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First Break Special Topic



Unconventional Resources and the Role of Technology

In keeping with the theme of the Annual Meeting this month in Vienna, we have focused not just on the exploitation of unconventional resources, but have also included some contributions which illustrate the innovative and forward thinking which distinguishes the professions serving the oil and gas industry.

Our first article, takes a clinical look at what is seen by many as an energy saviour, the development of unconventional gas resources. Based on the evidence of the US experience, Weijermars and Watson warn that the road ahead is by no means as clear as might appear with the economics of exploration and production a possible stumbling block. However the authors believe technology may well come to the rescue. Precisely what that technology might look like is covered by Jennings in a presentation of how Schlumberger has been developing its toolkit to exploit these resources.

Martin et al. provide one of the three articles showcasing some of the advanced technology now available to the E&P oil and gas industry. Their presentation covers some of the issues now being resolved in the modelling and interpretation of subsalt domains. Filippova et al. provide an admirable study of seismic inversion techniques. Finally Wild offers an excellent review of seismic anisotropy which deserves to become a reference for this significant methodology on the road to improving our understanding of the sub-surface.

Special Topics

January	<i>Data Management + Carbon Capture and Storage</i>
February	<i>Land Seismic</i>
March	<i>Modelling/Interpretation</i>
April	<i>EM/Potential Methods</i>
May	<i>Unconventional Resources and the Role of Technology</i>
June	<i>Rock Physics & Formation Evaluation</i>
July	<i>Well Technology + Passive Seismic</i>
August	<i>Near Surface Geoscience</i>
September	<i>Data Processing</i>
October	<i>Reservoir Geoscience and Engineering</i>
November	<i>Petroleum Geology and Basins</i>
December	<i>Marine Seismic</i>

More Special Topics may be added during the course of the year.

Unconventional Resources and the Role of Technology

Can technology R&D close the unconventional gas performance gap?

The performance of unconventional oil and gas companies is demonstrably uncompetitive compared to conventional oil and gas companies. Ruud Weijermars^{1*} and Steve Watson² highlight how technology deployment and rolling investment decisions are critical to improving the performance of unconventional field development projects.

Unconventional gas production is needed to improve security of gas supply, not only in North America, but also in Europe and the rest of the world. Thanks to the emergence of methods to recover shale gas, the US has averted an imminent decline of its domestically produced natural gas. Gas production companies must now demonstrate that the worldwide emerging unconventional business can exploit these future gas resources in an economic and sustainable fashion.

Leaders of unconventional gas companies have sometimes stated that the economics of shale gas could be much more attractive than for conventional gas. Such assertions often refer to the fact that initial investments until first gas production are generally lower than for conventional gas projects – but this is not a complete argument.

Negative margins for unconventional gas

In fact, unconventional gas operators have nowhere near outperformed conventional gas operators. The contrary is the case, as is clearly demonstrated in a recent study which compared the business fundamentals and financial metrics for the two peer groups (Weijermars and Watson, 2011). The two groups, each comprising five conventional and five unconventional gas operators, were benchmarked against each other using a range of five analytical tools: (1) retained earnings, (2) working capital source, (3) total shareholder return decomposition, (4) value driver inventory, and (5) margin analysis. The results of all five tests show that the peer group of unconventional gas operators steeply underperformed – even in absolute terms. Their metrics are consistently underperforming – and much lower – than for the peer group of conventional gas operators.

For example, the conventional peer group companies all have excellent margins, ranging between 33 and 52% in 2009 (Figure 1). In contrast, the margins for the representative unconventional gas operators are mostly negative.

Margins for Chesapeake, Petrohawk, and Devon ranged between –49 and –74% in 2009. EOG incurred less dramatic negative cash margins. Only XTO Energy, now unlisted due to its acquisition by Exxon as first announced in December 2009, managed to realize a positive operational profit by skilful hedging of its gas prices. The average 2009 gas sales price of 8.54 \$/Mcf realized by XTO was more than twice the average US spot market gas price for 2009, thanks to XTO's gas price hedging.

A central part of the benchmark study (Weijermars and Watson, 2011) pinpoints how the working capital cycles of conventional and unconventional companies are fundamentally different. Conventional operators have profits high enough to pay for shareholder dividends and new assets for real business growth. Unconventional operators need to continually raise new cash (equity and debt) from the market to pay for ongoing projects; generally 50% or more of the annual cash flow originates from financing operations.

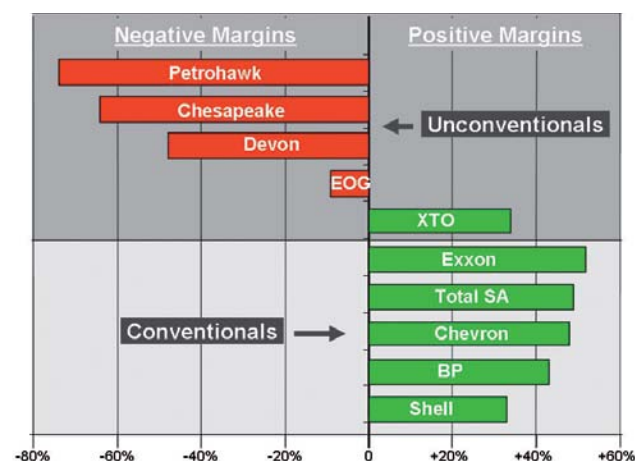


Figure 1 Pre-tax margins for conventional gas operators are all sound and positive, in spite of the historically low gas prices in 2009. In contrast, the margins of unconventional gas companies have been mostly negative, with Petrohawk and Chesapeake standing out as underperformers [Data source: based on 10-K and 20-F filings compiled by Weijermars & Watson, 2011].

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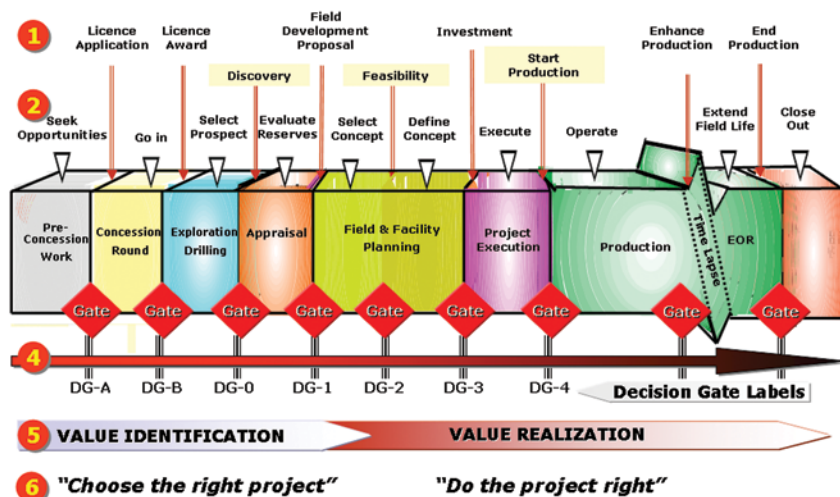


Figure 2 Traditional E&P workflow architecture for development of conventional upstream oil and gas projects. [Data source: Weijermars, 2009].

Here we further analyze the core of the problem of poor financial performance by unconventional gas companies. We highlight the role of prudent operational management with a focus on developing and deploying technology R&D to improve the margins of unconventional gas field projects.

Gas value assurance reviews

In conventional gas projects, significant upfront investments are made to tap into the whole of the interconnected gas reservoir at once, applying a tailor-made and optimized field development strategy. The present value of conventional gas fields is continually maximized by applying a rigorous value assurance review (VAR) system, using pre-determined decision gate-stages as part of the company's auditable records (Figure 2). As a result of the established VAR process, cash flows of traditional or conventional gas projects invariably perform adequately and deliver high IRRs.

In contrast, field development plans for unconventional gas operators are highly susceptible to economic pressures. The traditional VAR process does not provide a guarantee for profitable unconventional gas operations. A fundamental handicap for unconventional gas development projects is that optimized well development and maximization of net present value are marred by much higher subsurface uncertainty. There is no gas interconnectivity between wells in unconventional reservoirs and the lack of gas communication means appraisal well data give very limited information over the rest of the acreage under leasehold or licensed. High variations in reservoir quality cannot be excluded by initial appraisal wells. Sweet spots only emerge gradually and after considerable expenditure has been made while the drilling of new wells advances to cover the acreage acquired. The initial risk in new unconventional gas plays is therefore very large. Opting out also remains a hard decision throughout the field's development as that would mean deferred losses are moved closer to recognition.

Retained earnings gap

The solid performance of conventional gas operators can be juxtaposed to that of unconventional gas producers using their respective cash flow models. Concerns that the economic fundamentals of unconventional gas projects are not necessarily as good as some CEOs are touting, have recently been aired by many industry analysts. One critical business analyst characterized the modus operandi of unconventional gas companies as 'financial tinkering', another used the term 'opaque financial accounting'. Several Texan oilmen have separately expressed concern to us and one stated: 'The sooner the fools [under-performing operators] go bankrupt, the sooner the [gas] price will recover to a point that meets the needs of both smart operators and the general public.' Market leader Chesapeake (CHK) is considered to be in a 'death spiral' according to US market analyst Karl Miller. He writes this is 'due to years of creative structuring and accounting, which has put CHK in a very large financial hole'.

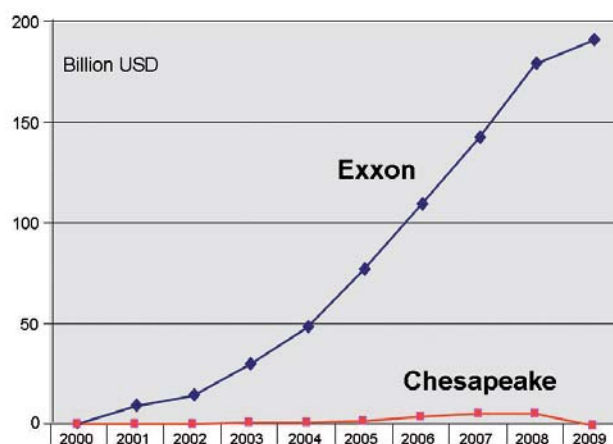


Figure 3 Retained earnings over the past decade are positive for Exxon, the world's leading conventional gas producer. Earnings retained by Chesapeake, North American leader in unconventional gas production, are clearly lagging and even turned negative in 2009 [Data source: based on 10-K filings compiled by Weijermars & Watson, 2011].

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Let us return to the financial fundamentals and examine what these say about the performance of major gas companies. Figure 3 compares the earnings retained by Exxon and Chesapeake for re-investment in the company over the past decade. Retained earnings are net profits retained by the company after payment of taxes, interest, and shareholder dividends. Exxon, the world's largest conventional gas producer, shows a handsome 190 billion USD of cumulatively retained earnings over the past decade. In contrast, Chesapeake, the leading producer of unconventional gas in the US, has no cumulative profits to show for its 2009 accumulated deficit (i.e., the negative retained earnings) amounted to \$1.3 billion.

Retained net profits are needed to acquire new assets and for investment in new and ongoing projects for generating future profits. When operational profits are absent – as illustrated in Figure 3 for Chesapeake and endemic for a substantial portion of the North American unconventional gas business – cash flow can only be maintained by asset sales and new financing. Such a business model is not sustainable and increasingly volatile if investors lose confidence in the future potential of unconventional gas operations.

Field development cash flows

The basis for earning operational profits that can be retained by the company lies in: (1) the quality of the gas reservoir in the geological subsurface, (2) the precision and cost of gas recovery technology, and (3) the prevailing gas price.

The wholesale gas price is commonly much higher in Europe than in the US (Weijermars and McCredie, 2011), which benefits unconventional gas projects emerging in Europe (Weijermars et al., 2011). Apart from gas prices, *ceteris paribus*, competition between operators is mostly determined by acreage quality and the ability to apply with precision adequate gas recovery technology while controlling cost and modelling uncertainty (Gray et al., 2007). Technology breakthrough is relied upon to bring a solution and improve the performance of unconventional natural gas companies.

Figures 4 and 5 show the annual source of retained earnings on a project basis for a conventional and unconventional gas field side by side. These graphs are illustrative only because reliable company data on a project basis are not publicly available. The conventional gas project pays back after 10 years (Figure 4), and the final NPV is in the order of \$0.5 billion when discounted at 10%.

A component of inverse modelling is included in Figure 5, using the earlier insight that unconventional gas operators struggle to generate retained earnings from their field projects. Pay-back would never occur if a common discount rate of 10% were applied, because the NPV of this synthetic project would turn negative for such a discount rate. The only way unconventional gas projects can meet CAPEX and OPEX demand is by additional cash injection from financing sources.

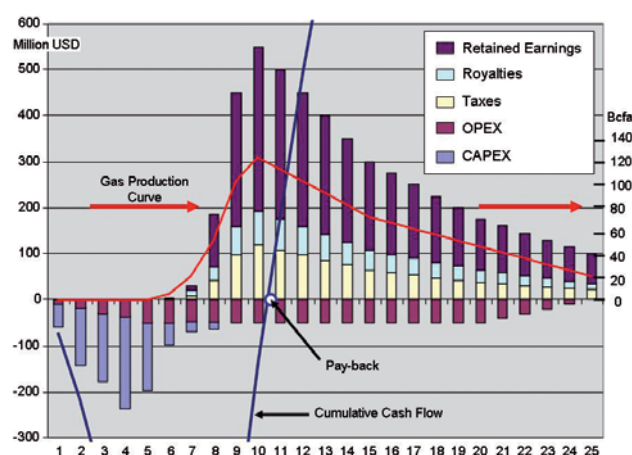


Figure 4 Conventional gas cash flow model, showing where retained earnings are generated. Production starts in year 6 of field development and EUR is 1.2 Tcf and NPV is \$2.3 billion, assuming a gas price of 5 \$/Mcf and discount rate is deliberately kept at 0%. Tax rate is 25% and royalty at 12%. Pay-back is after 10 years, but takes longer when discount rate is set (see Appendix for details)

Portfolio balancing may help to hedge against the risk of project underperformance or project failure. For each oil and gas company, a large number of projects jointly generate the total retained cash flow for the year. However, every individual gas development project still requires investment of CAPEX and OPEX before any positive net cash flow can start to contribute to the corporate retained earnings. The difference in performance between Exxon and Chesapeake is partly due to a better portfolio structure of Exxon's activities (vertically and regionally diversified). But the 90% unconventional gas production portfolio of Chesapeake mostly suffers from the marginal performance of many of its unconventional gas fields, as CAPEX and OPEX are too high and depress retained earnings. Chesapeake has chosen not to award any dividends to its shareholders over its 20 year history, but retained earnings have not yet benefited from this policy. What is needed is a step change to boost the economics of unconventional gas basins.

Can technology R&D restore cash flows?

In order to have positive netback on their invested capital, unconventional natural gas companies need to improve earnings and beat breakeven cost. Technology improvements are needed to bring down the breakeven cost of unconventional gas wells, as this breakeven cost is above prevailing wellhead prices for many unconventional gas wells, so operating efficiencies must be improved. The development and deployment of new and more efficient technologies that allow for increased recovery rates and cost reductions are essential for successful unconventional gas field development. The performance of each well in a field benefits from (Reeves et al, 2007):

- Detection of sweet spots, by being able to identify in advance where naturally fractured fairways exist

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- A better delineation of the productive pay interval in reservoir characterization
- The establishment of the threshold reservoir quality required for justifying the use of well stimulation technology and meeting corporate hurdle rates
- Enhanced production by improving recovery technology (CO₂ sequestration in CBM, nitrogen, etc.)

Well productivity is poorly constrained and history matching is not widely publicized and mostly kept proprietary. We need better models to predict production potential prior to commercial development. Play-based analysis is needed with an emphasis on detailed reservoir characterization (PTAC, 2006). This means a better understanding is needed of depositional environment, diagenetic history, drainage area size and shape, continuity of beds or layers within production zones, long-term recovery factors, recovery rates over time, natural fracture orientations, as well as of the effect of down-hole pressure and temperatures on reservoir quality.

Next to better subsurface characterization and technology improvements, above-ground issues also remain important. Geny (2010) has formulated useful suggestions that would help Europe create a successful framework for unconventional gas production:

- Increase land access and local support: involvement of operators by developing mechanisms that incentivize land-owners and integrate stakeholders in decisions impacting local socio-economic and environmental conditions.
- Improve communication on environmental impacts and address the growing public concerns arising from US operations. Environmental issues could be a killer to the nascent industry in Europe, and could be a serious brake to US shale gas operations. The US has just begun its environmental debate and this needs to be resolved for Europe to fully embrace unconventional gas.

Phase	Year	Concept/Technology	Efficiency Impact
Early Exploration	1883	Anticlinal Theory	Concept of 'Where-to-Drill'
	1900s	Rotary Drilling	Drill deeper
	1914	Seismograph	1D Subsurface imaging
	1924	Well Logging	Subsurface rock and fluid properties
	1930s	Offshore Drilling	Access to new areas and basins
	1960s	Digital Computer	2D Subsurface imaging data
	1970s	Directional Drilling	Cost efficient reservoir development & mmt.
Plateau	1980s	3D Seismic	More precise subsurface imaging
	1990s	3D Simulation	Predicting fluid movement
	1990-2000	4-D Seismic	
Shift	2000-2005	Reservoir Creation Smart Wells & Virtual Reality	Heavy Oil, Tight Gas, Shale Gas, Coalbed Methane, CO ₂ Flooding Multi-discipline collaboration, Improved time to decision, success rate, risk assessment, ROI
	2005-2020	Fracking & New Unconventional Technology	Breakthrough Technology from new R&D drive, Horizontal drilling & Multistage & Improved Unconventional Field Development Practices

Table 1 Major technology and concept innovations in oil & gas industry that lead to reserve replacement and advanced E&P efficiency; non-exhaustive selection by the authors.

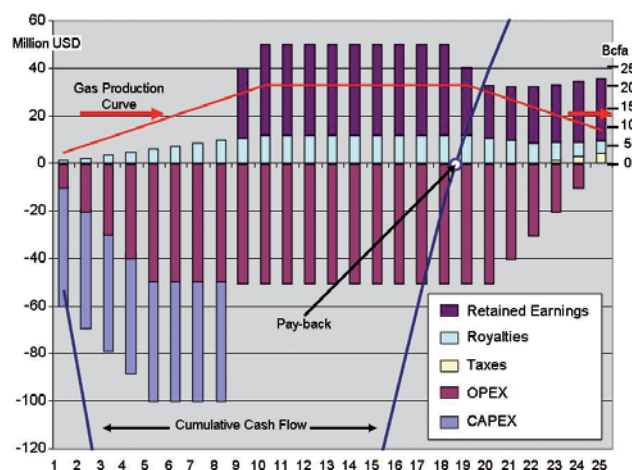


Figure 5 Unconventional cash flow model, showing annual retained earnings only kick in as soon as CAPEX is expended. Production starts in year 1 of field development, assuming wells of 0.2 bcfa at CAPEX of \$5 million each. EUR is 0.37 Tcf and NPV is \$160 million, assuming a gas price of \$5/Mcf and discount rate is deliberately kept at 0%. Tax rate is 25% and royalty at 12%. Pay-back is after 18 years, but takes longer when discount rate is set (see Appendix for details).

- Improve flexibility in E&P policies and environmental regulations, or adjust them to the specific requirements of unconventional gas exploitation, such as drilling and water permitting procedures, multi-pad application, and introducing the concept of play instead of block in the licensing process.
- Recognize that subsidies may be needed if future gas prices in Continental Europe drop below 10 \$/Mcf. Early developments might be stimulated by shallow, tight gas exploitation in Northern Europe (e.g., Germany), which could be an attractive segment from an operational and economic point of view, as the resource potential is large. Tight gas prospects can rely on other fracking fluids than water, offer similar economics as shale gas, and benefit from a favorable royalty rate such as in Germany that could be implemented in other countries. However, land footprint and spatial constraints remain important challenges.
- Develop a home-grown service segment: The development of indigenous shale gas plays in Poland and elsewhere in Europe required a local trained workforce and greater manufacturing capacity.

Finally, the profitability gap between conventional and unconventional fields remains real and large. A technology breakthrough may be needed to close the performance gap between the two reservoir classes. Table 1 shows some of the past innovation that helped the oil and gas industry forward. The call is now on another breakthrough technology to accelerate the development of new unconventional oil and gas resources. A strong candidate may be slim-hole technology, but other technology solutions may be underway. R&D in our view remains crucial to move the energy business from smart

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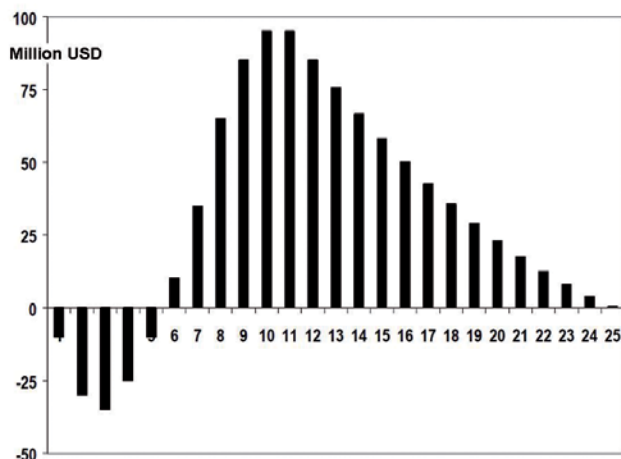


Figure A1 Annual cash flow (A in Eq. 1) over the lifecycle of a typical conventional oil and gas project.

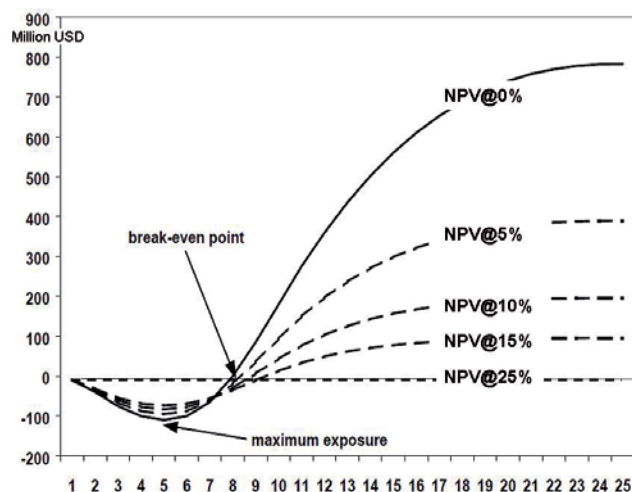


Figure A2 Net present value climbs to \$800 million if undiscounted for the time value of money (NPV@0% in Eq. 2); for a discount rate of 25% this project has NPV=0, which is the IRR for this project. [Data source: Jansen & Currie, 2009].

field operators toward unconventional gas exploitation that develops our planet's future gas resources.

Appendix: Primer in petroleum economics

1. **Cash Flow:** In any operational year the non-discounted Cash Flow (Surplus/Loss) = gross revenue-CAPEX-OPEX-royalties-tax. The annual non-discounted cash balance (A) follows from:

$$A = (P \cdot Q) - \text{CAPEX} - \text{OPEX} - (C_R \cdot P \cdot Q) - (C_T \cdot \text{Income}) \quad (1)$$

where P is wellhead gas price, Q is annual production, C_R is the royalty rate, C_T is the tax rate, and Income given by:

$$\text{Income} = (P \cdot Q) (1 - C_R) - \text{OPEX} - \text{D}(\text{CAPEX}) \quad (2)$$

with D the depreciation rate of capital investments (CAPEX).

Figure A1 plots the annual cash flow (A) for a typical conventional oil & gas project.

2. **NPV:** the total, discounted, cumulative cash flow, i.e., the cash flow aggregated over the lifecycle of the project (and should include cost of abandonment and remediation):

$$\text{NPV}_0 = \sum_{t=0}^n [A_t / (1+I)^t] \quad (3)$$

with discount factor 'I', the annual rate of discount accounting for the time value of money – commonly tied to financial market investment rates. SEC mandates a discount rate for proved reserve booking fixed at 10% ($I = 0.1$), which is also over field lifecycle t ; project time t starts at year 0 and ends at $t = n$. Risk weighed NPV is known as EMV, commonly taken for probabilities P10, P50, and P90. Figure A2 plots the NPV at various discount rates.

3. **IRR:** Internal rate of return is the average rate of return over the lifecycle of the project which is exactly that specific discount rate for which the NPV equals zero. The product of IRR and NPV can be used to rank potential investment projects. If setting a discount rate at 25% reduces the NPV to 0, then you have found the IRR; in the case of Fig. A2 the IRR=25% (and technically NPV=0).

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