

2009 Geothermal, Co-Production, and GSHP Supply Curves

May 19, 2010

Principal Investigator: Chad Augustine

Presenter: Tom Williams
National Renewable Energy Laboratory

Analysis, Data System and Education

- Geothermal Supply Curves
 - Estimate **capacity** and **cost** of geothermal resources
 - Input to regional market penetration models (NEMS, MARKAL, SEDS, ReEDS, and GCAM)
 - Use in DOE annual reporting and budget exercises
- Geothermal Technologies included
 - Hydrothermal (**update**)
 - Enhanced Geothermal Systems (EGS) (**update**)
 - Co-Produced Fluids (**new**)
 - Ground Source Heat Pumps (GSHP) (**new**)

		Hydro/EGS Update	Co-Pro	GSHP
Timeline	Start	03/15/09	03/01/10	03/01/10
	End	8/31/10	06/30/10	9/30/10
	% Complete	25%	30%	10%
Budget	2009	\$105k	--	--
	2010	\$78k	\$202k	\$263k
Barriers		<ul style="list-style-type: none"> • Lack of Available and Reliable Resource Information • Inconsistent Datasets, Assumptions, and Guidelines • Limited Suite of Models and Tools 		
Partners		n/a – NREL Analysis Projects		

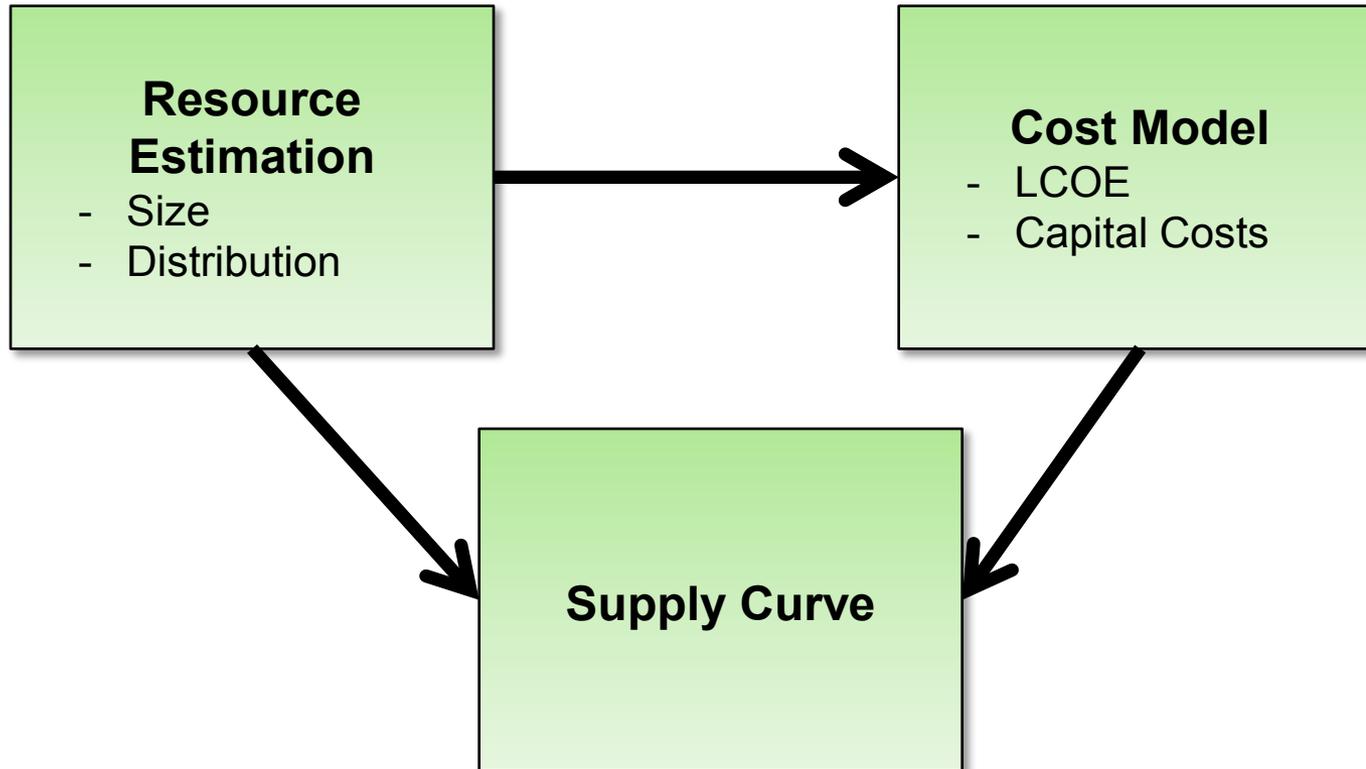
Project Objectives: Generate supply/deployment curve input for geothermal technologies for use in market penetration models

- Hydrothermal/EGS Supply Curve
 - Update supply curves developed in FY09 using newly available data and improved resource estimation and cost modeling techniques
- Co-Produced Supply Curve
 - Perform co-produced resource estimate
 - Create cost model for co-produced systems
 - Develop co-produced supply curve
- GSHP Deployment Curve
 - Identify applicability by geographic region
 - Develop system cost model
 - Develop curve of GSHP deployment costs by region

Relevance/Impact

- Supply curves estimate present and future costs of the geothermal resource
 - Used in market penetration models to predict future electricity landscape
- Supply curve input used in annual DOE exercises
 - Program Benefits Analysis (PBA)/GPRA
 - Budget discussions
- Curves do not currently exist for co-produced and GSHP resources
 - Not included in PBA
 - Difficult to quantify benefits of GTP RD&D

Supply Curve – Basic Approach



Hydrothermal/EGS FY09 Supply Curve

- Update of 2007 geothermal supply curve ([Petty and Porro, 2007](#))

Resource estimation

- Hydrothermal
 - Use identified hydrothermal sites and undiscovered hydrothermal resource estimates from USGS 2008 Geothermal Assessment
 - Assume undiscovered hydro is similar to identified sites in same state
- EGS
 - Near-hydrothermal field EGS estimate based on USGS 2008 Geothermal Assessment data for identified hydrothermal sites
 - Deep EGS (3-10 km) from SMU temperature vs. depth maps and heat-in-place methodology described in *The Future of Geothermal Energy* ([MIT, 2006](#))

Cost model

- Used Geothermal Energy Technology Evaluation Model ([GETEM](#)) to estimate capital costs and LCOE for hydro and EGS projects
- Expert input on technology component costs from 2009 GTP Risk Assessment ([Young et al., 2010](#))

Hydrothermal/EGS FY10 Update

Resource estimation

- Improve hydrothermal resource estimates
 - USGS providing detailed resource characteristic and uncertainty data
 - 250 geothermal sites described in terms of reservoir volume and temperature
- Update methodology used to characterize undiscovered hydrothermal resource
 - Collaborating with USGS on resource evaluation methods
- Update EGS resource estimation based on new temperature vs. depth maps coming from SMU (expected beginning May 2010)

Cost model

- Re-run GETEM models with updated cost indices
- Incorporate hydrothermal resource uncertainty

Co-Produced

Resource estimation

- GIS inventory of U.S. oil and gas wells from state agency data
 - 31 states expected in inventory (main O&G producers)
 - Data available online or by request (state agencies, APPG, SMU)
 - Collect/estimate fluid production data
- Estimate co-produced fluid resource temperature
 - 1st cut – Use SMU temperature vs. depth maps
 - 2nd cut – Cross check with BHT taken from individual well logs
- Estimate electric generation potential based on well flow rate, estimated temperature, and ambient temperature

System design/cost model

- Develop in System Advisor Model (SAM)
- Use to identify criteria for economically feasible wells

Co-production supply curve

- Use model to estimate costs of developing power plants at O&G wells identified from resource estimation that meet economically feasible criteria

Ground Source Heat Pumps (GSHP)

Resource estimation

- The United States will be divided into a number of geographic regions (6-10) based on a factor or set of factors (e.g., climate, utility rates, construction practices, etc.) using a GIS approach
- Estimate GSHP potential based on ambient air temperature, estimated ground temperature, and soil/rock type

System design/cost model

- Develop a cost model that incorporates resource map and local/regional installation costs
- Use to develop a deployment curve for the United States

Deployment Curve

- Use model to identify areas of cost savings (i.e., payback times) and potential energy trade-offs

Hydrothermal/EGS – FY09 Supply Curve

Resource		Resource Potential Capacity	
		Capacity (GW _e)	Source(s) and Description
Hydrothermal	Identified Hydrothermal Sites	6.39	USGS 2008 Geothermal Resource Assessment ¹ - Identified hydrothermal sites - Sites ≥110 °C included - Currently installed capacity excluded
	Undiscovered Hydrothermal	30.03	USGS 2008 Geothermal Resource Assessment ¹
Enhanced Geothermal Systems (EGS)	Near-Hydrothermal Field EGS	7.03	Assumptions based on USGS 2008 assessment ¹ - Regions near identified hydrothermal sites - Sites ≥110 °C included - Difference between mean and 95 th percentile hydrothermal resource estimate
	Deep EGS	15,908	NREL 2006 Assessment ² , MIT Report ³ , SMU Data ⁴ - Based on volume method of thermal energy in rock 3-10 km depth and ≥150 °C - Did not consider economic or technical feasibility

¹ (Williams, Reed et al. 2008)

² (Petty and Porro 2007)

³ (MIT. 2006)

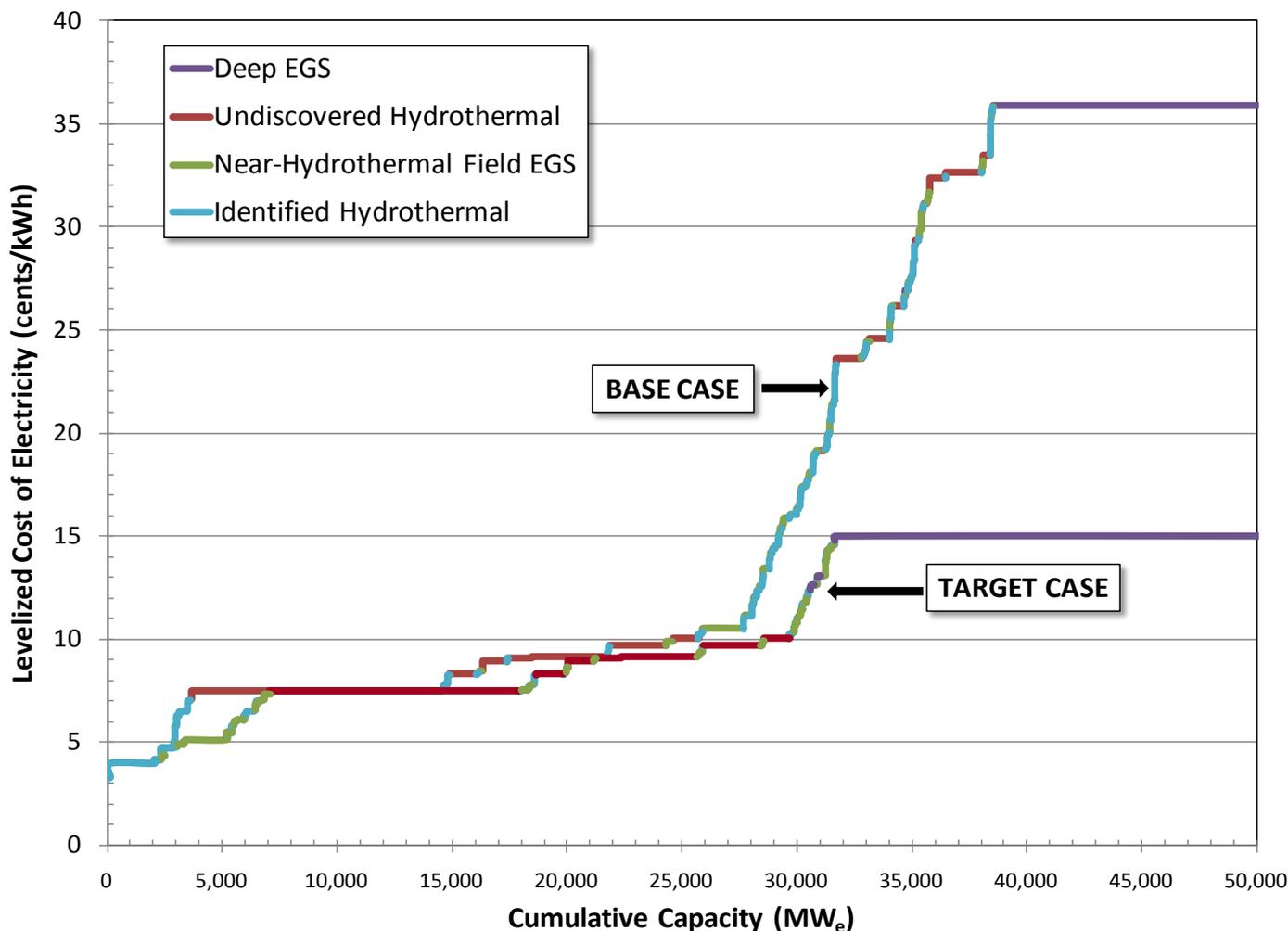
⁴ (SMU 2009)

*Technologies such as co-produced fluids, geopressed not assessed

[Augustine et al., "Updated U.S. Geothermal Supply Curve." Feb. 2010](#)

Accomplishments, Expected Outcomes and Progress (continued)

Hydrothermal/EGS – FY09 Supply Curve



LCOE estimated in GETEM using input from Risk Assessment

EGS Base Case:

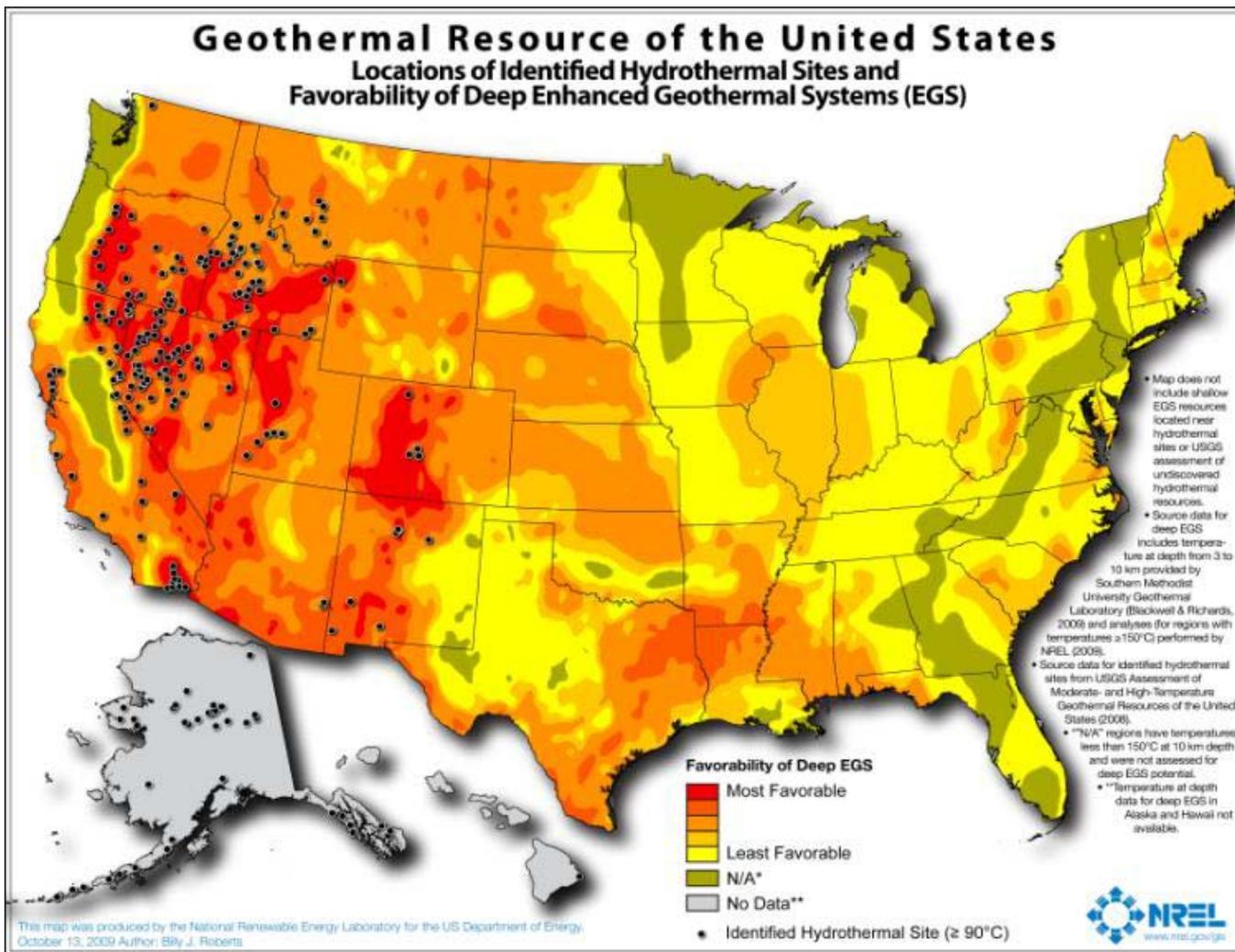
- 3%/year thermal drawdown rate
- 30 kg/s producer well flow rate

EGS Target Case:

- 0.3%/year thermal drawdown rate
- 60 kg/s producer well flow rate

Hydrothermal/EGS – FY09 Supply Curve

Augustine et al., "Updated U.S. Geothermal Supply Curve," Feb. 2010



Progress to Date

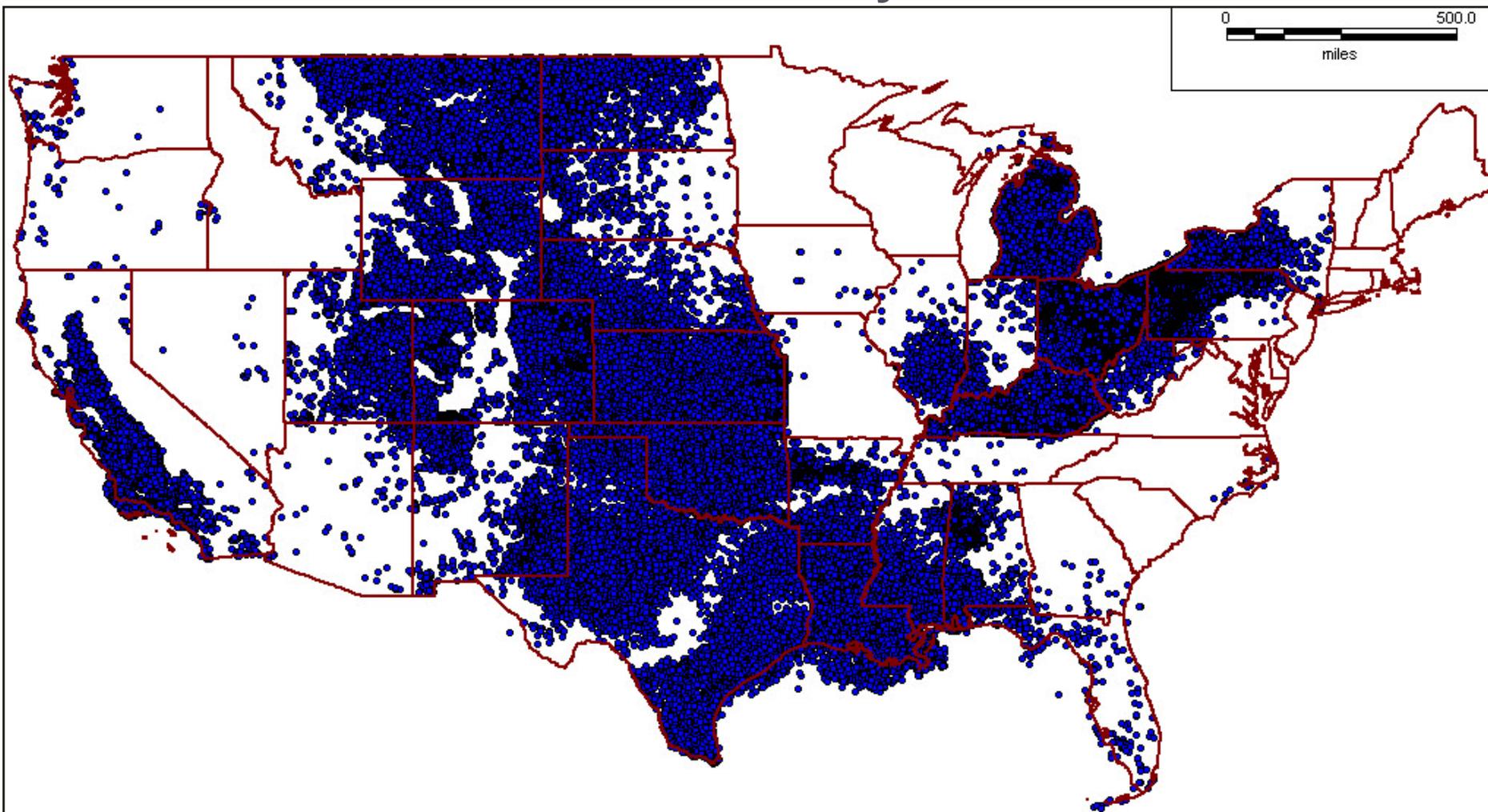
- Hydro/EGS FY10 Update
 - Detailed identified hydrothermal site data received from USGS
- Co-Produced
 - Over 2.5 million wells inventoried
 - Production data for over 350,000 producing wells
 - SMU temperature-at-depth maps integrated with well depths

Expected Outcomes

- Improved representation of hydrothermal and EGS resources
- Inclusion of co-produced and GSHP resources in future program benefits analysis
- User-friendly Co-Produced cost model for potential developers

Accomplishments, Expected Outcomes and Progress (continued)

Locations of Oil & Gas Wells Currently in Co-Produced Database



Milestones and Schedule

Milestone	Hydro/EGS Update	Co-Produced	GSHP
Resource Estimation	7/15/10	5/30/10	7/15/10
Cost Model	8/15/10	5/30/10	7/31/10
Supply/ Deployment Curve	8/31/10	06/30/10	8/31/10
Final Reports	9/30/10	9/30/10	9/30/10

- Collaboration with USGS and SMU on data sharing for hydrothermal/EGS/Co-Produced
- Data on oil & gas wells will be made available to National Geothermal Data System (NGDS)

- Future supply curves (FY11) will utilize data from NGDS
- Hydro/EGS – incorporate results from planned USGS paper on the near-hydrothermal field EGS resource
- Co-Produced – expansion to reservoir potential water production rather than current production
- GSHP – development of web-based GSHP cost-modeling tool based on system model developed in this project

- Supply Curve Projects:
 - Hydrothermal (**update**)
 - Enhanced Geothermal Systems (EGS) (**update**)
 - Co-Produced Fluids (**new**)
 - Ground Source Heat Pumps (GSHP) (**new**)
- Co-Produced and GSHP supply/deployment curves
 - Original analysis on geothermal technologies new to GTP portfolio
 - Will allow analysis of high-priority GTP tasks to be included in benefits analysis and budget exercises
- New tools from projects

Hydro/EGS:	Undiscovered hydrothermal resource estimation methodology
------------	---

Co-Produced:	GIS database of oil and gas wells SAM-based cost model for developers
--------------	--

GSHP:	Database of GSHP deployment costs by region
-------	---

Supplemental Slides

Augustine, C.; K. Young; Anderson, A. (2010) “Updated U.S. Geothermal Supply Curve.” NREL/CP-6A2-47458, Presented at Stanford Geothermal Workshop, Stanford, California, February 1, 2010. Available online: www.nrel.gov/docs/fy10osti/47458.pdf

.