GL Garrad Hassan

ROCK ISLAND PROJECT
Benefits Study

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2 October 2012

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TABLE OF CONTENTS

1 EXECUTIVE SUMMARY **1**

2 METHODOLOGY **4**

2.1 Study Design 4

2.2 Assumptions 5

3 RESULTS **8**

3.1 Productions Cost Benefits 8

3.2 LMP and Demand Cost Benefits 10

3.3 Environmental Benefits 13

LIST OF TABLES

Table 1-1: Illinois Demand Cost Savings by Scenario 3
Table 1-2: Environmental Benefits of Rock Island Project 3
Table 2-1: Data Assumptions for Study Scenarios (2016) 6
Table 2-2: Data Assumptions for Study Scenarios (2020) 6
Table 3-1: Total Variable Production Costs of Eastern United States 9
Table 3-2: Production Cost Savings by Type of Generation Reduction ($ Million) 9
Table 3-3: Illinois Demand Cost Savings by Scenario 11
Table 3-4: Detailed Illinois LMP Impacts from Rock Island Project 12
Table 3-5: Environmental Benefits to Eastern U.S. Due to Rock Island Project 13

LIST OF FIGURES

Figure 1-1: Production Cost Savings by Scenario 2
Figure 1-2: Change in 2016 PJM-NI LMP Due to Rock Island Project 2
Figure 3-1: Production Cost Savings by Scenario 8
Figure 3-2: Change in 2016 PJM-NI LMP Due to Rock Island Project 10
Figure 3-3: Change in 2016 MISO Illinois LMP Due to Rock Island Project 10

1 EXECUTIVE SUMMARY

GL Garrad Hassan (GL GH) was engaged by Clean Line Energy Partners to perform a benefit study for the Rock Island Project, a new HVDC transmission line designed to deliver wind energy from western Iowa into northern Illinois. The study methodology is based on analysis of market simulations for representative future years capturing the operational impacts of building the Rock Island Project. This report provides a quantitative analysis of benefits and impacts of the new transmission line under a variety of possible futures.

Overview of Methodology & Assumptions

GL GH utilizes Ventyx's PROMOD software, a detailed economic market model, to conduct analysis of energy market system operations under a defined set of future conditions. The analysis is based on a detailed simulation for all hours of each study year covering a broad range of load, outage, wind, and other system conditions. The software captures detailed transmission powerflow constraints and nodal market operation under security constrained economic commitment and dispatch. Simulations of future energy markets for two representative study years, 2016 and 2020, were performed to assess the economic impact of the Rock Island Project on system operations in Illinois and surrounding regions. The simulations encompassed energy markets and transmission grids throughout the eastern United States including PJM, MISO, SPP, the New York Independent System Operator, the Ontario Independent Electricity System Operator, Entergy, and Tennessee Valley Authority, as well as other utility systems in the southeastern U.S. that are not currently participating in RTOs. In order to develop a robust view of impacts and benefits, simulations were performed across several possible future market scenarios. Each scenario was evaluated both with and without the Rock Island Project and system operations were compared in order to identify benefits resulting specifically from the inclusion of the Rock Island Project. Study scenarios included the following:

<u>Business As Usual</u> – Energy demand grows under a moderate economic recovery with no major changes to existing environmental policy, generating technologies, fuel commodity prices, or other key energy market assumptions.

<u>Slow Growth</u> – Continuation of depressed economic conditions characterized by slow demand growth, continued low fuel commodity prices, and minimal transmission/generation expansion.

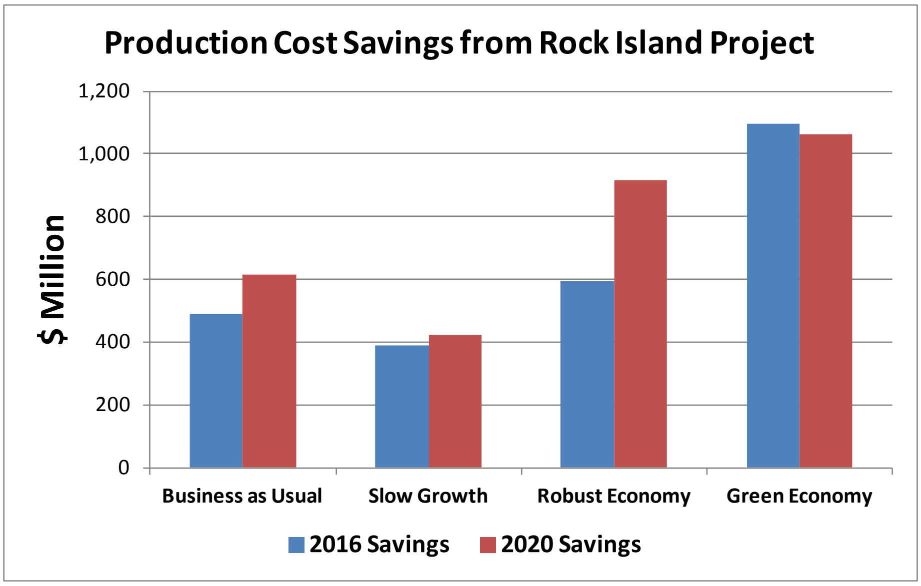
<u>Robust Economy</u> – Strong recovery in economic activity characterized by accelerated growth in electrical demand, higher fuel prices and emission allowances prices, and increased activity in new generation and transmission projects.

<u>Green Economy</u> – Expansion in environmental policy including carbon regulation and a federal renewable portfolio standard under robust economic conditions including high demand growth, an increase in fuel prices, and increased activity in new generation and transmission projects.

Summary of Benefits Results

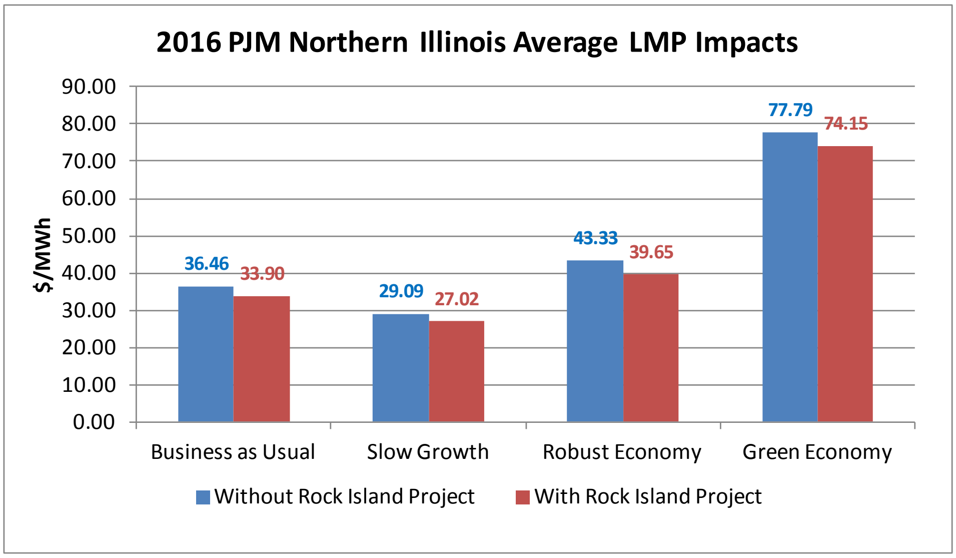
The Rock Island Project reduces total variable production costs in the eastern United States in both study years under each of the future scenarios, as shown in Figure 1-1.

Figure 1-1: Production Cost Savings by Scenario



The Rock Island Project also lowers LMP ($/MWh) in both the PJM Illinois region and the MISO Illinois region in both study years in each of the future scenarios. Figure 1-2 illustrates the impact of the Rock Island Project on PJM Northern Illinois (PJM-NI) average annual load-weighted LMP for the 2016 study year.

Figure 1-2: Change in 2016 PJM-NI LMP Due to Rock Island Project



Demand cost represents the cost to supply load to end-use customers in a region and is calculated by multiplying the average load-weighted LMP times the demand in each hour of the study year. The demand cost in each hour is then summed across the year to arrive at an annual demand cost value. Since the LMP for both the PJM and MISO regions of Illinois are driven lower by the addition of the Rock Island Project and the associated wind energy injection, it follows the demand cost will likewise be reduced. Table 1-1 below shows the impact of the Rock Island Project on Illinois Demand Cost.

Table 1-1: Illinois Demand Cost Savings by Scenario

(values in $ Million)		Business as Usual	Slow Growth	Robust Economy	Green Economy
2016	PJM Illinois Savings	301	236	452	446
2016	MISO Illinois Savings	19	13	36	46
2016	Total Savings	320	249	488	493
2020	PJM Illinois Savings	219	168	249	83
2020	MISO Illinois Savings	23	11	41	10
2020	Total Savings	242	179	289	93

The Rock Island Project reduces emissions of NOx, SO_2, CO_2, and mercury, and also reduces water usage in power generation in the eastern United States in both study years under each of the future scenarios as shown in Table 1-2.

Table 1-2: Environmental Benefits of Rock Island Project

		Business as Usual	Slow Growth	Robust Economy	Green Economy
2016	Reduction in NOx (tons)	8,330	11,671	8,363	7,561
2016	Reduction in SOx (tons)	16,155	17,836	17,248	11,900
2016	Reduction in CO2 (tons)	9,107,054	12,325,819	9,740,384	10,563,780
2016	Reduction in Hg (lbs)	140	163	133	201
2016	Reduction in Water Usage (MGal)	3,546	4,202	3,641	3,912
2020	Reduction in NOx (tons)	5,547	9,572	3,608	7,127
2020	Reduction in SOx (tons)	16,334	13,969	9,185	15,448
2020	Reduction in CO2 (tons)	7,073,812	11,074,945	5,545,692	7,857,886
2020	Reduction in Hg (lbs)	109	154	59	198
2020	Reduction in Water Usage (MGal)	3,102	4,013	2,616	3,514

Reduction of each of these emissions is a direct result of the reduced need for conventional, emissions-producing generation due to the addition of new wind resources facilitated by the Rock Island Project.

2 METHODOLOGY

GL Garrad Hassan has extensive experience in performing transmission benefits studies and utilizes industry best practices in establishing study design and assumptions. This section provides an overview of the key elements and processes employed to assess benefits for the Rock Island Project, including GL GH's approach to long-term transmission analysis.

2.1 Study Design

The PROMOD production cost model was used to perform simulations of future energy markets for two representative study years, 2016 and 2020, to assess the economic impact of the Rock Island Project on system operations in Illinois and across the eastern United States. The simulations encompassed energy markets and transmission grids throughout the eastern United States including PJM, MISO, SPP, the New York Independent System Operator, the Ontario Independent Electricity System Operator, Entergy, and Tennessee Valley Authority, as well as other utility systems in the southeastern U.S. and elsewhere that are not currently participating in RTOs. In order to develop a robust view of impacts and benefits, simulations were performed across several possible future market scenarios both with and without the Rock Island Project.

The study methodology used to assess the economic benefits of the Rock Island Project includes the following primary activities:

- Assumptions and scenario development – Study years and energy market scenarios are constructed to provide several plausible futures under which to evaluate the economic and environmental benefits of the project. A scenario-based approach is critical to ensure that economic results are robust across a variety of future conditions. For each scenario, specific assumptions are developed for modeling inputs such as future demand, future gas prices, new wind generation, and other key assumptions based on research and past modeling experience.

- Base Case simulations - A full set of simulations is performed for all study years and scenarios without the Rock Island Project included. Extensive quality assurance checks are carried out on these Base Case results to validate data accuracy through a general comparison of results against historical operations.

- Rock Island Project simulations – A second set of simulations is performed for all study years and scenarios that includes the Rock Island Project along with the wind generation supplying energy delivered over the Rock Island Project. The added wind capacity is not interconnected into the existing transmission grid and therefore can only be delivered via the Rock Island Project. Quality assurance checks are carried out with a focus on operation of the Rock Island Project to ensure that the modeled line flow, electrical loss rates, and other results align with design parameters.

- Benefit Analysis – Simulations with and without Rock Island are compared for each study year and scenario to assess the impact of the Project on system operations, costs, and emissions. The resulting economic and environmental benefits are driven by new wind generation facilitated by the Rock Island Project. This new wind generation offsets production costs (fuel and emission costs) from conventional generation and the zero variable cost of the new wind resources reduces LMP in Illinois, lowering demand cost (defined below).

2.2 Assumptions

GL GH maintains assumptions for expected future market conditions used to perform forward-looking planning studies. Basic market data for generators, demand forecasts, and fuel are provided by Ventyx under a data licensing agreement and reviewed by GL GH for accuracy and appropriateness. This section outlines the major data used in the assessment of benefits for the Rock Island Project.

Study Period – The time horizon for this study includes calendar years 2016 and 2020. The early year (2016) reflects a year near the expected in-service year for the Rock Island Project while the later year (2020) was selected to capture the impacts of future transmission and generation expansion under each of the defined study scenarios.

Study Scenarios – The economic analysis of the Rock Island Project considered 4 different future scenarios. A high-level description of each scenario is provided below, and detailed data assumptions for each scenario can be found in Tables 2-1 and 2-2. The study scenarios include:

Business As Usual – Energy demand grows under a moderate economic recovery with no major changes to existing environmental policy, generating technologies, fuel commodity prices, or other key energy market assumptions. Expansion of renewable generation is driven by current state mandates with moderate retirement of coal generation driven by market economics and existing environmental rules.

Slow Growth – Continuation of depressed economic conditions characterized by slow demand growth, continued low fuel commodity prices, and minimal transmission/generation expansion. Addition of new renewable generation expansion is driven by current state mandates with moderate retirement of coal generation driven by existing environmental rules.

Robust Economy – Strong recovery in economic activity characterized by accelerated growth in electrical demand, higher fuel prices and emission allowances prices, and increased activity in new generation and transmission projects. Expansion of renewable generation is based on current state mandates with moderate retirement of coal generation driven by existing environmental rules. This scenario includes the addition of the RITELine, PATH (Potomac Appalachian Transmission Highline), and Pioneer transmission projects in 2020, designed to move energy eastward from Illinois into markets in Indiana and Ohio, then on to the major demand centers near the eastern coast. These projects are representative of the anticipated expansion of the transmission grid needed to support robust load growth assumptions.

Green Economy – Expansion in environmental policy including carbon legislation and a federal renewable portfolio standard. This scenario includes high demand growth and increases in fuel prices and emission allowance prices (including carbon). Expansion of renewable generation is significantly higher than current state mandates with accelerated coal retirements driven by new emissions costs. This scenario includes the addition of the RITELine, PATH, and Pioneer transmission projects in 2020, designed to move energy eastward from Illinois into markets in Indiana and Ohio, then on to major demand centers near the eastern coast.

Table 2-1: Data Assumptions for Study Scenarios (2016)

2016 Assumptions	Business as Usual	Robust Economy	Slow Growth	Green Economy
Nat Gas Prices (Henry Hub Spot, $/MMBTU)	Medium: $4.72	High: Medium + $2	Low: Medium - $2	High: Medium + $2
Forced Coal Retirements (GW)	Medium: MISO - 11.5, PJM - 11.4	Low: MISO - 5.4, PJM - 4.1	Low: MISO - 5.4, PJM - 4.1	High: MISO - 21.8, PJM - 18.4
Carbon Pricing	No	No	No	Yes: $50/ton
NOx, SOx ($/ton)	Medium: NOx - 713, SOx - 1308	Medium: NOx - 713, SOx - 1308	Low: Medium -25%	High: Medium +25%
Load Growth	Medium: 1.4% peak, 1.7% energy	High: 2.1% peak, 2.5% energy	Low: 0.7% peak, 0.8% energy	High: 2.1% peak, 2.5% energy
Wind (Eastern US)	46.8 GW	46.8 GW	46.8 GW	78.2 GW
Transmission expansion	No	No	No	No

Table 2-2: Data Assumptions for Study Scenarios (2020)

2020 Assumptions	Business as Usual	Robust Economy	Slow Growth	Green Economy
Nat Gas Prices (Henry Hub Spot, $/MMBTU)	Medium: $6.10	High: Medium + $2	Low: Medium - $2	High: Medium + $2
Forced Coal Retirements (GW)	Medium: MISO - 13.5, PJM - 15.8	Low: MISO - 9.0, PJM - 9.51	Low: MISO - 9.0, PJM - 9.51	High: MISO - 21.8, PJM - 18.4
Carbon Pricing	No	No	No	Yes: $50/ton
NOx, SOx ($/ton)	Medium: NOx - 713, SOx - 1308	Medium: NOx - 713, SOx - 1308	Low: Medium -25%	High: Medium +25%
Load Growth	Medium: 1.4% peak, 1.7% energy	High: 2.1% peak, 2.5% energy	Low: 0.7% peak, 0.8% energy	High: 2.1% peak, 2.5% energy
Wind (Eastern US)	60.8 GW	60.8 GW	60.8 GW	111.6 GW
Transmission expansion	No	Yes – RITE, PATH and Pioneer	No	Yes – RITE, PATH and Pioneer

Transmission – GL GH utilizes powerflow cases provided by the North American Electric Reliability Corporation's (NERC) Eastern Interconnect Reliability Assessment Group (ERAG) and Multiregional Modeling Working Group (MMWG) in compiling these cases. This study utilizes the 2010 series 2016 Summer Peak case released in November 2011 for the underlying transmission topology. The study area topology was updated to reflect recent transmission planning documents including the MISO Transmission Expansion Plan (MTEP) and all approved MISO Multi-Value Projects (MVPs), SPP Priority Projects, PJM Regional Transmission Planning (RTEP) documents. Transmission contingency event data are derived from public sources including the NERC Book of Flowgates, ISO/RTO published congestion reports, and previous study experience in modeling North American markets. Also, as previously outlined, for the Robust Economy and Green Economy scenarios in 2020, additional EHV transmission projects were modeled.

Rock Island Project – The 3,500 MW Rock Island Project HVDC transmission line interconnects to the 765 kV bus at the Collins substation near Chicago, Illinois. Wind energy delivered via the Rock island Project utilizes an hourly profile derived from data published in the National Renewable Energy Laboratory's Eastern Wind Integration and Transmission Study (EWITS). EWITS wind profiles are used to maintain consistent time series data correlated with profiles on other wind farms in the region based on 2006 meteorological data. The hourly generation profile for the Rock Island Project injection is based on 3,500 MW maximum capacity with 4,349 MW of wind capacity feeding the line. The excess wind capacity accounts for losses of the converter stations and transmission and also allows for higher utilization of the transmission line with recognition that geographic diversity in the wind resource across the supplying wind farms make it unlikely that the total delivered wind power will exceed the 3,500 MW Rock Island Project capacity during a significant number of hours. The wind capacity supplying the Rock Island Project is not otherwise connected to the transmission grid and must utilize the HVDC line to be delivered.

3 RESULTS

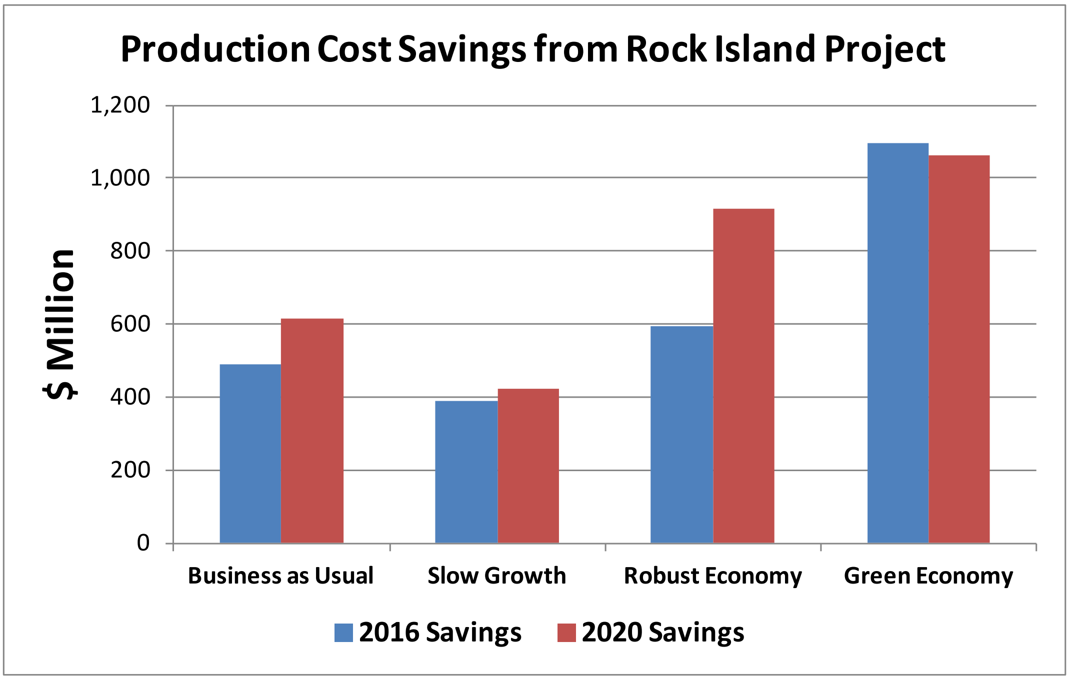
PROMOD simulations provide several key metrics that were used to assess the economic benefits of the Rock Island transmission project and the new wind generation it supports. These metrics include:

- Production Cost ($) – Total variable cost of generation to supply energy to meet annual demand including fuel costs, emission costs, variable operation and maintenance costs, and unit start up costs
- Locational Marginal Price ($/MWh) – Incremental cost of energy including impacts of transmission congestion and system electrical losses, averaged across all electrical load buses in Illinois
- Demand Cost ($) – The hourly electrical demand (MWh) at each bus multiplied by the hourly LMP ($/MWh) at that bus summed over all Illinois buses for all hours. This represents the total cost to purchase energy to supply total Illinois annual demand under RTO settlement rules
- Emissions Production (tons) – Total volume of emissions produced by generation units for sulphur dioxide (“SO_2”), nitrogen oxide (“NO_x”), mercury, and carbon dioxide (“CO_2”)

3.1 Productions Cost Benefits

The Rock Island Project reduces total variable production costs in the Eastern Interconnection in both study years under each of the future scenarios, as shown in Figure 3-1.

Figure 3-1: Production Cost Savings by Scenario



Total variable production cost includes the cost of fuel, variable operating & maintenance (VOM) costs, and the cost of emissions for NOx and SO_2 based on current emissions allowance markets. The Rock Island Project facilitates the development of over 4,000 MW of new wind capacity in Iowa which is delivered into the extra high voltage system at the Collins substation near Chicago. This new wind energy has zero variable cost and displaces higher cost conventional generation from gas and coal resources under ISO centralized economic dispatch rules, resulting in the cost savings shown in Figure 3-1.

Table 3-1: Total Variable Production Costs of Eastern United States

(values in $ Million)		Business as Usual	Slow Growth	Robust Economy	Green Economy
2016	Without Rock Island	90,203	71,627	107,129	183,536
2016	With Rock Island	89,713	71,238	106,537	182,438
2016	Savings	490	389	593	1,098
2020	Without Rock Island	114,865	82,182	157,300	233,041
2020	With Rock Island	114,249	81,760	156,385	231,981
2020	Savings	616	423	914	1,060

Table 3-2 below further breaks out the production cost savings from the Rock Island Project by generation type. The wind energy delivered over the Rock Island Project tends to offset marginal generation assets, which vary significantly across the future scenario. In the “Business as Usual” and “Robust Economy” cases more of the cost savings comes from combined-cycle units followed by coal resources. This is reflective of the expected breakdown of marginal resources under moderate to aggressive load and resource expansion. Also note that this table represents cost rather than energy volume (MWh), and wind displacing gas in an hour may result in more cost savings than an hour with wind displacing coal.

In the “Slow Growth” and “Green Economy” scenarios this order is reversed with most of the cost savings comes from coal followed by combined-cycle. The “Slow Growth” case reflects the higher prevalence of coal as a marginal resource under conditions that include lower demand and reduced generation expansion. Savings in the Green Economy scenario are driven significantly by the addition of a carbon cost assumption which makes coal more expensive relative to natural gas resources.

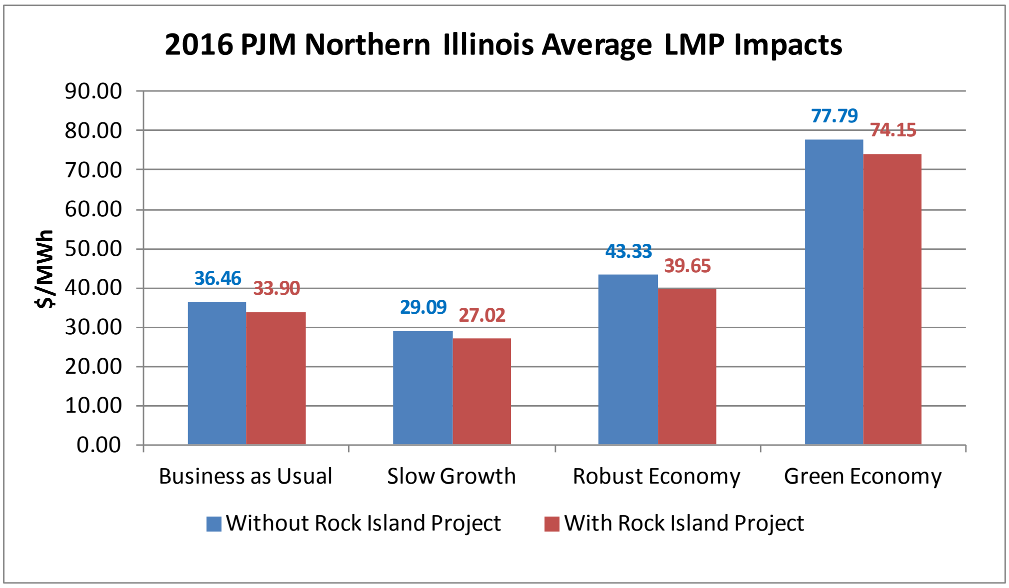
Table 3-2: Production Cost Savings by Type of Generation Reduction ($ Million)

(values in $ Million)		Business as Usual	Slow Growth	Robust Economy	Green Economy
2016	Coal	177	259	185	623
2016	Combined Cycle	266	60	338	392
2016	Combustion Turbine	43	66	62	62
2016	Steam Turbine (Gas/oil)	5	5	8	19
2020	Coal	148	273	86	533
2020	Combined Cycle	413	106	745	477
2020	Combustion Turbine	49	50	67	14
2020	Steam Turbine (Gas/oil)	5	-4	16	34

3.2 LMP and Demand Cost Benefits

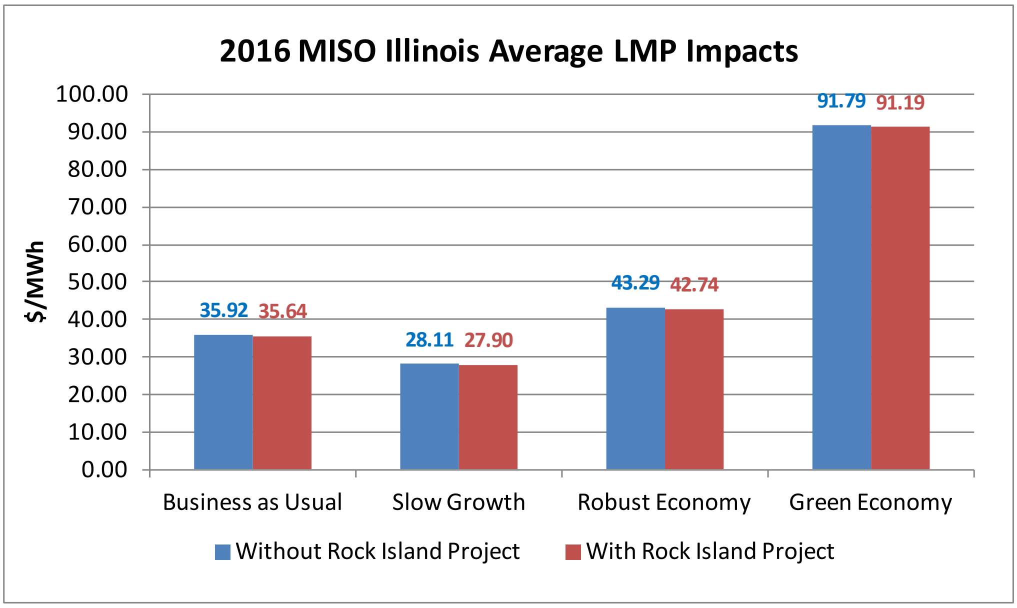
The Rock Island Project lowers LMP ($/MWh) in both the PJM Illinois region and the MISO Illinois region in both study years in each of the future scenarios. Figure 3-2 illustrates the impact of the Rock Island Project on PJM Northern Illinois (PJM-NI) average annual load-weighted LMP for the 2016 study year.

Figure 3-2: Change in 2016 PJM-NI LMP Due to Rock Island Project



Similar results are shown for the MISO Illinois region due to the Rock Island Project in Figure 3-3, although the impact on LMP is more muted due to the MISO Illinois region being further away from the injection point for the Rock Island Project.

Figure 3-3: Change in 2016 MISO Illinois LMP Due to Rock Island Project



Demand cost represents the cost to supply load to end-use customers in a region and is calculated by multiplying the average load-weighted LMP times the demand in each hour of the study year. The demand cost in each hour is then summed across the year to arrive at an annual demand cost value. Since the LMP for both the PJM and MISO regions of Illinois are driven lower by the addition of the Rock Island Project and the associated wind energy injection, it follows the demand cost will likewise be reduced. Table 3-3 below shows the impact of the Rock Island Project on Illinois Demand Cost.

Table 3-3: Illinois Demand Cost Savings by Scenario

(values in $ Million)			Business as Usual	Slow Growth	Robust Economy	Green Economy
2016	Without Rock Island	PJM Illinois	4,676	3,581	5,831	10,201
2016	Without Rock Island	MISO Illinois	2,247	1,671	2,825	5,912
2016	With Rock Island	PJM Illinois	4,375	3,344	5,380	9,755
2016	With Rock Island	MISO Illinois	2,228	1,658	2,789	5,865
2016	Savings	PJM Illinois	301	236	452	446
2016	Savings	MISO Illinois	19	13	36	46
2016	Savings	Total	320	249	488	493
2020	Without Rock Island	PJM Illinois	6,233	4,153	9,685	12,579
2020	Without Rock Island	MISO Illinois	2,801	1,808	4,595	6,959
2020	With Rock Island	PJM Illinois	6,014	3,986	9,436	12,496
2020	With Rock Island	MISO Illinois	2,778	1,797	4,555	6,949
2020	Savings	PJM Illinois	219	168	249	83
2020	Savings	MISO Illinois	23	11	41	10
2020	Savings	Total	242	179	289	93

Table 3-4 provides a detailed view of Illinois LMP impacts due to the Rock Island Project.

Table 3-4: Detailed Illinois LMP Impacts from Rock Island Project

(Values in $/MWh)				Business as Usual	Slow Growth	Robust Economy	Green Economy
2016	Without Rock Island	LMP OnPeak Avg	PJM Illinois	44.22	34.49	56.25	92.37
2016	Without Rock Island	LMP OffPeak Avg	PJM Illinois	29.45	24.21	31.65	64.60
2016	Without Rock Island	LMP Average	PJM Illinois	36.46	29.09	43.33	77.79
2016	Without Rock Island	LMP OnPeak Avg	MISO Illinois	43.55	32.07	54.75	105.69
2016	Without Rock Island	LMP OffPeak Avg	MISO Illinois	29.01	24.54	32.92	79.15
2016	Without Rock Island	LMP Average	MISO Illinois	35.92	28.11	43.29	91.79
2016	With Rock Island	LMP OnPeak Avg	PJM Illinois	42.10	32.88	52.61	89.39
2016	With Rock Island	LMP OffPeak Avg	PJM Illinois	26.50	21.72	27.95	60.37
2016	With Rock Island	LMP Average	PJM Illinois	33.90	27.02	39.65	74.15
2016	With Rock Island	LMP OnPeak Avg	MISO Illinois	43.15	31.92	54.06	104.88
2016	With Rock Island	LMP OffPeak Avg	MISO Illinois	28.84	24.27	32.49	78.75
2016	With Rock Island	LMP Average	MISO Illinois	35.64	27.90	42.74	91.19
2016	LMP Change	LMP OnPeak Delta	PJM Illinois	-2.13	-1.61	-3.65	-2.98
2016	LMP Change	LMP OffPeak Delta	PJM Illinois	-2.94	-2.48	-3.70	-4.23
2016	LMP Change	LMP Average Delta	PJM Illinois	-2.56	-2.07	-3.68	-3.63
2016	LMP Change	LMP OnPeak Delta	MISO Illinois	-0.40	-0.15	-0.70	-0.81
2016	LMP Change	LMP OffPeak Delta	MISO Illinois	-0.17	-0.27	-0.43	-0.40
2016	LMP Change	LMP Average Delta	MISO Illinois	-0.28	-0.21	-0.55	-0.60
2020	Without Rock Island	LMP OnPeak Avg	PJM Illinois	53.85	38.34	81.33	102.65
2020	Without Rock Island	LMP OffPeak Avg	PJM Illinois	37.64	27.46	51.28	71.54
2020	Without Rock Island	LMP Average	PJM Illinois	45.37	32.64	65.60	86.37
2020	Without Rock Island	LMP OnPeak Avg	MISO Illinois	54.40	36.55	87.05	124.15
2020	Without Rock Island	LMP OffPeak Avg	MISO Illinois	36.38	27.34	51.41	88.04
2020	Without Rock Island	LMP Average	MISO Illinois	44.96	31.72	68.37	105.20
2020	With Rock Island	LMP OnPeak Avg	PJM Illinois	52.39	37.08	79.79	102.58
2020	With Rock Island	LMP OffPeak Avg	PJM Illinois	35.74	25.84	49.14	70.32
2020	With Rock Island	LMP Average	PJM Illinois	43.68	31.20	63.74	85.70
2020	With Rock Island	LMP OnPeak Avg	MISO Illinois	54.10	36.43	86.59	123.91
2020	With Rock Island	LMP OffPeak Avg	MISO Illinois	35.96	27.04	50.61	87.79
2020	With Rock Island	LMP Average	MISO Illinois	44.60	31.51	67.73	104.96
2020	LMP Change	LMP OnPeak Delta	PJM Illinois	-1.46	-1.26	-1.54	-0.07
2020	LMP Change	LMP OffPeak Delta	PJM Illinois	-1.91	-1.62	-2.14	-1.23
2020	LMP Change	LMP Average Delta	PJM Illinois	-1.69	-1.44	-1.86	-0.67
2020	LMP Change	LMP OnPeak Delta	MISO Illinois	-0.31	-0.12	-0.46	-0.24
2020	LMP Change	LMP OffPeak Delta	MISO Illinois	-0.43	-0.30	-0.80	-0.25
2020	LMP Change	LMP Average Delta	MISO Illinois	-0.37	-0.21	-0.64	-0.24

3.3 Environmental Benefits

The Rock Island Project reduces emissions of NO_X, SO_2, CO_2, and mercury, and also reduces water usage in power generation in the eastern United States in both study years under each of the future scenarios as shown in Table 3-5.

Table 3-5: Environmental Benefits to Eastern U.S. Due to Rock Island Project

			Business as Usual	Slow Growth	Robust Economy	Green Economy
2016	Without Rock Island	NOx (tons)	1,423,542	1,124,315	1,629,927	1,062,298
2016	Without Rock Island	SOx (tons)	2,591,748	1,893,032	3,206,526	2,060,349
2016	Without Rock Island	CO2 (tons)	1,800,490,290	1,572,122,063	1,967,101,455	1,525,819,613
2016	Without Rock Island	Hg (lbs)	30,130	21,561	34,350	23,251
2016	Without Rock Island	Water (MGal)	659,366	557,960	717,928	570,069
2016	With Rock Island	NOx (tons)	1,415,212	1,112,644	1,621,564	1,054,737
2016	With Rock Island	SOx (tons)	2,575,593	1,875,196	3,189,278	2,048,449
2016	With Rock Island	CO2 (tons)	1,791,383,235	1,559,796,244	1,957,361,071	1,515,255,833
2016	With Rock Island	Hg (lbs)	29,991	21,398	34,218	23,050
2016	With Rock Island	Water (MGal)	655,820	553,758	714,287	566,157
2016	Reduction	NOx (tons)	8,330	11,671	8,363	7,561
2016	Reduction	SOx (tons)	16,155	17,836	17,248	11,900
2016	Reduction	CO2 (tons)	9,107,054	12,325,819	9,740,384	10,563,780
2016	Reduction	Hg (lbs)	140	163	133	201
2016	Reduction	Water (MGal)	3,546	4,202	3,641	3,912
2020	Without Rock Island	NOx (tons)	1,468,411	1,086,862	1,689,931	1,192,992
2020	Without Rock Island	SOx (tons)	2,649,819	1,754,880	3,429,218	2,308,675
2020	Without Rock Island	CO2 (tons)	1,873,943,746	1,535,452,119	2,086,172,945	1,616,740,696
2020	Without Rock Island	Hg (lbs)	34,866	27,016	38,718	25,195
2020	Without Rock Island	Water (MGal)	697,083	559,767	771,802	630,715
2020	With Rock Island	NOx (tons)	1,462,864	1,077,289	1,686,323	1,185,865
2020	With Rock Island	SOx (tons)	2,633,485	1,740,911	3,420,033	2,293,227
2020	With Rock Island	CO2 (tons)	1,866,869,934	1,524,377,174	2,080,627,252	1,608,882,810
2020	With Rock Island	Hg (lbs)	34,757	26,862	38,659	24,997
2020	With Rock Island	Water (MGal)	693,981	555,754	769,186	627,201
2020	Reduction	NOx (tons)	5,547	9,572	3,608	7,127
2020	Reduction	SOx (tons)	16,334	13,969	9,185	15,448
2020	Reduction	CO2 (tons)	7,073,812	11,074,945	5,545,692	7,857,886
2020	Reduction	Hg (lbs)	109	154	59	198
2020	Reduction	Water (MGal)	3,102	4,013	2,616	3,514

The total tons produced for each of these effluents is calculated by PROMOD during the simulation of each scenario by multiplying the hourly output of each generator times the appropriate emissions production rate. Reductions in mercury were calculated after completion of the PROMOD runs by multiplying unit-specific production rates for mercury times the annual energy production for each coal plant modeled in the study. Reductions in water usage (evaporation) were estimated using general water consumption rates for each unit type (coal, combined cycle, combustion turbine, etc.) combined with annual generation results from the PROMOD simulations. Reduction of each of these emissions is a direct result of the reduced need for conventional, emissions-producing generation due to the addition of new wind resources facilitated by the Rock Island Project.