Geothermal Energy

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Enel Stillwater - Courtesy of Enel Green Power – North America

Quadrennial Technology Review

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Installed Geothermal Capacity 1960-2007

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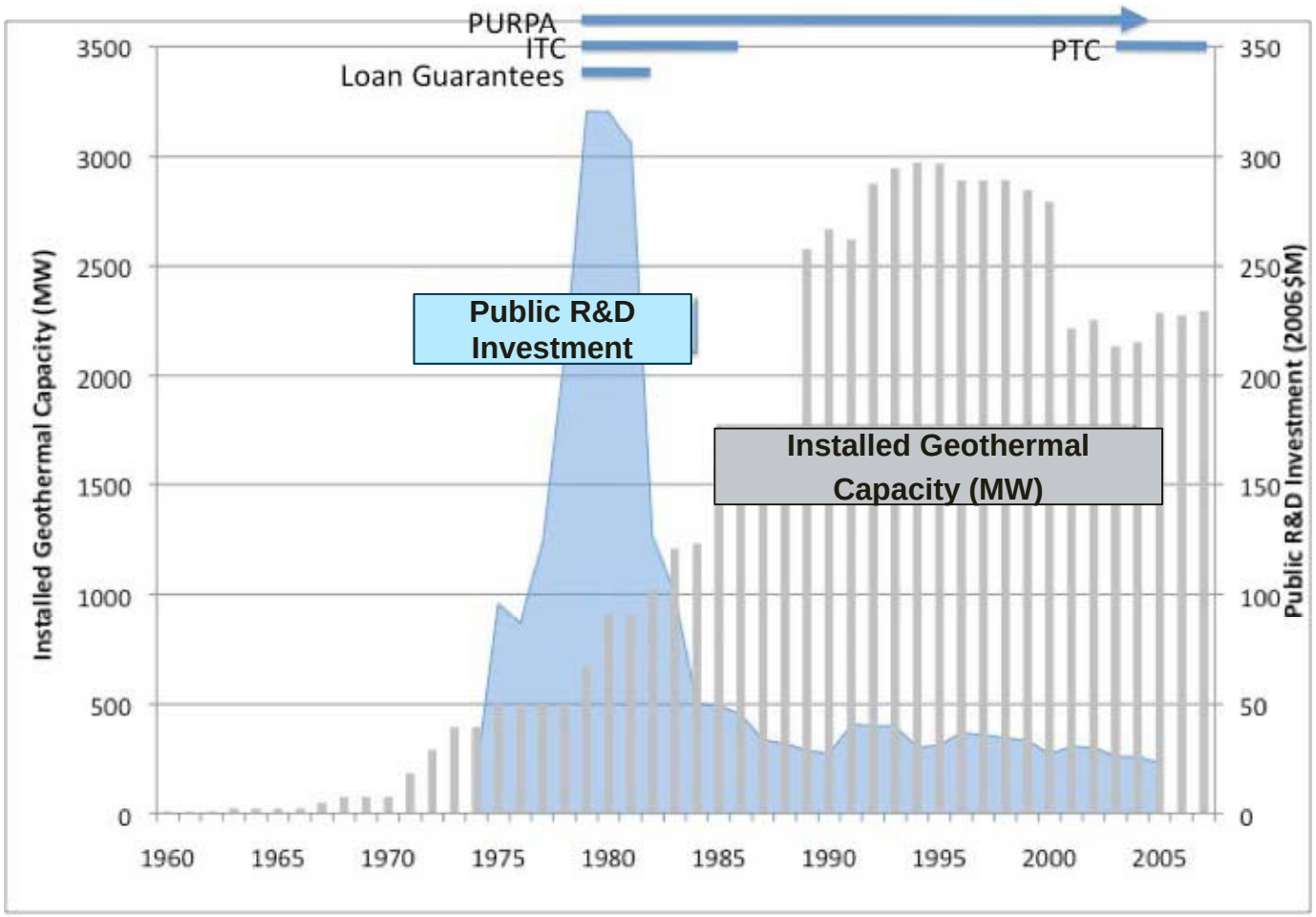
R&D investments and policy have driven geothermal energy growth since the 1980s.



From:
Policy Overview and Options for Maximizing the Role of Policy in Geothermal Electricity Development
(NREL) September, 2009

Geothermal Program History
Annual Budget 1976-2012

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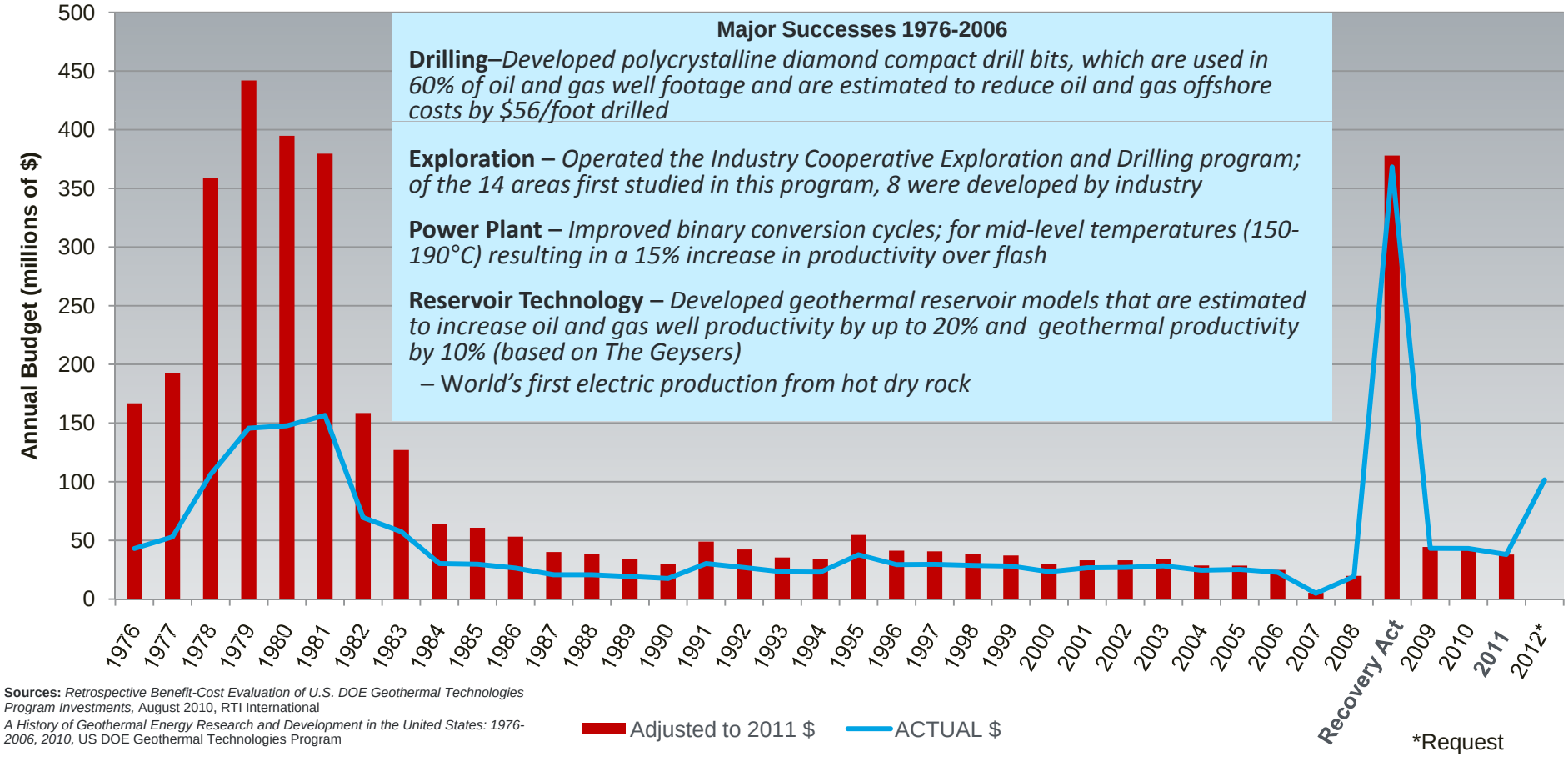
The Geothermal Technologies Program budget peaked in the late 1970s and early 80s, was nearly zeroed in 2007, and got a large spike from the Recovery Act.

Annual Budget for the Geothermal Technologies Program 1976 - 2012



Major Successes 1976-2006

Drilling–*Developed polycrystalline diamond compact drill bits, which are used in 60% of oil and gas well footage and are estimated to reduce oil and gas offshore costs by $56/foot drilled*

Exploration – *Operated the Industry Cooperative Exploration and Drilling program; of the 14 areas first studied in this program, 8 were developed by industry*

Power Plant – *Improved binary conversion cycles; for mid-level temperatures (150-190°C) resulting in a 15% increase in productivity over flash*

Reservoir Technology – *Developed geothermal reservoir models that are estimated to increase oil and gas well productivity by up to 20% and geothermal productivity by 10% (based on The Geysers)*

– *World's first electric production from hot dry rock*

Sources: *Retrospective Benefit-Cost Evaluation of U.S. DOE Geothermal Technologies Program Investments*, August 2010, RTI International

A History of Geothermal Energy Research and Development in the United States: 1976-2006, 2010, US DOE Geothermal Technologies Program

Renewable Energy Capacity 2000 to 2009

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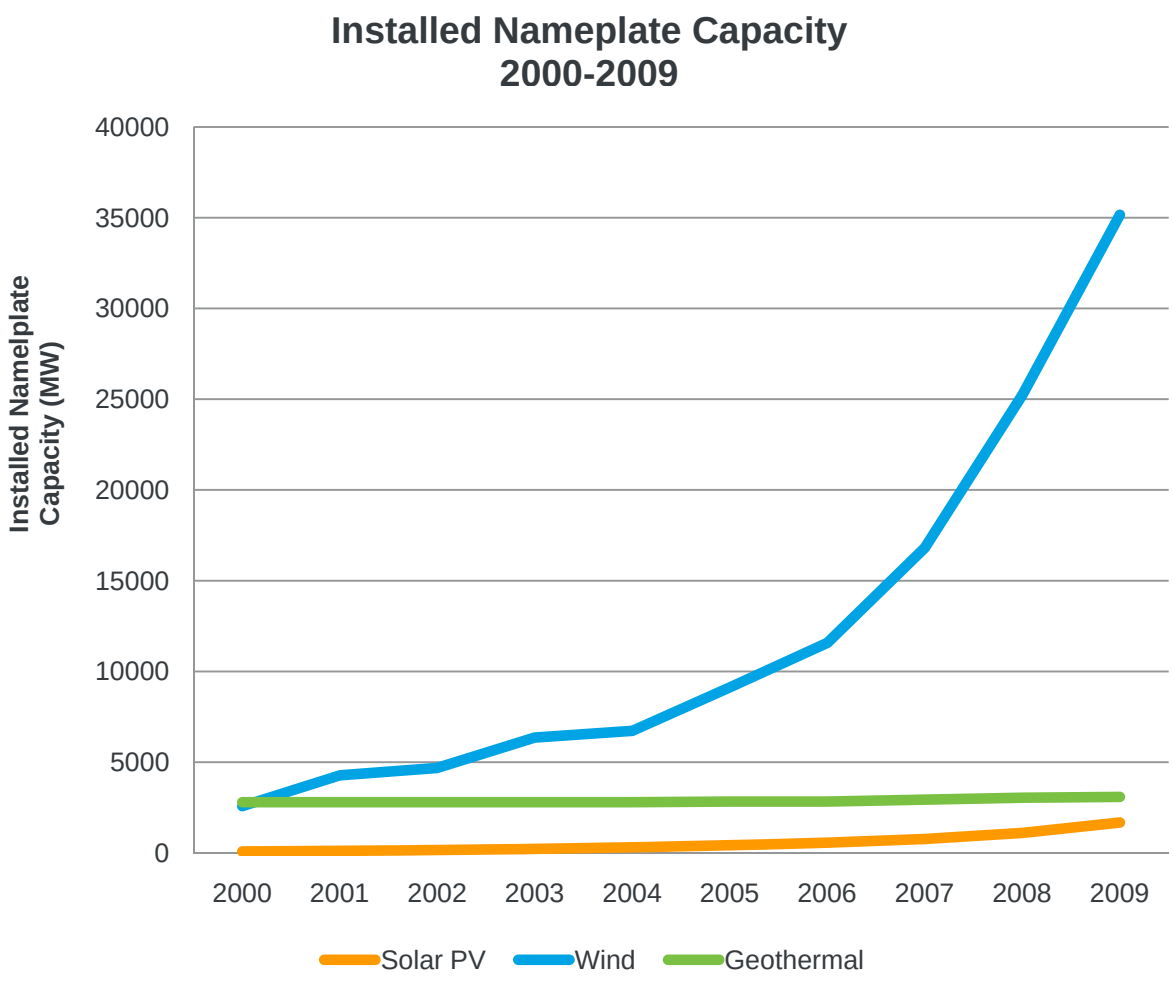
Annual growth of geothermal capacity lagged behind both solar and wind from 2000-2009.



Nameplate Capacity Annual Increase (Percent Over Previous Year)

Year	Geothermal	Wind	Solar PV
2000	2.20%	2.60%	26.90%
2001	0.00%	65.80%	31.70%
2002	0.00%	9.60%	39.20%
2003	0.00%	35.60%	44.80%
2004	0.00%	5.90%	38.00%
2005	1.10%	35.60%	35.80%
2006	0.10%	26.90%	33.40%
2007	3.70%	45.20%	36.20%
2008	3.50%	50.10%	43.50%
2009	1.50%	39.30%	51.60%

The Potential of Geothermal Energy

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The U.S. geothermal resource base is large and, except for identified hydrothermal resources, generally untapped.

Type of Geothermal Energy	Potential Capacity (GW_e)	Details
Identified Hydrothermal	6.4[1]	• Heat transferred convectively through naturally fractured rock containing in situ hot water and/or steam • Wide temp range (< 90°C to > 350°C). USGS 2008 defines low < 90°C; moderate 90-15°C; high >150°C • 3.1 GW currently installed, mostly in the Western US (Nevada and California)
Undiscovered Hydrothermal	30[1]	• Some hydrothermal resources (same temperature range as above) show no surface expression and are effectively hidden
Coproduced (Oil and Gas)	~12[2]	• Warm water is coproduced as a byproduct of hydrocarbon extraction in oil and gas wells • Cooler temperature range - under 150°C • Oil and gas operations currently treat the vast majority of water produced as waste
Geopressured (Gas)	>23[3]	• Hot brine trapped (pressurized) under impermeable caprock & layers of porous sedimentary reservoir rocks • Average temperatures typically range between 90˚C and 200˚C • These wells can contain natural gas that is not economical to produce alone
Permeable Strata Lacking Hydrocarbons	TBD	• Heat is transferred conductively through porous permeable rock in deep sedimentary basins • Average temperatures range from 130°C to 180°C (cooler than hydrothermal) • Natural permeability may reduce environmental risks (no fracturing needed) and financial costs • Potential for companion energy production from geologic carbon sequestration
Near-Field* EGS	7.0[4]	• Near hydrothermal fields; stimulation and/or injection expands or makes existing resource more productive • Resource estimate assumes temps > 110°C; will depend on temp of hydrothermal system in the vicinity • Existing surface infrastructure lowers the price of developing these resources
Greenfield EGS	15,908[4]	• In areas without existing geothermal development—generally both stimulation & fluid injection required • This resource assessment assumes that depth is between 4 and 10 km and temperature ranges from 150°C to over 350°C

[1] (Williams, Reed et al., 2008b) [2] (Tester et al., 2006) [3] (Muffler, 1979) [4] (Augustine et al., 2010)

* Resources in the Western U.S. only

Current Status – United States

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In 2010, only one geothermal power plant came online in the United States, however the Geothermal Energy Association (GEA) reports that there is about 5 GW in development in 15 states.

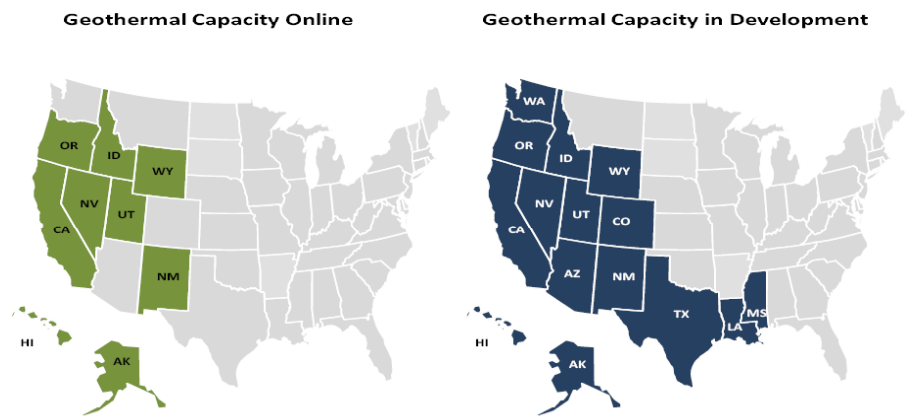
Capacity Growth

- In 2010 the only power plant to come online in the United States was Ormat's 15 MW Jersey Valley plant.
- The GEA reports that the US installed capacity is currently 3,102 MW.
- The GEA estimates that there is 5,102-5,745 MW under development. Of that, 756-772 MW is in the drilling to construction phases.

Source: Annual U.S. Geothermal Power Production and Development Report. GEA, April 2011

Geographic Impact

Figure 7: Maps of US States with Geothermal Capacity Online and Under Development



Source: GEA

Currently, geothermal power plants are generating power in nine states. The GEA reports that 170-193 projects are under development (in all stages from prospect to construction) in 15 states.

Current Geothermal Program Portfolio

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The Program currently supports a diverse portfolio that spans near- to long-term resources and low to high risk technology development. $400 million in Recovery Act funding played a big role in this strategy.

Four major pathways to increase geothermal power generation

Higher Risk

Lower Risk

Enhanced Geothermal Systems

- Potential—USGS estimates 500 GWe in the Western U.S. alone; NREL projects 16,000 GWe in the U.S.
- Funding—$70M (FY08-11, ARRA)

Innovative Exploration Technologies

- Potential—USGS estimates 30 GWe of undiscovered hydrothermal
- Funding—$110.2 M (FY11 and ARRA)

Permeable Sedimentary Resources

- Potential—USGS estimates up to 240 GWe (to be updated in 2012)
- Funding—$2 M (FY 11)

Low Temperature and Coproduced Resources

- Potential—USGS estimates up to 120 GW of untapped low-temperature geothermal resources
- Funding—$39.9 M (FY09-11 and ARRA)

Plus $170M in cross-cutting R&D through ARRA

Near-Term ----------→ Long-Term

Blue Ribbon Panel

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In March, the Program assembled a panel of 15 geothermal experts to identify the obstacles to geothermal energy growth, discuss the appropriate role of DOE, and recommend priority R&D areas for the Program.

Recommendation—narrow the focus of the Program and invest in critical areas of advancement, targeting near-term and long-term resources in parallel

Accelerate Near-Term Market Growth—Hydrothermal

- Develop an inventory of high-quality prospects using existing technology
- Advance exploration technologies to reduce the cost and risk of drilling
- Develop technologies that reduce O&M cost

Secure the Future—Enhanced Geothermal Systems

- Define the optimal conditions for EGS and identify the best prospects
- Model the feasibility of reservoir creation using existing technology
- Develop tools to optimize power production and reduce costs
- Demonstrate the ability to create and maintain a reservoir in multiple geologic conditions

The geothermal industry is small and has limited funding for R&D. High-risk R&D should be led by DOE, with appropriate private-sector cost share as technologies move closer to commercial applications.

Undiscovered Hydrothermal

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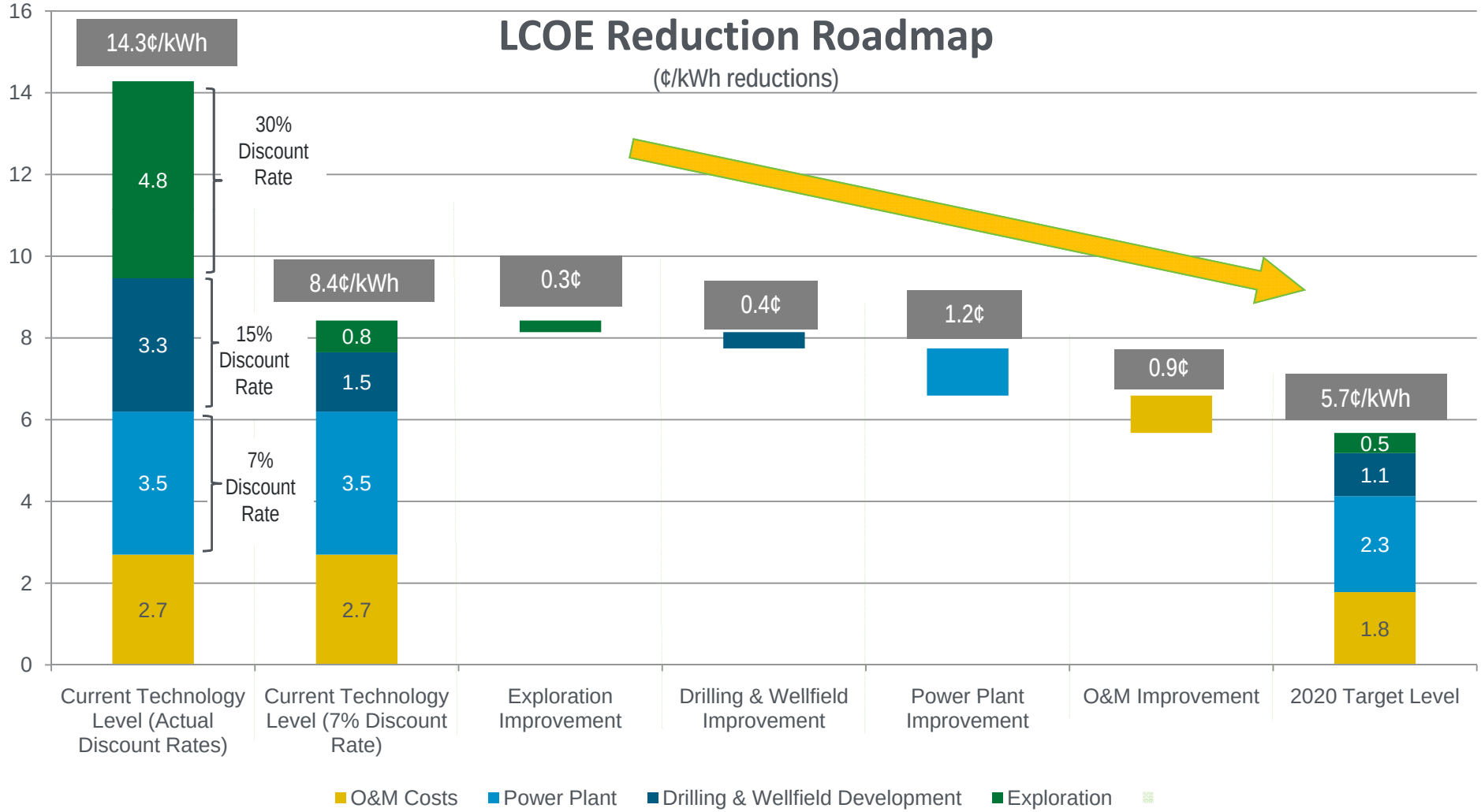
Primary cost drivers are exploration and drilling risk, power plant and O&M. Exploration cost and risk have led to high discount rates.



Enhanced Geothermal Systems (EGS)

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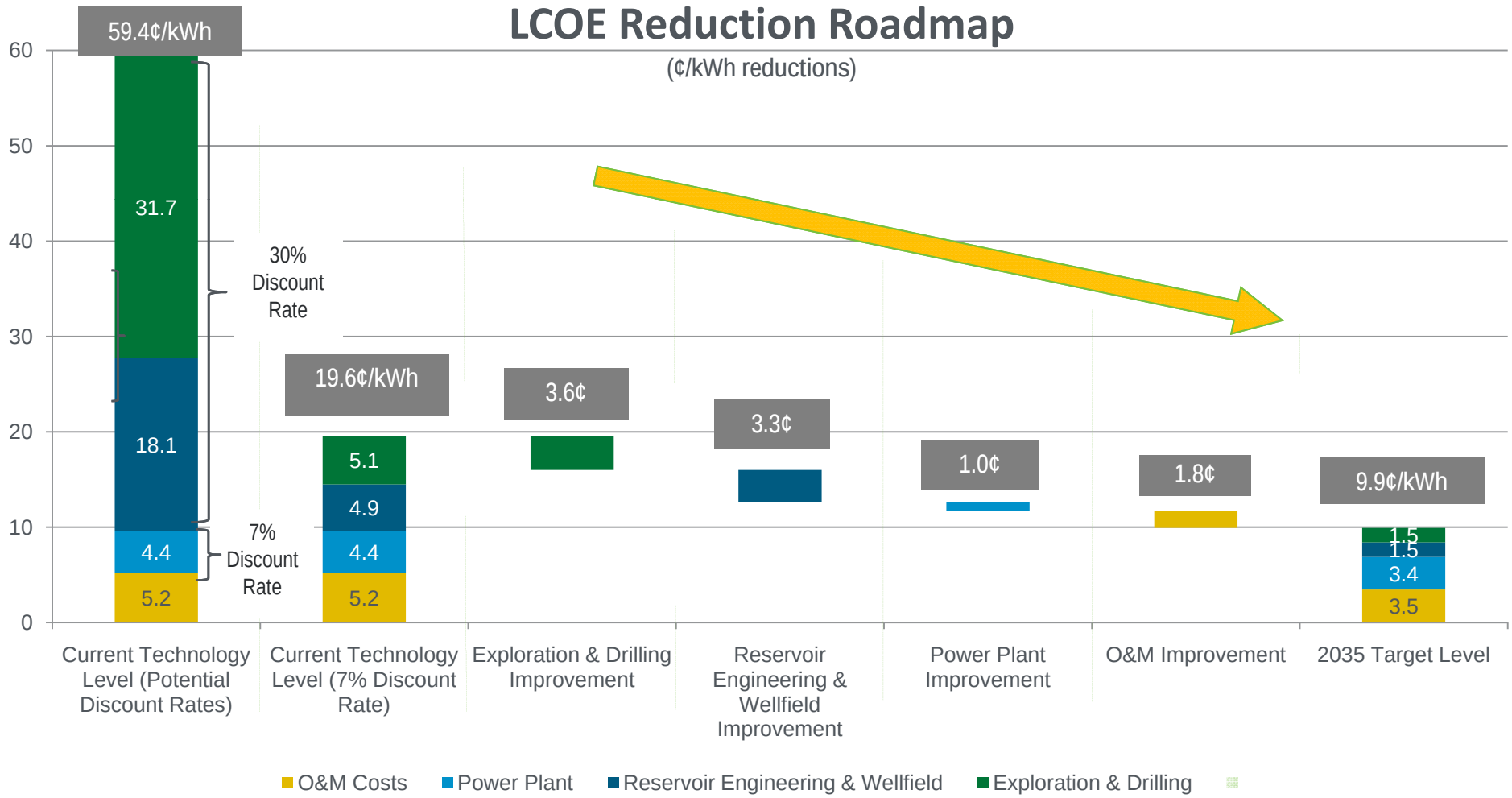
EGS cost drivers are drilling components and systems, and reservoir engineering. Drilling and reservoir engineering phases are anticipated to be the most risky from an investment perspective.



Performance and Cost Targets

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DOE's goal is to lower the cost of geothermal electricity, enabling it to be competitive with conventional energy sources and a major contributor to the U.S. energy supply.

Key Activity	Goals*
Innovative Exploration Technologies (Hydrothermal)	• Confirm 400 MWe and 1 GWe of undiscovered hydrothermal resources by 2014 and 2020, respectively • Reduce the cost of undiscovered hydrothermal energy to $0.06/kWh by 2020
Enhanced Geothermal Systems	• Establish technical feasibility of 5 MWe and sustain for 5 years • Reduce near-field EGS LCOE to $0.07/kWh and greenfield LCOE to $0.11/kWh by 2035

*Roadmapping workshops in June will refine performance and cost targets

Tools and Resources

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The Geothermal Technologies Program provides many publically-available guides, tools and resources aimed at supporting geothermal researchers, developers and policy makers.

http://www1.eere.energy.gov/geothermal/about.html

Area	Title	URL
Techno-Economic Models	The Geothermal Electricity Technology Evaluation Model (GETEM)	http://www1.eere.energy.gov/geothermal/getem.html
Drilling	The Handbook of Best Practices for Geothermal Drilling December 2010	http://www1.eere.energy.gov/geothermal/pdfs/drillinghandbook.pdf
Policy	Policymaker's Guidebook for Electricity Generation February 2011	http://www.nrel.gov/geothermal/guidebooks/electricity_generation/electricity_generation.html
Finance	Guidebook to Geothermal Power Finance March 2011	http://www.nrel.gov/docs/fy11osti/49391.pdf
EGS	The Updated U.S. Induced Seismicity Protocol May 2011	** Coming Soon** Check: http://www1.eere.energy.gov/geothermal/index.html
Geothermal Data	The National Geothermal Data System	** In Development** For more information, see: http://www.geothermaldata.org/ http://stategeothermaldata.org/
Exploration	Exploration Best Practices	**Coming in mid-late 2011** Check: http://www1.eere.energy.gov/geothermal/index.html
Reservoir Engineering, Exploration, Power Conversion and Drilling	*A History of Geothermal Energy Research and Development in the United States, 1976-2006* October 2010	http://www1.eere.energy.gov/geothermal/about.html