U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Machine Learning for Geothermal Applications

An Overview

Bill Vandermeer, Geothermal Technologies Office

Image: Calpine

Why Geothermal?

Beneath our feet lies vast, untapped energy potential. Geothermal…

…is an **always-on** renewable energy source that harnesses the earth's natural heat.

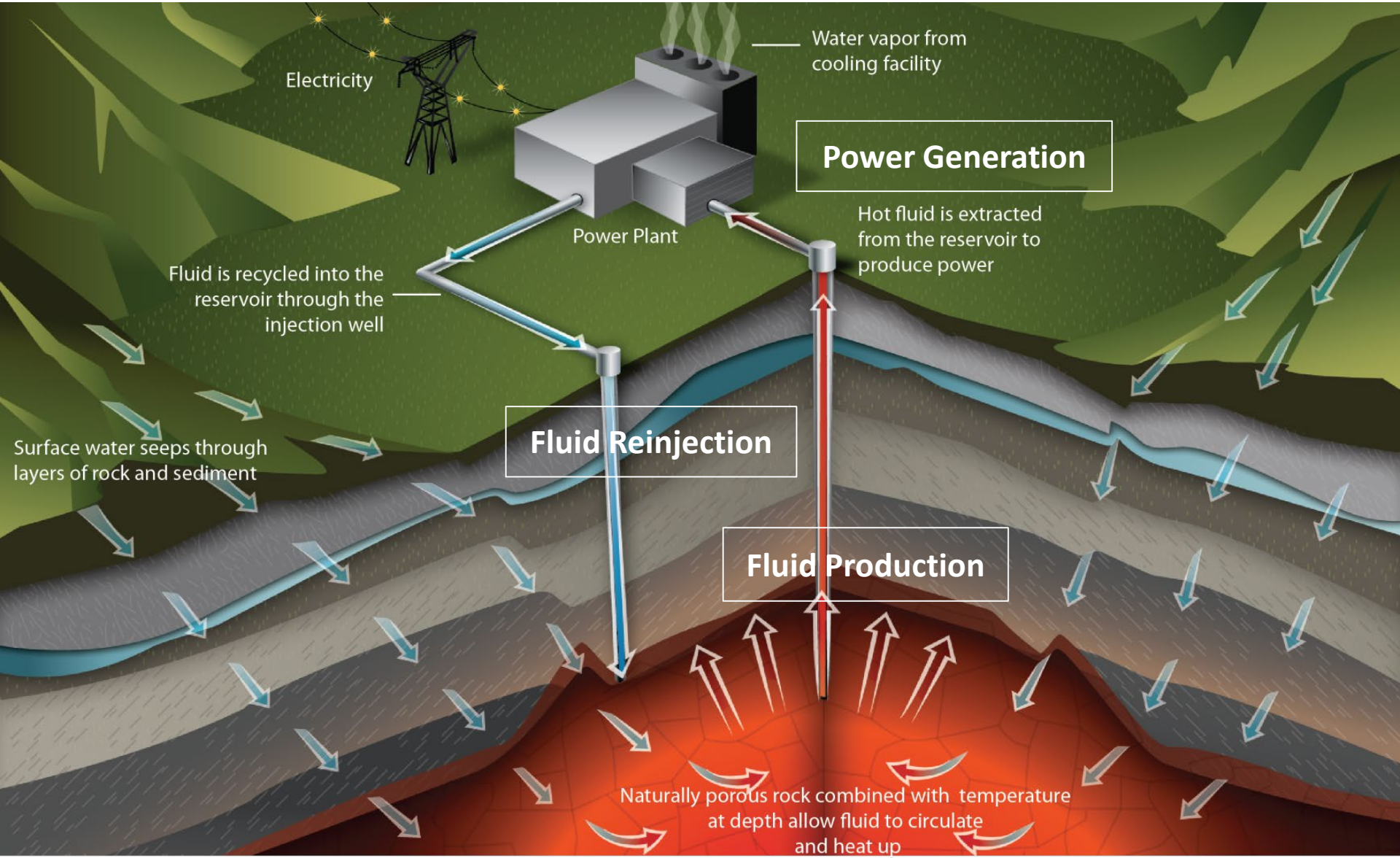
…improves domestic energy **security and diversity.**

…provides **baseload power** with flexible on/off.

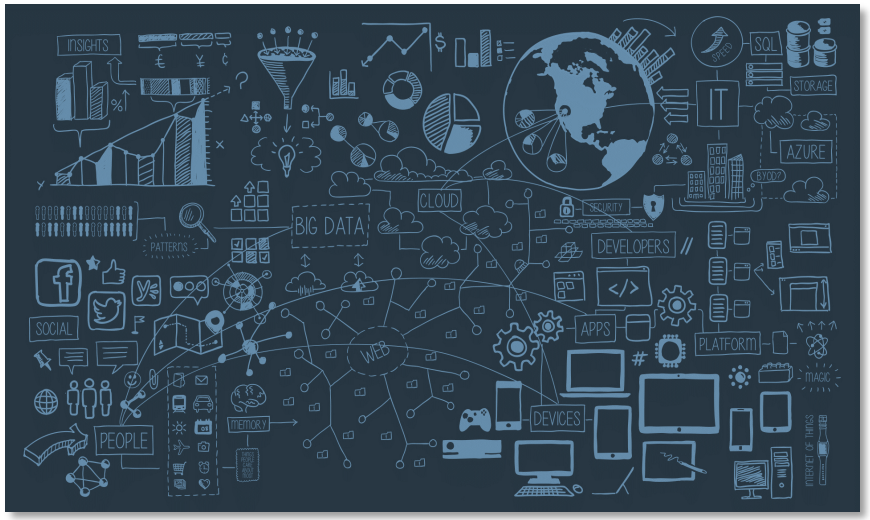
…creates thousands of **valuable energy sector jobs** and strengthens local economies.

…is on path to becoming a widely available renewable energy source. An **everywhere solution.**

Geothermal Fluid Circuit



Barriers and Challenges

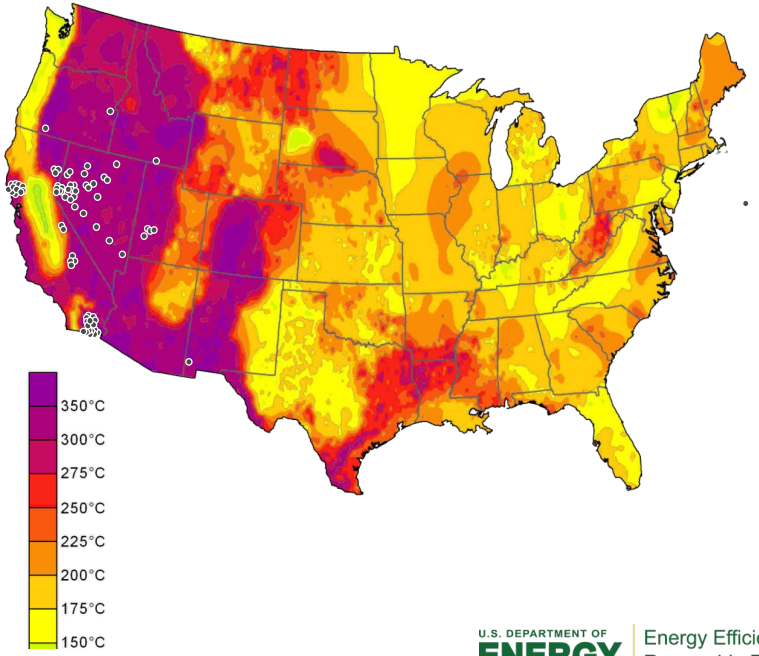


Machine Learning

- Availability of quality, labeled data sets
- Proprietary data sets

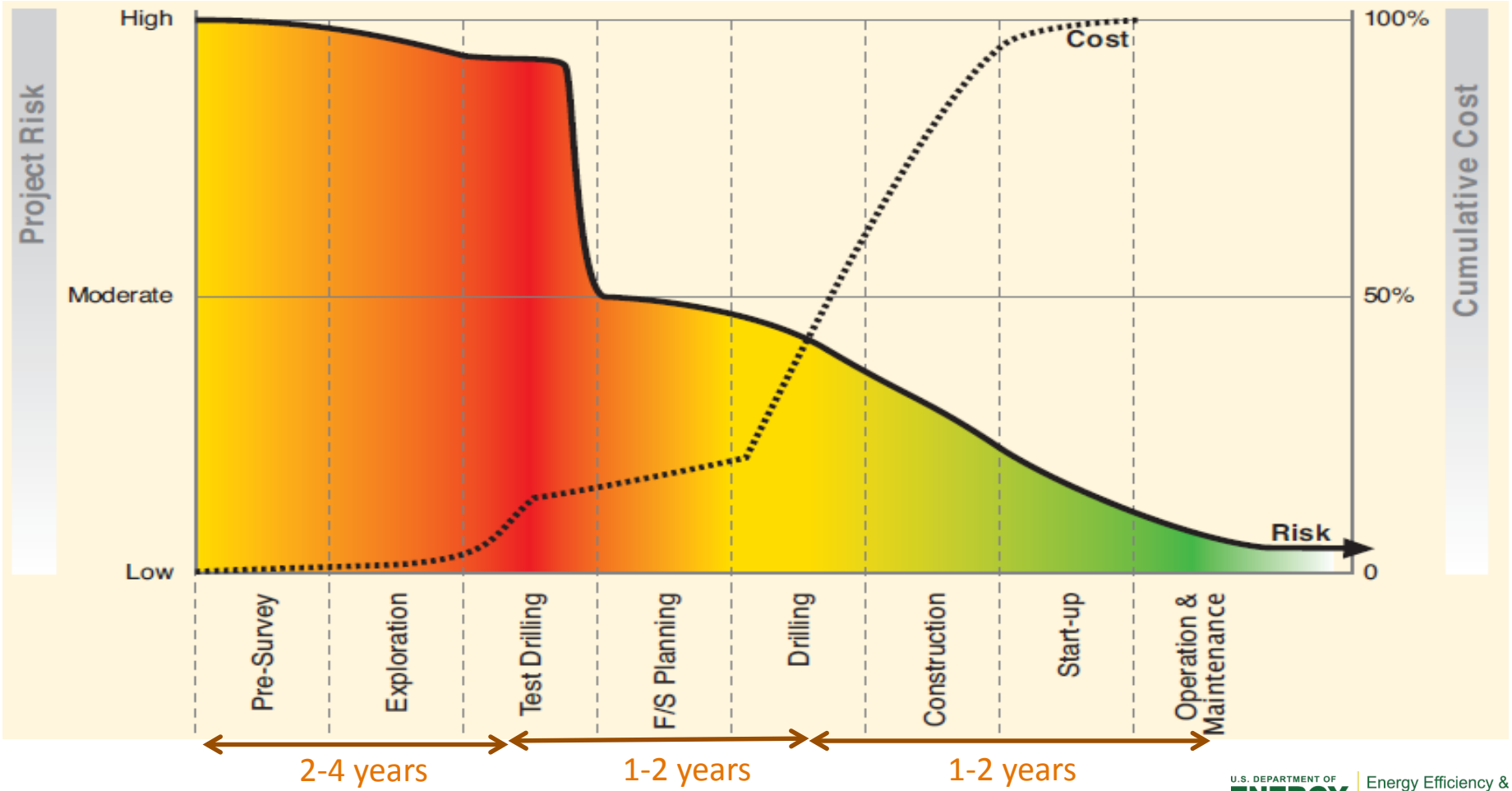
Geothermal

- Small community relative to other renewable technologies (e.g. solar, wind)
- High risk during exploratory drilling phase
- High costs during production well drilling phase



Risk versus Cost Profile for Geothermal Projects

The Geothermal Technologies Office (GTO) works to reduce costs and risks associated with geothermal development by supporting innovative technologies that address key exploration and operational challenges.



Currently Available Analysis, Data & Tools

GTO's **Techno-Economic Analysis, Data & Tools** includes the following widely-used geothermal tools and resources:

- **National Geothermal Data System (NGDS)**
- **Geothermal Data Repository (GDR)**
- Geothermal Electricity Technology Evaluation Model (GETEM)
- Geothermal Prospector

GDR is an open-source data repository used by industry to evaluate geothermal prospects.

Current Applications of Machine Learning for Geothermal

Machine learning solves two key seismic problems:

- ✓ Interpreting diverse, complex, multi-terabyte data volumes.
- ✓ Understanding the relationship of various types of data at once.

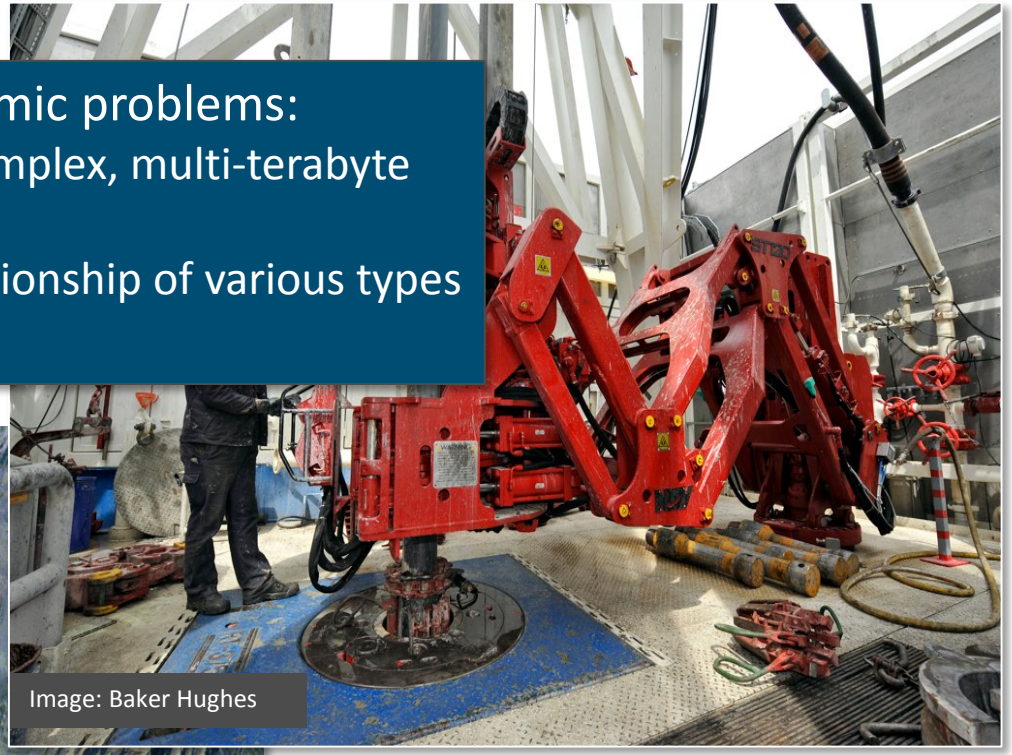
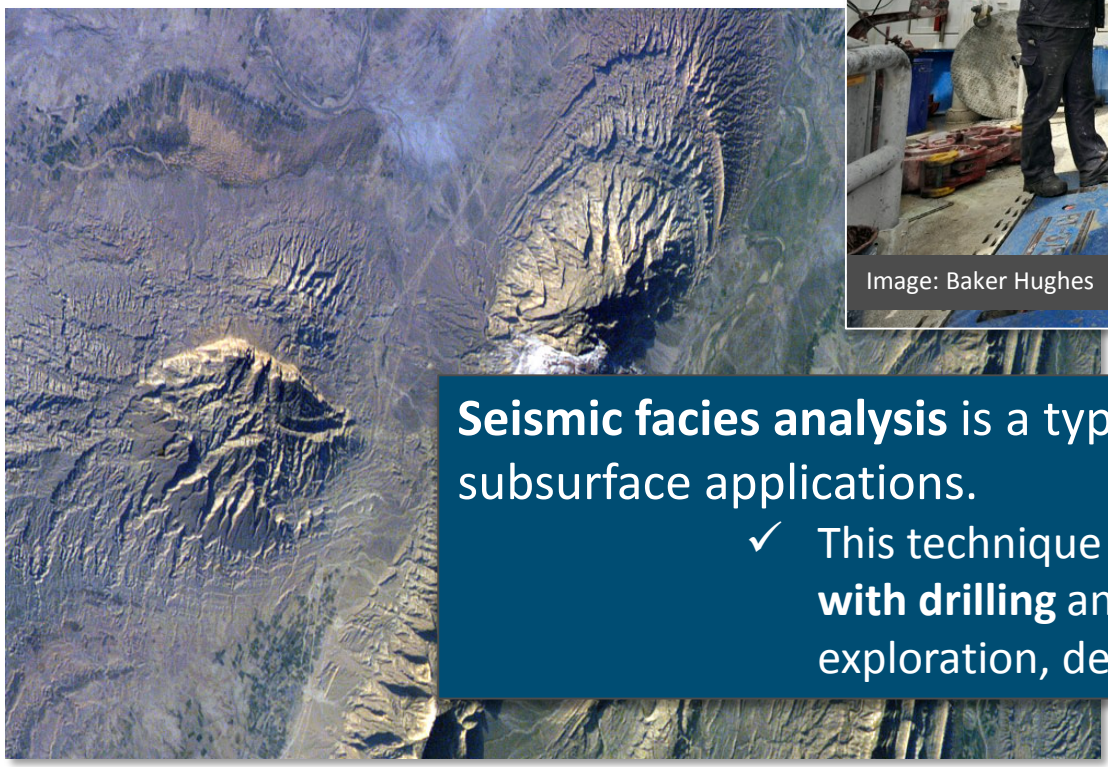


Image: Baker Hughes



Seismic facies analysis is a type of machine learning specific to subsurface applications.

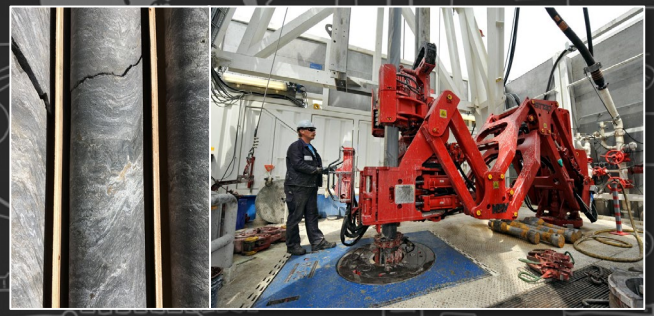
- ✓ This technique helps **lower the risks associated with drilling** and can be used in various stages of exploration, development, and well optimization.

Machine Learning FOA

Machine Learning offers substantial opportunities for technology advancement and cost reduction throughout the geothermal project lifecycle.

Topic 1
Machine Learning for Geothermal Exploration

Topic 2
Advanced Analytics for Efficiency and Automation in Geothermal Operations



Objectives include:

- Developing open community datasets for future work in ML
- Identifying data acquisition targets (+drilling) with high scientific value for future work.
- Identifying new signatures for detecting hidden geothermal systems.
- Optimizing power production through plant/reservoir monitoring and analytics.
- Improving prediction and detection of trouble events.

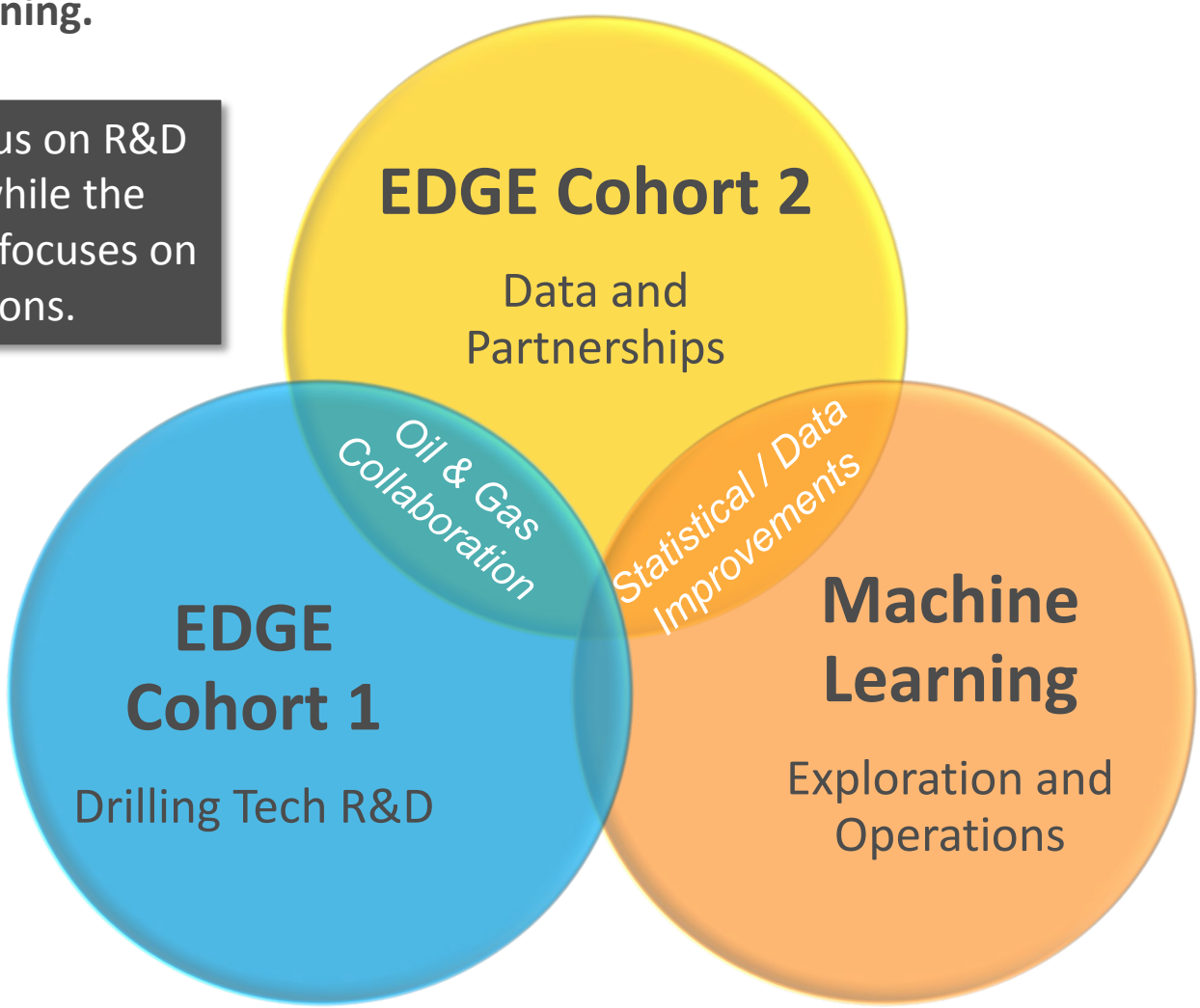
Awardees

Colorado School of Mines
University of Southern California
University of Arizona
University of Houston
University of Nevada-Reno
Pennsylvania State University
Livermore National Lab
National Renewable Energy Lab
Los Alamos National Lab
Upflow Limited (New Zealand)

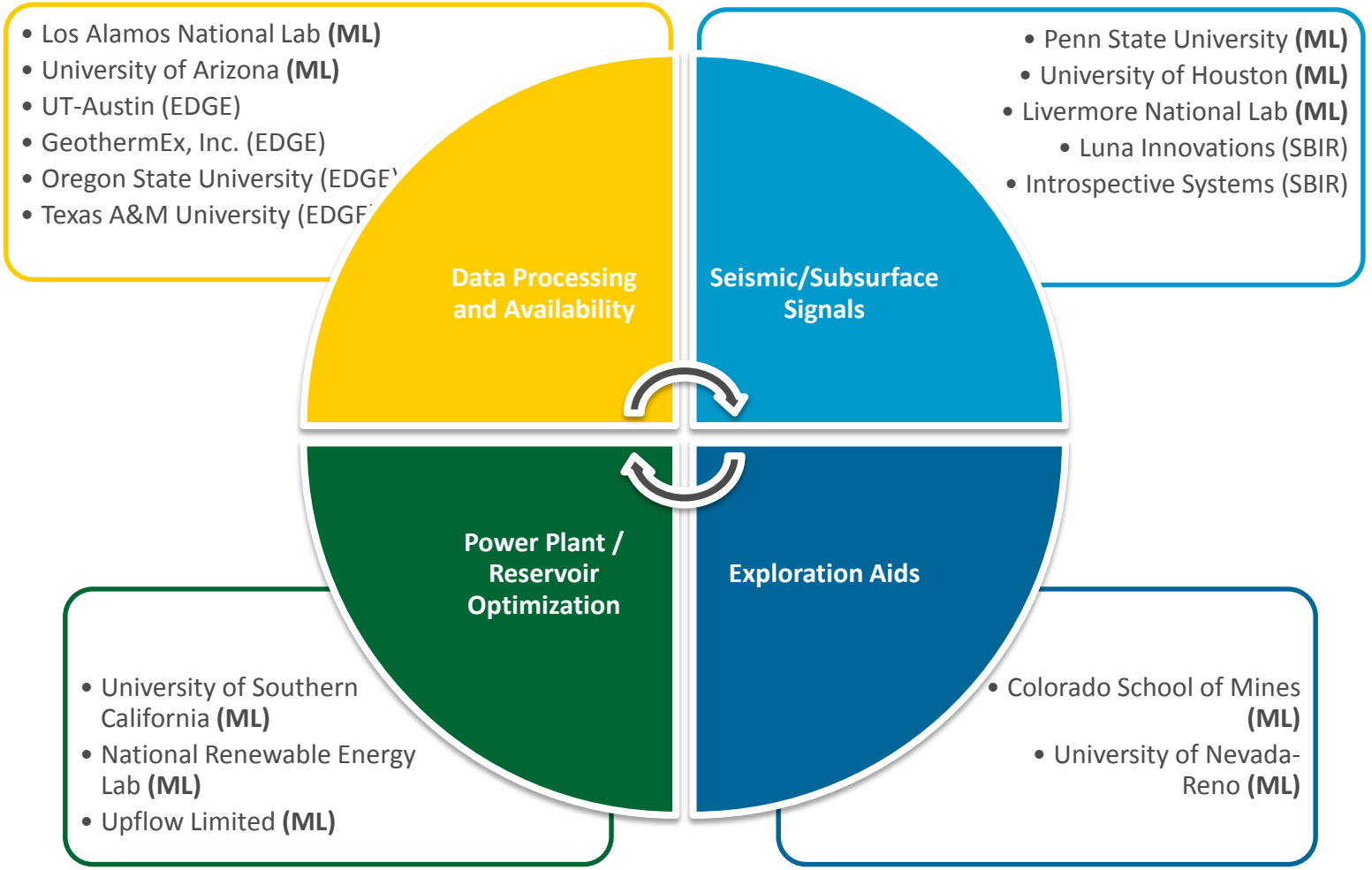
EDGE FOA and Machine Learning

Achieving **EDGE** drilling targets with **knowledge transfer, data, and partnerships** is a unique component of GTO's portfolio. **EDGE** further supports conjugate areas of research, including **Machine Learning.**

Initial **EDGE** awards focus on R&D in drilling technology, while the **Machine Learning** FOA focuses on exploration and operations.

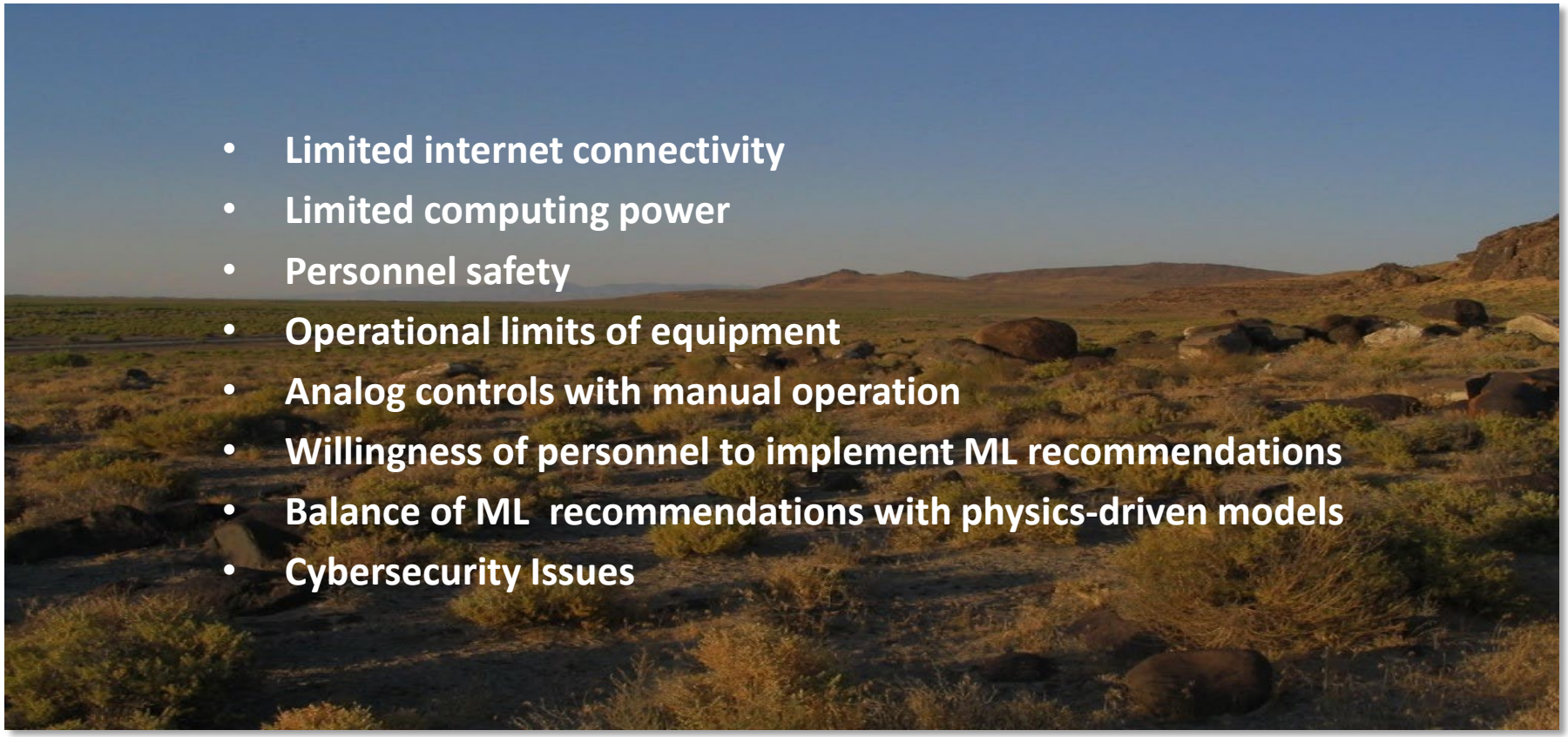


Categories of Active Projects (Short Term Vision)



Long Term Vision for ML in Geothermal

Tools that can be used to **provide real-time operational decision support** during highest risk/highest cost stages of geothermal development. These tools include various items essential to **remote site operations.**



Examples of Field Work Sites

Gabbs Valley, Nevada

Milford, Utah

Bottom images: FORGE Utah

Drilling Rig Controls

Image: CARE Industries

Comments?

Is the amount and quality of data in the NGDS/GDR going to be sufficient for machine learning applications following completion of current projects?

Are there additional pathways to leverage existing machine learning applications from other subsurface industries?

How does the geothermal community achieve the long term goal of providing operational decision support in (or near) real time in the most efficient manner?

Visit us at www.energy.gov/eere/geothermal
Contact us at DOE.geothermal@ee.doe.gov

NGDS: http://geothermaldata.org/
GDR: https://gdr.openei.org/