BUILDING A WORLD OF DIFFERENCE®

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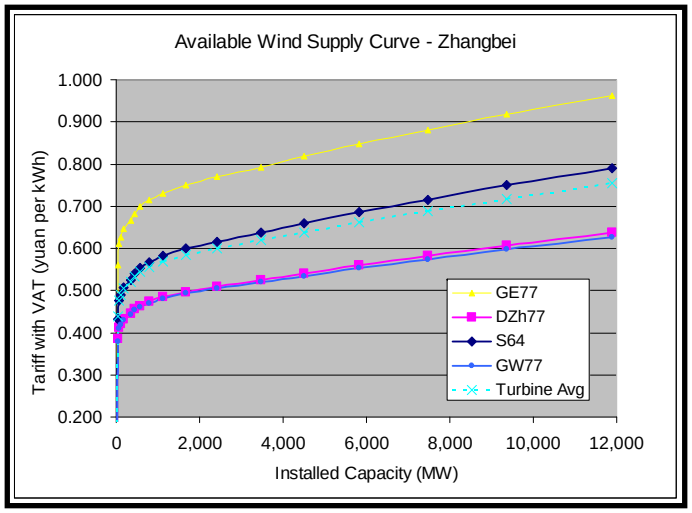
3: Supply Curve Development

Methodology

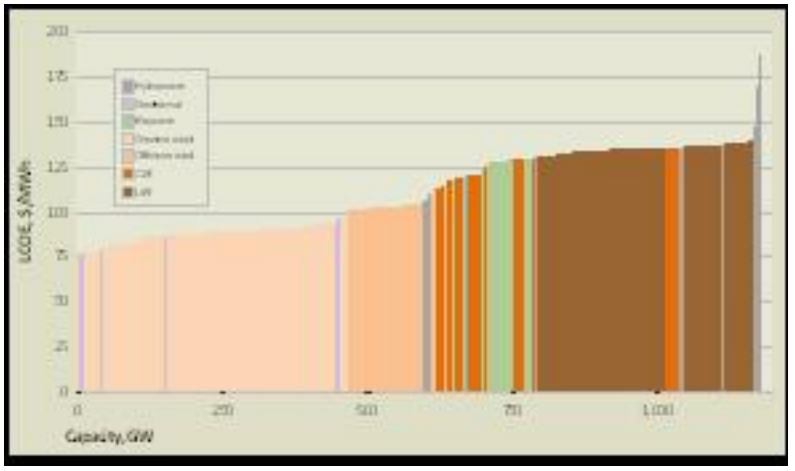
Supply Curve Development in China

- Supply curves for renewable energy typically reflect the cumulative quantity of various renewable resources/projects, ranked from lowest to highest cost.
- Supply curve can be comprised of a single technology or multiple technologies
  - Wind supply curve (Zhangbei) compares capacity of wind technologies and cost
  - RETI supply curve compiles all renewable energy options in a region into same supply curve

Zhangbei Wind Example



RETI Example



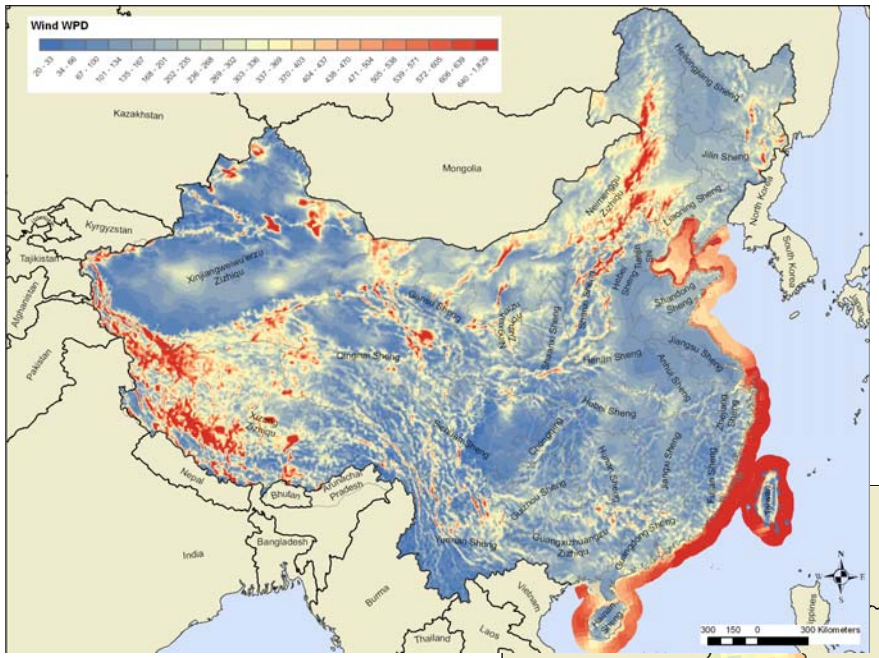
Steps to Developing Renewable Energy Supply Curve

1. Group resources with similar characteristics using GIS
2. Develop performance and cost assumptions to calculate cost (busbar cost = LCOE) for each Resource Group
3. Create supply curves using LCOE for specified regions by rank ordering lowest to highest cost resources

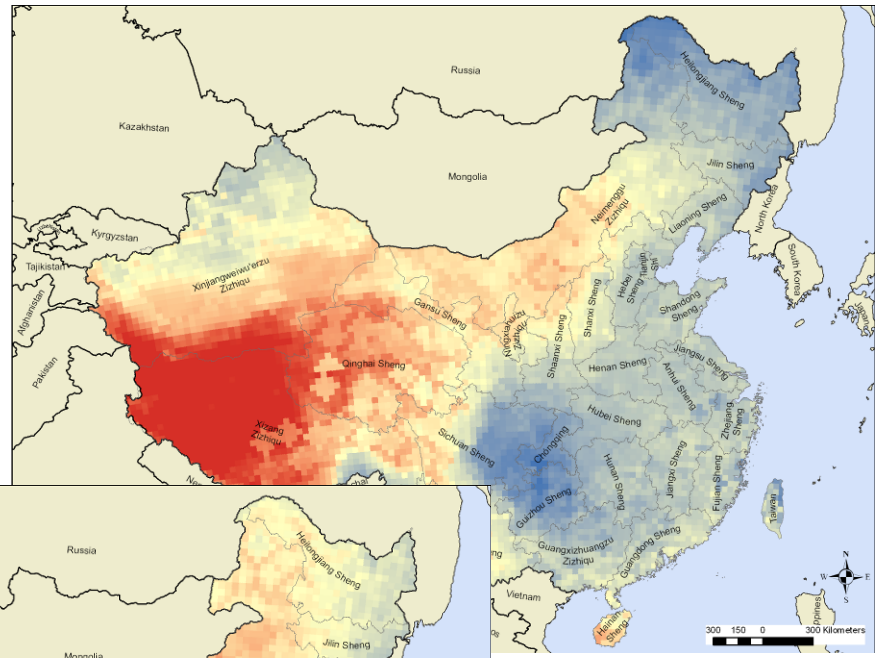
Group and Characterize Resources

- Using GIS maps, determine technical potential.
- Apply exclusions for ‘developable’ resources.
- Identify groups of similar ‘developable’ resource. Quantify resource.
- Determine location-specific performance of resource
- Determine location-specific cost structure of resource.

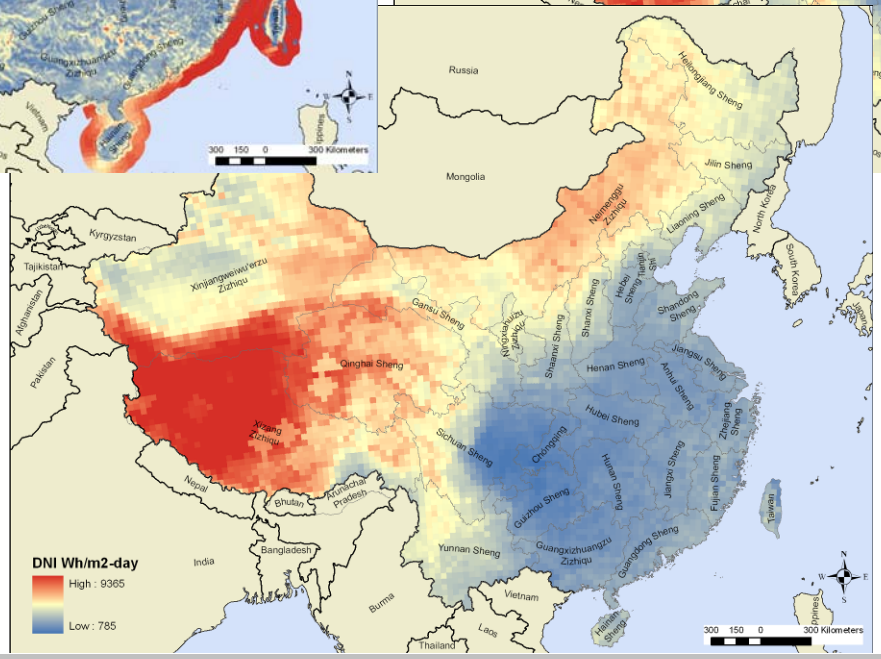
Technical Potential Using GIS Mapping



Wind



Solar PV



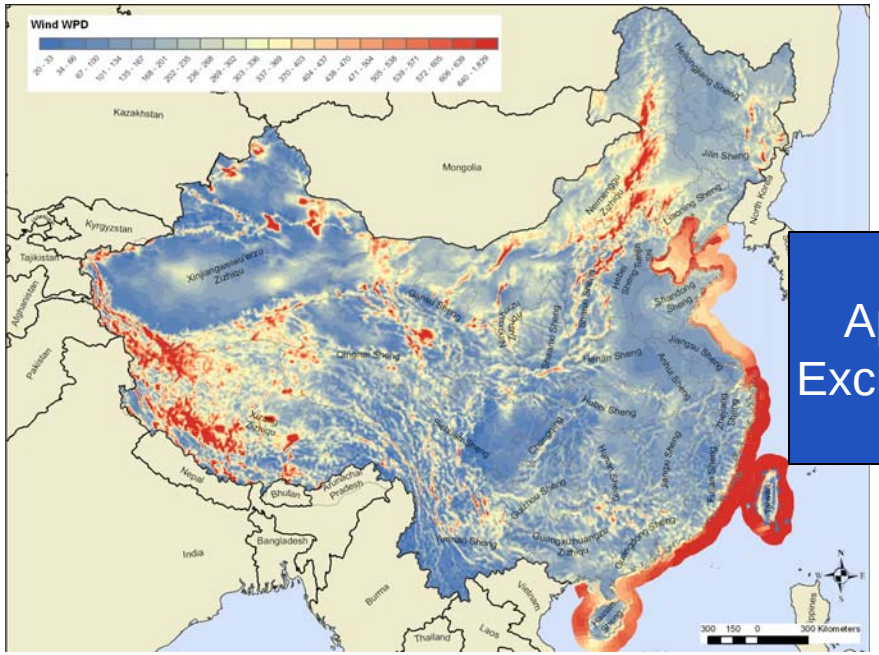
Solar CSP

GIS Resource Assumptions and Exclusions

	Onshore Wind	Offshore Wind	Solar PV	Solar CSP
Capacity	5 MW/km^2	5 MW/km^2	30 MW/km^2	30 MW/km^2
Efficiency	WPD/CF Used to calculate energy		15%	15%
Ground coverage ratio	–	–	50%	25%
Exclusions				
Protected areas	All Protected Areas Excluded			
Slope	Over 20%	Over 20%	Over 5%	Over 3%
Elevation	Over 5000 m	Over 5000 m	Over 4000 m	Over 4000 m
Depth	–	None	–	–
Distance from Shore	–	Over 100 km	–	–
Resource	Under 200 WPD	Under 300 WPD	None	Under 5 kWh/m^2-day
Land Use	Croplands 50%, Forests 90%	None	Croplands 100%, Forests 90%	Croplands 100%, Forests 90%

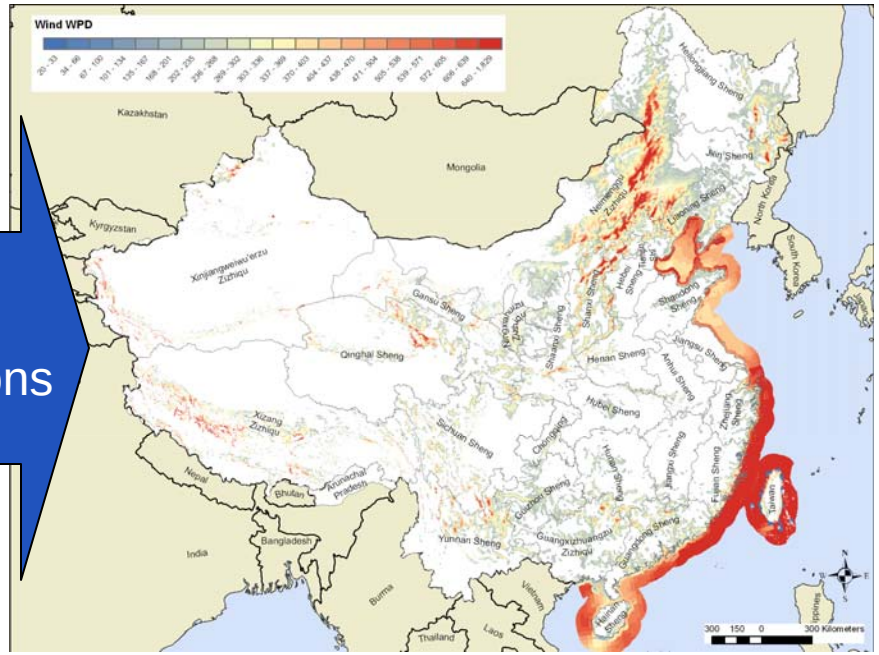
Wind Resource Assessment

Wind Resource



Apply Exclusions

After Exclusions Applied

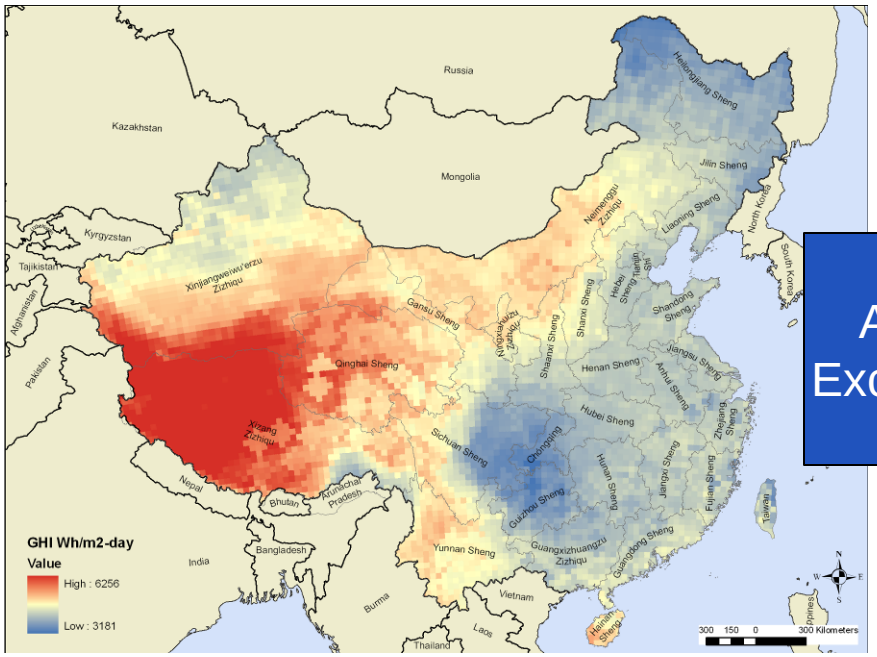


	Resource Class	Generation Potential TWh
WIND ONSHORE	3.1	5754
	3.2	3998
	3.3	4613
	4	1719
	5	749
	6	611
	7	211

	Resource Class	Generation Potential TWh
WIND SHALLOW OFFSHORE	13	257
	14	825
	15	1059
	16	715
	17	1972
DEEP OFFSHORE	23	1826
	24	1129
	25	1046
	26	1670
	27	593

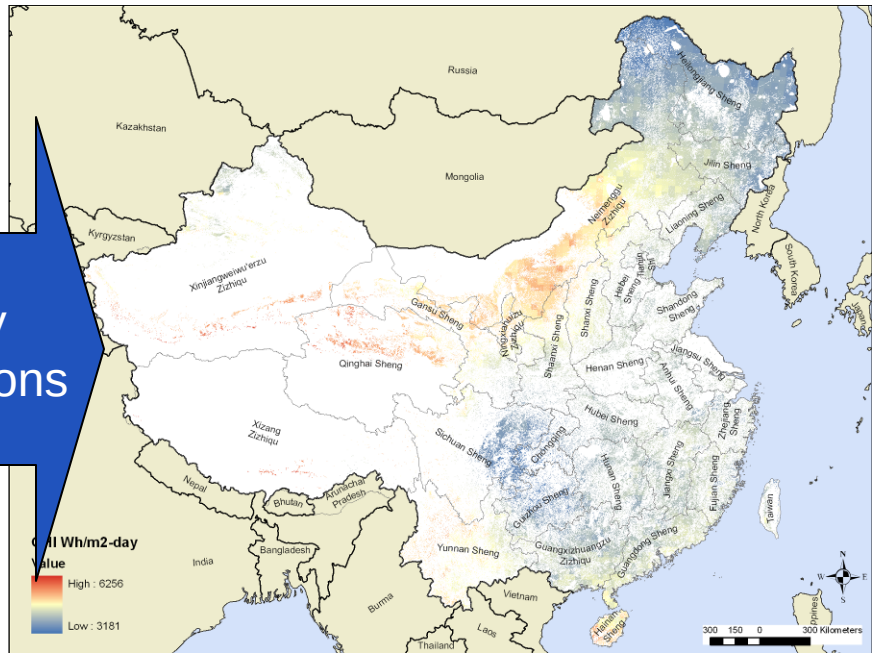
Solar PV Resource Assessment

Solar PV Resource



Apply Exclusions

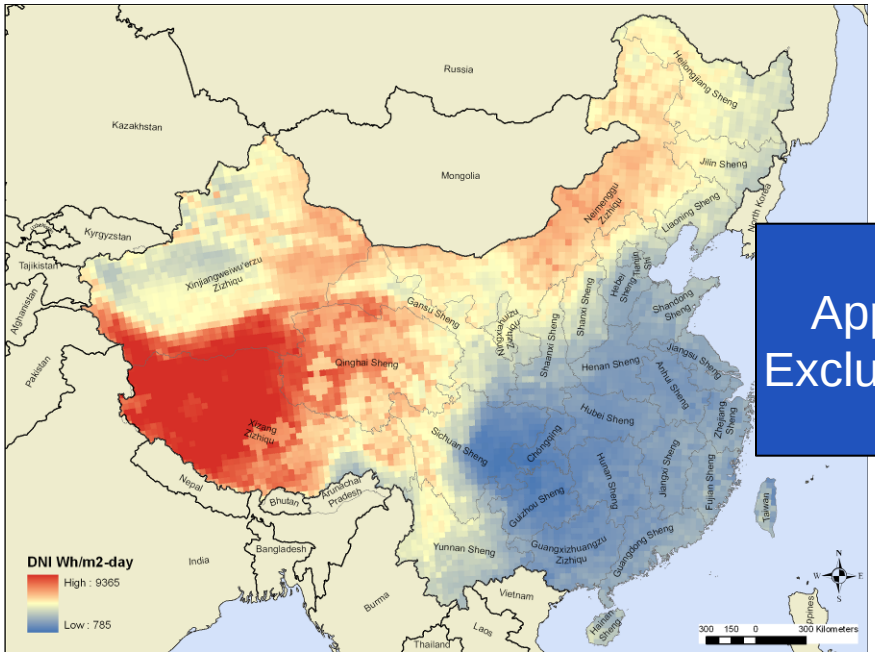
After Exclusions Applied



	Resource Class	Generation Potential TWh
SOLAR	1	23383
PHOTOVOLTAIC	2	239535
	3	20665
	4	39

Solar CSP Resource Assessment

Solar CSP Resource



Apply Exclusions

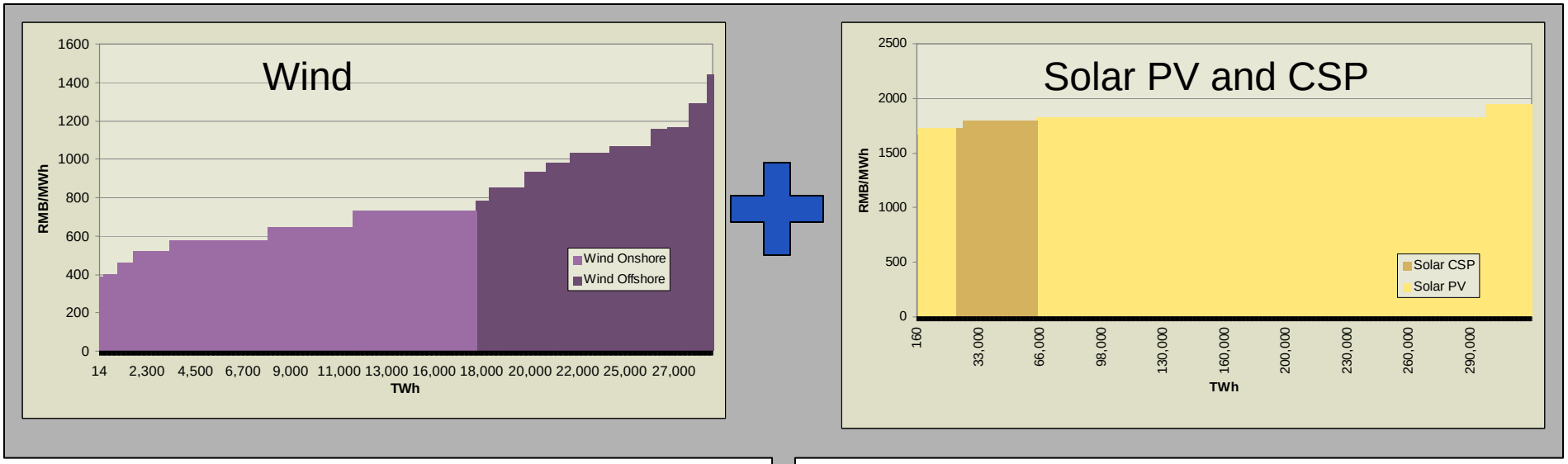
After Exclusions Applied

	Resource Class	Generation Potential TWh
SOLAR	1	39704
THERMAL (CSP)	2	3374
	3	299
	4	12

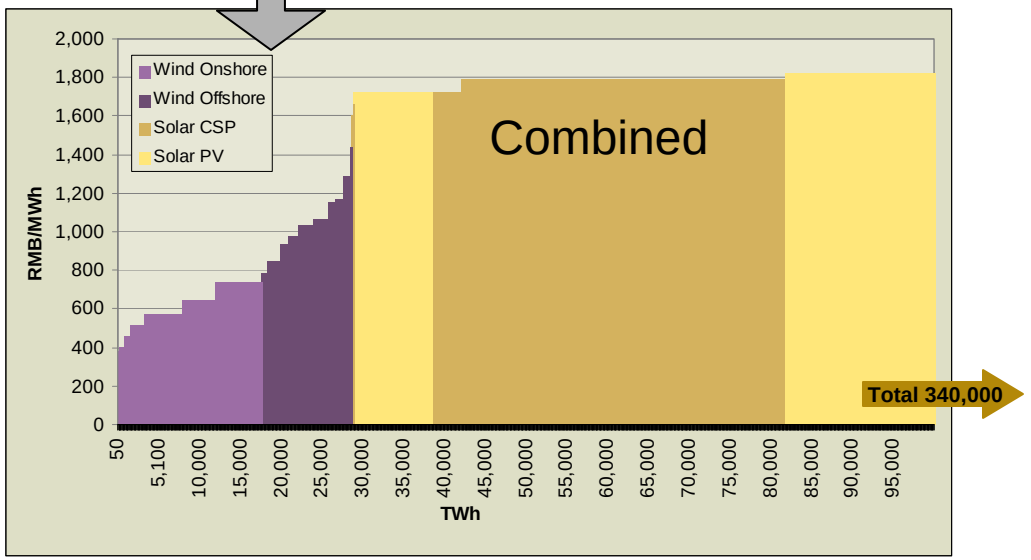
Performance and Cost Assumptions for LCOE

	Resource Class	Generation Potential TWh	Capital Cost RMB / kW	O&M RMB/kW-year	Capacity Factor	LCOE RMB/kWh
WIND ONSHORE	3.1	5754	9000	250	0.22	**0.73**
	3.2	3998	9000	250	0.25	**0.65**
	3.3	4613	9000	250	0.28	**0.58**
	4	1719	9000	250	0.31	**0.52**
	5	749	9000	250	0.35	**0.46**
	6	611	9000	250	0.4	**0.40**
	7	211	9000	250	0.42	**0.38**
WIND SHALLOW OFFSHORE	13	257	20000	800	0.34	**1.15**
	14	825	20000	800	0.38	**1.03**
	15	1059	20000	800	0.42	**0.93**
	16	715	20000	800	0.46	**0.85**
	17	1972	20000	800	0.5	**0.78**
DEEP OFFSHORE	23	1826	25000	800	0.34	**1.36**
	24	1129	25000	800	0.38	**1.22**
	25	1046	25000	800	0.42	**1.10**
	26	1670	25000	800	0.46	**1.01**
	27	593	25000	800	0.5	**0.93**
SOLAR PHOTOVOLTAIC	1	23383	20000	200	0.16	**1.94**
	2	239535	20000	200	0.17	**1.83**
	3	20665	20000	200	0.18	**1.72**
	4	39	20000	200	0.19	**1.63**
SOLAR THERMAL (CSP)	1	39704	30000	300	0.26	**1.79**
	2	3374	30000	300	0.27	**1.72**
	3	299	30000	300	0.28	**1.66**
	4	12	30000	300	0.29	**1.61**

China LCOE Supply Curves

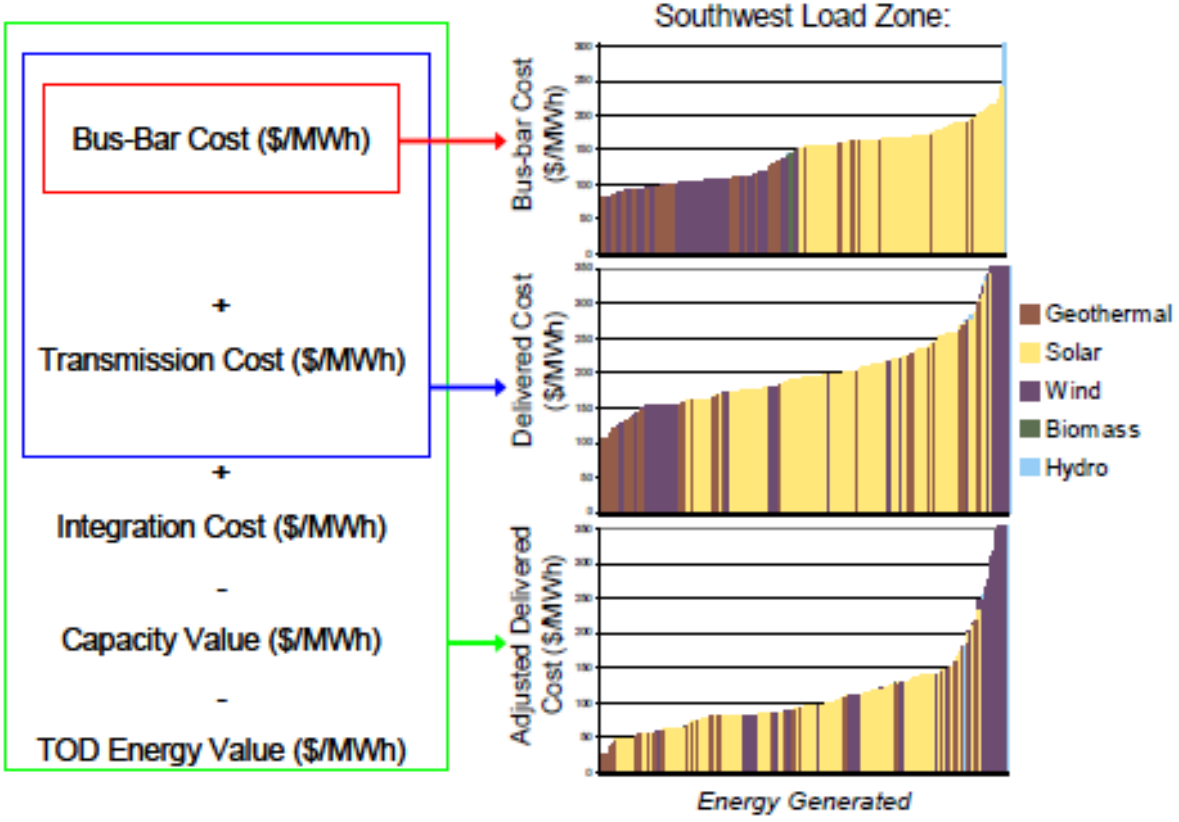


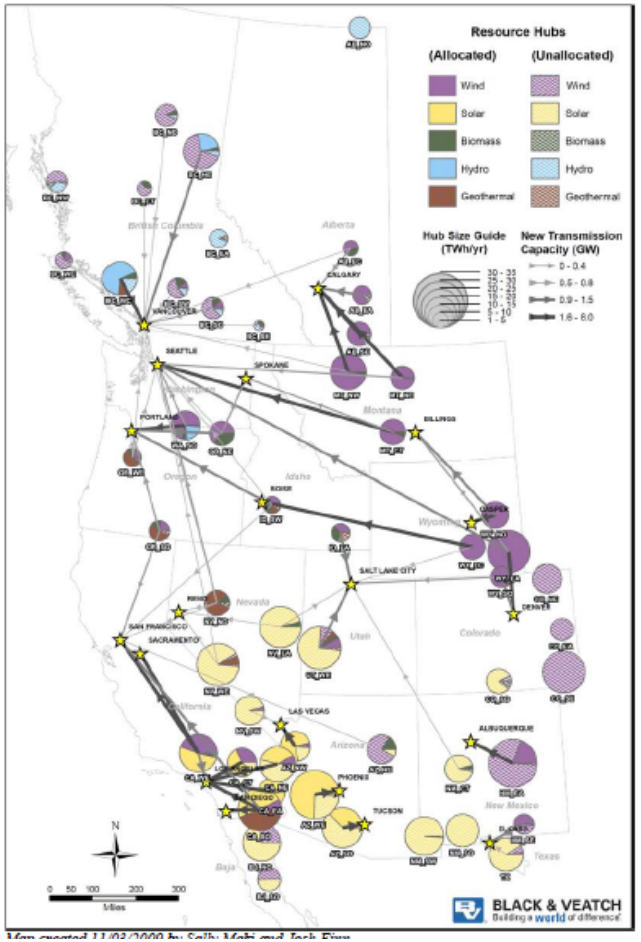
- Similar resources ranked from lowest to highest cost (LCOE)
- Combined for a national, multi-resource supply curve



Supply Curves for Different Cost Perspectives

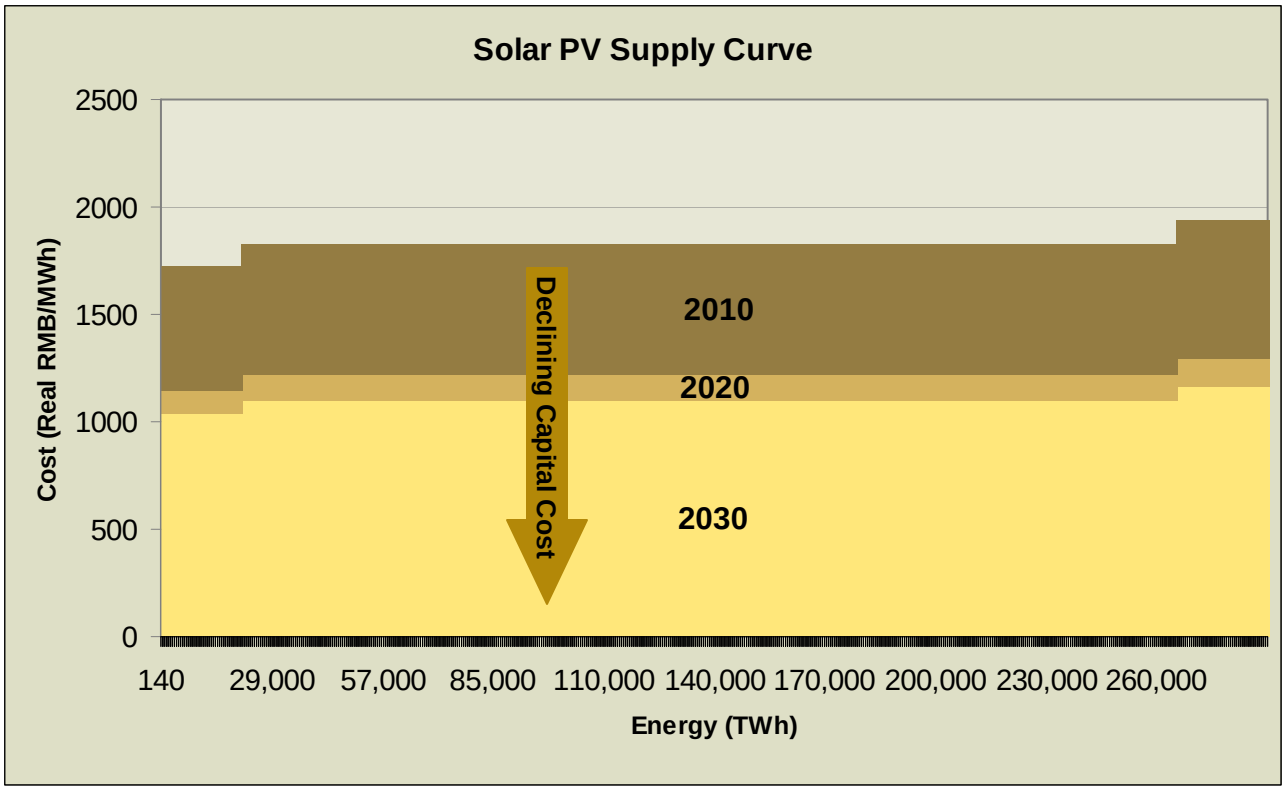
- Example: Western RE Zones; consideration of valuation, integration, and transmission, capacity planning, dispatch





Time Based Considerations

- Declining capital cost over time can alter the supply curve and will depend on point in time of analysis. Example below is for Solar PV.



Other Supply-Curve Modeling Considerations

- Renewable Energy Technology Coverage to Include
  - Wind, PV, CSP, biomass, hydro, geothermal, ocean
- Data for Renewable Energy Resources
  - Degree of geographic detail and validation
- Usability of Resulting Data / Modeling Tool
  - Analysis could be conducted in GIS, then exported to easier-to-use Excel format
- Development Time Frame
  - If multi-year analysis, consider intermediate potential for each milestone year
- Current Cost or Also Projected Cost
  - If projected cost, seek cross-technology consistency

Summary and Next Steps

- Different renewable energy technologies can be combined into a single supply curve
- Supply curves can represent different “costs”, depending on the scope of the analysis
- Supply curves can be refined with more detail and better accuracy, depending on goal of analysis