Characterize, quantify, and determine commerciality of gas hydrate and associated free gas resources in arctic regions through integrated academic, industry, and government collaborative research to promote safe, low cost, and environmentally responsible production of abundant, strategic, and secure energy resources.
• Research Alignment and Teams
• Gas Hydrate Resource Potential
• Alaska North Slope Review
• BP Gas Hydrate Research Program
  • Resource Characterization
  • Resource Development Modeling and Technology
Methane Hydrate Research Alignment and Interaction

U.S. Department of Energy

GOVERNMENT

Unconventional Resource Determination

3D Seismic & Well Data, Infrastructure

INDUSTRY

Resource Evaluation

Research/Expertise

Research Innovation

UNIVERSITY

3D Seismic

& Well Data,
Infrastructure

bp

bp

USGS

science for a changing world

bp

THE UNIVERSITY OF ARIZONA

UNIVERSITY OF ALASKA FAIRBANKS
Collaborative Research

- Industry-Focused Project Funding
  - Encourages Industry Collaboration
    - Enables Methane Hydrate Project Research
  - Ensures Research Fit-for-Purpose
    - Enables Long-Term Value
- Supports Industry & Government Goals
  - Enables Resource Decisions and Planning
- Industry – Academic Research Alignment
  - Research Topic Important to Both
  - Industry Not Inclined to Self-Perform
  - Industry-Directed Research Programs
  - Industry Expectations Clear
  - Industry-focused Research Results
Methane Hydrate Resource - Potential to Fill Projected Gap?

Enough Affordable Gas to Meet Demand?

Gas Volume (Tcf/year)

- Business-as-Usual
- HYDRATES
- IMPORTS
- CONVENTIONAL (Includes Deep Gas & Deep Offshore)
- UNCONVENTIONAL (Coals, Tight Sands, Shales)

Historical Data (EIA)  AEO 2001 Projection  Possible Scenario

Options to Increase Gas Supply

- Open Exploration/Production Areas
- Increase LNG Imports
- Develop Unconventional Resources
  - Coalbed Methane
  - Deep Gas
  - Shale Gas
  - Gas Hydrate
    - Best Gas Storage Capacity
    - Technically and Economically Challenging
Unconventional Gas Resources

Gas Storage Capacity Contrast

In-Place Gas Per Cubic Foot, 30% Porosity Reservoir

- Gas Hydrate
- Coal Bed Methane
- Tight Sands
- Devonian Shale
- Geo-Pressured Aquifers

After National Petroleum Council, 1992
Methane Hydrate Resource
Petroleum System Components

- **Source**  – Thermogenic - Biogenic
- **Migration**  – Fault Systems
- **Reservoir**  – Sub-Permafrost
  Shallow Sands
- **Trap**  – Complex Structural and
  Stratigraphic through 4D
- **Seal**  – Can Self-Seal
- **Stability**  – Pressure/Temperature
- **Gas/Water**  – Clathrate Structure
Gas Hydrate Resource and Prospect Requirements

- Petroleum System Components
- Industry Infrastructure
- Industry Acreage Access
- Production Technology (Familiar)
- Economics and Risk Assessment
  - Ultimate Recovery Potential?
  - Daily Production Rate?
  - Operating Cost?
  - Profitability?
- Research Support in Aligned Areas: Gulf of Mexico and Alaska
- North Slope Proven Gas = 35 TCF
- Prudhoe Bay 8 BCF/Day Production
- Reinjected Gas Reservoir Energy
ANS Methane Hydrate
Estimated In-Place Resource

EILEEN TREND

FREE GAS?

44 TCF

GAS HYDRATE & FREE GAS

TARN TREND

60 TCF?

GAS HYDRATE

MPU 100%

KRU 39%

PBU 26%

DIU

(After Collett, 1993)
Alaska Gas Hydrate Resource

Methane Hydrate Stability Field

Base of ice-bearing Permafrost
Geothermal gradient
Gas hydrate stability field

Modified After Collett, 1993
Alaska Gas Hydrate Resource
Historical ANS Perspective

- Initial ANS Exploration
- Prudhoe Bay Field Discovery
- NW Eileen #2 Gas Hydrate Test Well
- Oil-Focus Research Gap
- USGS Research Projects
- USDOE Gas Hydrate Projects
- BP EWE Seismic Study
- USGS Resource Assessment – 590 TCF
- ARCO Gas/Hydrate Study
- USDOE-BP Gas Hydrate Project
- Possible Pilot Development
Year/Phase/DOE Cost

2001

Project Proposal
DOE-Industry Alignment

2002

Wells of Opportunity – Acquire Data

I $2.0

2003

Characterize Reservoir/Fluid
Verify In-Place Resource
Drilling/Production RE/PE Studies

2004

Reservoir and Economic Modeling

2005

Production Test, Reserves Calc.

II $3.6

2006

Reservoir and Economic Modeling
Possible Pilot Development

III $7.6
Phase I: Assess/Aquire Data, Determine Resource Potential

- Interpret 3D Seismic and Well Data
- Characterize Reservoirs and Fluids
- Seek Sizable, >Continuous Resource
- Collect Data in Opportunity Wells
- Model Gas – Gas Hydrate Reservoir
- Evaluate Development Scenarios
- Design Drilling, Completions, Production Technology
- Decide Phase II Progression-Activities
- Select Candidate Operations Area(s)
Components and Collaborations

- **Gas Hydrate Productivity Studies:**
  - UAF, LBNL, PNNL, ANL
  - Control Gas Hydrate Stability
  - Assess Drilling/Completion/Production Ops
  - Model Thermodynamics – Productivity
  - Develop Production Scenarios/Technology

- **Resource Characterization Studies:**
  - UA, USGS, BPXA
  - Assess Shallow Conventional 3D Seismic
  - Evaluate Fluid Acoustic Properties
  - Incorporate and Acquire Well Data
Reservoir-Fluid Characterization
Gas/Hydrate In-Place Calculation

3D Seismic / Well Data Interpretations

- Stacked Fluvial-Deltaic / Marine Sands
- Disrupted Reservoir Continuity/Quality
  - Facies, Fluid, & Reservoir Heterogeneity
- Intraformational Unconformities
- Fault Compartmentalization
Geophysical Characterization
Reservoirs and Fluids

Possible Gas Hydrate
Possible Free Gas
Polarity Reversal
Trapping Fault
Milne Point 3D Seismic Line
Gas Migration: Fault Conduits

5002920376
MILNE PT. UNIT "A" NO. 1

Two-Way Travel Time (Seconds)

Permafrost Zone
Sagavanirktok Age Sandstone Sequence
Brookian Age Clastic Sequence
Shale Sequence
Fault

Approx. Base of Gas Hydrate Stability Zone

Courtesy USGS
MPU 3D Seismic Waveform Class
Potential Facies & Fluid Identifier

40ms Window, USGS Zone C
Petroleum and Reservoir Engineering Research

Relative Permeability (UAF, LBNL)

Drilling, Completion and Production Studies (UAF, ANL, others)

CO₂ to Enhance CH₄ Recovery (UAF-PNNL)
Preliminary Reservoir Model
(LBNL-BPXA-USGS-UAF-RS)

- 3 miles
- 2 miles
- 95ft

- Methane Hydrate
- Free Gas
- Water

- Sagavanirktok Fm, Unit C

- Calculate Recovery Factors
- Develop Production Scenarios

- 5 wells, centered in Free Gas area
Preliminary Reservoir Model
Gas Hydrate Dissociation

- Significant Production Increase due to Free Gas Dissociation from Gas Hydrate
- Significant Uncertainties: Use with Caution
Productivity Challenges

Gas Hydrate Production Methods

Depressurization
- Gas Out
- Impermeable Rock
- Gas
- Dissociated
- Free-Gas

- Endothermic heat of dissociation
- Temperature recovery lag time
- Hydrate self-preservation

Thermal Injection
- Gas Out
- Impermeable Rock
- Gas Hydrate
- Dissociated Hydrate
- Reservoir

- Large energy in Heats Host Rock
- Possible in-situ Electromagnetic

Inhibitor or CO₂ Injection
- Gas Out
- Impermeable Rock
- Gas Hydrate
- Dissociated Hydrate

- High cost
- PNNL Lab Testing
- Unk. Effectiveness

After Collett, 2000
Proof-of-Principle

\[ \text{CH}_4 \rightarrow \text{CO}_2 \]

**Theory:** Inject \( \text{CO}_2 \) to Recover \( \text{CH}_4 \) from Gas Hydrate

- Thermodynamically Favorable
- Offsetting Dissociation Enthalpy: Heat of formation for \( \text{CO}_2 \) hydrate \( \sim 20\% \) larger than \( \text{CH}_4 \) hydrate heat of dissociation
- Reforming \( \text{CO}_2 \) Hydrate Mechanically Stabilizes Hydrate-Bearing Sediments

**Results:** \( \text{CH}_4 \) from Gas Hydrate by Injecting \( \text{CO}_2 \)

- Temperature Reading Immediately Spiked from -2.5°C to 8°C
- Collected Gas Samples Displayed Strong Methane Peaks with Small to No \( \text{CO}_2 \) Peaks on GC Analysis
Interagency Gas Hydrate R & D
Objectives Attainable in Alaska

- **Short-Term:** 4-5/7
  - Determine Physical/Chemical Properties
  - Input Research to Databases and Website
  - Improve Distribution/Volume Assessment
  - Improve Geophysical Characterization Tools
  - Provide Samples and Use Sampling Tools

- **Mid-Term:** 3/3
  - Refine Characterization Tools
  - Estimate Recovery Potential
  - Develop/Test Production Methods

- **Long-Term:** 3/4
  - Economically Produce for Secure Gas Supply
  - Provide Knowledge/Tools Supporting R & D
  - Leader in Gas Hydrate R & D
BP Alaska Gas Hydrate Project Summary

- Alaska North Slope: Premier Area/Time
  - Resource – Infrastructure – Alignment
- Characterize and Quantify Resource
- Determine Production and Economic Resource Potential
- Develop Drilling, Completion, Production Technology
- Benefit Industry and Government
  - Assess Technical/Economic Hurdles
  - Convert Potential Resource into Reserves
  - Develop Huge/Unconventional Resource
  - Use Gas for Reservoir Energy &/or Sales