2015 Economic Study
Strategic Transmission Analysis – Onshore Wind Integration
Draft Results

Planning Advisory Committee Meeting

Jessica Lau and Wayne Coste

SYSTEM PLANNING

Outline

- Overview
- Background and Assumptions
- Study Results
- Appendix
  I. Scenarios
  II. Generation by Resource Type Metrics
  III. Air Emissions Metrics
  IV. Bottled-In Energy Metrics
  V. Interface Flow Metrics
  VI. LMP Metrics
  VII. Modeling Assumptions

Overview

- The ISO is performing three 2015 Economic Studies
  - Keene Road area wind development and analysis of local interface constraints (request by SunEdison)
  - Offshore Wind Deployment (request by Massachusetts Clean Energy Center)
  - Maine Upgrades Identified in ISO-NE's Strategic Transmission Analysis for Wind Integration – Onshore Wind (request by RENEW Northeast)
- Today the ISO is seeking PAC input on the draft results of the **Strategic Transmission Analysis – Onshore Wind**
  - Estimate extent that transmission constraints are binding
  - Measure the economic benefits of relieving those transmission system constraints
- This analysis includes future resources in some scenarios, but may not account for all the necessary transmission facilities associated with the interconnection of the resource
  - All future constraints may not be captured in this analysis
- Final study results and report will be completed after consultation with the PAC
  - The results may be used to inform the region on the needs for future transmission upgrades in the Maine area

Background

- The Onshore Wind – Strategic Transmission Analysis scope of work and assumptions were developed with PAC input at the May and June 2015 meetings
  - Scope of Work
  - Study Assumptions
  - Stakeholder Comments on Scope of Work

Background

Strategic Transmission Analysis

2012-2014

- ISO-NE conducted the Strategic Transmission Analysis for Wind Integration (**STA-WI**)
  - Designed to understand transmission constraints in Maine affecting wind resources in northern New England
  - Focused on potential upgrades that would not require major new transmission construction

2016

- ISO-NE will conduct an updated **Strategic Transmission Analysis for Maine** as discussed in 3/28/2016 PAC agenda item 2.0
  - The Maine transmission topology has changed
  - Some upgrades identified in the previous study have been implemented
  - Some upgrades are no longer appropriate for current system

Background

2015 *Economic Study of Strategic Transmission Analysis – Onshore Wind*

Study Objective: Evaluate the impact of increasing transfer capability along the Maine corridor

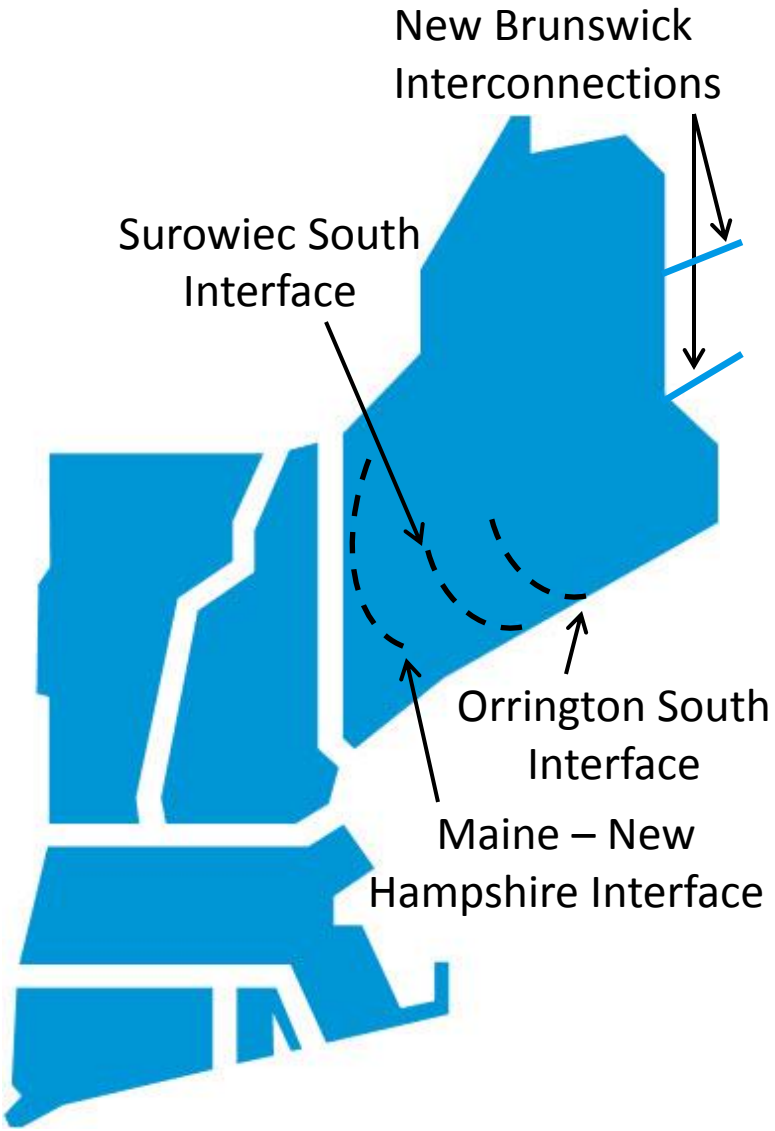
- The effect of increasing transfer limits of major ME interfaces
  - Were identified in the Strategic Transmission Analysis – Wind Integration
  - Higher ME interface limits are not directly attributable to specific transmission upgrades
- Pre-contingency thermal limits are respected in the Gridview software
  - Operation of wind resources can be constrained by local thermal limits
- Other local constraints are not modeled
  - Local, voltage and stability constraints
    - E.g. Keene Road, Wyman and Rumford areas
  - Could constrain the operation of impacted resources

Key Study Assumptions

Study Year 2021

- System Characteristics
  - 2015 CELT loads, EE & PV Forecast
  - FCA #9 resources with a Capacity Supply Obligation (CSO) and 2015 CELT resources without a CSO
  - NREL wind hourly profiles
  - Hourly imports and exports available for dispatch
  - 2015 EIA Annual Energy Outlook Fuel Forecast

ME Interface Export Limit	Pre-Upgrades Cases (MW)	Post-Upgrades Cases (MW)
Keene Road, Wyman, Rumford	Unconstrained	Unconstrained
Orrington South	1,325	1,650
Surowiec South	1,500	2,100
Maine – New Hampshire	1,900	2,300



Wind Scenarios

New England Wind Nameplate (MW)

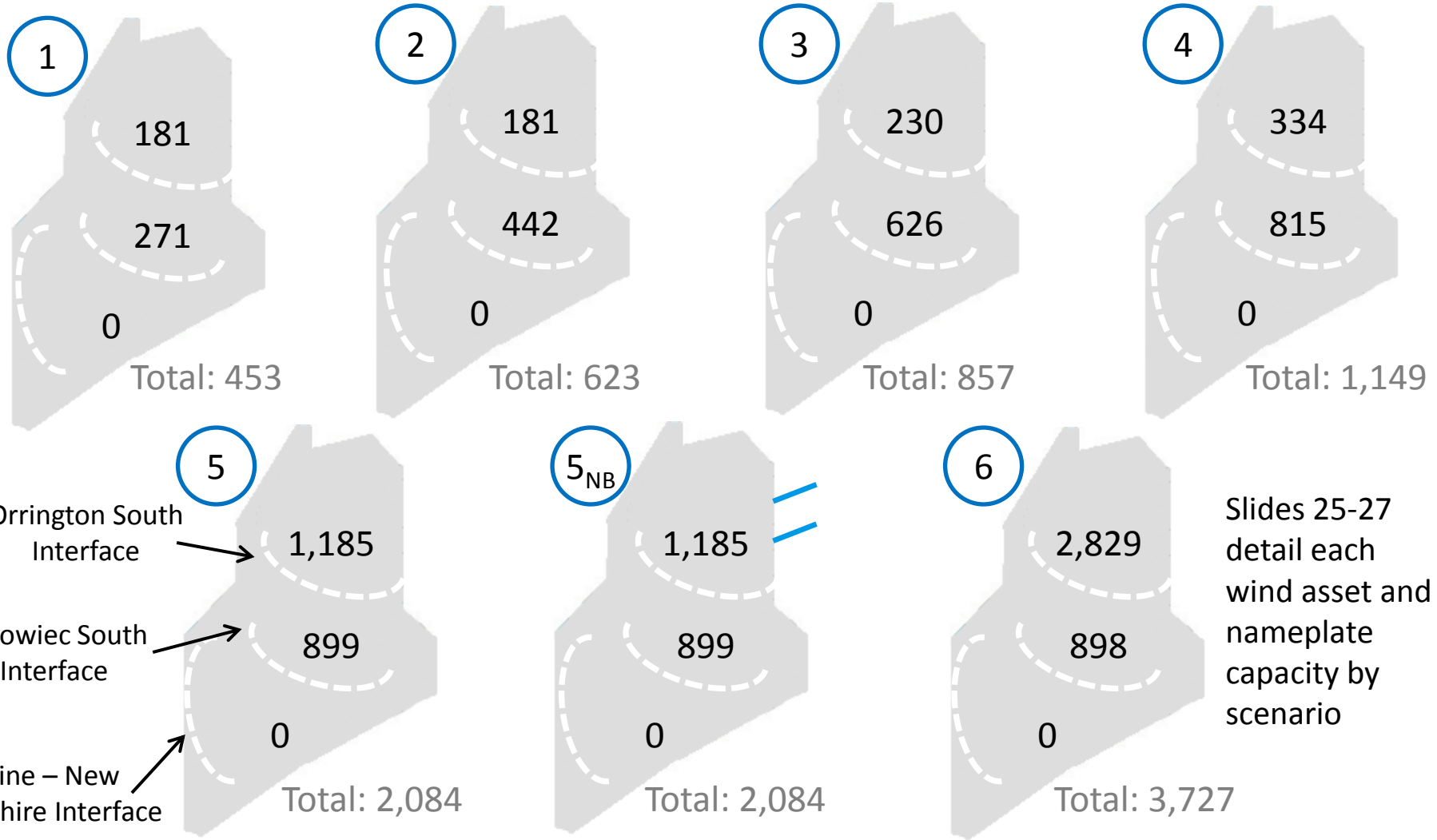
	Scenarios	Wind Nameplate (MW)		
		Maine	Outside of Maine	**New England Total**
1	**Existing Wind in New England (In-Service as of 4/1/15) ***	453	426	878
2	**RENEW Sensitivity 1 (Less Wind) ***	623	426	1,049
3	**Proposed Wind in New England with I.3.9 approval (as of 4/1/15)**	857	489	1,345
4	**RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) ***	1,149	426	1,575
5	**RENEW Sensitivity 2 (More Wind)***	2,084	426	2,510
5_{NB}	**RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch**	2,084	426	2,510
6	**All Future Queue Wind in New England (as of 4/1/15)**	3,727	678	4,405

Note: Values may not sum to total due to rounding

*Outside Maine, assumed only "existing wind" as of 4/1/15

Wind Scenarios

Maine Wind Nameplate (MW)



Slides 25-27 detail each wind asset and nameplate capacity by scenario

Note: Values may not sum to total due to rounding

DRAFT STUDY RESULTS

Summary of Draft Results

Study Year 2021

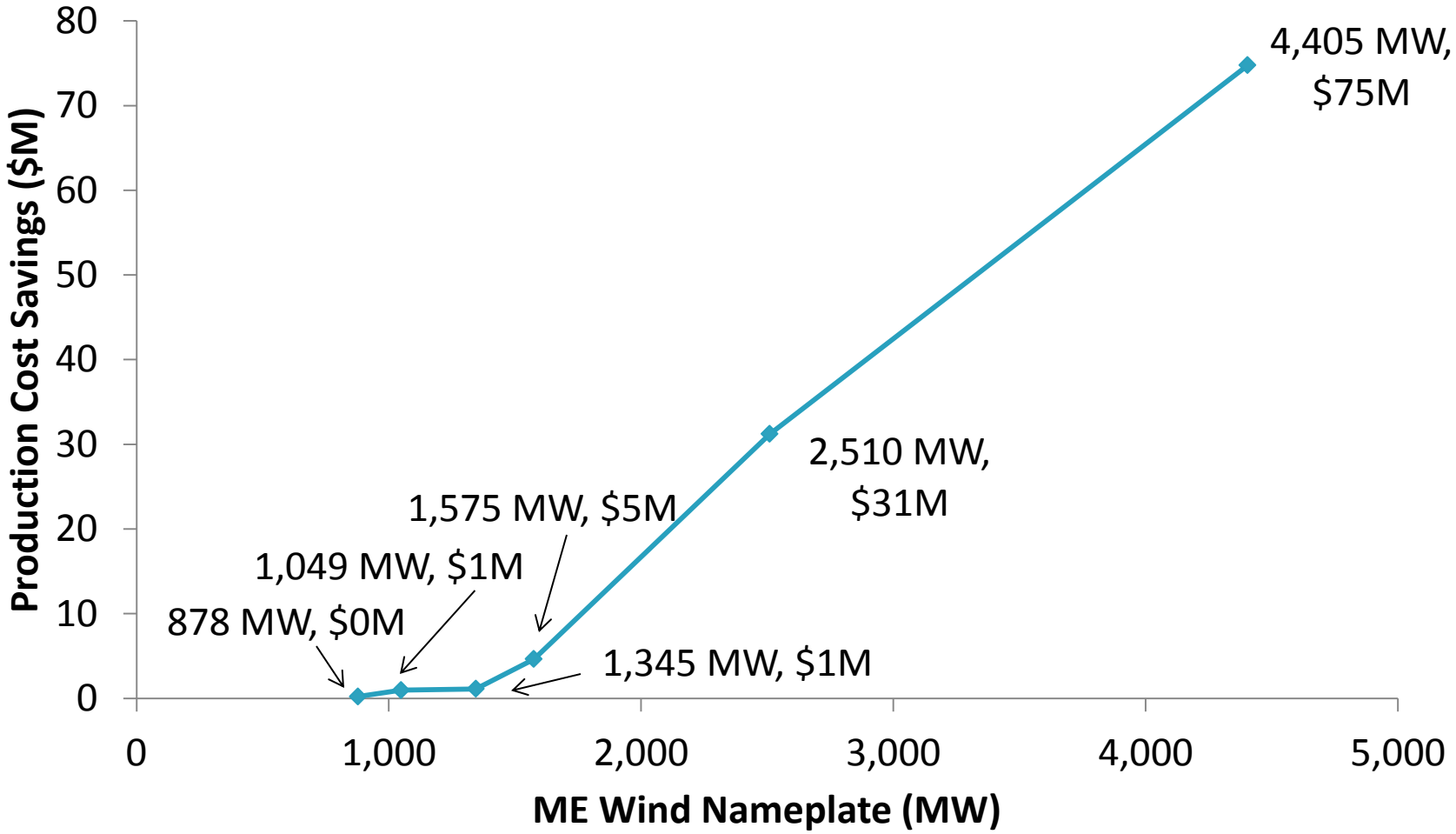
- For 453 MW to 1,149 MW of total wind integration in Maine
  - $0M to $5M production cost savings due to increasing Maine corridor interfaces
  - Orrington South interface becomes more constrained as more wind resources are added
- With 2,084 MW to 3,727 MW of total wind integration in Maine
  - $31M to $75M production cost savings result from increasing the Maine interface transfer limit constraints
  - Orrington South interface is the major constraint
    - Most wind resources are located north of Orrington South
    - Affects the ability to transport economically dispatched resources to South of Orrington (including New Brunswick imports)
  - Relieving the Maine corridor results in the North-South interface becoming increasingly constrained
- Reminder that the above calculations are associated only with the changes in transfer capabilities on the major interfaces
  - Bottled-in energy was observed due to both interface and local thermal constraints
  - Study does not reflect influence of future interconnections on local system constraints

Production Cost Savings due to ME Interface Upgrades ($M/Year)

	Scenarios	Production Cost		Production Cost Savings	Case Shows
		Pre-Upgrades	Post-Upgrades		
1	**Existing Wind in New England (In-Service as of 4/1/15) ***	3,668	3,667	**0**	***Little to no savings**: Infrequent interface constraints and small amounts of bottled-in energy*
2	**RENEW Sensitivity 1 (Less Wind) ***	3,639	3,638	**1**	
3	**Proposed Wind in New England with I.3.9 approval (as of 4/1/15)**	3,593	3,592	**1**	
4	**RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) ***	3,563	3,559	**5**	
5	**RENEW Sensitivity 2 (More Wind)***	3,458	3,427	**31**	***When > 2,084 MW of Maine Wind:** Production cost savings are realized from relaxing interfaces and releasing bottled-in energy*
5_{NB}	**RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch**	3,338	3,261	**78**	
6	**All Future Queue Wind in New England (as of 4/1/15)**	3,351	3,276	**75**	

Note: Values may not sum to total due to rounding
*Outside Maine, assumed only "existing wind" as of 4/1/15

Production Cost Savings ($M/Year) vs. New England Wind Nameplate (MW)



Note: New Brunswick sensitivity (1,000 MW of NB imports available for dispatch) is excluded in this graph

Load Serving Entity (LSE) Expense Savings due to ME Interface Upgrades ($M/Year)

	Scenarios	LSE Expense		LSE Expense Savings	Cases Shows
		Pre-Upgrades	Post-Upgrades		
1	**Existing Wind in New England (In-Service as of 4/1/15) ***	7,246	7,245	**1**	***Little to no savings**: Infrequent interface constraints and small amounts of bottled-in energy*
2	**RENEW Sensitivity 1 (Less Wind) ***	7,217	7,215	**1**	
3	**Proposed Wind in New England with I.3.9 approval (as of 4/1/15)**	7,178	7,177	**1**	
4	**RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) ***	7,167	7,165	**2**	
5	**RENEW Sensitivity 2 (More Wind)***	7,093	7,054	**39**	***When > 2,084 MW of Maine Wind:** LSE expense savings are realized from relaxing interfaces and releasing bottled-in energy*
5_{NB}	**RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch**	7,002	6,922	**80**	
6	**All Future Queue Wind in New England (as of 4/1/15)**	6,959	6,883	**76**	

Note: Values may not sum to total due to rounding
*Outside Maine, assumed only "existing wind" as of 4/1/15

Percent of Time Interface is at Limit (% of Year)

Orrington South is the most limited and leads to minimal congestion at Surowiec South and ME-NH

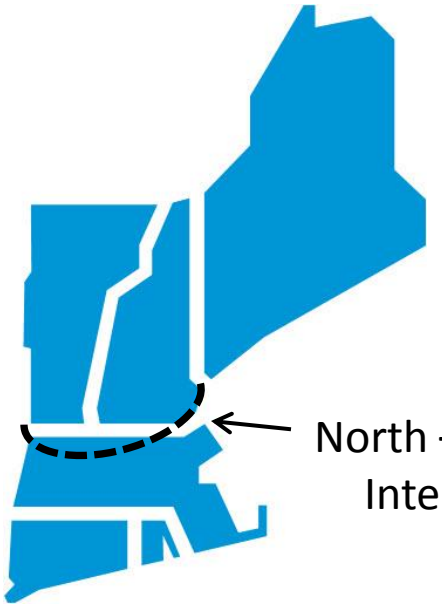
Scenarios		Orrington South Export Limit		Surowiec South Export Limit		ME-NH Export Limit	
		Pre-Upgrades (1,325 MW)	Post-Upgrades (1,650 MW)	Pre-Upgrades (1,500 MW)	Post-Upgrades (2,100 MW)	Pre-Upgrades (1,900 MW)	Post-Upgrades (2,300 MW)
1	Existing Wind in New England (In-Service as of 4/1/15) *	1	0	0	0	0	0
2	RENEW Sensitivity 1 (Less Wind) *	6	0	0	0	0	0
3	Proposed Wind in New England with I.3.9 approval (as of 4/1/15)	8	0	1	0	0	0
4	RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) *	13	0	4	0	0	0
5	RENEW Sensitivity 2 (More Wind)*	43	19	11	0	0	0
5_{NB}	RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch	83	57	12	0	0	0
6	All Future Queue Wind in New England (as of 4/1/15)	69	52	11	0	0	0

*Outside Maine, assumed only "existing wind" as of 4/1/15

Percent of Time Interface is at Limit (% of Year), Cont.

North – South Interface

	Scenarios	North-South Export Limit (2,675 MW)	
		Pre-Upgrade	Post-Upgrade
1	Existing Wind in New England (In-Service as of 4/1/15) *	0	0
2	RENEW Sensitivity 1 (Less Wind) *	1	1
3	Proposed Wind in New England with I.3.9 approval (as of 4/1/15)	2	2
4	RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) *	2	3
5	RENEW Sensitivity 2 (More Wind)*	3	9
5_{NB}	RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch	4	13
6	All Future Queue Wind in New England (as of 4/1/15)	6	17



When there is >2,084 MW of wind nameplate in Maine, the North-South interface begins to experience more congestion

*Outside Maine, assumed only "existing wind" as of 4/1/15

Maine Bottled-In Energy (GWh)

Operation of some wind resources were constrained by local thermal limits. This cannot be relieved by increasing Maine corridor transfer capability.

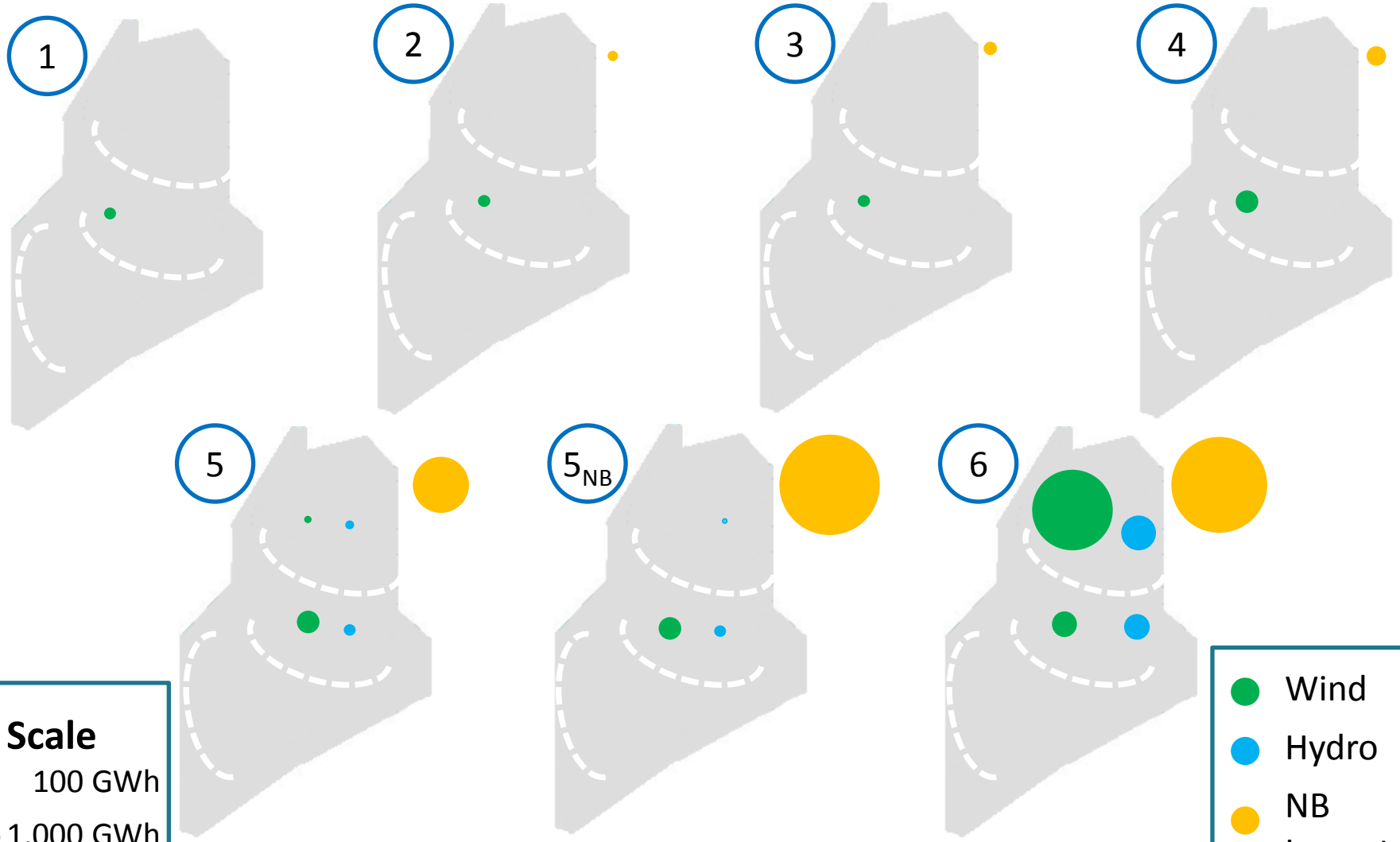
Scenarios	Wind ($0 Threshold Price)		Hydro ($5 Threshold Price)		NB Import ($10 Threshold Price)	
	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades
1	14	14	0	0	0	0
2	14	14	0	0	9	0
3	15	15	0	0	19	0
4	92	91	0	0	57	0
5	97	92	17	12	702	194
5_{NB}	92	89	13	12	2,435	1,028
6	1,641	941	362	270	2,174	1,560

Note: Values may not sum to total due to rounding

*Outside Maine, assumed only "existing wind" as of 4/1/15

Maine Bottled-In Energy (GWh)

Pre-Upgrades (approximately represented by shape size in subarea)



CO_2 Systemwide Reductions due to ME Interface Upgrades (kton**)

Changes (%) in CO_2 emissions are small relative to systemwide emissions of 32,000 kton/year

	Scenarios	CO_2 Reduction		Cases Show
		kton	(%)	*Overall, as wind penetration increases, there is more CO_2 reduction due to Maine interface upgrades.* *Negative CO_2 reduction occurs in cases 2 and 3 due to change in unit commitment after Maine interface upgrades. The system conducts least-cost dispatch and not least-emission dispatch. ($20 CO_2 cost is taken into account)*
1	**Existing Wind in New England (In-Service as of 4/1/15) ***	1	**0**	
2	**RENEW Sensitivity 1 (Less Wind) ***	-3	**0**	
3	**Proposed Wind in New England with I.3.9 approval (as of 4/1/15)**	-7	**0**	
4	**RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) ***	3	**0**	
5	**RENEW Sensitivity 2 (More Wind)***	216	**1**	
5_{NB}	**RENEW Sensitivity 2 (More Wind)* and 1,000 MW of of NB imports available for dispatch**	618	**2**	
6	**All Future Queue Wind in New England (as of 4/1/15)**	701	**2**	

Note: Values may not sum to total due to rounding

*Outside Maine, assumed only "existing wind" as of 4/1/15

**1 kton = 1,000 short ton = 2,000,000 lb

2015 Economic Study: Next Steps

- Review stakeholder comments and continue stakeholder discussions at future PAC meetings
- Develop report summarizing the Onshore Wind – Strategic Transmission Analysis Study

Questions

APPENDICES

I – Scenarios

II – Generation by Resource Type Metrics

III – Air Emissions Metrics

IV – Bottled-In Energy Metrics

V – Interface Flow Metrics

VI – LMP Metrics

VII – Modeling Assumptions

APPENDIX I

Scenarios

Table of Scenarios

Cases

Scenarios		Case Names	
		Pre-Upgrades	**Post-Upgrades**
1	**Existing Wind in New England (In-Service as of 4/1/15) ***	Pre-E	Post-E
2	**RENEW Sensitivity 1 (Less Wind) ***	Pre-Less	Post-Less
3	**Proposed Wind in New England with I.3.9 approval (as of 4/1/15)**	Pre-P	Post-P
4	**RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) ***	Pre-Base	Post-Base
5	**RENEW Sensitivity 2 (More Wind)***	Pre-More	Post-More
5_{NB}	**RENEW Sensitivity 2 (More Wind)* and 1,000 MW of of NB imports available for dispatch**	Pre-More-NB	Post-More-NB
6	**All Future Queue Wind in New England (as of 4/1/15)**	Pre-F	Post-F

*Outside Maine, assumed only "existing wind" as of 4/1/15

Wind Units by Scenario and Subarea (1/3)

BHE (MW)

Area	Name	1 Existing Wind in New England (In-service 4/1/15)	2 RENEW Sensitivity 1 (Less Wind)	3 Proposed Wind in New England with I.3.9 (as of 4/1/15)	4 RENEW Basecase - STA-WI Studied Wind (as of 10/1/13)	5 RENEW Sensitivity 2 (More Wind)	5_{NB} Sensitivity 2 (More Wind) and 1,000 MW of NB imports available for dispatch	6 All Queue Wind in New England (as of 4/1/15)
BHE	QP357_Passadumkeag Windpark	0.0	0.0	40.0	40.0	40.0	40.0	40.0
BHE	QP476_Wind	0.0	0.0	0.0	52.8	52.8	52.8	52.8
BHE	Rollins Wind Plant	61.8	61.8	61.8	61.8	61.8	61.8	61.8
BHE	Stetson II Wind Farm	26.3	26.3	26.3	26.3	26.3	26.3	26.3
BHE	Stetson Wind Farm	58.7	58.7	58.7	58.7	58.7	58.7	58.7
BHE	Bull Hill Wind	34.5	34.5	34.5	34.5	34.5	34.5	34.5
BHE	QP349_Pisgah Mountain	0.0	0.0	9.1	9.1	9.1	9.1	9.1
BHE	QP397_Hancock Wind Project	0.0	0.0	0.0	51.0	51.0	51.0	51.0
BHE	QP400_Wind	0.0	0.0	0.0	0.0	0.0	0.0	90.0
BHE	QP403_Pisgah Mountain Increase (see QP249)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
BHE	QP417_Wind	0.0	0.0	0.0	0.0	250.0	250.0	250.0
BHE	QP420_Wind	0.0	0.0	0.0	0.0	0.0	0.0	72.6
BHE	QP435_Wind	0.0	0.0	0.0	0.0	0.0	0.0	111.0
BHE	QP458_Wind	0.0	0.0	0.0	0.0	0.0	0.0	104.0
BHE	QP459_Wind	0.0	0.0	0.0	0.0	0.0	0.0	104.0
BHE	QP460_Wind	0.0	0.0	0.0	0.0	0.0	0.0	104.0
BHE	QP461_Wind	0.0	0.0	0.0	0.0	0.0	0.0	104.0
BHE	QP462_Wind	0.0	0.0	0.0	0.0	0.0	0.0	104.0
BHE	QP470_Wind	0.0	0.0	0.0	0.0	600.6	600.6	600.6
BHE	QP471_Wind	0.0	0.0	0.0	0.0	0.0	0.0	600.6
BHE	QP486_Wind	0.0	0.0	0.0	0.0	0.0	0.0	250.0
BHE Total		**181.3**	**181.3**	**230.3**	**334.1**	**1184.7**	**1184.7**	**2829.0**

Wind Units by Scenario and Subarea (2/3)

ME (MW)

Area	Name	1 Existing Wind in New England (In-service 4/1/15)	2 RENEW Sensitivity 1 (Less Wind)	3 Proposed Wind in New England with I.3.9 (as of 4/1/15)	4 RENEW Basecase - STA-WI Studied Wind (as of 10/1/13)	5 RENEW Sensitivity 2 (More Wind)	5_{NB} Sensitivity 2 (More Wind) and 1,000 MW of NB imports available for dispatch	6 All Queue Wind in New England (as of 4/1/15)
ME	GMCW	10.5	10.5	10.5	10.5	10.5	10.5	10.5
ME	Kibby Wind Power	149.6	149.6	149.6	149.6	149.6	149.6	149.6
ME	QP272_Oakfield II Wind – Keene Road	0.0	147.6	147.6	147.6	147.6	147.6	147.6
ME	Saddleback Ridge Wind	34.2	34.2	34.2	34.2	34.2	34.2	34.2
ME	Spruce Mountain Wind	20.0	20.0	20.0	20.0	20.0	20.0	20.0
ME	QP300_Canton Mountain Winds	0.0	22.8	22.8	22.8	22.8	22.8	22.8
ME	QP333_Bingham Wind	0.0	0.0	184.8	184.8	184.8	184.8	184.8
ME	QP350-1_Wind (Withdrawn as of 4/1/15)	0.0	0.0	0.0	92.0	92.0	92.0	0.0
ME	QP350-2_Wind	0.0	0.0	0.0	96.9	96.9	96.9	96.9
ME	QP393_Wind	0.0	0.0	0.0	0.0	84.0	84.0	84.0
ME	QP406_Canton Increase and CNR (see QP300)	0.0	0.0	0.0	0.0	0.0	0.0	3.6
ME	QP407_Saddleback Increase and CNR (see QP287)	0.0	0.0	0.0	0.0	0.0	0.0	1.2
ME	QP452_Wind	0.0	0.0	0.0	0.0	0.0	0.0	85.8
ME	Record Hill Wind	50.6	50.6	50.6	50.6	50.6	50.6	50.6
ME	WND_MISC_ME	6.3	6.3	6.3	6.3	6.3	6.3	6.3
ME Total		**271.2**	**441.6**	**626.4**	**815.3**	**899.3**	**899.3**	**897.9**

Wind Units by Scenario and Subarea (3/3)

BST, CMA/NEMA, NH, RI, SEMA, VT, WMA (MW)

Area	Name	1 Existing Wind in New England (In-service 4/1/15)	2 RENEW Sensitivity 1 (Less Wind)	3 Proposed Wind in New England with I.3.9 (as of 4/1/15)	4 RENEW Basecase - STA-WI Studied Wind (as of 10/1/13)	5 RENEW Sensitivity 2 (More Wind)	5_{NB} Sensitivity 2 (More Wind) and 1,000 MW of NB imports available for dispatch	6 All Queue Wind in New England (as of 4/1/15)
BST	WND_MISC_BST	12.2	12.2	12.2	12.2	12.2	12.2	12.2
CMA NEMA	WND_MISC_CMANEMA	4.0	4.0	4.0	4.0	4.0	4.0	4.0
CMA NEMA	Princeton Wind Farm Project	3.0	3.0	3.0	3.0	3.0	3.0	3.0
NH	Lempster Wind	25.3	25.3	25.3	25.3	25.3	25.3	25.3
NH	Granite Reliable Power	120.2	120.2	120.2	120.2	120.2	120.2	120.2
NH	QP415_Jericho Wind	0.0	0.0	12.1	0.0	0.0	0.0	12.1
NH	Groton Wind Project	50.5	50.5	50.5	50.5	50.5	50.5	50.5
NH	QP390_Wind	0.0	0.0	50.8	0.0	0.0	0.0	50.8
NH	QP543_Wind	0.0	0.0	0.0	0.0	0.0	0.0	28.4
RI	WND_MISC_RI	7.2	7.2	7.2	7.2	7.2	7.2	7.2
SEMA	WND_MISC_SEMA	22.9	22.9	22.9	22.9	22.9	22.9	22.9
VT	Sheffield Wind Farm	40.0	40.0	40.0	40.0	40.0	40.0	40.0
VT	Searsburg Wind	1.7	1.7	1.7	1.7	1.7	1.7	1.7
VT	Kingdom Community Wind	81.5	81.5	81.5	81.5	81.5	81.5	81.5
VT	QP532_Wind	0.0	0.0	0.0	0.0	0.0	0.0	19.9
VT	QP536_Wind	0.0	0.0	0.0	0.0	0.0	0.0	5.0
VT	QP488_Wind	0.0	0.0	0.0	0.0	0.0	0.0	96.9
WMA	QP396_Berkshire Wind Increase	0.0	0.0	0.0	0.0	0.0	0.0	4.8
WMA	QP539_CNR Only	31.7	31.7	31.7	31.7	31.7	31.7	31.7
WMA	QP477_Wind	0.0	0.0	0.0	0.0	0.0	0.0	30.0
WMA	QP535_Wind	0.0	0.0	0.0	0.0	0.0	0.0	5.0
WMA	Berkshire East Wind	16.7	16.7	16.7	16.7	16.7	16.7	16.7
WMA	WND_MISC_WMA	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Outside Maine Total		**425.6**	**425.6**	**488.5**	**425.6**	**425.6**	**425.6**	**678.4**

Maine Interface Upgrades

- Conceptual transmission upgrades
  - Used upgraded interface limits identified in the 2012-2014 Strategic Transmission Analysis – Wind Integration
  - Specific upgrades to accomplish changes are not defined
- Maine stability / voltage interface limit increases
  - Orrington-South
    - 2021 limit is 1,325 MW
    - 2021 plus upgrades limit is 1,650 MW
  - Surowiec-South
    - 2021 limit is 1,500 MW
    - 2021 plus upgrades limit is 2,100 MW
  - ME-NH
    - 2021 limit is 1,900 MW
    - 2021 plus upgrades limit is 2,300 MW

Scenario Specific

New Brunswick Imports

- Cases 1, 2, 3, 4, 5, and 6
  - Daily diurnal curves
  - Historical monthly maximum imports for 2013-2014
- Sensitivity case (5_{NB}) evaluate the impact of additional New Brunswick imports
  - Assumed 1,000 MW of available imports for dispatch ($10/MWh threshold price)

APPENDIX II

Generation by Resource Type Metrics

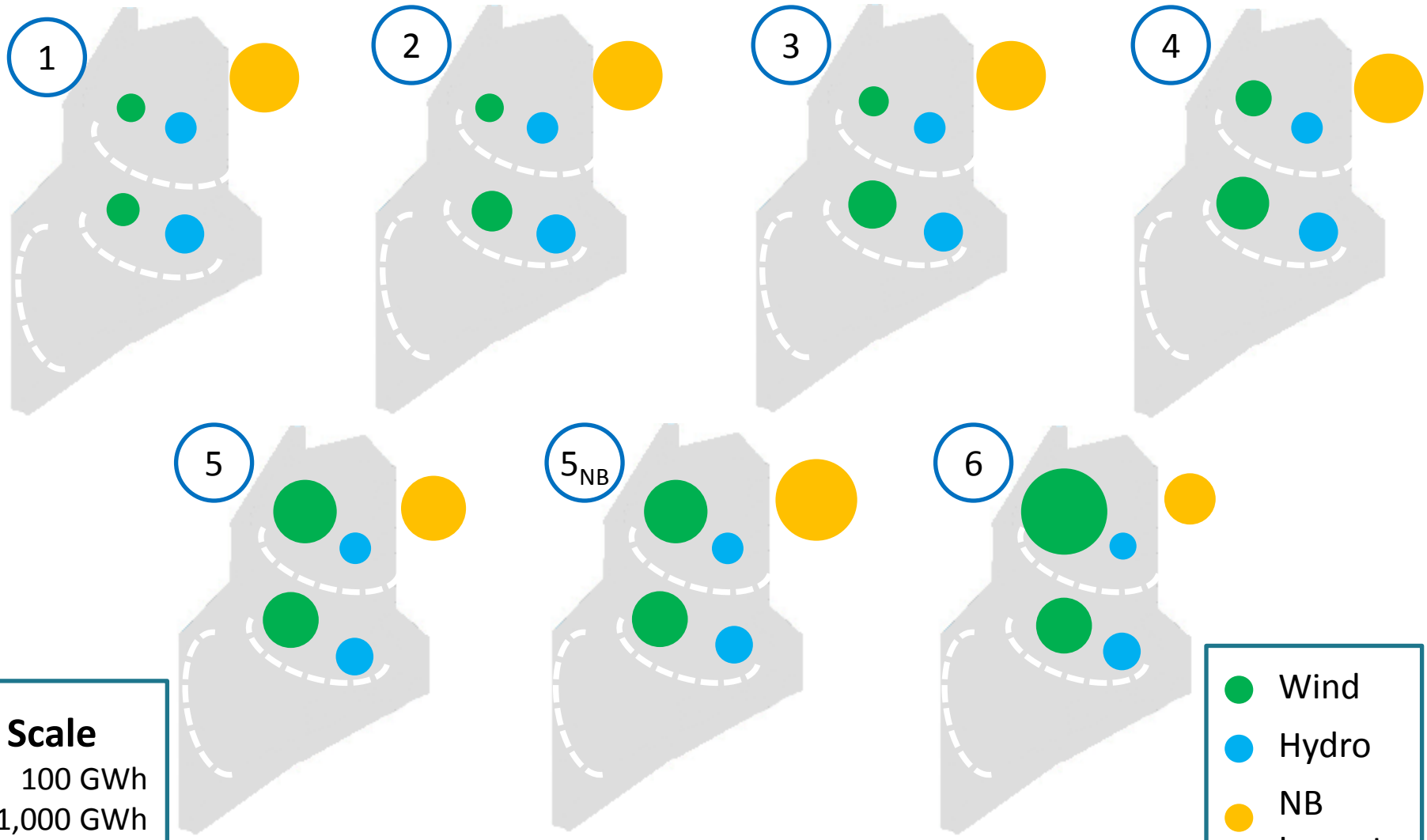
Maine Generation (GWh)

Scenarios	Wind ($0 Threshold Price)		Hydro ($5 Threshold Price)		NB Import ($10 Threshold Price)	
	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades
1	1,454	1,454	2,060	2,060	4,592	4,592
2	2,025	2,025	2,060	2,060	4,582	4,592
3	2,793	2,793	2,060	2,060	4,573	4,592
4	3,634	3,635	2,060	2,060	4,535	4,592
5	6,615	6,620	2,042	2,047	3,889	4,398
5_{NB}	6,620	6,623	2,046	2,047	6,325	7,732
6	10,058	10,758	1,698	1,790	2,418	3,032

Note: Values may not sum to total due to rounding
*Outside Maine, assumed only "existing wind" as of 4/1/15

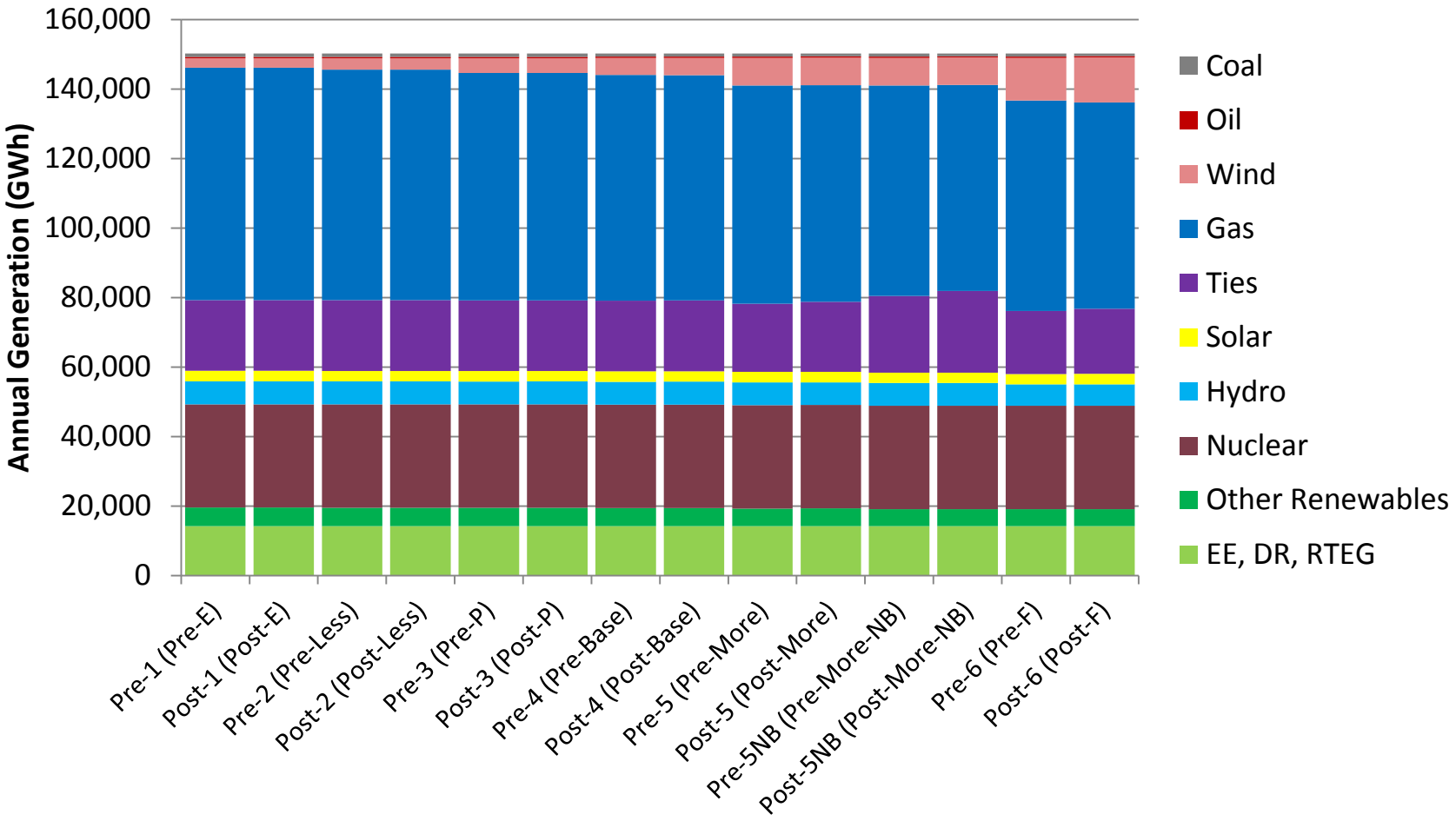
Maine Generation (GWh)

Pre-Upgrades (approximately represented by shape size in subarea)



Annual Generation by Resource Type

Graph



Annual Generation by Resource Type (GWH)

Table

Cases	Resource Type									
	EE, DR, RTEG	Other Renewables	Nuclear	Hydro	Solar	Ties	Gas	Wind	Oil	Coal
Pre-1 (Pre-E)	14,238	5,307	29,754	6,631	2,990	20,371	66,852	2,735	405	938
Post-1 (Post-E)	14,238	5,308	29,754	6,631	2,990	20,371	66,853	2,735	403	938
Pre-2 (Pre-Less)	14,238	5,279	29,754	6,625	2,990	20,362	66,325	3,324	405	919
Post-2 (Post-Less)	14,238	5,289	29,754	6,626	2,990	20,371	66,309	3,324	402	919
Pre-3 (Pre-P)	14,238	5,242	29,754	6,614	2,990	20,344	65,438	4,264	403	936
Post-3 (Post-P)	14,238	5,256	29,754	6,615	2,990	20,363	65,401	4,264	405	935
Pre-4 (Pre-Base)	14,238	5,179	29,754	6,611	2,990	20,308	64,951	4,933	407	850
Post-4 (Post-Base)	14,238	5,199	29,754	6,609	2,990	20,364	64,874	4,934	402	858
Pre-5 (Pre-More)	14,238	5,041	29,754	6,572	2,990	19,664	62,806	7,914	400	840
Post-5 (Post-More)	14,238	5,079	29,754	6,550	2,990	20,167	62,350	7,920	386	786
Pre-5NB (Pre-More-NB)	14,238	4,844	29,754	6,563	2,990	22,100	60,570	7,920	400	842
Post-5NB (Post-More-NB)	14,238	4,889	29,754	6,521	2,990	23,502	59,270	7,922	381	753
Pre-6 (Pre-F)	14,238	4,871	29,754	6,153	2,989	18,179	60,551	12,207	413	843
Post-6 (Post-F)	14,238	4,864	29,754	6,190	2,990	18,784	59,369	12,907	378	724

Annual Generation by Resource Type (GWH)

Table - Effect of Relaxing Maine Interfaces (Post minus Pre)

Scenarios	Resource Type									
	EE, DR, RTEG	Other Renewables	Nuclear	Hydro	Solar	Ties	Gas	Wind	Oil	Coal
1	0.0	1.0	0.0	0.0	0.0	0.0	0.8	0.0	-1.7	-0.1
2	0.0	9.6	0.0	1.0	0.0	9.2	-16.2	0.0	-3.4	-0.4
3	0.0	14.8	0.0	1.5	0.0	19.1	-36.6	0.0	2.0	-0.9
4	0.0	19.7	0.0	-1.9	0.0	56.1	-76.9	0.6	-5.6	8.0
5	0.0	37.9	0.0	-22.0	0.0	502.7	-455.7	5.5	-14.0	-54.3
5_{NB}	0.0	44.2	0.0	-41.4	0.0	1,402.4	-1,299.6	2.3	-19.1	-88.7
6	0.0	-6.5	0.0	36.7	0.3	605.0	-1,182.1	699.9	-34.3	-118.9

APPENDIX III

Air Emissions Metrics

CO_2 Systemwide Emission Reductions due to ME Interface Upgrades (k short ton**)

Changes (%) in emissions are small relative to systemwide emissions

	Scenarios	CO_2 Emissions (kton)		CO_2 Reduction	
		Pre-Upgrades	Post-Upgrades	kton	% of 32,000 kton
1	Existing Wind in New England (In-Service as of 4/1/15) *	31,775	31,775	1	**0**
2	RENEW Sensitivity 1 (Less Wind) *	31,483	31,485	-3	**0**
3	Proposed Wind in New England with I.3.9 approval (as of 4/1/15)	31,047	31,054	-7	**0**
4	RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) *	30,633	30,631	3	**0**
5	RENEW Sensitivity 2 (More Wind)*	29,462	29,246	216	**1**
5_{NB}	RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch	28,190	27,572	618	**2**
6	All Future Queue Wind in New England (as of 4/1/15)	28,250	27,549	701	**2**

Note: Values may not sum to total due to rounding

*Outside Maine, assumed only "existing wind" as of 4/1/15

**1 kton = 1,000 short ton = 2,000,000 lb

SO_2 Systemwide Emission Reductions due to ME Interface Upgrades (short ton**)

Changes (%) in emissions are small relative to systemwide emissions

	Scenarios	SO_2 Emissions (ton)		SO_2 Reduction	
		Pre-Upgrades	Post-Upgrades	ton	% of 3,200 ton
1	Existing Wind in New England (In-Service as of 4/1/15) *	3,054	3,050	4	**0**
2	RENEW Sensitivity 1 (Less Wind) *	3,020	3,014	7	**0**
3	Proposed Wind in New England with I.3.9 approval (as of 4/1/15)	3,010	3,016	-6	**0**
4	RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) *	2,923	2,901	22	**1**
5	RENEW Sensitivity 2 (More Wind)*	2,864	2,737	127	**4**
5_{NB}	RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch	2,817	2,614	203	**6**
6	All Future Queue Wind in New England (as of 4/1/15)	2,801	2,536	264	**8**

Note: Values may not sum to total due to rounding

*Outside Maine, assumed only "existing wind" as of 4/1/15

**1 short ton = 2,000 lb

NO_X Systemwide Emission Reductions due to ME Interface Upgrades (short ton**)

Changes (%) in emissions are small relative to systemwide emissions

	Scenarios	NO_X Emissions (ton)		NO_X Reduction	
		Pre-Upgrades	Post-Upgrades	ton	% of 9,300 ton
1	Existing Wind in New England (In-Service as of 4/1/15) *	9,284	9,283	1	**0**
2	RENEW Sensitivity 1 (Less Wind) *	9,199	9,199	-1	**0**
3	Proposed Wind in New England with I.3.9 approval (as of 4/1/15)	9,121	9,132	-11	**0**
4	RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) *	8,921	8,935	-14	**0**
5	RENEW Sensitivity 2 (More Wind)*	8,632	8,535	97	**1**
5_{NB}	RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch	8,314	8,108	205	**2**
6	All Future Queue Wind in New England (as of 4/1/15)	8,346	8,037	309	**3**

Note: Values may not sum to total due to rounding

*Outside Maine, assumed only "existing wind" as of 4/1/15

**1 short ton = 2,000 lb

APPENDIX IV

Bottled-in Energy

Bottled-In Energy (GWh)

BHE - RSP Subarea

Scenarios	Wind ($0 Threshold Price)		Hydro ($5 Threshold Price)		NB Import ($10 Threshold Price)	
	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades
1	0	0	0	0	0	0
2	0	0	0	0	9	0
3	0	0	0	0	19	0
4	0	0	0	0	57	0
5	2	0	5	4	702	194
5_{NB}	0	0	1	0	2,435	1,028
6	1,529	836	250	171	2,174	1,560

*Outside Maine, assumed only "existing wind" as of 4/1/15

Bottled-In Energy (GWh)

ME - RSP Subarea

Scenarios	Wind ($0 Threshold Price)		Hydro ($5 Threshold Price)	
	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades
1	14	14	0	0
2	14	14	0	0
3	15	15	0	0
4	92	91	0	0
5	97	92	17	12
5_{NB}	92	89	13	12
6	1,641	941	362	270

*Outside Maine, assumed only "existing wind" as of 4/1/15

Bottled-In Energy (GWh)

SME - RSP Subarea

Scenarios	Wind ($0 Threshold Price)		Hydro ($5 Threshold Price)	
	Pre-Upgrades	Post-Upgrades	Pre-Upgrades	Post-Upgrades
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
5_{NB}	0	0	0	0
6	0	0	0	0

*Outside Maine, assumed only "existing wind" as of 4/1/15

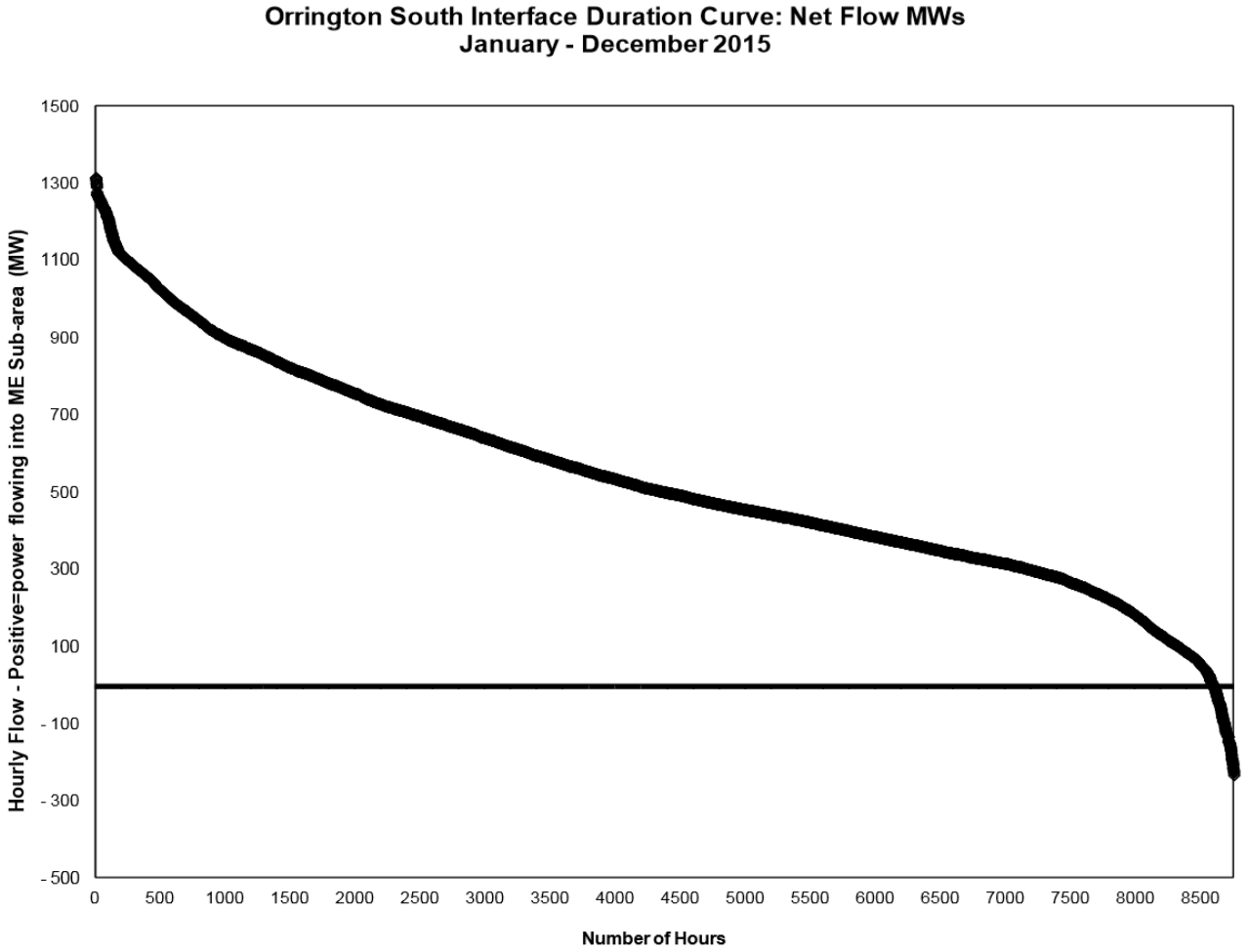
APPENDIX V

Interface Flow Metrics

- *Historical*
- *Draft Study Results*

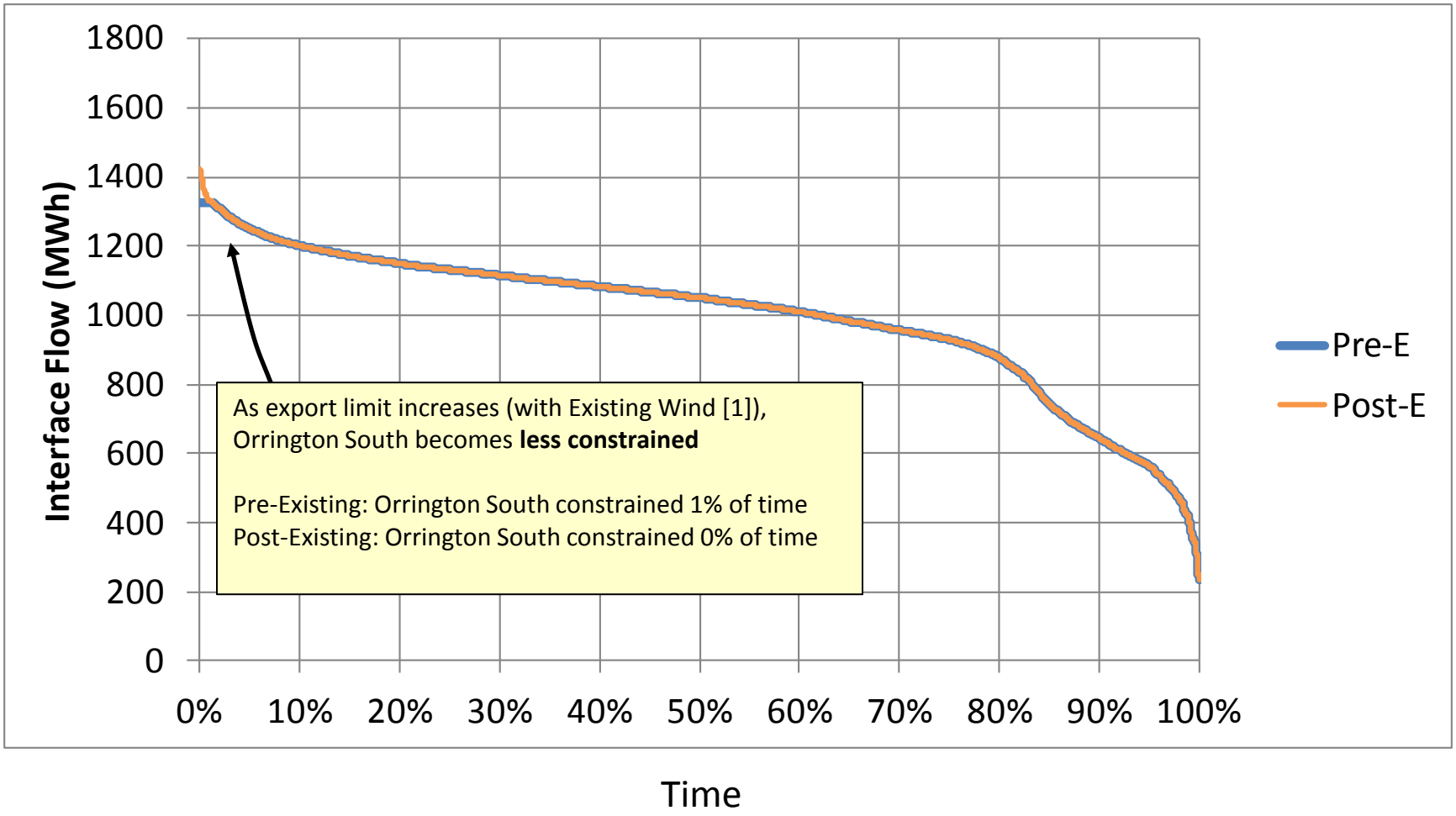
2015 Historical Interface Flow (MW)

Orrington South (1,325 MW limit)



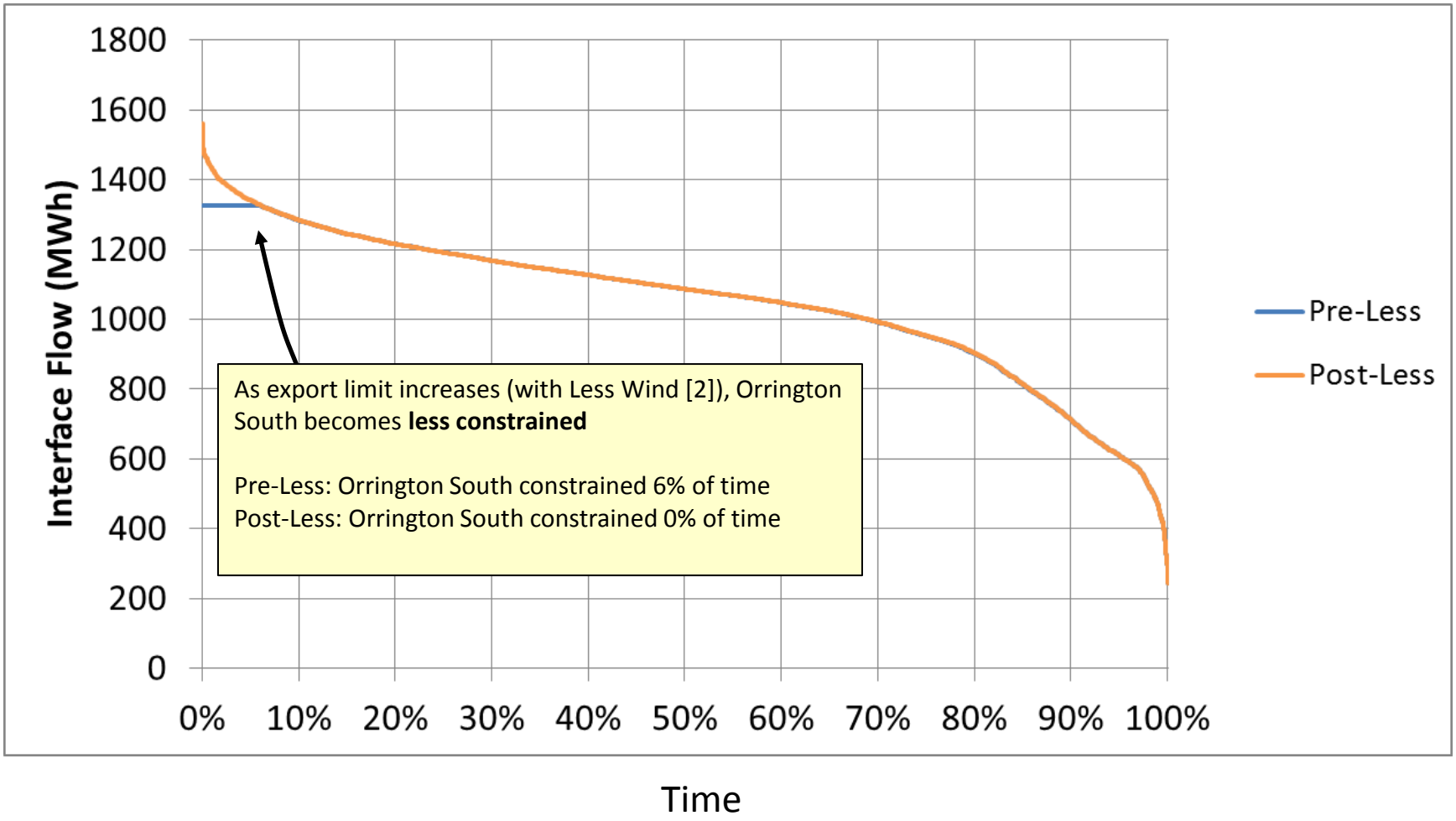
Interface: Orrington South – Existing Wind

Duration Curve



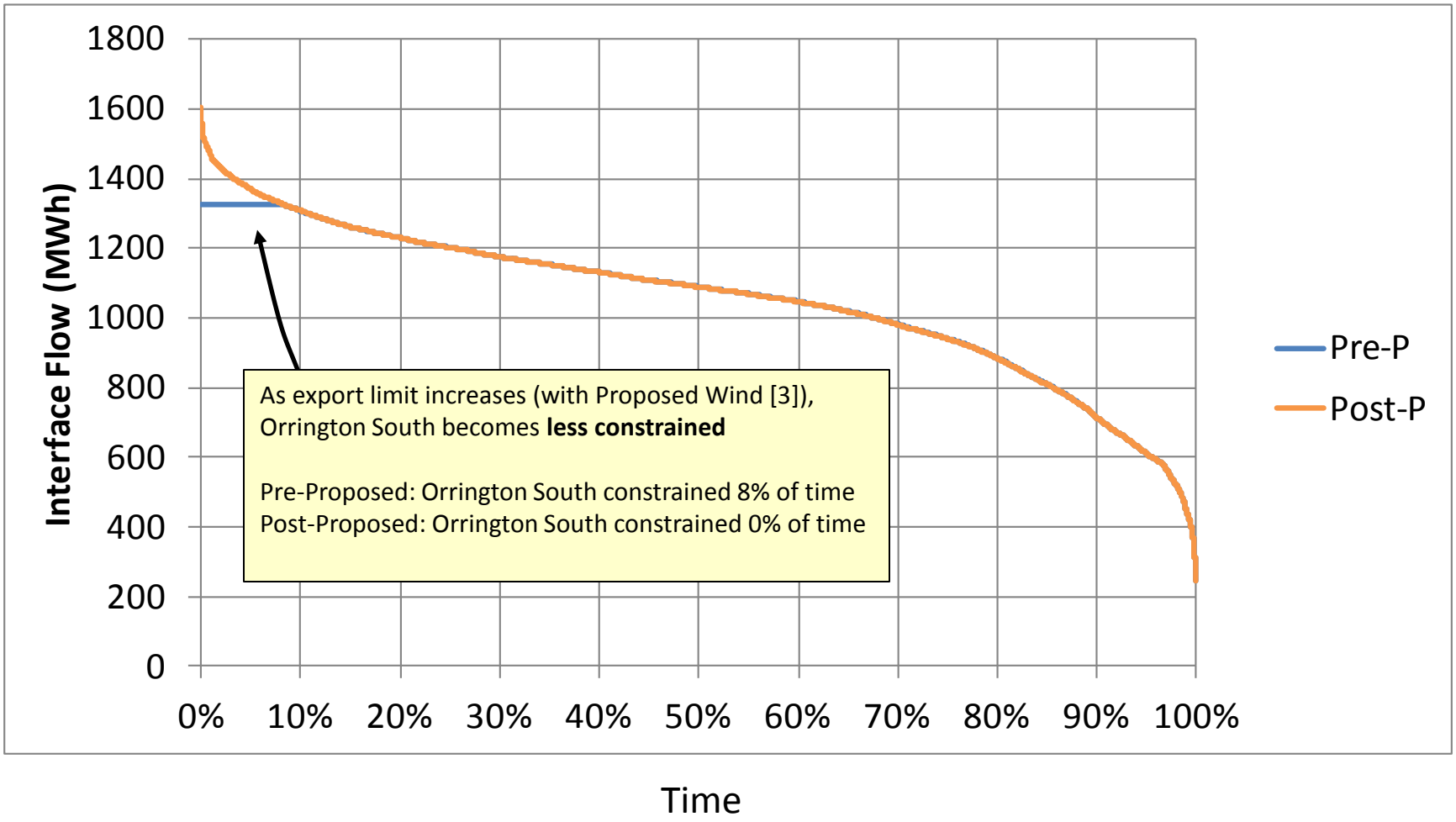
Interface: Orrington South – Less Wind

Duration Curve



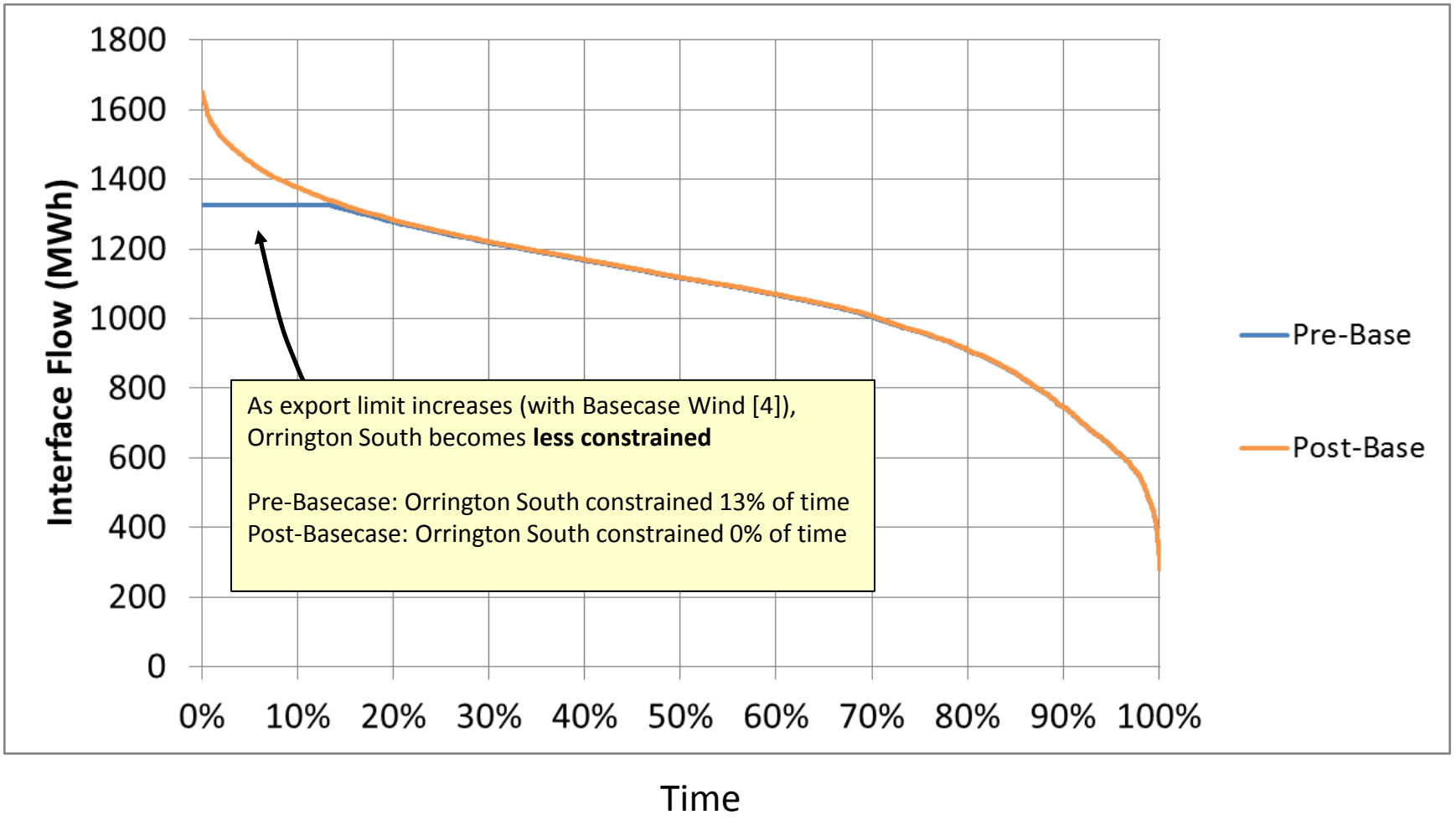
Interface: Orrington South – Proposed Wind

Duration Curve



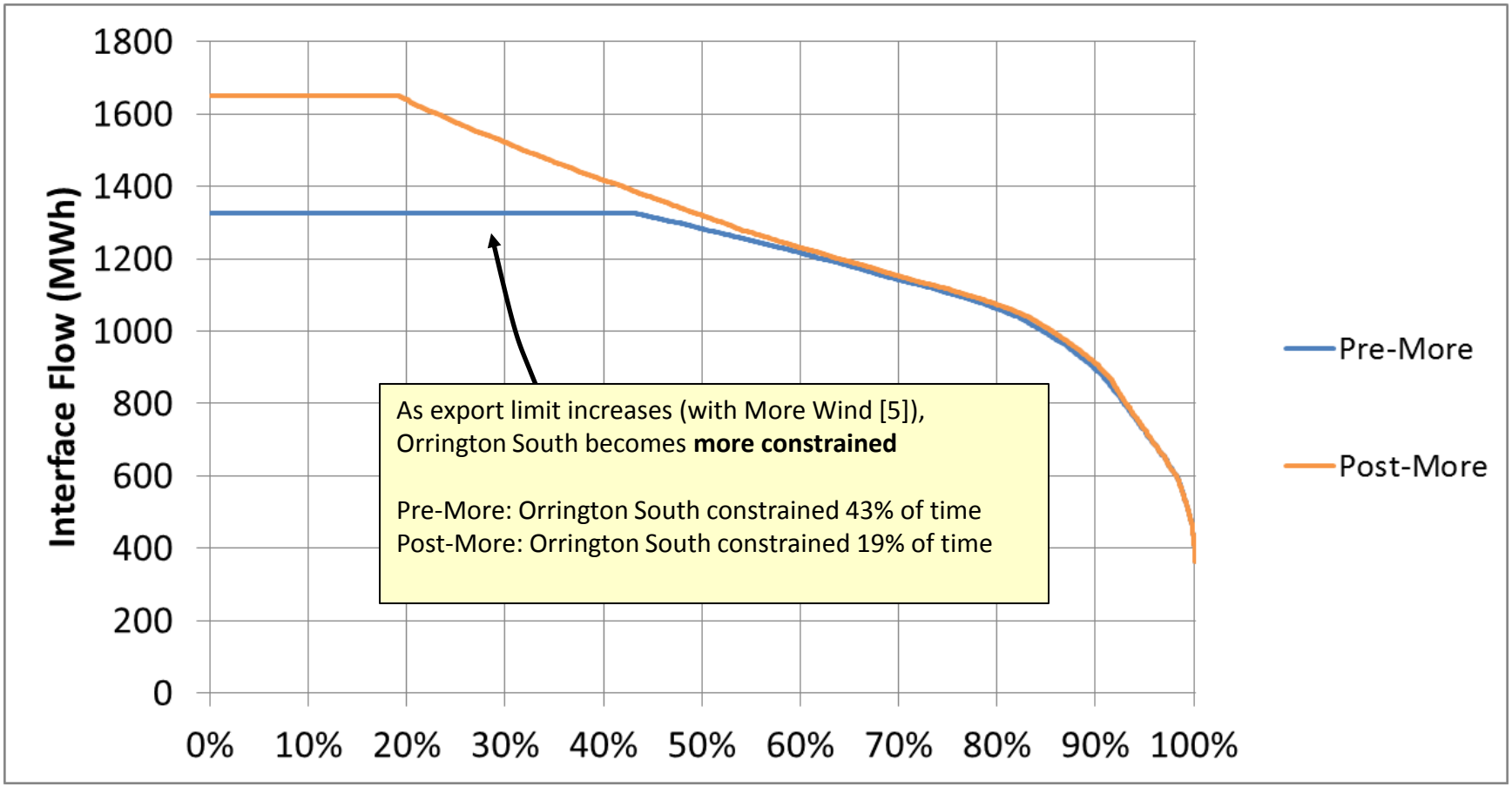
Interface: Orrington South – Basecase Wind

Duration Curve



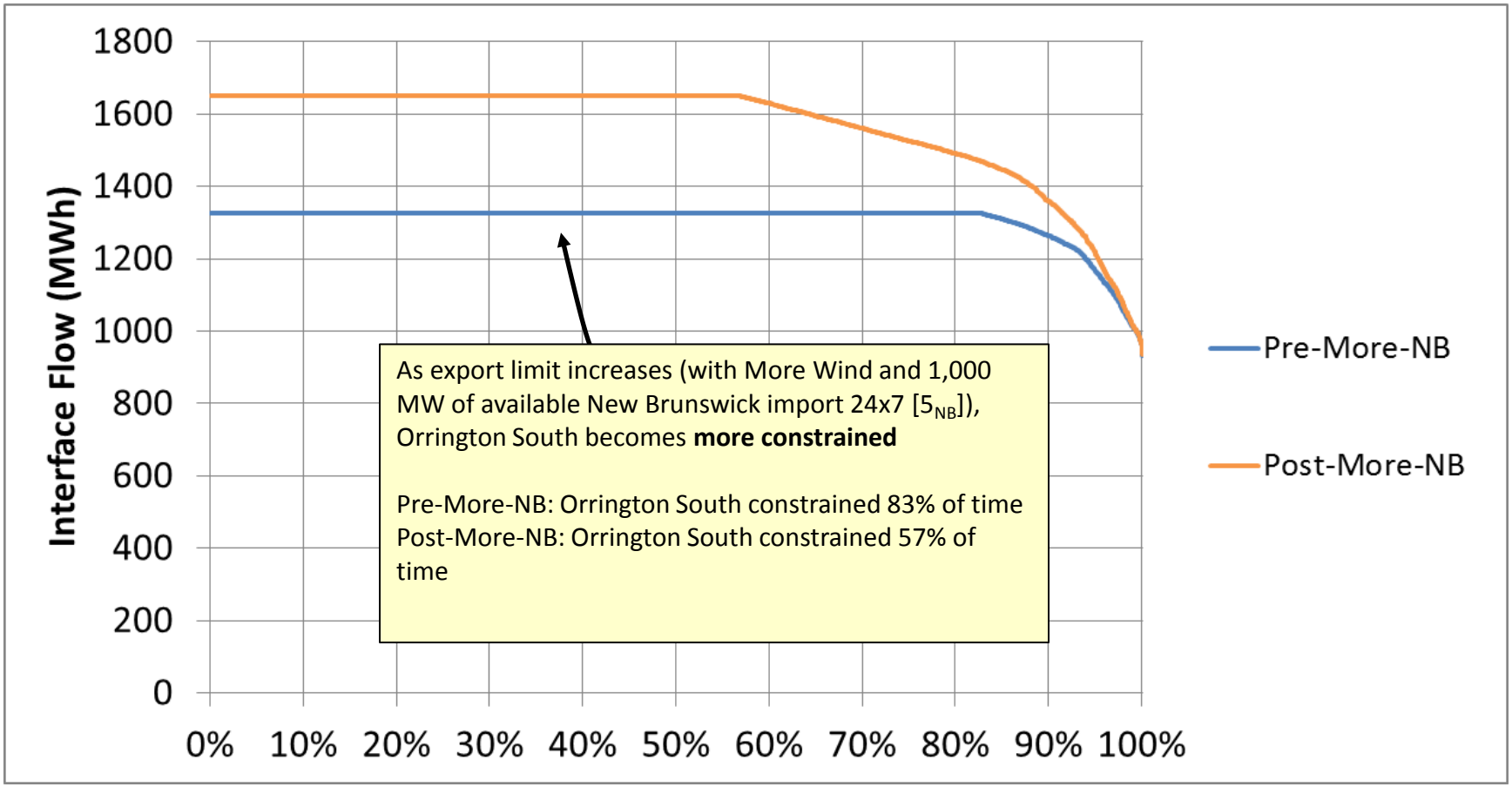
Interface: Orrington South – More Wind

Duration Curve



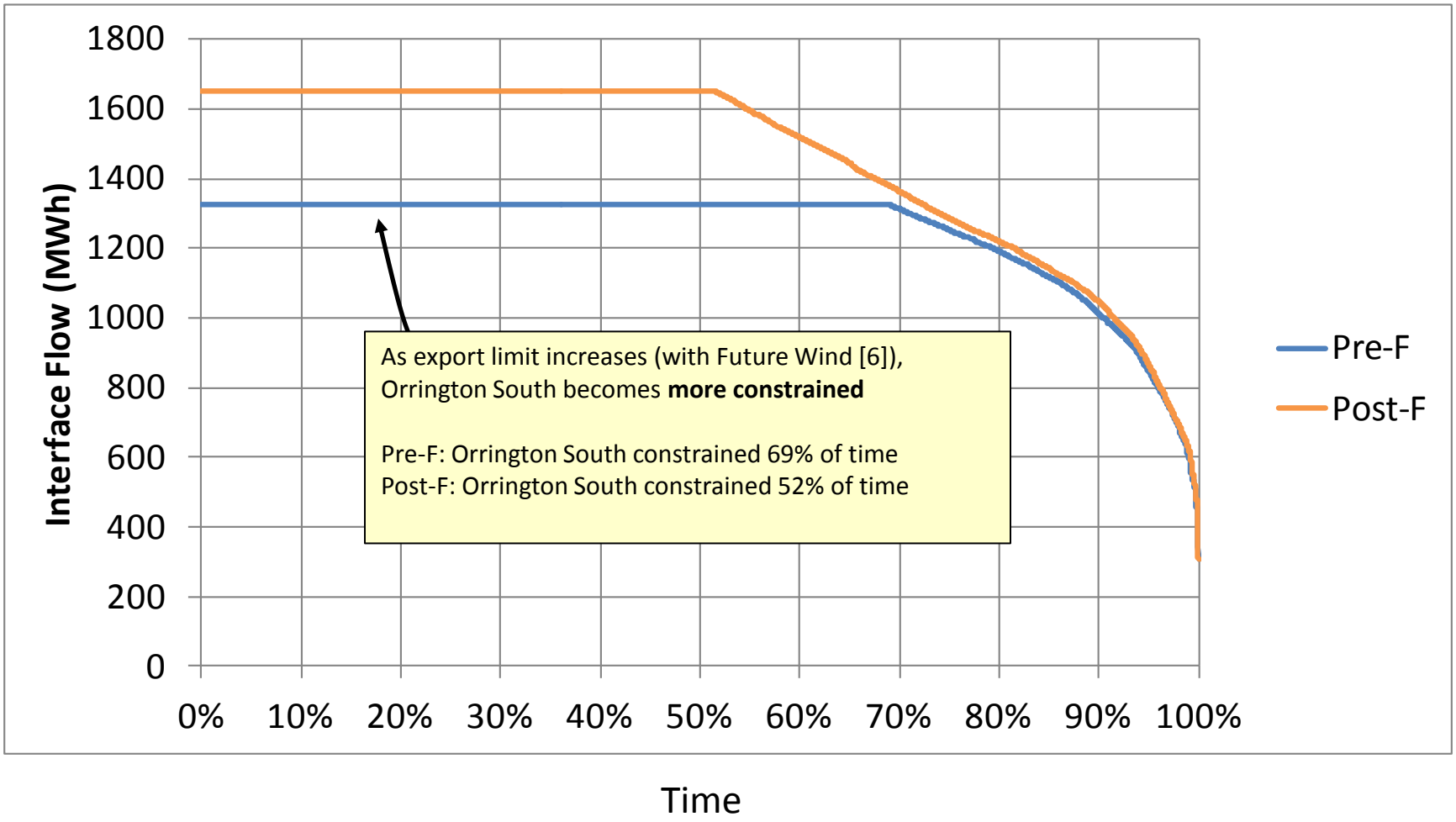
Interface: Orrington South – More Wind with NB at 1000 MW

Duration Curve



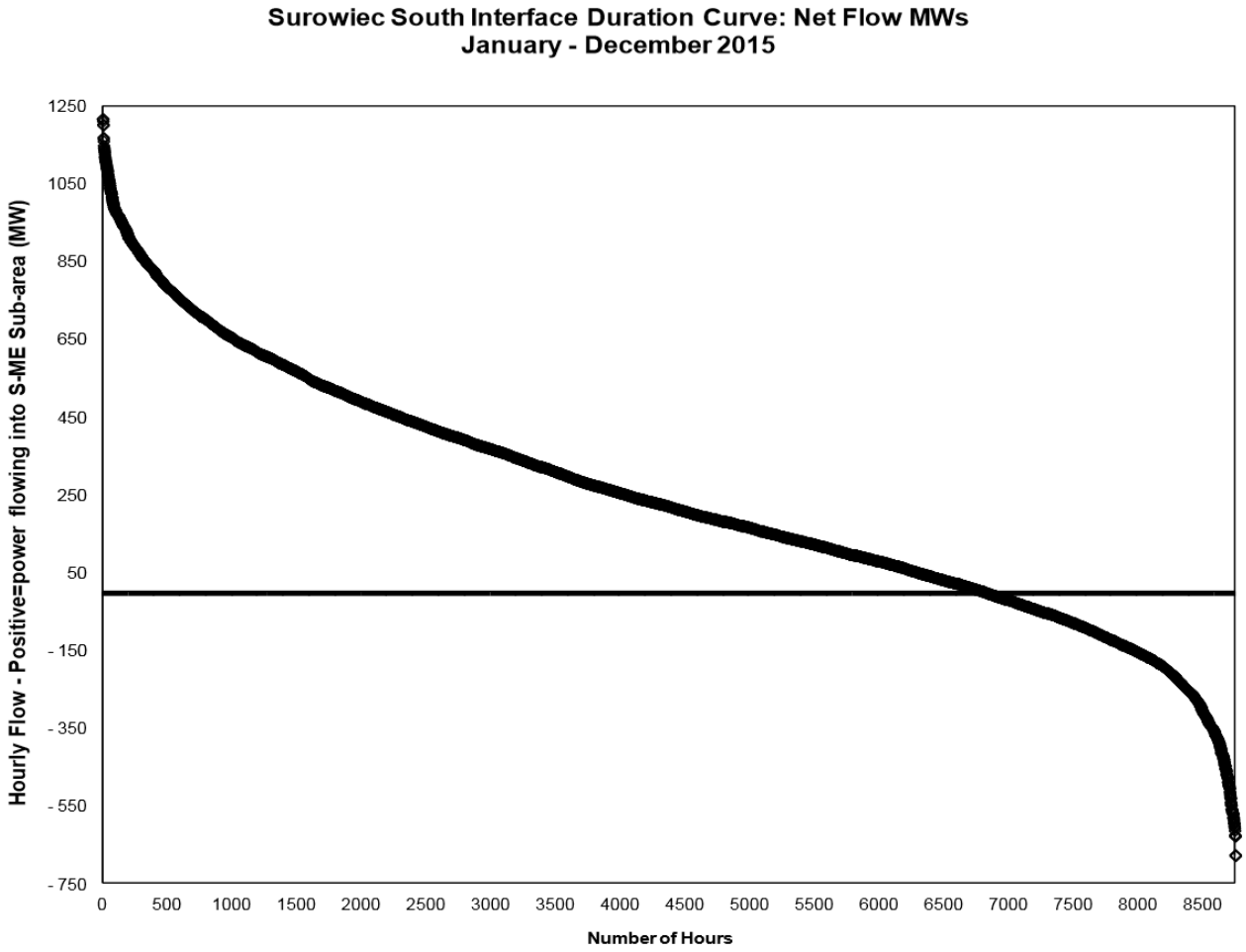
Interface: Orrington South – Future Wind

Duration Curve



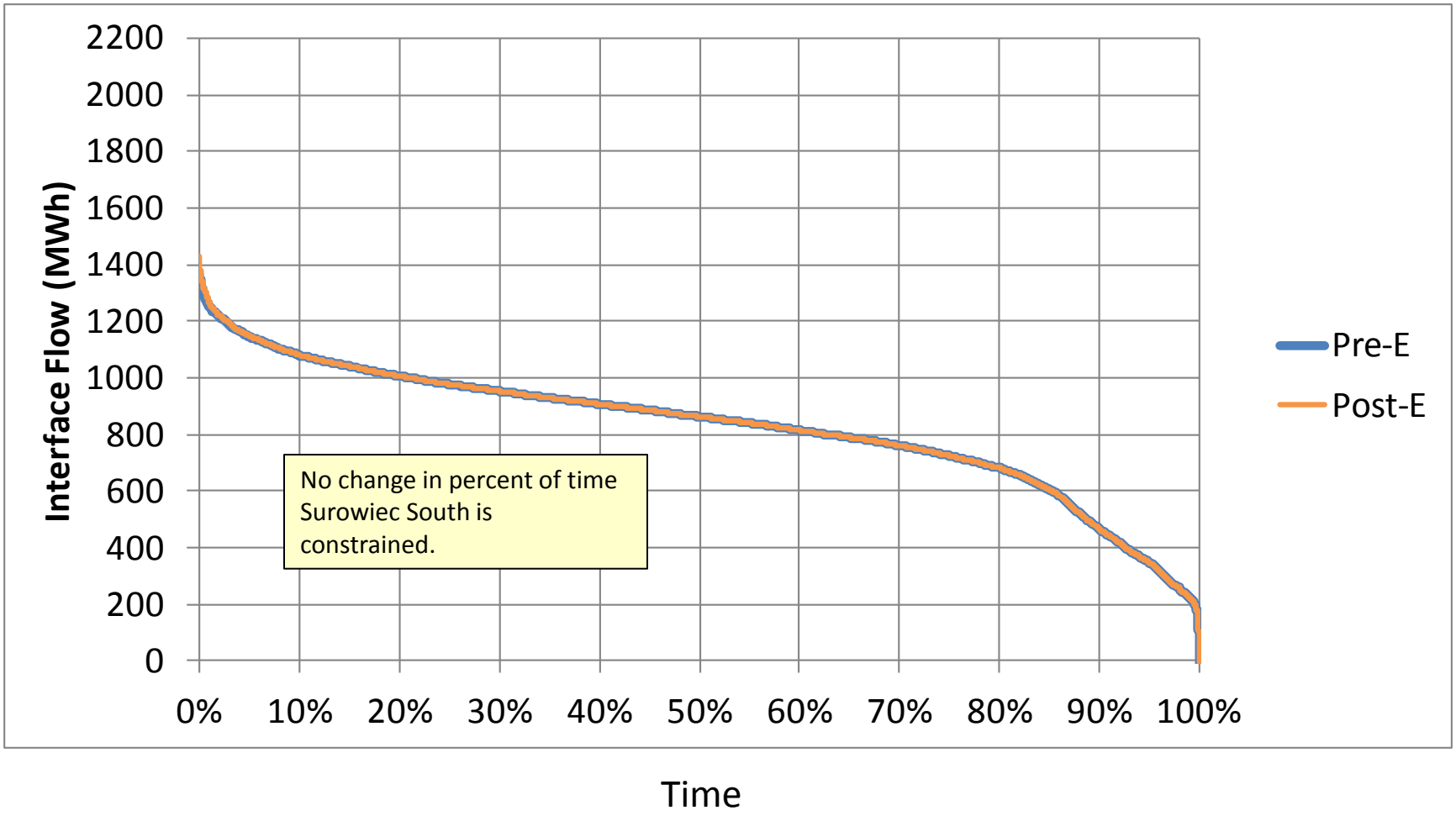
2015 Historical Interface Flow (MW)

Surowiec South (1,500 MW limit)



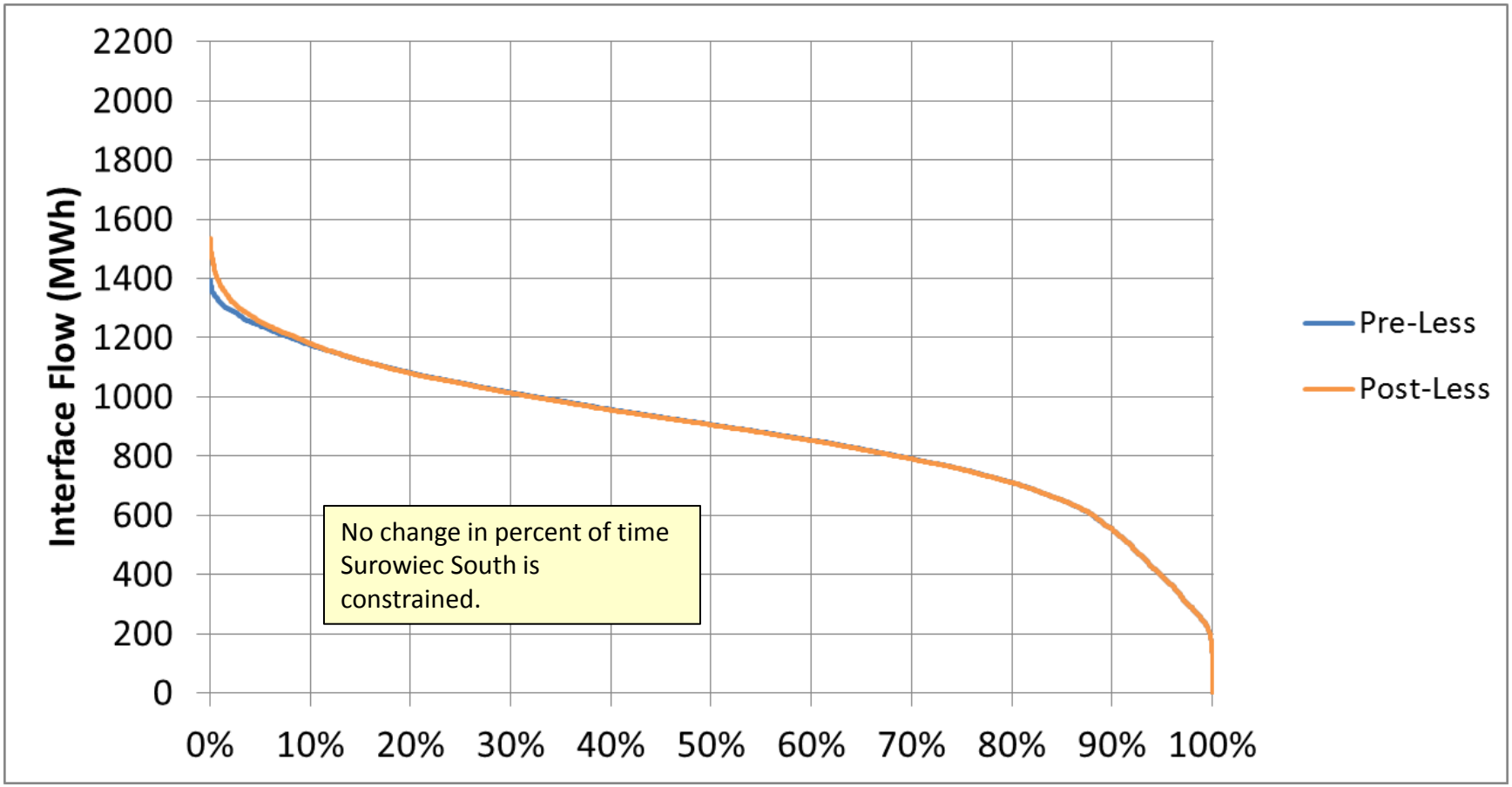
Interface: Surowiec South – Existing Wind

Duration Curve



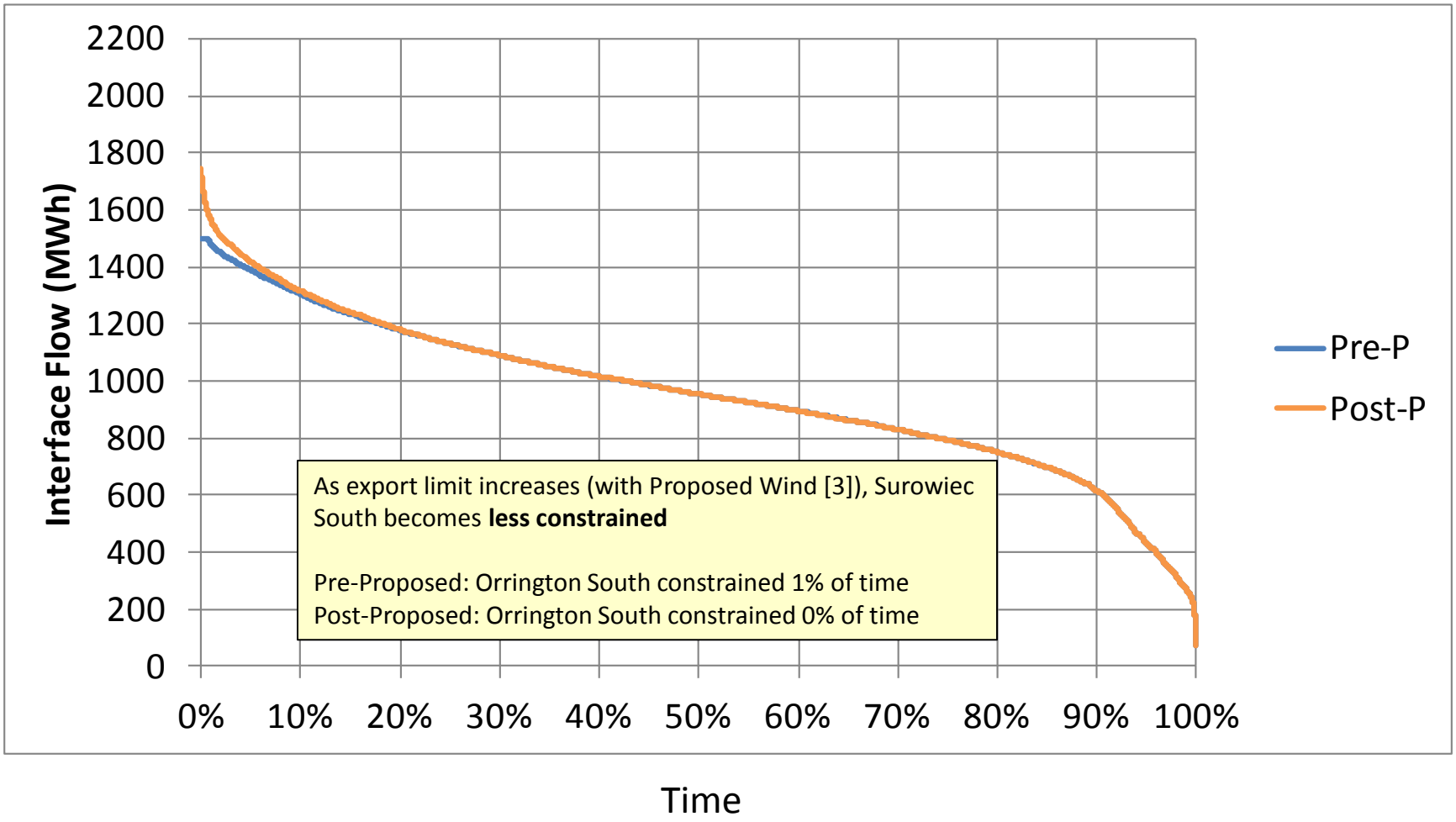
Interface: Surowiec South – Less Wind

Duration Curve



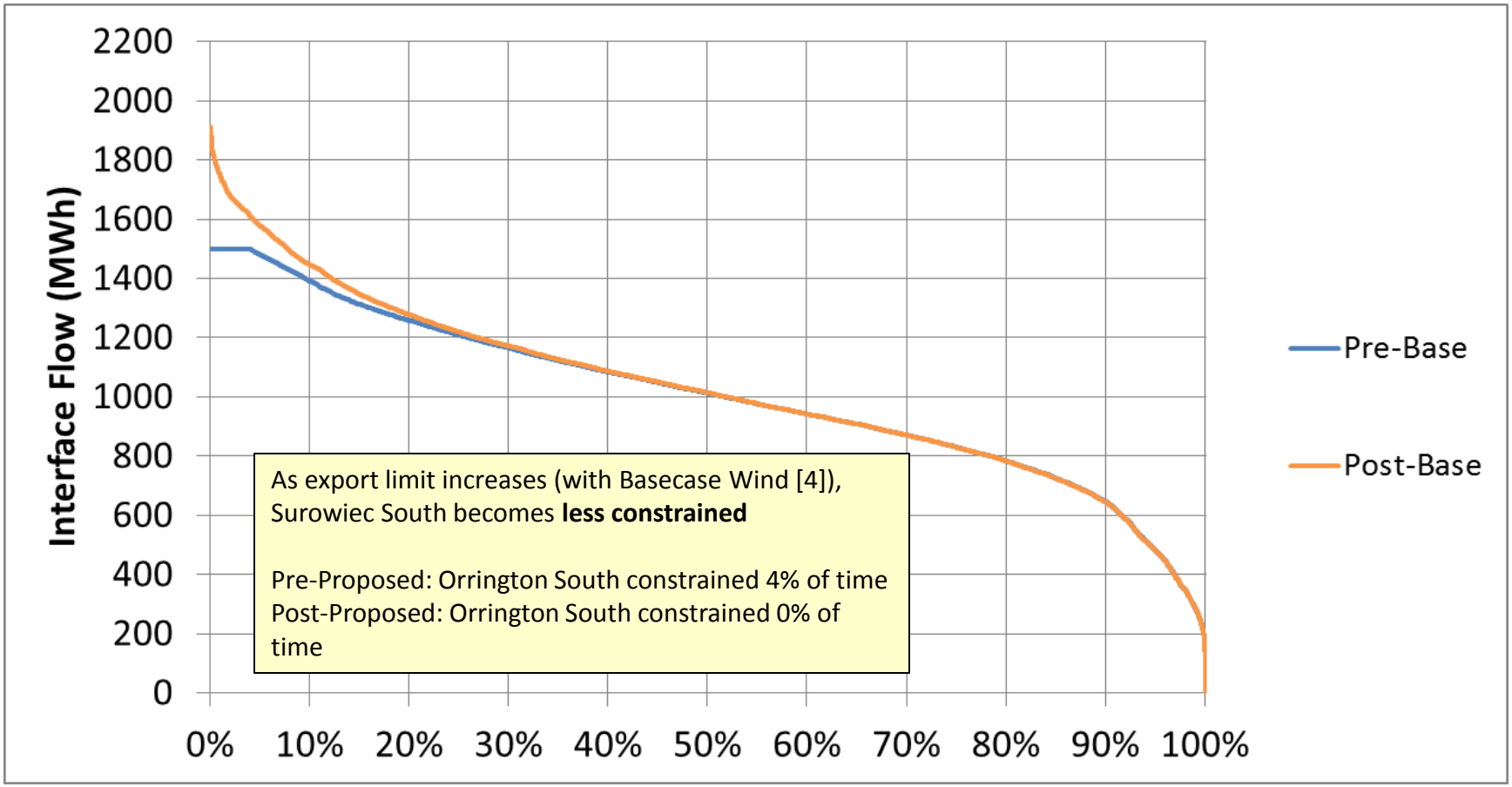
Interface: Surowiec South – Proposed Wind

Duration Curve



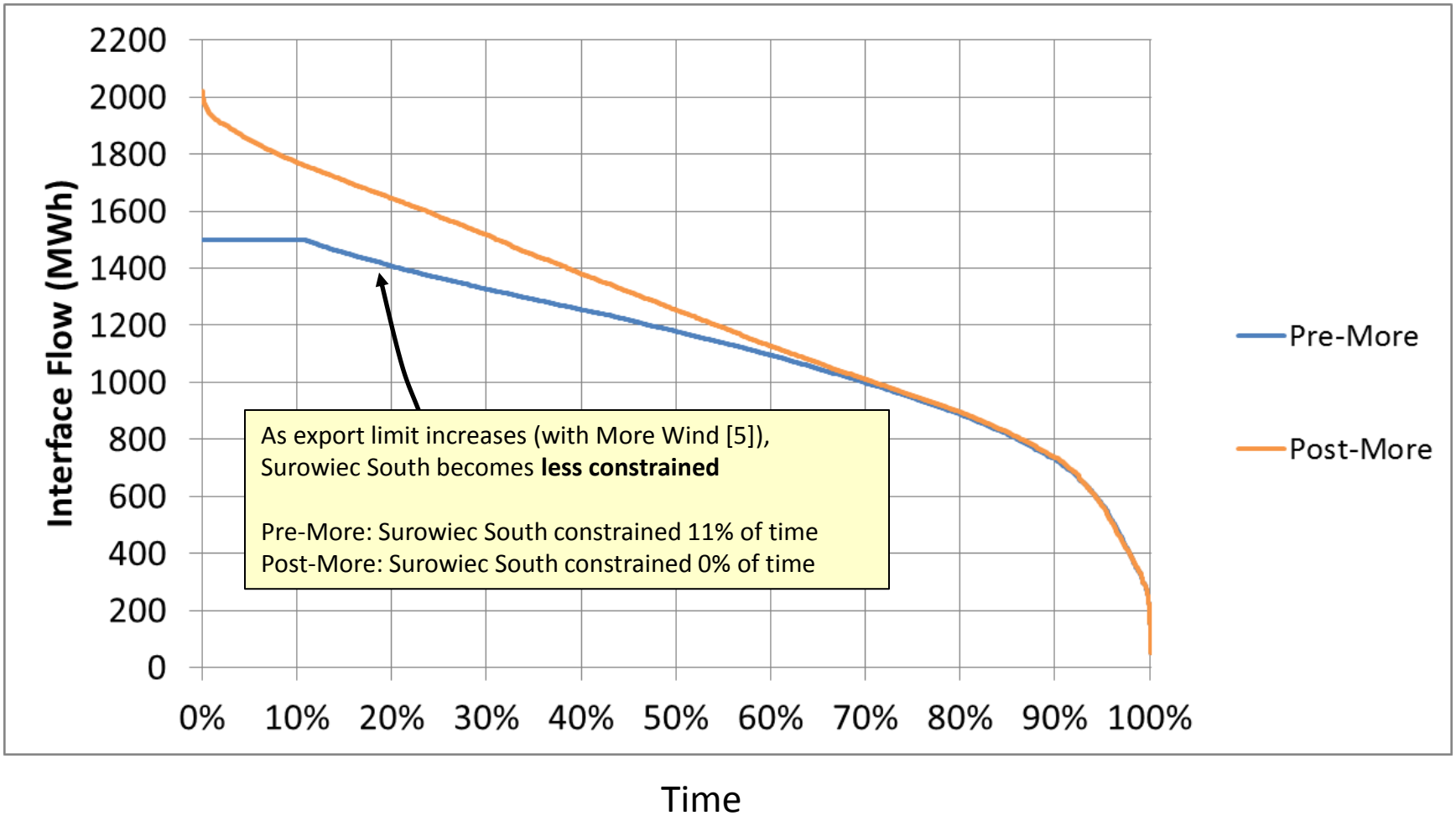
Interface: Surowiec South – Basecase Wind

Duration Curve



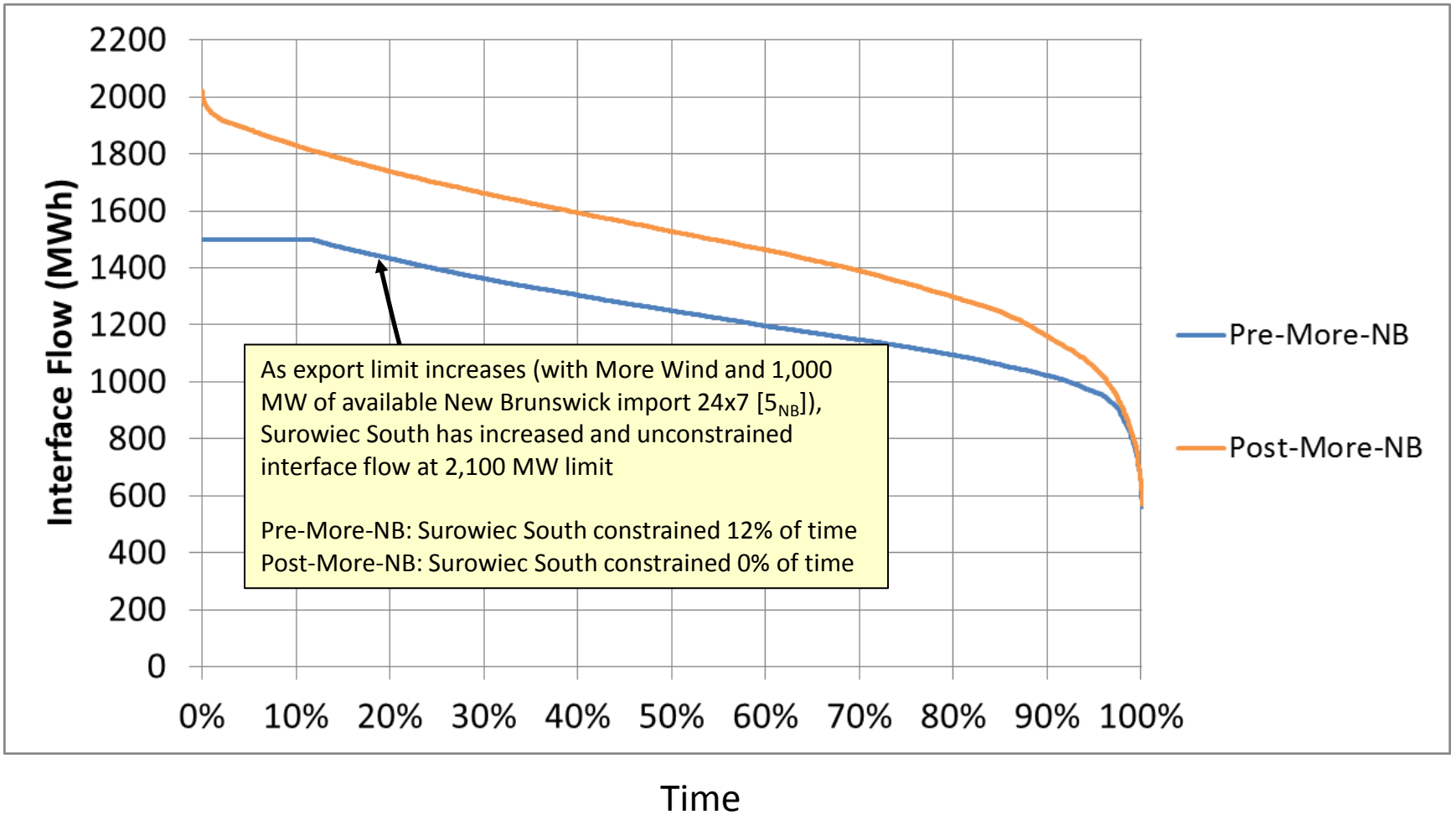
Interface: Surowiec South – More Wind

Duration Curve



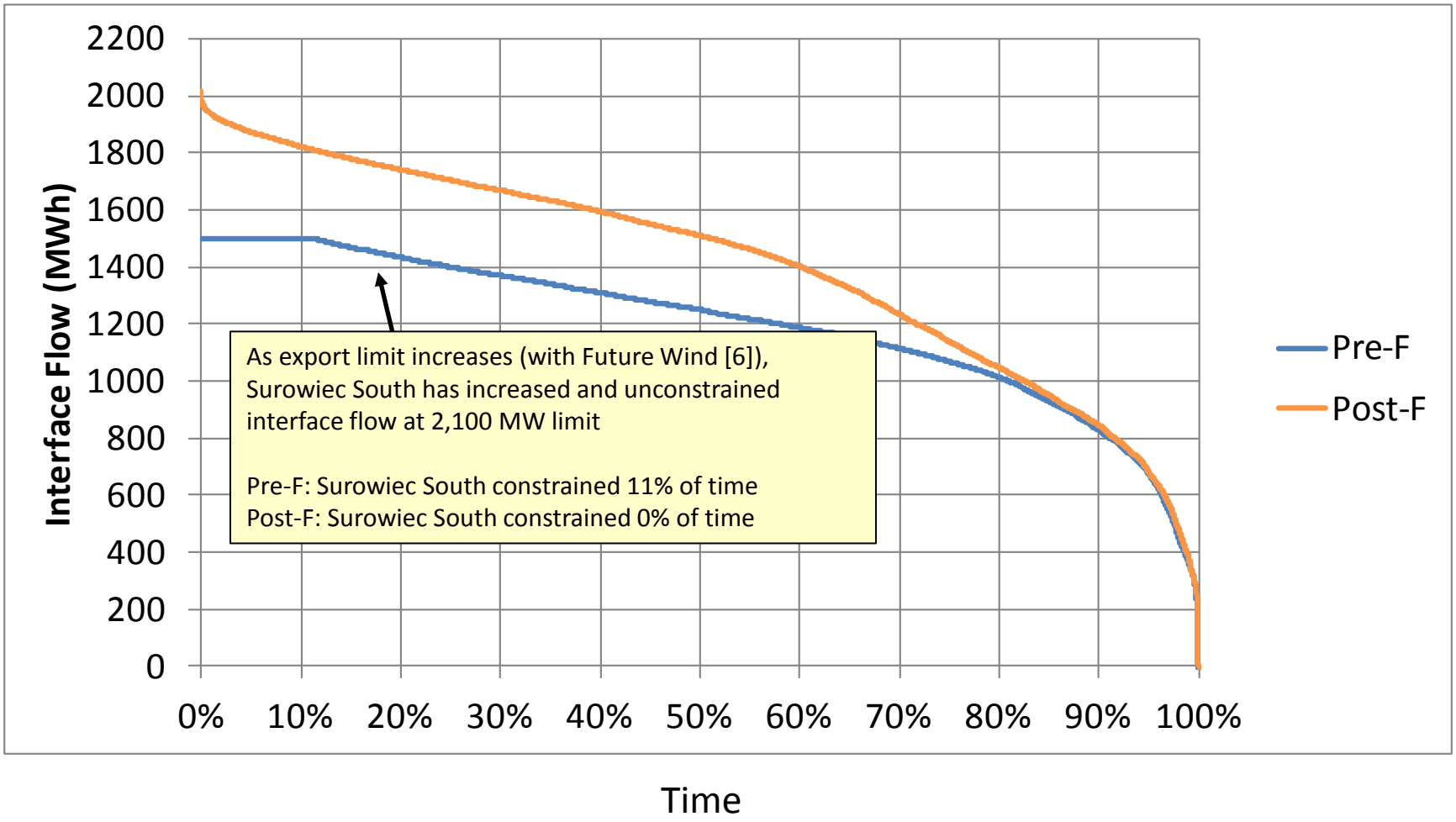
Interface: Surowiec South – More Wind with NB at 1000 MW

Duration Curve



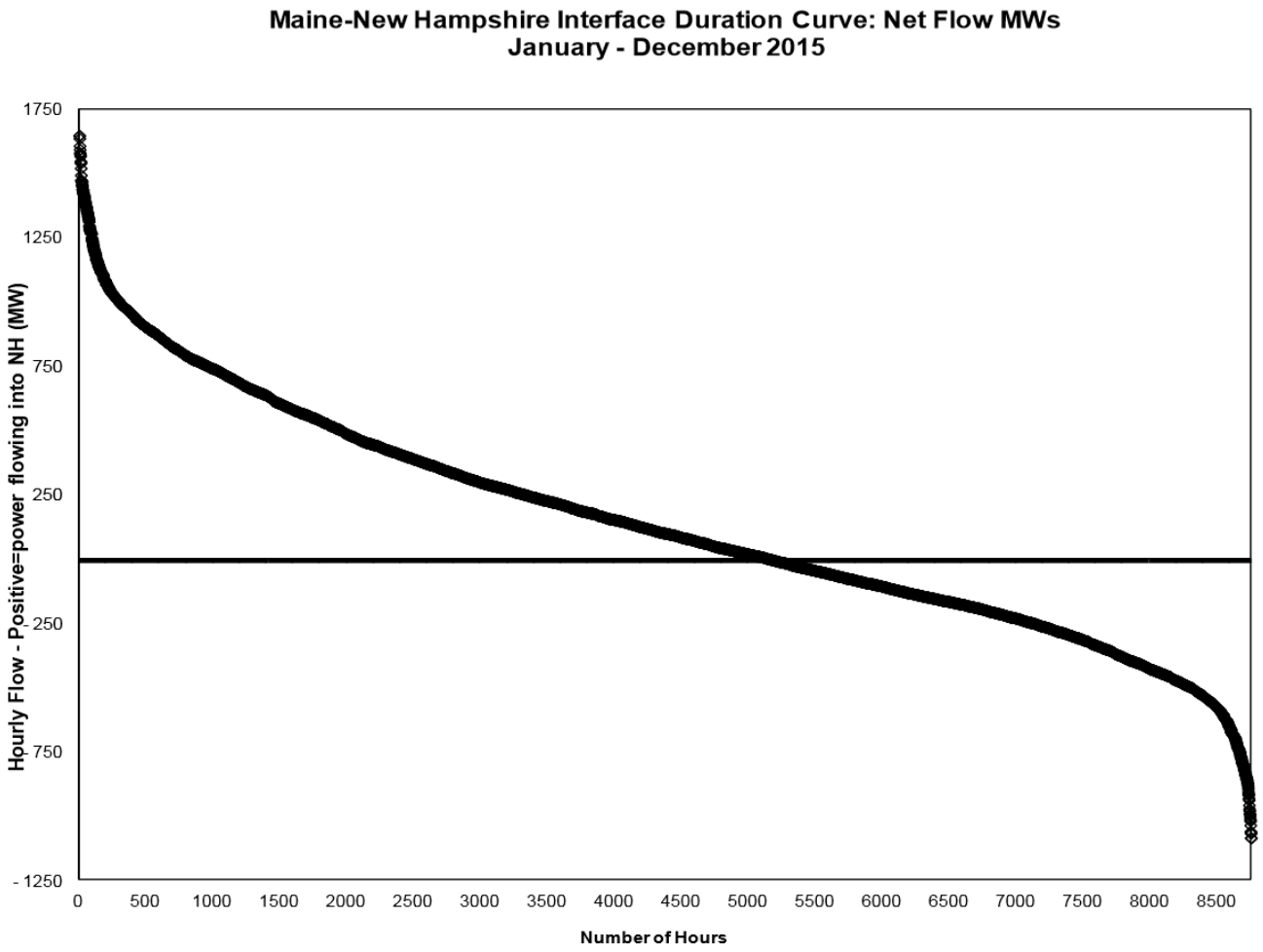
Interface: Surowiec South – Future Wind

Duration Curve



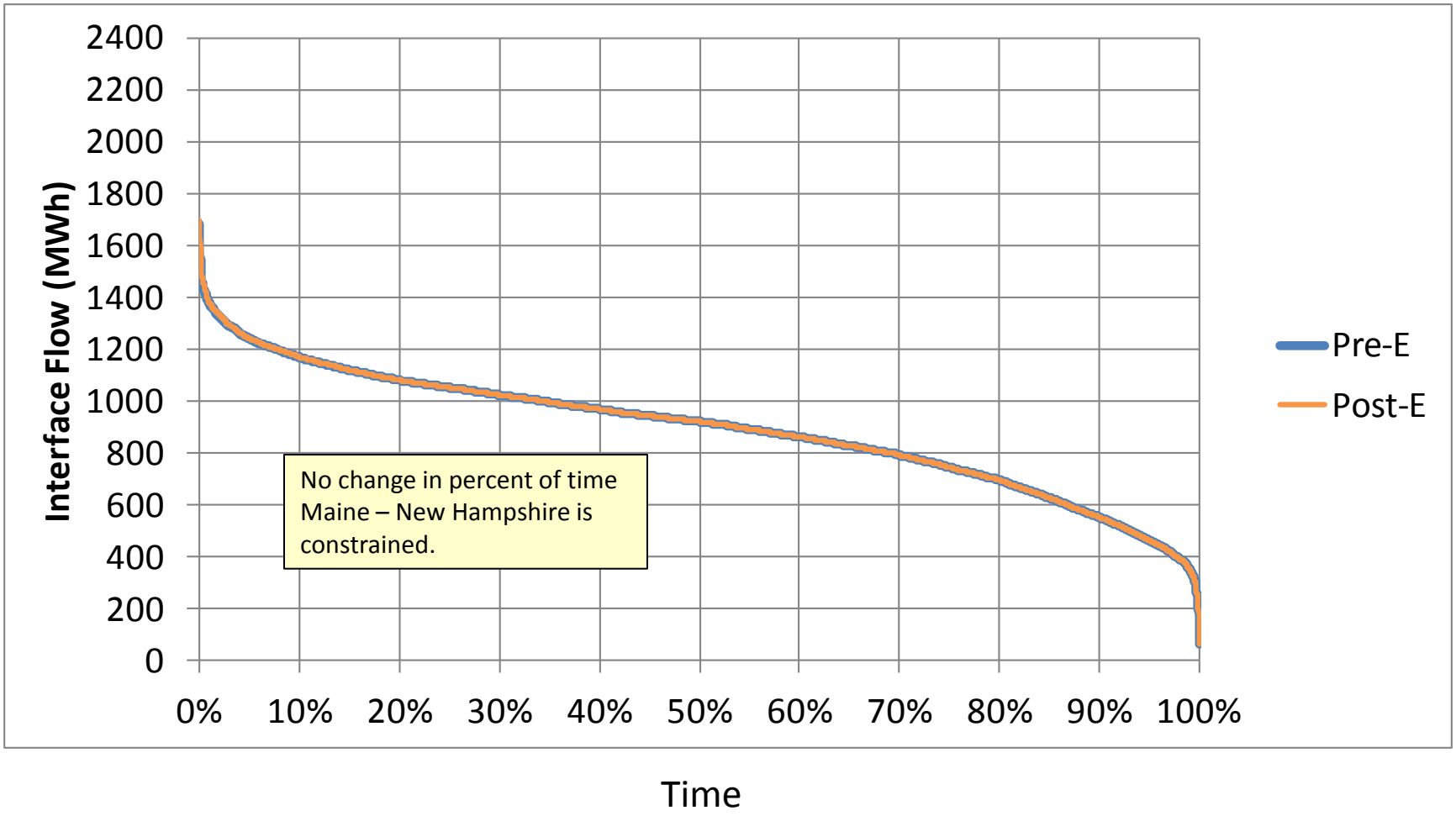
2015 Historical Interface Flow (MW)

Maine – New Hampshire (1,900 MW limit)



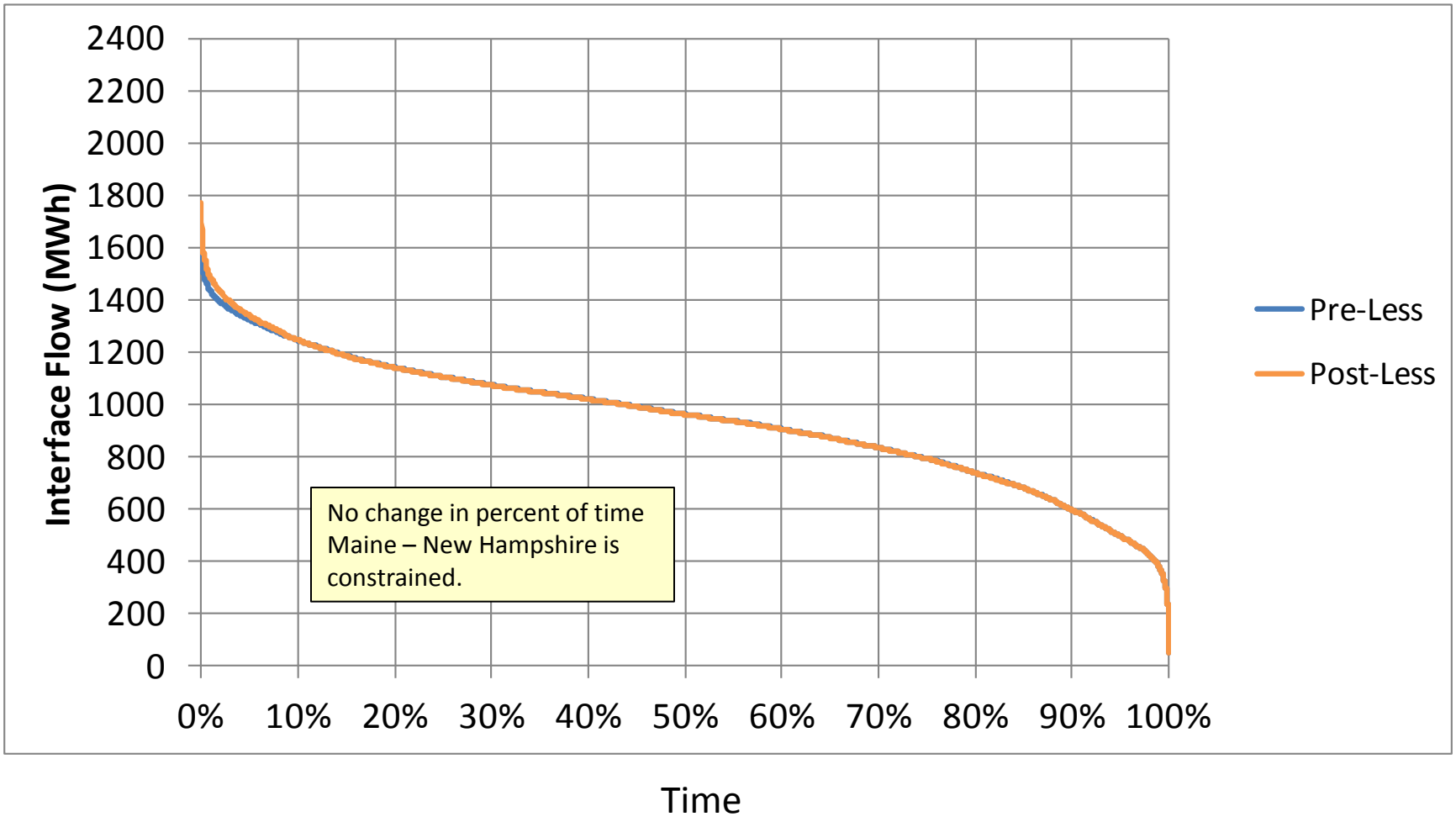
Interface: ME-NH – Existing Wind

Duration Curve



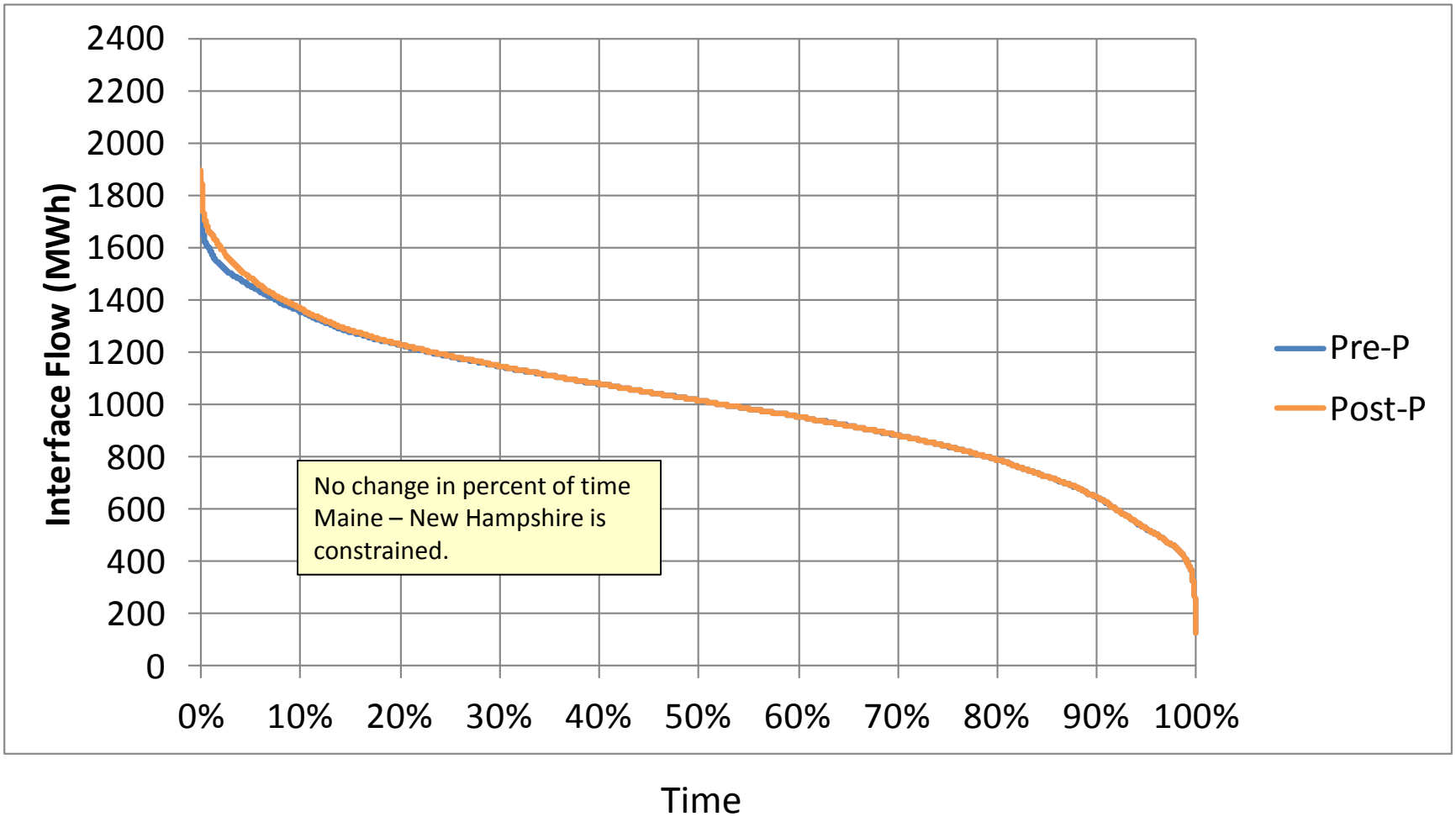
Interface: ME-NH – Less Wind

Duration Curve



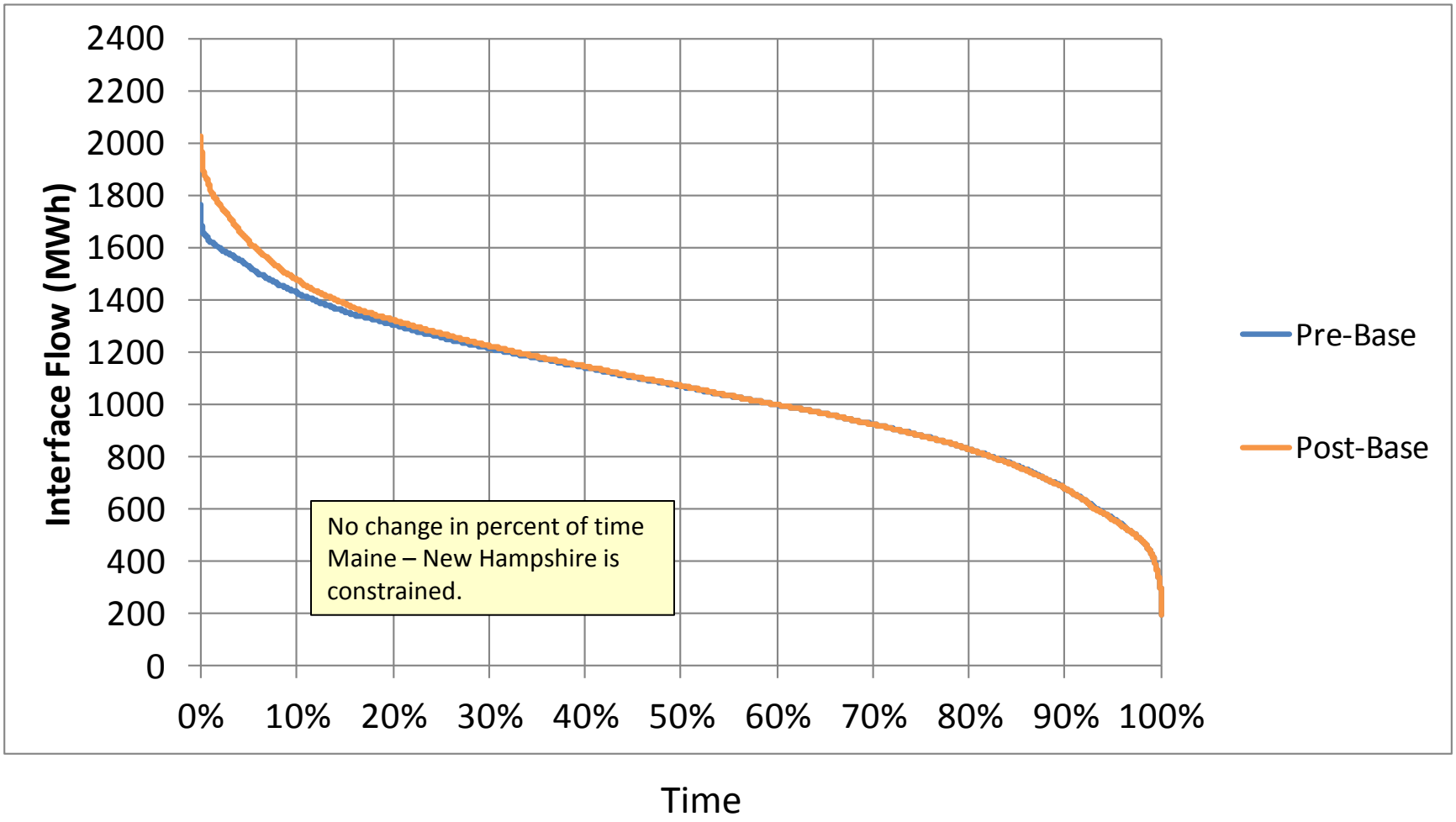
Interface: ME-NH – Proposed Wind

Duration Curve



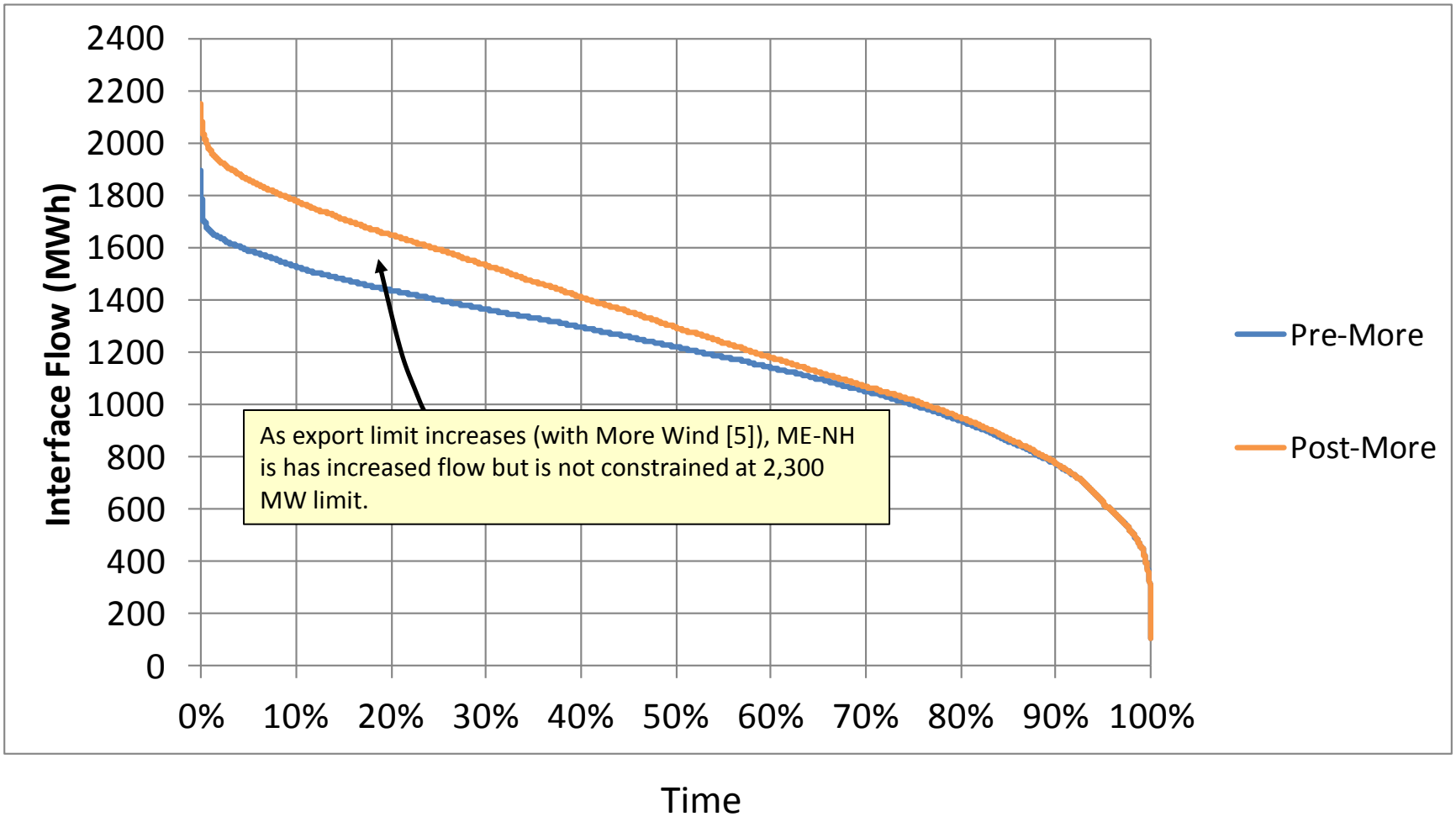
Interface: ME-NH – Basecase Wind

Duration Curve



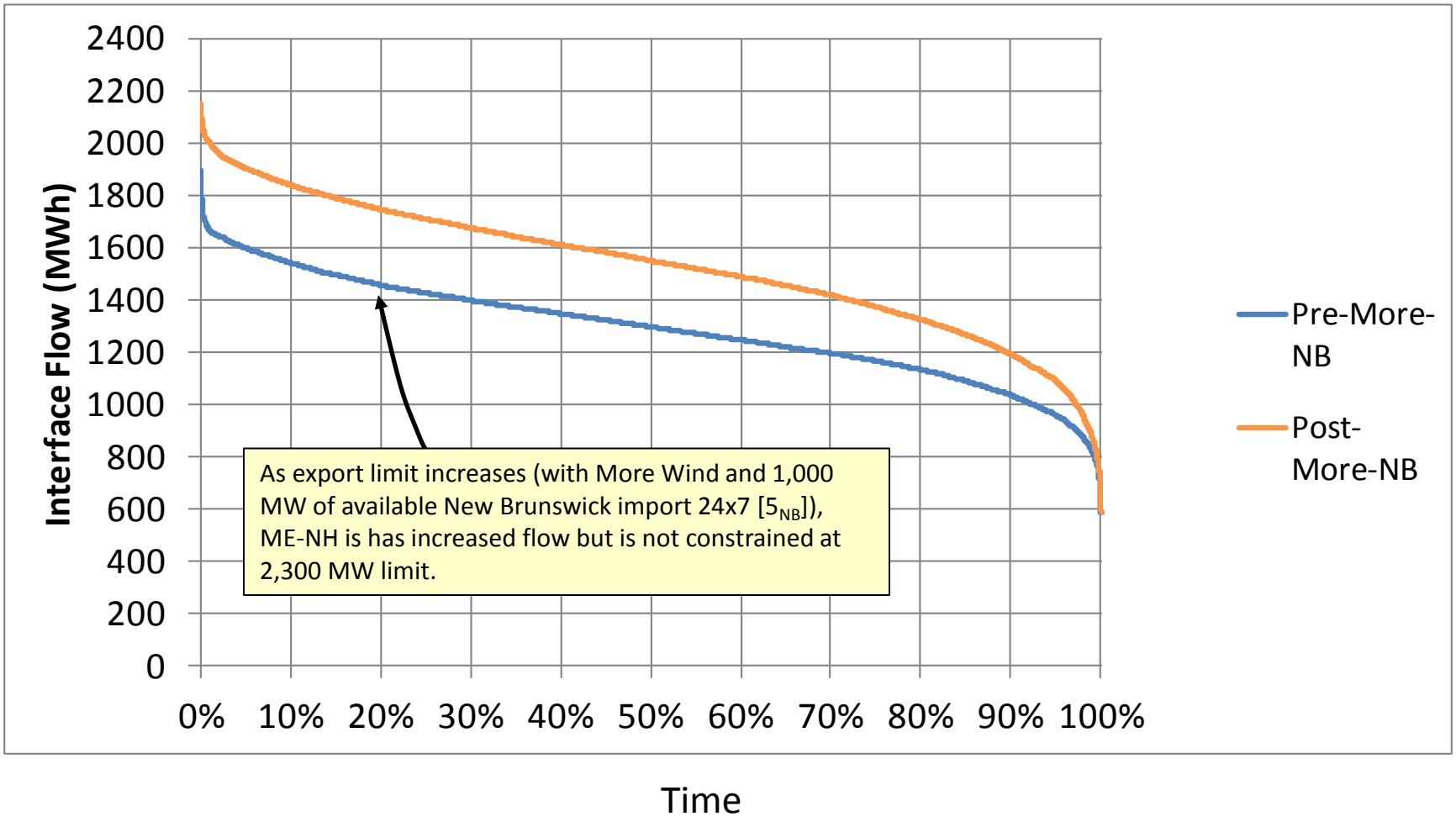
Interface: ME-NH – More Wind

Duration Curve



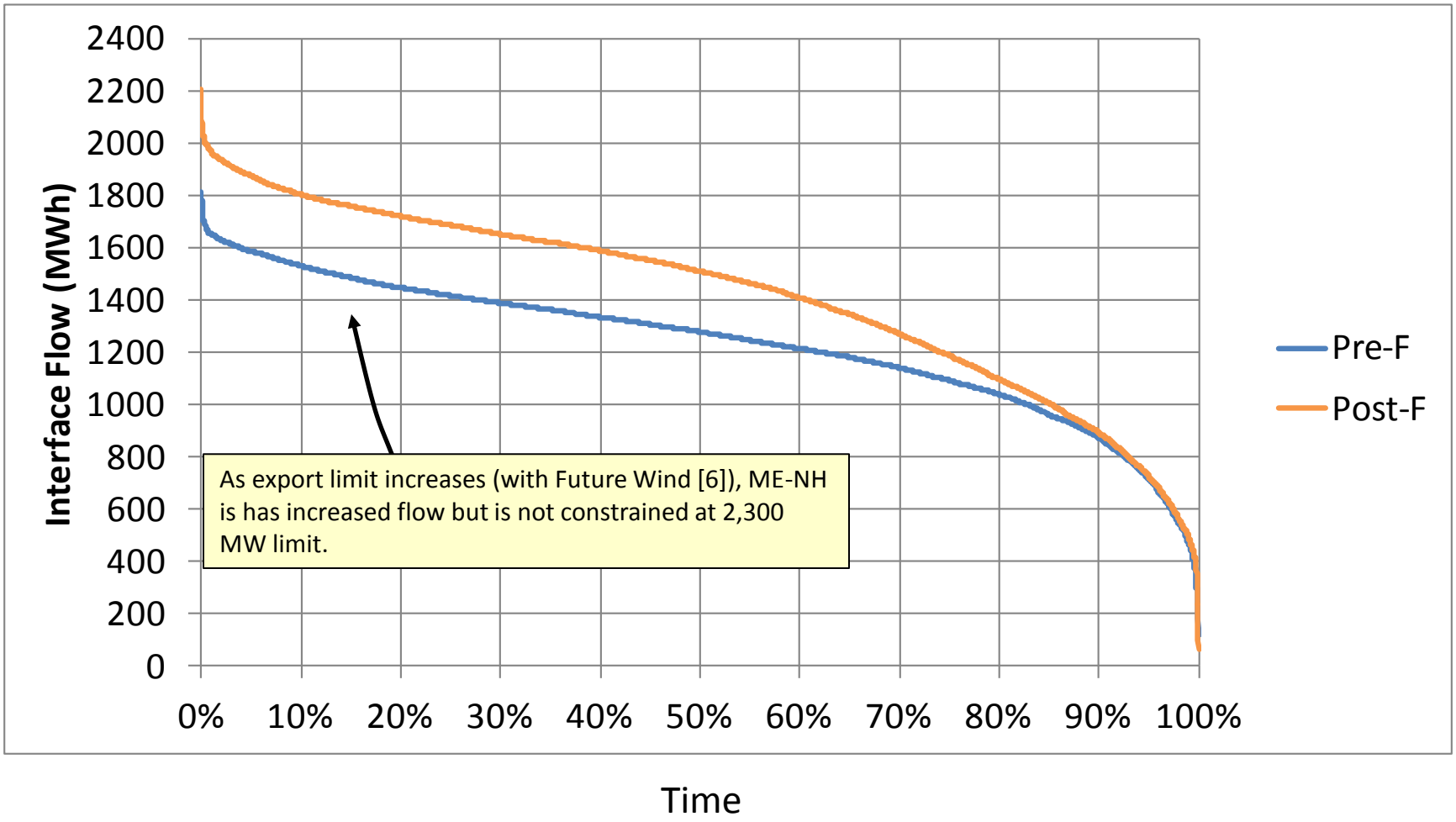
Interface: ME-NH – More Wind with NB at 1000 MW

Duration Curve



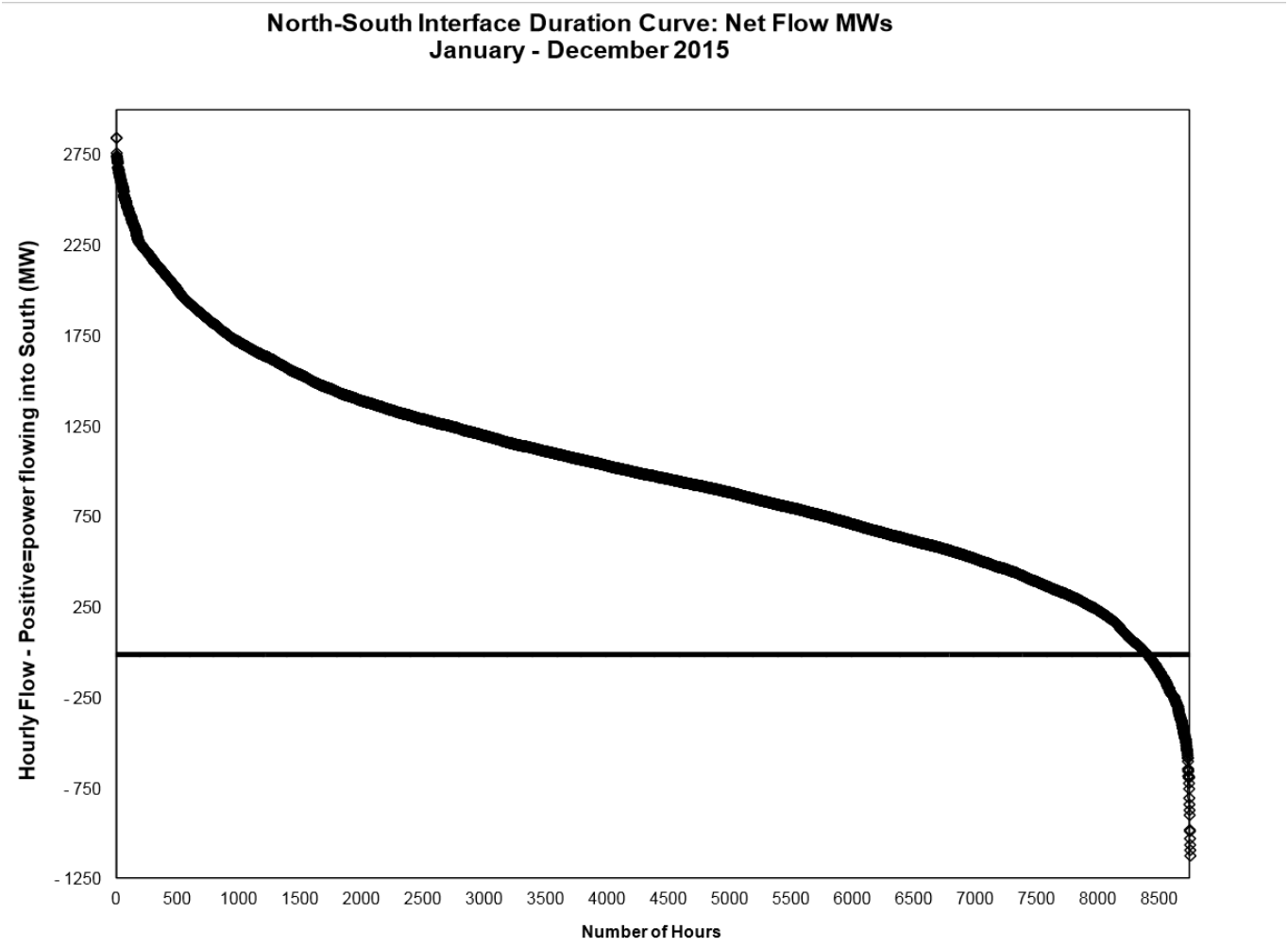
Interface: ME-NH – Future Wind

Duration Curve



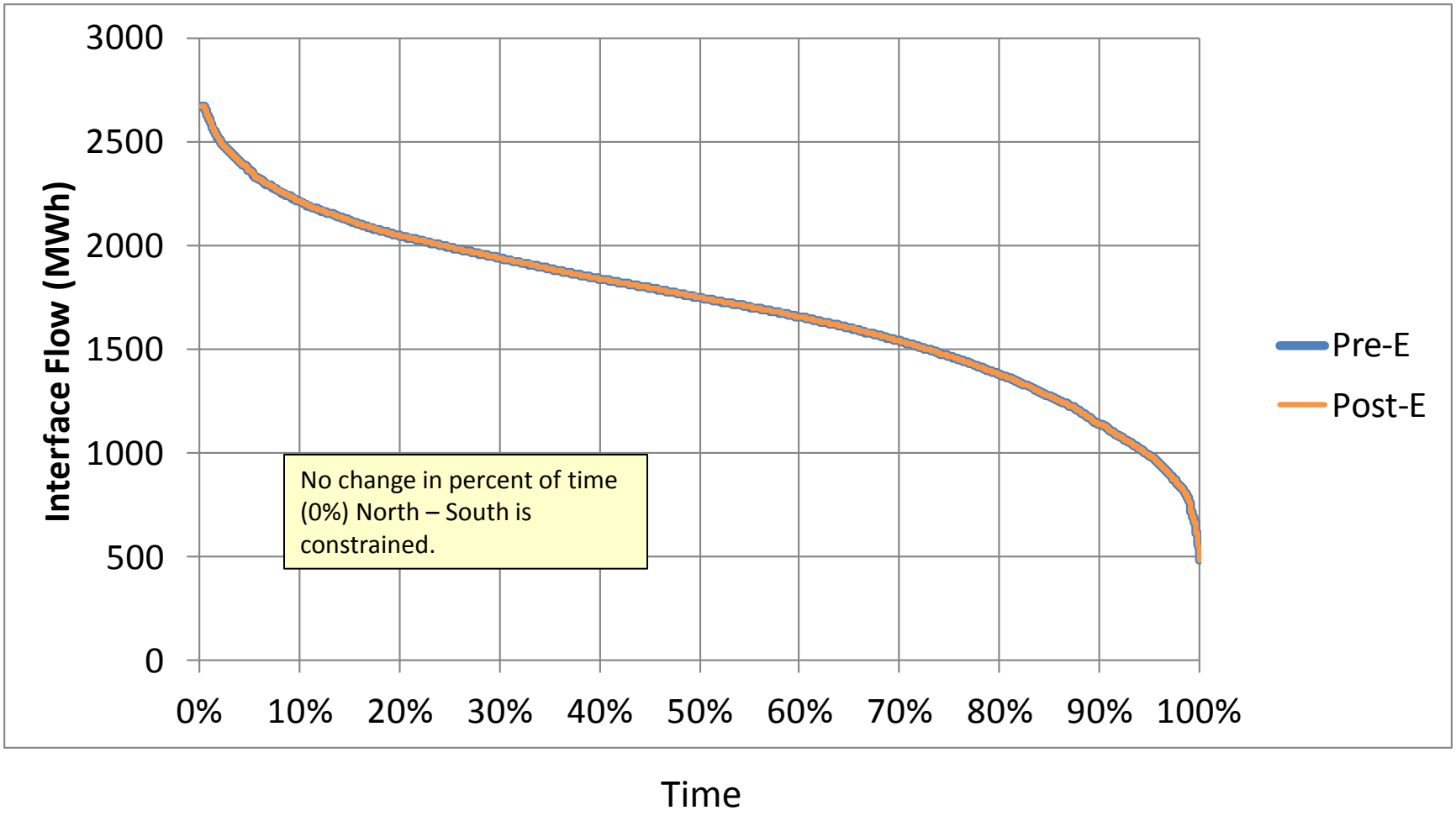
2015 Historical Interface Flow (MW)

North – South (2,675 MW limit)



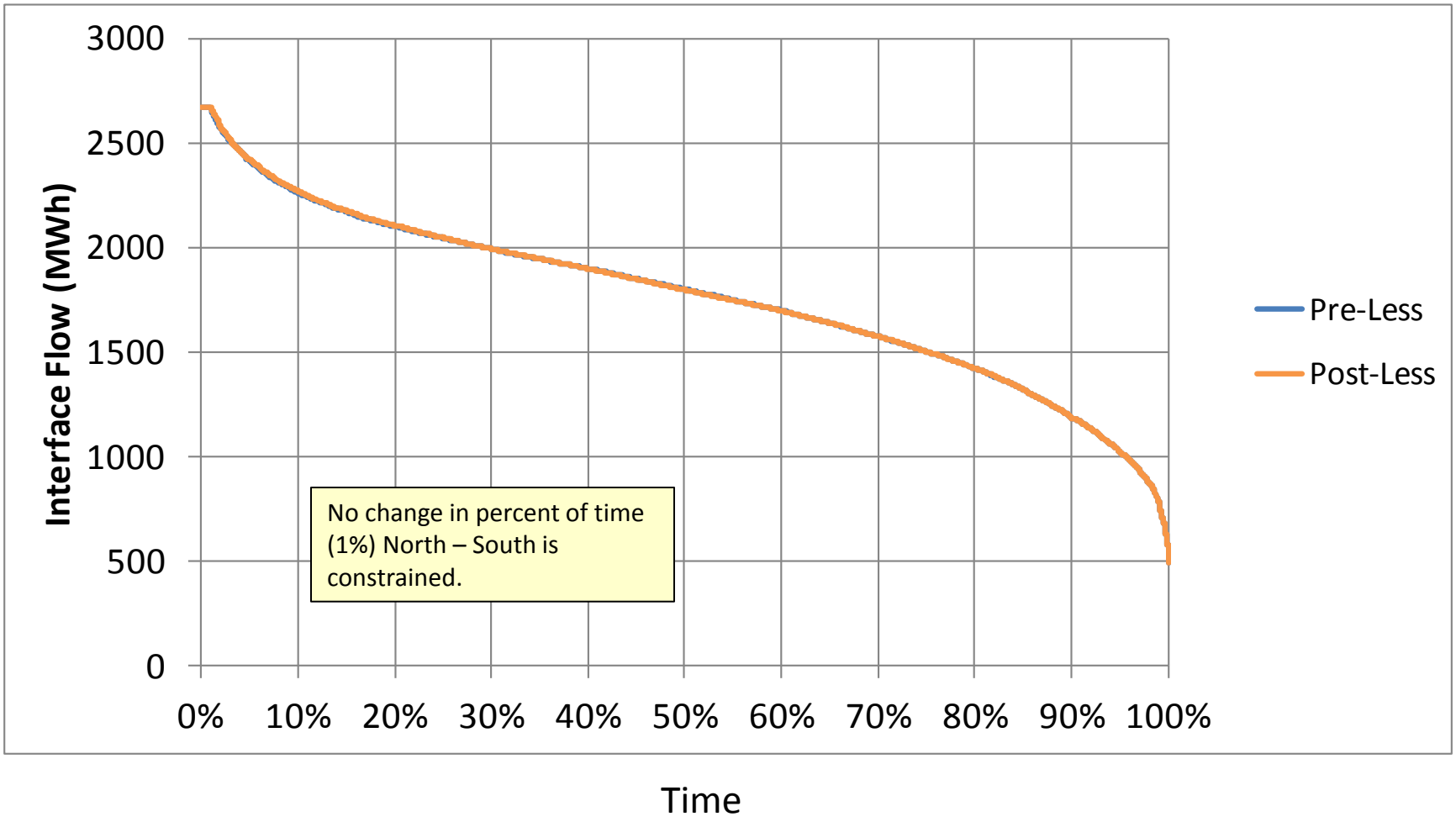
Interface: North-South – Existing Wind

Duration Curve



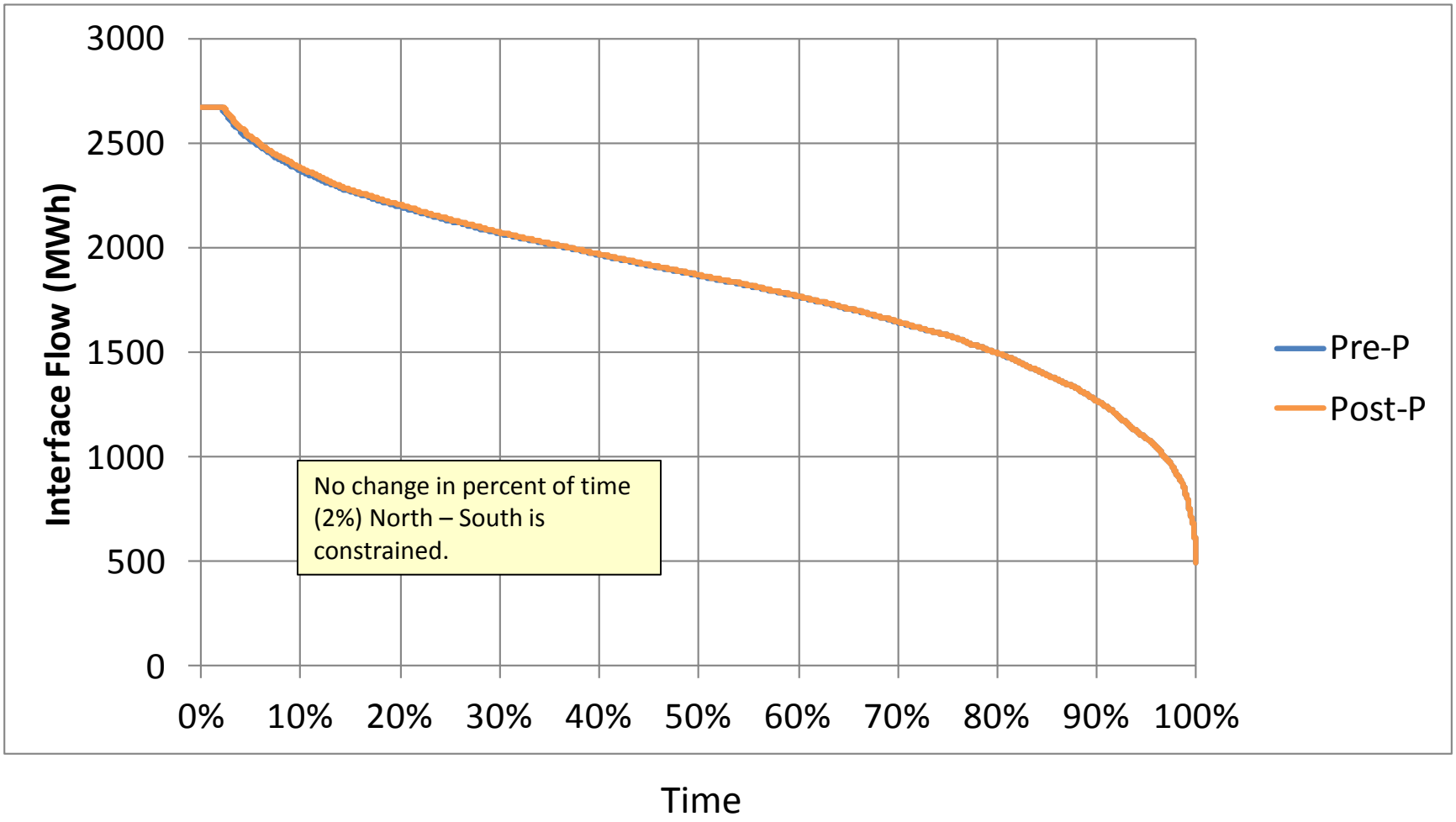
Interface: North-South – Less Wind

Duration Curve



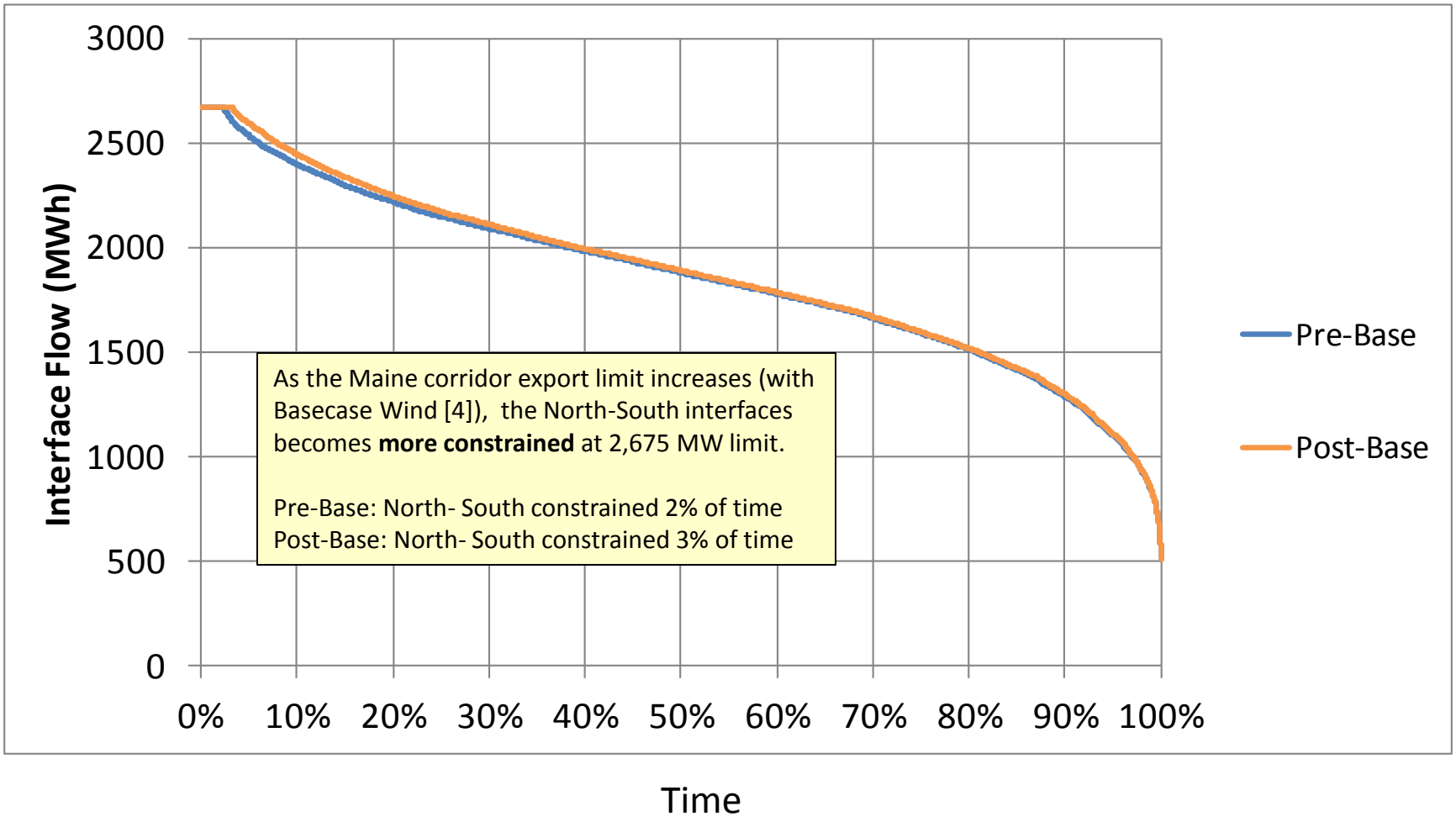
Interface: North-South – Proposed Wind

Duration Curve



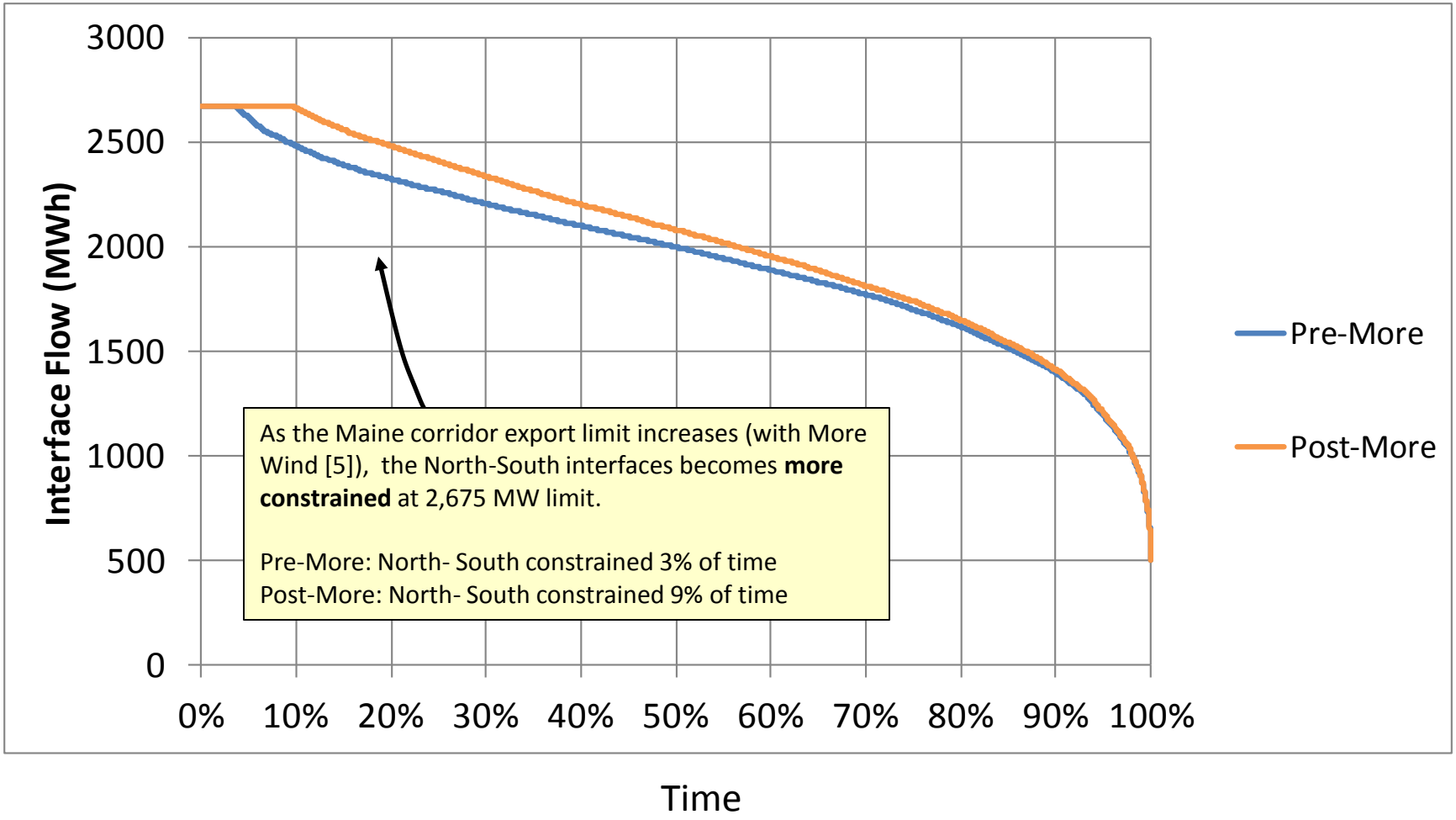
Interface: North-South – Basecase Wind

Duration Curve



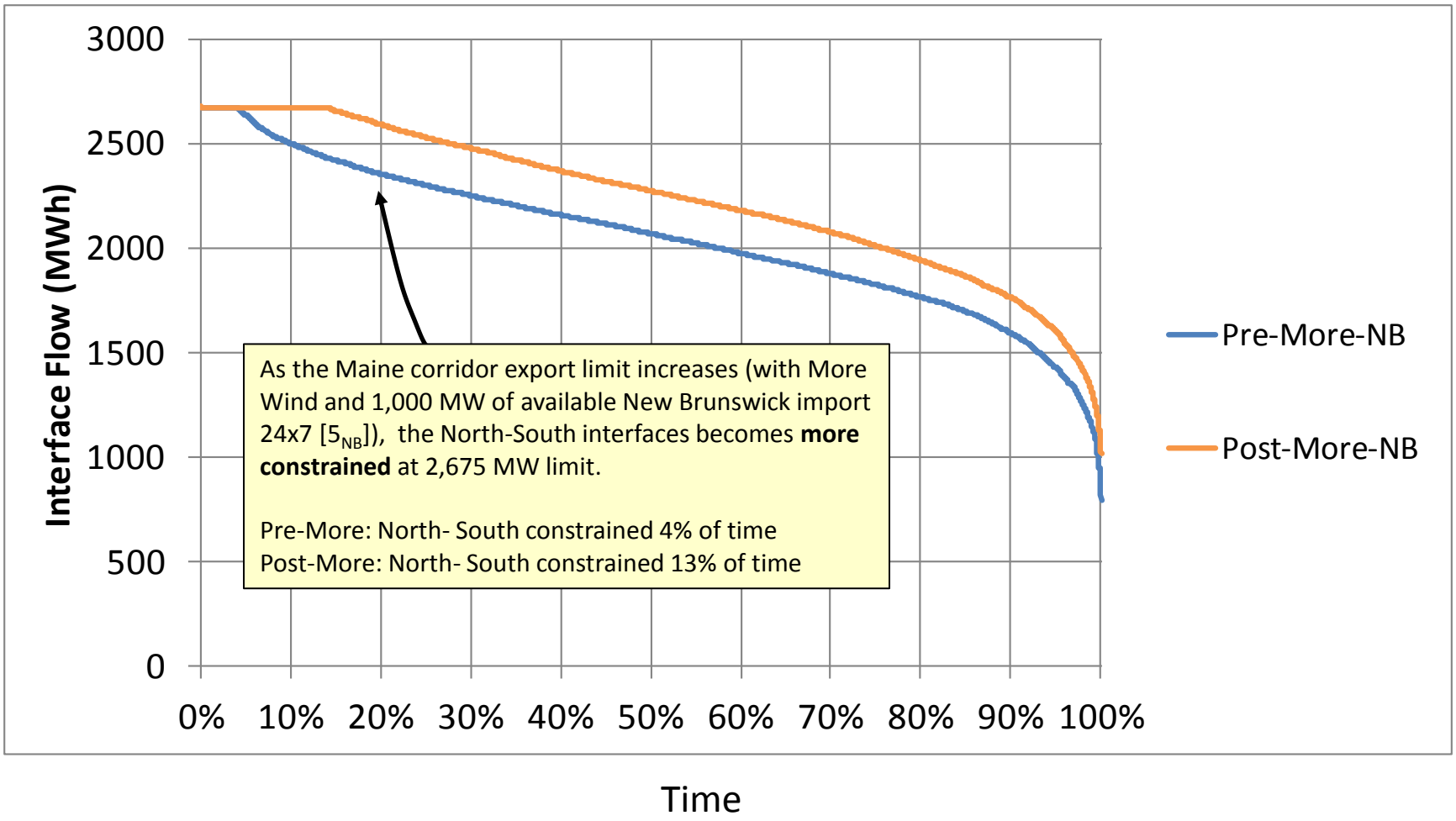
Interface: North-South – More Wind

Duration Curve



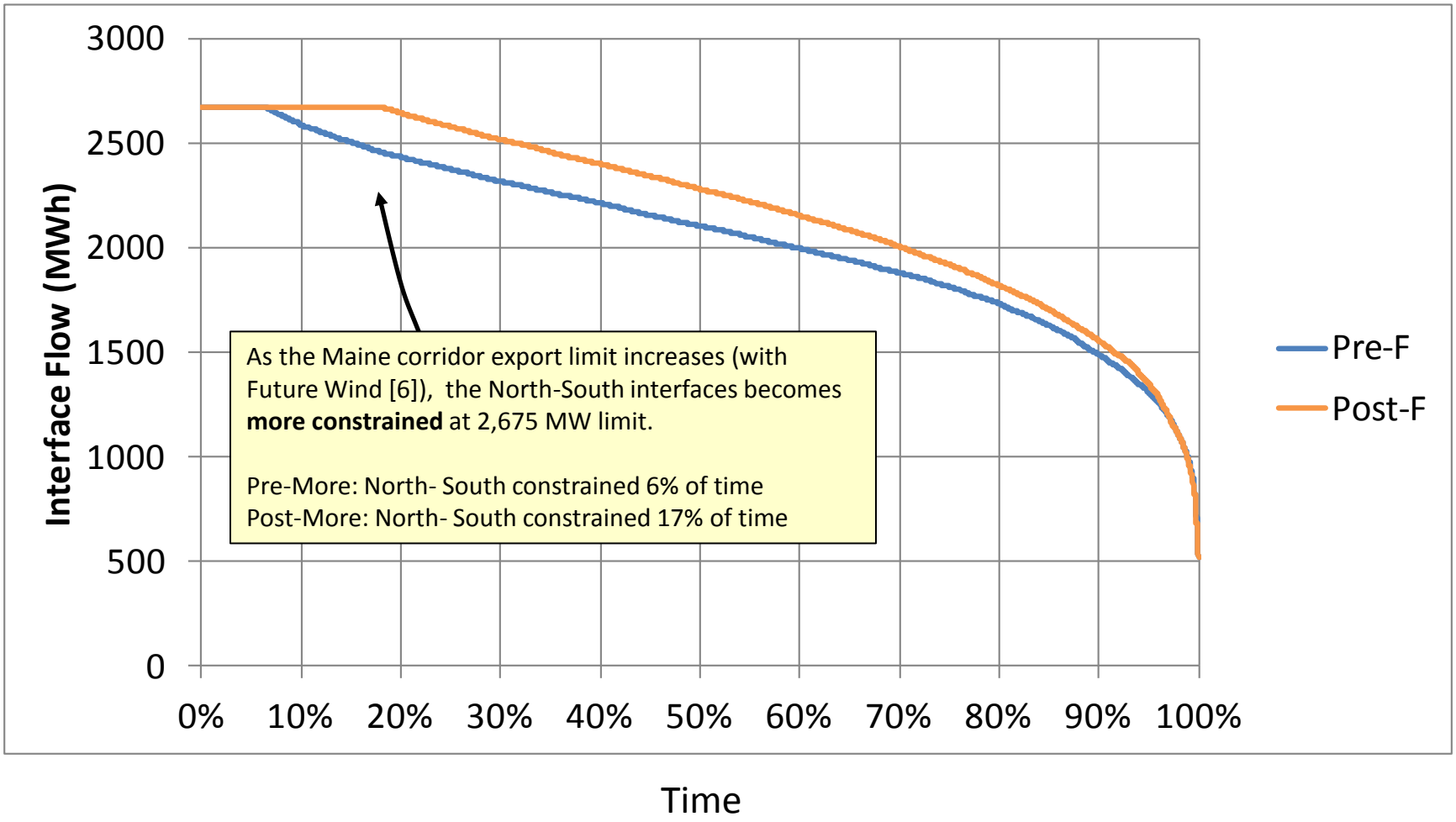
Interface: North-South – More Wind with NB at 1000 MW

Duration Curve



Interface: North-South – Future Wind

Duration Curve



APPENDIX VI

LMP Metrics

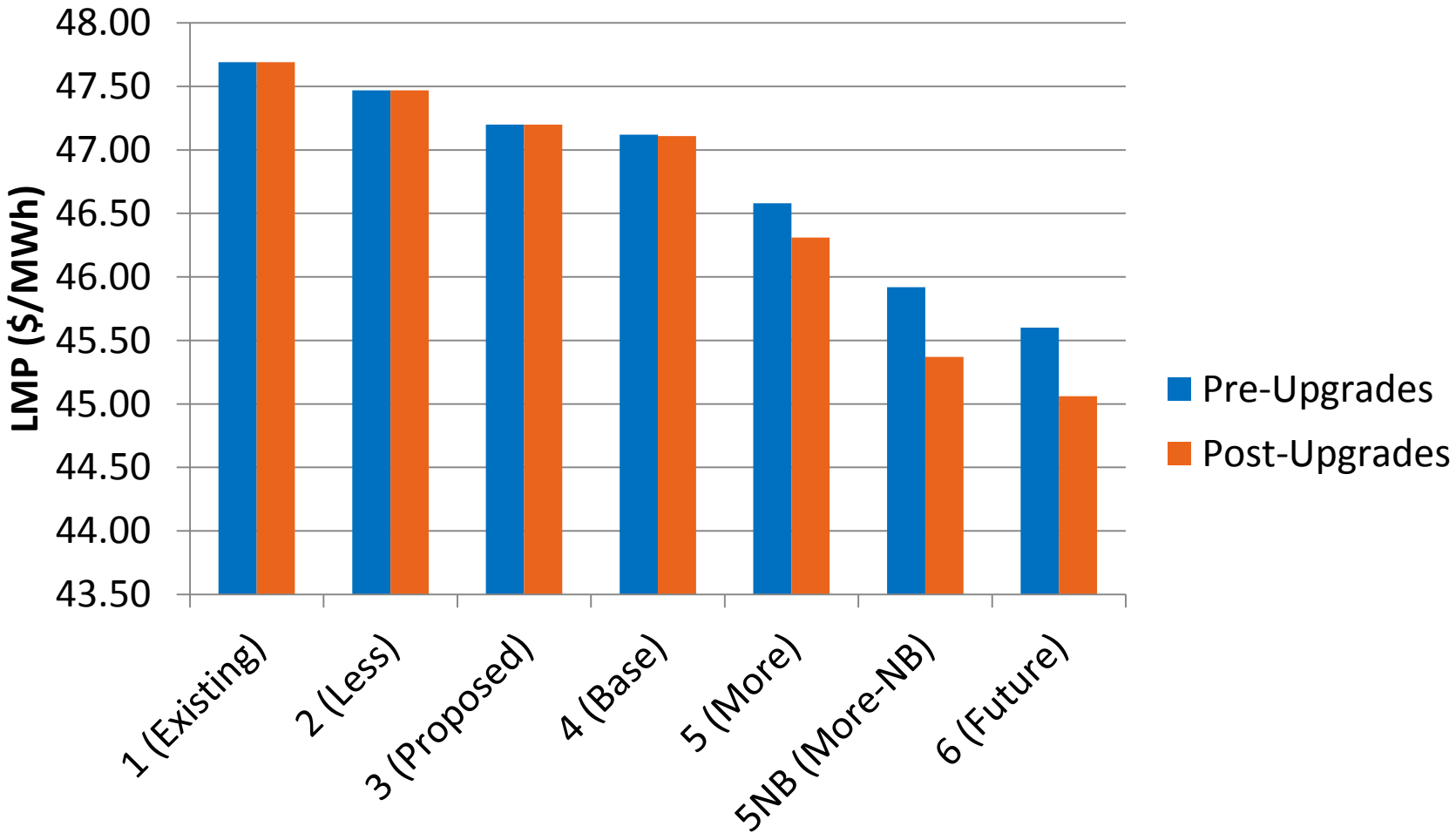
Summary

LMP Metrics

- LMP duration curves allow the effect of the three classes of study resources to be seen
  - At $0/MWh wind-on-wind competition spills wind
  - At $5/MWh hydro is spilled
  - At $10/MWh imports are curtailed

New England LMP – weighted by load ($/MWh)

Graph



New England LMP – weighted by load ($/MWh)

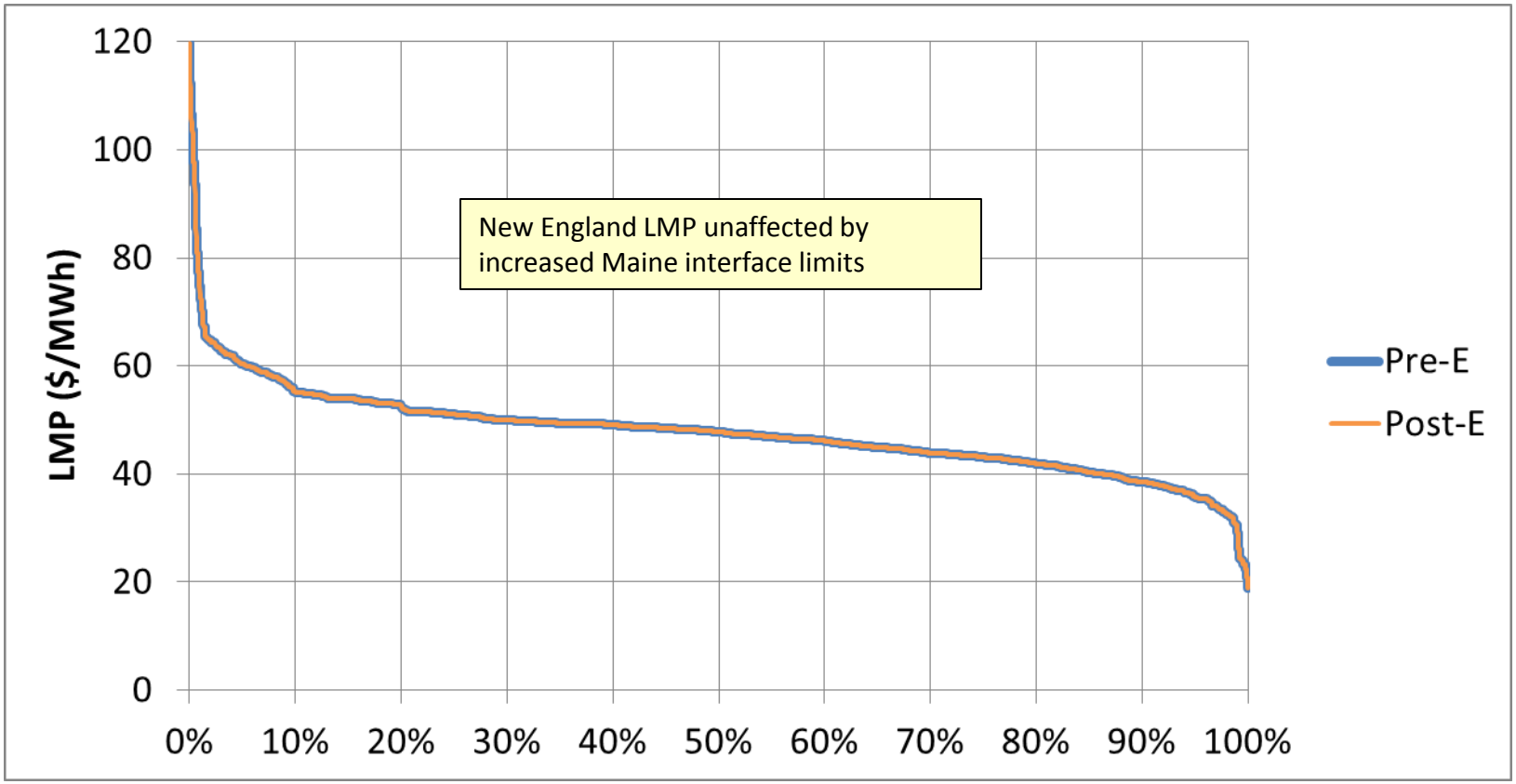
Table

	Scenarios	LMP ($/MWh)	
		Pre-Upgrades	Post-Upgrades
1	Existing Wind in New England (In-Service as of 4/1/15) *	47.69	47.69
2	RENEW Sensitivity 1 (Less Wind) *	47.47	47.47
3	Proposed Wind in New England with I.3.9 approval (as of 4/1/15)	47.20	47.20
4	RENEW Basecase – STA-WI Studied Wind (as of 10/1/13) *	47.12	47.11
5	RENEW Sensitivity 2 (More Wind)*	46.58	46.31
5_{NB}	RENEW Sensitivity 2 (More Wind)* and 1,000 MW of NB imports available for dispatch	45.92	45.37
6	All Future Queue Wind in New England Wind (as of 4/1/15)	45.60	45.06

*Outside Maine, assumed only "existing wind" as of 4/1/15

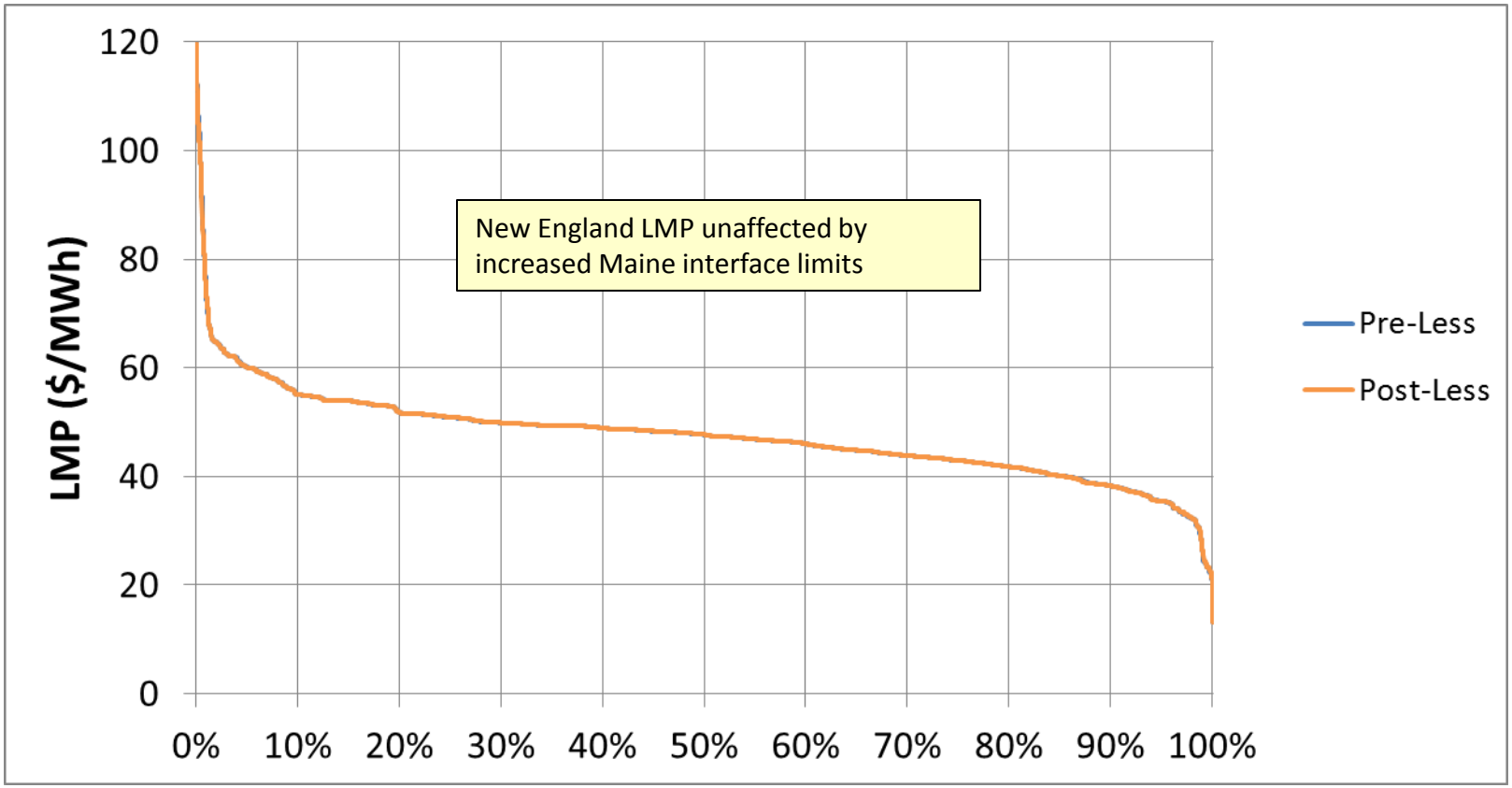
LMP: New England – Existing Wind

Duration Curve



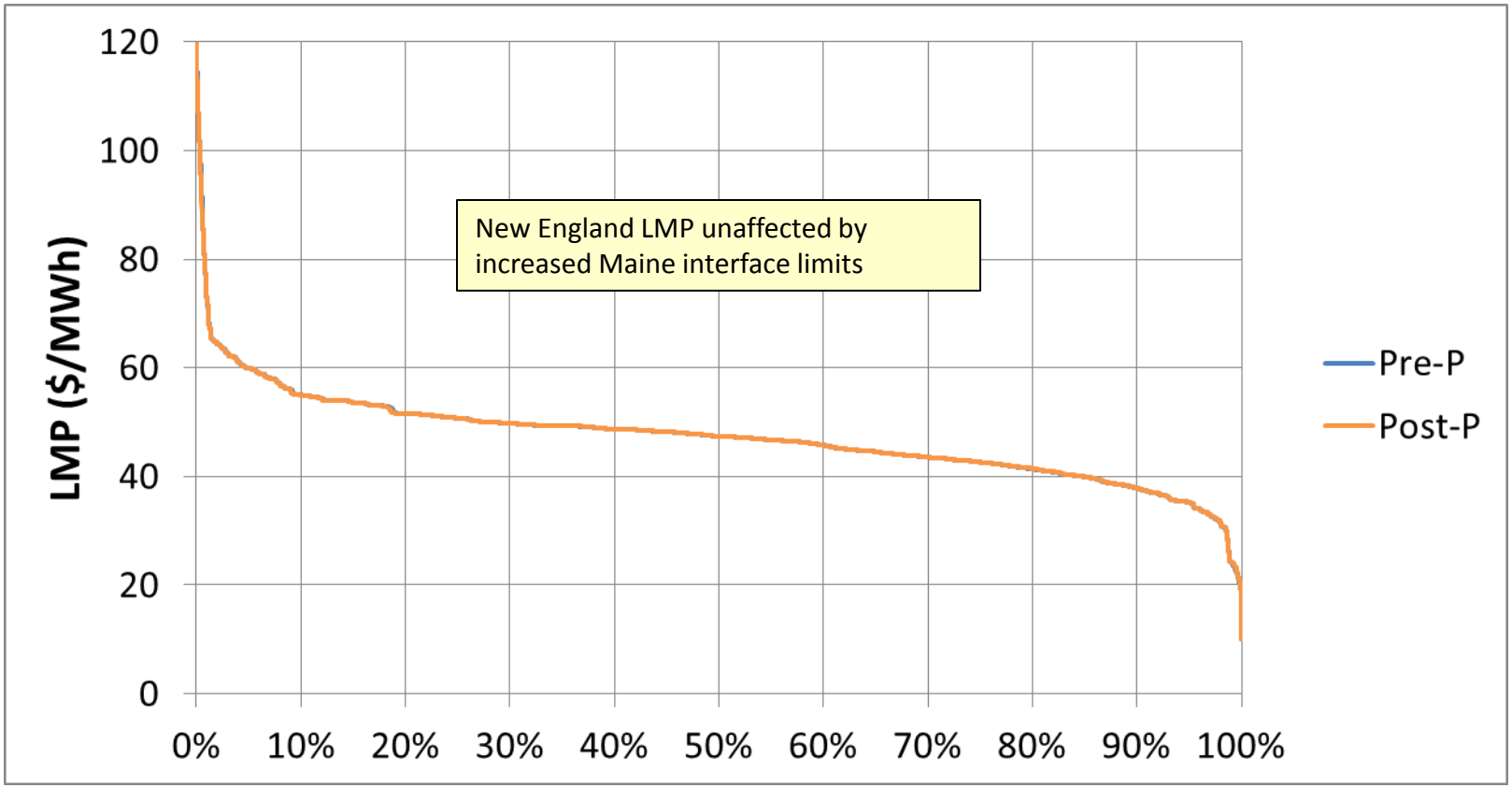
LMP: New England – Less Wind

Duration Curve



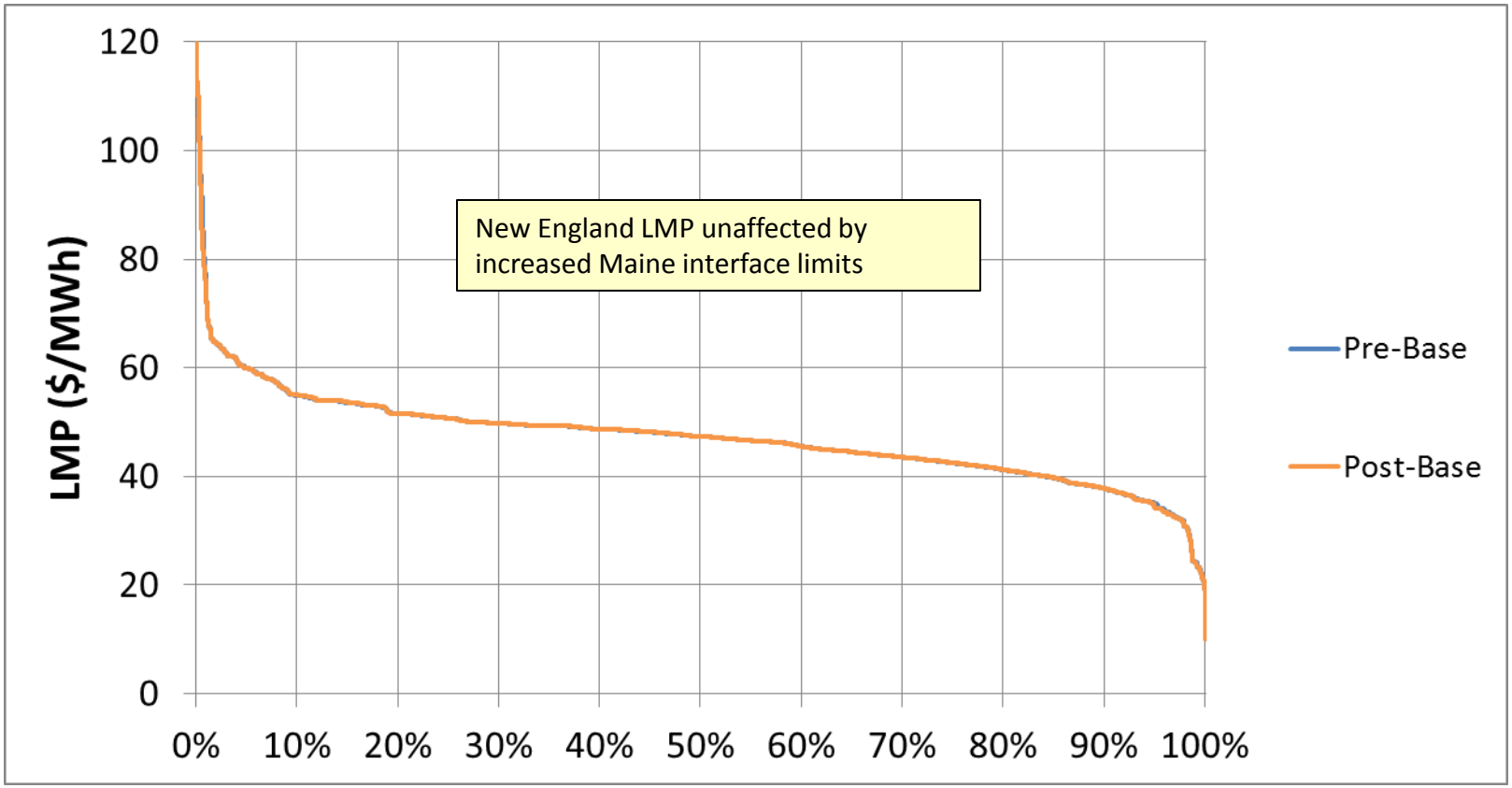
LMP: New England – Proposed Wind

Duration Curve



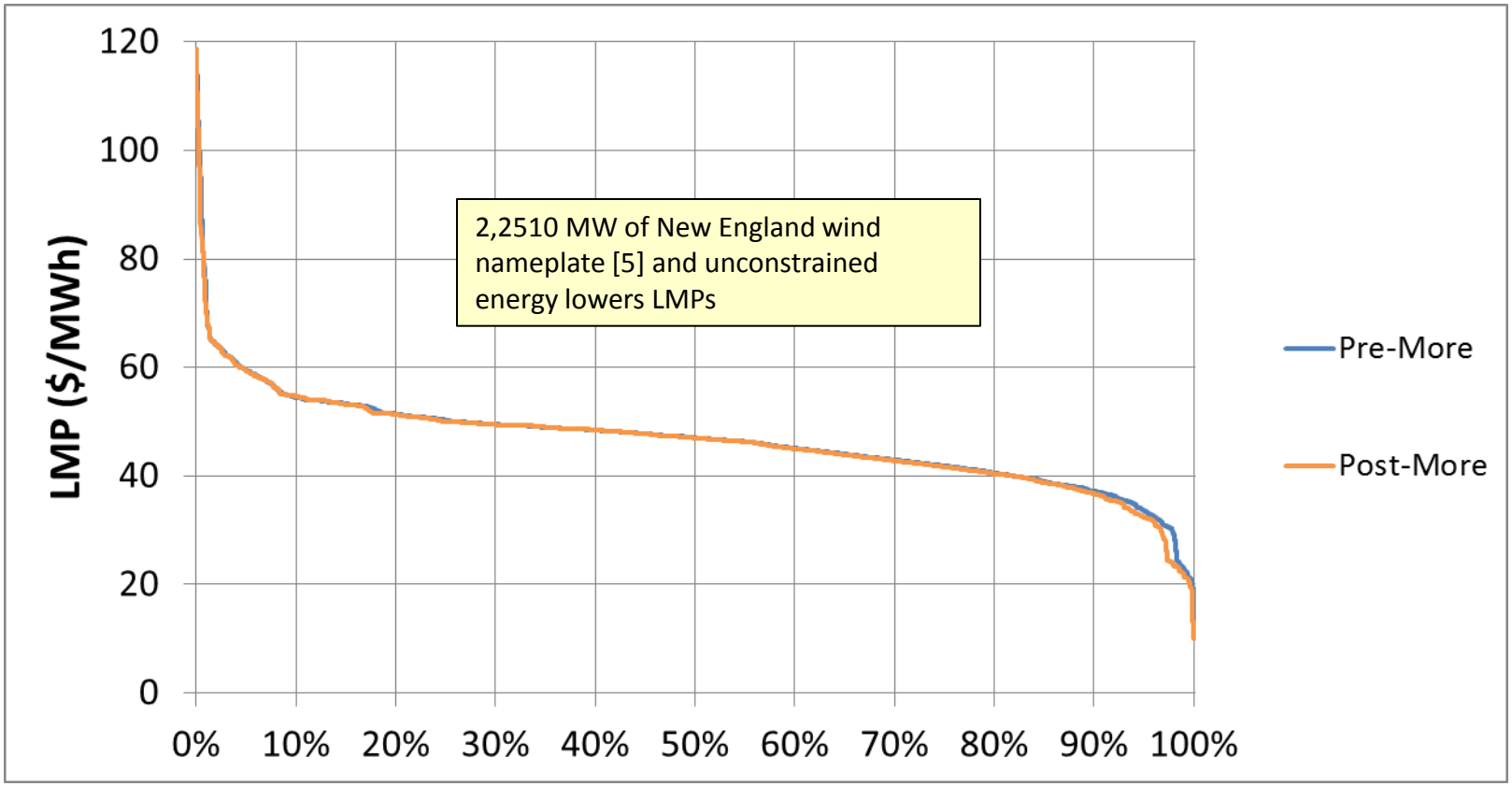
LMP: New England – Basecase Wind

Duration Curve



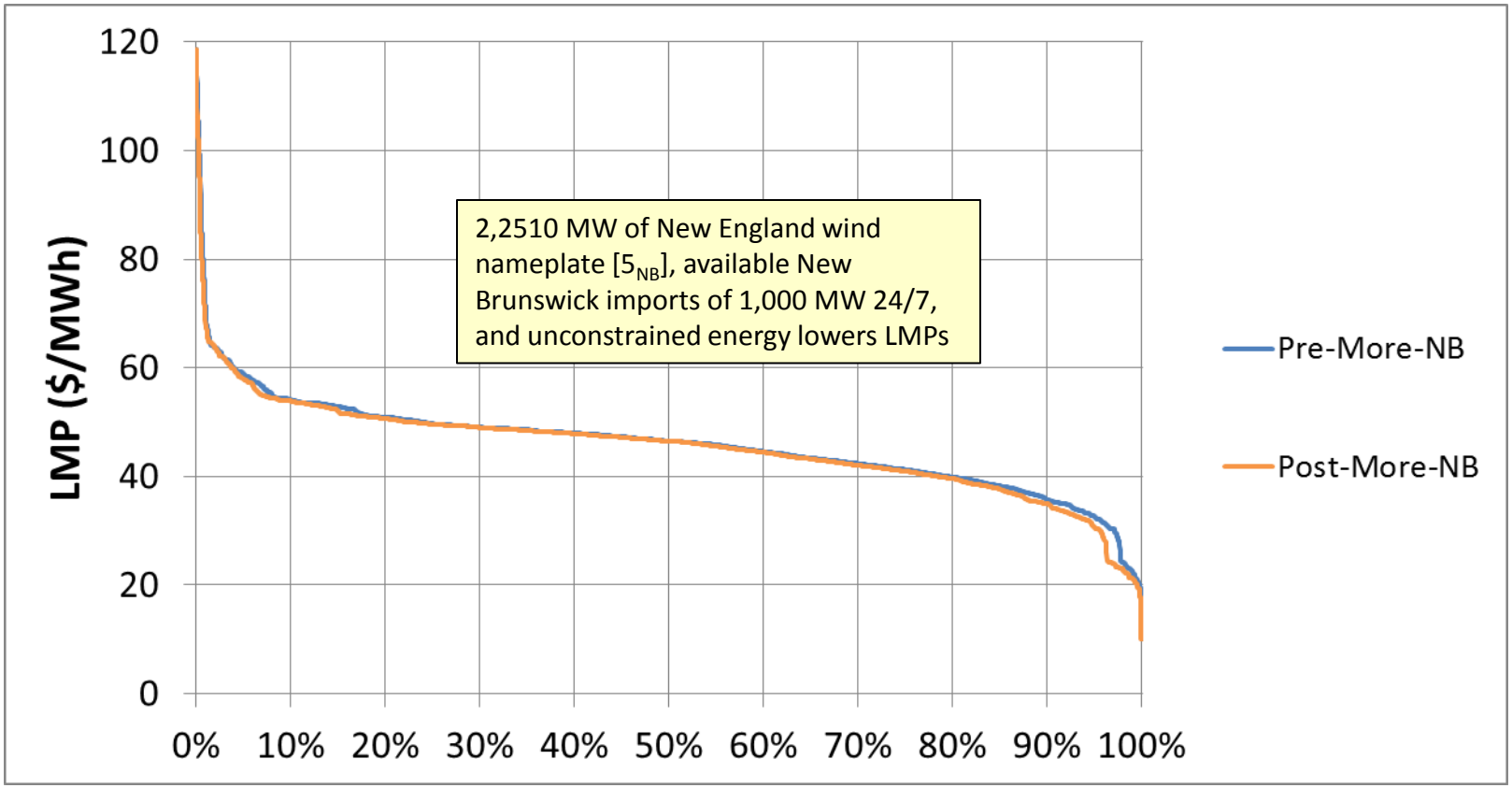
LMP: New England – More Wind

Duration Curve



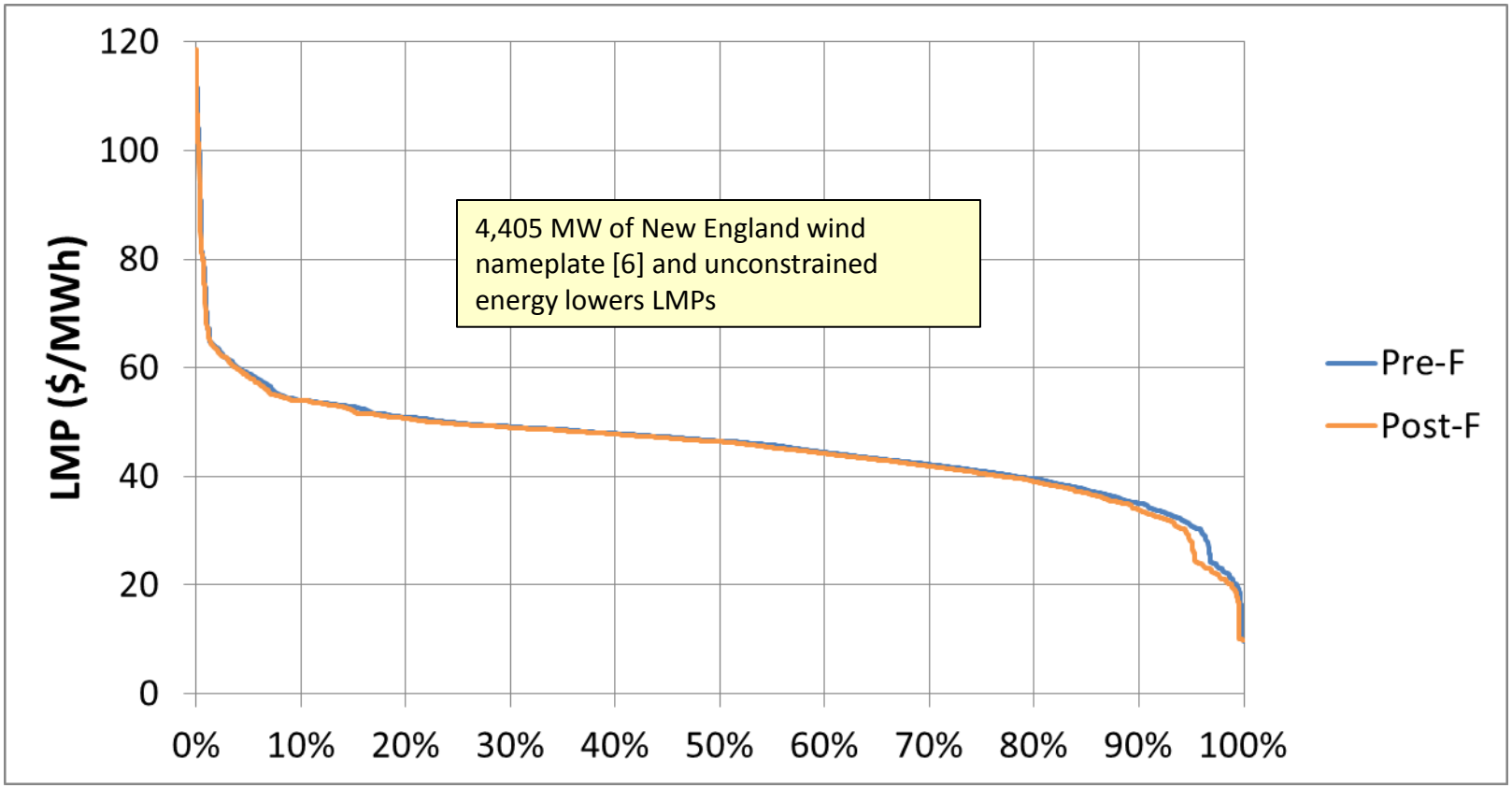
LMP: New England – More Wind with NB at 1000 MW

Duration Curve



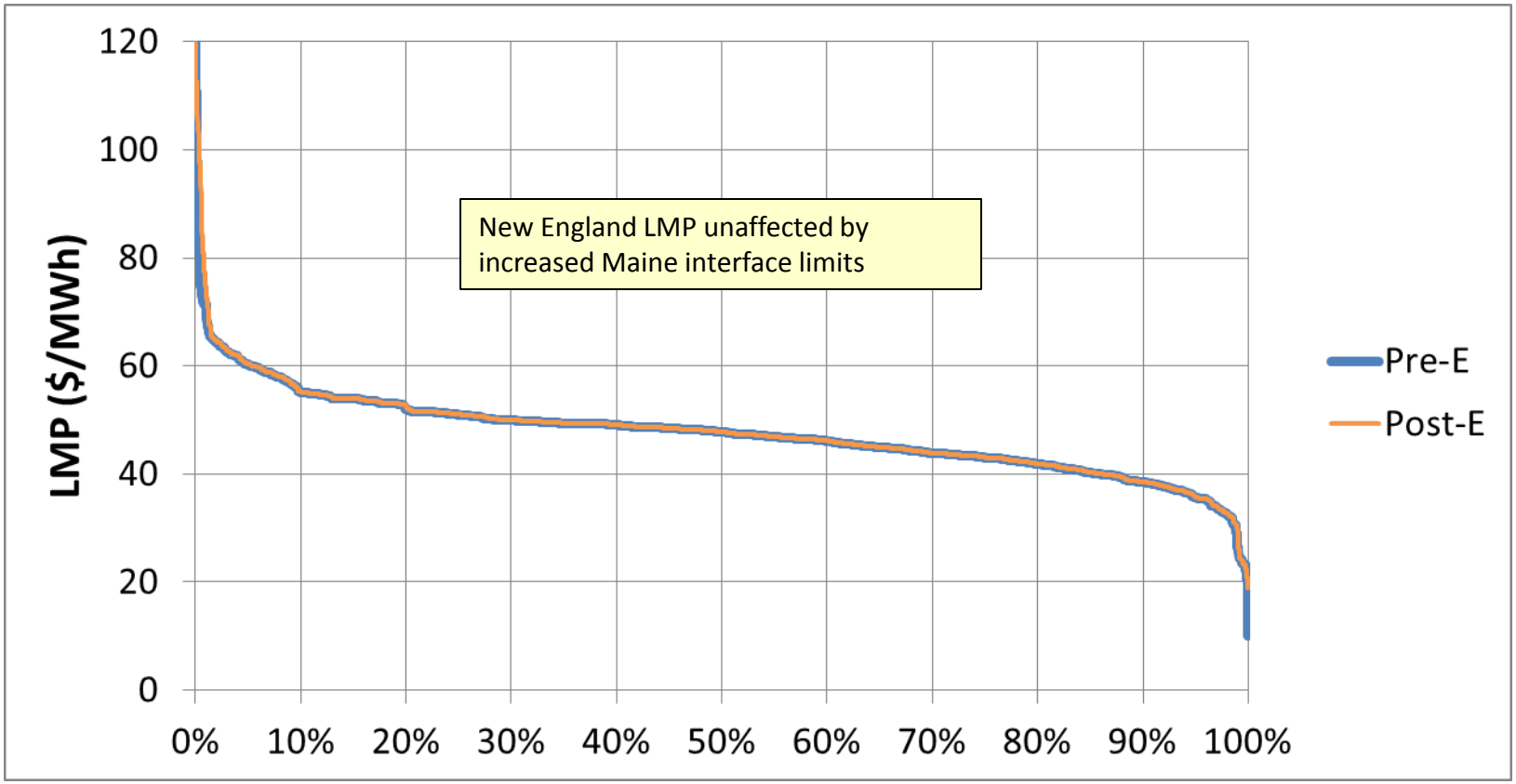
LMP: New England – Future Wind

Duration Curve



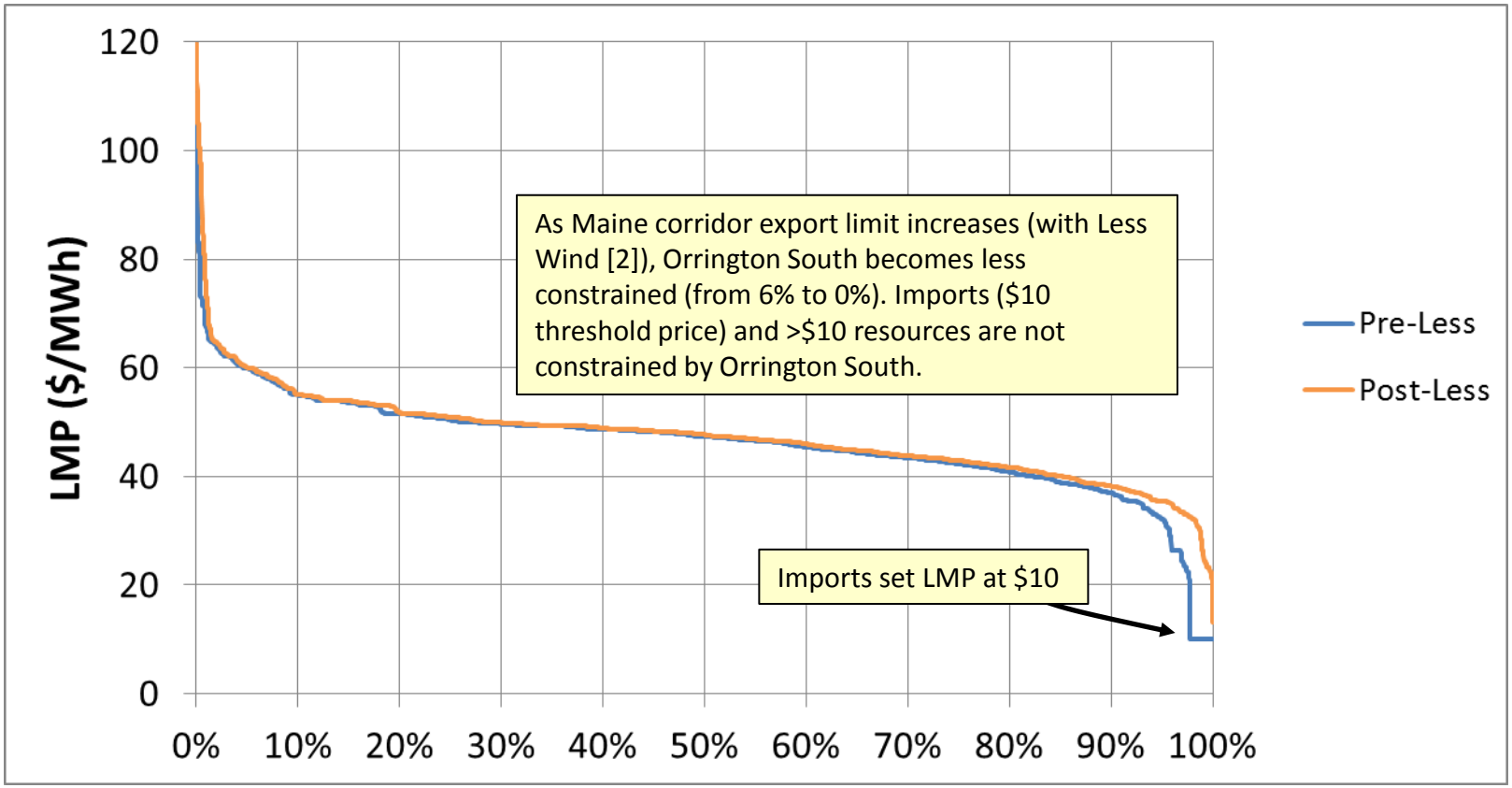
LMP: BHE – Existing Wind

Duration Curve



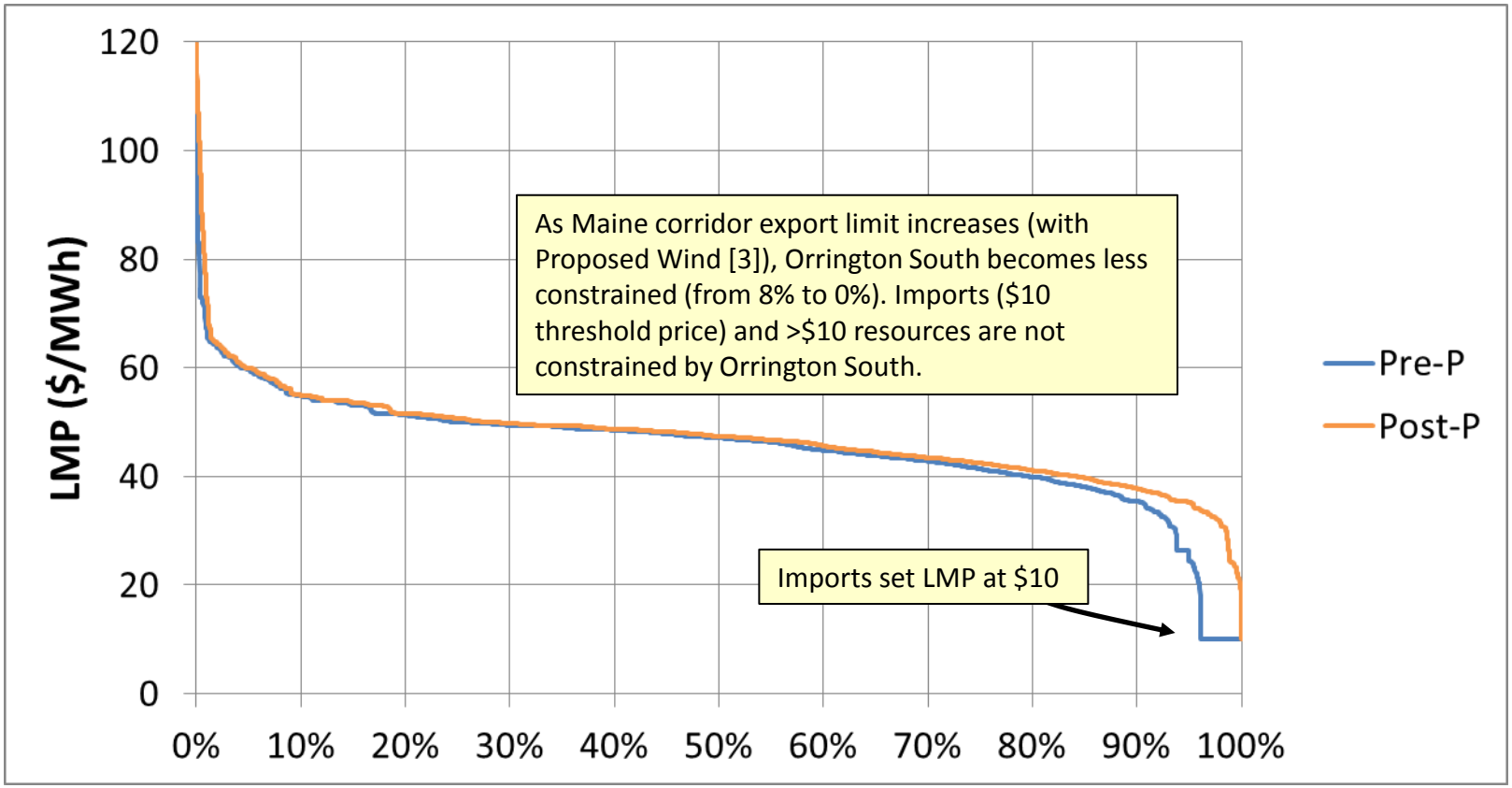
LMP: BHE – Less Wind

Duration Curve



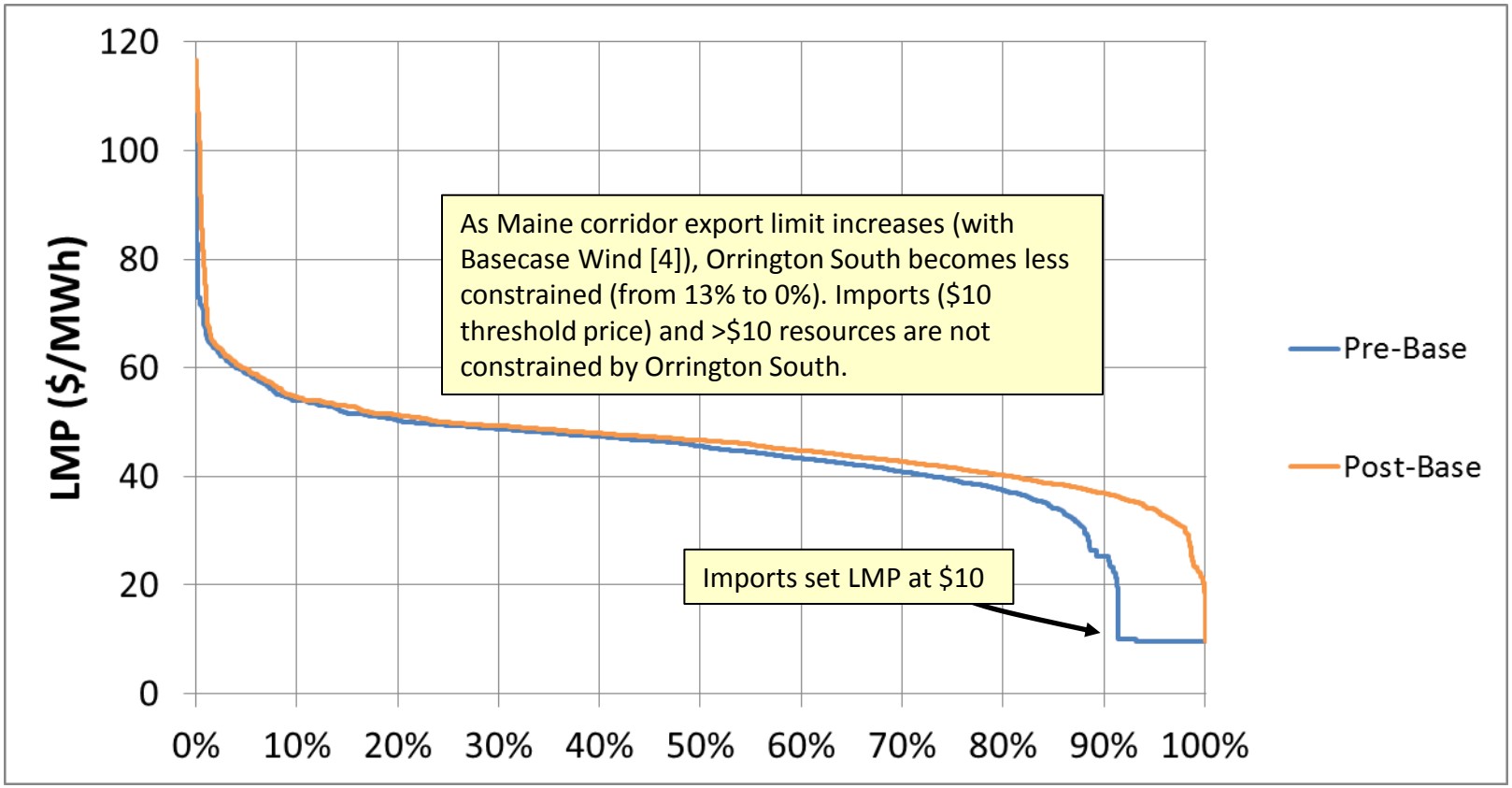
LMP: BHE – Proposed Wind

Duration Curve



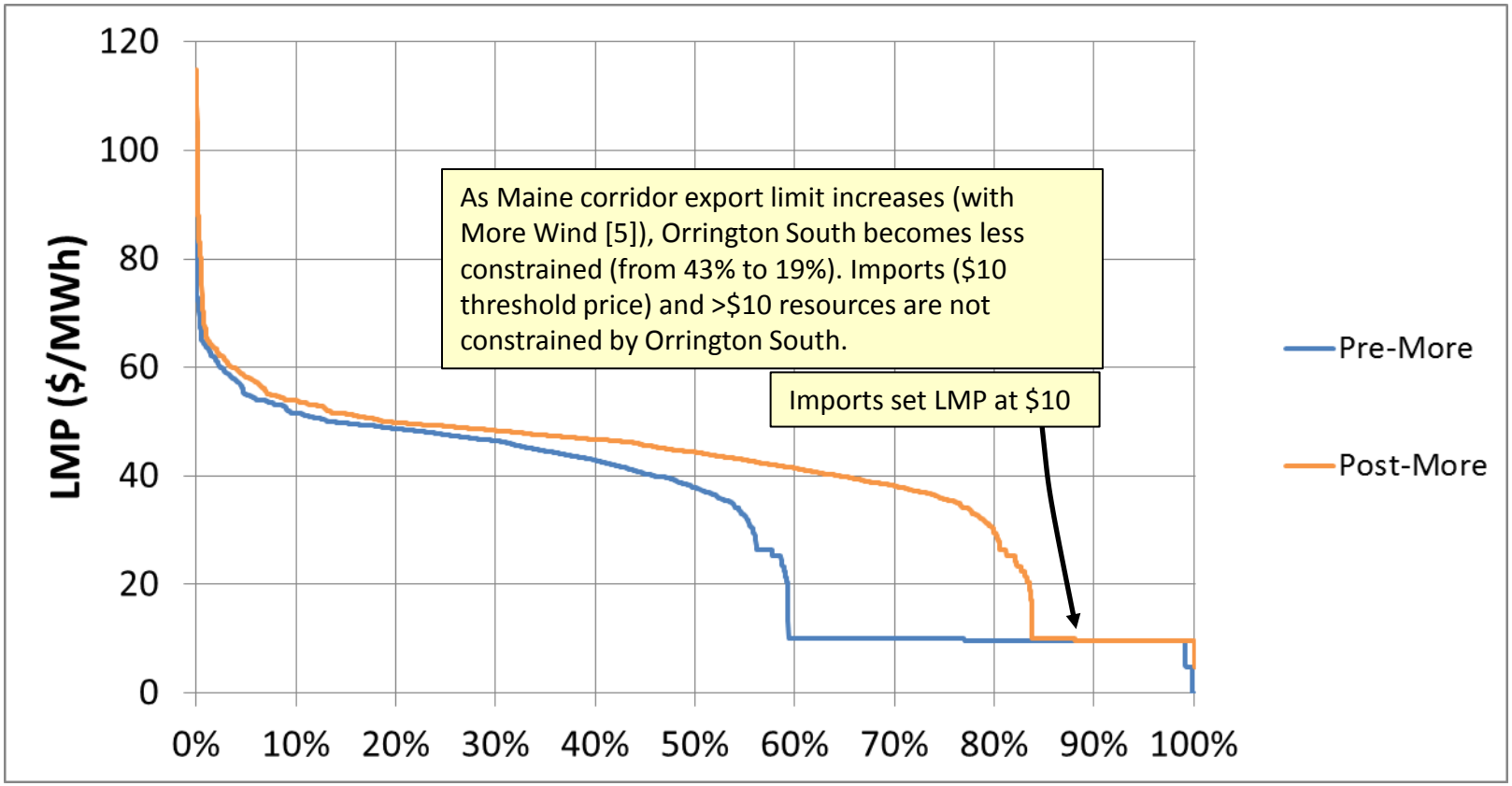
LMP: BHE – Basecase Wind

Duration Curve



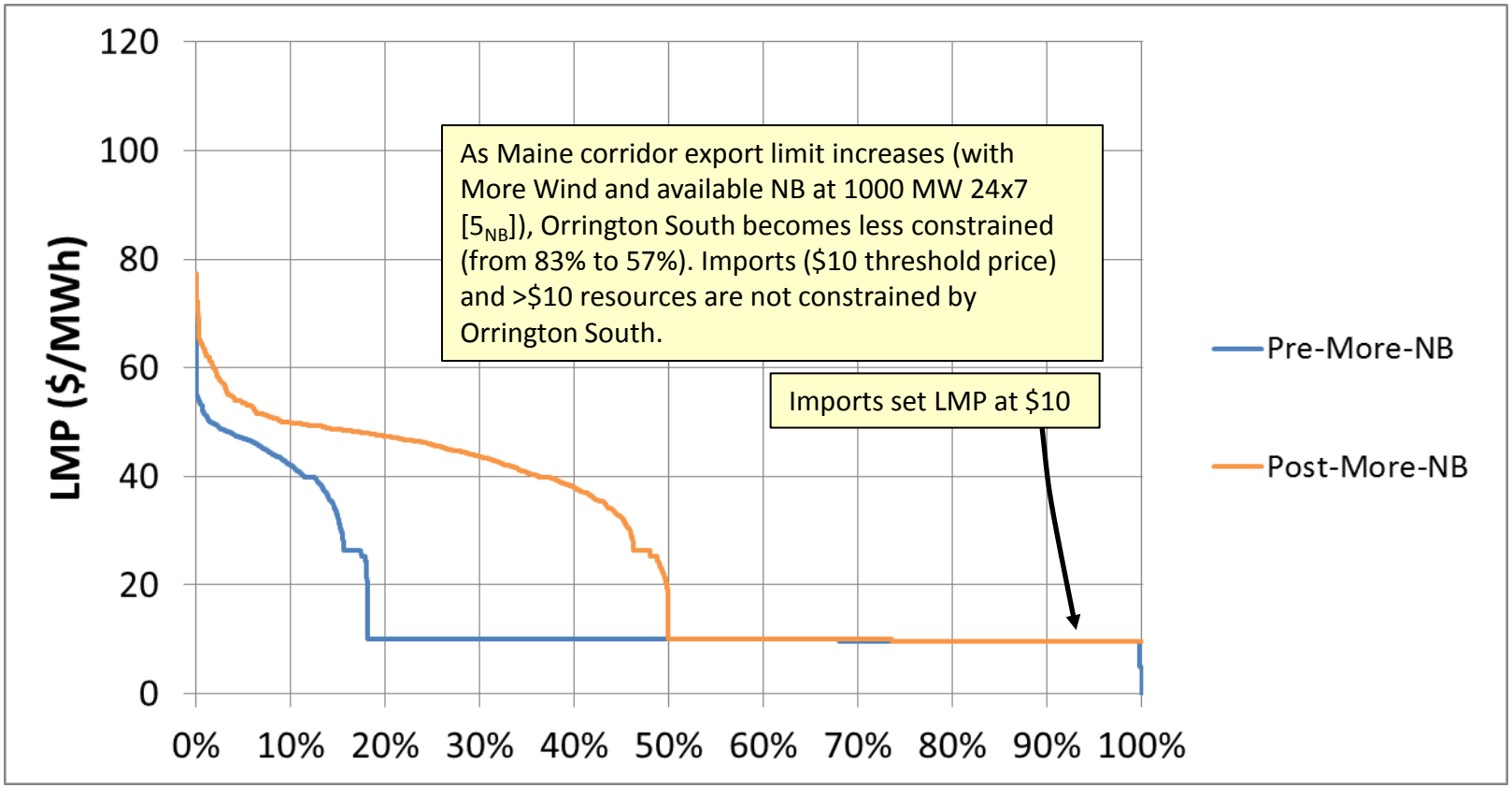
LMP: BHE – More Wind

Duration Curve



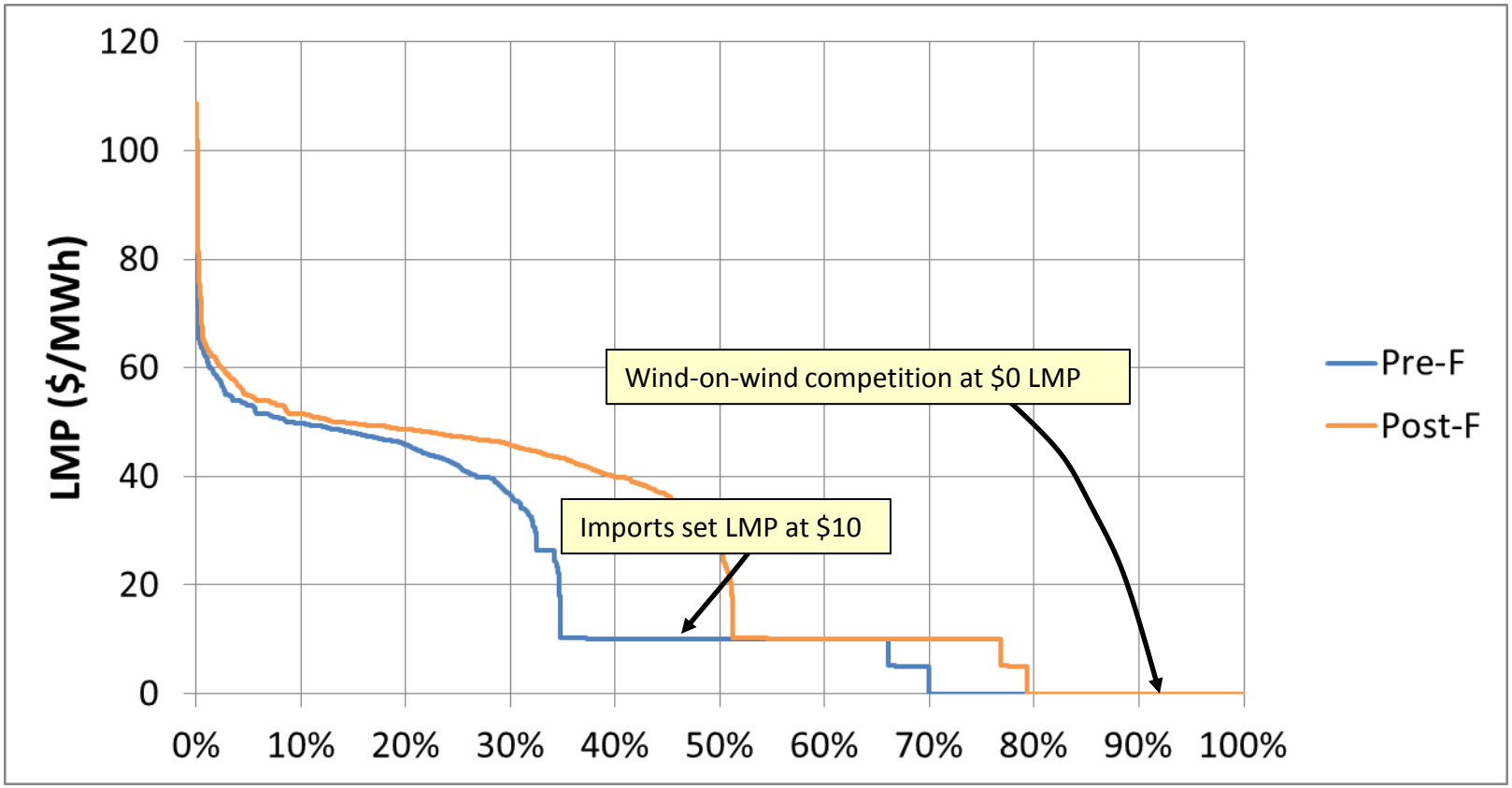
LMP: BHE – More Wind with NB at 1000 MW

Duration Curve



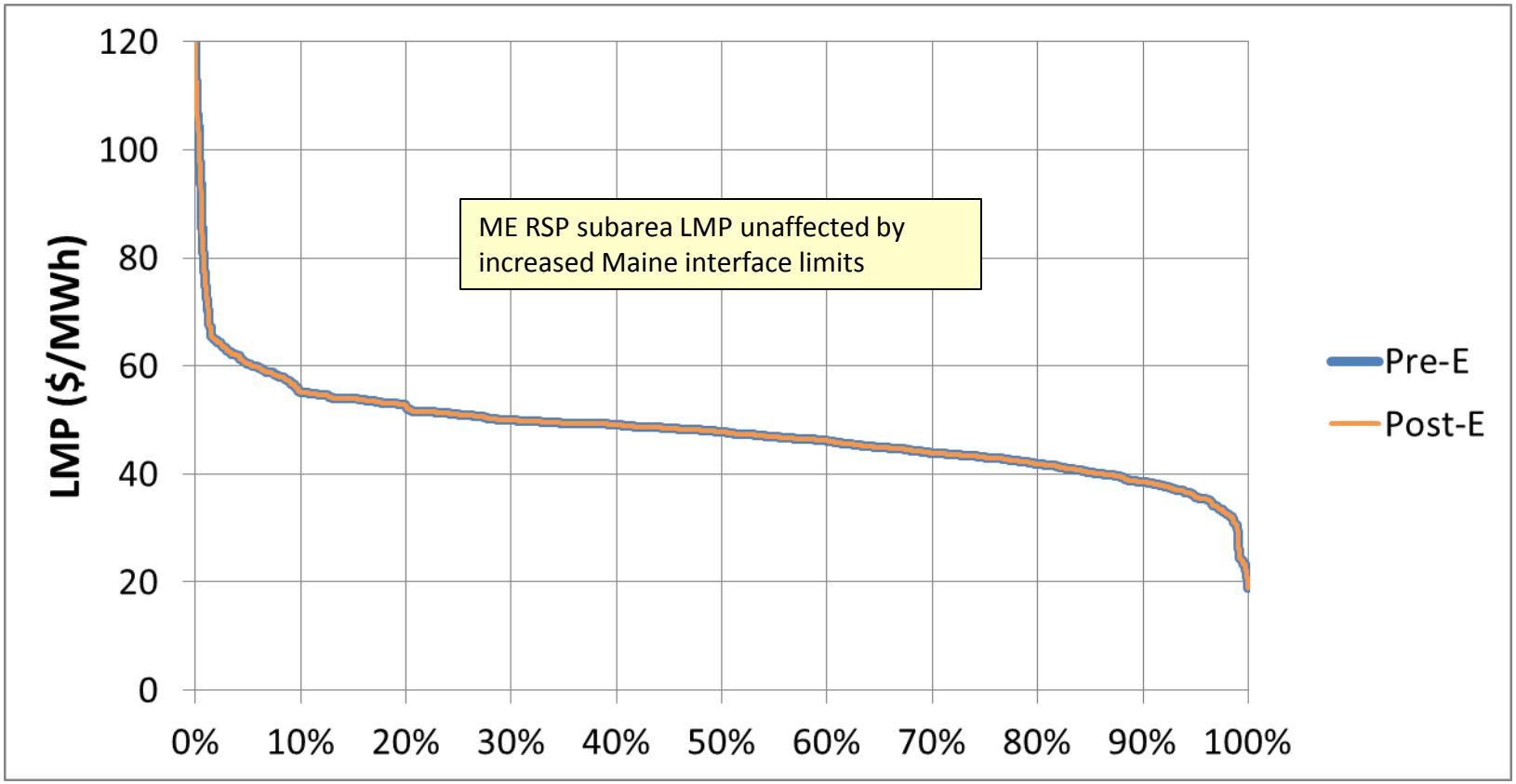
LMP: BHE – Future Wind

Duration Curve



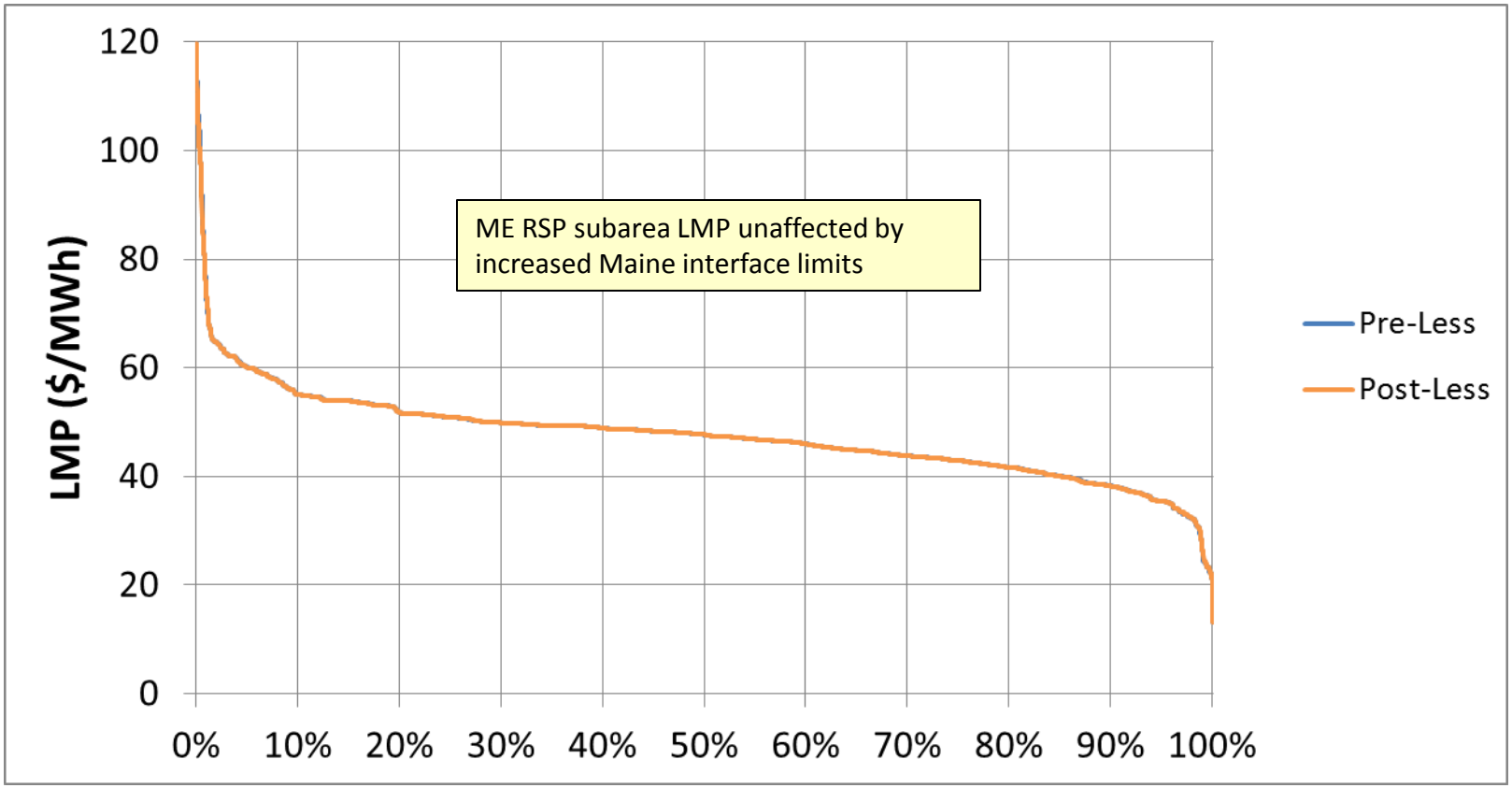
LMP: ME – Existing Wind

Duration Curve



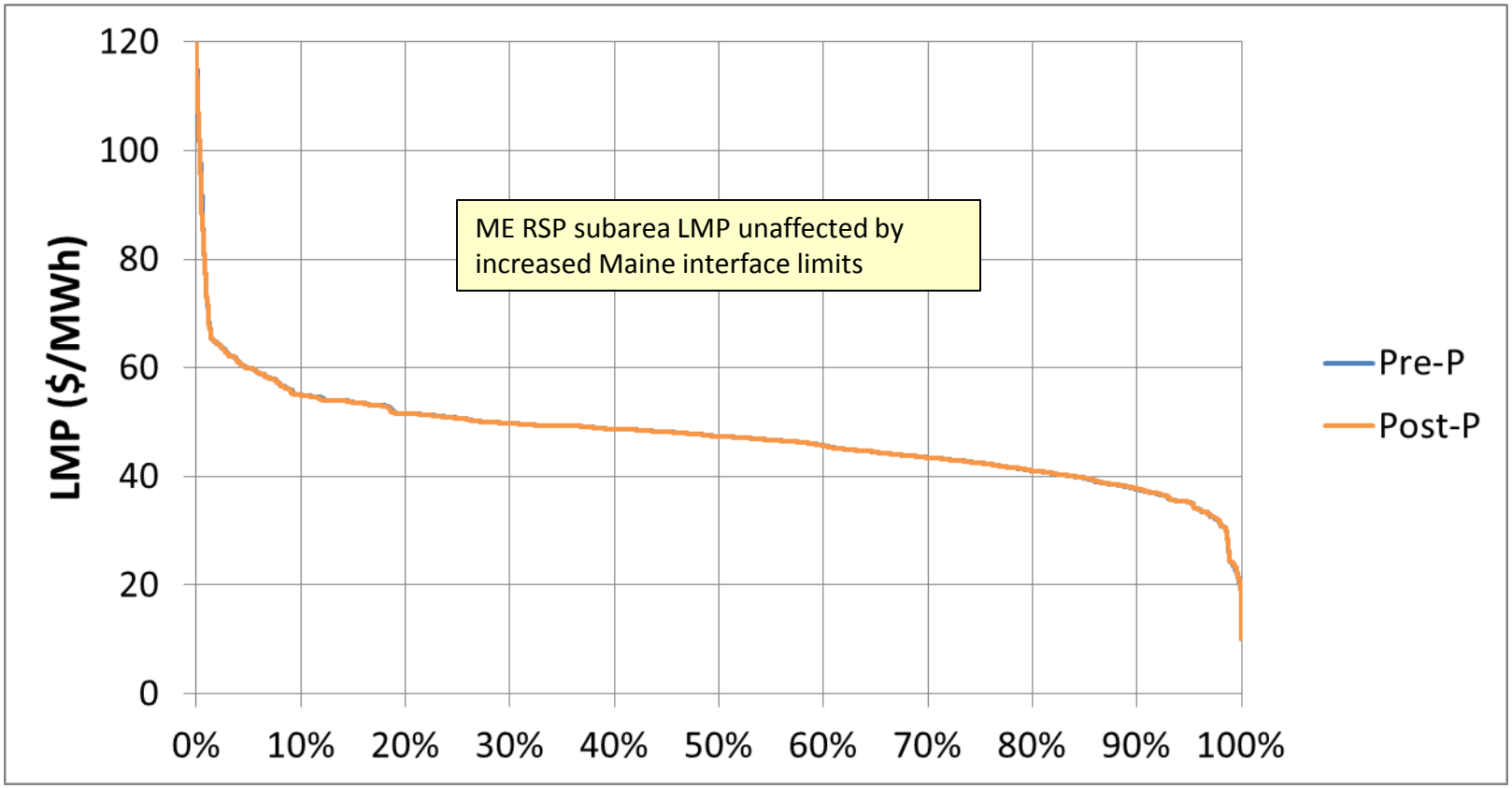
LMP: ME – Less Wind

Duration Curve



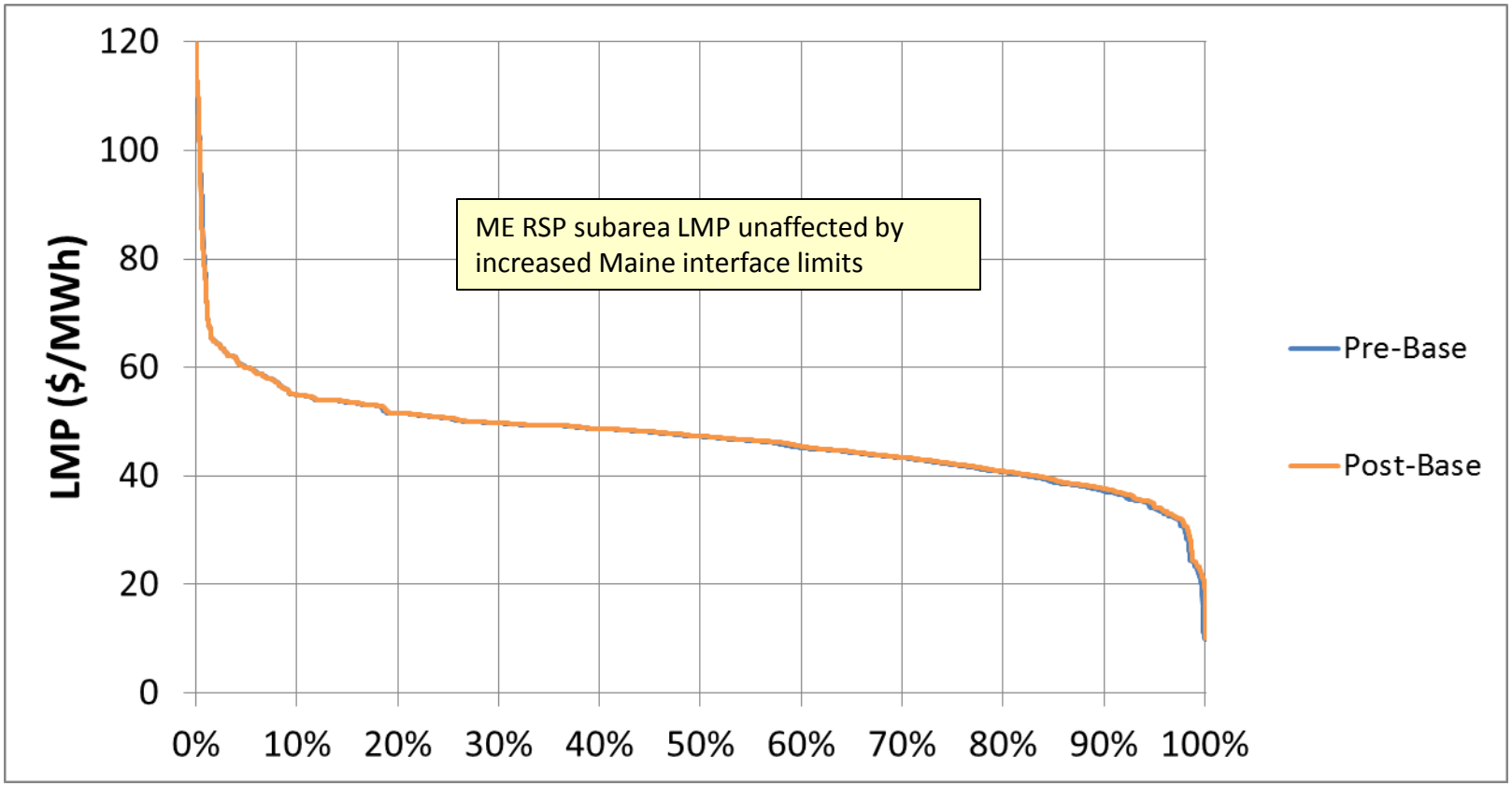
LMP: ME – Proposed Wind

Duration Curve



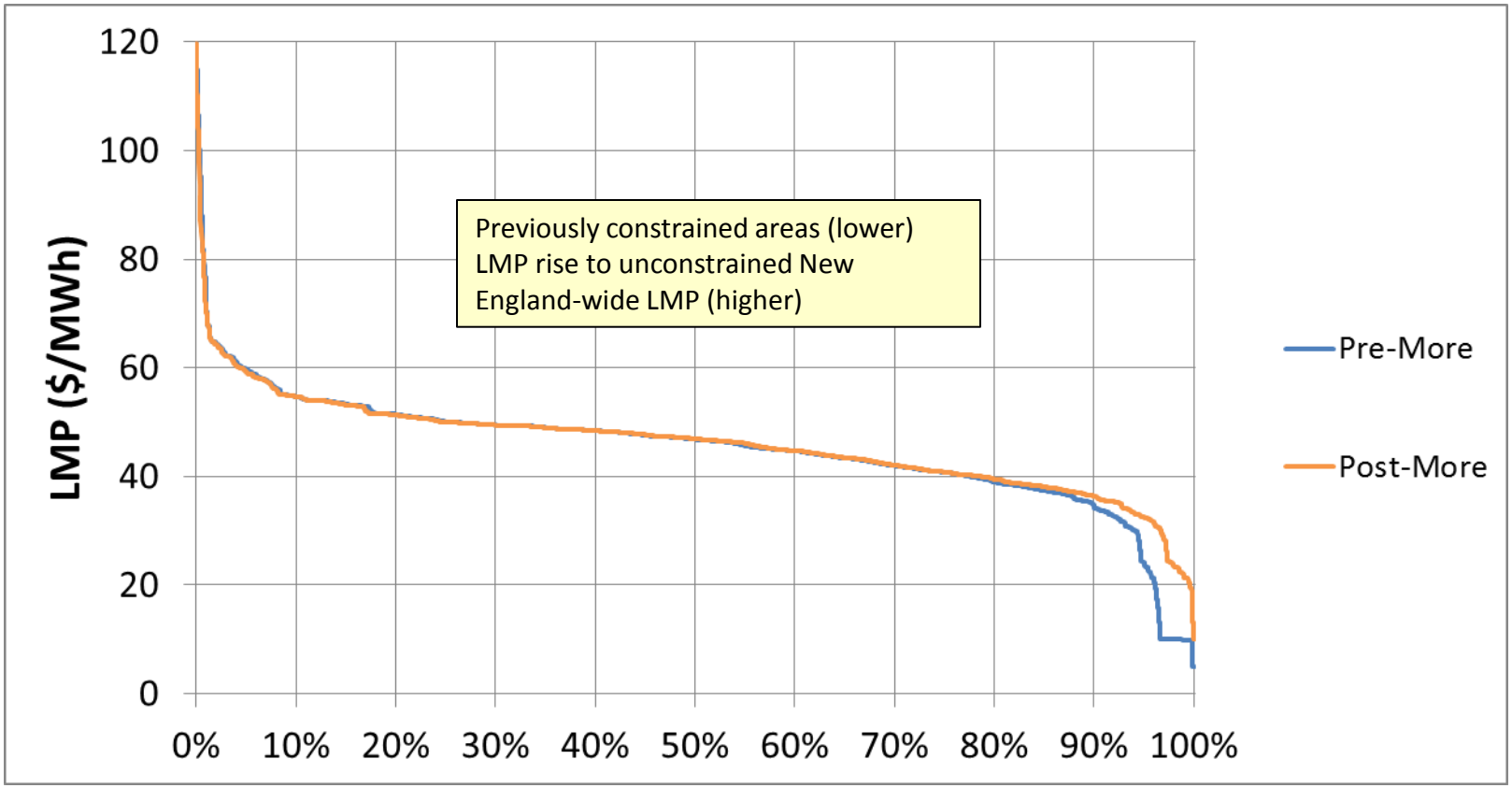
LMP: ME – Basecase Wind

Duration Curve



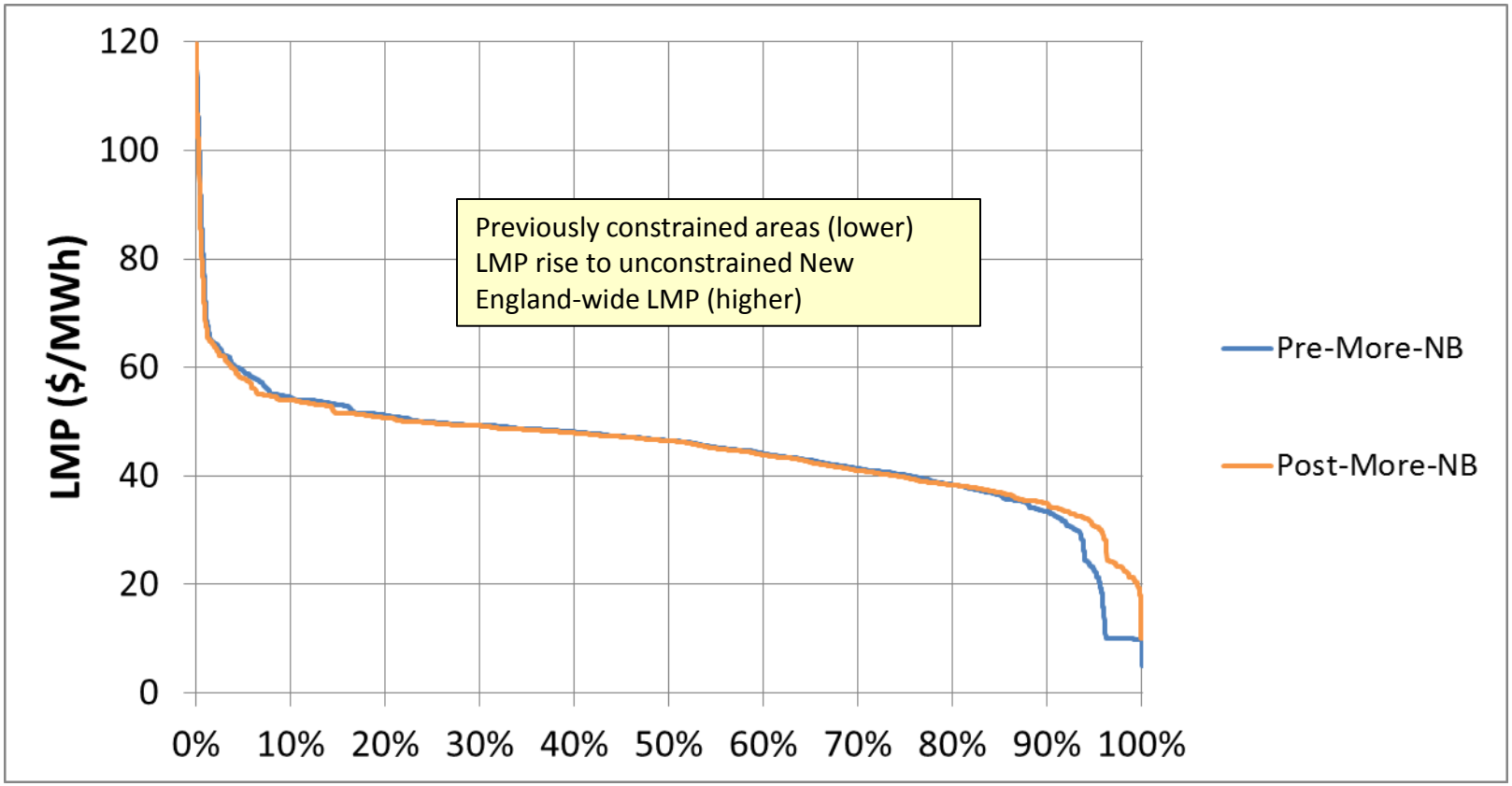
LMP: ME – More Wind

Duration Curve



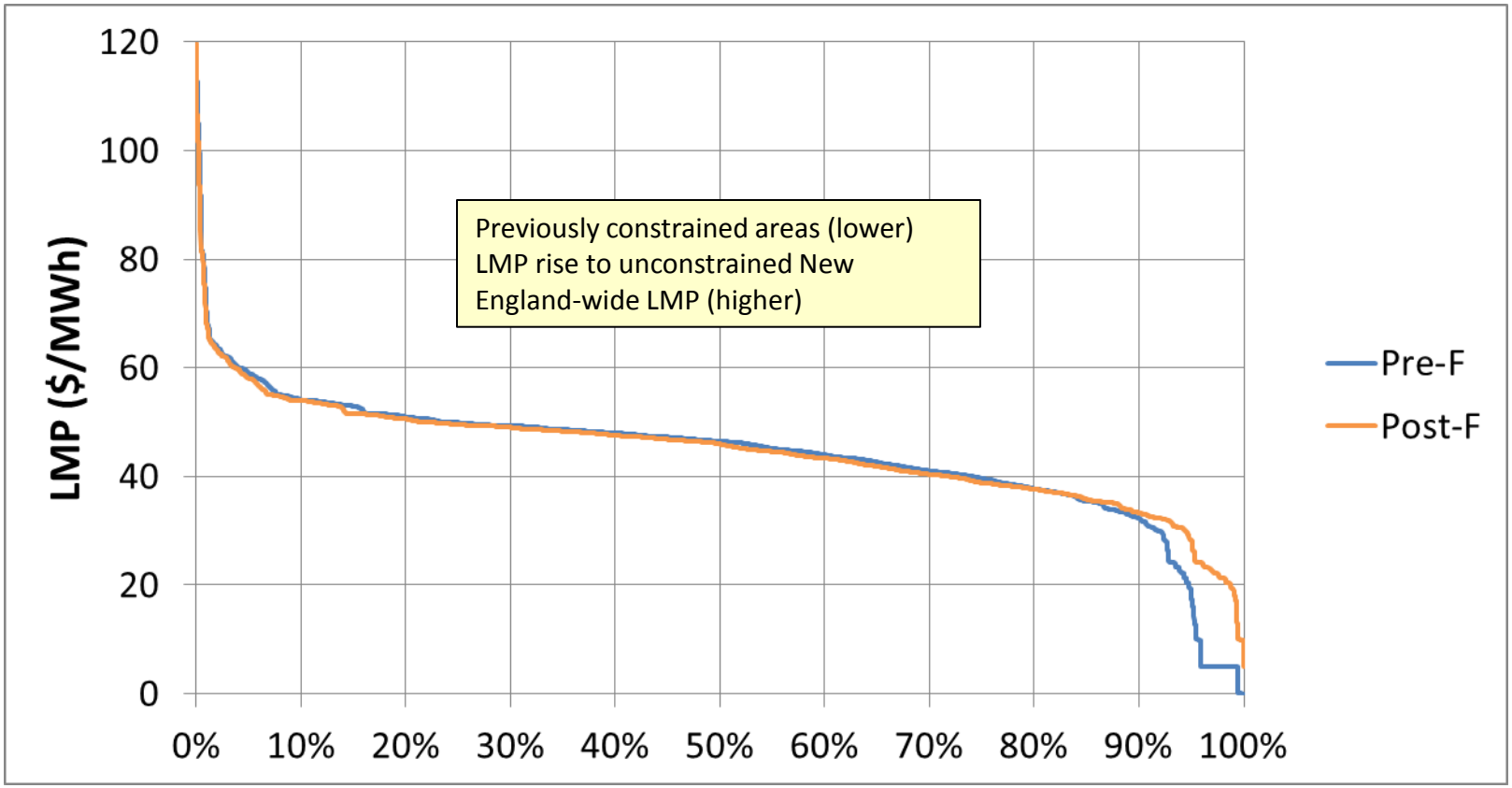
LMP: ME – More Wind with NB at 1000 MW

Duration Curve



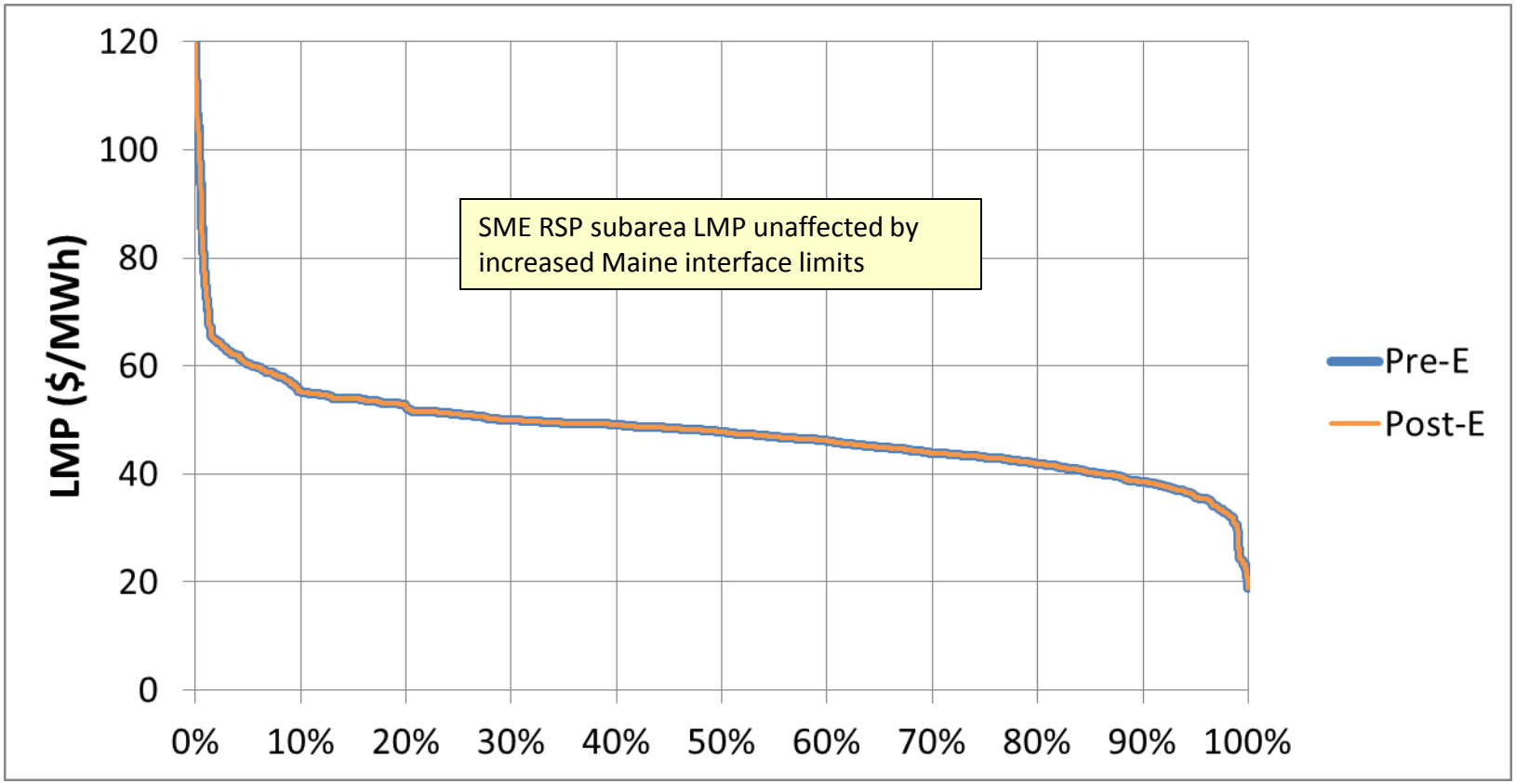
LMP: ME – Future Wind

Duration Curve



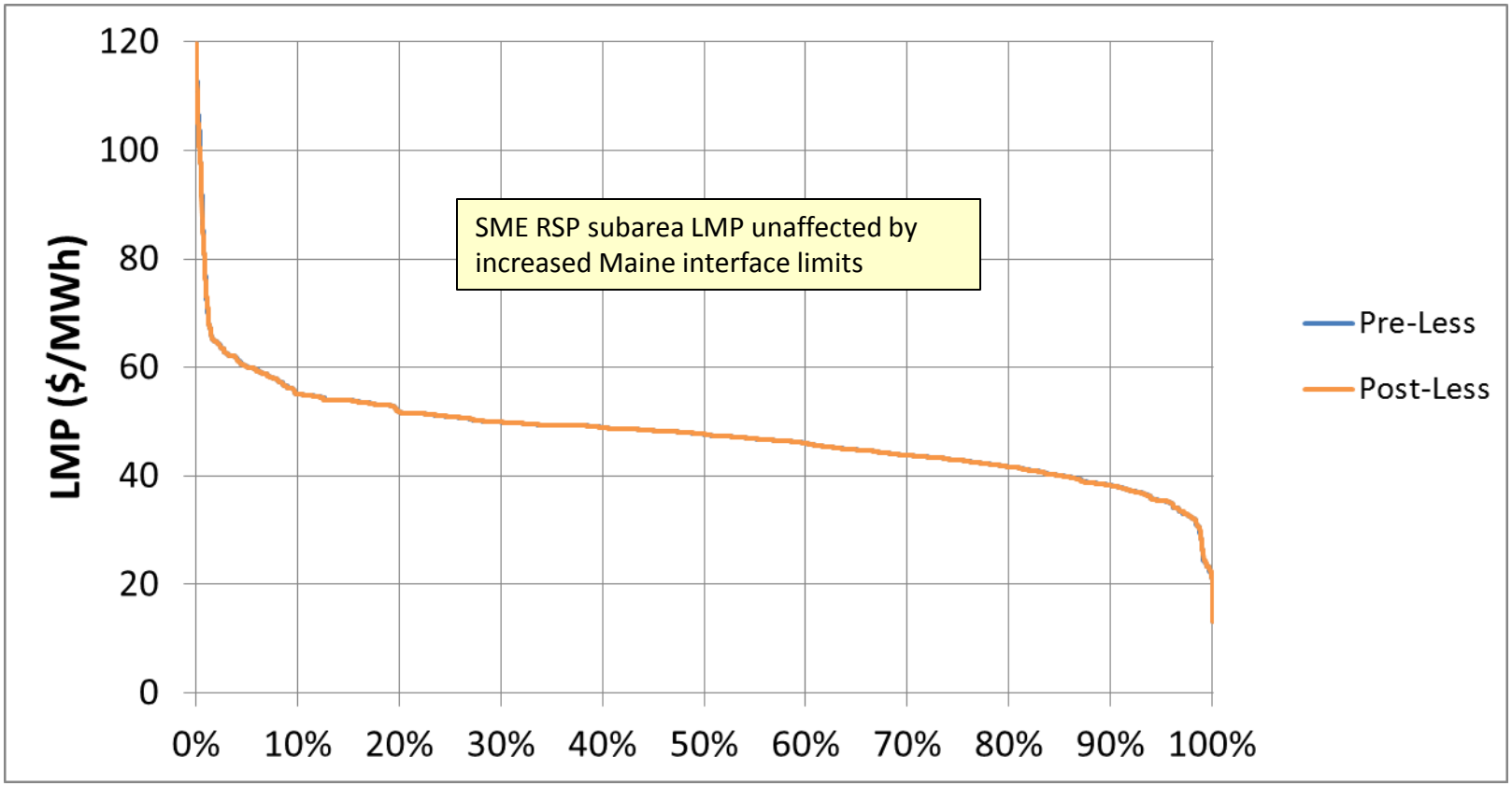
LMP: SME – Existing Wind

Duration Curve



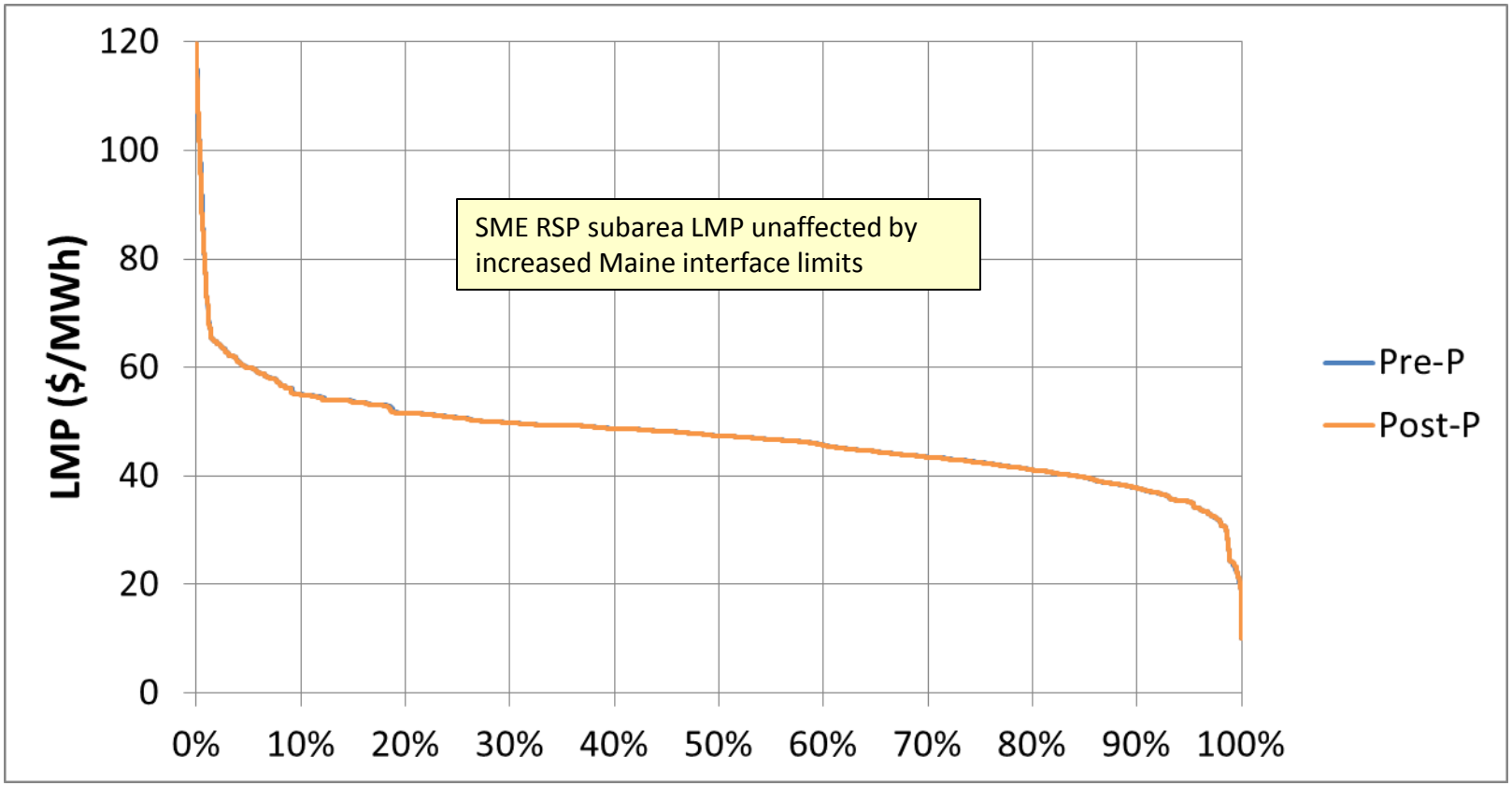
LMP: SME – Less Wind

Duration Curve



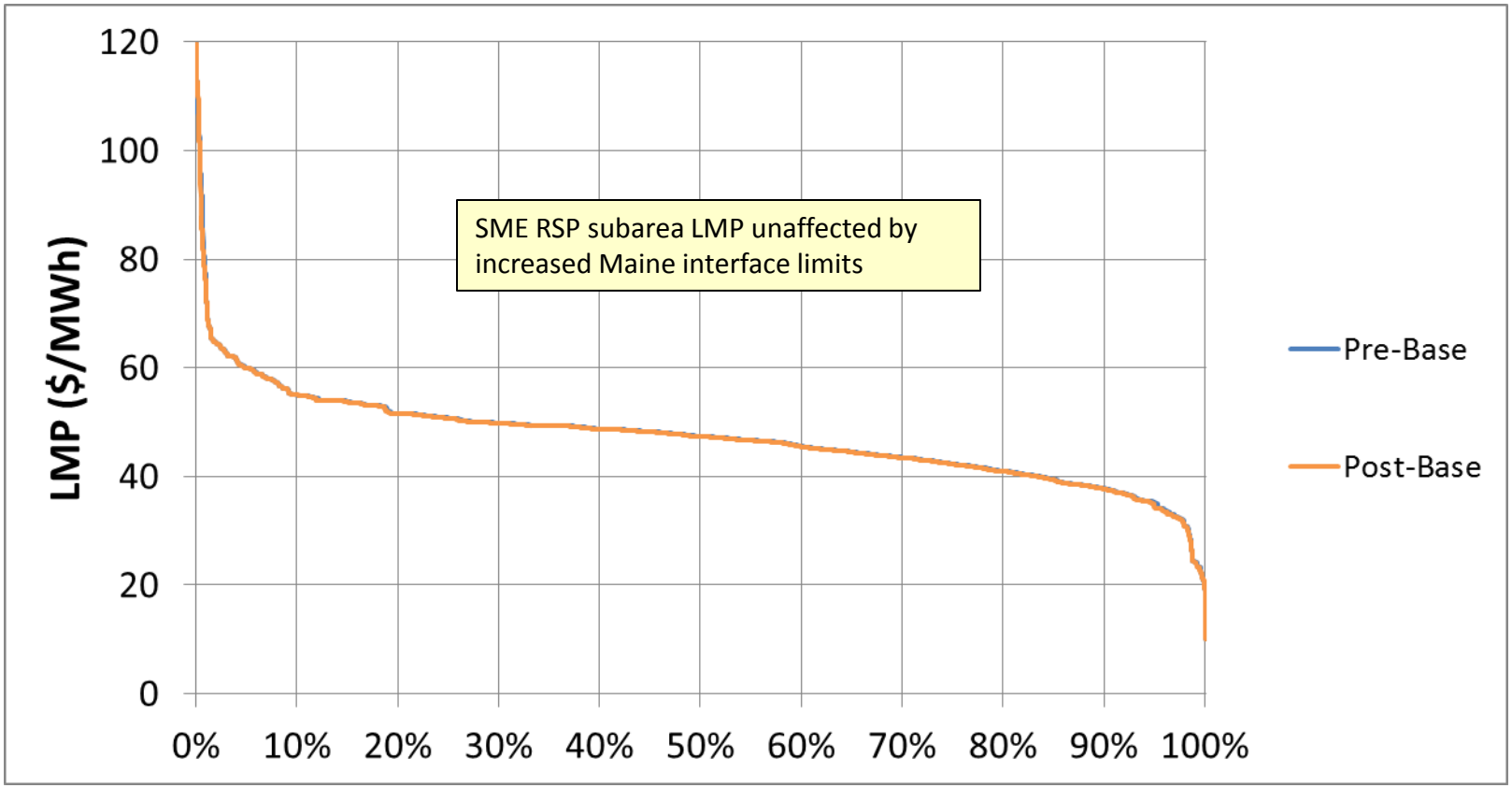
LMP: SME – Proposed Wind

Duration Curve



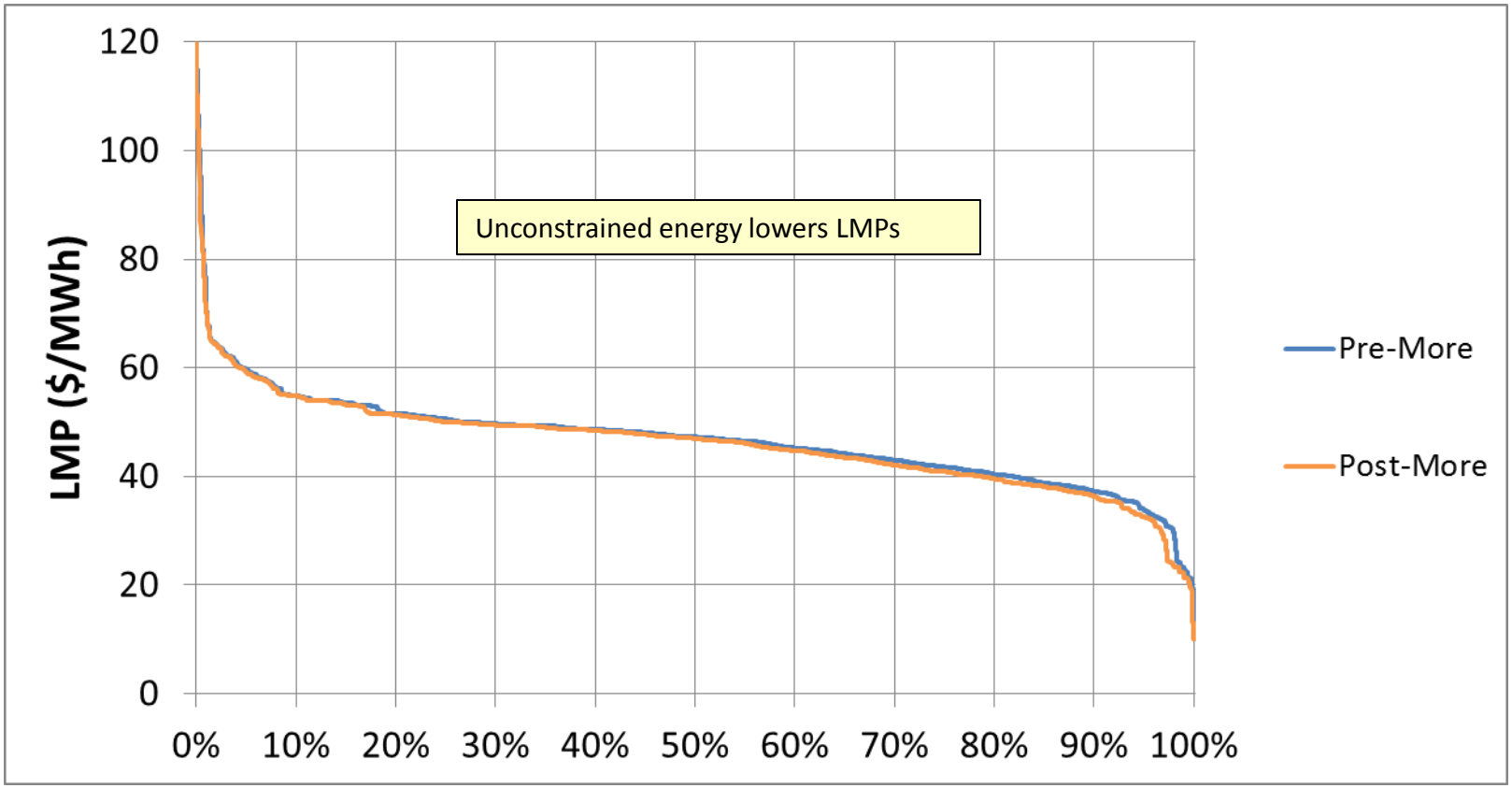
LMP: SME – Basecase Wind

Duration Curve



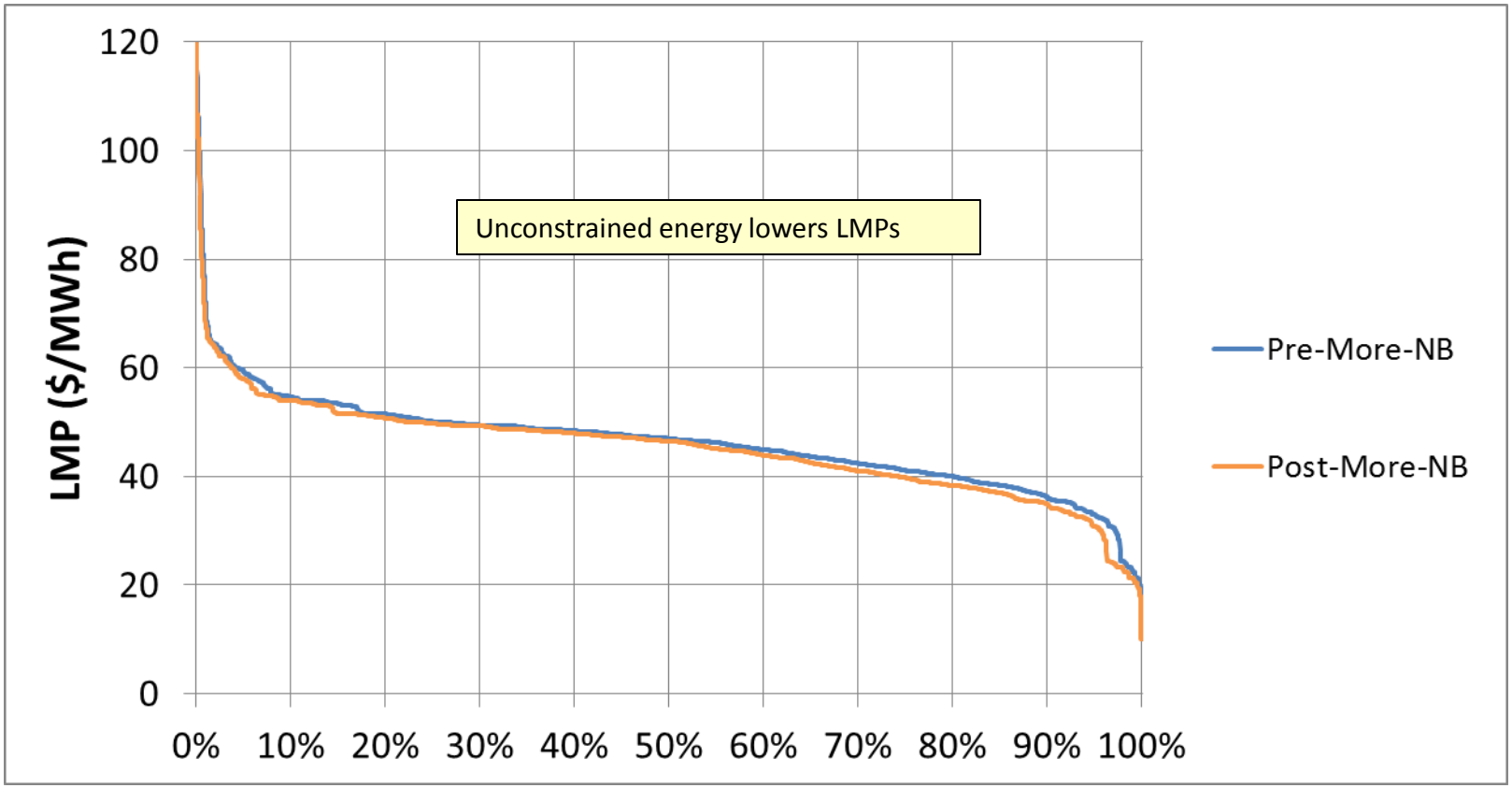
LMP: SME – More Wind

Duration Curve



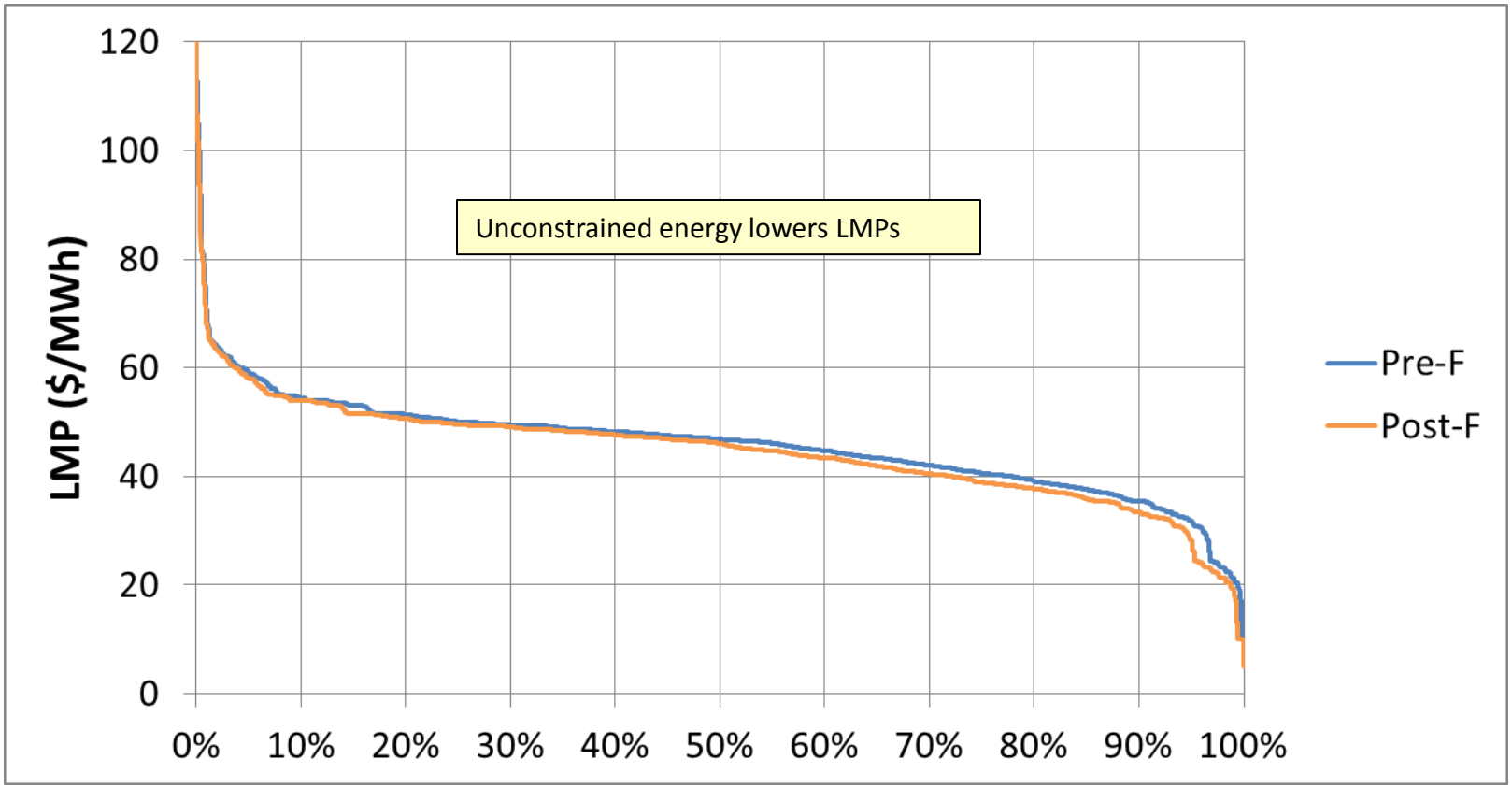
LMP: SME – More Wind with NB at 1000 MW

Duration Curve



LMP: SME – Future Wind

Duration Curve



APPENDIX VII

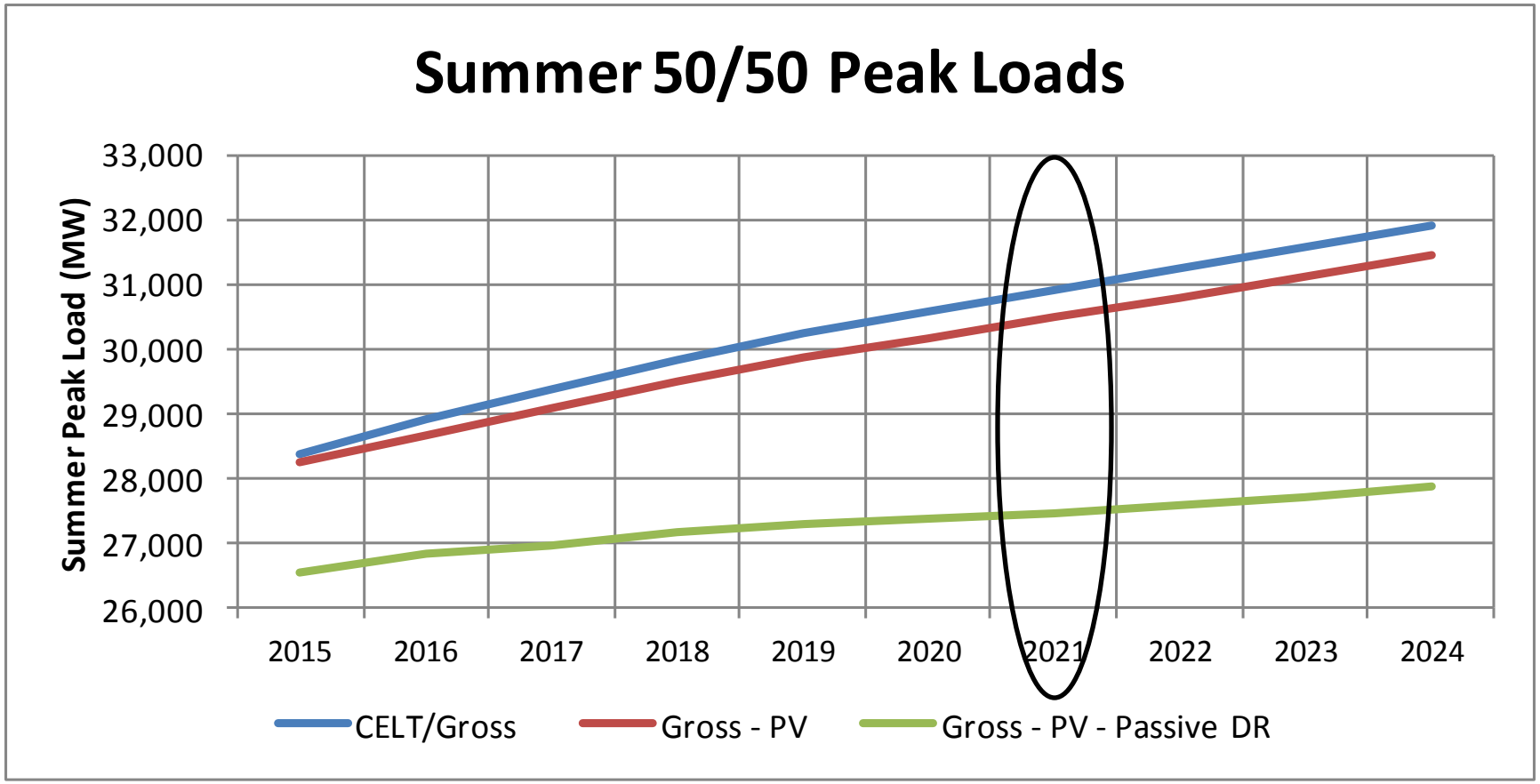
Modeling Assumptions

Base Economic Evaluation Model

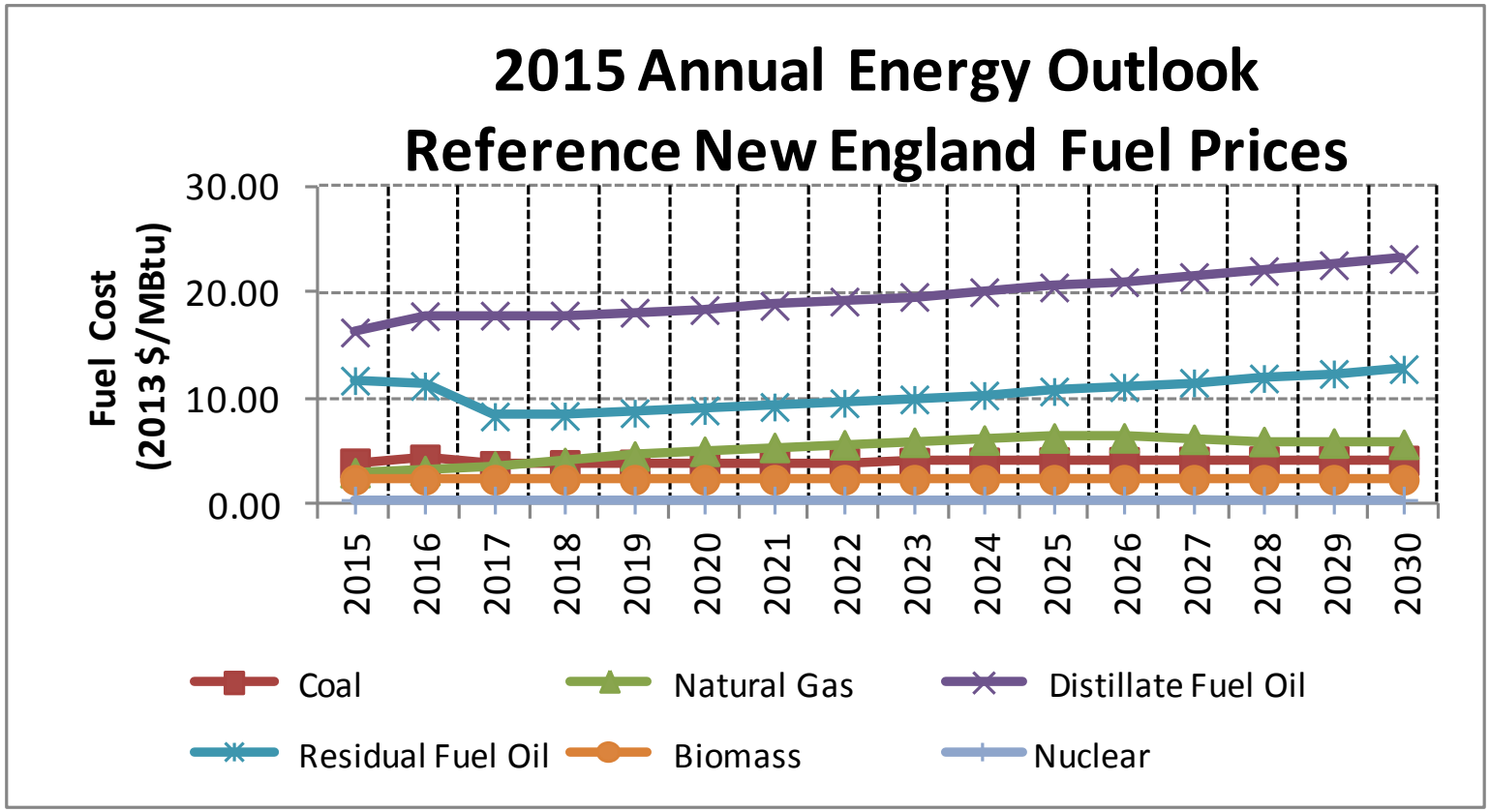
- System conditions consistent with FCA 9 (2018 / 2019) timeframe
  - Resources
  - Transmission capability
  - Demand
- Other economic assumptions
  - Fuel costs
  - Generator availability

Load: New England Peak Load Forecast

Effect of Behind-the-Meter PV and Passive DR



Fuel Price Forecast: EIA's 2015 AEO Base



Resource Assumptions

Overview

- Resources include
  - Cleared in Forward Capacity Auction #9
  - 2015 CELT resources
  - Other energy only resources
  - Wind in each study are specified by the economic study request
    - Wind resource production modeled based on 2012 NREL data
- Demand resources
  - Energy efficiency (EE) and photovoltaic (PV) – including forecasts
  - Active demand resources (DR)
  - Hourly profile based on 2006 weather (consistent with wind and PV data)

Resource Assumptions

Overview (Cont.)

- Dispatch threshold price
  1) Wind ($0/MWh)
  2) Hydro ($5/MWh)
  3) Imports ($10/MWh)

  *Note: Production cost is zero for these resources. An LMP below the threshold price will result in a resource self curtailing.
- Resources modeled as hourly profiles
  - EE, DR, RTEG
  - PV, wind,
  - Hydro
  - Imports
- Wind profiles based on 2012 NREL data
  - Capacity factors range is from 31% to 41%

Resource Assumptions

Thermal Units

- Points of interconnection for resources based on ISO-NE TPL case*
- Existing thermal units
  - Simulation study production cost parameters: Heat rate curve, Start-up cost, No-load cost and etc.
  - Primary and secondary fuel definition are based on 2015 CELT
- Operational limits
  - Minimum up time, Minimum down time and Start up time
  - Ramp rate limits
- Energy limits: assume no energy limits
- Future thermal units
  - Production cost parameters based on: unit type, technology and rating

*Source: NERC TPL Study 2021 Summer Peak Case (https://smd.iso-ne.com/operations-services/ceii/pac/2015/08/final_nerc_tpl_study_2021_summer_peak_case.zip)

Resource Assumptions

Thermal Units (Cont.)

- Combined cycle units
  - Individual machines from a combined cycle plant are modeled as a single generator at one of the machine's buses
- Outages
  - Thermal units derated to reflect the forced outages using Equivalent Forced Outage Rate (EFOR)
  - Planned maintenance schedule will be developed and held constant across cases

Resource Assumptions

Hydro Units

- Hydro units modeled using
  - Hourly energy generation profiles
  - Peak shaving bias
  - Used in previous economic studies
- Hydro units are assumed to have no maintenance outage

Resource Assumptions

Pumped Storage Units

- Modeled in peak shaving mode
  - Pumping during off-peak hours
  - Generating during on-peak hours
- Pumped storage physical parameters
  - Minimum pond size
  - Maximum pond size
  - Plant capacity factor
  - Based on assumptions used in previous studies

Resource Assumptions

Photovoltaic

- 2015 PV Forecast used for simulation year 2021
- Represented by a time stamped, chronological hourly solar PV profile
- National Renewable Energy Laboratory (NREL) has developed a simulated solar PV dataset based on 2006 weather
  - New England specific
  - Profiles by RSP area available
- Consistent with methodology used for wind profile

Resource Assumptions

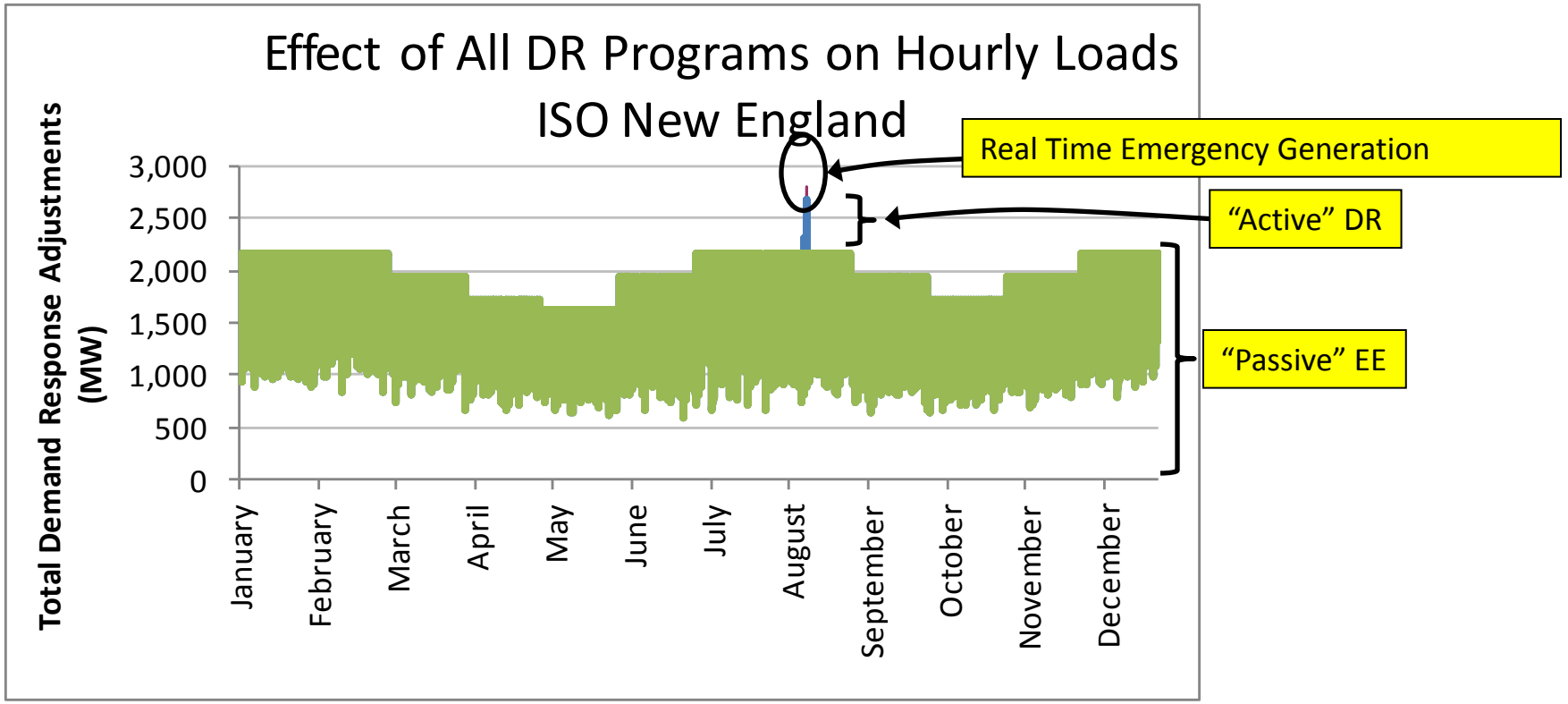
Demand Resources

- Active DR, EE and RTEG are modeled explicitly
  - Hourly profile for each category of demand side resource
  - FCA amounts used through capacity commitment periods
- Forecasts
  - The latest EE forecast through the year 2024 is reflected
  - Active DR and RTEG are held constant for years beyond capacity commitment period (same as other FCM resources)

Resource Assumptions

Demand Resources (Cont.)

- Hourly profiles are used to explicitly reflect energy efficiency (EE), active demand resources (DR) and real-time emergency generation (RTEG)



Operating Reserve Modeling

- Operating reserve requirement is determined in real time
  - Based on the first and second largest system contingencies
  - Resource profiles (hydro / wind / interchange etc) excluded
- Current operating reserve requirements
  - 125% of the first contingency in ten minutes split between
    - Ten-Minute Spinning Reserve (TMSR) = 50%
    - Ten-Minute Non-Spinning Reserve (TMNSR) = 50%
  - Thirty-Minute Operation Reserve (TMOR) not modeled
    - Assumed to be adequate
    - Provided by hydro, pumped storage and quick-start resources
    - Reasonable assumption except, possibly, at times of peak loads

Network Modeling

- Modeling of transmission network
  - ISO-NE TPL case*
  - Detailed modeling in ISO-NE region only
  - Representation for neighboring systems
    - Detailed network modeling not required for NY, NB and HQ
    - Base flows based on historical line flows

*Source: NERC TPL Study 2021 Summer Peak Case (https://smd.iso-ne.com/operations-services/ceii/pac/2015/08/final_nerc_tpl_study_2021_summer_peak_case.zip)

Network Modeling (cont)

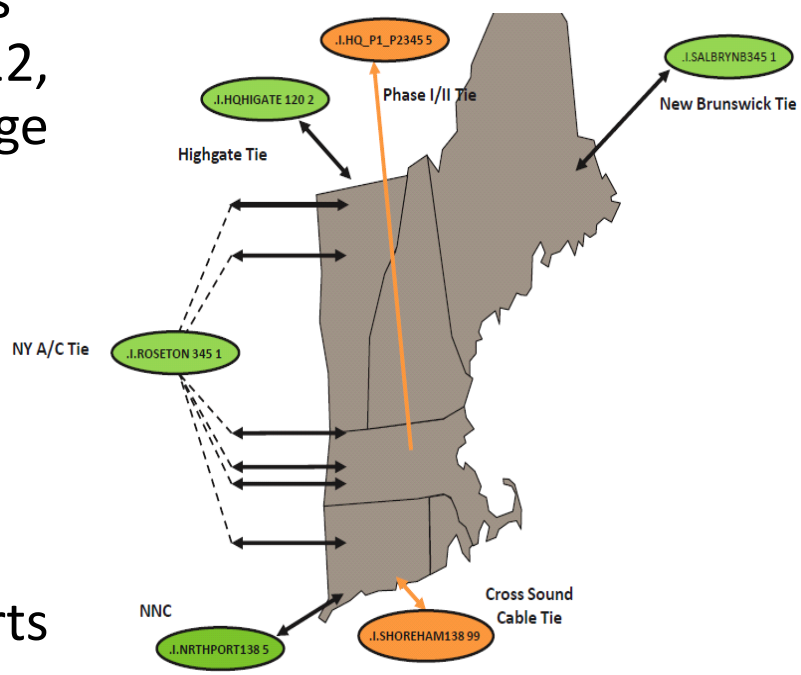
- Modeling of internal interface limits
  - The latest ISO-NE estimated internal interface limit values reflected
- Modeling of transmission line
  - All 230 kV and 345kV circuits ISO-NE region are monitored for thermal overloads
    - Nearly 300 branches monitored for thermal overloads
    - Includes transformers that step up to 230 kV and above
  - Generator step-up (GSU) transformers are excluded
    - Ensure a generating plant output is not limited by GSU modeling
- Monitoring of transmission line
  - 115 kV and above lines in areas of concern as appropriate
    - Maine for
      - Strategic Transmission Analysis – Wind Integration study
      - Keene Road study
    - SEMA / RI for off-shore wind study

Imports and Exports Modeling

- Hourly imports and exports over the following external interconnections are modeled based on average 2012, 2013 and 2014 historical interchange values*
  - New York AC
  - NNC
  - Cross Sound Cable
  - Highgate
  - HQ Phase II
- New Brunswick modeled as historical monthly maximum imports from 2013 and 2014

*The same approach used in previous economic studies for representing import/export assumptions

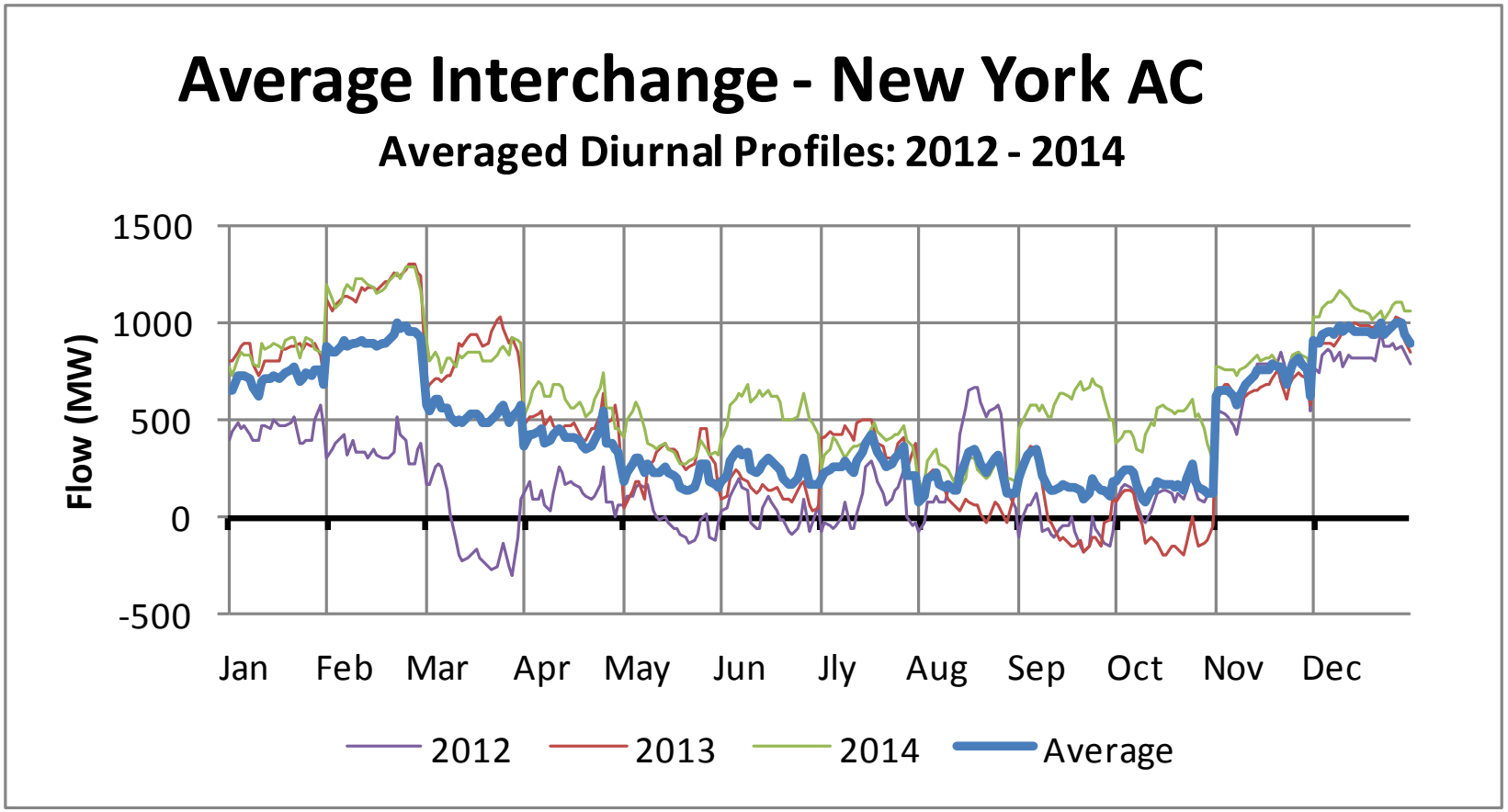
ISO -NE External Interface



Modeling of Imports/Exports

Imports and Exports Modeling

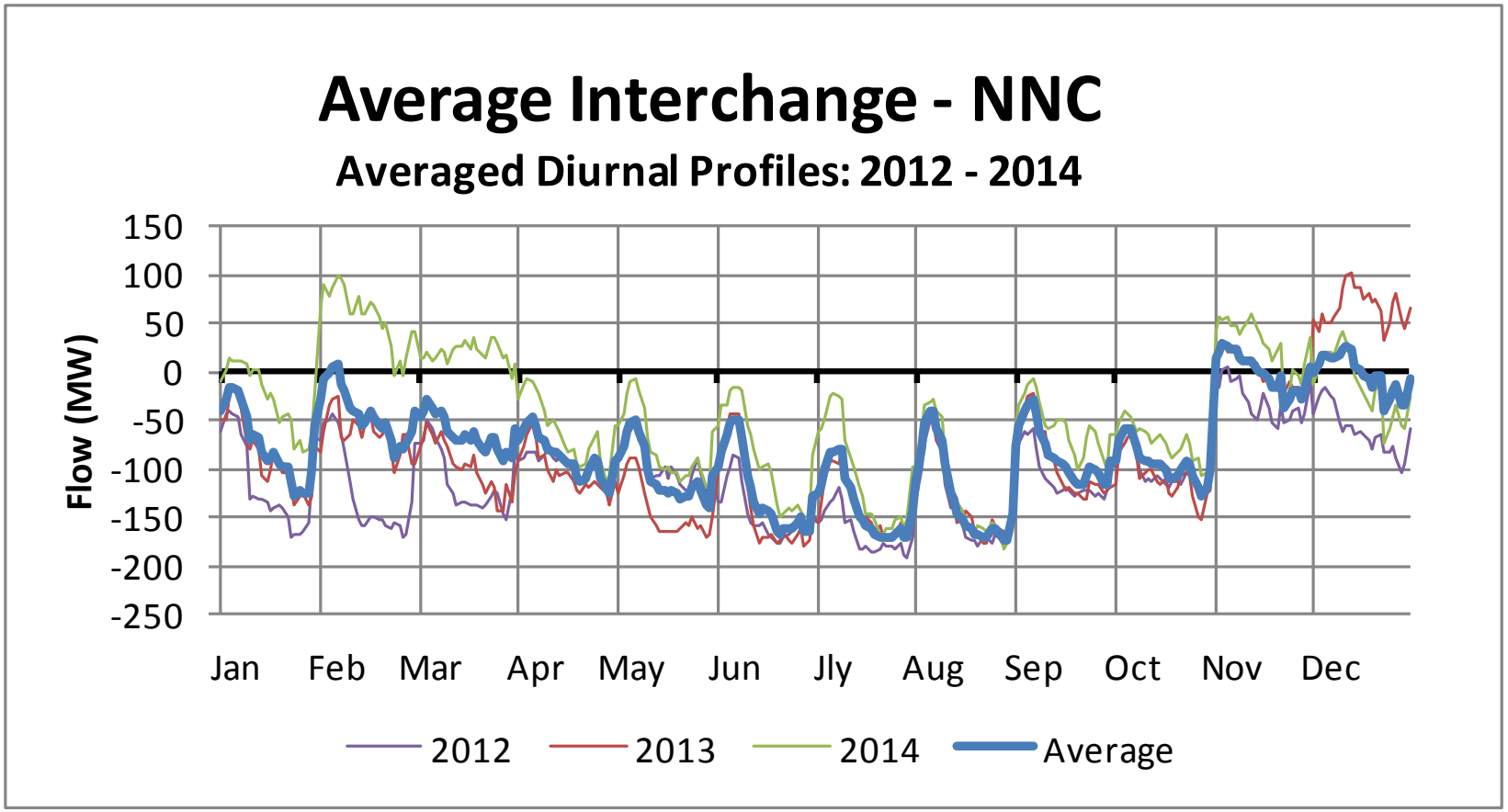
New England to New York - AC Interface



Note: positive values represent imports; negative values represent exports.

Imports and Exports Modeling

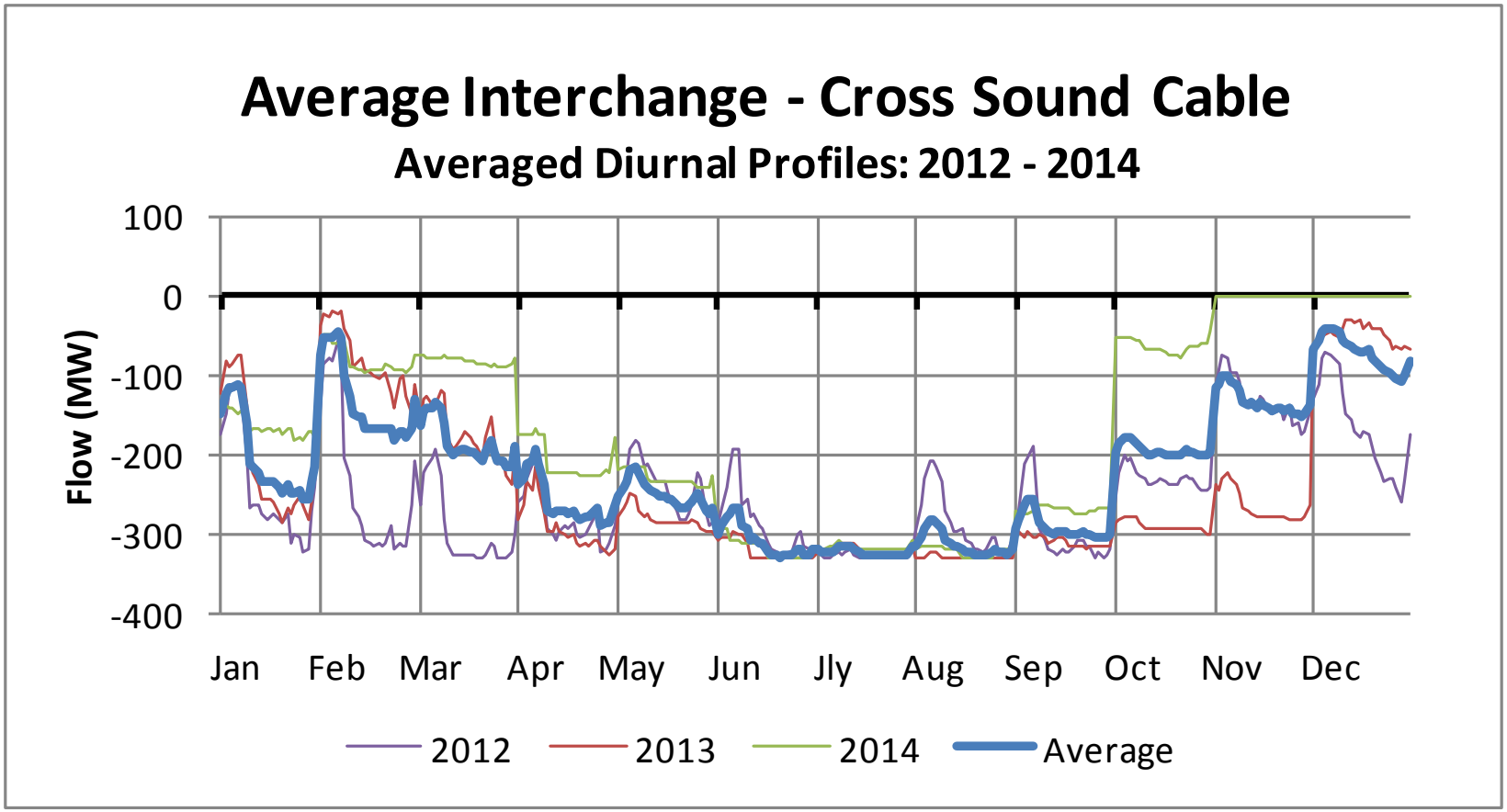
New England to New York - NNC Interface



Note: positive values represent imports; negative values represent exports.

Imports and Exports Modeling

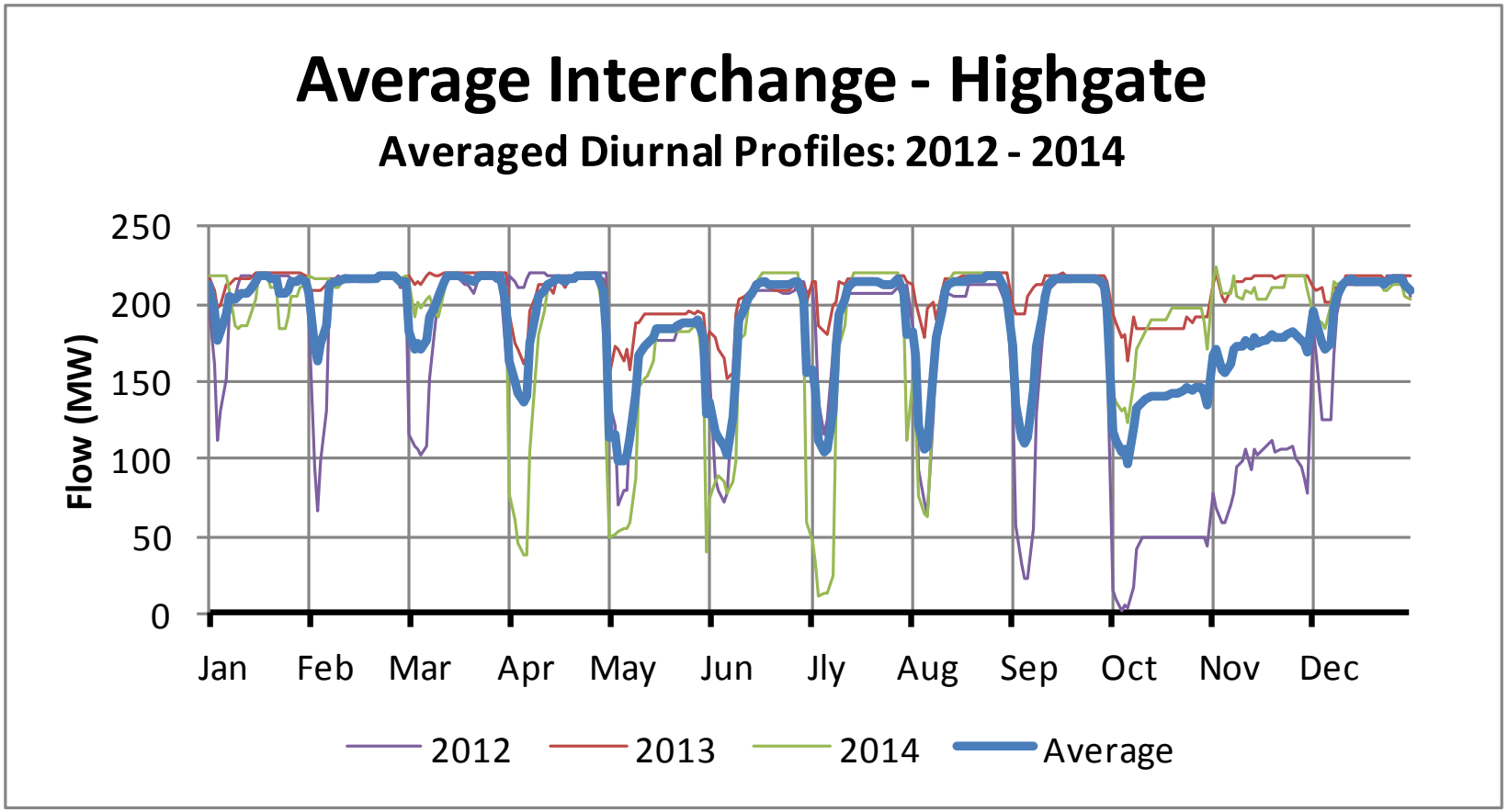
New England to New York – Cross Sound Cable



Note: positive values represent imports; negative values represent exports.

Imports and Exports Modeling

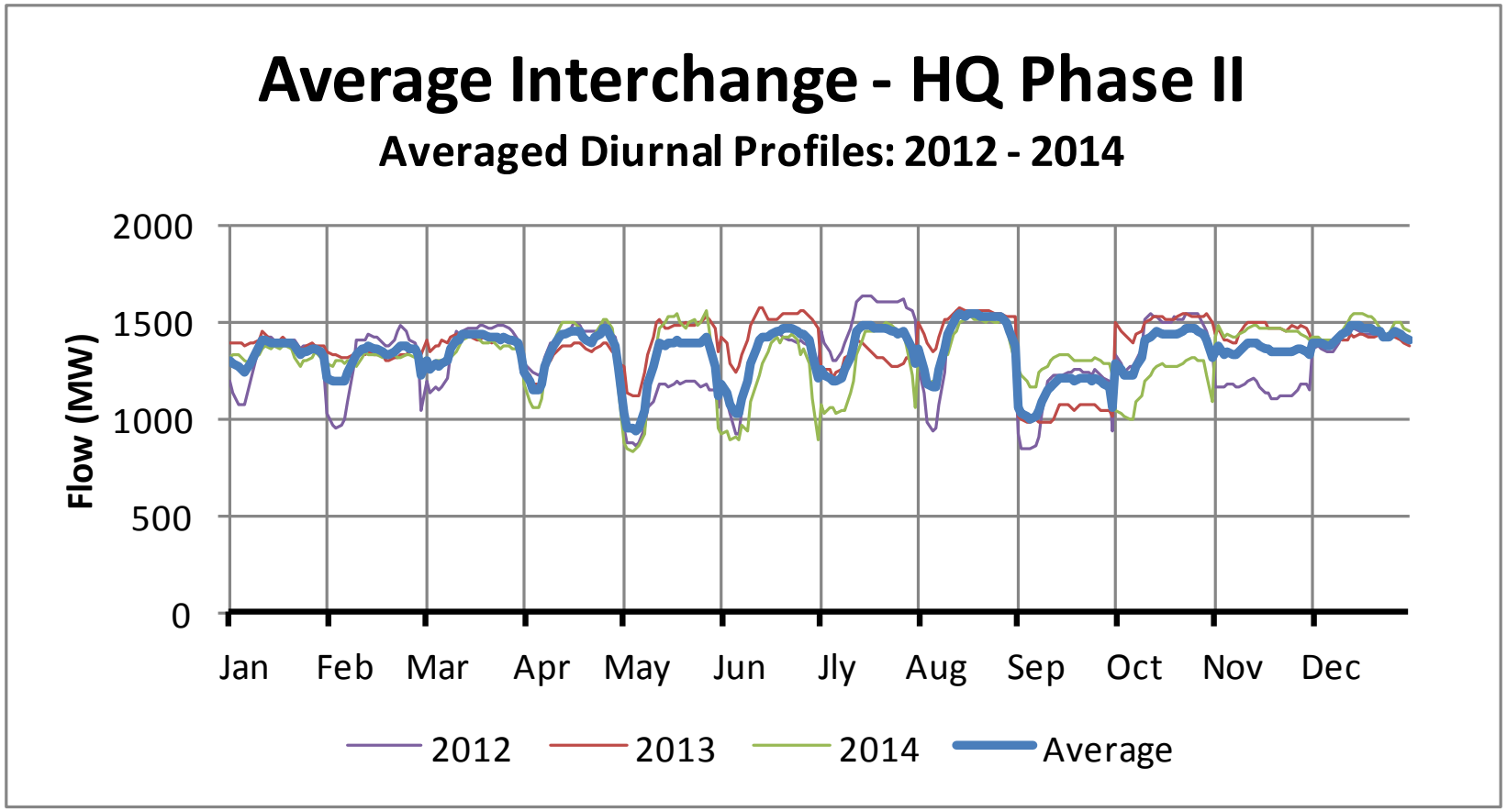
Quebec to New England: Highgate



Note: positive values represent imports; negative values represent exports.

Imports and Exports Modeling

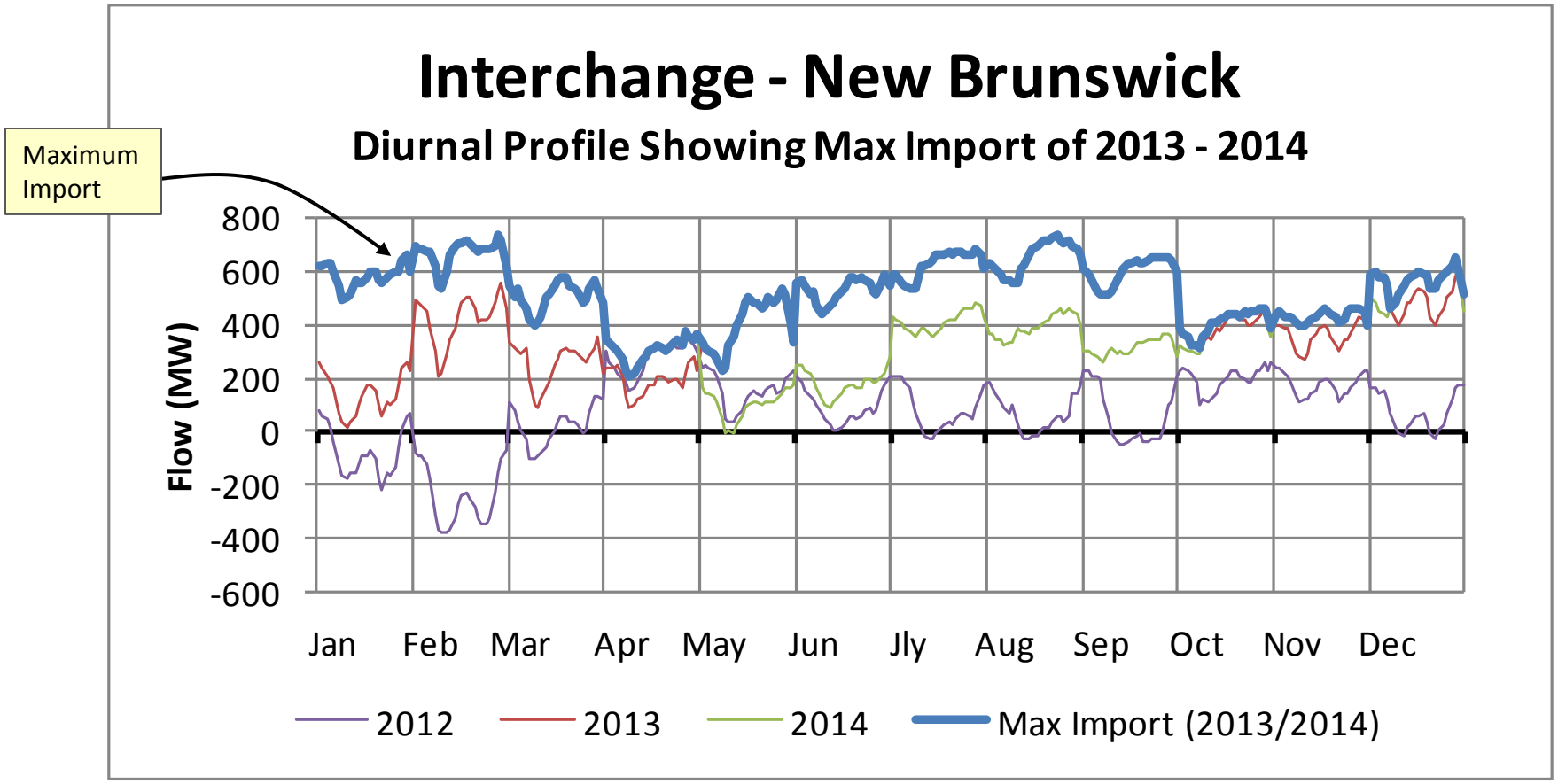
Quebec to New England: HQ Phase II



Note: positive values represent imports; negative values represent exports.

Imports and Exports Modeling

New Brunswick to New England



Note: positive values represent imports; negative values represent exports.

Questions