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Geothermal and Hydrocarbon Exploration: the Double Play Synergy

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ABSTRACT

Various synergies are possible in hydrocarbon exploration and geothermal energy development. In the Netherlands clastic aquifers which have been explored in the past by the hydrocarbon industry are now being developed for geothermal energy, deploying direct heat for greenhouse heating. Currently, over 5 geothermal doublets have been drilled and 10s of doublet systems are planned. Geothermal doublet systems have encountered associated gas and oil, which -because of small hydrocarbon quantities- have up till now been considered a concern, rather than a benefit to a geothermal project. A key question to exploration is whether more benefit to project developers can be achieved if the business case for hydrocarbon prospects and geothermal energy is combined into a so-called double play. This paper presents a quantitative evaluation of the potential benefits of the double play concept, in which the reservoir target for hydrocarbons and geothermal energy coincides in the subsurface. In order to quantitatively identify the added value of a double play we evaluate the monetary effects of a joint business case, arguing that Abortive exploration costs can be in part of the cases avoided by reusing the well for another application. We consider therefore two scenarios: the lucky and the dry-wet scenario. In the first one, the business case has been developed from a geothermal perspective in which case accidently a hydrocarbon reservoir may be found. We assume that the Net Present Value (NPV) for the hydrocarbon reservoir would be typically higher than the geothermal NPV and hence the name lucky as oil or gas production would be strongly favoured over geothermal production once a hydrocarbon reservoir would be proved by drilling. In the dry-wet scenario, the prospect has been developed from an oil/gas perspective and reflects the added value of reusing the well for a geothermal doublet. Through a simple example we demonstrate quantitatively the benefit of the double play in monetary risk and reward of an exploration project. Furthermore, we evaluated the potential effects of synergy for a synthetic portfolio of gas prospects in the Netherlands. It is shown that the potential benefits may be considerable and can lead to approximately 7 BCM of additional gas being produced, and in the order of 10 more geothermal doublets being developed.

1. INTRODUCTION

In hydrocarbon and geothermal exploration the term play refers to a presence of a combination of subsurface characteristics, in terms of properties, structure and underlying geological evolution, which are favourable for the presence of reservoirs in the subsurface. In a double play situation, the subsurface holds potential both for hydrocarbons and geothermal, and the business case can improve through the synergy in exploration and exploitation.

In this paper, we demonstrate the double play synergy in exploration for gas exploration and direct heat geothermal energy in sedimentary basins. Geothermal heat can be produced from sedimentary aquifers when natural permeability is sufficiently high to produce hot water from wells. Aquifers are present in sedimentary basins covering large areas of the world (Fig. 1). Temperatures in aquifers increase with depth in accordance with the geothermal gradient which ranges from approximately 10 to 100°C km-1. Up to 3 km depth, clastic aquifers can be sufficiently permeable to produce hot water from a well (Fig. 1, Van Wees et al., 2012), whereas at deeper levels fractured and carbonate reservoirs can potentially produce sufficiently high flow rates (e.g Van Oversteeg et al., 2014).

Geothermal aquifers agree in many settings to potential traps for oil and gas reservoirs. In fact geothermal exploration can take significant benefit from the data and knowledge, acquired by hydrocarbon exploration activities in the past (Kramers et al., 2012; Pluymaekers et al., 2012). However, even in mature explored basins remaining subsurface uncertainty is relatively large, and expensive drilling is needed to prove and appraise the economic viability of the resource. The Probability of Success (POS) of hydrocarbon exploration and geothermal exploration are typically 20-60% and 90% respectively (Van Wees et al., 2008; EBN, 2010, Van Wees et al., 2012). The potential advantage in the double play relate to sharing costs reaching the reservoir, but more importantly to the increase in the Probability of Success (POS) as the underlying uncertainties of the double play are largely not correlated. In this paper, we focus on the benefits of the latter synergy in terms of increasing the monetary value and reducing risk of individual prospects and portfolios prospects.

We demonstrate the quantitative framework of the double play exploration concept in Section 2. Subsequently we extend the concept for a portfolio of gas prospects and demonstrate the added value for a realistic portfolio of gas prospects and geothermal prospectivity in the Netherlands. In the Netherlands, clastic aquifers which have been explored in the past by the hydrocarbon industry are now being developed for geothermal energy. Currently, over 8 geothermal doublets have been drilled and 10s of doublet systems are planned. Geothermal doublet systems have encountered associated gas and oil, which -because of small hydrocarbon quantities- have up till now been considered a concern, rather than a benefit to a geothermal project. On the other hand many small hydrocarbon prospects exist onshore which are at present sub-economic (Lutgert et al., 2005) and which are economic through synergy in exploration.

A key question to exploration is whether more benefit to project developers can be achieved if the business case for hydrocarbon prospects and geothermal energy is combined into a so-called double play. This paper presents a quantitative evaluation of the potential benefits of the double play concept, in which the reservoir target for hydrocarbons and geothermal energy coincides in the subsurface. It is shown that the potential benefits for the Netherlands are considerable and may lead to approximately 7 BCM additional gas being produced, and significant more geothermal doublets being developed.

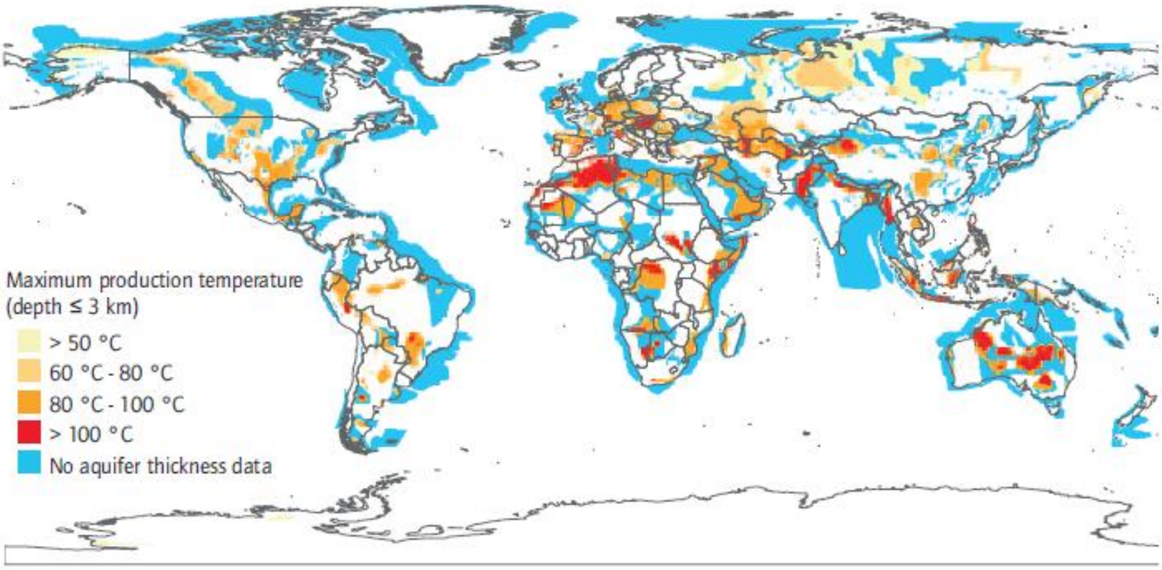


Figure 1: World map of deep aquifer systems modified from Penwell, 1984 (IEA, 2011). Overlain are expected average production temperatures for a depth corresponding to the sediment/interface; starting at excess temperatures of 40C relative to surface, and ranging to a maximum depth of 3 km. The map is based on heat flow data from Artemieva (2006) and sediment thickness information from Laske and Martens (1997). Local performance depends on natural heat flow conditions and surface temperature (source www.thermogis.nl/worldaquifer)

2. METHODOLOGY

In a portfolio of hydrocarbon or geothermal prospects an explorationist will target those prospects which are marked by a relatively high Expected Monetary Value (EMV), compared to the financial Risk:

$$\mathrm{EMV} = \mathrm{POS} * \mathrm{NPV} + (1\text{-}\mathrm{POS})*\mathrm{AE}$$

$$\mathrm{Risk} = (1\text{-}\mathrm{POS})*\mathrm{AE} \tag{1}$$

where POS is probability of succes, NPV is Net Present Value (in case of exploration succes) and AE is (abortive) exploration costs (negative). NPV can be calculated from cash flow calculations (e.g. Van Wees et al., 2012; Van Wees et al., 2008). For hydrocarbons, the NPV is closely related to the Mean Succes Volume (MSV), hydrocarbon quality and productivity of the reservoir and –in case of gas– distance to the gas infrastructure. In geothermal exploration, the temperature, drilling depth, injectivity and productivity are key. AE is largely determined by drilling costs and can be considered of the same order of magnitude for both gas and geothermal exploration. Typically the POS for hydrocarbon prospects is 18-40% (EBN, 2010), which is considerable lower than for geothermal prospects for direct heat production from aquifers, where Probability of Success is typically in excess of 70% (e.g. Van Wees et al., 2012). Conversely, the NPV is typically higher for hydrocarbons than for geothermal.

In order to quantitatively identify the added value of a double play we evaluate the monetary effects of a joint business case for exploration, arguing that abortive exploration costs can be in part of the cases be avoided by reusing the well for another application. We consider therefore two scenarios: the lucky and the dry-wet scenario. In the first one, the business case has been developed from a geothermal perspective in which case accidently a hydrocarbon reservoir may be found. We assume that the NPV for the hydrocarbon reservoir would be typically higher than the geothermal NPV and hence the name lucky as oil or gas production would be strongly favoured over geothermal production once a hydrocarbon reservoir would be proved by drilling. In the dry-wet scenario, the prospect has been developed from an oil/gas perspective and reflects the added value of reusing the well for a geothermal doublet.

So the added value for a double play consists of two different effect: The first is the *upside* of the lucky scenario allowing to achieve a higher NPV than anticipated before . The second consists of a *loss recovery,* by partially avoiding abandonment costs by oil/gas or geothermal production if the preferred options fails. Quantitatively the effects of the double play evaluates as:

$$\mathrm{EMV}_{dp} = \mathrm{POS}_{og}\,\mathrm{NPV}_{og} + (1\text{-}\mathrm{POS}_{og})\,\mathrm{POS}_{g}\,\mathrm{NPV}_{g} + \mathrm{risk}_{dp}$$

$$\mathrm{Risk}_{dp} = (1\text{-}\mathrm{POS}_{g})\,(1\text{-}\mathrm{POS}_{og})\,\mathrm{AE} \tag{2}$$

where subscript *og* denotes the oil/gas prospect and subscript *g* the geothermal prospect. Figure 3 illustrates the decision trees underpinning equations 1 and 2 for the single play and double play.

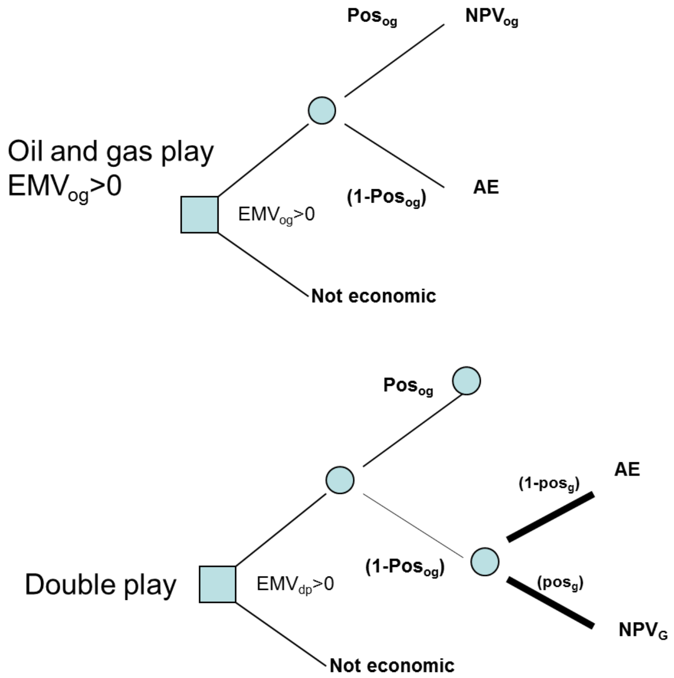
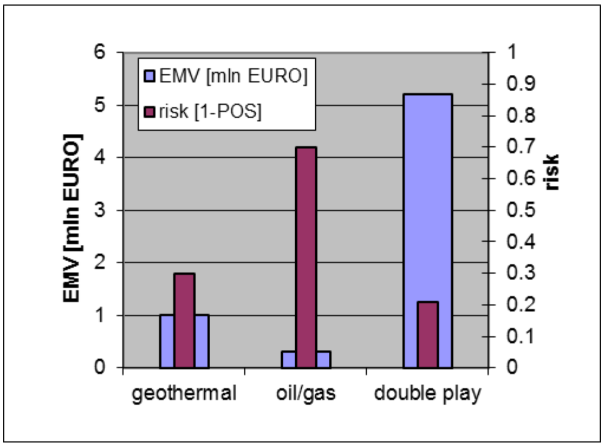


Figure 2: Decision tree (time pointing right) for the conventional single play and dry-wet scenario of the double play for the evaluation of EMV and risk (equations 1 and 2). Squares denote decisions and circles events with uncertain outcome represented by branches. Probabilities for the branches are denoted, and terms at terminating branches at the right end are corresponding to costs and revenues for that particular event. EMV is evaluated from traversing backwards to tree and summing weighted contributions of the braches (cf. Frick et al., 2010).

Figure 3 gives an example of the added value of the double play exploration concept working from the lucky or dry-wet scenario. The POS_{og} value 0.3 agrees with values for gas prospects in the Netherlands (e.g. Lutgert et al., 2005, EBN, 2010) and is a representative values for POS encountered worldwide (Van Wees et al., 2008). The POS_g value 0.7 is conservatively low. For explorative abandonment costs (AE) it is assumed for simplicity that these are equal for oil and gas and geothermal. The NPV value for oil/gas has been chosen significantly higher than geothermal.



parameter	value	
POSg	0.7	mln EURO
POSog	0.3	mln EURO
AE	-6	mln EURO
NPVg	4	mln EURO
NPVog	15	mln EURO

Figure 3: Example of EMV and Risk for a single play in geothermal and oil /gas exploration vs double play (lucky play and dry-wet scenarios), as a function of POSg, POSog, AE, NPVg, NPVog. Risk is expressed in expected loss divided over AE. Δ lucky and Δ dry-wet scenarios give the unplanned change in EMV and Risk as a consequence of the upside and loss recovery relative to the original play, geothermal and oil/gas respectively. For both double play perspectives, where unplanned upside and loss recovery are upfront included in the business case, the effect is a considerable higher EMV and lower risk.

The double play results in a significant reduction in risk and increase in EMV. The effect is relatively largest –in terms of relative increase in EMV and relative decrease of Risk- for the dry-wet scenario. It strongly suggests that a double play perspective can result in a significant change of the positioning of hydrocarbon prospects in a company's portfolio, which may result in more –

relatively small- prospects becoming financially attractive to be developed. It gives an example of the added value of the double play exploration concept working from the lucky or dry-wet scenario.

3. ADDED VALUE FOR A GAS PROSPECT PORTFOLIO

The effects of the double play concept have been evaluated for a synthetic portfolio of gas prospects which is representative for the Netherlands (status 2009). In the analysis EMVog en EMVdb have been predicted using *EXPLOSIM* (cf. Lutgert et al., 2005; Van Wees et al., 2008), which is a simulator for the exploration process.

From the year reports of NLOG (2009, Table 1) and EBN (2010) we constructed a synthetic dataset of prospects, based on reported onshore prospects (Table 1, Figure 4). Based on this information we derived 310 prospects with BCM>0.25 in line with the total number of reported prospects.

Table 1: Reported number of prospects and expected volume in different volume classes [BCM] (source NLOG, 2009). Average MSV and POSog has been derived by dividing expected volume over the number of prospects multiplied by the average volume of the class using the piecewise linear relationship relating prospect rank number to MSV (Figure 4).

Volume class	Number of prospects	Expected volume (MSV*POSog)	Average MSV	POSog
8 to 16	4	8.4	11.04	0.19
4 to 8	10	11.0	5.84	0.19
2 to 4	30	20.7	2.85	0.24
1 to 2	79	36.0	1.42	0.32
0.5-1	87	22.7	0.73	0.36
0.25-0.5	100	14.0	0.37	0.38
Totals	310	112.8		

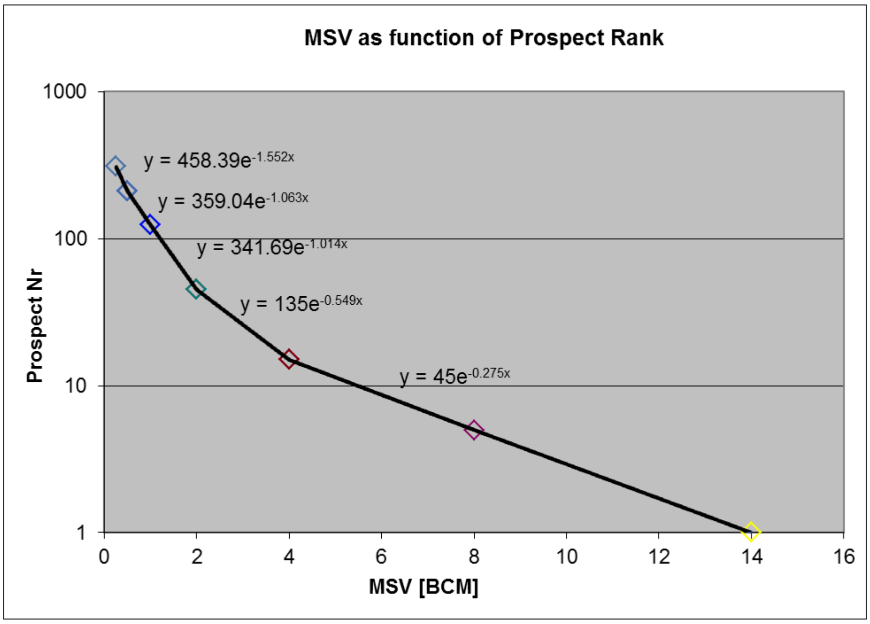


Figure 4: Piecewise linear relationship between the natural log of the prospect rank number in the portfolio and Mean Success Volume. De volume and prospect constraints (denotes by diamonds), corresponds to the class boundaries and number of prospects respectively reported in Table 1. The upper limit of MSV=14 has been chosen such that it is assumed that the linear relationship of class 4-8 BCM can be extended to higher volumes.

For the evaluation of EMV of the prospects a techno-economic models has been used for gas prospects adopting model parameters as defined by Van Wees et al. (2008), and adopting specific (uncertainty) values as listed in Table 2.

For simulation of the value of synergy it is assumed that the onshore prospects agree with locations of relatively good geothermal reservoir characteristics marked by POSg of 30% or higher. We adopt a value of 75% of the prospects to agree with potential for geothermal energy. This is based on relative percentage of overlap of existing gas fields and areas where POSg>30% (Fig. 5). Within this area approximately 1/3 is marked by POSg>70%.

Table 2: Constant prospect parameters

Parameter	Beschrijving	Waarde	Unit
Oil price	Oil price voor screening en productie	50	$/bbl
GHV	Gross heating value	37	MJ/Sm^3
CO2	CO2 gas content	3[b]	%
N2	N2 gas content	9[1]	%
POS standard deviation	Standaard deviatie in POS_{og}	0.19[2]	-
D	Distance to nearby gas hook-up point	13.5+1.2*MSV[3]	km
D standard deviation	Standard deviation in d	0.5*Dist	km

1 - Based on information of gas compositions at NLOG, 2 - Based on EBN (2010),3 - Based on existing gas infrastructure en following assumption that larger prospects can be marked by larger distances.

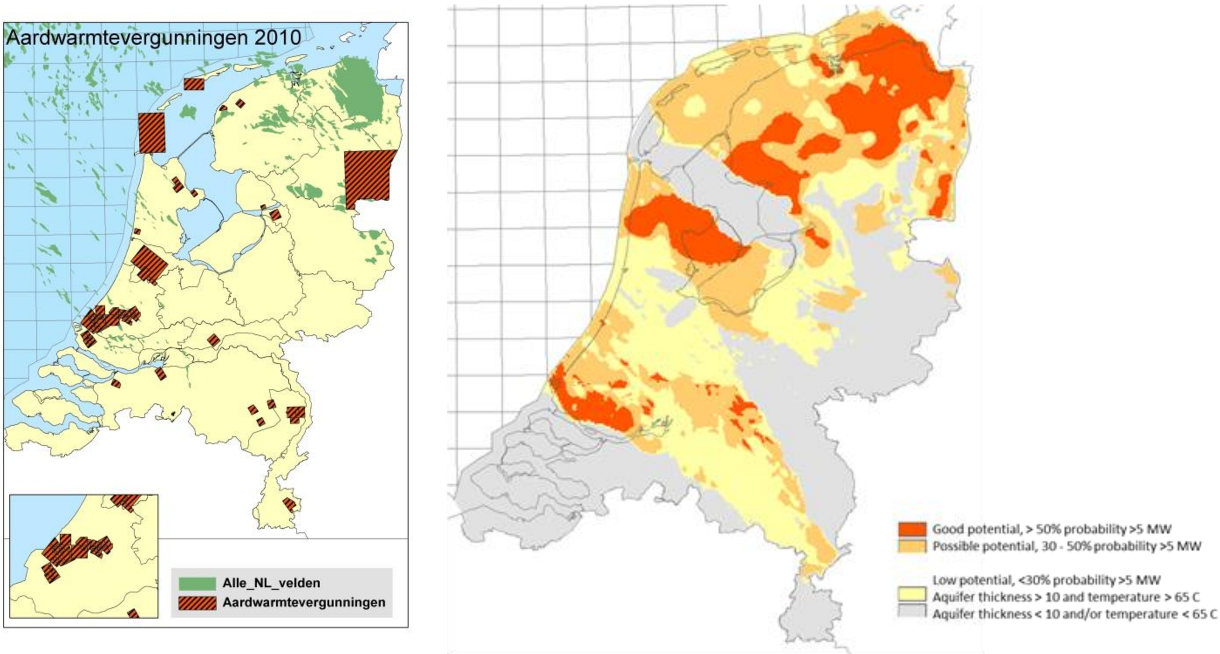


Figure 5: Correspondence of geothermal exploration licenses and existing gas fields (left) and geothermal POSg>30% (right) cf. Van Wees et al., 2012. Yellow and grey colors denote areas which are not well suited for geothermal in mapped clastic aquifers.

As the abandoned wells can be reused with POSg, we implemented the added value of the double play through a reduction in abortive exploration costs as listed in Table 3. In the simulator we have run two scenarios alternative to the default run, based on a POSg of 30% and 70% respectively. Based on information from geothermal exploration and geothermal potential (Kramers et al., 2012; Figure 5), we expect for the Netherlands that up to 50% of the gas prospects can correspond to POSg=30% and 25% to POSg=70%. This yields about 7.5 BCM extra gas to be developed, and approximately 10 successful geothermal doublets.

Table 3: Effect of different scenarios in POSg and relative share in prospect database. Extra gas as a function of double plays is estimated at 7.5 BCM.

POS_g	AE_{og}	Drillable prospects	Expected Volume [BCM]	Extra Gas [BCM]	Assumed share in prospects	Extra Gas [BCM]
0%	10 mln €	87	65	0	25%	0
30%	7 mln €	110	72	7	50%	3.5
70%	3 mln €	140	80	15	25%	4

4. CONCLUSIONS

There is a clear synergy possible in hydrocarbon and geothermal exploration if exploration wells can be used in a double play concept. In the Netherlands clastic aquifers which have been explored extensively by the hydrocarbon industry and are now targeted for geothermal energy. These qualify well for a double play. Through a simple example, we demonstrated quantitatively the benefit of the double play in monetary risk and reward of an exploration project. Furthermore, we evaluated the potential effects of synergy for a synthetic portfolio of gas prospects in the Netherlands.

It is shown that the potential benefits are considerable and may lead to approximately 7.5 BCM additional gas being produced, and in the order of an additional 10 geothermal doublets can be developed.

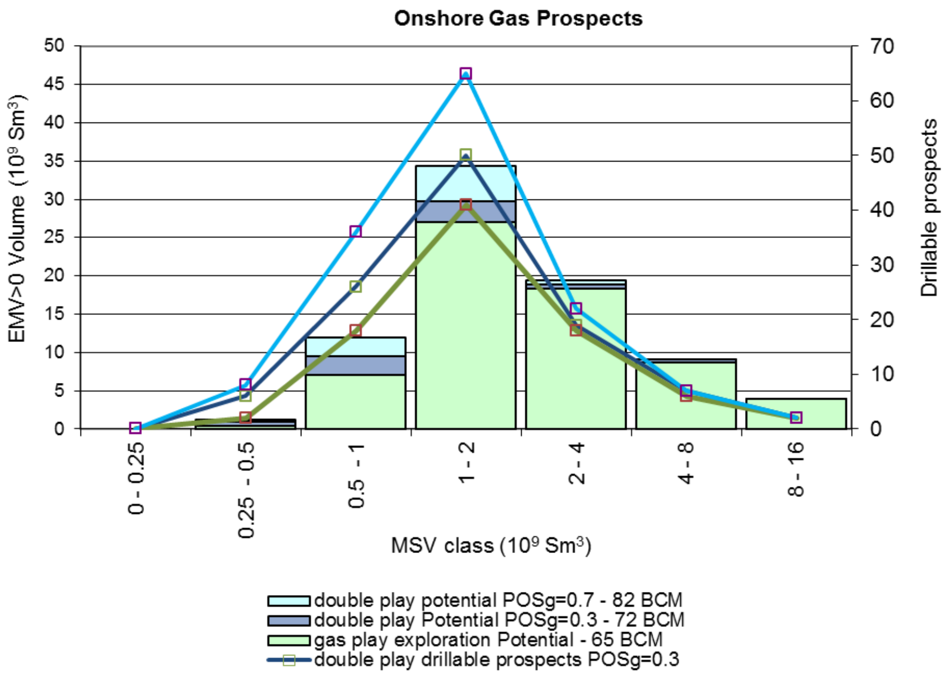


Figure 6: Increase in the expected volume of produced gas (histogram) and economically drillable prospects (curves)

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