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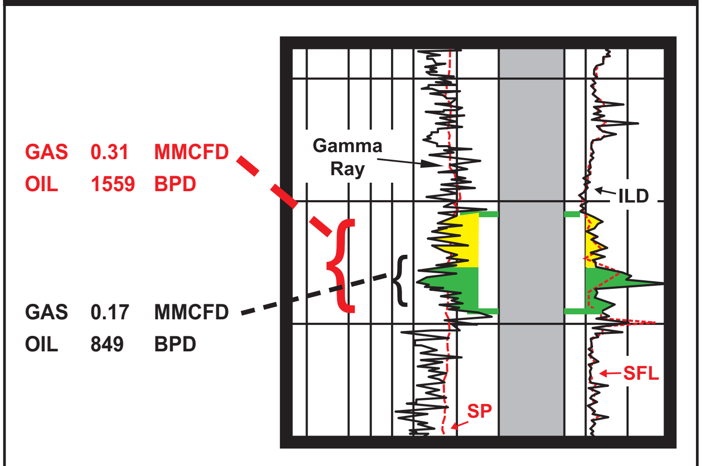
By-Passed Pay

High commodity prices are encouraging operators to search out untapped hydrocarbon volumes within mature fields. Paul Worthington looks at current trends and highlights some reported innovations.

By-passed pay relates to movable hydrocarbons that cannot be drained by any existing well and will be left behind in the subsurface if nothing is done. This definition is set in the context of conventional reservoirs. It excludes residual hydrocarbons, which are trapped in the reservoir.

Pay has usually been by-passed where the degree of reservoir complexity was not fully evident at the time of formulating a development plan. Because this explanation can be applied to virtually every reservoir, it follows that by-passed pay must exist in many fields. Moreover, its exploitation carries a lower risk and can be more cost effective than standard oilfield operations.

Fig. 1: Macuspana Basin: exploitation of by-passed hydrocarbons in a layered sand/shale sequence *(adapted from Gomez et al., 2001)*.



There are two types of by-passed pay. Type 1 is that which could be produced using an existing identified well, e.g. where a hydrocarbon-bearing interval has never been perforated. Type 2 is that which requires a side track or a new well in order to capture the reserves, e.g. unswept hydrocarbon volumes. On this basis alone, the term "by-passed pay" is inappropriate, because pay is a thickness that can only be measured at a wellbore. The phrase "by-passed hydrocarbons" would be more generally applicable.

For Type-1 situations, there are three scenarios.

A. Hydrocarbons were seen but not developed at the time of well completion, e.g. because there was no (gas) market at the time or the accumulation was too small to be economically attractive.
B. Hydrocarbons were present but not seen at the time of well completion, e.g. because of deep invasion, laminated sedimentary sequences, high capillarity, or simply because they occurred outside the pre-designated evaluation interval.
C. Unswept hydrocarbons become identifiable post-production, e.g. through premature well decline or early break-through of waterflood fronts.

Key messages for Type-1 situations include:

- monitor continuously commodity prices vis-à-vis evolving field and regional infrastructure so that workover opportunities can be generated;
- take advantage of deeper-sensing, through-casing logging technology;
- acquire sufficient data so that departures from classical reservoir character can be identified;
- be especially alert to laminated sand-shale systems, a major cause of by-passed pay;
- update concepts of reservoir connectivity during production;
- utilize realistic models for predicting well performance.

Figure 1 shows a Type-1 example from the Macuspana Basin, SE Mexico (Gomez et al., AMPG/AAPG Joint Conference, November 2001). The basin has been exploited since the early 1900s. The original interpretations of net pay are being re-visited in the light of contemporary understanding. The laminated sand/shale sequences (yellow in Fig. 1) were previously dismissed as water zones on the basis of a formation resistivity less than 2 ohm m. Yet, when perforated, they contributed to a near doubling of production from the target interval.

For Type-2 situations, there are also three scenarios.

D. Hydrocarbon occurrences were detectable seismically but not recognized, e.g. due to misinterpretation (especially in the presence of faulting) or erroneous depth conversion placing the structure too low.
E. Hydrocarbons were not indicated seismically, e.g. because of weak seismic imaging or inadequate spatial resolution.
F. Untapped hydrocarbon accumulations are indicated during development, e.g. through improved seismic data, early water production or a refined geological architecture.

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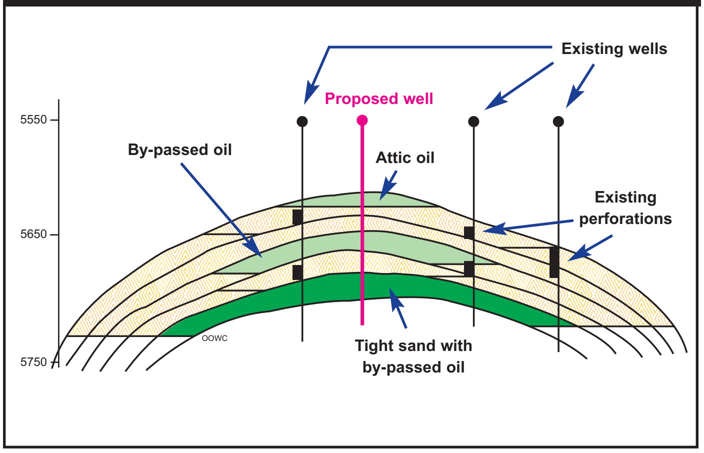
Key messages for Type-2 situations include:

- carry out a full reservoir appraisal (flanks contribute to volumes, too);
- integrate benefits from enhanced workstation technology, better seismic-to-well ties, and advancing reservoir characterization concepts;
- promote mid-life acquisition of sharper-sensing seismic data;
- consider the conjunctive use of inter-well geophysical deliverables such as seismic attributes and electromagnetic tomography, especially in complex reservoirs;
- revise geological concepts to conform with production data;
- monitor flood front(s) to ascertain their effectiveness;
- remember that reservoirs become more complex as more data are acquired.

Fig. 2: West Lutong Field: identification of by-passed hydrocarbons through the re-construction of the field-wide geological model *(adapted from Pauzi et al., 1999).*



A Type-2 example of geological re-evaluation is taken from the West Lutong Field, offshore Sarawak (Pauzi et al., SPE Paper 57266, 1999). Most of the wells are clustered around the crest. The field was in decline despite several attempted rejuvenations. The original geological model was a homogeneous tank. A revised geological model comprised shale-separated sand layers of variable reservoir quality and possibly some inter-layer connectivity. The new model revealed opportunities for accessing by-passed pay in its various forms (Fig. 2).

The recognition of Type-1 and Type-2 by-passed hydrocarbons is driven by (through-casing) well logs and (3D/4D) seismic data, respectively. The exploitation of by-passed hydrocarbons is likely to be more economic for larger fields. (Reported disappointments all relate to small accumulations.) Current trends are directed towards the re-interpretation of existing field databases, cross-hole geophysics, time-lapse seismic with permanent sensors, and unconventional reservoirs. The improvement of poorly-performing waterfloods remains a highly pertinent objective. The fruits of these ongoing efforts are evident in contemporary press releases from operators who specifically report the commercial discovery of (hitherto) by-passed hydrocarbons, with corresponding uplifts in reserves.

Paul F. Worthington is one of GCA's Principal Advisers. He also holds a visiting professorship in petroleum geoscience and engineering at Imperial College, University of London. His main interests include unitization and redetermination, reserves estimation, and reservoir characterization and management.

LNG - Smaller Projects Come on Board

The Liquefied Natural Gas (LNG) industry has seen strong growth rates over recent years with the expansion being underpinned by ever-larger train sizes. However, the industry is now seeing an increasing interest both in smaller LNG developments and in the potential to utilize Floating LNG (FLNG) facilities. Zoe Reeve takes a look at these emerging developments.

Evolution of the LNG industry has seen producers successfully exploit both technological advances and economies of scale in order to bring down unit costs. LNG train sizes have increased significantly over the life of the industry as shown in Fig. 1. Modern trains, such as those built in Qatar in recent years, have approached 8 Million Tonnes per annum (MMTe p.a.), and these will require about 10 Tcf of gas over 25 years of operation. Naturally, there are limited numbers of fields with such large gas reserves available. Moreover, such projects are multi-billion dollar developments that only a handful of oil companies and engineering, procurement and construction (EPC) firms can undertake. Some recent major LNG projects have experienced delays and/or start-up problems, while other industry players have questioned just how many major LNG projects the industry can deliver each year.

Fig. 1: Evolution of LNG Train Sizes

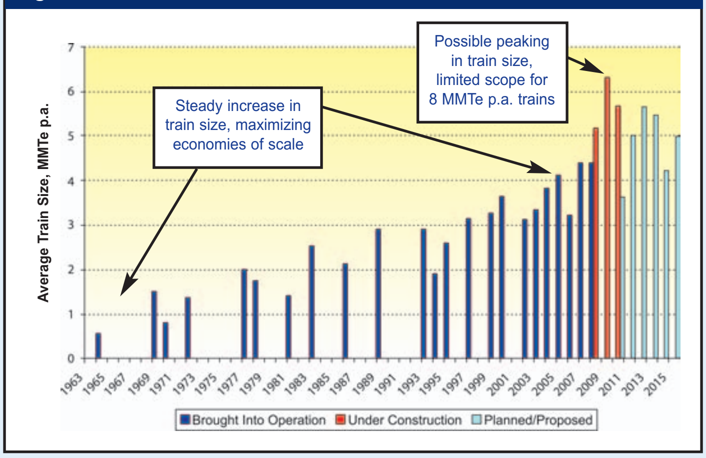
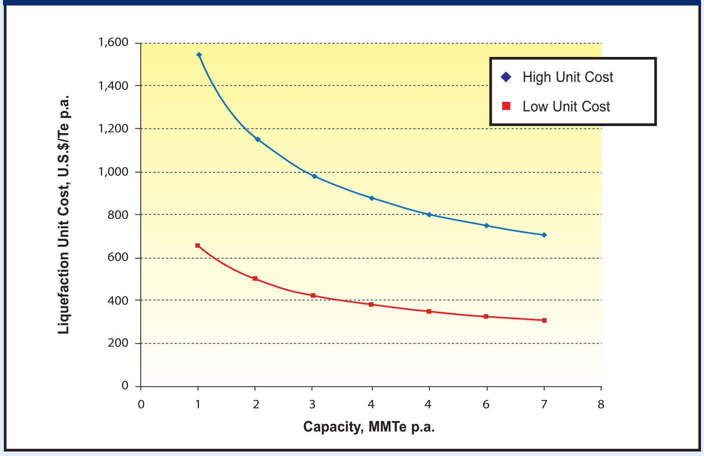


Fig. 2: LNG Plant Unit Costs



Not surprisingly perhaps, there is a growing awareness in the LNG industry that future developments should not be limited to mega-scale developments. Conventional wisdom has been that smaller scale LNG plants are generally uneconomic (although, of course, each case is unique) with some industry observers suggesting, for example, that any development less than approximately 3.5 MMTe p.a. is typically not viable. High gas prices have since improved the economics of LNG projects, so this traditional view may now be unfounded. Nevertheless, history highlights the belief that when it comes to LNG, bigger is better! The reason for this is simple – economies of scale. As illustrated in Fig. 2, as for any gas processing system, unit costs decrease as capacity increases. Tightness in the EPC arena has tended to push more recent project costs to the upper limit of the range shown.

So, if mid-scale LNG is to play a part in the future LNG industry, how will this come about? Can technological improvements and/or the advent of FLNG improve the economics of smaller scale plants that have not always been viable historically? Are liquefaction processes that have been proved to be economic in large scale trains necessarily the optimal process for smaller trains or are modified and/or alternative processes required?

In this regard, FLNG is attracting much attention. Conceptually FLNG facilities could be moved directly from one gas field, post-depletion, to another. Hence, smaller reserves are required to justify project commerciality. The facilities also reduce construction costs by eliminating land purchase and related expenses (e.g. permitting).

FLNG facilities are currently under consideration by a number of major companies, including Shell and Petronas. Shell is reportedly investigating using FLNG in the Browse Basin, and in other unspecified locations in South East Asia and West Africa, while Petronas is considering using FLNG for a deep water gas development off the State of Sabah. Another company looking to implement FLNG technology is Flex LNG, who is attempting to develop a 1.5 MMTe p.a. facility offshore Nigeria. The liquefaction process utilizes nitrogen refrigerant, thereby allowing a closer spacing of equipment and at the same time reducing equipment weight versus hydrocarbon-based refrigerant cycle. Recent orders for vessels placed by Flex LNG, combined with industry estimates of topside costs, suggest reported CAPEX of approximately U.S.$ 500 per Te p.a. When compared with the costs of traditional LNG processes for similar capacities (Fig. 2), the appeal of such technologies becomes clear. However, at present, these remain estimates, and until a project is developed and actual costs are reported, there will be a degree of uncertainty in the figures.

Other companies are staying land-based. For example, LNG Ltd is focusing on the development of 1-1.5 MMTe p.a. liquefaction trains in locations including Australia, Iran, Papau New Guinea and Indonesia. The company claims it can achieve CAPEX of just U.S.$ 350 per Te p.a., i.e. unit costs comparable to those of the larger scale plants. LNG Ltd suggests that this cost saving is due, at least in part, to utilizing ammonia as a refrigerant. This, it is claimed, combines high efficiency with a reduction in equipment needs relative to alternative LNG processes. LNG Ltd, amongst others, has also claimed that the combined use of standard equipment and modular construction does help to reduce costs although, until a plant is actually built, such figures again remain estimates.

In addition to technological developments, the LNG industry is also evolving commercially. Traditionally large plants have been developed with fixed supply contracts for almost all of their operational lives. However, more recently, some plants have sought to exploit the high-value spot market by earmarking some production for spot sales. Furthermore, there is emerging evidence that at least some financiers are warming to a higher percentage of production being uncontracted and hence available for spot sales. Such strategies may help smaller plants to increase revenue, but with a project-specific trade off between predictable long term contracts and potential higher-value spot sales. On the negative side, some financiers may be uneasy with the combination of new technologies/processes and an increased uncertainty over revenue streams.

Overall it is envisaged that large land-based LNG plants will remain the obvious and “safe” option, but a number of factors are enhancing the appeal of small/midscale LNG plants. These include:

- limited numbers of gas fields with large reserves;
- significant “stranded” gas resources;
- evolving business models that are not necessarily limited to large plants;
- emergence of new players looking at smaller scale opportunities;
- technological improvements/modifications;
- an increasing global demand for LNG that necessitates a mix of LNG plant sizes;
- emergence of floating technology.

Although the development of small/midscale land-based plants or floating plants will mark a move away from the comfort zone of many lenders/project sponsors, comprehensive due diligence coupled with appropriate risk mitigation should ensure that the step-out is one that the industry can manage successfully

Zoe Reeve is a Senior Consultant at GCA's UK office and a member of GCA's Downstream Oil, Gas and Infrastructure group. She has over 10 years experience in both refining and gas monetization processes: more recently she has been involved in a number of due diligence reviews and expert witness activities.

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GCA International Offices

Europe, Africa and the Middle East
Bentley Hall
Blacknest, Alton
Hampshire, GU34 4PU
England
Tel: + 44 1420 525366
Fax: + 44 1420 525367
email: gcauk@gaffney-cline.com


Bentley Hall, England

North America
1360 Post Oak Blvd
Suite 2500, Houston
Texas 77056 USA
Tel: + 1 713 850 9955
Fax: + 1 713 850 9966
email: gcah@gaffney-cline.com


Houston, Texas

South America
Avenida Pte. Roque Saenz
Pena-917, 2o Piso, Of. 1
C1035AAE-Capital Federal,
Buenos Aires, Argentina
Tel: + 54 11 4394 1007
Fax: + 54 11 4326 0442
email: gcaba@gaffney-cline.com

Asia Pacific
80 Anson Road, #31-01C
Fuji Xerox Towers
Singapore 079907
Tel: + 65 6225 6951
Fax: + 65 6224 0842
email: gcas@gaffney-cline.com


Singapore

Australia
Level 16, 275 Alfred Street
North Sydney, NSW 2060
Australia
Tel: + 61 2 9955 6157
Fax: + 61 2 9955 0624
email: gcasyd@gaffney-cline.com


Sydney, Australia

Russian Federation
8th Floor, Radisson SAS Slavyanskaya
Hotel & Business Centre
2 Europe Square, Moscow 121059
Russian Federation
Tel: + 7 495 941 8710
Fax: + 7 495 941 8711
email: gcarussia@gaffney-cline.com

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