

## 2009 Geothermal, Co-Production, and GSHP Supply Curves

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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"> <li>• Lack of Available and Reliable Resource Information</li> <li>• Inconsistent Datasets, Assumptions, and Guidelines</li> <li>• Limited Suite of Models and Tools</li> </ul> |          |          |
| Partners |            | n/a – NREL Analysis Projects   |          |          |

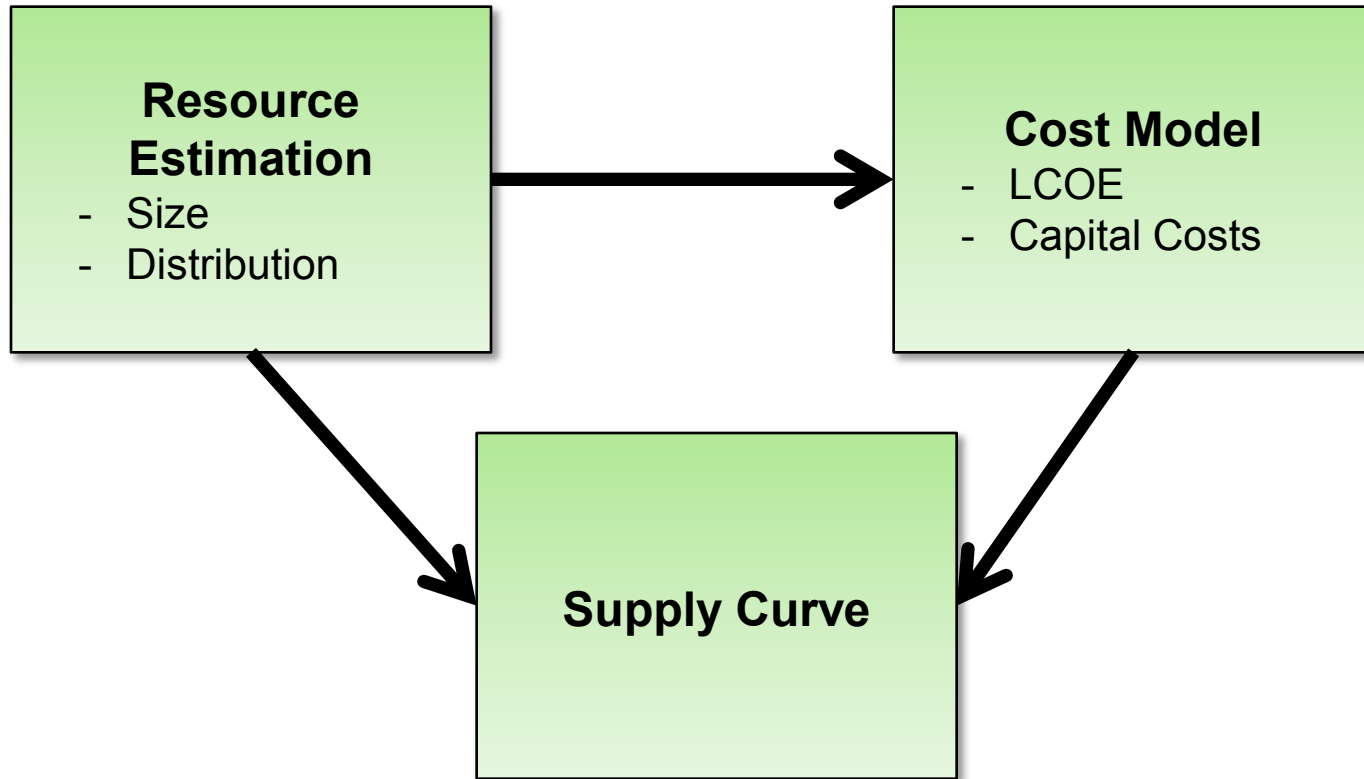
Project Objectives: Generate supply/deployment curve input for geothermal technologies for use in market penetration models

- 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
  - 1<sup>st</sup> cut – Use SMU temperature vs. depth maps
  - 2<sup>nd</sup> 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 <sub>e</sub> ) | Source(s) and Description   |
| Hydrothermal                      | Identified Hydrothermal Sites | 6.39                        | USGS 2008 Geothermal Resource Assessment <sup>1</sup><br><ul style="list-style-type: none"> <li>- Identified hydrothermal sites</li> <li>- Sites ≥110 °C included</li> <li>- Currently installed capacity excluded</li> </ul>   |
|                                   | Undiscovered Hydrothermal     | 30.03                       | USGS 2008 Geothermal Resource Assessment <sup>1</sup>   |
| Enhanced Geothermal Systems (EGS) | Near-Hydrothermal Field EGS   | 7.03                        | Assumptions based on USGS 2008 assessment <sup>1</sup><br><ul style="list-style-type: none"> <li>- Regions near identified hydrothermal sites</li> <li>- Sites ≥110 °C included</li> <li>- Difference between mean and 95<sup>th</sup> percentile hydrothermal resource estimate</li> </ul> |
|                                   | Deep EGS                      | 15,908                      | NREL 2006 Assessment <sup>2</sup> , MIT Report <sup>3</sup> , SMU Data <sup>4</sup><br><ul style="list-style-type: none"> <li>- Based on volume method of thermal energy in rock 3-10 km depth and ≥150 °C</li> <li>- Did not consider economic or technical feasibility</li> </ul>         |

<sup>1</sup> (Williams, Reed et al. 2008)

<sup>2</sup> (Petty and Porro 2007)

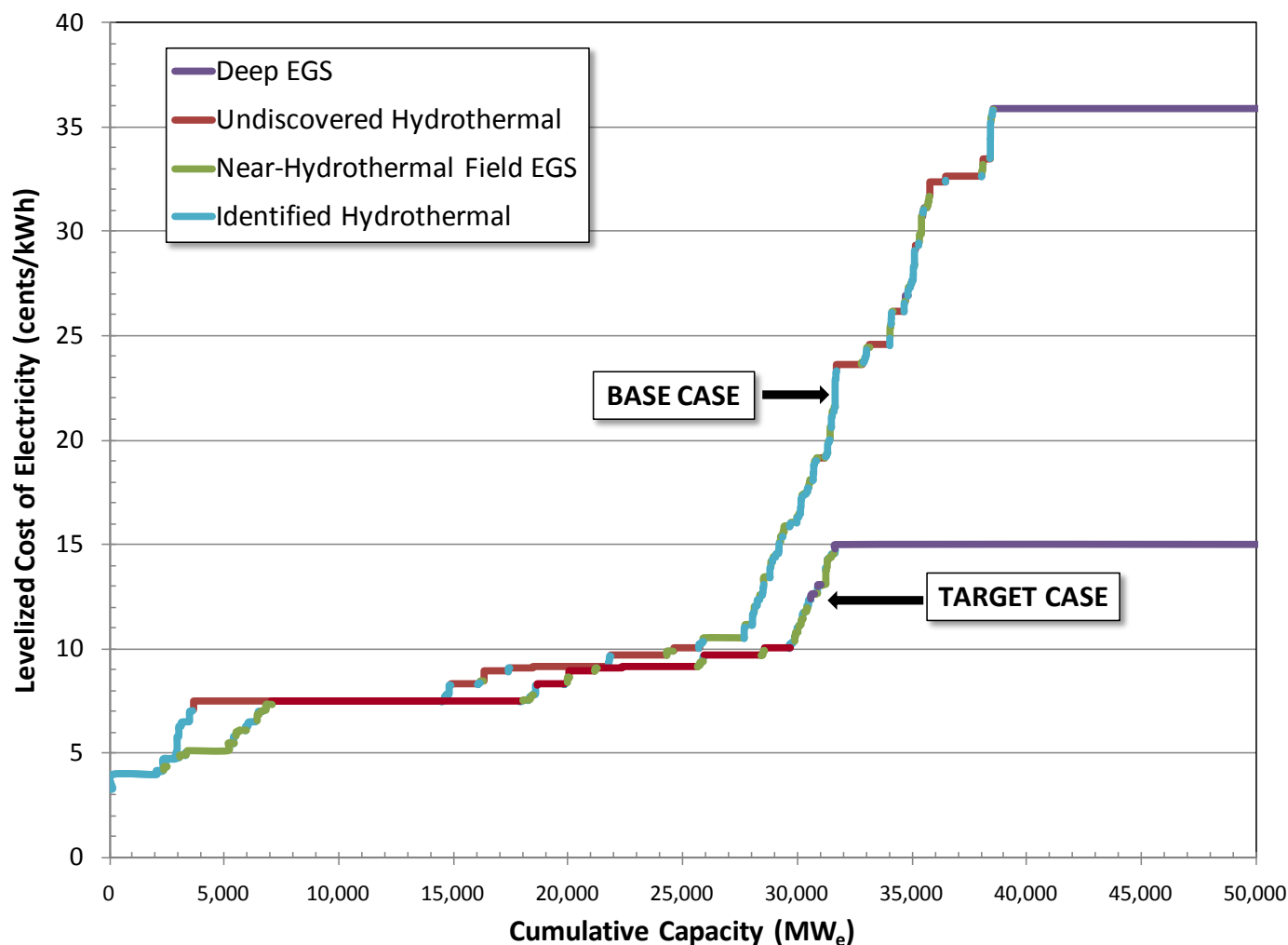
<sup>3</sup> (MIT. 2006)

<sup>4</sup> (SMU 2009)

\*Technologies such as co-produced fluids, geopressured not assessed

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

## 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

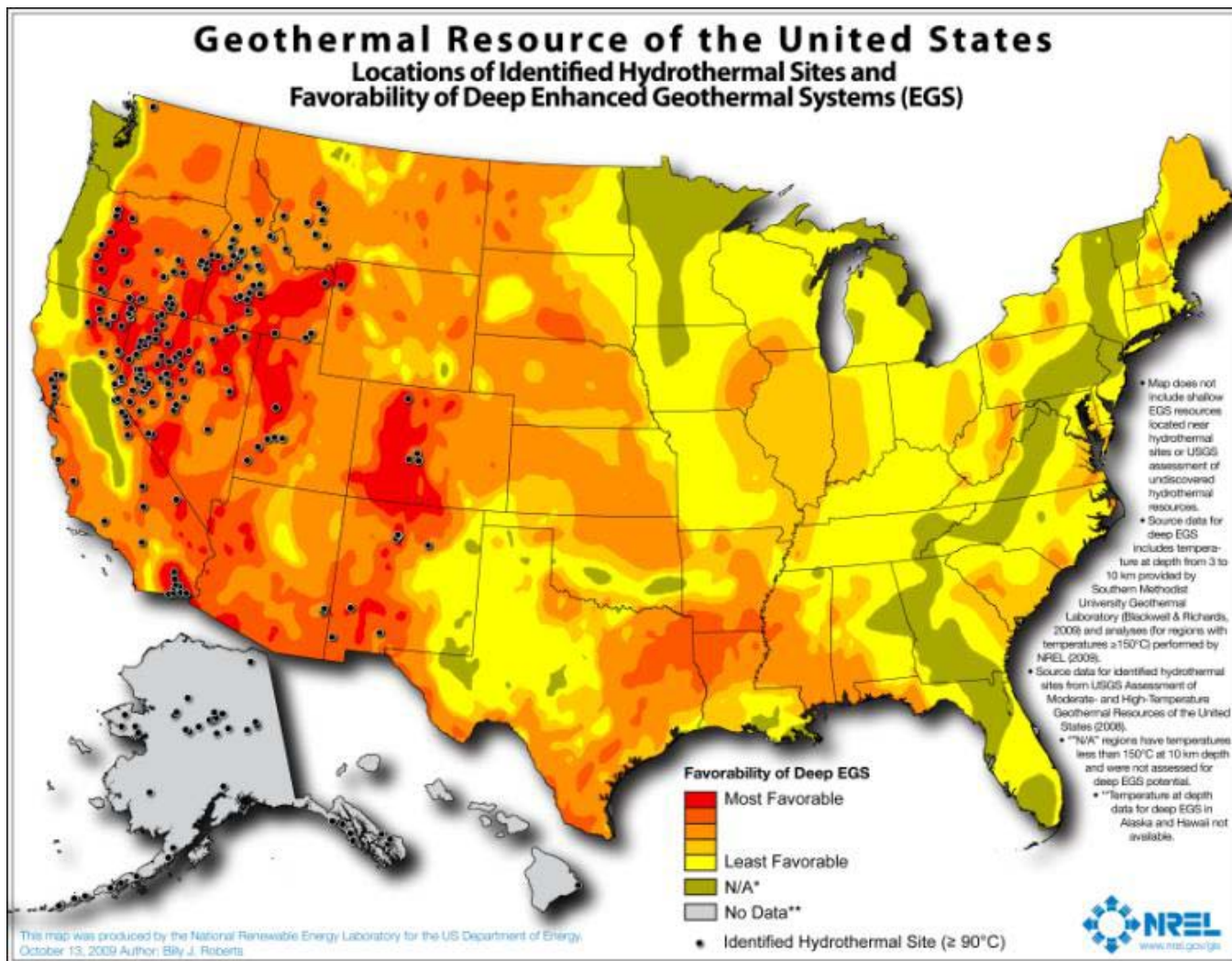
EGS Target Case:

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

# Accomplishments, Expected Outcomes and Progress (continued)

## Hydrothermal/EGS – FY09 Supply Curve

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



## Progress to Date

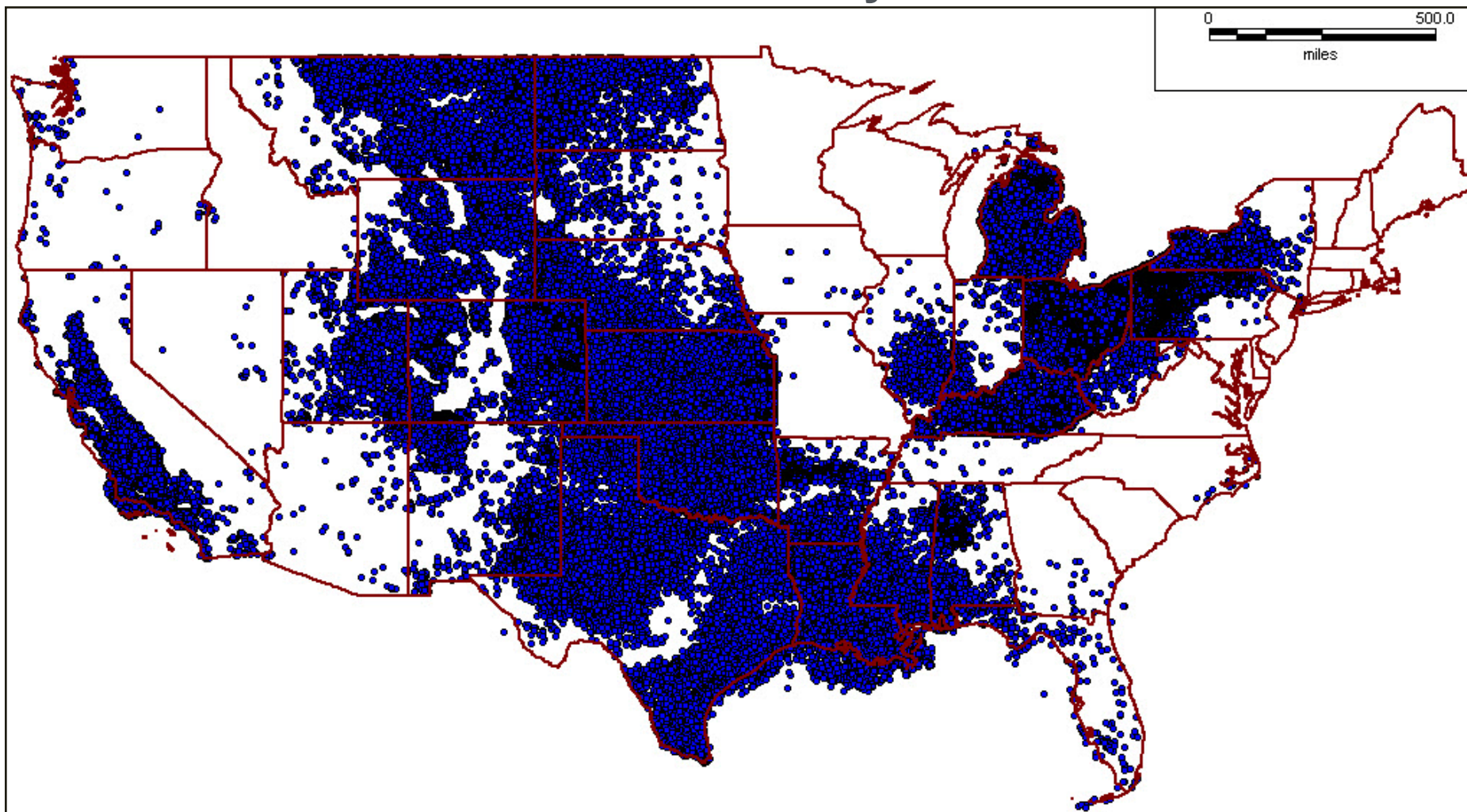
- Hydro/EGS FY10 Update
  - Detailed identified hydrothermal site data received from USGS
- Co-Produced
  - Over 2.5 million wells inventoried
  - Production data for over 350,000 producing wells
  - SMU temperature-at-depth maps integrated with well depths

## 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



## 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/<br>Deployment<br>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<br>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](http://www.nrel.gov/docs/fy10osti/47458.pdf)

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