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Future Directions for the U.S. Geological Survey's Energy Resources Program

The United States is a major consumer of geologically based energy resources from around the world and, given the recent growth, in domestic oil and gas production is now a net energy exporter. The U.S. Geological Survey (USGS) Energy Resources Program (ERP) is charged with providing unbiased and publicly available national- and regional-scale assessments of geologically based energy resources. The ERP portfolio includes research and assessments on both the domestic and the international endowments of technically recoverable hydrocarbon-based resources such as oil, natural gas, and coal, as well as assessments of other geologically based resources that may be important contributors to the future U.S. energy mix. These include geothermal, methane hydrates,¹ and uranium resources.

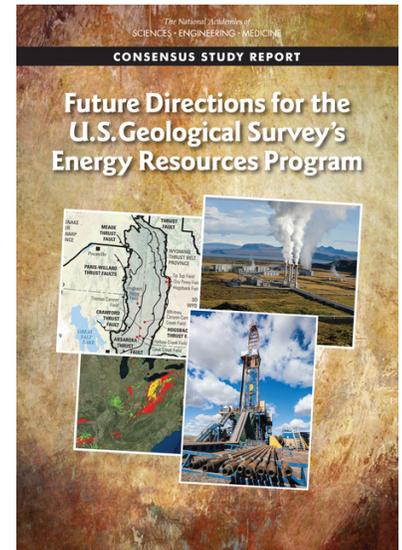
Produced at the request of the ERP, this report identifies geologically based energy resource challenges facing the United States and the world. It recommends ways in which ERP products and research could be developed over the next 10-15 years to most effectively address those challenges and better inform both USGS energy research priorities and the energy needs and priorities of the U.S. government.

GEOLOGICALLY BASED ENERGY RESOURCE CHALLENGES

The United States and the world will rely greatly on geologically based energy resources for at least the next 10-15 years. A secure, resilient, environmentally responsible, and economically competitive national energy supply is dependent on a collective effort to meet the following energy-related challenges identified in the report:

- 1. Maintaining a robust understanding of the national resource inventory and its associated uncertainties.** Resource development requires robust understanding of geology, geologic engineering, hydrology, coupled processes and their environmental impacts, and economic recovery of geologically based resources.
- 2. Exploring and developing geologic energy resources in an environmentally and socially responsible manner.** Understanding the subsurface environment and the impacts of resource development throughout the development lifecycle includes understanding: land and water use requirements;

¹ Methane hydrates are lattices of water-ice crystals trap methane gas. Major deposits of methane hydrates are found in continental sedimentary rocks in polar regions and in oceanic sediments where water is greater than 300 meters.



management of produced waters;² the potential for aquifer contamination; avoiding or mitigating induced seismicity; geologic sequestration of carbon dioxide (CO₂); and long-term geologic storage of radioactive and other energy wastes.

3. Overcoming technical and economic barriers to new resource development processes. Technology development and innovation are needed in areas including: developing energy resources that remain in the subsurface after recoverable resources are extracted; new or emerging geologic resources (e.g., methane hydrates); mitigation of environmental impacts (e.g., methane leakage associated with oil and gas production, reduction of produced fluid volume in oil and gas wells, and induced seismicity); and waste disposal or sequestration (e.g., of CO₂).

4. Adapting to variable power-generation sources (e.g., wind and solar) and related energy storage. Subsurface energy storage options require characterization of subsurface reservoirs, and knowledge of how resources can be stored, the impacts of storage, and how stored resources can be reversibly extracted.

MEETING INFORMATION NEEDS

The ERP provides subsurface geologic characterization and basin-scale modeling and assessments to support strategic development and innovation, but needs to respond quickly to technology advances and anticipate future information needs.

Recommendation 1: Focus new and continuing activities on geologic energy resources as consistent with the ERP mission and the information needs of the nation.

The ERP needs to stay focused on issues related to geologic energy resource development. The program can increase its relevance by prioritizing its activities through constant reevaluation of current and emerging energy trends and information needs and through products delivered in formats most useful to its stakeholders.

Recommendation 2: Give priority to geologically based research and products related to (a) existing and emerging continuous/unconventional oil and gas and produced water and (b) emerging technologies associated with geothermal energy, methane hydrates, and subsurface energy storage.

Continuous (unconventional) oil and gas exploration and development (i.e., that requiring high-water volume hydraulic fracturing) will dominate the energy sector for the next 10-15 years. The proprietary nature

of industry data means that ERP assessments are vital for informing national energy policy.

The ERP can improve its oil and gas and geothermal assessments by increasing the transparency of its assessment approaches and of the input data it uses. Assessments need to be seamlessly updateable with new information. Future assessments will be more useful if they include lifecycle-related information such as that necessary water resources, and the toxicity, disposal, and environmental impacts of produced waters. Input datasets and information about economic recoverability would also increase the utility of the ERP's resource estimates.

Continued ERP collaboration on methane hydrates-related research and expanded consideration of full-lifecycle environmental consequences of hydrate development is warranted. Priority on hydrates-related research needs to be reevaluated regularly given whether feasible hydrate production technologies are developed. Finally, understanding difficult-to-anticipate coupled processes (hydro/chemical/thermal/mechanical) related to subsurface energy storage and waste disposal also need to be high-priority areas for the ERP so that the long-term performance of engineered subsurface storage systems and their impacts are better understood.

Recommendation 3: Maintain strategic capabilities in areas such as conventional oil and gas, coal, uranium, and emerging energy sources; adjust emphasis on products and research in these and other areas based on demand for information.

The ERP needs new strategies to target its activities related to already well-characterized resources such as conventional oil and gas, coal, and uranium, as well as for emerging energy resources that might be important to the nation's energy mix. Decreased emphasis on such resources, however, must not come at the cost of important ERP capacity. Interest may emerge or reemerge on topics such as oil shales or bypassed residual oil zones, and the ERP needs to be ready to respond.

Targeting ERP assessments on newly discovered or less-well-characterized accumulations gives the program greater flexibility to strategically direct its capabilities. For example, coal resource assessments might focus on resources with specific applications (metallurgy, coal gasification, and extraction of rare-earth elements). Similarly, spatial information related to human health and safety aspects of energy resource development might be incorporated into new assessments.

ERP uranium-related products are unique among U.S. government agencies and industry. Recent ERP work in this realm includes new methods to estimate

² i.e., water extracted along with petroleum products; some of this water is naturally present in the subsurface and some is pumped into the reservoir during extraction to increase petroleum production.

undiscovered uranium resources, projects related to post-mining groundwater recovery; updated estimates of deposits in different host rocks, the remediation of legacy uranium mines, and research on groundwater impacts of uranium extraction by solution mining (the primary method of uranium mining in the United States) and its remediation. The current balance of assessment work and basic research related to uranium development is appropriate.

INTEGRATED APPROACHES FOR THE NEXT GENERATION OF PRODUCTS

Given the growing volumes of data available to refine resource assessments, the ERP needs to explore, identify, and apply new data analytics and machine learning tools, and approaches to its assessments. The ERP should identify advanced statistical approaches for estimating rock properties to produce increasingly reliable resource assessments with high spatial resolution.

Recommendation 4: Compile and incorporate data related to environmental impacts of resource development into ERP products.

Informed decision making requires a complete understanding of all the factors that affect the total costs of energy development, including mitigation and remediation of environmental impacts. ERP research on environmental factors associated with energy resource development is released independently of its resource assessments. ERP could apply its proven competencies incorporating geospatially relevant elements of its environmental research, as well as incorporating results from other public and private sources, into its resources assessments. ERP products could, for example, by overlaying maps of biodiversity and endangered and threatened species on energy resource maps.

Recommendation 5: Apply full-lifecycle and full-system approaches when considering geologic energy resources: from initial resource assessment to development, waste disposal, and the disposition of depleted or legacy sites.

Rather than compartmentalizing research results by subject area, the ERP needs to apply integrated lifecycle- and systems-based approaches to its analyses in ways that allow solid scenario analysis and estimation of impacts and total costs of resource development by decision makers. For instance, given the need to produce a volume of natural gas, information about where wells might be placed to minimize water needed and which extraction technologies might best mitigate expected environmental impacts will be instructive.

Recommendation 6: Improve assessments of geologic energy resources by quantifying resources according to quality and recoverability.

The ERP does not conduct economic analyses, but it could support such analyses by providing information to decision makers about when and how to develop specific resources to the greatest advantage. ERP assessments could include information about resource quality and economic recoverability as well as information that would support the development (by others) of robust energy resource supply curves.

Recommendation 7: Emphasize the development of multi-commodity and multi-reservoir geologic models at regional and basin scales.

System-level information (e.g., about multiple commodities, multiple reservoirs, and environmental impacts) in a single ERP product will help decision makers weigh the impacts of different development options or combinations of options. Typically, however, ERP products focus on individual energy resources at specific scales. Next-generation ERP assessments could combine regional data and numerical models to improve understanding of multi-commodity, basin-scale geologic energy resource inventories.

TARGETING, IMPROVING, AND REDUCING UNCERTAINTY IN ERP PRODUCTS

Some ERP assessment methodologies have not been reviewed in more than a decade. There have been numerous advances in oil and gas production technologies, in mining and processing technologies, and in digital data dissemination, as well as changes in the use and markets for these resources. New reviews of assessment methodologies may be warranted.

Recommendation 8: Become the recognized custodian of national-scale, publicly available geologic energy resource data.

There is no single source of consistent, national-scale geologic data to support geologic resource development, research, policy, and regulation. Federal, state, and private sector data are collected for specific purposes, making it difficult to combine them to create regional or national-scale data sets. Databases currently maintained by the ERP (e.g., of coal resources; geochemistry of source rocks, oil, and gas; and produced waters) are not always viewed by stakeholders as sufficiently comprehensive.

The ERP could expand its current data compilation, archiving, and dissemination functions and establish itself as the custodian and disseminator of national-scale, energy-related geoscience data for the United States. Priorities for meeting consumer needs include creating more easily updatable data sets; creating databases that accommodate new types of information when they become available; developing appropriate data-storage systems and database architectures; and improving web-delivery mechanisms.

Recommendation 9: Improve the timeliness of ERP products and related data.

Stakeholders are concerned that ERP products might be outdated and possibly irrelevant by the time of their release, given the time taken by the program to release them. ERP releases technical summaries of assessments (i.e., USGS fact sheets) to make information available to stakeholders as quickly as possible. However, those products are of limited use to many decision makers because they lack supporting data and descriptions of analytical methodologies. Product utility will increase if products represent the newest available data, are based on the latest advances in exploration and development technologies, and are delivered before resource development decisions need to be made.

Recommendation 10: Establish formal mechanisms for regular engagement with external parties and key stakeholders to identify and prioritize future ERP activities and to determine the impacts of ERP products and research.

The ERP has no formal mechanisms for stakeholder identification and interaction, nor does it have formal mechanisms for identifying stakeholder needs or ERP product impacts. Regular, formalized engagement with stakeholders could help the ERP establish program priorities; identify emerging issues; review ERP program competencies; and identify new geologic energy

resources and assessment and development methodologies. The program might pursue formal engagement with stakeholders by establishing an external advisory board of representatives from federal- and state-level entities and nongovernmental organizations to complement the recommendations of its existing internal advisory board.

Recommendation 11: Leverage and partner with other USGS units, other federal and state agencies, and other domestic and international organizations to more efficiently achieve the ERP mission.

The ERP methane hydrates research area is an excellent example of coordinated research that leverages expertise and resources of various external entities to advance the general state of knowledge. Following similar patterns, other ERP research areas could improve their respective breadths and reaches while increasing efficiency. For instance, the ERP could establish partnerships and combine its resources with those of state agencies with rich data sets and sample archives. The ERP has also benefitted greatly from short-duration focused research support to compliment the expertise in its program. In all its collaborative efforts, however, the ERP needs to preserve its reputation for objectivity and neutrality so that it continues to be a trusted source of information.

COMMITTEE ON FUTURE DIRECTIONS FOR THE U.S. GEOLOGICAL SURVEY'S ENERGY RESOURCES PROGRAM

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For More Information This Consensus Study Report Highlights was prepared by the Board on Earth Sciences and Resources based on the Consensus Study Report [Future Directions for the U.S. Geological Survey's Energy Resources Program \(2018\)](#). The study was sponsored by the U.S. Geological Survey. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; <http://www.nap.edu> or via the Board on Earth Sciences and Resources web page at <http://www.dels.nas.edu/besr>.

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