



## Natural Gas and the Vision 2030

### Summary

- Saudi Arabia holds the world’s sixth largest proven gas reserves and was the seventh largest producer of gas in 2015. Continued investment in gas has resulted in steadily rising output over the years, with a sizable ramp up in production in the last decade.
- Despite this, gas consumption has grown as fast as production. Competing demands, primarily from two sectors, petrochemicals and electricity generation, has meant the Kingdom has consistently consumed all its gas.
- Looking ahead, the pace of growth in Saudi gas demand is not likely to ease. Total electricity consumption will be pushed up by industrial development, in line with the Vision 2030, and rising population levels. Concurrently, the petrochemical sector, identified by the Vision to help increase the Kingdom’s non-oil exports, will see further capacity expansion.
- Accordingly, we forecast that Saudi Arabia will need to grow gas output by an annual average rate of either 3.7 percent, in the base case scenario, or 6.6 percent, in the high case scenario, in the decade to 2030. We also calculate that the government could save \$71 for every barrel of crude oil substituted by a barrel of equivalent of gas in electricity generation in 2030.
- Whilst a steady supply of gas is expected to come online between now and 2020, the greater challenge in exploiting gas will occur in the decade after. Due to the complicated geology of newer gas fields, the cost of developing such resources is likely to be higher than in the past.
- Nevertheless, we see the centrality of gas in the Vision 2030, and the unsustainable and costly alternative of using crude oil in electricity generation, as ensuring development is prioritized to meet demand in 2030.

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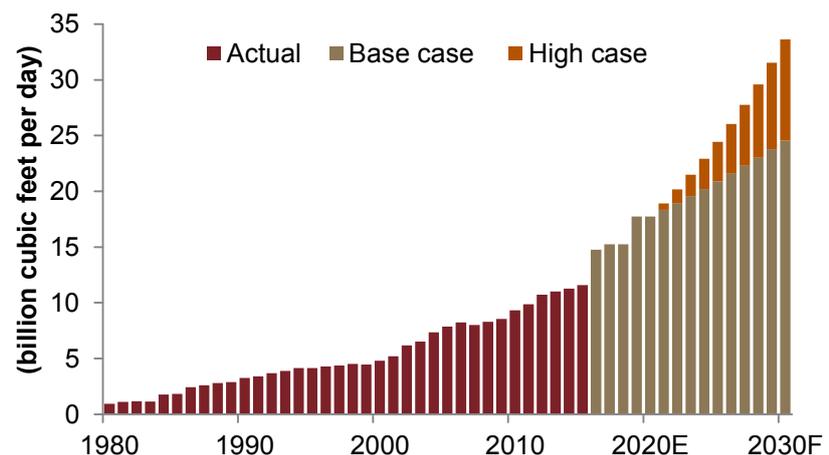
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**Figure 1: Saudi actual and forecasted raw gas production**





*There has seen a ramp up in Saudi gas production by 47 percent in the decade since 2005...*

*...but a steep rise in gas output has not been enough to satisfy domestic demand.*

*Competing demands from petrochemicals and electricity generation has meant all gas is consumed.*

*Gas development has been targeted in both the National Transformation Program (NTP) and the Saudi Vision 2030.*

*Raw gas output totaled 11.6 bcf/d in 2015, which, after processing, produced 8 bcf/d of sales gas.*

*Associated gas has, in the past, been important in developing the Saudi petrochemical sector...*

## Overview

Due to the prominent role that Saudi crude oil plays in both the domestic and global economy, the importance of the Kingdom's gas sector has perhaps been overshadowed in the past. Despite this, Saudi Arabia holds the world's sixth largest proven gas reserves and was the seventh largest producer of gas in the world in 2015. The last decade has seen sizable investment in the Saudi gas sector resulting in a 47 percent ramp up in production since 2005, reaching 11.6 billion cubic feet per day (bcf/d) in 2015.

This steep rise in gas output has not been enough to satisfy domestic demand as consumption has risen just as rapidly as production has in the last ten years (Figure 1). Competing demands, primarily from two sectors, petrochemicals and electricity generation, has meant the Kingdom has consistently consumed all its gas. The apparent shortfall of gas in Saudi Arabia is evidenced by the seasonally observed rise in direct crude burn for electricity generation during the sweltering summer months, which, on an energy equivalent basis, is much more expensive than using gas. Also, whilst petrochemical capacity has also increased rapidly in the last few years, ethane supply, the main source of current Saudi feedstock, naturally found in associated gas, has not.

The need to cater for increasing electricity (power) demand as well as rising petrochemical capacity in the years ahead means gas is likely to play a crucial role in the Saudi economy. This fact has not been lost to Saudi policy makers with gas development being targeted in both the National Transformation Program (NTP 2020) and the Saudi Vision 2030. Furthermore, in light of more recent comments from the Saudi Energy Minister, it seems that previous renewable energy targets are likely to be scaled back, which puts the emphasis on gas playing an even larger role in the Saudi economy.

## Gas in the Kingdom

### Production:

Saudi Arabia produced very little of gas prior to the 1980's. This changed dramatically once the government invested in gas infrastructure in order to utilize previously flared associated gas from crude oil production. Continued investment saw gas output steadily rising, but the decade to 2015 has witnessed a more rapid rise in production. Between 2005 and 2015, raw gas output rose by 47 percent to 11.6 bcf/d in 2015, which, after processing, produced 8 bcf/d of consumable sales gas.

More than two thirds of the Kingdom's sales gas is derived from the Ghawar field which yields both associated gas, a byproduct in the production of crude oil, and non-associated gas. Karan, Saudi Arabia's first off-shore non-associated gas field, which hit peak production in 2012, is another large contributor. Due to historically higher proportion of associated gas in Saudi production, any decision to raise or lower crude oil production, in the past, would have had an impact on gas output. This relationship has now become weaker as a result of investment in the development of non-associated gas fields, especially so in the last decade. In 2005,



*...but limited growth of associated gas recently has resulted in flatter output of petrochemical feedstock.*

*Saudi gas consumption has grown as fast as production...*

*...with the main factors for growth including: rapidly rising population, economic growth and, with it, demand for electricity.*

*The rapid rise in gas has not been enough to cover the production of rising electricity demand...*

around 42 percent of gas output in the Kingdom was associated gas. In 2015, associated gas made up a third of total sales gas output (Figure 2). The Kingdom's focus on non-associated gas was recently highlighted by two major gas field developments. The Hasbah and Arabiyah gas fields, which reached full capacity in mid-2016, have added 1.7 bcf/d of non-associated sales gas, with further non-associated fields expected to follow. Despite this, associated gas in the Kingdom has been an important asset for the development of the native Saudi petrochemical sector, since it is extracted alongside crude oil, at a very low cost, and yields ethane, which is a key feedstock used in the industry. In 2015, Saudi Arabia produced 0.8 bcf/d of ethane gas but limited growth of associated gas in the recent past has resulted in flatter output of the feedstock. Ethane is one of a number of natural gas liquids (NGLs) produced in Saudi Arabia. Other more prominent NGLs include propane and butane, both of which are referred to as liquid petroleum gas' (LPGs) and can also be used as feedstock for petrochemicals (Figure 3).

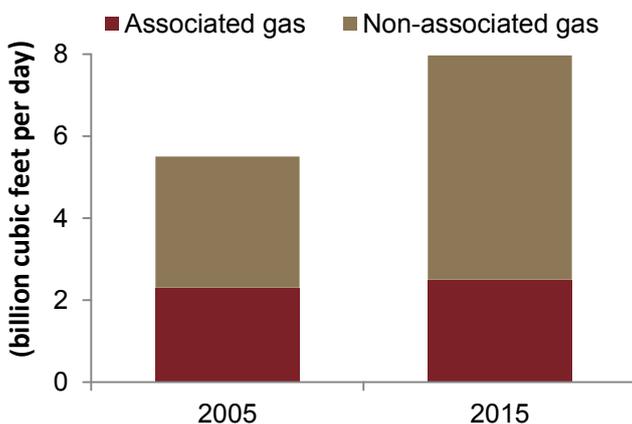
Consumption:

Saudi gas consumption has grown as fast as production, with all gas produced in the Kingdom being consumed. The main factors for growth in consumption include: a rapidly rising population, economic (and industrial) growth and, with it, demand for electricity. The pricing of gas below international levels has also been a contributor to the rapid rise in consumption.

Saudi Arabia's petrochemical sector has grown in tandem with the development of gas infrastructure. The Master Gas System, which developed gas gathering facilities and pipelines during the course of the 1980's, fed into the industrial cities of Yanbu and Jubail, laying the foundations for the petrochemical sector that Saudi Arabia now has. The main source of current Saudi petrochemical feedstock is ethane (Figure 4) which is found in associated gas, so the industry's growth has shadowed that of gas development. As such, in the decade to 2015, the petrochemical sector witnessed remarkable lift-off as evidenced by chemical capacity rising by 116 percent between 2005 and 2015 (Figure 5).

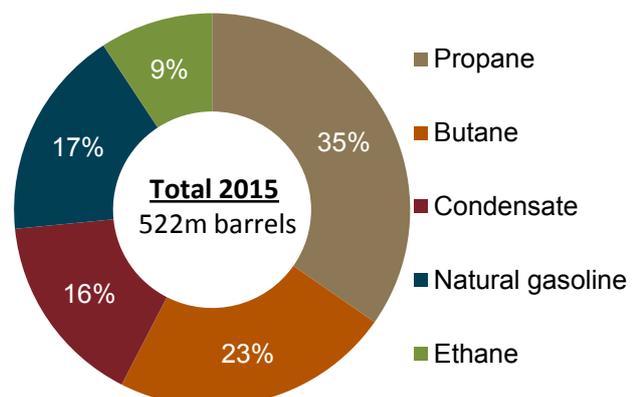
Rising population levels and industrial growth have also put pressure on electricity demand in the Kingdom. Energy sales of electricity have increased by 85 percent in the last decade and even with a

**Figure 2: Majority of Saudi gas is non-associated\***



\*Note: Sales gas

**Figure 3: Annual Saudi NGL production in 2015 (522 million barrels)**





*...with the shortfall of gas resulting in a rise in crude burn for electricity generation during summer.*

*The use of crude oil is an opportunity cost since it is more expensive than gas on an equivalent basis.*

*The government is looking at ways to make electricity consumption more efficient, including:*

*...raising electricity tariff for non-residential customers...*

*...using energy-efficient technologies' to increase overall national energy efficiency levels...*

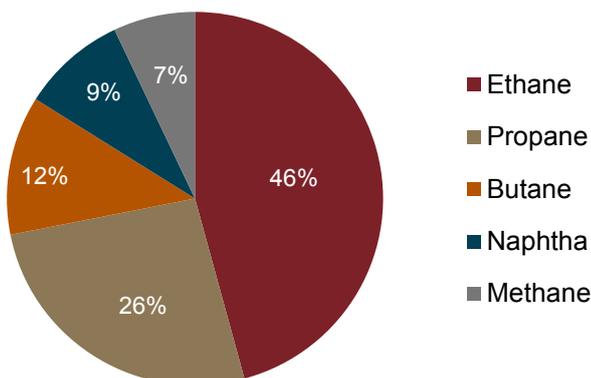
rapid rise in gas output it has not been enough to cover the production of rising electricity demand. The apparent shortfall of gas in Saudi Arabia is evidenced by the seasonally observed rise in direct crude burn for electricity generation during the summer months. In the last decade, direct crude burn during the summer has, on average, increased by 50 percent when compared to the rest of the year (Figure 6, Box 1). The burning of crude oil presents an obvious opportunity cost when considering the revenue lost from consuming a barrel of oil which would otherwise have been exported. Jadwa Investment calculates that the Saudi crude export price averaged \$36 per barrel (pb) in H1 2016, whilst the cost of selling crude oil domestically is around \$5 pb. Therefore, each barrel of oil consumed and not exported results in \$31 pb loss in export revenue.

### Box 1: Efficiency in electricity consumption

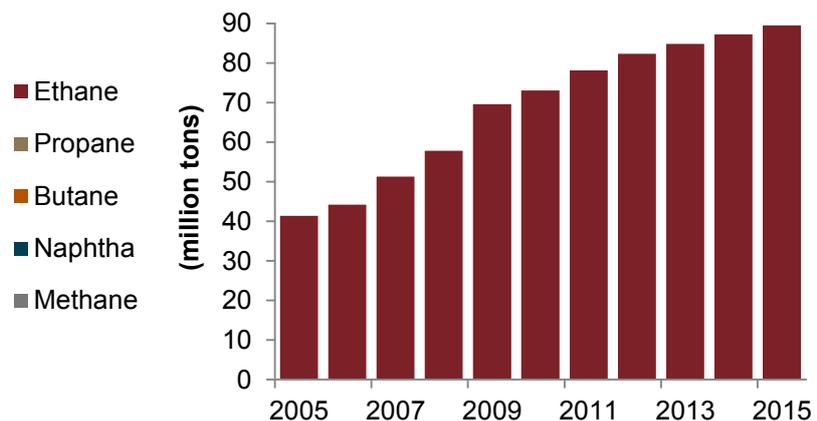
The unsustainable use of oil in electricity generation has prompted the authorities into looking at ways to make electricity consumption more efficient. In June 2010, Saudi Electricity Company (SEC) announced tariff rises for the government, commercial and industrial sectors. More recently, at the start of 2016, there was another round of electricity tariff rises, this time including higher consuming residential users. These recent rises pushed up the average per kilowatt hour (kWh) prices by 20 percent, from 13 halalas per kWh to 16 halalas per kWh currently. So far, there has been no reform of tariff prices for low consuming residential customers and we see no changes for such customers in the short-to-medium term.

A National Energy Efficiency Programme (NEEP) was also launched in Saudi Arabia in 2002 to facilitate the use of energy-efficient technologies' and to increase overall national energy efficiency levels. To that effect, the NEEP was involved in conducting energy audits on buildings, offering energy efficiency training, issuing energy efficiency standards and rolling out a labelling program for household appliances. The NEEP has now become the Saudi Energy Efficiency Center (SEEC) and is working on a coordinated energy efficiency policy, such as nationwide energy intensity targets, as part of the King Abdulaziz City of Science and Technology (KACST) organization.

**Figure 4: Saudi petrochemical sector feedstock usage**



**Figure 5: Saudi petrochemical capacity (2005-2015)**





*...and introducing renewables into the (electricity) generation mix.*

*For Saudi Arabia, exporting gas is not a viable option...*

*...it is more attractive as a substitute for higher internationally priced oil in domestic consumption.*

*The price at which gas is sold domestically in Saudi Arabia is one of the lowest in the world.*

*The NTP specifically refers to raw gas expansion...*

*...whilst the Vision 2030 sees gas as helping diversify the economy through industrial development.*

Also, through the King Abdullah City for Atomic and Renewable Energy (KA-CARE), Saudi Arabia is planning to introduce renewables into the (electricity) generation mix. In the recently published NTP, KA-CARE was set a target of pushing renewable energy to 4 percent of total energy used in the Kingdom by 2020.

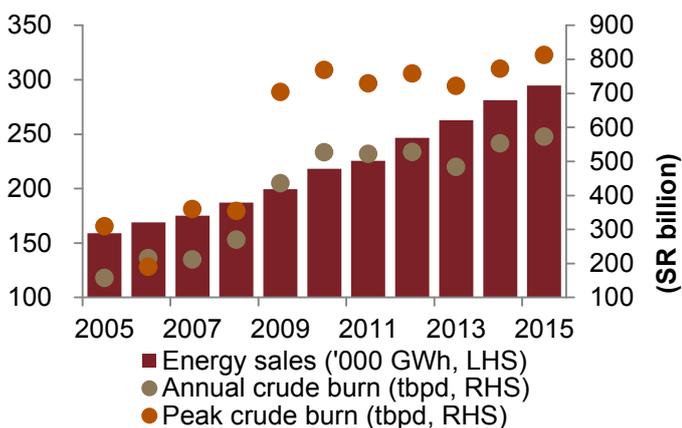
For Saudi Arabia, exporting gas is not a viable option. Firstly, building liquefied natural gas (LNG) terminals, in order to convert natural gas to liquid for exporting via ships, requires a huge amount of capital expenditure. Secondly, due to the fragmented nature of gas markets and the way gas contracts are formulated, the price of gas, on an equivalent basis, is always lower than the price of oil. For example, gas prices averaged \$12 barrel of oil equivalent (boe) in the US and \$29 boe in Asia versus the Saudi crude export price of \$36 pb in H1 2016. Both these factors therefore make gas more attractive as a substitute for higher internationally priced crude oil in domestic Saudi consumption.

The price at which gas is sold domestically in Saudi Arabia is one of the lowest in the world. Natural gas is priced at \$1.25 per million British thermal units (mmBtu), whilst ethane is fixed slightly higher, at \$1.75 mmBtu. The price of both fuels was increased at the start of 2016 from \$0.75 mmBtu previously. Even at these higher prices, Saudi gas is still approximately 50 percent cheaper than current US spot market prices and a significant 400 percent below spot prices in Asia. Considering gas consumption makes up around 38 percent of total domestic energy consumption in Saudi Arabia, the current pricing set-up represents a sizable discount.

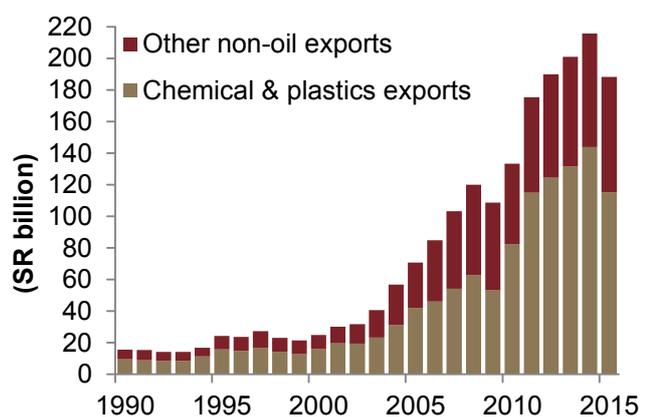
### Vision 2030 and natural gas

The need to cater for increasing power demand as well as rising petrochemical capacity in the years ahead means gas is likely to play a crucial role in the Saudi economy. This fact has not been lost to Saudi policy makers with gas development being targeted in both the NTP and Saudi Vision 2030. The NTP specifically refers to raw gas expansion, with production capacity targeted to rise from 12 bcf/d currently to 17.8 bcf/d by 2020. The NTP goes on to state that this will be done through increasing 'the volume of gas supplies through the development of exploration and reserves activities'. Whilst gas is not explicitly mentioned in the Vision 2030, it is nevertheless relevant to the other targets stated within it. Aside from fulfilling the Vision's

**Figure 6: Saudi electricity sales and annual vs. peak direct crude burn**



**Figure 7: Chemicals and plastics make up a large portion of Saudi non-oil exports**





*As renewable energy targets are scaled back, gas is likely to play an even larger role in Saudi economy.*

*Petrochemicals have been identified in both the NTP and Vision 2030 as a key sector to lead diversification...*

*...with the RCJY set some major targets for 2020.*

*Due to flatter oil production and associated gas supply, ethane rises will be more difficult to achieve...*

*...but the pressure for gas to facilitate the growth of the sector to 2030 will still remain.*

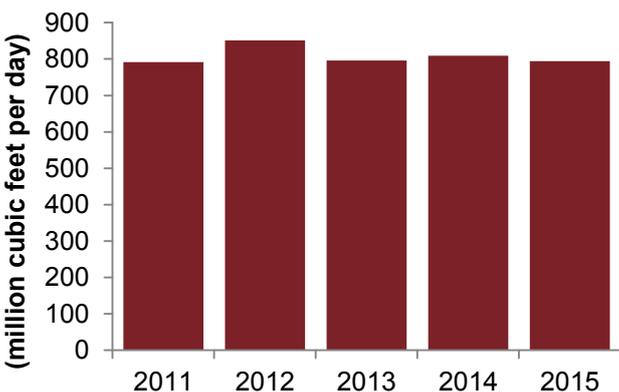
objective of ‘enhancing the competitiveness of the energy sector’, gas will also be a vital ingredient in helping diversify the economy through the development of industrial sectors, specifically mining and petrochemicals. Furthermore, in light of more recent comments from the Saudi Energy Minister, it seems that previous renewable energy targets are likely to be scaled back, which puts the emphasis on gas having an even larger role in the Saudi economy.

Petrochemicals:

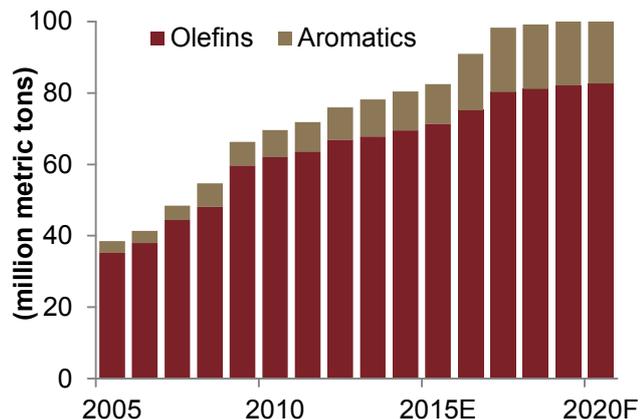
The petrochemical industry is a key pillar of the Saudi economy, which is evident through its contribution to Saudi non-oil exports. In value terms, chemical and plastic (petrochemical) exports from Saudi Arabia amounted to \$30 billion (SR115 billion) in 2015, comprising a substantial 60 percent share of total non-oil exports, similar to levels over the last 25 years (Figure 7). The prominent role of petrochemicals in the non-oil economy means it has been identified in both the NTP and Vision 2030 as one of the sectors to lead the continued push for diversification away from fossil fuel reliance. It is for exactly this reason that the Royal Commission for Jubail and Yanbu (RCJY), (set up in 1975 to ‘plan, promote, develop and manage petrochemicals and energy intensive industrial cities’) has the second highest cost borne by government for implemented initiatives under the NTP (SR41.6 billion). Accordingly, the RCJY has been set some major targets for 2020, which includes reaching an overall growth in revenue of 93 percent come 2020. In addition, petrochemicals is also one of the sectors identified by the Vision to help push the Kingdom’s non-oil export target up from 16 percent of GDP, currently, to 50 percent of GDP by 2030.

Whilst petrochemical capacity will increase in the years ahead, ethane supply rises, on the other hand, will be more difficult to achieve, at least until 2020. Flatter crude oil production, at around 10 million barrels per day (mbpd) and maturing oilfields have limited the growth of associated gas and, therefore, ethane. No new major crude capacity expansion has been planned by Saudi Aramco which means there is little prospect of higher ethane feedstock being made available in the near term (Figure 8). Although other feedstock is increasingly being brought into the mix, the most prominent being crude oil derived-naphtha (Box 2), the pressure for gas to facilitate the growth of the sector to 2030 will still remain, even as it faces up to an ethane supply decline in the next few years.

**Figure 8: Flatter Saudi ethane supply...**



**Figure 9: ...resulting in slower olefins capacity growth**





*The higher cost of cracking naphtha vis-à-vis ethane had discouraged its use in petrochemicals...*

*...but with ethane shortage looming, naphtha's use has become viable.*

*Continued population growth and industrial development, in line with the Vision, adds to rising electricity demand...*

*...peak electricity demand is forecast to rise by 20 percent, to 75 GW in 2020...*

*...and total 120 GW by 2030.*

*Therefore, if gas is to play a larger role in the generation mix...*

### Box 2: Naphtha as petrochemical feedstock

The petrochemical feedstock naphtha is a product of crude oil refining and hence its supply is relatively abundant in Saudi Arabia. In 2015, Saudi Aramco produced around 124 thousand barrels per day (tbpd) of naphtha, but only a small amount of this was used domestically. Although costlier than ethane feedstock, when naphtha is processed (cracked) it yields both olefins and aromatics (both are basic chemicals which are used to produce other more refined chemical products), whereas ethane yields mainly the former. The higher cost of cracking naphtha vis-à-vis ethane had discouraged its use in the Kingdom, but with an ethane shortage looming, naphtha's use has become viable. Projects such as Sadara Chemical Complex and Petro Rabigh II, which will become operational from 2016 onwards, will use naphtha, which, in turn, will result in aromatics output rising at the expense of olefins by 2020 (Figure 9).

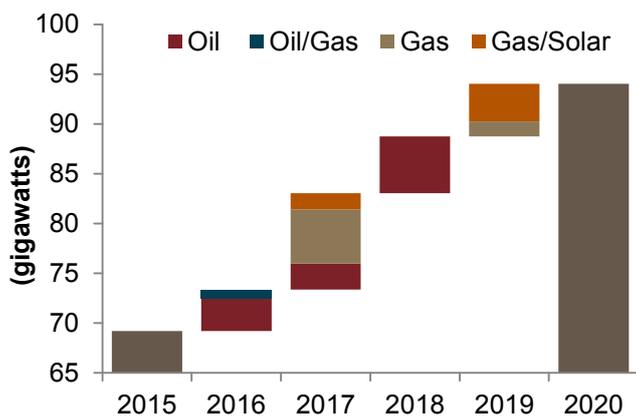
#### Electricity demand:

Saudi Arabia's total energy consumption is expected to continue rising as population growth remains strong and planned industrial development, in line with the Vision 2030, adds to rising electricity demand. Furthermore, with previous renewable energy targets likely being scaled back, the emphasis will be on gas to play an even larger role in the electricity generation mix, from around 50 percent currently, to potentially 70 percent in the medium-to-long-term.

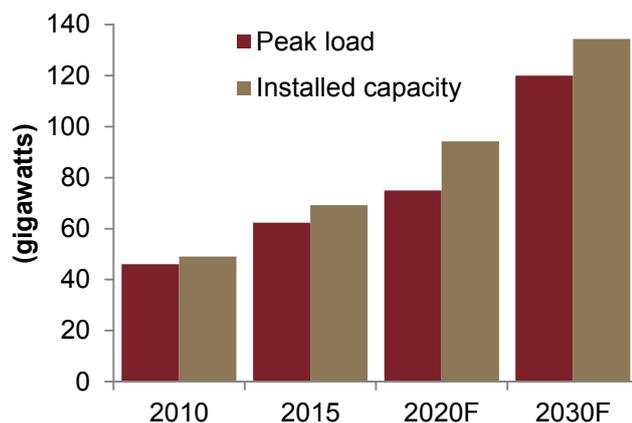
According to the Electricity and Cogeneration Regulatory Authority (ECRA), Saudi Arabia's installed electricity generating capacity amounted to 69 gigawatts (GW) at the end of 2015, which was around 7 GW more than the peak load requirement. Saudi Arabia is expected to add another 25 GW of generation capacity through 13 different projects by 2020, bringing total installed capacity to 94 GW. The NTP specifically states that reserve electricity generation capacity should equal 12 percent by 2020. Under current ECRA forecasts, peak electricity demand is forecast to rise by 20 percent, to 75 GW in 2020, meaning that reserve electricity generation capacity would stand at 24 percent (installed capacity of 94GW versus peak demand of 75GW), greatly exceeding the NTP target.

Although the Saudi government is actively aiming to reduce oil burning in electricity generation, only four of the 13 projects currently

**Figure 10: Saudi installed capacity rising to 94GW by 2020**



**Figure 11: Saudi electricity demand: peak load vs. installed capacity**





*...significant investment will have to be made to raise gas production levels in the next decade and a half.*

*Increasing the use of gas can also help achieve the Kingdom's carbon dioxide (CO<sub>2</sub>) emissions.*

*The assumptions behind how much gas will be needed by Saudi Arabia in 2030 include:*

*...total population reaching 37 million...*

*...electricity tariffs and gas prices held constant between now and 2030...*

planned to come online between now and 2020 are fully gas fuelled power plants. Three additional plants will have a mix of gas and solar power, whilst one plant will be fuelled by both oil and gas. In theory, this means the current power project pipeline capacity is dominated by oil-fired plants (Figure 10), but if fuel flexibility is stipulated in these plants, with the possibility of switching from oil to gas, this could see higher gas usage. Looking beyond 2020, according to KACARE, Saudi peak electricity demand is expected to total 120 GW by 2030. If we apply the NTP's reserve generation capacity target of 12 percent, this means that Saudi Arabia will have to have at least 135 GW of installed capacity come 2030, nearly double the 2015 capacity (Figure 11). In this context, if gas is to play a larger role in the generation mix, a significant level of investment and mobilization of resources need to be made in order to raise gas production levels in the next decade and a half.

#### Reducing CO<sub>2</sub> emissions:

Increasing the use of gas can also help achieve another target specified in the NTP and Vision 2030 relating to carbon dioxide (CO<sub>2</sub>) emissions. As a signatory of the Kyoto Protocol, developed by the UN's Framework Convention on Climate Change, Saudi Arabia is committed to combatting global warming. The inclusion of emission reduction targets in NTP underlines how seriously the Kingdom is taking its role in combatting pollution, with a two percentage point reduction in CO<sub>2</sub> emissions (per bcf/d) being targeted by 2020. Whilst an increase in renewable energy, to 4 percent of total energy used in the Kingdom, will help achieve these targets, so too will gas. Although the burning of gas in natural power plants produces carbon dioxide, it does so at lower quantities than burning oil. In effect, substitution of oil to gas will help deliver the Vision 2030's target of safeguarding the environment and natural resources.

### How much natural gas is needed?

With gas being so central to the Vision, this naturally leads to the question of how much gas will be needed by Saudi Arabia come 2030. Whilst the issue of forecasting future gas production is fraught with many challenges, we have attempted to put together a model with the underlying assumptions detailed in Box 3.

#### Box 3: Assumptions for 2030 gas forecast

The foundation of our gas forecast is based on demand outlook for electricity in the Kingdom out to 2030 and the use of gas in generating this forecasted electricity. Three key factors in our model result in rising electricity demand, both in absolute terms and per capita basis, between now and 2030. Firstly, we forecast that total population will reach 37 million (both Saudi and non-Saudi) up from 31 million in 2015. Secondly, we predict that the industrial push for diversification, especially targeting energy intensive sectors such as mining, will drive up the usage of electricity in the Kingdom. Thirdly, despite energy efficiency measures designed to help curb steep rises in electricity demand, the most effective tool in achieving efficiency of consumption, higher electricity tariffs and gas prices,



...the generation mix split between gas and other fuel types at 50 percent each in the base case...

...but rising to gas making up 70 percent in the high case.

As gas usage in the generation mix rises, gas supplied to other sectors declines on a proportional basis.

According to our base case, Saudi Arabia will need 25 bcf/d of raw gas in 2030...

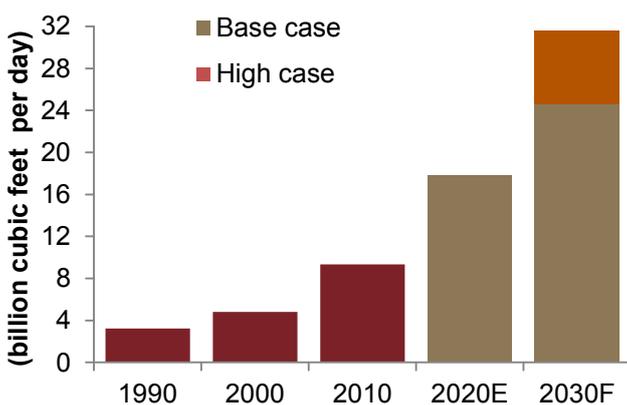
...with the high case scenario requiring 32 bcf/d of gas in 2030.

are held constant between now and 2030. Although in reality we do believe that prices will be adjusted upwards at some point in the next 15 years, the multifarious effects of price rises on a number of our underlying assumptions means it is convenient to keep them unchanged for the sake of our analysis. We do, however, recognize that any upward adjustment in tariffs and gas prices would likely lead to lower overall demand in 2030 than specified in our model.

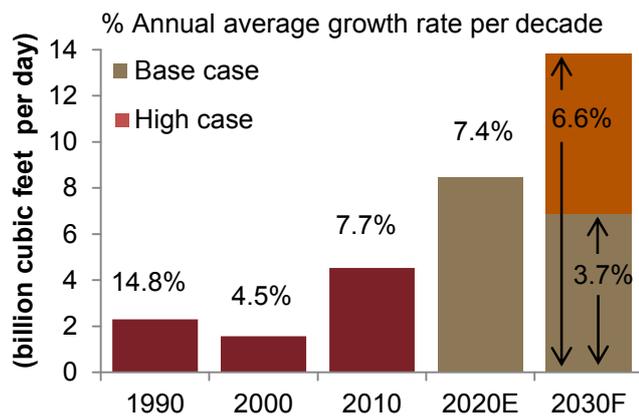
Another set of assumptions relate to gas usage both within the generation mix and in the economy as a whole. According to ECRA data, in the last eight years (between 2007 and 2015) gas made up around 45 percent of the generation mix, with crude oil, diesel and fuel oil making up the rest. We estimate the split between gas and other fuel types to be closer to 50 percent now, due to the commissioning of two gas fields, Hasbah and Arabiyah, during Q1 2016, and this makes up our base case scenario. In recent comments, the Saudi Energy Minister stated that gas could potentially contribute 70 percent of the generation mix, up from 50 percent currently. Whilst no specific timeline was given, our high case scenario assumes gas will make up 70 percent of the generation mix by 2030. As gas usage in the generation mix rises, we assume that gas supplied to other sectors of the economy, chiefly to the petrochemical sector, will have to decline on a proportional basis. According to ECRA data, in the last eight years, an average of 53 percent of total gas produced in the Kingdom was used by the power sector, with the rest likely being directed to petrochemicals. In order to capture rising demand of gas in other sectors, we have assumed the ratio of gas usage in the power sector versus other sectors to be fixed at 53 percent in our base case scenario, but rising to 58 percent in our high case scenario.

According to our base case scenario, Saudi Arabia will need 25 bcf/d of raw gas in 2030, which is just over double the raw gas output of the Kingdom in 2015 (Figure 12). Our high case scenario shows total raw gas required rising to 32 bcf/d in 2030. We see these as very achievable targets given that gas production is expected to reach 17.8 bcf/d by the end of this decade, resulting in the Kingdom requiring an additional 7 to 14 bcf/d of gas between 2020 and 2030. Looked at differently, Saudi Arabia would need to grow gas production by an annual average rate of either 3.7 percent, in the base case scenario, or 6.6 percent, in the high case scenario, in the decade to 2030. In either case, it would still be lower than actual or expected average annual growth rates of three out of the previous four decades (Figure 13).

**Figure 12: Saudi raw gas demand in 2030: base/ high case scenario: 25/32 bcf/d\***



**Figure 13: Actual and forecasted raw gas output and average annual growth rate per decade**



\*Note: no rises in electricity tariffs and gas prices in both cases: Base/high case gas equals 50/70 percent of the generation mix



A number of gas projects will push raw gas production to 17.8 bcf/d in 2020...

...all of which are non-associated and include the first ever unconventional gas supply in the Kingdom.

Unconventional gas production in the US started in early 2000s...

...and now accounts for 55 percent of total US gas output, up from 2 percent in 2000.

The increase in production has depressed US gas and petrochemical feedstock prices.

Similarly, the potential pay-off for developing the Kingdom's resources could be huge.

## Where will the gas come from?

A number of gas projects currently being worked on are expected to push the total raw gas production to 17.8 bcf/d in 2020, up from 11.6 bcf/d in 2015. All these fields are non-associated and also include the first ever development of unconventional (shale or tight) gas in the Kingdom. According to Saudi Aramco, unconventional gas from Turaif, in the North West, will be delivered to a gas facility in the Wa'ad Al Shamaal industrial city by the end of 2017. Around 50 mcf/d of unconventional gas is expected to feed into a power plant which, in turn, will be used for a phosphate mine operated by the mining company Maa'den. Although the gas produced from this field is relatively small, it is seen as a crucial step in unlocking the Kingdom's potentially vast reserve of unconventional gas.

### Unconventional gas:

Driven by a few mid-size gas companies willing to experiment with new technologies in the hope of fast returns, the US production of gas from shale formations started earlier and grew much faster than unconventional oil production. Unconventional gas production began in the early 2000s but now there are over 30 unconventional gas plays active in the US, with gas from these plays accounting for just over 55 percent of total US gas production, up from 2 percent in 2000. The ensuing increase in production has not only depressed US gas prices but also petrochemical feedstock prices (Figure 14). At the end of 2015, US ethane prices had dropped by 73 percent whilst propane prices were down 64 percent since 2010. The drop in prices has given the US petrochemical sector a huge incentive to invest in infrastructure. Accordingly, a large chunk of US petrochemical expansion projects will come on-line during the next few years, accounting for a sizable portion of global petrochemical capacity.

The great leap made by US unconventional gas companies in last two decades has opened up the potential for other countries around the world to replicate their success, including Saudi Arabia. Considering that some estimates point to the Kingdom having as much unconventional gas reserves as conventional reserves (Figure 15), the potential pay-off for developing these resources could be huge even taking into account the more challenging and complex nature of the task.

Figure 14: US ethane and propane prices

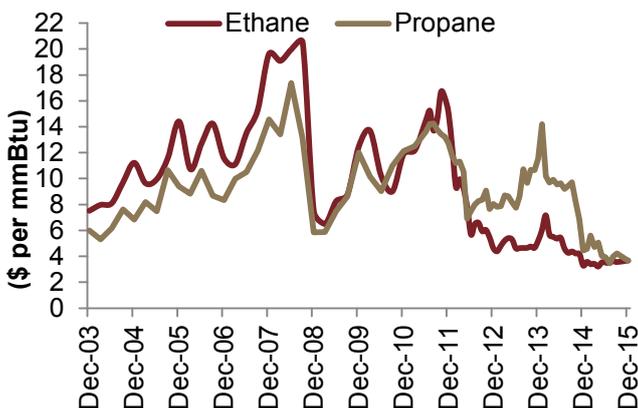
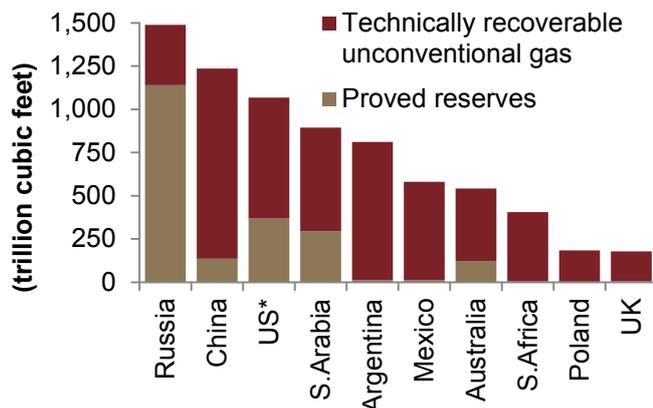


Figure 15: Top 10 technically recoverable\*\* unconventional gas vs. proved gas reserves\*\*\*



\*includes both conventional and unconventional gas  
 \*\*recoverable under current technology but not economically  
 \*\*\*recoverable under existing economic & operating conditions



Three major gas complexes, Wasit, Midyan, and Fadhili will add more than 5 bcf/d of raw non-associated gas to 2020.

The Midyan field will produce a more modest output of 75 mcf/d of non-associated gas.

Any potential shortfall in gas supply, during peak summer demand could be met through importing gas...

...something which Kuwait and the UAE have been successfully doing in recent years.

Conventional gas:

Most of the gas expected to come on-line between now and 2020 will be coming from non-associated sources. Three major new gas complexes, Wasit, Midyan, and Fadhili will add more than 5 bcf/d of raw non-associated gas (Figure 16).

According to Saudi Aramco, the Wasit gas plant, supplied by the Hasbah-Arabiya gas fields, recently added 2.5 bcf/d of raw non-associated gas (1.7 bcf/d of sales gas). The Hasbah-Arabiya fields were commissioned as recently as Q1 2016 and the impact on direct crude burn has been immediate. Latest available data shows that direct crude burn used to generate electricity during the initial summer months of 2016 has been lower than in recent years (Figure 17), thereby freeing up more crude oil to be used to increase either crude oil exports and/or higher value refined oil products. Another major project will be the Fadhili complex, which will process 2.5 bcf/d of raw gas from onshore and offshore fields, coming on-stream by 2019. In between both the Wasit and Fadhili projects is the Midyan field, which is expected to be fully operational by end 2016, producing a more modest output of 75 mcf/d of non-associated gas.

Imports:

Whilst we remain confident that the development of additional gas supplies in 2020 will be delivered on-time, any potential short term shortfall in supply, during peak summer demand for example, could be met through importing gas. Liquefied natural gas (LNG) import terminals are usually required for large amounts of imports, with the cost of these higher capacity projects reaching \$20 billion plus, but a more flexible and cost-effective option would be floating LNG (FLNG) terminals. The use of FLNG terminals, which reverts LNG into gas, has grown rapidly in recent years, particularly in emerging markets facing short-term supply shortages. Whilst Saudi Arabia currently enjoys an enviable status of being energy self-sufficient, the case for importing smaller levels of LNG over peak periods, is strong, especially so when other GCC countries, such as Kuwait and the UAE, have successfully begun seasonally importing LNG via FLNG terminals in recent years.

Figure 16: Saudi gas production in 2020

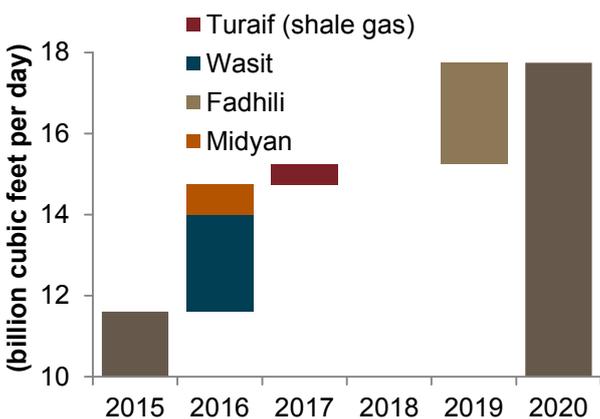
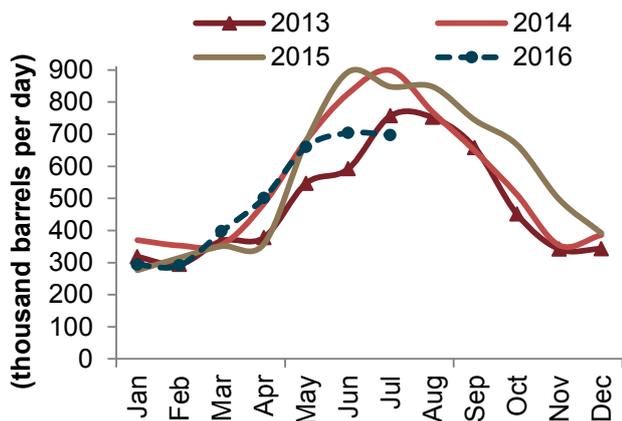


Figure 17: Direct crude burn down after increased gas from Wasit plant





## Challenges facing natural gas development

*The sources of the additional gas required in the decade to 2030 are not so apparent.*

*Gas exploration has moved to Rub' al-Khali, the Red Sea and the North Western region*

*Whilst some of these locations have yielded discoveries of gas, they are more complex...*

*...and will require simultaneous investment in pipeline infrastructure...*

*...all of which will add to time and cost of developing these gas fields.*

Whilst the supply of gas to 2020 has been mapped out, the sources of the additional gas required in the decade to 2030 are not as apparent. In recent years, gas exploration has moved to previously undeveloped areas, such as Rub' al-Khali (Empty Quarter in South East of Saudi Arabia), off-shore in the Red Sea or to the North Western region. Whilst some of these locations have yielded discoveries of gas, the more complex and challenging, and ultimately more costly, nature of these gas plays have required further deliberation before development.

### Conventional gas:

The Red Sea has seen increasing levels of exploration for gas. Initial studies and tests are being carried out since 2009 in both shallow water and deep sea water, although in early 2015 exploration in the latter area was reported to have ceased. The Red Sea is comparatively more challenging than other off-shore areas, such as in the North Sea for example, due to its uneven sea bed, deeper water levels, steep slopes and islands. Alongside these factors is the lack of infrastructure in the region, (Box 4) which together, is likely to result in higher costs of production. Nevertheless, a number of reported discoveries have been announced in the past and there are plans to continue exploring for gas in the area. On-shore exploration is also continuing, Aramco stated that it had discovered two non-associated gas fields during 2015, one in Edmee and another in the Rub' al-Khali. These fields were additional to the seven pure gas field discoveries in recent years (Table 1).

**Table 1: Recent Saudi gas field discoveries**

Project	Area	Type	
Turayqa	South East	On-shore non-associated	Conventional
Mihwaz	Central	On-shore non-associated	Conventional
Abu Ali	East	On-shore non-associated	Conventional
Faras	East	On-shore non-associated	Conventional
Amjad	East	On-shore non-associated	Conventional
Badi	East	On-shore non-associated	Conventional
Faris	South East	On-shore non-associated	Conventional
Edmee	East	On-shore non-associated	Conventional
Murooj	South East	On-shore non-associated	Conventional
Jafurah	East	On-shore non-associated	Unconventional

### Box 4: Gas infrastructure concentrated in the east

Currently most of the major gas pipeline network in Saudi Arabia, the Master Gas System, is concentrated in the East of the country due to both the historical and current (Table 1) abundance of oil and gas discoveries there. Naturally, therefore, the use of gas in the generation of electricity has become concentrated in power plants in the central or Eastern regions (Figure 18). Although work to expand the Master Gas System has recently commenced, through both increasing in existing pipeline capacity and adding more pipelines, further investment is likely to be required to encourage more gas usage across the whole of the Kingdom. In addition, any major gas development in the West of the Kingdom, especially so in the Red Sea, will require simultaneous investment in pipeline infrastructure, all of which add to time and cost of developing such gas fields.



*Unconventional gas exploration started back in 2011.*

*In Rub' al-Khali, it was the first time where IOC's were invited to participate in upstream gas projects...*

*...but have ceased exploration activities due to development being uneconomical.*

*There are broader challenges associated with unconventional gas development in the Kingdom....*

*...including more complicated geology...*

*...and water scarcity...*

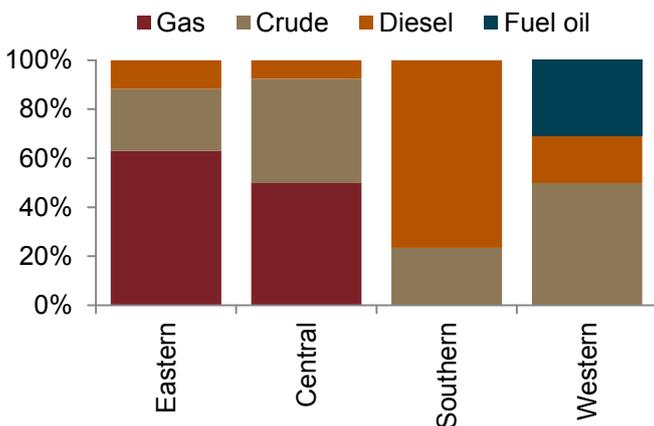
*...but exploration is, nevertheless, still ongoing.*

Unconventional gas:

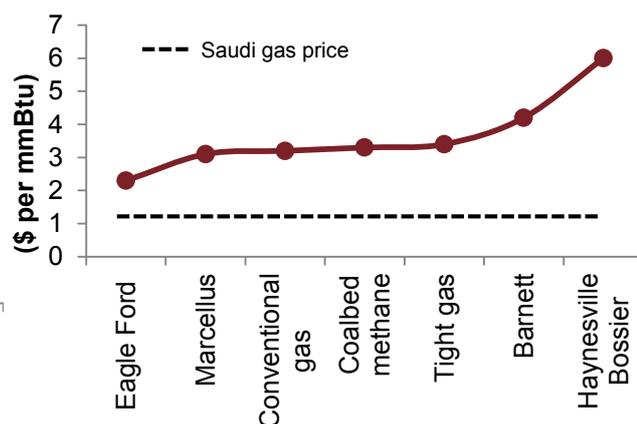
Unconventional gas exploration started back in 2011 and, as mentioned earlier, the Kingdom will see its first unconventional gas from the North Western region in 2017. More recently, it was reported that Aramco had made a promising shale gas discovery at the Jafurah field in the Eastern Al-Ahsa region. In another area of focus, in the Rub' al-Khali, the development of unconventional gas has hit some hurdles. Rub' al-Khali was the first instance where international oil companies (IOC's) were invited to participate in upstream gas projects within the Kingdom. Whilst drilling results were relatively positive, yielding a number of prospective finds, viable commercial production of unconventional gas from the area has remained elusive. Since 2011, all four of the IOC's permitted to participate in the area have either ceased exploration activities or exited their venture with Aramco altogether. The IOC's decisions to exit, all of which were taken independently of each other, were reportedly related to gas development being uneconomical, with the higher sulphur content of the gas, requiring higher levels of processing, adding to the development costs. The issue of high sulphur gas adds to the other broader challenges associated with unconventional gas development in the Kingdom.

Whilst Saudi Arabia has ample technically recoverable unconventional gas reserves, converting these reserves into economically recoverable resources is more challenging. For example, one of the factors related to the successful exploitation of unconventional gas in the US is due to shale deposits generally being larger and at shallow depths. Saudi Arabia's unconventional gas resources lie deeper in the ground, making them more challenging to extract. In addition, the extraction of unconventional gas is done through hydraulic fracturing (fracking), which is both energy and water intensive. This poses further challenges since, according to the World Resources Institute, many of the Kingdom's unconventional gas plays are located in areas of extremely high surface and groundwater stress, and arid conditions. All these factors combine to significantly raise the cost of production, but exploration is nevertheless still ongoing in Rub' al-Khali and other areas with Aramco currently taking sole responsibility for unconventional gas projects in the Kingdom.

**Figure 18: Usage of fuel type in electricity generation by region\***



**Figure 19: US gas break-even prices**



\*Note: Based on Saudi Electricity Company power plants which accounted for 70 percent of installed capacity in 2015



## The issue of pricing

*Saudi domestic gas prices are lower than the cost of developing unconventional gas resources...*

*...despite recent price hikes in the 2016 Saudi budget.*

*Price reform would encourage more efficient energy consumption and help develop high cost gas resources...*

*... although case for developing gas resources is not negated even if price reform is not taken...*

*...since it will still be cheaper than using crude oil for electricity generation come 2030.*

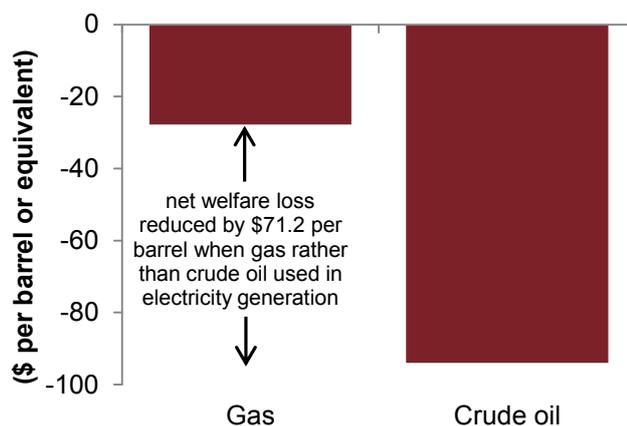
The current cost of developing unconventional gas in the US, which is the only large-scale producer of such gas globally, ranges between \$2.3 mmBtu to \$6 mmBtu. The lowest cost gas play, Eagle Ford, is almost double the sales price of domestic Saudi gas of \$1.25 mmBtu. Due to the more complex and challenging gas plays in Saudi Arabia, we suppose the cost of development in the Kingdom is likely to be at the higher end of the US shale gas cost curve, at \$6 mmBtu, putting it at nearly four times the current domestic gas price (Figure 19).

The 2016 Saudi budget included price increases for domestic energy products. Gasoline, diesel, crude oil, natural gas, fuel oil, and electricity tariffs were all raised. This points to the start of a new trend of reform in domestic economic policymaking, and could be followed by similar actions during the next few years. An effective price reform would not only encourage more efficient energy consumption, thereby lowering overall gas demand, it would also limit the drag on public finances (in the form of foregone revenue) in relation to the development of high cost gas resources, such as unconventional gas.

But even if the current domestic gas price structure is not adjusted, the case for developing gas resources is not negated if we consider, according to our calculations, that the export price of Saudi crude oil will reach \$98 pb in 2030. Assuming the price of crude oil remains at \$5 pb for domestic consumers, the loss of government revenue, when using crude oil for electricity generation, would total \$93 per barrel (\$98-\$5pb), and even higher for refined crude oil products. On the other hand, based on the higher cost estimate of unconventional gas, at \$6 mmbtu, the cost of producing a barrel of oil equivalent of gas would total \$35. Again, assuming the price of gas in domestic Saudi market remains unchanged, at \$1.25 mmBtu (or \$7.2 per boe), its use in the Kingdom would result in government revenue losses of \$27.8 per boe (\$35-\$7.2), much lower than the oil equivalent (Figure 20).

Therefore, when taken all together, we can see that striving to make gas a larger part of the generation mix is the most cost effective and sustainable solution, regardless of domestic energy price reform.

**Figure 20: Net welfare loss of using crude oil vs. unconventional gas in generating electricity in 2030\***



\*Note: assuming no domestic energy price reform



*The greater challenge in exploiting gas will occur in the decade to 2030...*

*...with Saudi Arabia's prospects highly dependent on the development of technology.*

*But the centrality of gas in the Vision, and the costly use of crude oil will ensure gas' development is prioritized in the years ahead.*

## Outlook

Whilst a steady supply of gas is expected to come online between now and 2020, it seems the greater challenge in exploiting gas will occur in the decade after. Considering the vast reserves of unconventional gas in the Kingdom, we expect the majority of additional supply from 2020 onwards, up to 14 bcf/d according to our high case scenario, will come from shale or tight gas. Of course, Saudi Arabia's prospects in developing these sources will depend on the development of technology that allows effective and efficient fracking of unconventional gas and also addresses the challenges related to water scarcity issues. Some of these issues are currently being looked into, for example, using LPG and/or carbon dioxide rather than water in fracking. Also, a part of the \$334bn 10 year investment plan, announced by Aramco in September 2016, will focus on research and development in order to specifically address such challenges, in addition to boosting exploration and development. Meanwhile, logistical challenges associated with transporting gas from the East to the West of the Kingdom will no doubt add to overall development costs. Meanwhile, an effective reform of energy prices would help facilitate a more rapid exploitation of gas resources, minimize losses in government revenue and, at the same, increase efficiency in consumption.

Overall, we believe both the centrality of gas in the Vision, and the unsustainable and costly alternative of using crude oil, will ensure that its development will continue to be prioritized in order to meet gas demand come 2030.

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