IHS ENERGY

IHS Response to Market Survey

Oil and Gas Recovery and Enhanced Techniques Including Economic Impact

August 28, 2015

Irena Agalliu, Managing Director
Tim Zoba, Vice President

I. Object
The object of this market survey has two objectives. One is to provide a detailed scientific study of enhanced oil recovery methods, particularly CO2 and to provide a timeline to implement this technology. The second is to review the current tax legislation, making recommendations for changes and including impact analysis for the State, political subdivisions, environment and energy industry.

II. PROPOSED SCOPE OF WORK AND APPROACH

Task 1 Scientific Information on Enhanced Oil Recovery

IHS understands that a Tender is being conducted for a 1-year agreement and that the North Dakota Legislative Management (NDLM) is interested in attaining scientific and economic information regarding the current potential of enhanced oil recovery (EOR) methods, with a primary focus on CO2 injection. IHS’s core subsurface team has experience and knowledge for assessment of both secondary and tertiary recovery methods through prior evaluations and reservoir studies that we have undertaken.

The scope of work provided here is therefore understood to be an indicator of the type of work anticipated. The scope of studies and technical services is as follows:

- Detailed analysis of the use of carbon dioxide for enhanced recovery from oil reservoirs
1. Feasibility of implementing various enhanced oil recovery methods
2. Timelines associated with implementation of enhanced recovery techniques

1.a Use of CO2 in enhanced oil recovery

The proposed scope of the analysis in CO2 flooding, or explained as the use of carbon dioxide in enhanced oil recovery, is as follows:

1) Overview of CO2-EOR technique background and fundamentals
2) Reservoir and Operational characteristics of CO2-EOR process
3) North America state of commercial CO2-EOR projects: Opportunities and Challenges

1.a.1 Overview of CO2-EOR technique background and fundamentals

The application of CO2 in EOR has been widely accepted by industry, the government, and environmental organizations for its potential for permanently storing CO2. With the proper reservoir conditions, CO2 EOR can add value by increasing oil recovery while offering permanent storage of CO2 at the same time. CO2-EOR targets the residual oil in depleted oil reservoirs and should be applied in depleted, light-oil reservoirs that have gone through primary recovery, and in some cases, secondary recovery (e.g., waterflood) methods. In summary, CO2 is injected into reservoirs to act as a solvent which mixes with the oil and causes oil volume expansion, viscosity reduction, and interfacial tension reductions which will assist the oil in more readily flowing within the porous media.

IHS will provide extensive scientific technical information on the basis of CO2-EOR recovery method. This knowledge will help North Dakota Legislative Management obtain a scoping level estimate of the potential incremental oil recovery from fields within the basins determined to be in-scope.

1.a.2 Reservoir and Operational characteristics of CO2-EOR process

Prior to selecting any secondary or tertiary recovery method, the fundamental question of what types of reservoirs are suitable for EOR considerations needs to be addressed as not all oil reservoirs could be considered as suitable candidates for CO2-EOR. Therefore, screening needs to be performed to select and rank the suitable reservoirs for the successful implementation of CO2-EOR. There are various criteria recommended for the technical screening of CO2-EOR reservoirs. Application of these criteria, which are mainly based on the general reservoir and oil properties, will facilitate a rapid evaluation and screening of the oil reservoirs suitable for CO2-EOR. Additionally, based on the intrinsic reservoir and oil characteristics, a parametric optimization method would be used for technical ranking of the North Dakota oil reservoirs appropriate for such recovery methods. Once the optimum values of oil and reservoir properties are defined, a weighting factor would be assigned to each parameter. Then, performance ranking would be considered by taking into account three key performance parameters – original oil-in-place (OOIP), CO2 EOR recovery factor and CO2 storage capacity. This methodology will enable IHS to identify the top oil reservoirs that are best suited for CO2-EOR and storage.

IHS will develop screening criteria (relevant reservoir and fluid parameters) to evaluate the feasibility of CO2 flooding. In essence, these criteria will address the following subsurface questions:

- Does the reservoir have enough residual oil saturation?
- Is the reservoir deep enough to allow the project to operate at the desired pressure (above minimum miscibility pressure for miscible process)?
- Is the reservoir homogenous enough to provide sufficient connectivity?
- Does oil property suit the desirable gravity and viscosity range?

In addition to confirming the suitability of a target reservoir for a CO2-EOR process, the operational aspects of CO2-EOR method should also be considered. IHS will identify the main operational concerns and associated best practices that each operator should consider before implementing this recovery method.
1.a.3 North America vs Worldwide state of commercial CO2-EOR projects: Opportunities and challenges

For the past four decades, CO2-EOR has demonstrated significant success for recovering additional oil. North America is the leader in successful implementation of CO2-EOR mechanism, which is primarily due to favorable geological circumstances in mature basins. However, other successful CO2-EOR projects have been launched worldwide. In order to ascertain the key variables that influence the success of EOR projects, IHS will conduct a performance review of the global reservoirs that currently apply CO2-EOR as a recovery method. This review will consider both performance opportunities and challenges. Some of the technical challenges are listed below:

- Favorable geology
- Interaction between CO2 and reservoir fluids
- Integrity of wellbores, surface facilities and relevant equipment
- Operating environment
- Reservoir surveillance
- Application to unconventional reservoir

IHS will review, compile, and report the technical challenges that could cause obstacle to the implementation of CO2-EOR method. IHS database which contains extensive information on the basins, plays and reservoirs with the region will be used in the research to support our geoscience and engineering team.

1.b Feasibility of implementing enhanced oil recovery

Since most EOR projects are economically sensitive and have a high performance threshold, which puts them at risk of meeting expectations, there tends to be a limited number of EOR projects launched. Not all reservoirs are responsive to EOR techniques; therefore, it is important to select the proper EOR mechanism for the target oil reservoir. It may be that other EOR methods are better suited than CO2-EOR for a certain reservoir. As such, alternative EOR processes to the CO2-EOR technique should be evaluated, and IHS will develop a methodology to develop an EOR method decision framework. Any strategy that results in increasing the amount of oil production shall be considered for EOR criteria. As presented in the figure below, IHS proposes a generic decision framework for a typical EOR screening project; however, it will be customized as necessary.

1.b.1 EOR Screening

The current successful EOR processes such as Gas-flooding, CO2-EOR, WAG and Chemical-flooding will be considered. An assessment of the most important technical uncertainties related to the application of these methods will be incorporated in the study to address the technical feasibility of such processes for the targeted oil reservoirs. A summary of key controlling parameters is presented below:

- Reservoir Uncertainty: degree of heterogeneity, geometry, extension and presence of top gas and aquifer, reservoir temperature and pressure
- Rock-Fluid Uncertainty: range of gas-oil relative permeability data set, compositional effect, rock-fluid interaction via chemical reaction
- Fluid-Fluid Uncertainty: Minimum Miscibility Pressure (MMP)

Once the most critical parameters are identified, the range of uncertainty associated with each parameter will be defined under three categories of “High”, “Medium”, and “Low”.
1.b.2 EOR Evaluation and Ranking
The objective of EOR screening study is to evaluate each process which will allow us to rank the EOR alternatives in order to replace the most favorable technique with CO2-EOR method. It is worth to note that in the absence of laboratory or field data, the performance of EOR processes would be evaluated using relevant analogues. Extensive comparison between current EOR projects using both IHS and publicly available data will be carried out, the selected EOR processes will be ranked, and the top three processes will be taken into the simulation phase.

1.b.3 Analytical Simulation
Performance prediction will be defined using analytical and numerical simulations and the most important uncertainties that can affect the efficiency of the selected EOR processes will be defined. Initially, an uncertainty matrix will be generated. Experimental Design (2-level and 3-level ED) technique will be conducted to identify the most important parameters and their interactions. Surface functions will be developed to relate the production performance to the ranked uncertainty parameters. The surface functions will be used along with the range of input parameters in a Monte-Carlo simulation. The Monte Carlo simulation generates a series of realizations of the parameters such that the ranges of each parameter would be honored.

1.b.4 Numerical Simulation to forecast EOR methods
IHS will use a compositional modeling approach to model gas/solvent injection phase behavior and the ability of the injectant to mobilize and recover incremental oil. For such study, a multi-component Equation of State (EOS) will be tuned to the available laboratory PVT data. All EOR methods will use a hypothetical reservoir model with averaged reservoir properties. The numerical simulation model should be able to take into account different considerations such as the effect of water invasion, gravity segregation, rock-fluid interaction and etc. The results of numerical simulation will be combined with economic criteria to determine the best process based on the recovery improvement.

1.c Potential timelines for implementation of enhanced oil recovery

1.c.1 Time Lines
The time line for EOR implementation would involve two phases: Subsurface Evaluation and Pilot Design. Each of these phases will be divided into sub categories as presented below:

Subsurface Evaluation
- EOR Screening
- Rock and Fluid Characterization
- Geology and Reservoir Assessment
- Production Forecast/Economic Evaluation

Pilot Design
- Well Conversion/Drilling & Completion
- Basic Design
- Detailed Design and Procurement
- Construction

IHS primary estimate of time required for each phase is provided in table below
Task 2 Current economic information and the estimated future annual potential economic impacts resulting from enhanced oil and gas recovery techniques

2.a Oil formations in the state of North Dakota

While the Bakken formation is the formation with the most current interest, there are other formations in North Dakota that have potential. Some of these are the Spearfish, Tyler Mission Canyon, Three Forks Prairie, Red River as well as others. IHS will study each of these reservoirs or any other reservoir that has proven production in the State. Each of these reservoirs will be characterized in terms of reservoir quality, production, known reserves, hydrocarbon types and a statistical estimate of yet-to-find (YTF) if there is sufficient data to source a statistical analysis. The estimates will be separated into conventional and unconventional as required.

2.b Application of existing tax incentives and foreseeable future

IHS has completed studies of the fiscal and tax regimes for the United States, Canada, multiple foreign locations and for each State in the U.S. The first step will be to review the existing North Dakota regulations. The next step will be to place these regulations into context relative to other nearby states, federal lands and adjacent Canadian regulations. Similarly the major North Dakota plays (conventional and unconventional) need to be placed into context relative to the other plays in North America that will be in competition. Once this is done then a prediction of future activity can be made that takes into account the tax and commercial competitiveness of the plays in North Dakota given IHS’s price forecast of supply and demand or any other forecast. In this section IHS will leverage its PEPS (Petroleum Economics and Policy Solutions) service along with publically available data. IHS has a team of dedicated fiscal experts who modeled most of the fiscal systems in the world and can offer valuable advisory in terms of petroleum tax comparisons.

IHS has extensive experience in advising / designing fiscal systems for governments. Tax incentives are common fiscal instruments that governments can activate to help operators in developing challenging areas. Tax incentives can take several different forms depending on the fiscal system. They can take various forms:

- Special credits or allowances for technically complex developments
- Royalty holidays for specific geologic zones
- Capex uplift for specific developments
- Production bonuses reductions or exemptions
- Income tax reduction or exemptions
- Cost recovery increase
- Windfall tax levy adjustments
- Bonuses reductions or exemptions

The table below gives a snapshot of tax incentives mostly used for marginal fields

<table>
<thead>
<tr>
<th>Country</th>
<th>Upfront Assistance Increase</th>
<th>Royalty Reduction</th>
<th>Income Tax Reduction Exemption</th>
<th>Production Bonus Reduction Exemption</th>
<th>Profits Bonuses Reduction Exemption</th>
<th>Cost Recovery Increase</th>
<th>Windfall Levy Adjustment</th>
<th>Special Benefits Reduction Exemption</th>
<th>Capital Cost Reduction Exemption</th>
<th>Assist Tax Inclusion Exemption</th>
<th>Profit Share Compensate</th>
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<td>1  Albania</td>
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2.c Recommendations for the elimination, modification or addition of tax incentives with the effect these changes might have on:

In order to make recommendations for changes to the current systems IHS would create a tax and fiscal model for conventional and unconventional oil and gas fields or plays. IHS develops comprehensive models in MS Excel that are used to evaluate oil and gas assets. This model would include the cost to drill, the cost to maintain production and the value of the production. Taxes would be incorporated at the State and County level as appropriate. Revenue would be split between the State, County, producer and land owner according to the current State regulations. Once completed the model can be used to create scenarios of hydrocarbon price levels and associated activity. Sensitivity analysis can be used to see the impact of changes to the tax under the various model assumptions. Recommendations with comments on the associated risks would be made once the work is complete.

The figure below represents the main flow of the workflow that IHS will follow to deliver the analysis.
IHS has a dedicated team of economists and statisticians that can cater to economic impact analysis. The typical workflow of our economic impact assessment involves:

- **North Dakota**
  At the State level the government take will be extracted from the model. In addition to the tax intake the associated economic activity in the supply and service sector can be estimated in terms of jobs and revenue.

- **Political subdivisions**
  The revenues collected from the production of oil and gas support many functions. These may be cities, counties, and schools but they also support general economic activity such as housing, services, industry and retail. Any change to the level of activity due to changes in the tax system will impact the direct funding but more importantly to local subdivisions will be the impact on local businesses. IHS has recently completed a study of the ancillary impact on local businesses of the oil boom at the State level. This same methodology can be used to define the economic base level of each political subdivision and then to extrapolate the impact of tax changes.

- **Environment**
  The environmental impact relative to noise, traffic, air, CO2 emissions, water etc. can be baselined using existing public domain or State provided studies. Each change to the tax structure will affect the plays differently so it will be necessary to map out which plays will win and which will lose. Once this is done an estimate relative to the baseline can be made for environmental impact for each play area.

- **Fossil energy industry including lignite**
  The impact on the industries can be estimated from previous observations of past changes to tax regimes and to previous IHS studies. It is generally accepted that decreasing the tax burden will increase economic activity, but how and where these tax changes are applied will affect the outcome. Any recommendations to modify the existing tax structure will be accompanied by an impact assessment on the energy industry including the production of lignite.
III. DELIVERABLE PROFESSIONAL FEE

Our professional fee for this project including travel is $635,000.00 (six hundred thirty-five thousand United States Dollars). The following table contains a breakdown of the fees for each individual task. We have anticipated invoicing in two milestones upon completion of respective tasks. The fees include the cost of travel to Bismarck for meetings and the cost of printing deliverables.

*Table 1: Professional Fee and Timing of Deliverables*

<table>
<thead>
<tr>
<th>No.</th>
<th>Task to be performed</th>
<th>Due Professional Fee</th>
<th>Schedule</th>
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<tbody>
<tr>
<td>1</td>
<td>Technical analysis</td>
<td>$150,000</td>
<td>8 weeks from effective date</td>
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<tr>
<td>2</td>
<td>Tax and economic analysis</td>
<td>$245,000</td>
<td>10 weeks from effective date</td>
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<tr>
<td>3</td>
<td>Ongoing Support</td>
<td>$240,000</td>
<td>Throughout 2016</td>
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<tr>
<td></td>
<td>Total</td>
<td>$635,000</td>
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</tbody>
</table>

IV. IHS TEAM

The IHS team for this project shall consist of five technical experts with background in tax, oil and gas regulations, geology and petroleum engineering. The following team will initially be engaged full time during the course of 8-10 weeks. It is anticipated support will be required during the year to answer questions and to work out details. In addition, two meetings will be held with the North Dakota Legislative Management Committee staff in Bismarck, for which the costs for IHS personnel are included. Additional meetings will be held during the evolution of the project via Webex or similar teleconferencing systems.

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Background</th>
<th>Role in the Project</th>
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</thead>
<tbody>
<tr>
<td>Irena Agalliu</td>
<td>Managing Director</td>
<td>Tax and Regulatory</td>
<td>Project Manager</td>
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<tr>
<td>Dan Bendig</td>
<td>Director</td>
<td>Geology and Geophysics</td>
<td>Project Consultant</td>
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<tr>
<td>Mohammad Tavallali</td>
<td>Principal Reservoir Engineer</td>
<td>Reservoir Engineering</td>
<td>Project Consultant</td>
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<tr>
<td>Ray Mireault</td>
<td>Senior Specialist</td>
<td>Reservoir</td>
<td>Reservoir Engineering</td>
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<tr>
<td>Aube Montero</td>
<td>Director</td>
<td>Economics and Modelling</td>
<td>Project Consultant</td>
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</table>

V. ABOUT IHS

We are a leading source of information and insight in critical areas that shape today’s business landscape, including energy and power; design and supply chain; defense, risk and security; environmental, health and safety (EHS) and sustainability; country and industry forecasting; and commodities, pricing and cost. Businesses and governments in more than 165 countries around the globe rely on the comprehensive content, expert independent analysis and flexible delivery methods of IHS to make high-impact decisions and develop strategies with speed and confidence. IHS has been in business since 1959, incorporated in the State of Delaware in 1994, and became a publicly traded company on the New York Stock Exchange in 2005. Headquartered in Englewood, Colorado, USA, IHS employs more than 8,500 people in more than 40 countries around the world.
Our clients include decision-makers at every level, across virtually every industry, from multinational enterprises to municipal governments; we can scale our offering to the scope of the client’s needs.

IHS serves:

- Corporations and governments in **165+** countries
- **Small businesses to Fortune 500**
- **75+%** of the Global Fortune 500
- **70+%** of the Fortune 1000

IHS Consultants advise companies, governments, financial institutions and technology providers operating on any point along the value chain for all key forms of energy. Our consultants leverage their broad expertise in energy strategy, policy and legislation and the deep industry expertise of the IHS research group to develop fact-based, comprehensive solutions that offer lasting value.

IHS is well known within the energy industry for its unparalleled energy industry knowledge and depth of experience, and its focus on delivering comprehensive, integrated and actionable analysis and judgment. The background of IHS’ research platform—strengthened and supported by the databases and analytical tools of IHS’ other energy businesses—have elevated IHS to a position unique among advisory firms. Business leaders appreciate the breadth and depth of IHS’ analyses as well as the experience and capability of the firm’s staff. Unlike general strategy and management consultancies, IHS’ experts focus exclusively on global energy and the factors that shape energy markets—including geopolitical driving forces and trends in energy policy and regulation across the globe.

Top decision makers trust IHS to help them successfully formulate strategies in the face of rapid change and uncertainty. IHS offers comprehensive, in-depth research and thought leadership on energy markets, industry dynamics, technology, economics, politics, regulation, and investment strategy. Companies value IHS’ independence, fundamental research, creativity, and original thinking. Among other benefits, these qualities allow IHS to provide clients with unbiased market assessments and cutting edge strategic energy insights—ahead of conventional wisdom.
IHS serves clients through membership-based advisory services, multiclient studies, and customized consulting projects. The synergies among these three areas create incremental value for clients, giving our clients a competitive advantage in the global marketplace.

**THE IHS ADVANTAGE**

Traditionally, energy market participants seeking assistance in creating an optimal business strategy were forced to choose between, on the one hand, economic and/or management consultancies and, on the other, energy market and/or industry analysis firms. IHS combines the strengths of both, thereby overcoming the individual weaknesses of each and offering clients seeking strategic help the opportunity to have an unmatched knowledge base and skill set.

With IHS global reach, all sectors of the energy industry and all energy products are covered in an integrated fashion. IHS has assembled teams to address virtually every type of energy industry issue.

**UNIQUE QUALIFICATIONS FOR CUSTOM CONSULTING PROJECTS**

IHS’ position at the forefront of industry developments through constant engagement with clients provides IHS a unique platform and unparalleled market and industry knowledge to be able to respond rapidly and practically to meet client needs. IHS is regularly engaged on custom consulting projects to address client-specific challenges. These projects are sometimes public and sometimes confidential, depending on the client’s request. Key features of IHS’ approach are:

- **World renowned experts.** IHS brings to its assignments a multidisciplinary team of world-class experts with hands-on experience from the industry.
- **Integrated energy focus.** IHS’ expertise spans the global energy business chain – from upstream oil and gas extraction, through midstream gas, oil refining, electric power, to energy services, technology sectors and end users.
- **Independence.** IHS has established a global reputation for objectivity and independent thought among our clients and the energy community at large, based on intellectual integrity and creative thinking.
- **Market-tested thinking and proven methodologies.** Our analyses are well grounded in current business realities through our constant dialogue with clients.
- **Proprietary models and databases.** IHS has an extensive inventory of qualitative and quantitative analytical models, tools and supporting data covering a wide range of energy-related questions.
ENERGY AND POWER

End-to-end coverage of fuel types and markets, delivering news analysis, research, technical information, forecasts and modeling solutions for the oil & gas, coal, power, nuclear, renewables and clean energy communities.

- Company, strategy & transaction valuations
- Supply & demand
- Integrated coverage of fuel
- Capital investment strategy
- Geopolitical outlooks & scenarios
- Exploration & production information
- Geological analysis software
- Infrastructure, process & power market data
- Wind, solar, biofuels market & technology
- Coal market coverage
- Regulatory policy and legal consulting

IHS Value to Individuals and Teams
More time for analysis and decision making

Without IHS

- Data Gathering, Aggregation & Transformation
- Analyze Data
- Management Response

With IHS

- Data Gathering
- Comprehensive Analysis & Strategic Insight
- Thoughtful & Informed Management Decisions

The “right decision” the first time
CAPABILITY IN RESOURCE ASSESSMENT

50 years of business acumen, analytical expertise and functional knowledge have made IHS the foremost source for critical information and insight. Our consultants apply a systematic, rigorous approach to energy resource assessment that delivers real value. Client benefits include:

• Consistent analysis that allows a direct comparison between opportunities in different basins, countries or situations
• Prioritizing an ranking of a diverse set of opportunities within an exploration portfolio
• Rapid assessment an ranking of available blocks within a license round
• Assessment of opportunities for unconventional gas production
• Cost-effective and thorough analysis that gives management confidence in conclusions reached

Our consultants combine their broad experience in evaluating plays, basins and countries on a global basis with IHS proprietary decision support tools and databases to build custom frameworks that solve client’s unique problems. Some evaluation tools and data we with global coverage include:

• Basin Data (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
• Basin Monitors (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
• Contracts Dataset (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
• Daily Alert on the Latest Worldwide E&P Activity- GEPS™ (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
• Energy Data Information Navigator – EDIN ™ Africa, CIS, Europe, Middle East, Far East, Latin America)
• Global Exploration & Production Activity - GEPS ™ (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
• International Exploration & Production Database - ADM Module Database ™ (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
• Midstream Database (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
• Site Screening Solution (Africa, Australasia, C.I.S., Middle East, Europe, Far East, Latin America)
IHS Energy Insight helps decision makers anticipate the energy future and formulate timely plans in the face of rapid change and uncertainty. Our experts are known for independence, fundamental research and original insight.

Integrated Research & Consulting
Global, Regional and Cross-Discipline

Strategy
New Ventures and Exploration
Asset Management

Country fiscal, political, regulatory, and environmental risk analysis

Company and goal valuations

Short and long-term country and regional macroeconomic analysis and forecasting

Energy supply, demand and pricing outlooks

E&P industry activity on contracts, bid rounds, farm-outs, farm-ins, services and drilling

Midstream and downstream research and analysis

Innovative online platform providing access to IHS information and insight

IHS EnerCom (Petroview)
Conferences, summits, workshops

IHS CERA (CERAWeek)
Energy analysis, markets, and technology

IHS Global Insight
Economic analysis, energy economics, forecasting

IHS PA Consulting
Economic analysis, market research, and strategy

IHS PEPS (Penton Energy Publications Service)
Energy news, reports, and analysis

IHS Market 
Research, analysis, and forecasting

IHS Energy Risk
Risk analysis and management

IHS PRCO
Market research and analysis

IHS Energy Outlook
Energy market insights

IHS Global Insight
Economic analysis, energy economics, forecasting

IHS PA Consulting
Economic analysis, market research, and strategy

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IHS Market 
Research, analysis, and forecasting

IHS Energy Risk
Risk analysis and management

IHS PRCO
Market research and analysis

IHS Energy Outlook
Energy market insights

New Ventures and Exploration

Global opportunity, economic, geological evaluation, and benchmarking

Databases, query and map oil and gas information

Integrate industry and proprietary data

Exploration and appraisal well planning

Global Window
Assessment, technical, and operating performance

EDN Desktop
Energy data analysis

Int1 Spatial Layer
Energy web services

IHS CERA
Publications, reports, and analysis

IHS PA Consulting
Economic analysis, market research, and strategy

IHS PEPS (Penton Energy Publications Service)
Energy news, reports, and analysis

IHS Market
Research, analysis, and forecasting

IHS Energy Risk
Risk analysis and management

IHS PRCO
Market research and analysis

IHS Energy Outlook
Energy market insights

Field development planning

Questor
Petabytes
SubPump

Global Field Data
Production
Reserves
Formation Tops
Well Log Data
Seismic Data
EDN Desktop
EDN
Petabytes
IHS Standards Expert
ESDU Process Engineering Solutions
ESDU SmartP屏
Construction Information Service
Regulations Management solutions

Maximise reserves recovery and optimise production

Reservoir analysis
Design, build, and maintain equipment that are efficient, safe, and compliant

Manage costs, defer, and improve investor confidence

Optimise maintenance, repair, and operating inventory

Reduce operating and capital costs

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28 August 2015
REGULATORY CONSULTING

IHS regulatory insight consulting provides insights with respect to petroleum legislation, licensing rounds, negotiations and promotion strategy in over 120 jurisdictions worldwide. Whether the issues are industrywide or client specific, our ongoing objective is to support clients in developing successful, transparent and fair licensing campaigns.

What we bring

Global Reach and Integrated Energy Focus
- Expertise across the full value chain
- Expertise across the globe
- Blend of quantitative fundamental analysis and expert judgment
- Access to proprietary IHS databases and software

Energy Policy and Regulation Expertise
- A team of legal and policy consultants that integrates research, consulting and industry expertise
- Experience in formulating energy policy & developing legislation
- Extensive legal databases covering energy legislation of over 150 countries across the globe

Licensing and Negotiation Strategy, Pre-Qualification of Bidders and Process Guidelines
- A team of strategy and policy experts specializing in assisting governments on promotion and licensing of acreage
- Proprietary databases tracking planned and ongoing licensing activity around the globe
- Proprietary global market analysis and forecasts

IHS Regulatory Insight Expertise

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VI. PROFESSIONAL BIOS

Irena Agalliu

Background

- Irena is a Managing Director in IHS Consulting Practice. She brings 16 years of contract negotiation, commercial and regulatory risk assessment, company activity analysis, bid evaluation, petroleum economics and policy and regulatory consulting experience.
- Prior to joining IHS, Irena was Legal Advisor for the National Petroleum Agency of Albania.
- Irena holds an LL.M. with distinction in Petroleum Law and Economics from Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP), University of Dundee, Scotland, and a JD from University of Houston Law Center. She is licensed to practice law in the state of Texas.
- Irena is a member of the Texas Bar Association of International Petroleum Negotiators (AIPN). She was elected to the Board of AIPN in 2008 and is serving as Vice President of External Affairs for the 2009-2011 terms.

Industry Experience

- Regulatory
- Oil & Gas
- Upstream
- Midstream

Selected Experience

- Bid Evaluation & Contract Negotiation – was involved in bid evaluation and negotiation of enhanced oil recovery licenses in Albania on behalf of the National Petroleum Agency. Was also involved as advisor to the Board of Directors of the national oil company of Albania for the negotiation of joint venture agreements for enhanced oil recovery. Developed a negotiator’s handbook for development contracts for an Asian NOC as well as a workshop on Development of Government Policy and Negotiation of Petroleum Agreements for an African nation. Recently advised the government of a Caribbean nation on bid evaluation for their offshore licensing round.
- Comparative Analysis of Fiscal Terms – has led the IHS research and consulting engagements related to comparison of fiscal terms by writing articles and presenting in industry forums on recent trends in fiscal terms, advising governments on optimization of their fiscal regime and supporting IHS CERA’s expert testimonials before legislatures or in support of international arbitration of investment disputes.
- Is currently managing a study for the US Department of the Interior comparing the US Federal oil and gas fiscal systems with other international and north jurisdictions competing for investments in upstream oil and gas sector.
- Country Entry and Company Activity – has prepared new country entry reports and company activity analysis for various national oil companies and international oil companies assessing the commercial and regulatory risks, providing competitive peer reviews and advising on investment strategies.
- Institutional Organization & Process Design – led the legal analysis and developed the regulatory process roadmaps in connection with institutional reorganization and process design for a national oil company.
Irena Agalliu (continued)

Background

- Irena is a Managing Director in IHS CERA Consulting Practice. She brings 18 years of contract negotiation, commercial and regulatory risk assessment, company activity analysis, bid evaluation, petroleum economics and policy and regulatory consulting experience.
- Prior to joining IHS, Irena was Legal Advisor for the National Petroleum Agency of Albania.
- Irena holds an LL.M with distinction in Petroleum Law and Economics from Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP), University of Dundee, Scotland, and a JD from University of Houston Law Center. She is licensed to practice law in the state of Texas.
- Irena is a member of the State Bar of Texas and Association of International Petroleum Negotiators (AIPN). She was elected to the Board of AIPN in 2008 and served as Vice President of External Affairs for the 2009-2011 terms and VP of Planning for the 2011-2012 term. She co-chairs the AIPN Oil and Gas Asset Valuation workshop.

Industry Experience

- Regulatory
- LNG
- Oil & Gas
- Climate Change
- Upstream
- Energy Policy
- Midstream

Selected Experience

- Bid Evaluation & Contract Negotiation – was involved in bid evaluation and negotiation of enhanced oil recovery licenses in Albania on behalf of the National Petroleum Agency. Was also involved as advisor to the Board of Directors of the national oil company of Albania for the negotiation of joint venture agreements for enhanced oil recovery. Developed a negotiator’s handbook for development contracts for an Asian NOC as well as a workshop on Development of Government Policy and Negotiation of Petroleum Agreements for an African nation. Recently advised the government of a Caribbean nation on bid evaluation for their offshore licensing round.
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- Country Entry and Company Activity – has prepared new country entry reports and company activity analysis for various national oil companies and international oil companies assessing the commercial and regulatory risks, providing competitive peer reviews and advising on investment strategies.
- Institutional Organization & Process Design – led the legal analysis and developed the regulatory process roadmaps in connection with institutional re-organization and process design for a national oil company.
Dan Bendig

Background

- Dan is a Director-Consulting at IHS in Houston. He brings over 28 years experience in oil and gas industry. His expertise is in international exploration from new venture to development projects. Project management experience includes multi culture virtual teams with up to 15 contributing team members. He has worked both 2-D and 3-D seismic data onshore and offshore as well as being proficient at workstation interpretations.
- Prior to joining CERA, Dan has been VP of Exploration, Chief Geophysicist and senior geophysicist. His early career was with a major oil company with assignments in London (twice), Aberdeen, Jakarta and Houston. Areas covered include the North Sea, North Africa, Indonesia, West Africa, northern South America and central USA.
- Dan holds a BS in Physics, a MA in Geology and a MSc in Stratigraphy. DPA # 5649

Industry Experience

- Exploration - Worldwide
- Development- North Sea
- Asset valuation – Worldwide
- SMT workstations
- Computer or paper interpretation
- Project Management
- Asset valuations

Selected Experience

Rank Wildcat Exploration

- Developed rank wildcat exploration along the northern margin of the Gulf of Mexico. This play is an analogue of the pre salt Brazilian oil play found along the South Atlantic margin. Lacustrine carbonates are interpreted to form during the opening of the GOM sourced by coeval organic rich carbonates. Seals are provided by the overlying Louann salt beds.

Regional Exploration

- Completed block screening study for the current Brazilian 11th round. Completed block evaluation and risking for the current Ecuadorian Suroriente round. Compared clients Africa and South American exploration performance to their set of peers highlighting the success factor that the peers were using. Project leader for a team charged with evaluating the petroleum potential of Algeria. Project involved multiple trips to data rooms in Algeria including trips to the Sahara. Later data evaluation and analysis identified the sweet spots in the eastern section of the county.

Appraisal and Development

- Led multiple teams of geologists, geophysicists and reservoir engineers assigned with moving exploration discoveries to producing fields in the North Sea. Project scope usually involved the planning and execution of 3-D seismic surveys, appraisal drilling to establish commerciality and the final drafting of a development plan.

Project Management

- Planned, budgeted and executed multi year programs involving up to 15 geotechnical staff. Annual budgets per project were is the six figure range with total operating costs exceeding $1MM. Capital costs for seismic were $2-5MM with well costs up to $25MM.
Aube Montero-Plop

Background
Aube is a Director in the IHS Energy Insight Upstream Consulting Practice based in the Dubai office. Aube specializes in both international and North American exploration and development economics topics. Aube brings 13 years of experience in the oil and gas industry. Prior to joining IHS Aube spent 5 years with Schlumberger as a Business Analyst in the UK and in the US. Aube holds a Master degree in Finance from the University Rene Descartes (Paris V). Aube also completed a certificate in Petroleum Projects Evaluation and Management at Texas A&M Harold Vance School of Engineering. Aube speaks fluent English, French and Spanish.

Industry Experience
Upstream Oil & Gas, Petroleum economics modeling, Advanced GIS analysis, Basins and Plays Statistical Analysis, Reserves and Production Analysis, Cost analysis and market forecasting, Conventional Gas in the U.S., Unconventional oil and gas plays, Petroleum Geology, Local Content

IHS Economic Software
Fiscal Modeling and fiscal software development (until 2008)
Aube participated in the development and support of ASSET™ a fiscal regime modeling software. Aube has worked with oil companies to help them design their fiscal systems in various countries. Aube taught the ASSET™ Software and Petroleum Economics courses at both beginner and advanced levels.

Selected Consulting Experience
Cost Location Factor Study: For a large IOC, managed a project building cost location factors for 13 gas monetization solutions across 35 locations in 30 countries. This major project delivered cost models, local factors but also a procurement database and a bespoke excel application enabling a systemic approach to capital cost evaluations.

Due Diligences, North American Unconventional Resources: For several clients considering acquiring assets in unconventional plays, managed and/or participating in projects estimating future production, costs, economics and above the ground risks. Also conducted research and created a method to evaluate precisely the commercial risk associated to the acreage offered in a particular deal. Plays involved were Barnett, Utica, Marcellus, Niobrara, Mississippian, Granite Wash, Tuscaloosa, Spraberry, Wolfcamp and Eagle Ford.

North America Unconventional Oil and Gas Play Ranking: Participated in 4 different large projects focusing on unconventional resources in the US. Roles varied from contributor to project manager. Leveraged IHS US database to provide and validate a detailed geological and commercial framework analysis of selected plays. Managed and delivered maps illustrating most of Unconventional North America plays activity, development type, productivity. Designed and maintained plays and operators scorecards.

International Resource Assessment (Basins and Plays): Ran and/or participated in strategic analyses for large projects focusing on resources located in Latin America, West Africa and Australia. Leveraged the IHS international databases to help rank and rate basins and plays. Led and conducted the related Yet-To-Find analyses. Led or participated to the score cards designs for the same projects.

Emerging Plays Upstream Strategic study: Latin America & Africa
Enabled clients understanding emerging plays and successful participants strategy in Africa and Latin America by conducting play level statistical analysis covering play characterization, potential and ranking and exploration trends. Also instrumental in assessing entry strategies of top operators.

Major Project Development Support: Delivered, for a government entity, a portfolio of deterministic economic models covering 32 different fiscal systems in 19 different countries. Models were developed in MS excel 2007 and allowed comparison of fiscal terms on key metrics such as NPV, IRR, Government Take, PI, economic limit and payout. Models also provided sensitivity analysis and break-even price calculations, for both conventional and unconventional hydrocarbons. Constructed and delivered a 3 days training course at the client site.
Dr. Mohammad Tavallali – Principal Reservoir Engineer, Reservoir Solutions

**Background:**
- Leads IHS’ Upstream Technical reservoir modelling and simulation group and specializes in analytical and numerical modelling of hydrocarbon recovery and reservoir characterization, particularly heavy oil reservoirs.
- Doctorate research focused on experimental and numerical modeling of thermal recovery in heavy oil reservoirs. Optimized well configuration and production profiles for Athabasca, Cold Lake and Lloydminster type heavy oil reservoirs in Alberta. Designed and fabricated a sophisticated 3-D low pressure steam assisted gravity drainage (SAGD) physical model which approximated real reservoir behaviour. Experimentally examined new development applications for SAGD well-configurations.
- Considerable experience in optimization of hydraulic fracturing for shale gas and CBM reservoirs, gas storage evaluations, wellbore modelling and flow characterization in pipes, fittings and wellhead facilities.
- Holds B.Sc. and M.Sc. degrees from Iran, and a Ph.D. in Petroleum Engineering from the University of Calgary.
- Member of Association of Professional Engineers and Geoscientists of Alberta (APEGA) and the Society of Petroleum Engineers (SPE).

**Work Experience:**
- IHS Fekete, 2011 to Present
  - Reservoir Engineer, Reservoir Solutions
- ATECH Application Technology, 2008 to 2011
  - Reservoir Engineer
- University of Calgary, 2006 to 2012
  - Ph.D. Research
- National Iranian Oil & Engineering Company (NIOEC), Tehran, Iran, 2004 - 2006
  - Process Engineer

**Selected Publications:**
Dr. Mohammad Tavallali – Principal Reservoir Engineer, Reservoir Solutions cont’d

**Selected Project Experience:**

- Reservoir/Wellbore/PVT modeling to estimate the Cumulative Volume of Released Oil from the MC252 Macondo Well in Gulf of Mexico (United States Department of Justice).
- Experimental and numerical modeling of SAGD under new well configurations for three selected reservoirs of Athabasca, Cold Lake, and Lloydminster.
- Deterministic analysis and numerical modeling of multi-fractured horizontal wells (more than 30 wells) in the Black Oil/Volatile Oil/Gas Condensate window of the Duvernay play. Studied the impact of Hydraulic Fracture Azimuth and well density on RF of the tight oil pool.
- Optimization of SAGD assessment for low viscous heavy oil of REX and GP Formations at Lloydminster area.
- Conducted reservoir simulation modeling to history match and optimize water flooding and infill drilling. Performed sensitivity studies to evaluate and select the best production scenario.
- Developed a stochastic methodology for history matching and sensitivity study of CSS project; CMG-STARS and Monte Carlo Simulation.
- Gas storage evaluation and optimization; Compositional modeling (CMG-GEM) and pseudo-miscibility option in Black-oil modeling (CMG-IMEX).

**Selected Project Experience:**

- Conducted pad analysis to explore possible reserve or frac-to-frac interference of the multi-fractured horizontal wells in Eagleford community and Bakken/Duvernay Formations.
- Conducted history match and field development plan for conventional and unconventional reservoirs; CMG-IMEX/GEM.
- Calibration and optimization of vertical and horizontal fracture extension in tight oil formations.
- Transient and Steady State multi-phase flow modeling; OLGA HD/Well Module, MAXIMUS, and F.A.S.T VirtuWell™, PIPESIM.
- Optimization of hydraulic fracturing and well density for Unconventional reservoirs; CMG: IMEX/GEM.
- Phase behavior modeling; CMG-WINPROP, PVT+, Calsep-PVTsim.
- Evaluation of hydraulic fracturing for declining CBM reservoirs; CMG-GEM, F.A.S.T CBM™.
- Conducted single well-test and interference test analysis; F.A.S.T WellTest™, PanSystem.
- Conducted analytical and numerical Rate Transient Analysis.
- Decline Analysis of oil and gas wells for future field development.
Ray Mireault – Senior Reservoir Development Specialist

Background:

• Leads multi-disciplinary technical teams responsible for integrated assessment and development of new and existing oil and gas fields. Scope of work encompasses geology, geophysics, reservoir engineering, well drilling and completions, design and construction of production facilities, economic evaluations, development planning and regulatory applications. Provides quality control and mentors technical staff and regularly called upon as an expert witness for regulatory hearings and legal actions.

• Technical expertise encompasses reservoir engineering, waterflood optimization, well performance assessment, well completions, H₂S/CO₂ disposal and sequestration, and Monte Carlo resource/reserve assessments.

• Technical advisor to IHS’ Reservoir Engineering software development team for wellbore modeling, reservoir surveillance and Monte Carlo risk assessment of exploration/development prospects.

• Member of the Association of Professional Engineers and Geoscientists of Alberta (APEGA) and the Society of Petroleum Engineers (SPE).

• Holds a B.Sc. Agricultural Engineering, University of Manitoba at Winnipeg, Manitoba.

Work Experience:

IHS Fekete, 1997 to Present

• Senior Specialist, Reservoir Development
• Manager, Production Optimization


Gulf Canada Resources Limited, 1978 to 1995

• Senior Engineer, Deep Plains Reserve Additions
• Specialist Exploitation Engineer, Western Canada
• Exploitation Engineer, Western Canada
• Reservoir Engineer, Western Canada
• Field Production Engineer, East Central Alberta
• Facility Project Engineer, Western Canada

Selected Publications:

Ray Mireault – Senior Reservoir Development Specialist cont’d.

Selected Publications Cont’d:


Selected Project Experience:

- Horizon Oil Ltd.; Production and injection well modeling for gas cycling/condensate recovery project Papua New Guinea.

- Confidential Client; Assessment of Marcellus Shale Gas Development Potential in Eastern U.S.

- Oilexco Inc.; Integrated Reservoir Simulation Studies, Drilling and Production plans for the Shelley and Brenda Oilfields, North Sea, U.K.

- REPSOL YPF; Integrated geology-reservoir field development studies for oilfields near Comodoro Rivadavia, Patagonia, Argentina.


- Enerplus Resources Fund; Slave Point Oil Development Geology/Reservoir Study, Golden Field, Alberta.

- Enerplus Resources Fund; Pouce Coupe South Boundary Lake B Pool Waterflood Optimization, Alberta.

- Enerplus Resources Fund; Progress Field Boundary Lake B&C Pools Waterflood Optimization. Alberta.

- EnCana Corp.; Maxhamish Chinkeh Formation Reservoir Study and Future Oil Development Potential.

VII. SELECTED CASE STUDIES

1. Reservoir Modeling Study of CO2 EOR Potential for an Ohio Naturally Fractured Tight Sandstone Reservoir

Situation
An operator developed a tight naturally fractured reservoir under primary production, achieving a recovery factor of 7% after 40 years of operations. IHS was asked to evaluate the viability of an immiscible CO2 EOR scheme. The client requested a detailed technical study and a sub-surface design for a CO2 pilot injection project.

What IHS did
IHS undertook an extensive static and dynamic data review including geology, past performance, fracture spacing, relative permeability, and PVT. A dynamic field model was generated and used to history match production to date. The model was then used to design the pilot project by optimizing well placement and spacing. Sensitivity studies were done to assess the impact of uncertainty in PVT and reservoir characteristics on simulation results. Fluid and reservoir characterization work necessary to reduce uncertainty and calibrate the model was recommended.

Impact
The study showed that an additional 20% of oil can be mobilized with CO2 injection, 60% of which can be captured by production wells within the pilot area. A range of production scenarios was generated taking into account uncertainty in input data. A pilot project was designed. Optimal well placement and spacing as well as optimal injection rates were specified. Recommendation were made to convert a number of producers into water injectors to create a shielding effect on the edges of the pilot area.
2. Case study: Survey of Miscible CO2 Projects in North America

**Situation**
A Japanese operator was pursuing a participation interest in an operating CO2 EOR project in North America.

**What IHS did**
IHS conducted a survey and screening of all active projects (136 in USA and 10 in Canada). Investment opportunities and barriers to investment were identified.

Typical project economics and fiscal terms were reviewed across various jurisdictions.
Recent CO2 EOR property transactions were reviewed for valuation comparison purposes.
The projects were assessed based on economic success, ease of CO2 sourcing, expected maturity and reservoir characteristics.

**Impact**
Following the initial screening, each candidate project was reviewed on an individual basis.
The projects were ranked as marginal, potential, reasonable and good candidates.
Finally, a few top picks were selected and recommended to the client.
3. Case study: CO2/H2S Injection Well Pressure Modelling

Situation
CO2 injection well operating pressures and temperatures are very different than industry experience with water injection wells or hydrocarbon gas storage wells. A methodology was required to accurately predict well and reservoir pressure behaviour through time.

What IHS did
- Identify the phase behavior of the injectate as it travels from the compressor to the wellhead and down the wellbore into the reservoir.
- Model the pressure and temperature profile through the reservoir for a given injection rate to estimate injection pressure and temperature at the bottom of the wellbore.
- Model the phase behaviour, flow patterns, friction pressure losses, temperature changes and hydrostatic head to determine the wellhead operating pressure using equation of state and finite element methods.
- Estimate operating conditions at the compressor discharge for compressor equipment design purposes.

Impact
- Several projects have demonstrated that the methodology generates reliable wellhead operating pressure estimates through time.
- Wellhead pressure is constant over a wide range of injection rates and as depleted reservoirs re-pressure, which is unlike water or hydrocarbon injection systems.
- Forecasts of lower wellhead operating pressures than would otherwise have been estimated have proven accurate and led to less installed compression with capital and operating cost savings. Installing too much compression has been a chronic issue for the industry.
- Overdesign of the compressor for too high a discharge pressure can create a catastrophic safety hazard if a backpressure control valve is used to compensate for the pressure mismatch.
4. Case Study: WAG and Gas Injection – Heavy Oil

Situation
A client was interested in investigating feasibility of various EOR process for improving the recovery of its heavy oil reservoir in Japan. Because of availability of local gas, immiscible gas injection and WAG were of special interest.

What IHS did
An EOR screening method and numerical simulation were used to estimate the impacts of WAG and gas injection. A single-well numerical model was built to estimate production under different injection scenarios. Of special interest were the unfavourable mobility ratio and how gravity forces could affect sweep efficiency.

Impact
First-pass EOR screening suggested that none of the EOR processes are suitable. However, based on the large degree of undersaturation along with the viscosity measurements suggesting significant mobility improvement associated with immiscible gas injection, a WAG-based EOR was recommended. An analogue operation was identified and used to draw learnings. Injection and production profiles for a number of cases were simulated and provided to the client for economic evaluations.
5. Case Study: Screen EOR Potential of a Heavy Oil Reservoir

**Situation**
A client with experience in cold production from the shallow Wabiskaw formation in Alberta, was interested to explore whether enhanced oil recovery (EOR) processes could be considered to improve production and expected ultimate recovery from its properties.

**What IHS Consulting did**
Addressing the client's question only required a first-pass screening-level assessment rather than an in-depth technical evaluation. IHS applied two different approaches: 1) use of EOR screening criteria, and, 2) study of analogues.

**Result**
The EOR screening criteria suggested that none of the steam-based techniques were suitable for this reservoir as a result of the combination of small pay thickness and high viscosity. Thus we determined that further study of polymer flooding and in-situ combustion was warranted. The evaluation of analogues suggested that though polymer flooding had proven successful for reservoirs with oil viscosities greater than those indicated by the screening criteria, this was not the case for viscosities as high as the property of interest. Although an in-situ combustion pilot project in a formation with similar properties was identified, there was insufficient data to permit further analysis.

Given the client's relatively low risk tolerance and the complexities of in-situ combustion, we recommended they continue with the cold production depletion strategy, at least until more data for the combustion pilot was available to further assess the viability of this method.
6. Assisted PEMEX with Regulatory and Commercial Aspects of the Energy Reform

Situation:
As Mexican Congress was moving towards approval of the sweeping energy reforms that ended the monopoly of the state oil company, the client sought IHS assistance to understand best practices related to opening up of the sector and assist them in their strategy moving forward.

What IHS Did:
IHS drew best practices from other national oil companies that had undergone reforms over the past two decades with respect to: strategic partnerships; success factors; contractual mechanisms for various types of assets; NOC autonomy; role of regulator, round zero process etc. SWOT analysis of Mexico’s upstream hydrocarbon sector and challenges associated with the reform Provided a round zero roadmap to assist the client in the process to justify retention of exploration and production acreage

Result:
IHS’s assistance enabled client to
• influence certain aspects of the energy reform,
• prepare for the round zero application process
7. Comparative assessment of the federal oil and gas fiscal systems for the US Department of the Interior

**Situation:**
The United States GAO published a report, which suggested that the US governments return on federal oil and gas leases was lower that the returns of other resource owners, calls for a reassessment of the federal oil and gas fiscal systems. Bureau of Ocean Energy Management (BOEM) and Bureau of Land Management (BLM) commissioned this IHS study to compare oil and gas fiscal systems that apply on federally owned offshore and onshore lands with oil and gas fiscal systems adopted by other countries that compete with the US in the upstream oil and gas industry.

**What IHS Did:**
This report compares the oil and gas federal fiscal systems against a selected peer group of jurisdictions that compete for investment in the upstream oil and gas industry. Developed a composite index that compares fiscal systems on government take as well as measures of profitability, revenue risk, and fiscal stability in relation to the relative prospectivity and policy objectives.

**Result:**
Informed the US Department of Interior and other branches about the competitive position of the US federal fiscal systems and ultimately influenced their policy decisions related to royalties on federal lands.