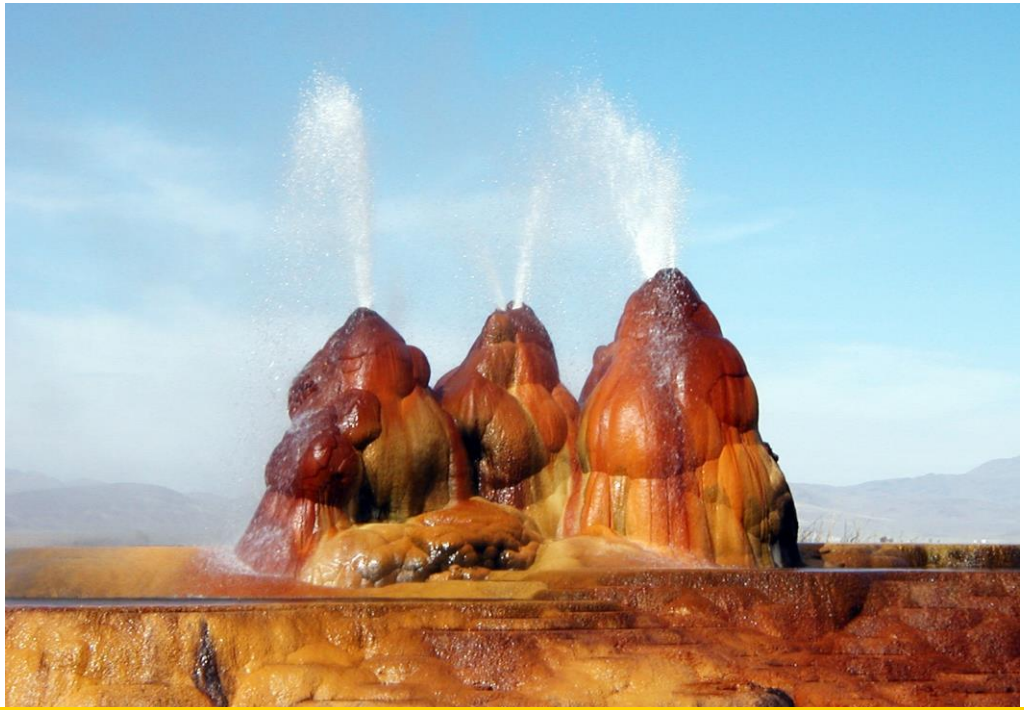


Geothermal Electricity Technologies Evaluation Model

GETEM

Project Officer: Timothy Reinhardt

Total Project Funding: $2,060K

May 11, 2015

Greg Mines, Idaho National Laboratory

Systems Analysis

This presentation does not contain any proprietary confidential, or otherwise restricted information.

Relevance/Impact of Research

Objective:

- Provide the GTO with a tool that can be used to estimate geothermal power generation costs using current technologies
- Provide method of showing impact of technology improvements on those generation costs
- Validate that model's estimates are representative of those costs encountered by the industry
- Make model both less arduous to use and more accessible to public
- Provide technical support to GTO as requested

Innovation:

- Incorporates all aspects of a project development when estimating generation costs
- Includes calculation of
  - pump setting depths
  - the effect of declining resource productivity (temperature) on power sales

Relevance/Impact of Research

Impact on GTO:

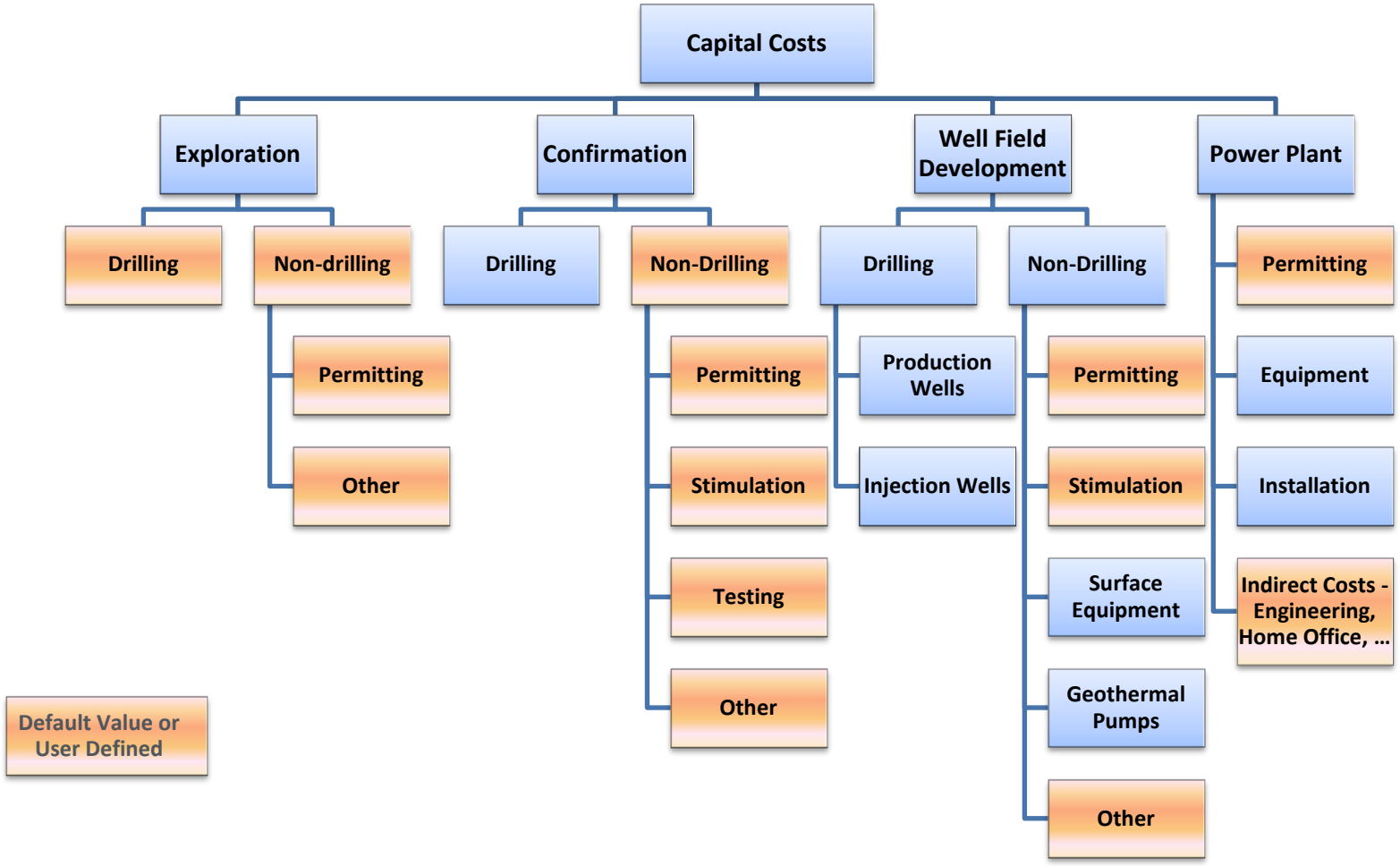
- Used by GTO to meet reporting requirements (GPRA), set program goals and quantify benefits of research program
- Used to generate supply curves for market penetration studies
- Costs used in market penetration models: NEMS, MARKAL, SEDS, ReEDS
- Costs to be used in Geothermal Vision Study (also used in other renewables' vision studies)
- Costs used in EIA Annual Energy Outlook Report
- Elements of GETEM also used in other models
  - System Advisory Model (SAM)
  - GEOPHIRES
  - GT-Mod

Scientific/Technical Approach

Approach:

- GETEM's estimates are based on either defined power sales or number of production wells
- Well field and power plant are sized based on scenario defined by User
- Capital cost estimates are made for each defined project phase
  - Exploration
  - Confirmation
  - Well Field Completion
  - Power Plant Construction/Startup
- Annual operating and maintenance (O&M) costs are estimated (include Royalties, makeup water (EGS), taxes and insurance)
- Impact of defined reservoir temperature decline on power generation is estimated over project life
- Cost and power generation estimates are used to determine levelized-cost-of-electricity (LCOE) utilizing a simple discounted cash flow method

Capital costs included in GETEM's estimate of generation costs



Scientific/Technical Approach

Early project risk quantified:

- Down select process that includes cost of evaluating/drilling unsuccessful sites
- Higher discount rates applied to exploration and confirmation costs

Validation:

- On-going activity to assess both model estimates and inputs used – both must be representative of what industry encounters
  - GTO effort from 2011-2012 to validate model approaches, inputs, and results thru series of interviews with industry experts
  - Model provided to industry with requests for comment
  - When sufficient information available, costs are estimated and compared to those for new commercial projects
  - Recent focus is using historical production/injection data to validate inputs and model estimates

Scientific/Technical Approach

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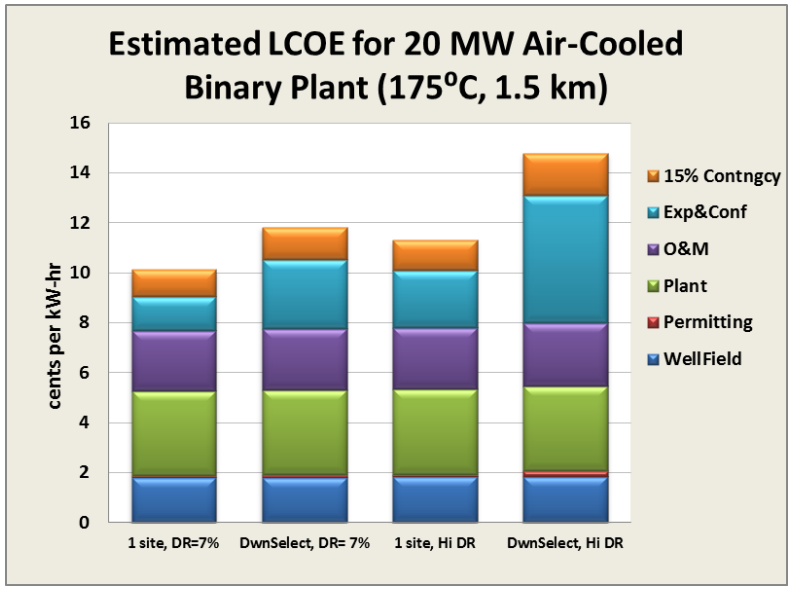
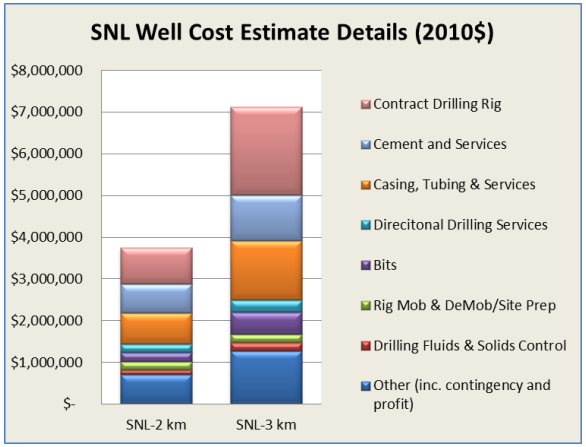
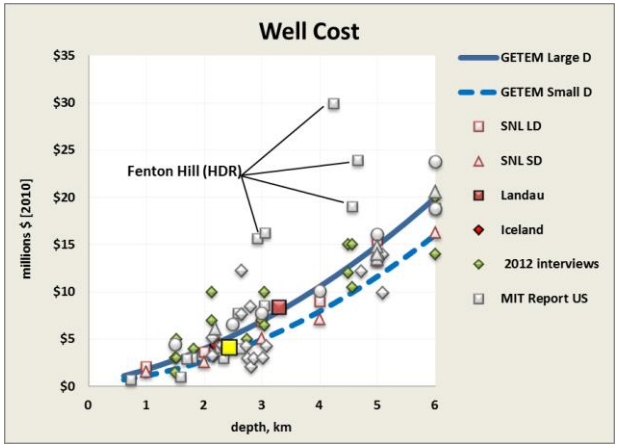
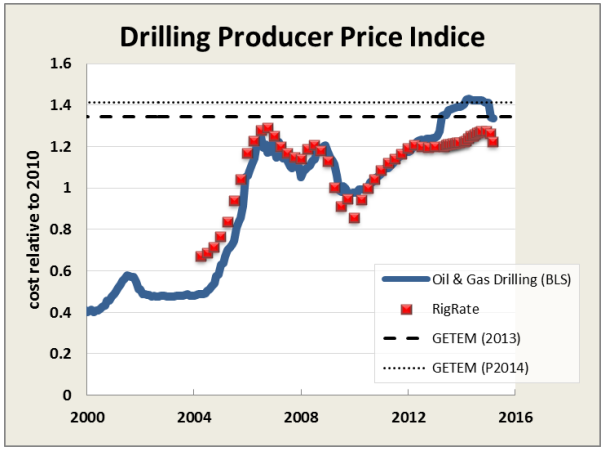
Issues:

- Quantifying risk for early project activities
  - Is calculated LCOE "too high" when using both 'down-select' process and high discount rates?
- Volatility in major cost drivers (drilling)
  - Drilling costs based on estimates made by Sandia National Laboratory in 2012 (basis 2010 dollars)
  - Bureau of Labor Statistics Produce Price Indices (PPI's) used to keep estimates 'current' – can lag by up to 16 mo.
  - Cost volatility compromises ability to depict current costs and to validate estimates









SNL provided estimates for 6 different depths, with 4 different completions at each depth

Accomplishments, Results and Progress

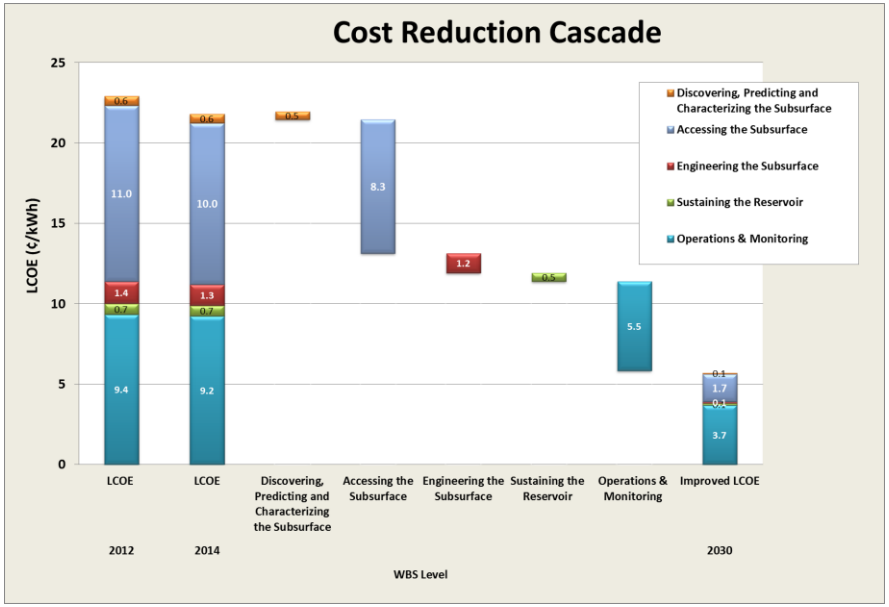
FY14/FY15:

- Model Changes:
  - Consolidated model worksheets to better integrate changes made in 2011-2013
  - Integrated default inputs
    - 1st step in developing more user friendly model
    - Based on inputs developed for GTO defined Hydrothermal and EGS resource scenarios
    - Minimal 'required' input - estimates based on defined resource type, temperature and depth
    - User can revise selected default values
- Support provided to Users and GTO researchers
  - EGI & Utah Geological Survey assessment of stratigraphic reservoirs
- Provided tech support to GTO efforts to assist EIA in understanding recent changes in geothermal capacity factors

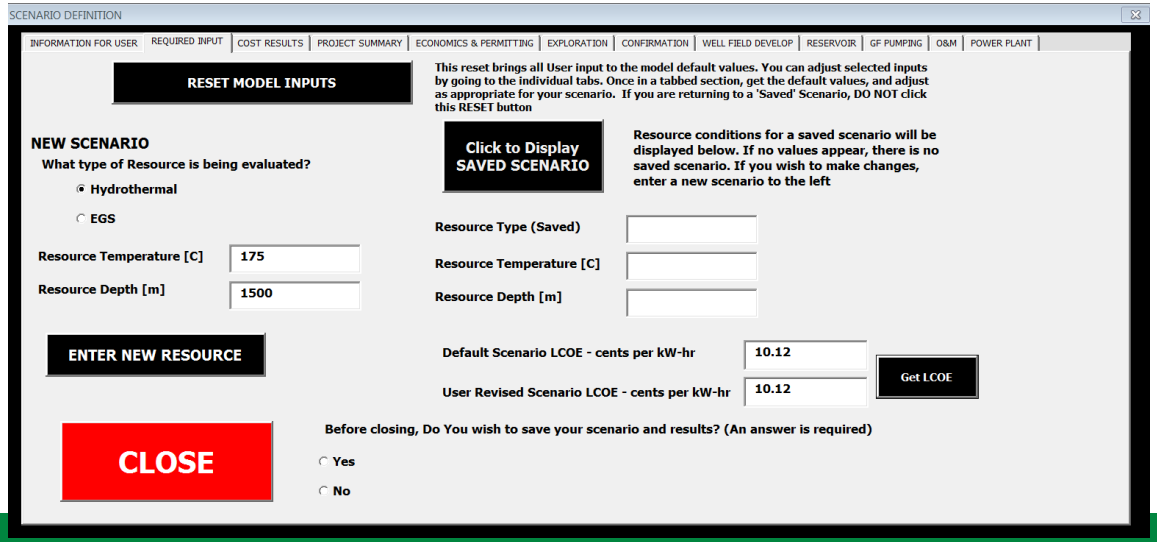
Accomplishments, Results and Progress

FY14/FY15:

- Modified model to accommodate estimating impact of technology improvements that are aligned with GTO WBS
- Developed Visual Basic interface (User Form) to facilitate use of existing model by general public

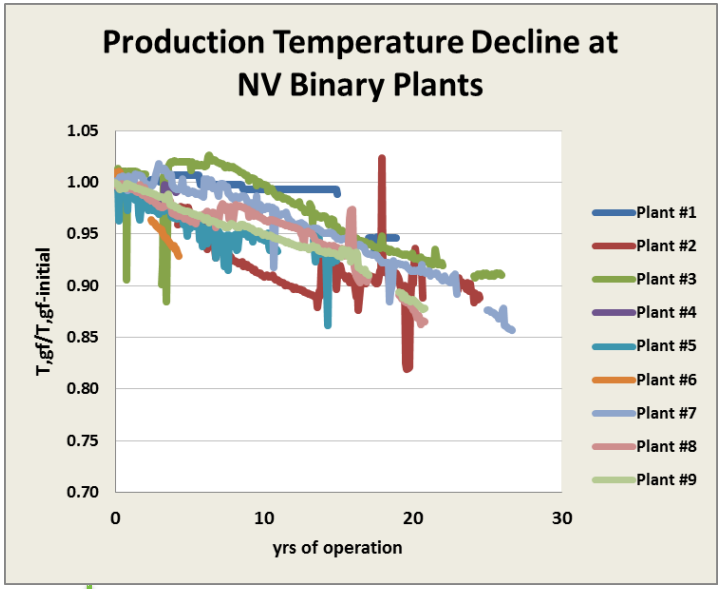


Required User Input



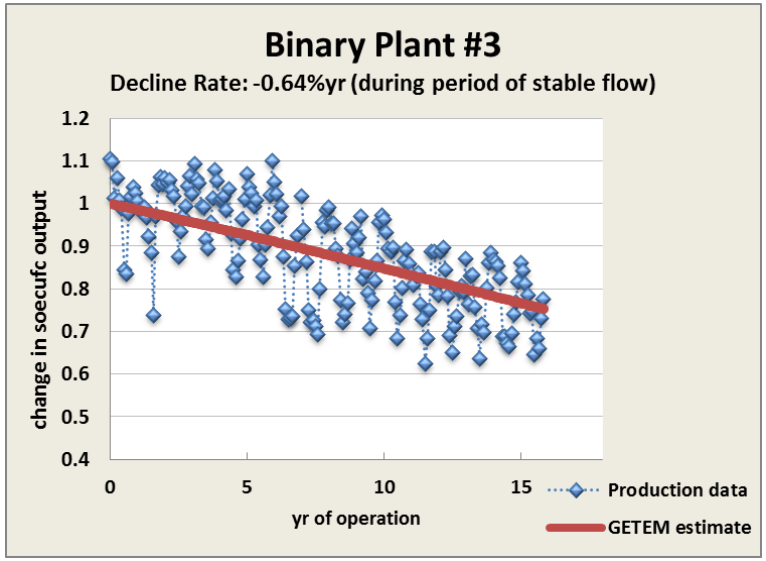
FY14/FY15:

- Validation:
  - Student interns complied historical data from NV geothermal operations that is being used in validating estimates of impact of resource decline
  - Issue: GETEM assumes constant brine flow; as temperature declines operators will increase flow to offset impact on output



- Annual decline : -0.45%
- GETEM Default: -0.4%

- GETEM predicts impact of temperature decline assuming
  - constant GF flow
  - 10°C ambient
- Predicted output based on available energy and 2nd law efficient (both change with fluid temperature)
- GETEM able to match change in performance when flow rates stable



Accomplishments, Results and Progress

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Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Integrate inputs from GTO defined resource scenarios into GETEM	Version of model developed with default inputs based on GTO resource scenario inputs	Feb 2014
Simple version of model in Excel format completed for web download by public	A version of model with Visual Basic interface is completed. The model has not been made available because issues relative to its estimate of early project risk	
Decision to move model to alternative platform	Decision was postponed pending review of User needs	
More robust model in alternative platform	If decision is made to move model to new platform – the platform will be C++	

Future Directions

The primary focus areas for the remainder of FY15 will be

- Support of the Geothermal Vision Study
  - Resolve methodology used to quantify impact of early project risk on generation costs
- Make simple Excel version of model available for download from INL's web site
- Determine future disposition of model
  - Where model to reside and how it will be maintained
  - How to provide model support to GTO (and others)
  - Decision on model transition to new platform (C++)
- Continue validation efforts
  - Industry input
  - Using historical production and injection data from NV

Future Directions

FY16 and beyond:

- Complete documentation and model transition to alternative platform
- Provide model support to the GTO, including maintenance
- Validation of inputs and results

No further revisions are planned for GETEM. If revisions are required, the GTO will provide funding specific for those changes.

Mandatory Summary Slide

- GETEM continues to provide the GTO with a means of estimating generation costs and how technology can impact those costs
- It identifies the major cost drivers for geothermal power production, and provides a means of both setting programmatic goals and prioritizing research areas
- The model's use is pervasive in the DOE's analysis efforts.
- Like any model, its estimates are only as good as the inputs used. If the model is to continue to provide service to the GTO, there should be an ongoing validation effort of both inputs and results.

Contributors

The following individuals have contributed to the development of GETEM

- Dan Entingh, PERI
- Chip Mansure, SNL
- Susan Petty, Black Rock
- Gerry Nix, NREL
- Marty Plum, INL
- Chad Augustine, NREL
- John Finger, SNL (retired)
- Erin Camp, Sentech, Inc
- Mark Paster, Consultant
- Ella Thohdal, SRA International
- Steven Hanson, SRA International
- Hillary Hanson, INL
- Christopher Richard, BCS, Inc.
- Greg Mines, INL
- Jay Nathwani, GTO