GE
Energy

TRC Conference Call – Western Wind & Solar Integration Study

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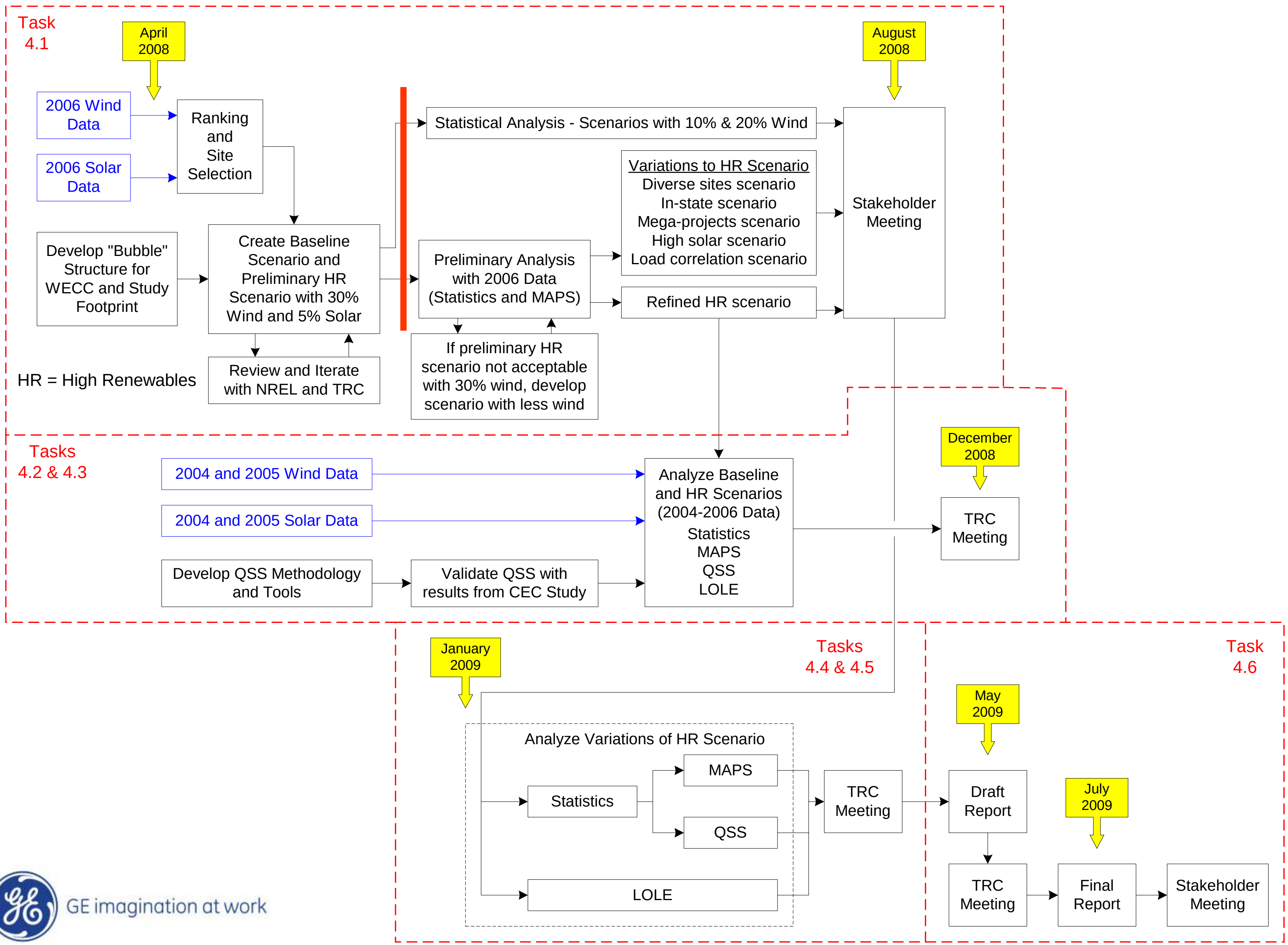
June 25, 2008

Project Schedule



GE imagination at work

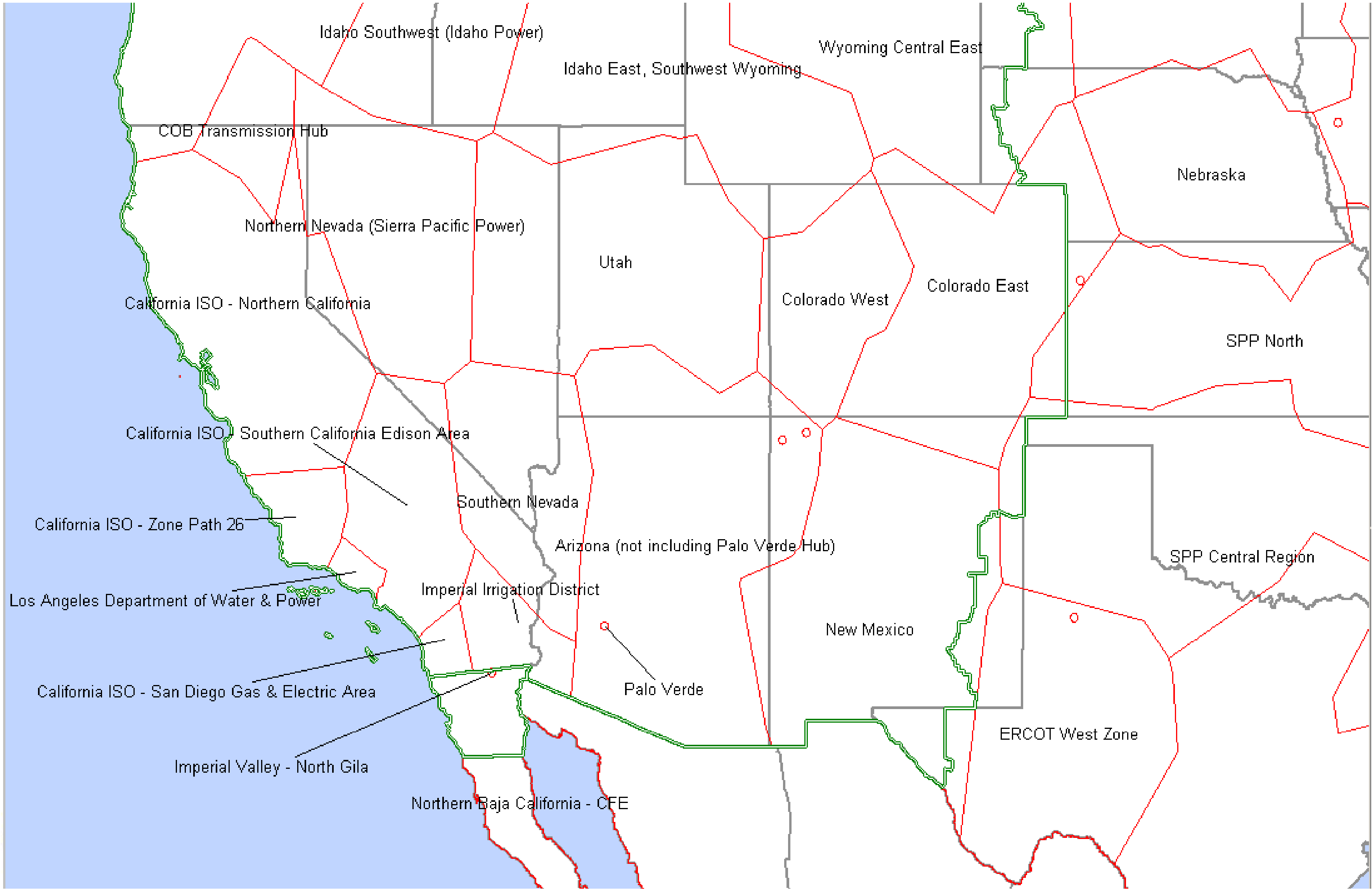
Data - Hourly

- Hourly wind profiles for 2004, 2005, and 2006 (actual and meteorological forecast) provided by 3TIER.
- Hourly PV and CSP profiles for 2004, 2005, and 2006 (actual and forecast) provided by NREL.
- Historical loads by transmission zone from Energy Velocity (EV) database, escalated to 2017 using the NERC forecasts.
- Initial review of in-footprint hydro generation looks promising. During commitment process, hydro will be adjusted based on forecasted wind.
- Balance of system generation data (i.e capacities, heat rates, emissions, etc) based on EV database.
- Remaining system data (fuel and O&M costs, etc) based on internal database.
- Transmission zones, transmission areas, control areas as defined by EV database.
- WECC path ratings updated to include feedback received to-date.

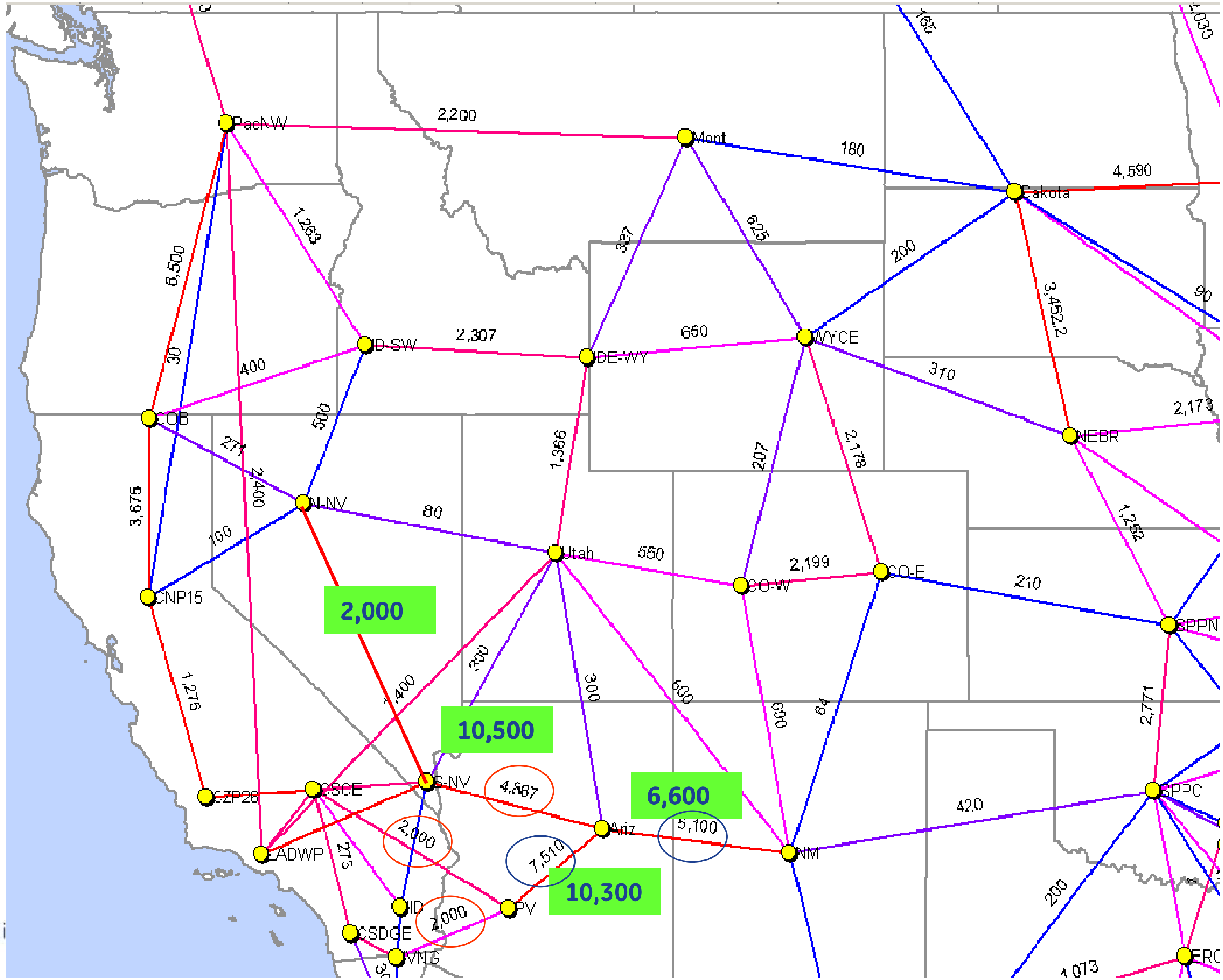
Data – Subhourly, Other

- Wind: 10-minute profiles for 2004, 2005, and 2006 provided by 3TIER.
- Solar: fragmented, various 1-minute to 15-minute profiles.
- Load: fragmented, various 1-minute and 10-minute profiles.
- Transmission system: multiple power flow scenarios provided

Transmission Areas



Updated WECC Path Ratings

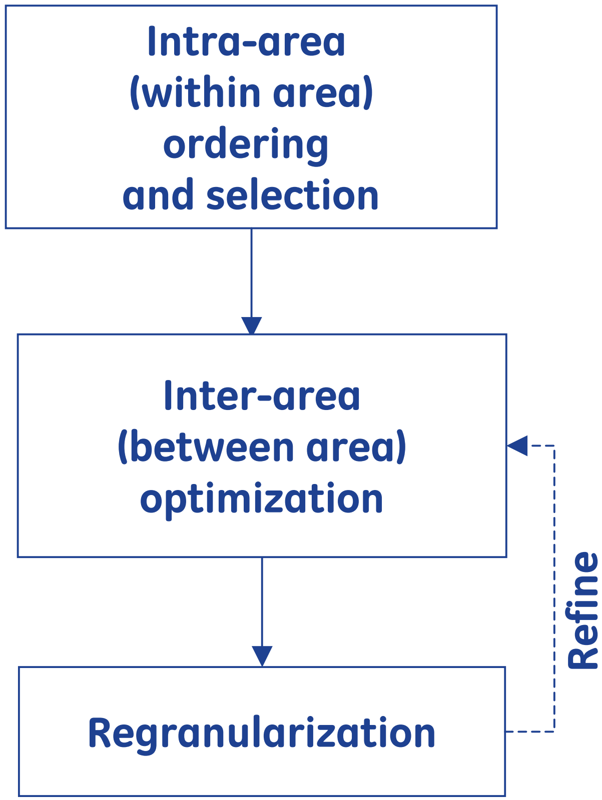


Scenarios for Analysis by August

- Baseline Scenario
  - 2017 Load, 2008 Wind & Embedded Solar
- High Renewable In-Area Scenario (% by Energy)
  - 2017 Load
  - In Footprint: 30% Wind, 5% Solar (70% CSP, 30% PV)
  - Out of Footprint: 20% Wind, 3% Solar (70% CSP, 30% PV)

Algorithm Overview

4 Stage process:



Order the available wind, PV and CSP sites within each area in descending order of preference, based on pre-selection of existing plants, and a mix of energy value, geographic diversity and capacity value. Select top sites necessary to meet energy target (e.g. 30% for wind in-study footprint) with in-area resources. Intra-area selection is run once for each of wind, PV and CSP. Result is In Area Scenario.

Adjust selection of top sites, by replacing in-area site with remote sites, based on minimizing costs of wind, PV and CSP generation equipment, new transmission and losses. Inter-area optimization is run once for each of wind, PV and CSP.

Hueristically adjust continuously optimized site selection and transmission reinforcements to reflect discrete nature of components, including whole wind and solar plants and realistically sized transmission reinforcements. Regranularization is performed once, to combine results of all three optimization runs.

Refinement will run Inter-area optimization with rationalized transmission reinforcements, to better utilize the new transmission. Results are additional study scenarios.

Intra-area (within area) ordering

Discussion of philosophy and notation.

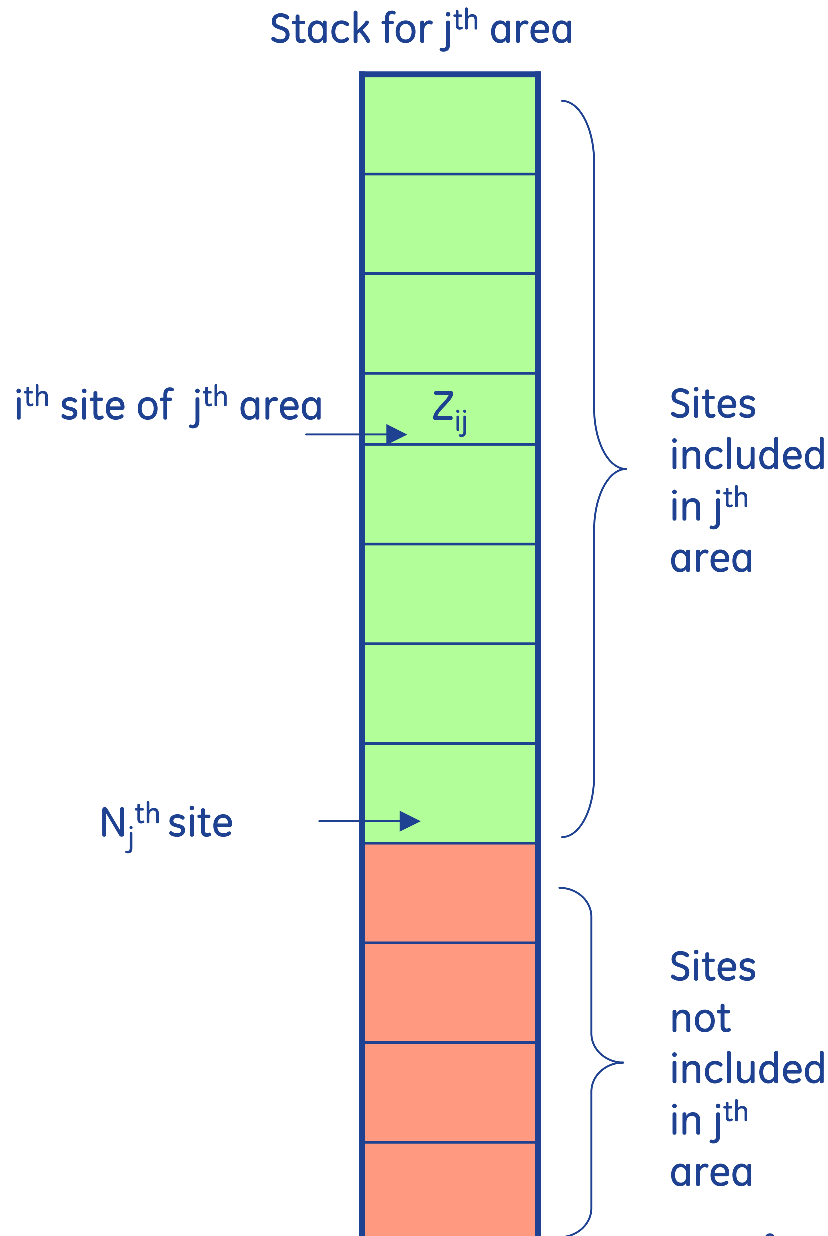
The intent of the intra-area ordering is to create a list of candidate sites within each area that is sorted from best to worst, according to the criteria presented in the following pages.

For the study there are 8 areas within the study system and 7 outside. At any point in the intra-area ordering, we will be concentrating on the j^{th} area.

Within that area, there will be a subset of sites selected. The count of sites in the j^{th} area at any point will be N_{j}. Any specific site within the stack is the i^{th} .

Thus, the value associated with any characteristic (say) Z of the i^{th} site of j^{th} area will be Z_{ij}

And, the cumulative value associated the entire stack down to the i^{th} site will be denoted with an underscore. For example, the sum of all values of Z down to and including the i^{th} site of j^{th} area will be a $\underline{Z}_{ij}$



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Inter-area (between area) ordering

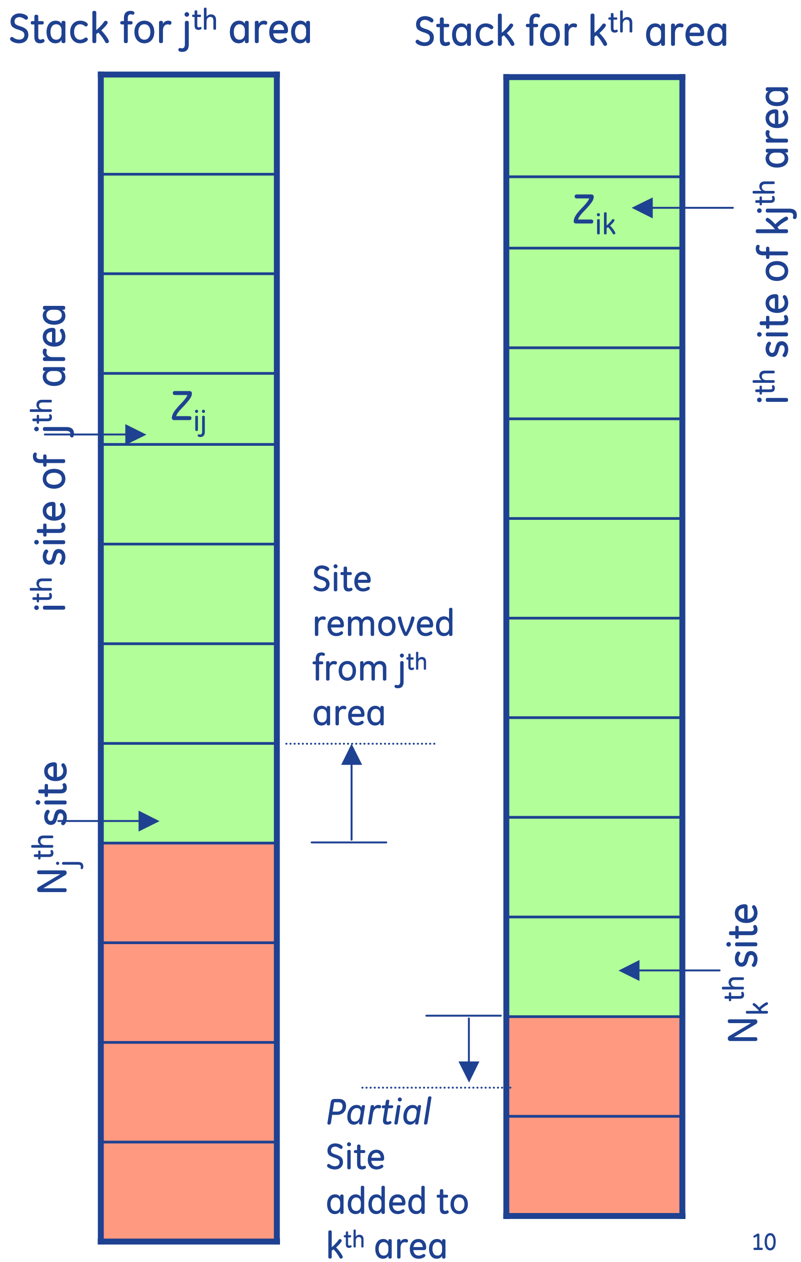
The intent of the inter-area ordering is displace less valuable sites from one area, making it a net importer, while replacing the energy with more valuable sites in another area, making it a net exporter. The total renewable energy will be held constant. Thus, within the study, pairs of the 8 areas will be compared (repeatedly).

For notation purposes, throughout the following discussion, the area losing in-area renewables will always be the j^{th} area, and the area adding renewables for export will always be the k^{th} area.

Thus, the value associated with any characteristic (say) Z of the i_{th} site of j^{th} (importing) area will be Z_{ij} or Z_{ik} for the exporting area.

Parameters related to inter-area quantities will be denoted as Z_{jk}. For example, the power transfer to the j^{th} area from the k^{th} area, will be denoted as PT_{jk}.

Since energy production between sites is not constant, fractional sites will be added to the k^{th} area when entire sites are deleted from the j^{th} area.



GE imagination at work

Creating a physically sensible scenario

At the conclusion of the descent, plant indices in each area and for each renewable technology must (obviously) be rounded off to integer values, but the more challenging need is for transmission to be rationalized:

In general, every area may be connected to every other area by new transmission, and rating (and possibly direction) of these connections will be different for each of the 3 renewable technologies.

For each pair, if $PT_{jk} * TDF \geq L_{jk}$, then $(PT_{jk} * TDF - L_{jk})$ is the incremental amount of MW rating needed between areas j and k, with a length of D_{jk}.

The incremental ratings for PV and CSP will be added, then the largest incremental rating between the wind and the combined solar technologies will be considered. Alternative routings will be considered.

Lines of very low rating (small PT_{jk}) can be discarded.

Lines of moderate rating and length, may be replaced with equivalent new capability representative of the type of transmission typical in the affected areas (e.g. 230kV or 345kV in much of the study area).

Lines of substantial rating, may be replaced with new EHV or HVDC equivalent capability, suitably rated. This could be based on representative SIL, or perhaps multiples of 100MW, in the case of HVDC.

Objectives and Constraints on Wind and Solar Plant Siting

Assumptions:

1. Need to strike a balance between quality of wind and solar resources and distance from load centers
2. Geographic diversity within regions has value
3. Existing transmission limits apply to inter-area exchange of wind, but may be discounted due to other firm commitments
4. Cost of transmission can reasonably be approximated by $/MW-mile metrics
5. Exchange of wind (and solar) power between regions at less than available inter-area transfer levels incurs no incremental transmission reinforcement cost
6. Hard limit/objectives
   a. 30% wind energy inside footprint; 5% solar (70% of which is CSP, 30% PV)
   b. 20% wind energy outside footprint; 3% solar (70% of which is CSP, 30% PV)
   c. Pre-selected wind plants are included (Baseline Scenario)
7. 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 of wind sites with transmission and losses
8. Given that Wind and the 2 types of Solar energy production are not interchangeable (due to the project hard limits), the optimization should be run independently for each of Wind, PV, and CSP.
9. Intra-area site selection for 8 areas inside footprint and 7 areas outside footprint will give In-Area Scenario
10. Inter-area site swapping for 8 areas inside footprint (outside footprint will not change) will give input to the next study scenario

Parameters

Many parameters could be adjusted to examine sensitivity to various assumptions, and to help populate scenarios for later in the project.

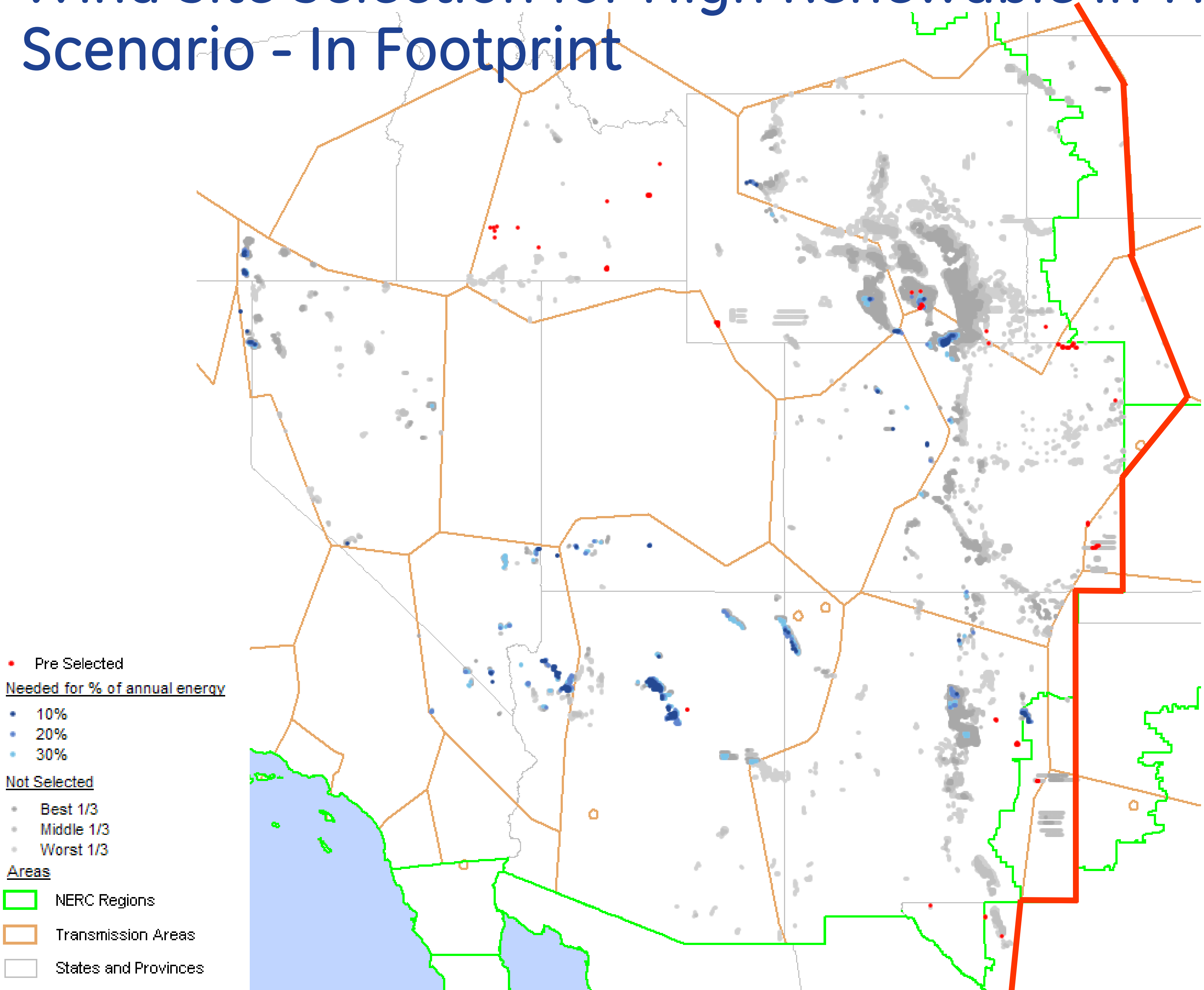
Intra-area parameters :

- W_d(EW,NS) initial value: (1., 1.) for Wind
- W_{GD} initial value: 0.0002 pu/mile (2% bonus for 100 miles of diversity) for Wind
- W_d(EW,NS) initial value: (0.0,1.41) for Solar
- W_{GD} initial value: 0.0002 pu/mile (2% bonus for 100 miles of diversity) - for Solar
- W_{cv} initial value: \$100,000 \$/MW-year (\$500/kW for new installed peaker capacity, 20% capital recovery factor)

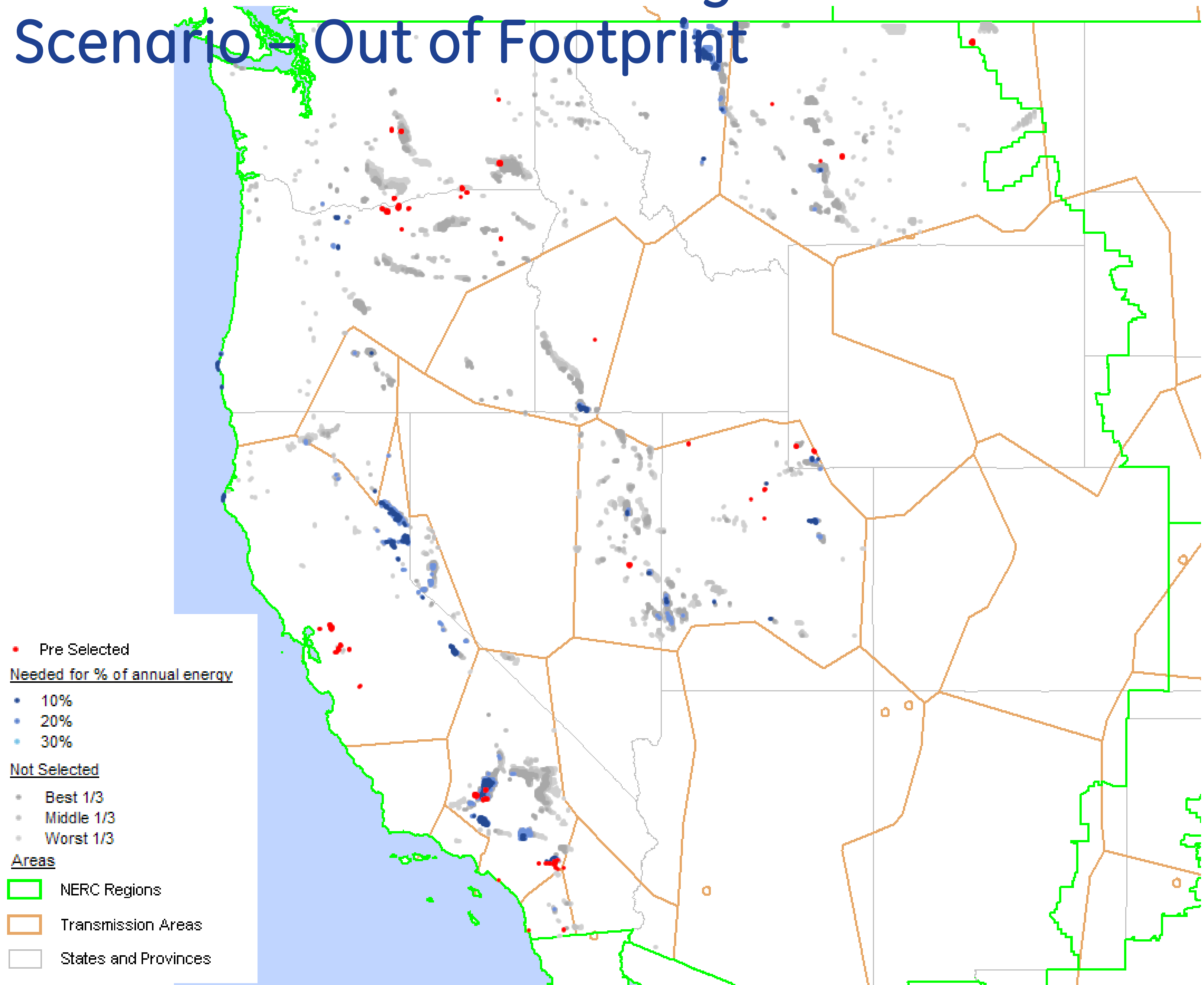
Inter-area parameters:

- FCR_j initial value: 0.20 (20%) (by area)
- TCC_j initial value: \$2M/MW (by area) for Wind
- TCC_j initial value: \$4M/MW (by area) for CSP Solar
- TCC_j initial value: \$4M/MW (by area) for PV Solar
- TCF initial value: \$160/MW-mile-year (\$800/MW-mi, 20% capital recovery factor)
- TDF initial value: 0.7 (70%, no dimensions)
- GDP initial value: 0.0005 (5% per 100miles)
- LDF initial value: 0.0001 (1% per 100 miles)

Wind Site Selection for High Renewable In-Area Scenario - In Footprint



Wind Site Selection for High Renewable In-Area Scenario – Out of Footprint

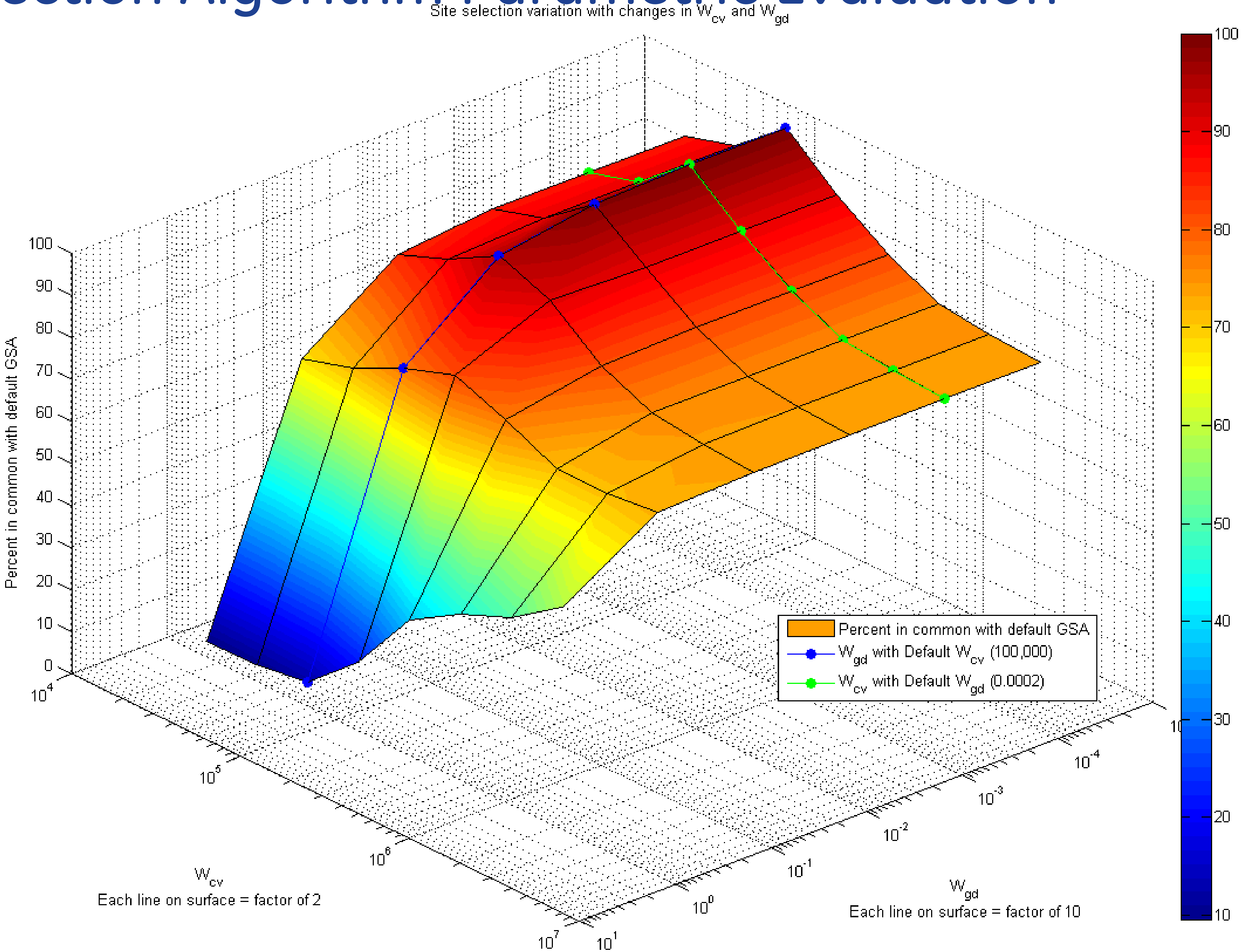


Wind Site Selection for High Renewable In-Area Scenario – Tabular Summary

In Footprint Transmission Area	Annual Load Energy (GWh)	Number of Sites Needed for 30%	Total Number of Possible Sites
Arizona	100,516	366	958
Colorado East	61,372	162	2,838
Colorado West	8,717	27	84
Idaho East, SW Wyoming	12,449	47	2,447
New Mexico	30,208	87	2,977
Northern Nevada	14,460	51	712
Southern Nevada	39,642	164	321
Wyoming Central East	22,155	53	7,373

Outside Footprint Transmission Area	Annual Load Energy (GWh)	Number of Sites Needed for 20%	Total Number of Possible Sites
COB Transmission Hub	1,459	5	309
Northern California	128,944	335	771
Southern California Group	224,214	479	2,006
Idaho Southwest	17,962	40	482
Montana	14,161	33	1,165
Northwest	178,359	390	3,211
Utah	41,433	99	1,479

Selection Algorithm Parametric Evaluation



Analysis for August Meeting

- MAPS Analysis
  - Baseline & High Renewable In-Area Scenarios
  - Transmission Area
  - 2006 Load Shape
- Hourly Statistical Analysis
  - Baseline & High Renewable In-Area Scenarios
  - Transmission Area, Transmission Zone, Control Area
- Subhourly Selected Statistical Analysis
- Additional Candidate High Renewable Scenarios
  - Between-Area Scenario
  - High Solar Penetration
  - Mega Wind Projects
  - Etc