Preliminary Results – Joint ISO-NE, NYSRC and NYISO study on Tie Benefits

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Presentation Overview

- Progress to date
  - February 23 meeting between ISONE / NYSRC / NYISO staff
    - Discussed outstanding data and modeling issues
    - Established a schedule for next steps
  - Allocation of workload for MARS based studies
    - ISONE to take the lead on ISONE / NYSRC tie study
    - NYISO to take lead on 2006 Northeastern Coordinated Plan for ISONE / NYISO / PJM Joint study
- Details of methodology and procedure for Joint ISONE / NYSRC tie study described in this presentation

Background

- This study serves two purposes
  - ISO New England Tie Benefits update
  - Joint New York / New England Tie-Specific tie benefits
- Review of fundamentals
  - Over last year, fundamental concepts presented to PSPC
  - Better understanding of tie benefits and reliability calculations
    - Theory not completely understood by all committee members
    - Bring everyone to same page
- Before extending theory to “Tie Specific” tie benefits
  - Need to have solid foundation on tie benefits
  - Understand the MARS Model and characteristics in detail
  - Understanding what we are doing is critical to:
    - Interpreting the results
    - Extending the theory

Goal of this meeting

- Review the status of this joint study
  - What we have done
  - What the preliminary results show
  - Discuss results
- Solicit comments and concerns
  - Methodology
  - Assumptions
- Identify next steps

Review of the Study Scope

ISO-NE, NYSRC and NYISO Study Scope

- Study scope document
  - Established parameters of two related tie benefits studies
    - Multi-area modeling of the Northeast using NPCC CP-8 data
      - Control area to control area tie benefits
      - Cut aggregate control areas ties to determine respective contribution
    - Desired NYISO / NYSRC specific interconnection tie benefit study
      - Increased complexity of analytical techniques required
      - Improved analytical framework needed as basis of consensus building
  - Developed a sound framework for quantifying tie-specific benefits
    - Extension of fundamental ICR concepts to tie benefit issues
- Approved by Committees
  - PSPC on 11/10/2005
  - NYSRC ICS on 11/30/2005

Scope: Purpose

- The purpose of this study is to
  - Assess boundary conditions and the reliability benefits of transmission interfaces between NYISO and ISONE
  - Recognizing transmission constraints within both control areas
  - This assessment of boundary conditions will allow:
    - For more accurate modeling of emergency assistance
    - Resulting in improved reliability calculations and
    - More accurate determination of control area and locational reserve requirements

Scope: Background

- NPCC reliability criterion states that:

  Each Area's resources will be planned in such a manner that after due allowance for scheduled maintenance, forced and partial outages, interconnections with neighboring areas, and available operating procedures, the probability of disconnecting non-interruptible customers due to resource deficiency, on the average, will be no more than once every ten years.

- Part of this evaluation is:
  - Consideration of emergency assistance from external control areas
  - Adjusted for grandfathered contracts and estimated external capacity purchases

Scope: Procedure and Assumptions

- The General Electric Multi-Area Reliability Simulation (MARS) will be used as the primary analytical tool for this analysis. The MARS model will include:
  - The most recent database used by ISO-NE, combined with the most recent database used by NYISO, updated for the latest assumptions.
  - All known generators and their associated MW ratings and transition rates.
  - The transfer limits of the transmission system between Zones and/or Areas in both directions.
  - Groupings of interface flows that would limit the total flows to less than the sum of the individual flows into or out of an area
  - The transition rates for the cable interfaces
  - Daily peak loads for each of the zones and areas
  - Emergency operating procedures
  - All firm transactions between areas and zones
  - Generator maintenance schedules
  - Load forecast uncertainty
  - Latest locational capacity requirements for constrained zones in NY and NE

Scope: Process

- Initial reliability simulation will be run to achieve design reliability levels
  - The LOLE result will be compared to the LOLE criterion target of disconnecting firm load 0.1 days per year.
  - If the LOLE result is higher or lower than 0.1 days per year, MARS is re-run in an iterative process
    - Increasing/decreasing capacity in the zones or groups of zones
    - Defined by the critical import interfaces in order to attain the 0.1 LOLE
- The goal will be to:
  - Maximize the amount of capacity that can be removed within the control area to satisfy the LOLE reliability criterion
  - The MARS function table “MOD-MDMW” will be used
    - Facilitate capacity shifts between regions
    - Avoid potential distortions associated with shifting of individual units

Scope: Establishing the Base Case

- The LOLE indices to be considered will be:
  - NYISO LOLE and the ISO-NE LOLE considering internal transmission limits
  - When these both simultaneously attain 0.1 days per year with the minimum amounts of capacity this defines a base case
- A final step is to check that none of the surrounding areas are more reliable on an isolated basis
  - If they are, then their loads are increased until this is no longer the case
  - This is done so that there is not an over-dependence on the neighboring systems

Scope: Tie Benefits

- Critical interfaces between NYISO and ISO-NE control areas will be cut to determine the reliability benefit of each group of ties
  - For example, the 1385 and Cross-Sound Cable can be evaluated individually, but …
  - They must also be treated as a group in order to determine the simultaneous tie benefits
- With the interface ties cut
  - The system will then be re-solved for 0.1 LOLE
  - The difference between the basecase and the interface cut case represents tie benefits

Scope: Sensitivity Cases

- Sensitivity testing will include
  - Reliability impacts of increased transfer capability across ISONY/NE transmission interfaces as appropriate.

Implementing the Scope

Implementing the scope

- Basic Concepts
  - Each area satisfies minimum NPCC reliability criterion (0.1 d/y)
    - Each area must have a minimum amount of capacity
    - May support more, but must have at least this minimum amount
  - Minimum capacity does not mean that it must be physically located within control area boundaries
    - Highgate is a Quebec resource considered to be "in" New England
    - Other Vermont contracts also considered to be "in" New England
    - NYPA contract is from New York considered to be "in" New England
    - All these previously acknowledged as resources "in" New England
  - Capacity transactions affect available transmission capability
    - Reduces transfer capability available for tie benefits to buyer
    - Increases transfer capability available for tie benefits to seller

Step 1: Minimum Control Area Capacity

- All control areas are brought to 0.1 days per year reliability criterion neglecting internal constraints
  - Reflects inter-control area support, constraints and limitations
    - Transmission may constrain between areas with diverse loads
      (ISO-NE and Quebec also NYISO and Quebec)
    - Transmission may not constrain between areas with correlated loads
      (ISO-NE and NYISO)
  - Minimum capacity framework
    - Theoretically consistent with development of minimum ICR
      - Appropriate minimum capacity conditions to determine tie benefits
      - Determine tie benefits to each control area in a consistent manner
      - Control area decision to have more capacity than needed for “criterion” is assumed to compensate for un-modeled risks that if modeled would bring that area to “criterion”
    - Surpluses above minimum would be available to support ICAP sales

Step 2: Apply Internal Constraints

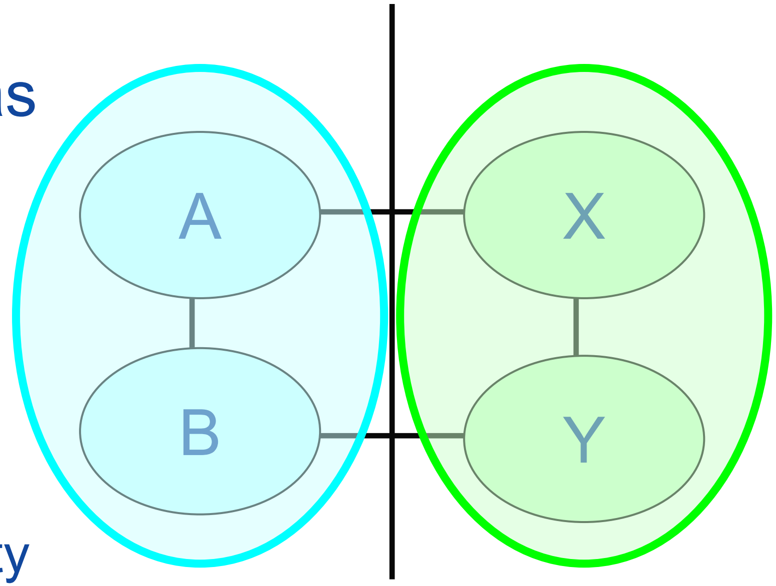
- Apply internal constraints to each control area
  - Without internal constraints, tie benefits to specific areas are undefined
  - Interconnection specific tie benefits will be driven by these internal limits
- Focus on only the major internal interfaces
  - New York
    - Rest-of-State
    - Zone J
    - Zone K
  - New England
    - South of Maine/New Hampshire
    - Connecticut
    - Southwest Connecticut
    - NEMA ignored because it cannot be distinguished from ROP for Tie Benefits
  - Internal constraints resolved via minimum locational requirement
- Locational requirements allocate minimum capacity to sub-regions
  - Inefficient location of capacity requires capacity above minimum needed to satisfy the reliability criterion

Step 3: Quantify Tie Benefits

- With minimum control area capacity configurations defined
  - Minimum total control area capacity
  - Minimum sub-area capacity requirements
    - Based on internal transmission constraints
    - Satisfying the pool-wide LOLE reliability criterion
- Isolate control areas and determine total tie benefits
  - Aggregate tie benefits for each control are same as unconstrained
  - Quantify range of acceptable tie benefits at each interconnection
    - Tie benefits may be affected by increasing / decreasing transfer limits
    - Overlapping combinations of acceptable tie benefits are possible
- Need to extend the Tie Benefit framework

Extending Tie Benefit Framework

- Basic tie benefit framework needs to be extended
  - Does not include concepts related to specific interconnections
  - Extension of the control area by control area paradigm
- Develop an illustrative system for discussion purposes
  - Two control areas (Blue & Green)
  - Each has two sub-areas (AB or XY)
- Without internal constraints, areas
  - Can satisfy their reliability criterion
  - Have minimum amount of capacity
  - Internal capacity location irrelevant
    - When internal constraints neglected
- May be affected by tie capability
  - Capability ranges from zero to infinity

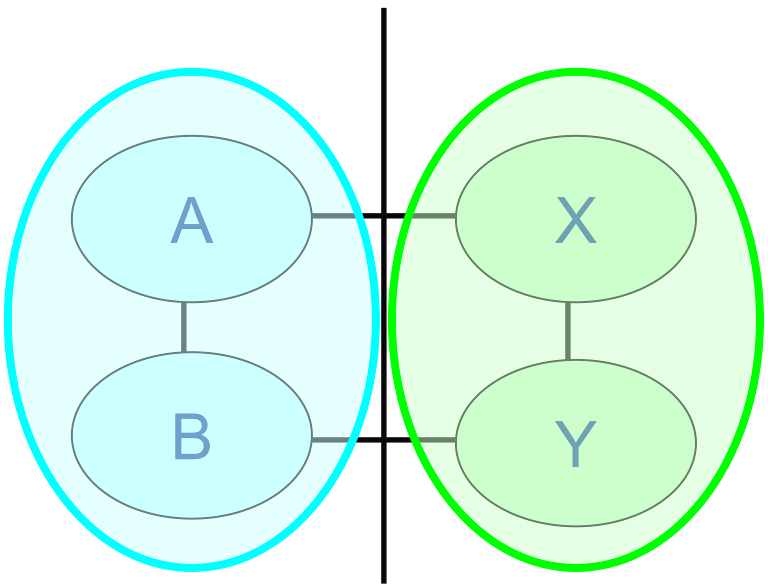


Technique for Bringing All to Criterion

- Calculate base case, extract LOLE for each control area
  - Add an increment of capacity in each area … one at a time
  - Calculate resulting ∂ (LOLE)/∂ (MW) for each area
  - Develop a Jacobean matrix of these partial derivatives
  - Identify control area where increments have the greatest impact
    - Subject to constraint that total capacity is to be minimized
    - Estimate changes
  - Input estimates of capacity changes into each area
- Reiterate steps until minimum global capacity is attained
- Process sensitive to transmission configuration
  - Transmission change may result in change to Jacobean matrix
  - Key concept in quantifying interconnection specific tie benefits

Illustrative System Control Areas at Criterion

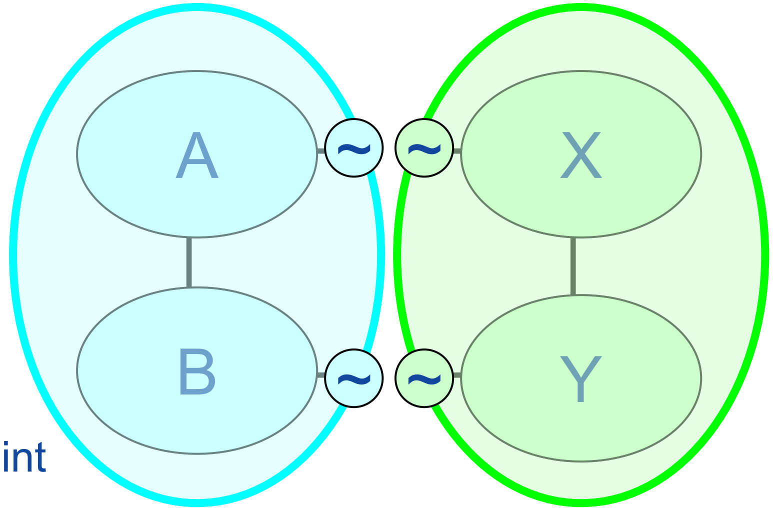
- Bring both control areas to criterion,
  - Each control area will have an LOLE index of 0.1
  - These two control areas may have higher combined LOLE
    - With zero transmission, combined LOLE could be, say, 0.70
    - With strong interconnections, combined LOLE could approach 0.18



  - Considering tie constraints
  - Neglecting internal constraints
  - Minimum capacity requirements
    - Minimum in both control areas
    - Minimum capacity requirements is the level below which control areas cannot have less
  - Inter-area purchases not precluded

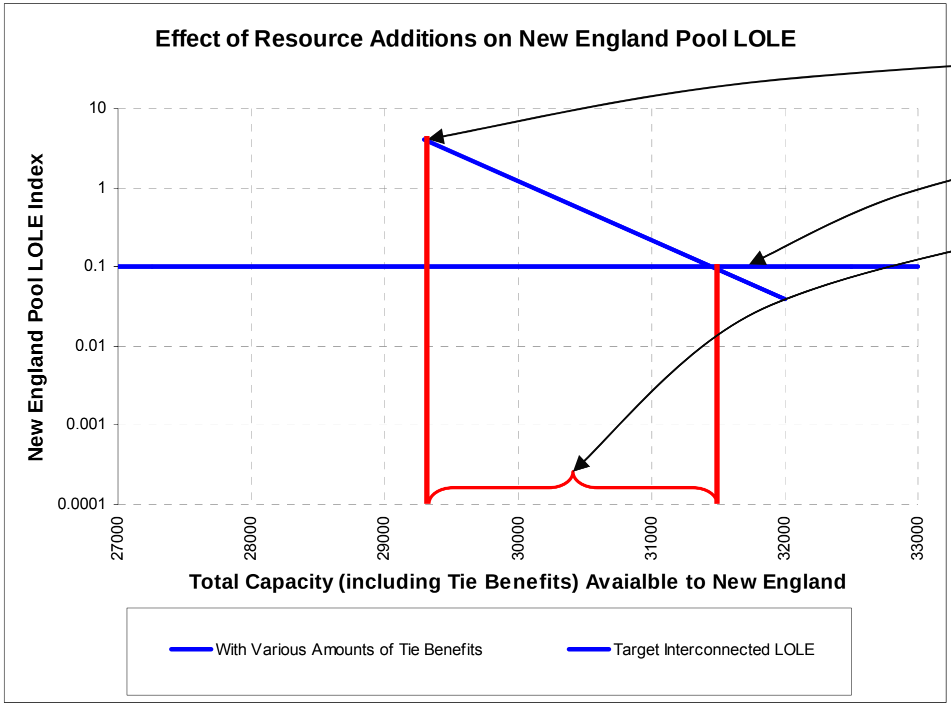
Tie Benefits At Interconnection Points

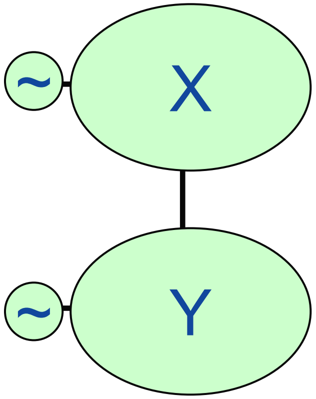
- Each interconnection can be associated with a firm capacity equivalent
  - With no internal control area transmission constraints
    - Allocation is not important
    - Summation of all firm equivalents is a constant
    - $TB_{total} = TB_{at\ A} + TB_{at\ B}$
  - With internal constraints binding
    - Allocation may have boundaries
    - Too few TB at one point will
      - Increase control area LOLE
      - Increase control area capacity
      - Provide results incompatible with multi-area model results
      - Require “more” at the another point



Determining Tie Benefits - Unconstrained

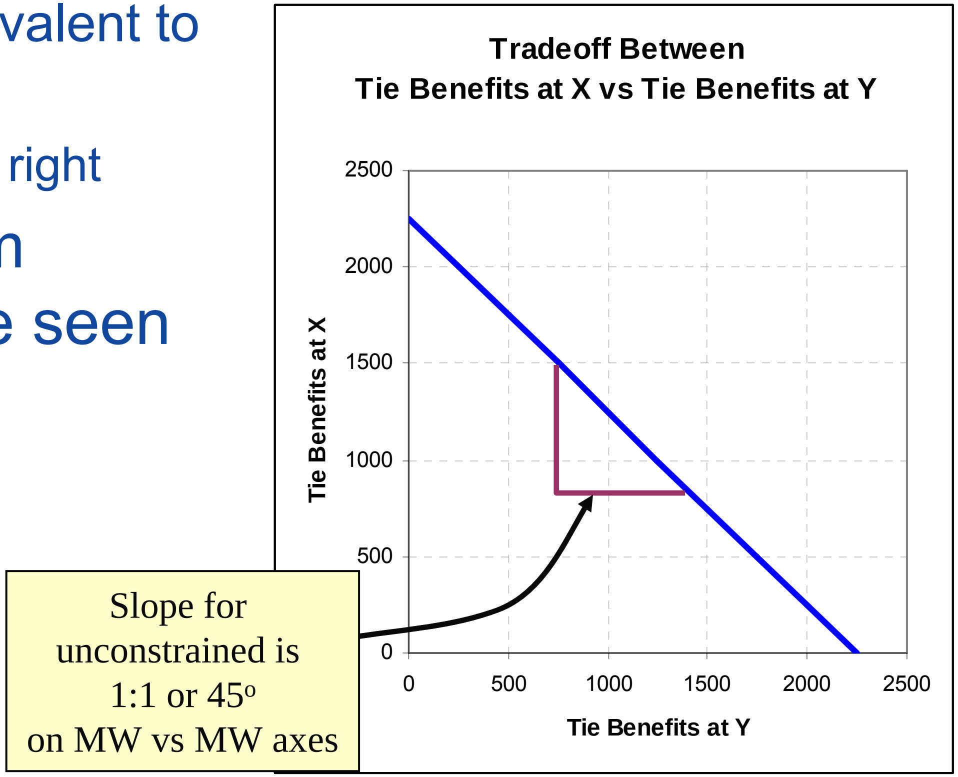
- In a multi-area model, tie benefits still defined as the firm capacity equivalent necessary to bring the isolated control area back to its interconnected LOLE
- Location of firm capacity equivalent not significant





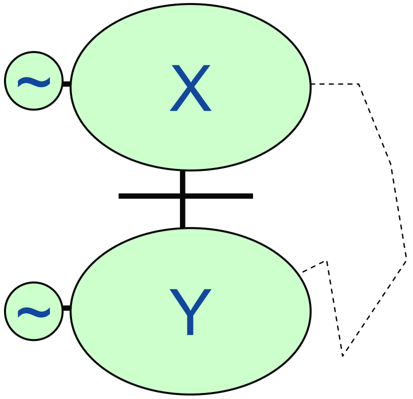
Tradeoff One Interconnection vs. Others

- In an unconstrained system
  - Location of the Tie Benefits does not matter
  - One MW into "X" is equivalent to
    - One MW into "Y"
    - Illustrated as shown to right
- In a constrained system saturation effect can be seen



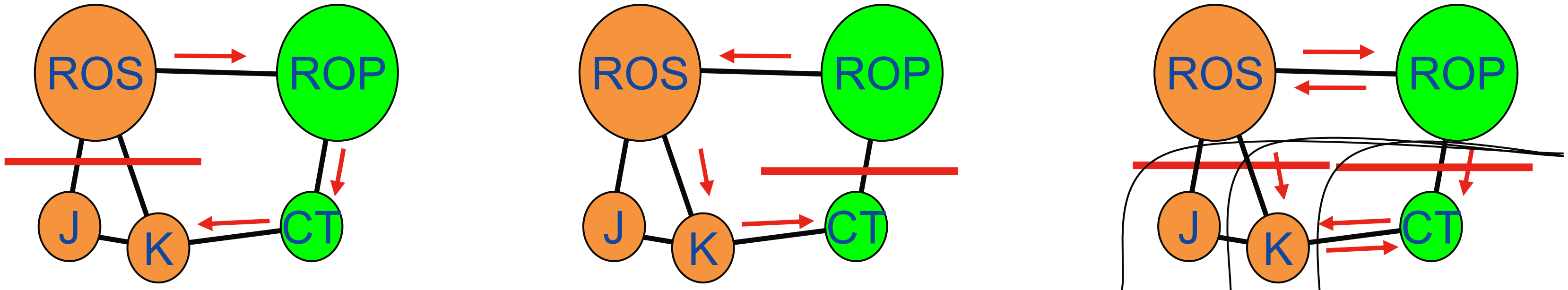
Effect of Internal Constraints

- With internal constraints
  - Ties into one sub-area may not be substitutable on a 1:1 basis with ties into other sub-areas
  - Effect of $TB_{\text{at X}}$ different than $TB_{\text{at Y}}$
- Internal constraints can be affected
  - Location of capacity among the sub-areas
    - Determines severity of constraint
    - Limited capacity available in neighboring area
    - Limited capacity available when needed
- Internal constraints may be circumvented by using available transfer capability in neighboring control areas (loop flow)



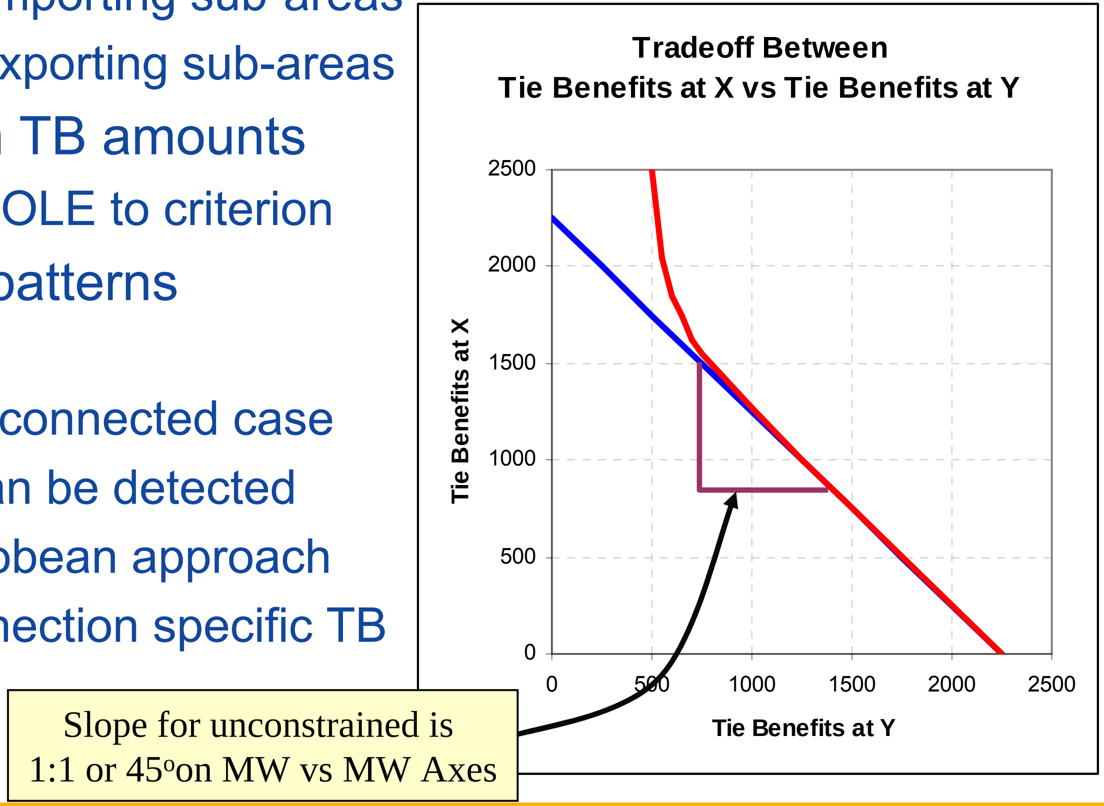
Example: Effect of External Transmission

- Tie benefit framework recognizes that surplus capacity is available from one area to another on a probabilistic basis
  - Limited internal transmission may affect LOLE indices
  - Interconnections with other control areas
    - Provides access to additional supply resources
    - Provides access to transmission routes around constraints (loop flow)
  - In the presence of internal constraints, external ties may:
    - Provide alternative paths to augment internal transfer capability



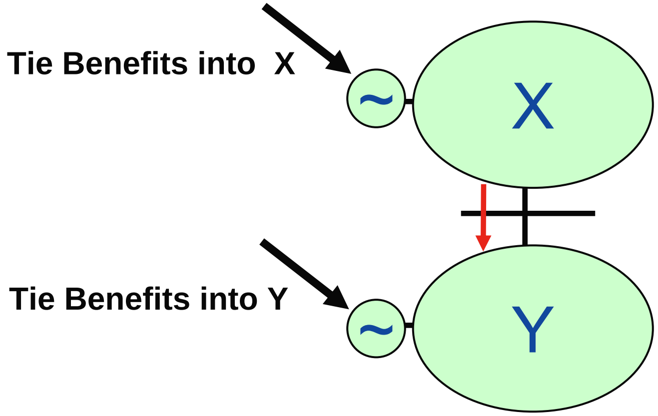
Tradeoff With Internal Constraints

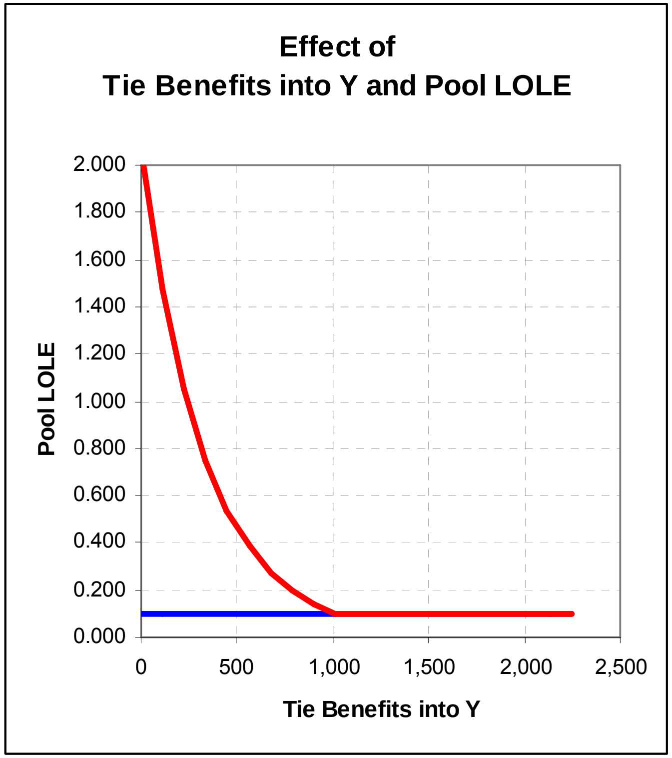
- With internal constraints firm capacity TB equivalents
  - May be more effective in certain areas than in others
    - More effective in importing sub-areas
    - Less effective in exporting sub-areas
  - Combined minimum TB amounts
    - Must return pool LOLE to criterion
  - May change LOLE patterns among sub-areas
    - Compared to interconnected case
    - These changes can be detected
    - Allocation via Jacobean approach
    - Basis for interconnection specific TB



Sub-Area Tie Benefit Effect on LOLE

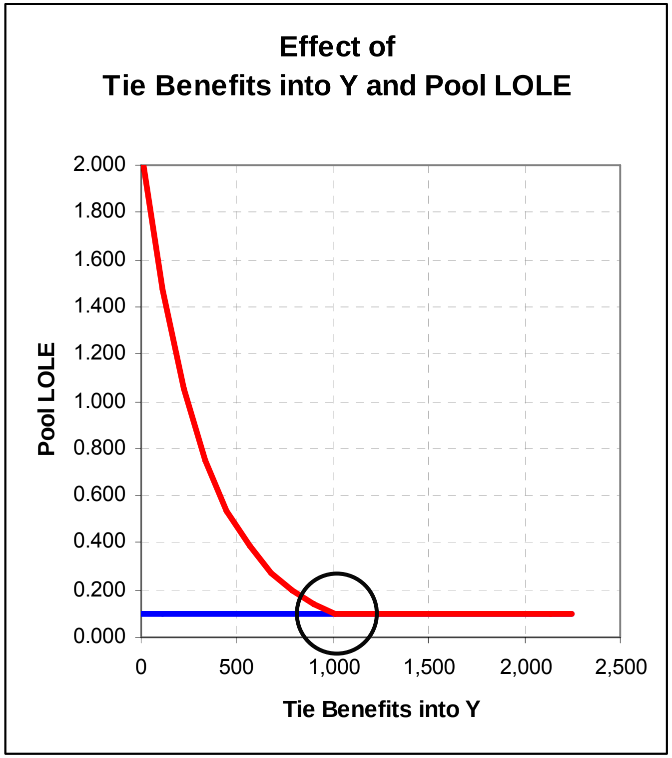
- As tie benefits "into Y" are decreased in favor of "into X"
  - With less than 1000 MW tie benefits "into Y", pool LOLE rises
    - No longer consistent with interconnected multi-area results
    - Sets minimum "into Y" boundary value
  - Sub-Area LOLE impact may be distinct
    - Further refinements on boundaries
  - Can be extended to areas "A" and "B"





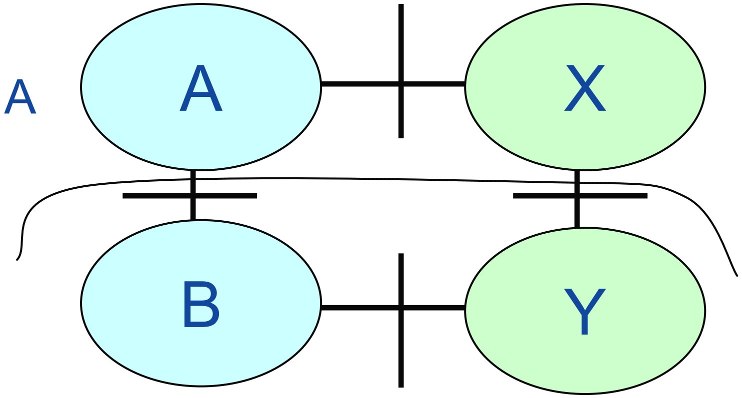
Sub Area LOLE Can Provide Information

- Sub area specific LOLE can help establish boundary limits on appropriate locational Tie Benefits
  - Need at least 1000 MW into Area Y
  - More MW into Y is acceptable
  - Fewer MW is not acceptable
  - $TB_{total} = TB_{at\ X} + TB_{at\ Y}$
  - Up to a limit
    - More $TB_{at\ X}$ could substitute for $TB_{at\ Y}$
- Assertion that $TB_{at\ X} + TB_{at\ Y}$
  - Constant amount when consistent with multi area modeling
  - Minimum capacity conditions



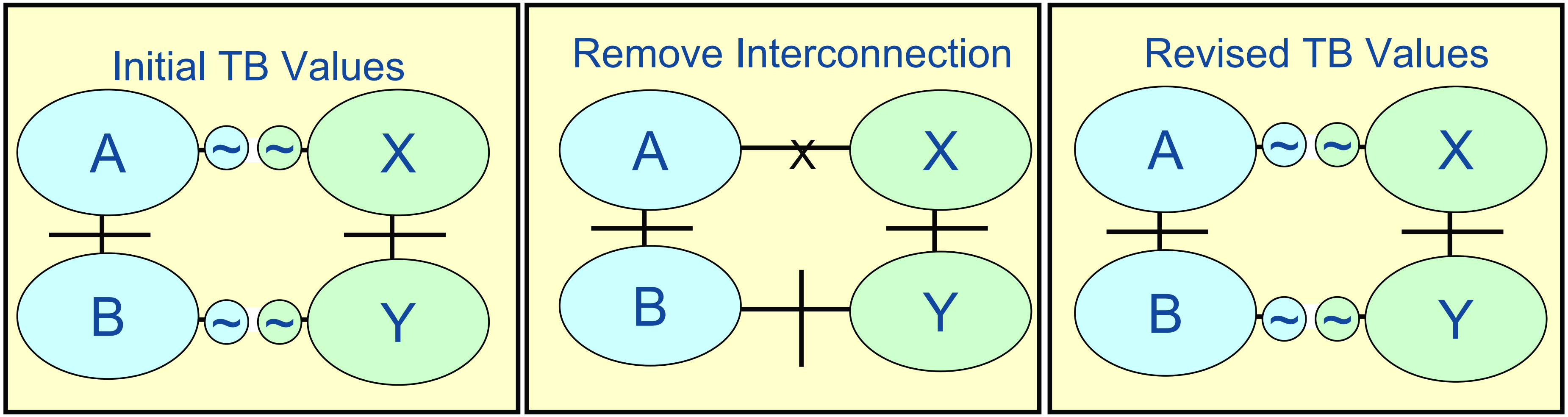
Loop Flow Considerations

- With internal constraints, there are several factors to consider
  - Amount of capacity in each bubble
  - Interface capability between control areas
- Under extended framework,
  - Minimum capacity in each control areas can be quantified
  - With areas B and Y import constrained
    - Minimum aggregate capacity in B and Y may be necessary
    - Loop flow may allow X to support A
      - A then supports B
      - B then supports Y
    - Removal of tie_{AX} may decrease tie benefits to both areas
      - Increase pool requirements
      - Increase locational requirements



Quantifying Tie Benefits of Specific Tie's

- Using Jacobean approach recalculate tie benefits into each sub area
- Removal will (in general case) affect
  - Total tie benefits between areas
  - The tie benefits (boundaries) into each sub areas
  - Difference in tie benefits can be quantified at each interconnection point for each interconnection removed



The MARS LOLE Index

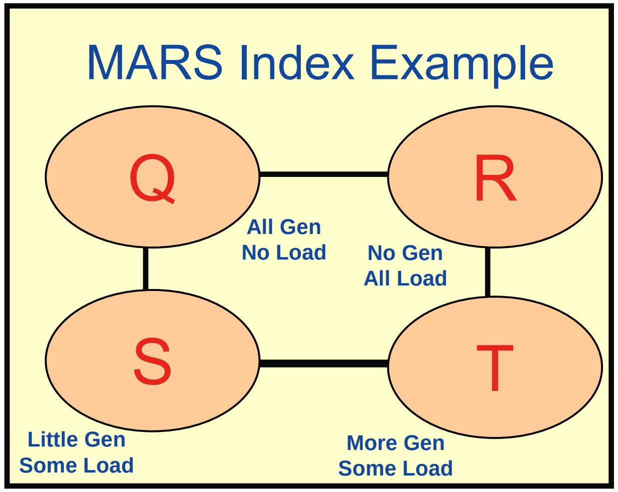
MARS LOLE Index Characteristics

- LOLE index characteristics are important
- MARS control area level LOLE indices to be used
  - Control area indices based on individual sub-area LOLE indices
  - Union of LOLE events across all sub-areas of a control area
- Sub-areas of a control area do not need to be contiguous
  - Non-contiguous sub-areas may have an impact
- Emergency operating procedure constraints ignored
  - Use NPCC CP-8 modeling assumptions
  - In actuality, benefits of some emergency operating procedures
    - Unlikely to be shared with other control areas
    - Operational issues may preempt ability to share
    - May result in minor increases in control area capacity requirements
- External control area assistance order may have impact

Understanding the MARS Index

- Four sub-areas with no constraints
  - One sub-area has only generation
  - One sub-area has only load
  - Two sub-areas have balance of both

Sub Area	Iter 1	Iter 2	Iter 3	Iter 4	Iter 5	Iter 6	Average
Resource							
Q	1100	1100	900	1100	700	900	
R	0	0	0	0	0	0	
S	350	450	510	450	510	490	
T	549	355	549	450	549	549	
Load							
Q	0	0	0	0	0	0	
R	1000	1000	1000	1000	1000	1000	
S	500	500	500	500	500	500	
T	500	500	500	500	500	500	
Surplus MW	-1	-95	-41	0	-241	-61	
Pool LOLE	Yes	Yes	Yes	No	Yes	Yes	
Pool LOLE 'Hit'	1	1	1	0	1	1	0.83
Q LOLE 'Hit'	0	0	0	0	0	0	0.00
R LOLE 'Hit'	1	1	1	0	1	1	0.83
S LOLE 'Hit'	1	1	0	0	0	1	0.50
T LOLE 'Hit'	0	1	0	0	0	0	0.17



MARS Sub-Area LOLE Index Characteristics

- Control area wide considerations
  - If control area has sufficient resources
    - It will satisfy its own loads first
    - Before providing assistance to other control areas
- Generation only sub-area (no load) always has zero LOLE
- For a sub-area that has only load and no generation
  - LOLE ‘hit’ will occur whenever there is a control area wide shortage
  - LOLE ‘hit’ will NOT occur if another part of the control area is short and this sub-area is “export” constrained to the “short” area
- For a sub-area with BOTH load and resources
  - LOLE ‘hit’ will occur whenever there is a control area wide shortage and the sub-area is deficient in that shortage hour
  - LOLE ‘hit’ will NOT occur if the area is initially not in shortage

MARS Combined Control Area Indices

- When New England has 0.100 days/year LOLE ***and*** New York has 0.100 days/year LOLE
  - Union of LOLE events for both control areas is 0.162 days/year
    - This is true even in absence of binding transmission constraints
    - Due to MARS index definition
      - Why should New England get an LOLE ‘hit’ when New York is short
      - Why should New York get an LOLE ‘hit’ when New England is short
      - No load loss sharing between control areas (each area is responsible)
  - If modeled as a single combined large control area (NPCC-US)
    - LOLE for combined area would be approximately 0.162 days/year
      - Even without binding transmission constraints
      - LOLE would now be shared internally within large control area
    - LOLE for both control areas could be brought to 0.100 days/year
      - But the areas need more capacity to improve combined reliability
      - Flexibility in locating capacity in either area absent sub-criterion

MARS Contract Modeling

- MARS can represent contracts between control areas
  - Define originating sub-area
  - Define destination sub-area
  - Designate a transmission interface link as the contract path
- Removal / Transfer reduction of contract path
  - Contract flow has priority rights on contract path link
  - Uses as much transmission capacity as necessary
  - Contract still flows if transmission link is deleted
    - Firm load increase in originating sub-area
    - Firm resource increase in destination sub-area
    - Similar to a firm increase or decrease in ‘native’ capacity
- Contracting allows for improving reliability in one area vis-à-vis another area

NPCC without
Internal Transmission Constraints

NPCC MARS Model

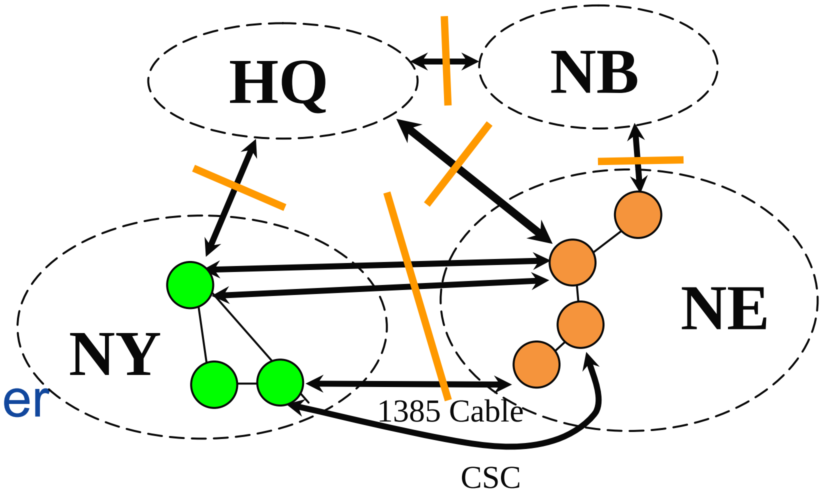
- NPCC model consists of four control areas
  - New England
  - New York
  - Hydro Quebec
  - Maritimes
  - Ontario excluded from base case due to run-time considerations
- Each control area brought to criterion
  - Criterion of 0.100 days/year LOLE
  - NPCC wide LOLE is 0.340 days/year for all four areas
    - New York and New England have summer LOLE contributions
    - Quebec and Maritimes have winter period LOLE contributions
  - New York and New England wide LOLE is 0.162 days/year
- HQ Phase II modeled at 1500 MW at 3% unavailability

Effect of Excluding PJM and Ontario

- Results presented here do not include PJM or Ontario
- Not included because
  - Run time issues
  - These distant control areas are less significant due to study focus
    - Tie-specific “Tie Benefits” between New York and New England
    - Time frame 2006/07 before PJM interconnection to Zone K
- Effect on New England and New York
  - Tend to increase tie benefits to both NE and NY
  - Reduce total amount of capacity required in both control areas
  - Less capacity required everywhere due to more tie benefits
    - New England uses “local” (HQ and NB) tie benefits even more
    - Fewer tie benefits would need to be delivered to New York

Annual vs. "Summer Only" Modeling

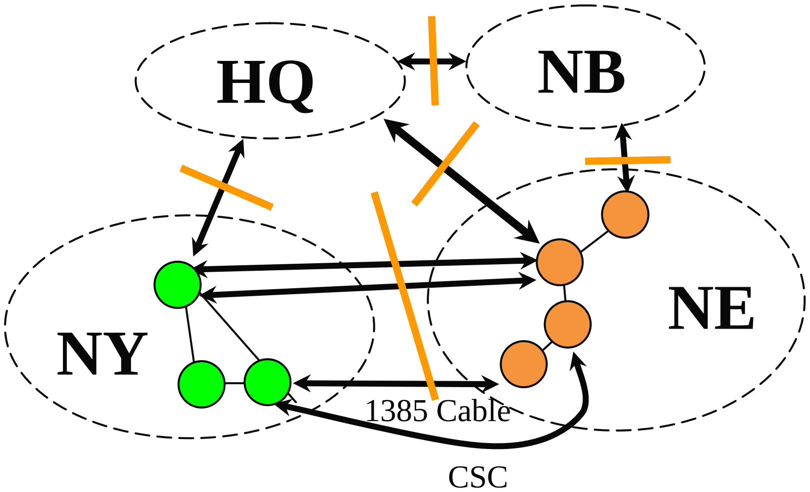
- MARS is a slow model to run in an iterative mode
  - Reasonable, accurate approximations would be useful
  - Focus on summer risk appropriate once benchmarking is done
- Benchmark shows
  - Quebec and Maritimes have
    - All risk in winter months
    - No significant risk in summer
  - New York / New England have
    - All risk in summer months
    - No significant risk in winter
- Modeling summer months
  - June, July, August and September



Modeling of First Step

- LOLE framework using annual basis
  - All control areas brought to 0.100 days/year
  - Respects inter-area transmission constraints
  - Neglects intra-area transmission constraints
  - Minimum amount of capacity in the NPCC areas
- Internal constraints handled in second phase
- Summer only approximation

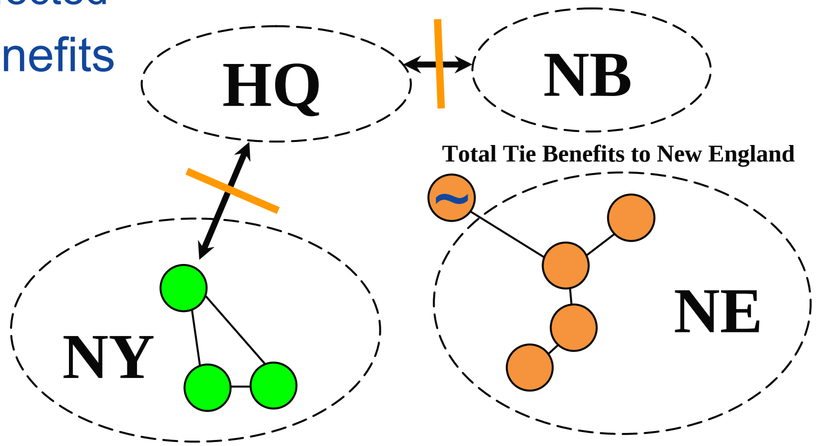
Area	Annual Interconnected	Summer Only Interconnected
_HQ_	0.100	0.000
_MT_	0.100	0.000
_NE_	0.100	0.100
NYPP	0.100	0.100
NPCC	0.340	0.162



Results of First Step for New England

- Using annual period
  - Cut all ties into New England
  - Add firm capacity equivalent back to New England to get total tie benefits
    - When 1,955 firm MWs added to New England
      - New England LOLE reverts to 0.1 day/year
      - All other control areas are unaffected
    - Base amount of "Natural" Tie Benefits
- New York is worse than 0.100

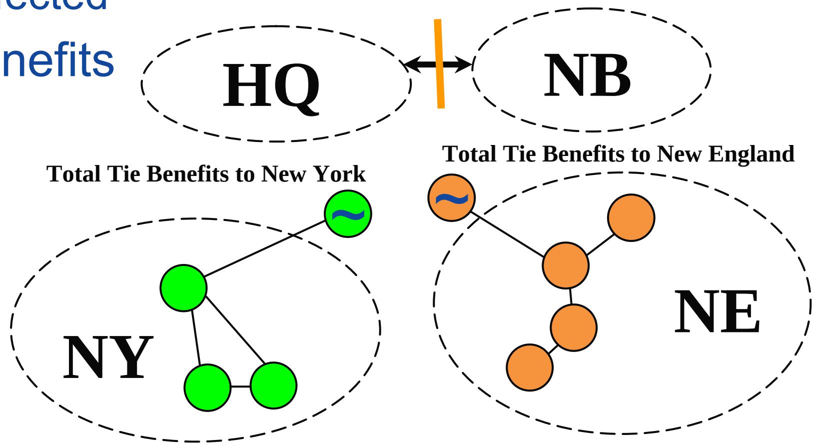
Area	Annual Interconnected	Annual Isolated with Zero MW of TB	Annual Isolated with 1955 MW of TB	Summer Only Isolated with 1955 MW of TB
_HQ_	0.100	0.439	0.439	0.000
_MT_	0.100	0.234	0.234	0.000
_NE_	0.100	2.087	0.100	0.100
NYPP	0.100	0.787	0.787	0.787
NPCC	0.340	3.077	1.403	0.848



Results of First Step for New York

- Using summer only period
  - Cut all ties into New York
  - Add firm capacity equivalent to New York to get total tie benefits
    - Existing 787 MW firm contract
    - When 1945 firm MWs added to New York
      - New York LOLE reverts to 0.100 day/year
      - All other control areas are unaffected
    - Base amount of “Natural” Tie Benefits

Area	Summer Only Isolated from New England	Summer Only Isolated	Summer Only Isolated with 1945 MW of TB into NY
_HQ_	0.000	0.000	0.000
_MT_	0.000	0.000	0.000
_NE_ at 1955	0.100	0.100	0.100
NYPP	0.787	1.981	0.100
NPCC	0.848	2.019	0.190



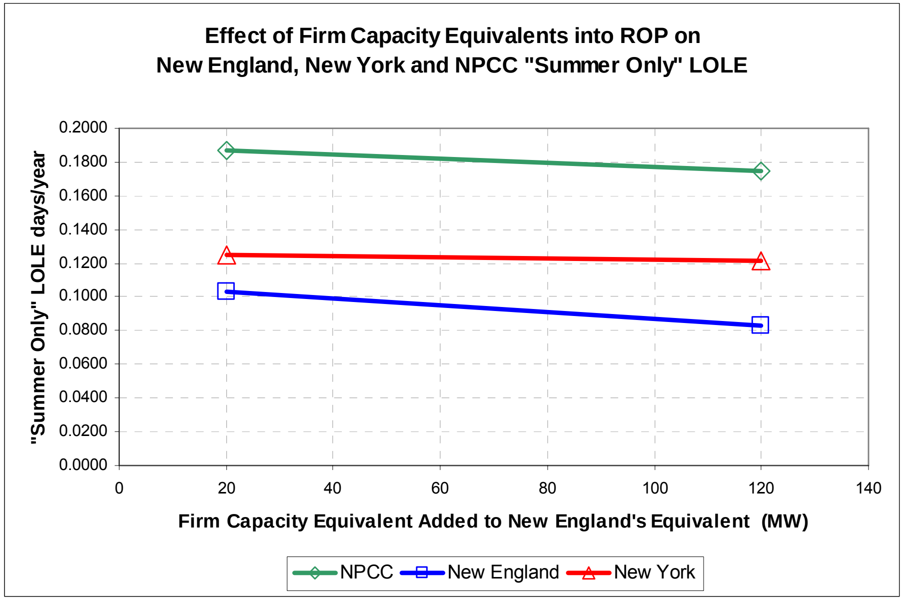
Modeling of Second Step

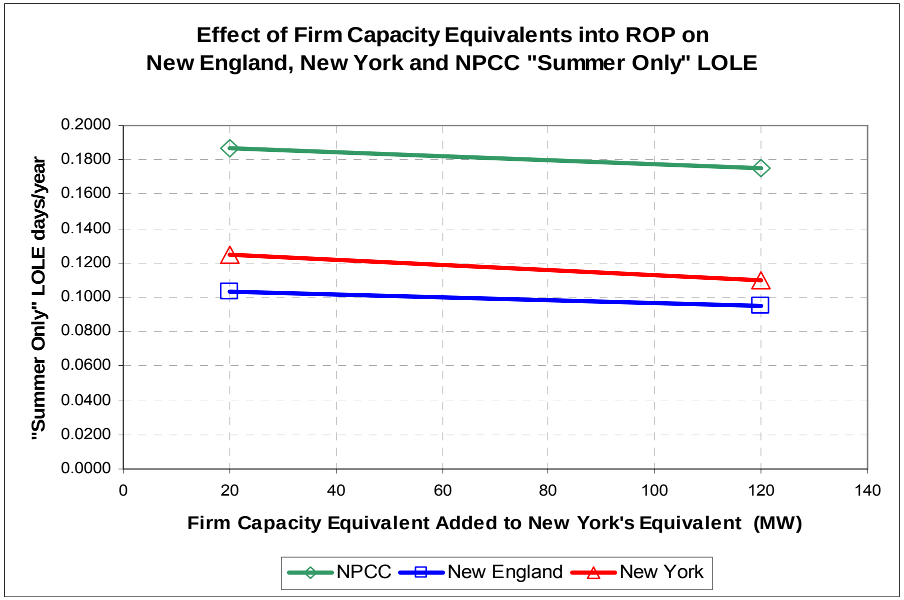
- Focus on the summer period only
  - Cut ties individually and add firm capacity equivalents at each tie
    - Quebec to New England
    - Quebec to New York
    - New Brunswick to New England
    - New York to New England
  - Each interconnection can have a firm capacity equivalent defined
    - Control area ownership of firm capacity equivalent affects LOLE
      - Reduces LOLE in each control area differently
      - Quantify two equivalents for each interconnection
        - One representing impact on New York
        - Another representing impact on New England
    - Unique solution for each interconnection may be possible
      - Return both areas back to their interconnected LOLE values
      - This is how MARS calculates LOLE

Effect of Firm Capacity Equivalent Owner

- To return the NPCC region back to interconnected
  - Control area assignment of firm capacity equivalent is important
  - If assigned to New England
    - Will be used to eliminate New England LOLE before released to assist New York

Note: Conceptual graph needs to be updated

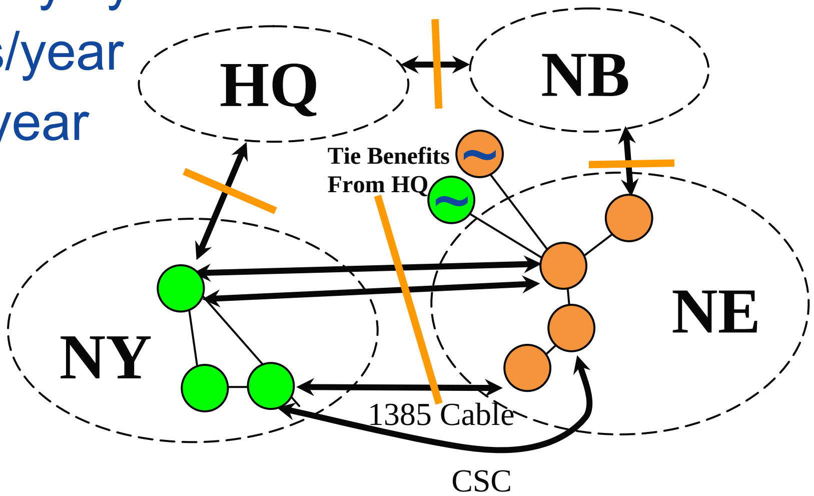




Results of Second Step (I)

- Cut ties for: Quebec to New England
  - Quantify firm equivalents for both New York and New England
  - To return NPCC "Summer Only" back to interconnected values*
    - Tie Benefits from Quebec to New England via Phase II: 475 MW
    - Tie Benefits from Quebec to New York via Phase II: 900 MW
- Return to interconnected control areas LOLE values
  - New England returned to 0.100 days/year
  - New York returned to 0.100 days/year
  - NPCC returned to ~ 0.162 days/year

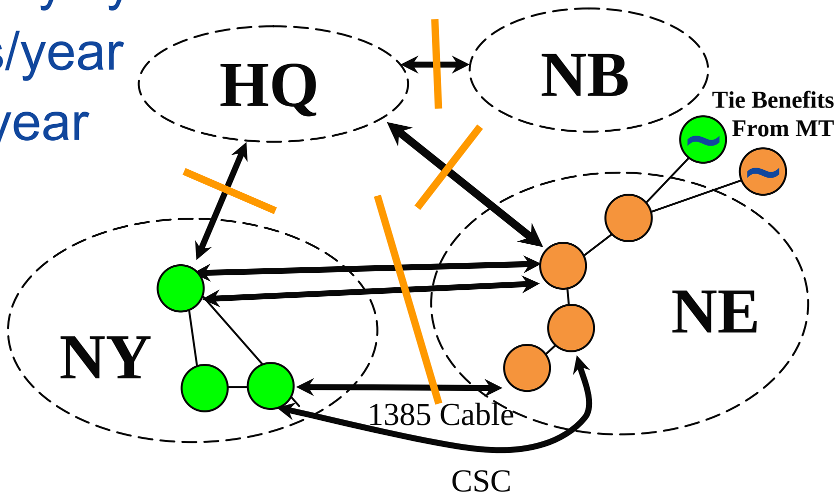
Area	Summer Interconnected	Summer Interconnected without Quebec	Summer Only NE_share: 475 NY_share: 900
_HQ_	0.000	0.000	0.000
_MT_	0.000	0.000	0.000
_NE_	0.100	0.402	0.098
NYPP	0.100	0.360	0.101
NPCC	0.162	0.464	0.161



Results of Second Step (II)

- Cut ties for: Maritimes to New England
  - Quantify firm equivalents for both New York and New England
  - To return NPCC "Summer Only" back to interconnected values
    - Tie Benefits from Maritimes to New England: 350 MW
    - Tie Benefits from Maritimes to New York: 325 MW
- Return to interconnected control areas LOLE values
  - New England returned to 0.101 days/year
  - New York returned to 0.103 days/year
  - NPCC returned to ~ 0.163 days/year

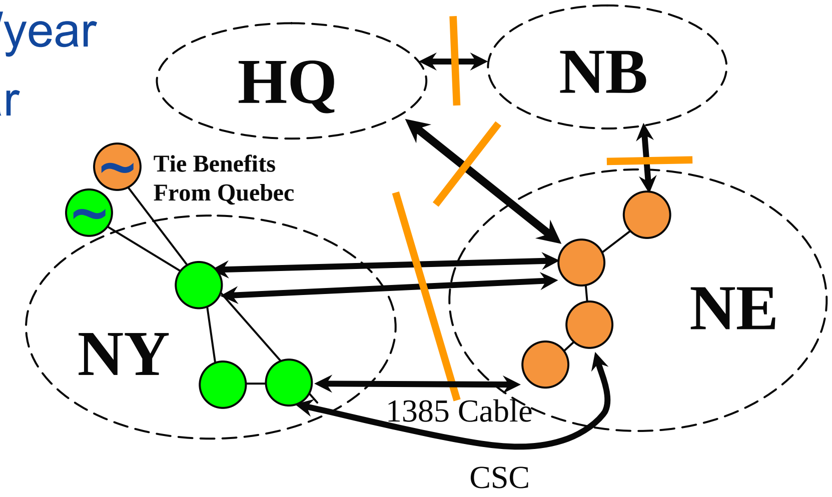
Area	Summer Interconnected	Summer Interconnected w/out Quebec	Summer Only NE_share: 375 NY_share: 300	Summer Only NE_share: 350 NY_share: 325
_HQ_	0.000	0.000	0.000	0.000
_MT_	0.000	0.000	0.000	0.000
_NE_	0.100	0.221	0.101	0.101
NYPP	0.100	0.142	0.104	0.103
NPCC	0.162	0.271	0.163	0.163



Results of Second Step (III)

- Cut ties for: Quebec to New York
  - Quantify firm equivalents for both New York and New England
  - Existing 787 MW capacity contract from Quebec to New York
  - To return NPCC "Summer Only" back to interconnected values
    - Tie Benefits from Quebec to New England via Chateauguay: 210 MW
    - Tie Benefits from Quebec to New York via Chateauguay: 510 MW
- Return to interconnected control areas LOLE values
  - New England returned to 0.100 days/year
  - New York returned to 0.100 days/year
  - NPCC returned to ~ 0.162 days/year

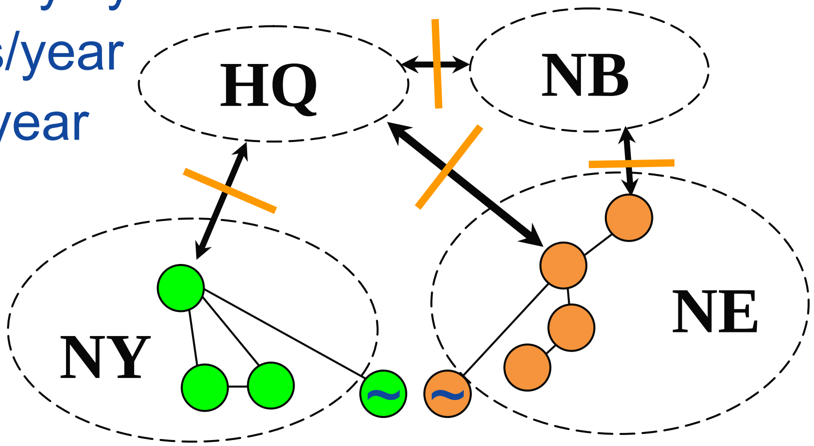
Area	Summer Interconnected	Summer Interconnected without Quebec	Summer Only NE_share: 300 NY_share: 800	Summer Only NE_share: 210 NY_share: 510
_HQ_	0.000	0.000	0.000	0.000
_MT_	0.000	0.000	0.000	0.000
_NE_	0.100	0.193	0.068	0.099
NYPP	0.100	0.349	0.047	0.098
NPCC	0.162	0.443	0.094	0.161



Results of Second Step (IV)

- Cut ties for: New York to New England
  - Quantify firm equivalents for both New York and New England
  - To return NPCC "Summer Only" back to interconnected values
    - Tie Benefits from New York to New England: -100 MW
    - Tie Benefits from New England to New York: 1200 MW
- Return to interconnected control areas LOLE values
  - New England returned to 0.100 days/year
  - New York returned to 0.100 days/year
  - NPCC returned to ~ 0.162 days/year

Area	Summer Interconnected	Summer Interconnected without NE/NY	Summer Only NE_TB: -100 NY_TB: 1200
_HQ_	0.000	0.000	0.000
_MT_	0.000	0.000	0.000
_NE_	0.100	0.086	0.101
NYPP	0.100	0.788	0.107
NPCC	0.162	0.830	0.198



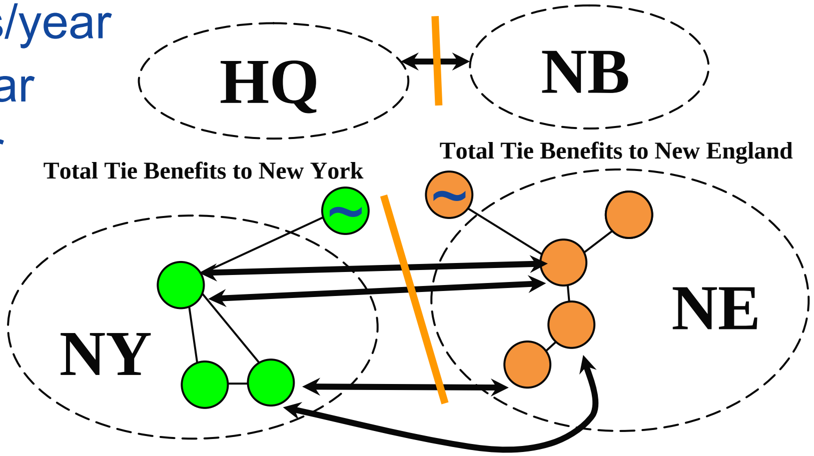
New York Tie Benefits From New England

New England Tie Benefits From New York

Results of Second Step (IV – Approach 2)

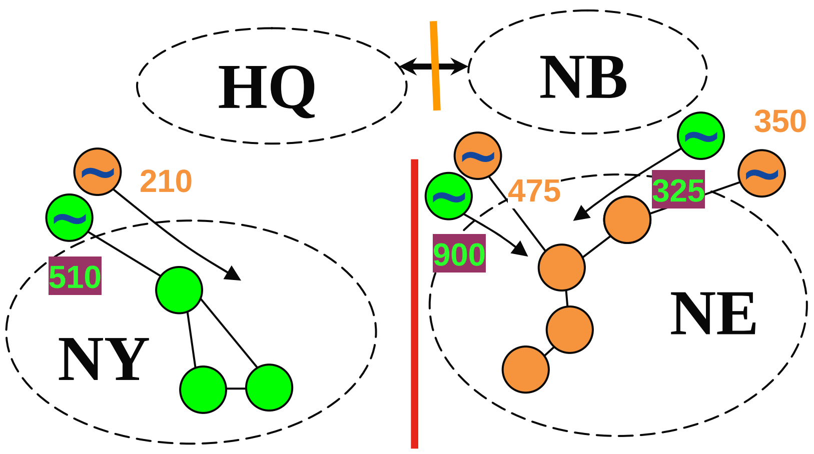
- Cut all ties and replace with total tie benefits into NE and NY
  - LOLE of New York and New England should be 0.100 days/year
  - Then interconnect New England to New York again and note improvement in LOLE
  - Return both areas to 0.100 day/year by adjusting total tie benefits
    - Tie Benefits to New England: 1955 MW – 1325 MW = 630 MW
    - Tie Benefits to New York: 1945 MW - 1250 MW = 695 MW
- Return to interconnected control areas LOLE values
  - New England returned to 0.100 days/year
  - New York returned to 0.100 days/year
  - NPCC returned to ~ 0.162 days/year

Area	Summer Isolated with Total TB NY 1945 MW NE 1955 MW	Summer Interconnected with Total Tie Benefits NE/NY	With Adjusted Tie Benefits NY_2_NE: 630 NE_2_NY 695
_HQ_	0.000	0.000	0.000
_MT_	0.000	0.000	0.000
_NE_	0.100	0.022	0.100
NYPP	0.100	0.021	0.099
NPCC	0.162	0.040	0.145



Net Support to Each Region Across Interface

- When looking at the interface between New York and New England, previous case showed
  - New York needed additional 1200 MW to get back to 0.100 d/y
  - New England could reduce 100 MW to get back to 0.100 d/y
    - Caused by each control area ‘capturing’ other’s tie benefits
    - Net adjustment needed to return MARS index follows logically



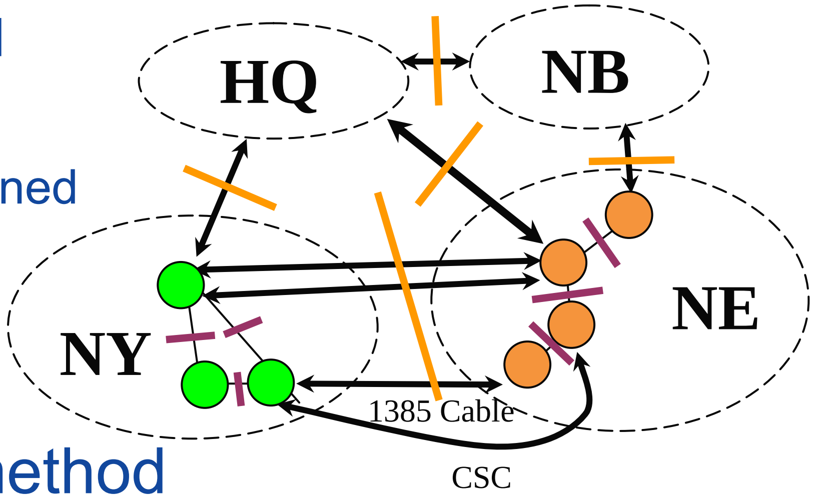
	Physical into New York	Physical into New England
From MT NE Share		350
From MT NY Share		325
From Phase II NE Share		475
From Phase II NY Share		900
From Chateuguay NE Share	210	
From Chateuguay NY Share	510	
Total	**720**	**2050**
Equivalent Tie Benefits	1945	1955
Difference	**1225**	**-95**
Results of Previous Case	**1200**	**-100**

<= See two slides earlier

Next Step: Tie Specific Tie Benefits

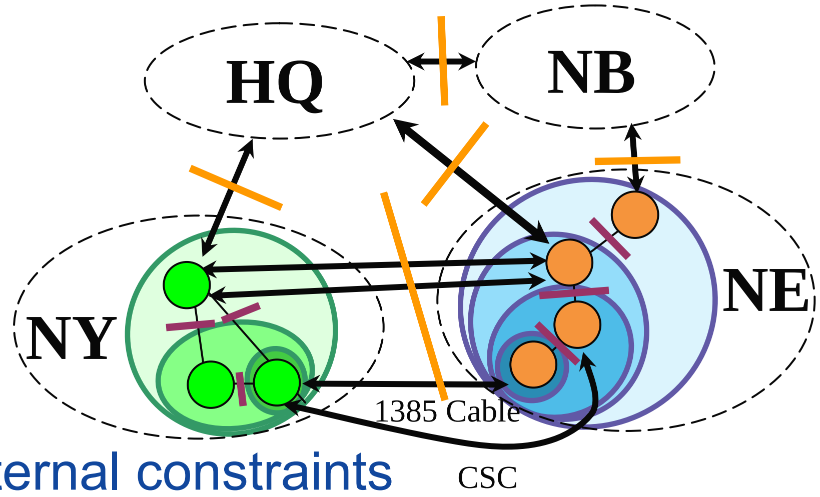
Include Internal Constraints

- Under all these conditions:
  - Minimum Capacity in NPCC
  - Each control area at 0.100 days/year LOLE
  - Internal transmission constraints
- Minimum locational capacity requirement must be defined
  - Each interface defines a locational need
  - Various way to satisfy each need
  - More capacity than minimum
    - Makes control area less constrained
    - Less ability to distinguish between interconnections
- Approach conceptually similar to Rau/Zeng winter capacity method



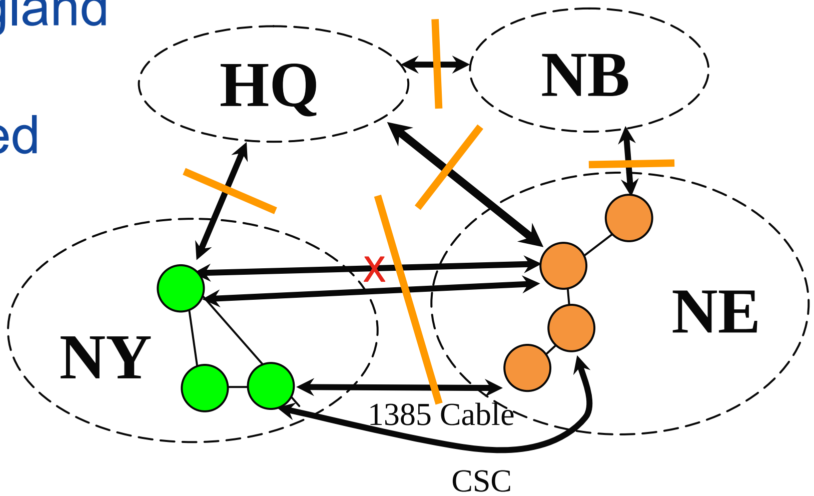
Minimum Local Sourcing Requirements

- To evaluate tie benefits, minimum capacity requirements must be satisfied on import side of each interface
  - Develop sub-area groupings that need to meet 0.100 days/year
    - Total New England, South of Maine New Hampshire,Total Connecticut, Southwest Connecticut
    - Total New York, Zones J and K and Zone K
  - Each import constrained zone
    - May have more resources
    - Cannot have fewer resources
      - At control area minimum
      - Surplus control area resource provides more flexibility
  - These set boundary conditions
  - Total tie benefits based on no internal constraints



Removing One Specific Interconnection

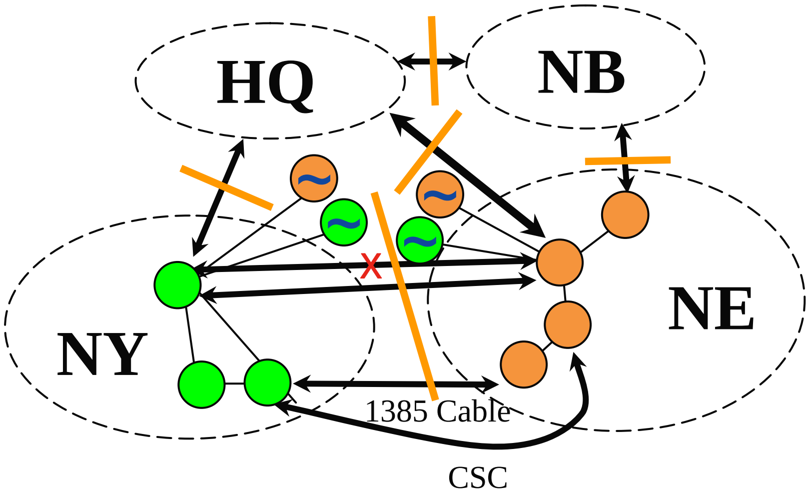
- Neglecting internal constraints
  - Removing one interconnection may have zero impact
    - Ability to re-route flows across other interconnections
    - No impact until aggregate transmission becomes binding
    - When interfaces become binding, it increases local sourcing requirement of the entire control area
  - Illustration below shows elimination of one interconnection between New York and New England
  - Results may be different when internal constraints are considered



Area	Summer Only Interconnected All Links	Summer Only Interconnected Minus One Link
_HQ_	0.000	0.000
_MT_	0.000	0.000
_NE_	0.100	0.100
NYPP	0.100	0.100
NPCC	0.162	0.162

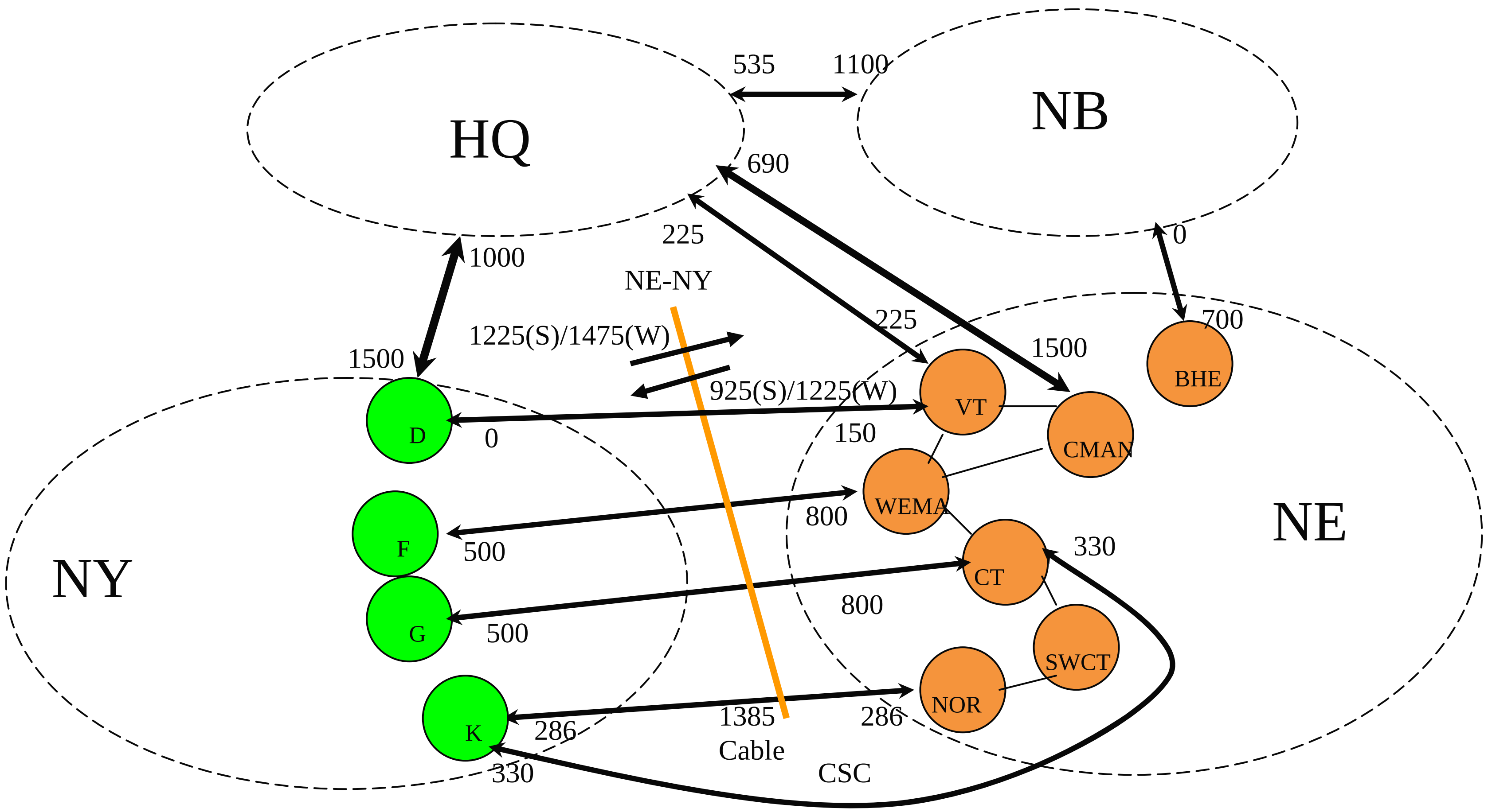
Theory Extension: Individual Tie Analysis

- Each interconnection may have multiple effects
  - Primary effect on control area level LOLE
  - Secondary effect on sub-area LOLE
  - Theory should allow for each interconnection to have
    - Different effect on each control area
    - Sub-areas may be affected differently requiring more “knobs-for-adjustment”
- Local sourcing requirements may have influence
  - Actual amounts
  - Theoretical minimum



Inter-Control Area Transmission Constraints

- 2005 NPCC CP-8 interface limits on ties and interfaces



Alternative Models and Evaluation Conditions For Internal Transmission Constraints

Adjustments For Internal Constraints

- Generalized process for minimum locational capacity
  - Implemented using dMW-mod table
- Remove capacity from sub-areas one area at a time
  - Quantify impact of generation $LOLE_G$ index
  - Quantify impact of transmission on $LOLE_T$ index
  - Without selected additions can get to global minimum capacity
- Remove capacity from groups of areas defined by interfaces
  - Each interface determines
    - Minimum limit of how much capacity must be located within an area
    - Minimum limit affected by $LOLE_T$ associated with transmission
  - "As-Is" vs. "At Criteria" affects maximum amount $LOLE_T$ allowed

Alternative Models and Evaluation Conditions

- Different ways to calculate minimum internal requirements
  - MARS Model using LICAP Protocol
    - Two area representation – import constrained area vs. outside area
      - One interface at a time
      - Allow pool LOLE (including import constrained area) to rise to 0.105 days/year LOLE
        - “As-Is” or
        - “As-Forecast” or “At-Criterion”
  - MARS model using all internal interfaces simultaneously
    - Each interface defines a minimum requirement (locational capacity)
    - Allows zero additional LOLE associated with transmission constraints
    - Sequentially nested areas on the cusp of binding transmission limits

$$0.0 \text{ days/year} < LOLE_T < \text{epsilon} \ll 0.1 \text{ days /year}$$

Effect of Internal Interfaces

- Interface constraints can be alleviated in three ways
  - Increase transfer capability
  - Increase amount of internal capacity
  - Decrease internal load
- Without internal constraints
  - Individual external ties are indistinguishable
    - Provided that total transfer limits don't change
    - If total transfer limits change, then effect will be seen on aggregate
- Addition or removal of ties would have an impact if total transfer between control areas increased or decreased

Tie-Specific “Tie Benefits”

Removing Ties Between Control Areas

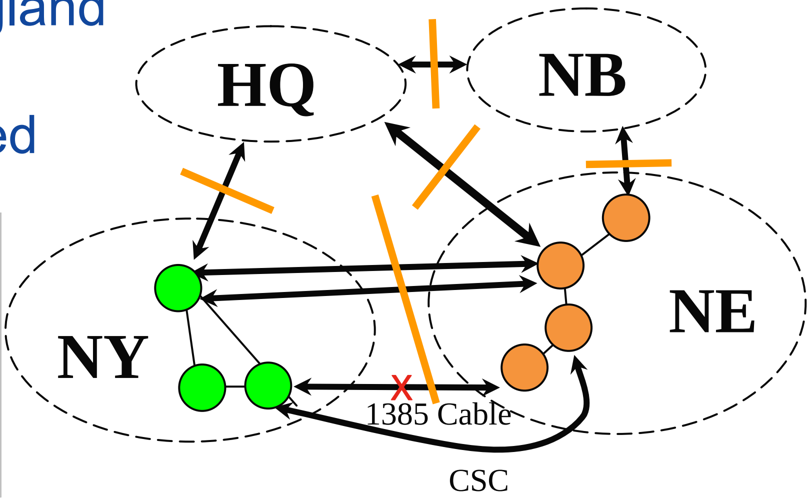
- Previous tie benefit analysis
  - Removed all interconnections between control areas
  - Developed equivalent firm capacity equivalents
  - Neglected internal control area
- Impact of removing some / derating ties
  - Transfer capability reduced, but not eliminated
  - Amount of tie benefit reduction depends on
    - Slope of tie benefit vs. transfer capability curve
    - Could be negligible if unused transfer capability exists
- Next slide shows effect of total tie derating without internal transmission constraints

Derating an Interface by Removing One Link

- Neglecting internal constraints
  - Removing one interconnection may have zero impact
    - Ability to re-route flows across other interconnections
    - No impact until aggregate transmission becomes binding
    - When interfaces become binding, it increases internal capacity requirement of the entire control area
  - Illustration below shows elimination of one interconnection between New York and New England
  - Results may be different when internal constraints are considered

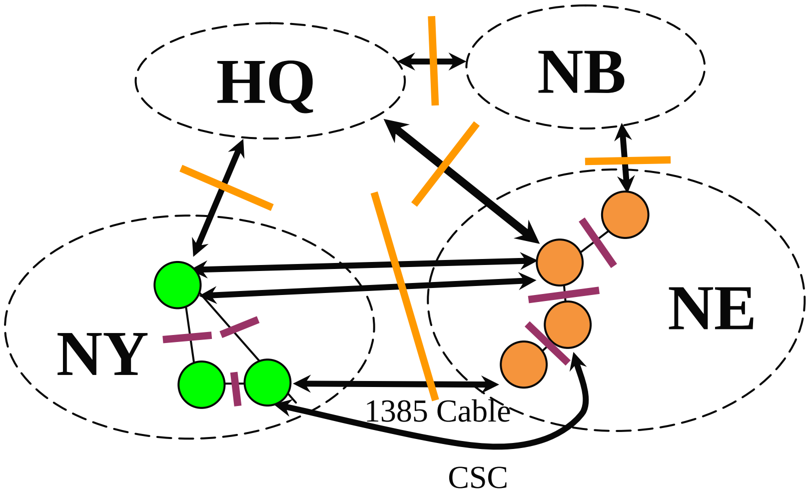
Area	Summer Only Interconnected All Links	Summer Only Interconnected Minus One Link
_HQ_	0.000	0.000
_MT_	0.000	0.000
_NE_	0.100	0.100
NYPP	0.100	0.100
NPCC	0.162	0.162

	Transfer to NE		Transfer to NY	
Link	All Ties	Without One Tie	All Ties	Without One Tie
PV-20	150	150	0	0
WEMA-D	500	500	800	800
CT-G	500	500	800	800
1385	286	0	286	0
Total	1436	1150	1886	1600
AC Limit	925	925	1225	1225
Net Limit	925	925	1225	1225



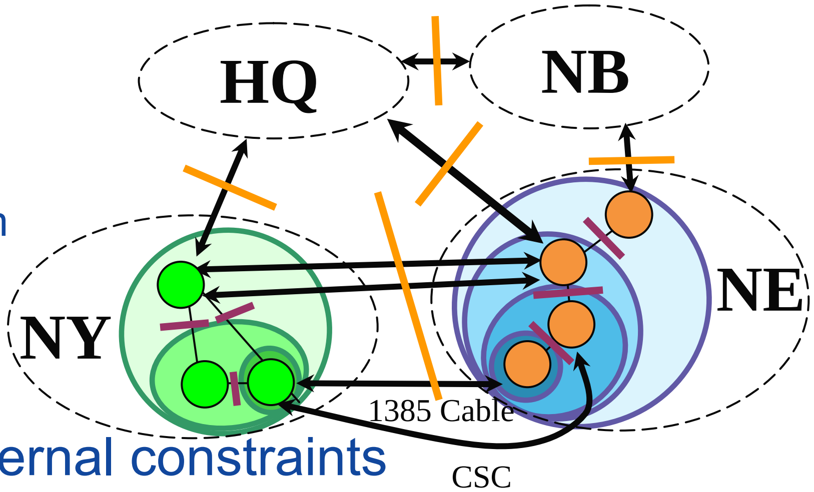
Begin Including Internal Constraints

- Respect these conditions:
  - Minimum capacity in NPCC
  - Each control area at 0.100 days/year LOLE
  - Maintain conditions after including internal transmission limits
- Minimum locational capacity requirement must be defined
  - Each interface defines a locational need
  - Various way to satisfy each need
    - Add more capacity to importing side of interface
    - Increase transfer capability
    - Interconnect to a neighboring control area



Minimum Local Sourcing Requirements

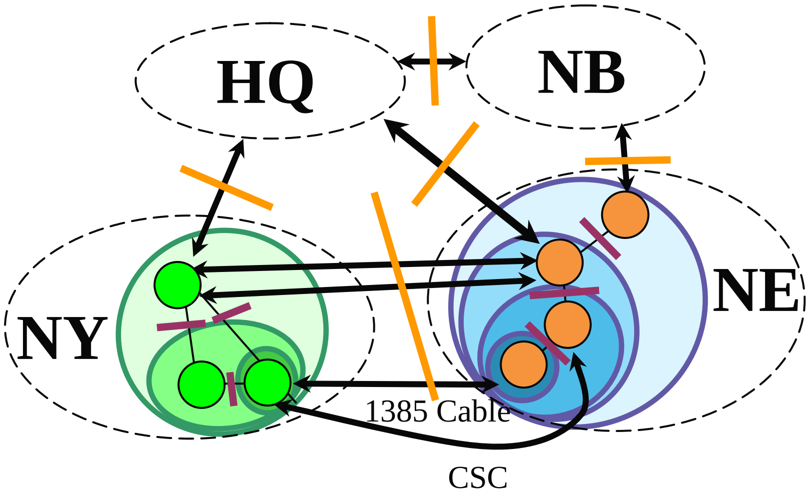
- To evaluate tie-specific tie-benefits, minimum capacity requirements must be satisfied on import side of each interface
  - Develop sub-area groupings that need to meet 0.100 days/year
    - Total New England, South of Maine / New Hampshire, Greater Connecticut, Southwest Connecticut
    - Total New York, Zones J and K and Zone K
  - Each import constrained zone
    - May have more resources
    - Cannot have fewer resources
      - Based on control area minimum
      - Surplus sub area resources provides more flexibility
  - These set boundary conditions
  - Total tie benefits based on no internal constraints



Anatomy of a Solution

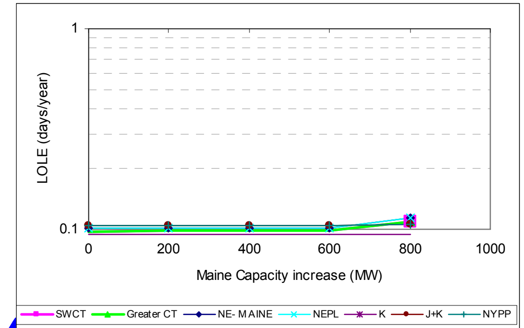
Calculation Process

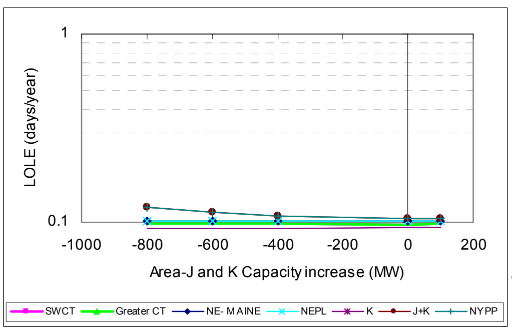
- Calculate MARS indices for each grouping shown below
- Calculate sensitivity of the LOLE in each area to capacity shifts in each area
  - E.g. develop Jacobean matrix of partial derivatives
  - More subtle than previous because of capacity “shift” not additions
    - In NY Shift out of J or K into ROS
    - In NE shift out of SWCT, CT, ME into ROP
  - Capacity shift need to be just enough to create rise in LOLE in import constrained area
  - Effect is internalized to target control area … no impact on external control areas

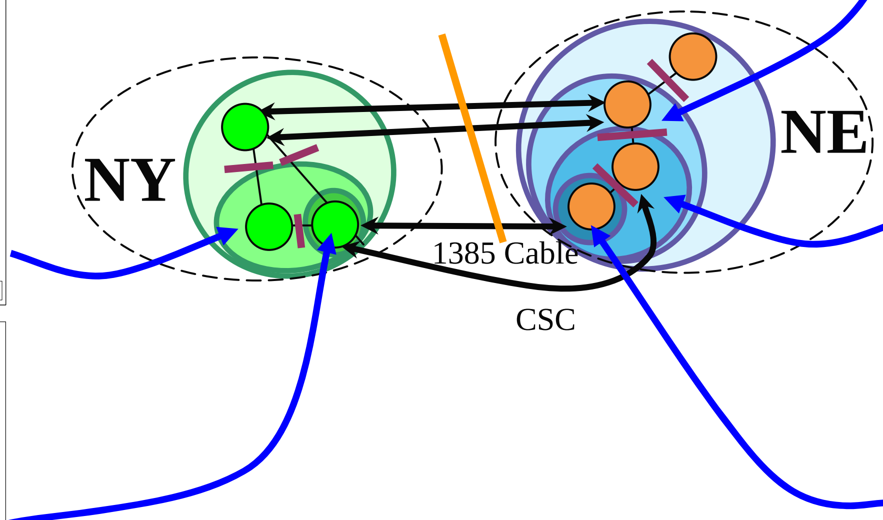


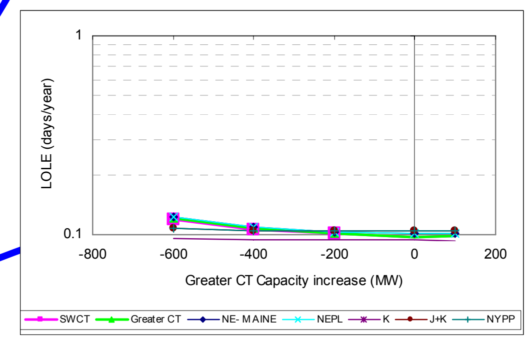
Anatomy of a Solution

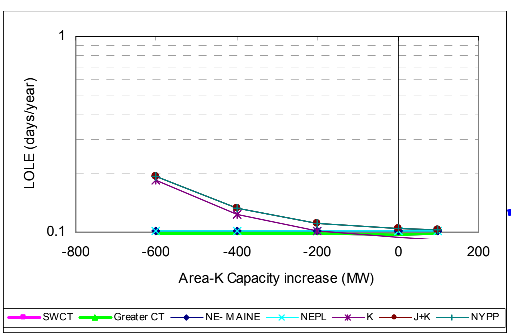
- Each area has sensitivity to capacity shifts
  - Sub areas nested within larger supersets
  - As import constraints bind, superset LOLE rises
  - Find point where curve begins to shows change

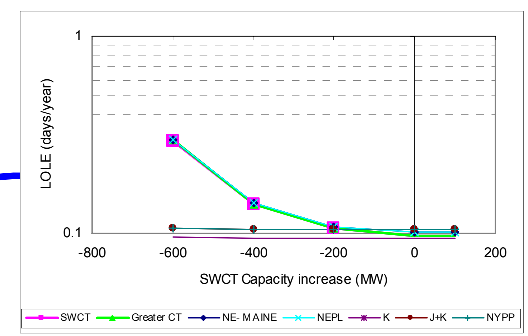










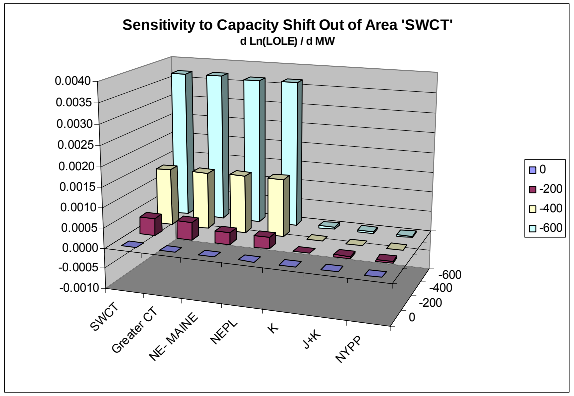


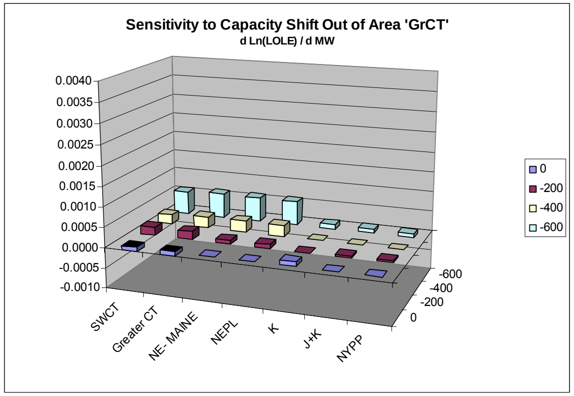
Effect of Nesting

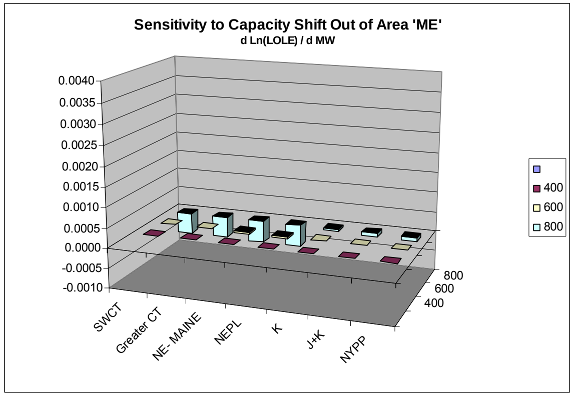
- Capacity is shifted out of import constrained areas into unconstrained ROP or ROS sub-areas
  - Due to nesting of sub areas within supersets and MARS index
    - An LOLE increase in one sub-area affects the LOLE of all supersets
    - Behavior similar to the RSP incremental curves
      - A one MW capacity shift from a small area has bigger LOLE impact
      - Than a one MW capacity shift from a large area
  - Dominant impact remains within originating control area
    - Negligible impact on adjacent control area
    - Eg. Capacity change in Area K affect SWCT LOLE negligibly
- Analyses assume all sub-areas are initially unconstrained
  - Minimum internal capacity requirements eliminate impact of transmission constraints in the base case

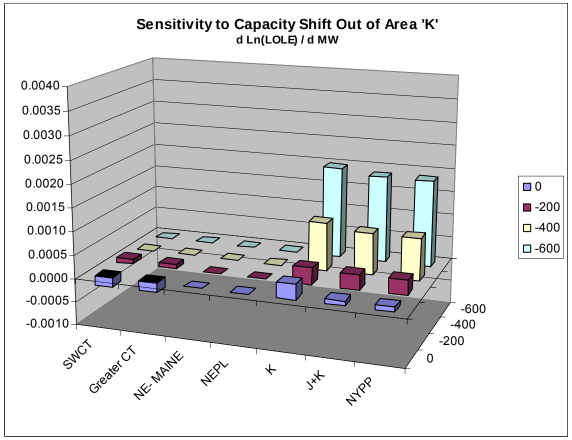
Effect of Capacity Shifts on Control Areas

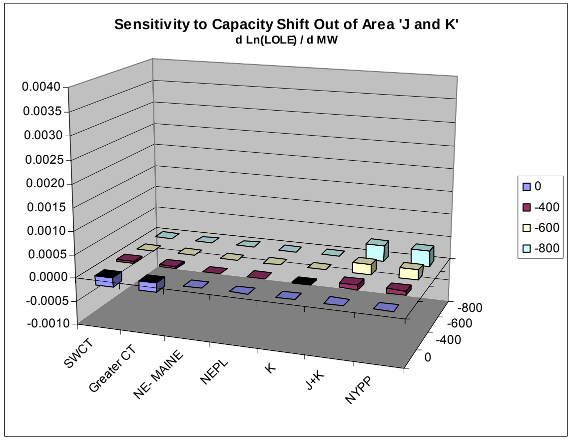
- Dominant impact of shift is within originating control area
  - New England capacity shifts only affect New England supersets
  - New York capacity shifts only affect New York supersets





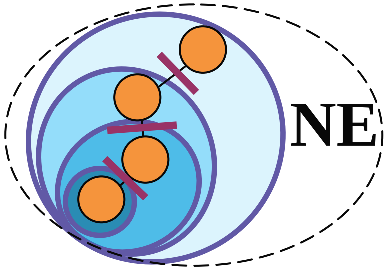




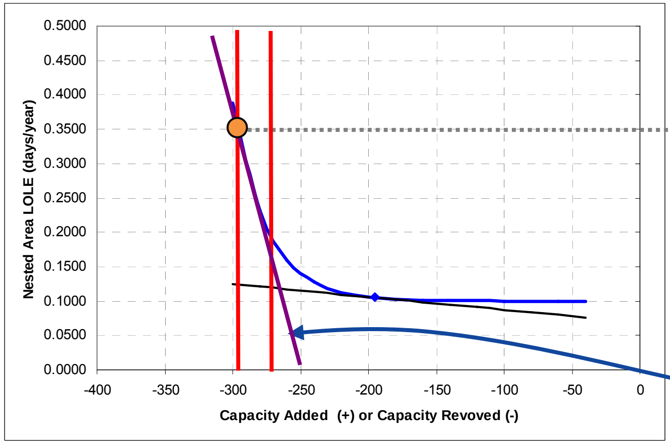


Anatomy of a Solution

- Assume SWCT is capacity deficient (High LOLE)
  - Large change in SWCT due to change in capacity
  - Nesting of sub areas means
    - LOLE for GrCT must be >= SWCT LOLE
    - But $\frac{\partial LOLE_{GrCT}}{\partial MW_{SWCT}} \ll \frac{\partial LOLE_{SWCT}}{\partial MW_{SWCT}}$
    - Therefore additions in SWCT more effective than GrCT

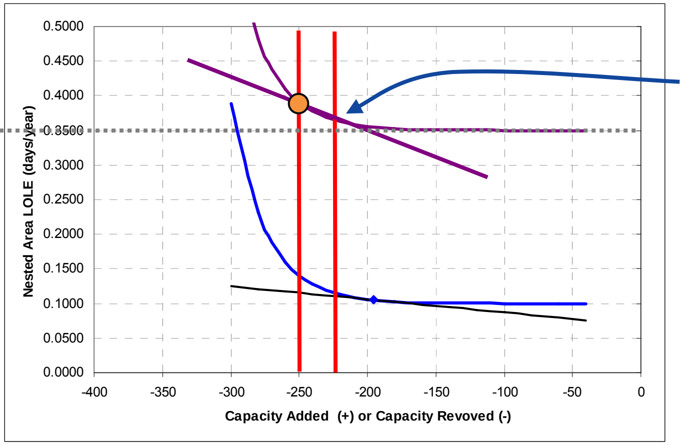


SWCT



$$\frac{\partial LOLE_{SWCT}}{\partial MW_{SWCT}}$$

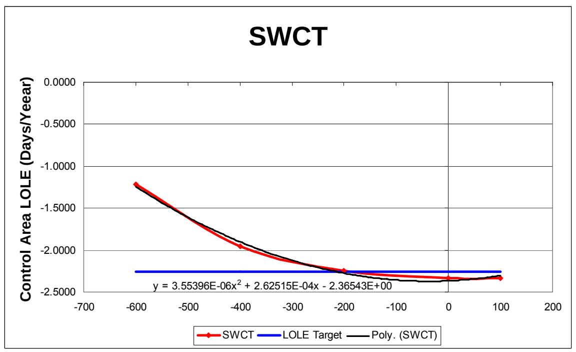
Greater CT

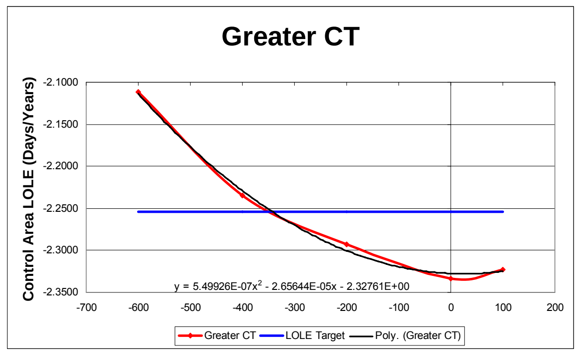


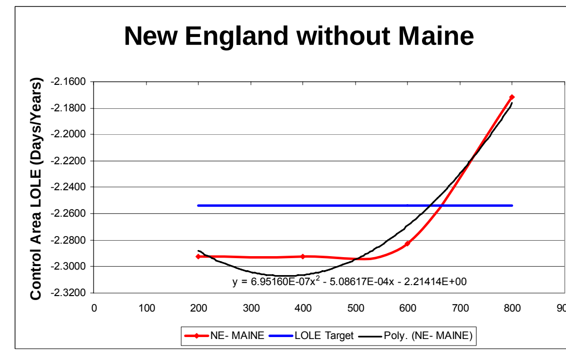
$$\frac{\partial LOLE_{GrCT}}{\partial MW_{SWCT}}$$

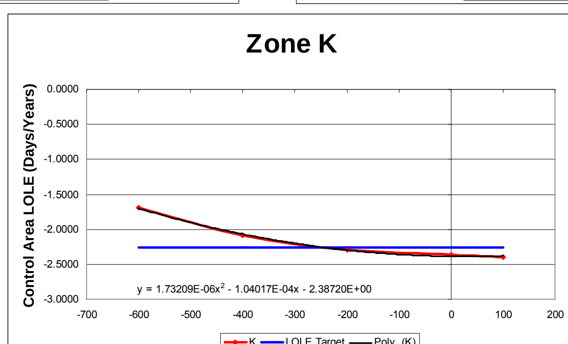
Sensitivities to Nested Area Capacity

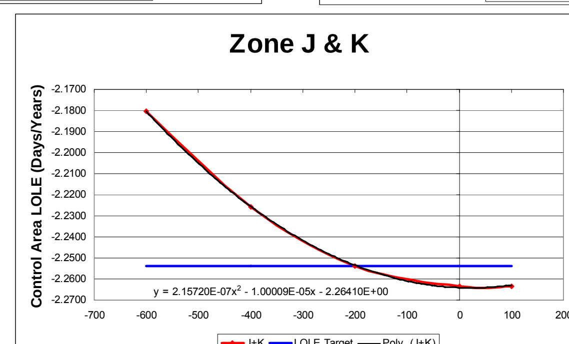
- Sensitivities of Ln(LOLE) to capacity additions by area
  - Second order polynomial approximation appears good
  - Allows estimation of values of capacity additions to meet 0.105 d/y
  - Each curve determines capacity changes within specific nested area











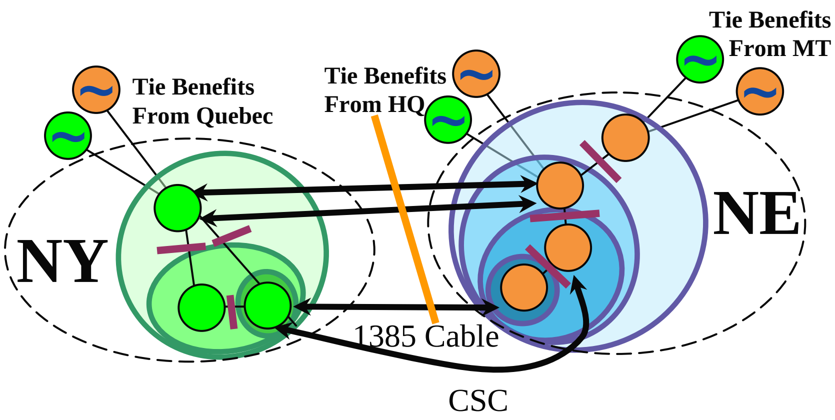
Estimating Minimum Internal Capacities

- Goal is to have: $0 < LOLE_T <= \text{epsilon}$
- Based on these nested superset curves
  - Amount of capacity needed to attain 0.105 days per year LOLE
    - Can be estimated analytically
    - New values can be tested and revised iteratively
    - Some convergence tolerance is needed
  - Effect of the 0.105 days per year LOLE target
    - $LOLE_T$ across each interface could be up to 0.005 d/y (epsilon)
    - $LOLE_T$ Compounds across each interface
      - Creates a control area LOLE that become higher that 0.100 d/y
      - For example, with three serial interfaces could be up to 0.115 d/y
- When acceptable solution is attained
  - Minimum capacity is in appropriate import constrained areas

Minimum Local Sourcing Requirements

- Need to determine minimum internal capacity requirements
  - Each nested area has minimum to satisfy the LOLE criterion
  - Virtually eliminate the $LOLE_T$ associated with transmission
  - Minimize capacity in Zone K and SWCT
  - Minimize capacity sequentially in supersets from these areas
- Minimum capacity increases need and maximizes benefits

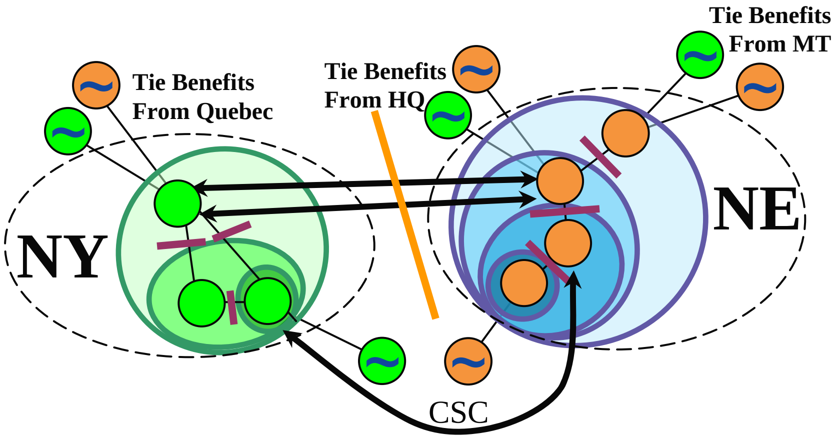
		LOLE of Grouping
New York		
	Total	0.1060
	Zones J & K	0.1020
	Zone K	0.1000
New England		
	Total	0.1020
	South of ME/NH	0.1010
	Connecticut Import	0.0990
	SWCT Import	0.0990



Effect of Removing 1385 Line

- Removal of a critical interconnection
  - Eliminates paths for capacity support into import constrained areas
  - All interfaces are on the verge of binding
    - Removal of link increases $LOLE_T$ into an import constrained sub-area
    - Shallow slope portion of the $LOLE_T$ import curve for alternative links
  - New England captures a portion of the NB and HQ tie benefits allocated to New York

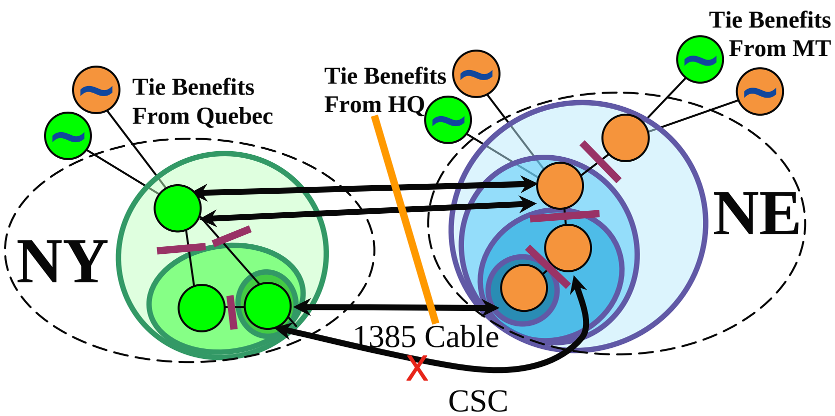
Effect of replacing 1385 with Firm Capacity Equivalent Tie Benefits					
		Base Case	Without 1385	Tie Benefits	After Tie Benefits
New York					
	Total	0.1060	0.1180	40	0.1060
	Zones J & K	0.1020	0.1130	0	0.1020
	Zone K	0.1000	0.1110	40	0.0990
New England					
	Total	0.1030	0.1020	-40	0.1030
	South of ME/NH	0.1010	0.1010	0	0.1020
	Connecticut Import	0.0990	0.0990	0	0.1000
	SWCT Import	0.0990	0.0990	-40	0.1000



Effect of Removing Cross Sound Cable

- Removal of Cross Sound Cable
  - Eliminates one path from New England to New York
  - Reduced total NE/NY transfer capability by 330 MW
  - Reduces NY share of available tie benefits from NB and HQ

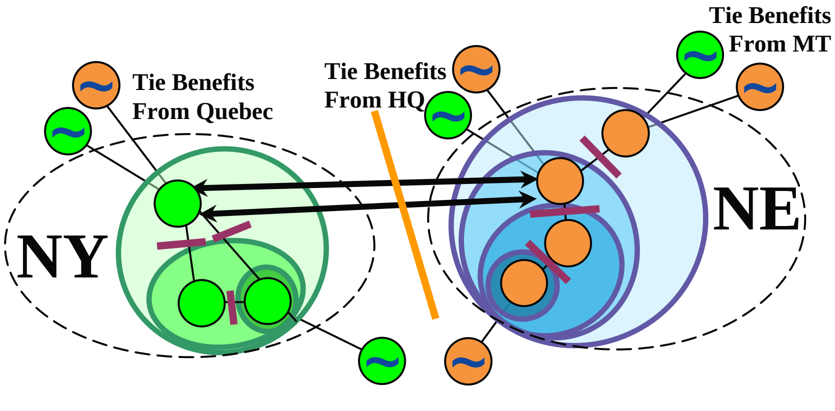
Effect of replacing CSC with Firm Capacity Equivalent Tie Benefits					
		Base Case	Without CSC	Tie Benefits	After Tie Benefits
New York					
	Total	0.1060	0.2260	330	0.1070
	Zones J & K	0.1020	0.2180	0	0.0990
	Zone K	0.1000	0.2160	330	0.0960
New England					
	Total	0.1030	0.0940	-200	0.1010
	South of ME/NH	0.1010	0.0940	0	0.1010
	Connecticut Import	0.0990	0.0910	0	0.0980
	SWCT Import	0.0990	0.0900	-200	0.0970



Effect of Removing Both 1385 and CSC

- Effect is approximately the sum of both previous results

Effect of replacing 1385/CSC with Firm Capacity Equivalent Tie Benefits					
		Base Case	Without Either	Tie Benefits	After Tie Benefits
New York					
	Total	0.1060	0.2830	370	0.1030
	Zones J & K	0.1020	0.2750	0	0.0970
	Zone K	0.1000	0.2730	370	0.0930
New England					
	Total	0.1030	0.0930	-240	0.1040
	South of ME/NH	0.1010	0.0930	0	0.1040
	Connecticut Import	0.0990	0.0900	0	0.1010
	SWCT Import	0.0990	0.0900	-240	0.1000

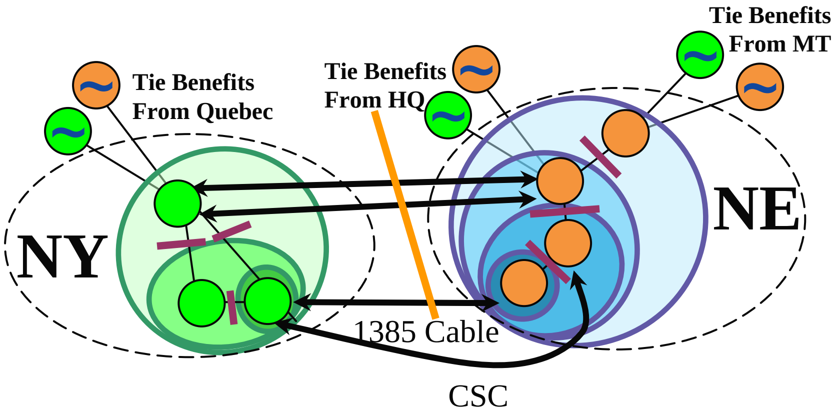


Sensitivity Case

Sensitivity Case – Effect of Load Shifting

- Effect of placing Zone K on the cusp of transmission import limits while interconnected will maximize tie benefits from Greater Connecticut
  - Shift 240 MW from Zone K to ROS and Zone K LOLE will increase
  - Increasing import capability into Greater Connecticut has no effect
  - Increasing CSC capability decreases LOLE in Zone K and all NY

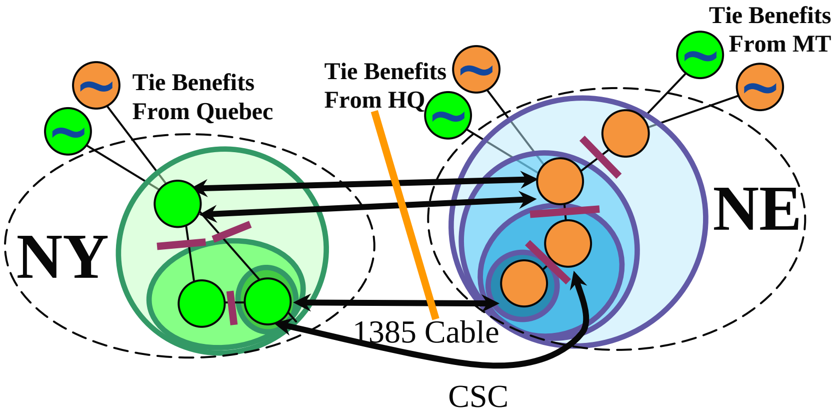
Sensitivity cases associated with load shifting from Zone K to ROS					
		Base Case	Shift 240 MW to ROS	Then Increase CT Import 300 MW	Then increase CSC by 330 MW
New York					
	Total	0.106	0.129	0.128	0.065
	Zones J & K	0.102	0.126	0.126	0.063
	Zone K	0.100	0.124	0.124	0.062
New England					
	Total	0.103	0.102	0.101	0.107
	South of ME/NH	0.101	0.101	0.100	0.106
	Connecticut Import	0.099	0.099	0.098	0.105
	SWCT Import	0.099	0.099	0.098	0.105



Sensitivity Case – HQ Equivalents

- Issue of Phase II allocation under review
  - Previously allocation of 475 MW NE / 900 MW NY was questioned*
    - Ownership has distinct trend but low sensitivity to $LOLE_{NE}$ vs. $LOLE_{NY}$
  - Several hypothesized reasons
    - New England / New York interface was a possible impediment
    - MARS's "passing through a deficient area" logic
    - Priority table for inter-control area assistance

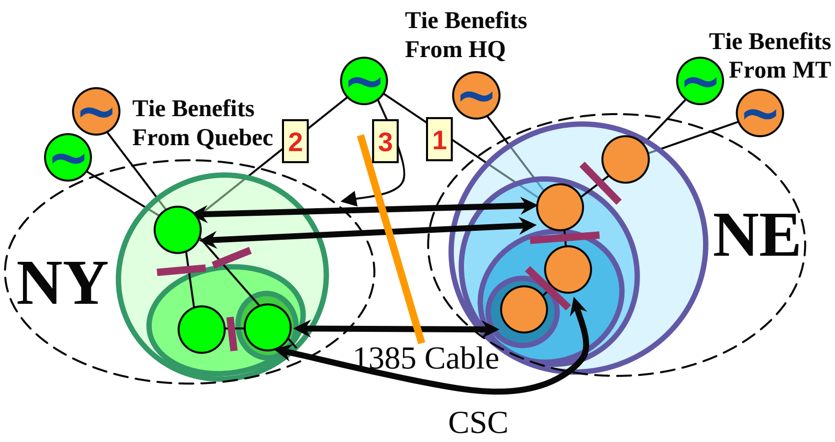
Sensitivity cases associated with HQ representation					
		Base Case	HQ Without Phase I/II	NE 480 / NY 950	NE 900 / NY 475
New York					
	Total	0.106	0.264	0.100	0.101
	Zones J & K	0.102	0.242	na	na
	Zone K	0.100	0.236	na	na
New England					
	Total	0.103	0.404	0.100	0.098
	South of ME/NH	0.101	0.403	na	na
	Connecticut Import	0.099	0.393	na	na
	SWCT Import	0.099	0.393	na	na



Sensitivity Case – Effect of NE / NY Interface

- Sensitivity Cases
  - New York share of Phase I/II connected directly to ROS
    - Increases NE/NY by 900 … avoids "pass through deficient area" logic
    - LOLE $_{NY}$ improves greatly while LOLE$_{NE}$ degrades slightly
      - Reinforces previous observation that NE/NY interface is constraining
      - NE/NY interface locks-in HQ benefits to NE and is a barrier to NY
  - Increasing NE/NY interface by 900 MW is similar
    - Effect of "pass through deficient area" logic can be seen

Sensitivity cases associated with HQ				Case 1	Case 2	Case 3
		Base Case	HQ Without Phase I/II	NE 455 / NY 900	NE 455 w/ Direct NY 900	NE 455 / NY 900 1825 MW Interface
New York						
	Total	0.106	0.264	0.107	0.058	0.081
	Zones J & K	0.102	0.242	0.102	0.055	0.078
	Zone K	0.100	0.236	0.100	0.053	0.077
New England						
	Total	0.103	0.404	0.103	0.111	0.105
	South of ME/NH	0.101	0.403	0.102	0.110	0.105
	Connecticut Import	0.099	0.393	0.100	0.108	0.103
	SWCT Import	0.099	0.393	0.100	0.108	0.103



Verification of Key Observations: Simplified Model vs. MARS

Many Factors Can Influence Tie Benefits

- There are a number of factor that can influence tie benefits
  - Some have a small influence
  - Some have a large influence
- This fundamental review of tie benefits includes understanding these effects
  - Preference
  - Effect of OP-4
  - Transfer Limits

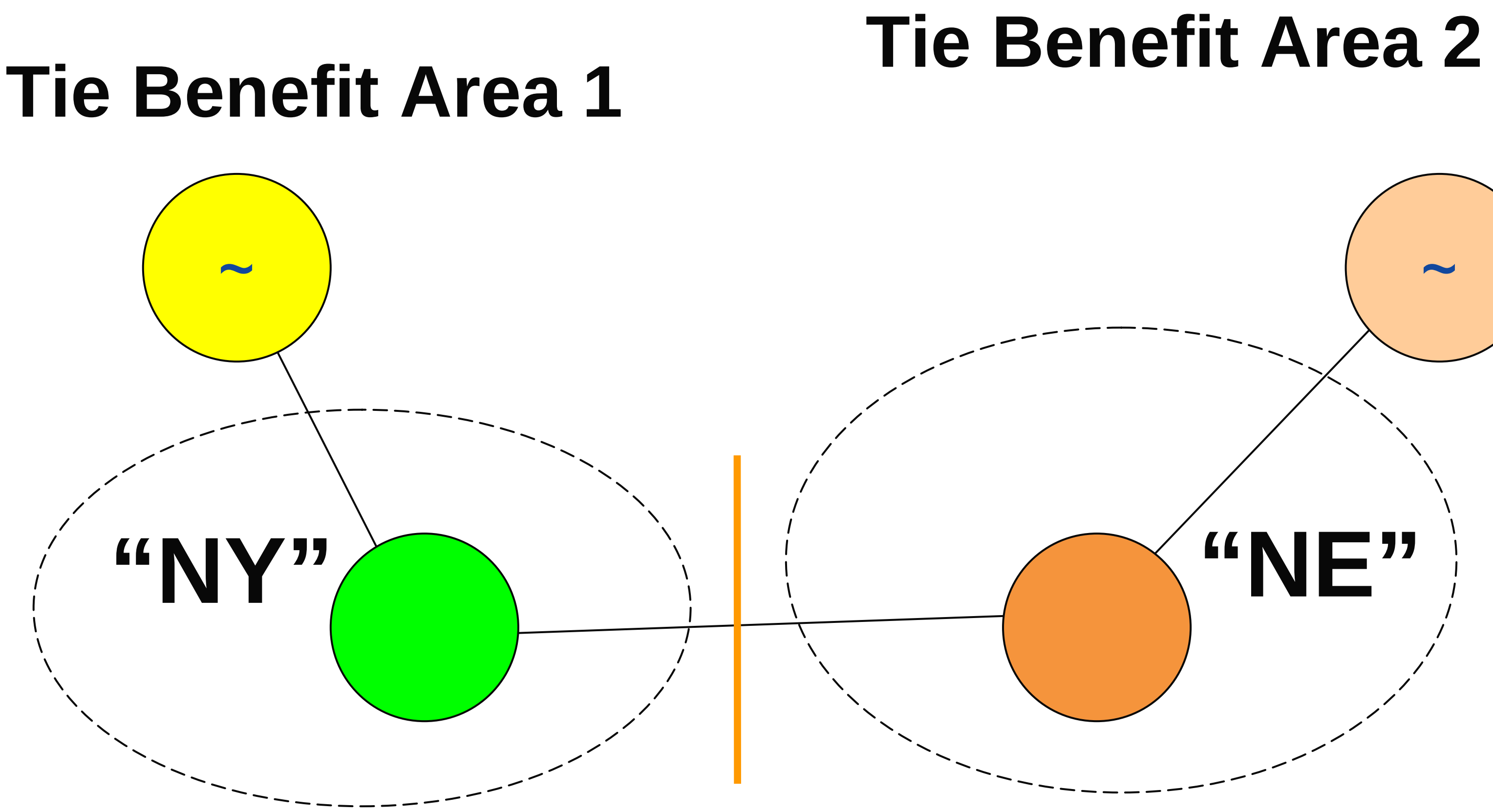
MARS is a Sophisticated Simulation Tool

- Sophistication integrates the effect of many competing concepts
  - Highly sophisticated models may become “black boxes”
  - Cause and effect are not transparent
  - Results may appear counterintuitive
- A simplified model may be useful
  - To illustrate and explore concepts
  - To validate results using hypothetical data
- Capacity outage distribution representation
  - Mean capacity available in each area
  - Assumed standard deviation
  - External area tie benefits are assumed firm capacity equivalent

Simplified Spreadsheet Model for Illustration

- Four area model
  - Two provide only a firm capacity equiavalent (eg. HQ and NB)
  - Two have
    - Adjustable amount of capacity to bring LOLP to criterion
    - OP-4 resources to be shared or to be used exclusively by the owner
    - Variable amount of interconnection capability between then
    - Resemble NE and NY unconstrained systems
    - Assume normal capacity outage distribution
- Monte Carlo based
  - 5000 replications
  - One peak load point
  - LOLP used as Index
  - LOLP calculated in various ways

Framework For Simplified Model



Evaluate Preference

- Preference is the ability of one area to “grab” third-party tie benefits first to:
  - Resolve their capacity deficiency first
  - If any tie benefits remain, they can assist the second area
  - Tie benefits may be limited by transmission constraints
  - Amount of preference can be changed

Simplified Model - Process

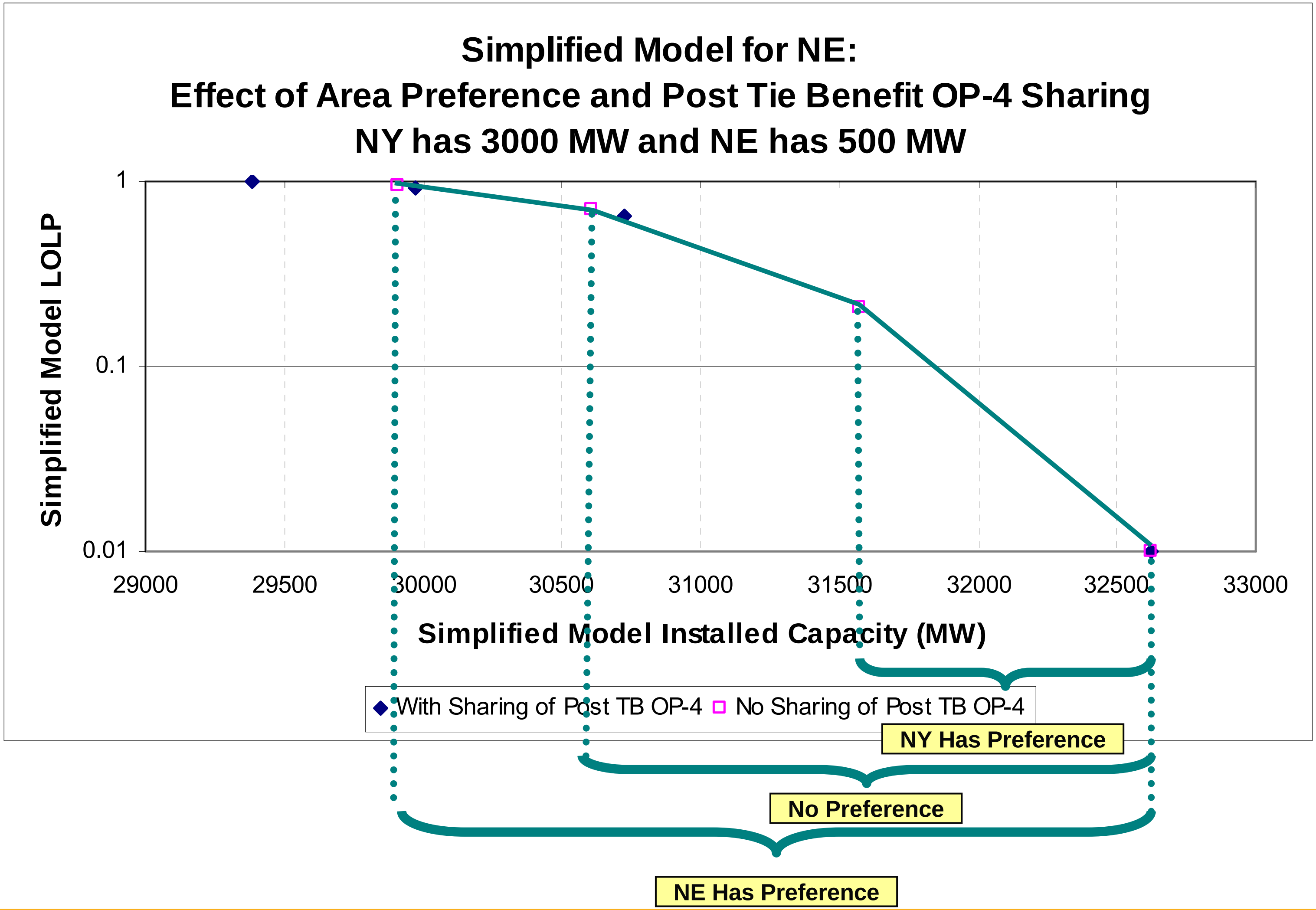
- Random draws on capacity (NE and NY independently)
- Calculate “raw” capacity NE-NY surplus / deficiency state
- Resolve as much of deficiency as possible within NE-NY
- If TB preference is allowed, the preferred area gets as many tie benefits as it can from “other area”
- Then all remaining unused TB can be used by host area
- Then remaining tie benefits can be used anywhere needed
- Then post-TB OP4 used to resolve remaining deficiency
- Then sharing maximum post-TB OP4 to resolve remaining deficiency
- Calculate indices

Simplified Model – Effect of Preference With / without Sharing of Post TB OP-4

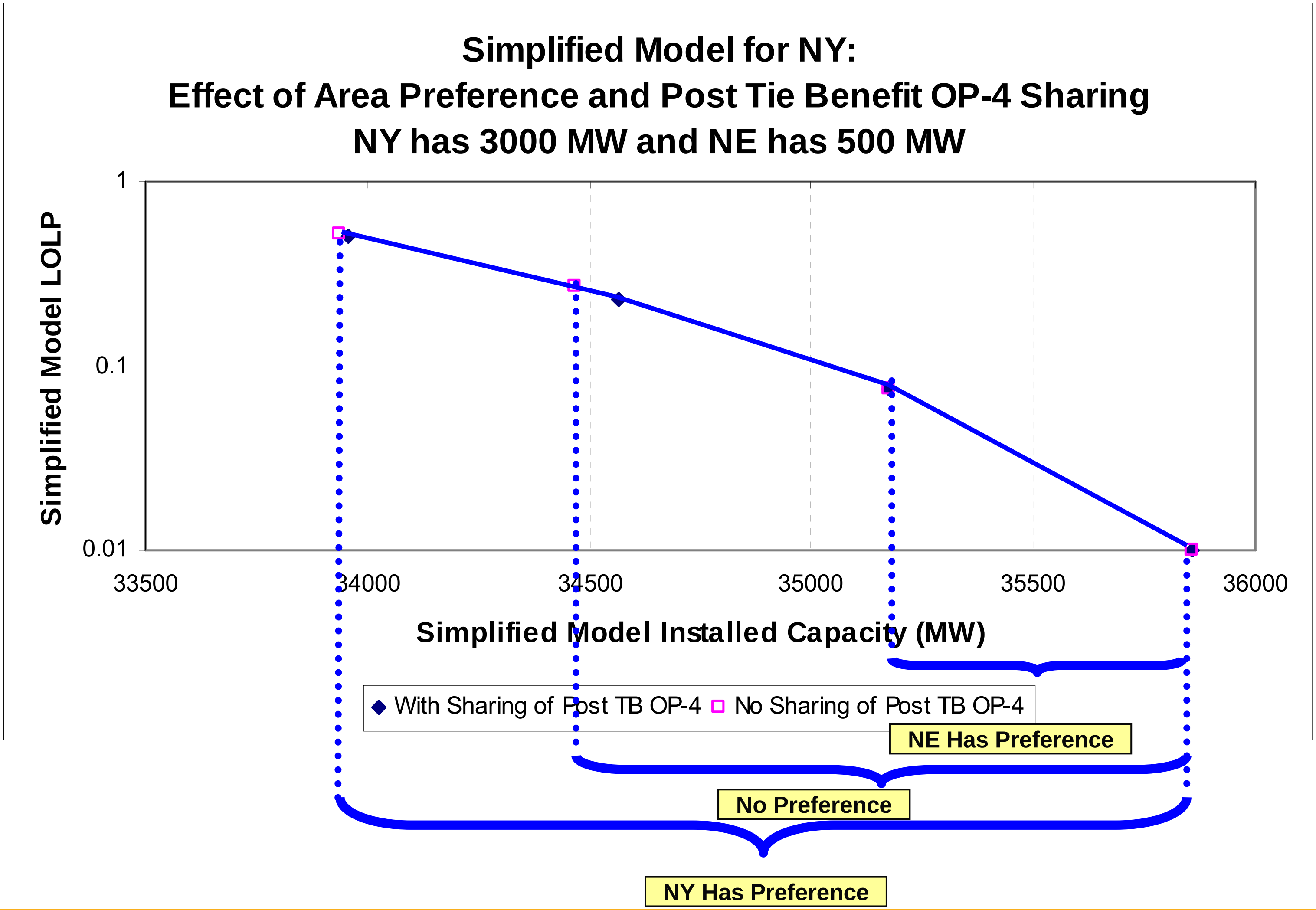
Simplified Model - Analysis

- Preference matters
  - Results show that preference can significantly affect tie benefits
  - Preference affects both New England and New York
- Sharing of OP-4 results
  - Assume NE had 500 MW of post-TB OP-4 that could be used to augment tie benefits to New York
  - Assume NY had 3000 MW of post-TB OP-4 that could be used to augment tie benefits from New England

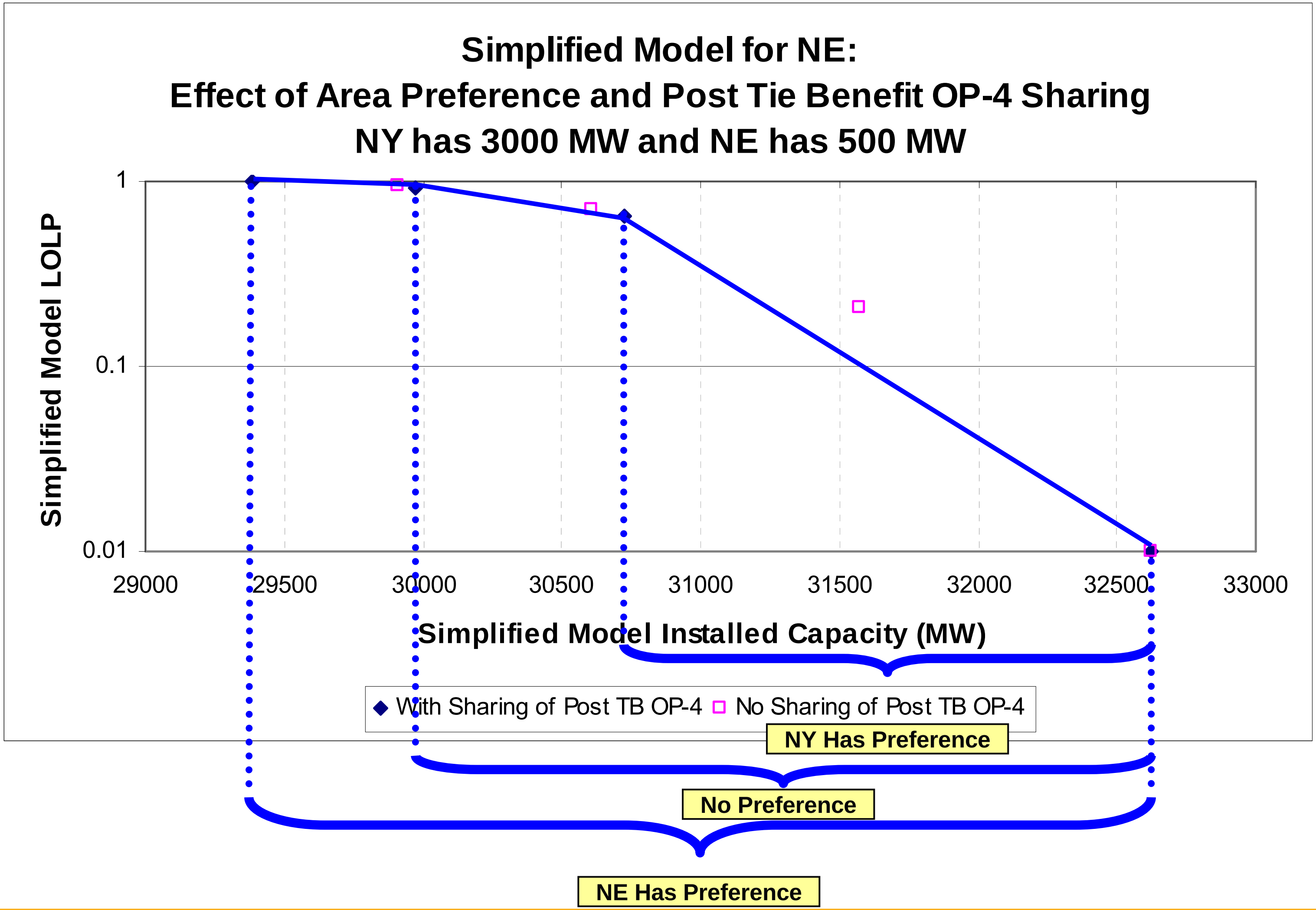
With Preference / Sharing OP4



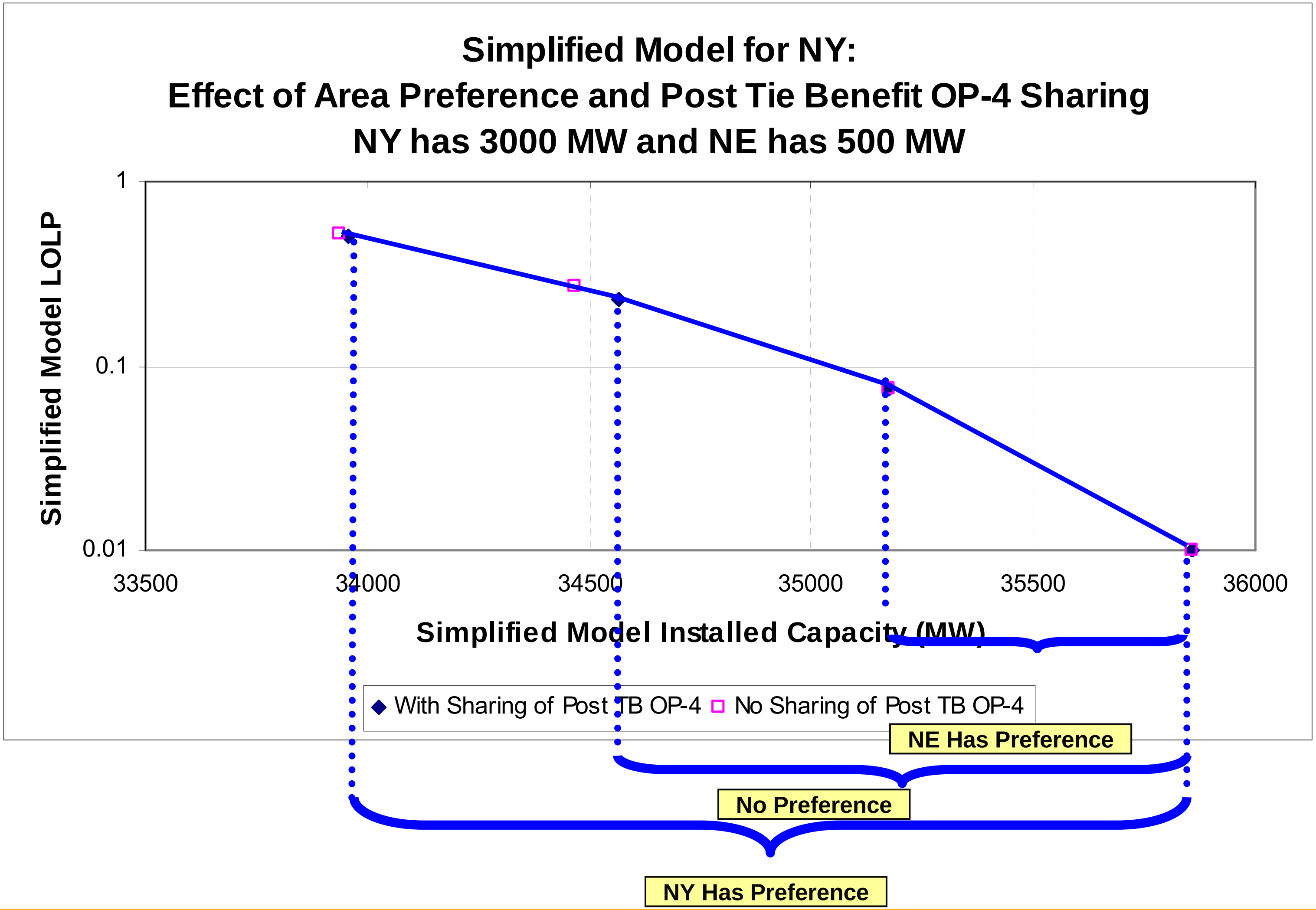
With Preference / Sharing OP4



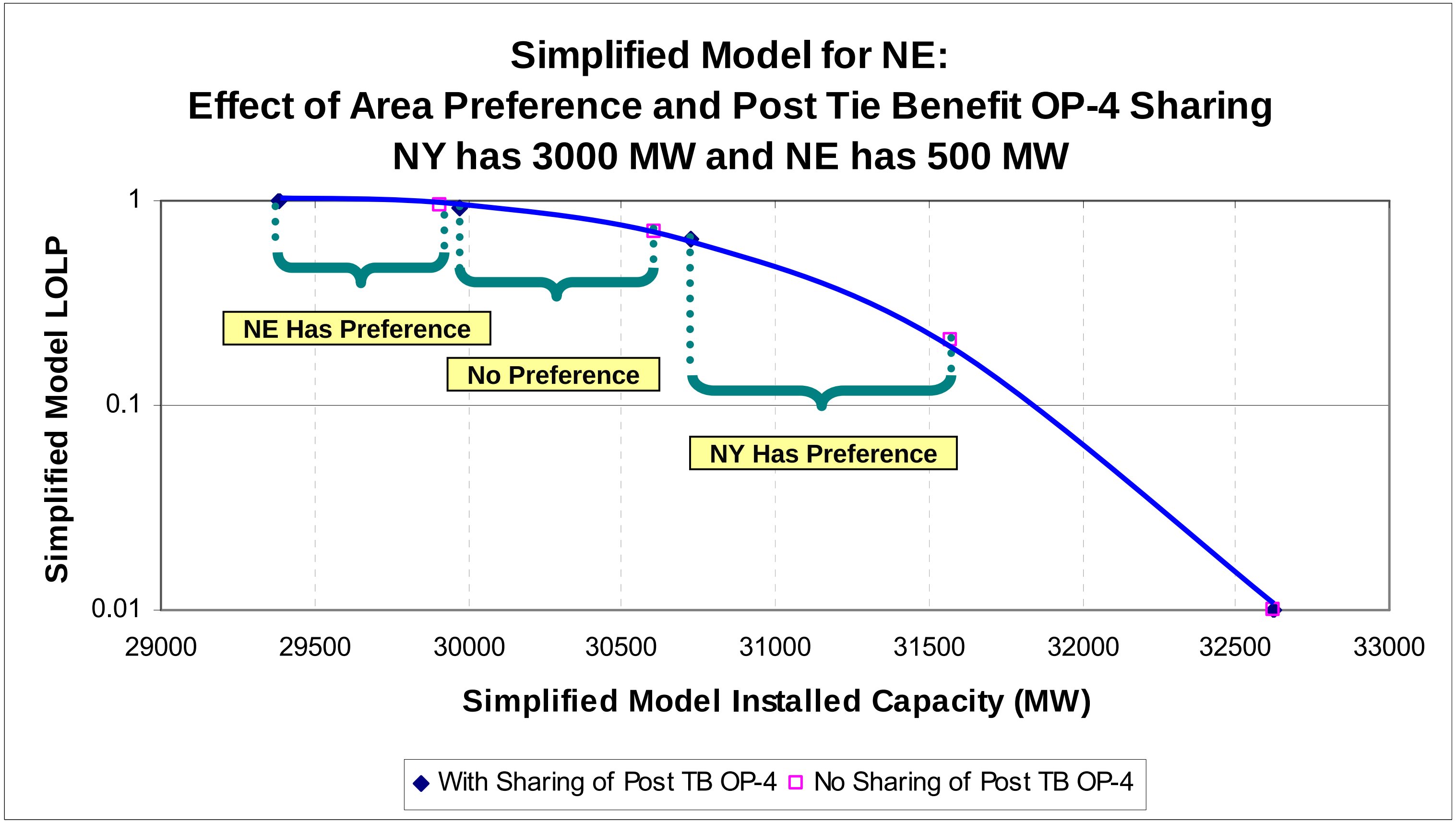
With Preference / No OP4 Sharing



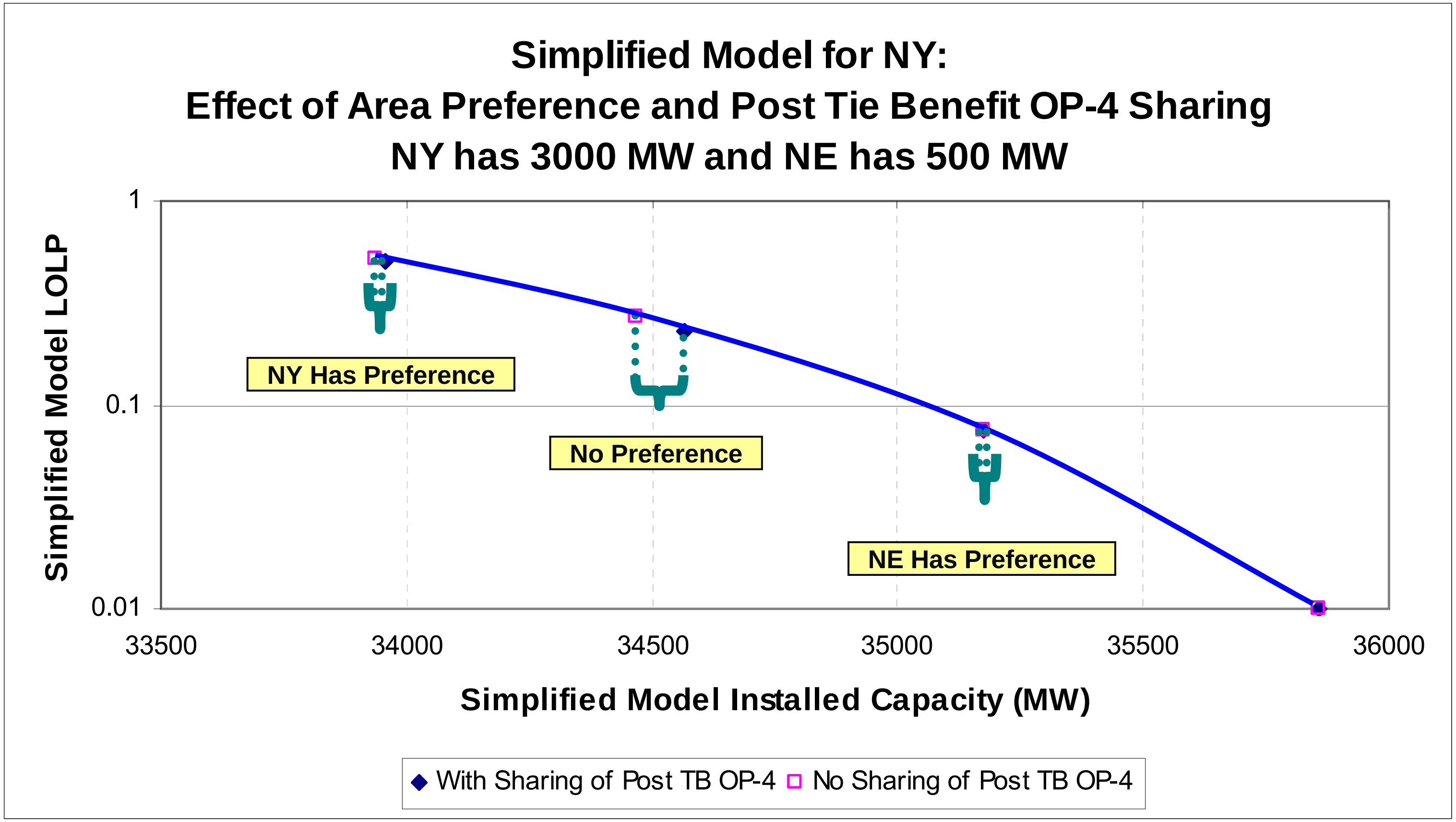
With Preference / No OP4 Sharing



Effect of Sharing and Preference



Effect of Sharing and Preference

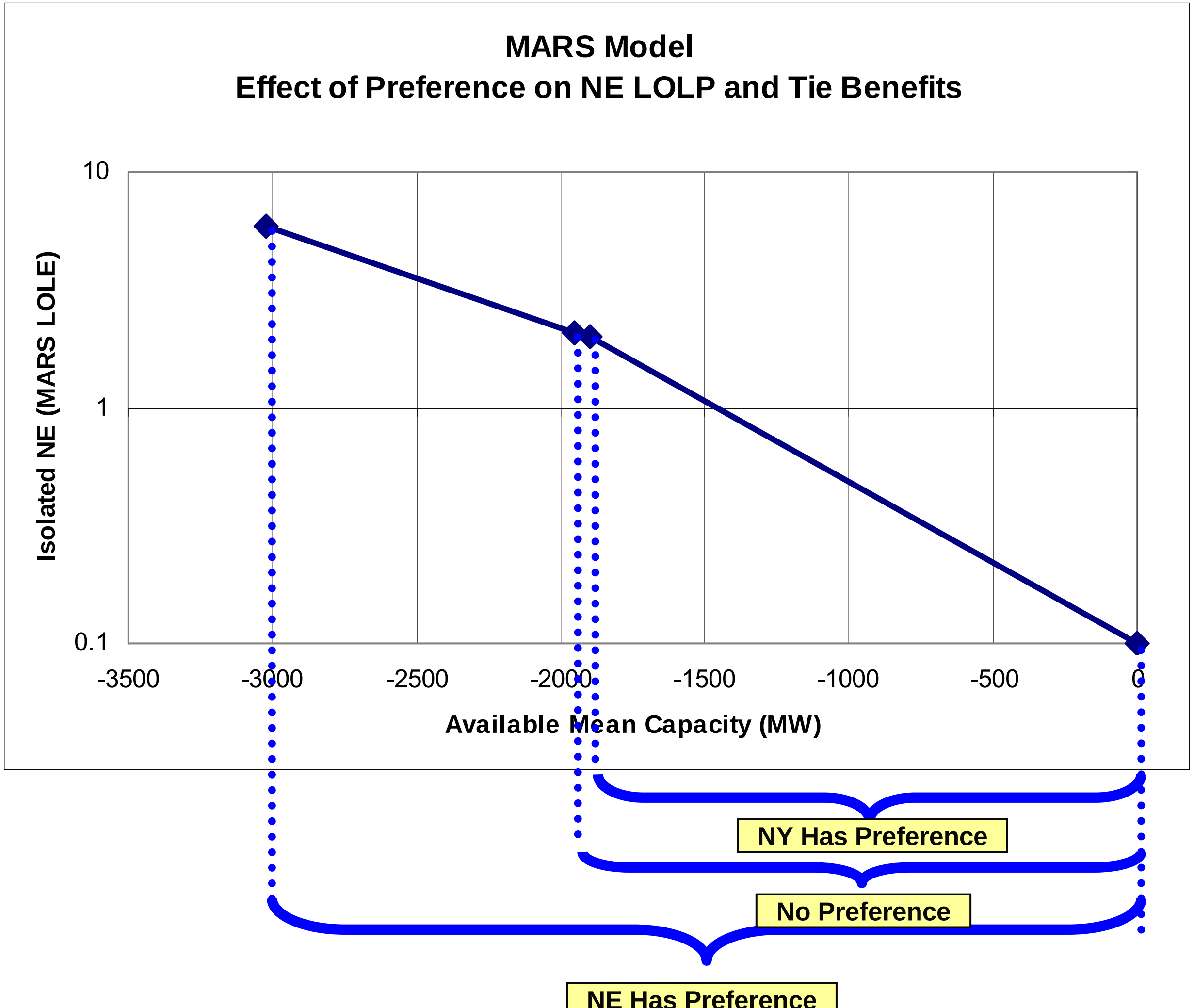


MARS Results

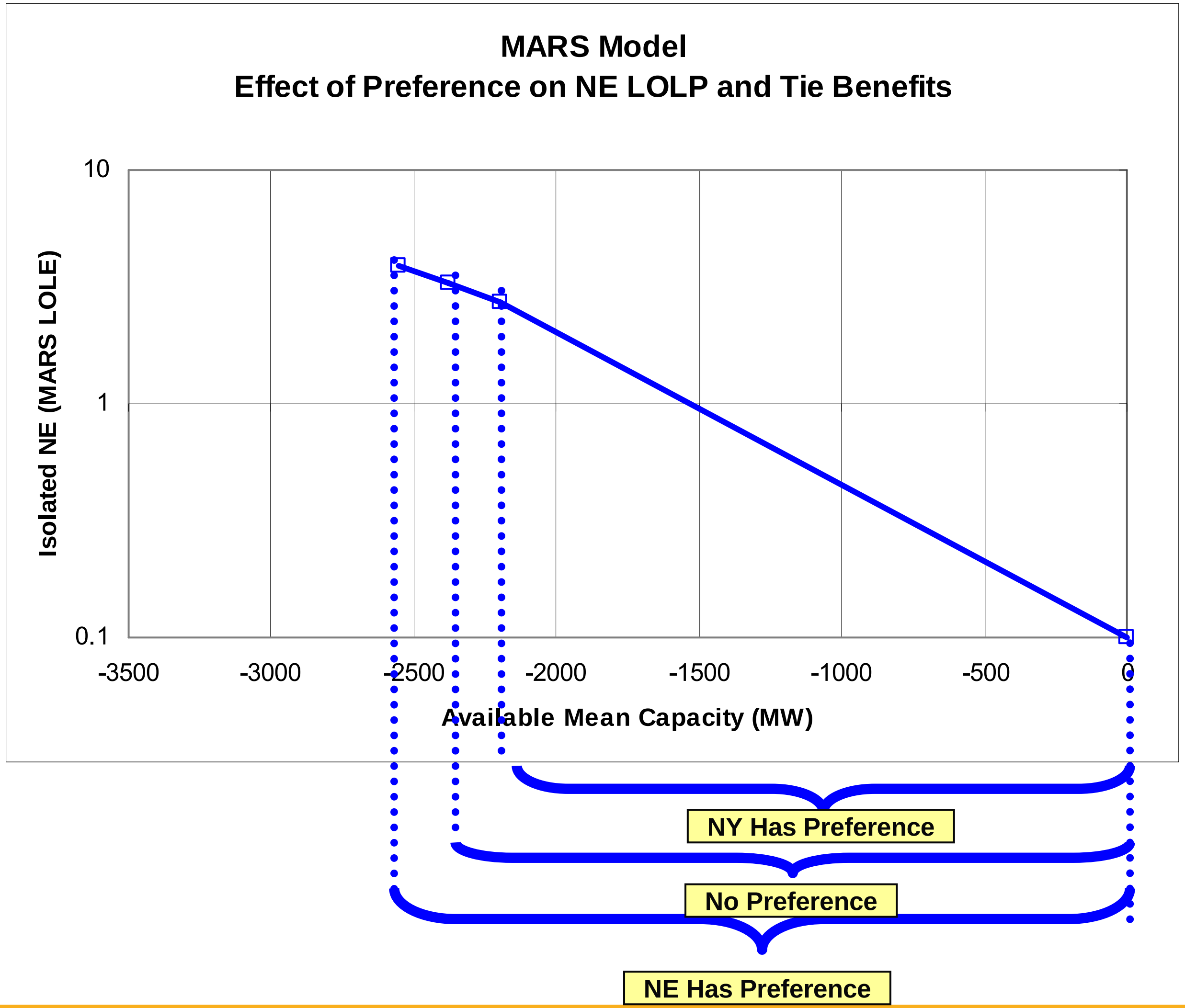
Preference and OP4 Analysis with MARS

- Control area preference can influence tie benefits
  - Simplified model illustrates concept
  - Adding transfer capability between control areas can degrade one system and enhance another
- Effect of OP4 treatment can resemble preference
  - MARS model appear consistent with the hypothesis that
    - Tie benefits are calculated first
    - Then OP-4 ‘capacity relief’ is made available to host area
    - Unused OP-4 ‘capacity relief’ is not available to external areas
  - Consistent with current CP-8 modeling protocol
- Further analysis of this phenomenon appears warranted

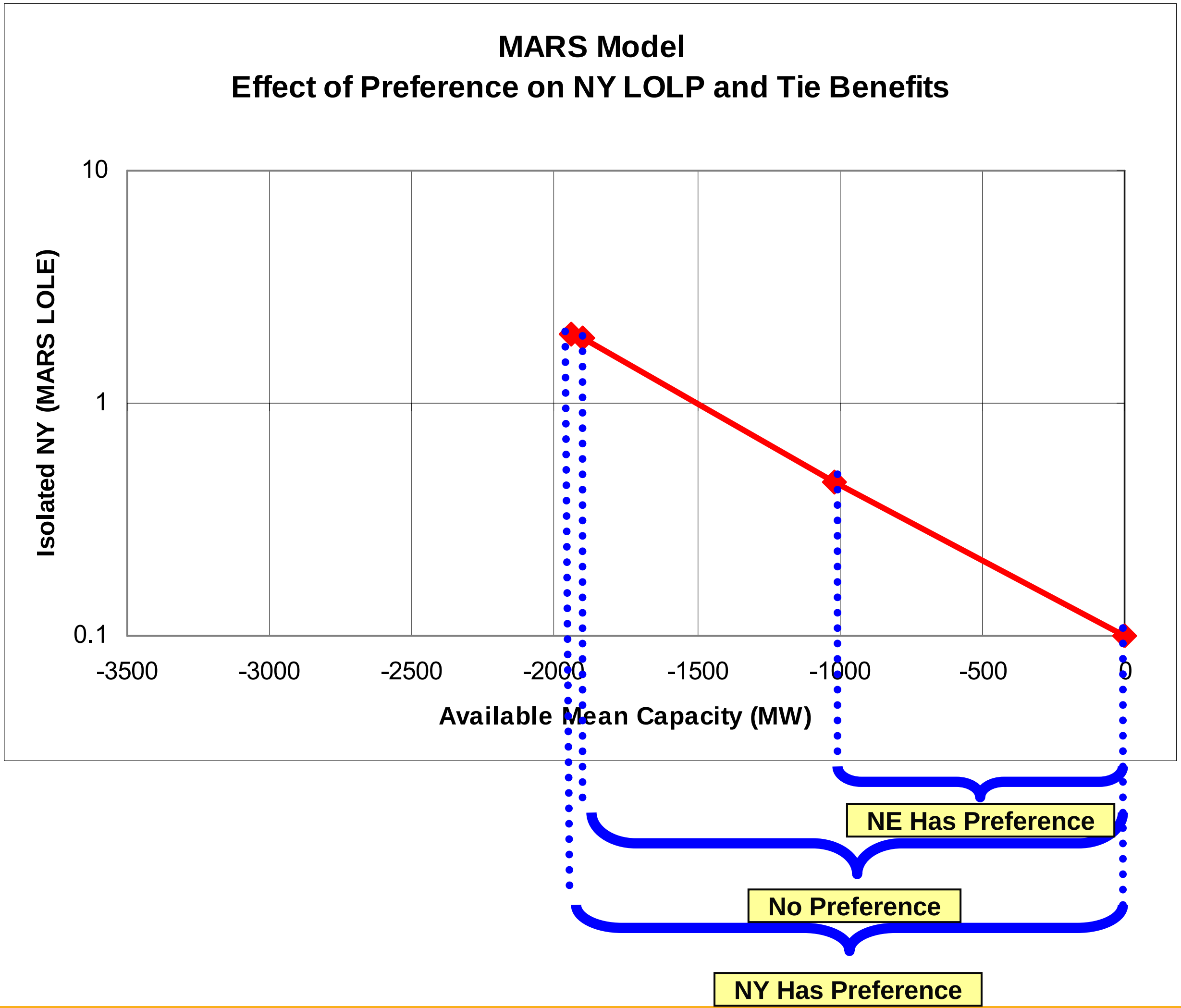
MARS Results NE: With OP4



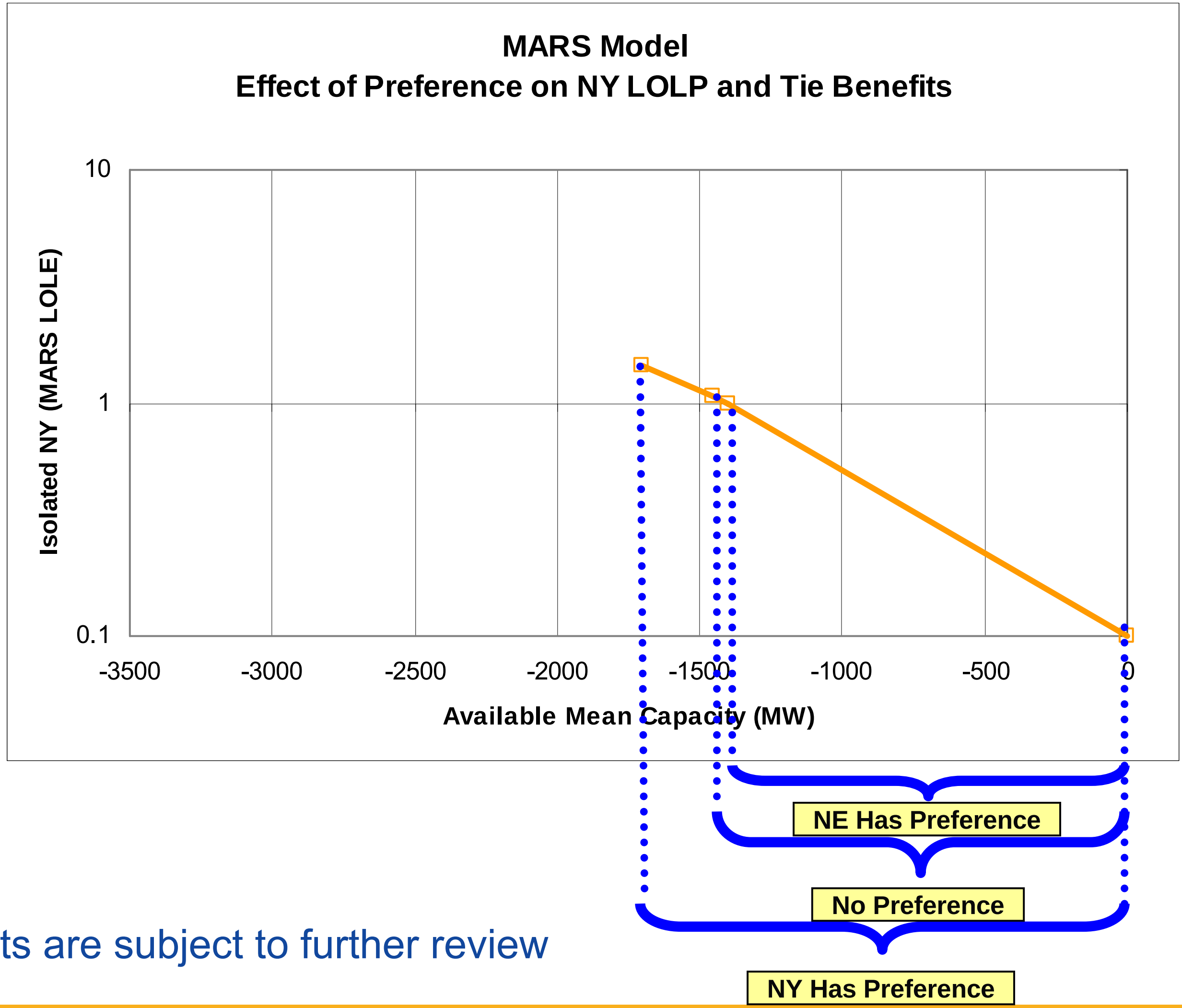
MARS Results NE: No OP4



MARS Results NY: With OP4



MARS Results NY: No OP4



These results are subject to further review

Questions?