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BLACK & VEATCH

Renewable Energy Transmission Initiative Phase 1 Work Plan

Black & Veatch

Plenary Stakeholder Group

January 22, 2008

Agenda

- Introduction
- Brief Renewable Energy Market Overview
- Overall Phase 1 Approach
- Phase 1A Work Plan and Schedule
- Expectations for Feedback
- Supply Curve Concepts

Introductions

Ryan Pletka

Ric O'Connell

Tim Mason

Black & Veatch: Introduction

- Global consulting, engineering, and construction
- Key Sectors: Energy, Water, Information, Government Services
- Involved in more megawatts of power generation than any other company (~200,000 MW)
- 9,000 employees in over 100 offices (7 in California)

Black & Veatch
Global Renewable Energy Group

- Multidisciplinary group of about 150 staff across company
- Services from R&D to turnkey EPC projects
- Experienced in all energy sources – no favorites
  - Wind
  - Hydro
  - Solar Thermal
  - Biomass
  - Landfill Gas
  - Anaerobic Digestion
  - Ocean Energy
  - Solar Photovoltaic
  - Geothermal
  - Ethanol / Biodiesel
- Key renewables offices
  - Kansas City, MO
  - San Francisco, CA
  - Sacramento, CA
  - Denver, CO
  - Washington DC
  - Raleigh, NC
  - Ann Arbor, MI
  - London, UK

National Solar Thermal Test Facility

Black & Veatch Renewable Energy Highlights

- NREL - CA concentrating solar power
- CEC – RPS / PIER Program Support (sub to KEMA & ICF)
- Texas CREZ – 6000 MW 345 kV wind-transmission loop
- LADWP – RPS support (2003-2005), RE assessment in CA, NV, AZ, UT
- SMUD – RPS Support (2005-Present)
- PG&E – RPS Support (2006-Present)
- SDG&E – expert witness on Sunrise Powerlink

Black & Veatch Renewable Energy Highlights

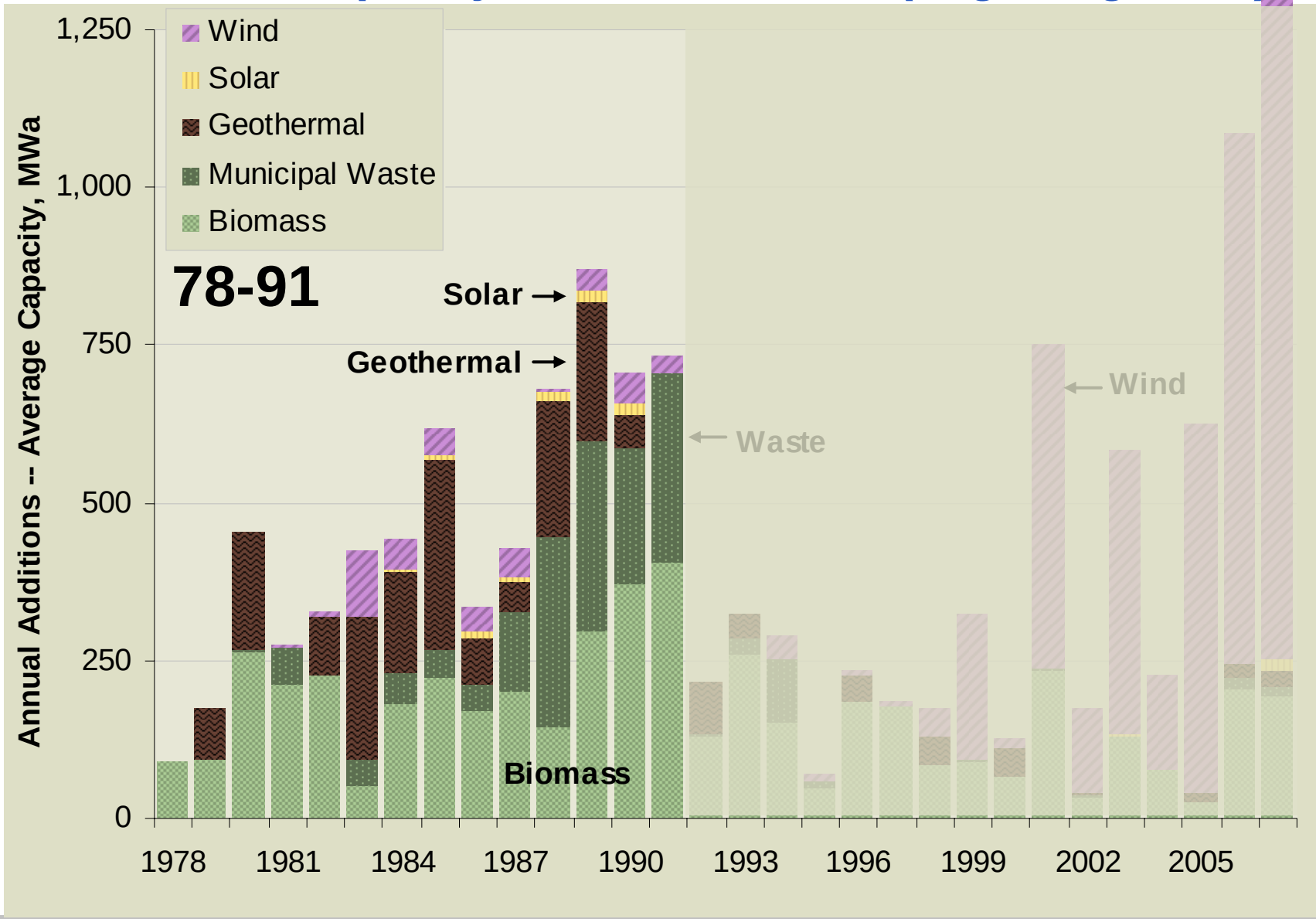
- Sempra – Engineer for La Rumorosa Wind Project
- Arizona – Detailed RE assessment for Arizona Public Service, Tucson Electric, and Salt River Project.
- Nevada Power / Sierra Pacific Power – RPS support (2006-Present)
- EPRI – 2007 RE Technical Assessment Guide
- AWEA – Wind Vision 2030
- WREGIS – Implementation Support (sub to APX)
- Tehachapi Wind Projects Due Diligence

Also Involved in Many Major Western Transmission Initiatives…

- Sunrise Powerlink
- Tehachapi Transmission Project
- Navajo Transmission Project
- PacifiCorp Gateway South Project
- TransWest Express Project, Frontier Project
- TransAmerica Generation Grid Project
- Panhandle Loop Project
- New Mexico's Wind Energy Project

Renewable Energy Market Overview

Annual Electric Capacity Additions, MWa (avg. megawatt)



Black & Veatch Analysis of data from Global Energy Decisions Energy Velocity database; biomass includes landfill gas; 2007 data preliminary.

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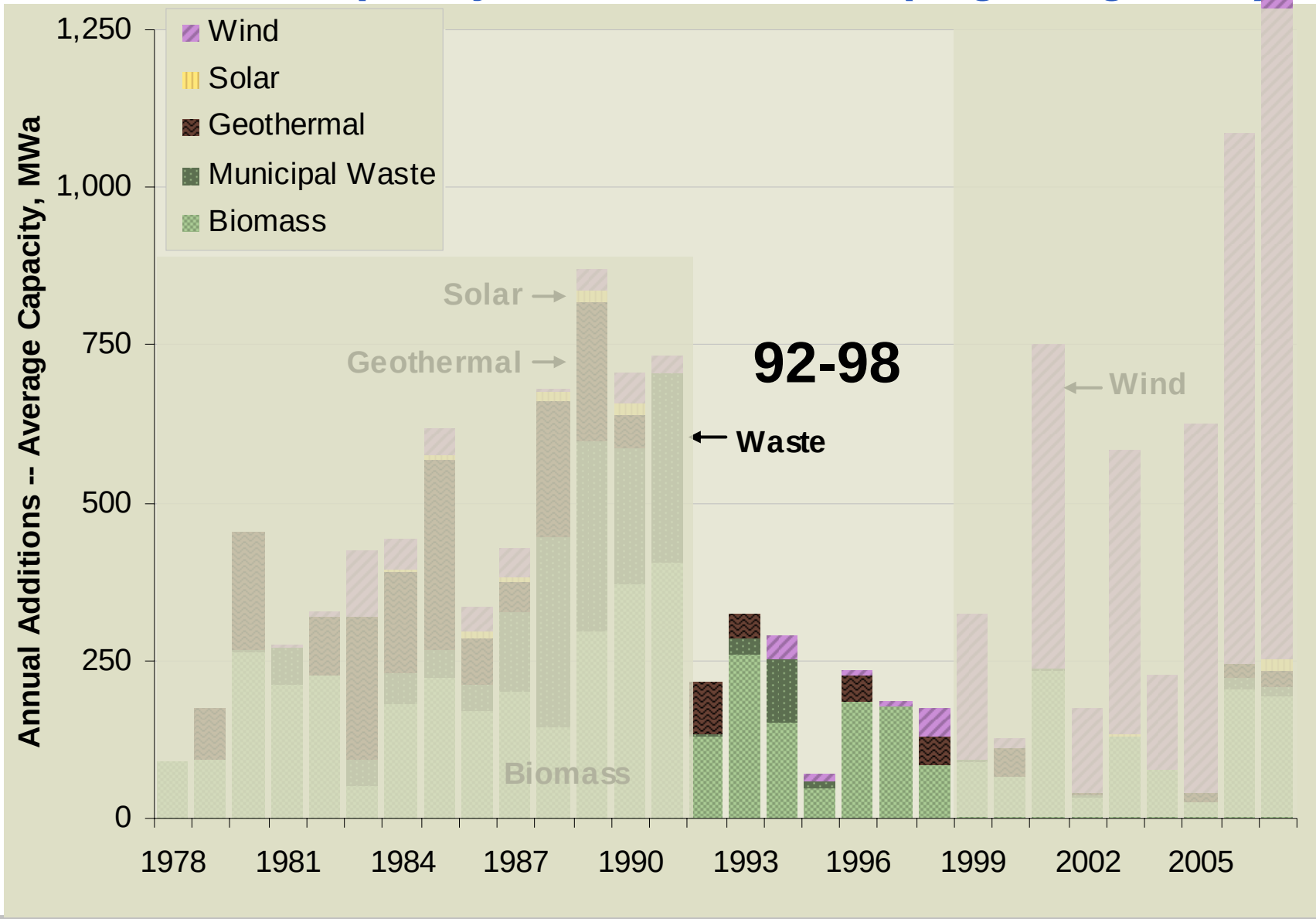

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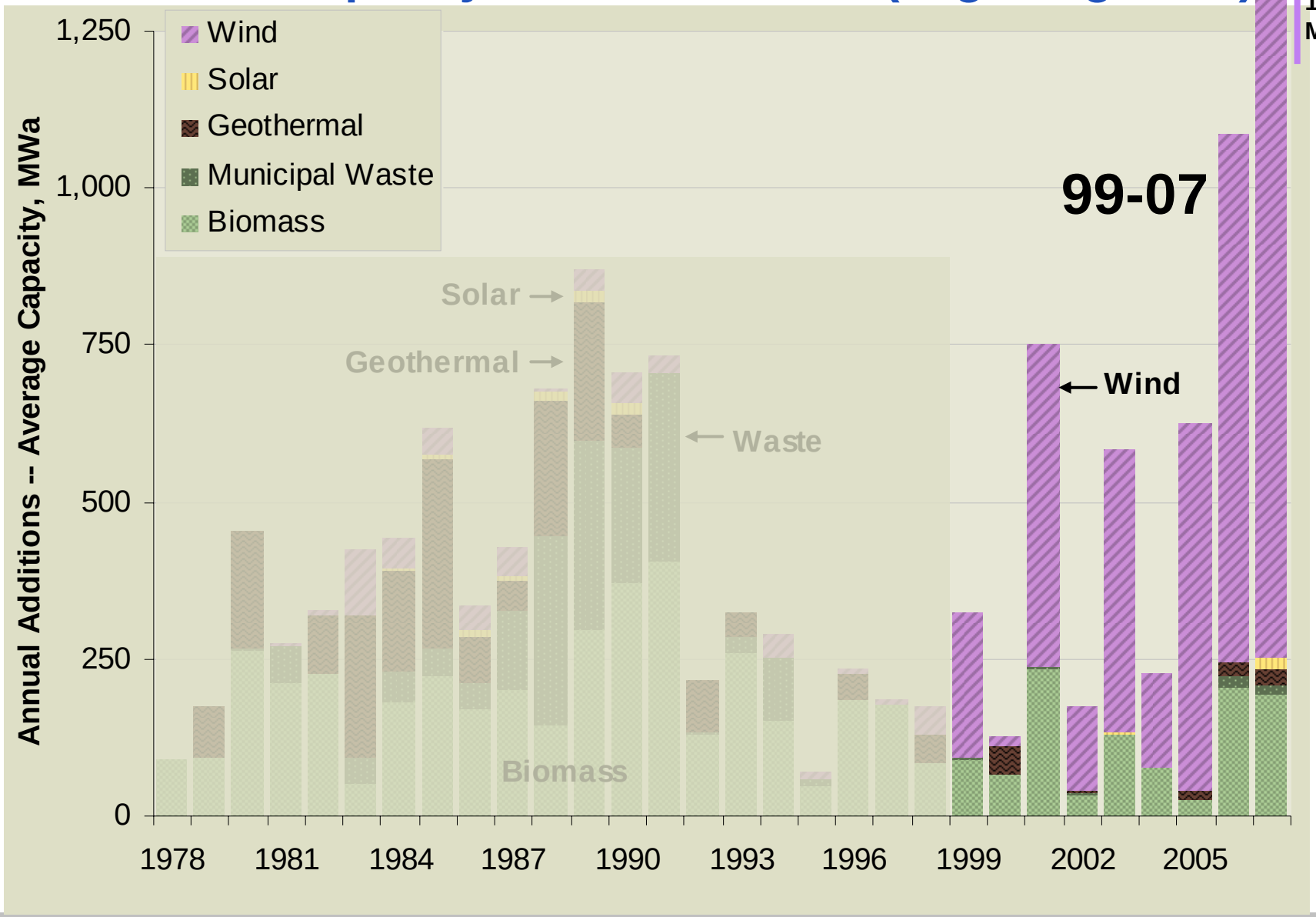

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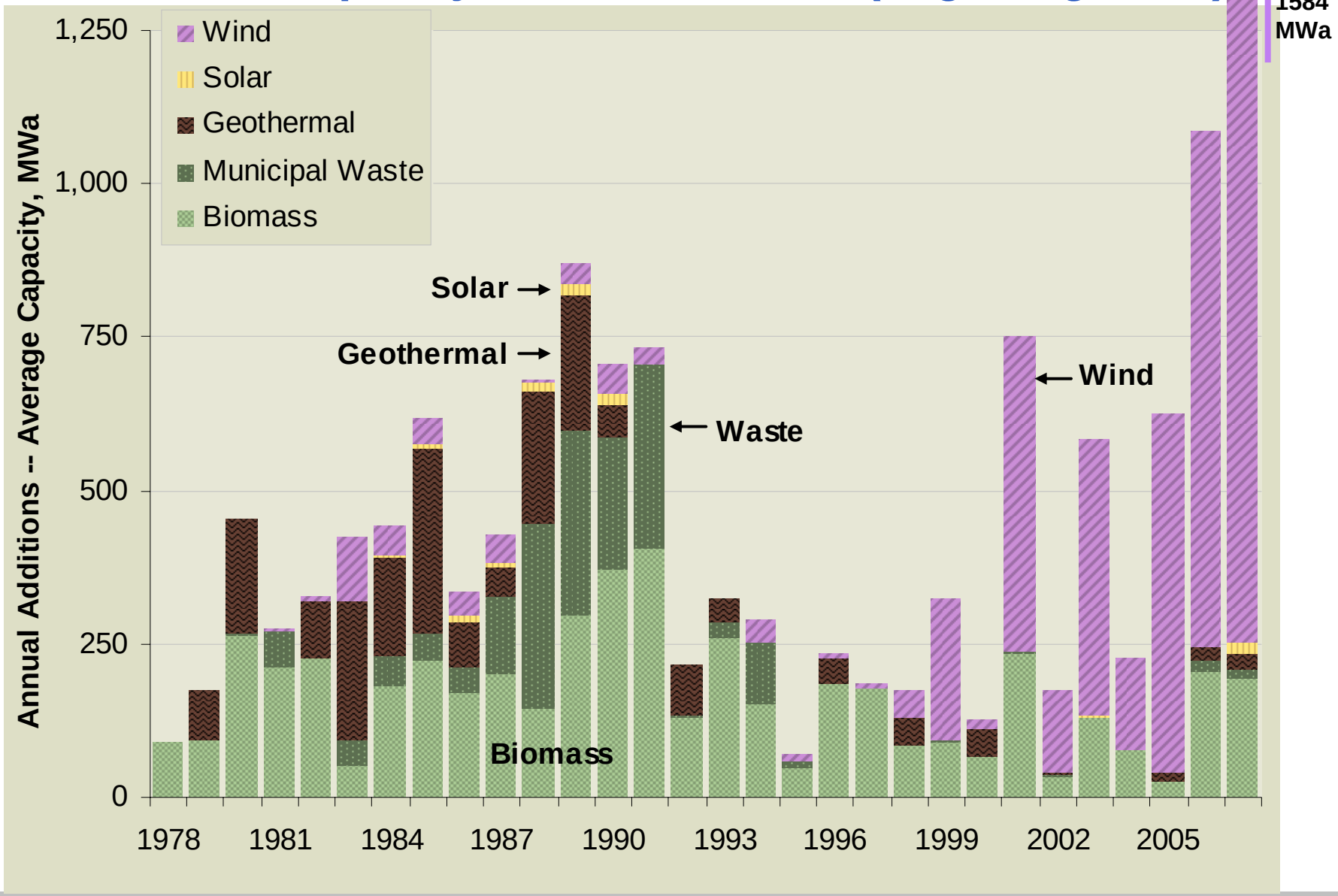

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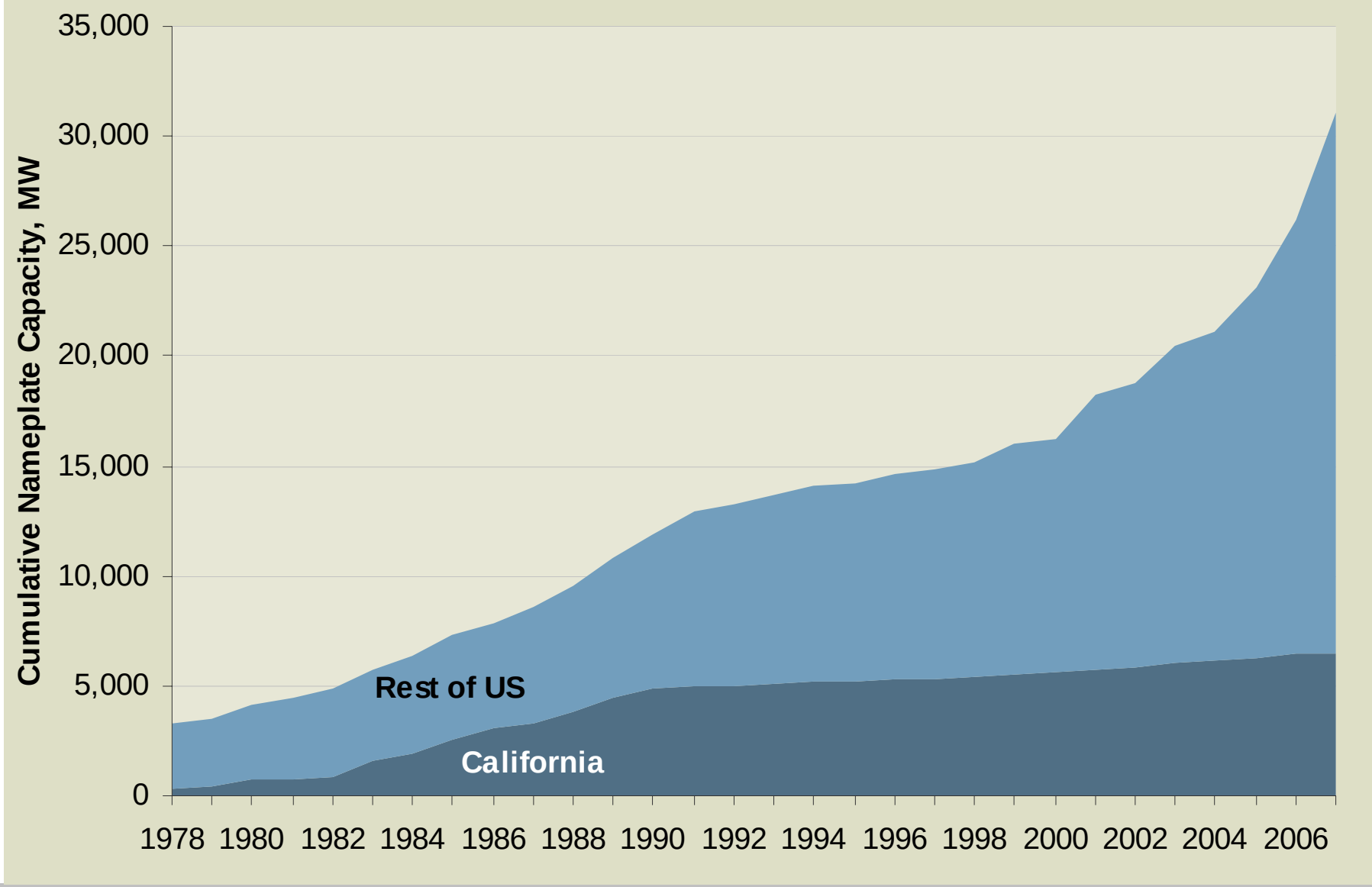
Cumulative Non-Hydro Nameplate Renewable Energy Capacity



Black & Veatch Analysis of data from Global Energy Decisions Energy Velocity database

RETI Phase 1

- Objective: Identify a list of promising Competitive Renewable Energy Zones (CREZ)
- Part A:
  - Establish basic assumptions, methodology, and resource screening
  - January - March
- Part B:
  - CREZ identification and characterization
  - April - August

RETI Phase 1A – Scope of Work

1. Literature review
2. Development of base study assumptions
3. Development of approach to resource valuation, transmission cost assessment, and other concepts
4. High-level technology/resource assessment and screening by geographic region
5. Stakeholder engagement and outreach
6. Project management and coordination

1. Literature Review (see handout)

- General
  - 2007 IEPR, and supporting reports
  - CEC Interstate Generation & Delivery (renewables) w/ GIS shape flies
  - B&V AZ Renewable Energy study
  - IID renewables study
  - NV PUC proposed generation
  - WGA Clean & Diversified Energy Advisory Committee (CDEAC) reports
- Hydro
  - Idaho National Laboratory
  - FERC
  - PIER CA small hydropower study w/ Navigant update
  - Canada (REN) w/ BC hydro atlas
  - Mexico (CFE)

Example Data Source – Idaho National Lab Hydro Assessment

PlantName	StreamName	OwnerName	Capacity (MW)	PlantType	DamStatus
GENESSE	RED CLOVER CR,LAST CHANCE CR	NORTHWEST POWER CO	35.000	DIV	U
NEW JONES FORK	S FK SILV	SACRAMENTO MUD	35.000	ROR	WO
PARKS BAR	YUBA R	SUTTER-YUBA WATER & PWR A	36.000	STG	WO
CLAVEY RIVER	CLAVEY R,TUOLUMNE R	CLAVEY RIVER HYDROELEC CO	36.000	ROR	WO
ROCK CREEK UNIT 3	N FK FEATHER R	PACIFIC GAS & ELECTRIC CO	37.000	ROR	U
ROCKLAND	N FK SMITH R	N/A	40.000	STG	U
DOWNIEVILLE	N YUBA R	N/A	40.000	DIV	U
HOBO	MILL CR(KERN R)KERN R	HOBO HYDRO PNSP	44.000	DIV	WO
UPPER MCCLOUD 3	MCCLOUD R	SANTA CLARA,CITY OF	45.000	ROR	WO
JUNCTION	DINKEY CR,N FK KINGS R	KINGS RIVER CONS DIST	48.000	DIV	U
MARYSVILLE	YUBA R	CORPS OF ENGINEERS	50.000	STG	WO
CARQUINEZ	CARQUINEZ STRAIT,SAN PABLO BAY	PACIFIC WATER & PWR INC	50.700	ROR	WO
NEW POTTER VALLEY	E FK RUSSIAN R	CA DEPT OF WATER RESOURCI	51.000	DIV	U
TABLE MOUNTAIN	PIT R	CORPS OF ENGINEERS	54.000	STG	WO
ANDERSON FORD	MAD R	BUREAU OF RECLAMATION	56.000	STG	U
DINKEY CREEK 2	DINKEY CR,N FK KINGS R	KINGS RIVER CONS DIST	60.000	DIV	U
HAAS ANNEX	N FK KINGS R	SACRAMENTO M U D ET AL	60.000	ROR	U
DINKEY CREEK 1	DINKEY CR,N FK KINGS R	KINGS RIVER CONS DIST	60.000	DIV	WO
CROSS COUNTY	DRY CR,MOKELUMNE R	AMADOR,COUNTY OF	79.000	ROR	WO
WAMBO BAR	N YUBA R	YUBA COUNTY WATER AGENCY	79.000	STG	WO
KNIGHTS FERRY	STANISLAUS R	NHPS/COE	94.000	STG	U
ANGELS CAMP	ANGELS CR,CLOVEY CR	PACIFIC GAS & ELECTRIC CO	130.300	DIV	WO
CLAVEY RIVER	CLAVEY R,TUOLUMNE R	TUOLUMNE,COUNTY OF ET AL	154.000	DIV	WO
INDIAN VALLEY	N YUBA R	NHPS/COE	160.000	STG	U
TRENTON	ANGELS CR,CLOVEY CR	PACIFIC GAS & ELECTRIC CO	176.000	DIV	WO

1. Literature Review (see handout)

- Solar
  - NREL satellite resource data
  - B&V CA SCP study
  - CA PUC CSI Info
  - CEC solar resources paper
  - Solargenix solar thermal benefits study
  - Navigant CA rooftop PV potential
  - NREL CA CSP master plan and map
  - National Solar Radiation Database
- Biomass
  - CEC Biomass SVA
  - WGA Biomass task force report
  - UC Davis biomass assessment

Example Data Source - UC Davis Biomass Assessment (CEC)

1. Literature Review (see handout)

- Landfill Gas
  - EPA LMOP database
- Wind
  - CEC
    - High resolution wind maps
    - Seasonal wind speed maps
    - Intermittency Analysis Project
    - Wind performance report summary 2002-2003
    - Strategic value analysis
    - Wind turbine technologies effect on transmission system operations and performance
    - CA wind energy resource modeling and measurement

1. Literature Review (see handout)

- Marine
  - B&V Carbon Trust report
  - EPRI tidal in-stream assessment
  - EPRI wave power w/ SF studies
  - PIER wave resources report
- Geothermal
  - GeothermEx 2004 report (to be updated)
  - MIT enhanced geothermal paper
  - WGA geothermal task force report
  - CA Division of Oil, Gas, & Geothermal Resources
  - CEC geothermal strategic value analysis

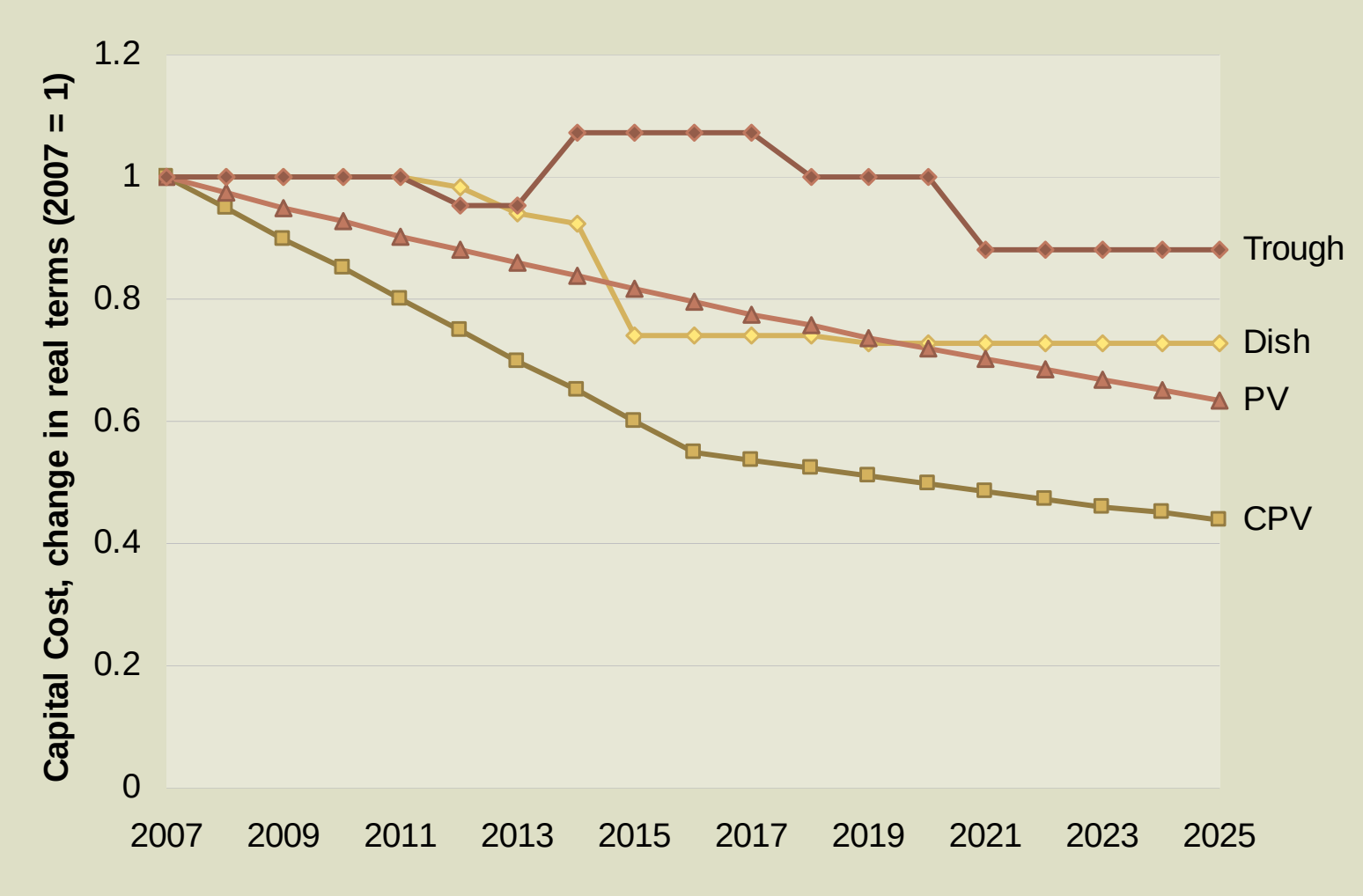
2. Assumptions

- Financial assumptions for use in modeling
- Renewable energy incentives
- Renewable energy demand
- Transmission
- Economic assumptions to support resource valuation
- Renewable technology-specific assumptions

Example Assumption:

Projected Relative Capital Cost for Solar Technologies

(from study for Arizona Utilities)



Source: B&V

3. Methodological Issues

- Resource assessment
- Treatment of existing contracts, short-listed contracts and transmission queue
- Project identification, characterization and screening
- Technology development
- Resource valuation
- Supply curve creation
- CREZ identification, characterization and economic ranking

4. High-level technology/resource assessment and screening by geographic region

- Landfill Gas
- Digester Gas
- Solid Biomass
- Solar Photovoltaic
- Solar Thermal
- Hydropower
- Onshore Wind
- Offshore Wind
- Geothermal
- Wave Energy
- Marine Current

Resource Assessment – RETI Phase 1A Study Area

Identify Most Promising Opportunities for Further Study in Phase 1B

- For example:
  - Northwestern Nevada Geothermal
  - Southern California Solar Thermal
- Screening Factors
  - Technically viable
  - Commercially available by 2020
  - Most economical over the study timeframe
  - Resources with significant potential to meet CA RPS

Phase 1A Deliverable: List of Screened Resources

	CA	OR	WA	NV	AZ	MX	BC
Landfill Gas							
Digester Gas							
Solid Biomass							
Solar Photovoltaic							
Solar Thermal							
Hydropower							
Onshore Wind							
Offshore Wind							
Geothermal							
Wave Energy							
Marine Current							

Phase 1A Deliverable: List of Screened Resources

	CA	OR	WA	NV	AZ	MX	BC
Landfill Gas							
Digester Gas							
Solid Biomass							
Solar Photovoltaic							
Solar Thermal							
Hydropower							
Onshore Wind							
Offshore Wind				No	No		
Geothermal							
Wave Energy				No	No		
Marine Current				No	No		

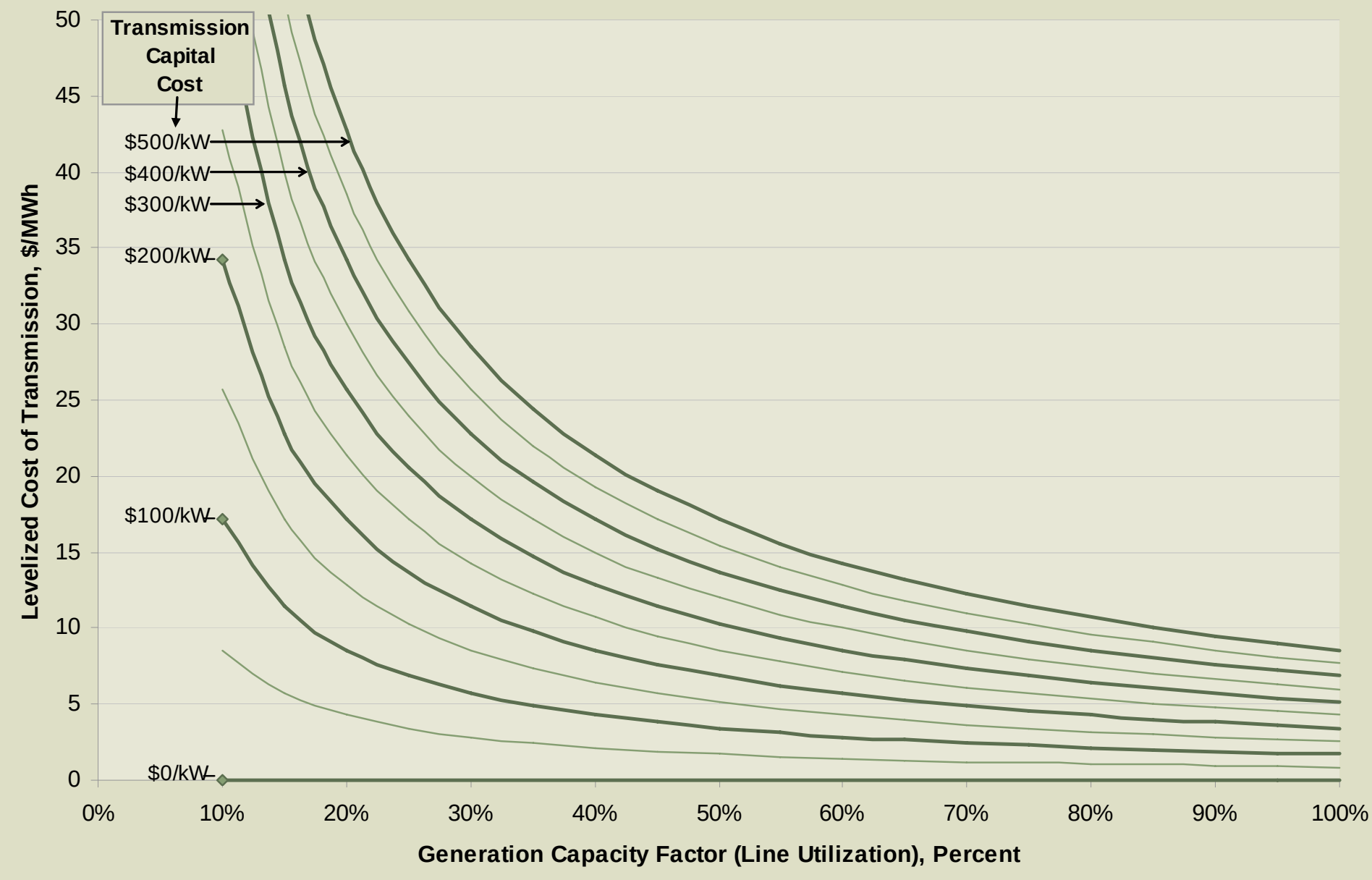
Phase 1A Deliverable: List of Screened Resources

	CA	OR	WA	NV	AZ	MX	BC
Landfill Gas							
Digester Gas							
Solid Biomass							
Solar Photovoltaic							No
Solar Thermal							No
Hydropower							
Onshore Wind							
Offshore Wind				No	No		
Geothermal							
Wave Energy				No	No		
Marine Current				No	No		

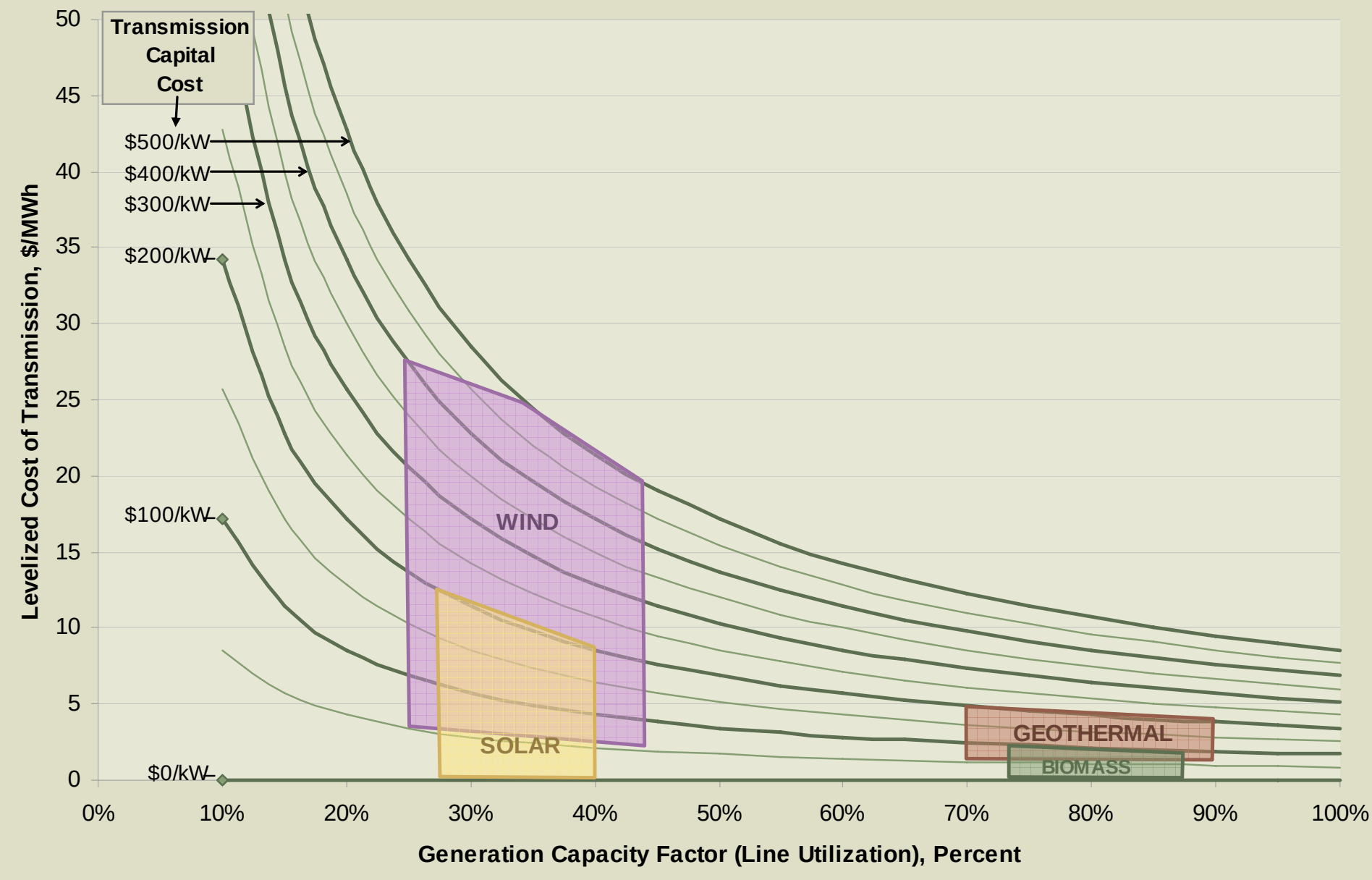
"Typical" Transmission Capital Costs

- Relatively High Costs (~$200+/kW)
  - Wind
  - Geothermal
  - Solar Thermal
- Moderate Costs (~$50-100/kW)
  - Nuclear
  - Coal
  - Combined Cycle
- Low Cost
  - Solar PV
  - Landfill Gas
  - Cogeneration
  - Biomass
  - Biomass Co-firing

Transmission Cost for Dedicated Renewables Lines



Transmission Cost for Dedicated Renewables Lines



5. Stakeholder engagement and outreach

- February 27 (San Francisco) Stakeholder Steering Committee Meeting
  - Preliminary high-level resource assessment of theoretical/tech potential
  - Preliminary identification of non-viable resources proposed to be removed from assessment
  - General study assumptions (technology capital cost, O&M cost, financing assumptions, future cost and performance, etc.)
  - Approach to resource valuation and forecasting technology development

5. Stakeholder engagement and outreach

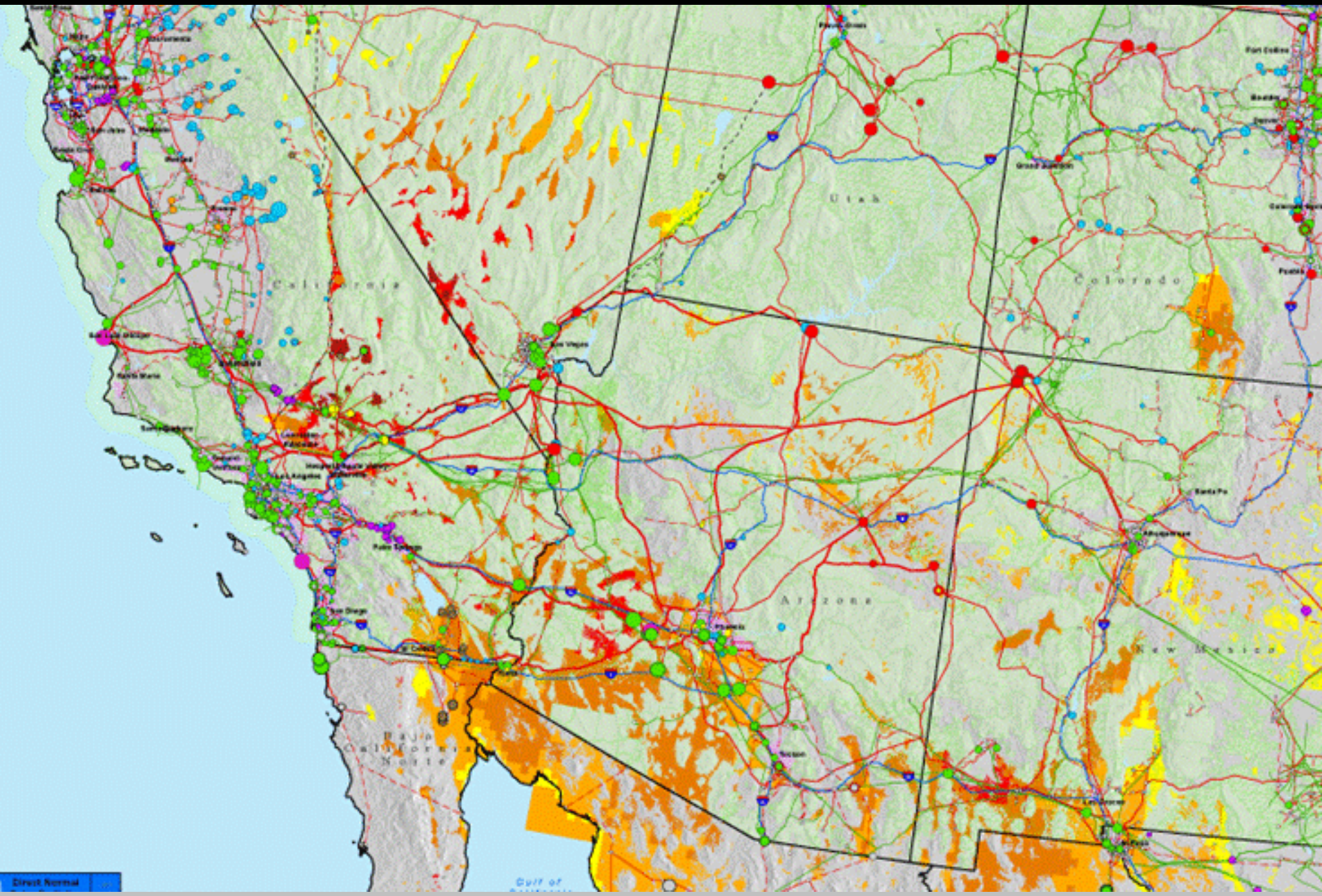
- March 14 – Phase 1A Report Released
- March 26 (Sacramento) Stakeholder Steering Committee Meeting
  - Present and discuss results of Phase 1A Report
  - Approach to project identification
  - Approach to characterization and screening
  - Approach to supply curve creation
  - Approach to CREZ identification and characterization

Stakeholder Feedback and Input

- Assumptions
- Methodology
- Resource Assessment
- Results…

…build consensus and momentum for Phase 1B

Phase 1A Assessment: Solar Thermal Resources (with land exclusions)



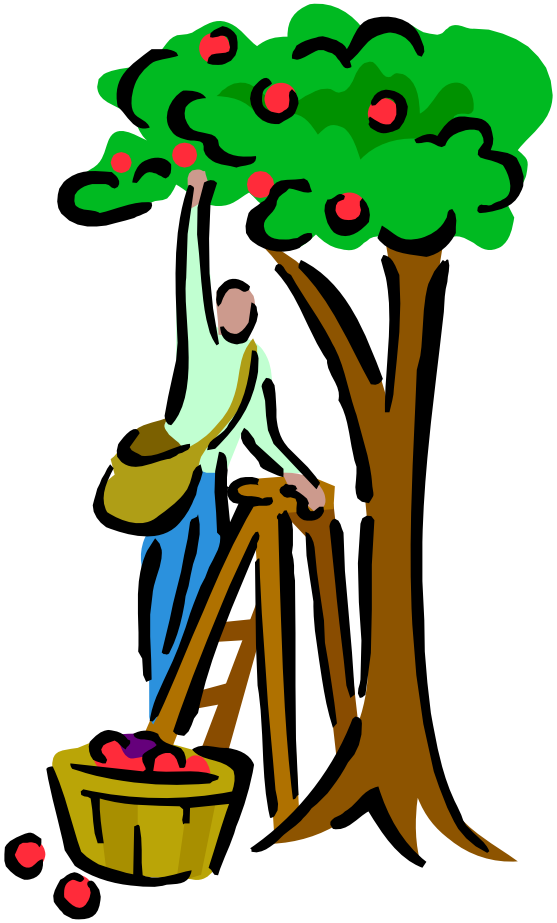
Source: NREL

Phase 1B Assessment: Solar Thermal Projects

Phase 1B Assessment: Solar Thermal Projects

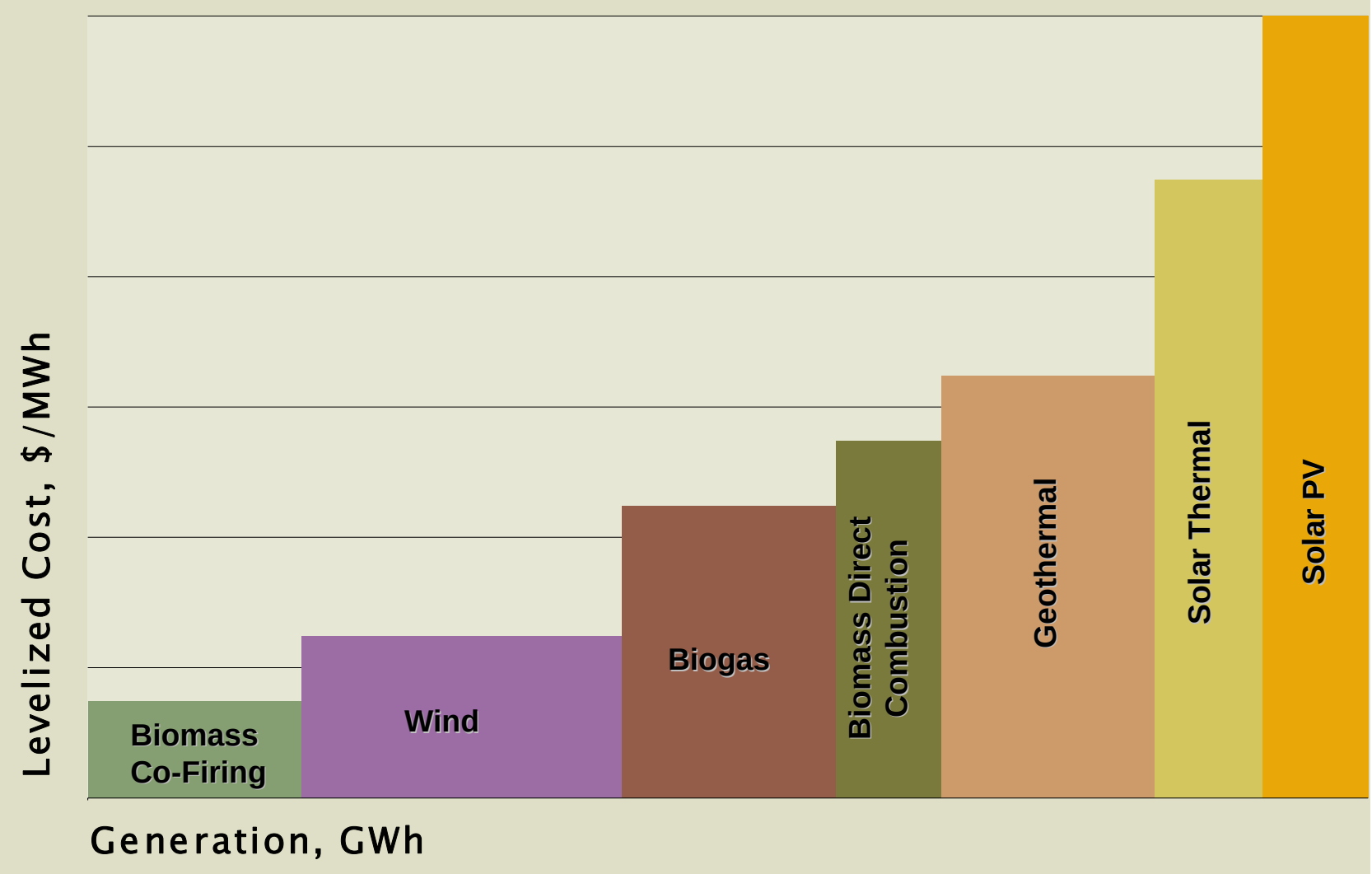
Properly Characterizing Resource Cost

- Renewables costs vary tremendously based on resource quality
- Limited number of very good renewable project sites
- Costs rise as “low-hanging” projects are developed
- Supply curves capture these effects

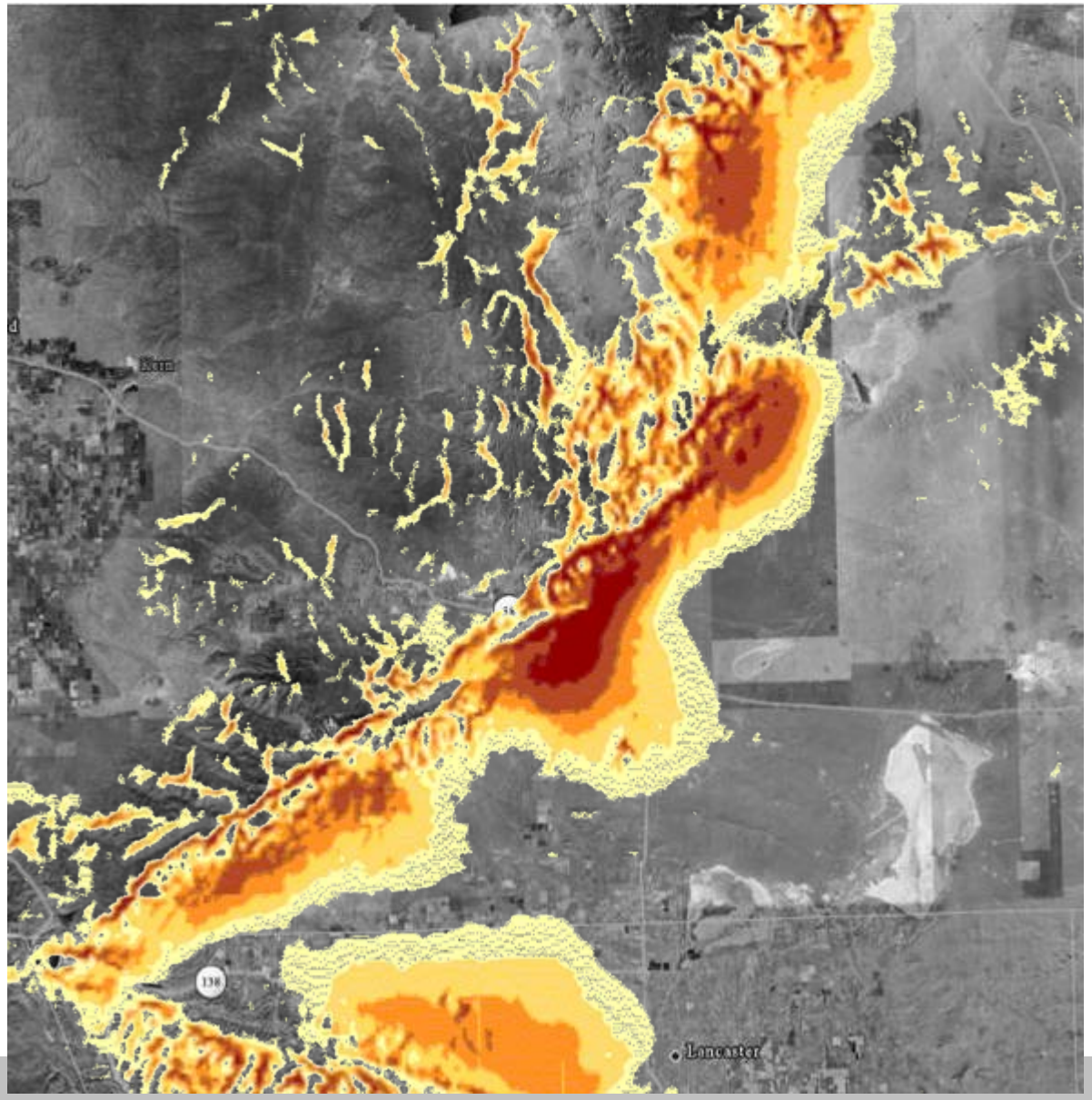


Example Supply Curve Development

CONCEPTUAL



Tehachapi example



Tehachapi California Area Wind Resources

Wind Power Density at 50m (Source: AWS)

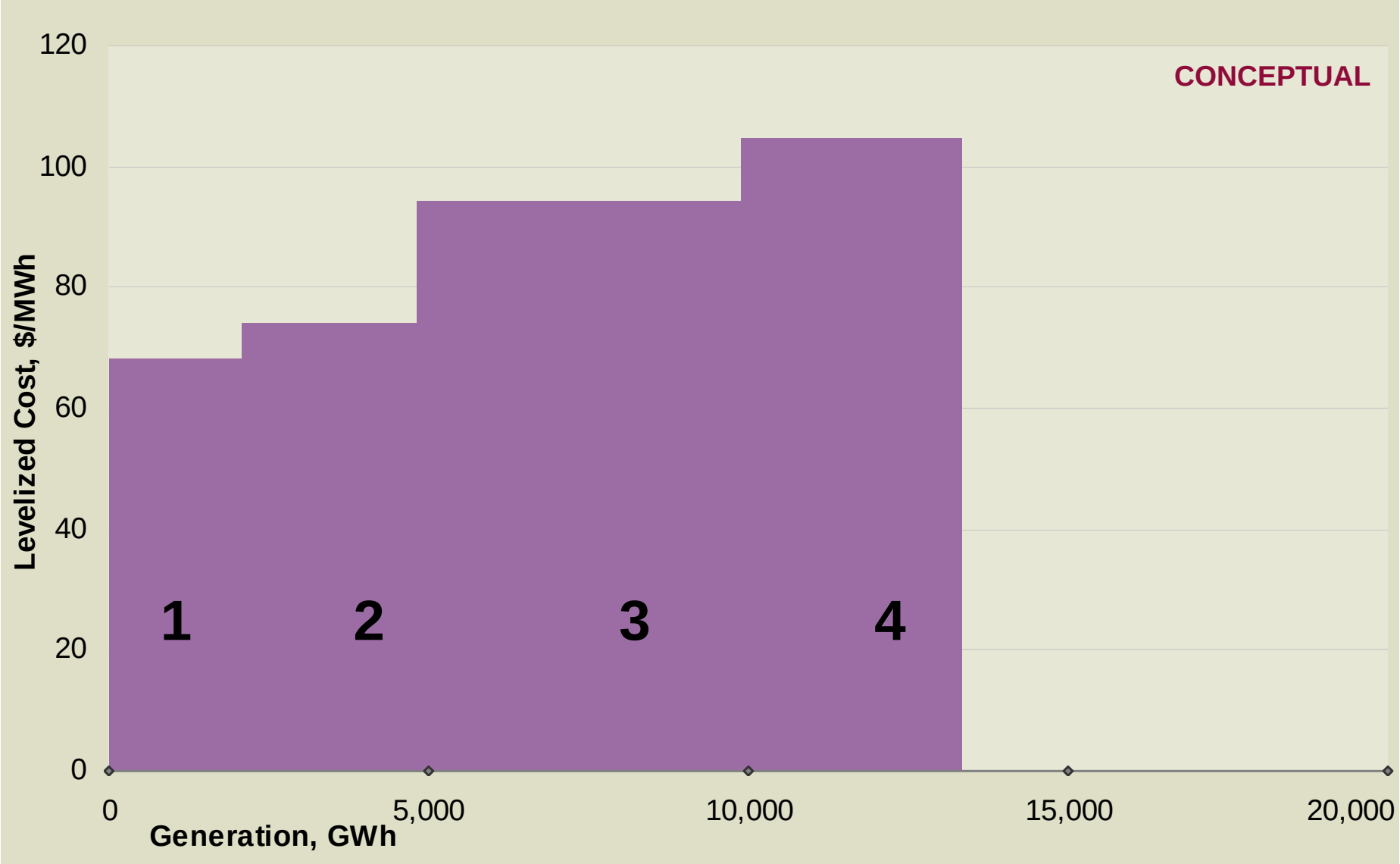
Additional Generating Technology Assumptions

Premise: Best Resources Developed First

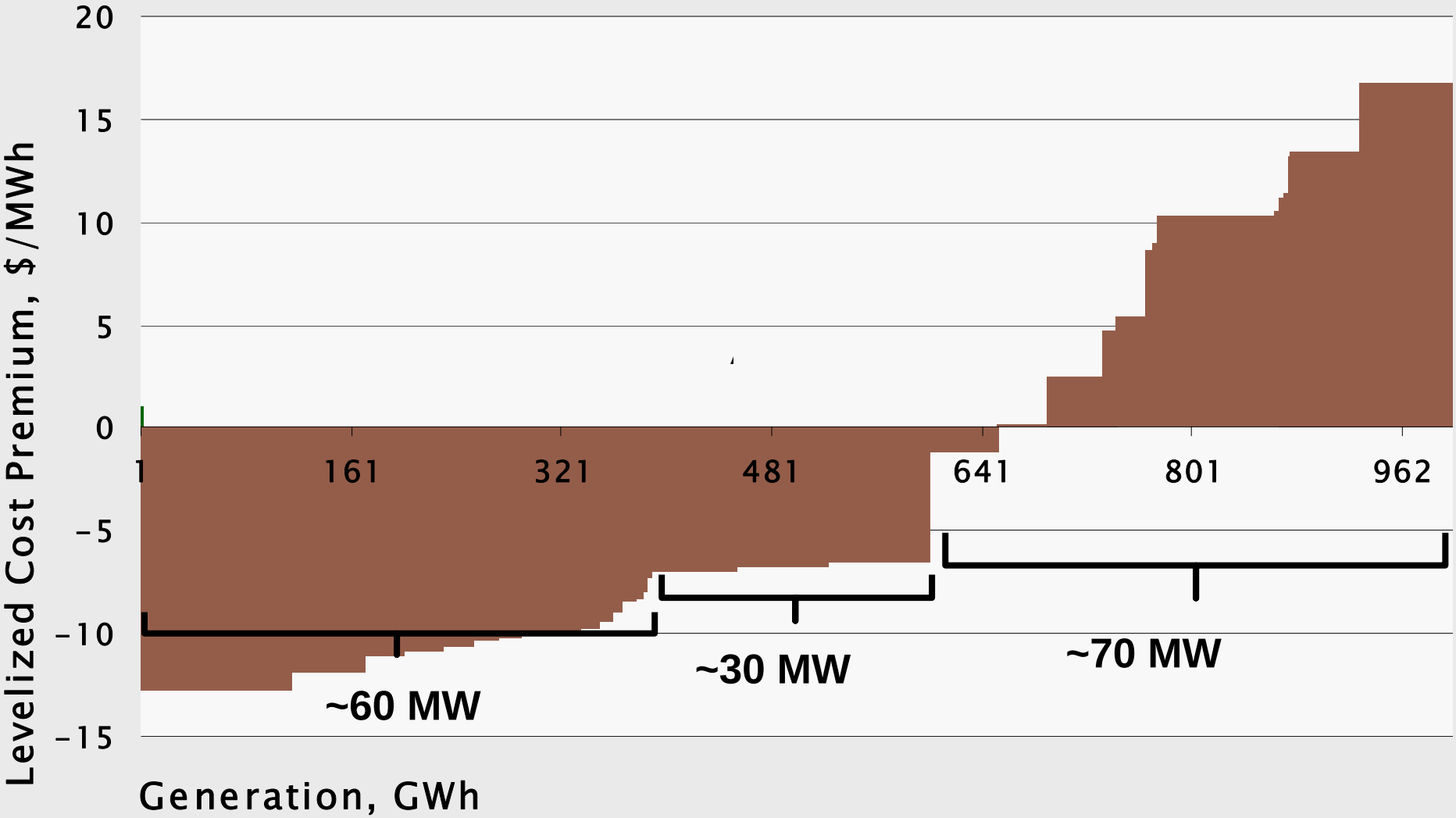
Phase	MW	Capacity Factor	Wind, $/kW	Transmission, $/kW
1	700	36%	1,900	296
2	900	35%	2,000	312
3	1700	34%	2,200	611
4	1200	33%	2,400	625

CONCEPTUAL – FOR EXAMPLE ONLY

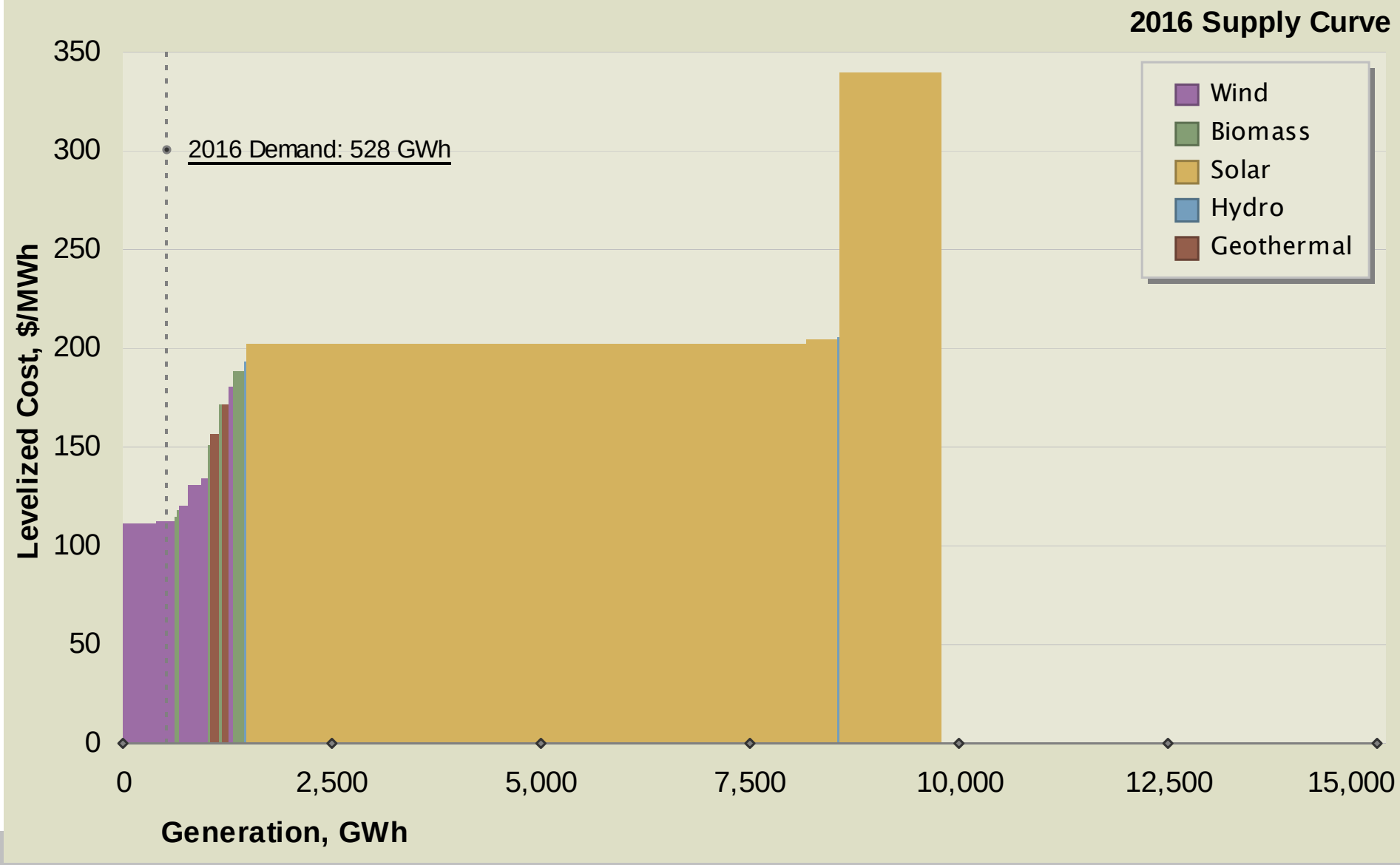
Simplified Tehachapi Wind Supply Curve



Pennsylvania Biogas Supply Curve -- 2006
Premium over Avoided Costs



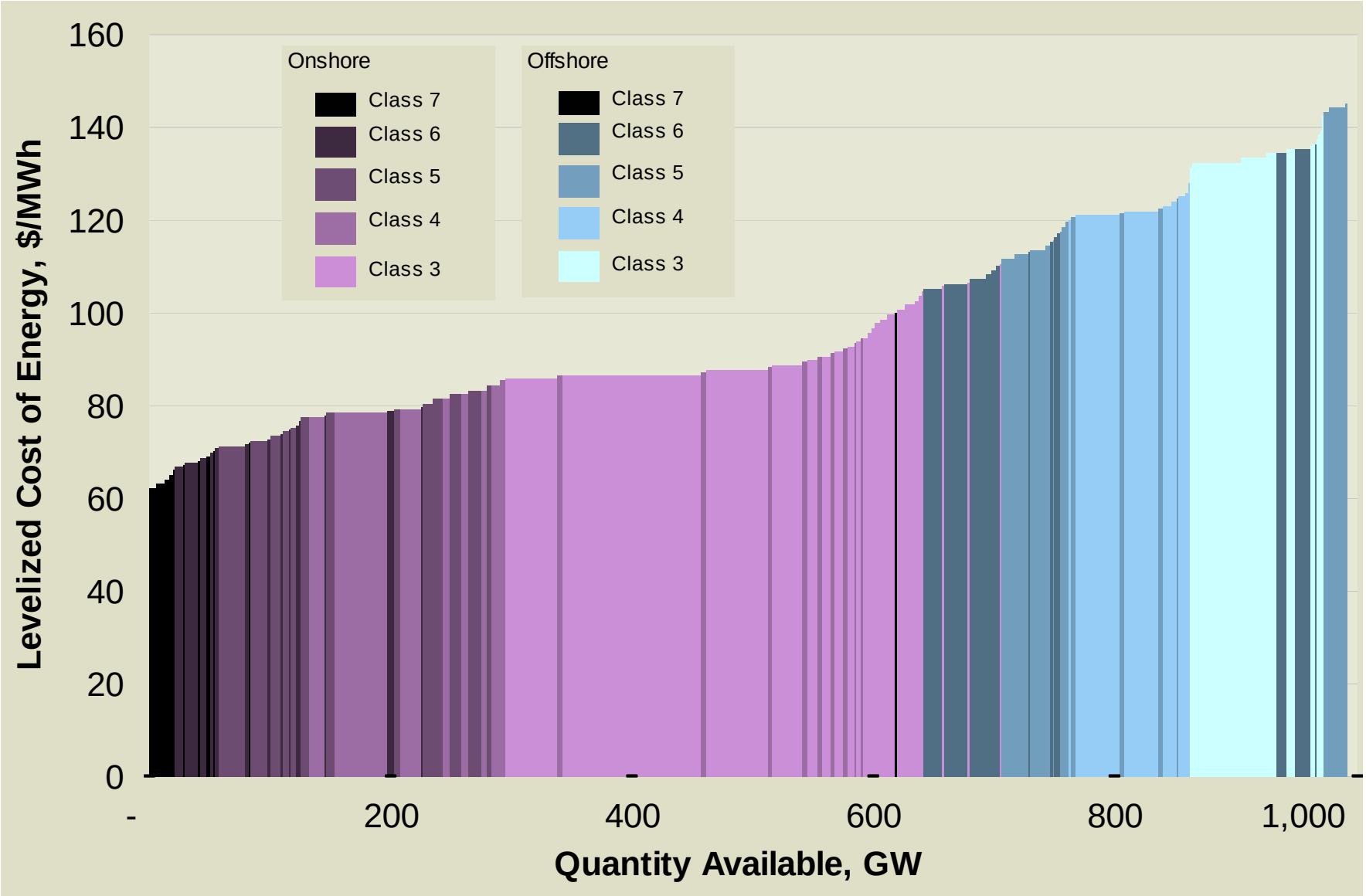
Arizona Renewables Supply Curve - 2016



Relevant Analysis from AWEA Wind Vision

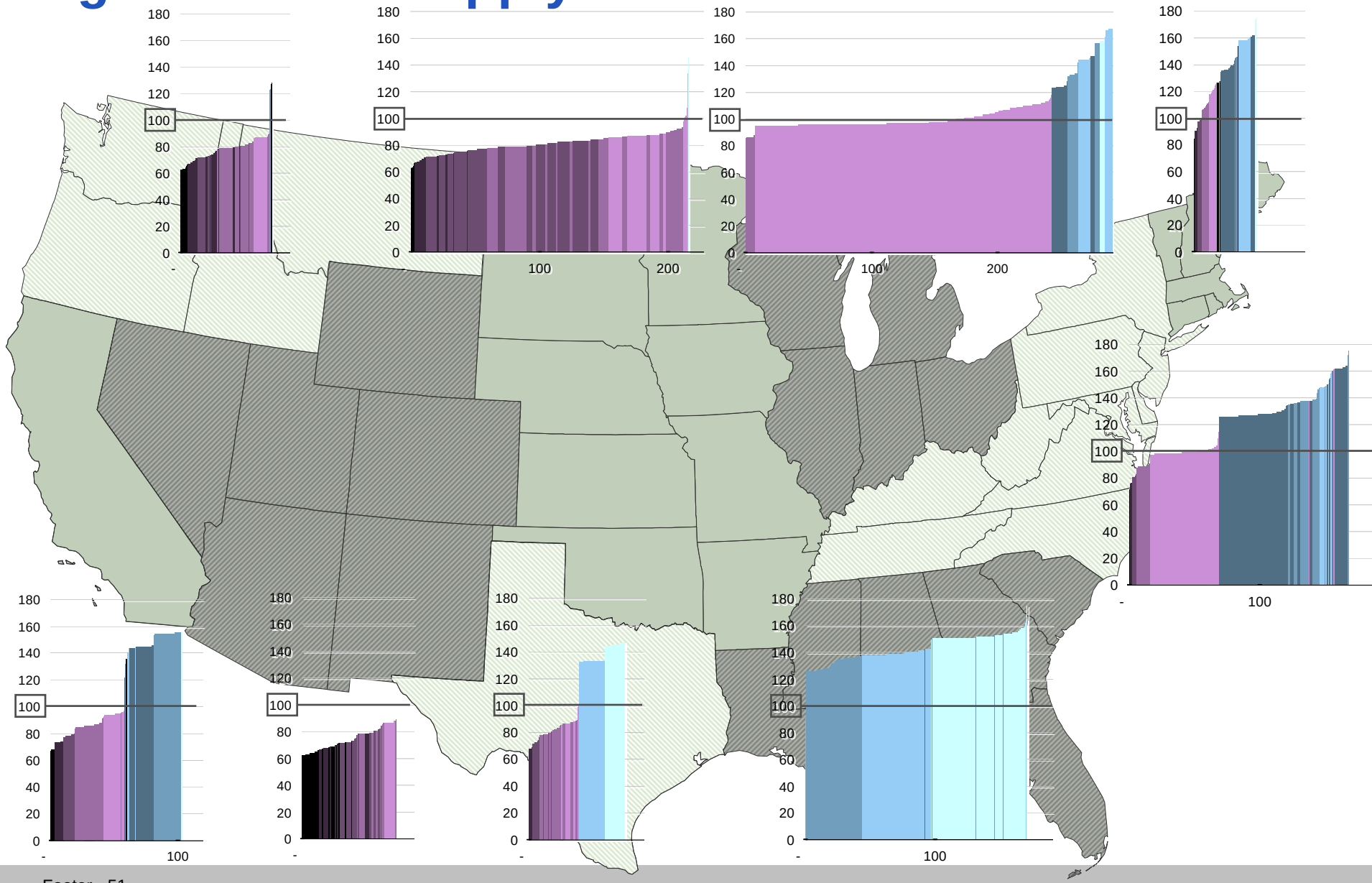
- Black & Veatch collaborated with AWEA, NREL and various stakeholders in 2007 on analysis for the Wind Vision project
- NREL's WinDS capacity expansion model used to simulate build-out of 20% wind
  - Where wind is built
  - Where it is delivered
  - Transmission needs

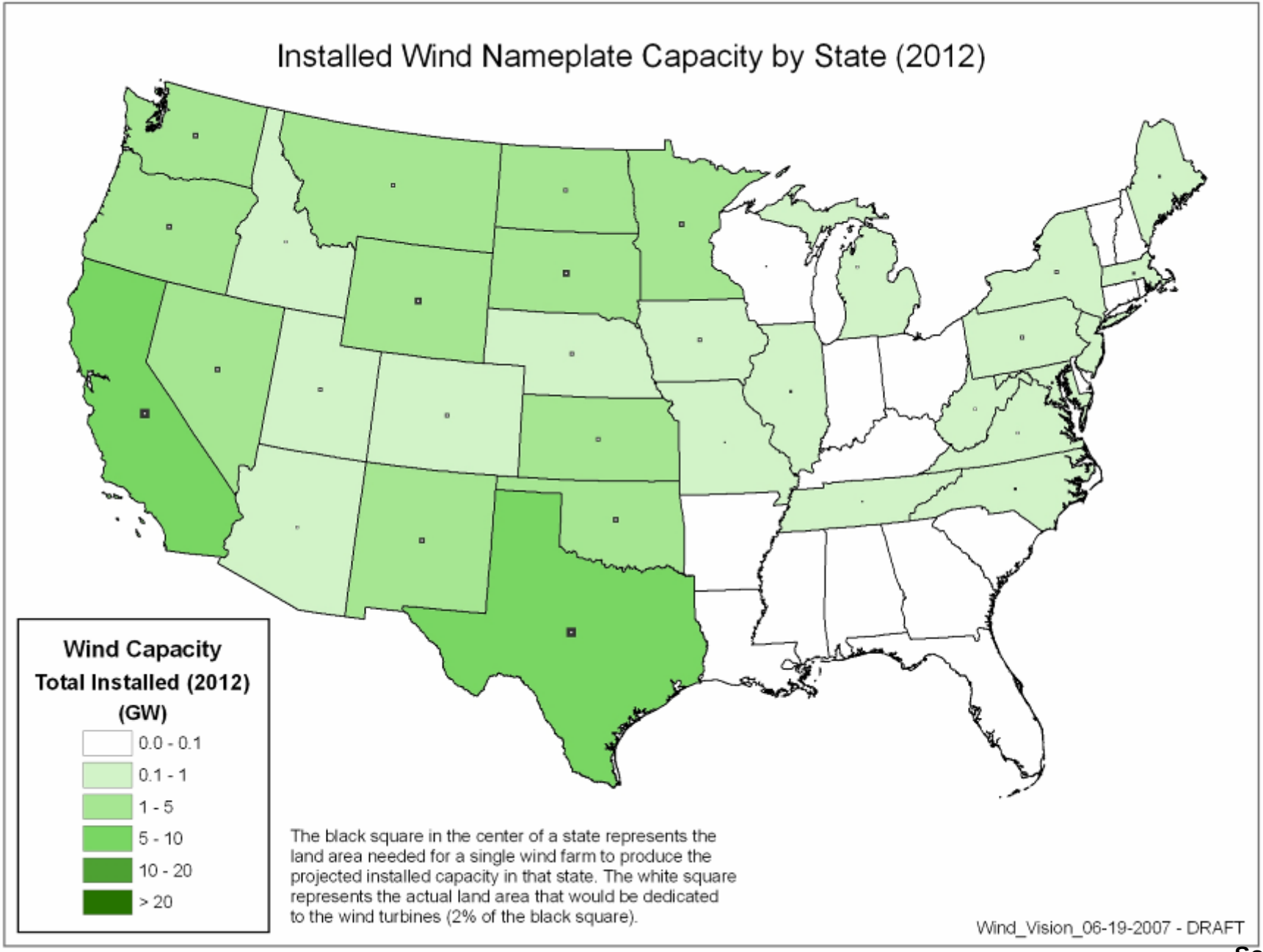
US Wind Supply Curve - 10% Available Transmission



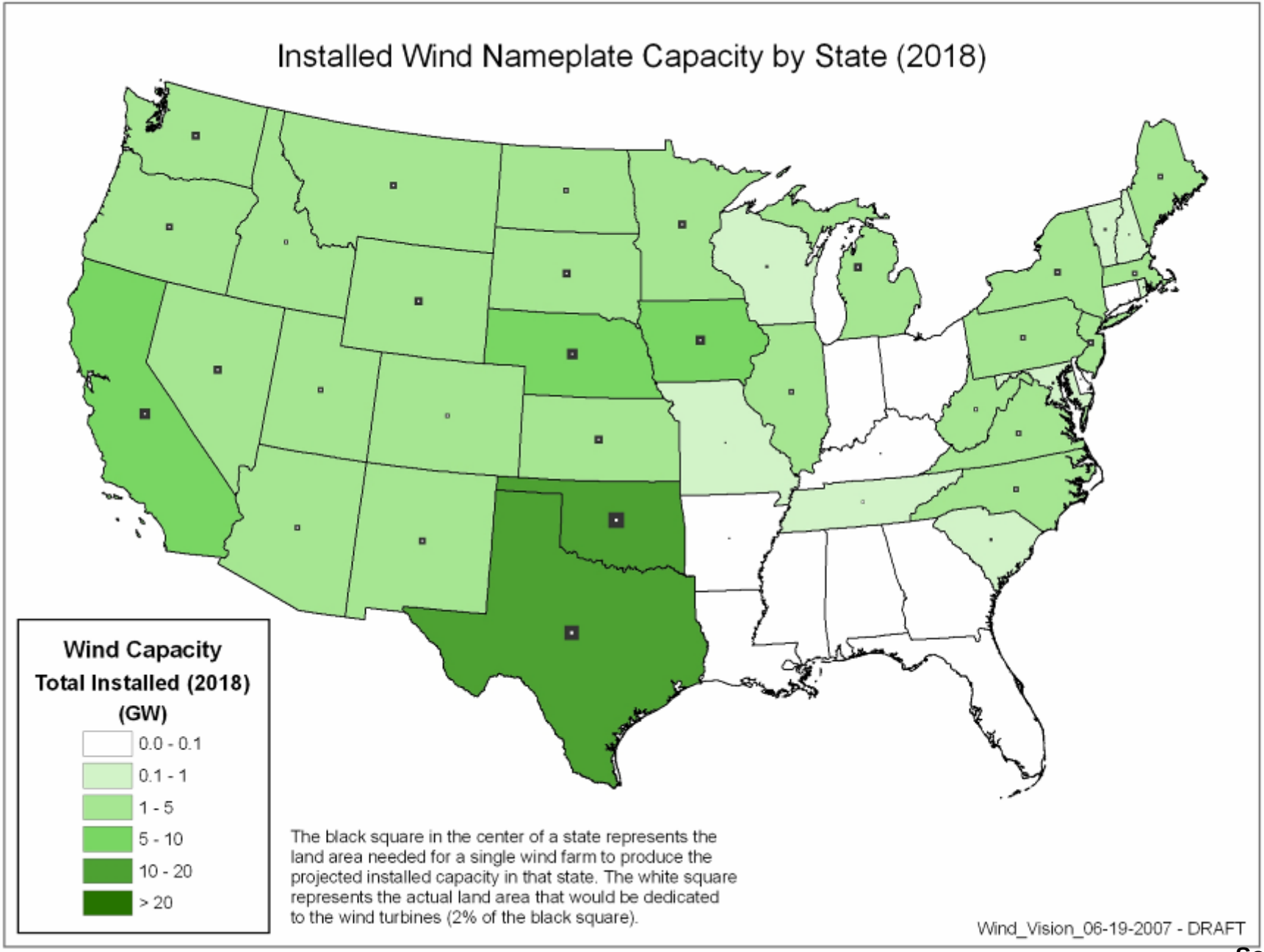
Optimistic 2010 Costs w/o PTC, $1,600/MW-mile, w/o Integration costs

Regional Wind Supply Curves




Installed Wind Nameplate Capacity by State (2012)
Wind Capacity
Total Installed (2012)
(GW)
0.0 - 0.1
0.1 - 1
1 - 5
5 - 10
10 - 20
> 20
The black square in the center of a state represents the land area needed for a single wind farm to produce the projected installed capacity in that state. The white square represents the actual land area that would be dedicated to the wind turbines (2% of the black square).
Wind_Vision_06-19-2007 - DRAFT

Source: NREL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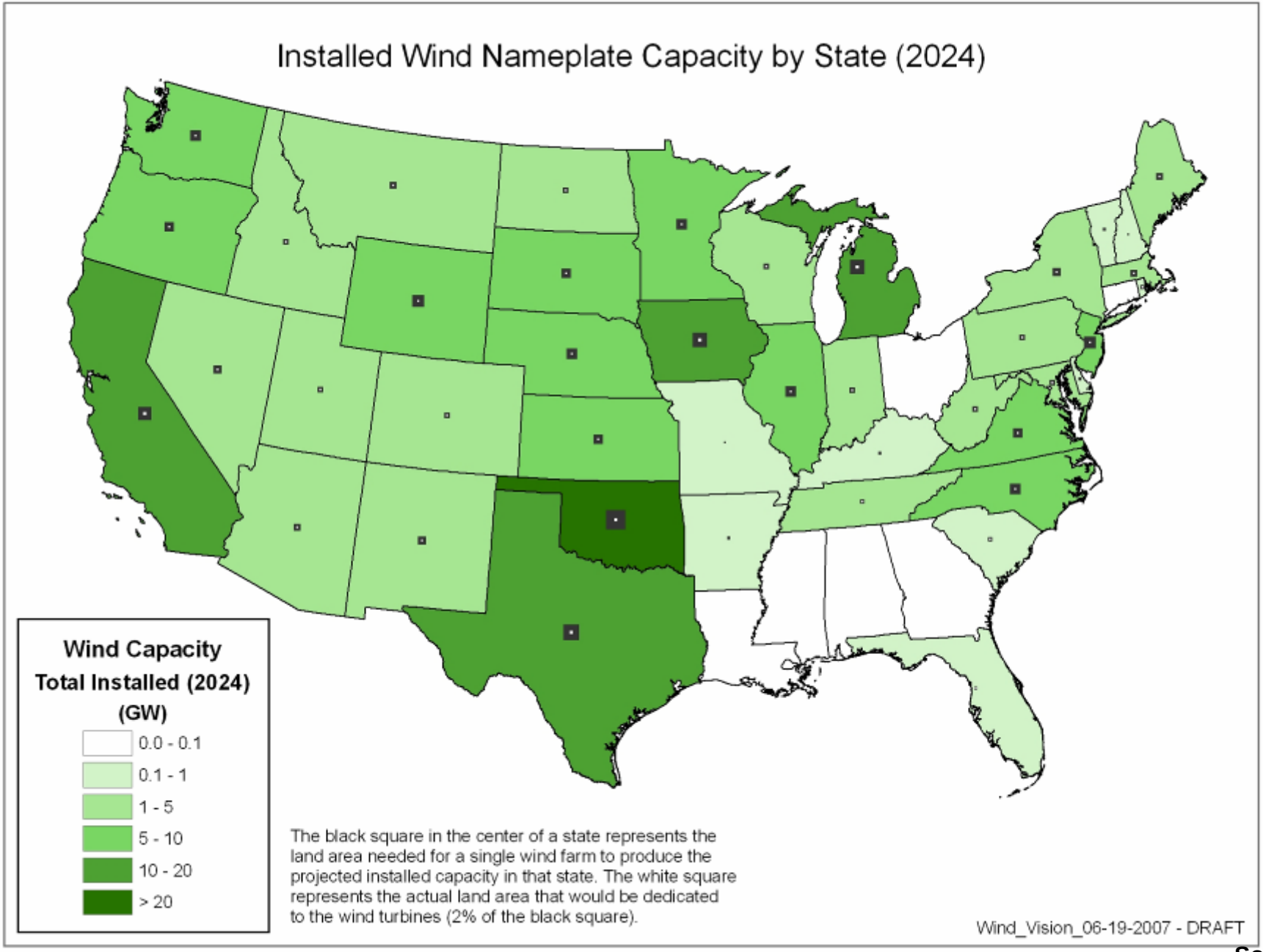
Installed Wind Nameplate Capacity by State (2024)
Wind Capacity
Total Installed (2024)
(GW)
0.0 - 0.1
0.1 - 1
1 - 5
5 - 10
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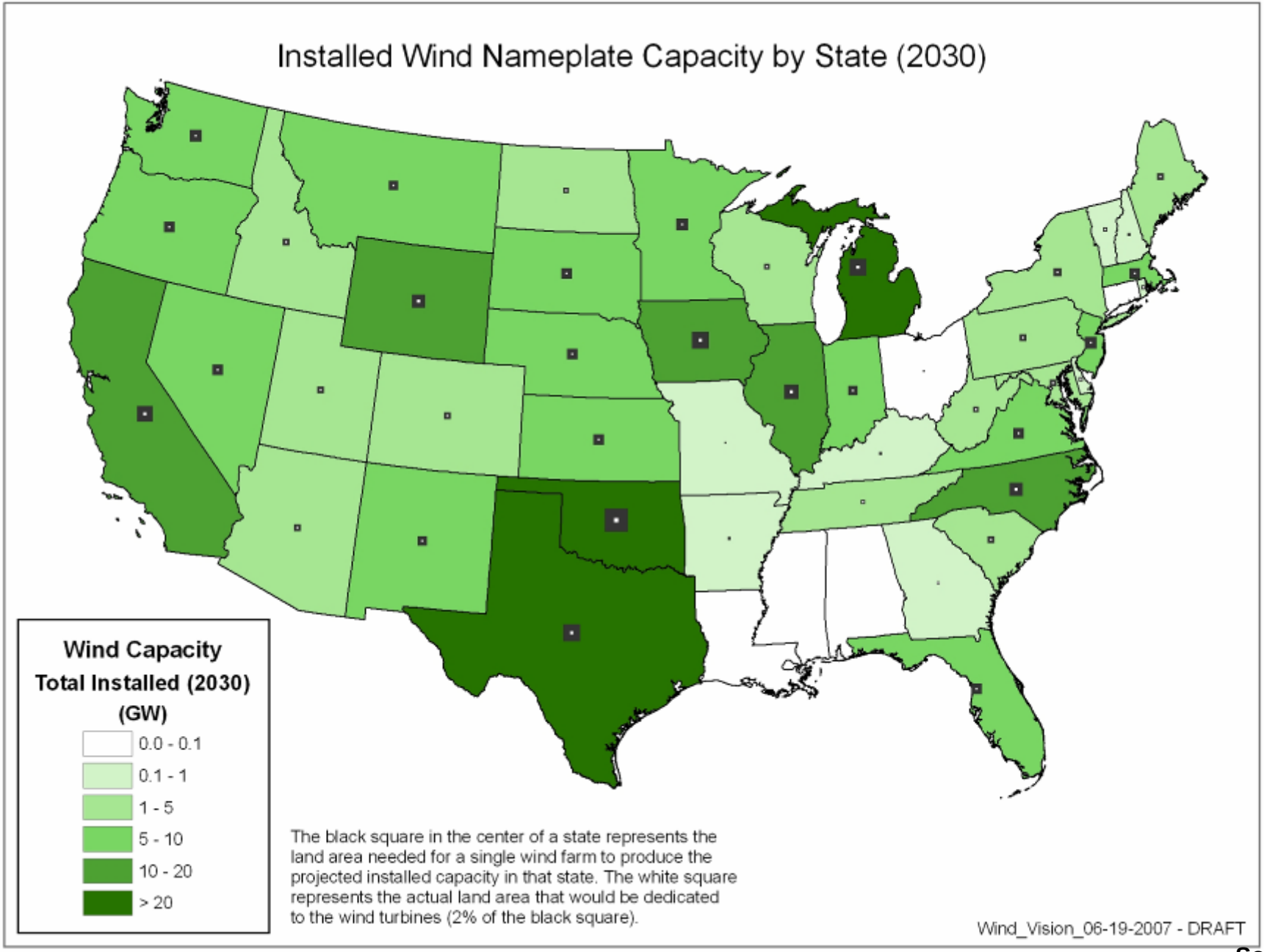
Installed Wind Nameplate Capacity by State (2030)
Wind Capacity
Total Installed (2030)
(GW)
0.0 - 0.1
0.1 - 1
1 - 5
5 - 10
10 - 20
> 20
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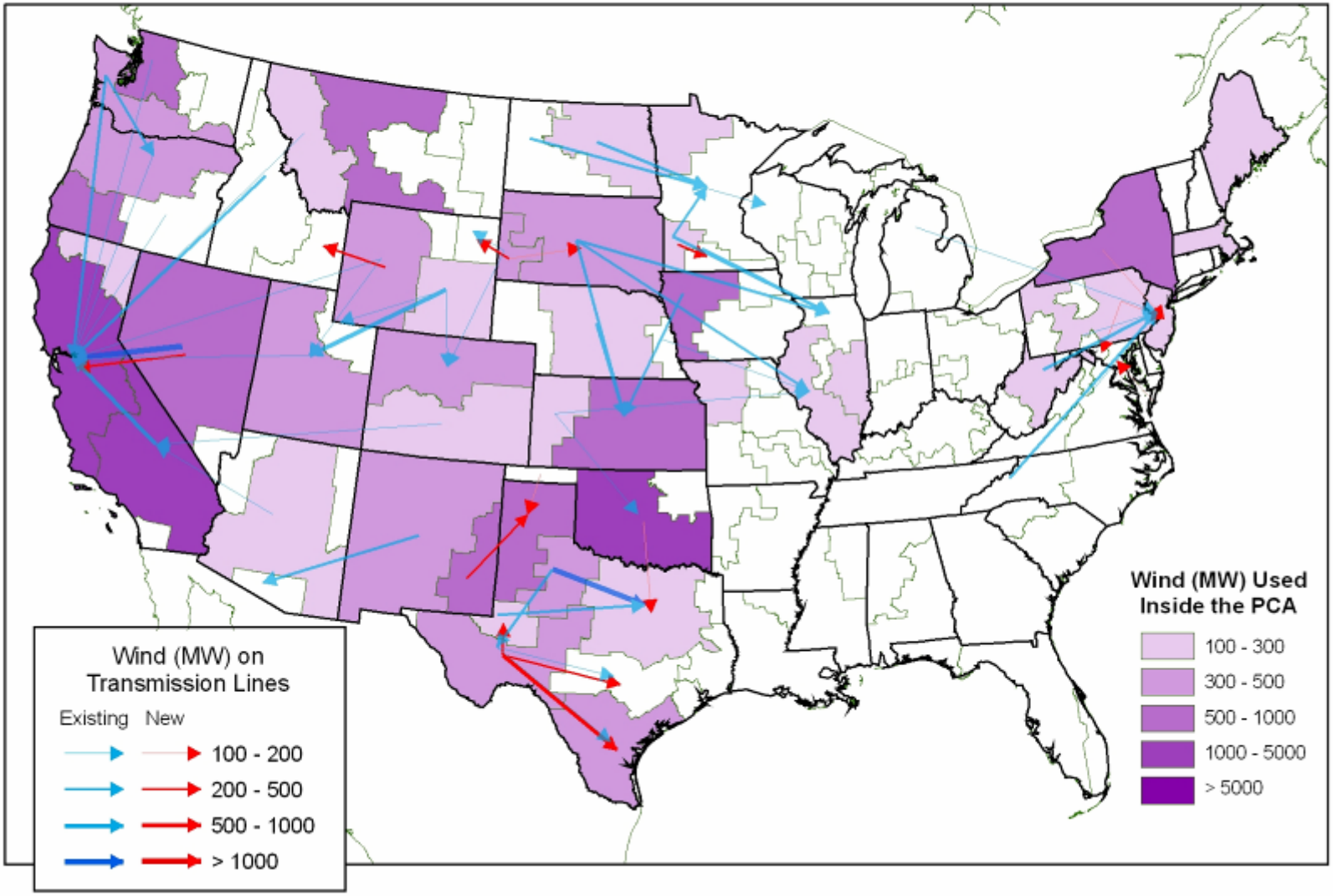
Wind_Vision_06-19-2007 - DRAFT

Source: NREL

2012 - Between PCA Transfers and In-PCA Use for Wind (All Classes)

Total Between PCA Transfer >= 100 MW (all power classes, onshore and offshore)
Arrows originate and terminate at the centroid of the PCA for visualization purposes; they do not represent physical locations of transmission lines.

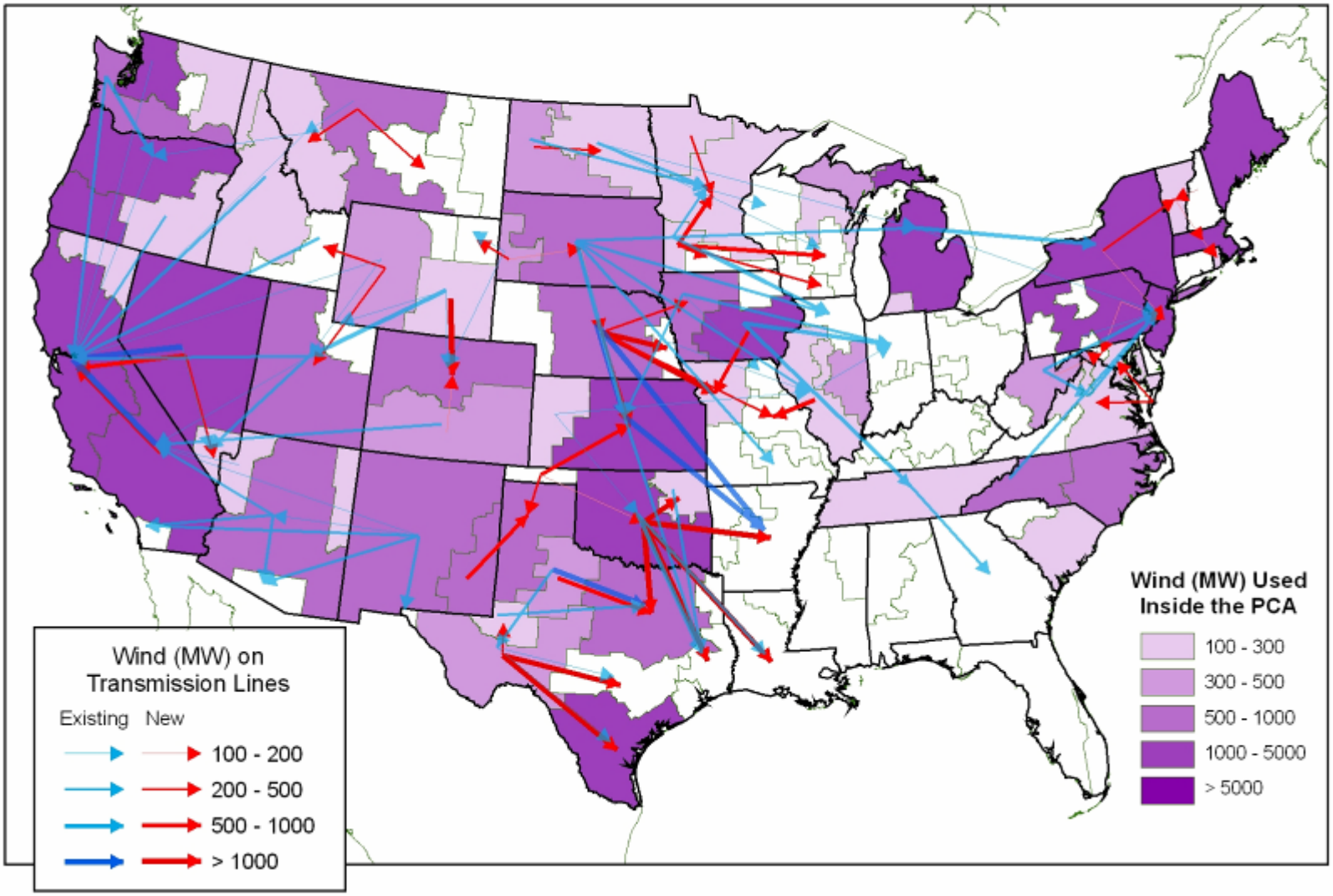


Wind_Vision_06-19-2007 - DRAFT

Source: NREL

2018 - Between PCA Transfers and In-PCA Use for Wind (All Classes)

Total Between PCA Transfer >= 100 MW (all power classes, onshore and offshore)
Arrows originate and terminate at the centroid of the PCA for visualization purposes; they do not represent physical locations of transmission lines.

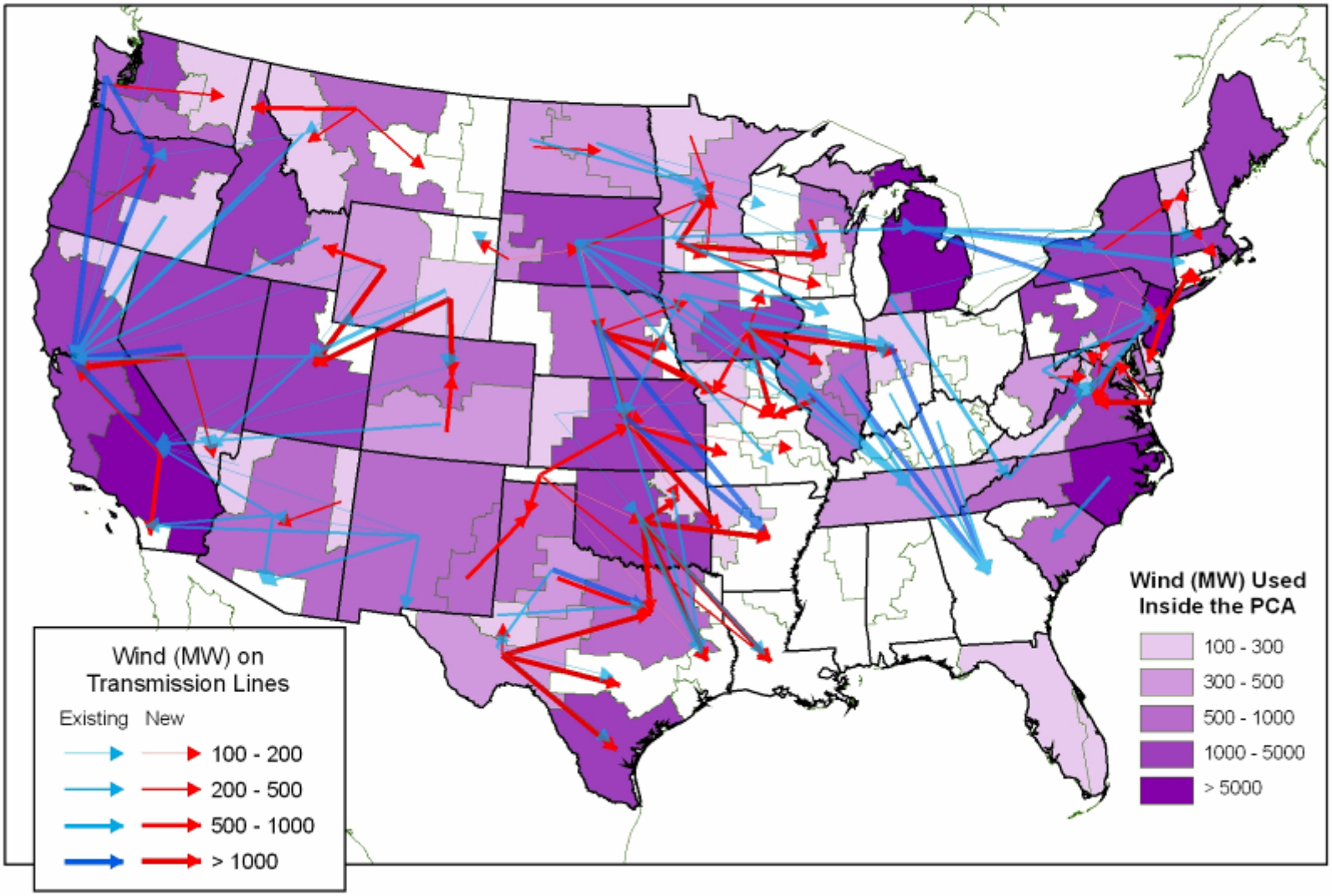


Wind_Vision_06-19-2007 - DRAFT

Source: NREL

2024 - Between PCA Transfers and In-PCA Use for Wind (All Classes)

Total Between PCA Transfer >= 100 MW (all power classes, onshore and offshore)
Arrows originate and terminate at the centroid of the PCA for visualization purposes; they do not represent physical locations of transmission lines.

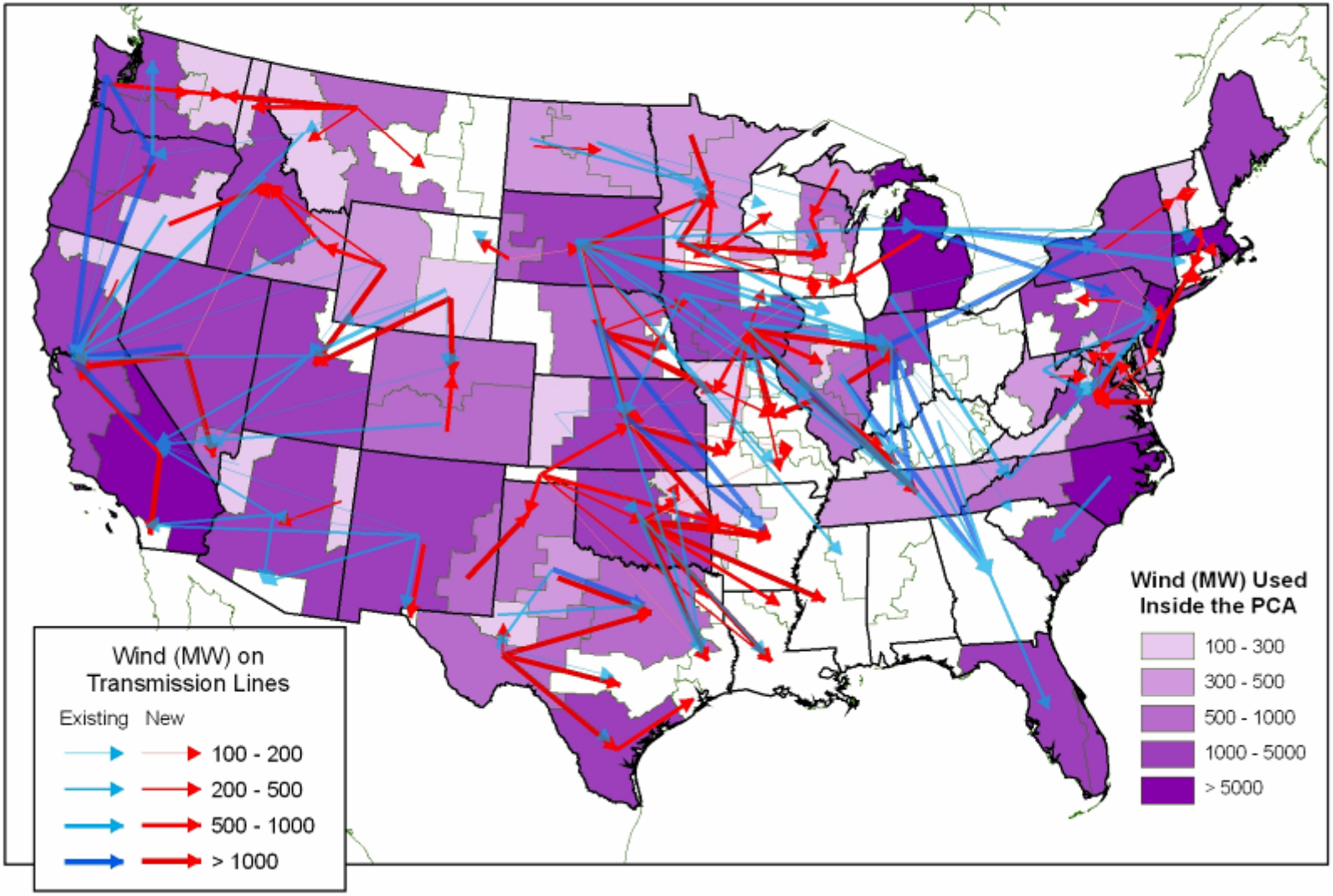


Wind_Vision_06-19-2007 - DRAFT

Source: NREL

2030 - Between PCA Transfers and In-PCA Use for Wind (All Classes)

Total Between PCA Transfer >= 100 MW (all power classes, onshore and offshore)
Arrows originate and terminate at the centroid of the PCA for visualization purposes; they do not represent physical locations of transmission lines.



Wind_Vision_06-19-2007 - DRAFT

Source: NREL

Thank You!

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