Net Environmental Impacts of Transmission Systems

New Criteria for Evaluation of Proposed Transmission Lines in the Midwest

Wind on the Wires and
The Union of Concerned Scientists

Summary: Transmission system capacity is a critical issue in many parts of the country, particularly for new market participants such as wind power. In the Upper Midwest significant new transmission has not been built for nearly two decades while electricity consumption has continued to grow at a steady pace. Several major new transmission proposals are imminent in the Midwest.

Each state makes decisions on new transmission proposals on several levels including policy, regulatory, and siting/routing. Achieving regional consensus on the policy level prior to undertaking the regulatory and siting proceedings is critical to success. This requires a clear understanding of the purpose of and need for proposed new transmission lines over time. The primary drivers for new transmission are reliability of the power system, economics of the delivered electricity, and regional environmental impacts. Reliability criteria for new transmission are well established. Economic criteria for new transmission are under development in many regions including California, PJM, and the Midwest. However, regional environmental criteria have not been incorporated to date to any significant degree in transmission planning.

This paper outlines a scope and an initial method for estimating net environmental impacts, based on regional air emissions, of new transmission expansion and demonstrates the method on a set of exploratory transmission lines in the 2003 Midwest Independent System Operator (MISO) Transmission Expansion Plan. The method applies an integrated production cost model that produces hourly dispatch throughout the year for generators in the region. This allows estimation of the net environmental impacts of the proposed transmission line based upon the new regional generation mix facilitated by the line and the resulting change in regional air emissions. The method can provide quantitative regional environmental information regarding particular transmission proposals for decision makers such as public utilities commissioners. The case study results illustrate the potential for a significant reduction in regional air emissions with the addition of remote wind power and new transmission to move it to market. The proposed methodology could be developed further to include evaluation of other environmental impacts besides air emissions, including potential impacts from transmission and generation such as land-use, water, wildlife/biodiversity, habitat fragmentation, wetlands, and from mining, transporting, and burning coal.

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Overview

Transmission system capacity is a critical issue in many parts of the country, particularly for new market participants such as wind power. In the Upper Midwest significant new transmission has not been built for nearly two decades while electricity consumption has continued to grow at a steady pace. Several major new transmission proposals are imminent in the Midwest.

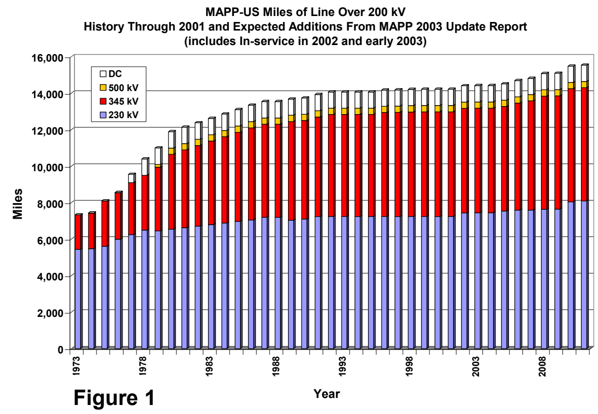

Figure 1

New transmission proposals have been driven largely by reliability and lowest delivered cost. While these technical and economic factors are critically important, the primary challenge for success is achieving regional consensus on the purpose of the new transmission. The power grid is regional in nature and is becoming more so. Regional support for a determination of need hinges on a clear understanding of the purpose and use of the new lines over time. Environmental concerns which are key to regional consensus are often raised or considered too late in the process, with insufficient information, to have any role other than simply stopping the project.

The US electrical transmission system's primary historical function has been to connect power plants owned by vertically integrated utilities with its major load centers. A secondary purpose has been to provide avenues for the point-to-point transfer of blocks of energy between nearby regions allowing more efficient use of power generation facilities and to provide power in the event of failure of individual generating or transmission facilities. With continued transition toward open access and regional planning and markets, the transmission system is being called upon to serve a broader role. In addition to traditional reliability functions, the grid has a growing role in delivery of economic benefits through the delivery of low cost electricity and in delivery of environmental benefits through the delivery of cleaner renewable energy.

Transformation of decision-making on transmission expansion is underway. Vertically integrated utilities have traditionally planned for both transmission and generation to meet their native load requirements and have focused primarily on reliability impacts and savings from contracted purchases and sales. Independent System Operators (ISOs) have the responsibility to provide non-discriminatory access to all parties and must undertake transmission planning accordingly. However, investments in new generation are made in the marketplace by private companies or by utilities subject to regulatory oversight. A utility may have regulatory conditions or requirements placed on its generators that must be coordinated with the rules and procedures that govern access to and planning for transmission. ISO planners must consider broader objectives that value the benefits to all participants in the region including retail customers, generation owners, and transmission owners.

Each state makes decisions on new transmission proposals on several levels including policy, regulatory, and siting/routing[1]. Achieving regional consensus on the policy level prior to undertaking the regulatory and siting proceedings is critical to success. This requires a clear understanding of the purpose of and need for proposed new transmission lines over time. The primary drivers for new transmission are impacts to reliability of the power system, economics of the delivered electricity, and regional environmental impacts.

Reliability criteria for new transmission are well established. The North American Electric Reliability Council (NERC) was created to maintain electric system reliability and adequacy in North America by establishing standards applicable to generators, transmission systems, and electric control areas. NERC is responsible for reliability standards for electric transmission planning. NERC's planning standards[2] apply to the bulk electric system (generation, transmission, and interconnections operated above 100 kV) and state the fundamental requirements for planning reliable interconnected bulk electric systems. The planning standards define the reliability of the interconnected bulk electric system in terms of its ability to supply the aggregate electrical demand and energy requirements of their customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements; and its ability to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements. In addition to planning standards, individual regions may develop their own regional planning criteria. These are evaluated to ensure that the regional criteria are consistent with NERC's planning standards.

Economic criteria for new transmission are under development in many regions including California, PJM, and the Midwest. The California Independent System Operator (CAISO) has developed a methodology for evaluating the economic benefits of transmission investments in a restructured electricity market[3]. The method examines the impact a transmission expansion would have on increasing transmission users' access to generation sources and demand areas, the impact on incentives for new generation investments, the impact on increasing market competition, and the inherent uncertainty associated with critical market drivers (e.g. natural gas prices, demand growth, and hydro power conditions). Under a FERC order, PJM is developing a plan for economic expansion of the transmission system based on the assessment of unhedgeable congestion.[4]

Modeling techniques to evaluate the environmental effects of policy decisions on the generation and load have been developed and applied by a number of researchers[5].

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[1] *State-Level Electric Transmission Line Siting Regulations Directory*, Edison Electric Institute, 2001. http://www.eei.org/industry_issues/energy_infrastructure/transmission/siting_directory.pdf

[2] NERC Operating Policies and Planning Standards, http://www.nerc.com/standards/

[3] *A Proposed Methodology for Evaluating the Economic Benefits of Transmission Expansions in a Restructured Wholesale Electricity Market*, CAISO and London Economics International, February 2003. http://www.caiso.com/docs/2003/03/18/2003031815303519270.html

[4] *Order on Rehearing and Compliance Filing Regarding Transmission Expansion Projects Needed to Promote Competition, FERC, October 24, 2003.* http://www.pjm.com/documents/downloads/ferc/2003orders/20031024-rto1-2.pdf

[5] *Predicting Avoided Emissions from Policies that Encourage Energy Efficiency and Clean Power*, Synapse Energy Economics, June 2002. http://www.synapse-energy.com/Downloads/report-otc-avoided-emissions-report.PDF

Modeling Techniques and Estimating Environmental Outcomes, Commission for Environmental Cooperation of North America, June 2002. http://www.cec.org/files/PDF/5_modeling-e.pdf

However, to date the analytical methods have not included the effects of new transmission lines while environmental criteria for new transmission have focused primarily on direct impacts from siting and routing.

The electric utility industry is the largest single source of air pollution in the United States. Emitting more than 60% of the sulfur dioxide, 20% of the nitrogen oxides, 40% of the mercury, and 40% of the man-made carbon dioxide released into the nation's air[6], electrical generating plants contribute significantly to devastating environmental problems such as acid rain, smog and global climate change. Air pollution from coal-fired power plants also compromises our health. It contributes to respiratory diseases such as asthma and contaminates fish populations that are consumed as food with toxic metals such as mercury.[7]

This paper outlines a scope and an initial method for estimating net environmental impacts of new transmission expansion based on air emissions and demonstrates the method on a set of exploratory transmission lines in the 2003 MISO Transmission Expansion Plan. The method applies the results of an integrated production cost model that produces hourly dispatch throughout the year for generators in the region to other data sources to estimate impacts of new transmission. The results of the production cost model are used to estimate the net change in air emissions under different generation and transmission scenarios. This allows an estimate of net environmental impacts of the proposed transmission line based upon the new regional generation mix facilitated by the line and the resulting change in regional air emissions. This information could be combined with other environmental impacts such as land use, water, wildlife, habitat, and others to determine the overall net environmental impact. The method can provide quantitative environmental information regarding particular transmission proposals for decision makers such as public utilities commissioners for use in a regulatory proceeding involving transmission upgrades or new lines.

Context for Transmission Expansion in the Upper Midwest

Figure 2

	Wind Power, MW			
			% of State Consumption in 2010[3]	
	Existing[1]	Total Potential[2]	5%	10%
Illinois	50	6,980	2,668	5,336
Iowa	471	62,900	827	1,654
Minnesota	563	75,000	1,250	2,499
Nebraska	14	99,100	559	1,118
North Dakota	66	138,400	220	440
South Dakota	44	117,200	187	374
Wisconsin	53	6,440	1,363	2,726
Total	1,261	506,020	7,073	14,147

Notes:
1. Nameplate MW, American Wind Energy Association, January 2004, http://www.awea.org/
2. Avg MW (approx. 1/3 of nameplate capacity), *An Assessment of Windy Land Area and Wind Energy Potential*, Pacific Northwest Lab,1991
3. Wind power nameplate capacity; 35% net annual capacity factor and % consumption based on energy and growth from Energy Information Administration, 2001, http://www.eia.doe.gov/cneaf/electricity/st_profiles/profiles.pdf

Wind

Wind energy is the fastest growing energy technology. The Midwest is projected to become a substantial provider of wind powered electricity, a market worth billions of dollars to the regional economy. The rapidly growing markets for new

6 *Reducing Power Plant Emissions: EPA's New Proposed Rules for Interstate Air Quality and Mercury* and http://www.epa.gov/cleanenergy/impacts.htm . U.S. Environmental Protection Agency, February 2004
7 *License to Pollute,* Izaak Walton League of America and the Clean Water Fund, October, 1997. http://www.iwla.org/reports/license.html

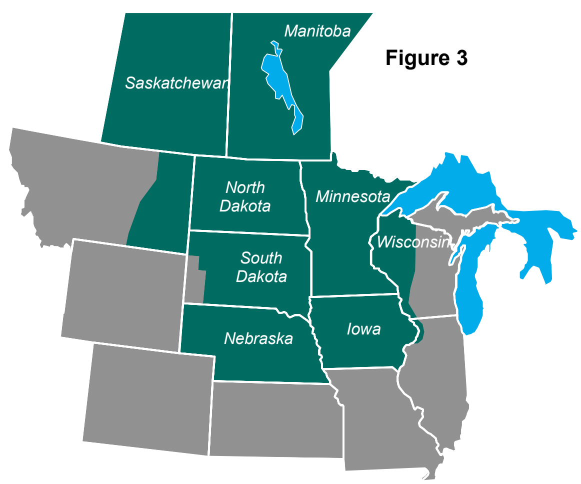
wind power development in the Midwest result from steadily improving economics, strong environmental benefits, growing utility loads, and increasing state and national policy support. The economics of wind power correlate strongly to average annual wind speed and therefore wind power is very site dependent. Rapid construction time for wind energy relative to other generation technologies further amplify transmission impacts.

Coal/Lignite
The upper Midwest currently relies on coal for over 75% of the region's electricity. A number of proposals for new coal fired generation are under development including several potential new lignite projects. The goal of Lignite Vision 21 Project, an Industry/Government partnership created by the North Dakota Industrial Commission, is construction of one or more lignite-fired base load generation facilities in western North Dakota to provide low cost energy to meet the energy growth demands of the region. The Upper Great Plains Transmission Coalition ("UGPTC") is comprised of coal, wind, and transmission interests in the Upper Great Plains region of North Dakota, South Dakota, and Minnesota. The mission of the UGPTC is to resolve the transmission export constraints so that wind and lignite produced electrical energy can be transmitted to remote markets within the region.

Midwest Transmission Planning and Regulatory Oversight

Mid-Continent Area Power Pool
The Mid-Continent Area Power Pool (MAPP), the NERC Regional Reliability Council for the upper Midwest, has 32,000 MW of peak demand, 41,000 MW of capacity, and 20,000 miles of transmission across six state and two Canadian provinces. MAPP is a voluntary association of utilities and other electric industry participants that operated to facilitate the pooling of generation and transmission services.

Figure 3

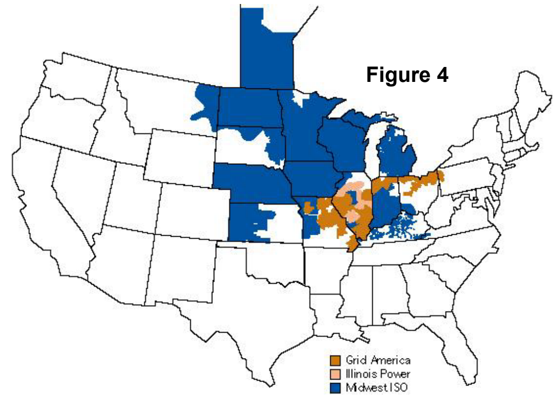


The goal of MAPP is to ensure that the regional interconnected electric system is operated securely and efficiently and that the economic benefits of power pooling are equitably shared through coordination, consistent standards, and enforcement. MAPP members are required to prepare and maintain comprehensive plans for their transmission facilities. MAPP biennially prepares a ten year Regional Plan. The Regional Plan integrates the transmission plans developed by individual members and subregional planning groups, for the purpose of enabling the transmission needs of MAPP members and the region generally to be met on a consistent, reliable, environmentally acceptable, and economical basis[8]. However, the Regional Plan does not include environmental analysis.

[8] MAPP Restated Agreement, Article 8.6.4.

Midwest Independent System Operator

The Midwest Independent System Operator (MISO) has 111,000 MW of peak load, 122,000 MW of capacity, and 112,000 miles of transmission across 15 states. The MISO generation interconnection queue is dominated by natural gas. There are also a number of proposals for large new coal plants, wind power facilities, and hydro plants.



MISO's primary responsibilities include ensuring reliability of the transmission system and administering a single, system-wide Open Access Transmission Tariff (OATT). MISO has the responsibility for regional transmission planning and has direct authority over the process to add or expand generation connected to the MISO transmission system. MISO is authorized to provide non-discriminatory open access transmission service over the transmission systems of its members, to receive and distribute transmission revenues, and to be responsible for regional system reliability. MISO annually develops a Transmission Expansion Plan (MTEP) to assure the reliability of the Transmission System that is under the operational and planning control of the Midwest ISO, and identify expansion that is critically needed to support the competitive supply of electric power by this system. The MTEP incorporates the MAPP Regional Plan. The MTEP does not include environmental analysis.

Early in 2004, MISO launched a Regional Expansion Criteria and Benefits (RECB) Task Force to define criteria to be used to justify inclusion of transmission expansion proposals in the MTEP for reasons other than maintaining system performance within reliability standards, and to recommend a mechanism to allocate the costs of these expansions.

Organization of MISO States

The Organization of MISO States, Inc. is a non-profit, self-governing organization of representatives from each state with regulatory jurisdiction over entities participating in MISO, a regional transmission organization as defined by the Federal Energy Regulatory Commission (FERC). The purpose of the OMS is to coordinate regulatory oversight among the states, including recommendations to MISO, the MISO Board of Directors, the FERC, other relevant government entities, and state commissions as appropriate. The OMS plans to establish project specific multistate project siting teams to evaluate new transmission proposals. The OMS plans to review and evaluate the expansion criteria recommendations of MISO's RECB Task Force.

North Dakota The North Dakota Public Service Commission requires a Certificate of Need and a Route Permit for electric transmission lines greater than 115 kV[9]. Environmental assessment and alternative routes are considered in the application approval process.

[9] North Dakota Century Code Chapter 49-22, Energy Conversion and Transmission Facility Siting Act. http://www.state.nd.us/lr/cencode/T49C22.pdf
North Dakota Administration Code Article 69-06, Energy Conversion and Transmission Facility Siting. http://www.state.nd.us/lr//information/acdata/html/69-06.html
North Dakota Public Service Commission, http://www.psc.state.nd.us/psc/jurisdiction/siting-consinfo.html

South Dakota Any utility proposing to construct a transmission line 115 kV and above must obtain a permit from the Public Utilities Commission[10]. The permit application must include environmental studies prepared relative to the facility. If the proposed transmission line is a trans-state line, which originates and terminates outside of South Dakota and 25% or less of the design capacity is for use within the state, additional criteria are required including a showing that the proposed trans-state transmission line and route will not pose a threat of serious injury to the environment nor to the social and economic condition of inhabitants or anticipated inhabitants in the siting area.

Iowa Utilities seeking to construct a transmission line of 69 kilovolts or more and which is located outside the boundaries of a city must request a franchise from the Iowa Utilities Board (IUB), which is the permit authorizing the construction, operation and maintenance of the line[11]. The petition to the IUB for a franchise must include demonstration that the proposed line is necessary to serve a public use and represents a reasonable relationship to an overall plan of transmitting electricity in the public interest. The general assembly's intent with regard to the development of electric power generating and transmission facilities shall be implemented in a manner that is cost-effective and compatible with the environmental policies of the state, as expressed in Title XI[12].

Minnesota Utilities seeking to build a transmission line of 100 kV or greater enter into a two stage regulatory process. In the first stage, the utility applies for a Certificate of Need from the Public Utilities Commission[13]. The utility must show that the demand for electricity cannot be met more cost effectively through energy conservation or load management. The utility must also demonstrate the relationship of the project to overall energy needs, as well as document the ways in which the line will enhance or protect environmental quality. Once the Certificate of Need is granted, the utility then must obtain a construction permit from the Environmental Quality Board. The EQB is directed by the State's Power Plant Siting Act[14] to designate routes that will minimize adverse human and environmental impact, ensure that electric energy needs are met in an orderly and timely fashion, and ensure the continuing reliability and integrity of the electric power system. As part of the permitting process, the EQB prepares an Environmental Impact Statement and holds a contested case hearing. Minnesota resource planning statute[15] and rules require utilities to file biennial reports on the projected energy needs of their service areas over the next fifteen years, their plans for meeting projected needs, the analytical process they used to develop their plans, for meeting their needs, and their reasons for adopting the specific resource mix proposed to meet projected need[16].

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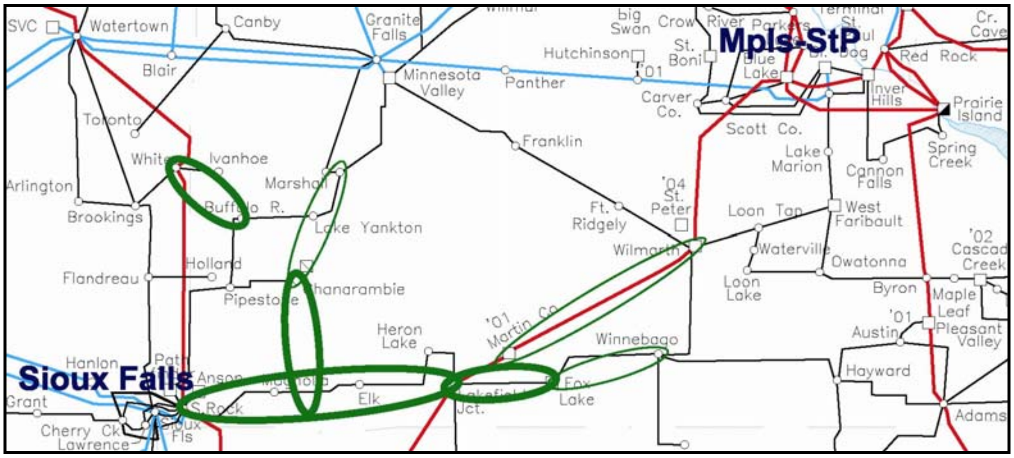
[10] South Dakota Codified Law 49-41B, Energy Conversion and Transmission Facilities. http://legis.state.sd.us/statutes/index.cfm?FuseAction=DisplayStatute&FindType=Statute&txtStatute=49-41B
[11] Iowa Code Chapter 478 Transmission Lines, http://www.legis.state.ia.us/IACODE/2003/478/
[12] Iowa Code Chapter 476.53, Electric generating and transmission facilities, http://www.legis.state.ia.us/IACODE/2003/476/53.html
[13] Minnesota Statute 216B.243, http://www.revisor.leg.state.mn.us/stats/216B/243.html
[14] Minnesota Statute 116C.51 to 116C.69, http://www.revisor.leg.state.mn.us/stats/116C/
[15] Minnesota Statute 216B.2422, http://www.revisor.leg.state.mn.us/stats/216B/2422.html
[16] *2003 Minnesota Biennial Transmission Projects Report*, November 2003. http://www.minnelectrans.com/MnTransPlanBinder1.pdf

New Transmission for Wind Power in Southwest Minnesota

A unique combination of communities, environmentalists, and utilities came together recently in support of several hundred miles of new high voltage transmission lines to move 825 MW of wind power to the Twin Cities from southwest Minnesota, resulting in a successful Certificate of Need ruling for the needed facilities from the Minnesota Public Utilities Commission in 2003[17].

Figure 5



Xcel Energy had filed an application for four Certificates of Need for high voltage transmission lines in SW Minnesota for up to 825 MW of outlet capacity for wind-generated energy on Buffalo Ridge. The Commission attached conditions to the Certificates of Need that were developed by Wind on the Wires and supported by a broad set of stakeholders in the proceeding. The conditions require Xcel Energy: 1) to move up the purchase of a total of 825 MW of wind energy, from 2012 to 2006 (to match the schedule for the new lines); 2) to request firm network service for at least 825 MW of wind power from MISO within fifteen days of obtaining the Certificates of Need and to designate the new wind generators as network resources; and 3) to set aside 60 MW for small locally owned (community/farmer) projects in SW Minnesota.

The critical factors for timely success in this transmission case were: regional consensus on and support for the purpose of the lines (to transmit new wind power); a rigorous, open, peer reviewed interconnection & transmission service study of an aggregated 825 MW; direct involvement of the affected communities; and CON conditions which ensure to the extent possible that the capacity on the new transmission lines will be used to deliver wind power to Xcel Energy's retail load.

[17] Minnesota Public Utilities Docket No. E-002/CN-01-1958

Net Environmental Impacts Analysis Methodology

Objective

An initial method is outlined for estimating net environmental impacts of new transmission expansion based on regional air emissions. The method applies an integrated production cost model that produces hourly dispatch throughout the year for generators in the region for various transmission scenarios. This allows estimation of the net environmental impacts of the proposed transmission line(s) based upon the new regional generation mix facilitated by the proposed line(s) and the resulting change in regional air emissions. The method can provide quantitative environmental information regarding particular transmission proposals for decision makers such as public utilities commissioners for use in a regulatory proceeding involving transmission upgrades or new lines.

Methodology

The approach applies a production cost model that is integrated with a power flow case and an emissions database for regional generators. A security constrained dispatch process determines the optimum economic generation schedule that will satisfy the loads (including losses) and interchange schedule, while observing security criteria, reserve criteria, and generation operating constraints. Security criteria include keeping pre-contingency power flows within normal ratings and post-contingency power flows within emergency ratings for all monitored bulk transmission facilities and holding the power flow across transfer interfaces within the transfer stability limits. A linear security constrained dispatch is performed on an hourly basis throughout a full year. This allows estimation of the net environmental impacts of the proposed transmission line based upon the new regional generation mix facilitated by the line and the resulting change in regional air emissions.

Methodology steps include:

- Identify need for the proposed new transmission (desired new generation and markets).
- Identify proposed new transmission option(s).
- Use a production cost model (e.g. PROMOD IV or GE MAPS), with integrated transmission model, to simulate dispatch conditions for a base case and for a case with the proposed new generation and transmission.
- Calculate the annual dispatch of each generator in the region with and without the new transmission and new generation.
- Calculate net annual change in regional air emissions (CO_2, SO_2, NO_x, Hg) facilitated by the new facilities using dispatch results linked with the U.S. Environmental Protection Agency's Emissions and Generation Resource Integrated Database (eGrid)[18] for each existing generator and EPA's Emission Factors[19] for each new generator. Alternatively, some production cost models have integrated emissions modules which can be used.

[18] U.S. EPA Emissions & Generation Resource Integrated Database, http://www.epa.gov/cleanenergy/egrid/index.html .
[19] U.S. EPA Emission Factor and Inventory Group, http://www.epa.gov/ttn/chief/ .

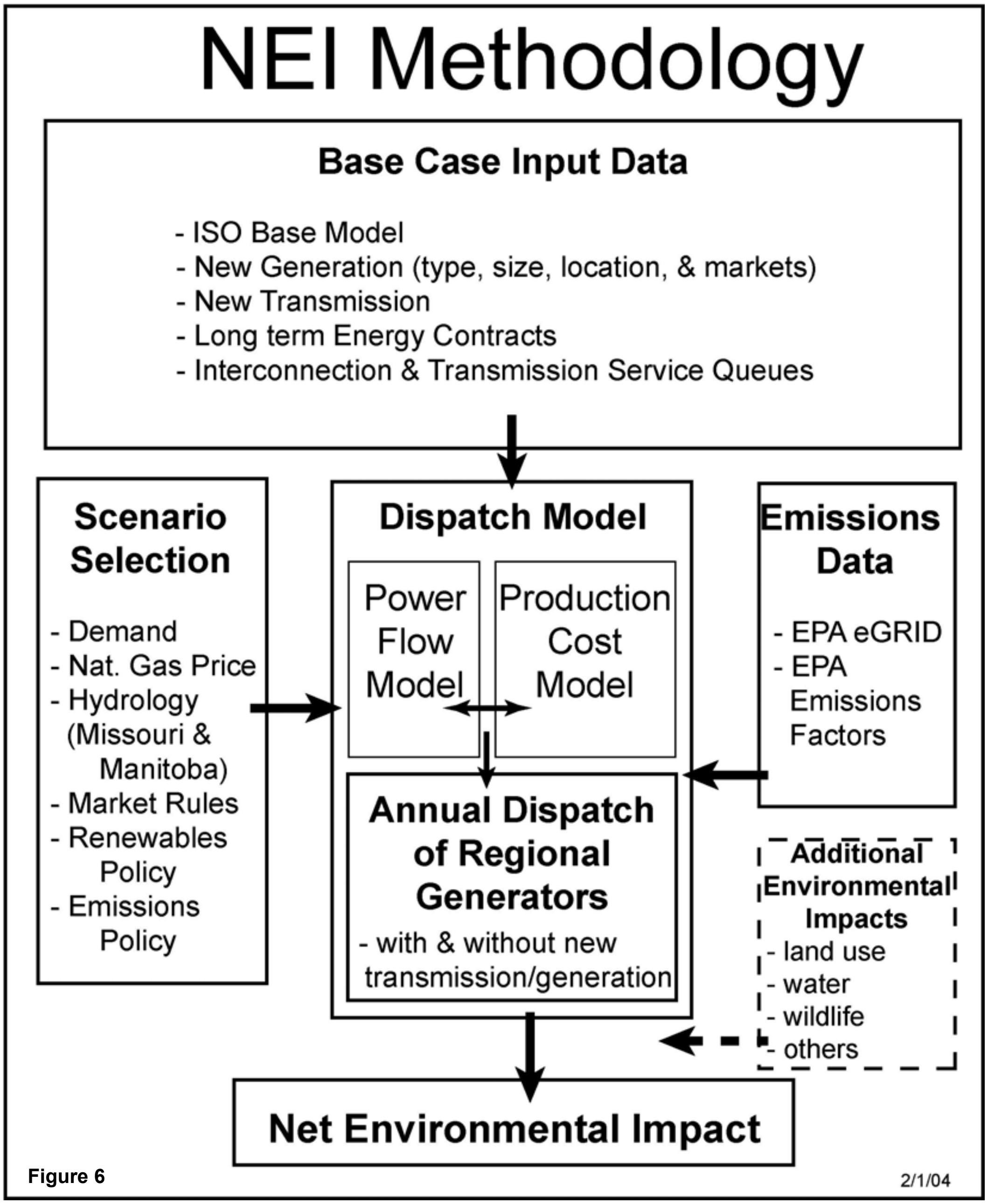


Figure 6

The proposed methodology could be developed further to include evaluation of other environmental impacts besides air emissions, including potential impacts from transmission and generation such as land-use, water, wildlife/biodiversity, habitat fragmentation, wetlands, and from mining, transporting, and burning coal.

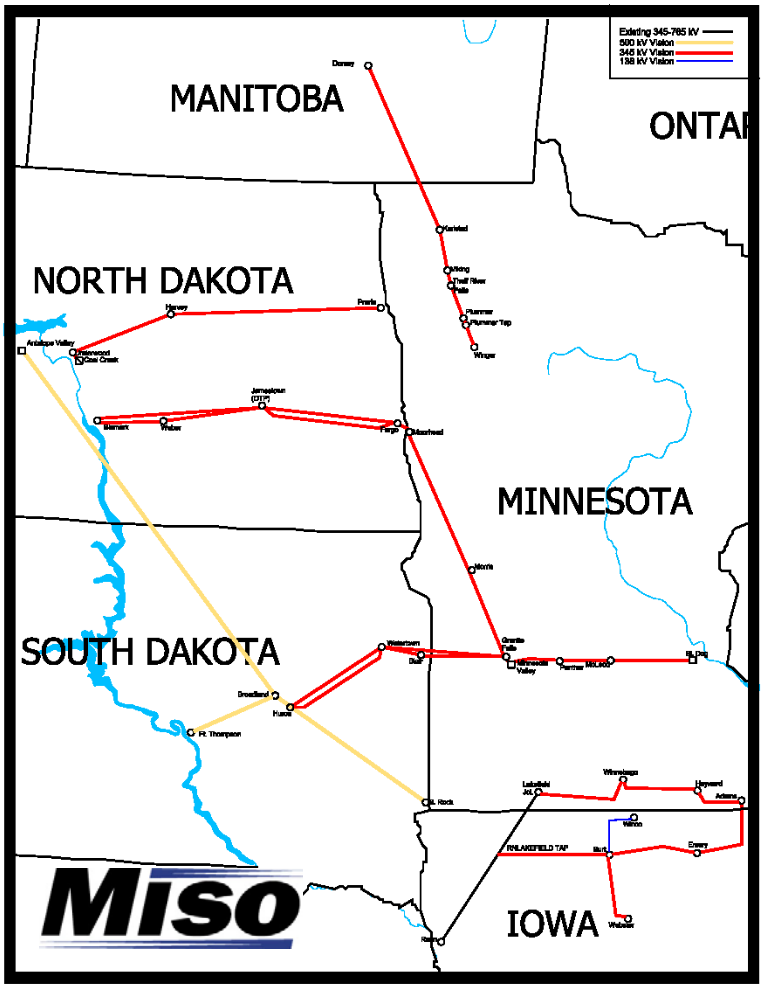
Key limitations of the NEI methodology include assessment of air emissions but not other environmental impacts of transmission lines and generation, simplified assumptions embedded in the security constrained unit commitment and dispatch model, not accounting for emissions changes resulting from generators responding to wind's time varying output, and not accounting for utility plans to clean up emissions from existing generators.

Case Study: MTEP-03 Northwest Exploratory Transmission

The Midwest ISO developed a five year Transmission Expansion Plan in 2003 (MTEP-03)[20] to assure the reliability of the Transmission System that is under the operational and planning control of the Midwest ISO, and identified expansion that is critically needed to support the competitive supply of electric power by this system. The MTEP gives consideration to a variety of market perspectives, including demand-side options, generation location, and transmission expansion. The MTEP does not include environmental analysis.

MISO evaluated several possible generation and transmission development scenarios. In addition to the base (reliability) case, evaluated generation scenarios were high natural gas (the queue), high coal, and high wind power[21]. For analysis of these commercial transmission scenarios a production cost simulation tool was used which produces one year of bi-hourly production and dispatch with transmission network constraints.

Figure 7



MISO considered eleven separate configurations of exploratory transmission, in various combinations with generation scenarios. The Northwest Exploratory Scenario, shown at right, facilitated delivery of both new coal-fired generation and new wind power.

The purpose of a yearly production cost simulation under different transmission and generation development scenarios is to provide relative results for the purposes of comparing various development and expansion options. Losses are factored into the load data as part of the load to be served. Incremental loss due to different generation dispatches is not modeled. Voltage, reactive power, and stability constraints are not modeled explicitly.

[20] *Midwest ISO Transmission Expansion Plan,* June 2003, http://www.midwestiso.org/plan_inter/documents/expansion_planning/MTEP%202002-2007%20Board%20Approved%20061903.pdf

[21] Based on the *Midwest Wind Development Plan* developed by Wind on the Wires and the American Wind Energy Association, June, 2002. http://www.solpath.com/luna/admin/documents/2002_Midwest_Wind_Development_Plan_060102.pdf

Results

The production cost model data set from the MTEP-03 was analyzed for the MAPP region. The graph at right shows the generation mix (percent of energy, GWh) for the MAPP region for the MTEP 2007 Base case (base generation and base transmission) and for the 2007 High Wind case with the Northwest Exploratory Transmission included. The fuel mix for the MAPP region in year 2000 from the EPA's eGRID is included for reference.

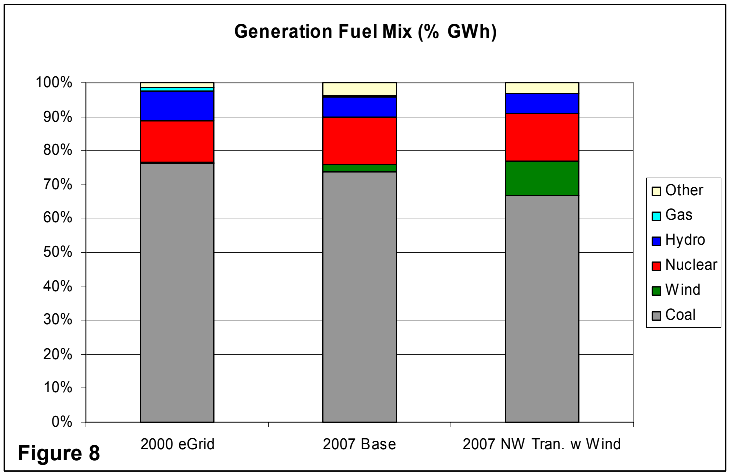


Figure 8

The 2007 annual regional air emissions (CO_2, SO_2, NO_x, Hg) from electrical generation were calculated for each scenario by linking the annual dispatch results with the EPA eGRID for existing generators and with EPA Emission Factors for new generators. The graphs at right and below illustrate the potential for a reduction in regional air emissions with the addition of new remote wind power and new transmission to move it market. Changes for the 2007 Base case compared to year 2000 range from a 12% increase in NO_x to a 22% increase in CO_2. Changes for the 2007 High Wind case with the Northwest Exploratory Transmission compared to the 2007 Base case range from a 6% decrease in SO_2 and Hg to a 12% decrease in NO_x.

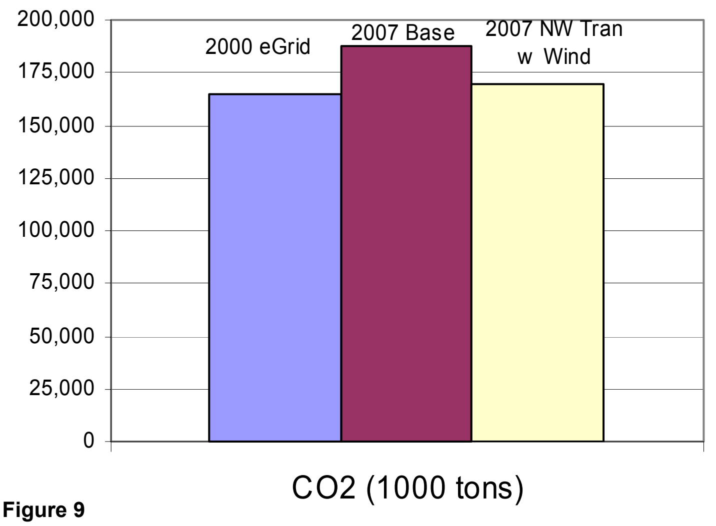


Figure 9

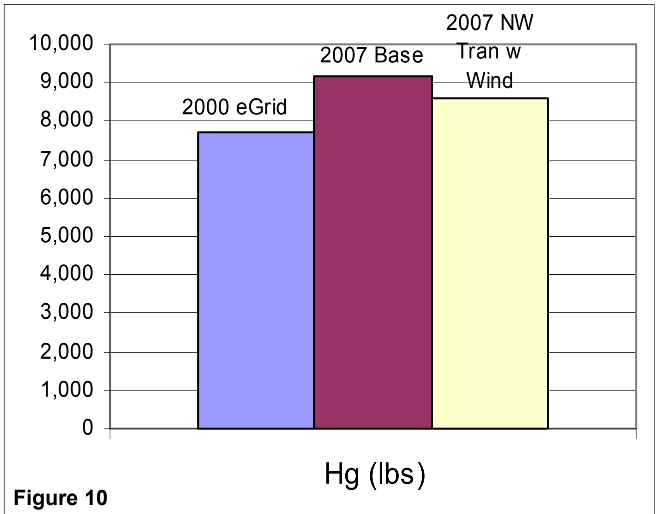


Figure 10

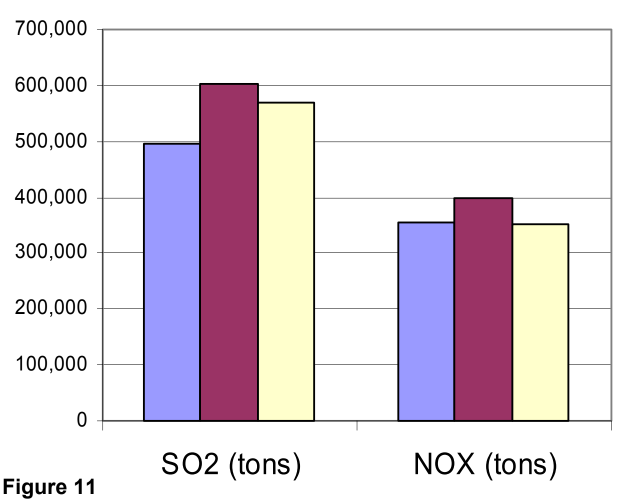


Figure 11

Summary and Recommendations

- To date, analyses have not fully considered the regional environmental impacts that new transmission lines and upgrades have on the operation of the electricity grid and environmental criteria for new transmission lines have focused primarily on the direct impacts from siting and routing.

- Achieving regional consensus on the purpose and use of the new lines and upgrades is critical to success. This requires a clear understanding of the regional environmental impacts over time.

- State regulations for siting and routing require consideration of a broad range of environmental impacts.

- Criteria for transmission expansion could include a net environmental impacts test to demonstrate consistency with state policies and regulations.

- The case study illustrates that building new lines to support remote wind power development can result in significant reductions of regional emissions.

- The initial approach to estimating net environmental impacts outlined in this paper still has many shortcomings and should be further developed and improved.

  The proposed methodology should be developed further to include evaluation of other environmental impacts besides air emissions, including potential impacts from transmission and generation such as land-use, water, wildlife/biodiversity, habitat fragmentation, wetlands, and from mining, transporting, and burning coal.

  Follow up work could also include analysis of additional scenarios in the MTEP-03. For example, an MTEP case was run in which all transmission constraints were relieved. Comparison of this case, with and without the new wind power, to the base case would highlight the displacement of natural gas and inefficient coal generation with wind power. Other follow up could include an analysis of the MTEP-03 cases to determine the location of the existing plants that were affected by the new transmission and wind power. When the affected plants are located, the fuel usage change, and general direction, power transfer design levels, and budget for economical operation of transmission expansion to supply wind energy to the market can also be determined.