GE
Energy

Western Wind & Solar Integration Study

Candidate Scenarios for Future Analysis

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Stakeholder Meeting
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Variations on the High Renewable Scenario

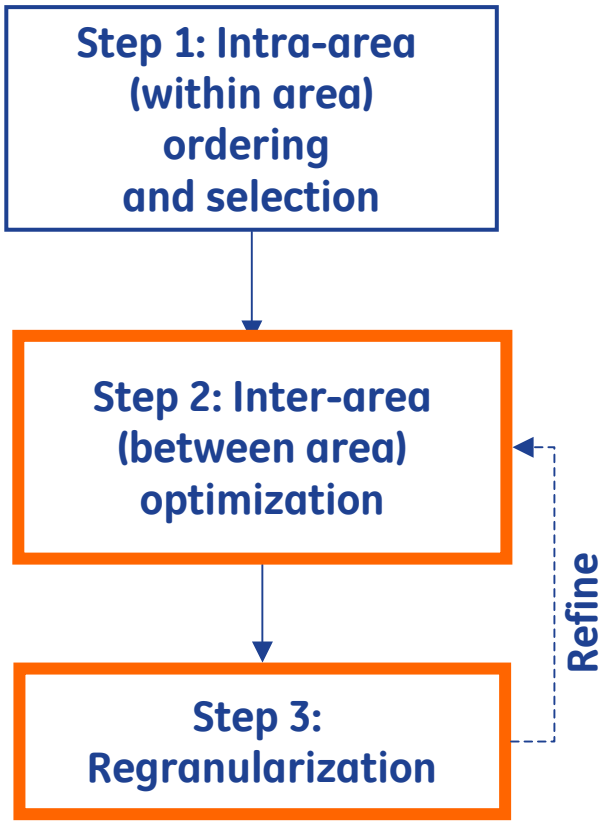
- Objectives
  - Examine sensitivities to different potential strategies:
  - Impact on economics
    - variable cost of operation, displacements,…
  - Impact on operations
    - ancillary services, balancing, …
- General
  - All variations start from 30% In-Area scenario;
  - Total renewable energy held constant (unless otherwise noted)

Candidate Scenarios

- Candidate Scenarios
  - "Mega Projects" scenario
    - maximum cost benefit for capital
  - "Local Priority" scenario
    - consider externalities and local priorities
  - "High Solar" scenario
    - quantify incremental impact of additional solar
  - "High Capacity Value" scenario
    - quantify impact of wind development coordinated with load patterns
- Other scenarios considered
    - High Geographic Diversity
    - Lower Renewables Penetration

Global Siting Algorithm Overview

A continuation of the algorithm used to select in-area sites.



Adjust selection of top sites, by replacing in-area site with remote sites, based on minimizing costs of generation equipment, new transmission and losses.

Heuristically adjust continuously optimized site selection and transmission reinforcements to reflect practical constraints

Wind and Solar Plant Siting between Areas: assumptions and constraints

1. Need to strike a balance between quality of wind and solar resources and distance from load centers
2. Existing transmission limits apply to inter-area exchange of wind, but may be discounted due to other firm commitments
3. Cost of transmission can reasonably is approximated by $/MW-mile
4. Inter-area exchange of wind (and solar) power at less than available inter-area transfer levels incurs no incremental transmission reinforcement cost
5. Inter-area exchange of energy incurs losses which increase with distance
6. Given that Wind and Solar energy production and location of consumption are fixed, global optimization is primarily a cost minimization problem, i.e. balance capital costs between generation and transmission, considering losses
7. Independently adjust for each of Wind, PV, and CSP w/storage.

Inter-area ordering

Intent is to displace less valuable sites from one area, making it a net importer, while replacing the energy with more valuable sites in another area, making it a net exporter. The total renewable energy is held constant.

Algorithm Parameters:

Transmission Costs:

Expected range: $800-1600 /MW-mile

Transmission Diversity Factor (TDF)*:

70%

Wind Capital Cost:

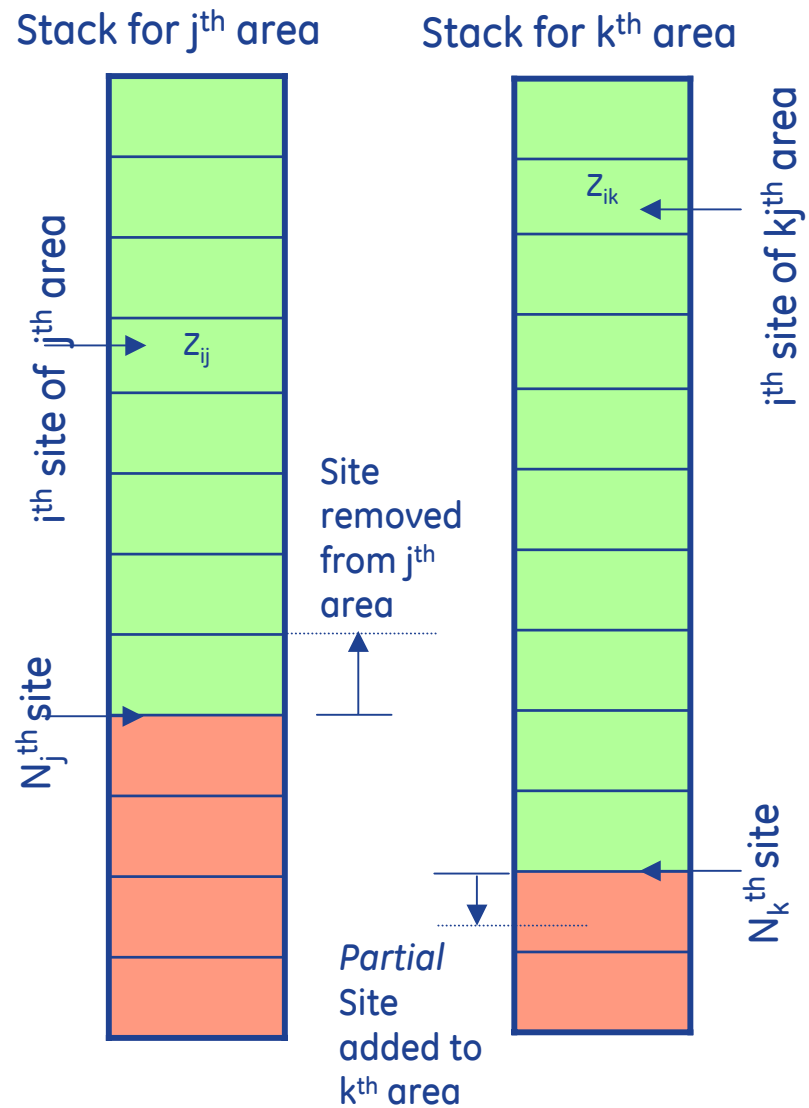
$2000/kW

Solar Capital Cost:

$4000/kW

Losses:

1% Energy/100 mile separation (cost penalty only)



*** TDF: Temporal diversity of net exports approximated by assuming 1.0 MW of generation for export uses 0.7 MW of transfer capability**

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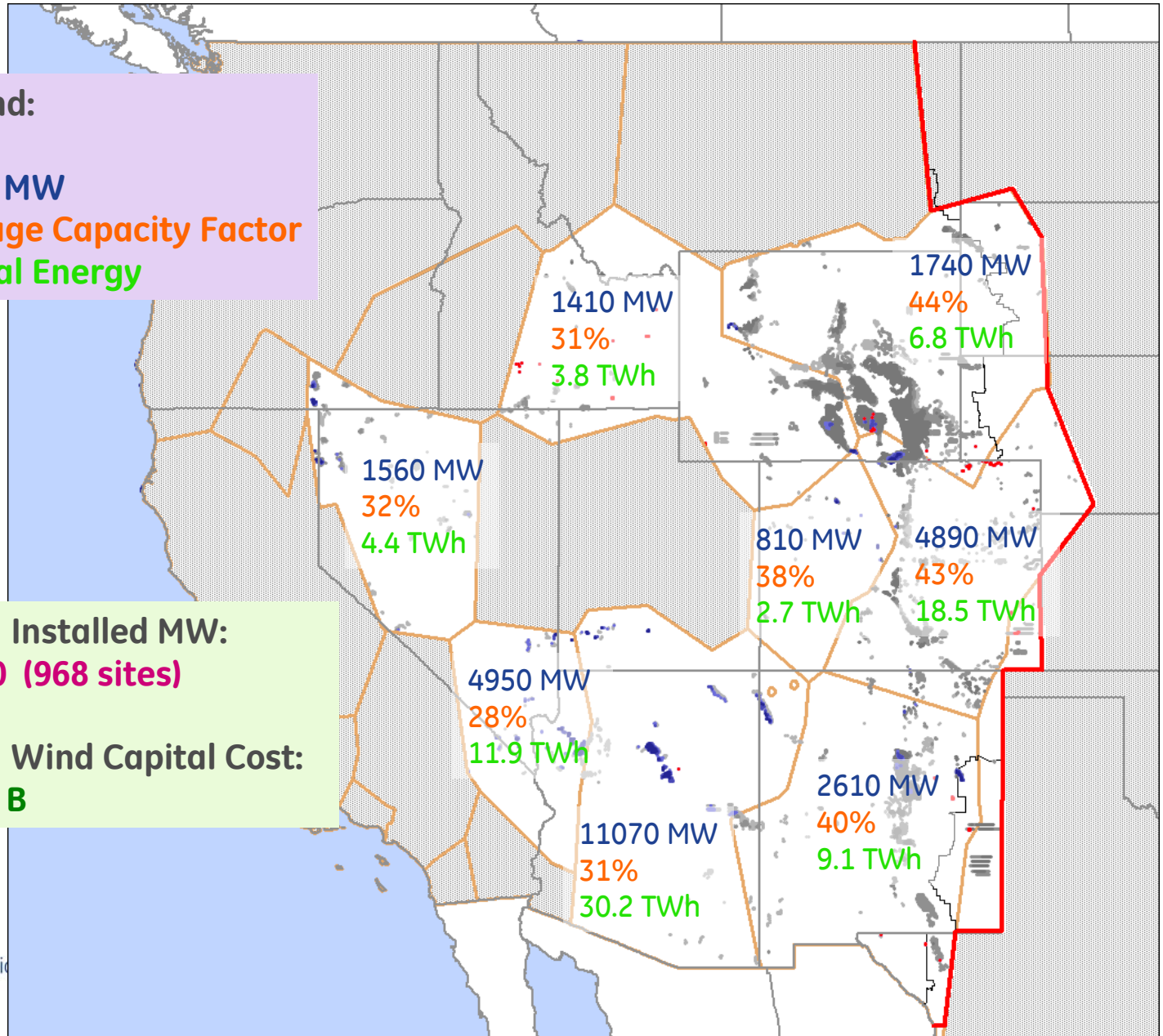
In-Area scenario - Wind



Legend:

Wind MW
Average Capacity Factor
Annual Energy

Total Installed MW:
29040 (968 sites)

Total Wind Capital Cost:
$58.1 B

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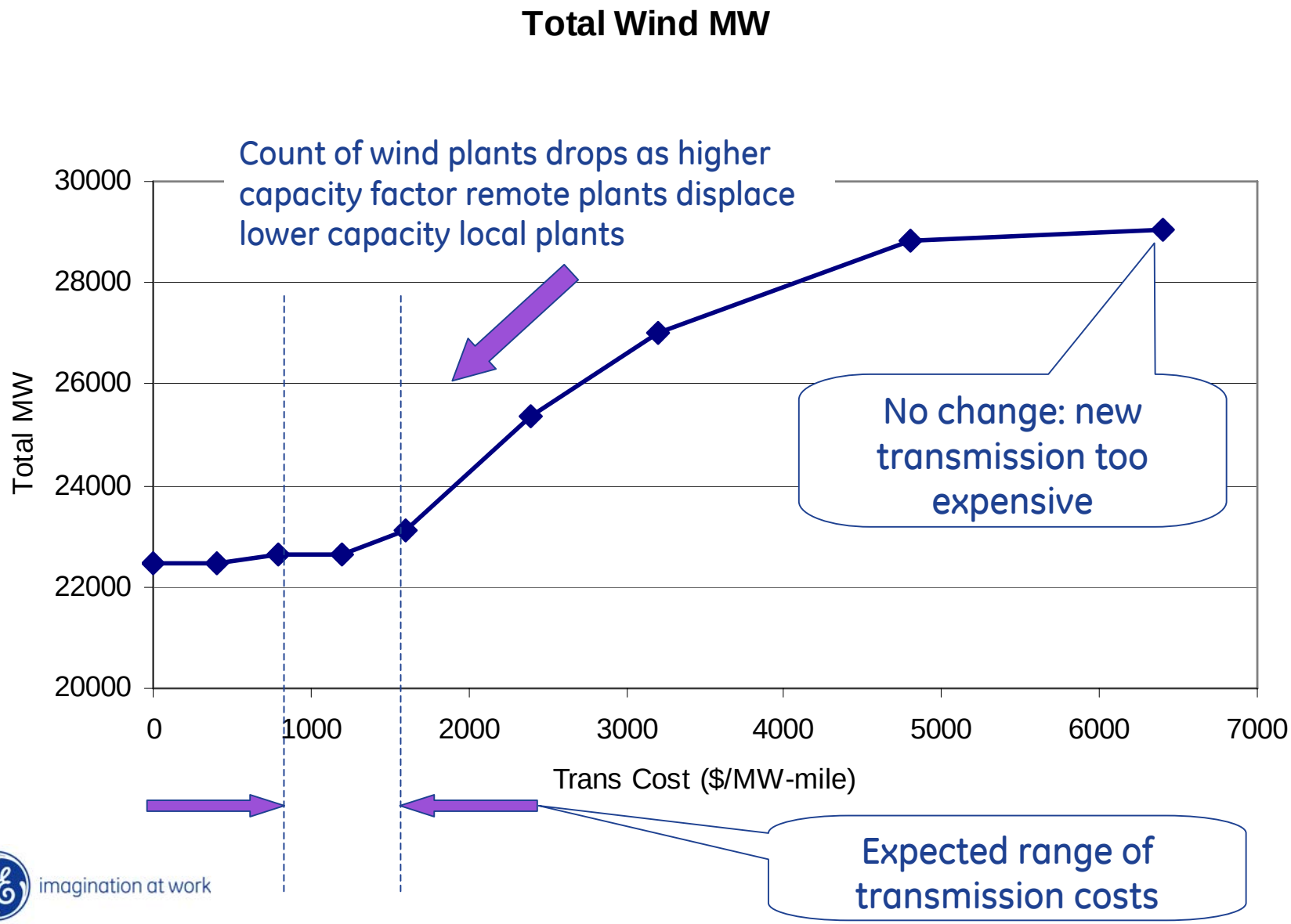
Inter-area Redistribution



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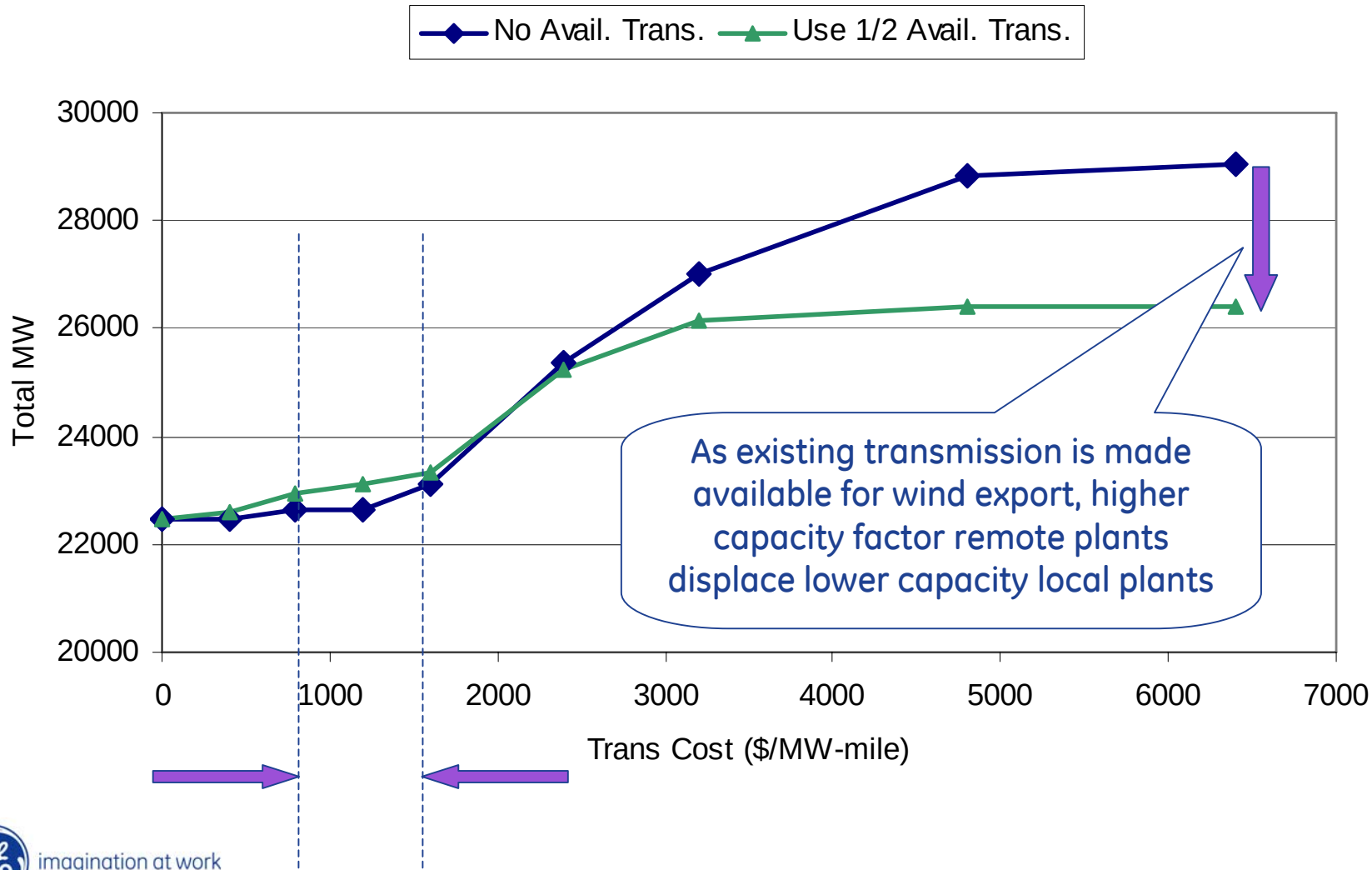
Inter-area Redistribution



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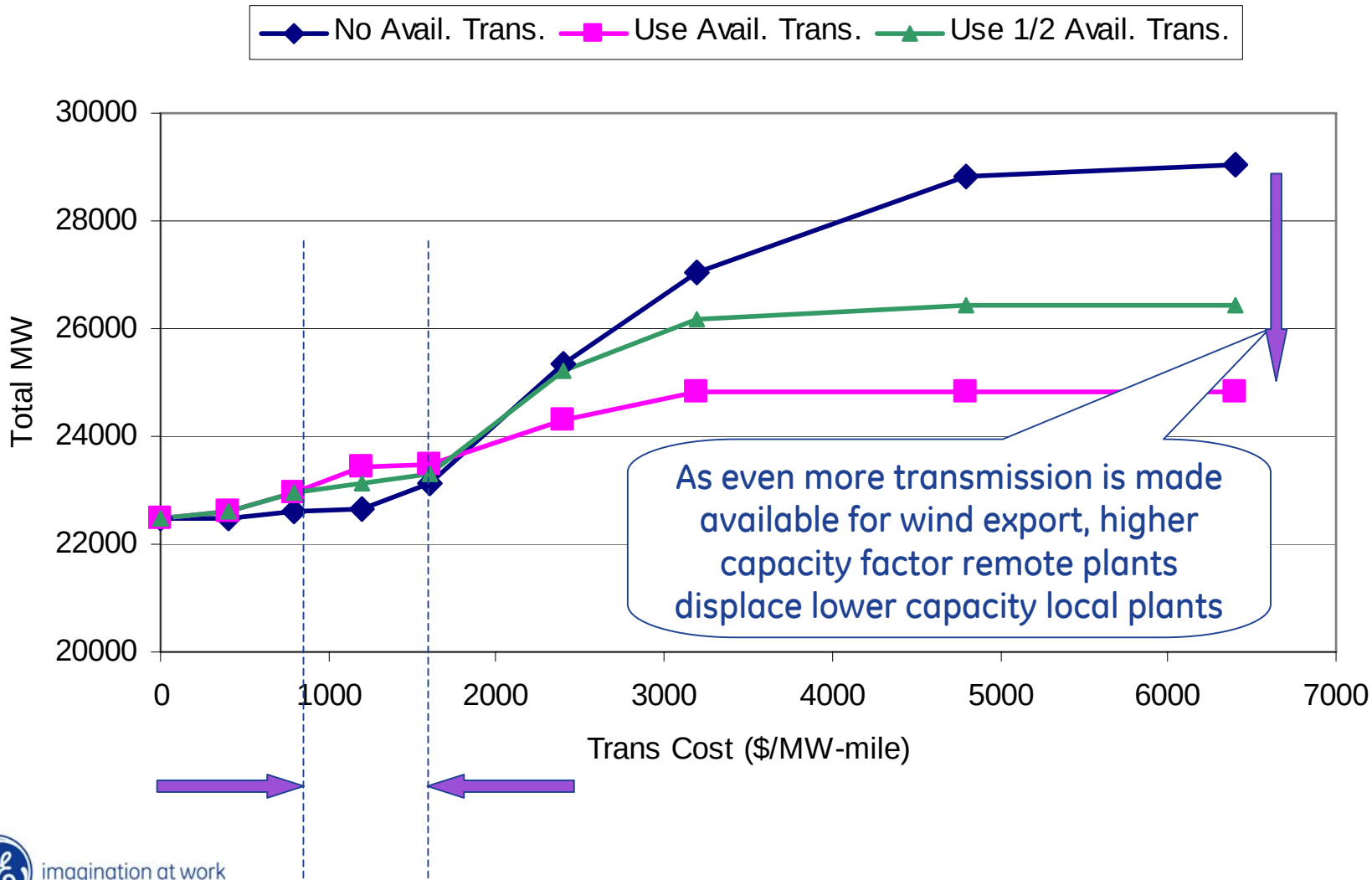

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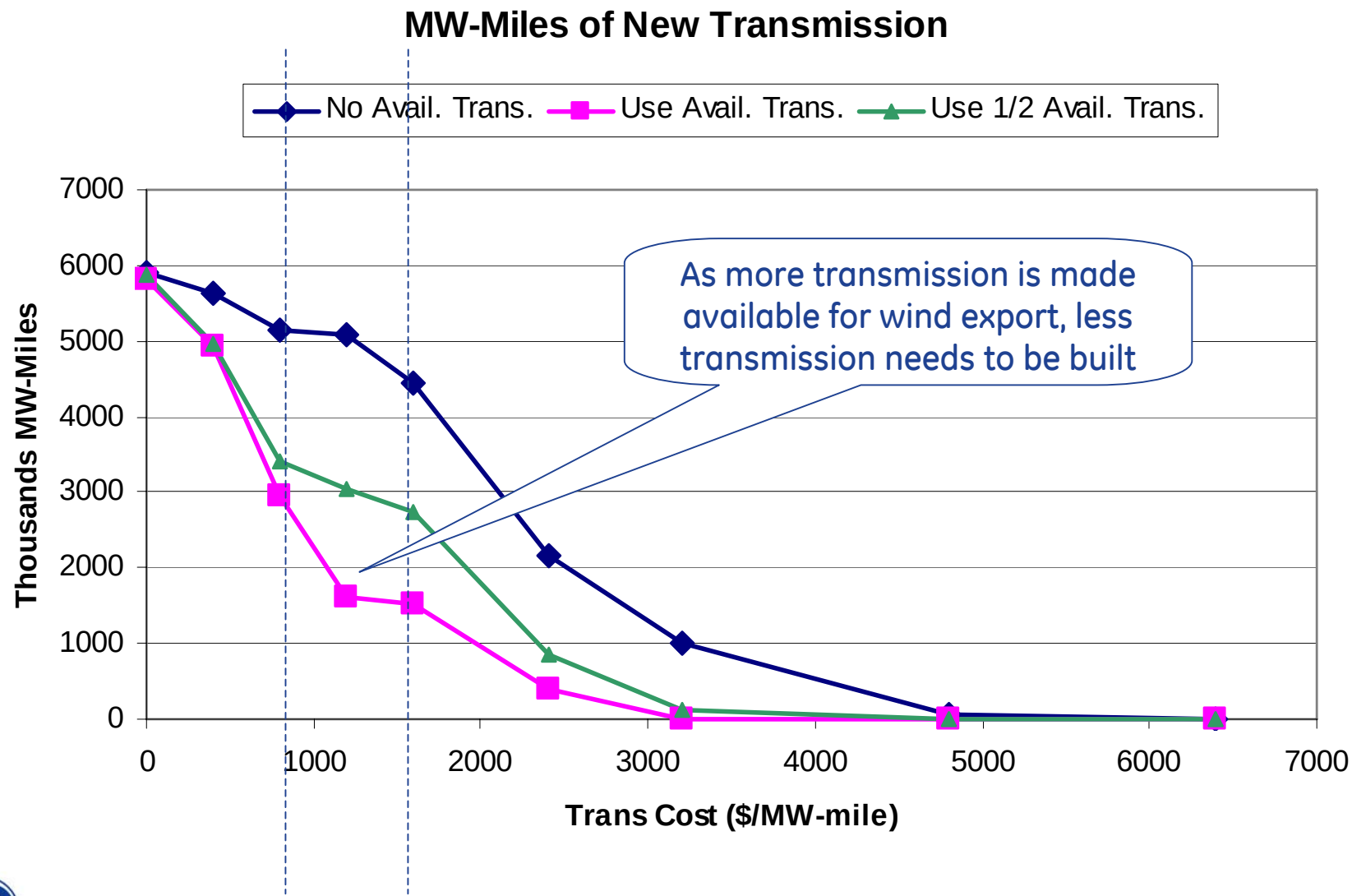

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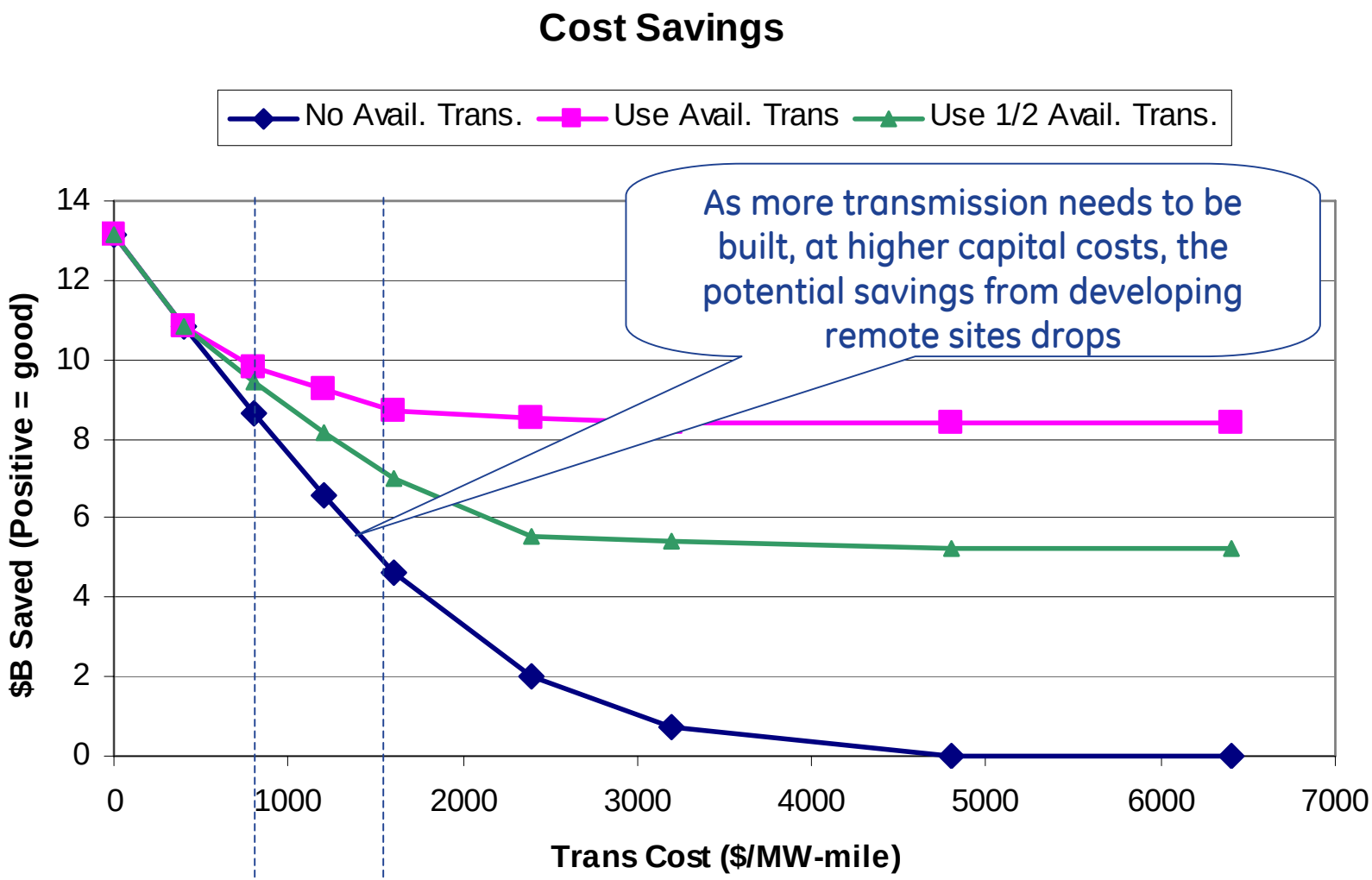

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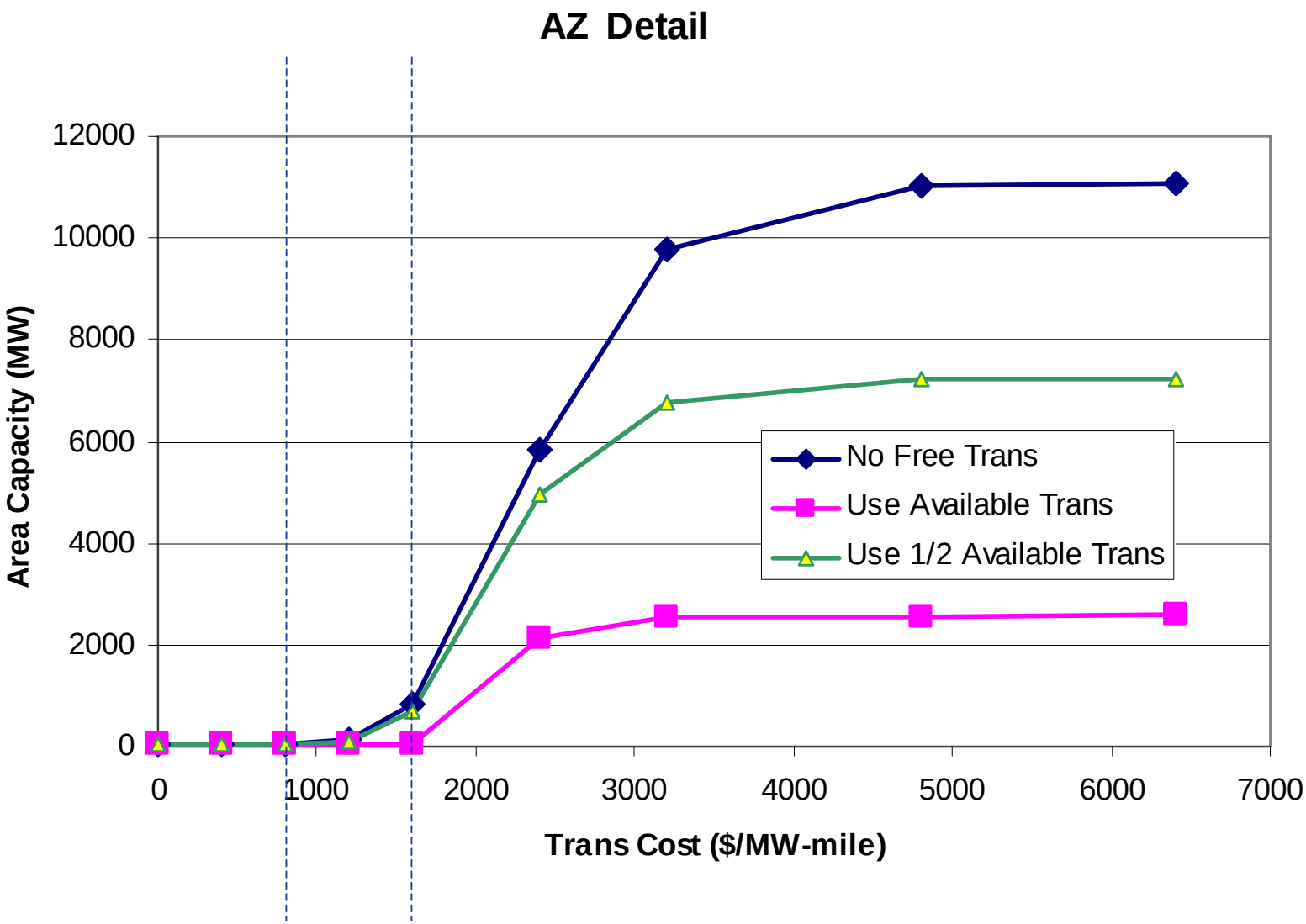

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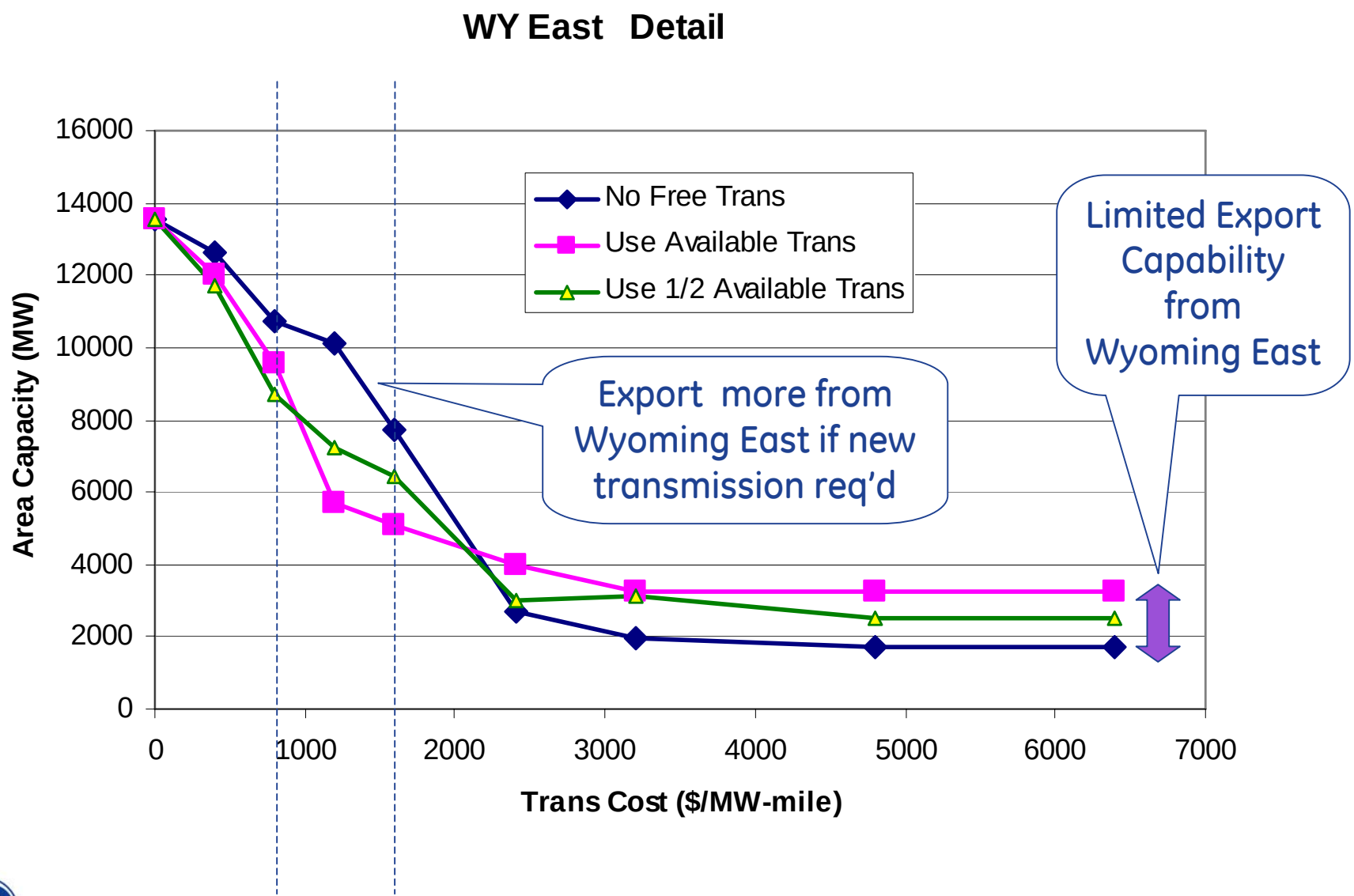

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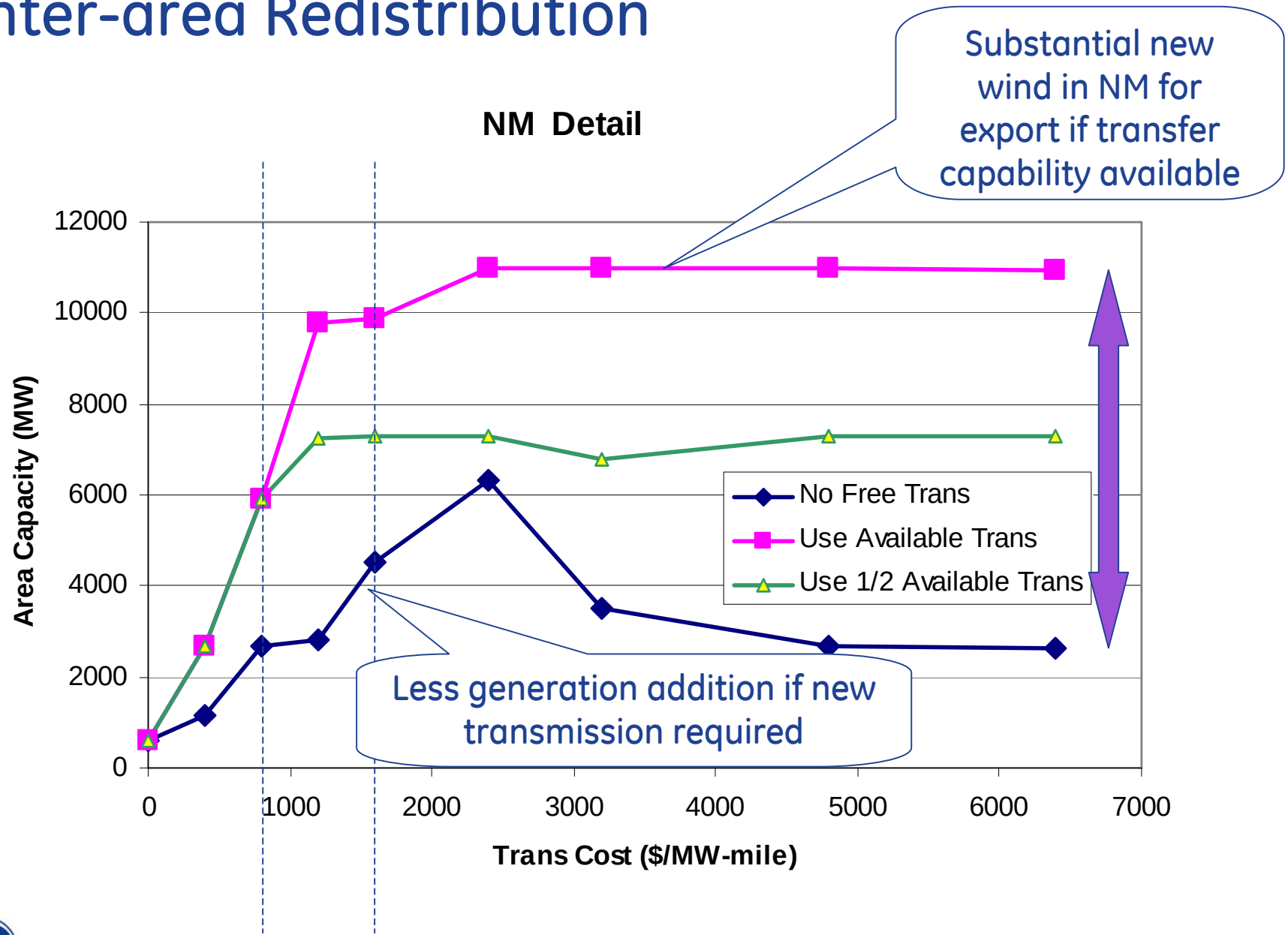
Inter-area Redistribution



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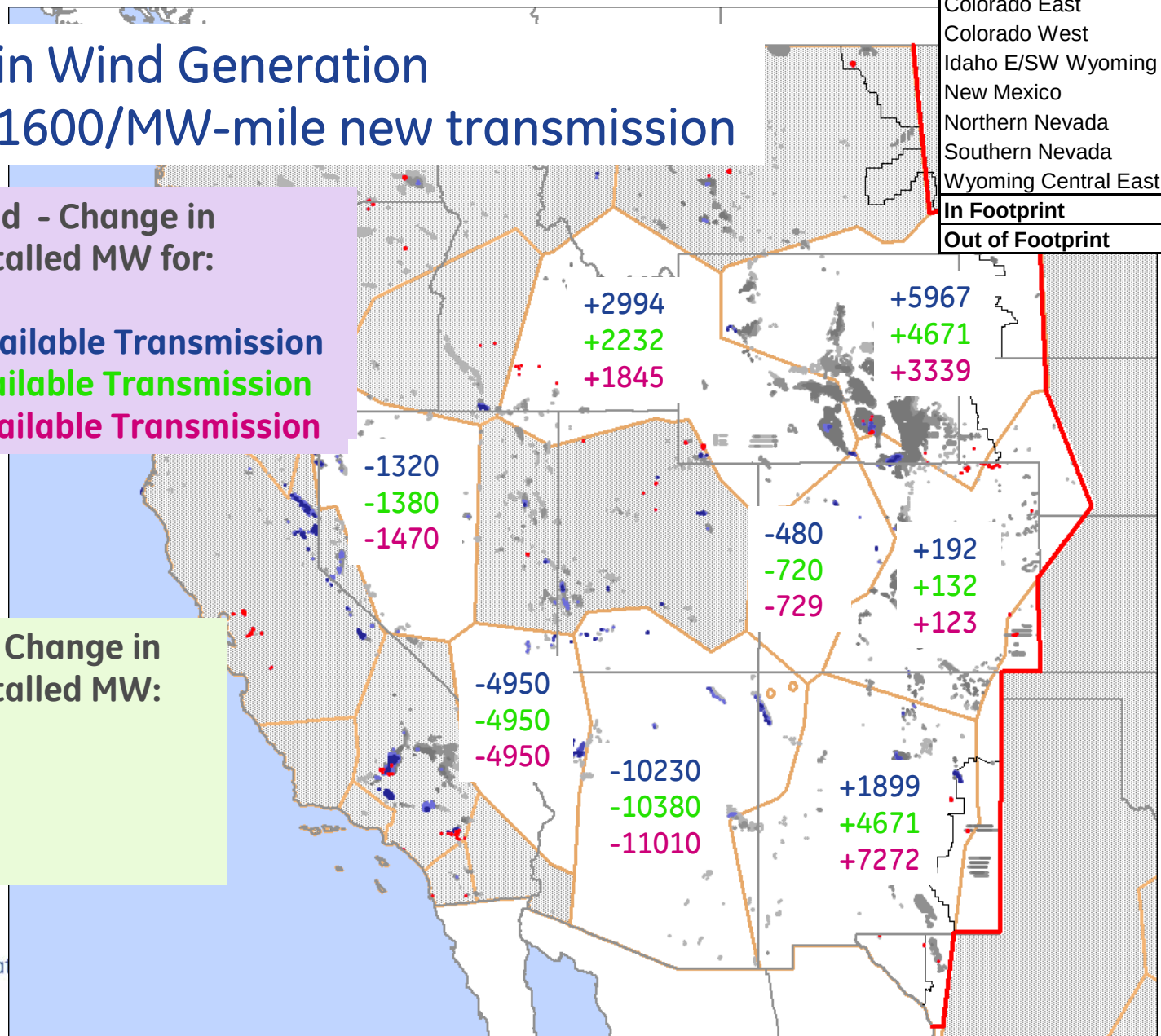
Inter-area Redistribution

Shift in Wind Generation
For $1600/MW-mile new transmission

Areas	Wind Rating (MW)
Arizona	11,070
Colorado East	4,890
Colorado West	810
Idaho E/SW Wyoming	1,410
New Mexico	2,610
Northern Nevada	1,560
Southern Nevada	4,950
Wyoming Central East	1,740
In Footprint	**29,040**
Out of Footprint	**42,060**



Legend - Change in Installed MW for:

No Available Transmission
½ Available Transmission
All Available Transmission

Total Change in Installed MW:

-5928
-5727
-5580

Inter-area Redistribution

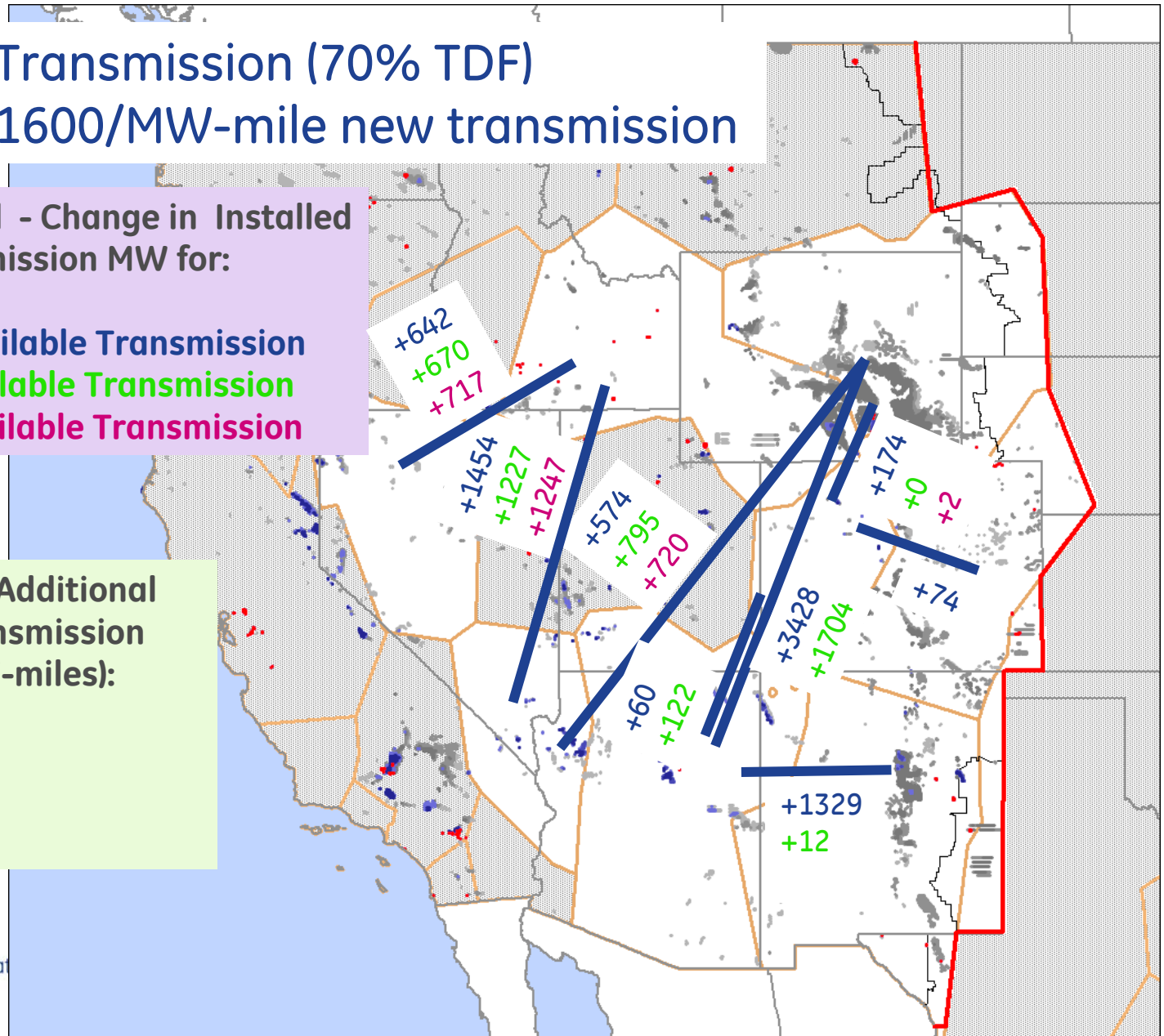
New Transmission (70% TDF)
For $1600/MW-mile new transmission

Legend - Change in Installed Transmission MW for:

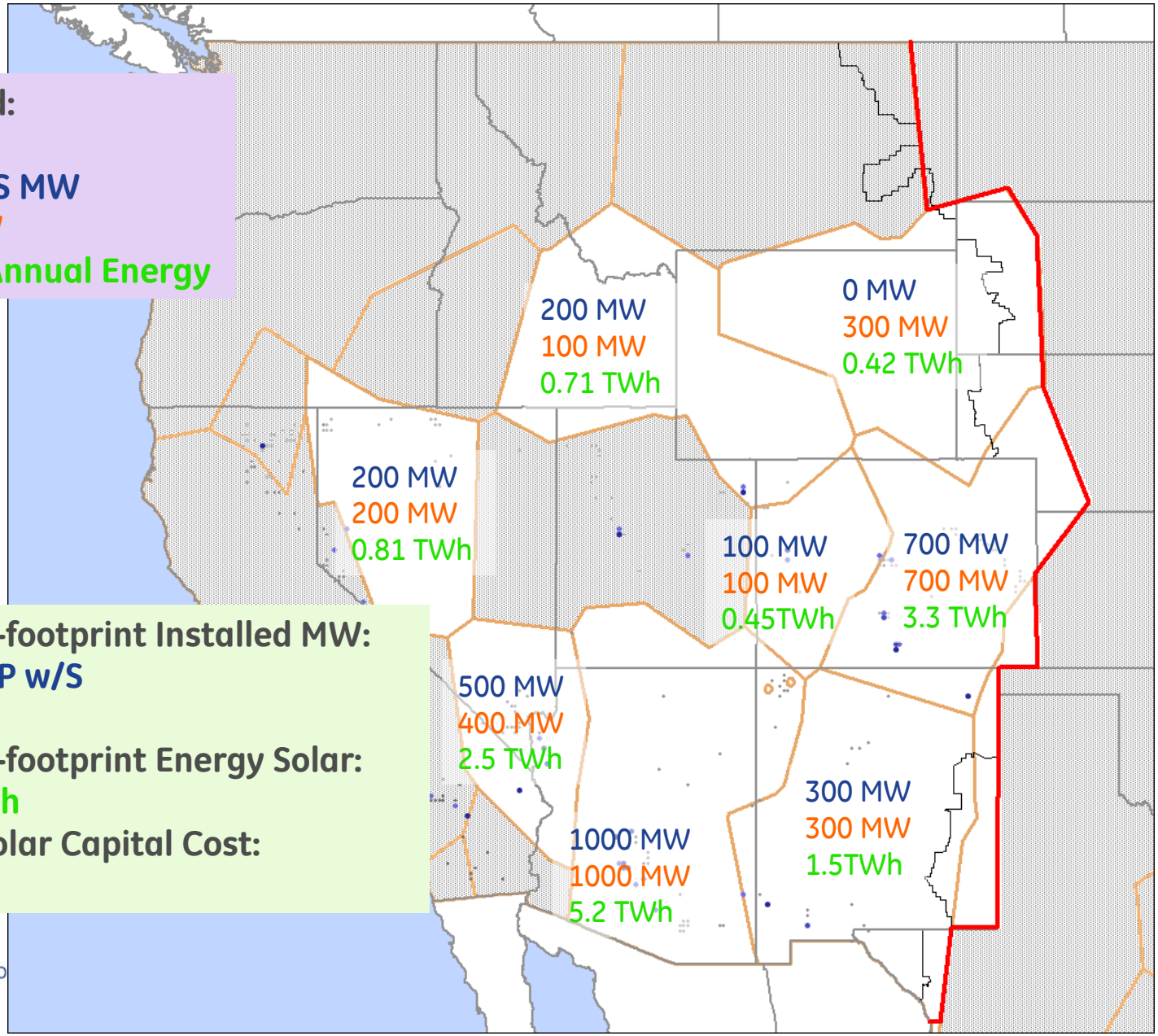
No Available Transmission
½ Available Transmission
All Available Transmission

Total Additional Transmission (GW-miles):

+4446
+2744
+1507



In-area scenario - Solar



Legend:

CSPw/S MW
PV MW
Solar Annual Energy

Total In-footprint Installed MW:
3000 CSP w/S
3000 PV
Total In-footprint Energy Solar:
15.0 TWh
Total Solar Capital Cost:
$24 B

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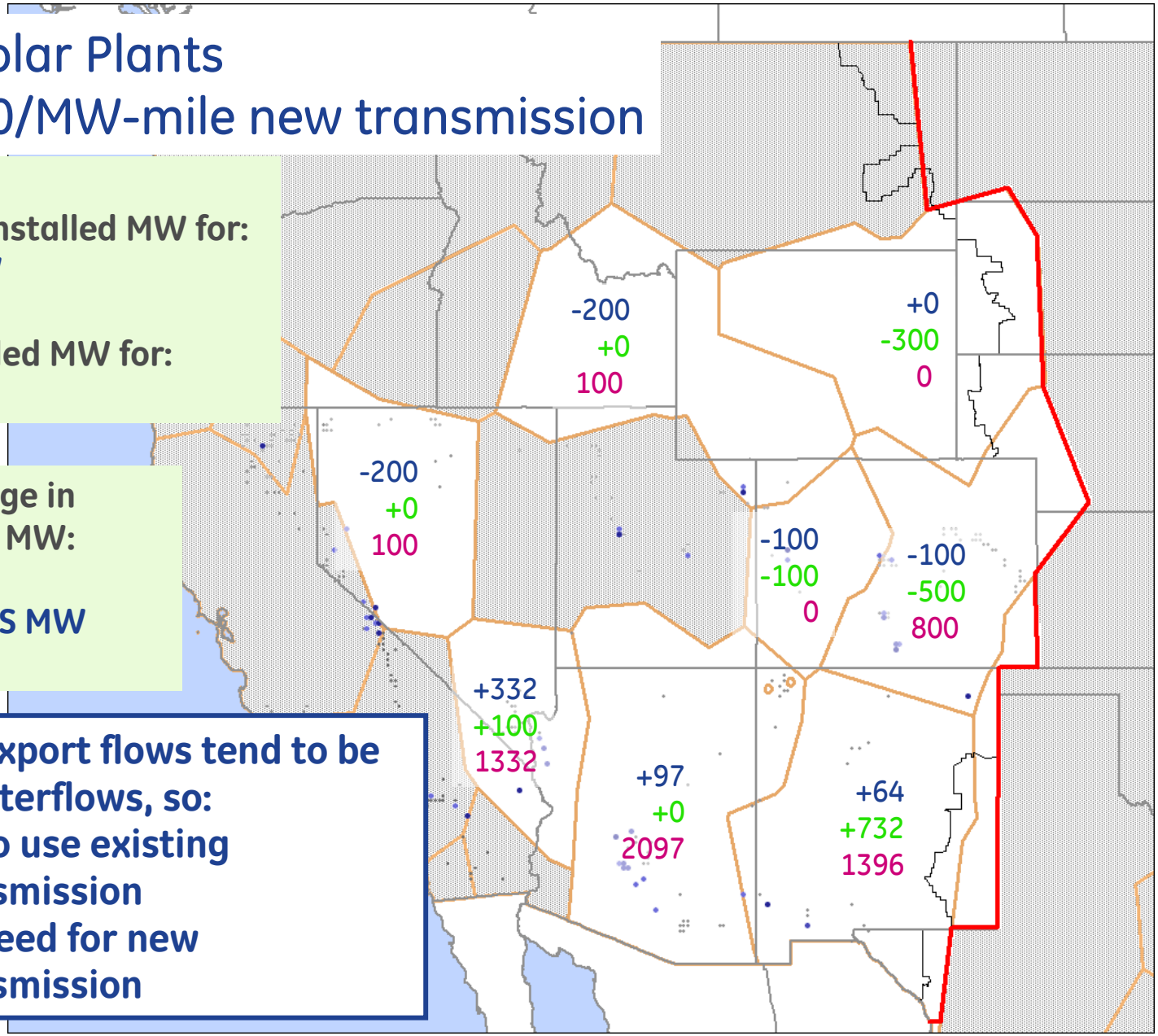
Inter-area Redistribution - Solar

Shift in Solar Plants
For $1600/MW-mile new transmission

Key -
Change in Installed MW for:
CSPw/S MW
PV MW
Total Installed MW for:
Total Solar

Total Change in Installed MW:

-107 CSPw/S MW
-68 PV MW



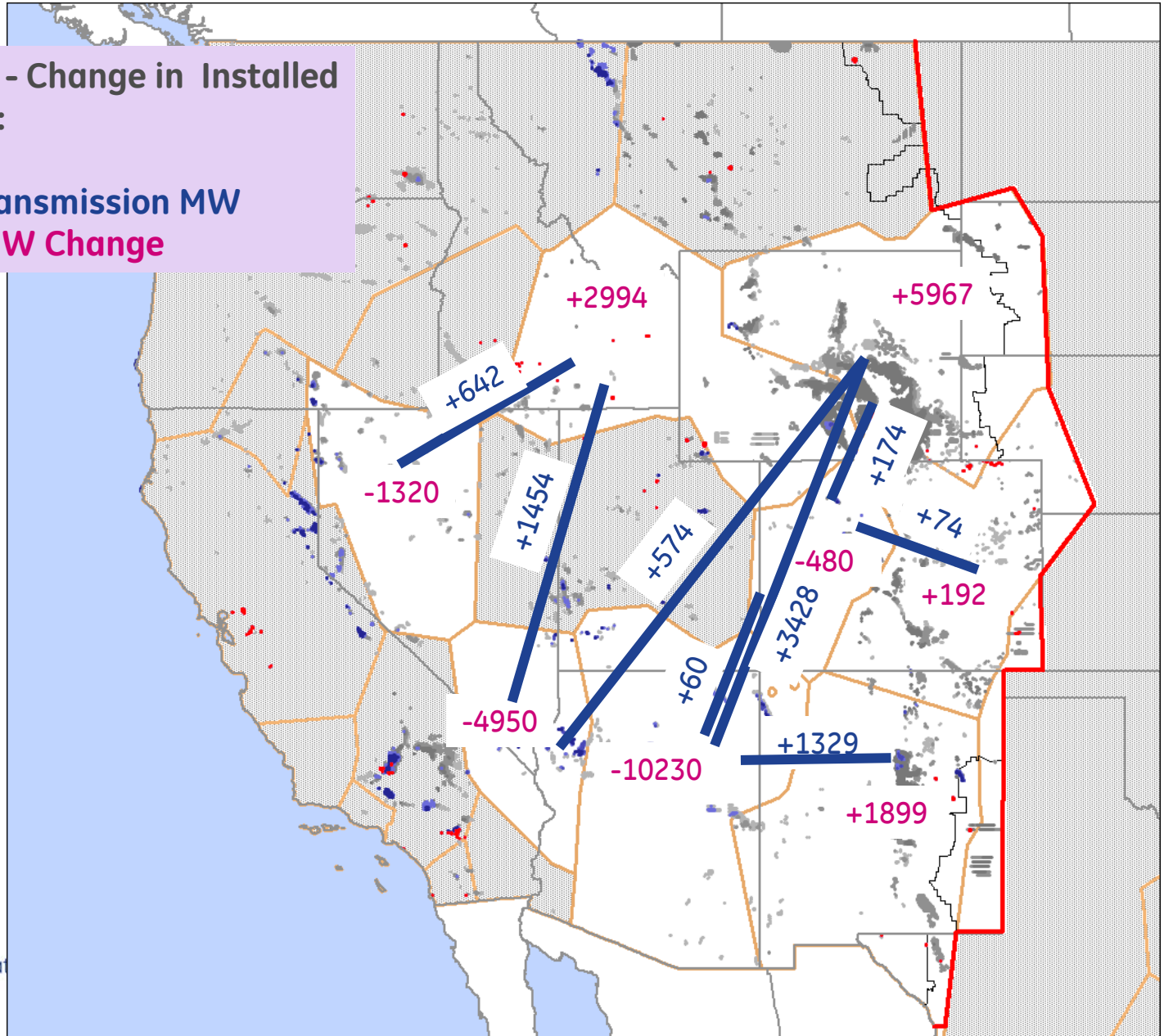
Solar export flows tend to be counterflows, so:

- **OK to use existing transmission**
- **No need for new transmission**

“Mega project” Distribution

- Based on all new transmission build-out
- Global low cost objective:
  - $1600 MW-mile transmission
  - $2000 MW wind generation

Preliminary "Mega project" Distribution



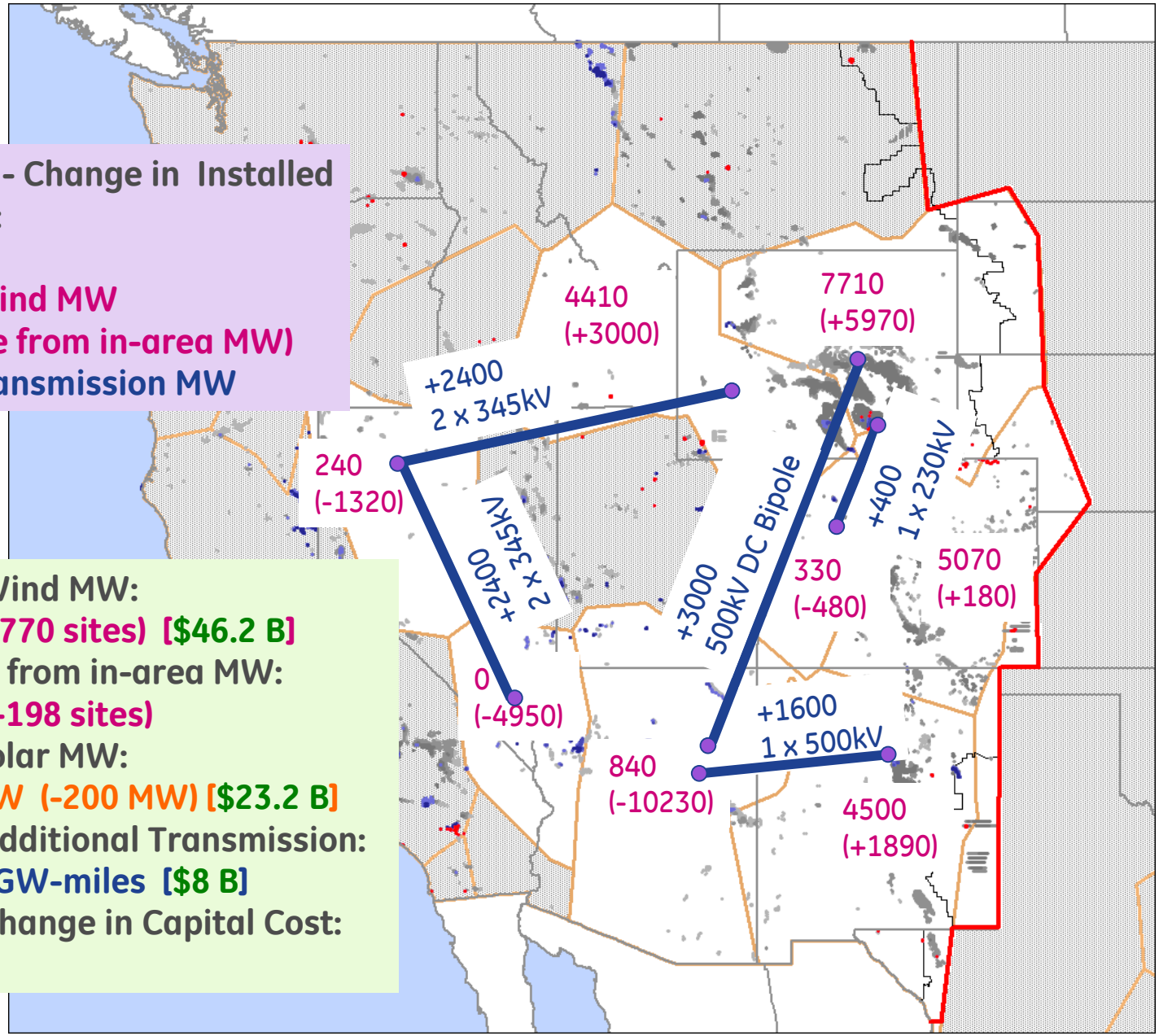
Legend - Change in Installed MW for:

New Transmission MW
Wind MW Change

Regranularized “Mega project” Distribution

- Refine distribution identified by global algorithm to rational components
- Use ‘whole’ 30 MW wind plants
- Use ‘whole’ 100 MW solar plants
- Use typical transmission rating
  - 345 or 500 kV AC for bulk interties
    - 1200 or 1600 MW/circuit, respectively
    - Select kV depending on predominant voltage in vicinity
  - HVDC for long distance and high power
    - i.e. > 2 circuits of EHV AC
  - Select in-footprint routes
  - Disregard/consolidate small incremental ties to local transmission voltage level (e.g. 230kV/400 MW)

Mega Project Scenario – Power



Legend - Change in Installed MW for:

Final Wind MW
(Change from in-area MW)
New Transmission MW

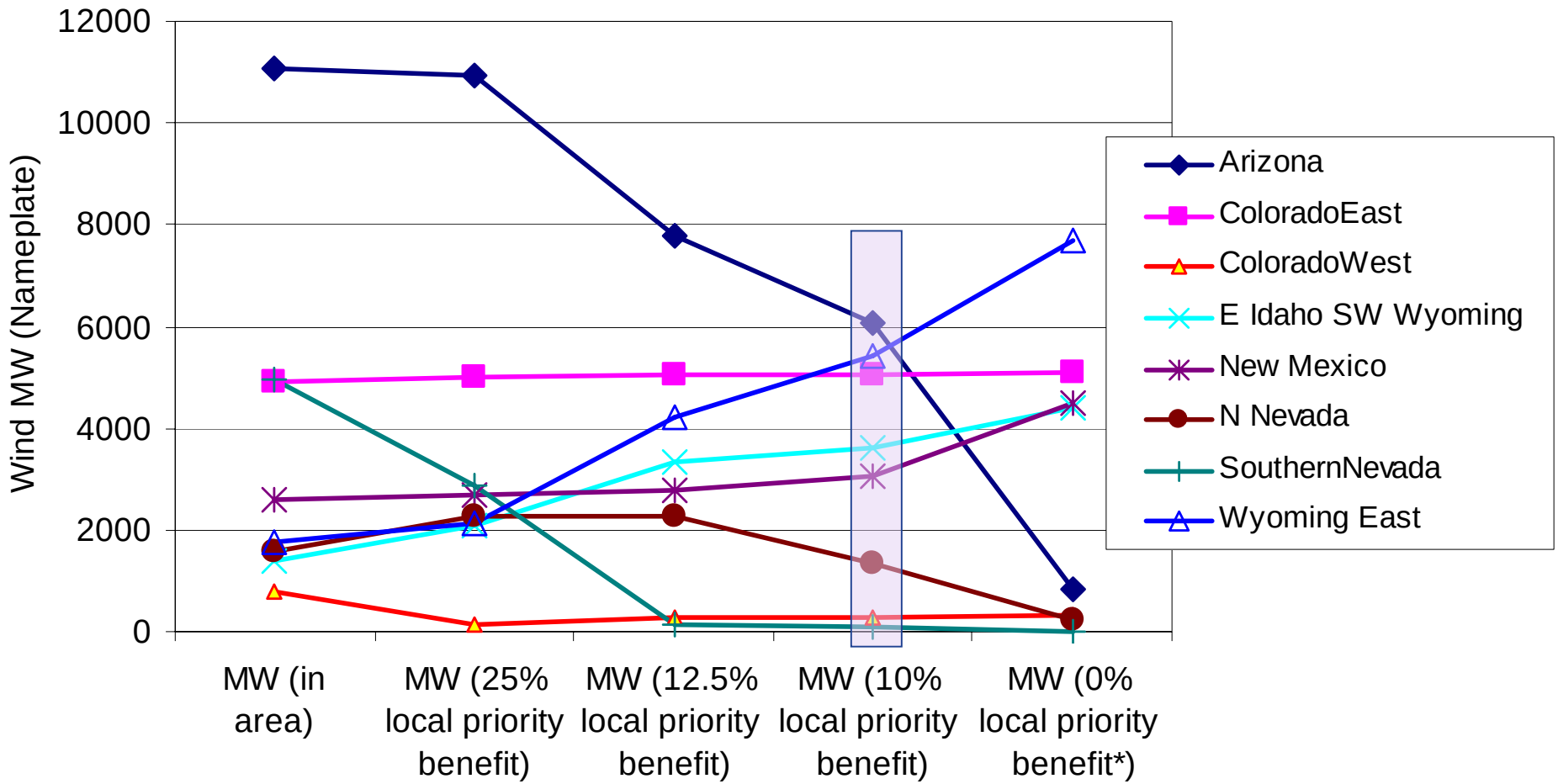
Total Wind MW:
23100 (770 sites) [$46.2 B]
Change from in-area MW:
-5940 (-198 sites)
Total Solar MW:
5800 MW (-200 MW) [$23.2 B]
Total Additional Transmission:
+ 5000 GW-miles [$8 B]
Total Change in Capital Cost:
-$4.7 B

Local Priority Inter-area Redistribution

- For areas with globally less cost effective wind sites (i.e. Nevada and Arizona) externalities may still favor development of local (in-area) sites
  - Externalities could include increased employment, retained tax revenues, etc.
- Local benefits effectively reduce the annual carrying cost of in-area generation
- Allow use of transmission in base case dedicated to renewables (i.e. 500 MW between North and South Nevada)

Local Priority Inter-area Redistribution

Importing Systems (Arizona & Nevada) realize external economic benefits that effectively reduce annual carrying cost of generation built locally



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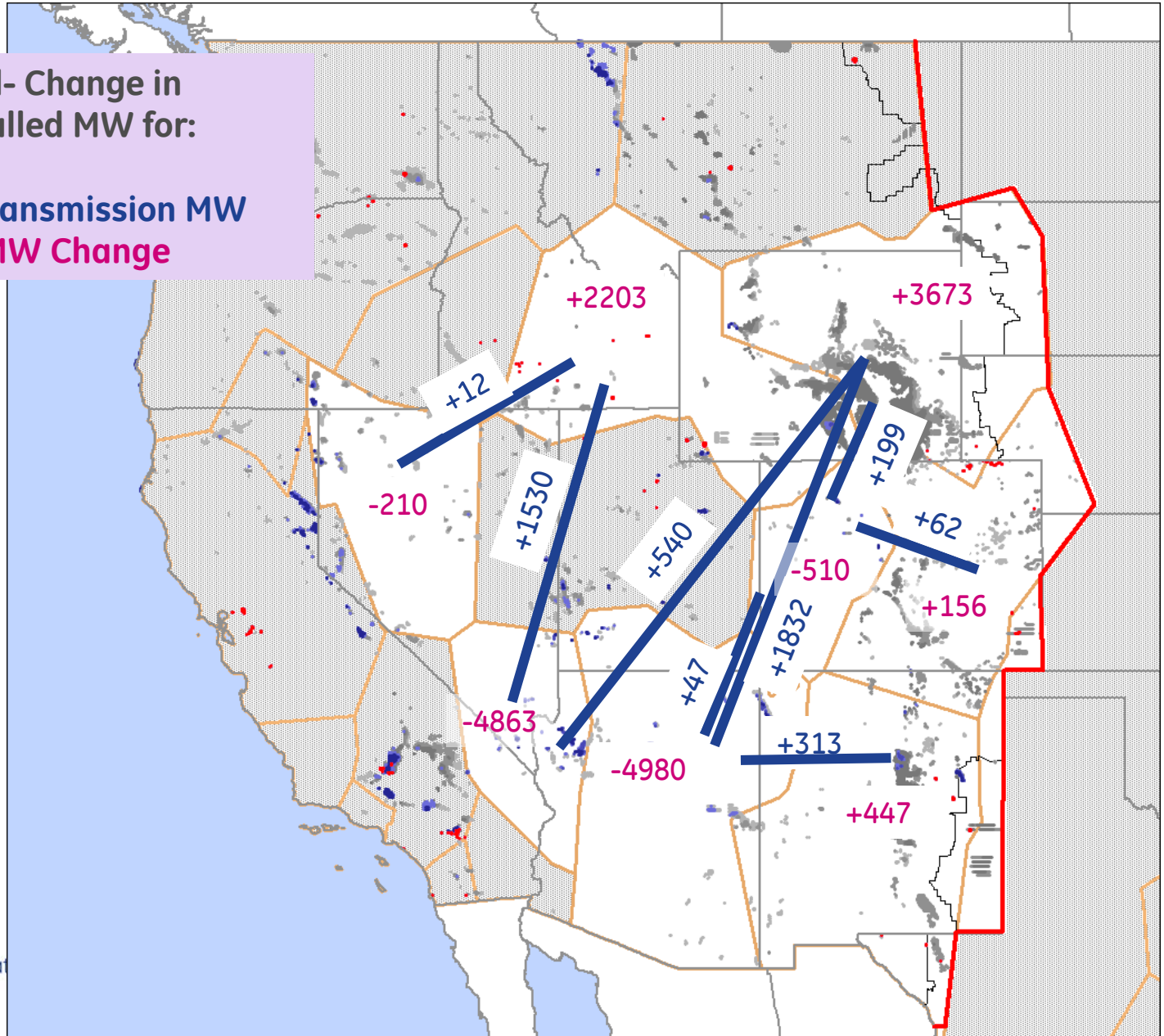
* 0% local priority benefit case does not include access to 500MW N-S Nevada transmission

Preliminary "Local Priority" Distribution

Legend- Change in Installed MW for:

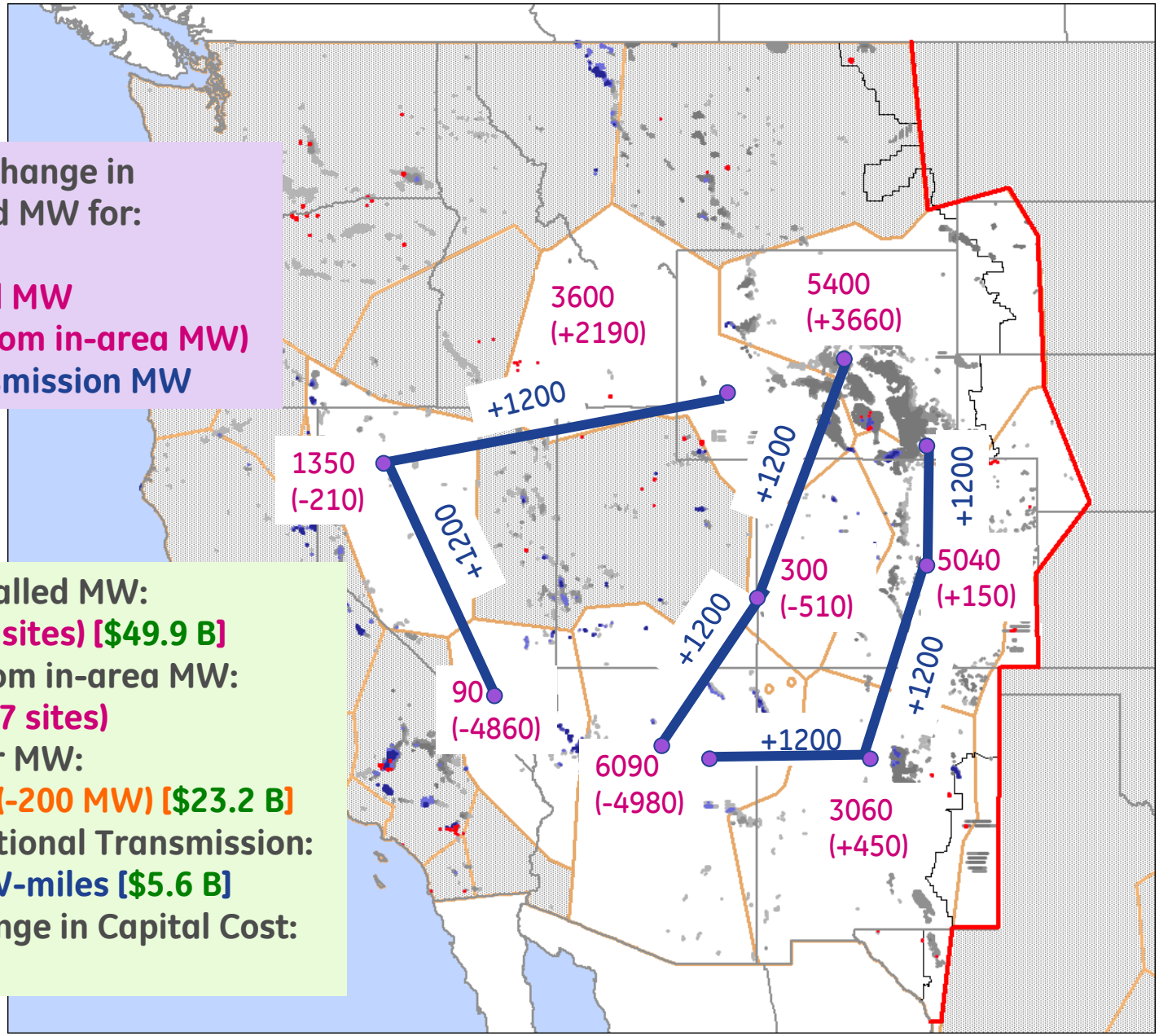
New Transmission MW
Wind MW Change



Regranularized “Local Priority” Distribution

- Refine distribution identified by global algorithm to rational components
- Use ‘whole’ 30 MW wind plants
- Use ‘Mega Project’ solar plants
- Use rational rating transmission
  - Use 345 kV AC (1200 MW/circuit) for bulk interties
  - Select in-footprint routes
  - Favor diverse routes, with intermediate substations
  - Disregard/consolidate small (<600 MW) incremental ties

Local Priority Scenario



Legend - Change in Installed MW for:

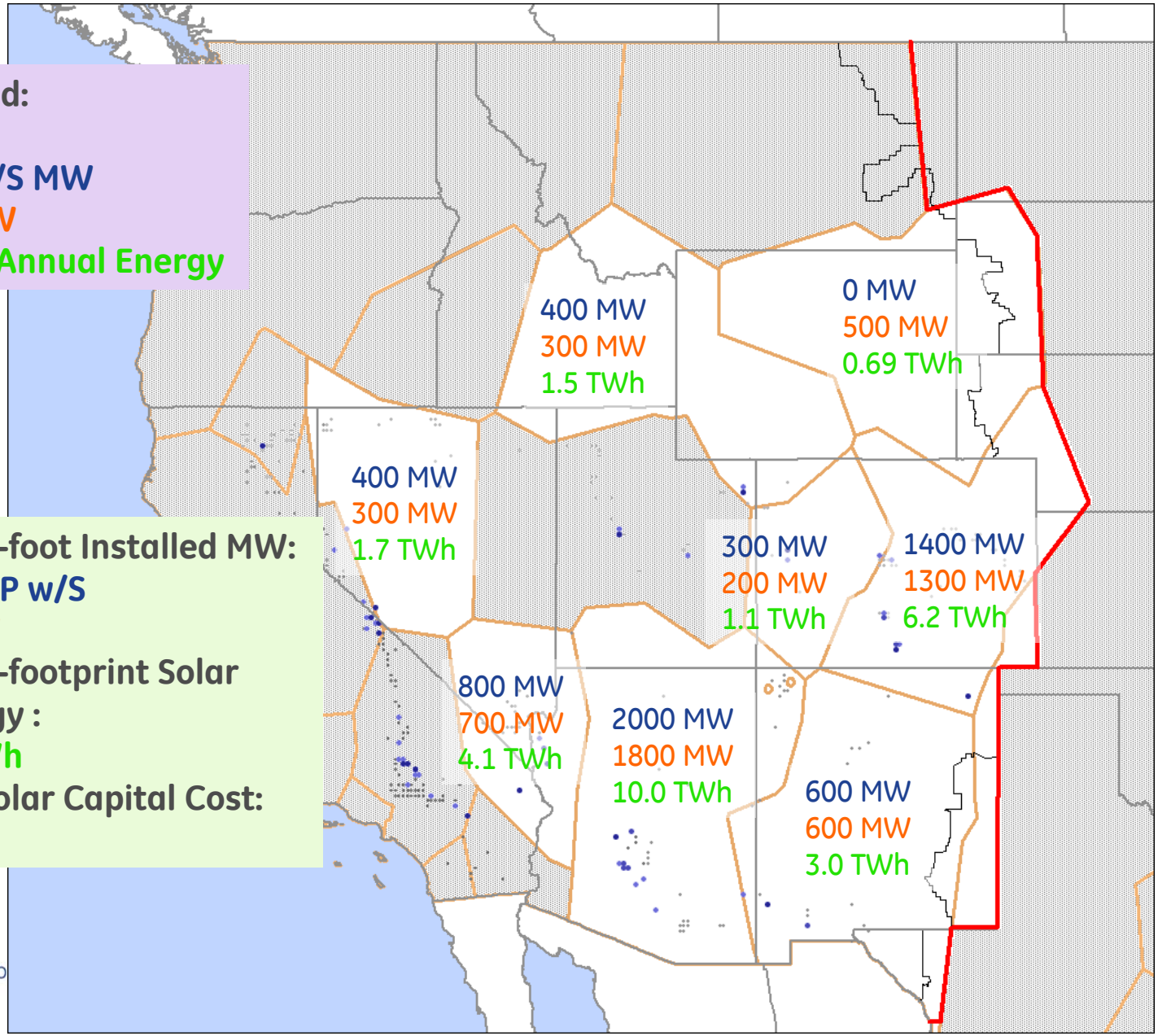
Final Wind MW
(Change from in-area MW)
New Transmission MW

Total Installed MW:
24930(831 sites) [$49.9 B]
Change from in-area MW:
-4110 (-137 sites)
Total Solar MW:
5800 MW (-200 MW) [$23.2 B]
Total Additional Transmission:
+ 3500 GW-miles [$5.6 B]
Total Change in Capital Cost:
-$3.4 B

High Solar Scenario

- Double Energy Production for all Solar Resources:
- 10% In-footprint
  - 7% CSP with storage
  - 3% PV
- 6% Outside-footprint
  - 4.2% CSP with storage
  - 1.5% PV
- Respect limitations of available sites
- Use 30% In-area Wind Distribution
- No new inter-area transmission

High Solar Scenario



Legend:

CSPw/S MW
PV MW
Solar Annual Energy

Total In-foot Installed MW:
5900 CSP w/S
5700 PV
Total In-footprint Solar Energy :
28.5 TWh
Total Solar Capital Cost:
$46.4 B

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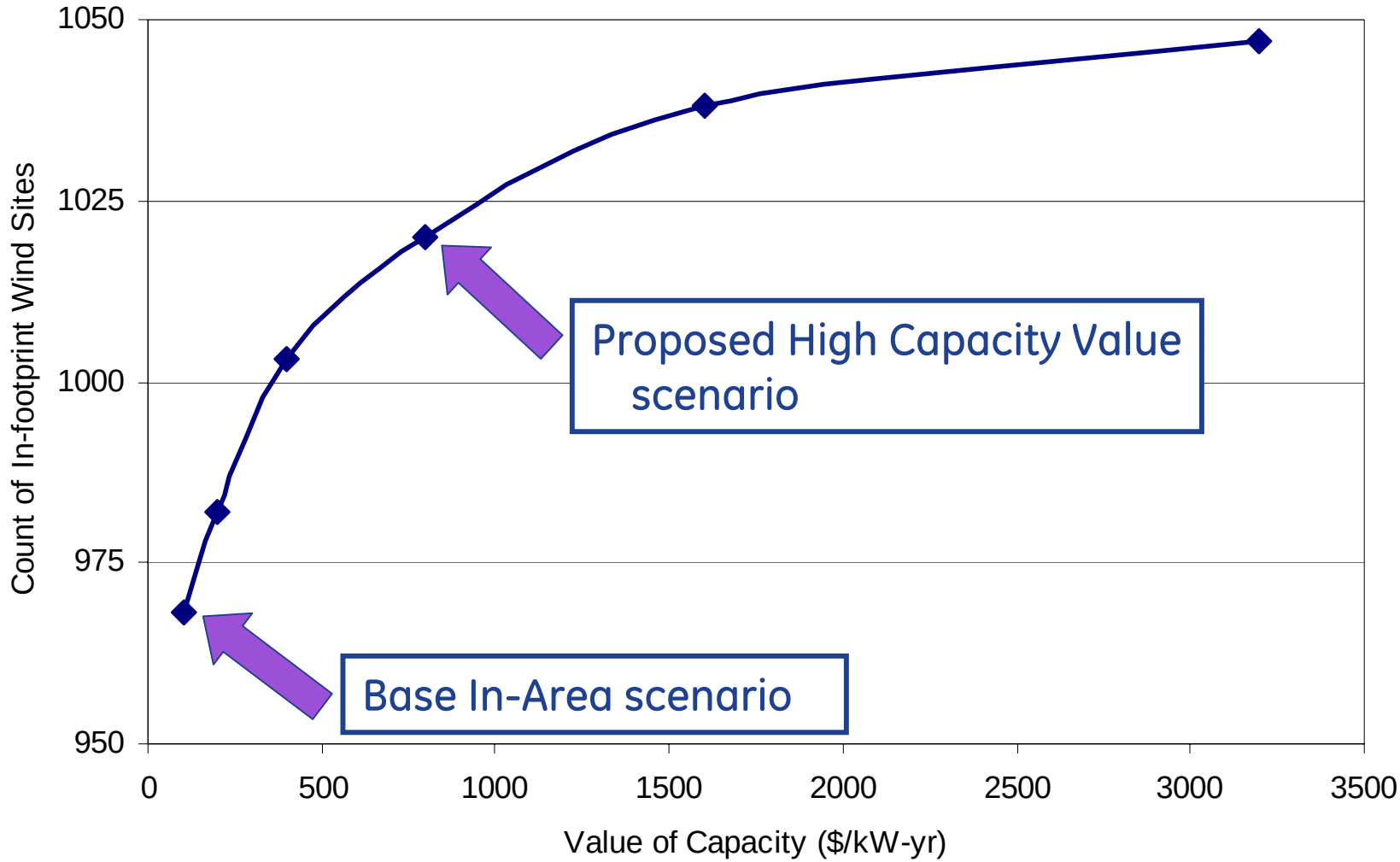
High Capacity Value Scenario

- What is scenario?
  - Assign higher value to wind plant capacity value
  - Reselect wind sites by area
  - Use 30% In-area Solar Distribution
  - No new inter-area transmission

- What do we hope to learn?
  - How much does the value of energy production (per MWh) increase?
  - Does total value of energy production (per $/MW/yr) increase?
  - Does better coincidence of wind production with peak loads result in better/easier operation?

High Capacity Value Scenario



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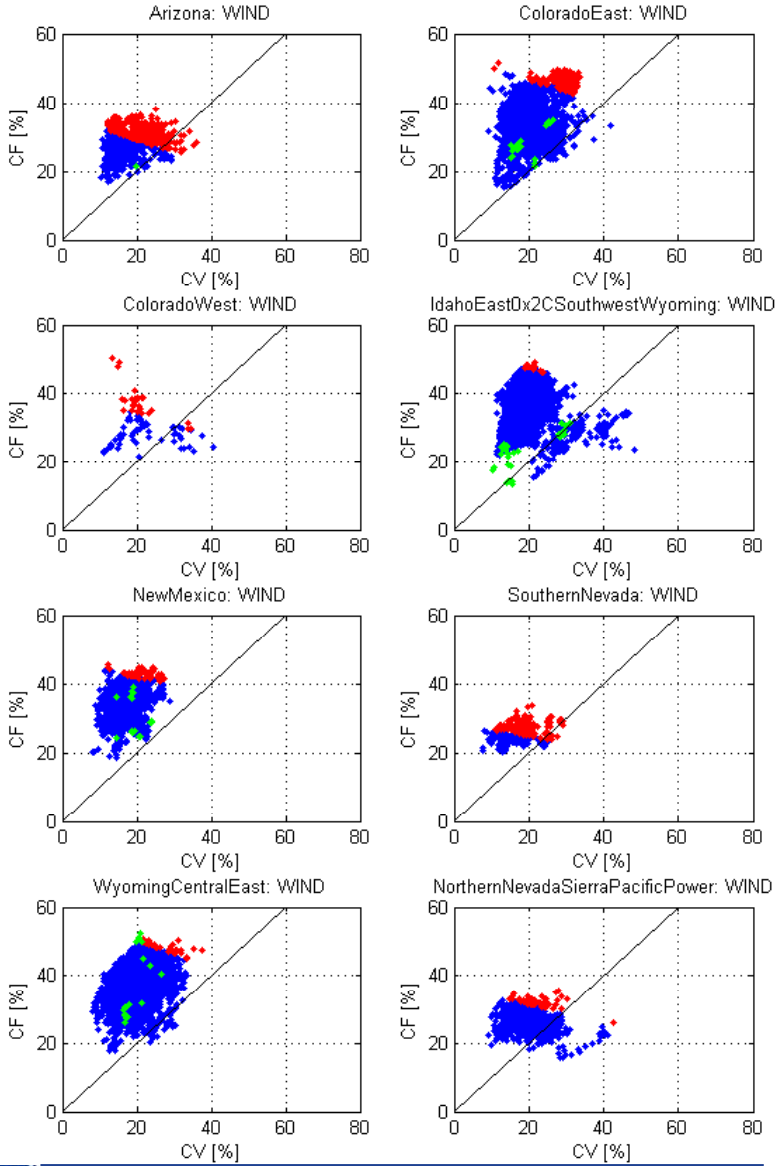
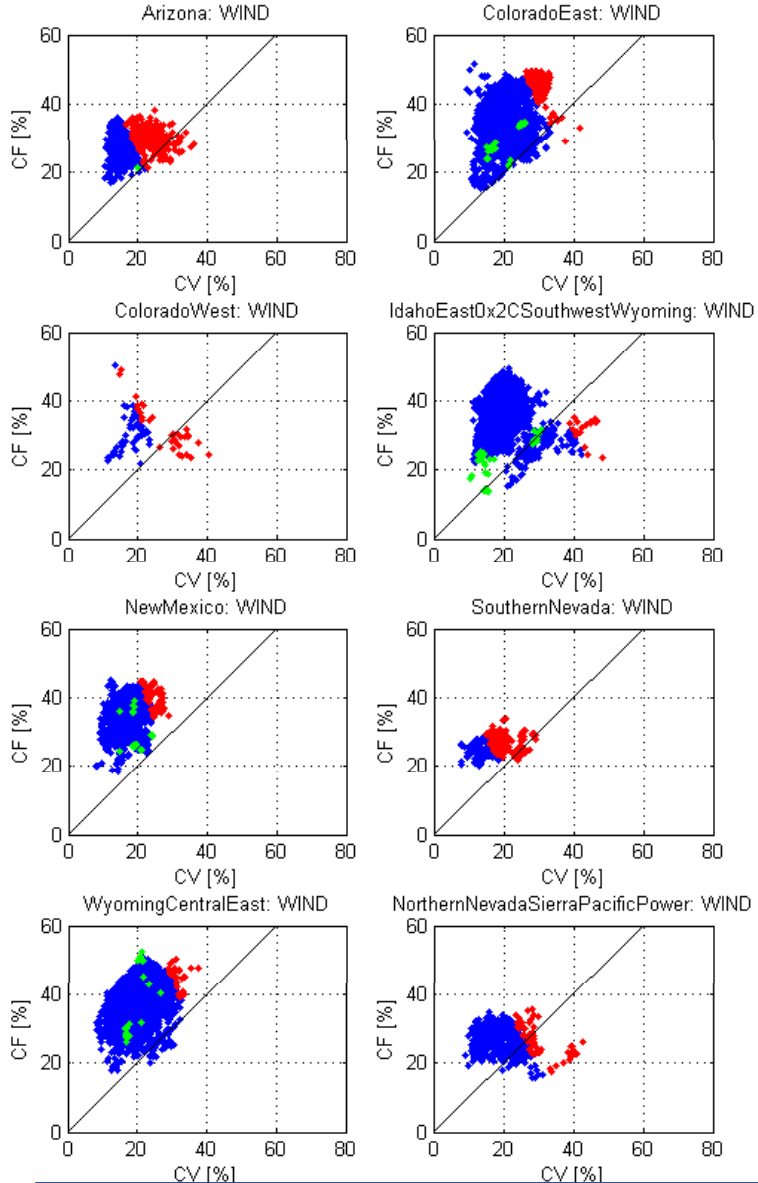
High Capacity Value Scenario



Capacity Value:$100/kw-yr



Capacity Value:$800/kw-yr

Wrap up

- 4 New Candidate Scenarios
  - “Mega Projects” scenario
  - “Local Priority” scenario
  - “High Solar” scenario
  - “High Capacity Value” scenario
- Next steps
  - Analysis
    - Statistics
    - Production simulations
    - QSS time simulations
  - Examining Operational Issues
    - in hourly and subhourly timeframes
    - exploring mitigation alternatives