IEA's Gas & Oil Technology
Collaboration Programme

Offshore Mature Field Development

Report from the GOT CP Technology Conference in London, June 13, 2016

Executive Summary

- *Easy oil and gas is gone. Today, 16% of global oil & gas is from tail end production, growing to 25% by 2040. The average recovery is ~ 35% globally, while technology has put the North Sea in the lead at 45% or higher.*
- *Brownfield – enormous potential, not one silver bullet. Multiple technologies and techniques will need to be developed and applied in order to achieve the full value of the resources being developed in mature areas, including subsea processing, EOR/IOR, gas infrastructure.*
- *300 offshore gas wells in the Dutch sector are at risk of "watering out", techniques for de-liquefaction and water control must be applied actively.*
- *More than 50% of proven oil resources in Norwegian fields will be left behind when production ends. Improving recovery by even just a few percentage points represents enormous value. Maintaining reservoir pressure is key. The case of Ekofisk: 17 to 50% by: More wells. Flexibility. Technology implementation.*
- *The Oil and Gas Authority (OGA) under DECC has launched UK MER: A new strategy to maximize the economic recovery of offshore oil and gas in the UK through better collaboration between companies and improved cost-efficiency. Risked EOR potential in the UKCS is in the range of 0.6-1.2 Billion bbl. LoSal EOR holds promise, 4 proposals under review through ITF. Miscible gas-EOR and CO2-EOR opportunities should be linked to CCS policy. Chemical EOR would benefit from combination with LoSal.*
- *US Outer Continental Shelf (OCS): Produced to date 19 Billion bbl oil. Average recovery rate 31,6%. Focus on max recovery from existing fields & infrastructure and max recovery from large deep-water developments. Water-flooding for pressure maintenance and sweep has yielded > 45% recovery. Now reduced focus on high cost production in mature developments due to low oil price. Mad Dog II (first oil 2020) will implement 140-210k bbl/d LoSal® waterflood. Potentially 15 Billion bbl oil recovery with Next Gen CO_2-EOR technology.*
- *EOR in the Pacific Outer Continental Shelf: History, current areas of interest, projects/research, future looking, potential/opportunity for government/industry collaboration and need for public outreach/education*
- *"Reservoir Technical Limits" toolkit by BP used in >200 oil and gas fields, has added new opportunities for reserves growth in mature fields. RTL offers consistent identification and description of opportunities (what is doable), facilitates more efficient decision making, and provides advice on best areas/fields to deploy a particular technology.*
- *EOR is injection of a fluid that does more than maintain pressure. EOR processes are usually most effective if applied as soon as a field is developed. There is less risk associated with applying tertiary EOR processes in heterogeneous reservoirs than originally thought.*
- *The National IOR Centre of Norway operates on microscopic level, all the way up to field scale. The research is based on applicability, through close cooperation with industry, in a multidisciplinary team of consisting of geologists, chemists, engineers, physicists and mathematicians.*
- *Subsea wells & satellites have provided tremendous value for Statoil as an operator, also by prolonging life of ageing infrastructure. New technology for light well intervention has achieved 50-65% cost reduction. Statoil is implementing subsea compression to boost late life recovery in Gullfaks and Åsgard fields. The Subsea Factory will bring subsea recovery on par with platforms. Standardization and simplification of subsea systems (Cap-X™) enables cost efficient tie-back development.*
- *Safe Marine Transfer (SMT) has developed a qualified a game-changing (low cost) solution to inject required production chemicals at the point of consumption, eliminating important cost elements such as complex umbilicals and enabling new subsea solutions such as long-offset subsea wells and subsea low salinity water injection.*
- *EBN, the governmental look-out post for stimulating operators to take advantage of new opportunities in the Netherlands, is pushing the sector to produce max from the subsurface in a safe and responsible way. EBN states that the average recovery factor in NL ~ 80%. A 5% increase is 60 BCM. Techniques such as Radial Jet Drilling and Fracking can add 30% reserves.*
- *Efficiency and confidence in the reserve potential are critical for realization of additional reserves in the Norwegian Continental Shelf. Petoro estimates that 120 mill bbl extra oil can be gained over the next 10 years by more intense drilling and wells. New technology adds value if supported by business drive, management push and change management. The current KPI structure is less than optimal for driving innovation and optimization.*
- *ENGIE's project of a 220 kV AC power supply from the Gemini windfarm to existing/new offshore installations is an example of how Oil & Gas infrastructure can be reused by combining with offshore wind, driven by national requirements of zero emission, conversion of fuel gas to sales gas and extended tail end production. New regulations for air emissions will force offshore generators out of service!*
- *The TKI Upstream Gas program, led by TNO, is set up in response to the major challenge of maximizing recovery from depleted fields in the Dutch sector, providing a platform for joint R&D projects and JIPs with industry involvement in areas such as basin modelling/analysis, EGR potential, production optimization, P&A, produced water treatment etc.*

Key Takeaways

Solutions are needed for stranded gas. The audience expressed a sense of urgency: Utilization of fields and infrastructure is time critical. R&D, and technology demonstration and deployment must be accelerated before it is too late. Why does it take 30 years to implement new technology in our industry? There are environmental concerns to be addressed, also keeping in mind that tail end production is energy intensive. Access to data is critical! Should be shared and disseminated to industry. What should be done to maintain high technology content as the responsibility of tail end production is passed on from the large IOCs to less experienced operators with minimum tech staff? Incentives and decision making should be adapted to the new challenges. More field pilots are needed to demonstrate new solutions. Secrecy should be replaced by open collaboration.

Where Do We Go from Here?

- Piloting! Get out of the lab and into the field
- But costly, need an over-arching body.
- Risk aversion, risk sharing is key.
- Should GOT establish a Lessons Learned repository?
- Now is a good time to try a new approach
- Need a joint R&D program for the North Sea, and avoid duplication of effort
- Importance of networking – help to chase funding from various sources. GOT can be an arena

Welcome and Keynote

Prof Ann Muggeridge (Imperial College) welcomed GOT participants to the meeting and provided an overview of the mission of Imperial College and its School of Mines and polytechnic university.

Jostein Dahl Karlsen (GOT Chairman) gave an overview of the GOT role in the IEA and its collaboration stimulus objective across international boundaries. There are three broad-stream technology focus areas (Greenfield, Brownfield and Unconventional) the GOT is building upon. This program of work has evolved based upon the Rystad Energy reports which evaluated and developed a value (or benefit) for various technology gaps in the focus areas if these gaps are filled. There are four brownfield workshop sessions in the agenda, each addressing different perspectives through the workshop presentations: (1) Governments' perspective on opportunities and challenges in the North Sea and US offshore, (2) Subsurface complexity, (3) Technology to unlock resources, (4) Late life of fields.

Nils Henrik Bjurstrom (Rystad Energy) spoke about some of the work Rystad Energy has carried out for GOT and contained in two reports named "Quantifying the Value of New Technology" for Conventional and Unconventional resources, respectively. Bottom line is that easy oil and gas is gone. Today, 16% of global oil & gas is from tail end production, growing to 25% by 2040. The average recovery is ~ 35% globally, while technology has put the North Sea in the lead at 45% or higher. He presented an overview of the brownfield technologies and identified their respective value, in terms of barrels of oil equivalent produced, if matured. The technologies were segregated into 3 groups. These were: Technologies Easy to Develop; Demanding Technologies (2 x the Easy Effort); and Challenging Technologies (4 X the Easy Effort.) Specific technologies were highlighted and evaluated, including: New Low Cost Well Design; Extended Reach Drilling; Smart Completions; Seafloor Processing; Unmanned platforms & automation; Facility Integrity Management (Corrosion); EOR – IOR; Structure Integrity & Life Extension. Of these 8 technologies the following three were down-selected and identified as areas for further work and value with common or broad interest.

1. Subsea Processing
2. Small Scale Gas Transportation
3. EOR-IOR

A key finding in the study is that multiple technologies and techniques will need to be developed and applied in order to achieve the full value of the resources being developed.

Paul E. Goedemoed (NAM/Shell) presented the challenge of maximizing gas recovery in the brownfield North Sea Dutch sector where there are ~300 offshore gas wells of which ~100 are shut-in due to liquid loading. The challenge is to develop techniques to manage the inflow of water, which if not controlled kills the well. This water also deposits salt in about 20% of the wells, which then must be removed to minimize plugging of perforations. Well performance can be improved by optimizing inflow (stimulation, water shutoff, etc.) as well as outflow (reduced WHP, compression, tubing size). Several of the

water management techniques were reviewed to illustrate current brownfield technology challenges, in particular the SURPRISE well optimization software, N_2 injection and gas lift.

Session 1: Opportunities and challenges in the North Sea and Offshore USA – Government's Perspective – moderated by Torgeir Knutsen (Ministry of Petroleum and Energy, Norway)

Mariann Dalland (Norwegian Petroleum Directorate) presented IOR Experiences on the Norwegian Continental Shelf. Norway has 82 producing fields with 4 new fields added and 4 fields in the sanctioning stage. It is an active region where reservoir recovery factors are being improved. The Ekofisk chalk field has improved from an original 17% ultimate recovery to a current 50% in 340 wells. Statfjord is up from initially around 34% to 66% using hub/satellite development and gas injection. Horizontal subsea wells unlocked the otherwise stranded oil rim at the Troll Oil field. To achieve this level of improvement requires flexibility in reservoir management for future IOR-EOR Operations. In summary: (1) Understand the reservoir; (2) Have efficient well drilling; (3) Reduce the production of unwanted chemicals; (4) Collaborate across licenses regarding new IOR technologies. When asked what one improvement would benefit field development, the response was improved reservoir simulation models with high degree of confidence.

Dave Puckett (UK Oil & Gas Authority) presented the UK efforts to Maximize Economic Recovery (MER UK) of assets in the UK sector. 2015 exploration saw 60% success with >150 mmboe discovered. Production is at 1,6 mmboe/day, up by 9%. The issue is cost, a situation that requires efficiency improvements and sustainable transformation. The OGA is a new UK regulatory authority and they are developing their opportunity matrix for technologies. Some important Enhanced Oil Recovery (EOR) technologies are included in a new EOR Strategy. The 2014 Wood Report mentioned the importance of EOR to improve recovery. An SPE Paper provides an overview of EOR opportunities in the UKCS. Examples of EOR technology are:

1. Clair Ridge low salinity water injection project.
2. Miscible Gas EOR within the Magnus Field is an example of this technology.
3. Chemical EOR with the Captain Polymer EOR being a leader.
4. CO_2 EOR is a longer term opportunity. CO_2 sources for injection and sequestration have been identified but currently there are no CCS Projects are in place. There is a new Lord Oxburgh CCS Report, due in September 2016, which should provide the government's position on CCS.

Nathan Sinkula (US BSEE) addressed the past, present and future of EOR offshore USA. Currently 80% of offshore production is from deepwater. Water flooding is used extensively – 200 WI wells in OCS and 833 WI wells in GOM. The US is interested in maximizing production recovery from all existing offshore wells. Nathan reviewed the range of IOR-EOR technologies that have been used offshore US over a long time frame. The Ursula Princess (sulfate reduction) and the Mad Dog field (LoSal) developments are the active projects currently using EOR-IOR in the US.

Session 2: The Complexity of Subsurface

Moderator: Ingrid Anne Munz (Research Council of Norway)

Craig Smalley (Imperial College) presented the Reservoir Technical Limits Management System for continuous recovery improvement in mature fields. This is a strategy or process to characterize and present expectations for reservoir management. The presentation provided an overview of the process and illustrated its impact by evaluating mature fields in a consistent way. Several papers have been published to further explain this reservoir management strategy.
During Q&A Mr. Smalley stated one of the benefits of this strategy is that it helps compare and evaluate alternative reservoir management approaches.

Ann Muggeridge (Imperial College) presented the modeling of effectiveness for Tertiary EOR in Heterogeneous Reservoirs. Reservoir models were developed using a series of important parameters to predict the performance of Tertiary EOR. The parametric studies illustrate there is less risk in employing Tertiary techniques than originally thought. Consequently, the basic message is to start EOR processes earlier in the reservoir's life in order to maximize reservoir recovery.
During Q&A it was pointed out that rock wettability is also an important factor and in the reported studies an "average" wettability value was used in the model.

Kristin Flornes (National IOR Centre of Norway) discussed the joining of forces to recover more oil on the Norwegian Continental Shelf. The IOR Centre is a major research initiative funded by Operators and government with a budget last year of ~58 Million Kroner. The Centre's target vision for 2021 is Low Salinity Water Injection and Polymer Flooding. Lab testing of polymer degradation and shearing of the polymers has developed some new patented methods for minimizing such degradation. The IOR Centre has also developed a new open source IOR simulator that compliments commercial software. This software is available to the Centre's sponsors.

Session 3: Ground Breaking Technology to Unlock Resources

Moderator: Rene Peters ((TNO)

Per Gerhard Grini (Statoil) discussed Statoil's work in Subsea Recovery, Subsea Compression and the Subsea Factory. Statoil operates 535 subsea wells with 50% of total production coming from subsea facilities and expects more subsea production in the future. The focus has been to reduce operating cost and to maximize production from the subsea facilities. The efforts have focused on:

1. Light or riserless subsea well intervention. Developing these intervention tools deployed from a workboat has reduced the cost of such operations by 50 to 65% when compared to using rigs for such interventions. Further, the operation's duration has been reduced by 48%.
2. Subsea Processing started with separation (Tordis Field) and most recently has focused on subsea compression. Two compression systems have been developed and their functional specs are included in the presentation materials. One is a wet gas compressor and the other separates the hydrocarbon liquids and pumps them separately from the gas compression (Aasgard and Gullfaks Sor fields.) These are complex machines and the most extensive testing and qualification program was run with this equipment prior to its offshore installation.
3. The Subsea Factory is a generic name and currently there are 4 alternative configurations depending upon the type of reservoir for which it is to be installed – Brownfield, Subsea-to-Host, Extended Reach and Deep-water.
4. The Cap-X Project. This is a special wellhead template for use in the far Northern seas. It is operationally optimized to reduce costs by 30% compared to existing wellhead template systems.

Jim Chitwood (Safe Marine Transfer) presented SMT's game-changing technology to enable long-distance tie-backs and subsea processing. This TRL-4 technology has two aspects:

1. There is a complete design for a 3,000 bbl dual barrier chemical storage and injection system. This provides for chemical storage near the point of injection and it requires only an electrical power umbilical (with control fiber optic lines) for operation. The system stores chemicals in 3 x 1,000 bbl bladders that may be further subdivided to best meet the chemical needs of the field. This system displaces the need for a chemical or hydraulic umbilical from the host facility. It is operationally efficient to install and recover and a business is envisioned to provide this chemical injection as an OPEX service. The benefit of this storage and injection system is the enabling of long distance tie-back wells which are currently not feasible to operate through umbilicals due to their size, cost and flow restrictions.
2. The chemical storage and injection system is delivered by an SMT shuttle with a payload capacity of ~600 tons. It is installed on the seafloor with 2 x AHTS plus an ROV spread. The shuttle's installation and recovery is efficient, safe and cost effective. Technically, the shuttle's payload may be any subsea integrated and commissioned process, IOR or EOR equipment that would also benefit from the similar safe and cost efficient installation and recovery services.

During Q&A a question was raised about using the Chemical System in Arctic areas. Chemical volume for effective production between chemical refill (ice-free periods) together with the redundancy of injection equipment should provide for extended and reliable operation.

Berend Scheffers (EBN) presented EBNs mission in the Netherlands to identify opportunities for Operators. This includes both innovation and technology development. The objective is to encourage cost reduction and/or increase producible reserves. Work is required to maximize Dutch infrastructure use before it is required to be abandoned. The motto for platforms is Repurpose > Reuse > Recycle.

Roy Ruså (Petoro) reflected on New Technology in Mature Fields. Petoro represents the state's interest in all the Norwegian fields. The starting point for success is collaboration. A key message was: If you want to go fast; go alone. If you want to go far; go together.
Over 40% of a field development cost is in drilling the wells. Improvements are required but, management will have to balance both short-term and long-term implementation together with a robust Management of Change process for success. The Norwegian technology strategy forum OG 21 is both alive and active providing input, however technology deployment or innovation is not significantly recognized in the Oil and Gas Industry. The Boston Consulting Group identifying the 50 most innovative companies in the world did not include a single O&G industry representative.
During Q&A he was asked how Petoro promotes utilization of new technologies. This is accomplished by providing input to the field development teams.

Session 4: Late Life of Fields

Moderator: Morten Wiencke (GE O&G)

Rene van der Meer (Engie GDF Suez) discussed reuse of old infrastructure in the Dutch Sector by combining O&G with offshore wind activities. Both the platforms and the wind turbines are connected to a common electrical power grid. To comply with NOx emissions, platform generators will need to be electrically netted where some turbines are turned off and other turbines are operated at optimum conditions. In the event of no wind power, power will be available through the network from shore. Presentation slides and pictures illustrate this emerging cooperation.

Rene Peters (TNO Energy) presented TKI Upstream Gas, a national innovation program in NL on upstream gas that provides a platform for joint R&D programs and JIPs. The program has a funding of approx. 3M€/year until 2019 and brings together most industry/operator stakeholders and research under one umbrella with a common R&D roadmap covering basin analysis, field development and performance, drilling and completion, well and flowline performance, infrastructure, decommissioning and abandonment, and HSE.

Wrap-Up Discussion – Where Do We Go from Here?

A broad number of topics were raised by the workshop participants during this wrap-up. The concepts captured included:

- Need to understand the economics of stranded oil and gas assets.
- Is there a sense of urgency – does R&D need to be accelerated?
- Significant infrastructure is currently not economic and being abandoned and lost.
- Have not seen discussion today regarding environment issues like NOx, produced water, etc.
- There seems to be a more stringent regulatory environment due to environmental issues and concerns.
- Academics would like to promote big data sharing, especially with operators.
- Governments could collaborate on innovation issues … What is working and what does not work.
- Software Issues
- Small operators are currently handing tail-end production without significant resources or knowledge often residing in the larger operators.
- Why does it take 20 years for O&G technology uptake? Problem seems to reside with risk management or aversion. Could risk reduction processes impact this behavior?
- There is a strong need for pilots to accelerate technology into the field
- There needs to be a better method for sharing lessons learned.
- Low Oil prices opens doors for new technology introduction if it provides economic benefit.
- The value and benefits analysis needs to be prepared for new technologies (i.e. like the Rystad process) to help justify its development.
- Programs like the compression project could be accelerated if there were solid application needs providing market pull.
- There needs to be a focus on where R&D funds are effectively spent (avoid duplication)
- There needs to be a technology showcase for stakeholders to support tech development.
- There needs to be license partner alignment for mature fields. Majors and mature fields do not currently align.
- Is there a possibility to unitize mature assets and use existing infrastructure more efficiently?
- There is need for collaboration at the government level for the North Sea.

- Researchers are starting some North Sea issues collaboration effort.
- Could collaboration be encouraged with IEA funding?
- Is there a possibility for a networking alliance of researchers, etc.?
- Currently there is no good way to avoid duplication of research.

With this generous input the chairman concluded the meeting.

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