# 2015 Economic Study
# Keene Road Constraints

*Draft Results*

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SYSTEM PLANNING

# Outline

- Executive Summary
- Background and Assumptions
- Additional Results
- Appendix
  - Scenarios
  - Interface Flow Metrics
  - LMP Metrics
  - Scope of Work & Modeling Assumptions

# 2015 ECONOMIC STUDY
# KEENE ROAD CONSTRAINTS

*Executive Summary*

# Overview

- The ISO is performing three Economic Studies for 2015
  - 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 (request by RENEW Northeast)
- Today the ISO is seeking PAC input on the draft Keene Road study results
  - Estimate extent that transmission constraints are binding
  - Measure the economic benefits of relieving those transmission system constraints
  - Consider a variety of scenarios
  - Final study results and reports will be completed after consultation with the PAC
- This analysis includes future resources in some scenarios, but does not account for the transmission facilities required to meet minimum interconnection requirements
- The results may be used to inform the region on the needs for future transmission upgrades in the Keene Road area

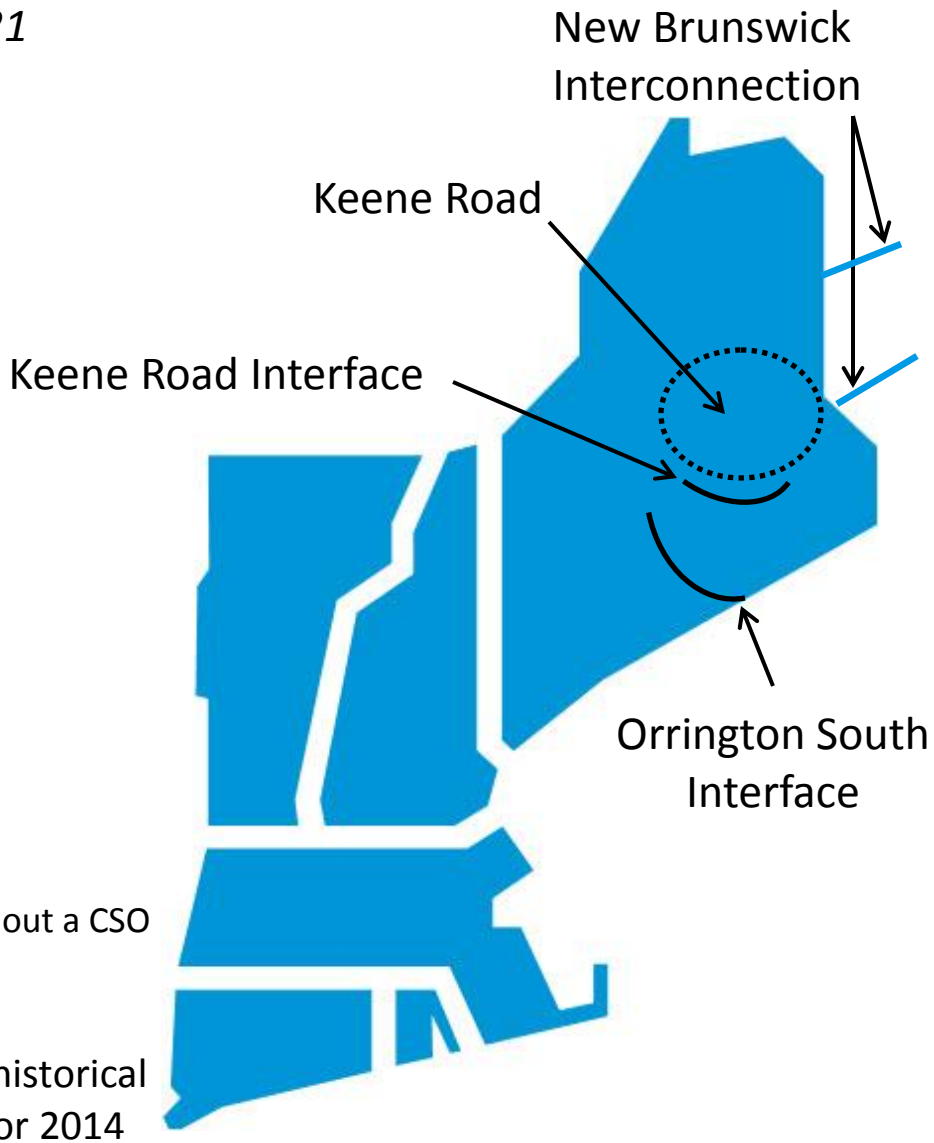
# Background

- As a result of discussions with the PAC, the May 2015 draft scope of work and assumptions were revised
  - http://www.iso-ne.com/static-assets/documents/2015/06/a9_2015_economic_studies_keene_rd_upgrades_scope_of_work_revised_draft.pdf
  - http://www.iso-ne.com/static-assets/documents/2015/06/a9_2015_economic_studies_assumptions_scope_of_work_revised_draft.pdf
  - http://www.iso-ne.com/static-assets/documents/2015/06/a9_2015_economic_studies_scope_of_work_stakeholder_comments.pdf
- The latest assumptions are available in the Appendix

# Study Scope –Keene Road Constraints

*Key Study Assumptions for Study of Year 2021*

- Keene Road Area
  - Peak Load: 38 MW
  - – Interface export limit
    - 175 MW – Existing case
    - 225 MW – Upgraded case
    - Unconstrained case
  - – Non-Wind resources (SCC)
    - Hydro: 90 MW (125 MW nameplate)
    - Other: 20 MW
  - – Total nameplate wind
    - 147 MW – Existing case
    - 187 MW – Proposed (I.3.9) case
    - 240 MW – Future (Queue) case
- New England
  - – Total wind development in New England
    - 878 MW – Existing case
    - 1,345 MW – Proposed (I.3.9) case
    - 4,417 MW – Future (Queue) case
  - – 2015 CELT loads
  - – FCA #9 resources and 2015 CELT resources without a CSO
  - – EIA fuel prices
  - – NREL wind and PV hourly profiles
- Imports from New Brunswick (NB) reflect the historical maximum imports for each month from 2013 or 2014

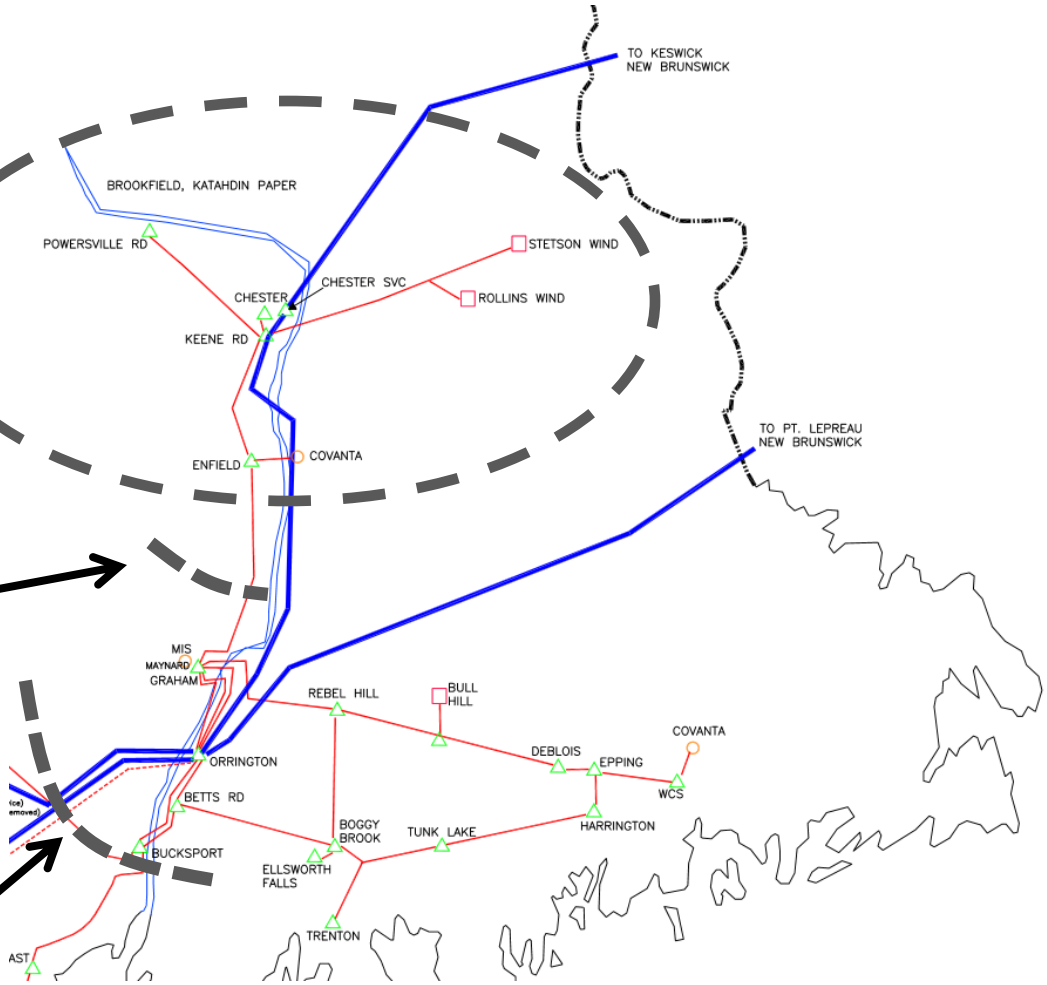


# Keene Road Geographic Area

Keene Road Area

Keene Road Export Interface

Orrington South Interface (1,325 MW Limit)



# Summary of Draft Results for Year 2021

*Single year results presented for discussion*

- Increasing the Keene Road export limits from 175 MW to 225 MW
  - Base Case: existing Keene Road resources (as of April 1, 2015) while increasing Keene Road export limit from 175 MW to 225 MW
    - Annual production cost savings of $1.4M
  - Across all scenarios
    - Production cost savings in the range of $0M to $5.7M per year
    - $CO_2$ emissions reductions ranging from 0 ktons to 35 ktons of systemwide emissions
- Increasing Keene Road export limits from 175 MW to unconstrained shows
  - Production cost savings in the range of $0M to $8.2M per year
  - Changes in $CO_2$ systemwide emissions range from
    - 1 kton increase resulting from changes in unit commitment
    - 47 kton decrease resulting from reduced dispatch of emitting units
- The Orrington South constraint affects the ability to transport capacity and energy resources to South of Orrington (including New Brunswick imports)
  - Constrained 1.1% to 8.6% of the time with existing and proposed wind
  - Constrained 70% of the time with future wind expansion throughout New England
  - Constrained up to 92% if New Brunswick imports assumed to be 1,000 MW 24x7

# Total Nameplate Wind by Scenario (MW)

| | Keene Road [1] | North of Orrington [2] | Other/South of Orrington [3] | New England [1 + 2 + 3] |
|---|---|---|---|---|
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 147 | 33 | 698 | 878 |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 187 | 33 | 698 | 918 |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 240 | 33 | 698 | 971 |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 187 | 44 | 1114 | 1345 |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 240 | 2590 | 1587 | 4417 |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 240 | 2590 | 1587 | 4417 |

*Outside of Keene Road, only "existing wind" is assumed

Note: Reference Appendix I for the specific wind units in each scenario

# Draft Results

*Production Cost Savings ($M/Year)*

| | Keene Road Export Limit | | Case Shows |
|---|---|---|---|
| | Increase from 175 MW To 225 MW | Increase from 175 MW to Unconstrained | |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 1.4 | 1.4 | Savings due to increased Keene Road export capability with existing wind behind Keene Road (147 MW nameplate) |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 3.1 | 4.0 | With increased export capability, production cost savings increase with additional I.3.9 wind behind Keene Road (187 MW nameplate) |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 5.7 | 8.2 | With increased export capability, production cost savings increase further with additional queue wind behind Keene Road (240 MW nameplate) |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 2.6 | 2.8 | Even with the addition of all wind with I.3.9 approval, upgrades to the Keene Road interface still provide savings. |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 0.4 | 0.4 | Competition between Keene Road wind and other queue wind north of Orrington reduces the savings by over 90% from the Future Keene Road Wind in Queue cases ($5.7M or $8.2M to $0.4M) |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 0 | 0 | Competition with NB imports and other queue wind eliminates most benefits of increased export capability |

*Outside of Keene Road, only "existing wind" is assumed

# Observations

- Increasing the Keene Road Interface from 175 MW to 225 MW
  - Shows production cost benefits
  - Production cost benefits increase when wind is added only behind Keene Road
  - Production cost benefits do not necessarily increase when wind is added north of Orrington South
- Constraints on the Orrington South interface were evident for
  - Large scale development of wind in North of Orrington South and/or
  - High levels of imports from New Brunswick

# 2015 Economic Study: Next Steps

- Review stakeholder comments and continue stakeholder discussions at future PAC meetings
- Summarize Keene Road Study in a report
- Conduct studies on two other 2015 Economic Study requests
  - Offshore Wind Deployment (request by Massachusetts Clean Energy Center)
  - Maine Upgrades Identified in ISO-NE's Strategic Transmission Analysis for Wind Integration (request by RENEW Northeast)

# STUDY OF KEENE ROAD CONSTRAINTS

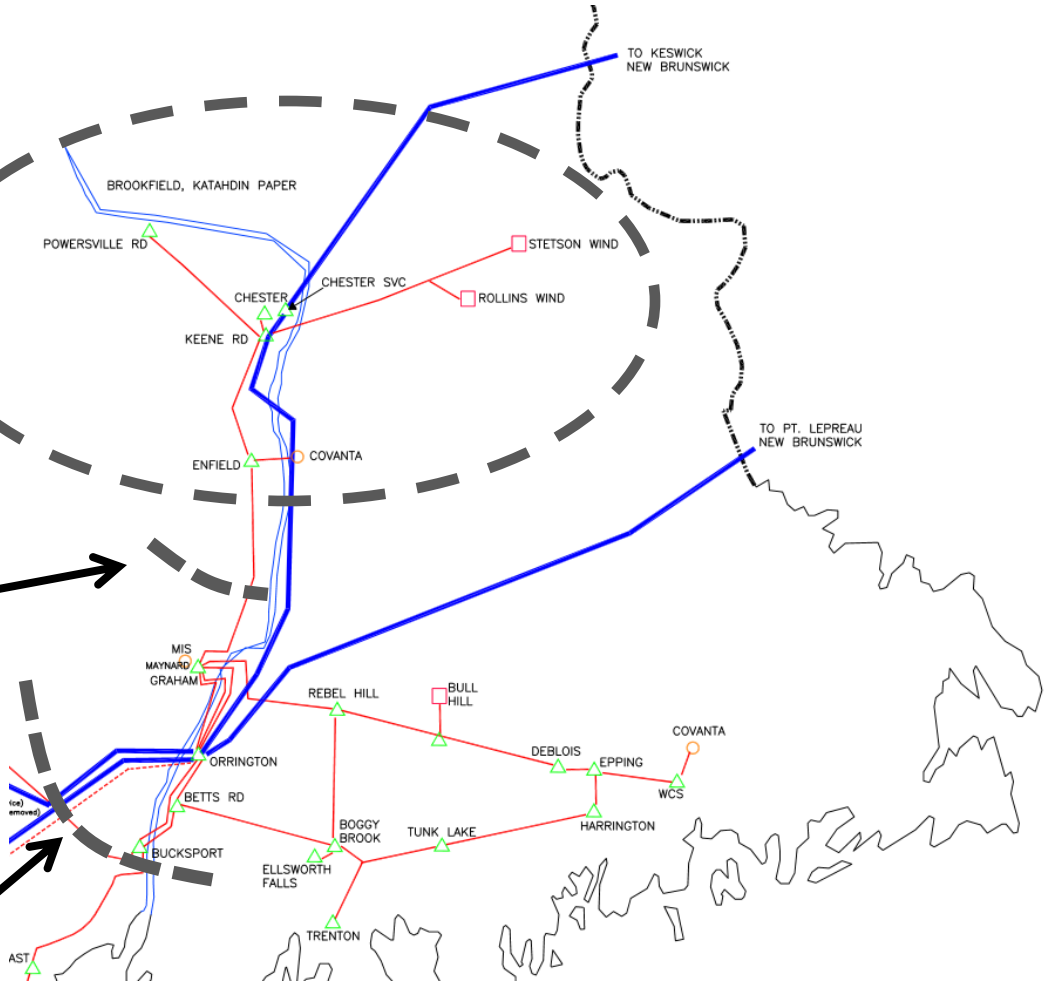
*Background and Assumptions*

# Keene Road Geographic Area

Keene Road Area

Keene Road Export Interface

Orrington South Interface (1,325 MW Limit)



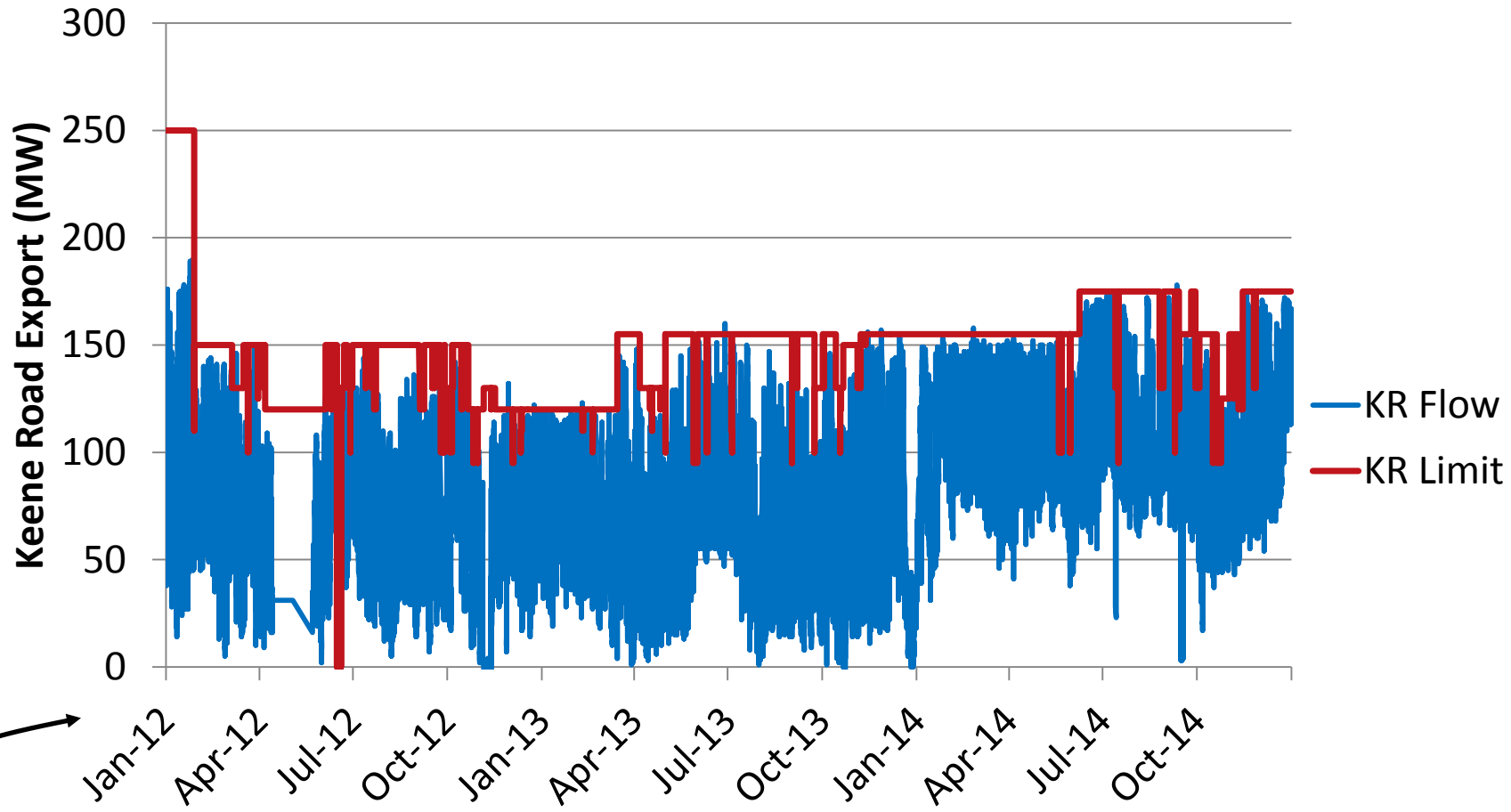
# Curtailment of Resources in the Keene Road Area

- Major drivers of historical curtailment
  - Competition for export capacity over Keene Road interface
  - Curtailment exacerbated by transmission construction (e.g., MPRP)
  - Other system constraints such as Orrington South
  - Minimum generation conditions
- Assumption: dispatch order (threshold price)*
  1) Wind ($0/MWh) – has highest dispatch priority
  2) Hydro ($5/MWh) – is reduced before wind
  3) Imports ($10/MWh) – is reduced before hydro and wind

  *Note: Production cost is zero for these resources. An LMP below the threshold price will result in a resource self curtailing.

# Historical Keene Road Interface Export

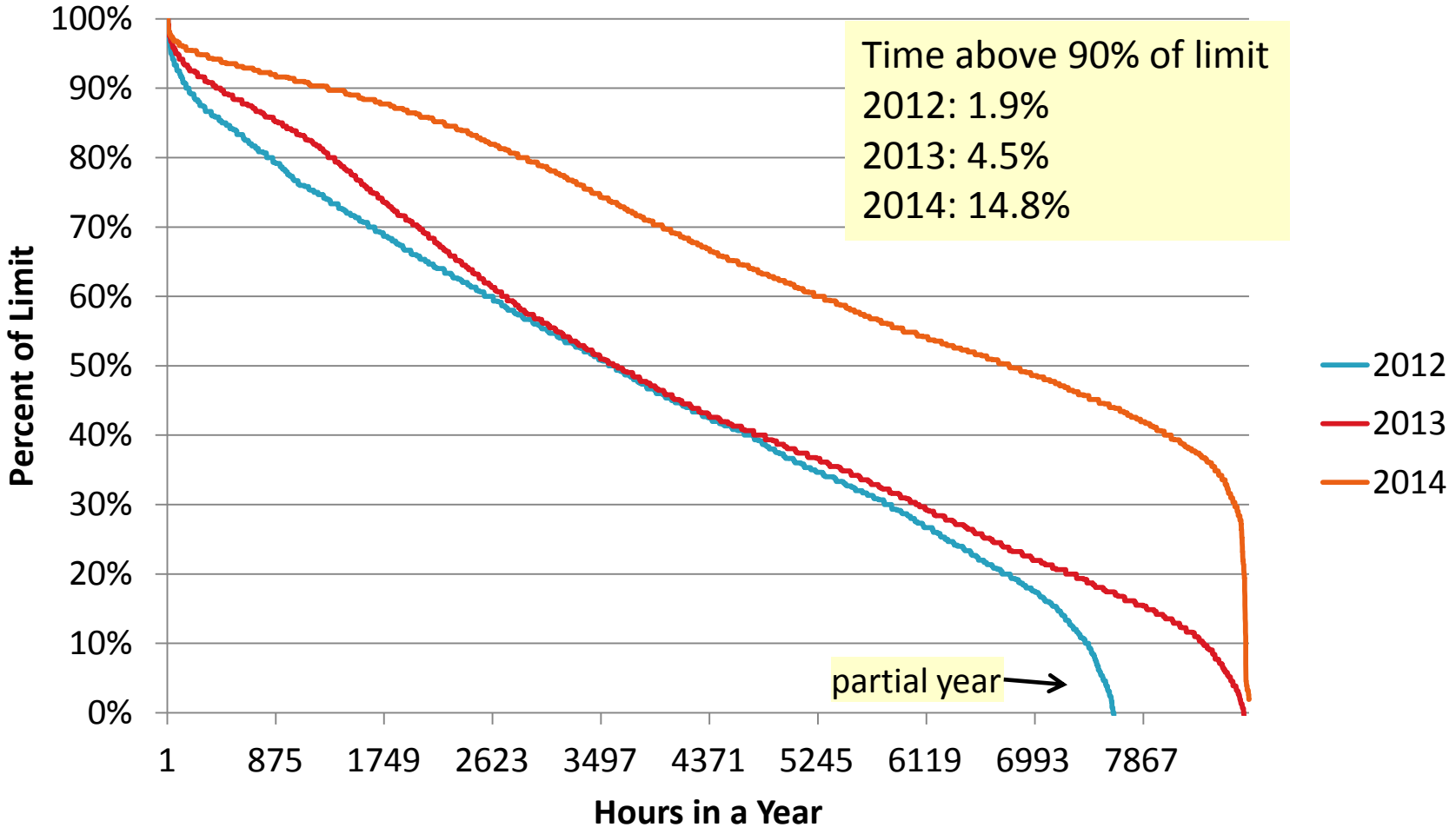
*Chronological Flows*




Keene Road had some net imports. These are not shown on the graph.

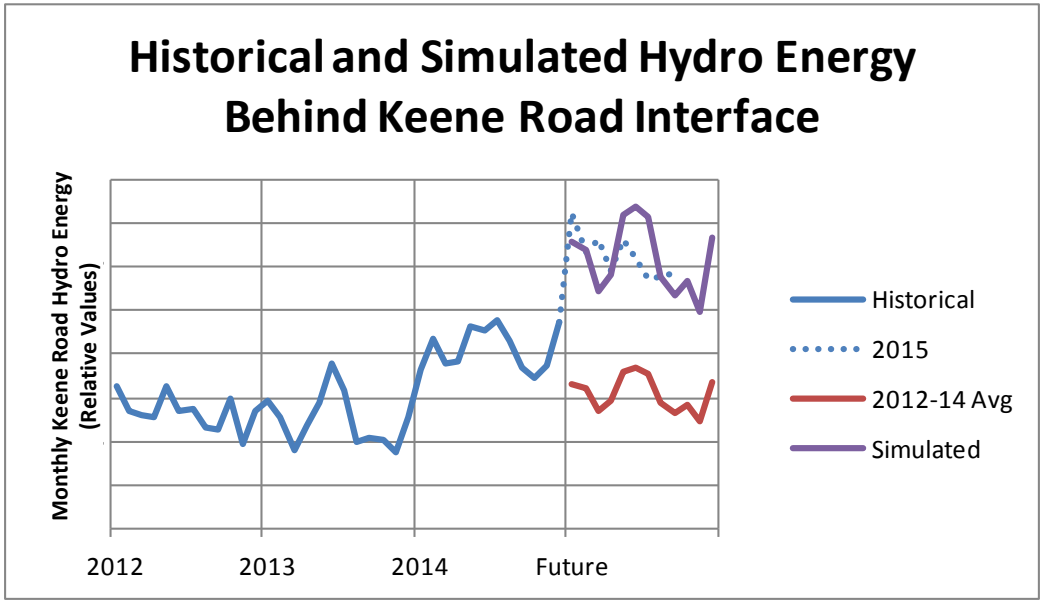
# Historical Keene Road Interface Export

*Percentage of Limit Duration Curve 2012-2014*



# Gross Demand in Keene Road Area

- Gross electrical energy demand within Keene Road area
  - Paper mills closings reduce demand
  - Hydro generation previously consumed by local demands now available for export
  - Significant increase of net hydro energy seen in 2014 and 2015
- Assumption: High amounts of hydro were simulated to reflect load retirements and expected increases in net hydro production



# Future Market Changes

- Magnitude and frequency of future curtailments could change due to market improvements scheduled for 2016 & 2017
  - "Do not Exceed" dispatch will be implemented
  - Allows hydro and wind resources to express their willingness to curtail based on submitted bids

# STUDY OF KEENE ROAD CONSTRAINTS

*Additional Results*

# Draft Results: Percent of Time Interface is at Limit

*Adding wind only behind Keene Road increases time Keene Road Interface is at limit*
*Adding resources north of Orrington South increases time Orrington South Interface is at limit*

| | Keene Road Export Limit (175 MW) | | Keene Road Export Limit (225 MW) | | Keene Road Export Limit (Unconstrained) | |
|---|---|---|---|---|---|---|
| | Keene Road | Orrington South | Keene Road | Orrington South | Keene Road | Orrington South |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 16.4 | 1.1 | 0.9 | 1.7 | | 1.8 |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 27.7 | 1.1 | 7.2 | 2.1 | | 2.6 |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 39.7 | 1.3 | 20.3 | 3.2 | | 4.5 |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 27.1 | 5.9 | 6.7 | 8.6 | | 8.9 |
| 3B **All New England Wind in Queue (as of 4/1/15)**** | 9.9 | 70.0 | 0.8 | 70.1 | | 70.1 |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7**** | 10.2 | 92.3 | 1.0 | 92.3 | | 92.3 |

*Outside of Keene Road, only "existing wind" is assumed
**Orrington South constraint dominates and Keene Road resources compete with other resources north of Orrington, including wind-on-wind competition

# Draft Results: Bottled in Energy (GWh) North of Keene Road

*Higher export capability allows more higher priced resources be exported*

| | Wind | | Hydro | | Case Shows |
|---|---|---|---|---|---|
| | **175 MW Limit** | **225 MW Limit** | **175 MW Limit** | **225 MW Limit** | |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 0 | 0 | 22 | 2 | Increase in export capability allows more hydro to be exported |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 9 | 9 | 73 | 8 | With additional I.3.9 wind behind Keene Road and increased export capability, more hydro energy can be exported |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 22 | 9 | 164 | 58 | With queue wind behind Keene Road and increased export capability, more hydro energy can be exported |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 9 | 9 | 72 | 8 | With additional I.3.9 wind and increased export capability, more hydro energy can be exported. |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 208 | 207 | 248 | 231 | Competition with other north of Orrington wind masks benefits of increased export capability |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 199 | 199 | 234 | 215 | Congestion because of NB and other north of Orrington wind masks benefits of increased export capability |

*Outside of Keene Road, only "existing wind" is assumed

# Draft Results: New England Load Serving Entity (LSE) Energy Expense Savings ($M)

*Increased export capability reduces LSE energy expense in Southern New England, but increases LSE energy expense within Keene Road in some hours*

| | Keene Road Export Limit | | Case Shows |
|---|---|---|---|
| | **Increase from 175 MW To 225 MW** | **Increase from 175 MW to Unconstrained** | |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | -1.9 | -1.9 | Benchmark. While production cost decreases, total LSE Energy Expense increases with additional export capability . The LSE expense increases in the Keene Road area. This exceeds the LSE expense savings in the rest of New England. |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 0.2 | -1.2 | While production cost decreases, total LSE Energy Expense increases or decreases with additional export capability |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 6.9 | 9.0 | Maximum reduction in total LSE Energy Expense from a New England wide perspective |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 3.2 | 3.4 | For an increase in export capability, additional total LSE expense savings is seen with all I.3.9 wind |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 0.5 | 0.5 | Competition with other wind mutes the benefits of Keene Road expansion by 90% ($6.9M or $9.0M to $0.5M) |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 0.0 | 0.0 | Congestion at Orrington South compartmentalizes benefits of lower LMP into north of Orrington area |

*Outside of Keene Road, only "existing wind" is assumed

# Draft Results: Systemwide Reductions of $CO_2$ (kton)

*Changes in $CO_2$ emissions are small relative to systemwide emissions of 40,000 kton/year*

| | Keene Road Export Limit | | Case Shows |
|---|---|---|---|
| | **Increase from 175 MW To 225 MW** | **Increase from 175 MW to Unconstrained** | |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 0 | -1 | With existing wind behind Keene Road and increased export capability, $CO_2$ emissions can increase or decrease based on changes to economic dispatch and unit commitment |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 7 | 4 | With additional I.3.9 wind behind Keene Road and increased export capability $CO_2$ emissions are reduced |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 35 | 47 | With queue wind behind Keene Road and increased export capability, $CO_2$ emissions are reduced |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 20 | 20 | With additional I.3.9 wind and increased export capability, $CO_2$ emissions can increase or decrease |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 4 | 4 | Competition with other queue wind north of Orrington reduces the $CO_2$ benefits |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 0 | 0 | Competition with NB imports and other queue wind eliminates most $CO_2$ benefits of increased export capability |

*Outside of Keene Road, only "existing wind" is assumed

Note: Increased export capability causes unit commitment changes for units across New England

# Draft Results: Implied Range of Capital Investment Attributable to Production Cost Savings ($M)

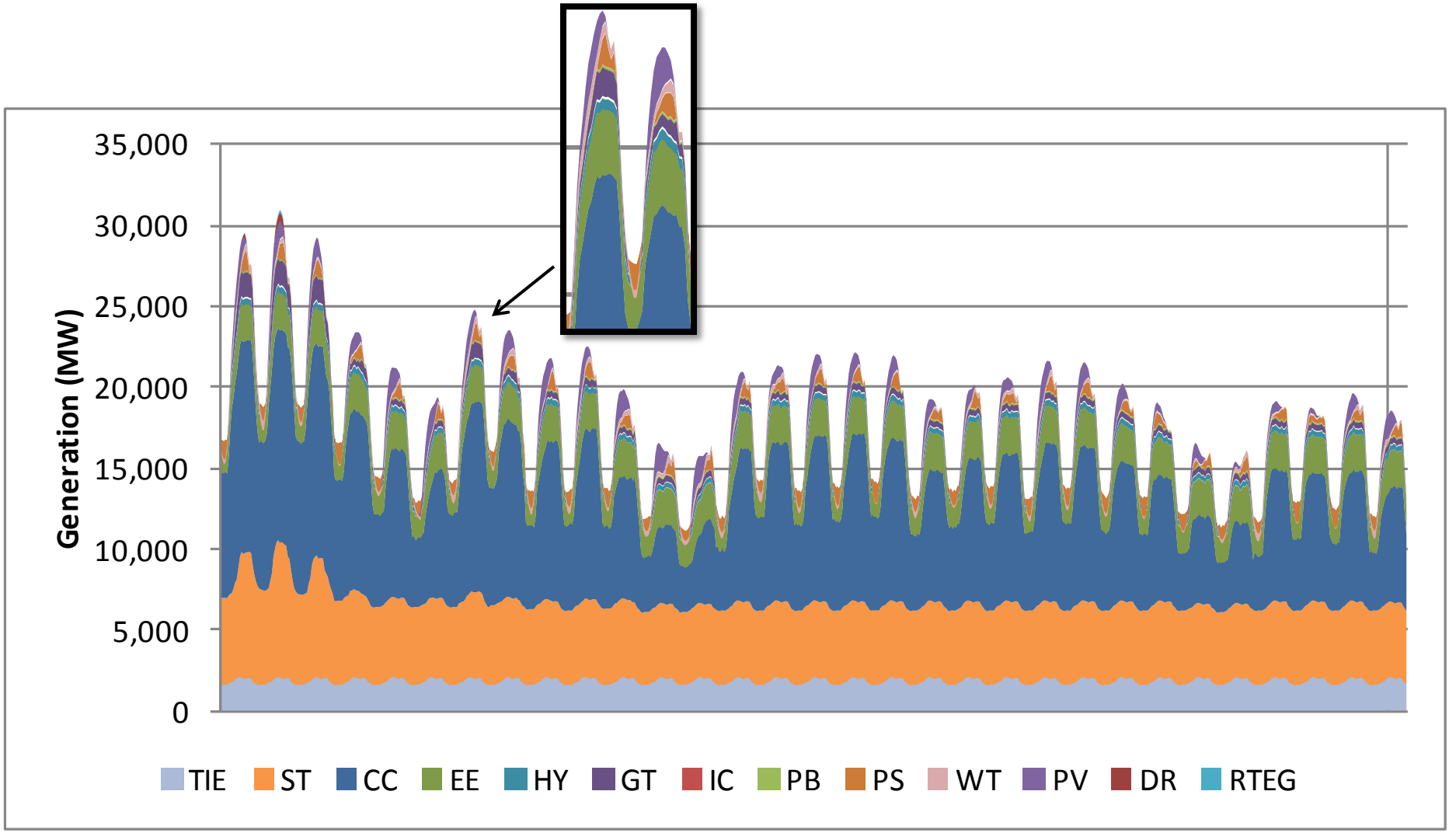
*Range based on 14% and 16% Annual Carrying Charges*

| | Keene Road Export Limit | | Case Shows |
|---|---|---|---|
| | **Increase from 175 MW To 225 MW** | **Increase from 175 MW to Unconstrained** | |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 8.8 – 10.0 | 8.8 – 10.0 | Implied range due to increased Keene Road export capability with existing wind behind Keene Road (147 MW nameplate) |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 19.4 - 22.1 | 25.0 - 28.6 | With increased export capability, implied range increases with additional I.3.9 wind behind Keene Road (187 MW nameplate) |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 35.6 - 40.7 | 51.3 - 58.6 | With increased export capability, implied range increases further with additional queue wind behind Keene Road (240 MW nameplate) |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 16.3 - 18.6 | 17.5 – 20.0 | Keene Road interface increase provides additional implied range for development of all wind interconnections with I.3.9 as compared with existing wind resources |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 2.5 - 2.9 | 2.5 - 2.9 | Competition between Keene Road wind and other queue wind north of Orrington reduces the implied range by over 90% from the future Keene Road Wind in Queue case (from $35.6M or $58.6M to $2.5M or $2.9M) |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 0.0 – 0.0 | 0.0 – 0.0 | Competition with NB imports and other queue wind eliminates most benefits of increased export capability |

*Outside of Keene Road, only "existing wind" is assumed

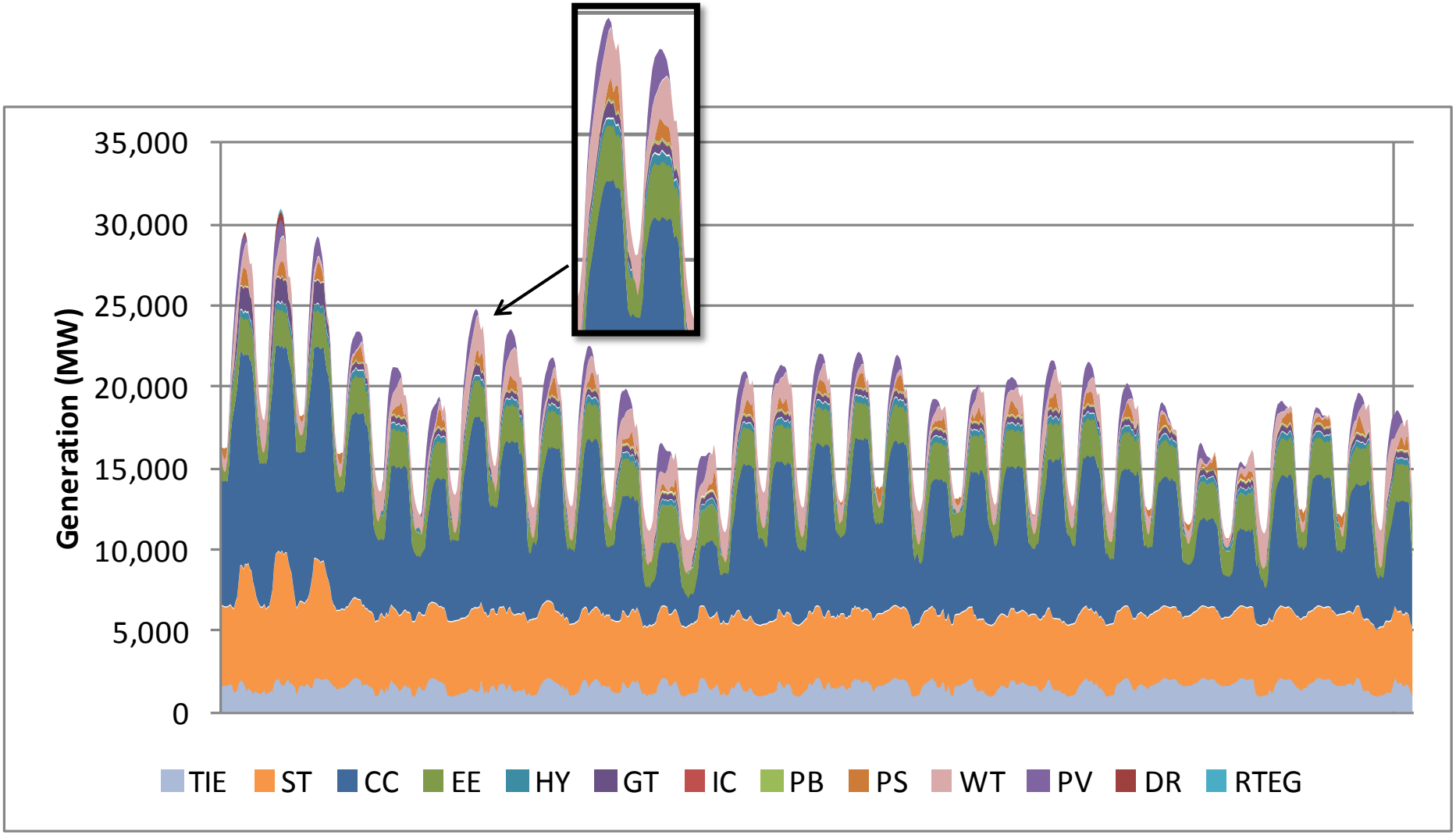
# Energy By Resource Type: August 2021

*Existing Wind – Keene Road at 175 MW Limit*



# Energy By Resource Type: August 2021

*Future Wind (all queue wind) – Keene Road Unconstrained*



# Questions

# APPENDICES

*I – Scenarios*

*II – Interface Flow Metrics*

*III – LMP Metrics*

*IV – Scope of Work & Modeling Assumptions*

# STUDY OF KEENE ROAD CONSTRAINTS

*Appendix I – Scenarios*

# Table of Scenarios

| | | Keene Road Export Limit Scenarios | | |
|---|---|---|---|---|
| | | **175 MW** | **225 MW** | **Unconstrained** |
| **Wind Scenarios** | 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 175E | 225E | UC-E |
| | 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 175P-KROnly | 225P-KROnly | UC-P-KROnly |
| | 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 175F-KROnly | 225F-KROnly | UC-F-KROnly |
| | 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 175P | 225P | UC-P |
| | 3B **All New England Wind in Queue (as of 4/1/15)** | 175F | 225F | UC-F |
| | 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 175F-NB | 225F-NB | UC-F-NB |

*Outside of Keene Road, only "existing wind" is assumed

# Scenario Specific

*Keene Road Export Limit*

- Base case (175 MW)
  - Assumed current Keene Road export limit
- Sensitivity cases evaluate the impact of improving the Keene Road export limit
  - Sensitivity 1 (225 MW)
    - Assumed 50 MW increase from 175 MW due to 50% series compensation
  - Sensitivity 2 (unconstrained/“UC”)
    - Keene Road export limit assumed unconstrained

# Scenario Specific

*Wind*

- Base case (Existing Wind or “E”)
  - Use only existing wind resources as of April 1, 2015
- Sensitivity cases evaluate the impact of additional wind development from resources currently in the queue
  - Sensitivity 1 (Proposed Wind or “P”)
    - Include additional New England wind resources with Proposed Plan Approval (PPA) as of April 1, 2015
  - Sensitivity 2 (Future Wind or “F”)
    - Include all New England wind resources in the interconnection queue as of April 1, 2015
- Sensitivities of higher New Brunswick imports

# Scenario Specific

*Wind Nameplate*

| | Total Wind Nameplate (MW) | Keene Road | North of Orrington (exclude Keene Road) |
|---|---|---|---|
| (E) Existing Wind Projects | 878 | 147 | 33 |
| (P) + PPA Wind | 1345 | 187 | 44 |
| (F) + Future Queued Wind | 4417 | 240 | 2590 |

# Scenario Specific

*Wind – by Subarea (1)*

| Area Name | Wind Resource Name | Existing | Proposed | Future |
|---|---|---|---|---|
| Keene Road | QP357_Passadumkeag Windpark | 0.0 | 40.0 | 0.0 |
| Keene Road | QP476_Wind | 0.0 | 0.0 | 52.8 |
| Keene Road | Rollins Wind Plant | 61.8 | 0.0 | 0.0 |
| Keene Road | Stetson II Wind Farm | 26.3 | 0.0 | 0.0 |
| Keene Road | Stetson Wind Farm | 58.7 | 0.0 | 0.0 |
| Area Total | | 146.8 | 40.0 | 52.8 |
| | | | | |
| BHE | Bull Hill Wind | 34.5 | 0.0 | 0.0 |
| BHE | QP349_Pisgah Mountain | 0.0 | 9.1 | 0.0 |
| BHE | QP397_Hancock Wind Project | 0.0 | 0.0 | 51.0 |
| BHE | QP400_Wind | 0.0 | 0.0 | 90.0 |
| BHE | QP403_Pisgah Mountain Increase (see QP249) | 0.0 | 0.0 | 0.1 |
| BHE | QP417_Wind | 0.0 | 0.0 | 250.0 |
| BHE | QP420_Wind | 0.0 | 0.0 | 72.6 |
| BHE | QP435_Wind | 0.0 | 0.0 | 111.0 |
| BHE | QP458_Wind | 0.0 | 0.0 | 104.0 |
| BHE | QP459_Wind | 0.0 | 0.0 | 104.0 |
| BHE | QP460_Wind | 0.0 | 0.0 | 104.0 |
| BHE | QP461_Wind | 0.0 | 0.0 | 104.0 |
| BHE | QP462_Wind | 0.0 | 0.0 | 104.0 |
| BHE | QP470_Wind | 0.0 | 0.0 | 600.6 |
| BHE | QP471_Wind | 0.0 | 0.0 | 600.6 |
| BHE | QP486_Wind | 0.0 | 0.0 | 250.0 |
| Area Total | | 34.5 | 9.1 | 2545.9 |

# Scenario Specific

*Wind – by Subarea (2)*

| Area Name | Wind Resource Name | Existing | Proposed | Future |
|---|---|---|---|---|
| ME | GMCW | 10.5 | 0.0 | 0.0 |
| ME | Kibby Wind Power | 149.6 | 0.0 | 0.0 |
| ME | QP272_Oakfield II Wind – Keene Road | 0.0 | 147.6 | 0.0 |
| ME | Saddleback Ridge Wind | 34.2 | 0.0 | 0.0 |
| ME | Spruce Mountain Wind | 20.0 | 0.0 | 0.0 |
| ME | QP300_Canton Mountain Winds | 0.0 | 22.8 | 0.0 |
| ME | QP333_Bingham Wind | 0.0 | 184.8 | 0.0 |
| ME | QP350_Wind | 0.0 | 0.0 | 96.9 |
| ME | QP393_Wind | 0.0 | 0.0 | 84.0 |
| ME | QP406_Canton Increase and CNR (see QP300) | 0.0 | 0.0 | 3.6 |
| ME | QP407_Saddleback Increase and CNR (see QP287) | 0.0 | 0.0 | 1.2 |
| ME | QP452_Wind | 0.0 | 0.0 | 85.8 |
| ME | Record Hill Wind | 50.6 | 0.0 | 0.0 |
| ME | WND_MISC_ME | 6.3 | 0.0 | 0.0 |
| Area Total | | 271.2 | 355.2 | 271.5 |

# Scenario Specific

*Wind – by Subarea (3)*

| Area Name | Wind Resource Name | Existing | Proposed | Future |
|---|---|---|---|---|
| BOSTON | WND_MISC_Boston | 12.2 | 0.0 | 0.0 |
| Area Total | | 12.2 | 0.0 | 0.0 |
| | | | | |
| CMA NEMA | Princeton Wind Farm | 3.0 | 0.0 | 0.0 |
| CMA NEMA | WND_MISC_CMANEMA | 4.0 | 0.0 | 0.0 |
| Area Total | | 7.0 | 0.0 | 0.0 |
| | | | | |
| NH | Lempster Wind | 25.3 | 0.0 | 0.0 |
| NH | Granite Reliable Power | 120.2 | 0.0 | 0.0 |
| NH | Groton Wind | 50.5 | 0.0 | 0.0 |
| NH | QP390_Spruce Ridge Wind Farm | 0.0 | 50.8 | 0.0 |
| NH | QP415_Jericho Wind | 0.0 | 12.1 | 0.0 |
| NH | QP543_Wind | 0.0 | 0.0 | 28.4 |
| Area Total | | 196.0 | 62.9 | 28.4 |

# Scenario Specific

*Wind – by Subarea (4)*

| Area Name | Wind Resource Name | Existing | Proposed | Future |
|---|---|---|---|---|
| RI | WND_MISC_RI | 7.2 | 0.0 | 0.0 |
| Area Total | | 7.2 | 0.0 | 0.0 |
| | | | | |
| SEMA | WND_MISC_SEMA | 22.9 | 0.0 | 0.0 |
| Area Total | | 22.9 | 0.0 | 0.0 |
| | | | | |
| VT | Kingdom Community Wind | 81.5 | 0.0 | 0.0 |
| VT | QP488_Wind | 0.0 | 0.0 | 96.9 |
| VT | QP532_Wind | 0.0 | 0.0 | 19.9 |
| VT | QP536_Wind | 0.0 | 0.0 | 5.0 |
| VT | Searsburg Wind | 1.7 | 0.0 | 0.0 |
| VT | Sheffield Wind Plant | 40.0 | 0.0 | 0.0 |
| Area Total | | 123.2 | 0.0 | 121.7 |
| | | | | |
| WMA | Berkshire Wind Power Project | 16.7 | 0.0 | 0.0 |
| WMA | QP396_Berkshire Wind Increase | 0.0 | 0.0 | 16.7 |
| WMA | QP477_Wind | 0.0 | 0.0 | 30.0 |
| WMA | QP535_Wind | 0.0 | 0.0 | 5.0 |
| WMA | QP539_CNR Only | 31.7 | 0.0 | 0.0 |
| WMA | WND_MISC_WMA | 8.8 | 0.0 | 0.0 |
| Area Total | | 57.2 | 0.0 | 51.7 |

# Scenario Specific

*New Brunswick Imports*

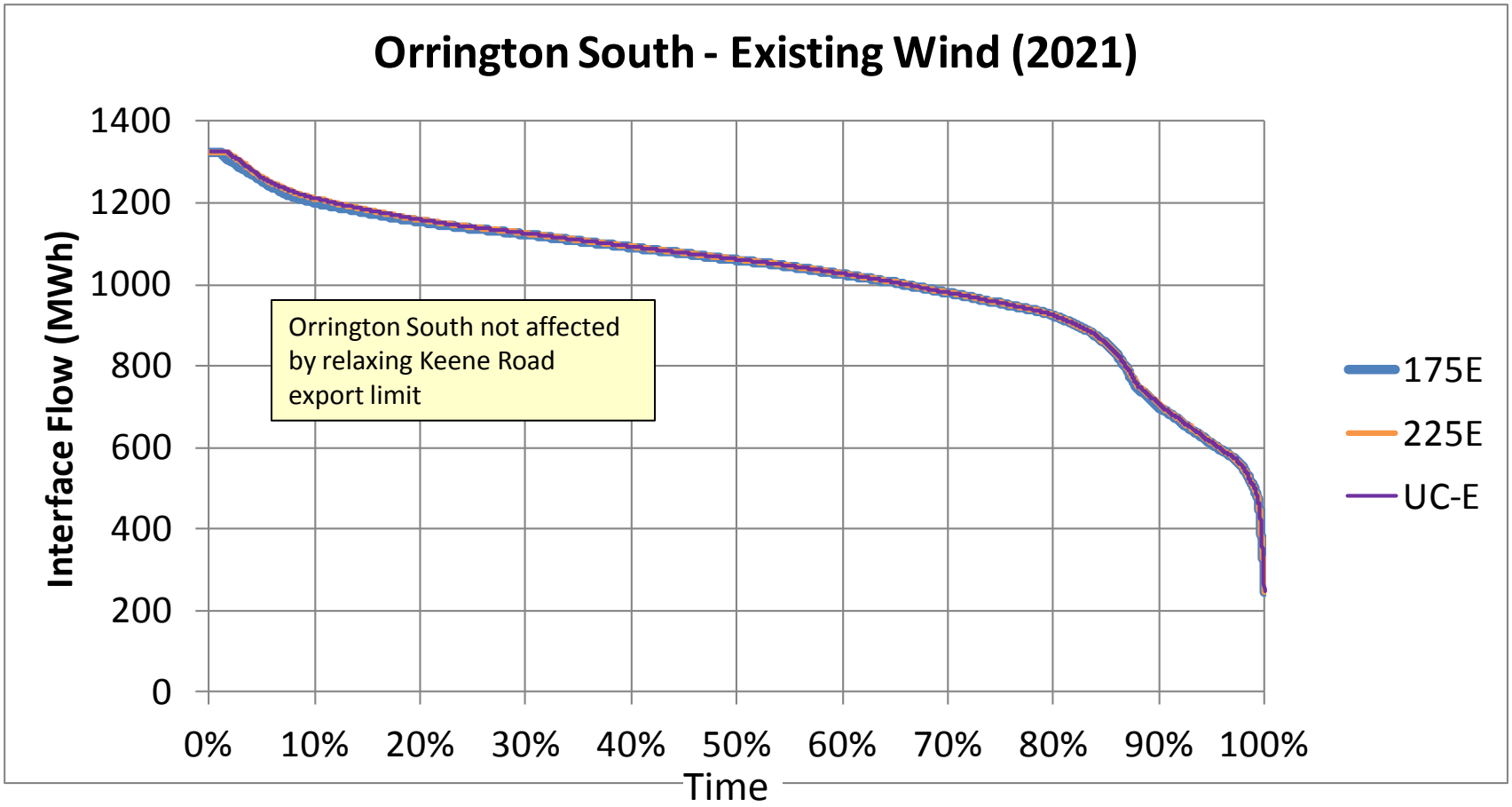
- Base case
  - Daily diurnal curves
  - Historical maximum imports by month for 2013-2014
- Sensitivity cases evaluate the impact of additional New Brunswick imports
  - Assumed import of 1000 MW for all hours
  - Applied to all Future wind scenarios (F)

# STUDY OF KEENE ROAD CONSTRAINTS

*Appendix II – Interface Flow Metrics*

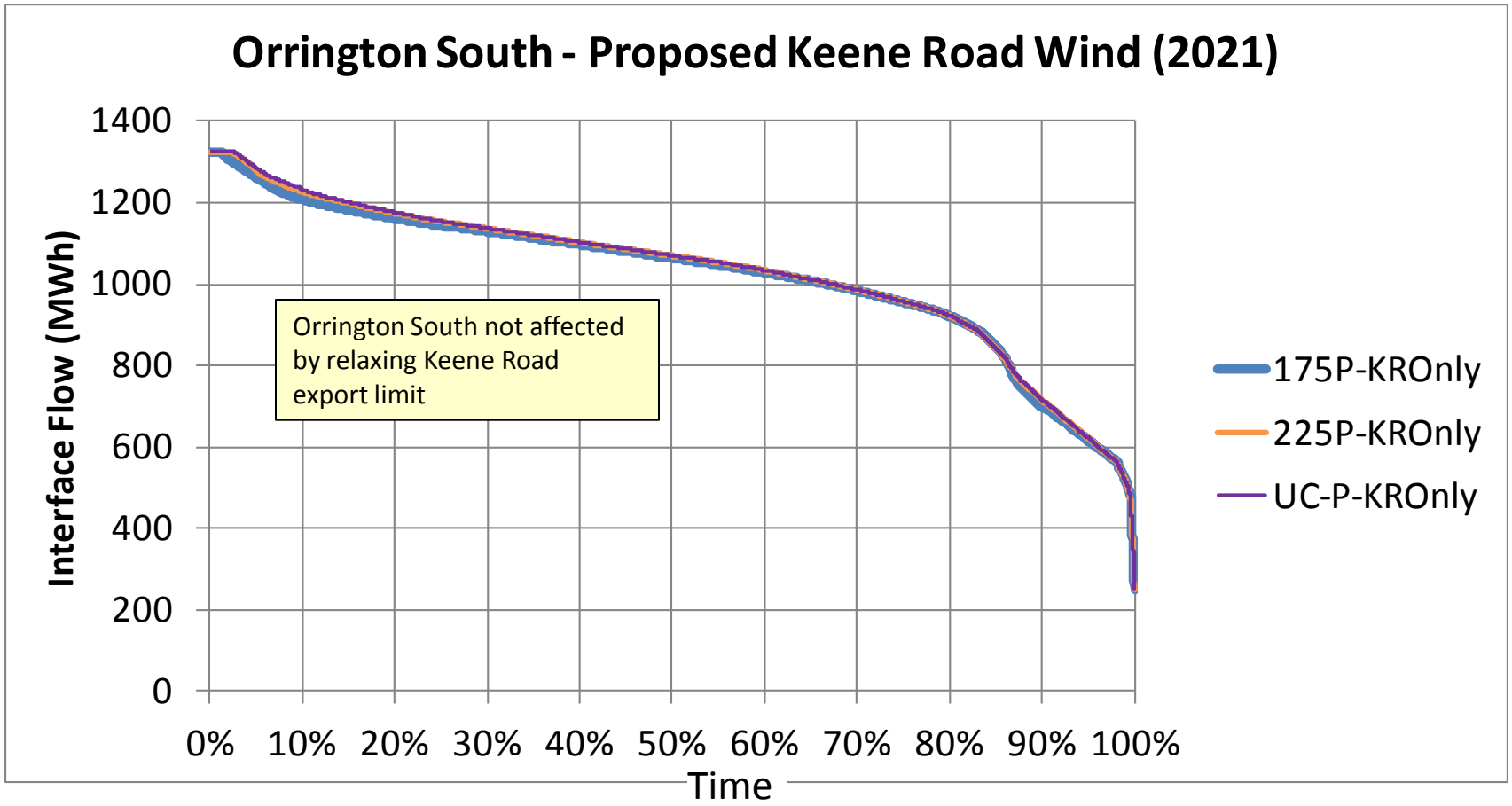
# Interface: Orrington South – Existing Wind

*Duration Curve*



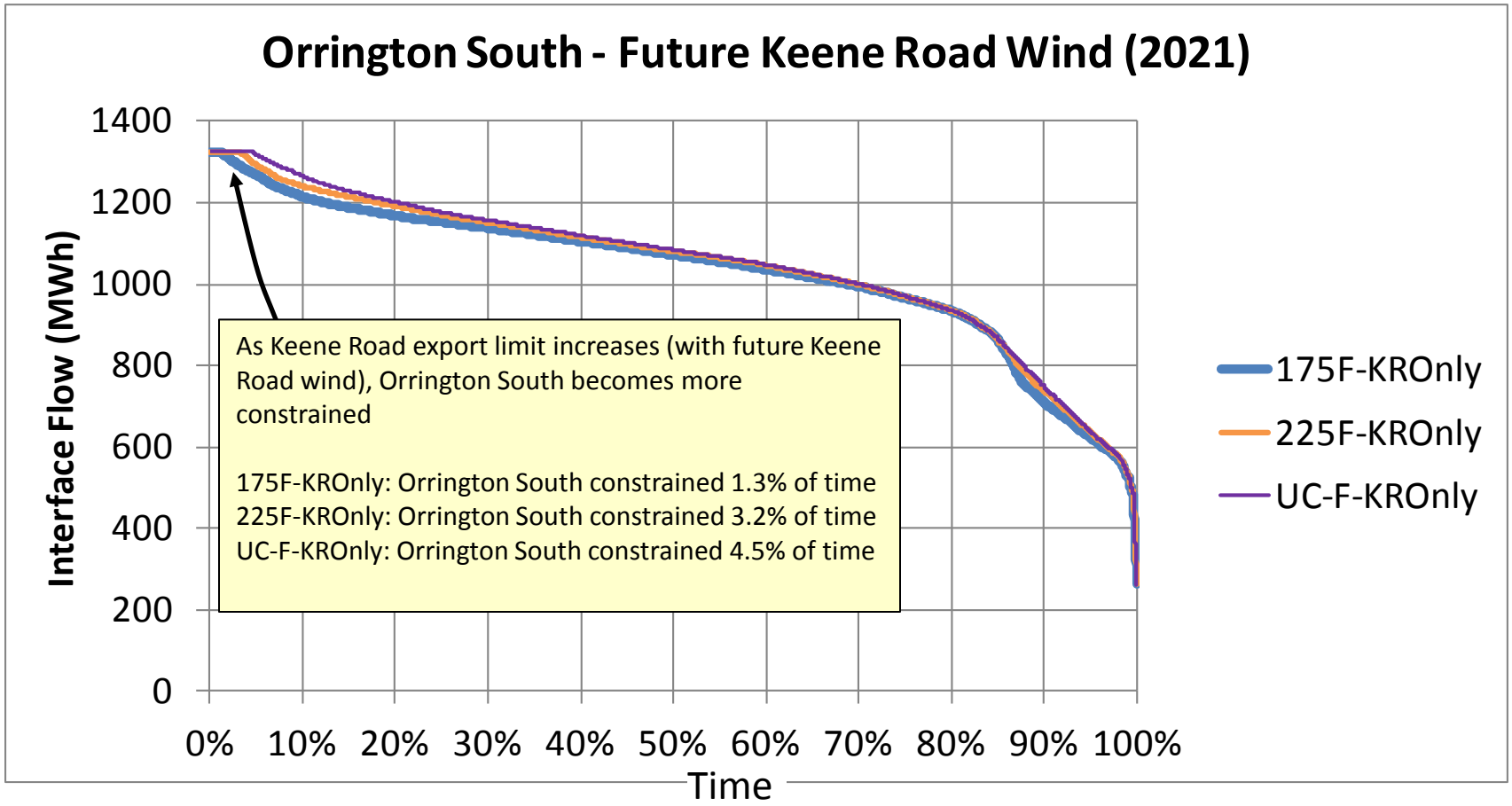
# Interface: Orrington South – Proposed Keene Road Wind

*Duration Curve*



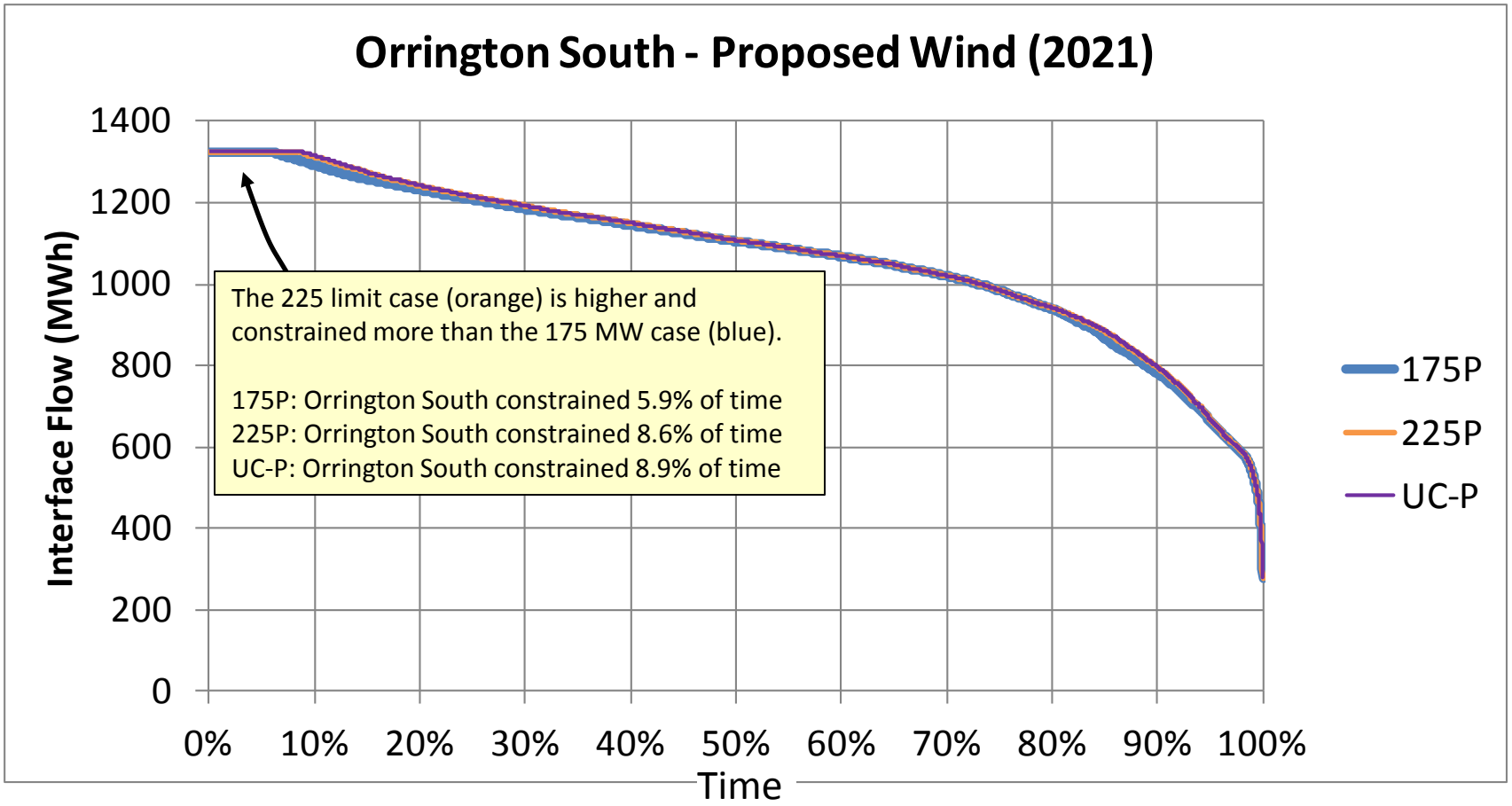
# Interface: Orrington South – Future Keene Road Wind

*Duration Curve*



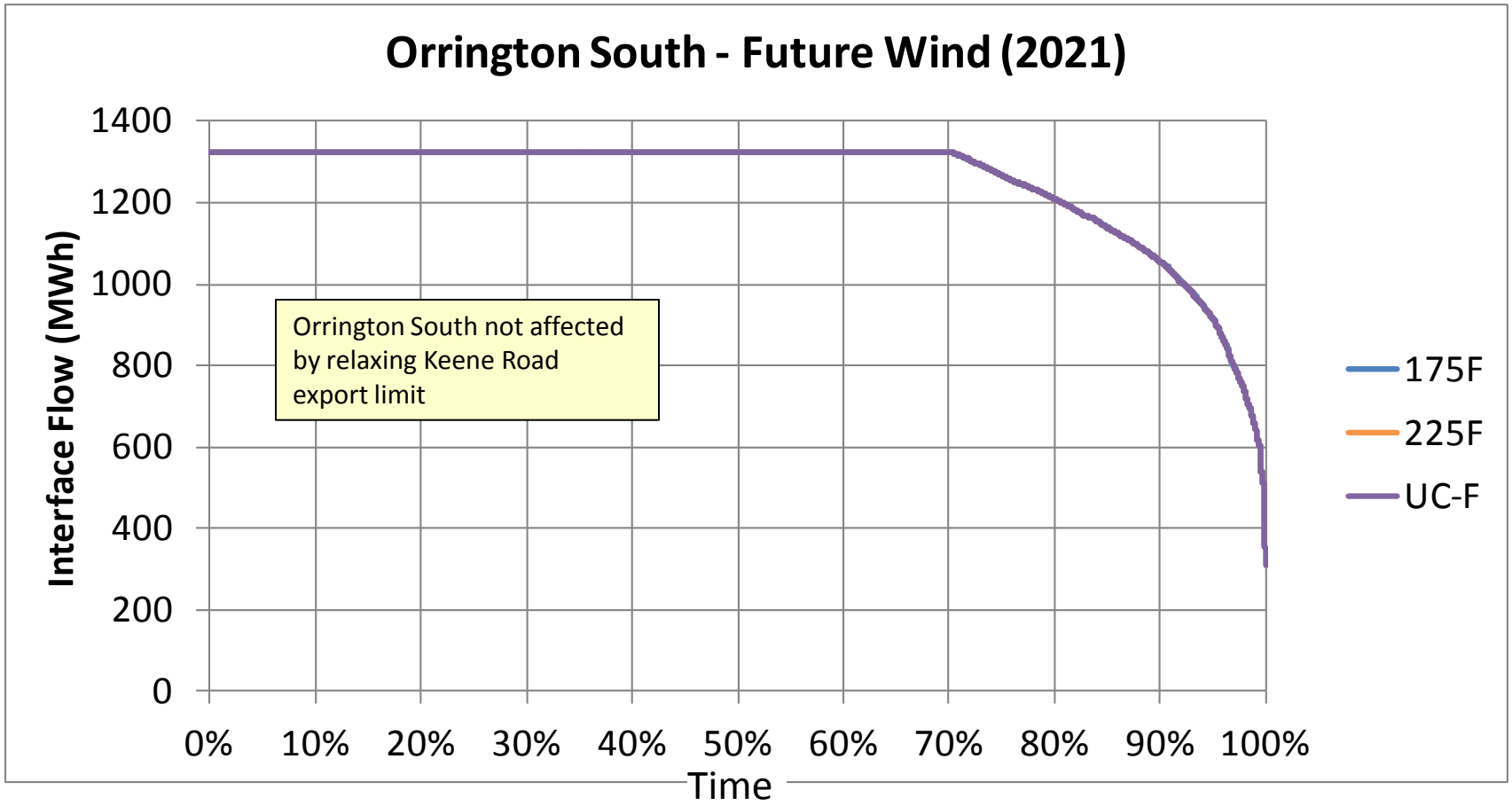
# Interface: Orrington South – Proposed Wind

*Duration Curve*



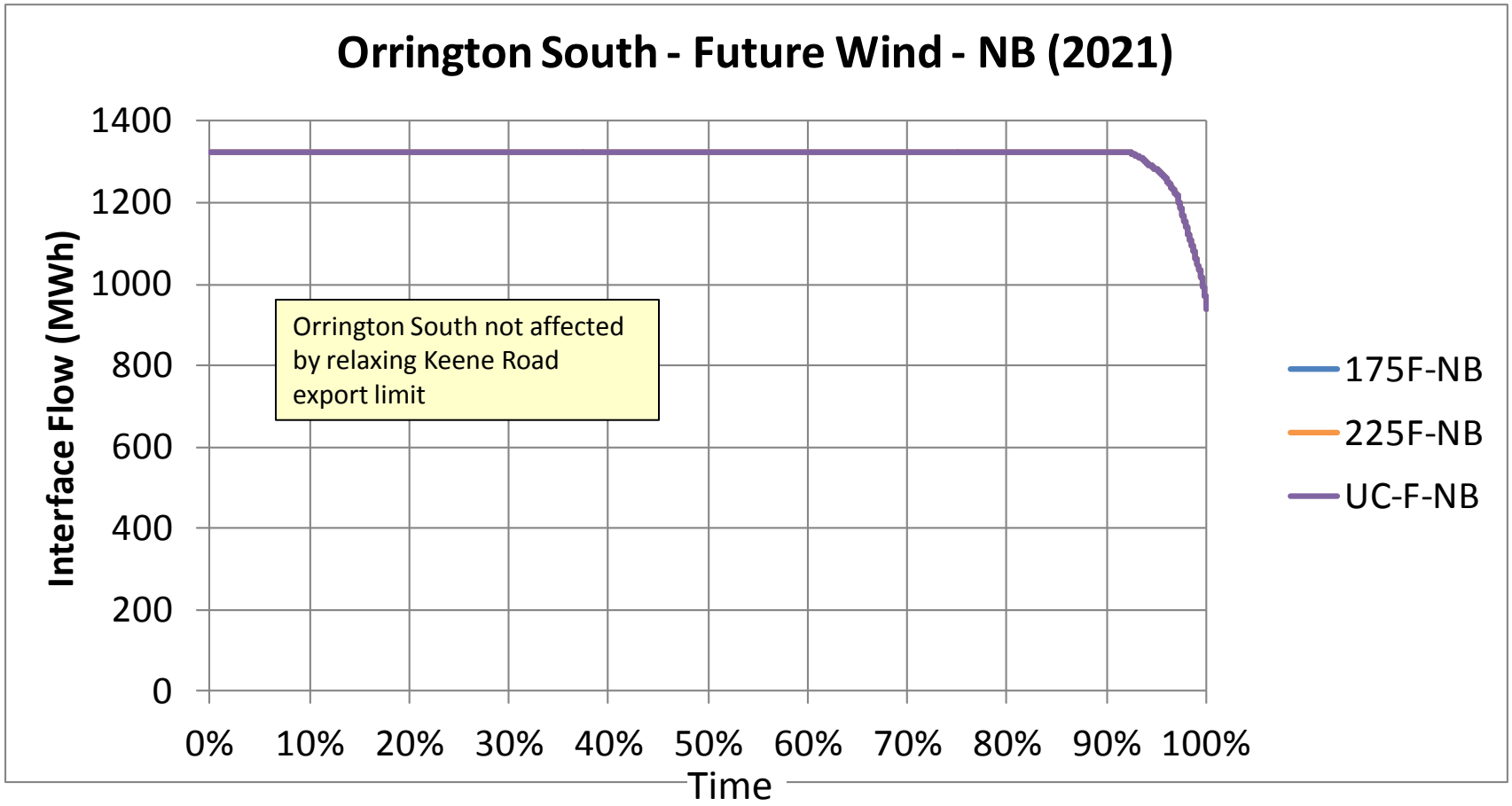
# Interface: Orrington South – Future Wind

*Duration Curve*



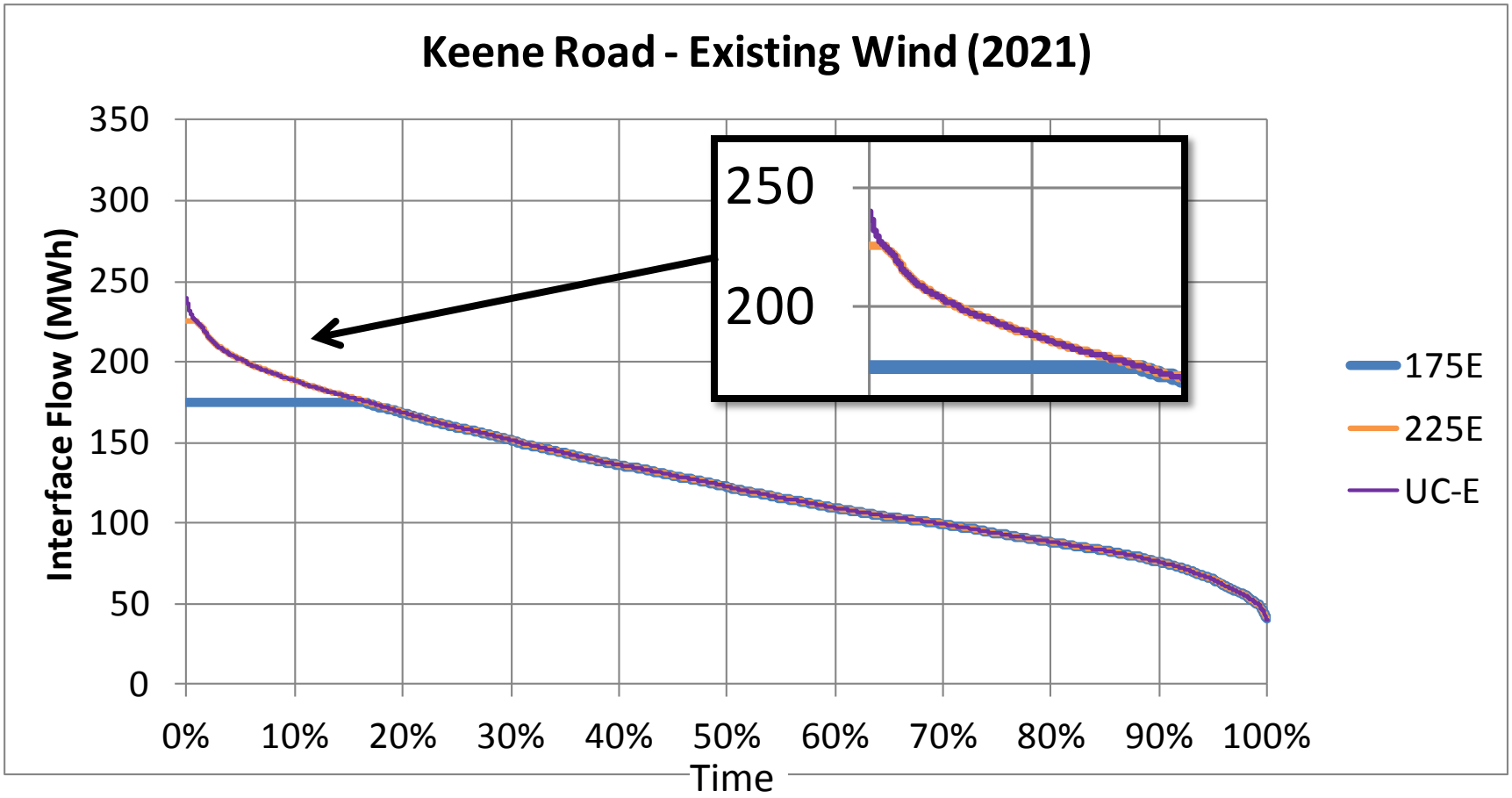
# Interface: Orrington South – Future Wind with NB at 1000 MW

*Duration Curve*



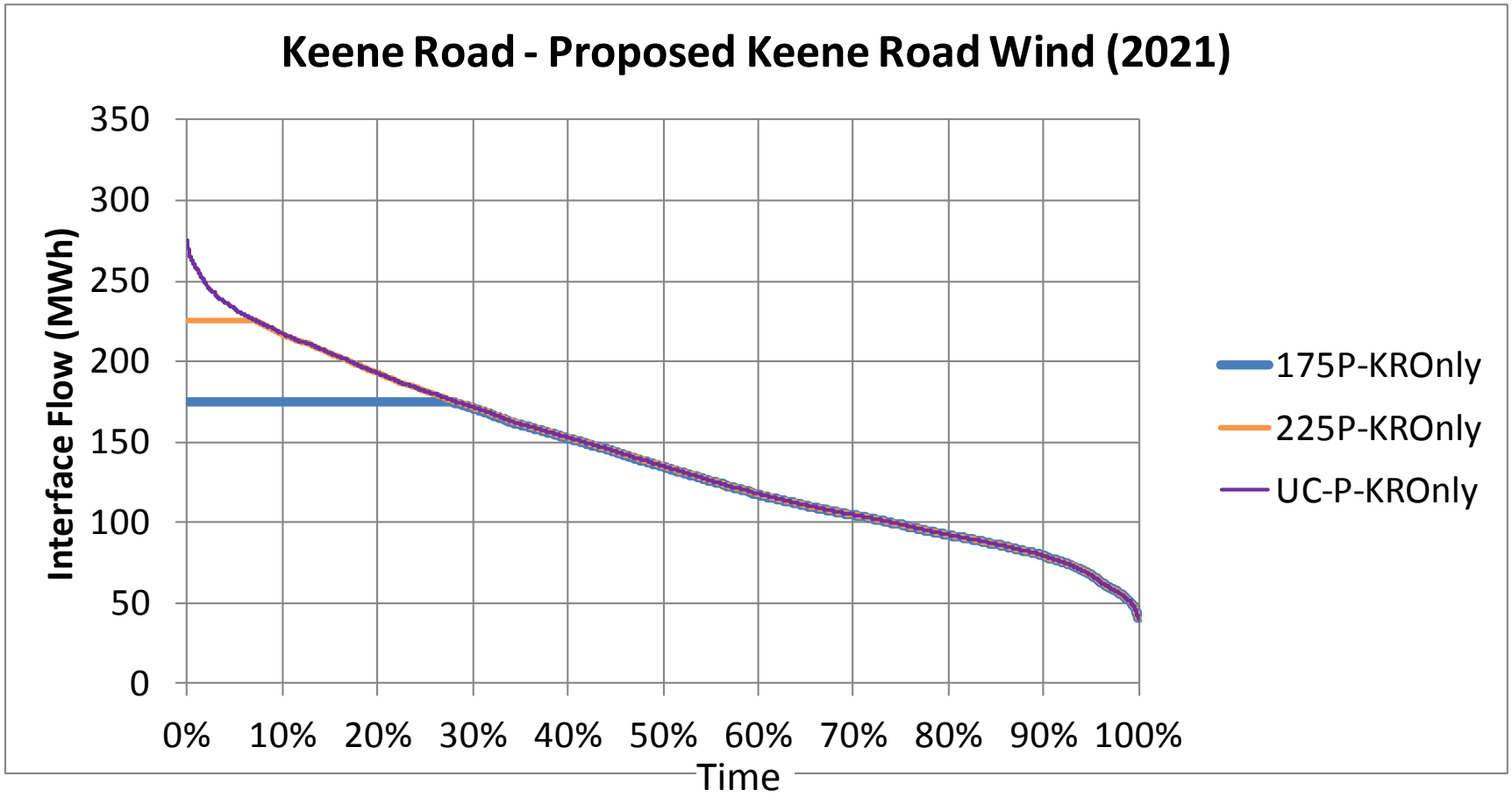
# Interface: Keene Road – Existing Wind

*Duration Curve*



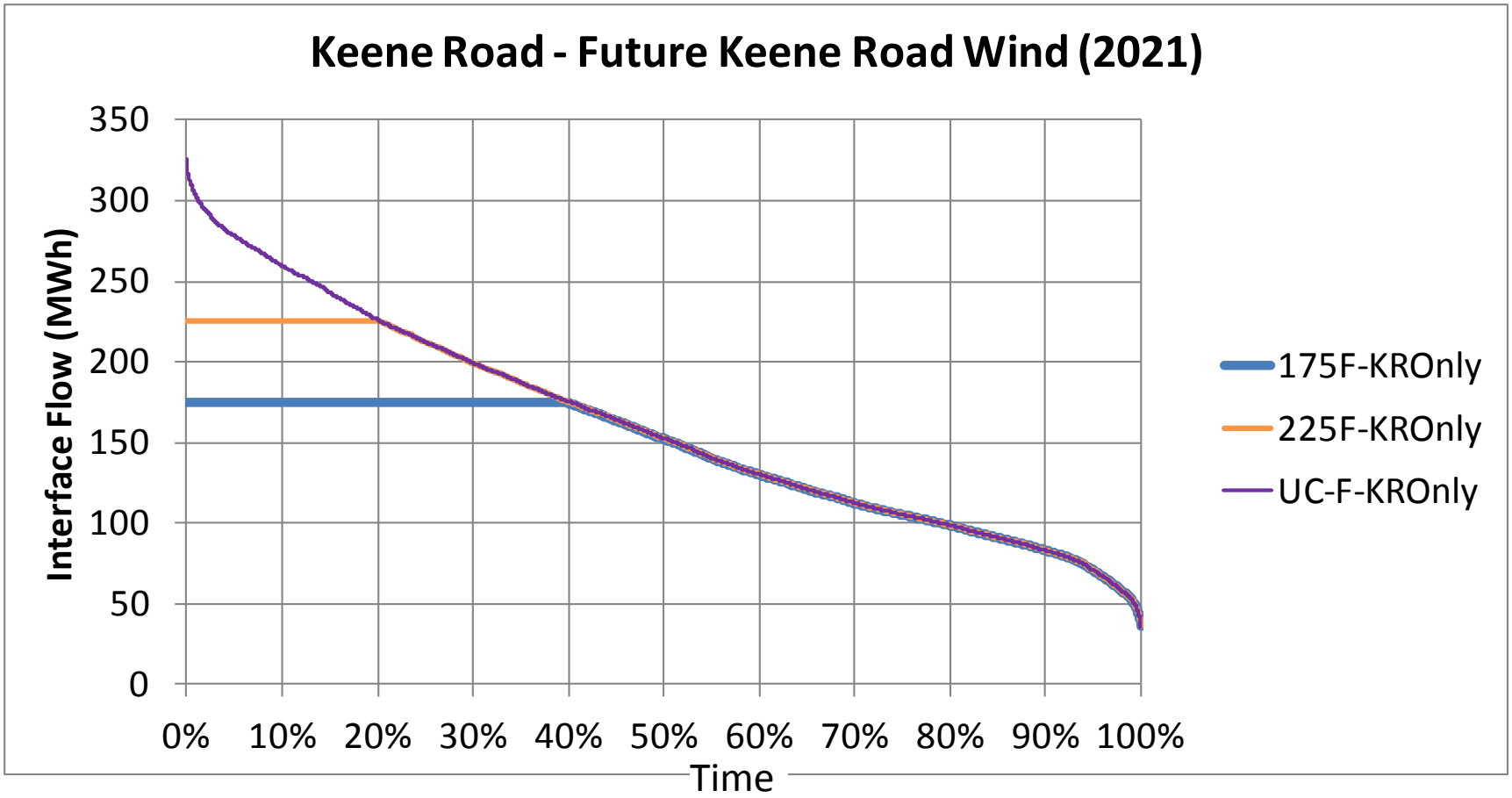
# Interface: Keene Road – Proposed Keene Road Wind

*Duration Curve*



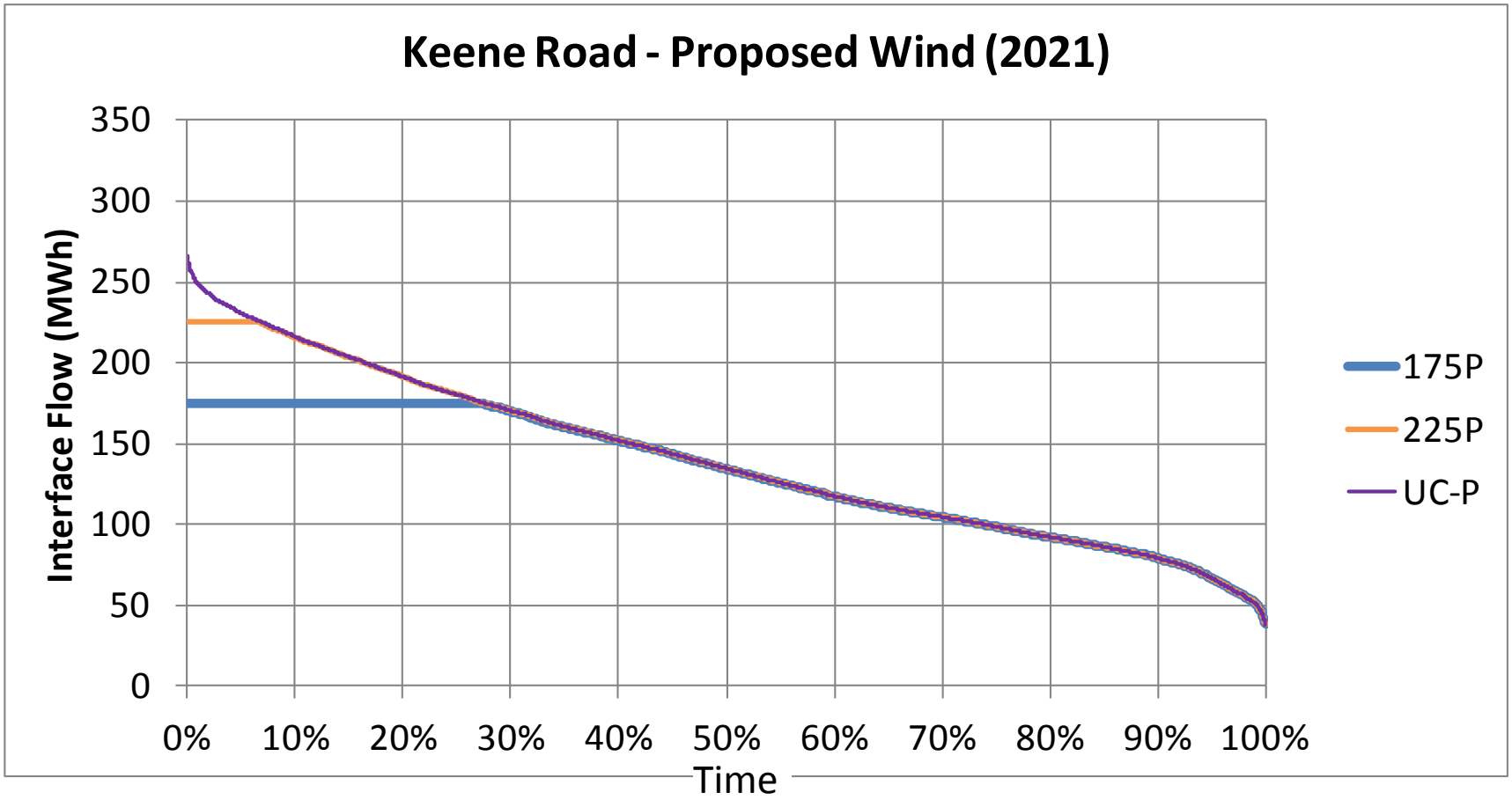
# Interface: Keene Road – Future Keene Road Wind

*Duration Curve*



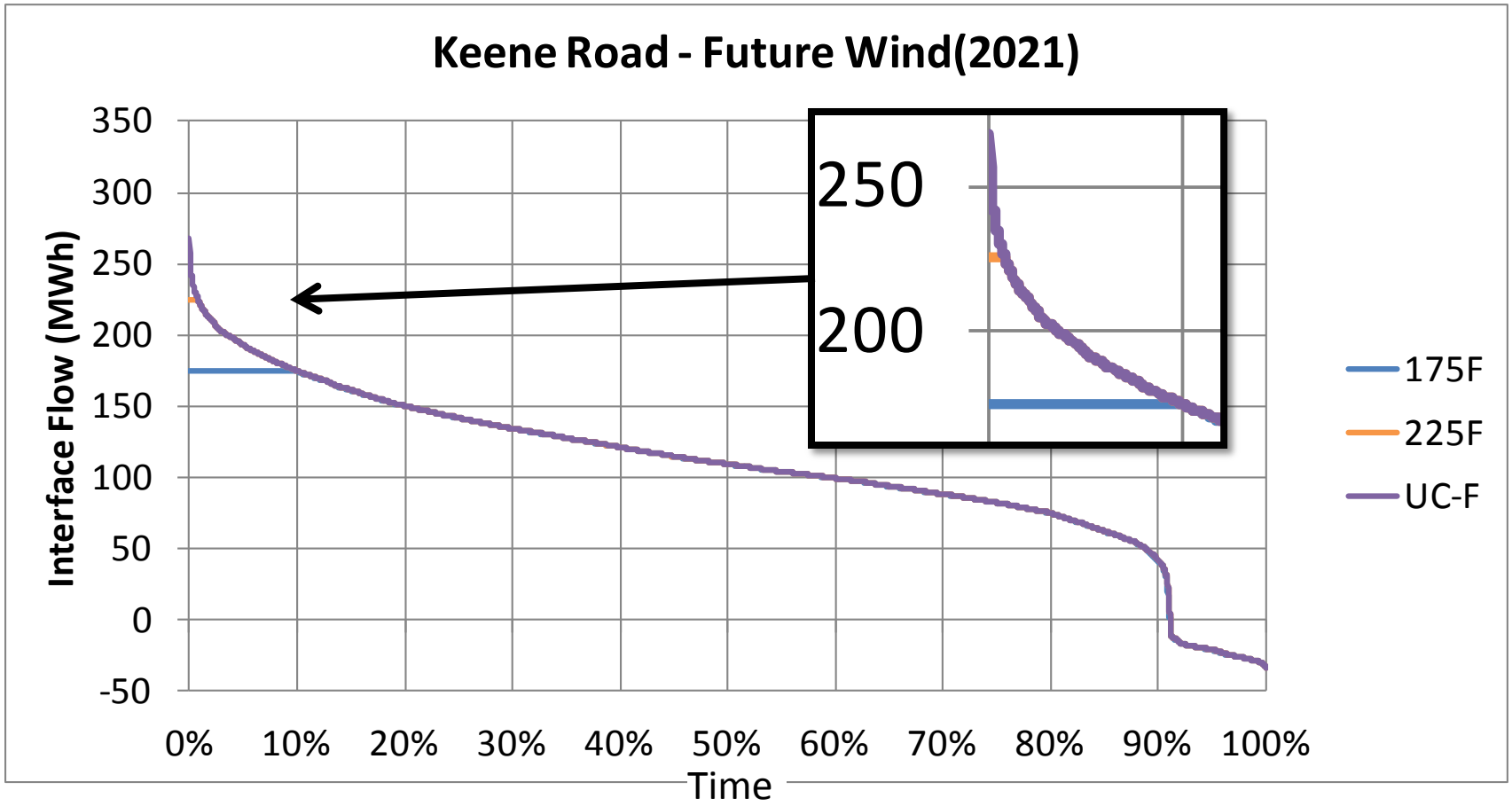
# Interface: Keene Road – Proposed Wind

*Duration Curve*



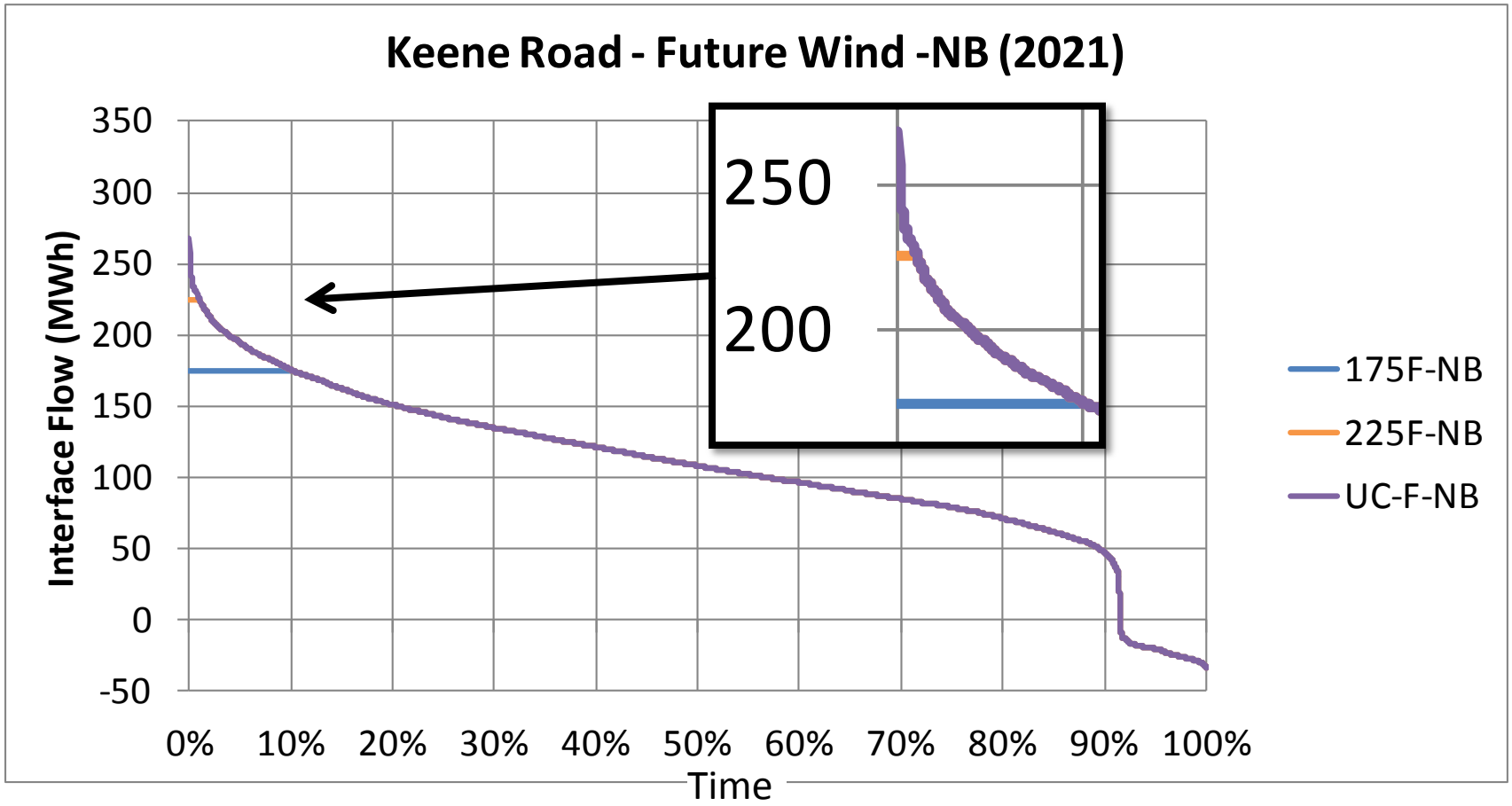
# Interface: Keene Road – Future Wind

*Duration Curve*



# Interface: Keene Road – Future Wind with NB at 1000 MW

*Duration Curve*



# STUDY OF KEENE ROAD CONSTRAINTS

*Appendix III – LMP Metrics*

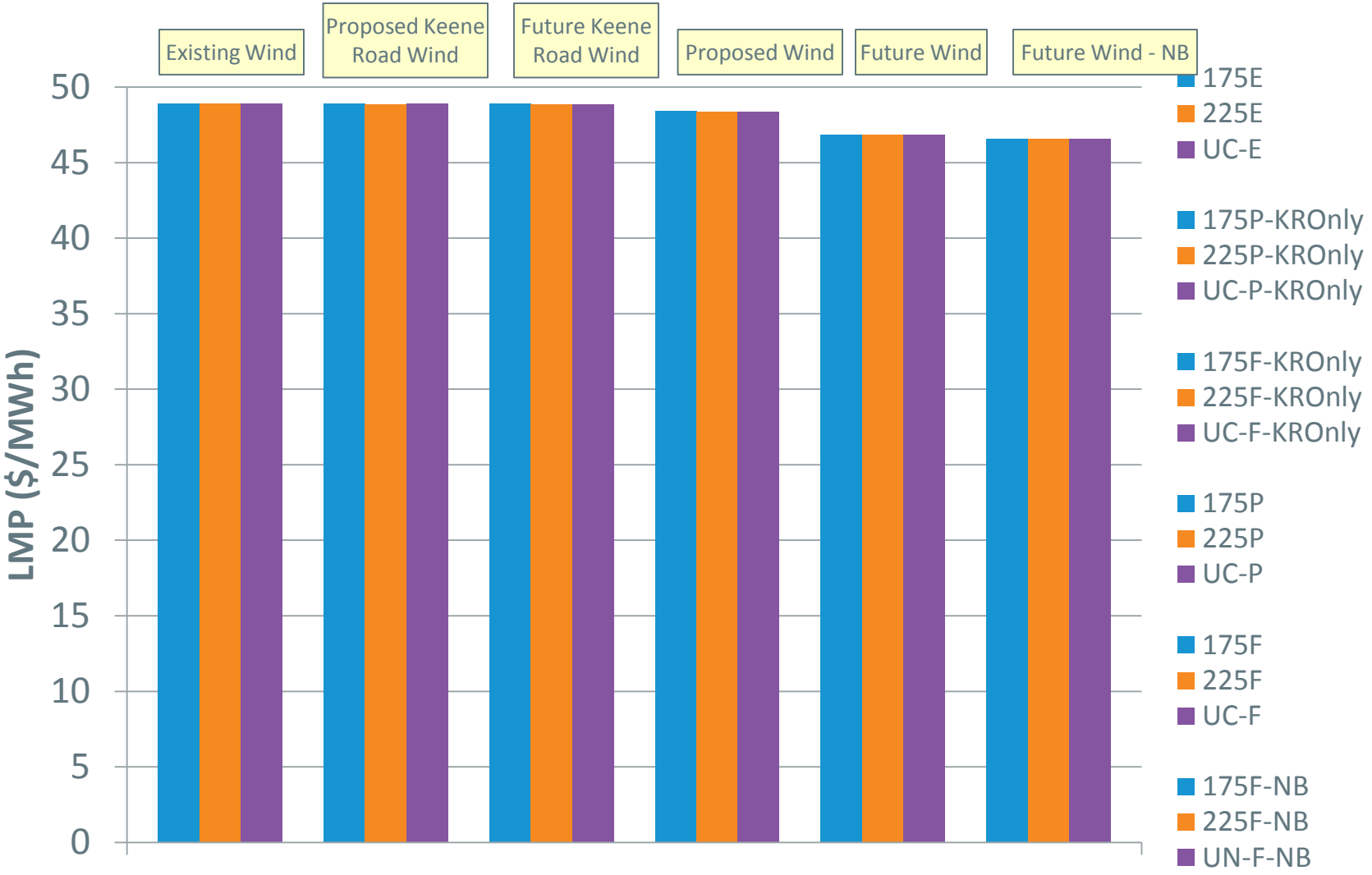
# Summary

*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
- LMP Metrics presented
  - Southern Maine LMPs are assumed representative of the rest of New England LMPs
  - Bangor (Maine) LMPs includes Keene Road area
  - Keene Road LMPs are exclusively behind Keene Road interface

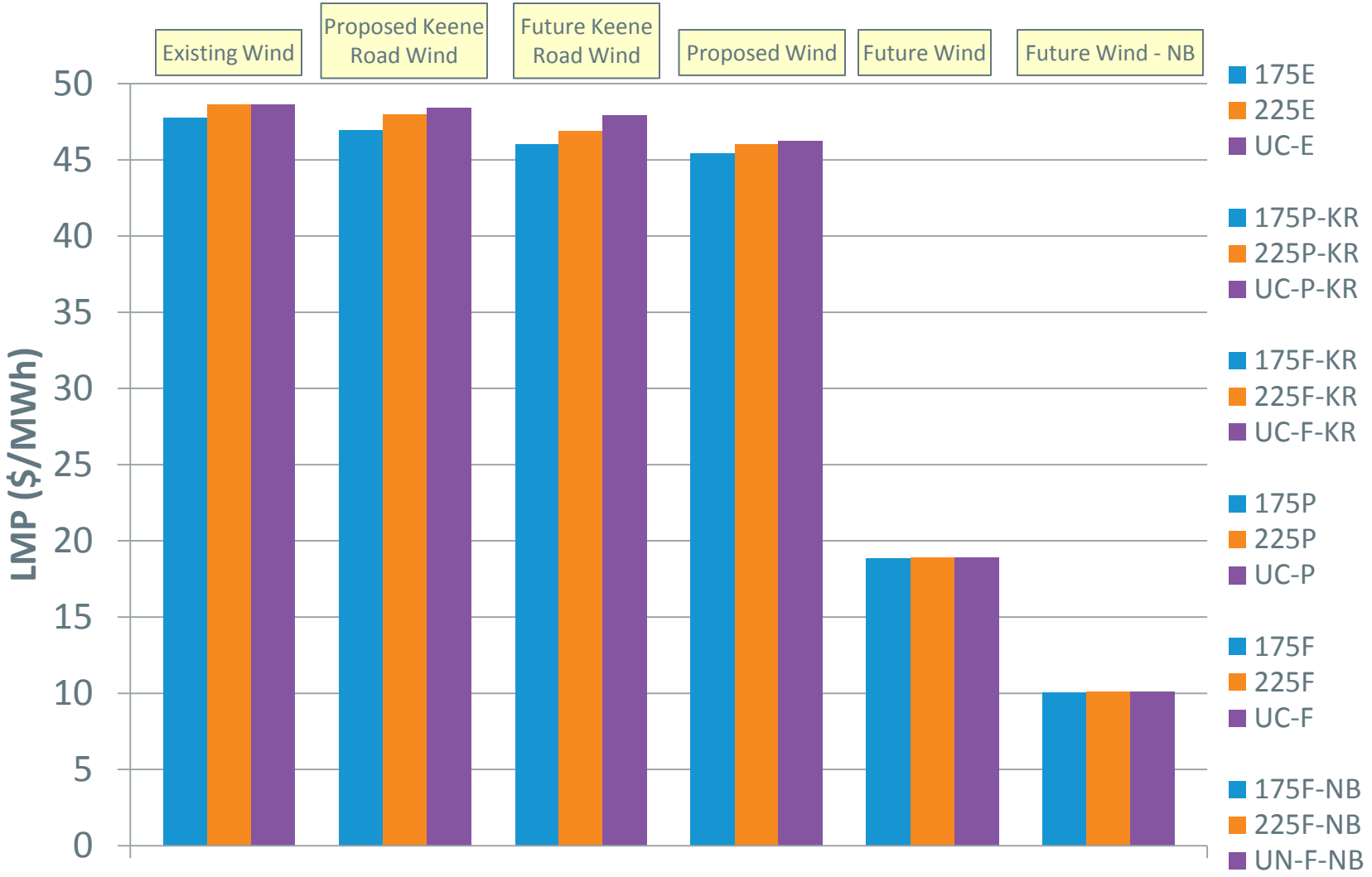
# LMP – Southern Maine ($/MWh)

*Southern Maine prices unaffected by Keene Road export limit*



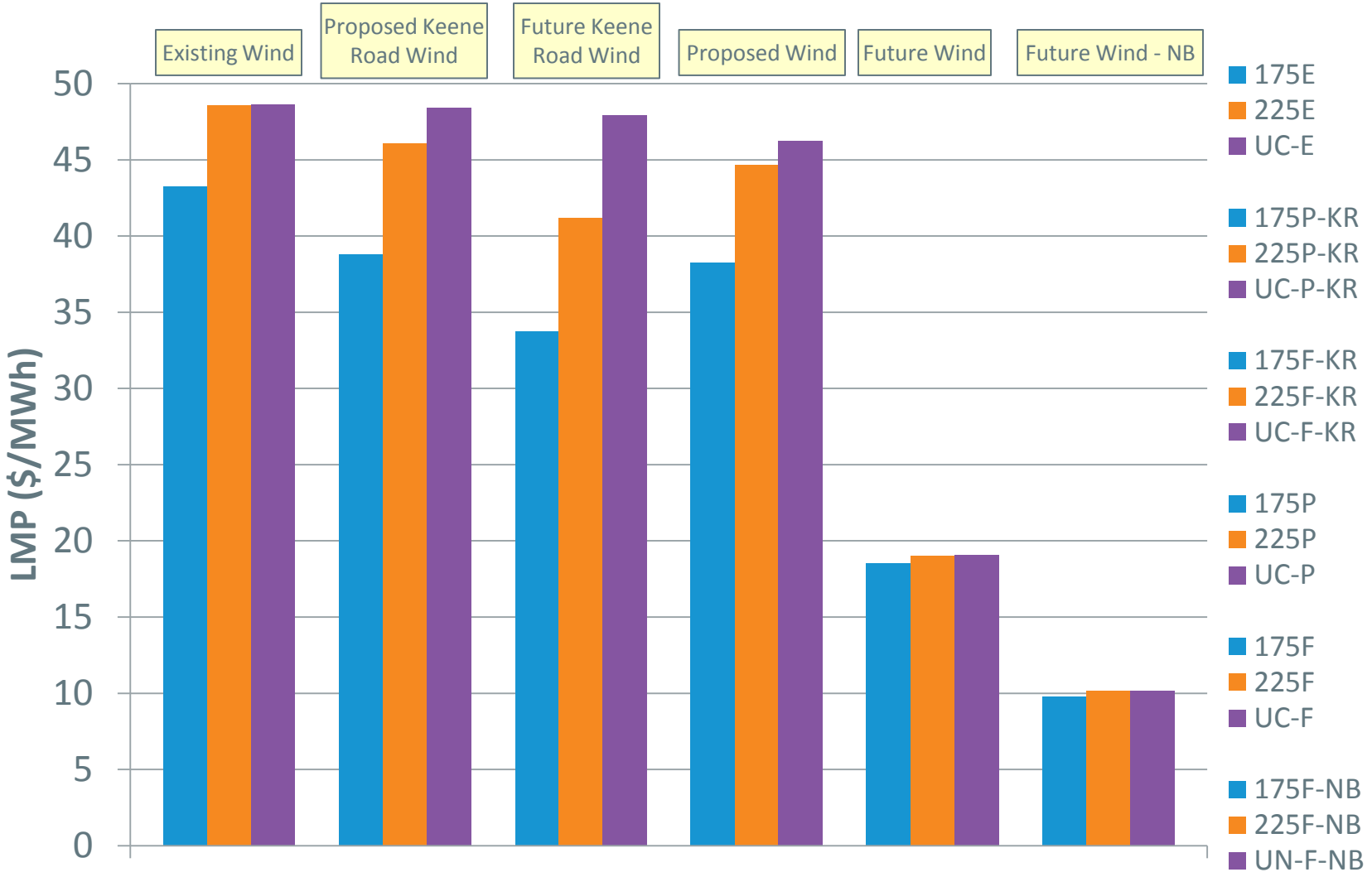
# LMP – Bangor ($/MWh)

*Increased export capability reduces LMPs in Southern New England, but increases LMPs within Keene Road in some hours*



# LMP – Keene Road($/MWh)

*Increased export capability reduces LMPs in Southern New England, but increases LMPs within Keene Road in some hours*



# LMP – Southern Maine ($/MWh)

*Table*

| | Keene Road Export Limit Scenarios | | |
|---|---|---|---|
| | **175 MW** | **225 MW** | **Unconstrained** |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 175E<br>48.91 | 225E<br>48.92 | UC-E<br>48.92 |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 175P-KROnly<br>48.89 | 225P-KROnly<br>48.88 | UC-P-KROnly<br>48.88 |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 175F-KROnly<br>48.93 | 225F-KROnly<br>48.86 | UC-F-KROnly<br>48.84 |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 175P<br>48.40 | 225P<br>48.37 | UC-P<br>48.37 |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 175F<br>46.86 | 225F<br>46.86 | UC-F<br>46.86 |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 175F-NB<br>46.59 | 225F-NB<br>46.59 | UC-F-NB<br>46.59 |

*Outside of Keene Road, only "existing wind" is assumed

# LMP – Bangor ($/MWh)

*Table*

| | Keene Road Export Limit Scenarios | | |
|---|---|---|---|
| | **175 MW** | **225 MW** | **Unconstrained** |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 175E<br>47.74 | 225E<br>48.62 | UC-E<br>48.63 |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 175P-KROnly<br>46.92 | 225P-KROnly<br>47.99 | UC-P-KROnly<br>48.40 |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 175F-KROnly<br>46.04 | 225F-KROnly<br>46.88 | UC-F-KROnly<br>47.93 |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 175P<br>45.42 | 225P<br>46.02 | UC-P<br>46.23 |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 175F<br>18.83 | 225F<br>18.89 | UC-F<br>18.89 |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 175F-NB<br>10.05 | 225F-NB<br>10.08 | UC-F-NB<br>10.08 |

*Outside of Keene Road, only "existing wind" is assumed

# LMP – Keene Road ($/MWh)

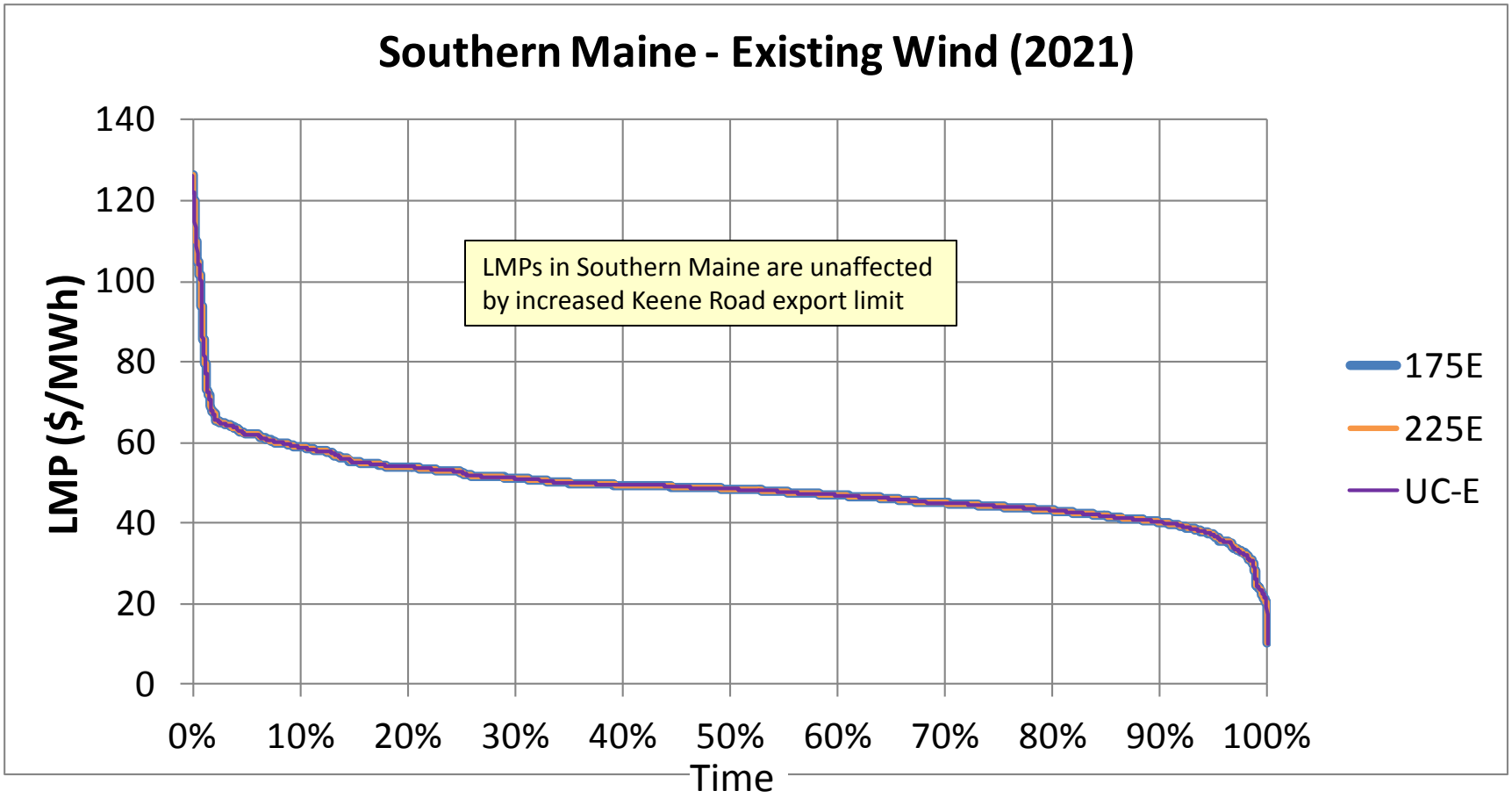
*Table*

| | Keene Road Export Limit Scenarios | | |
|---|---|---|---|
| | **175 MW** | **225 MW** | **Unconstrained** |
| 1 **Base case with Existing Keene Road Wind (as of 4/1/15) *** | 175E<br>43.25 | 225E<br>48.56 | UC-E<br>48.63 |
| 2A **Proposed Keene Road Wind with I.3.9 (as of 4/1/15) *** | 175P-KROnly<br>38.83 | 225P-KROnly<br>46.06 | UC-P-KROnly<br>48.40 |
| 2B **Future Keene Road Wind in Queue (as of 4/1/15) *** | 175F-KROnly<br>33.72 | 225F-KROnly<br>41.18 | UC-F-KROnly<br>47.93 |
| 3A **All New England Wind with I.3.9 (as of 4/1/15)** | 175P<br>38.27 | 225P<br>44.67 | UC-P<br>46.23 |
| 3B **All New England Wind in Queue (as of 4/1/15)** | 175F<br>18.51 | 225F<br>19.03 | UC-F<br>19.07 |
| 4 **All New England Wind in Queue (as of 4/1/15) and 1,000 MW of imports from NB 24x7** | 175F-NB<br>9.80 | 225F-NB<br>10.15 | UC-F-NB<br>10.19 |

*Outside of Keene Road, only "existing wind" is assumed

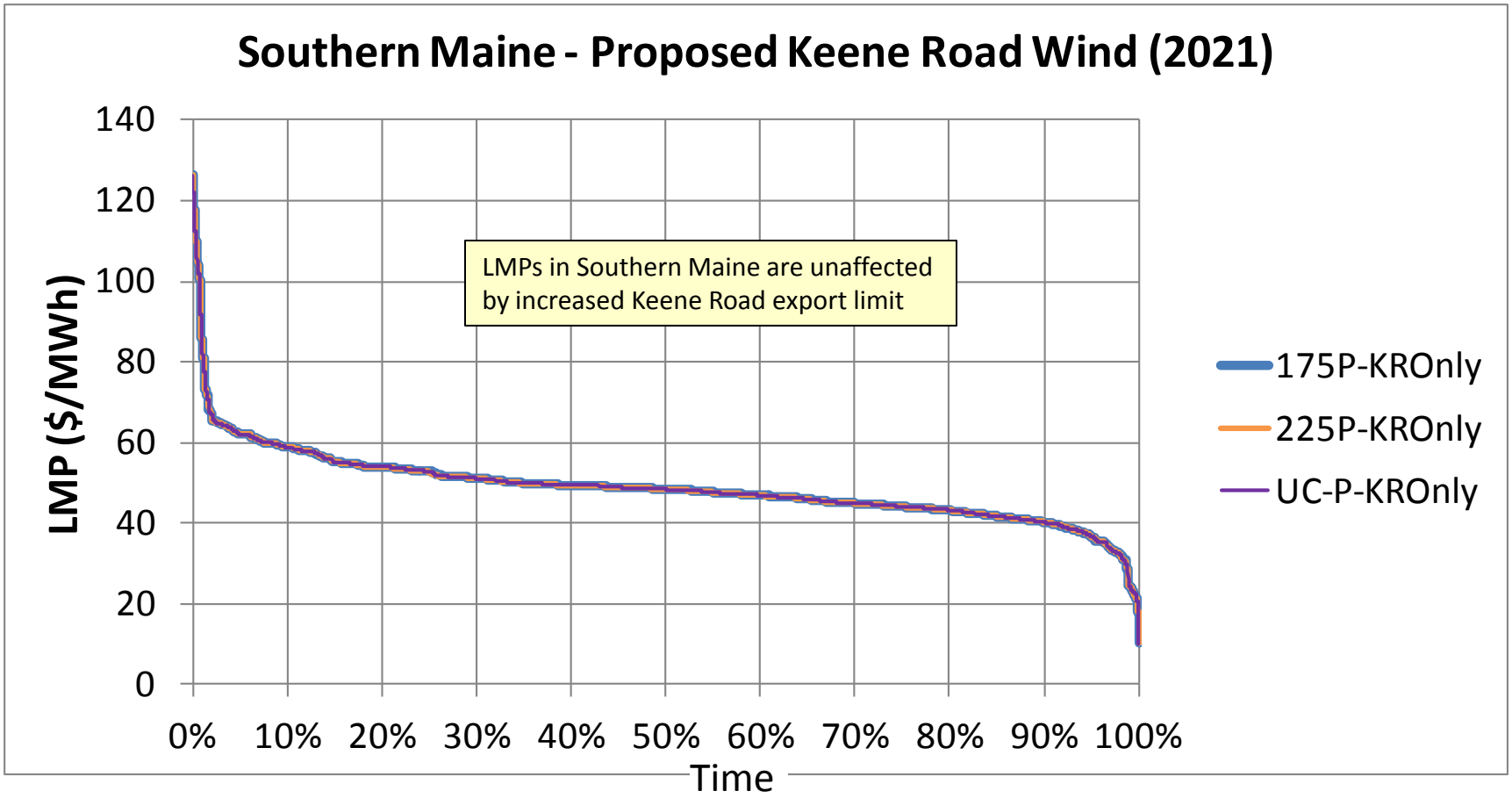
# Southern Maine LMP – Existing Wind

*Duration Curve*



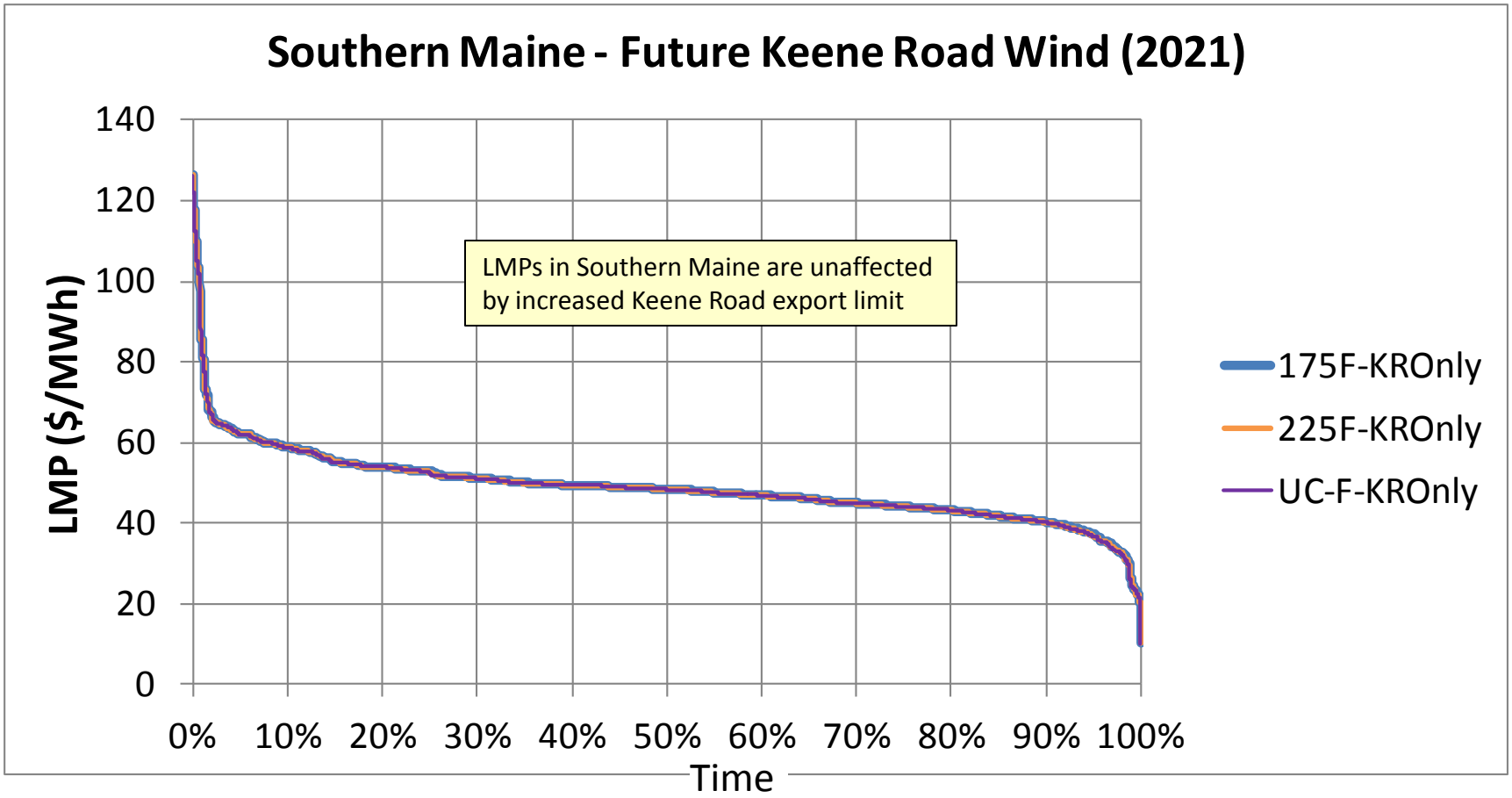
# Southern Maine LMP – Proposed Keene Road Wind

*Duration Curve*



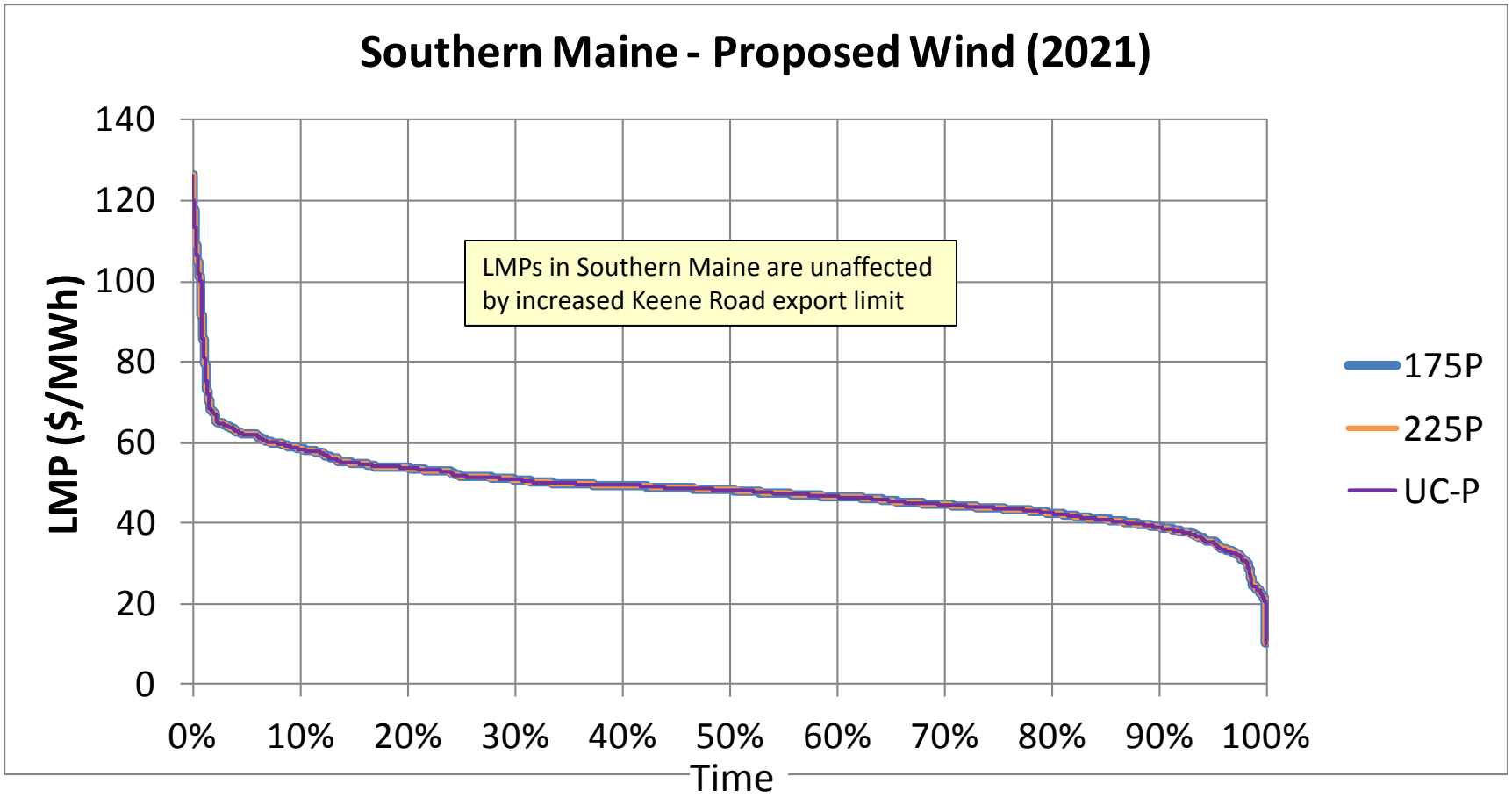
# Southern Maine LMP – Future Keene Road Wind

*Duration Curve*



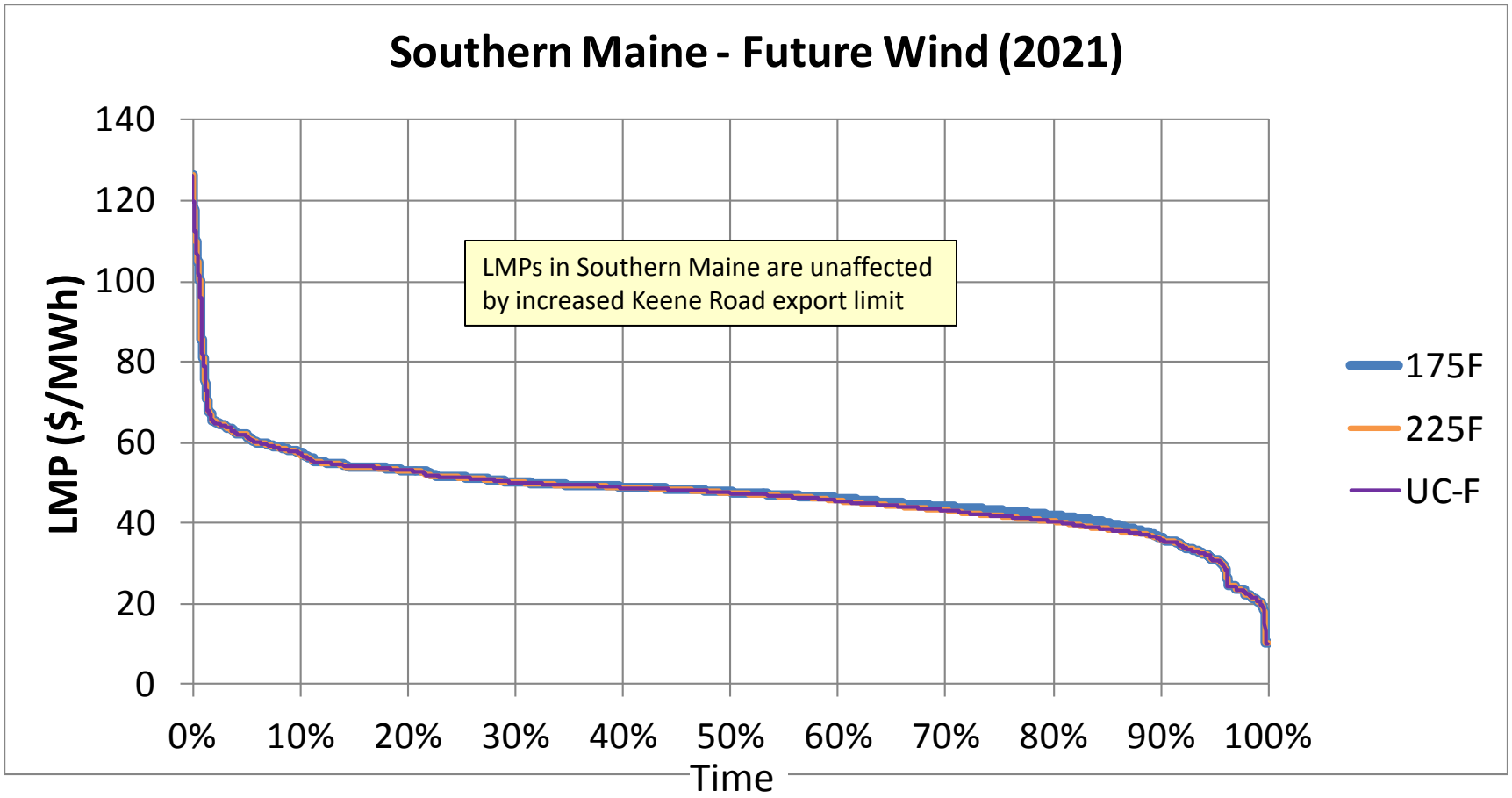
# Southern Maine LMP – Proposed Wind

*Duration Curve*



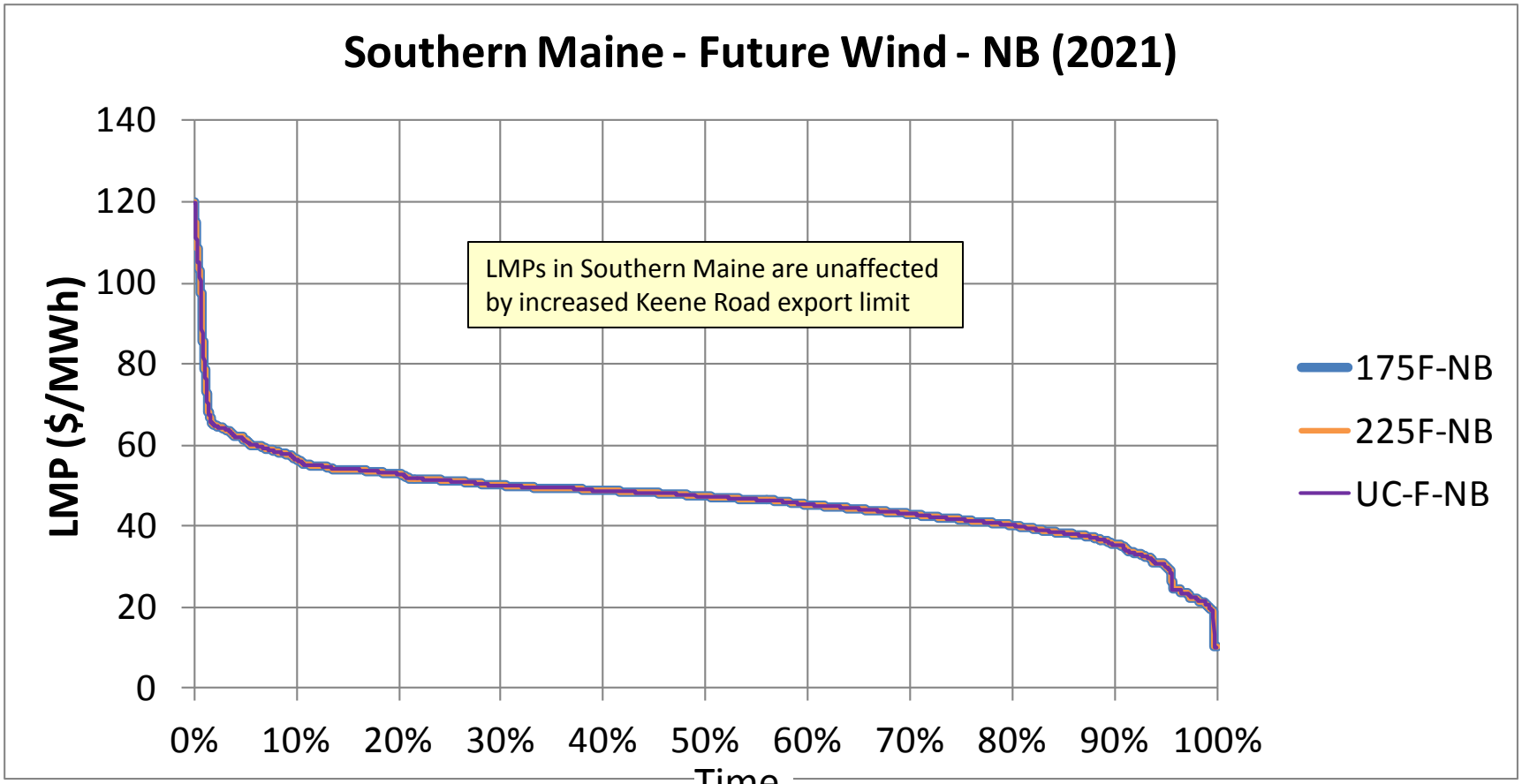
# Southern Maine LMP – Future Wind

*Duration Curve*



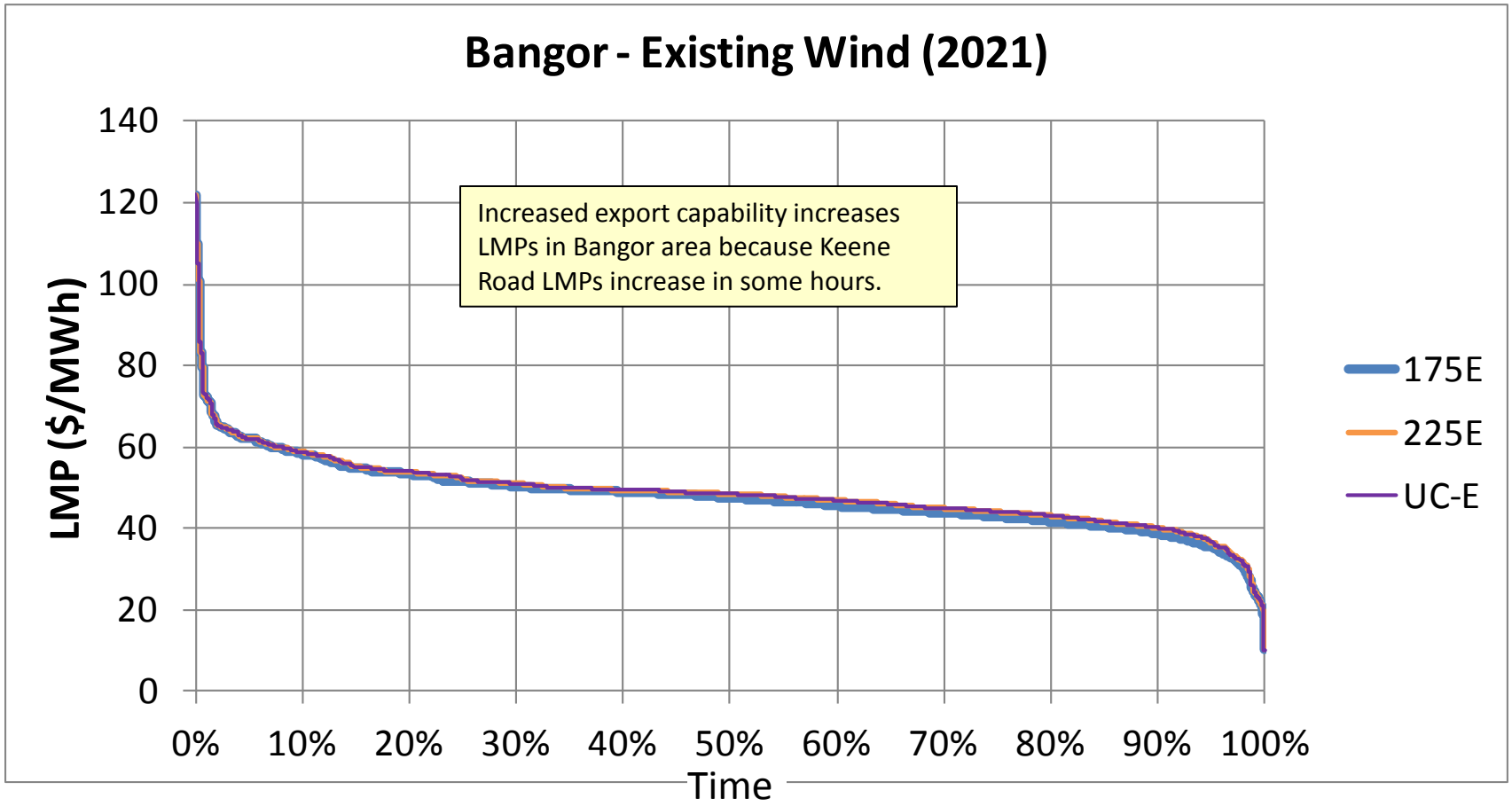
# Southern Maine LMP – Future Wind with NB at 1000 MW

*Duration Curve*



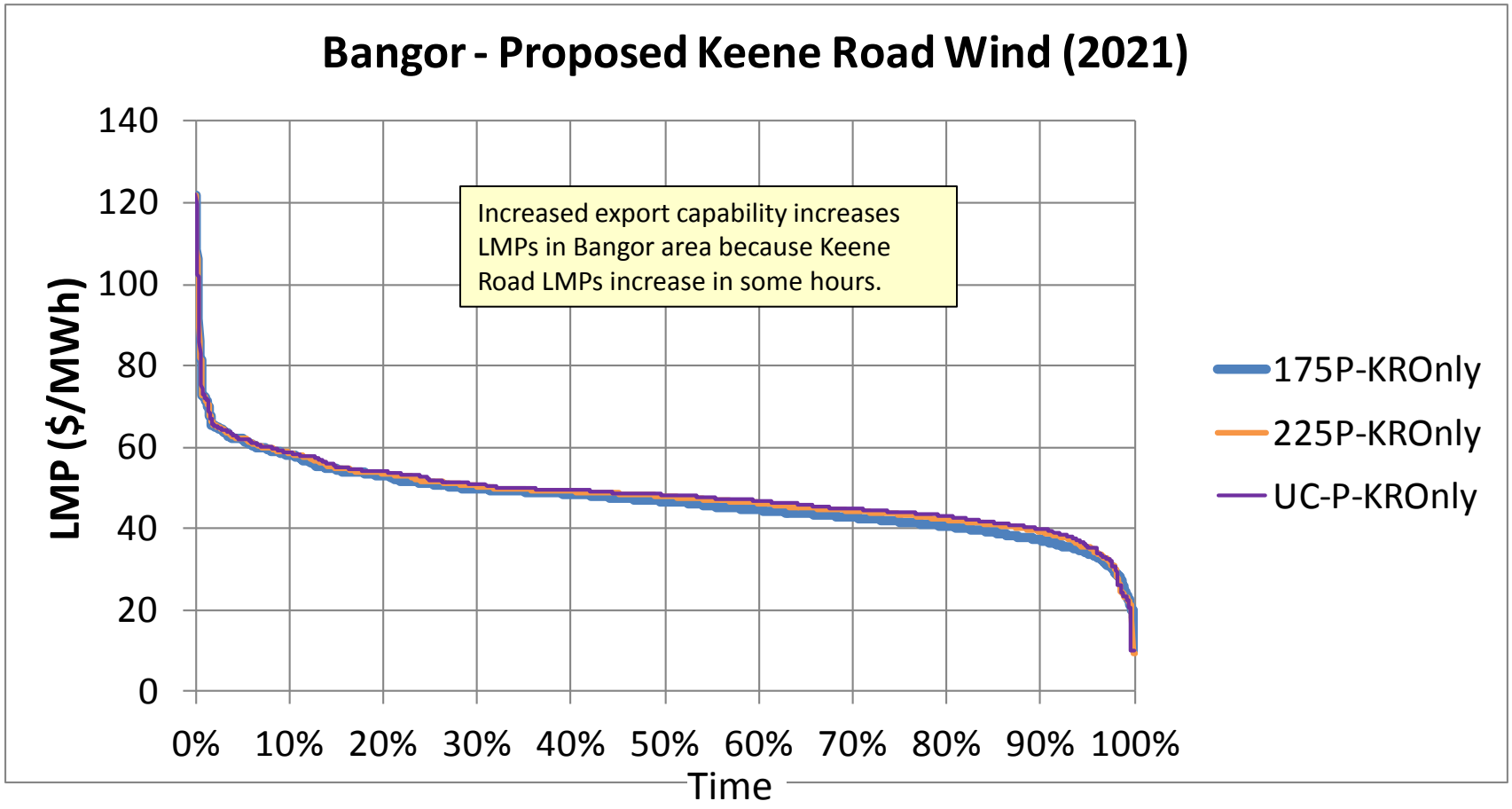
# Bangor Area LMP – Existing Wind

*Duration Curve*



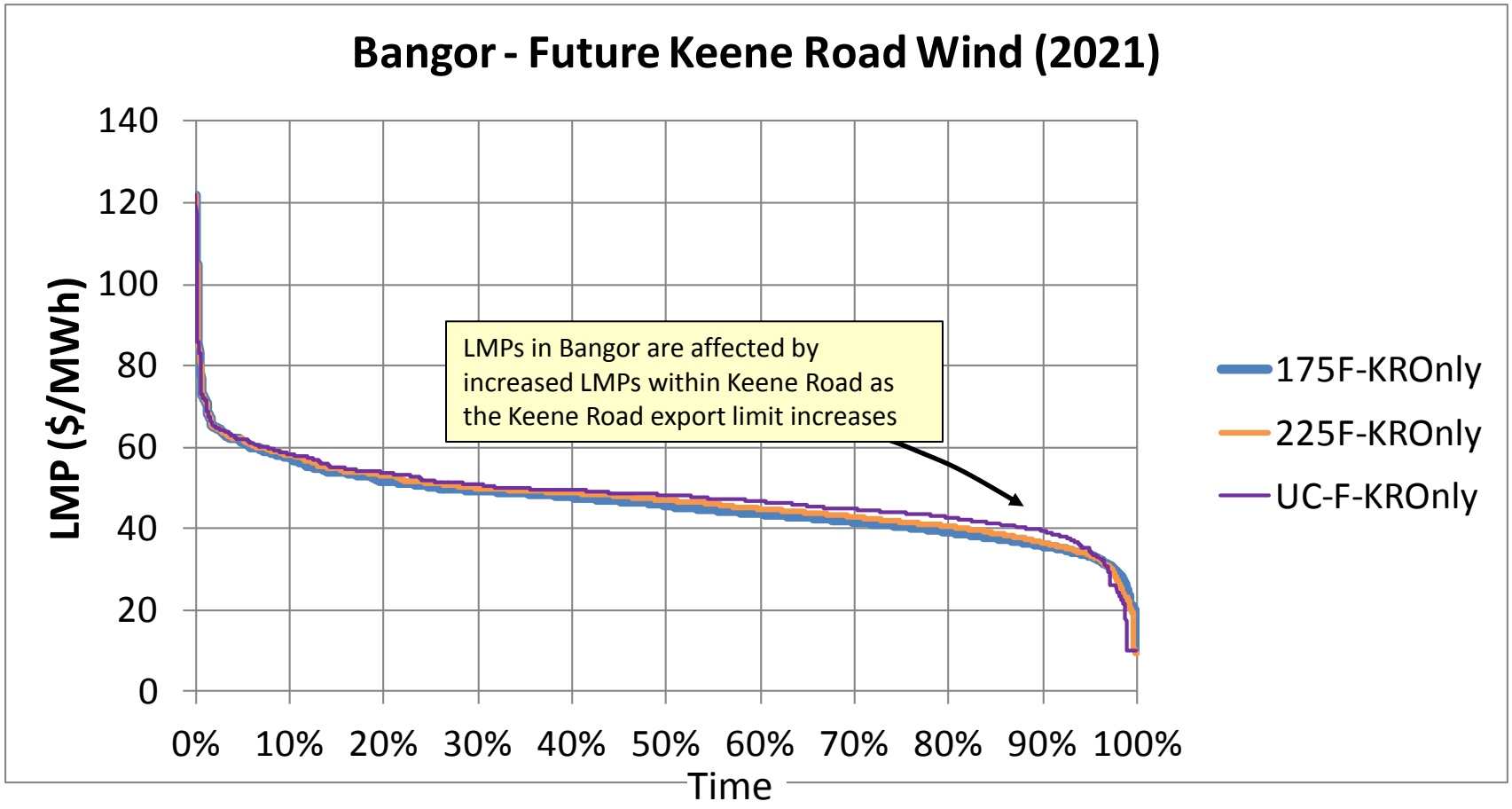
# Bangor Area LMP – Proposed Keene Road Wind

*Duration Curve*



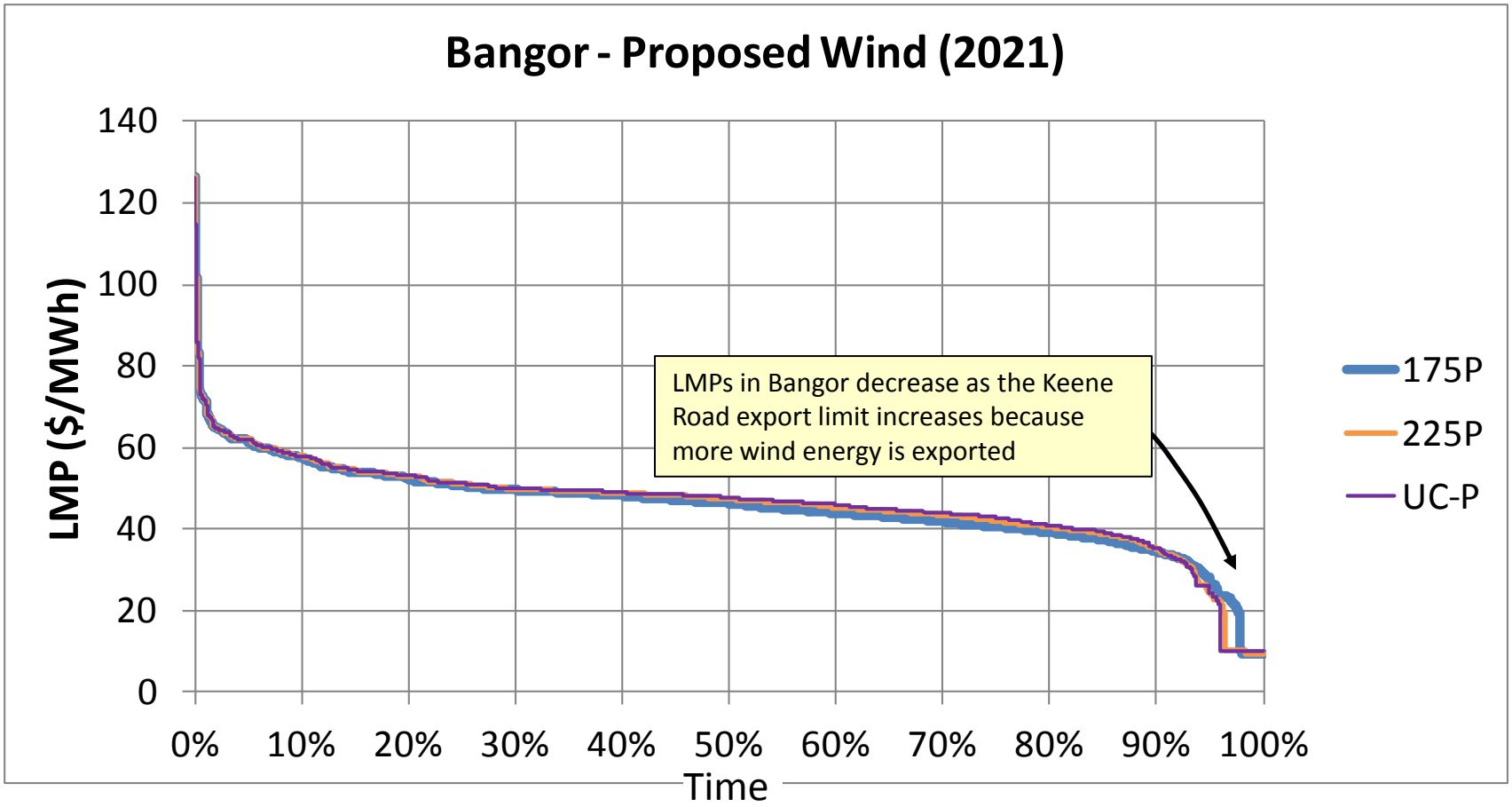
# Bangor Area LMP – Future Keene Road Wind

*Duration Curve*



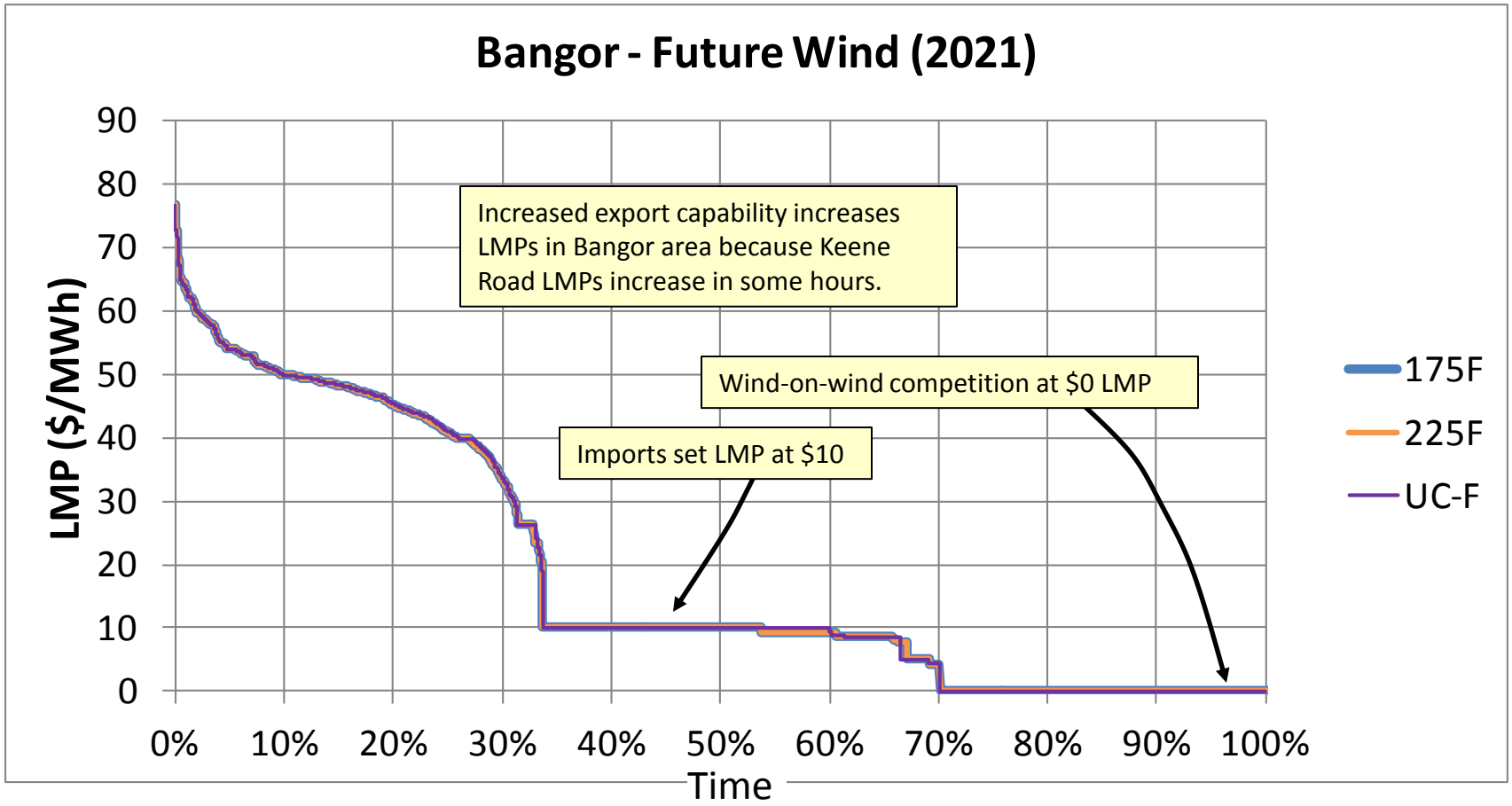
# Bangor Area LMP – Proposed Wind

*Duration Curve*



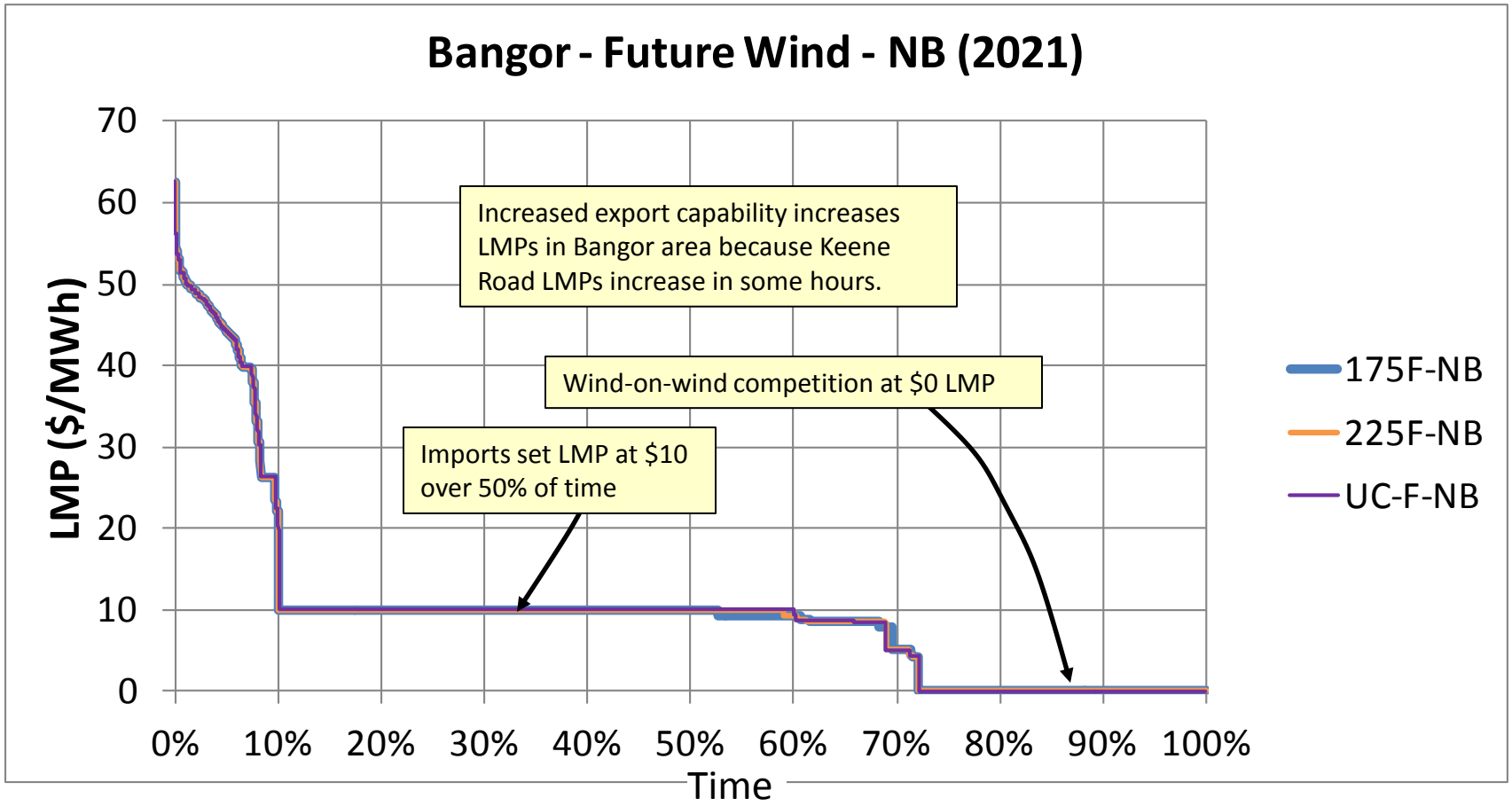
# Bangor Area LMP – Future Wind

Duration Curve



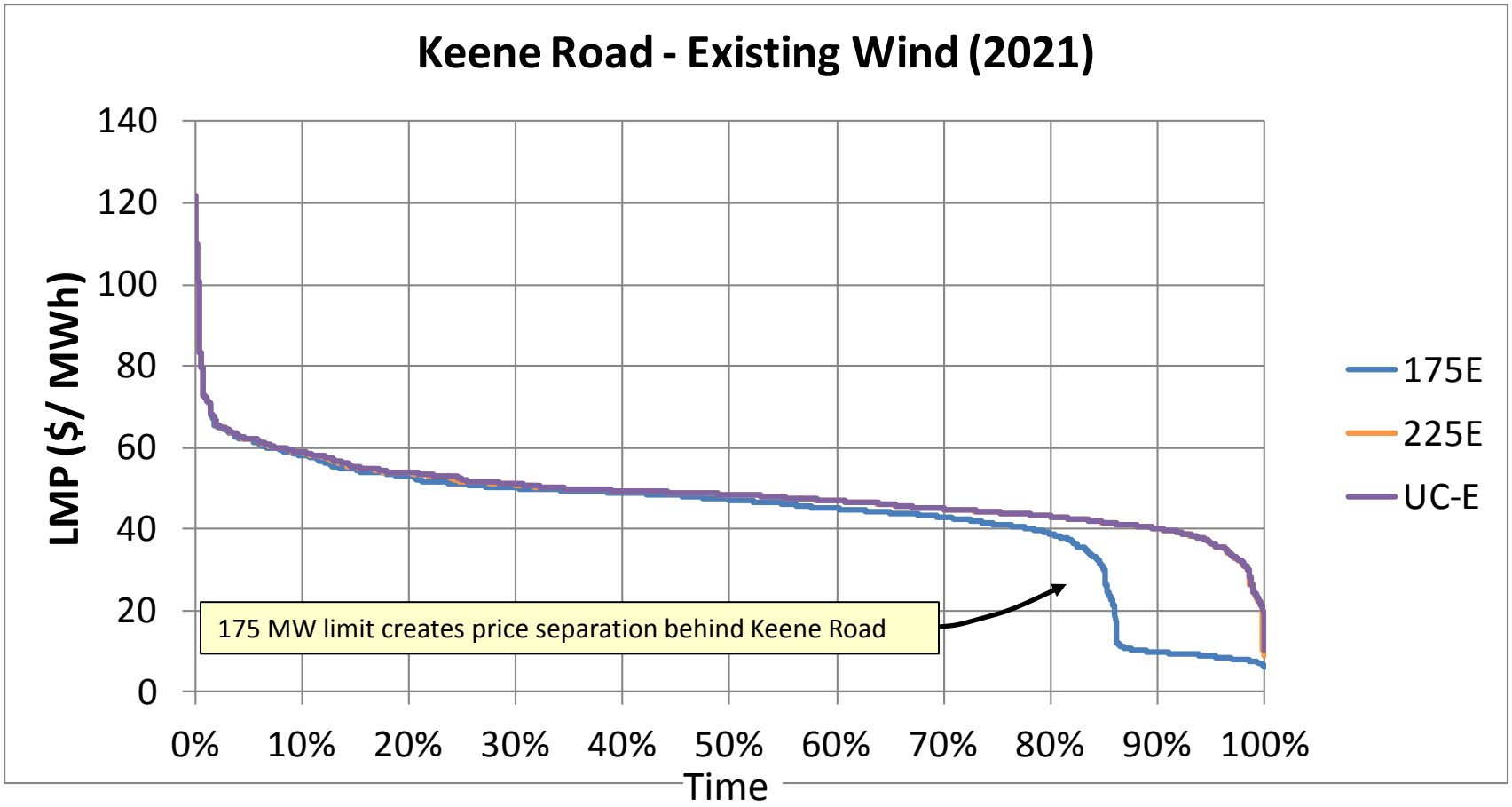
# Bangor Area LMP – Future Wind with NB at 1000 MW

*Duration Curve*



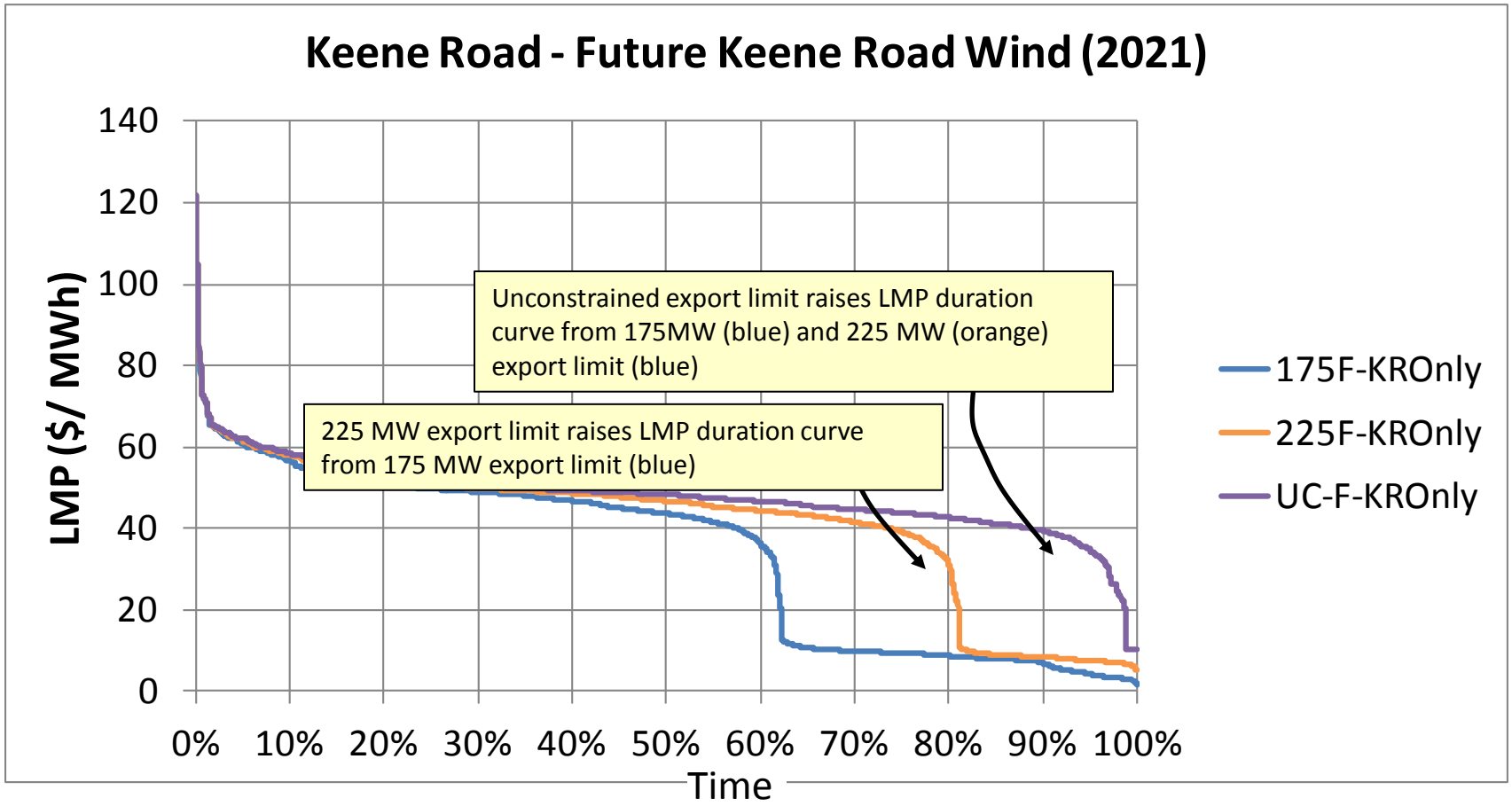
# Keene Road LMP – Existing Wind

*Duration Curve*



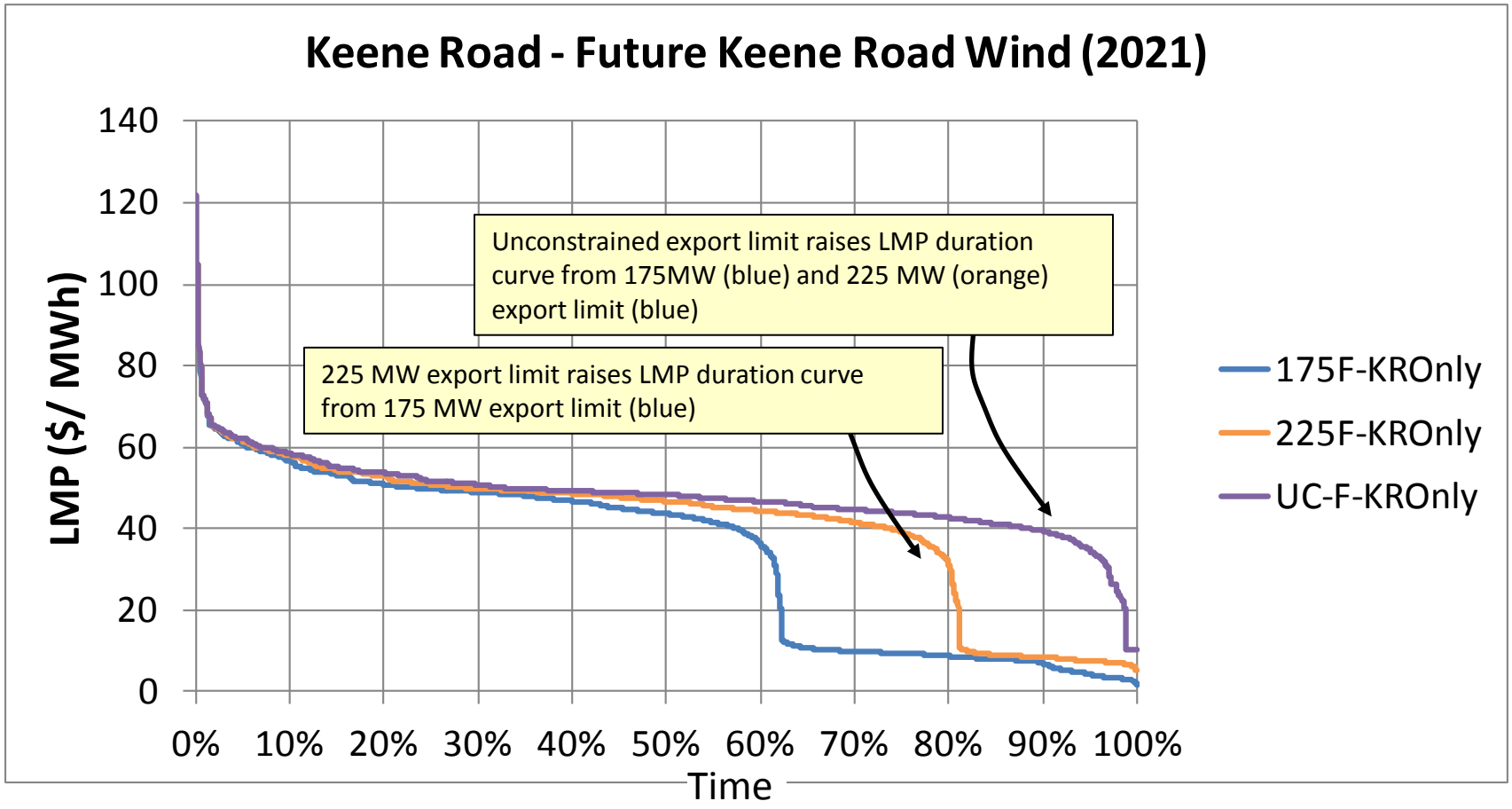
# Keene Road LMP – Proposed Keene Road Wind

*Duration Curve*



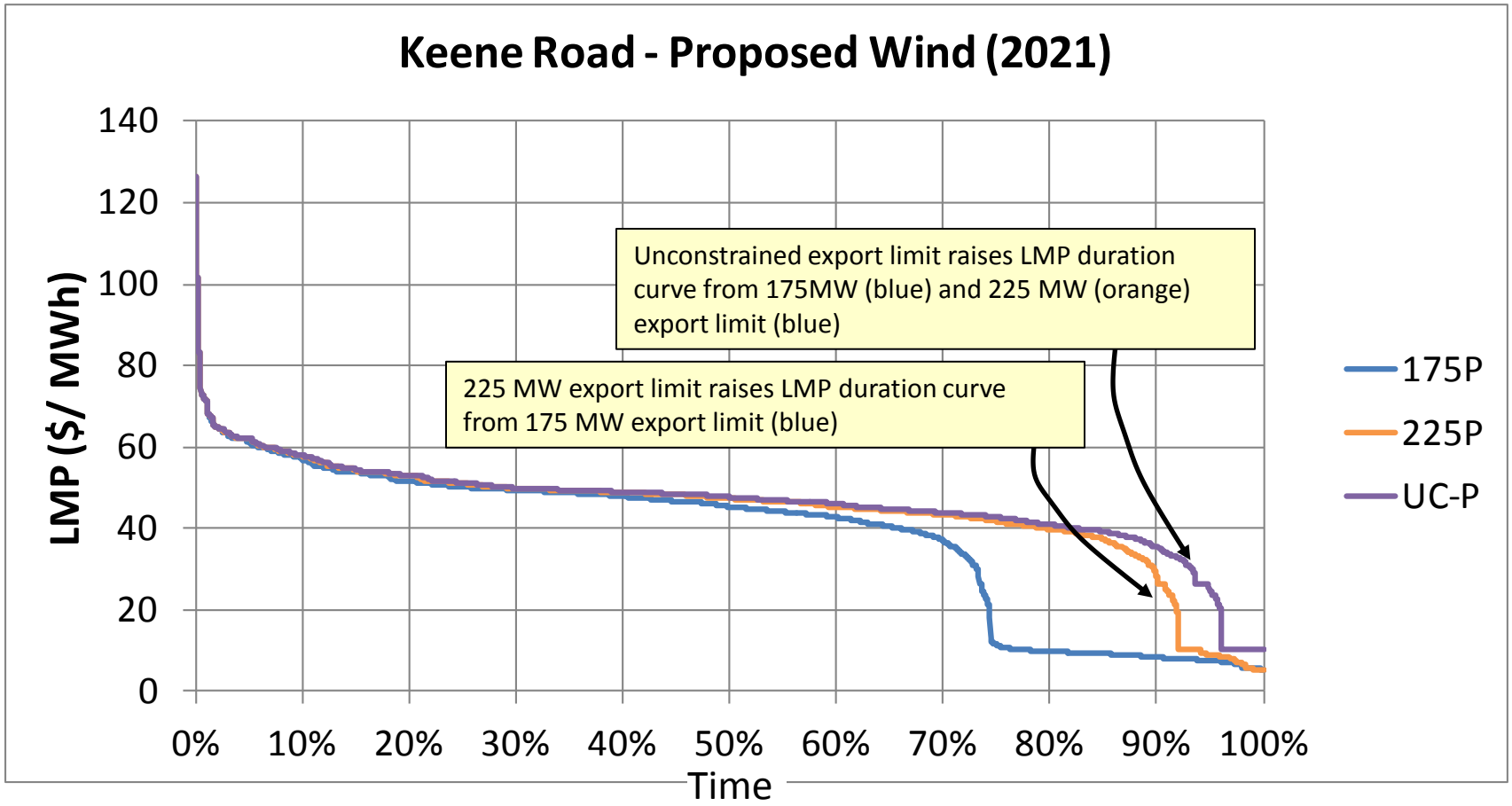
# Keene Road LMP – Future Keene Road Wind

Duration Curve



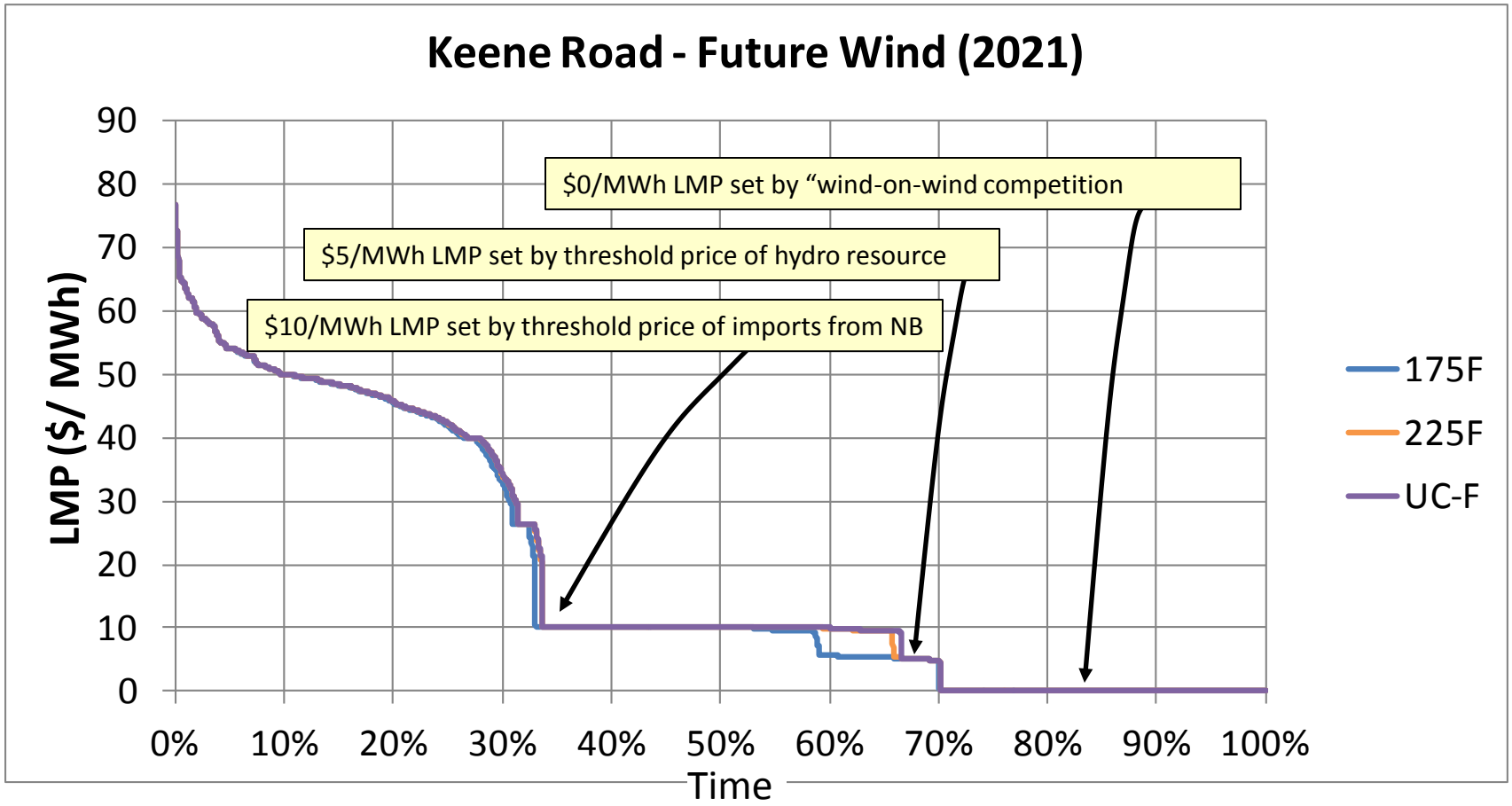
# Keene Road LMP – Proposed Wind

*Duration Curve*



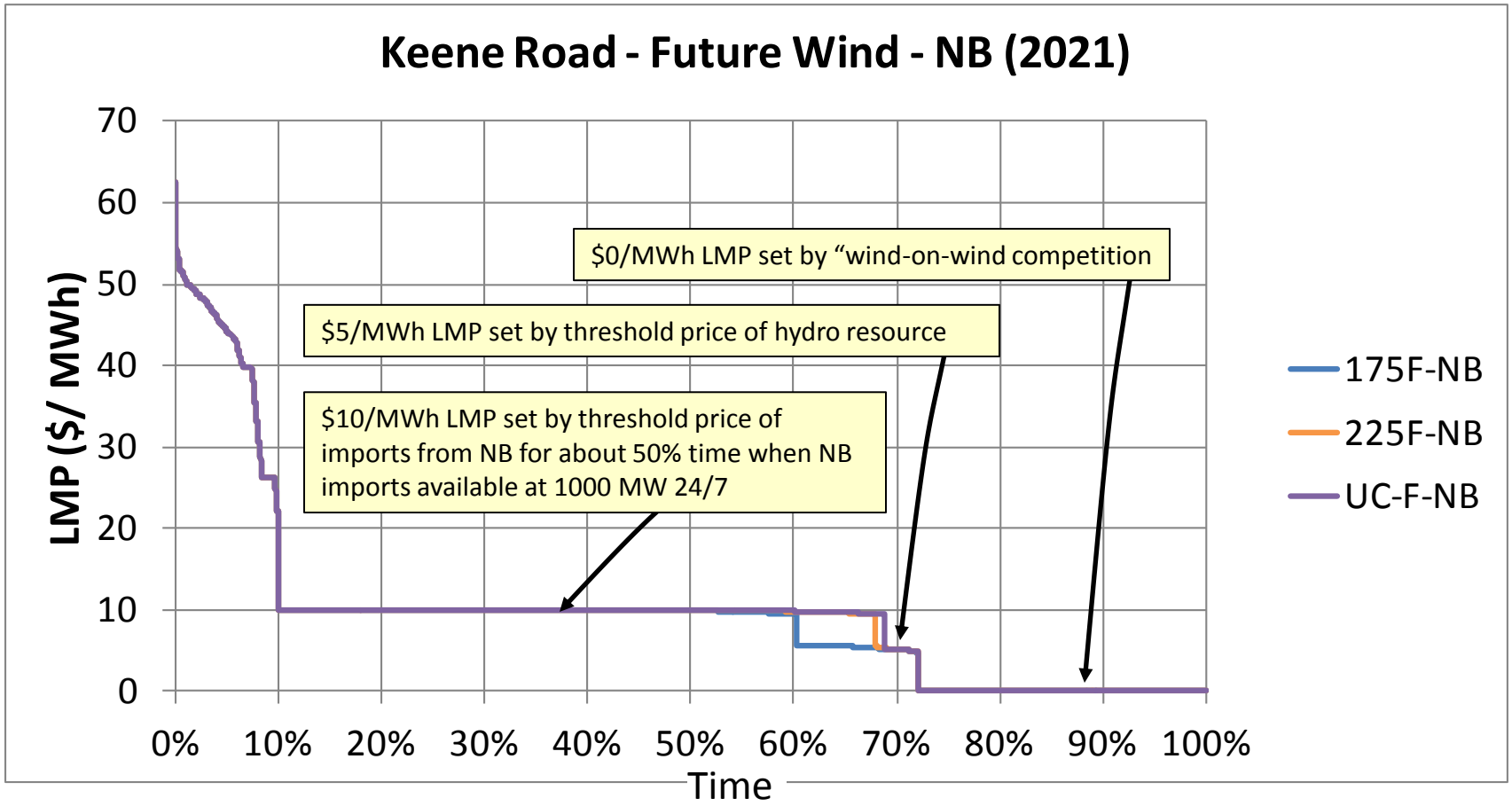
# Keene Road LMP – Future Wind

*Duration Curve*



# Keene Road LMP – Future Wind with NB at 1000 MW

*Duration Curve*



# STUDY OF KEENE ROAD CONSTRAINTS

*Appendix IV – Scope of Work & Modeling Assumptions*

# Three 2015 Economic Study Requests

- Keene Rd. Interface [SunEdison]

http://www.iso-ne.com/static-assets/documents/2015/04/a6_sun_edison_presentation_economic_study_keene_rd.pdf

- Impact of Offshore Wind Deployment on New England's Wholesale Electricity Markets and Operations [Massachusetts Clean Energy Center ]

http://www.iso-ne.com/static-assets/documents/2015/04/a6_cec_presentation_economic_study_offshore_wind.pdf

- Impact of Maine Upgrades Identified in ISO-NE's Strategic Transmission Analysis for Wind Integration [RENEW Northeast (RENEW)]

http://www.iso-ne.com/static-assets/documents/2015/04/a6_presentation_renew_strategic_transmission_analysis_wind_integration_economic_study_req.pdf

# Keene Road Economic Study Background

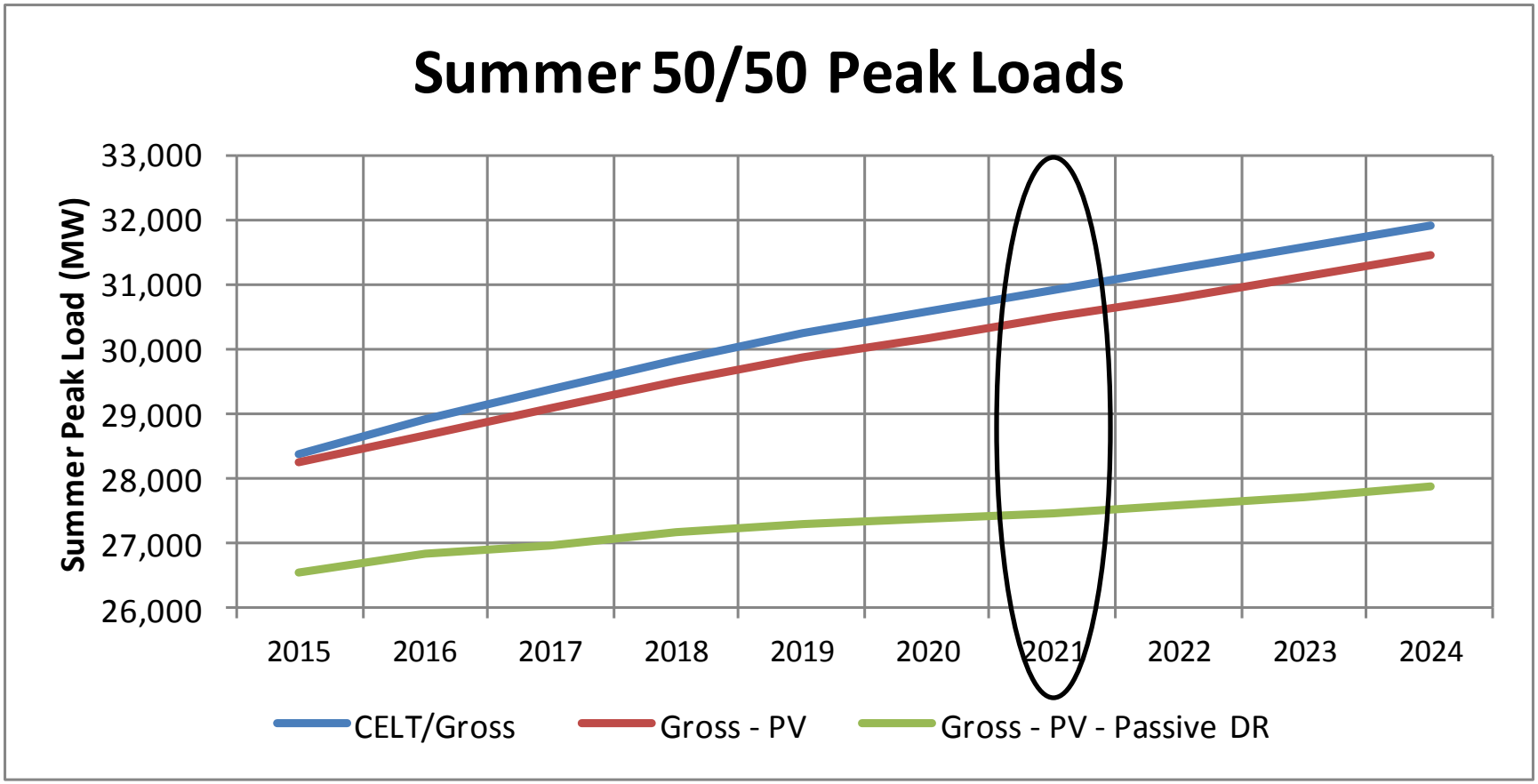
- The ISO-NE Strategic Transmission Analysis Wind Integration Study
  - Presented to the PAC May 21, 2014 and December 18, 2013
  - Evaluated alternatives for reducing congestion
  - Identified 50% series compensation as a conceptual solution
  - Increase in export limit assumed to be 50 MW
- If warranted, develop high level cost estimates for
  - One or more potential transmission solution(s)
  - Ensure sufficient detail to enable a valid comparison of economic benefits versus costs

# Base Economic Evaluation Model

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

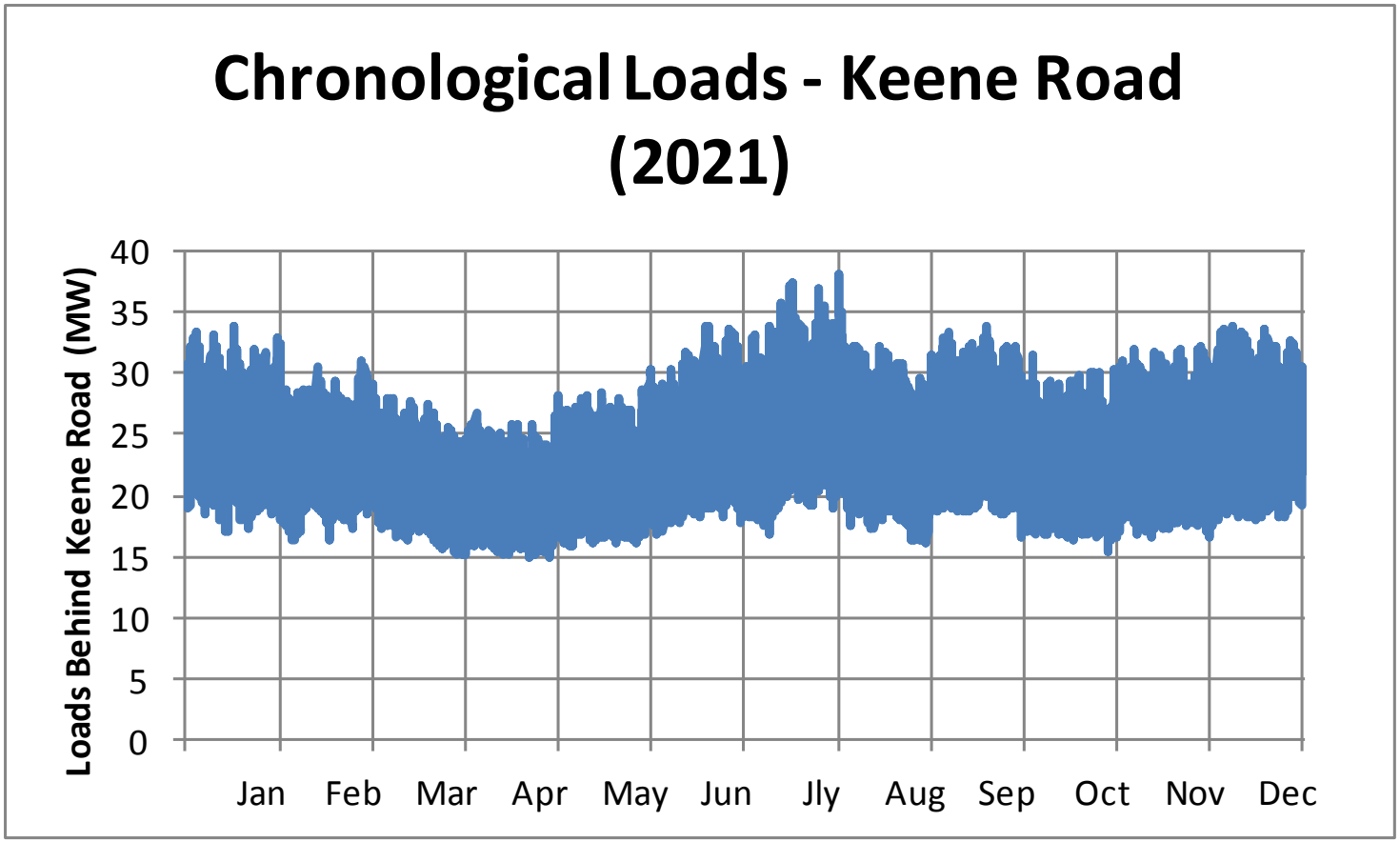
# Load: New England Peak Load Forecast

*Effect of Behind-the-Meter PV and Passive DR*



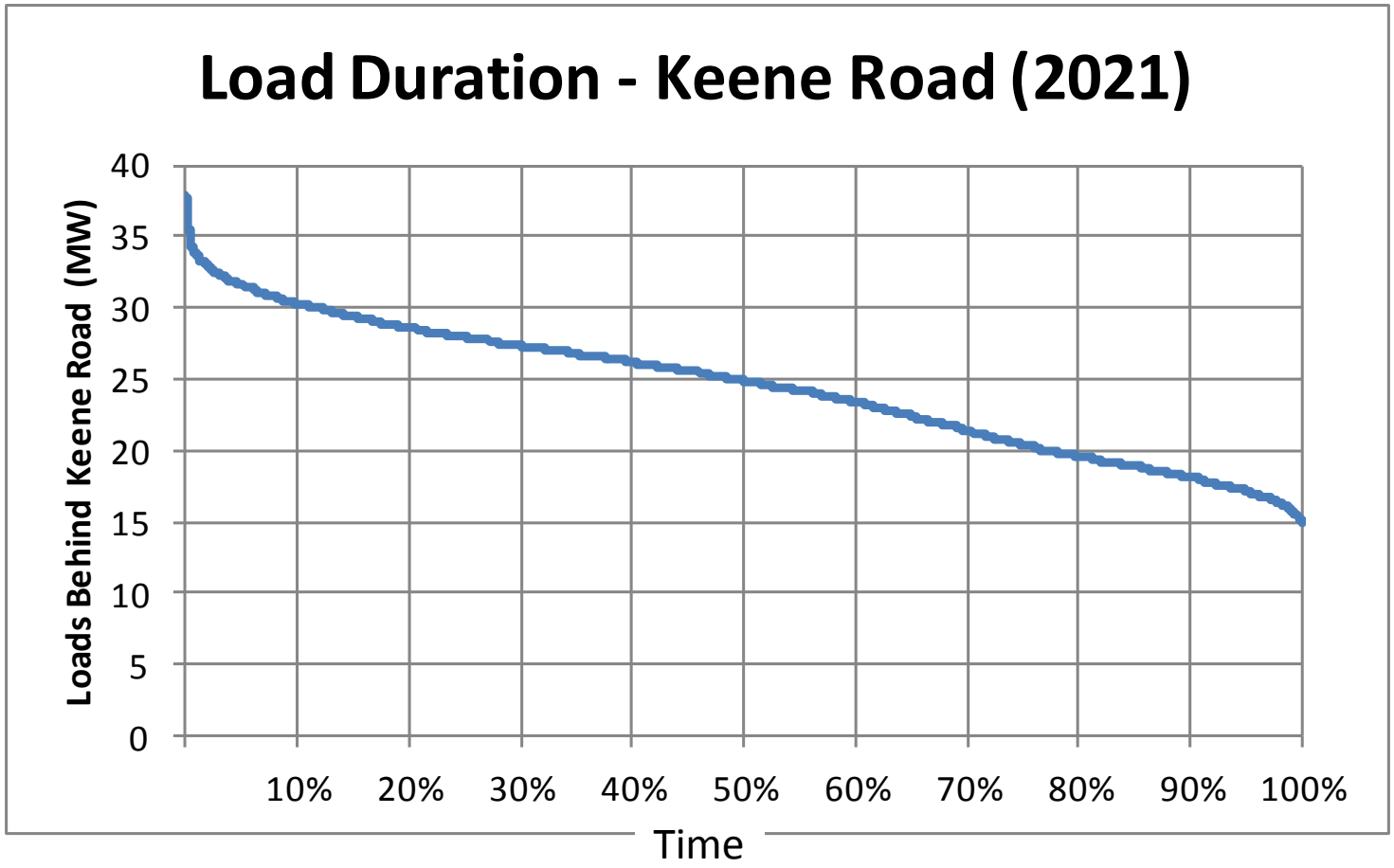
# Load: Keene Road Net Loads Assumed

Chronological

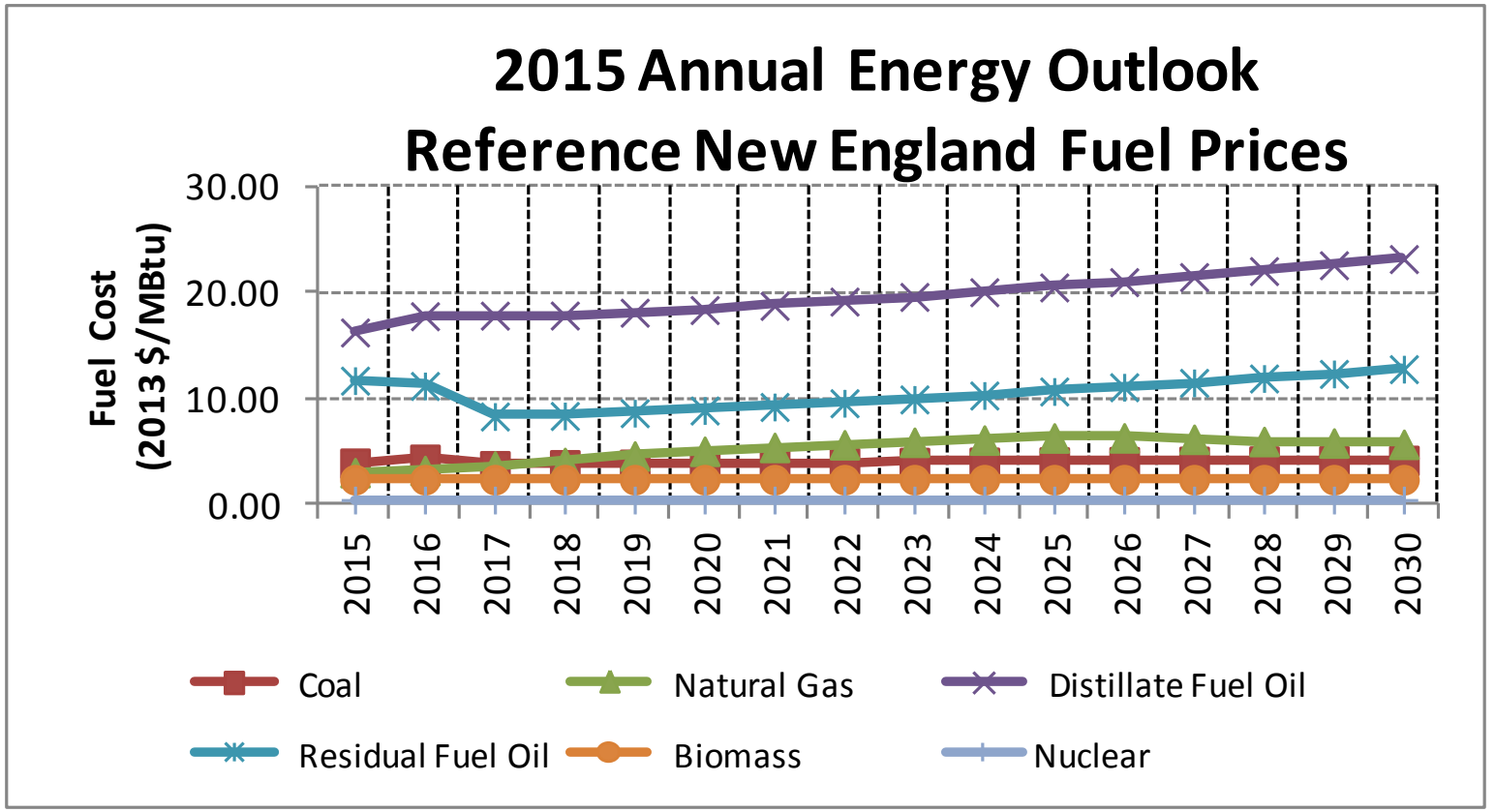


# Load: Keene Road Net Loads Assumed

*Duration Curve*



# 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%
  - Keene Road average capacity factor is 38%

# 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

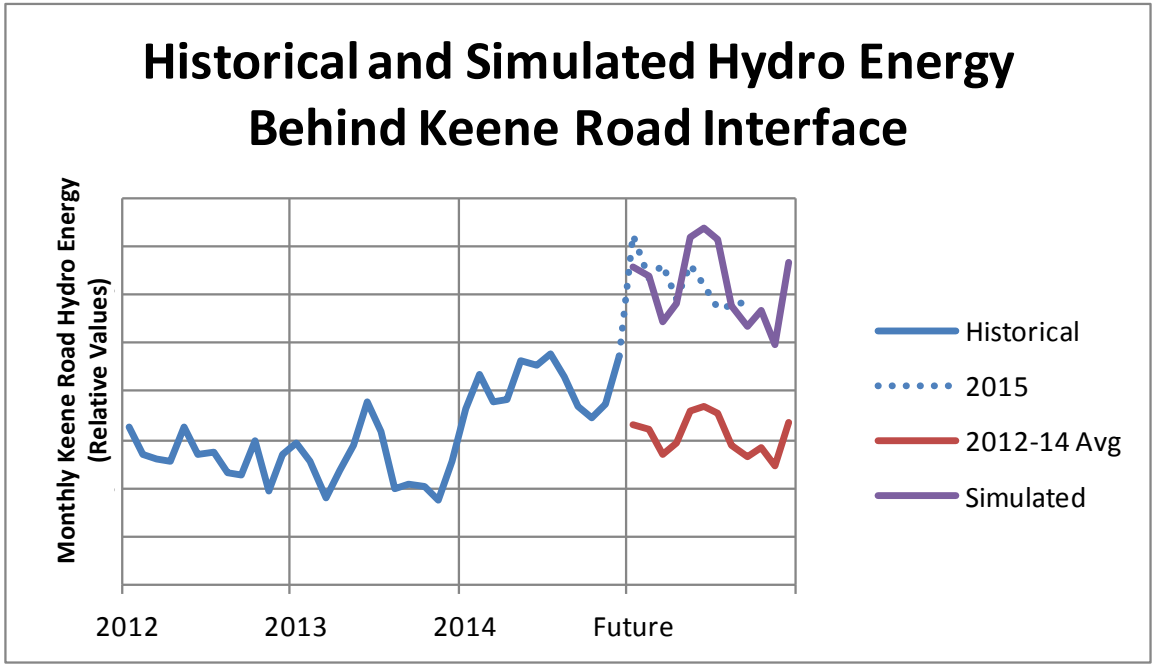
*Hydro Units*

- 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

*Monthly Hydro Generation in Keene Road*

- The first nine months of 2015 (dotted blue) indicated hydro energy production approximately twice the three-year-average (red). The simulated energy (purple) represents twice the three-year-average.
- It is assumed that the gross electrical energy demand within Keene Road area is decreasing, due to :
  - Paper mill closings
  - Hydro generation previously consumed by local demands now available for export



# 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

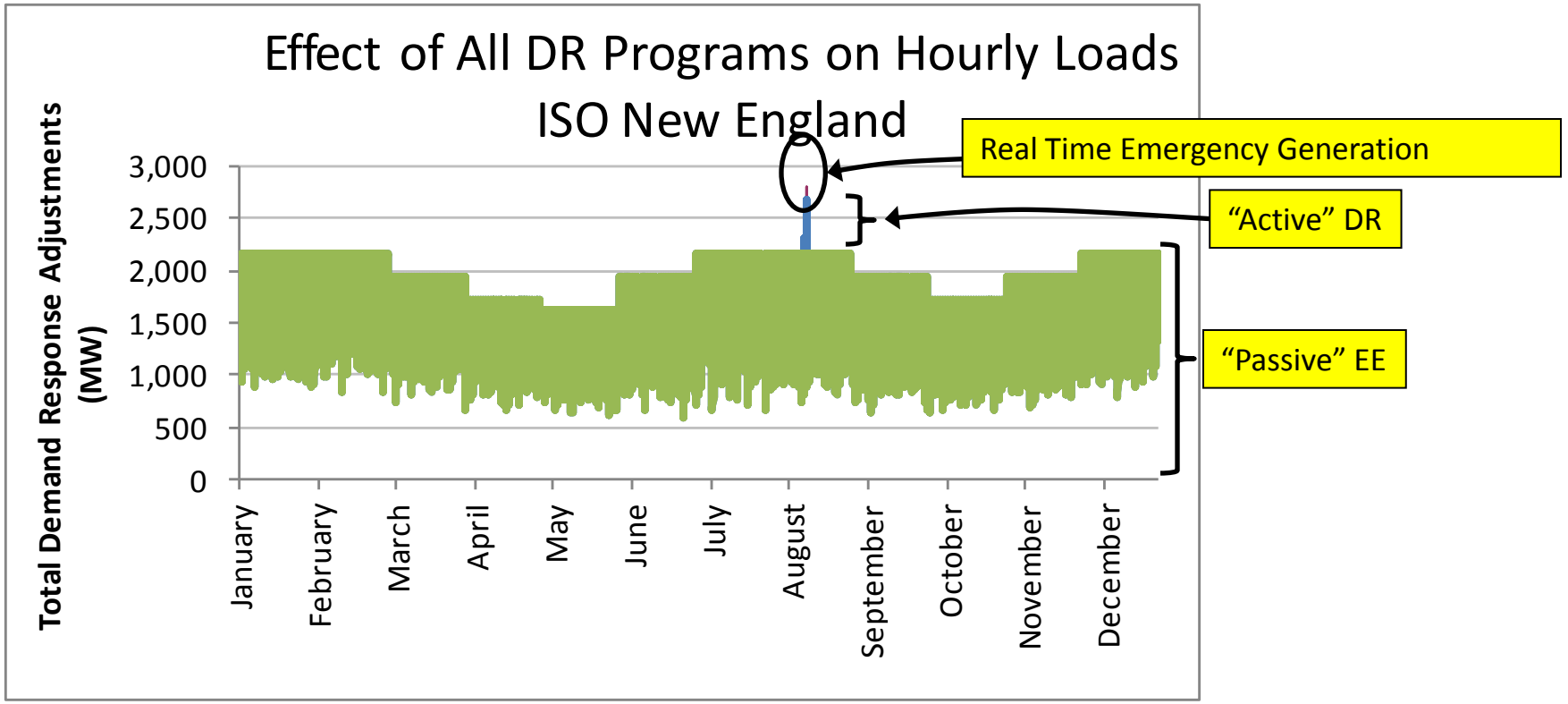
*Demand Resources*

- 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)

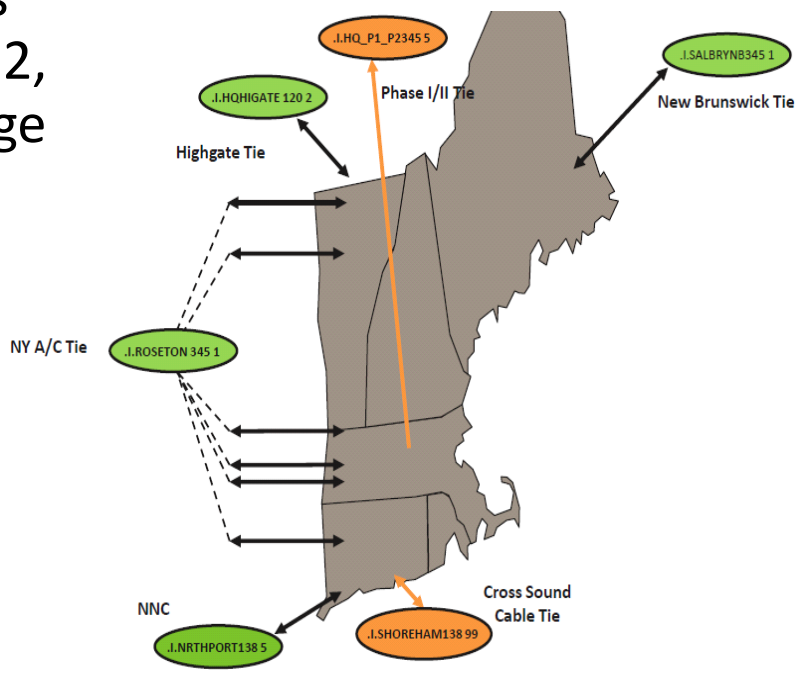
- Modeling of internal interface limits
  - The latest ISO-NE estimated internal interface limit values reflected
- Modeling of transmission line
  - All 230 kV and 345kV circuits ISO-NE region are monitored for thermal overloads
    - Nearly 300 branches monitored for thermal overloads
    - Includes 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 maximum imports by month for 2013 – 2014

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

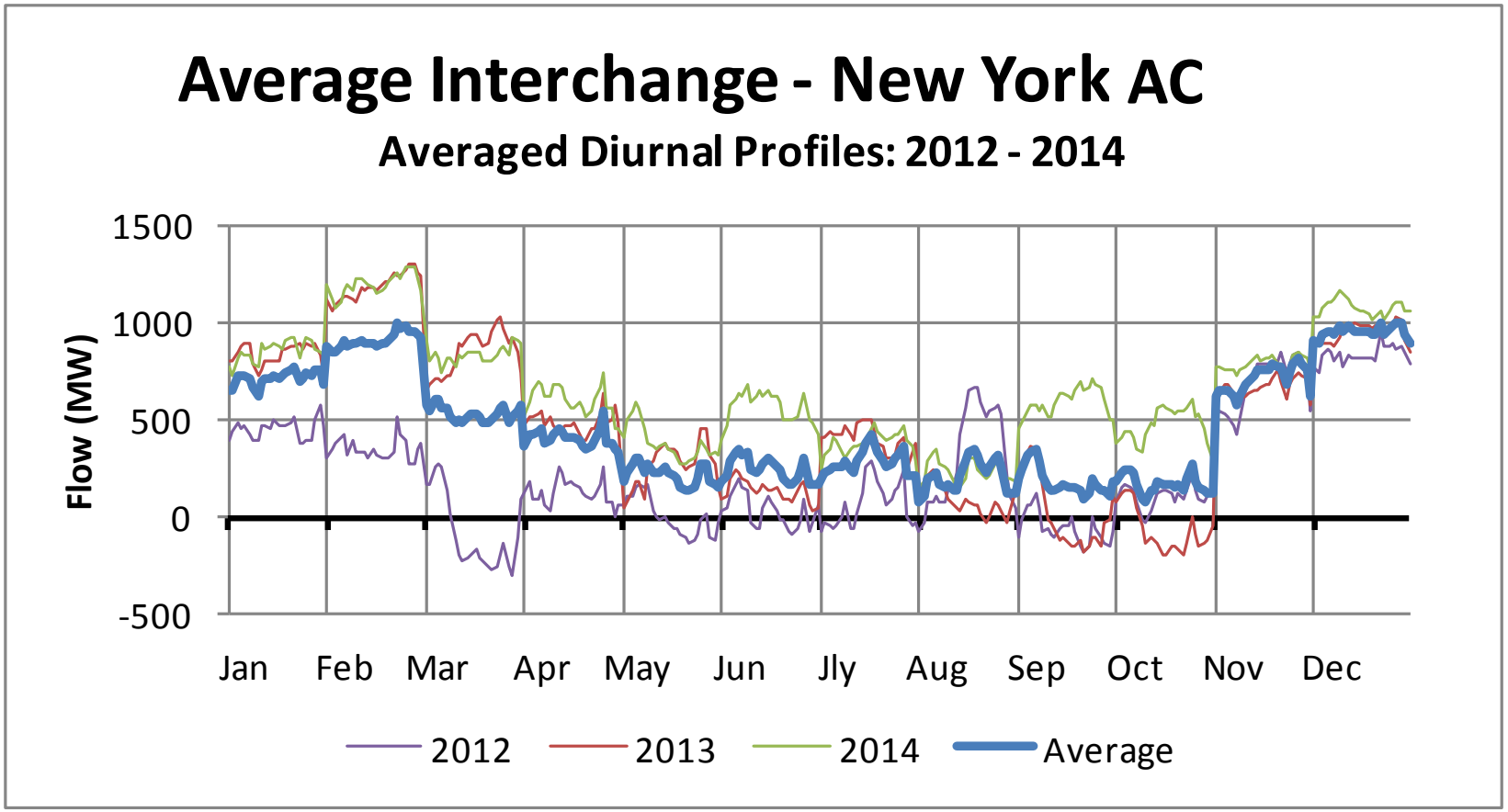
ISO -NE External Interface




Modeling of Imports/Exports

# Imports and Exports Modeling

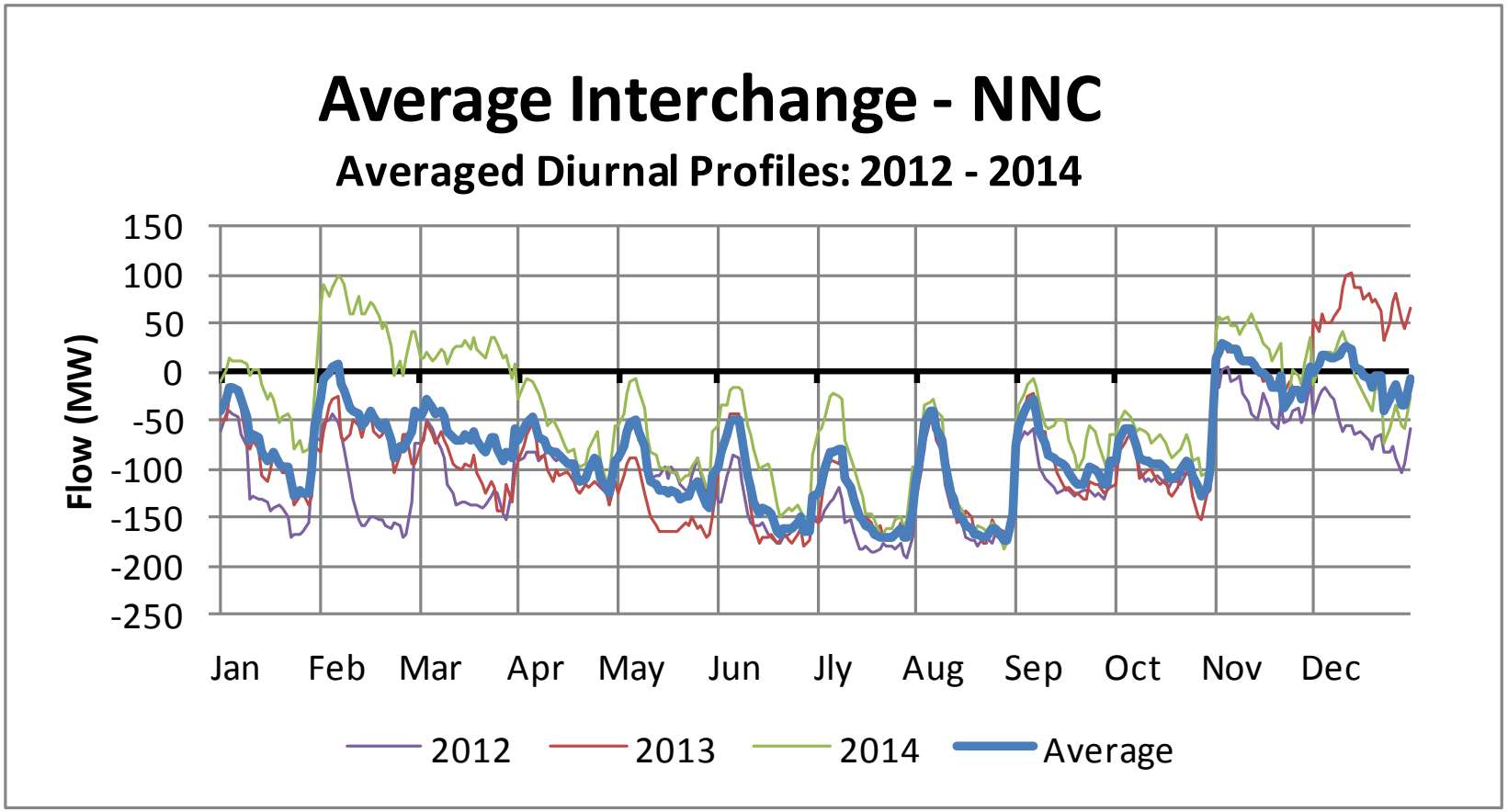
*New England to New York - AC Interface*




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

# Imports and Exports Modeling

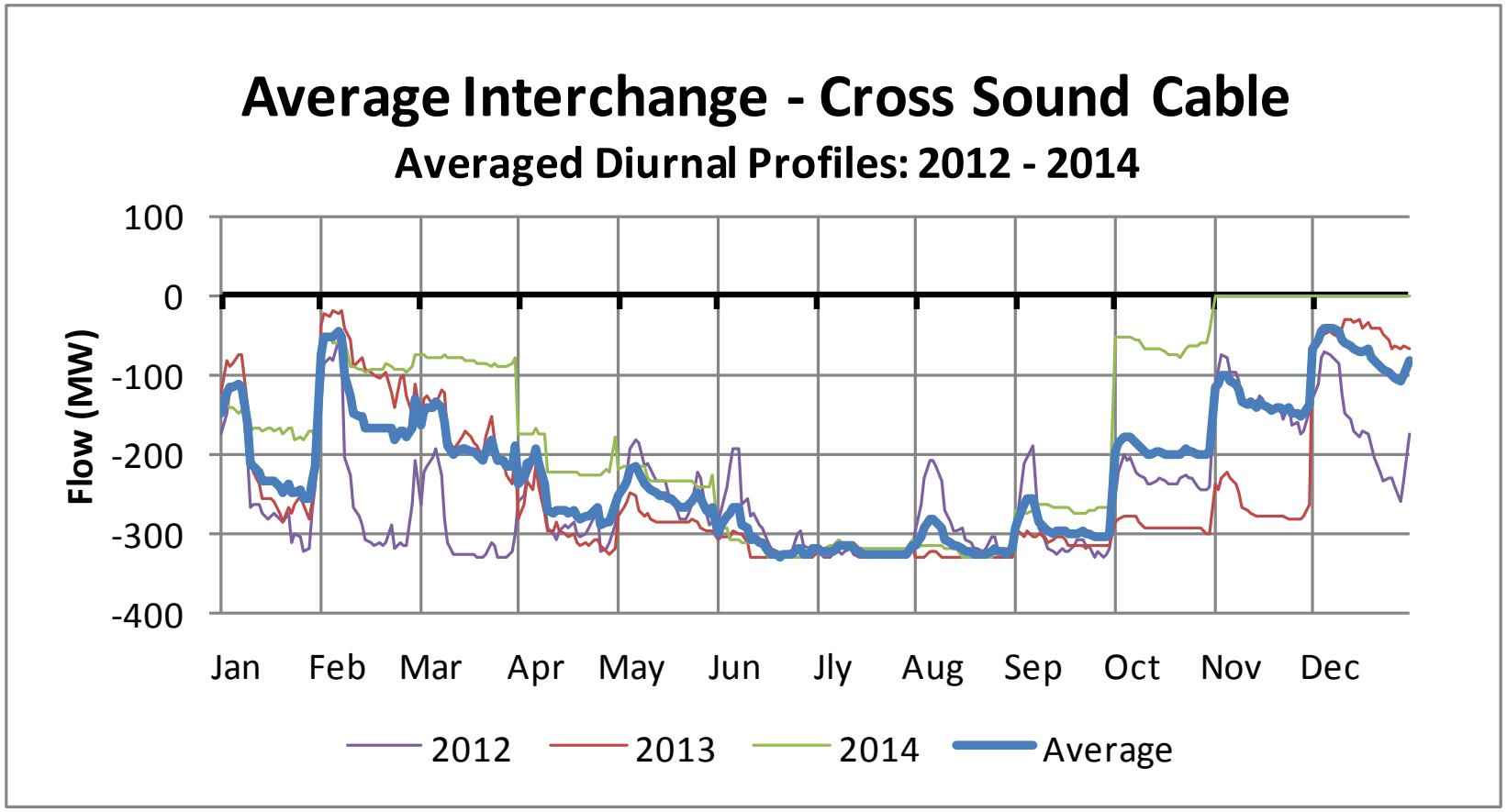
*New England to New York - NNC Interface*




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

# Imports and Exports Modeling

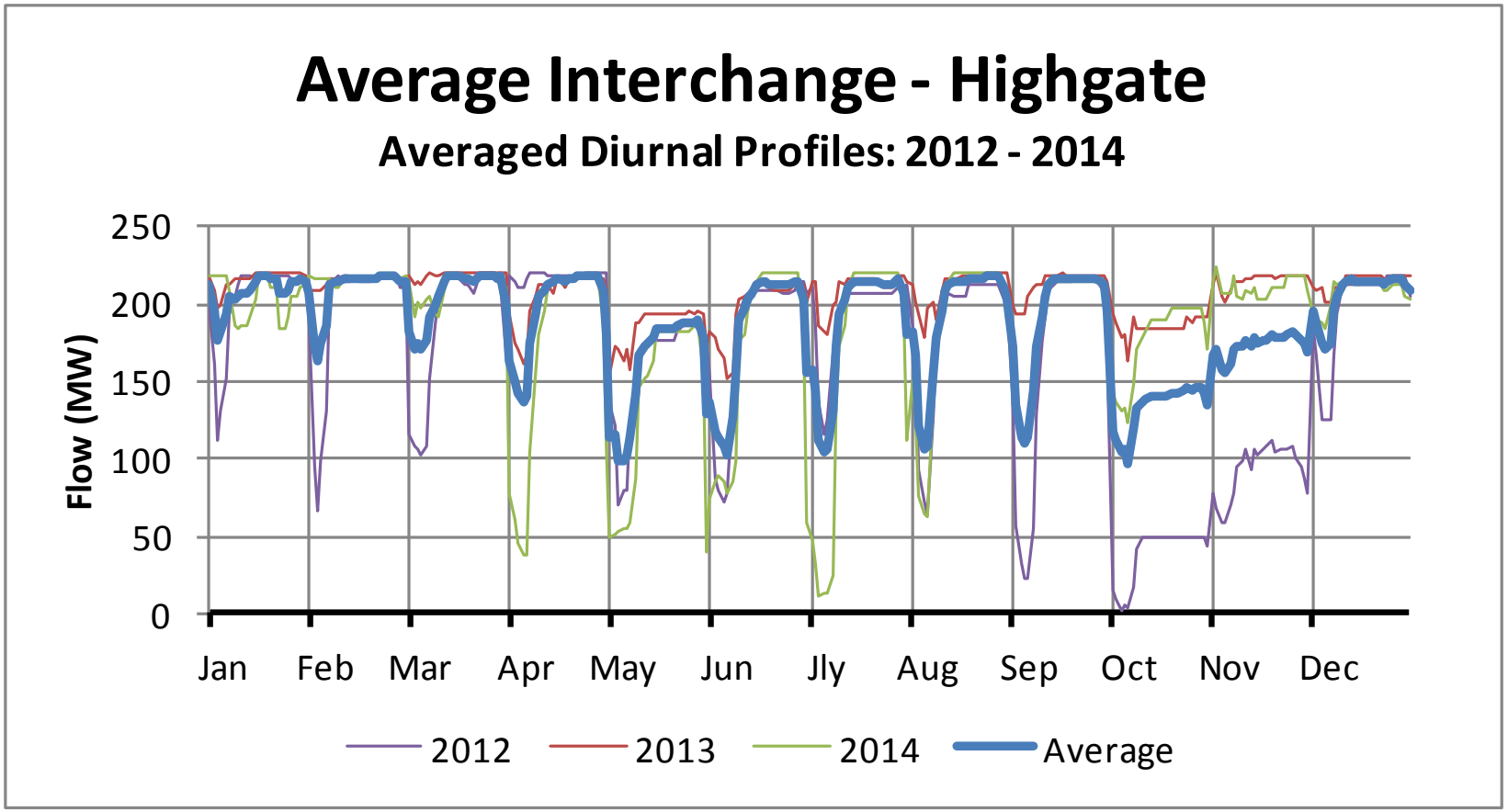
*New England to New York – Cross Sound Cable*




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

# Imports and Exports Modeling

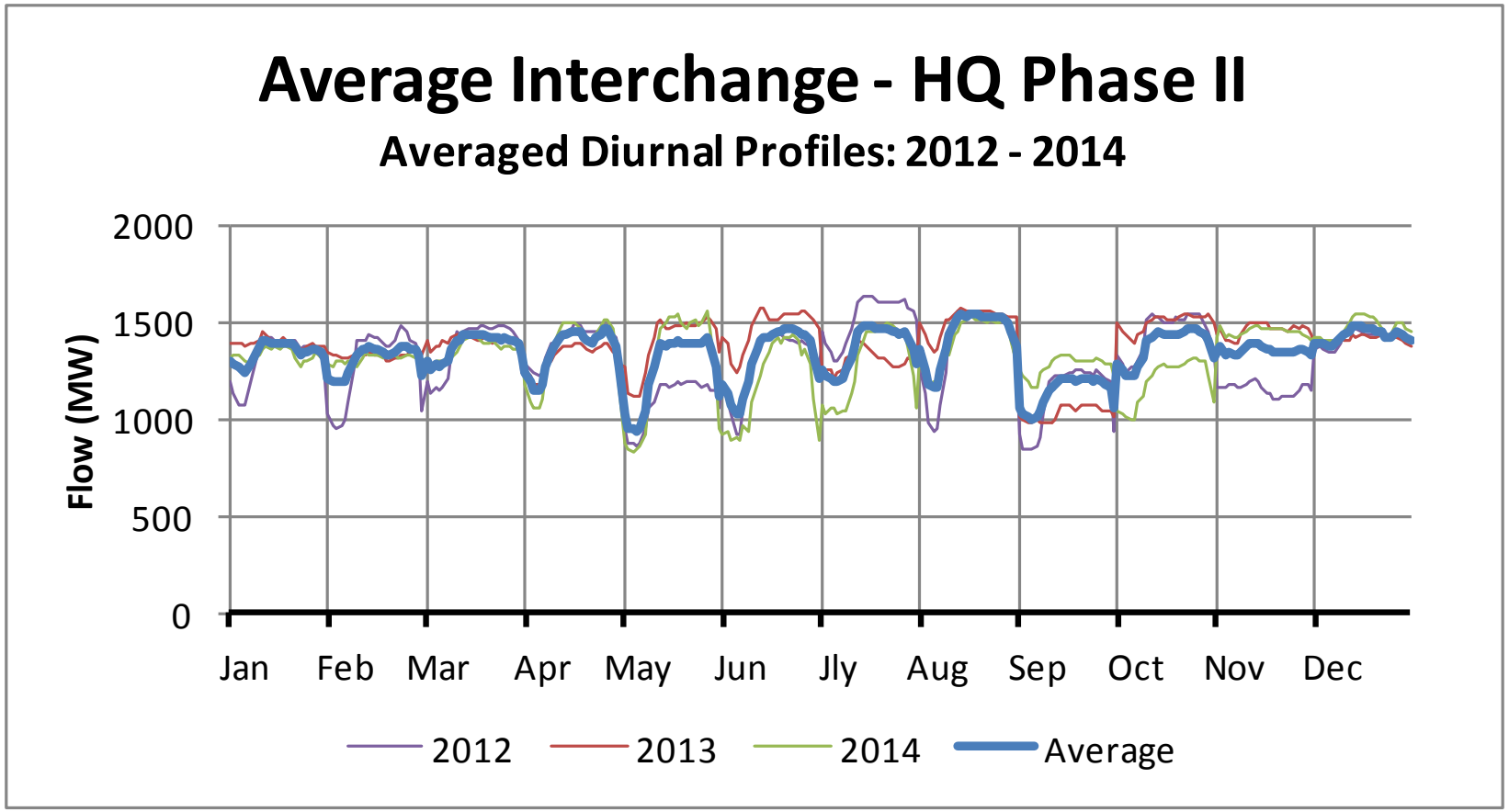
*Quebec to New England: Highgate*




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

# Imports and Exports Modeling

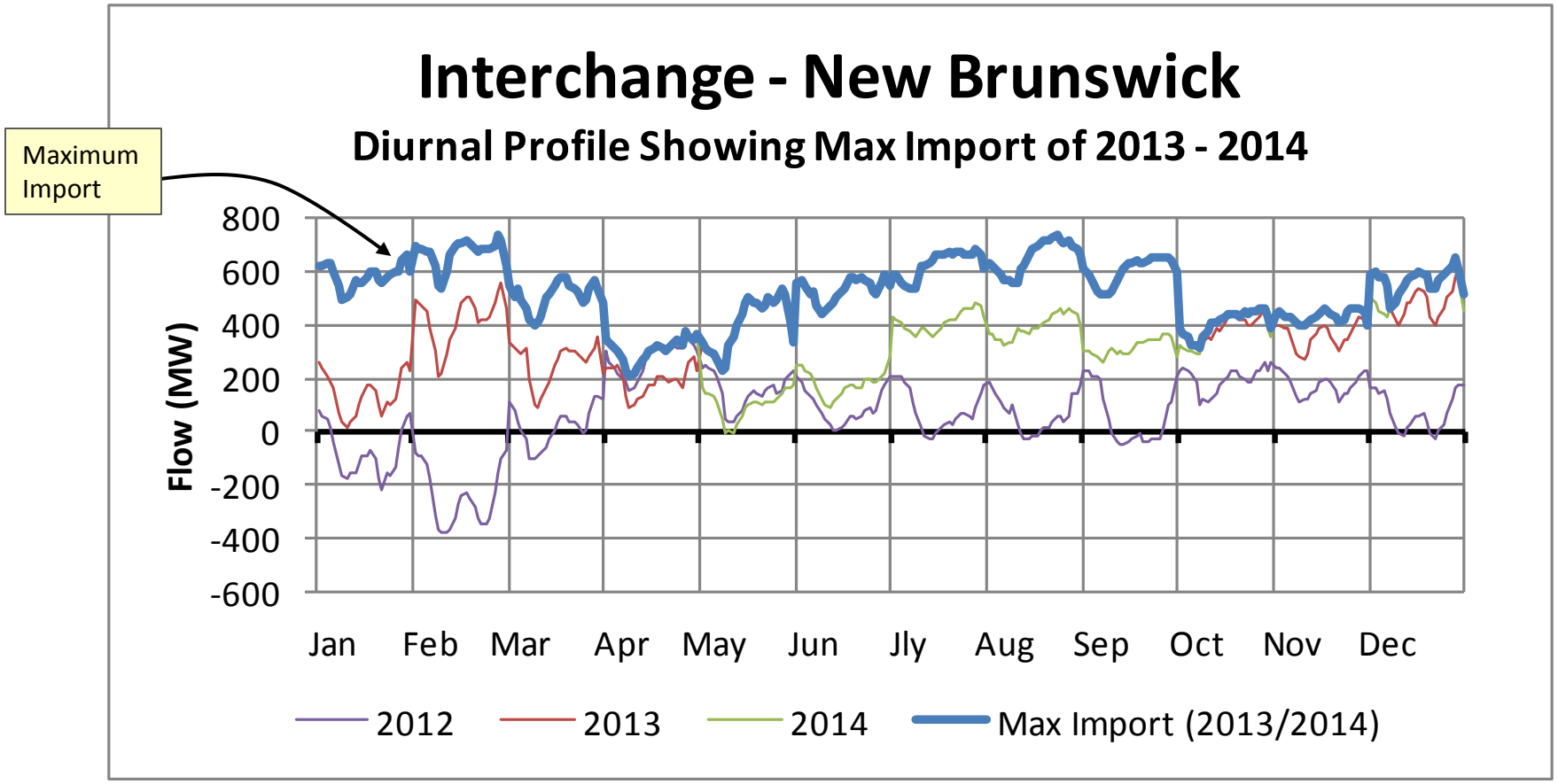
*Quebec to New England: HQ Phase II*




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