Benefits Analysis, RPSEA 2007 Unconventional and Small Producer R&D Portfolio

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U.S. DEPARTMENT OF ENERGY

Presentation Outline

- **Purpose: debrief the committee on the benefits analysis that NETL has conducted for the RPSEA Unconventional Gas and Small Producer R&D Portfolios**
  - Background information
  - Methodology
  - Results
  - Peer review
  - Plans for the coming year

RPSEA 2007 Unconventional Gas and Small Producer R&D Portfolio

- **26 projects**

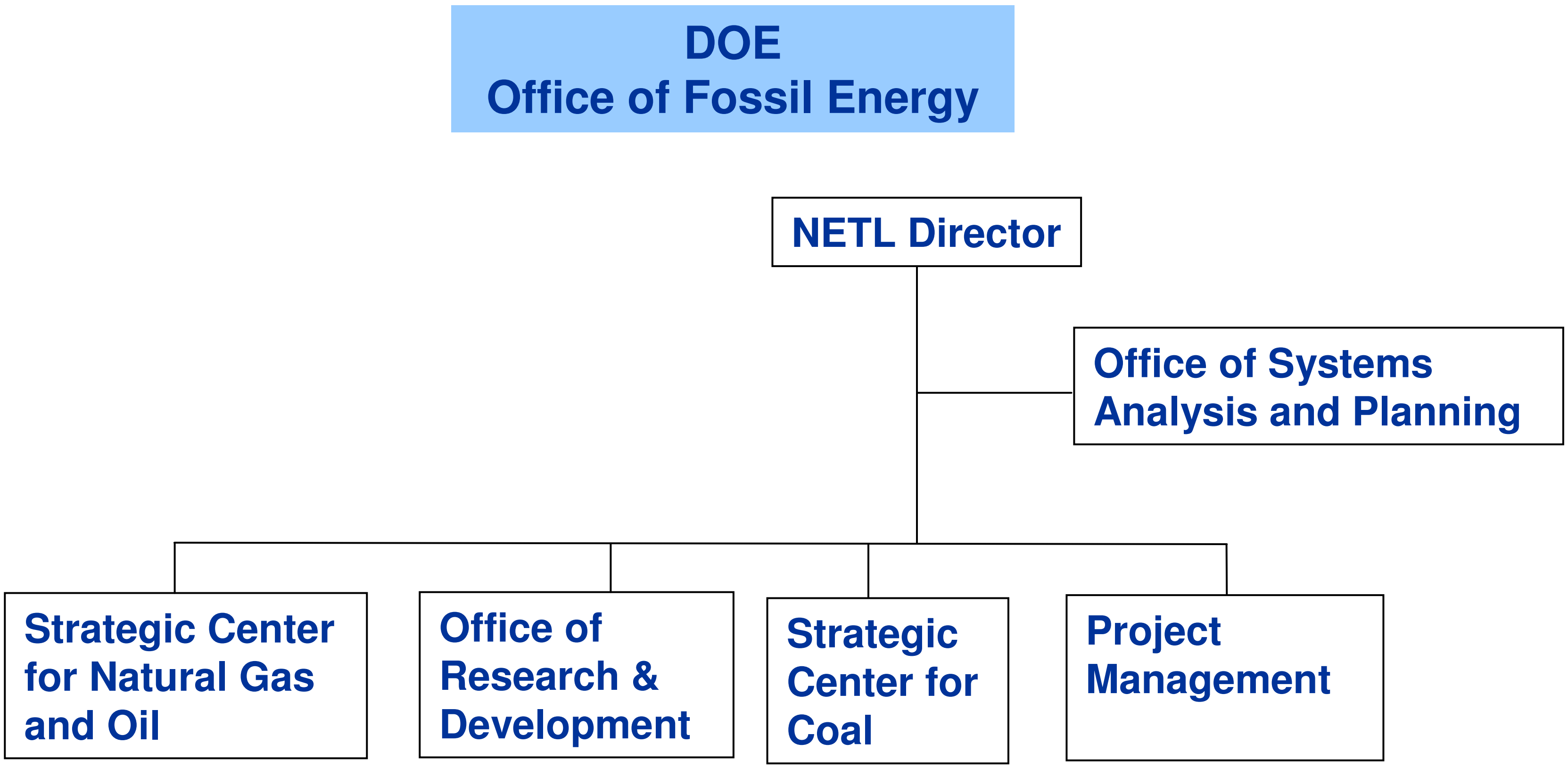
- **36.7 MM$ total investment**
  - 20.9 MM$ Federal investment
  - 15.8 MM$ industry cost share (43%)

- **Varied**
  - Technologies, target resources
  - technological maturity (white papers – field tests)
  - project size (115K – 7.5 MM$)

Objectives of the Benefits Analysis

- EPAct 999 requirement by statute
- Articulate the value of the research portfolio to DOE management, OMB, and stakeholders
- Provide NETL and RPSEA with information that can be used in portfolio management and future solicitations

Organizational Context for Objectivity



Unconventional Gas and Small Producer Benefits Analysis Team

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- *Al Yost (NETL/SCNGO)*

- Phil DiPietro (NETL/OSAP)
- Tim Skone (NETL/OSAP)
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- Harry Vidas ICF
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Expenditures to date are 2 federal FTEs and 0.5 $MM contract dollars, represents 1.7% of R&D portfolio

Timeline of Benefits Activities

March 2008	Projects Awarded
August 2008	Benefits Analysis Methodology Selected, brief RPSEA, FE HQ
January 2009	Draft results previewed to RPSEA, FE HQ
March 2009	Peer Review Conducted
June 2009	Peer Review Report completed
September 2009	Briefing to FACA committee

3-Step Analysis Methodology

- **Step 1: Evaluate each project and estimate its impact on domestic oil and gas resources**
  - 2-page business plans
  - cost and environmental benefits cast in terms of resource impacts
- **Step 2: Run all projects through a standard algorithm to develop a 30-year production profile**
  - cost competiveness
  - capital intensity
  - market competition
- **Step 3:Aggregate project-level results and derive royalty and other benefits**

Guiding Principles for the Benefits Analysis

- **Transparency**
  - embrace professional judgment
- **Technology-centered, not model-centered**
  - capture the story of each project
- **Apply an appropriate level of rigor**
  - update/expand as research progresses
- **Finite time horizon (30 years)**
  - Longer and you start counting resources that might become available without the program

Step 1: Estimate Project Recoverable Resources

Structure of "2-Page" Business Plan

1. **Problem Statement**
   - Description of problem and why it is important
   - Resource effected

2. **Project Scope**
   - Description of work, how it address problem

3. **Benefits Approach and Results**
   - Presentation of an analytical expression that provides the project benefit
   - Definition of variables in the analytical expression, citations, assumptions supporting numbers for each

Step 2a Adjust the Project level Resource

- **Adjust the project-level recoverable resource based on project three criteria**
  - Profitability
  - Capital Intensity
  - Market Competition

- **Adjustment for each factor is a multiplier 0.2, 0.5, and 0.8 based on a low, medium, or high characterization**

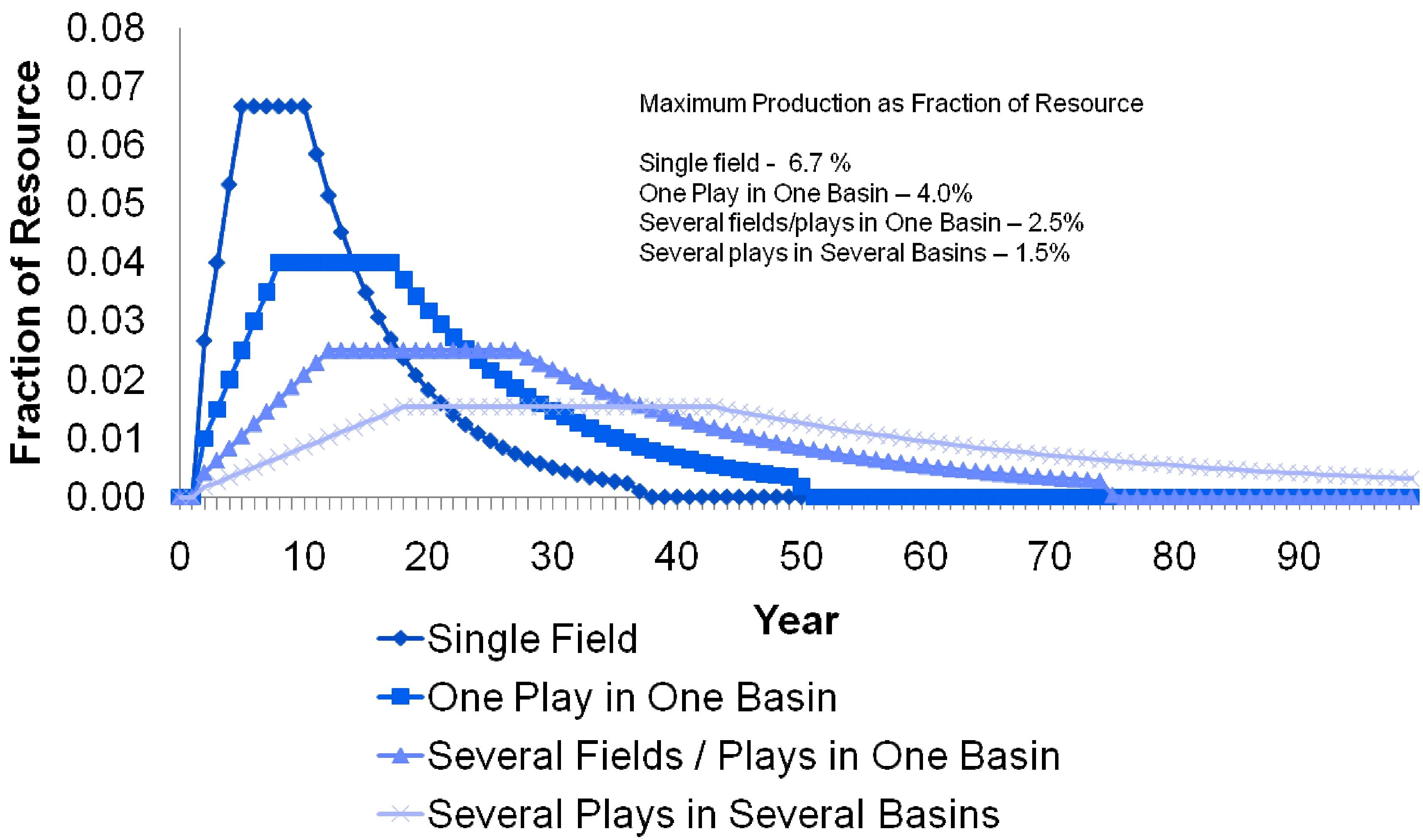
- **Overall adjustment is between 1% and 50%**
  - 0.2 x 0.2 x 0.2 = 0.008
  - 0.8 x 0.8 x 0.8 = 0.512

Step 2b Production Profile

- **Assign a production profile shape based on the breadth of resource to which the project applies**
  - Narrow range, steep profile with production over a short period of time
  - Broad range, slower production

- **Again applying the characterization factors for profitability, capital Intensity, and market competition adjust the shape of the profile**
  - Height of the plateau, slope of the ramp up
  - Total area under the curve stays the same

Step 2: Base Production Profiles



Step 3: Aggregate into Portfolio Summary

Benefits of RPSEA FY2007 Unconventional Natural Gas and Small Producer Portfolio					
Benefit	**# of Projects**	**Funding (MM$)***	**Recoverable Resources (Step 1)**	**Production Through 2040 (Step 2)**	**Present value of anticipated Royalties, (MM$)** (step 3)**
Oil	4	3.0	**3.0 Bbbl**	0.12 Bbbl (4%)	62
Natural Gas	13	22.7	**19.7 Tcf**	1.6 Tcf (8%)	140
None at this time	9	11.0			
Total	26	36.7			203

* Numbers presented include cost share from industry. Overall the portfolio contains 43% industry cost share. Oil-producing projects have 41%, natural gas 43%, and the no benefit yet projects42%.
** Calculated using an assumed average royalty payment of 12.5%, 35% of gas production and 12% of oil production is on federal lands, 8% discount rate, and NG and crude oil prices from the AEO 2009 reference case extrapolated

External Peer Review

- **An external expert peer review of a benefits estimation methodology for UNG & SP Projects was held in Morgantown, WV on March 18 – 19, 2009**

Expert Review Panel

- Chuck Boyer, Schlumberger
- Lance Cole, Petroleum Technology Transfer Council
- Dave Hill, EnCana Oil & Gas (USA) Inc.
- Richard Hughes, Craft & Hawkins Department of Petroleum Engineering, Louisiana State University
- Hill Huntington, Energy Modeling Forum, Stanford University
- John Martin, New York State Energy Research and Development Authority
- Richard Nehring, NRG Associates

Sample Comments from the Peer Review

- ***The benefits estimation methodology presented is a solid, well-thought-out, and usable program for understanding and estimating the value of the NETL R&D program.***
- ***The technology side of the benefits methodology – Very Good.***
- ***I just thought the approach was reasonable and I really liked the transparency.***
- ***The topic is extremely difficult. The group has embraced the objective actively. My comments focus on areas where they might improve the analysis but should not be interpreted as being negative about the significant progress that has been done to date.***

Actionable Comments from Reviewers

1. Consider using stochastic instead of deterministic methods for determining technically recoverable resource

2. Engage subject matter experts within the project area to provide review and input for project analysis.

3. Make sure risk and uncertainty is included in benefits calculation, account for the probability of success.

4. Re-visit the benefits methodology for jobs impacts (Input/Output model).

5. Improve consistency in approach used for different projects

6. Develop a method of capturing environmental benefits

7. List the exogenous risk factors which must be overcome for project to achieve its full benefit.

Summary

- **Estimated increase in domestic resource production through 2040 caused by the 2007 RPSEA R&D portfolio in Unconventional Gas and Small Producers**
  - 1.6 TCF natural gas
  - 120 million barrels of crude oil
- **Present value of estimated Federal Royalty payments**
  - 203 million dollars.
- **The portfolio has other benefits**
  - reduced cost of energy
  - improved energy security
  - increased economic growth
  - reduced impacts on the environment
- **We expect the benefits estimate to increase as the RPSEA research evolves and we are more able to gauge the benefits**

Plans for Next Year

- Conduct benefits analysis on the 2008 awards
- Conduct benefits analysis on the NETL complementary program
- Re-assess benefits for 2007 award projects based on latest results from the work
- Fully implement suggestions from the peer review

Thank you!

Benefits Analysis Project Example

Near Miscible CO2 Application to Improve Oil Recovery

Performers

- University of Kansas Center for Research, Inc.
- Tertiary Oil Recovery Project (TORP)
- Carmen Schmitt, Inc. (small producer)

Funding

- Total: $342,714
- % Industry cost share: 20%
- Duration years: 2

Benefits Example: Step 1

- Problem statement: Incomplete characterization of the Arbuckle is potentially holding back domestic oil production in the form of CO_2 EOR
- Scope of work
  - Perform laboratory tests on fluids and core samples, construct a compositional simulation model, and run a reservoir simulation.
  - The plan is that the simulation will indicate near miscible activity and spur a pilot scale test . . . Which would then lead to an EOR flood in the Arbuckle
- Benefits equation:
  - **Increase in Reserves = OOIP * $FRAC_{CO2}$ * RF_{CO2}**

  Where,

  - **OOIP =** Original Oil in Place in the Arbuckle
  - **$FRAC_{CO2}$ =** Fraction of OOIP that is amenable to CO_2 flooding
  - **Rf_{CO2} =** Incremental Recovery factor from a near miscible CO_2 flood
- Key assumption: Near miscible behavior is well understood, benefits do not cascade beyond the Arbuckle

Benefits Example: Step 1 (cont.)

Increase in Reserves = OOIP * $FRAC_{CO2}$ * RF_{CO2}

- OOIP = 6.0 Bbbls
  - 2.0 Bbbls ultimate recovery / 33%
- $FRAC_{CO2}$ = 50%
  - Early estimate based on notion that not all of the formation will be high enough pressure
- RF_{CO2} = 4%
  - Confirmed value from the proposal
- 6.0 Bbbls * 50% * 4% = 120 MMbbls

Benefits Example: Step 2

- **Algorithm inputs**
  - Profitability multiplier 0.2
  - Capital intensity multiplier 0.2
  - Competition multiplier 0.8
- **Adjustment to resource estimate:**
  - 120 MMbls * 3.2% = 3.8 MMbbls
- **Production Curve**
  - Starting year 2012 (pilot test begins)
  - Single play resource curve
    - 7 year ramp up
    - Max production rate per year is 4% of the resource
  - Algorithm inputs cause ramp up to be extended to 8.4 years and max production reduced to 3.3%
- **Production through 2040 - - 2% of initial 120 MMbbl estimate**

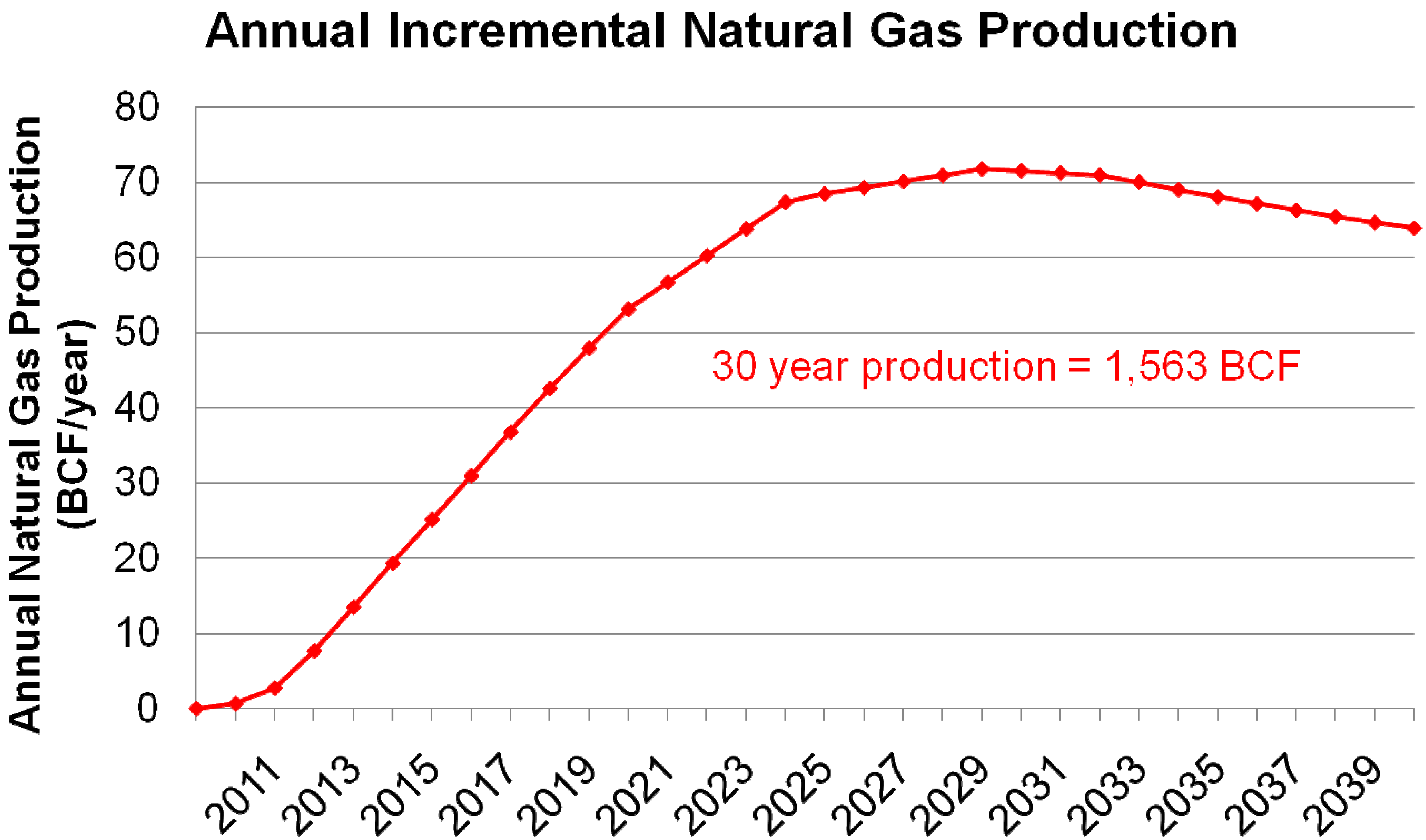
Step 3: Deriving Royalty Impacts

$$\text{Benefit} = \sum_{p=1}^{26} \sum_{yr=SY_p}^{2040} oil_{p,yr} \times oil\_price_{p,yr} \times R\_rate_{oil} \times \%\_FED_{oil} \times \frac{1}{(1+\text{Discount})^{yr-2010}}$$

$$+ \sum_{p=1}^{26} \sum_{yr=SY_p}^{2040} NG_{p,yr} \times NG\_price_{p,yr} \times R\_rate_{NG} \times \%\_FED_{NG} \times \frac{1}{(1+\text{Discount})^{yr-2010}}$$

P =	project; yr = year
SY_p =	start year for each project (yr production starts)
$Oil_{p,yr}$ =	oil production from project p during year yr
$NG_{p,yr}$ =	natural gas production from project p during year yr
R_rate =	U.S. acreage royalty rate paid for crude oil, NG (12.5%) (could have it change over time if you want)
%_FED =	percent of oil and natural gas production that comes from federal lands (35% for natural gas, 12% for crude oil)
Discount =	discount rate for future revenue streams (8%)

Projected 30 year Incremental Production as a Result of RPSEA UNG & SP Projects



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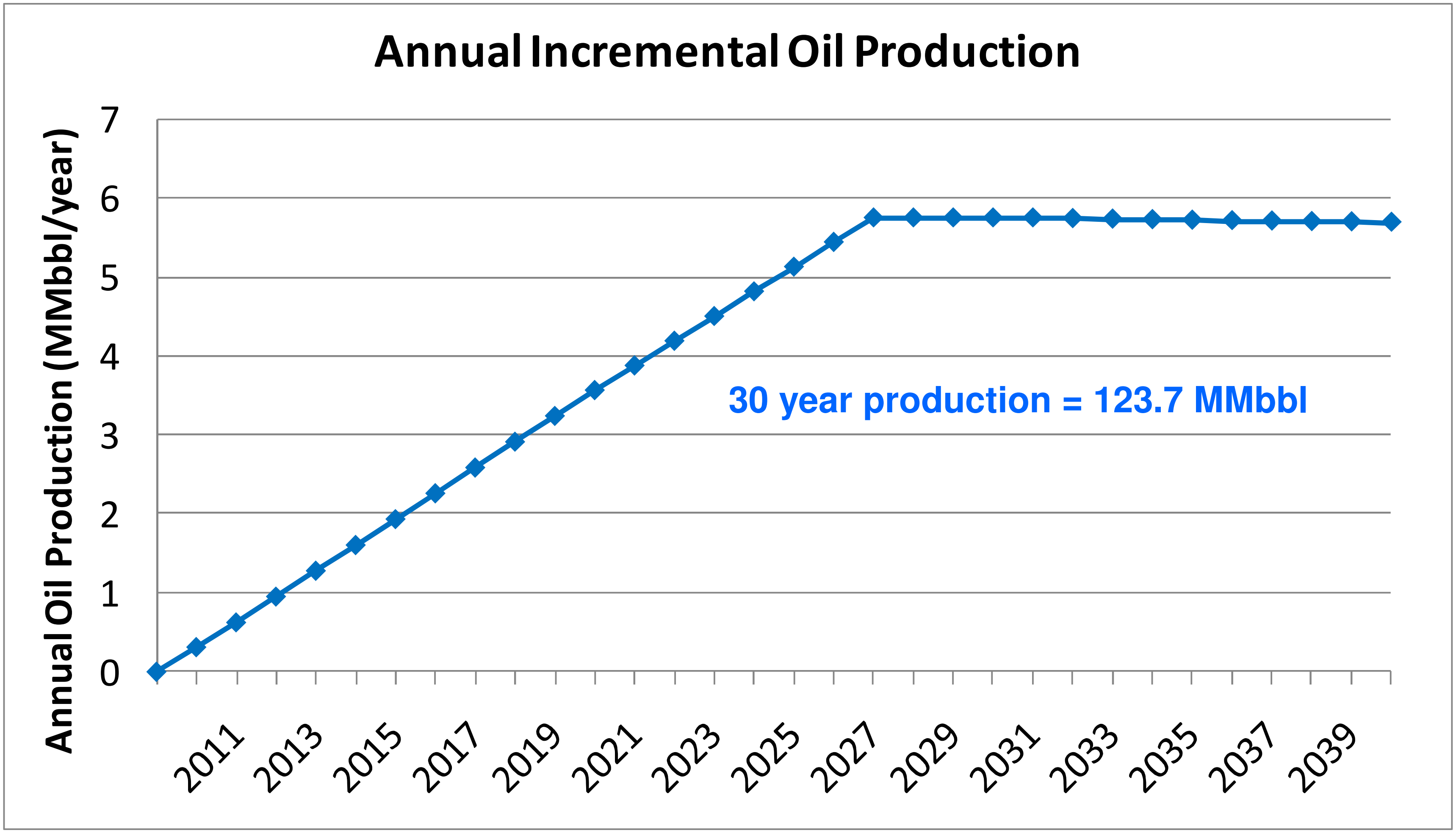

Step 1: Estimate Project Recoverable Resources

Sample information sources for constructing "2-Page" Business Plans

- **Commercial Information Sources**
  - NRG Associates – Oil and Gas Database
  - Warlick International – North American Unconventional Natural Gas Market Report
  - Hart Energy Publishing, LP – Unconventional Natural Gas Report
  - American Petroleum Institute-Joint Association Survey on Drilling Costs
  - Energy Information Agency (EIA)
- **Data from project performer in proposal**
  - Referenced sources found in proposal
- **RPSEA**
  - Project reviews
  - Regular meetings
- **NETL Experts**

Sample Project "2-Page" Business Plan

EPAct 999 Project Benefits Analysis Sheet	Small Producers	2008

Project Title	Near Miscible CO_2 Application to Improve Oil Recovery				
Contract #	07123-03				
Performer(s)	University of Kansas Center for Research, Inc.; Tertiary Oil Recovery Project (TORP); Carmen Schmitt, Inc. (small producer)				
Funding Total	$342,714	**% Cost Share**	20%	**Duration (yrs)**	2

Problem Statement

CO_2 flooding is not being pursued at the Arbuckle formation in Kansas, partially because the reservoir pressure is so low that the flood would behave as "immiscible" resulting in an anticipated rate of enhanced oil recovery that is not high enough to make projects economically viable. An immiscible CO_2 flood can enhance recovery by both swelling the oil and reducing its viscosity. This mechanism has been shown to result in up to roughly half of the incremental oil per volume of CO_2 injected as a fully miscible flood. There is potential for even greater recovery in the loosely defined "near miscible" pressure regime. A more rigorous characterization of the specific CO_2 EOR mechanism within the Arbuckle, specifically one that takes into account potentially favorable displacement mechanisms at near miscible reservoir conditions, could show a favorable increase in the estimated amount of oil recovery and tip Arbuckle CO_2 projects toward economic viability. This incomplete characterization of the Arbuckle is potentially holding back domestic oil production.

Project Scope

Two graduate students, under the guidance of a university professor, will conduct laboratory scale experiments on core and fluid samples from the Arbuckle provided by Carmen Schmidt Inc. They will measure phenomena known to indicate CO_2 flood performance at a sequence of pressures approaching the calculated minimum miscibility pressure. They will construct a compositional simulation model based on the Peng-Robinson equation of state using previously collected PVT data and tune the model to match the laboratory results. They will then conduct reservoir simulations of CO_2 flooding in the Arbuckle and estimate enhanced oil recovery and CO_2 storage capacity within these Arbuckle reservoirs.

Benefits Approach and Results

A successful laboratory modeling and testing effort could lead to a pilot scale CO_2 injection in the Arbuckle which could lead to a commercial-scale flood.

The maximum potential benefits of this project may be stated as incremental reserves and calculated using the following simple equation. These benefits assume successful laboratory studies followed by successful pilot projects involving Arbuckle reservoirs followed by large scale commercial flooding.

> **Incremental reserves** = OOIP * near miscible recovery factor * fraction of Arbuckle amenable to CO_2 flood
>
> Where,
>
> OOIP - The Arbuckle's OOIP can be estimated at roughly 6.0 billion barrels, of which 33 % has been recovered to date via primary recovery and water flood. Carmen Schmidt operates in 5 Arbuckle reservoirs estimated to contain an OOIP of 850 million barrels.
>
> Near miscible incremental recovery factor - (3-5% was referenced in the proposal and can be supported by immiscible floods discussed in the literature)
>
> Fraction of Arbuckle OOIP amenable to CO_2 flood - Unknown, data not available to assess this number. Will assume 100% to generate maximum potential.

The estimated 3-5% recovery factor for near miscible CO_2 flooding can be supported by case studies from the literature.

- An immiscible flood in the Avile reservoir was estimated to recover 4% of OOIP.[1]
- A series of four immiscible projects in Trinidad were estimated to have incremental recoveries ranging from 2 to 8% of OOIP.[2]
- An assessment of North Dakota CO_2 flooding potential noted that 8% is a widely used empirical value for miscible flooding in West Texas carbonates and that immiscible CO_2 floods generally recover 50% or less of what is recovered in miscible floods[3].

Evaluation of the specified benefits equation gives a maximum potential of 180 to 300 million barrels of oil as a result of CO_2 flooding in the Arbuckle. Research will need to proceed to pilot test level before realistic estimates can be made. At this early stage, benefits will be estimated assuming only Carmen Schmidt operated fields. This assumption applied to the equation gives an estimate of 34 million barrels. The research indicates that the potential for near-miscible behavior in borderline formations is well-understood within the oil and gas industry. As such, it is unlikely that this work will cause incremental domestic oil production beyond the Arbuckle.

References

[1]Brush, R.M., Davitt, H.J., Aimer, O.B., Arguello, J., Whiteside, J.M.,"Immiscible CO_2 flooding for Increased Oil Recovery and Reduced Emissions", SPE 59328

[2]Mohammed-Singh, L.J., Singhal, A.K., "Lessons from Trinidad's CO_2 Immiscible Pilot Projects 1973-2003", SPE 89364-MS

[3]Nelms, R.L., Burke, R.B., "Evaluation of Oil Reservoir Characteristics to assess North Dakota Carbon Dioxide miscible flooding potential", http://www.mines.edu/Research/PTTC/casestudies/NDflood/index.html

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