM pg 37

electric generation promise to make the situation worse. A power line was permitted recently and will help, but not alleviate this condition.

Pennsylvania
Limits on power flows from generation heavy western Pennsylvania to eastern Pennsylvania have persisted for years. Proposals for High Voltage Direct Current (HVDC) line to bypass the AC system and deliver from predominantly coal generation in western Pennsylvania and West Virginia, dubbed at one time "Coal-by-Wire," have lacked traction. Such a proposal seems to require a coalition of buyers to support the project, and such a coalition has never formed.

Delmarva Peninsula
Geography sometimes makes congestion almost inevitable. The Delmarva Peninsula is such a case. Growth at the southern end has increased pressure on the grid to provide consistent access to market-based electric power. Reducing reliance on aging generators with significant air emissions adds to a complicated situation.

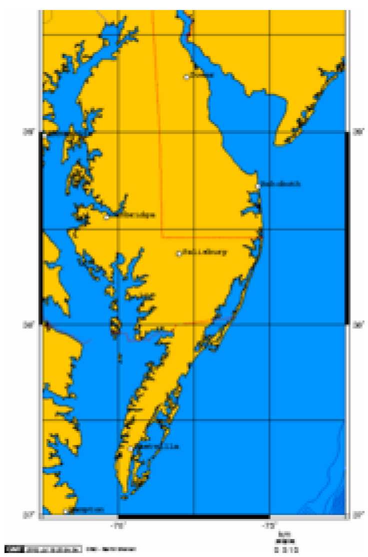

**Figure 6: Map: http://en.wikipedia.org/wiki/Delmarva_Peninsula (October 27, 2005)**

District of Columbia
Washington DC and its immediate vicinity is an intense energy user. The city relies on transmission and nearby coal generation for electric power. There are inherent congestion issues in the district. Congestion effects would be exacerbated if environmental controls or high operating costs lead to closure of some local generation.

**Seams**
The system operator in each market area (New England, PJM, New York) manages congestion within its borders. There are, however, transfer limits between market areas. These are shown on the map on page 3 of this report. These transfer limits can be seen as congestion, since they can serve to prevent lower cost power from moving freely throughout the northeast AC transmission system. These transfer limits also serve the interests of reliability, however, by preventing prevailing power flows from becoming too

great in any direction. Large power flows over great distances can lead to system instability and unacceptable vulnerability to contingencies leading to reliability problems. For the purposes of distributed generation deployment at this time, transfer limits at seams represent a second order issue at best.

**Distribution Systems**

Distribution system network congestion is beyond the scope of this assessment. This issue is important, however, to distributed generation interconnection in urban distribution systems with a network configuration. Operating a distribution network, as distinguished from a radial system, is complex. For any given system node, a spectrum of system conditions can exist. Interconnection standards should be able to be more illuminating regarding how distributed generation can contribute to a distribution network with the least burden from engineering studies.

### Non-attainment Areas: A Different Form of Congestion?

Much of the Northeast U.S. is in non-attainment under the Clean Air Act for ground level ozone. This means that for enough hours in the year and for a sufficient duration, ozone levels are higher than regulations permit. States are directed to take steps to attain ozone standards. These regulations are connected to health outcomes, like incidences in asthma, for example. Emissions from electric power generation, especially $NO_x$, are key precursors to this problem.

Meanwhile, the least expensive and most common distributed generation type is a combustion turbine. Many of these units have high emission rates per unit of energy output, though some can reduce this through investments in controls.

Non-attainment status acts as congestion does, forcing higher cost generation solutions to operate in a region because there is no more capacity to operate lower cost, more polluting machines. In Texas, where non-attainment prevails in part of the state, output-based emission standards are used to permit distributed generation, and more stringent standards apply in attainment areas. These minimize the impact on air quality while adding some cost in comparison to a similar installation in an attainment area.

**Concluding Remarks**

There is increasing attention on the cost of congestion and policy solutions to address it. Distributed generation is generally under-represented in these discussions.

The Northeast U.S. has modeled different ways to introduce distributed generation to address congestion, including the PJM Market Window, the Southwest Connecticut emergency resource solicitation, and the deployment activity in New York. Engaging utilities to be consistently active partners in DG deployment for congestion relief and reliability support would add significant momentum.

Obstacles to this step change in utility support for DG include:

- the standard planning and engineering practices of many utilities which tend to look at power flows as one-way to the customer, not two-way with the customer as a resource;

- the connection between utility profits and sales that does not sufficiently reward more efficient service;
- interconnection and rate practices that add unreasonable burdens to the distributed generation project balance sheet;
- technology which is still a little too exotic or complex for many customers.

A state where utilities and system operators actively seek distributed generation and other distributed resources as solutions to system congestion and reliability concerns would lead to a dramatic increase in deployment.

**B. Natural Gas Availability in the Northeastern U.S.**

The purpose of this section is to examine the availability of natural gas in the northeast and connect that to the prospect of distributed generation development in this region.

The use of natural gas for power generation in the Northeast U.S. has grown significantly in the last several years, nearly 32% from 1997 to 2004.[12] Natural gas is also the optimal fuel at present for most combustion and fuel cell-based distributed generation systems. It is appropriate for clean reciprocating engines, many CHP systems, and fuel cells.

Particularly desirable DG applications using natural gas operate as CHP systems, and make use of chilled water as well hot water. Higher pressure gas supply allows for more robust systems.[13]

To date utility planning is not serving to target places that have above average long run marginal costs where distributed generation would provide distinct and significant value to the utility system. If states begin to require this from utilities, and if this value can be shared with distributed generation owners, this would add an important new factor to influence new DG investment. More generally, a combination of benefits, representing electric system and environmental benefits accrue from distributed generation, yet regulation and policy are not organized to return commensurate value to DG owners and operators.[14]

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[12] EIA Natural Gas Navigator, http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_a_EPG0_veu_mmcf_a.htm, (October 28, 2005)

[13] Vanderpas, Jim UTC Power Technologies, April 6, 2005 http://www.northeastchp.org/nechpi/archive/nechpi2005/presentations.htm (October 28, 2005)

[14] For a deeper discussion of unrealized DG value, see Massachusetts Distributed Generation Collaborative 2005 Annual Report, Attachment C, A Framework for Developing Win-Win Solutions for Distributed Resources in the Massachusetts, Massachusetts Technology Trust and EPRI DER Public/Private Partnership Market Integration Team, May 31, 2005. http://www.masstech.org/renewableenergy/public_policy/DG/resources/Collab_2005Collab05_05_31_AnnualReportAttC.pdf (October 28, 2005)

While overall firm sales growth has led to physical improvements in the natural gas pipeline system, certain limitations to natural gas availability for distributed generation persist:

- Natural gas is still not available in many areas, primarily less populated areas;
- Significantly more gas is purchased with interruptible contracts. Interruptions for non-firm gas appear to have increased a tick in probability.[15]

Fortunately, while availability limitations may influence the choices of some customers, there remain ample reasons for customers to consider and choose distributed generation independent of natural gas availability

- Natural gas is available in the population centers in the northeast.[16] Facilities are in place to maintain high reliability for firm gas deliveries. In these locations and many rural areas in between are the lion's share of distributed generation opportunities and the full range of applications.
- Propane can also be used for most of the same applications as natural gas and is being used for DG in areas where natural gas is not available.[17]

The recent step increase and volatility of natural gas prices has caused a pause in distributed generation development. Since electric rates in many Northeast states are capped, or do not vary the short term costs of fuel, the business case for distributed generation has, at least temporarily, gotten more tenuous with narrowing "spark spreads."[18] As the increased price of natural gas finds its way through to ultimate electric consumers, it is likely that the business case will revert to one more similar to what prevailed earlier this decade.

From the broadest of perspectives, the *availability* of natural gas is a far lesser influence on the deployment rate of distributed generation, as compared with factors such as regulatory incentives for or against DG, applicability of distributed generation and CHP system technology to an increasing proportion of end uses, and the price of natural gas. This is the case today and is likely to continue for some decades.

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[15] For a deep discussion about this, see www.iso-ne.com for a report on the 2004 Cold Snap. Generally, many natural gas applications run on interruptible contracts for economic reasons – DG reliability for grid support is not sufficiently valued to provide payments that would support firm gas contracts in many cases. And reliability is still good.

[16] Maps of natural gas coverage in New England, New York, New Jersey, Pennsylvania, Maryland and the District of Columbia are available at http://www.duke-energy.com/businesses/trans/pipelines/us/storage/maritimes.asp, www.nega.com, www.iroquois.com, http://www.duke-energy.com/cinergy_merger/asset_map.asp, http://www.tennesseeadvantage.com/map/default.asp, http://www.columbiagastrans.com/tco_map.html.

[17] Propane is fueling a CHP system at the Green Mountain Coffee Roasters manufacturing facility in Waterbury, Vermont. For a discussion of the potential for other fulels to support CHP, see also Lamar, Jr., Paul, Opportunity Fuels for CHP, April 6, 2005.
http://www.northeastchp.org/nechpi/calendar/events/presenters.htm (October 28, 2005)

[18] Spark spread refers to the difference in market price between natural gas and electricity.