Estimation and Analysis of Life Cycle Costs of Baseline EGS

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Analysis, Data System and Education

Project overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Timeline

- **Start date:** January 8, 2010
- **End date:** January 7, 2012
- **10% Funds release date:** March 31, 2010
- **Percent complete:** Just initiated
- "Soft" kick-off occurred in March 2010
- Final start and end dates will be defined after contract is signed

Budget

- **Total funding:** $1,672,550
- **DOE share:** $1,335,727
- **Awardee share:** $336,823
- **Funding in FY09:** $0
- **Funding for FY10:** $854,905 (approximate, pending approval, includes cost share)

Barriers

- Lack of robust datasets and comprehensive models for decision making (Barriers X and Y)
- Limited insight into interactions with electricity markets for long-term EGS applications (Barrier T)
- Poorly understood infrastructure barriers for EGS development (Barrier V)
- Inadequate clarity and articulation of environmental, economic, and security benefits (Barrier W)
- Lack of understanding of applicable current policies and impacts (Barrier U)
- Lack of coordination and integration of program elements (Barrier S)

Partners

- Pennsylvania State University
- Scitech Patent Art Services Inc

Our 6 objectives will be achieved with a well-defined work plan and set of activities …

1 Assess costs and drivers by market penetration

- Review paper and patent literature
- Interview leading experts, vendors, and engineering firms
- Estimate and validate capital costs and cost drivers
- Model component impacts on LCOE

2 Evaluate market, supply-demand economics

- Identify major technology type, dominant regions, and leading vendors for each cost component
- Model supply and demand curves for each component
- Evaluate supply chain impacts on costs and resulting LCOE impacts

3 Estimate impact of innovation based on patent analytics

- Inventory and characterize patents data
- Compare EGS technology areas with intense patenting activity
- Conduct similar patent analytics for analogues
- Develop learning curves and technology evolution forecasts

4 Explore cost impacts of new innovations

- Identify synergistic technology and process options
- Develop models to evaluate such emerging options
- Analyze regulatory outlook for support of novel options
- Evaluate cost implications associated with emerging options

5 Leverage findings for outreach, R&D, and policy needs

- Distill findings and categorize by relevance to type of stakeholder
- Collaborate with relevant partners to facilitate student education
- Identify R&D and policy implications
- Schedule and organize outreach activities

6 Project management and reporting

- Provide reports and other deliverables in accordance with the Federal Assistance Reporting Checklist
- Lead workshops and make presentations to disseminate and facilitate utilization of project output and findings

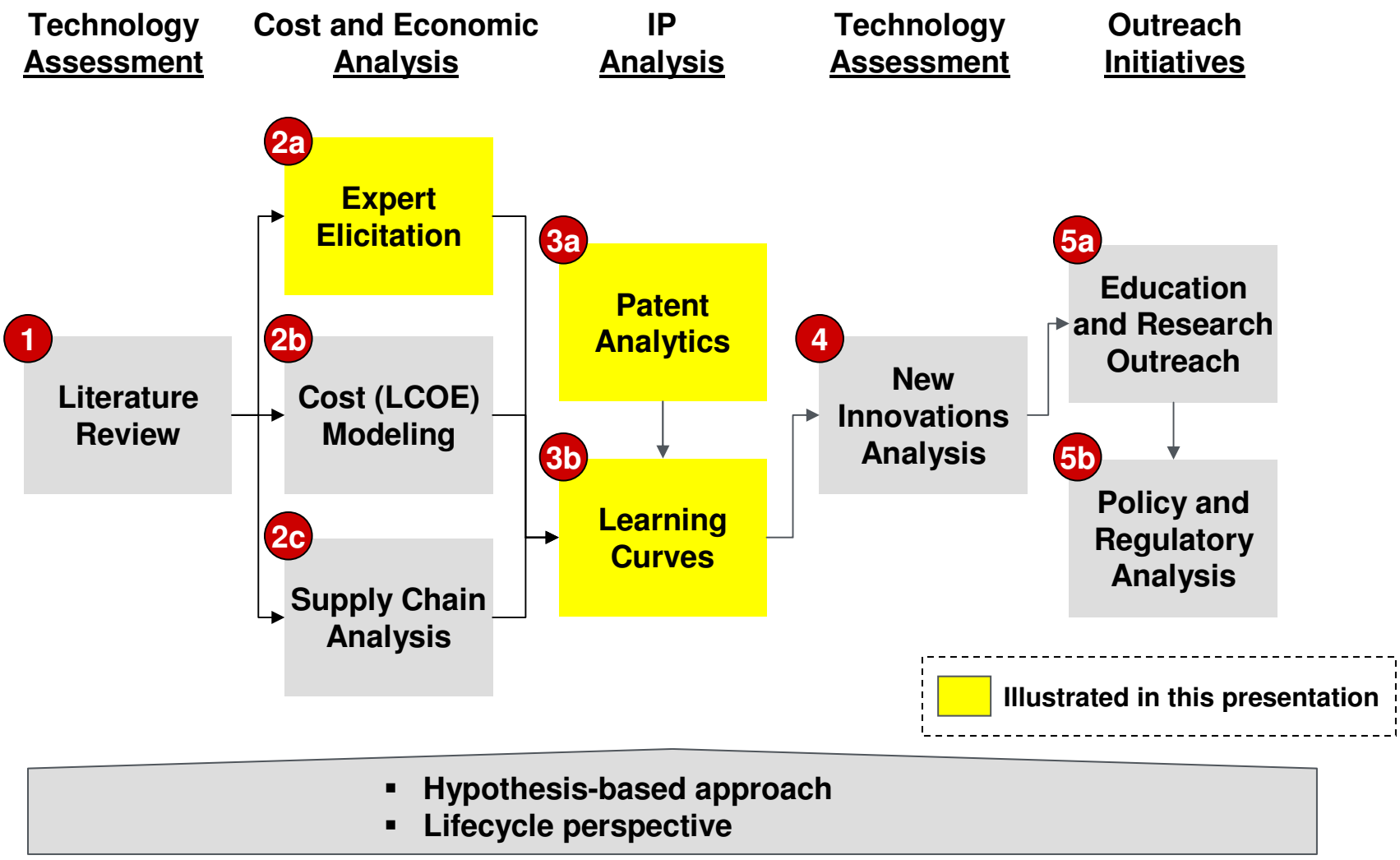
… Resulting in outcomes that will help understand and reduce EGS costs

1	2	3	4	5
Assess costs and drivers by market penetration	**Evaluate market, supply-demand economics**	**Estimate impact of innovation based on patent analytics**	**Explore cost impacts of new innovations**	**Leverage findings for outreach, R&D, and policy needs**
▪ Identification of most expensive components ▪ Impact of each component on LCOE ▪ Comparison of LCOE with coal and natural gas ▪ Identification of component-wise cost reduction targets for parity with coal and gas	▪ Assessment of market economics for potential new entrants ▪ Identification of supply chain issues and resulting cost reduction opportunities including LCOE impact	▪ Forecasts of technology evolution and learning curves ▪ Impact of learning curves on costs ▪ Description of the technology state through patent analytics ▪ Identification of technology gaps and corresponding R&D needs	▪ Assessment of a synergistic IGCC-EGS configuration including CO2 capture and use in supercritical form for EGS ▪ Identification of economic, environmental, and efficiency benefits of IGCC-EGS configurations	▪ Development of skills and capabilities in students and professionals ▪ Dissemination of technology gaps and R&D needs ▪ Articulation of policy and investment incentives

Project's Major Impacts

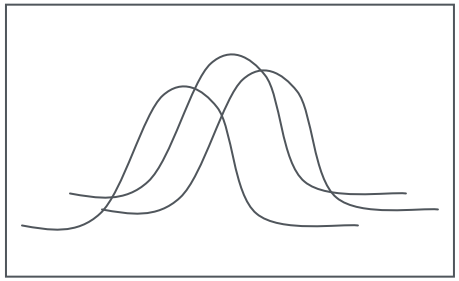
- A clear understanding of the current cost structure and …
- … Its dependence on markets
- The benefits of innovation
- The impact of synergistic process configurations, and …
- Widespread dissemination of the findings for use by the geothermal community

A hypothesis-based, lifecycle approach will guide the methods used in this project



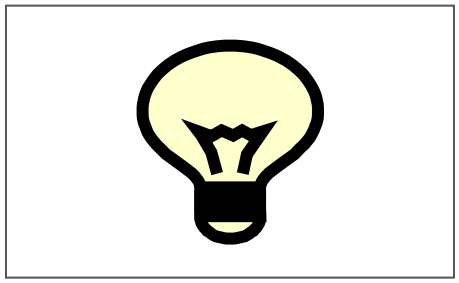
Expert elicitation will help us tap cutting-edge insights systematically and rigorously

- Researchers
- Vendors
- Project Developers
- Investors
- Engineering Firms



Cost Estimate Distributions

Data Validation



New Insights

Project Impacts of Expert Elicitation

- Access to cutting-edge cost estimates from a wide variety of stakeholders
- Insight into cost and performance uncertainties of emerging technologies
- Profiles of risks and their analysis for impacts on key project metrics
- Codification of tacit expert knowledge for various uses
- Validation and triangulation of project assumptions and data from multiple sources

Our expertise in patent analytics will help us understand major trends, …

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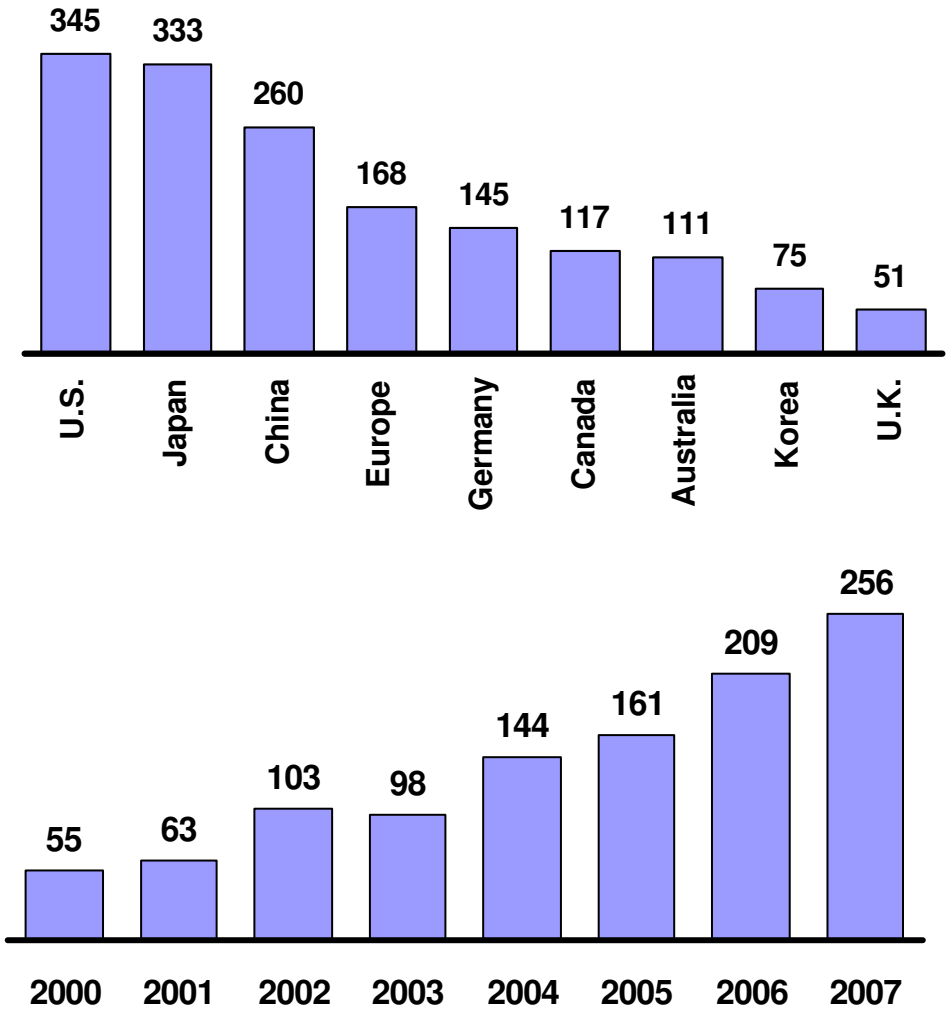
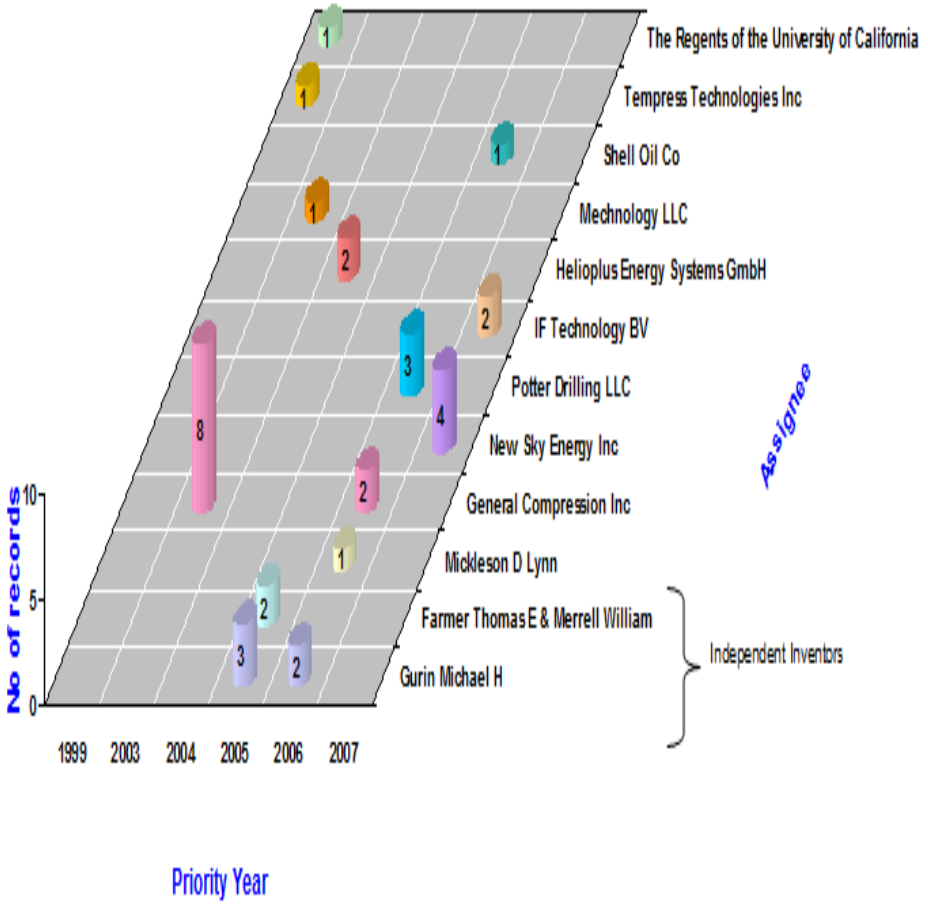
Number of Patents by Country and Year

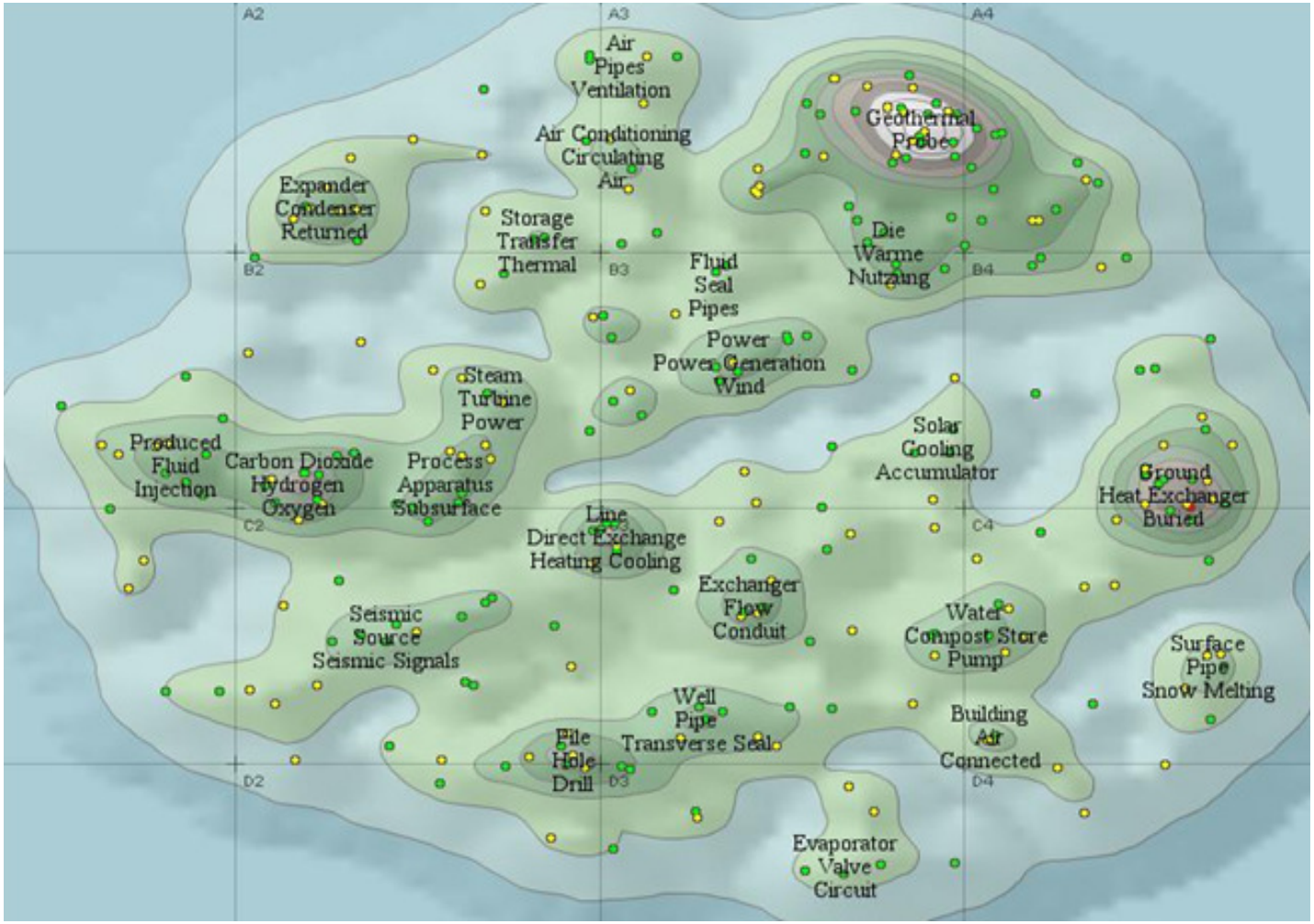


Number of Patents on Supercritical CO_2



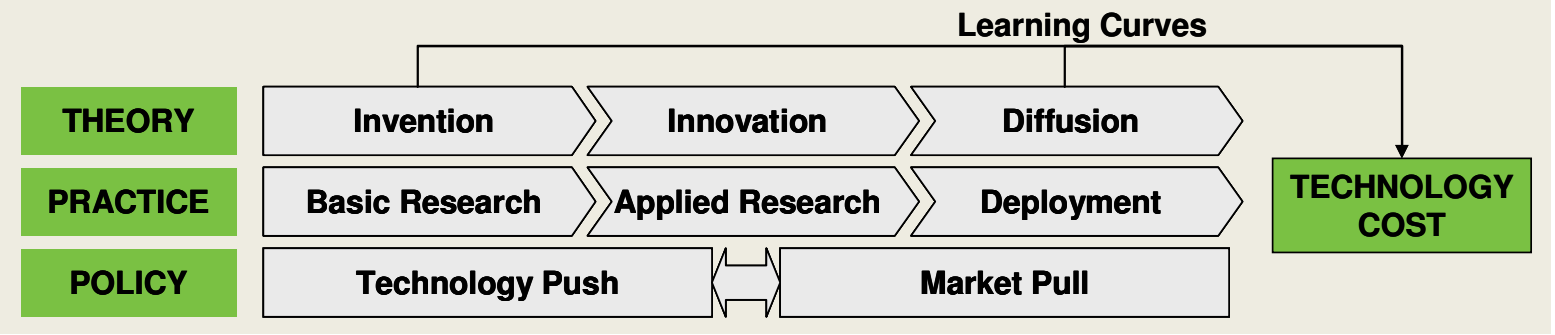
… Generate innovation maps to identify cost and performance implications, and …

Key Areas of Patent Activity in Geothermal Energy

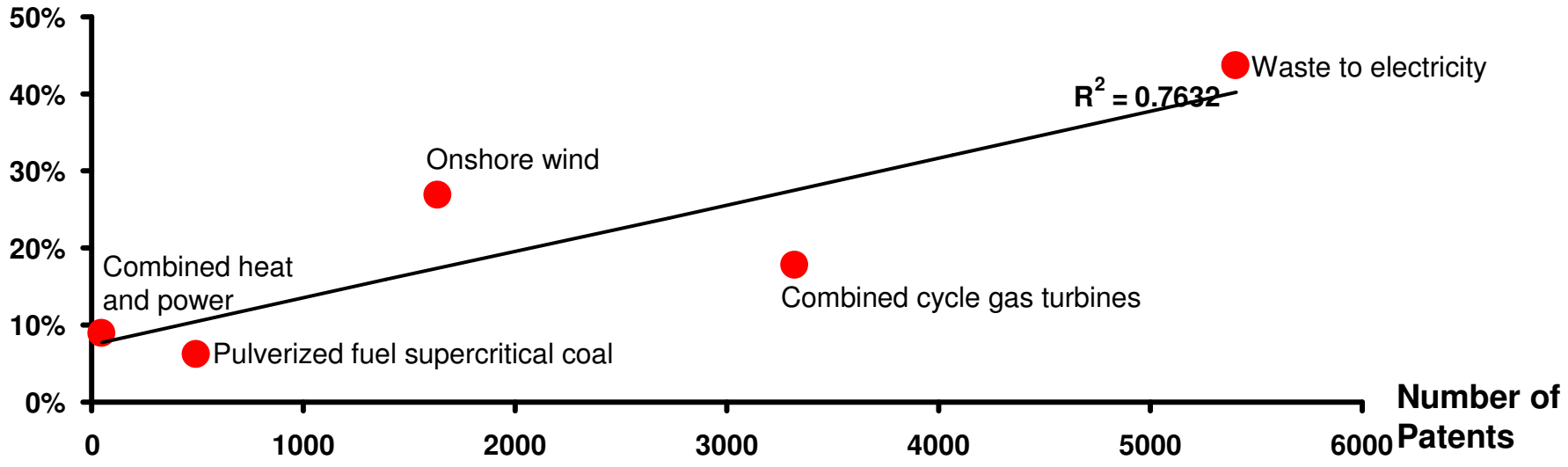


… Forecast EGS learning curves using case studies of previous energy technologies

Conceptual Model for Estimating Learning Curves



Cost Reduction Due to Learning by Research



Source: T. Jamasb, *The Energy Journal*, 28 (3) 2007

We will use milestones and decision criteria to focus on the most value-added objectives

Project Milestones		
	Task / Milestone	**Period**
Task 1	**Assess costs and drivers by market penetration**	
	Identification of most expensive components	1Q
	Impact of each component on LCOE	2Q
	Comparison of LCOE with coal and natural gas	3Q
	Identification of component-wise cost reduction targets for parity with coal and gas	4Q
Task 2	**Evaluate market, supply-demand economics**	
	Assessment of market economics for potential new entrants	3Q
	Identification of supply chain issues and resulting cost reduction opportunities	4Q
Task 3	**Estimate impact of innovation based on patent analytics**	
	Description of the technology state through patent analytics	2Q
	Forecasts of technology evolution and learning curves	4Q
	Impact of learning curves on costs	6Q
	Identification of technology gaps and corresponding R&D needs	8Q
Task 4	**Explore cost impacts of new innovations**	
	Assessment of a synergistic IGCC-EGS config. incl. CO2 capture and use in supercritical E	4Q
	Identification of econ., environ., and efficiency benefits of IGCC-EGS configs.	6Q
Task 5	**Leverage findings for outreach, R&D, and policy needs**	
	Distill findings and categorize by relevance to type of stakeholder	6Q
	Collaborate with relevant partners to facilitate student education	On-going
	Identify R&D and policy implications	7Q
	Schedule and organize outreach activities	On-going

Project Management Decision Criteria

- **After 12 months:** No-go if experts and patent, cost, and other data are not available
- **After every milestone:** Review and adjust hypotheses as required to reflect new data, findings

The project has just begun and will be executed per the identified work plan

Progress to Date

- Initiated project through a “soft” kick-off in March 2010 after 10% of the funds were authorized for expenditure pending full approval
- Initiated identification of secondary research and experts for interviews
- Attended an energy conference organized in Houston, TX
- Conducted a few expert interviews on market, technology, and financing
- Completed and submitted a number of reports in response to U.S. DOE

Path Forward

- Continue the execution of Tasks 1 and 2
  - Assess costs and drivers by market penetration
  - Evaluate market, supply-demand economics

Our proven credentials in analyzing energy technologies and economics …

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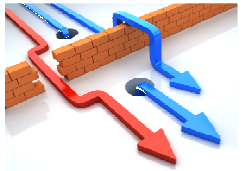
Our Staff has Proven Expertise …



Strategy setting skills for growth, cost optimization, and organizational excellence

Operations experience, e.g., plant start-ups, capital projects, field studies, and Six Sigma

Commercial energy value chain expertise with 100+ years of total staff experience

… Gained in Leading Organizations…

Booz | Allen | Hamilton

Deloitte.

booz&co.

ConocoPhillips

PENNSTATE

ExxonMobil

CLINTON FOUNDATION

… and Recognized by Major Awards

NATIONAL ACADEMY OF ENGINEERING

NATIONAL SCIENCE FOUNDATION

A C S

… Coupled with established partners and vendors …

PENNSTATE

- Leading research university with $765 million in 2009 funding
- Project collaborator, Department of Energy and Mineral Engineering, is a leading interdisciplinary energy research and education provider
- Established leaders in education, geothermal energy, and power plant technology will collaborate with the prime contractor on this project

SCITECH PATENT ART

- Leading provider of patent research and analytics services
- Serves a number of Fortune 500 clients in multiple industry segments
- Qualified and talented staff with experience in multiple domains

… Will help us deliver value on schedule and per our project management plan

Schedule

		Year 1				Year 2			
		1Q	2Q	3Q	4Q	5Q	6Q	7Q	8Q
Task 1	Assess costs and drivers by market penetration								
Task 2	Evaluate market, supply-demand economics								
Task 3	Estimate impact of innovation based on patent analytics								
Task 4	Explore cost impacts of new innovations								
Task 5	Leverage findings for outreach, R&D, and policy needs								
Task 6	Project management and reporting								

Project Management

- Review progress of project and deliverables against schedule with team each month
- Review progress of project and deliverables against schedule with partners every quarter
- Review and adjust hypotheses as required after completion of each milestone with the team
- Provide reports and deliverables in accordance with the FAR Checklist
- Organize informal advisory panel to review quality and progress of deliverables

We will bring insights on market, innovation, and policy measures to reduce EGS costs …

- Deliver a clear understanding of the current EGS cost structure
- Describe the cost structure's dependence on markets
- Forecast the benefits of innovation on EGS cost reduction
- Explore the impact of synergistic process configurations
- Disseminate widely project findings for use by the geothermal community

… With our energy expertise, clear approach, rigorous tools, and competent partners

- Our project will facilitate insights into the cost of EGS and how it can be reduced through market, innovation, and policy measures
- We have a well-defined approach that will be executed using a set of scientifically rigorous methodological tools
- In addition, we and our partners bring extensive experience in the analysis of energy technologies and economics
- Finally, the project has just started and will initially focus on understanding the first two tasks:
  - Assess costs and drivers by market penetration
  - Evaluate market, supply-demand economics