



ENTER

SHELL GLOBAL SUPPLY MODEL OIL & GAS: A VIEW TO 2100





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ESTIMATING FUTURE OIL AND GAS PRODUCTION CAPACITY IN A CHANGING ENVIRONMENT

1. INTRODUCTION



Wim Thomas
Chief Energy Advisor

This brochure provides an overview of the long-term global supply modelling methodology we use in Shell to estimate potential future industry-level oil and gas production in support of our scenarios work.

As our scenarios work shows, oil and gas demand will remain significant in the coming decades, even as renewables rise meteorically. This tool allows us to systematically explore future production potential taking into account the best available resource base estimate, present and future technologies, and societal developments in acceptable operating procedures.

Development of such a sophisticated tool involves a wide range of experts from numerous areas in the business, all of whom I'd like to thank for their years of dedication.

We hope you find this brochure helpful in gaining an insight into how we approach forecasting oil and gas production in Shell.



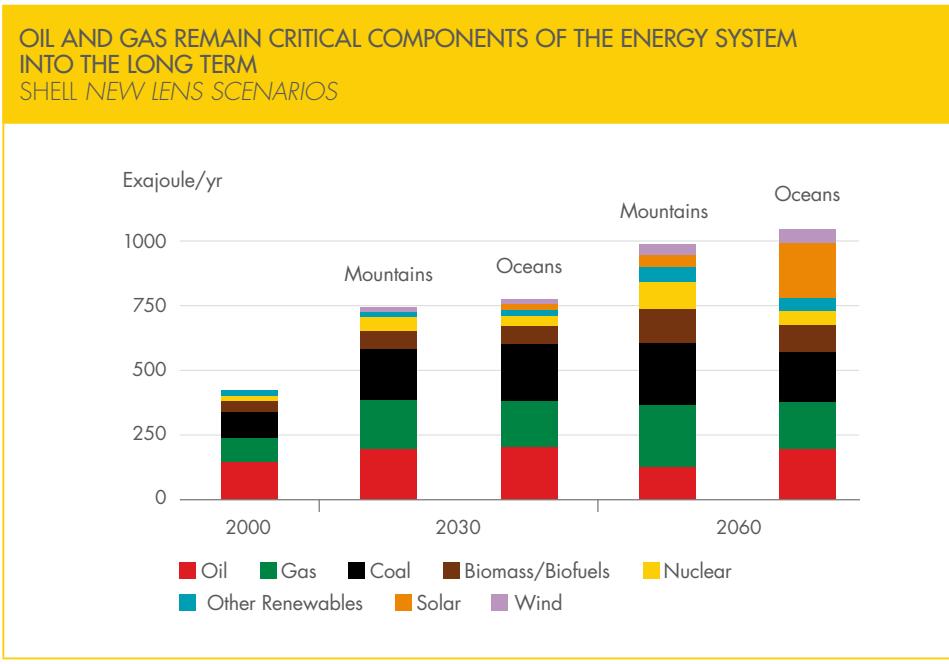
Richard Moore
Senior Energy Advisor,
Principal Developer of the GSM

The Global Supply Model (GSM) is a top-down model which allows us to form our own view of long-term oil and gas production potential.

We collate data from a range of external data providers and combine that with our own internal sources and analyses to build a Shell view of future production potential. This also allows us to explore key uncertainties and enables us rapidly to quantify different production scenarios for strategic studies and for our wider analysis of the global energy system. Increasingly sophisticated versions of the tool have been used for studies in Shell for a number of years including our 2013 New Lens Scenarios work and we have recently completed the latest version which can now explicitly handle associated gas and natural gas liquids.

We continue to work on the GSM, both in terms of its oil and gas supply forecasting capability and the prediction of key parameters linked to production, such as oil quality, carbon footprint and cost of supply.

2. WHAT IS THE GSM?



What is the GSM?

- The GSM is a Shell proprietary global oil and gas production model used for quantifying scenarios.
- The GSM marries techno-commercial and geo-political mechanisms to forecast industry-level future production based on scenario assumptions.
- The GSM forecast draws on detailed modelling work and analysis such as our North American shale oil model.
- The GSM is a top-down tool that uses asset-level data aggregated by resource type and geographical location for 90 countries. It forecasts to 2100 for fixed or variable prices.
- The GSM has the capability to forecast upstream CO₂ footprint at the same granular level as oil and gas production. Future versions may also be able to forecast investment costs.
- The GSM is Visual Basic/Excel-based and can produce a wide variety of customised graphs. Data can be exported for further analysis/post-processing and comparison with other forecasts, as well as being key inputs for Shell's World Energy Model and scenario analyses.

What is its purpose?

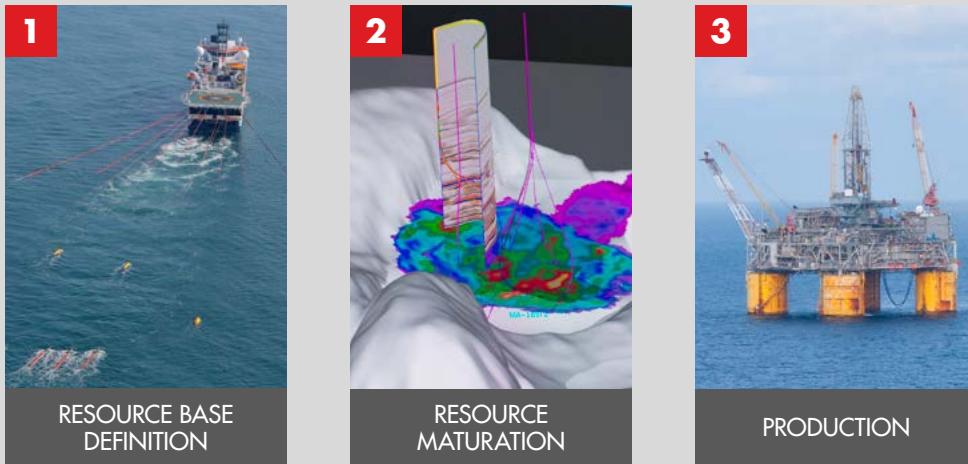
- The GSM provides plausible oil and gas production profiles tailored to Shell-specific scenarios.
- The GSM helps to find answers to key questions around uncertainties on oil and gas supply at a global and country level, e.g.
 - How much production potential is in which country and from what sources?
 - How much supply will be available for a prescribed oil price trajectory?
 - Which resource types are produced and what is the upstream environmental footprint?

Who are its customers?

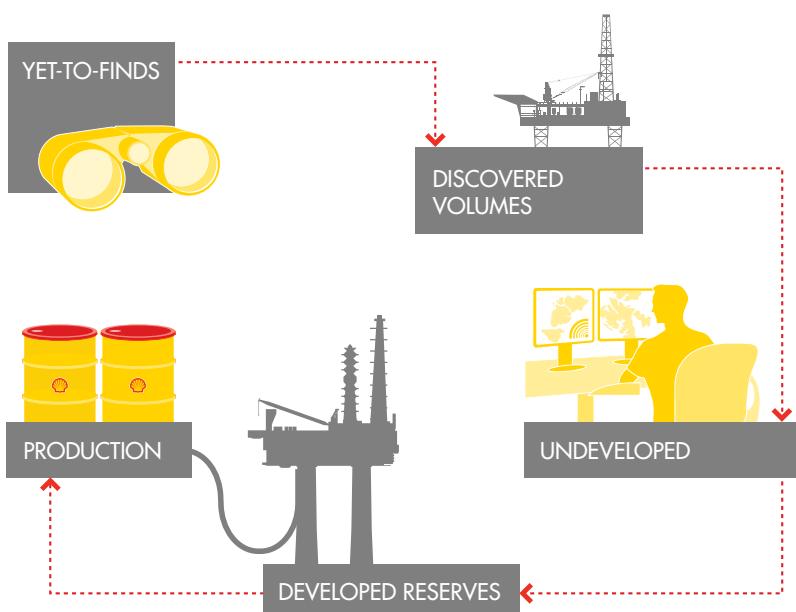
- Within Shell, the GSM is a key reference model for strategy/planning groups in both the corporate centre and the businesses.
- Externally, the GSM contributes to Shell Scenarios publications.

3. HOW DOES THE GSM WORK?

The GSM has three principal components:



Resources are matured from exploration to production:



What are the key modelling principles?

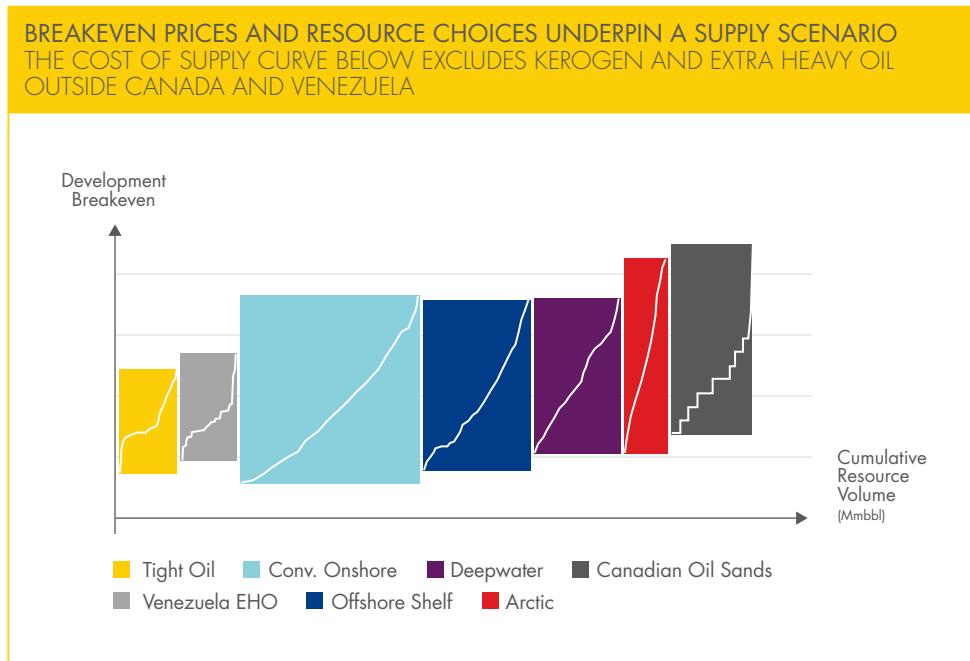
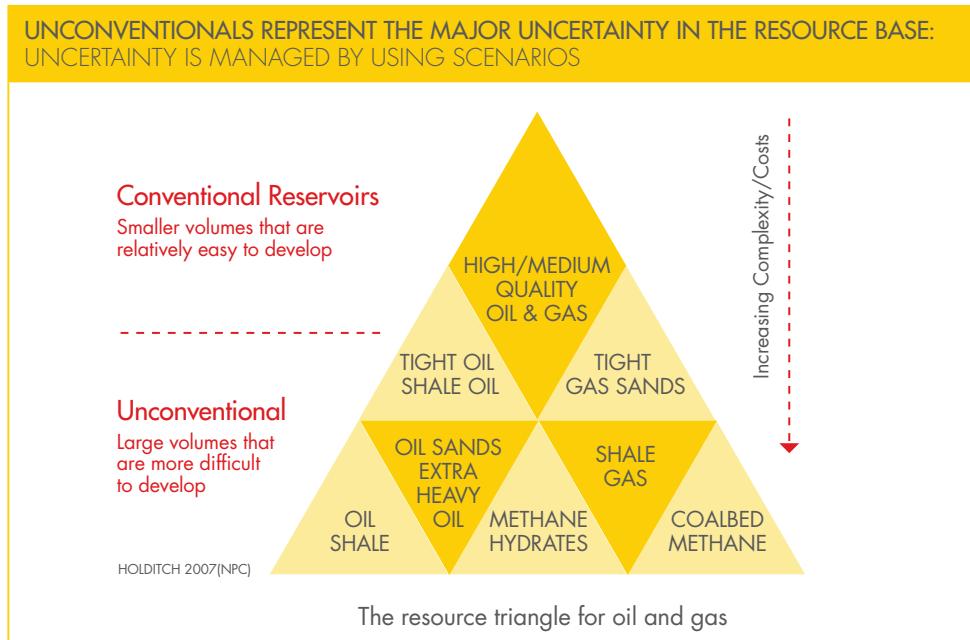
The GSM combines superimposed Hubbert-like* curves at a level of granularity that maximises the benefits of a top-down empirical approach while retaining sufficient data to be relevant and representative.

Cost of supply curves are employed to make forecasts oil price sensitive. Both technical assumptions and policy choices on resource utilisation can be incorporated.

- Resource and production data is aggregated from external and internal sources much of which are at field level. Tens of thousands of individual assets are compressed into approximately 500 active developed reserve/production "buckets", each fed by a resource maturation chain (Undiscovered, Discovered, Undeveloped and Resource Growth due to recovery factor increase).
- Resources are matured from exploration through discovery to developed reserves using maturation archetypes tuned with country and regional data.
- Cost of supply curves control how much resource is economic to mature at a given oil price.
- Production growth constraints can be applied to the model to reflect e.g. geopolitically imposed or other takeaway/upstream constraints.
- Crude oil and non-associated gas are the primary calculations with associated gas and associated liquids (condensate/natural gas liquids) as secondary calculations.
- Oil and gas supply is the core engine with environmental and, in the future, cost estimation being a secondary derivation from production and resource maturity.



* M.K. Hubbert, Shell Development Company, "Nuclear Energy and the Fossil Fuels", American Petroleum Institute Spring Meeting, 1956



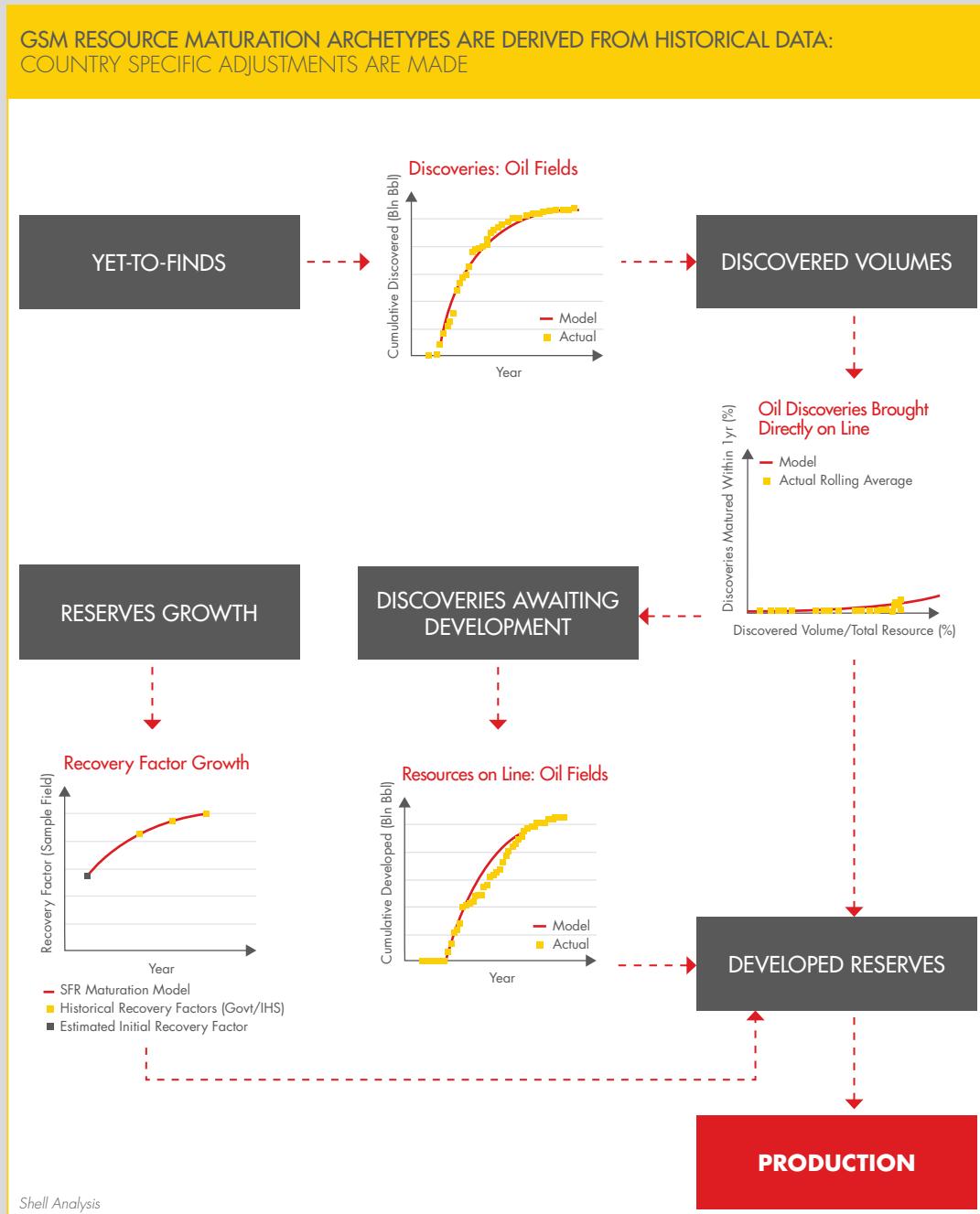
1. Resource base definition

The recoverable resource base underpins any production forecast and this can be varied per scenario depending on assumptions of technology progress and policy choices. Data providers have differing views on the expectation (2P – Proven & Probable) resource base, even for producing assets. This indicates the level of uncertainty in estimates and allows ranges to be explored. Uncertainty derives from estimates of in-place volumes, the recovery factor, the economics of recovery, the impact of technology advancement over time and the licence to operate from society and governments.

Conventional oil and gas has been the main focus of the industry since its inception. As a result, the in-place resource is quite well defined and the major uncertainty lies in the extent of recovery. Globally, the recovery factor for conventional oil fields averages about 35%. The technical limit through improved and enhanced recovery techniques nears 70%, so the assumptions on the extent to which technologies such as water or gas flooding, chemical injection and thermal techniques are applied are critical.

- Enabled by the oil price increase over the period 2004-2014, unconventional resources now represent a significant proportion of the recoverable resource base and recovery estimates may increase further as technology develops and/or the oil price increases. The in-place volumes of unconventional oil are very large but production techniques are complex. Costs can be high and recovery factors are generally low. Initially modest estimates for extra heavy oil and bitumen from Venezuela and Canada have increased due to advances in surface mining and steam-assisted recovery and, now, resource potential is recognised in other countries such as Russia and Kazakhstan. Similarly, early estimates of the potential from shale gas and oil were low but advances in horizontal drilling and multiple fracture stimulation have enabled production in North America to move rapidly down the cost curve. Research & Development work continues on oil production from kerogen ("oil shales") and gas from methane hydrates.
- Assumptions on the economics of recovery are key and are incorporated into the GSM.



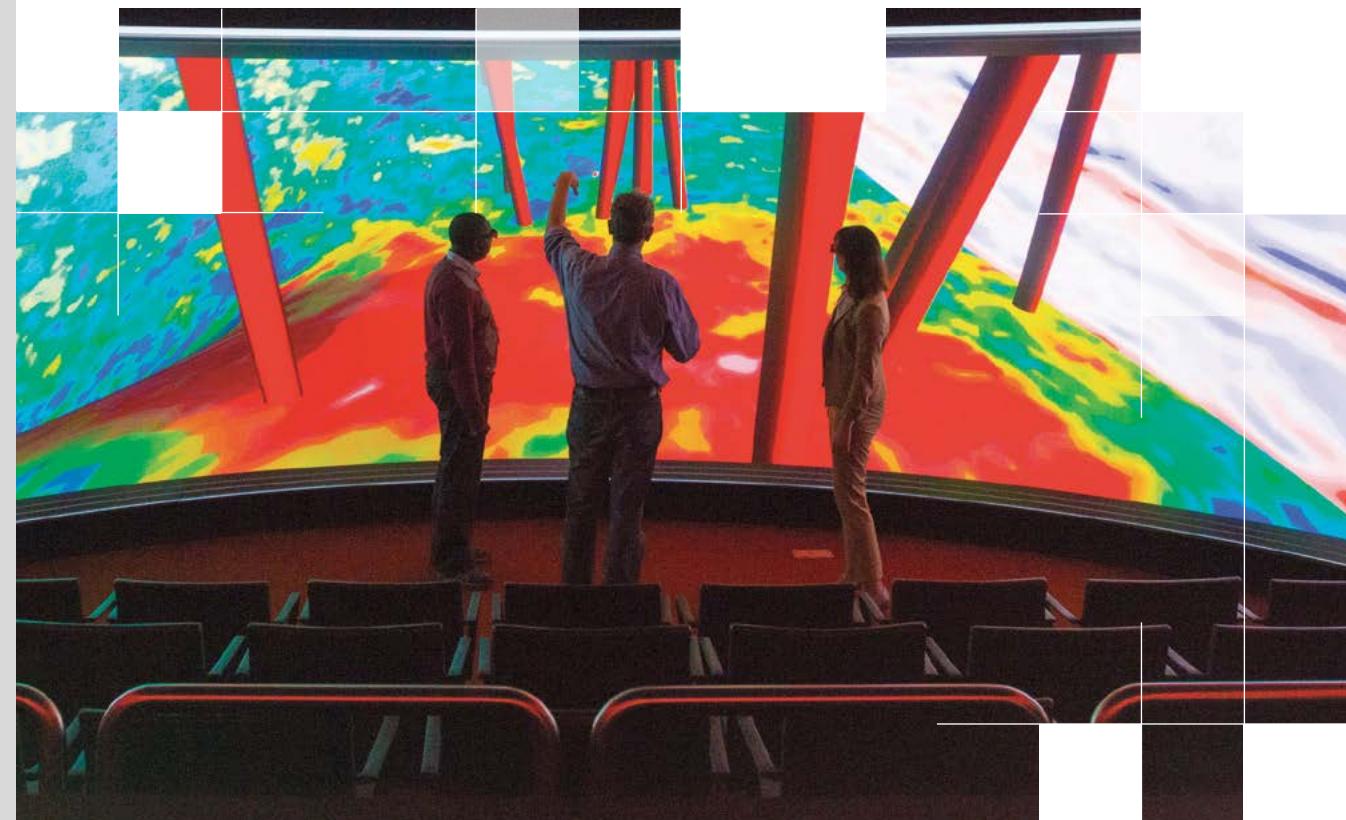


2. Resource maturation

The real-life maturation process of resources through the exploration phase to discovery, development planning and, ultimately, production is reflected in the GSM.

- Discovered volumes are brought into production over time, also using a creaming curve.
- Reserves growth is introduced over time as recovery factors are assumed to increase with technology progress.
- Country-specific factors to adjust archetypes are derived from historical data either for the country in question or using a regional average.
- The resource volume in each category has a cost of supply relationship making the maturation rate oil price sensitive.

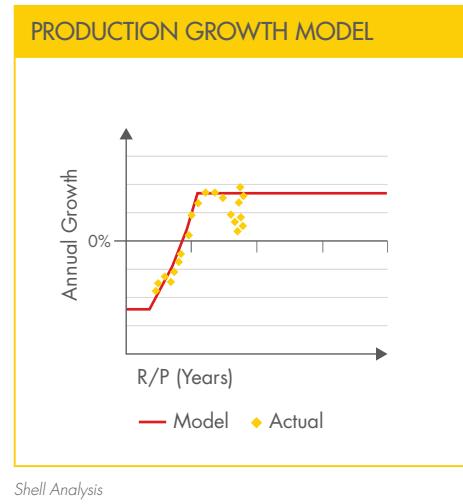
to existing production facilities, but most volumes transition into a planning phase.



GSM production archetypes are derived from historical data:

country-specific adjustments are made

- Annual production growth is estimated from an R/P ratio algorithm.
- Exogenous overwrites can be used to constrain or promote production where required in each scenario.
- Algorithms are tunable by country resource type and geographical setting for each scenario.



Shell Analysis



3. Production

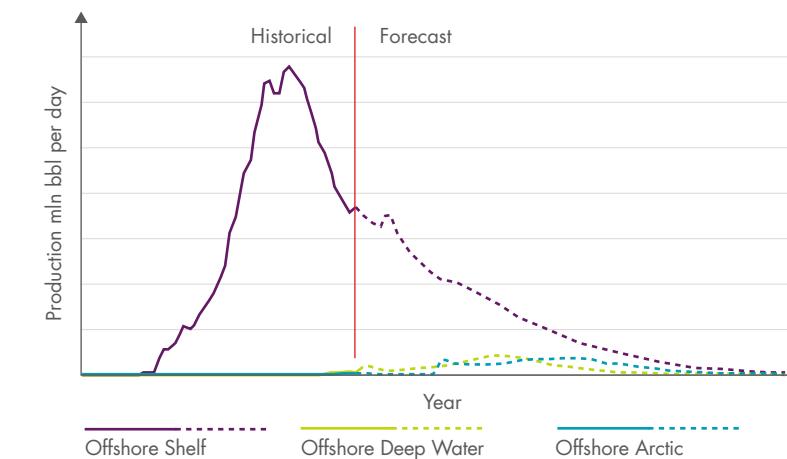
Production is driven by the level of (2P) developed reserves. If the ratio to production is high, production can be increased but beyond a certain point there is insufficient resource remaining to maintain production and decline is unavoidable.

- Production is governed by an empirically derived relationship between R/P ratio (developed reserves/production) and production growth.
- The maximum growth rate is adjusted for each country using a country-specific or regionally derived factor.

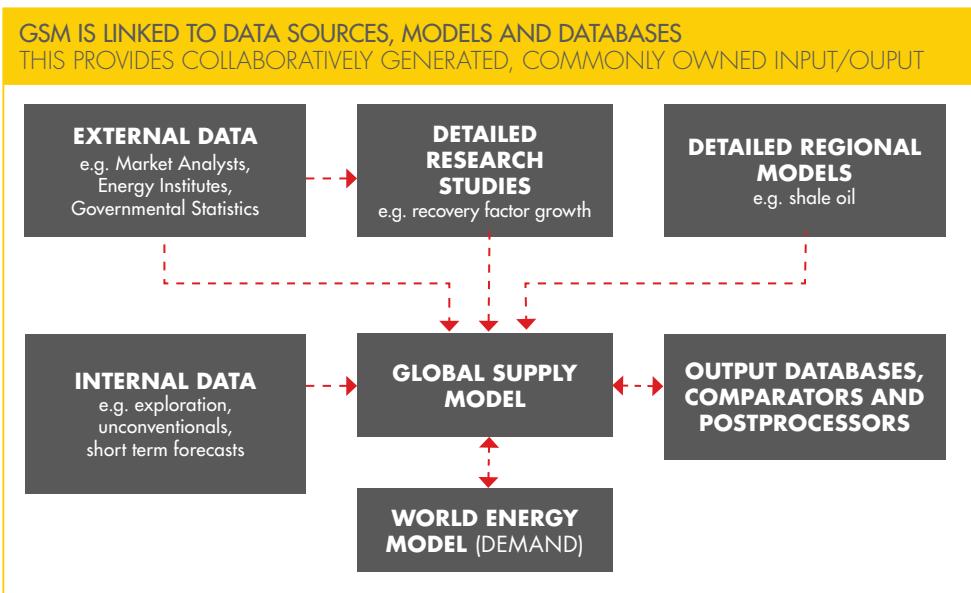
■ A series of Hubbert-like production curves emerge, superimposed for different resource types and geographical locations. This allows the phasing of production as technological progress enables discovery and production of new plays.

- For countries that do not behave in a techno-economic manner, a series of alternative controls are available that allow (e.g. geopolitical) control of production. For example, OPEC production scenarios can be developed.
- Knowledge from within Shell or from external sources (e.g. detailed short term forecasts) can also be incorporated into the model through production controls.

EXAMPLE COUNTRY: OIL PRODUCTION BY LOCATION



Shell Analysis



Main limitations of the GSM

The GSM does many things, however it is also important to be aware of its limitations. Many of these areas are dealt with elsewhere in the business and some are brought into the model as exogenous inputs following collaborative work with other parts of the company or external data providers.

The GSM is a long term production trend forecaster. Short term production forecasts are generally better represented by more detailed, often bottom up, assessments/analyses which can then be reflected in the model using the GSM's production control functionality.

The GSM does not balance supply with demand, rather it calculates production and resource maturation based on an exogenous input of oil price per year, where the oil price input may reflect a view on supply versus demand.

The GSM is not a reliable forecasting tool at asset or company level. Rather, it requires a sufficient sample size of fields in each aggregated "bucket" to enable the "law of large numbers" to represent behavior at a granular but not detailed level.

The GSM generates a production projection for a particular long term expectation resource base scenario, not a proved (1P) reserve case.

A GSM production projection and its underlying resource scenario is determined by many assumptions, including technical, geo-political, policy and price. The production projection can only be fully understood in the context of these underlying scenario assumptions and the assumed resource response.

Implementation

GSM is a Visual Basic, Excel-based linear processing model.

- GSM has a graphical user interface and output data feeds into databases and postprocessors. GSM also has a Spotfire® based postprocessor for more general data manipulation.
- Forecasting is undertaken collaboratively to use the knowledge on resources and shorter-term production from across the company and generate integrated long term views.

How does the GSM combine top-down and bottom-up approaches?

The level of aggregation together with the use of empirically generated averaging processes is sufficient to enable rapid top-down forecasting for different scenario cases, balanced with the retention of sufficient detail to provide meaningful output/insight at the strategic level.

- Data is aggregated from the many thousand discovered fields and yet-to-find basin estimates into about 500 active GSM production buckets, each fed by a chain of three resource maturation buckets.
- Internal robustness of the calculation parameters, e.g. consistency of country-level factors together with the consistency of GSM forecasts versus external forecast providers, indicates that forecasting is representative across a range of oil prices and resource base scenarios.

How does the GSM integrate with other models and business applications?

The GSM works as a calculation engine for the World Energy Model and as one of the tools for strategic studies in both the upstream and downstream parts of the business.

- Oil and gas production is expected to provide a significant part of long-term global energy needs. It is therefore a key input to the World Energy Model's estimation of long term energy transitions.
- Country level oil and gas scenarios input into business decisions either within country or in the globalised arena of integrated gas and oil pricing work.
- Volume and oil quality projections are provided via GSM and its bespoke post-processor, including simple refinery yield calculations.
- Consistent data is shared across different businesses and processes using databases fed from the GSM.



4. MAIN SCENARIO UNCERTAINTIES

Uncertainties within the supply landscape pose key challenges:
a scenario approach is taken

Geopolitics

- OPEC behaviour and Middle East Geopolitics are very significant for oil: OPEC controls half of the remaining conventional resource base and will maintain a key influence until its oil production peaks. Estimates of resources in key major resource holders such as Saudi Arabia retain considerable uncertainty.
- Other major resource holders such as Russia have considerable influence.

Supply

- Development of unconventional shale oil and gas: Recovery efficiencies are currently far lower than for conventional

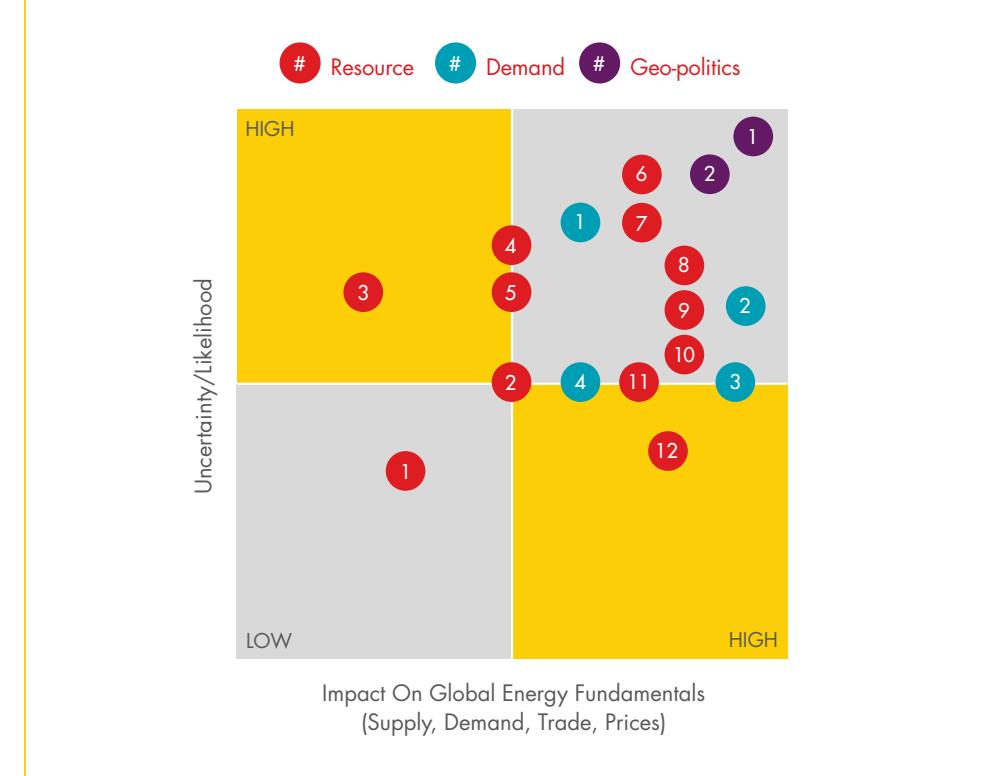
resources and economic recovery could be increased with further technology advances. Shale gas (e.g. China) and tight oil (e.g. Russia) are prevalent worldwide, but both technical and political uncertainties remain.

- Methane Hydrates, Kerogen and Extra Heavy Oil outside Canada/Venezuela could become increasingly important from the 2030s onward.

Demand

- Demand could be impacted due to increases in efficiencies and the availability/competitiveness of alternative energies.
- CO₂ policies or mitigation techniques could impact demand significantly.

GLOBAL OIL & GAS UNCERTAINTY MATRIX (2016-2100)

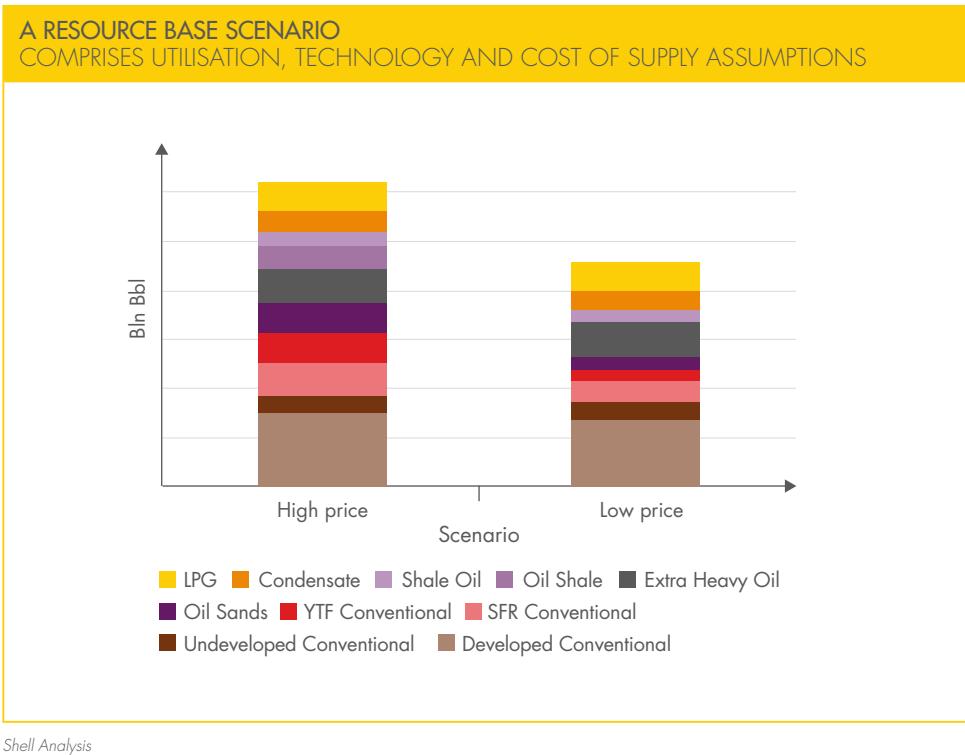


UNCERTAINTY EXAMPLES

1	Non-major resource holder supply	10	Kerogen & Extra Heavy Oil
2	Middle East gas growth	11	Methane Hydrates
3	Canadian oil sands growth	12	Long-term oil field capex deflation
4	Enhanced/improved oil recovery	1	OPEC behaviour and Middle East geopolitics
5	Exploration	2	Major gas resource holder strategy
6	Middle East resource base	1	Carbon Capture and Sequestration (CCS) breakthrough
7	North American Liquified Natural Gas (LNG) exports	2	Global CO ₂ policies
8	Tight oil recoveries	3	Inter-fuel competition in power
9	Tight gas recoveries	4	Accelerated non-oil transport growth



5. GSM SCENARIO OUTPUTS



GSM outputs: production cases depend on scenario choices relating to the key uncertainties

- Resource base
- Technology
- Prices

- Geopolitics
- Licence to operate
- Demand and export limitations

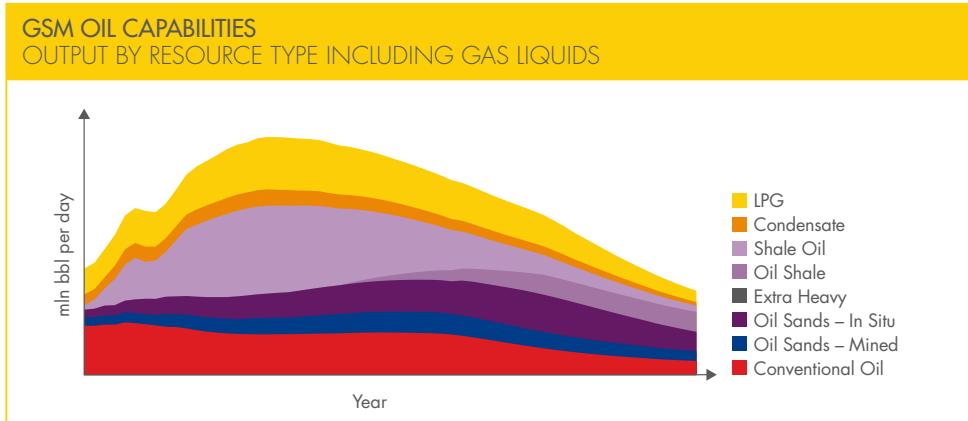
The example scenario outputs over the next two pages illustrate the capabilities of the model which is designed to provide strategic insight by providing output at an appropriate level of detail for various resource base assumptions and other inputs that can be easily varied to test multiple cases.



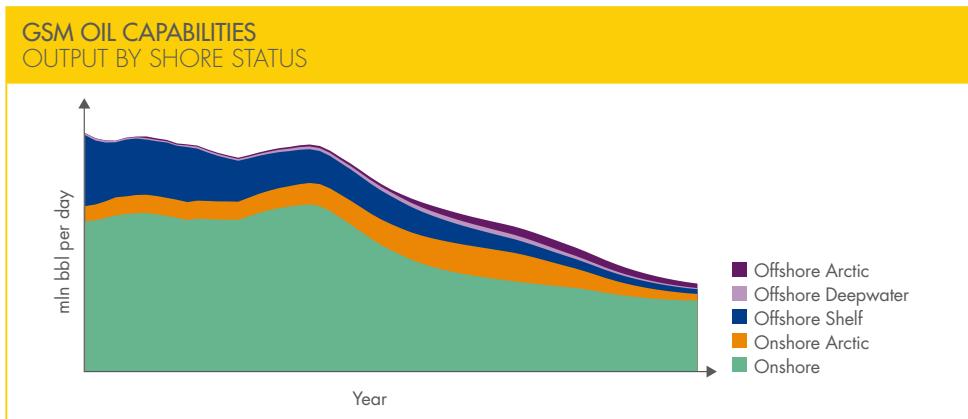
5. GSM SCENARIO OUTPUTS

BY RESOURCE TYPE AND SHORE STATUS AT WORLD,
REGIONAL OR COUNTRY LEVEL

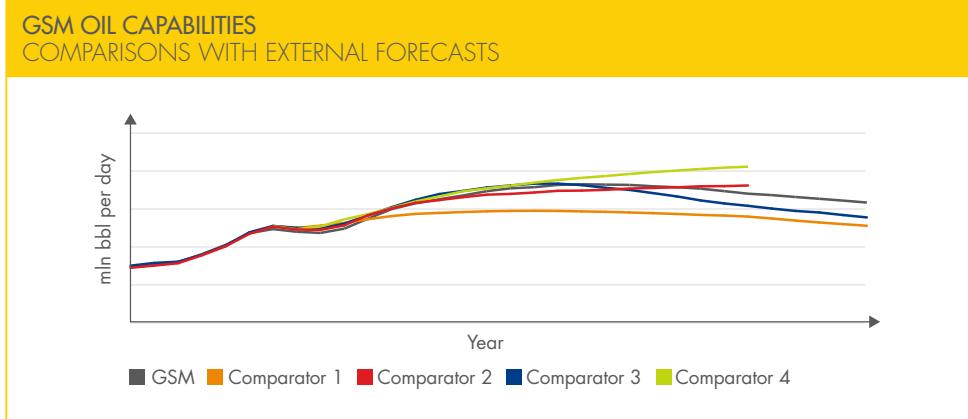
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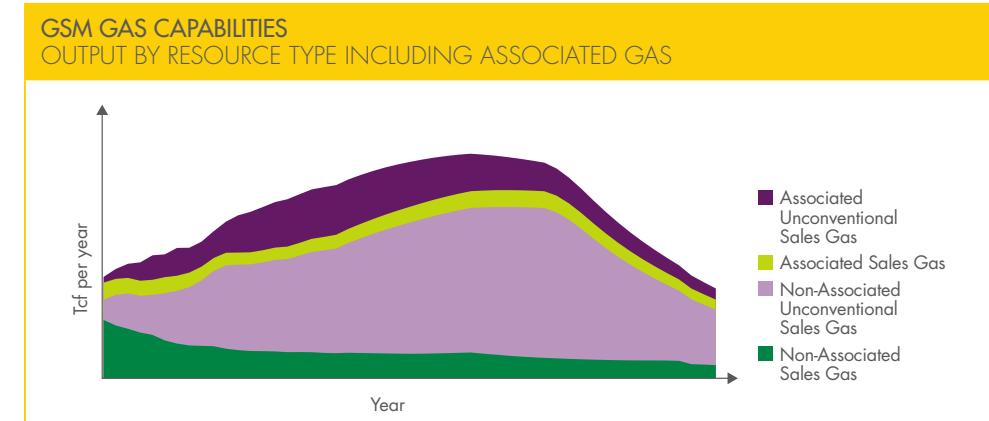
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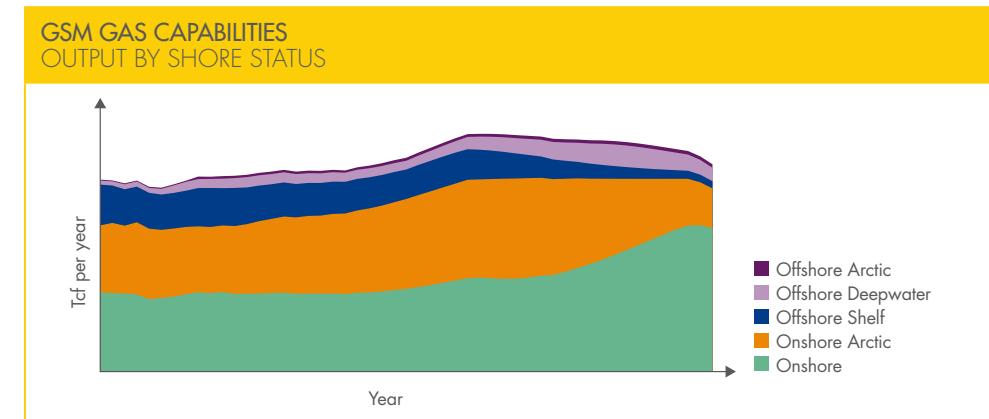
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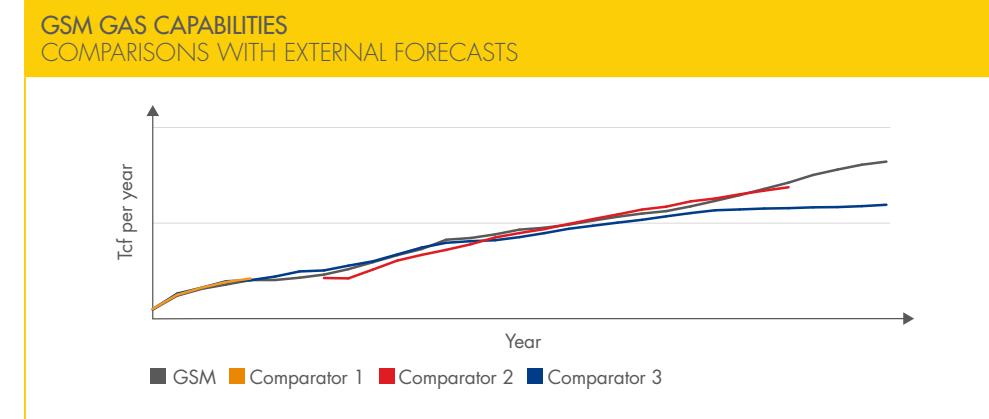
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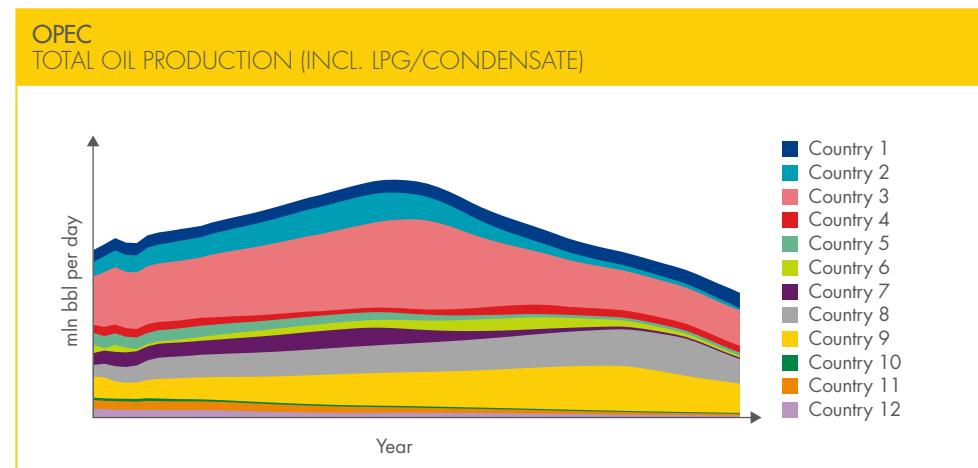
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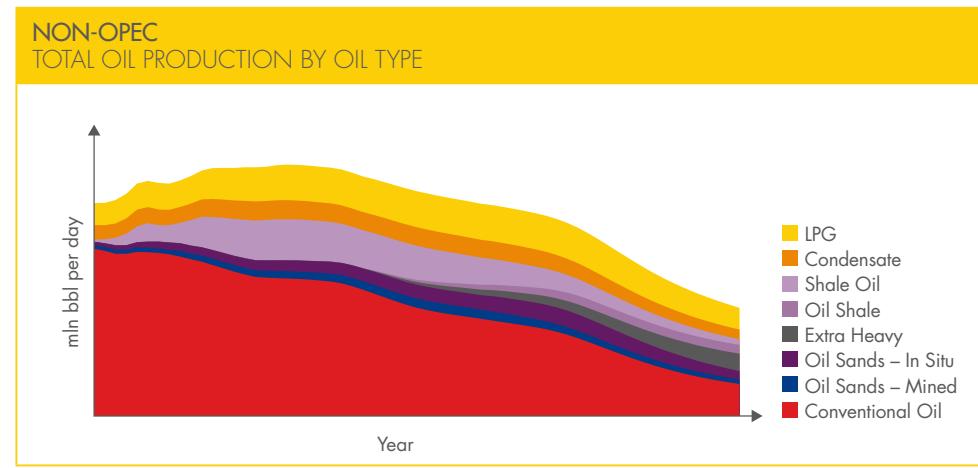
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A possible OPEC/non-OPEC scenario

- The Middle East increases its dominance as new super-producers emerge.
- Some countries remain politically unable to grow production.
- Shale Oil growth resumes as oil price recovers. The rest of the world follows.
- Rising oil price stimulates improved/ enhanced oil recovery, kerogen and extra heavy oil/bitumen.
- NGLs increase as crude bifurcates into light and heavy.



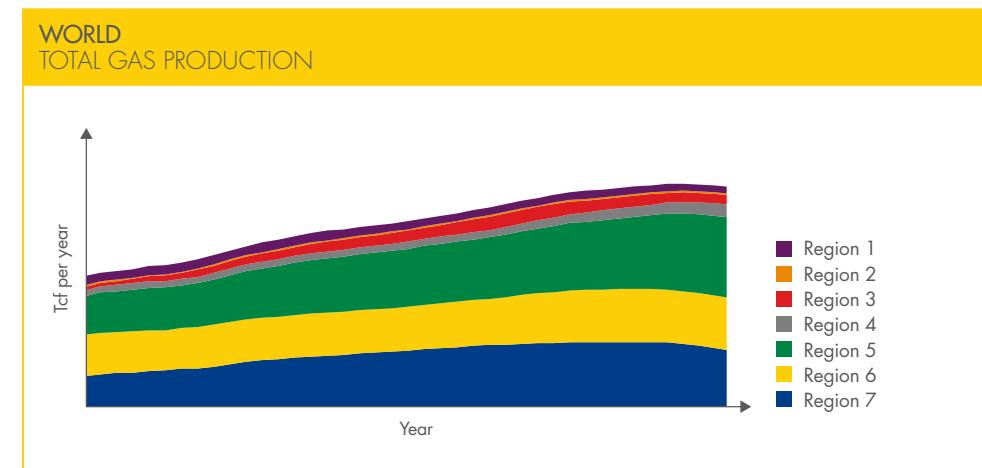
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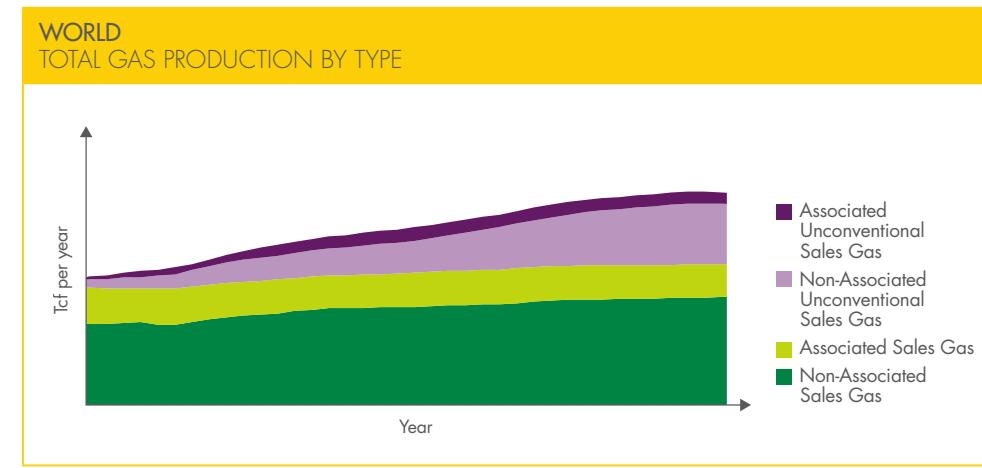
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A possible gas growth scenario

- Growth predominantly from 8 key countries.
- Strong North American exports assumed.
- Middle East realises its gas potential.
- LNG and trans-regional pipeline gas compete for market share.
- Non-associated gas dominates with massive unconventional gas growth.
- Methane hydrates could provide further growth mid-century.



Shell Analysis



Shell Analysis

HISTORY OF THE GLOBAL SUPPLY MODEL

Late 1990s

Global oil and gas modelling project initiated in Shell's Exploration and Production Think Tank.

Early 2000s

Resource base updated, investment estimation incorporated and production cases for Shell's "Business Class" and "Prism" scenarios generated.

2010

Model transitioned from the Upstream Business into Corporate Strategy.

2016

GSM version 2 completely re-programmed and released as a single oil and gas model with revised resource base, forecasting by resource type and geographical location by country. Production is separated into oil and non-associated gas together with "secondary" associated fluids (associated gas, condensate and LPG). Resource maturation and production algorithms revised and re-parameterised providing a "data rich" model. GSM's top-down oil and gas algorithms were calibrated to correspond with Shell's recently developed detailed activity and cost-based North American Shale oil supply model. Methane hydrates and kerogen embedded in the model. Cost of supply included to provide an oil price sensitive forecast. Comparator and post-processing databases created.

2002

2002 Separate R/P based conceptual models delivered forecasting of oil and gas at country level.

2008

Resource base updated and production cases for Shell's "Scramble" and "Blueprints" scenarios generated.

2012

GSM version 1 delivered forecasting at country level with a revised conventional resource base and a "heavy oil" and unconventional gas modelling capability. Used for input to Shell's "New Lens" Scenarios: "Mountains" and "Oceans".

6. WHO ARE THE PEOPLE INVOLVED?

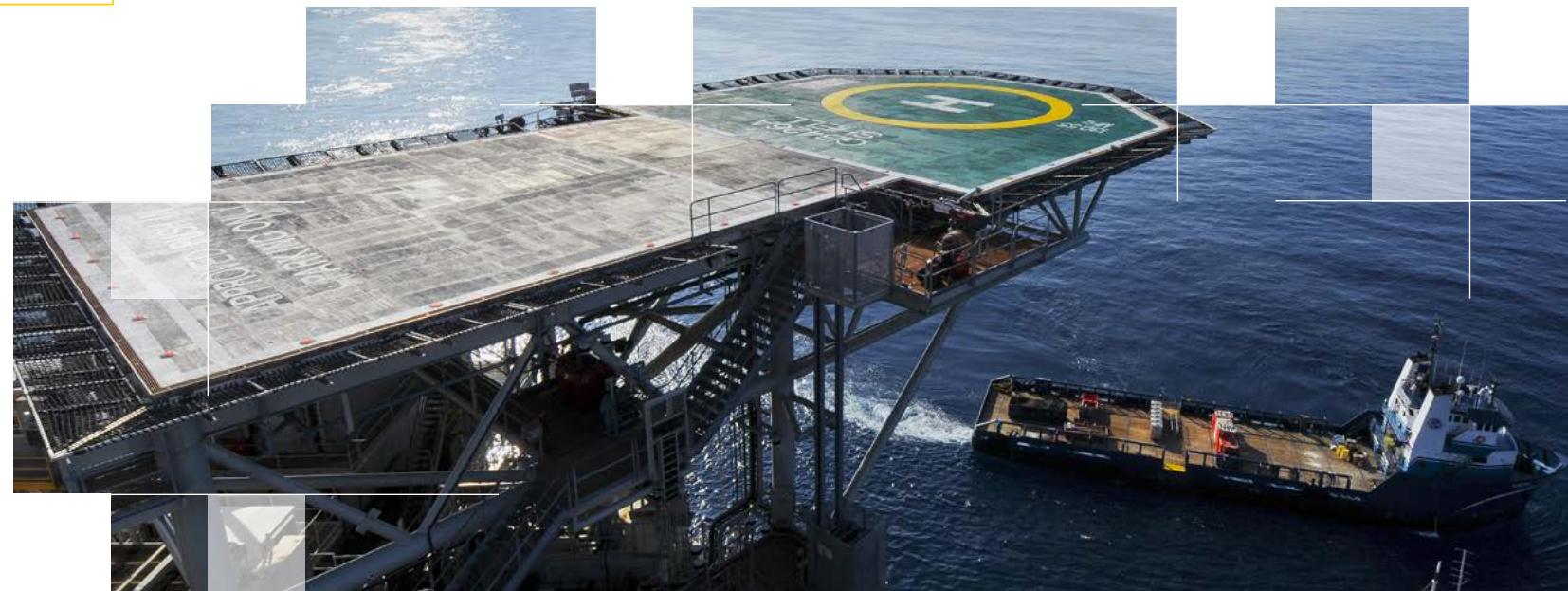
Several Shell colleagues have worked directly or indirectly on the GSM over the last decade. This ranges from development modellers such as Kees Langeveld, who created the original concept, specialist programmers like Bram Otto, who completely redesigned the model and brought it to state-of-the-art programming, to explorationists and technology experts in conventional, unconventional and enhanced oil recovery, who contributed their insights for modelling the future. And many other colleagues, past and present, in other parts of Shell with detailed knowledge of short and medium term oil and gas production in their regions. Recent collaborative work with Ken Ng and Patrick Richter in the Oil Market Strategy Group and Aldo Spanjer in the Integrated Gas Strategy Team has been instrumental in the rapid progress since 2014.

In particular, I would like to thank Richard Moore, being the principal developer since 2011, and his present team members Tom Venderbosch and Sobhan Abolghasemi.

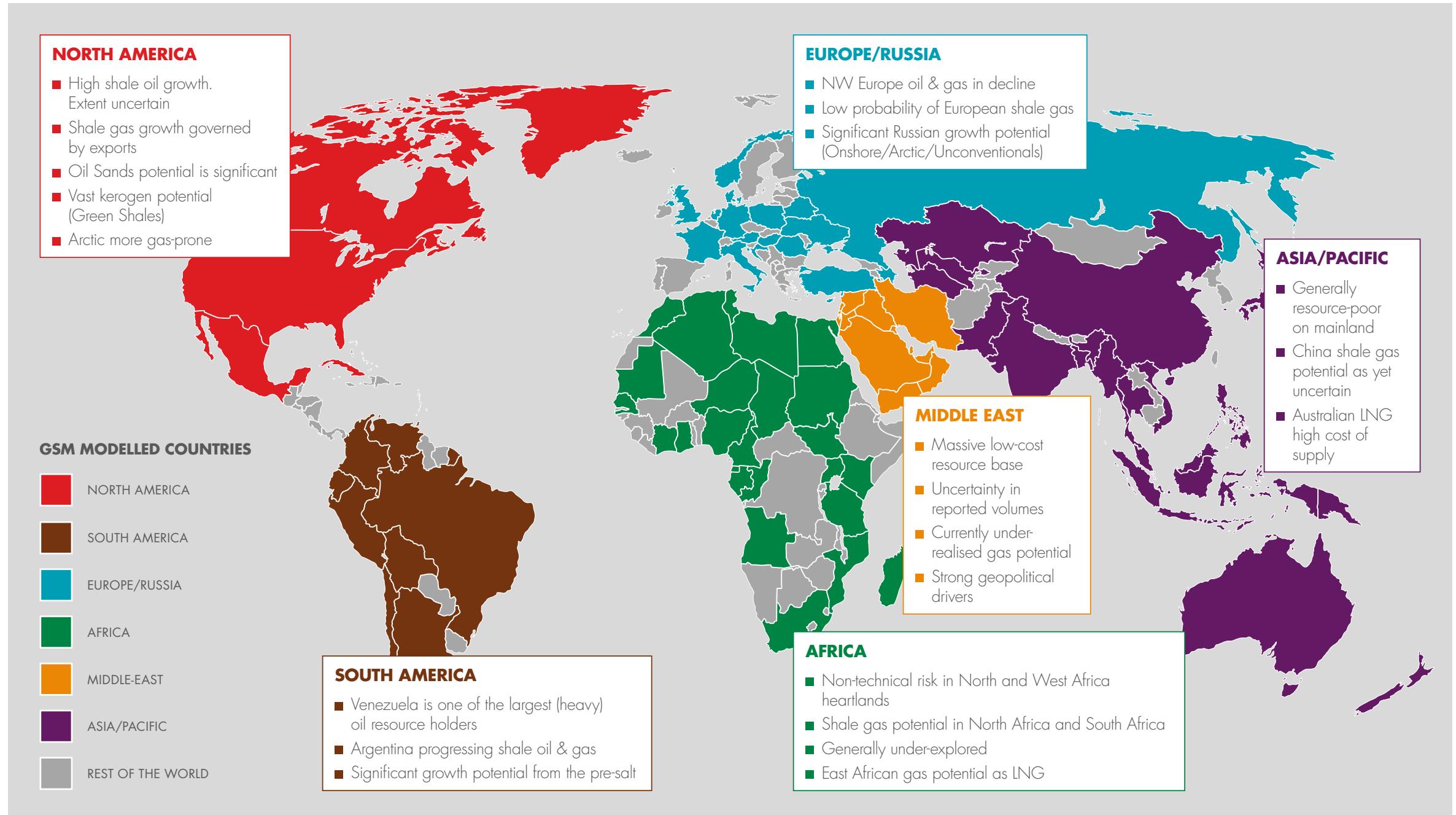
Wim Thomas

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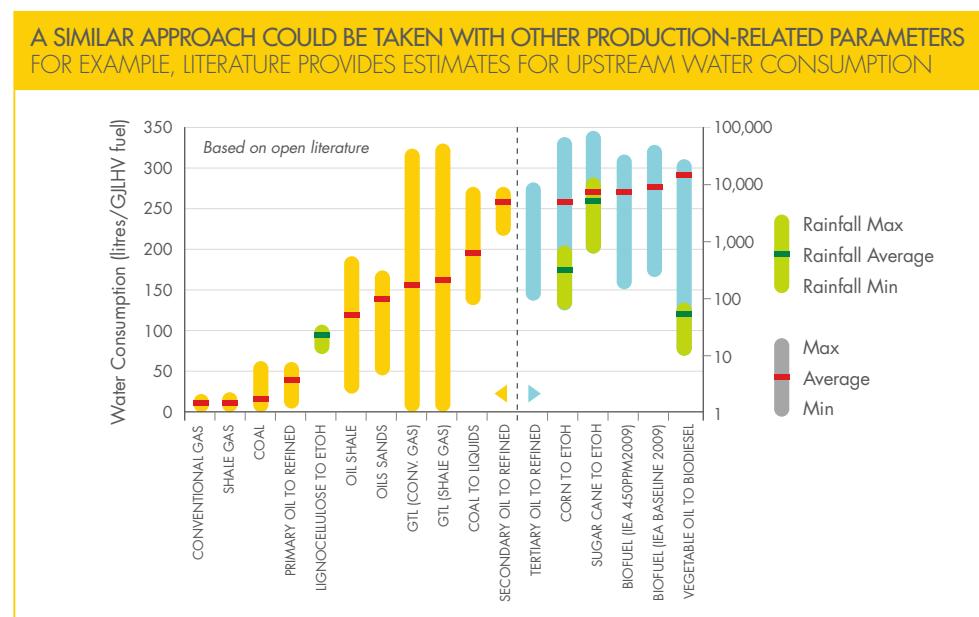
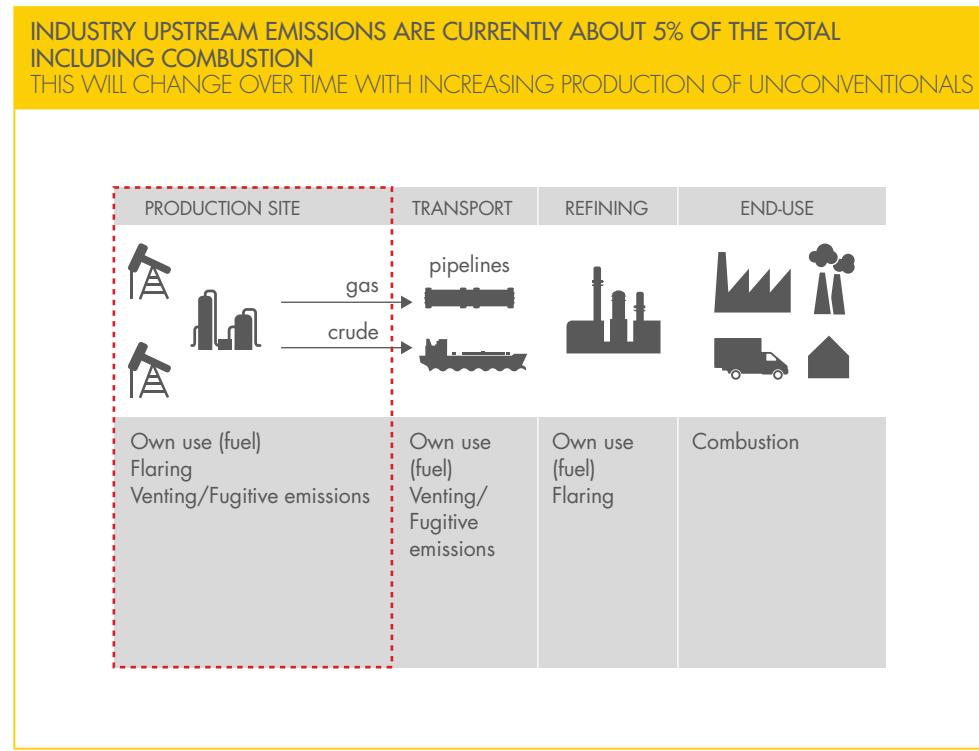
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APPENDIX A: SUPPLY COUNTRIES MODELLED



APPENDIX B: ENVIRONMENTAL MODULE



GSM methodology for "derivative" forecasts

The GSM can be used to forecast production-related variables and the forecasting of the upstream CO₂ footprint is a good example. The level of detail of the production model allows generic relationships to be applied:

- At a country or regional level;
- By resource type;
- By geographical location; and
- In relation to the maturity of the producing area (cumulative production/resource base).

The relationships can also be varied with time to represent influences such as policy.

Upstream CO₂ modelling method

Upstream CO₂ equivalent emissions performance is estimated from production using ratios derived from literature.

- Well site CO₂ emissions are sub-divided into own use (fuel), flaring and fugitive (methane) emissions.
- Ratios were derived from historical data and more detailed models. For own use in conventional oil, the relationship included the maturity of the producing area.
- Future policy-related improvements can be incorporated through improvement factors.

Future work

The pilot testing in 2015 demonstrated a feasible methodology which can be expanded to cover other environmental parameters.

- Relationships can be further refined and incorporated into the wider CO₂ emission forecasting of the World Energy Model.
- Detailed work on, for example, upstream water consumption could be undertaken to augment the higher level estimates from the World Energy Model.



This brochure contains data from Shell's New Lens Scenarios. The New Lens Scenarios are a part of an ongoing process used in Shell for 40 years to challenge executives' perspectives on the future business environment. We base them on plausible assumptions and quantifications, and they are designed to stretch management to consider even events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes and investors should not rely on them when making an investment decision with regard to Royal Dutch Shell plc securities. It is important to note that Shell's existing portfolio has been decades in development. While we believe our portfolio is resilient under a wide range of outlooks, including the IEA's 450 scenario, it includes assets across a spectrum of energy intensities including some with above-average intensity. While we seek to enhance our operations' average energy intensity through both the development of new projects and divestments, we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10-20 years.

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate legal entities. In this brochure "Shell", "Shell group" and "Royal Dutch Shell" are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words "we", "us" and "our" are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. "Subsidiaries", "Shell subsidiaries" and "Shell companies" as used in this brochure refer to companies over which Royal Dutch Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to as "joint ventures" and "joint operations" respectively. Entities over which Shell has significant influence but neither control nor joint control are referred to as "associates". The term "Shell interest" is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

This brochure contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as "anticipate", "believe", "could", "estimate", "expect", "goals", "intend", "may", "objectives", "outlook", "plan", "probably", "project", "risks", "schedule", "seek", "should", "target", "will" and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this brochure, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell's products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions. No assurance is provided that future dividend payments will match or exceed previous dividend payments. All forward-looking statements contained in this brochure are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell's Form 20-F for the year ended December 31, 2016 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward-looking statements contained in this brochure and should be considered by the reader. Each forward-looking statement speaks only as of the date of this brochure, April 2017. Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this brochure.

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