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The Oil Industry: Challenges and Strategic Responses

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PRESENTATION LETTER

The energy industry is experiencing very significant changes, and it is probable that we will see more dramatic uncertainties in the future. Climate change is one of the main issues that are affecting the environment, but as the authors of this study have clearly put into context, there are many other issues that are affecting and will disrupt the Oil and Gas (O&G) industry.

One of the significant contributions of this study is the detailed analysis of the context in which energy companies, and particularly O&G companies, are working and developing their activities. The study identifies those issues in the "New Landscape", in which not only climate change has been considered, but also the social concerns and new market trends, the technological development and applications and regulations.

The study carefully identifies issues and topics in each of those blocks, and discusses them so as to understand the context and, what is more relevant, to infer which challenges will face the O&G industry.

The analysis carried out revolves, in a very detailed manner, around specific challenges that are, in turn, grouped into seven general categories; the first four of which are 'energy transition to a low-carbon economy', 'social acceptance and license to operate', 'changes in consumer preferences and consumer empowerment', and 'reduce GHG and pollutant emissions in the industry processes and reduce the carbon intensity of products'. All of these general challenges may be grouped under the heading of 'fighting climate change and reducing environmental impact'.

A second block of general challenges are grouped under the heading of 'energy products markets and competition', which consists of 'regional decrease in demand for conventional oil products', 'greater competition at a global and regional scale' and 'greater competition from alternative energy products'.

The merit of this study, 'The Oil Industry: Challenges and Strategic Responses', goes beyond the in-depth analysis it conducts of the context of today's energy and the energy of the future. It also looks at the strategies and, furthermore, it identifies and explains general strategies and 50 specific responses that the oil & gas industry may put in practice, with some of which are already being executed. These issues may be said to comprise the core of the study and for doing that, the authors also analyze some business models, and the oil product demand and supply examining the current state and the future uncertainties. In my opinion this is also key as uncertainty is the key characteristic of the oil & gas industry today.

I would also like to thank the authors of this study Eloy Álvarez and Manuel Bravo for their dedication to this study. I am aware that their intention was to add value through providing insight into the present-day circumstances, and particularly into the future of an industry that is subject to considerable uncertainty and that will most definitely experience considerable changes in the future.

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EXECUTIVE SUMMARY

For some years now, the fight against climate change and the efforts to begin low-carbon energy transitions have been the forces driving very relevant changes in the energy industry. Thus, to a certain extent, it is quite common to emphasize the need to increase and reinforce the development of renewable energies, and there are several analyses that examine the energies and technologies that are going to play a pivotal role in the future energy landscape. However, it is not so common to look in such detail at the industries that apparently, and according to popular consensus, have no future, or at least not a brilliant one.

This document looks at the oil industry, from exploration and production (E&P) to refining, in order to identify the challenges and the strategic responses that industry players are already developing, or may attempt to implement, so as to become a leader in the future energy sector.

New landscape for the oil industry

First, the document examines the issues that are considered a part of this new landscape and groups them into the following four categories: climate change policies and transition to a low-carbon economy, social concerns and new market trends, technological developments and their applications, and regulations.

Climate change policies and their corresponding legislation are key issues for the oil industry, as well as the means to cope with the energy transition to a low-carbon economy.

Social concerns and new market trends are also essential aspects to the industry. In this group, the study identifies and analyzes the factors dealing with renewables and their future, new approaches to mobility, energy efficiency, and the change in consumer preferences and empowerment. Regarding social concerns, other topics that are not so critical are also identified and examined, including peak oil demand, supply security, and the security and protection of critical infrastructures. In addition, another topic for discussion is how the changes in the global oil and gas product markets affect -and will influence- the oil industry.

Likewise, technology is a relevant matter. In an industry where technological developments have been key since their inception, some specific technologies are under analysis, as they could be considered examples that may frame the future of the industry in one way or another. Namely, these include carbon capture and storage, information and communication technologies (ICT), catalyst technologies and vehicle technology.

The analyses carried out in this document show that an important group of issues have arisen from regulations. Under this heading, a diverse list of topics must be considered, such as environmental legislation, ecosystem protection, product regulations, safety risk analysis, waste management, transportation safety, and monitoring, reporting and compliance. These regulatory issues show quite clearly that not only is the industry affected by complex environmental regulations, but also that there are many other regulatory questions that are essential for its future.

These four main groups have resulted in the identification of numerous challenges and responses, all with a varying level of granularity. On the one hand, there are general strategies that are likely to be addressed and implemented in a timelier manner; on the other hand, deeper analysis has led to a range of specific responses to industry challenges.

To better understand the general strategies and specific responses, it is advisable to use the supplementary document, 'The Oil and Gas Value Chain and the Oil Refining Process'. One of the objectives of the value chain is to create oil and gas products that satisfy consumer needs. In this document, value chain activities are structured with a traditional approach: upstream (E&P), midstream (transportation, storage and trading) and downstream (also including trading, and essentially refining, petrochemicals, distribution, and retail and marketing). In this section, we will focus just on E&P and refining.

Exploration and production

The upstream business is clearly a critical part of the value chain. The upstream industry has four factors of intrinsic complexity and two additional factors that make it even more complicated. The first four factors refer to complexity in terms of resources, projects, the industry, and safety discipline; and the other two are a loose control of costs and government action.

In this context and in order to maintain profitability and cash returns to shareholders, the E&P industry has reduced capital expenses and the investment in exploration, as well as operational costs. At the same time, it has made several adjustments both to the portfolio and the operating models.

In E&P, a distinction should be made between conventional and unconventional fields, and also regarding the different types of contracts. Particular attention is paid to digital technologies along the E&P value chain.

One of the challenges of the oil industry is to deal with different types of oil fields and with changes in oil prices, in addition to responding to price variations and to the changing environment in terms of investment decisions.

For many years, the oil and gas (O&G) industry has been aware that easily-exploitable reserves are decreasing and can be found farther away from the existing logistics infrastructure and the major oil routes. As a result, projects have become more technically and commercially complex. Neglecting opportunities to improve collaborative efforts, and the need to keep impeccable safety records would mean that any minor negative changes in external economic factors would erase the existing margins.

The E&P landscape has seen a dramatic reshuffling over the last three years, born out of necessity, following the crash in oil prices in late 2014. The players exploiting those types of development-targeted resources have decided to react and adapt to the challenging economic environment.

In an effort to keep company cash flows positive during the downturn in oil markets, a number of new processes and strategies have been adopted. Despite one or two companies had already begun to implement such changes before prices fell in order to improve margins, these players and other E&P operators were not properly prepared.

E&P capital expenditure (CAPEX) is estimated to have fallen by 18% per annum from 2014 to 2016, to around US$518 billion, and has recovered by some 4% the following year. Companies have reduced their CAPEX significantly, delaying projects or cancelling them straight away. Striving to cut down operational expenditure (OPEX), headcounts have been reduced globally and companies have become more thorough when ranking projects, investing only in the most important ones according to their profitability. As a result, service companies have suffered a bitter blow, and revenues from vertical integration are not guaranteed. All these factors imply that the current supply surplus may turn into a deficit in the near future, as production from brownfield projects declines and the lack of investment from new resources kicks in.

When comparing the different types of industry players, it is clear that independent oil companies have suffered the most, with many going under insolvency proceedings. Consolidation has also been prominent among many of the largest players. By combining portfolios, companies have been able to develop economies of scale and scope. Additionally, merger and acquisition (M&A) deals between operators, oilfield service and midstream companies have been evident, with potential benefits across much of the upstream value chain.

Refining

Refineries are a key element in the value chain of the oil industry. After describing the main processes in a refinery, its complexity is the next matter to deal with.

Refineries range from simple to very complex, depending on the number of units they combine and their type; conversion units are the main indicator of their complexity. A low-complexity refinery is one with limited or no conversion capacity, and typically also limited desulfurization capacity. Therefore, it has to process light and sweet (low sulfur) crude oils to achieve a profitable mix of marketable products. Low-complexity refineries produce more lower-value products, like fuel oils and asphalts. Furthermore, high-complexity refineries can process heavier and sourer crudes to make predominantly higher-value products.

The complexity of refineries has evolved over time, due to the increase in market competitiveness. Heavier and harder-to-process crude oils have started being processed, and more stringent sulfur content product specifications have arisen. As heavier crude oils generate more residual products when distilled, a refinery needs conversion capacity in order to process the bottom of the barrel with a positive economic impact. This involves significant CAPEX investments to build the new units, but it also noticeably increases the complexity of processes and operations. A higher degree of expertise and more advanced planning and support tools are required to run the refineries. In turn, heavier and lower-quality crude oils are sold at a discount price, which makes them an attractive opportunity to capture increased margins for more complex refineries that process them.

Refineries with higher complexity may operate in multiple economic scenarios or processing tranches. In order to maximize the economic value of the operations, refiners operate by filling their conversion units (coker, fluid catalytic cracker, hydrocracker, visbreaker) in their most economical setup. As capacity is exhausted for a unit, that tranche's capacity is capped and a new, less economical tranche starts with a new setup. Refineries process crude oil until the last barrel provides a positive net cash margin.

Oil product demand and supply

It is neither possible to understand the challenges of the oil industry nor visualize the strategic responses, without examining the supply and demand of oil products. Demand analyzed by type of use and region, as well as the factors affecting demand, such as economic growth, efficiency in transportation, biofuels, taxes and future demand for marine fuels, are studied in the document.

Future demand for oil products will be defined by combining market and regulatory factors that influence the relative competitiveness of oil vs. alternative fuels, in addition to global economic growth. However, the availability of an extensive electric car offering, the regulatory willingness to decarbonize the economy, and even consumer sentiment, will play an important role in oil product demand. But if the global regulatory push towards a greener economy continues to be strong, difficult times could be awaiting the oil industry.

Refining supply is the other side of the coin. Capacity evolution is examined, as well as factors that affect refining margins. Given the influence of specific regulations with an impact on demand, consideration is given to the cap-and-trade schemes and taxation, as well as to new technologies and digitalization in the refining processes in particular.

The refinery industry will inevitably embrace more digitalization in the future, but the rate at which individual companies can profit from it will depend on their willingness to invest in, test, and adapt to these new technologies. As digitalization is still relatively new to the refining industry (in the context of Industry 4.0), many of the technologies are still in their initial stages, and real-life results are not readily available, which means that companies must make detailed analyses and develop strategies regarding which technologies to adopt, and how to adapt their operations to maximize their benefits.

In the general framework of issues that appear in the new oil industry landscape, and having identified, considered and analyzed the situation and perspectives in E&P and refining, some strategic priorities for players in the refining industry arise. Refiners are pursuing diverse strategic alternatives to foster their growth and ensure their long-term sustainability, summarized in two basic objectives: increase profitability and protect margins, and develop growth opportunities. Regarding the first objective, refiners develop large transformation and operational excellence programs, which include processes and culture, skills and know-how. Raising the level of integration/coordination across the value chain is also necessary to capture synergies and optimize integrated margins.

In relation to the development of growth opportunities, several alternatives are pursued, such as trading, conversion, niche markets and products, and portfolio management.

General strategies, business models and responses to specific challenges

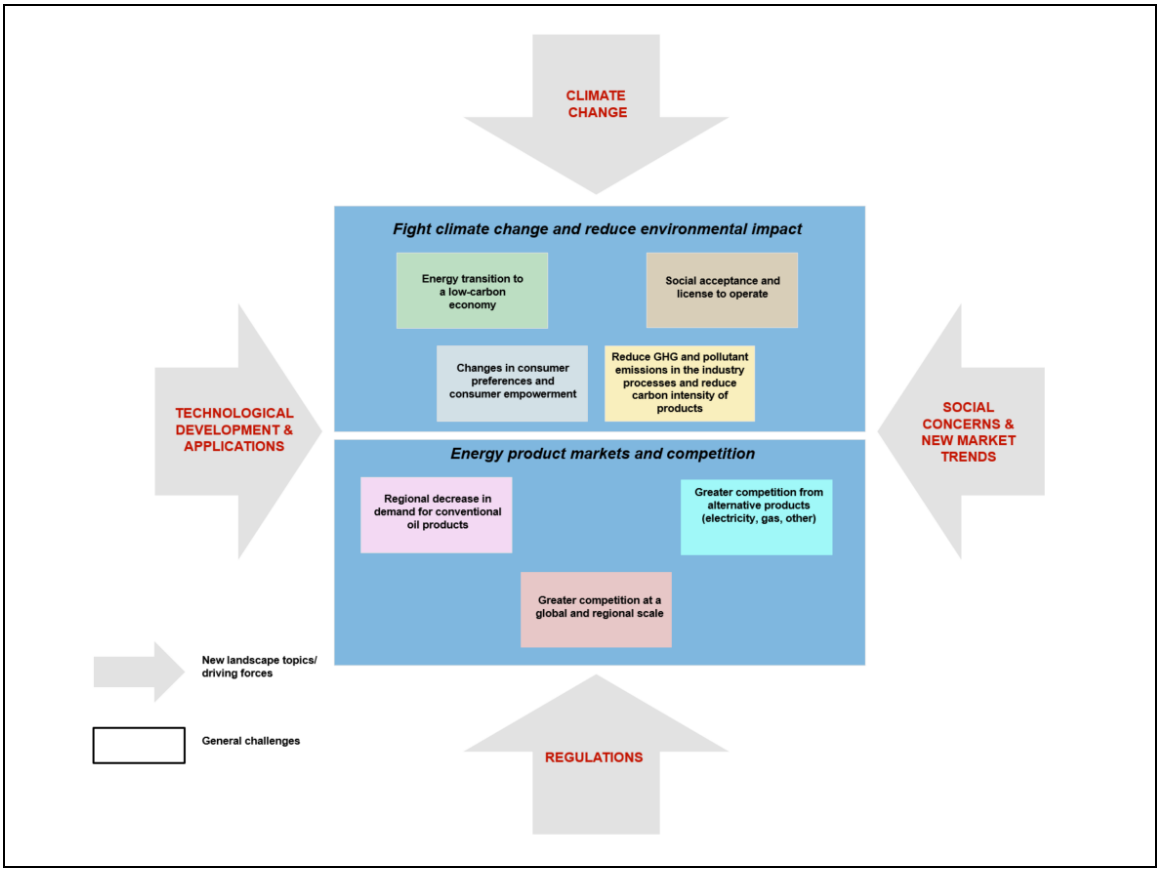
At first, we identified the new landscapes and then performed a review along the value chain (E&P and refining). The study has been able to identify some aspects of future investment decisions, future supply and demand, and some strategic priorities for the players in the refining industry. Subsequently, it is the right time to address issues regarding general challenges, strategies and specific responses.

To do so, it is convenient to summarize the new landscape topics, which are shown for illustrative purposes in the following figure.

This figure displays the general challenges that are found in this document. Namely, 'Energy transition to a low-carbon economy', 'Social acceptance and license to operate', 'Changes in consumer preferences and consumer empowerment' and 'Reduce GHG and pollutant emissions in the industry processes and reduce the carbon intensity of products'. There are also three more challenges: 'Regional decrease in demand for conventional oil products', 'Greater competition from alternative products' and 'Greater competition at a global and regional scale'.

These general challenges can, in turn, be classified into two main blocks. The first block refers to general challenges and strategies - fighting climate change and reducing environmental impact - and to social trends, whether of a general nature or in consumer preferences. The second block is basically related to energy product markets and competition (at a global or regional scale, from new entrants or new products).

New landscape driving topics and general challenges



Source: own elaboration.

The main advantage of identifying seven general challenges and classifying them into two main blocks is that it allows us to think about it and visualize which broad or general strategies the industry might react to. As it can be seen in the table above, four general strategies are identified in response to the challenges in the first block: 'Enter and/or reinforce activities in the gas value chain', 'Enter and/or reinforce activities in renewable energies (electricity, transportation, buildings)', 'Approach and/or reinforce to converge with utilities towards energy companies' and 'Reinforce integration and accelerate implementation of ICT and digitalization in all business operations from upstream to retail'. At the risk of oversimplification, it could be said that the strategies mentioned refer to developing companies that look at energy in an integrated way, considering non-traditional products or energies from the oil industry, and that at the same time reinforce activities in the value chain.

In the second block of challenges, which are mainly related to energy product markets and competition, the general strategy regards a traditional approach to improving economic performance, and considering company size is consistent with a global market and greater competition. Here, the strategy of ICT and digitalization is also considered to be relevant. In short, three general strategies are included in this second block: 'Improve performance, results and ROA-ROCE, by maximizing value creation along the O&G value chain (full vertical integration or "governance") and developing new products', 'Evolve to be a relevant player at a global or regional scale' and 'Efficient implementation of ICT and new technologies through the O&G chain'.

General challenges and general strategies

General challenges	General strategies[1]
Fight climate change and reduce environmental impact	
• Energy transition to a low-carbon economy • Social acceptance and license to operate • Changes in consumer preferences and consumer empowerment • Reduction of GHG and pollutant emissions in industry operations and carbon-intensity products	• Enter and/or reinforce activities in the gas and electricity value chain • Enter and/or reinforce activities in renewable energies (electricity, transport, buildings) • Approach and/or reinforce activities, in order to converge with utilities towards energy companies • Reinforce integration and accelerate implementation of ICT in all business operations, from upstream to retail
Energy product markets and competition	
• Regional decrease in demand for conventional fuel oil • Greater competition at a global and regional scale • Greater competition from alternative energy products	• Improve performance results, ROA-ROCE, by maximizing value creation along the O&G value chain (full vertical integration or governance) and developing new market-demanded products[2] • Evolve to be a relevant player at a global or regional scale • Implement ICT and new technologies efficiently through the O&G chain

Source: own elaboration.

Specific challenges, specific responses and business models

For each of the general challenges, one general response or general strategy has been identified in this document. Thereafter, in Section 3.2, each of the general challenges has been further analysed and broken down into several more in-depth challenges, also referred as specific challenges.

Whilst the general challenges will certainly effect each and every type of player within the O&G industry (outlined below) to some extent, the type of player will be critical when addressing the more detailed specific challenges and their relevant specific responses.

One important issue related to the general strategies has to do with business models. In this regard, the most important players - according to their type of player in the industry- are the following: a) major international oil companies (IOC), b) national oil companies (NOC), c) independent companies in E&P, d) refiners and petrochemical,

[1] These strategies may be developed by organic growth or M&A.

[2] For instance, distributed resources, energy efficiency, energy networks, and petrochemicals.

e) midstream operators, f) specialized service companies, g) new entrants, h) specialized technology or new product companies.

In all cases, several objectives may be considered: 1) increase profitability and improve return on assets, 2) maintain market share, 3) reinforce core businesses, 4) reinforce the O&G value chain and 5) create/develop new businesses.

Taking into account the abovementioned objectives, the following types of business models may be suggested by the identified players.

Players, business models and main objectives

Type of player	Type of business model	Main objectives
Major IOCs	- Reinforce control of the core business along the value chain and integrate operations - Expand business activity, fitting the main activity[3] - Expand business towards diversifying the energy mix offer (utilities), becoming global energy companies	1, 2, 3, 4, 5
NOCs[4]	- Reinforce control of the core business along the value chain and integrate operations - E&P and refining in existing local markets - Increase corporate activities - Expand business activity, fitting the main activity - Expand business towards diversifying the energy mix offer (utilities), becoming global energy companies	1, 2, 3
Independent companies in E&P	- Acquisitions: fields and companies in E&P – Specialization in types of upstream play or region exploited - Expand business activity, fitting the main activity	1, 2, 3
Refiners/Petchem.	- Refinery conversion investments - Expansion in other geographies - Expand business activity, fitting the main activity and diversification	1, 2, 5
Midstream operators	- Internationalization, new geographies -Integration of transportation and distribution businesses	2, 3

(cont.)

[3] This also applies to some NOCs.

[4] Including previous NOCs that were later privatized (such as Gazprom).

Players, business models and main objectives (cont.)

Type of player	Type of business model	Main objectives
Specialized service companies[5] (cont.)	- Specialization and diversification - Integration by M&A	2, 3, 5
Specialized technology and/or new product companies	- Create and develop products that increase added-value to those existent in the market	2, 3, 5
New entrants (Private Equity) and trading houses	- Refining business	1, 5

Source: own elaboration.

[5] This does not include pure EPC players.

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OBJECTIVE AND SCOPE OF THE STUDY

Oil and gas are essential energy sources, used as fuel for transportation and in the production of basic chemicals, among numerous other purposes. As the global population rapidly increases, global energy consumption must have to increase, In spite of the great advances in alternative energies, which are increasing their contribution to the energy mix, the evolution in previous decades indicate that the actual total oil and gas demand will also most certainly increase in the years to come.

Since the beginning of the commercialized oil and gas (O&G) era, the industry has constantly evolved to adjust to the external factors of the outside world needs. Combined with the intricate dynamics between the internal segments of the industry, often referred to as the Upstream, Midstream, and Downstream, the O&G industry displays complex trends. The end-to-end process of the location of petroleum resources, extraction, transportation to market, and ultimately the sale to the customer, has seen technical advances and environmental complications, and even influenced political events. Highlighted by challenges presented as a result of the decay of oil prices in recent years, many experts believe the industry is at a pivotal point, with toughest challenges and the need for transformation ahead.

Oil and gas prices and uncertainty in the main global markets, are likely to have a profound effect on the decisions made by O&G companies regarding exploration, appraisal development and operations. In addition to commodity prices, there has been increasing volatility in the relationships between industry, government policy makers and communities.

Hence, the general object of this study will consist of analyzing the evolution of the industry within the new landscape and assess the challenges and strategies in response to them that de O&G industry must have to face in the coming years. In addition, this is complemented by a description of the value chain operations and market aspects as support and comprehension facilitator In summary, this document presents the in-depth strategic-focused conclusions that can be made from critically reviewing the current value chain.

In this document, Chapter 1 first analyzes the new landscape and challenges that O&G companies are facing in respect to the four subject areas that has been considered to conform the new landscape: climate change policies and challenges, social concerns and new market trends, technological developments and applications, and regulations. Within each of these categories, a number of key developments and trends have been defined and described, along with the multiple challenges and decisions that industry players shall face.

The dynamics of demand and supply are discussed in Chapter 2, along with the future uncertainties and factors that will have a profound effect on this balance. Within this chapter, the evolution of investments in E&P is also discussed, leading on to aspects of investments with regards to refining, and subsequently portfolio management.

As a kind of conclusion, Chapter 3 pairs the new landscape issues identified in Chapter 1, with seven general challenges and related strategies for the industry. Furthermore, a second level of challenge and response granularity has been identified, which companies shall address in order to remain competitive in the new era of O&G industry. These two chapters, which deal with the strategic responses and business models, should be read jointly, as they try to look at the current situation - and future perspectives of the O&G industry, and how industry players may respond with different strategies, be they of a general or a more specific nature.

1. NEW LANDSCAPE AND CHALLENGES OF THE OIL INDUSTRY

There are several issues that are considered to be part of the new landscape for the oil industry. They are identified and examined in this chapter and have been grouped into the following categories: climate change policies and transition to a low-carbon economy, social concerns and new market trends, technological development and applications, and regulations.

Within each of these categories, several challenges associated have been identified and reflected in Table 1.

TABLE 1. New landscape

1.1 Climate change policies and transition to a low-carbon economy	1.2 Social concerns and new market trends	1.3 Technological developments and applications	1.4 Regulations
• Climate change policies and legislation • Energy transition to a low-carbon economy	• Renewables • New approaches to mobility • Energy efficiency • Change in consumer preferences and consumer empowerment • Peak oil demand • Security of supply, ensuring supply under disruption • Security and protection of critical infrastructures • New global markets	• Carbon capture and storage • Information and communication technologies (ICT) • Catalyst technologies • Vehicle technology	• Environmental legislation • Ecosystem protection • Product regulations • Safety risk analysis • Waste management • Transportation safety • Monitoring, reporting and compliance

Source: own elaboration.

In addition, how, and to what extent, the new landscape develops differs greatly by geographic region, and often by the politics associated with that area are revised in this chapter. After the new landscape and the related categories are revised and discussed from a global perspective throughout this chapter, a summary of the challenges dealing with the main categories are provided at the end of each section.

These challenges will be revisited again in Chapter 3, where an analysis of the challenges are performed along with their associated strategic responses.

1.1. Climate change policies and transition to a low-carbon economy

1.1.1. Climate change policies

Climate change resulting from the contribution of human-made greenhouse gas (GHG) emissions has now obtained an almost complete consensus from the scientific community. Two facts provide evidence supporting the idea that the climate is changing: 1) the Earth's 2015 surface temperatures were the warmest since modern record-keeping began in 1880, and 2) the highest ever ocean heat content was recorded that same year. This issue is increasingly important, given that GHGs are being emitted at a higher rate than the earth carbon sinks can capture, resulting in significant risks in the foreseeable future. Some resulting impacts that are thought to be closely related have already been witnessed, including sea level rise, loss of biodiversity and extreme weather events. This challenge needs to be addressed globally and, for this reason, the United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992, as an international cooperation framework to fight climate change by limiting the global temperature increase, and to mitigate and deal with any inevitable impacts. Under this umbrella framework, at the 21st Conference of the Parties (COP 21), held in Paris in 2015, global leaders committed their nations to keeping the global temperature increase well below 2°C above the temperature from pre-industrial times, thus reaching the most ambitious agreement since the signing of the Kyoto Protocol in 1997.

The COP 21 received a lot of media coverage, and was deemed a success for a number of groups, including: a) governments - the Paris Agreement was adopted and carries legal force (although not all parts of it are binding), in addition other bilateral financial agreements were reached during the conference, including pledges to the Green Climate Fund and to the Least Developed Countries Fund, among others; b) investors and companies - providing a long-term and more stable framework for investors; since having reached a common agreement, it provides a clear indicator that the transition to a low-carbon economy is underway, and that governments intend to support the process; and c) NGOs and civil society – the mention of a 1.5°C goal was unexpected, and there were also mentions of food security and humanitarian concerns.

The Paris Agreement made it a legal obligation for those who signed and ratified it to submit emission-reduction targets: a) each Party shall prepare, communicate and maintain successive Intended Nationally Determined Contributions (INDC) that it intends to achieve, and b) each Party shall communicate its nationally determined contribution (NDC) every five years. The commitments made in the INDCs themselves are not legally binding, but more a statement of intent.

TABLE 2. Mitigation targets of major global emitters

Country	Pledge	Target year	Base year	Long-term pledge
China	Peak	2030	n.a.	None
USA	26-28%	2025	2005	Reductions of 80% or more by 2050
EU	40%	2030	1990	Reduce emissions by 80-95% by 2050 from 1990
India	n.a.	2030	2005	None
Russia	25-30%	2030	1990	2030 target is a stepping stone for long-term objective
Japan	26%	2030	2013	None
Brazil	37%	2025	2005	None
Indonesia	29%	2030	BAU	None
Mexico	25%	2030	BAU	Reduce 50% of emissions by 2050 from 2000
Iran	4%	2030	BAU	None
Canada	30%	2030	2005	None
South Korea	37%	2030	BAU	None
Australia	26-28%	2030	2005	None
Saudi Arabia	n.a.	2030	n.a.	Reduce 130 million tonnes of CO_2 a year by 2030

Source: own elaboration.

The COP 21 confirmed the EU's intentions to reducing GHG emissions, as the commitment set a new goal: a 40% reduction in the levels of GHG emissions by 2030, as compared to 1990 level, and aiming to achieve a reduction of 80-95% by 2050 (vs. 1990 levels). Hence, the emissions cap that it is set by the ETS shall be reduced, and consequently, the price of emission permits shall increase (emission permits - allowances - are freely quoted in the market exchange, in a similar way to a company's shares, with a price based on supply/demand balance). Data from 2016 sets GHG emissions in the EU-28 down by 23% (an absolute reduction of 1,255 million tonnes of CO_2-equivalents) compared to 1990 levels - on track to exceed its 2020 target.

In the United States, the California Air Resources Board (CARB) has ongoing initiatives, known as Reducing Air Pollution Programs (ARB Programs) – these comprise 20 application areas (for example: Climate Change, Fuels, Particulate Matter (PM), Smoke Management, Toxics, Vapor Recovery). The Climate Change Programs aim at reductions of approximately 30% and 80% in GHG emissions, by 2020 and 2050, respectively, compared to 1990 levels.

The general trend of these Climate Change policies leads to regulations for controlling the usage of fossil fuels and encouraging a transition towards renewable or lower-carbon energy sources. It is clear to see that both drivers will negatively impact the suppliers of oil and gas products, the refining industry and the O&G industry in general. Furthermore, the future adoption and implementation of new regulations is inevitable, and O&G companies need to develop strategies so that they are best positioned to withstand these changing legal and market conditions, adopting strategic responses discussed in Chapter 3, such as adjusting processes to increase energy efficiency, process integration and inventory optimization, reducing fuels and other products carbon footprint and fostering carbon capture and storage.

With the transportation sector representing 14% of annual global GHG emissions, and the petrochemical and refining sectors contributing around 4% per year, O&G companies are being challenged to address their role in climate change, and are experiencing increasing difficulty in obtaining licenses to operate due to social acceptance aspects, among other reasons. While in the past, as long as an O&G project was shown to be technically feasible, it would have been permitted; however, this is no longer the case, since public participation in environmental decision-making has gained importance. The O&G industry also faces competition from the lower-carbon energies, where a larger contribution of renewables can be reached, that become more attractive with regard to climate change.

O&G companies are operating in a far more complex environment today and facing more varied stakeholders and demands. While in the past the state was the main stakeholder counterparty for many O&G companies, today these companies have the state and local stakeholders (i.e. media, non-governmental organizations) as well. This shift is explained by the fact that government institutional capacity is diminishing, and this forces societies of producing states to look directly to International Oil Companies (IOCs) to fill the financial and welfare provision gaps. Subsequently, this stakeholder mutation has increased the cost and the way of doing business for O&G companies, creating additional threats to value.

1.1.2. Energy Transition to a low-carbon economy

Historically, energy transitions have been understood to be changes in primary energy supply and final energy demand over time, as considered in the book *Energy Transitions: History, Requirements, Prospects* (Smil, 2010).

These transitions have been quite different, depending on each country and historical moment. In any case, a combination of prices, technologies and consumer needs were conforming the changes, and the pace of those changes. Nowadays, the policies fighting climate change, which differ by country and region, have the aim of moving towards energy systems that are lower in carbon content and in GHG emissions. Analyses carried out by different institutions and experts have shown that the challenge is on such a large scale that, recognizing the relevance of energy supply and consumption in GHG emissions, it should not be possible to achieve the targets set, if the approach does not also focus on the economy and the society as a whole. That is to say, it is necessary to address changes, not only in the electricity generation and in the primary energy mix and the structure of the final energy demand by the different sectors (i.e. industry, buildings, transportation, etc.).

Therefore, it can be said that one of the main issues in the new landscape is the energy transition to a low-carbon (low GHG emissions) economy, in such a way that the emphasis is on changing the energy mix structure and the economy as a whole (i.e. goods demand, recyclability, energy from wastes, etc.)

As several sections of this Chapter 1 explain, the policies put in place and their implementation are different, depending on countries and regions. All in all, a common denominator is clear: the trend will be towards more contribution of renewables in the primary energy mix and of fossil fuels, in particular of those with higher carbon content.

Therefore, as a consequence of the various issues identified here in the “new landscape,” one clear challenge for society as whole is to be part of the energy transition to a low-carbon economy.

1.1.3. Challenges related to climate change policies, and transition to a low-carbon economy

O&G companies must be selective about the projects they plan to develop, by addressing the entire value chain efficiency increase they provide, in order to reduce the carbon intensity of fuels to be produced. Companies are starting to be challenged from a financial perspective, to invest in schemes and technologies, which promote the reduction of GHG emissions. On that note, it is also worth mentioning that companies must also engage in discussions with governments, to ensure that their production and environmental policy are aligned with the countries’ INDCs and other environmental regulations and requirements.

As highlighted previously, the transportation and the petrochemical and refining sectors account for 14% and 4% of global GHG emissions per year, respectively. As O&G companies are experiencing increasing difficulty in obtaining licenses to operate - it is of paramount importance that these companies take relevant measures to demonstrate to the public that they are aware of their responsibilities, not just as leaders in production of energy, but also environmental champions, contributing to lowering GHG emissions, and ensuring safer operations for people and for our planet. Companies must convince a wide range of stakeholders that O&G can play a responsible and continued role in the energy supply mix in the future.

Challenges related to the new landscape of climate change are indicated in the following table:

TABLE 3. Climate change policies and transition to a low-carbon economy	
New landscape issues	**Challenges (for industry players)**
Climate change With the Paris summit agreement, all signing countries committed to designing and developing policies to reduce carbon emissions, or their growth rate, to ensure the world temperature increase would be well below 2°C above pre-industrial times. The policies are not yet legally binding, and therefore, compliance with them is voluntary.	• Adapt the global challenge to the regional particularities, given the different degrees of adoption by country/region • Achieve the acceptance, or at least minimize the social rejection, of fossil fuels • Effectively reduce the emission intensity, throughout the entire chain, of the fuels produced • Increase the efficiency of industry operations
Energy transition to a low-carbon economy Countries are supposed to draw up and adopt policies to reach their own INDCs, among them the following: foster renewable energies, increase energy efficiency, promote activities that demand less energy and alternative energies (lower in emission intensity), set taxes for GHG emissions, regulate new developments for oil production and refining installations, etc.	• Apply carbon capture and storage, and CO_2 transportation for enhanced oil production and/or underground storage of CO_2 • Ensure required investments to reduce GHG emissions are put in place • Find ways to reduce their energy products' emission intensities, such as: promoting conversion and blending • Develop and implement ways to produce cleaner energies and fuels

Source: own elaboration.

1.2. Social concerns and new market trends

1.2.1. New landscape issues

Renewables

a. Europe

On November 30, 2016 the European Commission published its proposal to recast Renewable Energy Directive 2009/28/EC (RED I) with a new directive known as RED II, not yet in force.

The goal of RED II is to build upon the RED I directive's goal of reducing greenhouse gas emissions, by setting forth a mandate on renewable energy contribution to final energy use, for the period from 2020 to 2030. After June 14th, 2018 council meeting it was agreed that the RED II proposal will set a new renewable energy binding target for the EU of 32% of the final energy that is consumed and an upwards revision clause by 2023.

The proposal sets out mandates for increasing renewable energy use in three sectors: electricity (RES-E), heating and cooling (RES-H&C) and transportation (RES-T). In this regard, to help meet targets, it is proposed that several support schemes, subsidies, loans, favorable tax regulations, etc., can be applied.

The impacts of RED II implementation vary across the O&G sector: a) refiners will be negatively impacted by RED II and its promotion of renewable fuels, since it establishes the following new mandates for 2030: 1) a minimum contribution target of 6,8% for advanced biofuels, renewable fuels from non-biological origin, waste based biofuels and renewable electricity in the total amount of transport fuels consumed in a calendar year and 2) a maximum contribution of 3,8% of liquid biofuels, produced from food and feed crops, in transport fuels

O&G producers will be negatively impacted, due to: 1) the effort to maximize the share of renewables, including gas and electricity in the transport energy mix, 2) conventional biofuels from food and feed crops currently account for approximately 5% of EU transportation fuel consumption, while the implementation of RED II aims to limit it to maximum 3,8% and 3) the target for renewable energy contribution in transport energy will be set by each Member State within its National Renewable Energy Action Plan, which at least shall comply with the national contribution figure set in the directive for the respective Member State.

Alternative energy vehicle manufacturers will benefit from the implementation of RED II as the directive: 1) indirectly promotes the use of renewable electricity in transportation if the difference between total renewables (6,8%) and advance biological fuels (3,8%) established minimums is considered; 2) sets a minimum level of consumption for advanced biofuel and renewable liquid and gas fuels producers

b. United States

The Renewable Fuel Standard (RFS) program was established as part of the Energy Policy Act of 2005, and this program mandated biofuel volumes for 2006 and 2007. The Energy Independence and Security Act of 2007 (EISA) expanded the biofuel mandate volumes (now referred to as RFS2) and extended the date through 2022.

RFS2 divides the renewable fuel requirement into four separate, but nested, categories, based on their greenhouse gas (GHG) emission reduction: total renewable fuels, advanced biofuels, biomass-based diesel, cellulosic biofuels.

The Renewable Identification Numbers (RINs) are how the EPA ensures compliance with RFS2. These are generated when a biofuel is produced by a renewable fuel producer, and they are assigned to that batch of fuel. Assigned RINs can then be separated by blenders, and subsequently sold to obligated parties, such as fuel refiners and importers. Obligated parties that purchase separated RINs to fulfill the Renewable Volume Obligation (RVO) then retire the RINs to meet compliance. Refiners and importers of gasoline or diesel, under the Clean Air Act, are obligated to participate in the RIN market, by buying RINs from renewable fuel producers, if they do not have blending capabilities. Independent refiners are calling for the EPA to shift the point of obligation (POO) of RFS2 compliance further downstream from the refineries, with the goal of reducing the billions of dollars that the said independent refiners spend on compliance.

c. Asia

Asian countries are also incentivizing the development of a renewable energy sector, by setting targets and implementing policy. The ASEAN (Association of Southeast Asian Nations) established a collective target of securing 23% of its primary energy from renewable sources by 2025. All Southeast Asian countries adopted medium- and long-term renewable energy targets, and officially joined the Paris Agreement, committing to GHG reduction targets.

Environmental protection and climate change mitigation are a key driver. Most countries in the region have set energy-efficiency targets, with varying scopes, time frames and objectives. Additionally, energy security is another driver for scaling up renewable energy.

Focusing on increasing renewable energy in the Power, Heating and Cooling, Cooking and Transportation sectors, Southeast Asia has been implementing policies at different levels, and through different instruments: a) national policy, b) tax incentives, c) grid access, d) regulatory instruments, and e) other.

From the efforts towards renewable supporting schemes, there are several pros and cons that can be found listed in Figure 1.

This is worth mentioning, as challenges to the O&G industry in relation to renewables include: a) facing decreased demand for oil products, as a consequence of the irruption of alternative energy sources, b) embracing renewables as part of the value offering of a traditional O&G player, c) contributing to the design development of production facilities for these biofuels (bio-refining process) and d) adapting retail stations to new fuels, or creating new supply points.

FIGURE 1. Pros and cons of renewable support schemes

	Auctions	Feed-in tariff	Mandates/quota system	Green certificates	Net metering
?	System that sets a target of renewable capacity, allocating contracts to the lowest bidders	Dedicated long-term tariff that covers the overcost associated with renewable production	Minimum shares of renewable energy in the mix of utilities	Tradable renewable certificates that create a revenue stream for the RES operators	End users offset retail electricity purchases using output from own generation
	Increase in the cost-effectiveness of renewable support Local content requirements develop the local renewable industry	Quick investment stimulation in immature markets Potential to promote a certain technology over the rest	Clear objective to fulfill Project funding without compromising budgets from Governments	High compatibility with competitive price determination	Gains in efficiency associated with on-site consumption Avoiding losses in energy production (grid as a storage system)
	If the auction is not well designed, it could become uncompetitive Certain risk of uncompleted projects	Difficulties in setting the right tariff, exposure to overpaying Risk of creating artificial market imbalances	Potentially higher near-term electricity supply costs Centrally planned/mandated, and not market-based	Rise in electricity prices as generators pass through certificate costs Only the most cost-effective technologies are supported Increase in certificates near zero, due to an oversupply of renewables	Higher network costs associated Minority in taxes due to lower electricity consumption In developed systems, the same grid costs must be paid by fewer consumers

Source: The Boston Consulting Group.

New approaches to mobility

The trends in mobility are changing rapidly. The complex issues of mobility trends may be explained by aspects such as: social trends, technological, economic, competition and environmental. At the risk of simplifying, within social trends, it can be observed that is taking place a shift from consumers who meet their own mobility needs, individually, by owning a vehicle, to a situation in which the mobility needs is satisfied by public transportation or vehicle sharing. Though not predominant so far, this trend is gaining relevance, and it would not be surprising if it turned out to be the preferred way of meeting mobility needs in the future. Such a trend can certainly not be considered universally valid, but it is currently clear in some European countries.

This trend, however, must be put into the framework of a more holistic view of future mobility. In this regard, urbanization and infrastructure design will also become more relevant, as they should be taken into consideration to provide future mobility solutions.

Technology is also changing mobility; for instance, the incorporation of information and communication technologies (ICT) will not only allow improving safety[6], but also facilitate route optimization and car sharing, which in turn, can improve energy efficiency (less consumption/passenger-kilometer). These types of improvements, "ceteris paribus," will drive decreasing fuel demand.

Economic aspects will affect the feasibility of implementation of new technologies, and therefore, must accompany the penetration and development of ICT and "alternative energies" in transport, such as electricity, gas or advance biofuels

Competition, whether promoted by the market or by political policies, will also be a factor that may be decisive in influencing or determining the future demand of O&G fuels. It will be key in the success of alternative fuels (electricity, natural gas, biofuels or liquefied petroleum gases (LPG)). Competition could also result in an increase in energy consumption efficiency and, furthermore, competition will entail, not only new entrants, but also changes in the strategies of the incumbents.

Last, but not least, are the environmental aspects embedded in current and new regulations, which are addressed in detail in several sections of this document. Regulations have numerous, and in some cases very profound, effects on mobility trends and, in turn, on O&G industry, like the CAFE standards in the USA or average emission limits for car manufacturers in the EU. Additionally, the recent Directive on Alternative Fuel Infrastructures (DAFI) will inevitably imply more electric vehicles, and more gas (natural, biogas and LPG) in the transportation sector, as a consequence of further developments of related infrastructures. This will affect the O&G industry,

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[6] Safety will imply the design and automation of vehicles, implementing the relating solutions, and incorporating information and communication technologies into the infrastructures, as well as the necessary connectivity among vehicles and between vehicles and infrastructure.

not only in fuel demand, but also in the way customers are identified and their needs are met.

Also within environmental regulations, the new rules on sulfur emission control, particularly within EU waters, are already affecting passenger transport ships, and therefore will subsequently have a negative impact on demand of high sulfur marine bunkers.

Hence, a variety of factors or aspects, ranging from social to technological to economic, are currently affecting, and will affect even more deeply, the mobility of the future. All in all, these aspects will imply that there will be lower global demand for oil fuels.

Many mobility trends will have implications that cannot yet be identified or assessed in detail. The main challenge for oil incumbents, from exploration and production, to refining and marketing, shall be the continuous scouting of trends, and ideally, a flexible and quick response. In Chapter 3, some strategic responses to this issue will be addressed.

Energy efficiency and consumption-related targets

Around the world, in different geographies, nations are aligning and devoting efforts towards sustainability by setting efficiency targets, monitoring and auditing, and creating financing programs for energy efficiency increase, in the production of electricity and other final energy products, and in energy use in buildings and in the industry and transportation sectors. A summary of related targets for the EU, the US, Japan, China and Brazil, may be viewed in Table 4.

TABLE 4. Global energy efficiency and consumption-related targets

Nation	Energy efficiency-related targets
	Increase energy efficiency 20% as reduction in primary energy consumption by 2020 vs. business-as-usual scenario Increase energy efficiency 32.5% as reduction in primary energy consumption by 2030 vs. business-as-usual scenario
	Doubling energy productivity by 2030
	17% reduction in electricity supply by 2030
	15% improvement in energy efficiency by 2020
	10% increase in energy efficiency by 2030

Source: own elaboration.

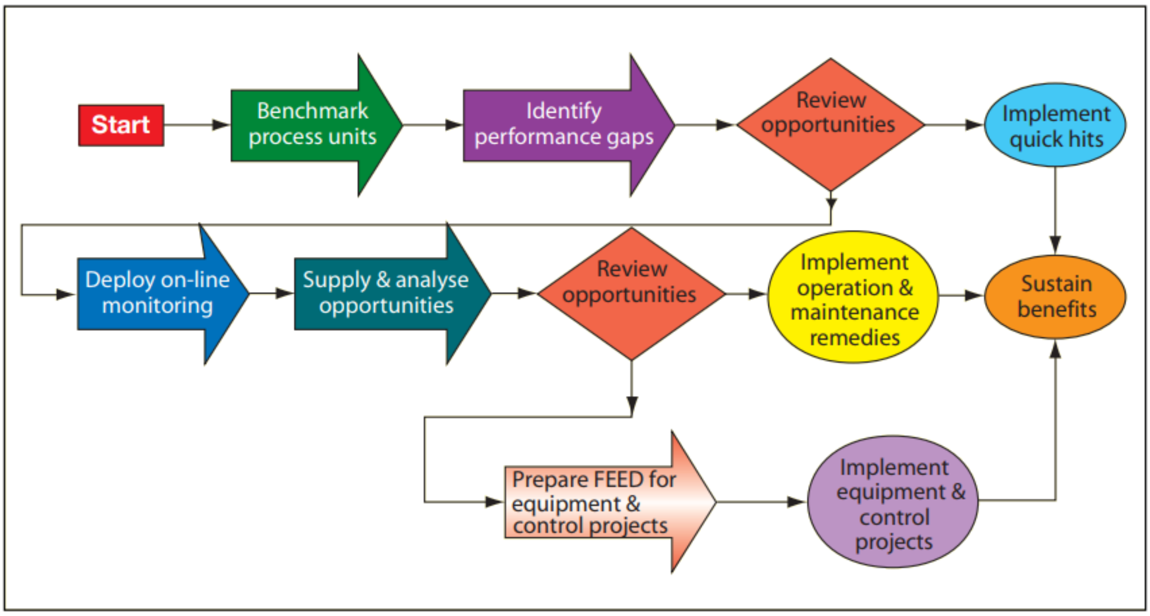
Strong drivers are pushing energy efficiency (EE) globally, among them the following: a) technology; materials and systems innovation are ahead of the adoption curve, pushing down prices and increasing efficiency of new technologies, b) transparency;

technological solutions increase the ability to monitor and benchmark energy-demand data in real time, increasing the ability to intervene and to measure success, c) industry professionalization; with several EE markets (especially in the EU) starting to mature, increasing available financing and the ability of players to tap existing market potential while decreasing customer reluctance and d) political drive; with regulators around the world (particularly in Europe) introducing policies to improve EE and promote investments in public sectors. Energy efficiency improvement is then fostering technological developments and new business models.

In the O&G sector, improving energy efficiency under climate change policies (mentioned in previous paragraphs) surges with both opportunities and challenges.

Principal challenges include managing the need for investment and the switch to consuming alternative cleaner energy sources or enhanced specs products. One example of such opportunity was mentioned at the EU Refining Forum in Brussels (December 1, 2017). During this expert meeting, Eurobitumen stated that, "Low rolling resistance road surfaces can reduce fuel consumption and emissions by up to 6%."

FIGURE 2. Energy efficiency – work process methodology



Source: UOP/Honeywell.

Figure 2 proposes a roadmap to foster energy efficiency and GHG emissions initiatives, by adopting a comprehensive energy-management program (in the EU, these energy-efficiency programs are a requirement of the IPPC Directive). Recent studies indicate that typical possible benefits can range from a 12% to 25% energy reduction for refineries operating in the fourth quartile of energy efficiency.[7]

Changes in consumer preferences and consumer empowerment

As it was discussed above, all the big issues considered in the "new landscape" – namely, climate change, social concerns and market trends, technological developments and regulation – are going to influence consumer demand in the future.

Although this is not the place to analyze in detail how these former big issues of the new landscape will affect consumer demand, several issues are identified and explained in the different sections of this chapter. The variety of issues and the quite different types of intermediate and final consumers will imply multiple different changes in what consumers need and want. Some examples may be sufficient to illustrate this such as: the desire for products that have less GHG intensity, emission regulations that impose stricter product quality in terms of less impact on the environment, or that lead to decreasing consumption or abandoning certain energy sources, how ICTs change consumers assessing different possibilities and make purchase decisions, or how local trends in transportation (i.e. car sharing vs. property) affect fuel demand. It is currently difficult to identify all changes that are taking place nowadays, and even more difficult (and in practice, impossible) to visualize changes in future consumer needs and desires.

In this regard, a reasonable approach should be continuous scouting and market intelligence, and a philosophy of trying to anticipate and respond to changes in consumer needs and preferences.

Consumer empowerment is growingly supported by some institutions, such as the European Commission. The "idea" here is try to place the consumer at the center of decisions, and to "push" consumers to be better informed and more active. When referred as consumer empowerment, on many occasions, it particularly refers to electricity consumers and domestic consumers with a regulated tariff. In this case, consumer empowerment may also be connected to distributed electricity generation.

One future trend is the progressive penetration of electric vehicles and, therefore, of the infrastructure for electricity supply to those vehicles, which may be provided at homes, at shopping centers or at public recharging posts. The matter on how consumer empowerment could effectively be implemented in this case, will be a relevant aspect how the O&G industry will enter into the electricity supply market for electric vehicle users.

[7] Source: UOP.

Peak oil demand

In recent decades, the world has become accustomed to the steady increase in oil demand, as a primary energy source, in particular for transportation. However, efficiency gains, and the opportunity to substitute oil with other energy alternatives, are casting doubts on continued demand growth in developed countries, which up until now, have been the largest consumers. While it is true that peak oil has been, or will be, reached in the future in some geographical areas (the European peak achieved in the early 1990s), it is not evident when this will happen on a global basis. Current predictions of peak oil demand range from 2020 to the mid-2040s, based on different assumptions regarding the main drivers, such as the penetration rate of alternative fuel and electric vehicles. In any possible scenario, three drivers will shape the nature and pace of the transition: economics, availability and sustainability. Questions that will remain important include the following: What are consumers prepared to pay? What sources can meet our needs with scale and speed? What priority is given to sustainability?

The oil industry will continue to be far from insignificant. Oil demand will continue to grow in key sectors where there are no easy substitutes, such as aviation, freight transportation and petrochemicals, which are expected to grow to a total demand of 12 million barrels per day (Mbpd) by 2040, according to the IEA. Moreover, even in a world after peak oil, there will be a need to keep developing new resources, as the decline from currently producing fields is close to 6% on an annual basis. In this sense, exploration activity is to remain important, in particular considering that conventional discoveries have recently dropped to a 70-year low, and the reduction in exploration expenditure in recent years points to a bleak outlook. While shale resources have surged in the last decade, the production from conventional fields will remain as important as ever, as they represent more than 80% of the O&G production today. In any case, it will be challenging for the O&G industry the transition from a growing to a shrinking business, making it particularly important for operators to be cost efficient.

Security of supply, ensuring supply under disruption

The security of the energy supply, at affordable prices, has been an objective for all nations. In particular for oil, this has become truly important since the oil crisis of 1973-74, which led to the establishment of the International Energy Agency and the US Strategic Petroleum Reserve (SPR), the largest stockpile of government-owned emergency crude oil reserve in the world.

The existence of eight maritime chokepoints, accountable for more than 60% of global oil transportation, makes it particularly challenging to maintain the global security of supply of oil and LNG vessels. These narrow maritime channels expose oil tankers to multiple threats, such as theft by pirates, shipping accidents and terrorist attacks, but they also are subject to political unrest and wars. The same applies to natural gas pipelines that connect exporting countries with importing regions, such as Europe, given how vulnerable these infrastructures are to attacks.

A well-recognized policy tool to alleviate supply disruptions is to maintain strategic stocks at a national level, on top of the commercial stocks that private operators keep to running their operations smoothly. Countries belonging to the IEA are mandated to hold stock levels equivalent to at least 90 days' worth of consumption, but the legal framework varies across countries. Only since the year 2000, the US SPR and the IEA have intervened in oil markets more than 10 times, several of them related to the impact of hurricanes.

Another lever that is used to balance the markets is to control demand, with two systems in place: 1) fuel switching, to temporarily replace oil use with other energy sources, whenever it is possible, and 2) imposing restraints, such as driving restrictions or car speed reduction.

Most countries will keep on depending highly on O&G imports to meet their energy needs. However, renewable energies, particularly wind, solar and biomass, are already contributing positively to diversifying supply, and reducing oil and gas import dependence.

Security and protection of critical infrastructures against terrorism and cyberattacks

Energy security is a critical issue for countries, given the high reliance on energy for the correct development of society. In this sense, the infrastructures that produce and supply energy are regarded as critical.

Terrorist organizations have always been interested in targeting O&G facilities, with the Middle East, Africa and Latin America being the most troubled regions. Many of these attacks can occur over the sea, as around 60% of the world's oil is shipped using 3,500 tankers, through a reduced number of chokepoints. Pipelines are the other relevant target for terrorists, given that they are very easily sabotaged - a simple explosive device can stop the normal operation of pipelines for weeks. Operators are taking actions to prevent terrorism from harming energy infrastructures, such as deploying advanced surveillance equipment, increasing system redundancy or deploying patrols over the air or on the ground.

Additionally, the digitalization of operations in the O&G industry has led to a notable increase in the incidence of cyberattacks, to such an extent that energy was the second-most prone industry to cyberattacks in 2016, behind the financial sector. The costs associated with the nearly 100 cyberattacks reported in 2016 are material; according to the industry certification body, DNV GL, the cost to energy and utilities averaged US$12.8 million per company each year in business and equipment damage.

New Global Markets

Oil has is a paradigmatic example of a product that is traded globally, and sold in locations far away from where it is produced. Trade, in terms of producing and exporting countries, has increased in distances and volumes transported.

However, several factors have led the global oil markets to experience changes, and they will continue to do so. Some factors may be identified as drivers of these changes:

Firstly, in the evolving nature of the global demand structure for oil products, China has exceeded the US as the world's largest consumer.

Secondly, a reduction in gasoline and gasoil consumption is forecast for Europe; other parts of the world will see the contrary, in terms of overall consumption. Furthermore, the aim of obtaining the maximum value from different types of crude oil under the new legal framework for refined products, and the development of transportation equipment, will imply changes in the structure of refineries, as can be seen in this study, resulting in a more diversified range of refined products. Therefore, changes in the market structure and specifications of oil products are likely to intensify.

Thirdly, there is the change in the geographical distribution of oil-product supply. The increase in oil production in North America, the Middle East and the Asia-Pacific region, the closing of refineries in Europe and the construction and opening of new refineries in the Middle East and Asia-Pacific, will modify trade patterns and affect markets.

Fourthly, the change in oil-producing methods will also influence the markets. A very clear example here is the production of shale oil in the United States. This affected the market, not only with regard to the trade pattern, aside from geopolitical implications, but also, and perhaps more importantly, with regard to the new relationship between value and cost.

Fifthly, it is important not to forget the relevance of the futures and derivatives markets. The size of the markets and the churn rates will most likely increase. As the volume of physical markets, despite climate change policies, is expected to grow, the volume and number of paper markets will also increase further (opening of the Chinese oil futures market), and therefore, markets are likely to experience more price differences.

Finally, it should be assumed that all of these factors will interrelate, making markets more complex. These challenges will bring more volatility and more uncertainty into the balance of supply and demand, at both regional and global levels.

In comparison with oil, the development of gas markets has been slower. National trade was by pipeline supply until the '80s (gas market liberalization in the US), international trade was through one supplier/distributer, and price based on reference to oil products.

LNG sales that began to show some relevant penetration from 2000 onwards, paved the way for subsequent regional developments. The increase in the construction and operation of liquefaction plants and regasification terminals since the decade of the 2000s, has increased the volume of LNG traded, and diversified the points of origin and destination, resulting in a greater competition with regards to pricing. Nowadays, there are more than 18 exporting countries and some more importing countries.

Though to a large extent, gas prices outside the US continue to be the result of bilateral negotiations for the purchase and sale of large volumes of gas on a long- term basis, the rising number of suppliers and volumes of international trade (pipeline and LNG), the increase in the number of LNG exporting/importing facilities, and the number of players in the gas industry, have set the foundation for the development of new types of regional markets. Additionally, the size of the United States gas market, along with the deregulations, has pioneered gas markets such as Henry Hub, in which the competition is between gas supply and demand.

Nowadays, trends in the gas market show higher intensity (liquidity and volume) and confluence of prices in the regional markets (i.e. Europe, Far East) for some spot types of trade, and various price references for different bases (Asia-Pacific, Europe), which complement the bilateral (or OTC) pricing of long-term contracts. This situation creates challenges in terms of arbitrage, and in terms of the eventual convergence of pricing in different regions, as prices with an increasing number of sources or supply are progressively better defined in terms of gas supply and demand, and less in reference to international oil prices.

1.2.2. Challenges related to social concerns and new market trends

Renewables are undoubtedly gaining an increasing share in the energy mix, and this will ultimately result in a decreasing demand for oil and gas products. The challenge here is to adapt by incorporating alternative energy sources into existing portfolios, and then by ensuring they are brought to market efficiently.

Changes in mobility trends and energy efficiency bring about new challenges, as traditional transportation fuels could be replaced by other forms of energy, such as electricity or hydrogen. As these new energies become more socially desirable and economically competitive, O&G players must find ways to remain price competitive, or perhaps make the decision to enter these new markets as well.

The biggest challenge related to energy efficiency for the O&G industry, is facing investment decisions in the sector, and decreasing activity in refineries as a result of lower demand for oil products in transportation, under “ceteris paribus” conditions.

For many years, peak oil has been a subject of discussion within the industry, and the concept brings about several challenges. Operators must ensure avoiding cost creep, while targeting more technically-difficult reservoirs to produce from. In addition, the price of oil will continue to play an important role and present problems for oil companies, as the market may begin to shrink and intensify competition, along with volatility aspects that provide uncertainty for operations.

Challenges related to supply security include finding intuitive ways to cut response time to adapt to situations of scarcity. This could be achieved by improving storage operation methodologies and making the routes to markets more flexible.

The dynamics of global markets are constantly changing, and they present a number of challenges for the industry. Companies must keep a close eye to the evolution of supply and demand. They must be aware of new policies and trends within geographic regions that lead to transition at different consumption levels or to different types of petroleum products. The process to obtain the maximum value from different types of crude oil could also lead to a more diverse range of petroleum products, and to changing marketing and sale strategies, which companies must also monitor to ensure that they stay competitive. In addition, trading and futures markets are very likely to become more complex, and this requires the correct formulation of an approach to deal with such complexity.

Challenges related to the new landscape of social concerns and market trends are indicated in the following table.

TABLE 5. Social concerns and new market trends

New landscape issues	Challenges (for industry players)
Renewables The continued interest in renewables will result in lower demand for oil and gas products	• Adapt retail stations to new fuels, or create new supply points • Face decreased demand for oil products as a consequence of the irruption of alternative energies • Commingle renewables in oil fuels as part of the value offering • Contribute to the development of production facilities for biofuels (bio-refining process)
New approaches to mobility Mobility trends are changing rapidly. Important trends in certain geographies to note include the shift from the individual ownership of vehicles to public transportation and vehicle sharing. In addition, electric vehicle penetration is beginning to develop and bring competition	• Adapt to the implementation and growth of new mobility trends • Remain competitive in final prices, as alternative energy-fueled vehicles become more cost efficient • Face increased competition in final energy demand, due to the irruption of new entrants • Adapt commercialization and marketing strategies, and modify ad hoc the refining structure

(cont.)

TABLE 5. Social concerns and new market trends (cont.)	
New landscape issues	**Challenges (for industry players)**
Energy efficiency Around the world, nations are aligning toward sustainability by increasing energy efficiency. One very prominent trend here is the shift towards a sustainable world, often by increasing electrification of economic sectors	• Gain social appreciation for the industry, due to the efforts to reduce environmental impacts • Face potential decreased activity in refineries and lower demand for oil products, under "ceteris paribus" conditions
Peak oil demand As the easy-to-recover oil reservoirs continue to dry up, projects will become more technically and financially complex Efficiency gains and the opportunity to substitute oil by other energy sources are casting doubts on continued oil demand growth in developed countries	• Continue the optimization of oil recovery in conventional fields • Maintain cost discipline throughout the value chain, in particular in E&P • Remain competitive compared to other players in the context of a shrinking market • Contribute to preventing boom-and-bust investment cycles in E&P, as a way to reduce price volatility • Adapt strategies to reduce own reserves, in the event that the demand starts decreasing • Ensure that oil products remain competitive, resulting in the delay of transition to other energy supplies
Supply security, ensuring supply when facing disruption Oil is the largest energy source on a global level. The failure of supply puts the economic development of countries and the well-being of citizens at risk. Supply security taken in a broad sense means ensuring supply availability and affordability	• Maintain crude oil and product storages capable of overcoming any global or local supply disruption • Improve oil production and/or refining to reduce costs and draw response measures to face or adapt to a scarcity situation • Guarantee affordable prices for consumers, while under pressure from alternative energy price reductions • Deliver a continuous smooth product supply, as O&G projects become larger, more hazardous and more remote
Global markets The evolving nature of the global demand structure makes that it is constantly changing, with alterations in the oil-producing methods and the geographic distribution of the of oil products supply. In addition, there is a constant need to maximize the value obtained from different types of crude oil	• Expand the portfolio of petroleum products, including petrochemicals • Remain competitive with a greater number of competitors, utilizing different marketing and sales strategies • Devise instruments to face the complexity in trading and futures coverage operations

Source: own elaboration.

1.3. Technological developments and applications

Oil companies are continually pushing their technological knowledge, in order to improve margins, reduce their environmental footprint and enhance safety. The key elements for reaching these objectives consist of increasing the efficiency, reliability and availability of production facilities, and reducing impact and waste from surface installations and production facilities. These elements can be directly applied to any one of the steps of the O&G value chain: exploration, production, transportation, refining, and distribution. They are so diverse that they offer the possibility of applying many different horizontal technologies with the ability to provide marginal value to each of the abovementioned improvement streams. The challenge for O&G companies, then, is to know not only these technologies, but also how their potential deployment in each one of the stages of the value chain, in addition to those already applied, can provide the greatest value added.

In this section, those technological developments whose application is expected to provide the greatest impact on the O&G industry in the near future will be discussed, as well as the specific challenges that their deployment poses for O&G companies.

Carbon capture and storage

As has been indicated in the first section, in the Paris climate summit agreement, and its subsequent ratification by the signatory countries of their National Determined Contributions (NDC), the global community agreed to reduce its greenhouse gas emissions to reach the global temperature target well below 2°C above pre-industrial temperatures, and to balance emissions and reductions by the second half of the century. Countries must then launch the development of regulations and other actions to reduce emissions, to comply with their NDC. These regulations and measures could impact the oil product market, and then in the medium- and long-term oil industry; they could contribute to emission reduction, an action which should be taken by the oil companies to facilitate NDC compliance, by reducing fuel-emission intensity and collaborating with its product users to do so. In either one of this two cases, carbon capture and storage (CCS) is the best technology capable of providing significant emission reductions, particularly from the use of fossil fuels in power generation and industrial processes.

CCS entails the capture of CO_2 from an anthropogenic source, transportation to a suitable place and injection into deep geological formations, such as saline and hydrocarbon-bearing formations, for permanent storage. The E&P industry is very experienced in well drilling and maintenance, and in the case of CO_2 utilization for Enhanced Oil Recovery (EOR) in producing oil from the injection area. Wells are also critical components of CCS projects, and are drilled for multiple purposes: searching suitable geological formations, CO_2 injection, monitoring and verifying injected CO_2, etc. The oil industry is then best positioned to create a large application for the CO_2 captured from power plants and other industrial installations, by fostering its utilization/storage in EOR, and at the same time, to overcome possible future restrictions in the use of oil products.

The first large-scale project to inject CO_2 into a field, for the purpose of increasing oil recovery, began in the area of Val Verde in Texas in 1972. The CO_2 for this project was initially sourced from a waste stream of CO_2 by-products from several natural gas processing facilities in the area, which had been separated from the natural gas produced, compressed and transported by a long-distance pipeline several hundred kilometers away, and injected into the Scurry Area Canyon Reef Operators Committee oilfield (SACROC). Since 1972, this project has utilized more than 140 million tons of CO_2, 80 million of which have stayed trapped in the reservoir.

This first CO_2-EOR project provided important knowledge for subsequent practices, including injection techniques, CO_2 behavior in underground reservoirs, storage rates and petroleum production rates.

Since the launch of the Val Verde project, the number of CO_2-EOR projects has continuously increased in the US. The US is the world leader in CO_2-EOR projects; there are currently more than 100 projects like SACROC in operation, as well as more than 5,000 km of CO_2 pipelines, with an increase in production yield of about 650,000 barrels/day.

Regarding CO_2 injection permits, in the US they are issued by the Environmental Protection Agency's (EPA) Underground Injection Control Program (UIC). This program issues three types of permits for CO_2 injection wells: Class II (EOR), Class V (experimental) and Class VI (geologic storage).

In the EU, CO_2 geologic storage is regulated by Directive 2009/31/EC, which permits injection and storage, while the process to select suitable injection sites corresponds to each Member State. In Europe, the commercialization of CCS has not advanced very much; however, two active CCS regional networks working to develop common trans-border solutions for the transportation and geologic storage of CO_2 have been created: The North Sea Basin Task Force (the UK, the Netherlands, Norway, Germany and Belgium) and the Baltic Sea Region CCS network (Estonia, Germany, Finland, Norway and Sweden).

Current IEAGHG (IEA Greenhouse Gas R&D Programme) activity is based on: a) evaluating GHG emission reduction technologies, b) facilitating the implementation of potential mitigation solutions, c) spreading the data and results from evaluation studies and d) facilitating the collaboration between international research, development and demonstration activities (R,D&D).

Information and Communication Technologies (ICT)

Digital technologies are widely used in the O&G industry, and have provided great advantages in design, as well as operational strategies and production optimization. However, it is the adoption and deployment of core technologies enabling the Internet of Things (IoT) – which essentially integrates sensing, communications and data analysis – that currently display the greatest opportunity within the industry.

So far, the use of digital technologies has been aimed at improving the design, reliability and optimization of operations, but the main obstacle to achieving all of their potential advantages, remains within the fragmented implementation, generally in "silos," and with applying commercial packages (commercial off-the-shelf) that were not aligned with the standards required for the exchange of information, and which therefore could not be used to respond quickly to the priorities of the company. The development of wireless sensors and remote sensing technologies is often paired with low energy transmission and communication protocols. Combining these sensors with wearable information systems and cloud computing, such digitalization, can provide additional value to the industry, and serve as a platform to create applications with potential to maximize value from all data and information available. The challenge for the oil industry in the coming years, therefore, is in creating and developing these platforms where "silos" do not exist, and which anyone can use in order to generate added value for the company.

In summary, IoT offers a great number of possibilities for the development and implementation of new applications in the O&G industry, at any stage in the value chain. A common feature of these systems is the lack of solutions with general validity that can be implemented, independently of the greater system structure, priorities and specific objectives of each company.

Digital and simulation technologies

Digital technologies provide the basic tools for maximizing efficiency and reliability, enhancing safety and minimizing the environmental impact of O&G production and treatment facilities. They are increasingly present at all stages of the O&G value chain, from the operational technologies used to locate and exploit hydrocarbon resources, to those needed for taking the hydrocarbons to the marketplace and bringing them to the final consumption market. The three major sectors of the O&G industry - upstream, midstream and downstream - can all benefit from digital technologies, by engineering simulations of their processes and operations, and by adopting computer-aided instrumentation and control technologies.

In the upstream sector, advanced simulation technology can provide a description of reservoir rocks and modelling, predict multiphase fluid flow through them for production-phase simulation, and assess the information needed for a precise design of a field development plan, and for optimizing oil extraction and production. It also enables more efficient design and engineering and maintenance operations of deep-water and surface structures and equipment.

Simulation technologies also play an important role in the downstream sector, in basic process design and analysis, and in detailed engineering design. In addition, they can be utilized in the development of virtual models of refining and distribution structures, and in maintenance operations and management of turnaround stages. In this regard, process engineering would allow: a) analysis of alternative flow schemes through thermal and computational fluid dynamics (CFD), b) equipment type definition, specifications and design, c) reaction systems and reactor simulation and design, as well as their integration in the overall scheme flow, and d) selection of the best catalyst and operating conditions for optimal production. Finally, simulation technologies allow the dynamic modelling of process units featuring plant operation conditions, which can be used for operator training, and for visualizing plant behavior under feedstock changes.

Data acquisition and validation

O&G businesses aiming to improve the reliability of their production facilities and production optimization are continually handling greater volumes of data and information, both internal and external. They must therefore plan methods and procedures for the collection, treatment and analysis of such information to be used in decision-making. Digitalization involves multiple sensors, instruments and physical equipment that are connected to each other, requiring little or no human intervention, and which can share data and information in real time. Such an exchange enables the global monitoring and integration of operations, remote configuration and optimization.

O&G production facilities include tens of thousands of intelligent elements generating and transmitting field data in real time in a continuous manner, producing an enormous volume and data flow, which must be assigned to an element in a timely manner, and validated for its use in decision-making.

The treatment of primary field data implies checking the integrity and evaluating the accuracy of the raw data, by identifying data-entry errors. It usually entails an irreversible reduction in the volume of data, by means of temporal averaging (i.e. every five minutes) or spatial averaging (i.e. data from a certain area). Data validation entails verifying whether or not a combination of values satisfies an acceptable set of combinations.

In an automated data-processing system, procedures for data treatment and validation can easily be incorporated into the basic software. The computer can be programmed to scan data values for extreme values, outliers or ranges, and to check that the values satisfy an acceptable combination. These checks can be further refined to account for time and other cyclic conditions. Questionable data values are then flagged to indicate a possible error.

Vehicle technology – improvements in combustion engines

The increasingly stringent regulations on vehicle efficiency and emissions promoted in countries such as the Member States of the EU, the US or Japan, have boosted the interest of the automotive industry in developing combustion engines equipped with ignition systems that result in the achievement of highly-efficient and low-pollutant vehicles. A promising alternative to the two conventional ignition systems – by spark ignition (SI) or by compression ignition (CI) – is the so-called homogeneous charge compression ignition (HCCI). In comparison with SI engines, HCCI engines can yield 15-30% reductions in fuel consumption, emitting lower levels of nitrogen oxides (NOx). They can also achieve thermal efficiencies that are comparable to diesel engines, with lower NOx and particulate emissions.

A homogeneous charge is reached when the composition and thermodynamic conditions of the air/fuel mixture are uniform throughout the combustion phase. In an HCCI engine, this can be achieved by premixing air and fuel, and compressing the mixture until it reaches the temperature for auto-ignition to occur. However, HCCI engines present several problems related to ignition stability that must be solved before entry into commercial production. The lack of ignition stability stems from the fact that HCCI engines are more sensitive to the ignition characteristics of the air/fuel mixture than SI and CI engines, and that limits their range of operation. Thus, at high loads and speeds, the heat release rate during compression leads to knocking, whereas at low loads, misfire could occur. For this reason, a large number of studies and testing on experimental engines has been carried out, in order to determine the ignition characteristics of the fuel, and the conditions for controlling the ignition that allow a robust introduction into the market.

Many ignition control systems have been studied and proposed for HCCI engines, including spark controlled compression ignition (SCCI), variable compression ratio (VCR) and exhaust gas recirculation (EGR), fuel composition and additives, which isolated or combined, could be used in order to have the combustion controlled on a cycle-by-cycle basis in production engines. As a result of the extensive work carried out, it was announced as the first commercial HCCI engine, for introduction into the market in 2019.

The commercial development of HCCI engines could lead to changes in fuel specifications in the future and/or cause changes in automotive-fuel consumption patterns.

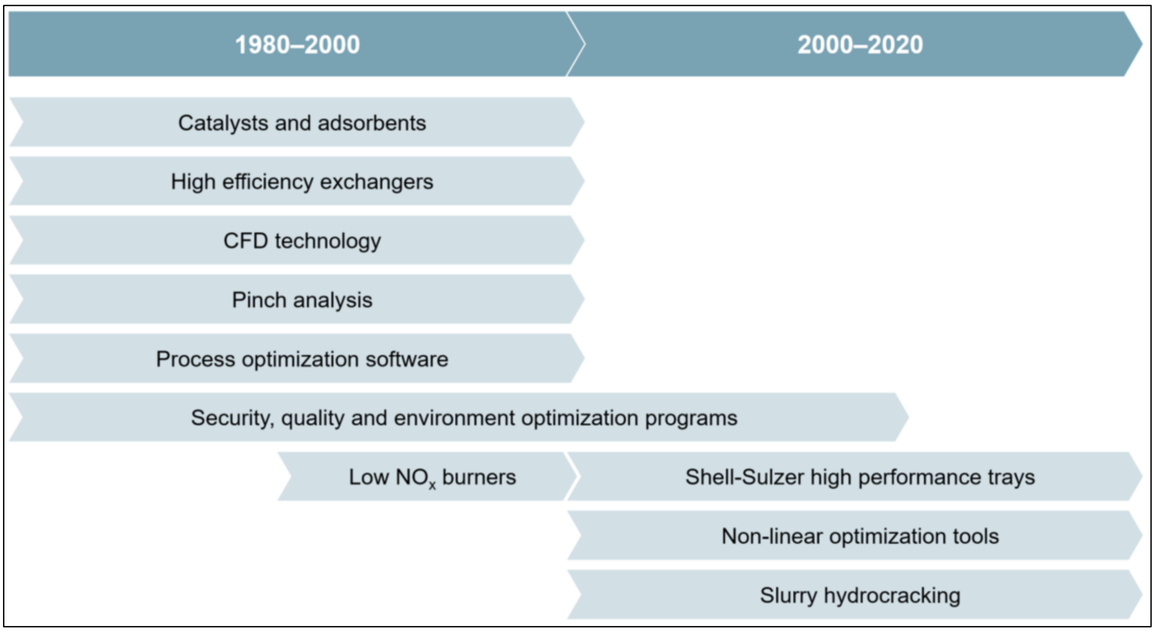
Other challenges for the O&G industry are: a) foreseeing companies' applications, together with the integration of these technologies within the operation management and business management systems, to reduce costs, minimize environmental impact, enhance safety, and improve the maintenance and availability of production installations, b) preparing implementation requests to service companies, with a clear objective to be reached and definition of how the results will be evaluated, and c) preparing knowledgeable implementation teams with their own personnel and contractors.

1.3.1. New downstream and digitalization technologies

Following the subchapter on technology, it would be appropriate to dive deeper into digitalization focusing on the refining industry.

Refining is no different from other industries in that new technologies and the digital revolution will cause disruption. For a refinery player to continue to perform well in the changing market climate, it will be needed to have a strategy whereby it is not only agile enough to analyze and incorporate new opportunities when they appear, but to be also innovative enough to foresee and play a role in the development of new technologies within the industry. This section will discuss new refining and digitalization technologies that will impact the refining landscape in the future.

FIGURE 3. Key technologies developed in the refining industry since the 1980s



Source: The Boston Consulting Group.

New production and conversion technologies

The refining industry is a very technologically-intensive business, though in recent decades, the pace of development in truly innovative production and conversion technologies has slowed down. Some new technologies have contributed to increasing efficiency within the refining industry, however, and will continue to do so in the future.

Different factors explain why game-changers aren't expected in the refining industry anytime soon:

The focus of refineries is on positioning themselves in the best scenario to deal with future market developments, and in order to do so, their best options are to focus on increasing efficiency, optimizing operating margins and capital expenditure, and capitalizing on the opportunities in new units typically stemming from increased conversion capacity by processing bottom residues (540°C+).

In reality, when looking at how much pure refining companies invest in R&D (e.g. Phillips 66, Valero, Tesoro, Enap, Saras, S-oil), around 0-2% of their earnings, the figure is very low when compared to R&D investments from chemical companies (e.g. Dow, BASF, Monsanto, Mitsubishi Chemical, DSM), which invest around 5-15%, or even pure upstream players (e.g. Statoil, ConocoPhillips, Rosneft, Anadarko), which reinvest 0-4% of their earnings on average. There are even several refinery players that do not invest anything in R&D (the same as for upstream players).

The elevated CAPEX requirements, and the uncertainty regarding the viability and effectiveness of new technologies, make investment decisions a matter of the trade-off between new and proven conversion technologies with potentially-inferior financial performance. As of now, the most relevant technologies being considered are: a) catalyst technologies, b) residue treatment units, c) gas to liquids, d) digitalization

Catalyst technologies

Catalytic reactions are becoming an increasingly fundamental part of the refining process; their contribution to refining margins is significant, along with their weight in overall refinery energy consumption. Catalyst design and development have represented the greatest technological advances of the refining industry in recent decades. In this field, the most significant advance is in the nanoengineering of catalysts for process optimization, and particularly that corresponding to hydrocracking and hydrotreating. Nanocatalyst engineering (the use of nanoparticles as the catalyst) seeks to control catalyst physicochemical properties at the nanometer scale, the key objective being to produce a catalyst with 100% selectivity, very high activity and stability, to provide high conversion efficiency, longer run times and lower energy consumption.

The research on nanocatalysts in homogeneous and heterogeneous reactions has undergone extraordinary growth in the last decade, and catalysts containing transition metal nanoparticles have been developed for hydrogenation, hydrodesulfurization and hydrocracking in heterogeneous and homogeneous reaction systems. Thus, colloidal transition metal nanoparticles have been synthesized for homogeneous catalysis, like in the case of the ENI Slurry Technology (EST) for residue upgrade, which provides a high concentration of a highly-active catalyst to maximize upgrading. The catalyst is dissolved in the residue, and fed to the reactor. After the hydroprocessing process, the catalyst is recovered, together with the asphaltenes, and recycled. Almost complete conversion to middle distillates can be obtained, with high selectivity and optimum hydrogen consumption.

The high selectivity and activity of the nanocatalyst allow achieving higher hydrogenation and conversion rates than conventional catalysts at lower pressures, and therefore, also attain lower energy consumption in hydrotreating and hydrocracking operations.

Residue treatment units

Slurry hydrocracking technology has generated high expectations, due to its impressive conversion rates (over 95%, mainly in the middle distillate range), its high-quality products and its low-to-no sensitivity to metals and CCR, which allows for a wide range of crude residues to be processed. If the initial figures are confirmed, slurry hydrocrackers could set a new standard for future investments. They currently present high risk, due to their lack of industrial experience to justify the significant investment required: around US$1 billion for a 25 kbpd unit. Companies like Eni, Honeywell UOP and KBR have committed to developing this technology, through pilots of varying relevance. An Eni EST unit and a KBR VCC unit have been in operation since 2014; the licensors claim that five UOP and four KBR units have already been licensed, and a strategic agreement has been signed between Eni and Total to develop the EST technology. If the announced yields and costs are confirmed, at today's prices the return on investment would be of over 20-30%, which results to be very attractive for refiners and could potentially alter the market dynamics in the future.

Residue FCC units can be high-margin investments, if they are propylene-focused, while this is not currently quite the case when production is focused on gasoline. These units' present limitations in the feedstock processed, since they require high-quality feedstock with low CCR or metal residues, and they also require investments in hydrotreating, in order to process the production to meeting specifications. The quality of the product is inferior to that of slurry hydrocrackers and the yield is around 85% (counting coke and fuel gas as non-converted).

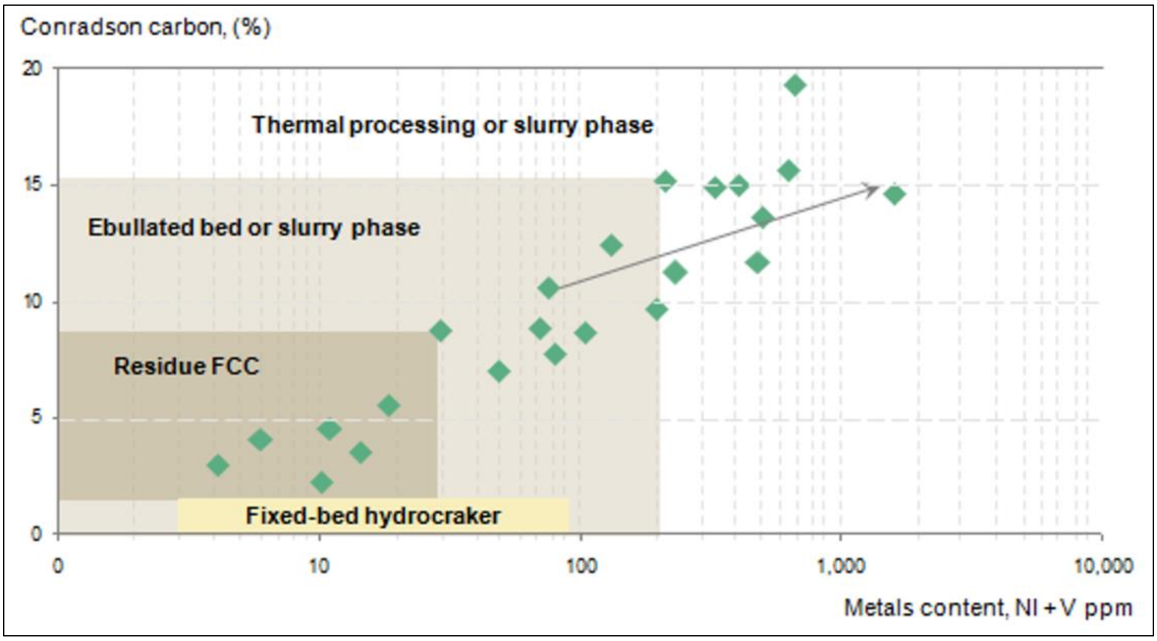
Cokers continue to be an attractive technology (typically with 65-70% conversion rates), primarily in markets that are highly-concentrated on gasoline production, and with high metal and CCR crude oils. Nonetheless, these units are the most exposed to the light-heavy price differentials, due to coke production (around 30% wt) they have suffered from relatively low return on investments in the recent market environment (2011-2014).

Ebullated bed hydrocracker is a proven technology with more than 20 industrial units in operation, and conversion rates of around 75-85%. The investment required is approximately 120% of that for a coker unit, and their ability to use bitumen as feedstock is a key profitability factor. As with residue FCC units, ebullated beds have limitations in terms of the quality of the feedstock they can process (CCR and metals).

Fix-bed residue hydrocracker is a technology with numerous industrial references (over 60), but limitations in feed quality (mostly metals), compared to the other alternatives mentioned, seem to limit its potential. Nonetheless, this technology now has a good opportunity to be used as a desulfurization unit to treat residue before it is fed into residue FCC units, since regulations on sulfur emissions and content of fuels are becoming stricter.

Residue upgrading has been, and will continue to be, a hot topic for the refining industry in the near future, in particular after the approval of the restrictions in sulfur content in marine fuels. A comparison of some parameters may be seen in Graph 1. If slurry technologies mature, and answers are provided for key questions regarding real investment costs, availability, operating stability, pitch use and industrial yields, they will change the market by offering higher returns on investment. Cokers are an old technology, but still quite profitable in highly gasoline-oriented markets, while residue FCC units are a great option for propylene-oriented refineries interconnected with a petrochemical complex.

GRAPH 1. Options in residue upgrading technologies based on CCR and metal content



Source: Hydrocarbon processing, 2011.

Digitalization in the downstream industry

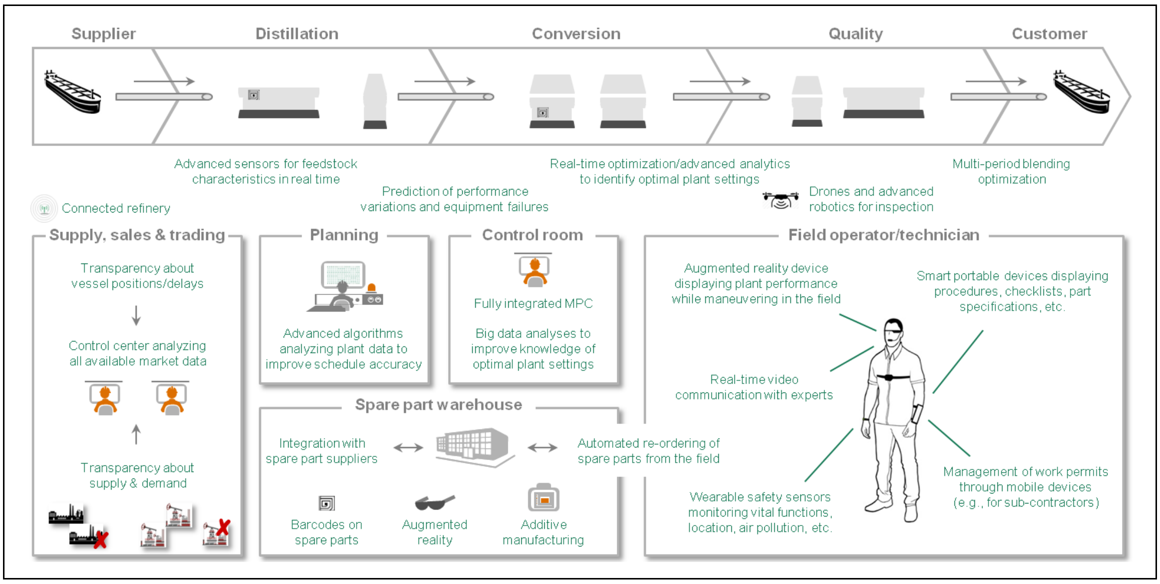
The refining industry as a very technologically-intensive business has suffered major changes over the last century, although the introduction of new technologies and digitalization has been rather slow, because it is a conservative industry. One of the most significant developments introduced was linear programming, which was developed since the 1950s and 1960s. Over the years, more complex models were introduced, enabled by the availability of increasing computational power. Another important development, which started to be implemented during the 1980s, was digital instrumentation and control, which allowed extensive data logging, storage, treatment and the implementation of advanced control algorithms.

Refining companies have shown growing interest in digital technologies, due the operational benefits they provide, while being cautious about their implementation. Companies have a solid foundation on process technology application, with a broad range of process optimization. Compared with process technology, digital technology is less mature regarding asset management and maintenance, since equipment has to be designed and constructed to allow data acquisition, and analysis software is not completely developed as well and needs to be equipment-specific. Digital instrumentation and data storage, however, have improved the inspection techniques that allow the application of predictive maintenance systems of in service equipment. They also see digital as an opportunity to further exploit the potential of an integrated end-to-end supply chain process, and to improve the effectiveness of the workforce by enhancing them with more tailored, real-time information.

Typically, the digital transformation in downstream operations is driven by software developers and service companies, who are making big efforts in developing software covering a growing field of applications and data-driven services, expanding their digital offering along the entire “data value chain”. All large vendors (incl. GE, Honeywell UOP, ABB, Schneider Electric, Aspen, and Emerson) focus their offering towards software and services, and most of them offer comprehensive platforms/suites covering the entire “data value chain” (e.g. platforms that are open to external application developers, scalable digital ecosystems, including hardware, software, intelligent devices and services). Furthermore, some vendors focus on consolidating data from different customers, and combine all available data into business insights for their clients. In addition, vendors and companies are willing to participate in the race towards *more standardized platforms/digital environments*, which will potentially shape the future industrial world.

Several applications on how new technologies can enhance the oil industry are illustrated in Figure 4, with a particular focus on refining.

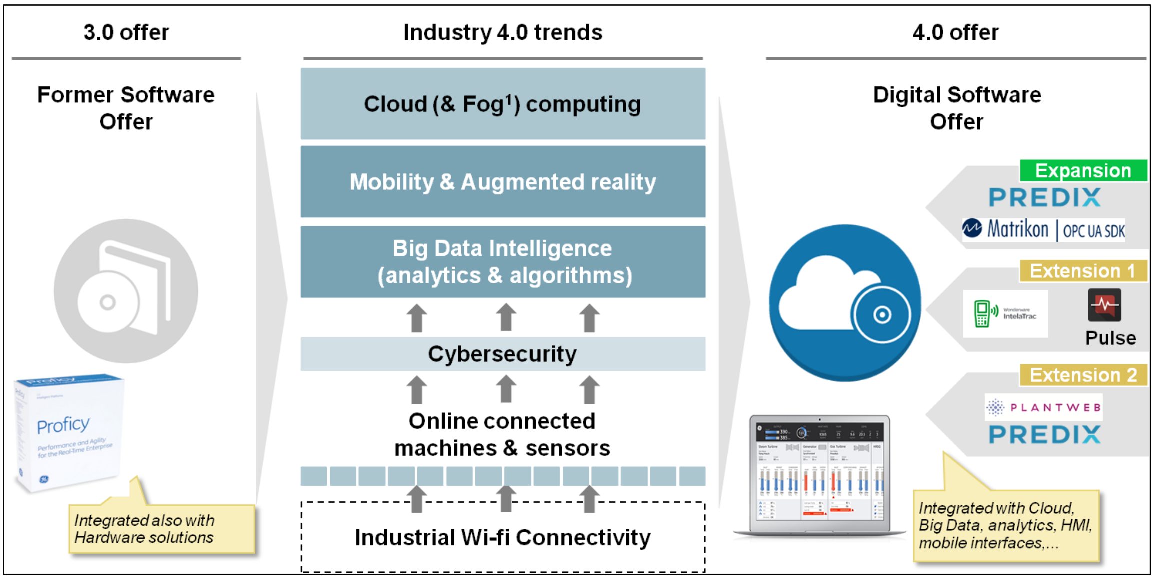
FIGURE 4. New technologies that will enhance refineries



Source: The Boston Consulting Group.

Online analytical instruments and advanced sensors, allow application of artificial intelligence to *big data and analytics* in order to assess and improve plant performance and asset availability; additionally *mobile devices* enhance information availability and activity scheduling (see Figure 5).

FIGURE 5. Industry 4.0 trends and offers0



Source: The Boston Consulting Group.

Refinery digitalization has introduced improved economic performance and working conditions, among other benefits. They can be summarized along five dimensions: a) plant availability and reliability, b) yield and process settings, c) staff efficiency and external spending, d) commercial margins/prices, and e) staff safety.

1.3.2. Challenges related to technological developments and applications

Challenges relating to the new landscape issues in technological developments and applications, are indicated in the following table:

TABLE 6. Technological developments and applications

New landscape issues	Challenges (for industry players)
Technologies The number of technological developments in last two decades has been impressive, and will continue to be so, mainly supported by applications of digital technologies, although their penetration in the downstream industry has been rather slow.	• Adapt and optimize refinery structures to maximizing margin and, at the same time, minimizing environmental impact • Design and implement process and procedures to allow increasing operation flexibility to adapt to market and new regulation changes • Analyze and request the catalysts that best satisfy the binomial relation feedstock/expected products • Foresee potential integration of new business units, such as petrochemicals, or special non-fuel petroleum products • Envision how a company can successfully integrate these technologies, along with existing applications, within the operation management and business management systems, in order to reduce costs, minimize environmental impact, enhance safety, and improve the maintenance and availability of installations • Prepare implementation requests to service companies, with a clear objective to be reached and definition of how the results will be evaluated • Prepare knowledgeable implementation teams with their own personnel and contractors • Adapt/react to the potential new products and specifications
Digitalization Digitalization allows monitoring and control, store, review and assessing the information on operation data, service equipment and all other gathered by operators, process engineers, operation programmers and strategists, citing among them: Online analytical instruments, advanced and dynamic control protocols Process plant dynamic simulators Continuous monitoring of service equipment Expert equipment Advanced analytics Mobile communicated equipment Installation and interconnection of low-cost self-powered sensors with wireless communication capacity Mobile equipment with low energy consuming communication protocols	

Source: own elaboration.

1.4. Regulations

1.4.1. Regulations of industry operations

Environmental legislation

O&G industry operations have a potential variety of impacts on the environment, in general, common to any stage of the value chain, upstream and downstream, though there are those more specific to upstream (e.g. offshore E&P). The environmental impacts can be avoided, minimized or mitigated with proper operation design, planning and management. The industry has been very proactive in developing standards and producing guidance documents and operation recommendations, which can be prescribed by regional or local environmental regulations.

The environmental impacts that are mostly addressed in the environmental regulations are the following: a) atmospheric impacts, which are those due to emissions arising from operations, whether local and long-range pollutant emissions, or those non-polluting with a global impact, like those related with climate change. Combustion, flaring, venting and fugitive are the primary emissions from O&G operations; b) aquatic impacts are those that can affect marine and surface waters, and are linked to production water, drilling muds, cuttings and well-treatment chemicals, spills, wash, drainage, process, sanitary and cooling; c) soil impacts arise from soil occupation, construction disturbances, contamination resulting from spillage and leakage, solid waste disposal and those related to access, opening and restricted areas; d) ecosystem impacts are those that occur to various components of the biosphere, as a result of other operational impacts, if they are not properly controlled. Changing plant and animal habitats through variations in water, air and soil quality, disturbances due to noise, light and changes in soil vegetation cover, may directly affect ecology; and e) potential accidents and emergencies during operations, such as oil, gas and hazardous chemical spillages, well blowout, explosions, unplanned plant upsets and shutdowns, fires (internal or external), natural disasters and sabotages that threaten people and the environment.

Environmental regulatory control, which is usually the responsibility of the national competent authority, shall take into account all these impacts, and require operators to have avoidance or mitigation measures in place at the project stage permitting. This can be supported by a set of guidelines and standards that provide more details on specific requirements, negotiated when granting the licensing of the O&G project. In the EU, the adopted legislation, which must be transposed and enforced by the Member States, established in the Directive 2011/92/EU, amended by Directive 2014/52/EU, on the assessment of the effects of public and private projects on the environment. This directive, transposed and enforced by the Member States, establishes that O&G projects (in particular: petroleum and natural gas extraction for commercial purposes), where the amount exceeds 500 tons/day or 500,000 cubic meters/day in the case of gas, oil refineries and pipelines with a diameter of more than 800 mm and length of more than 40 km, are required to deliver an environmental impact assessment for drawing up the permit. In the case of the surface storage of oil and natural gas, or the underground storage of natural gas, according to this directive, the competent authorities shall determine the need for a case-by-case environmental impact assessment.

Regarding permits to operate, in the EU, oil refineries, gas liquefaction units, combustion installations of more than 50 MW and waste disposal and recovery installations of more than 10 tons/day[8], is required a permit issued according to Directive 2010/75/EU, the IPPC (Integrated Pollution Prevention Control) directive. According to this directive, on issuing the permit, the competent authorities shall ensure that the installations are to be operated in accordance with the following criteria: a) all appropriate pollution prevention measures are taken, and best available technologies are applied, so that no significant pollution is caused, and energy is used efficiently; b) waste generation is prevented, and where waste is generated, it shall be prepared for reuse, recycling or recovery; if this is technically or economically impossible, it shall be disposed off so as to avoid or reduce impacts on the environment; c) the necessary measures are taken to prevent accidents and limit their consequences; and d) the necessary measures are taken, upon the definitive cessation of activities, in order to avoid any risk of pollution, and return the site to its original state, regarding soil and groundwater contamination. In this regard, the technical feasibility of the measures shall be taken into account.

Regarding BAT (best available techniques) reference documents, the conclusions drawn in that corresponding to mineral O&G refineries has been legally adopted by the EU through Decision 2014/738/EU. Additionally, the EU has launched the development of a BAT reference document on upstream hydrocarbon exploration and production (Best Available Techniques Reference Document for Mineral O&G Refineries).

Regarding the impact of potential accidents, the regulations require operators to carry out hazard assessment and analysis of risk scenarios to take preventive measures for risk avoidance and/or reduction, and to prepare and submit internal emergency plans: a) in the case of O&G offshore exploration and production, the EU adopted Directive 2013/30/EU, establishing the minimum requirement for preventing major accidents in offshore O&G operations, and limiting their consequences. This directive requires operators to ensure that offshore O&G operations are carried out on the basis of systematic risk management, so that the residual risk of major accidents to persons and the environment are acceptable; b) in on-shore installations containing flammable liquid hydrocarbons and/or flammable gases, EU Directive 2012/18/EU (Seveso III Directive) requires the operator to

[8] Upstream O&G production can be subject to Directive 2010/75/EU through combustion installations for energy generation and waste disposal.

prepare a safety report and implement a safety management system, including the internal organization, to prevent major accidents.

Protection of environment and especially protected areas

By nature, the O&G industry is environmentally intrusive throughout the entire petroleum life cycle (Upstream, Midstream, Downstream and Marketing). Due to the risks of impact on the environment, and in particular, on ecosystems, this industry is under increasing pressure, from governments and civil society, to minimize its environmental impact.

All oil-related activities that require fixed installations (exploration, production, pipeline transportation, refining or storage) need administrative authorization by the government under whose authority the area falls. The authorization requests that they comply with the legal requirements in force in the area, and with international regulations (in offshore activities, it is required to comply with the UN Convention on the Law of the Sea); in any case, an environmental impact analysis is required (in EU Directive 2011/92/EU, on the assessment of the effects of public and private projects on the environment), it shall cover all aspects regarding the project: activity, location, installations (fixed or temporary), material movements, discharges, emissions, environmental and population impacts, impact on specially protected environment and wild life). Especially nowadays, a focus is placed on the following demands/challenges: a) production, reduction, treatment, discharge and transportation of hazardous waste at the source, b) stricter permit discharge and emission regulations from surface installations for crude oil production and refineries, c) stricter controls of spills, discharges and emissions of oil transportation by sea and pipelines, and d) recuperation of production sites after abandonment. Simultaneously, international oil companies are facing a reality of increasingly strict national and international regulations, standards and guidelines.

The main levels of environmentally and ecosystems -related regulations, norms and standards are: a) international, b) national, c) industrial associations and d) corporate self-regulation/guidelines. The balance between various regulatory levels and their relative importance primarily depends on the specific type and nature of activity in question. The higher the exposure to international effects – pollution or other trans-border risk – the more preponderant is the role of international law.

Product regulations[9]

The specifications of petroleum products are determined by their use, in order to achieve maximum efficiency, and within this framework, minimize health and

[9] Note – this section deal with some key aspects of regulation related to oil products. A more detailed review is carried out in the next paragraph 2.4.2 referring to regulations in the oil demand products.

environmental risks, whether during the handling of the product itself, or through the residual products resulting from its use.

The specification of petroleum products for a particular use has been developed and adapted from the accumulated experience of decades of application. The products have been defined, based on macroscopic characteristics, such as the boiling point range, volatility and other physical, thermal, chemical and rheological properties, without needing to specify their detailed chemical composition. Industry practice is to manufacture and market petroleum substances according to the physicochemical parameters specified in the standards (i.e. ASTM, ISO or EN). Different samples from the same substance in a refinery will show some variability in detailed composition, while remaining within the specifications that identify the substance.

The regulations are mainly focused on aspects relating to health and environmental impacts, particularly on automotive fuels, since they are widely distributed to individual consumers, who are also exposed to their combustion products, and they must allow compliance with the consumption efficiency requirements.

Regulations on gasoline specify minimum octane numbers: motor octane number (MON) and research octane number (RON), for high engine efficiencies. Additionally, regulations address volatility and maximum vapor pressure, as related to engine operation and subsequent environmental impacts. Also outlined are maximum limits for olefin, benzene and aromatic content, based on the consideration of health aspects, and maximum sulfur content to control sulfur dioxide emissions, which can have both environmental and health impacts. Other limits, like maximum oxygen content and allowed oxygenated compounds, are also specified.

Regarding diesel, the regulation established values focusing on the minimum cetane index, maximum density and distillation point (95% distilled at 360°C), all leading to a reduction in soot particulate emissions (PM), maximum content of polycyclic aromatic hydrocarbons (PCA) with regard to health issues, maximum sulfur content to reduce the health and environmental impacts of sulfur dioxide combustion emissions, and finally, the maximum content of the biodiesel, fatty acid methyl ester (FAME), to ensure operability and consumption efficiency.

In addition, in the regulation described above, on the physical properties of transportation fuels, the EU has adopted the regulation on the registration, evaluation, authorization and restriction of chemicals (REACH), petroleum products among them. Its objective is to improve the protection of human health and the environment from the risks posed by chemicals. The REACH regulation places responsibility on industry to manage the risks from chemicals, and to provide safety information on them. The oil industry has registered 191 petroleum substances under the regulation, with a total of 971 million tons manufactured or imported in the EU[10].

[10] CONCAWE, Petroleum substances under REACH.

The biggest challenges for the oil industry in applying the REACH evaluation of the hazards of petroleum substances, are the unknown and variable compositions, which means that it is impossible to determine the precise chemical composition at the level of each constituent. Commercial petroleum substances have a variable detailed composition, depending on their origin, and such a large number of constituents makes it difficult to represent a standard composition of any one specific petroleum substance. Then, to determine the hazardous properties of petroleum substances, a methodology should be developed in order to generate a representative structure that will allow for a preliminary screening of the hazardous properties of a substance.

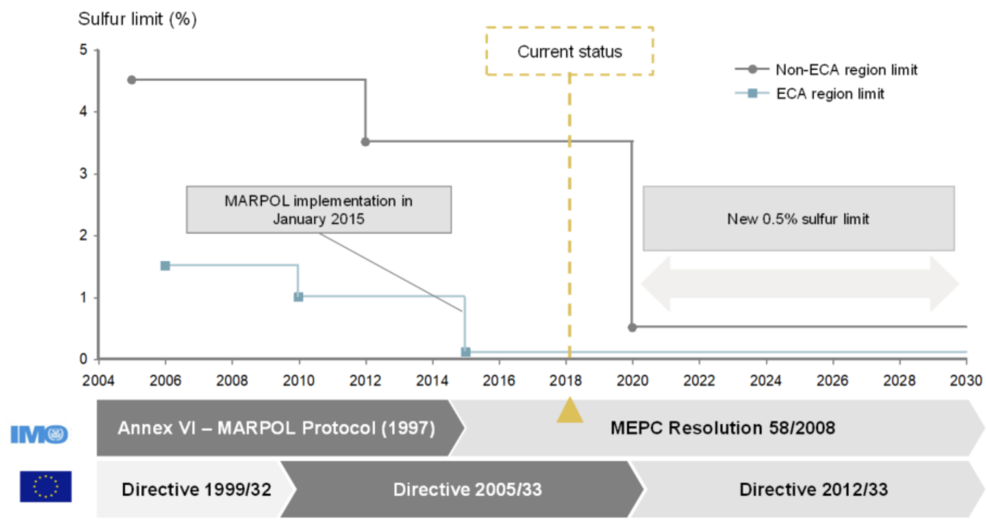
Marine fuels[11]

Marine fuels are the fuels used by ships at sea, outside countries' territorial waters, then their specifications are not regulated by any regional or country legislation and fall below the jurisdiction of International Maritime Organization (IMO). Marine Environment Committee (MEPC) in responsible to address environmental aspects under IMO, and then to set fuel specifications that can affect marine environment.

In October 2016, the 70th session of the Marine Environment Protection Committee (MEPC), announced the decision to enforce a global sulfur cap of 0.5% (mass %) in fuels used by ships or control SOx emissions to a value equivalent to that of such fuel, as of January 1, 2020.Regulations regarding sulfur oxide (SO_X) emissions from ships are defined in Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL Convention). Annex VI has set progressive stricter regulations (Graph 2) to control emissions from ships that present major risks to both the environment and human health.

[11] This section may also be considered within the scope of regulations impacting demand of oil products (2.4.2), as it is clear that it impacts demand. It has however been maintained here in order to maintain consistency with the previous section.

GRAPH 2. Evolution of marine fuel sulfur content cap



Source: IMO, European regulations, BCG analysis.

This decision has several implications for the bunker fuel market, as it has typically relied on the use of high-sulfur fuel oil as a cheap fuel for commercial transportation. There are several alternatives to comply with the new regulations, these are listed below.

Installation of "scrubbers" in ships to reduce SO_x emissions from exhaust gases. Exhaust gas scrubbers are cleaning systems which allow ships to continue using cheaper high-sulfur fuel oil. The basic principle is to bring a fluid (sea water) with the capacity to absorb SO_x in the effluent in contact with the exhaust gas, to reach the SO_x/CO_2 ratio equivalent to that of 0.5% sulfur fuel. The absorbed SO_2 is converted by reaction with alkali material in sulfite. The scrubber has to be fitted in the ship, although onboard ships it has not yet proven to be viable.

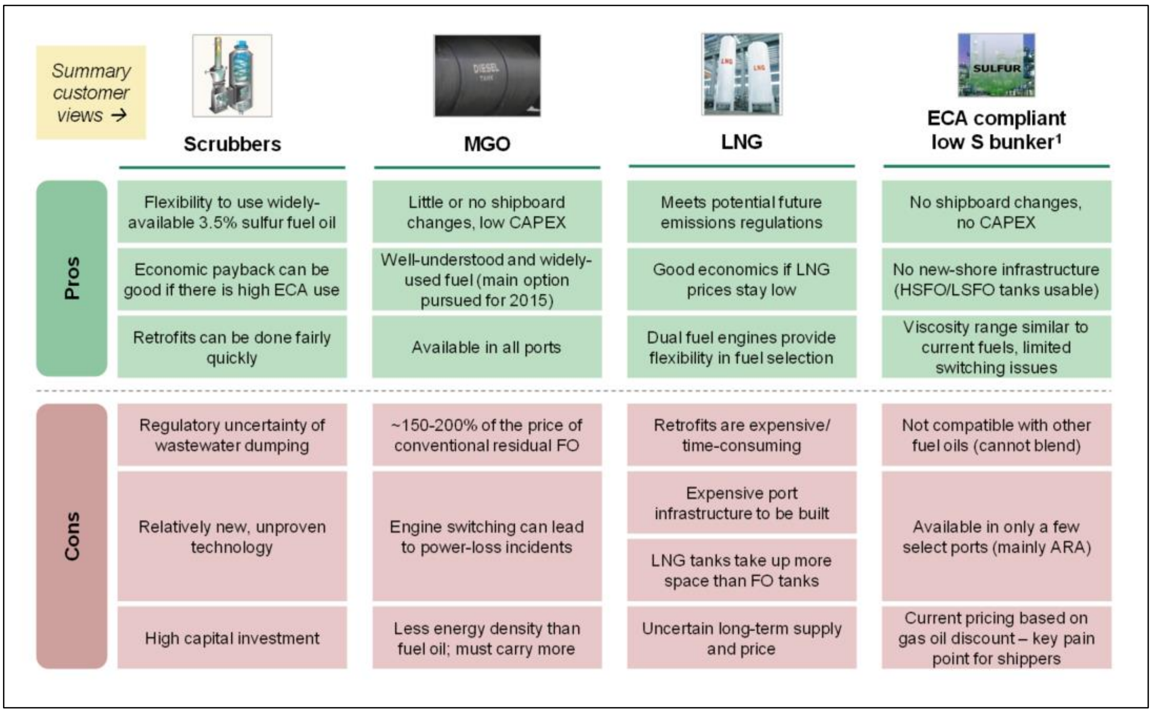
Use of marine gasoil (MGO) as bunker fuel. Both MGO and marine diesel are potential options, though the most viable solution is the former. It is manufactured from light and heavy gasoil fractions, is readily available, and has properties that are similar to those of diesel and heating gasoil fuel. Investment in refineries would be required to supply the additional demand of MGO.

Use of Liquefied Natural Gas (LNG) as bunker fuel. LNG is natural gas that has been converted to liquid form to ease transportation and storage (it is stored at -162°C in cryogenic tanks). The liquefaction process involves the removal of nuisance components (such as sulfur compounds, CO2 and heavy Hydrocarbons) to give a methane rich liquid, requires however more space than the traditional fuel oil tanks for the same ship autonomy.

Desulfurization of heavy fuel oil to comply with the new 0.5% limit in sulfur content. The solutions used consist of adding residue desulfurization units in refineries, to lower the sulfur content of traditional bunker fuels. Several studies consider that the investment necessary to desulfurize residue, in order to yield a reasonable product, would be almost equal to the cost of using distillates (gasoil) as bunker fuel. Another solution is the desulfurization of FCC feed followed by light cycle oil desulfurizing and blending.

BCG has interviewed several players in the industry, to get their point of view on the advantages and disadvantages of each of these alternatives. Each option is seen with potential, but there is no consensus yet: low sulfur fuel oil and MGO could be very expensive fuels, while scrubbers and LNG require a high upfront investment to be made by not-so-buoyant shipping companies. Figure 6 contains a summary of the main pros and cons of each of the alternatives identified during the interviews.

FIGURE 6. Main pros and cons of each of the options available, to comply with the 0.5% sulfur limit



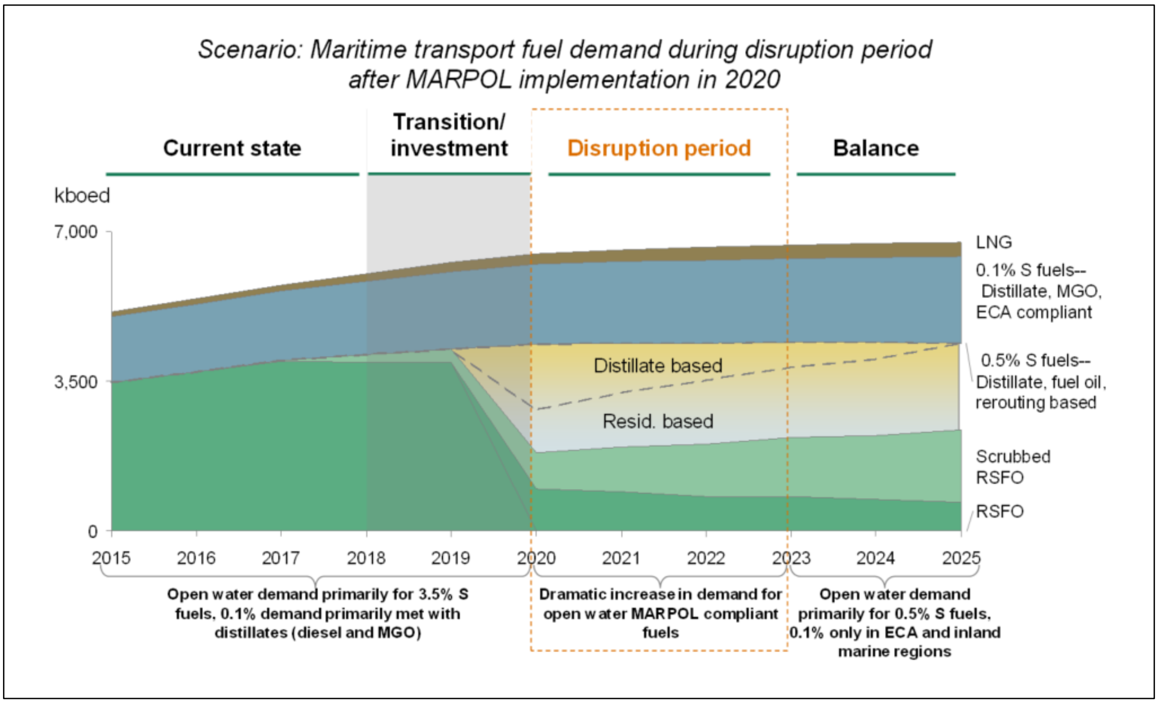
Summary customer views →	Scrubbers	MGO	LNG	ECA compliant low S bunker[1]
Pros	Flexibility to use widely-available 3.5% sulfur fuel oil	Little or no shipboard changes, low CAPEX	Meets potential future emissions regulations	No shipboard changes, no CAPEX
Pros	Economic payback can be good if there is high ECA use	Well-understood and widely-used fuel (main option pursued for 2015)	Good economics if LNG prices stay low	No new-shore infrastructure (HSFO/LSFO tanks usable)
Pros	Retrofits can be done fairly quickly	Available in all ports	Dual fuel engines provide flexibility in fuel selection	Viscosity range similar to current fuels, limited switching issues
Cons	Regulatory uncertainty of wastewater dumping	~150-200% of the price of conventional residual FO	Retrofits are expensive/ time-consuming	Not compatible with other fuel oils (cannot blend)
Cons	Relatively new, unproven technology	Engine switching can lead to power-loss incidents	Expensive port infrastructure to be built; LNG tanks take up more space than FO tanks	Available in only a few select ports (mainly ARA)
Cons	High capital investment	Less energy density than fuel oil; must carry more	Uncertain long-term supply and price	Current pricing based on gas oil discount – key pain point for shippers

Note: Different solutions proposed by different players = desulfurized resid, lower sulfur gasoil, vacuum gasoil with gas oil.
Source: BCG interviews.

Each of the alternatives will have a different impact on the refining industry, and in some of them, the outcome might be positive. In the short term, as the market takes a clear direction, a surge in MGO/diesel consumption is expected, whereas high sulfur fuel oil (HSFO) demand might drop significantly. In such a scenario, refinery margins could increase, as well both MGO/diesel prices; conversion units' margins would also increase. In case shipping companies opted for installing scrubbers, the refining industry would see little to no difference, as demand for HSFO is expected to remain unchanged. In a scenario where LNG takes a dominant role, the refining industry would have to keep being competitive; however, a drop in demand for an abundance of its products would contribute to a decline in margins, leading to lower utilization rates, distillation overcapacity or refinery closures, reducing crude oil consumption.

The solution chosen will depend on multiple factors, with the current and expected cost competitiveness of the fuel being a key one. Some analysts see the use of low sulfur fuel oil (LSFO) as the most plausible solution, already in the short term, while others foresee a slower transition to MGO/diesel and LSFO. Graph 3 shows the evolution of maritime transportation fuel demand, in a scenario where a lack of residue desulfurization capacity in 2020 causes a partial switch to MGO, which that is gradually reverted, as LSFO (0.5%S) production increases. Fuel desulfurization and MGO use, during the transition period, are an alternative for complying with the new sulphur emission regulations.

GRAPH 3. Scenario where LSFO (0.5%S) takes the role of the main MARPOL-compliant fuel



Note: HSFO use after 2020 assumed to be non-compliance. 0.1% S fuels include diesel used by 4T engines.
Source: BCG analysis.

Safety, risk analysis and management

Safety elements and risk management, along all the steps of the value chain, are important elements in the O&G industry, since both the operational conditions, and the oil and other chemical components linked to them, are known hazards that pose serious health and environmental risks.

Despite the huge quantities of oil, oil products and gas that are handled every day, and the fact that only some production, refining and transportation activities experience serious accidents; as these accidents have caused such high direct economic costs and environmental problems that seriously damaged the reputation of the company involved, and that of the whole sector, worsening their public image, the granting of licenses to operate has been made legally more complex.

Creating a health, safety and a risk management culture within the organization, including long-term commitments and management leadership, will then receive special attention. It must be initiated by corporation leadership, and made visible throughout the organization, by means of a consistent and transparent risk policy, which clarifies the goals it intends to pursue and applied down to the working level. Information on the existence and characteristics of the corporate risk assessment and management system is a required element for obtaining approval on O&G projects, and for starting up operations.[12]

The risk-management process in the O&G industry generally involves the following steps: a) planning: identify the resources needed (people, analysis team, etc.), collect data on standards and legal obligations and formulate protection aims; b) hazard identification: identify potential hazards and threats capable of causing loss, harming health and the environment, or damaging the functional integrity of the installation; c) risk assessment: evaluate risks arising from identified hazards and threats, rank and prioritize risks based on severity; d) risk control: develop and implement preventive measures to eliminate or minimize the risk of an incident or accident; e) periodic review and reassessment: assess the effectiveness of risk control measures, and maintain the continual review and improvement of risk management activities. If new hazards are identified during operations, or their impact changes significantly, the associated risk shall be assessed, and the control options re-evaluated; and f) record keeping: develop the risk-management records and management plan. Risk management documentation can include risk assessment data, risk control measures and periodic evaluation and performance results.

Furthermore, an internal emergency response plan shall be prepared, taking into account the risk assessment carried out on the basis of the most recent identification of major hazards. An internal emergency plan plays a major role in protecting the installation and people, and shall not be separated from the risk management plan. The most important tasks of an emergency management plan are: a) creating the conceptual, organizational and procedural conditions needed to deal with an accident as effectively as possible, and b) establishing special structures (e.g. task forces) to respond in case of emergency.

[12] EU Directive 2013/30/EU on the safety of offshore O&G operations, and Directive 2012/18/EU on the control of major accident hazards involving dangerous substances.

Waste management

The O&G industry generates substantial quantities of potentially hazardous waste, given the products and materials involved in day-to-day operations. In particular, the following are the most relevant types of waste: drilling muds, oily and salty water, used lubrication oils, spent catalysts, vehicular waste (tires, oil filters, antifreeze, etc.), plastic containers and metal oil drums.

From these, wastewater management is one of the most relevant elements, given that 1) it plays a significant role throughout the life cycle of O&G wells and in refining processes; 2) volumes generated are large. In well drilling, water is used to help circulate mud, which cools the drill bit, with volumes between 30 thousand and 300 thousand liters per well. For hydraulic fracturing, the volumes are much higher, between 500 thousand and 1.5 million liters, depending on the number of stages and the length of the horizontal laterals. Water is also used for secondary and enhanced oil recovery, in particular with water flooding and steam-assisted gravity drainage. Refining processes make use of water, as well, representing around 50% of the volume, although it depends on whether there is a water recirculating system, and on how much is recycled.

One of the major issues for recycling produced water is related to the high variability of its quality, typically containing different concentrations of heavy metals and salt, dissolved gases, suspended solids, oil, grease, and even radioactive material. In this sense, it has proven uneconomical to treat wastewater for use outside the oilfield, for which the purity of water needs to be ensured.

Transportation safety issues and regulations

Within the O&G industry, there are four main methods of transport: pipeline, ship tanker, barge, and rail and road transportation by truck.

In North America, there has been a large focus on a number of major pipeline developments over the past few years, and in particular, on three recently-approved oil pipelines – Trans Mountain, Line 3, and Keystone XL. Pipeline transportation, and its implications to human health and safety, have been the subject of great discussion. Accidents like the 2010 natural gas pipeline rupture in San Bruno, which killed eight people, brought much criticism to the construction of the new O&G pipeline infrastructure.

When compared to rail and road transportation, however, studies have shown pipelines to be the safest method of transporting O&G. Given the amount of O&G that is shipped through the pipeline infrastructure, there have been very few incidents. A study of spillages has found that, between 2004 and 2015, pipelines experienced approximately 0.05 occurrences per Mboe transported[13]; in addition to the low

[13] The Fraser Institute – *Safety First: Intermodal Safety for O&G Transportation.*

accident rates, 70% of occurrences resulted in spills of less than one cubic meter. Finally, it was also noted that only 17% of pipeline occurrences took place in the pipeline itself, with the majority of spills occurring in facilities, which also have secondary containment procedures in place for such an event.

In a region such as Europe, which has many Member States, technical issues of pipeline infrastructures arise, as each independent state has a distinct control and supervision system for handling the daily operations of the transmission system.

Regulations in recent years, and particularly for the transportation of gas, have tried to address points such as establishing reverse flow possibilities, which despite being technically relatively easy, hinder competition and decrease supply security, if not present. Another issue relates to energy efficiency (currently up to 5% of energy is used for transportation[14]), and subsequently potential safety, as a result of pressure to increase volumes through several other transportation networks. Additionally, it has been proposed to try to implement a higher degree of technical and engineering standardization (e.g. size of piping, with pressures as a result) across regions, so as to ease integration and transmission among countries.

Continuing on from the EPA's 2015 Clean Power Plan initiative to regulate greenhouse gas emissions from existing power plants, new regulations were released in 2016, in an effort to reduce the emissions of methane and volatile organic compounds from the petroleum industries, including pipelines. Regulations to reduce direct emissions from pipeline systems will affect how pipelines are operated and maintained, with the aim of increasing public safety and reducing harm to the environment.

With regard to crude oil transportation by road, in Europe, there are set regulations outlined by The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). These rules were first brought into force in 1968, with amendments taking place regularly since their entry. They provide transportation standards and agreements for dangerous goods and road vehicle construction on a global level. Conditions must be satisfied, with particular regard to packaging and labelling, as well as construction, equipment and operation of the vehicle carrying the goods in question.

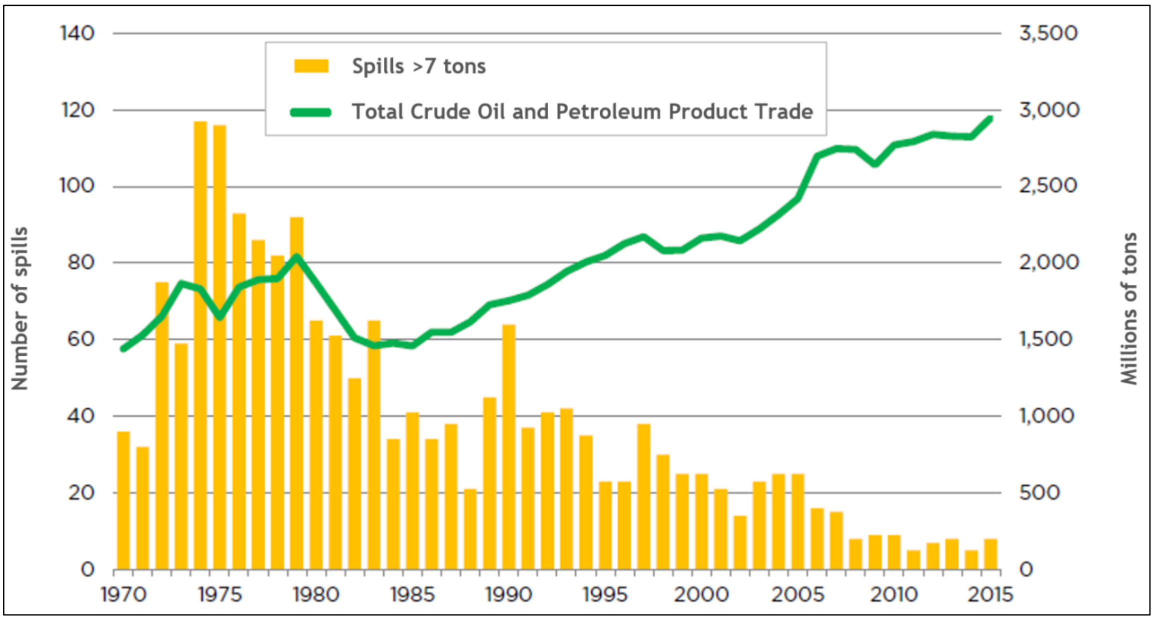
Rail transportation of O&G in the US displays similar safety characteristics to pipelines. Overall, very few incidents have occurred in general, and when they have, there were more related to natural gas than to oil. In addition, more incidents have occurred in facilities than in rail transportation, itself.

Economics entail one aspect of transportation safety that cannot be ignored, particularly when comparing rail to the other modes. As the volumes transported by pipelines are rapidly growing, pressure is being put on rail transportation to grow,

[14] European Parliament - Directorate-General for Internal Policies – Gas and Oil Pipelines in Europe.

and to include more cars per train. While a train with 100 cars may be able to carry some 70,000 barrels of crude oil between Alberta and the Gulf Coast over a three day period, the Keystone XL pipeline is able to deliver 830,000 barrels per day[15].

GRAPH 4. O&G value chain activities



Source: Fraser Institute

Marine transportation safety of O&G has improved dramatically since the 1970s. Global figures indicate that there were a total of 543 spills with a size between 7 and 700 tons throughout the 1970s, while in the period from 2010 through 2015, only 35 spillages occurred (see Graph 4). For the number of spills that are considered large – over 700 tons – the figures for the aforementioned time periods show a decrease from 245 to 12 incidents[16]. This reduction in accidents is largely due to a greater commitment to safety, combined with computer-assisted design and operation, which have resulted in the modern fleets of ships being more maneuverable and durable than their predecessors. In addition, one of the most important changes to tankers has been the new double-hull design. This multi-barrier safety procedure has become mandatory in new ships, since the Exxon Valdez oil spill of the early 1990s, with all single-hulled vessels being phased out worldwide by the end of 2015.

Monitoring, reporting and compliance with reporting guidelines

O&G are fundamental energy sources for the world. They are the largest contributors to the global energy mix, and the economic development and welfare of citizens depend on their supply, since they not only are the source of transportation and home

[15] Forbes – Pick Your Poison For Crude – Pipeline, Rail, Truck Or Boat.

[16] The Fraser Institute – *Safety First: Intermodal Safety for O&G Transportation.*

fuels, but also provide the basic materials for polymers and other materials useful to the modern world. This fundamental role makes them a source of income, for both producing and importing countries, through taxes and other levies. However, O&G activities, which include searching, producing, treating and moving crude oil and transformed products, generate and use hazardous components and operations, and the subsequent risk of exposure to them. In addition, all these processes produce non-toxic greenhouse gases, which in turn, cause global warming.

For the above reasons, companies in the O&G industry are regulated; their operations must be authorized by the competent authorities, which require them to remit specific environmental impact assessments, in order to issue the permits, and ask them to retain records and reports of their activities, which are to be made available to the regulatory authority for inspection.

It is then essential to have a monitoring system that constantly monitors operation data and facility conditions, from which high-quality data can be obtained that helps deliver ways of maximizing the economic recovery of resources and fiscal control.

In addition to the monitoring and reporting requirements of elements relating to economic and fiscal aspects, the competent authorities require monitoring and reporting on aspects with regard to compliance with environmental safety legislation. These include the following: a) in the US, the Environmental Protection Agency (EPA) operates an air pollution monitoring program, and a water quality monitoring program, addressed to monitoring and compliance with the corresponding laws – The Clean Air Act and The Clean Water Act – during O&G developments, and b) in the EU, Directive 2010/75/EC establishes the Member States, as the competent authorities, to set emission limits, the measuring methodology and the obligation to report annually on emission control results.

Regarding greenhouse gas emissions, the US EPA's Greenhouse Gas Reporting Program, which took effect in 2010, requires O&G companies, including operators of facilities that contain petroleum and natural gas, to calculate and report their greenhouse gas emissions.

In the EU, according to Directive 2003/87/EC (Emissions Trading Directive), the operators of oil refining installations must monitor and verify CO2 emissions, in accordance with the guidance issued by the European Commission and the directive criteria, and report them to the competent authority at the end of each calendar year.

Third-party programs

Some oil company organizations, like IPIECA (International Petroleum Industry Environmental Conservation Association), have started to develop internal voluntary reporting standards. IPIECA has worked with IOGP (International Association of O&G Producers) and API (American Petroleum Institute) to produce its O&G Industry Guidance on Voluntary Sustainability Reporting. This guide provides best practices for reporting on environmental impacts, climate change, health and safety.

A more general initiative is that developed by GRI (Global Reporting Initiative), a multi-stakeholder organization founded in the US by CERES and UNEP (United Nations Environment Program), which provides a voluntary sustainability reporting framework, to enable greater company transparency. The framework includes an O&G guideline that lays out the principles and indicators that the oil companies can use to measure and report their economic, environmental and social performance.

1.4.2. Regulations impacting demand of oil products

Regulations have typically been one of the key elements in defining relative penetration or market shares of alternative products that serve the same need. In this regard, transportation means and their energy sources are no exception. The following are some examples: a) different taxation of vehicles and fuels incentivizes consumer behaviors towards the cheapest alternative; b) regulations on efficiency directly impact average fuel consumption per kilometer driven; c) air quality and pollutant emission standards can impact product quality, prices and demand, and then the refinery product mix and structure; and d) subsidies and incentives towards electric vehicles, such as free parking or free tolls, or lower taxation for alternative-fuel vehicles (such as vehicles running on gas), are another example of regulations that drive consumer behavior.

In the coming years, these types of regulations are expected to play an even greater role in shaping the future of the oil industry in general, and of the refining industry in particular.

Included in this section there will be a dive into transportation efficiency, biofuels and taxes.

Transportation efficiency

Carbon dioxide emissions from road transportation have become a major concern, as one of the driving factors of global warming. During the past decades, several policies and regulations have been put in place, in order to reduce the emission of pollutants of internal combustion engines (ICE) vehicles. Lowering the fuel consumption of ICE vehicles is something car manufacturers have been leveraging to lower car emissions of both pollutants, such as CO, hydrocarbons, NO_X, PM, and greenhouse gases, such as CO_2. Regulations on CO_2 emissions are driving a previously-unseen increase in new car efficiency, as CO_2 emissions are directly related to consumption, as opposed to other pollutants that are more dependent on fuel specifications and engine design, and can be managed with the help of catalysts in the exhaust system. From the refining-industry point of view, higher ICE efficiency is translated into lower products demand.

In Europe, it wasn't until 2009 that regulations were put in place, specifically to limit the CO_2 emissions of new cars. CO_2 emissions from ICE vehicle regulation was first established through Regulation 443/2009/EC, which set emission performance standards for vehicle CO_2 emissions. An amendment to the original regulation (Regulation 333/2014) defines the modalities for reaching the 2020 target, to reduce CO_2 emissions from new passenger cars.

FIGURE 7. Electric car incentives in Western Europe (2017)

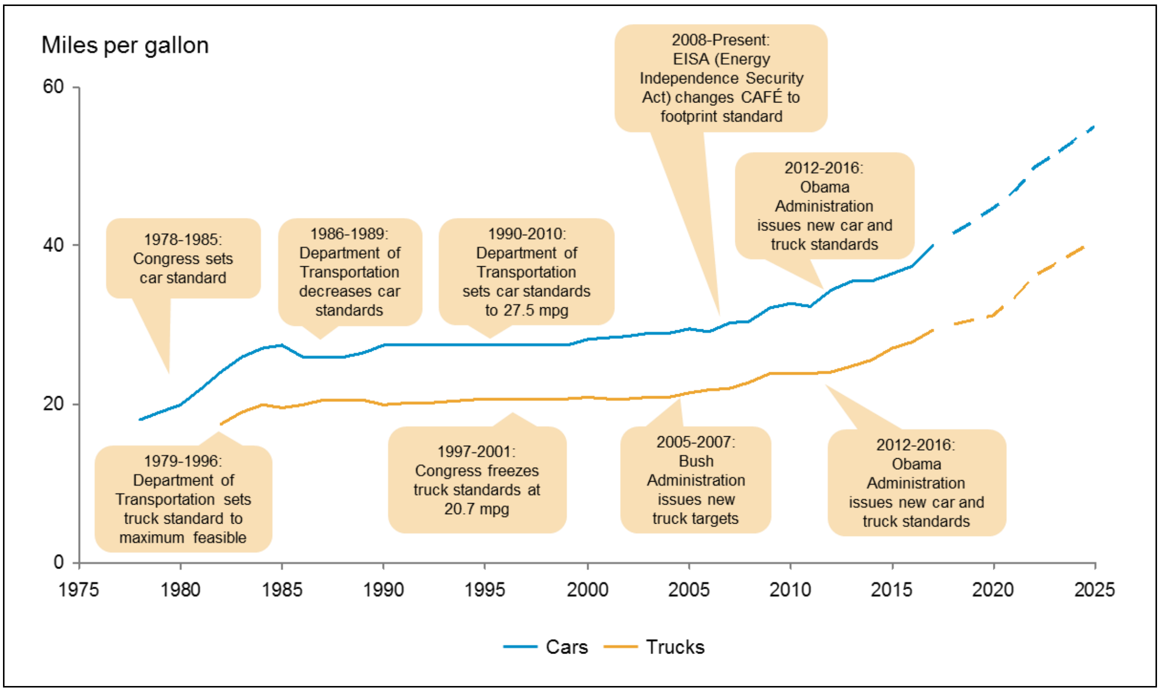
	Purchase grant one-time	**Ownership tax** annual	**Company car tax** annual
	**€4,000** grant	**No tax** at all	**120%** deductible
	**< €10,000** grant	**50% or 100%** discount	**No tax** at all
	**£4,500** grant	**No tax** at all	**9%** instead of 17%
	**€4,000** grant	**No tax** at all	**< €8,000** discount
	**No VAT** on purchase	**NOK 455** instead of NOK 2820	**50%** discount
	**No purchase** tax	**No tax** at all	**4%** instead of 22%

Source: EVBOX, Royal Norwegian Ministry of Finance, Norsk elbilforening.

The European Commission has also encouraged Member States to introduce differentiated taxation that helps consumers move their choice towards more fuel-efficient cars. In the EU, support for alternative fuel vehicles takes place, either through the exemption or reduction of the registration tax for electric vehicles, or through direct incentives to purchase electric or low-emission vehicles (see related examples in Figure 7).[17]

[17] Note: For further detail see Álvarez Pelegry, E., Menéndez Sánchez, J., Bravo López, M. "Movilidad sostenible: El papel de la electricidad y el gas natural en varios países europeos" (2017) Cuadernos Orkestra.

FIGURE 8. Evolution of US fuel economy standards for passenger vehicles and trucks



Source: ICCT - The International Council on Clean Transportation; National Highway Traffic Safety Administration (NHTSA); Center for Climate and Energy solutions (C2ES).

The US Congress initially established CAFE (Corporate Average Fuel Economy) standards, through the Energy Policy and Conservation Act of 1975, mainly in response to the 1973 oil embargo that OPEC established against the US and its allies that supported Israel during the Yom Kippur war. The objective of the CAFE standards was to reduce US dependence on oil imports, as they proved to be an unreliable source of energy. The CAFE standards are imposed on the average fuel economy (in miles per gallon) of the passenger cars or light duty vehicles (LDV) sold by a manufacturer in a given year.

The National Highway Traffic Safety Administration (NHTSA), which is the agency responsible for enforcing the standards, and for fining non-compliant auto manufacturers, has collected more than US$800 million in fines since the start of the CAFE program; in turn, the Environmental Protection Agency (EPA) calculates the fuel economy level for manufacturers, and sets the related CO_2 emission standards. Figure 8 shows the evolution of the US CAFE standards on fuel efficiency and related key events.

Currently, under the federal Clean Air Act, California is the only state with the ability to set its own motor vehicle emission standards, as long as they are stricter than those set at the federal level. Once California standards are approved, other states can implement California's standards.

China's first fuel efficiency standards for passenger cars were set in 2004, by the National Standard GB 19578-2004, which was first implemented in July 2005. Since

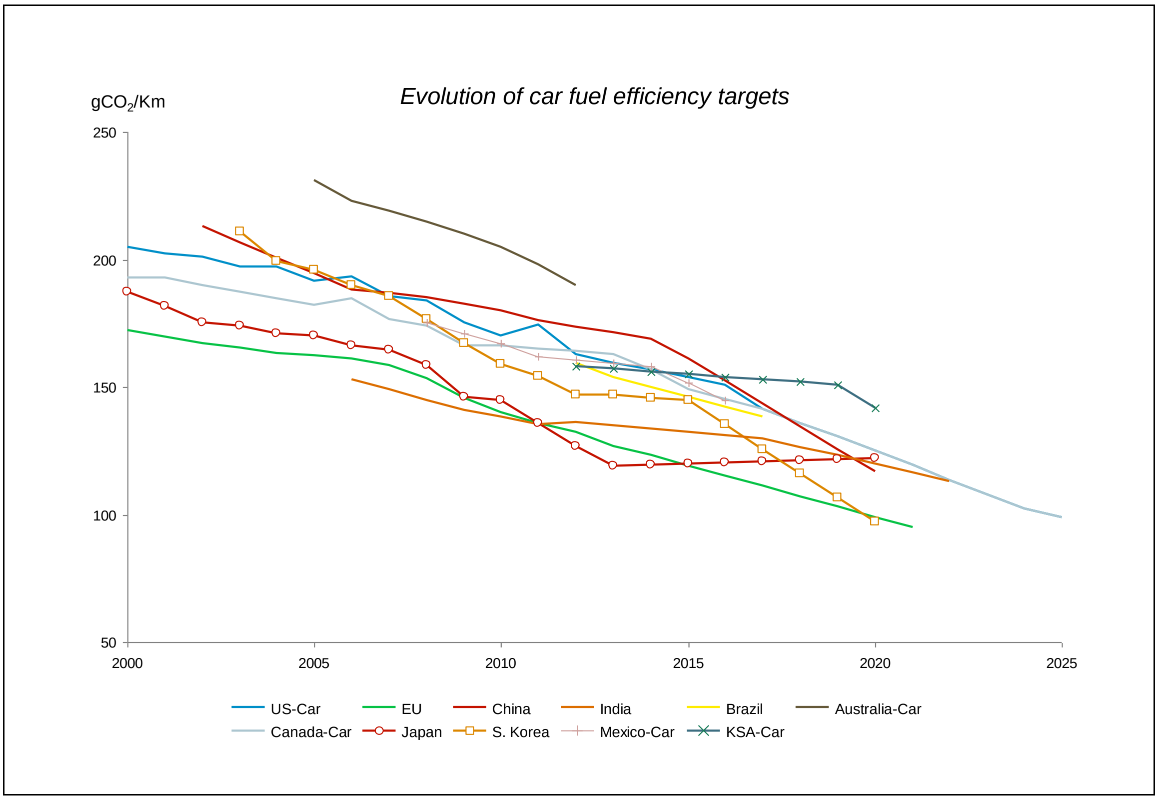
2006, China also offers tax incentives to consumers that purchase efficient vehicles, and in 2010, it also introduced fiscal support for costumers willing to purchase alternative energy vehicles (i.e. electric or gas powered), as opposed to other countries' practices.

Other countries, such as Japan, Brazil, Canada, India, Mexico, or South Korea, have also set or proposed fuel efficiency or GHG emission standards for passenger cars and LDVs.

The regulations in these markets cover a significant share of global car sales, which impact the decisions of vehicle manufacturers around the world. Car manufacturing companies are global businesses that sell their cars to multiple markets around the globe.

Costs associated with adapting car models to local market regulations are high, thus, car manufacturers have a natural tendency to homogenize their product offering. This supports the case of a worldwide vehicle efficiency increase, even in countries that have not set their own emission standards.

GRAPH 5. Evolution of car fuel efficiency targets (NEDC)



Note: NEDC stands for New European Driving Cycle, and is a methodology for evaluating road transportation fuel consumption.
Source: The International Council on Clean Transportation (ICCT)

In the short/mid-term future, more stringent standards are expected in almost all regions/countries, as the global economy, especially in developed countries, continues its decarbonization process. Graph 5 shows the evolution of the targets set by different countries.

For the refining industry, efficiency regulations have a direct impact on the demand for its main products (gasoline and diesel). In the long term, if efficiency gains (combined with electric vehicle and other alternative-fuels penetration)[18] are able to curb the current growth trend, the outlook for the refining industry will be much darker, as gasoline and gasoil/diesel account for around 56% of the refinery products globally.

Biofuels

Biofuels, such as ethanol, have been used since the invention of the internal combustion engine as an energy source. In 1826, Samuel Morey received the first U.S. patent for an internal combustion engine that ran on a blend of ethanol and turpentine (derived from pine trees), and in 1908, Henry Ford designed and developed the original Model T, which was intended to run on ethanol, gasoline or kerosene.

Discoveries of huge petroleum deposits have prevented the escalation of gasoline and diesel prices, and reduced the attractiveness of biofuels. However, in this new area of growing social concern about global warming caused by carbon dioxide emissions, biofuels have regained popularity, as they can play a role in reducing CO_2, when they are produced from renewable biomass[19].

After years of expansion, the consumption of biofuels is expected to continue to increase, albeit at a slower rate, and greater consumption growth will be concentrated in areas where biomass is readily available (see Graph 6).

Regarding the US, the consumption of biofuels is set by the Renewable Fuel Standard (RFS), which is a national policy that requires fuel producers and importers to replace or reduce a certain quantity of petroleum-based transportation fuel or heating oil, with the long-term consumption objective of 36.0 billion gallons yearly. The quantity is set annually by the Environmental Protection Agency (EPA), by November the preceding year, after the evaluation of transportation fuel consumption and the amount and type of biofuel expected to be produced. In the last 5 years, the biofuel volume required to be blended with fuel oil increased from 15.2 billion gallons in 2012 to 18.8 billion gallons in 2017. The figure set for 2019 is 19.88 billion gallons.

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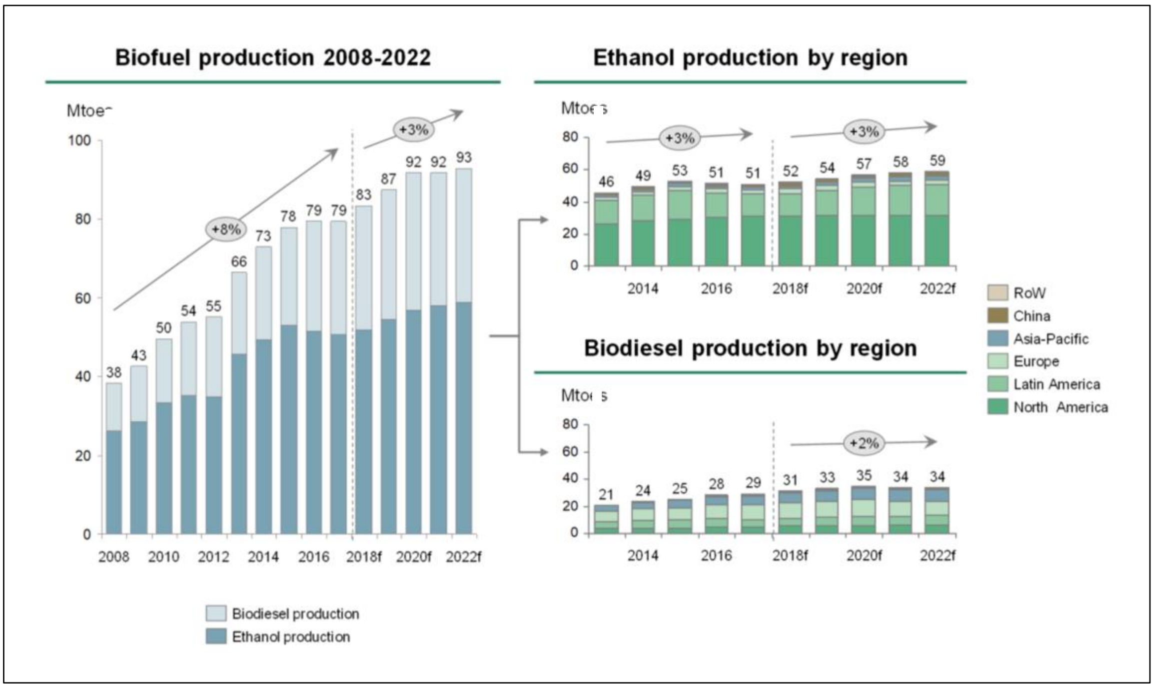
[18] In the long term, electric vehicle (EV) sales might have an important impact on this efficiency trend, depending on how regulations evolve, as their direct GHG emissions (from tank to wheel) are null: if regulations include them in the calculation of overall fleet efficiency, car manufacturers might choose to boost EV car sales, to comply with targets, instead of focusing on ICE efficiency improvements. On the contrary, if EV does not count in the sold fleet emission calculation, car manufacturers will have to continue focusing on ICE efficiency.

[19] Biomass is considered to be renewable, only when the consumption rate is equal to the recovery rate.

GRAPH 6. Evolution of biofuel production and forecasts

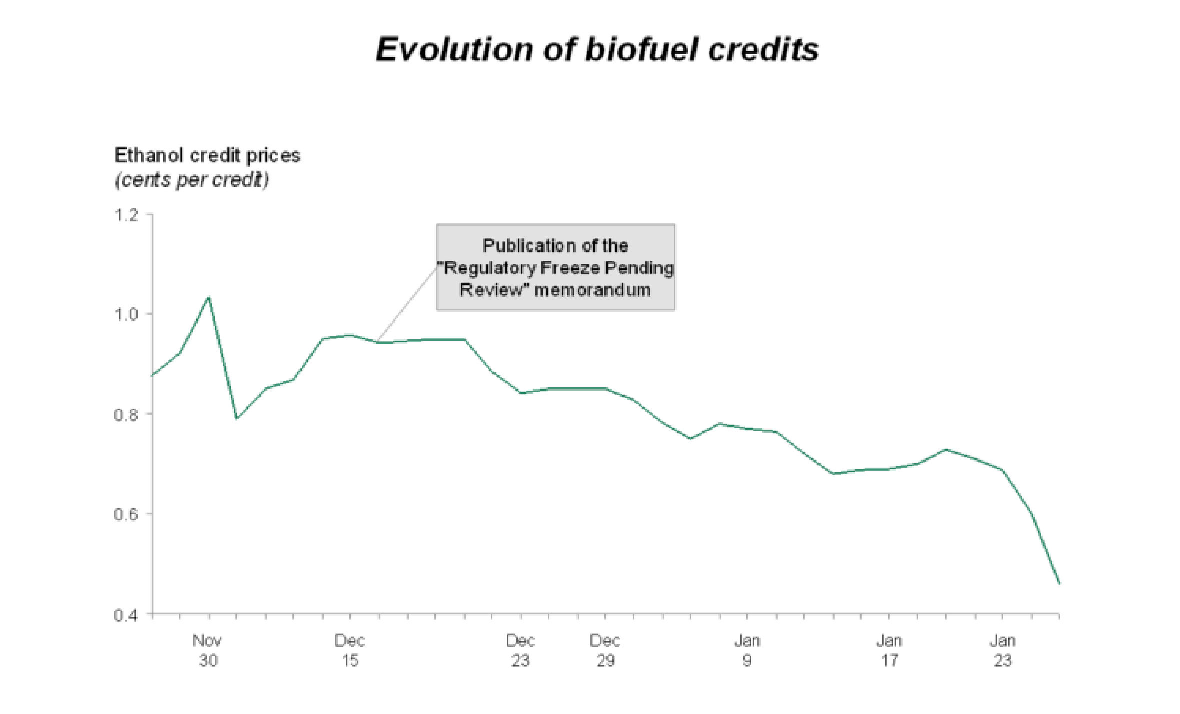


Source: 2014 and 2017 IEA Renewable Medium Term Market Report.

Biomass-based diesel generates Renewable Identification Number (RIN) credits, which are used by refiners and importers of gasoline and diesel to meet the RFS targets for the use of biomass-based diesel, advanced biofuels, and total renewable fuels. Biomass-based diesel RINs, also known as D4 RINs, are more valuable than D6 RINs for grain-based ethanol, given their flexibility in meeting multiple RFS targets. Increases in RFS targets for biomass-based diesel have led to increasing D4 RIN prices, promoting growing levels of biomass-based diesel consumption in 2015 and 2016. D4 RIN is biomass-based diesel (biodiesel, renewable diesel, cyanobacteria, etc.) and D6 RIN is renewable fuel (corn ethanol, starch – agricultural residues, etc.).

Nonetheless, in January 2017, a memorandum from President Trump, entitled “Regulatory Freeze Pending Review,” postponing the effective dates of certain published regulations, was made public. By this act, The Environmental Protection Agency delayed any regulations published in the Federal Register between Oct. 28, 2016 and Jan. 17, 2017. This has strongly impacted RINs, which plummeted to their lowest value since November 2015, as seen in Graph 7. USA was immersed in a great uncertainty on what will happen with ethanol production in the short term.

GRAPH 7. Evolution of biofuel credit prices in the USA



Source: Data compiled by Bloomberg.

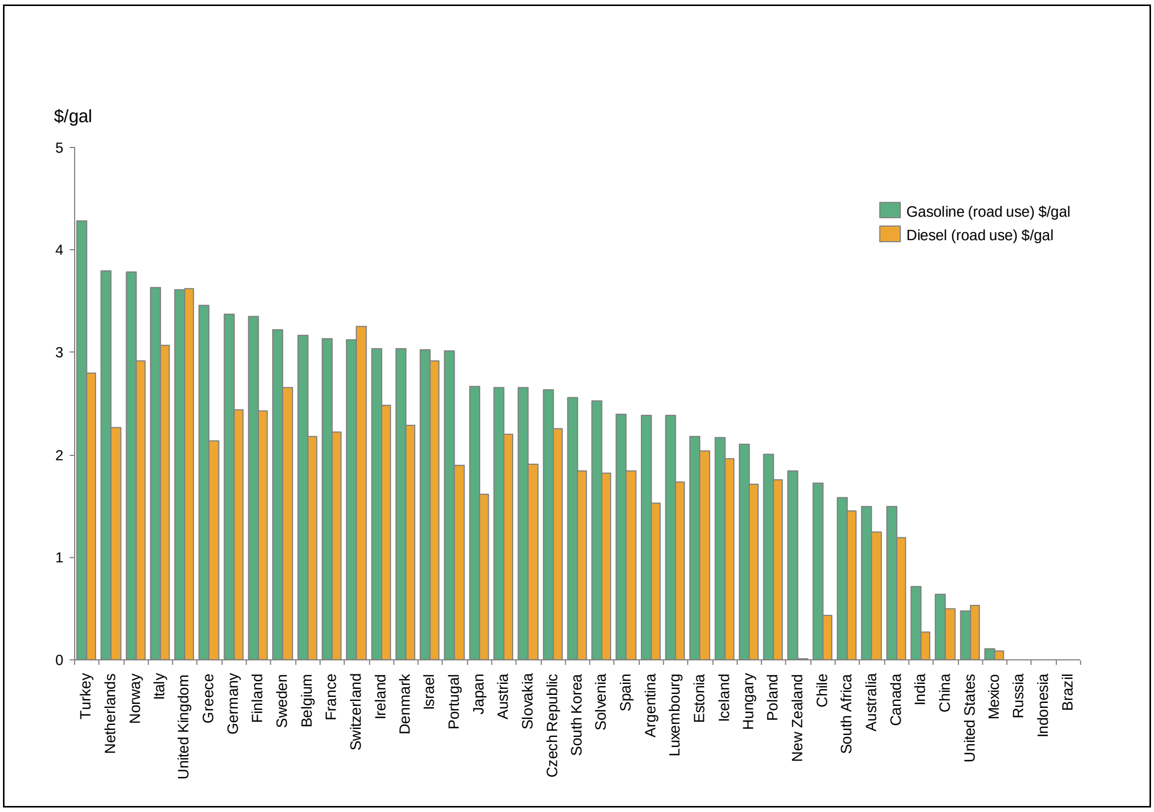
The European Union has enacted several criteria to ensure that renewable alternatives to fossil fuels in the transportation sector are promoted and consolidated. By 2020, the EU aims to have a global average of renewable energy share of 20% of final energy consumption (although each country has its own targets, which in some cases, are more ambitious) and, for each and every EU country, 10% of the transportation fuel coming from renewable sources such as biofuels. Additionally, the EU has set rigorous sustainability criteria for biofuels and bioliquids, to ensure that they are produced in a sustainable way, guaranteeing a reduction in carbon emissions and protecting biodiversity. Only those biofuels and bioliquids complying with these criteria can be eligible for counting towards national renewable energy targets.

EU countries have already agreed on a new renewable energy target of at least 32% of final energy consumption in the EU as a whole by 2030 (see section 2.2), in a cost-effective manner, as part of the EU's energy and climate goals for 2030. Regarding biofuels, they have defined an additional specific objective to develop the decarbonization potential of advanced biofuels, and to clarify the role of food-based biofuels post-2020 (no more than 7% by 2020 reduced to 3,8 in 2030).

Taxes

Different taxation rates on fuels and vehicles could drive consumer behavior towards the cheapest alternative. Taxes on transportation fuels are a relevant element impacting their consumer price and demand. There are significant differences in fuel taxes across regions and countries. Graph 8 shows that taxes for gasoline are generally higher than for diesel, and are the highest in Europe and Japan.

GRAPH 8. Taxation of road fuels in different countries (2016)



Source: Alternative Fuels Data Center (US Department of Energy).

The European Commission legislates the taxation of energy products, by the provisions of Council Directive 2003/96/EC. The Energy Taxation Directive (Annex I) establishes the minimum excise duty rates that Member States must apply to energy fuels for heating and transportation, and for electricity. However, road transportation fuel tax rates between Member States differ from one Member State to the next.

Fuel taxes impact demand for transportation fuels (gasoline and diesel) in three different ways, as described below.

Impact the relative competitiveness of different oil products. While in the US, gasoline taxes have been lower than diesel taxes, keeping diesel in a marginal position, in Europe, lower diesel taxation has led to its high utilization and, in recent years, the majority of car sales in Europe have been diesel cars. For the refining industry this has helped balance the product demand mix: the excess of diesel in the US is exported to Europe (short in diesel), while the excess of gasoline in Europe is exported to the US, where there is a deficit.

Finally, impact the competitiveness of oil products vs. alternative energy sources, such as biofuels, power, hydrogen or gas. If one fuel had a high enough taxation to impact its own economic competitiveness, in comparison with others (on an equivalent energy content basis), then its consumption would diminish.

Other

Besides efficiency, pollution, GHG emission targets and oil products taxation, there are several other ways in which regulations can impact demand for oil products. Below, there are some examples of political measures and developments that have, or will have, an either direct or indirect effect on oil product demand.

Several cities are partially banning the circulation of cars. For instance, Paris authorities restricted traffic in the city in December 2016, due to a surge in pollution that was causing concern over public health. It was thought to be the most intense peak in pollution in the last 10 years. Likewise, Madrid banned half of the cars from street roads, to fight air pollution, sometimes during periods when pollution levels were higher. This was the first time a Spanish city applied this kind of measure. Pollution levels have forced the city of Madrid to establish a protocol assuming several measures, depending on the pollution level. In a worst-case scenario of persisting and acute air contamination, city officials would ban all vehicles from entering the downtown area contained within the M-30 ring road. Another scenario contemplates a system of allowing cars on city streets alternately, depending on whether their license plates are odd- or even-numbered. This is what was implemented in December 2016. Other less-restrictive scenarios contemplate speed limits and parking bans.

Other cities, such as Bogotá, introduced different and more complex measures. The prospect of alternative day use wasn't successful, as many brought a second cheap car with a different license plate. Because of this, they decided to introduce an alternative measure, which the government calls *Pico y Placa* (peak and plate). This measure banned cars from circulating during the peak traffic hours, two days per week. They built upon the Mexican model *Hoy no Circula* (today it doesn't circulate), which banned cars from circulating in the city one day per week, depending on the last number of their number plate. The Colombian model sought to improve on this last one, by switching the combinations of days and numbers every year, making it harder to circumvent the measure by buying another car.

A different approach is followed by cities like Barcelona, which are favoring electric vehicles through toll and parking cost exemptions, and other perks. For instance, the city council grants all the electric vehicle owners with an identification card which offers them some benefits. Card holders can recharge at the electric recharging points of the city for free. In addition, it allows them free park to the electric vehicle in the regulated areas of the city (green and blue parking spaces).

1.4.3. Climate Change Regulations

Governments and organizations have become increasingly aware of, and concerned about, the impact of production and consumption of fossil fuels on the environment. As a result, many different forms of regulation have been adopted by developed economies to control GHG emissions, and many plans have been put in place to further control emissions in the future. The general trend of these regulations is to foster compliance with the GHG reduction commitment, and encourage a transition towards low carbon economy, then they can vary significantly based on geography.

Two different examples of regulations will be covered in this section, to illustrate some of the challenges that are, and will continue to be, faced by the O&G industry. Namely, the carbon dioxide cap and trade models and taxation. The concept of the former is presented with focus on the Emissions Trading Schemes (ETS), adopted, in particular, in the EU.

Carbon dioxide cap-and-trade models

Different models have been employed by different countries and organizations for reducing carbon dioxide emissions in the industry sector. The most commonly-used example is the cap-and-trade model, in which a CO_2 emissions cap is set, and then allowances (permission to emit a certain amount of CO_2) are provided to the industrial sub-sectors and production sites. The overall objective is to promote energy efficiency by setting a cost for the CO_2 emitted above the cap. If a production site emits less CO_2 than its granted allowance, then it is free to sell its extra allowance, and any other site exceeding their allowance shall purchase the balance that they require. The price of CO_2 is determined by supply and demand. This model is designed to create a relatively self-sustaining market in CO_2 allowance trading, minimizing the involvement required from governments.

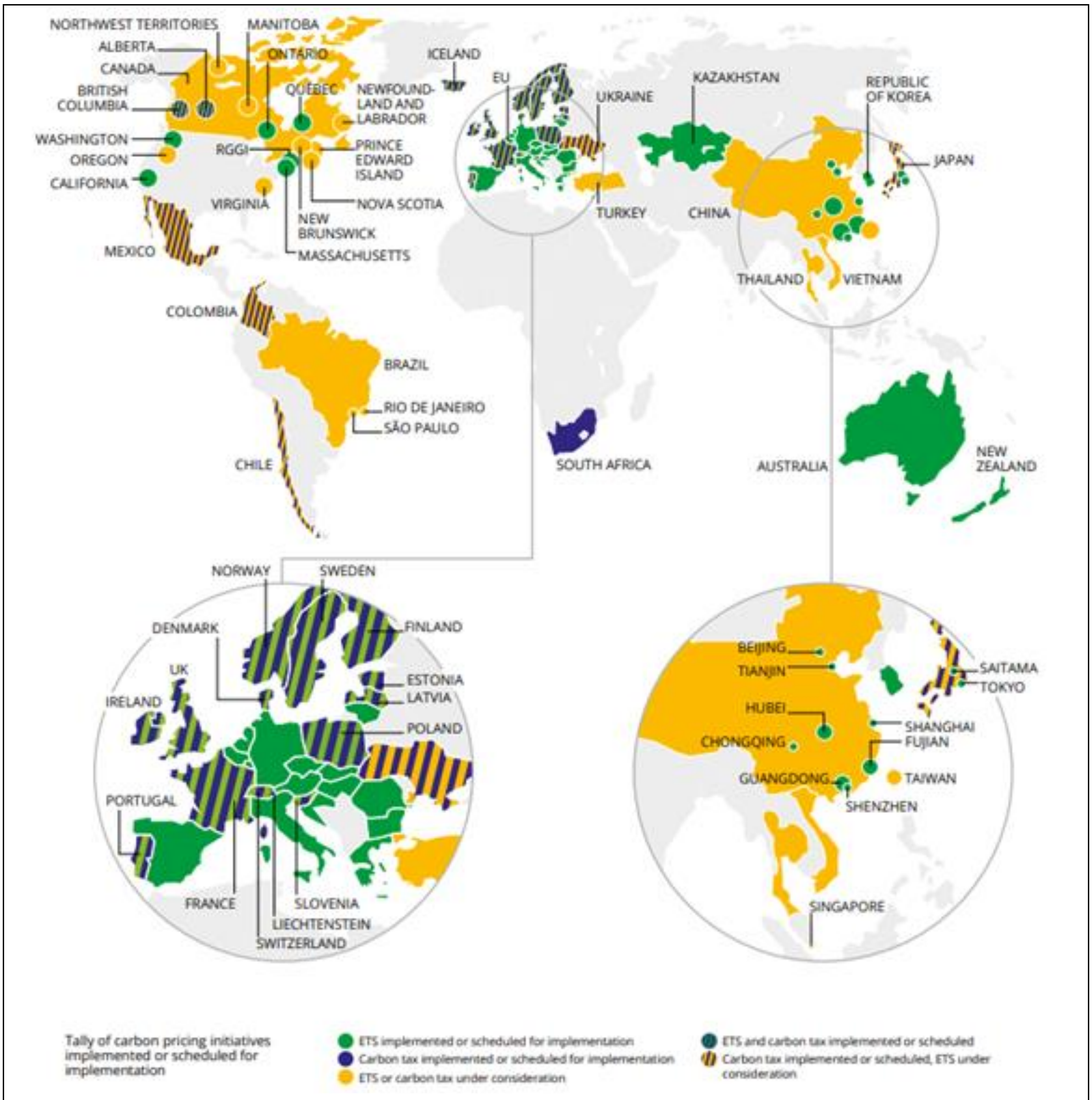
The impact of these schemes on industry, in particular on the refining industry, depends on three key factors: 1) the cap of CO_2 emissions set for all industrial sector; 2) the amount of free allowances provided for each subsector; and 3) the energy efficiency of each production site. All of them impact the supply and demand of the CO_2 allowances, and in turn, their price.

One example of the cap-and-trade model is the Emissions Trading Scheme (ETS) introduced by the European Union in 2005, with the objective of reducing 2020 emission levels to 21% below 2005 emission levels, in a cost-efficient manner.

Emissions trading systems

Emissions trading systems (ETS) are instruments that aim at reducing gas emissions, and as mentioned before, are based on the *cap-and-trade* principle. The creation of such systems for greenhouse gas (GHG) emissions has generated carbon markets. In the case of the industrial sector, this allows companies to trade with GHG allowances (permits to emit CO_2). According to the International Carbon Action Partnership (ICAP) *Status Report 2017*, "by 2017 there would be 19 emissions trading systems (ETS) in force across four continents (17 implemented and two scheduled for 2017: China and Ontario), covering 35 countries, 15 states or provinces, and seven cities". China and Ontario have been confirmed in 2017.

FIGURE 9. Overview of existing, emerging, and potential carbon-pricing instruments (ETS and tax)



Source: World Bank, Ecofys and Vivid Economics. 2017. State and Trends of Carbon Pricing 2017 (November), by The World Bank, Washington, DC.

Typically, a cap is set by the jurisdiction of the specific ETS, on the total amount of GHG that can be emitted by the actors under these concrete regulations, and can be reduced every year to achieve an overall reduction plan, according to the country or region's pledge, e.g. the EU's long-term pledge is to reduce emissions by 80-95% by

2050, over the levels recorded in the 1990s. The use of this trading system introduces flexibility, and ensures the most cost-effective strategies among the players, which will optimize the emissions cut with a minimum cost objective.

As can be seen in Figure 9, the number of carbon pricing instruments is increasing, i.e. there are multiple scheduled ETS or carbon tax systems, depending on the obliged subject, and there are countries considering the implementation of one of these emission control instruments. In 2016, there was total coverage of about 7 Gigatons of carbon dioxide equivalent, which represents around 13% of global greenhouse gas emissions. Moreover, if the Chinese national ETS is introduced, the coverage of GHG emissions could increase from 13% to around 25% of global GHG emissions.

Although the EU ETS is currently the world's major carbon market, with 31 countries involved (all 28 EU countries, plus Norway, Iceland and Liechtenstein), there is an increasing number of carbon-pricing instruments, like the Korea ETS (2015), or the Portugal carbon tax (2016). According to the International Emissions Trading Association (IETA), "56 jurisdictions, including 35 national and 21 subnational jurisdictions, have put a price on carbon through an ETS", by March 2016. China, the world's largest emitter of GHG, has taken a step forward, in 2017, to host the largest carbon market in the world.

ETS in the European Union

The EU emissions trading system (EU ETS) has the overall reduction target of, by 2030, reducing GHG to about 40% below 1990 levels, which implies an annual reduction of around 1.74%. The EU emissions trading scheme is divided into three phases (see Figure 10). Phase III of the EU ETS introduced harder measures, and included more sectors, setting a new emission goal: reduce GHG emissions by 20% in 2020 vs. 1990 levels. The Paris Climate Change Agreement signed in December 2015 confirmed the EU's intentions regarding reducing emissions, as the commitment set a new goal: to reduce GHG emissions by 40% in 2030 vs. 1990 levels, aiming to achieve a reduction of 80-95% by 2050 (vs. 1990 levels). Hence, the number of allowances will be reduced, and consequently, the price of allowances will increase.

However, the acquisition of allowances differs, depending on the sector. This is why, in this phase, four large industrial subsectors are established, and treated independently: a) power companies need to acquire allowances for 100% of their emissions; b) industrial sectors under risk of carbon leakage have allowances that are fixed, according to the emissions of the top 10 plants in the sectoral benchmark, including refining and chemical sectors; c) air transportation has a specific scheme, in which allowances are distributed by airline, and those emissions corresponding to trips with destination of origin in the EU, will be taken into account; d) the free emissions of industrial sectors without a risk of carbon leakage are gradually reduced, so that in 2020 they will only receive 30%, and thus have to acquire the remaining emissions.

FIGURE 10. European ETS implementation schematics

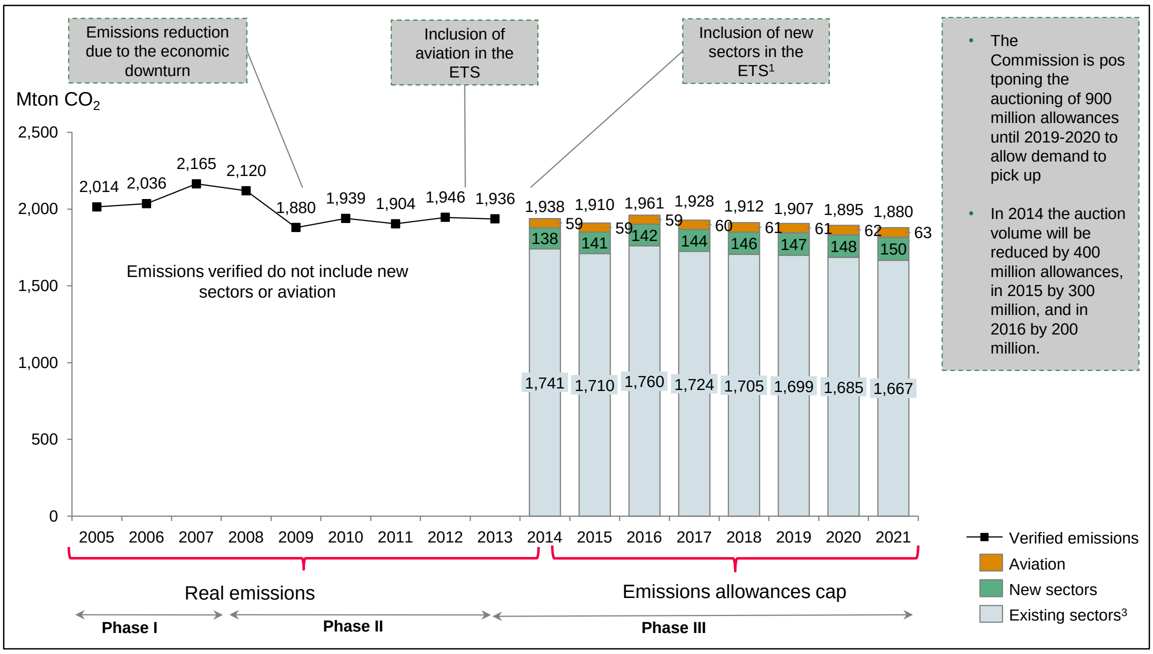
	Phase I 2005-2007	Phase II 2008-2012	Phase III 2013-2020
What it introduces	Establish a carbon price Define free trading of allowances across the entire EU Create the infrastructure required to control, register and verify affected companies' actual emissions	Based on the verified emissions registered in Phase I, the Commission reduced the volume of allowances permitted in Phase II by 6.5% vs. 2005 levels	Substitution of the national allowance limit system for a single limit, across the entire EU Gradual move towards auctioning all allowances, instead of the free allocation system
Objectives	No emissions objective for 2007: "Practical learning" phase	8% emission reduction vs. 1990 levels by 2012 Compliance with the Kyoto Protocol	20% emission reduction vs. 1990 levels Reaching up to 30%
Industries involved	Coverage of 52% of CO_2 emissions in the EU	Coverage of electricity and energy sectors (refining, coke production) and energy-intensive industries (cement, ferrous metals, minerals, pulp and paper)	New industries to be included Petrochemicals and aluminum Aviation1 CCS2
Allowance allocation	95% of allowances are freely allocated to facilities, auctioning the remaining 5%	90% of allowances are freely allocated to facilities, auctioning the remaining 10%	At least 50% of allowances will be acquired by auction, as a prior step to applying this purchasing scheme to all allowances in 2027: • Electric utilities: 100% auctioning since 2013 • Industry: 20% auctioning in 2013, to reach 70% by 2020, and finally 100% by 2027 • Carbon leakage: allocation of free emissions until reaching the emissions of the 10% least-emitting facilities identified through a sectoral benchmarking Allowance reduction by 21% vs. 2005
	Despite allowances only being allocated to companies affected by the ETS, anybody (individuals, institutions, NGOs or other organizations) can purchase and sell on the market, as companies do		

Source: BCG analysis.

Graph 9 shows the reduction of allowances from the start of Phase III, which has increased the pressure in the CO_2 market.

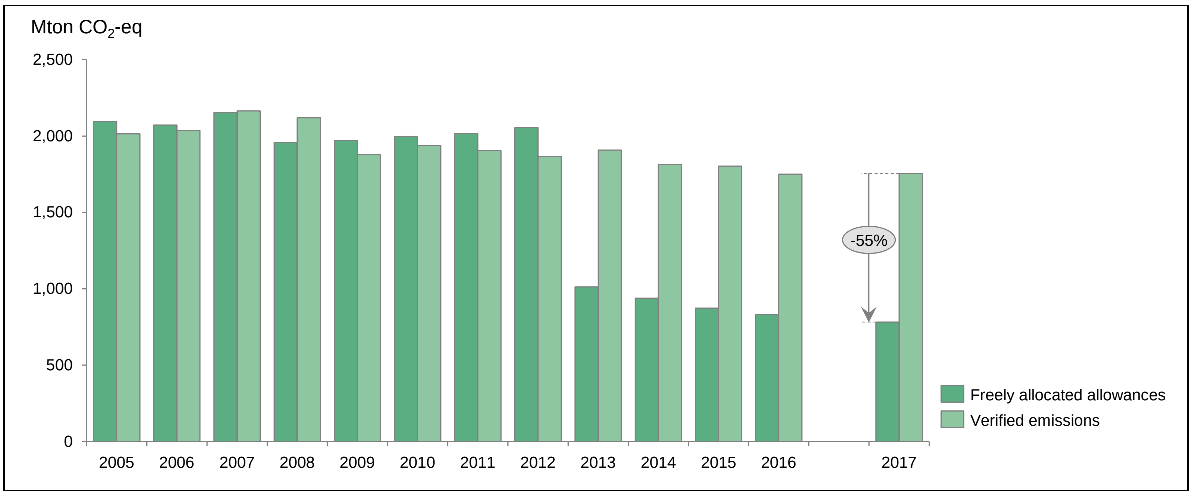
The implementation of Phase III has added risk to some 1.5 Mbpd of refining capacity in the EU, mainly hydroskimming due to loss of margin. Moreover, the number of freely-allocated allowances in the EU ETS has decreased considerably; the last data available shows that, for stationary installations, the quantity of verified emissions doubles the freely-allocated allowances (see Graph 10).

GRAPH 9. Allowance reductions since Phase III



Note: Inclusion of aviation takes place in 2012 with 97% of the average of emissions in 2004 – 2006; 2. CO_2 emissions of bulk production of organic chemical products, hydrogen, ammoniac and aluminum; N_2O emissions of the nitric acid production, and PFC emissions of aluminum production; 3. This figure could vary depending on the airlines that are included in the ETS; 4. Norway allocations included.
Source: The EU ETS: Point Carbon; EEA.

GRAPH 10. Free allowances and emissions for stationary installations



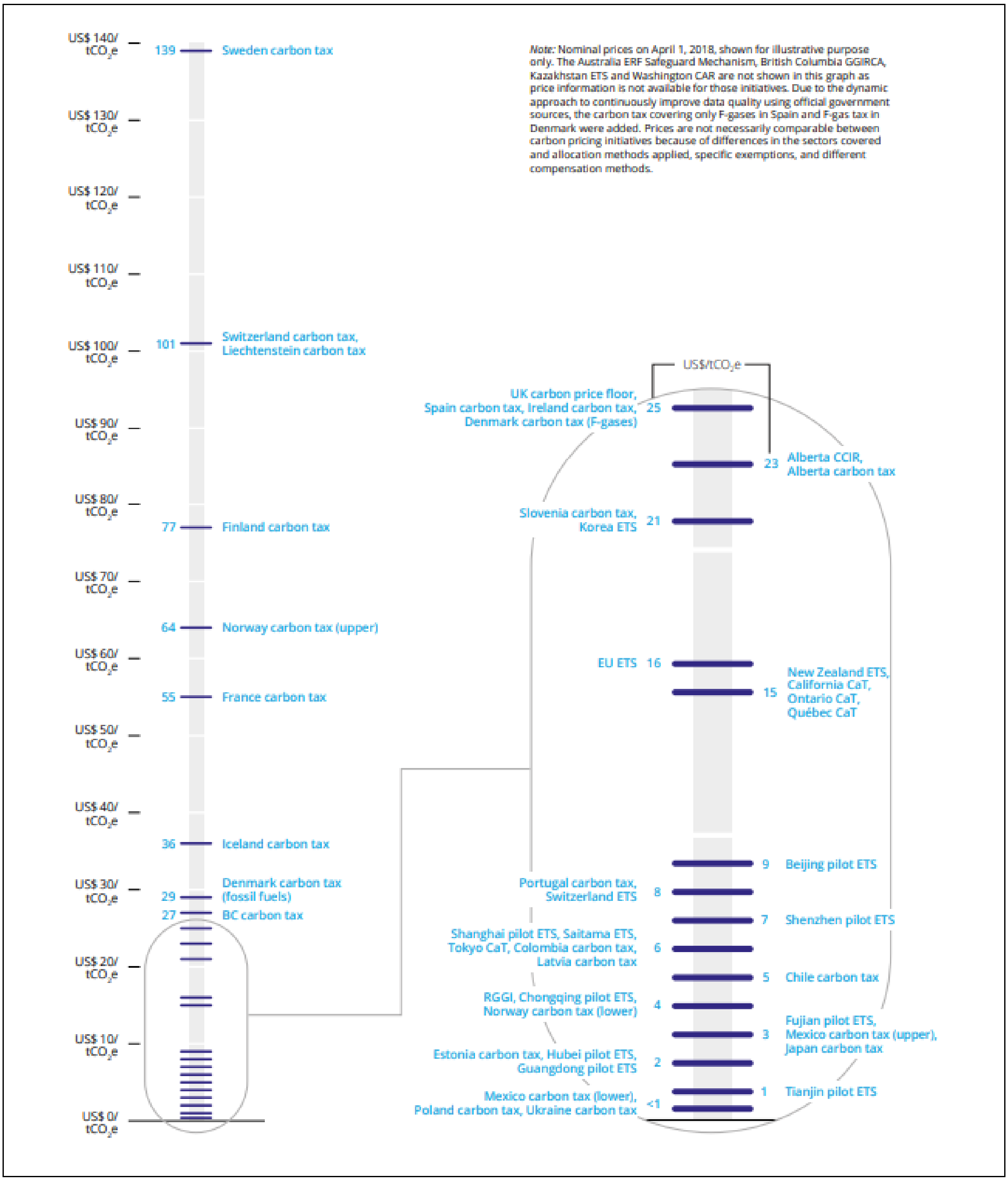
Note: BAU – Business As Usual.
Source: European Environment Agency.

Taxation

Taxes - both environmental and corporate - are an important element in defining the relative competitiveness of different countries' and regions'. The regulations on taxation that apply to refineries and refined products vary worldwide, as there is a different taxation system for each country or region, although in some regions, such as the European Union, there are common strategies and initiatives.

One of the most common initiatives that has been adopted by several countries is the Carbon Tax, a form of pollution tax that sets a price for each ton of CO_2 equivalent emitted, considerably impacting product prices and then demand. An illustration of the prices from the different carbon-pricing programs implemented by a range of countries is shown in Figure 11.

FIGURE 11. Prices of existing carbon-pricing initiatives (2016)



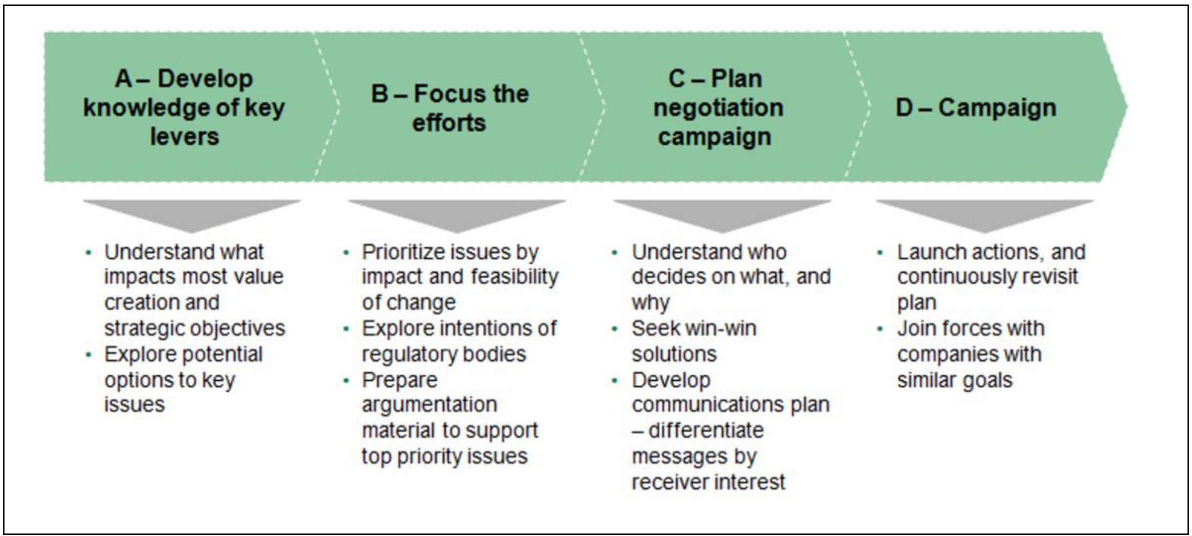
Source: World Bank, Ecofys and Vivid Economics.

1.4.4. A brief review of some impacts of regulations for refiners

Section 2.4 has discussed regulations with implications on energy supply and demand. The extent to which refining business will be impacted depends on a number of factors: a) the rate at which new regulations are introduced and existing regulations are tightened, b) the location of the refinery operations, c) the complexity of the refinery, and d) the preparedness of the refinery.

The last of these points is the key lever that a refinery controls, in order to ensure that it can continue to operate successfully as the regulatory environment evolves. A systematic approach to assuming greater ownership of the regulatory process and its outcomes is key to a refinery performing well in these uncertain conditions – key steps are identified below.

FIGURE 12. Key steps to taking ownership of the regulatory process



Source: BCG analysis.

Based on an analysis (EU Petroleum Refining Fitness Check: Impact of EU Legislation on Sectoral Economic Performance, 2015) performed by the European Commission, the most relevant pieces of EU legislation with regard to the refining industry are as follows:

a) the introduction of biofuels as substitutes for fossil-based fuels is the most relevant implication of the Renewable Energy Directive for EU refineries, as it could imply a significant reduction in demand for fossil-based fuels. Moreover, additional expenditure by refineries, related to biofuel production, amounted to €0.5 million/year per refinery (2000-2012), and grew to €0.9 million/year (2009-2012), according to industry data (Concawe, 2014);

b) the Energy Taxation Directive set minimum excise rates for fuels, which are aimed at reducing divergent tax rates in EU countries. Although it had a slight impact, by reducing gasoline and diesel demand (0.17% and 0.10%, from 2004 to 2008, and

0.27% and 0.32%, from 2009 to 2013, respectively), this measure did not affect around 60% of the Member States, which represented approximately 86% and 78% of gasoline and diesel markets in the EU, respectively, as their taxation levels were already higher than the minimum set by the ETD;

c) the EU Emissions Trading System policies did not imply relevant costs for the oil refining sector; on average, EU refineries achieved an increase in income, due to the surplus of emission allowances during the 1st phase. However, the ETS reduced the competitiveness of EU refineries, with regard to other regions, and in particular, low conversion refineries, for which the cost of CO_2 could be more significant, in comparison with their margin. EU refineries have seen their production levels significantly reduced, though it cannot only be attributed to the ETS, since it was mainly due to the EU recession;

d) the Fuel Quality Directive regulates the environmental specifications of petrol/gasoline, and diesel, and sets rules to calculate CO_2 reduction default values for biofuels. Implementation of this directive has implied a significant investment for refineries. Solomon Associates (2014) provided an estimate of the annual capital investment costs for meeting fuel specifications during the 2000-2012 period: around €0.14/bbl for all clean fuels, €0.06/bbl for gasoline and €0.08/bbl for diesel and gasoil;

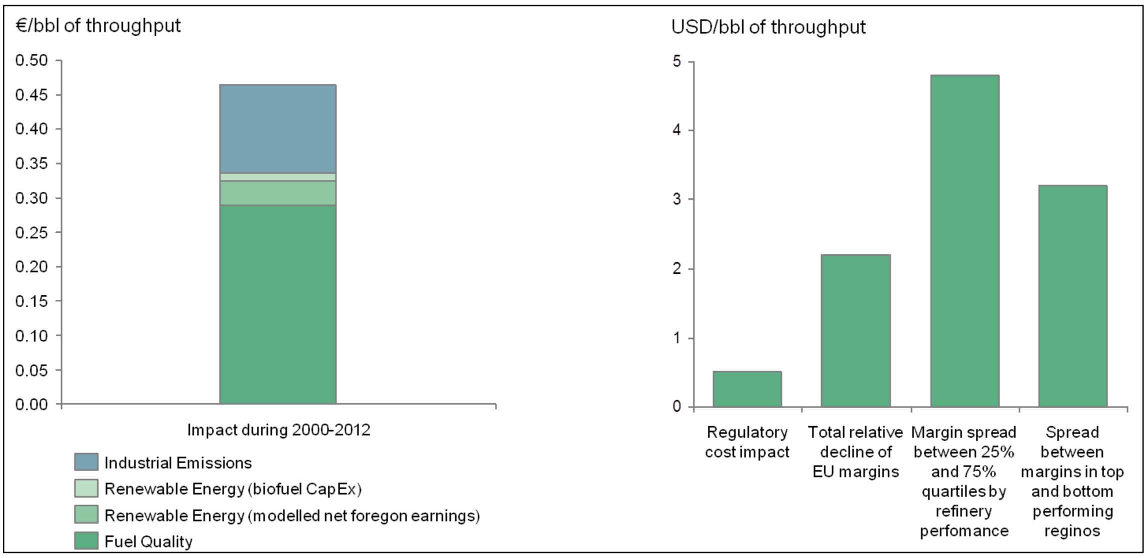
e) the Industrial Emissions Directive, Directive 2010/75/EC, which includes the Integrated Pollution Prevention and Control Directive 2008/1, and the Large Combustion Plants Directive 2001/80, implied an average capital expenditure of €5 million/year per refinery, in order to comply with emission and effluent regulations. The associated cost implied a margin reduction of approximately €0.13/bbl; and

f) the directive relating to Sulfur Content of Certain Liquid Fuels (including Marine Fuels), Directive 2016/802/EU, which implied sulfur content reductions, has not had a relevant impact on refineries so far, because the specification on sulfur was achieved by using low-sulfur crude oils and re-blending,; however, it will have an impact as of 2020, with the entry into force of the IMO to which it is linked.

The impact of EU legislation on the investments and competitiveness of EU refineries can be summarized in the following diagrams of Graph 11.

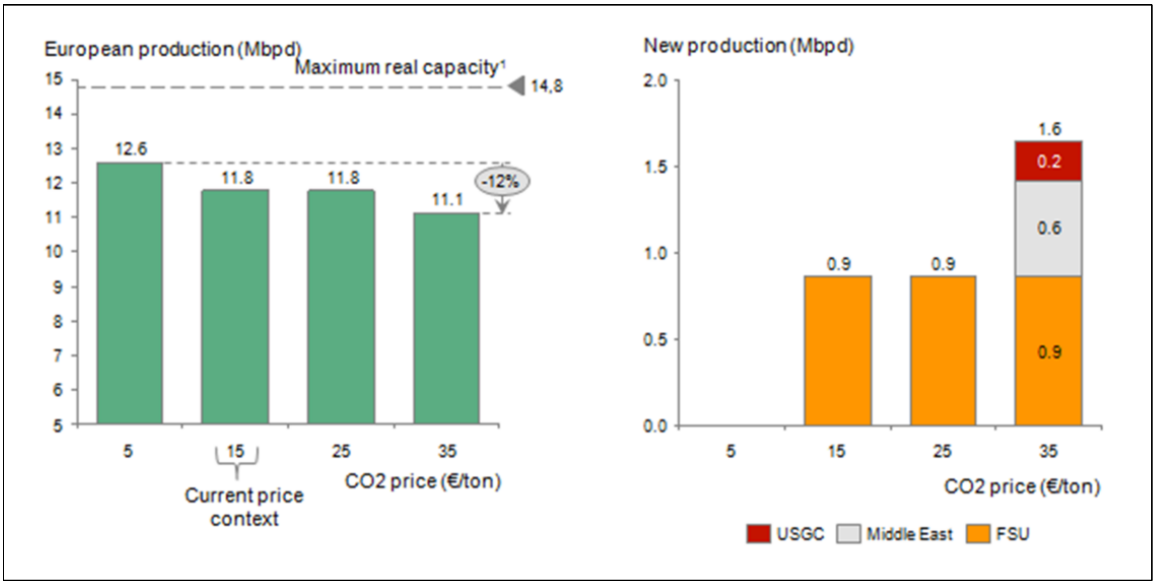
Specifically, it is also interesting to note the impact on production from European refineries. The impact on production from European refineries is related to the amount of the overall free allowances granted to the sector, and the resulting CO_2 market price, but could result in a significant drop in margins for some refineries, and in production moving to more efficient sites or less regulated countries, resulting in lower refinery utilization (see Graph 12, which is useful for illustrative purposes only).

GRAPH 11.
Left: The average estimated quantifiable impact of the legislation on EU refineries during the 2000-2012 period, per barrel throughput
Right: Comparison of the quantified total cost effect of legislationwith other performance parameters of EU refineries



Source: EU Petroleum Refining Fitness Check: Impact of EU Legislation on Sectoral Economic Performance.

GRAPH 12. Projected European production relocation based on CO_2 price



Source: BCG analysis.

Up to approximately 1,500 Kbpd of refinery production could be displaced from Europe. This production would be transferred to FSU, USCG and the Middle East.

TABLE 7. Regulations	
New landscape issues	**Challenges (for industry players)**
Regulations License to operate in E&P, refining, pipeline transportation and other installations Energy efficiency: setting requirements to reduce energy consumption and CO_2 emissions (European Energy Efficiency Directive) ETS schemes Energy taxation: setting a value for CO_2 emitted in fuel and fuel taxes Stricter international regulations on pollutant emissions (i.e. SOx, NOx and others) Product regulations limiting the presence of hazardous components of high concern in oil products Minimum requirements of advanced biofuels and/or renewables in transportation fuels Regulations on liquid and solid waste reduction and discharge Measures and legislative proposals to boost sustainable growth	• Reduce land occupation, energy consumption, discharges and other environmental impacts in E&P and refining • Maintain and improve efficiency and efficient incorporation of renewable energies in their activities • Implement efficient processes to reduce sulfur in fuels and adjust their properties for engine requirements to allow low NOx burning • Develop and implement ways to reduce/eliminate these hazardous components from fuels • Improve waste reuse, treatment and elimination (reinjection) processes • Increase health and safety in operations • Reduce harmful spillages and pollutant emissions, with the goal of achieving "zero release" • Improve the current record figures of incidents in production, transportation and refining, and inform society on them • Organize a quick global industry response (operational and financial) to any emergency that could occur • Satisfy the increasing number of stakeholder demands, complyingwith responsible environmental measures • Develop and implement a risk management policy

Source: own elaboration.

1.4.5. Challenges related to regulations

The development of new regulations will lead to new challenges for the O&G industry. The industry is under constant pressure to enforce more stringent regulations, and especially those related to environmental impact. O&G players need to ensure that they take measures to reduce land occupation and energy consumption, improving efficiency gains, while under new financial environments in the industry, as discussed in previous sections.

Companies are also being challenged to reduce hazardous components in fuels and the pollutants that are emitted. In addition, the industry must find ways to reduce/reuse waste, and particularly water, which is used in large quantities in the production and refining processes.

Finally there are the challenges related to reduce incidents, organize quick responses, develop and implement risk management policies and satisfy the increasing number of stakeholder demands complying with responsible environmental measures. A relation of points related to the new landscape and of the challenges may be seen in Table 7 above.

2. OIL PRODUCTS DEMAND AND SUPPLY: CURRENT STATE AND FUTURE UNCERTAINTIES

Whilst it is common throughout most industries to refer to the two terms, supply and demand, in this order, in this document the two subjects are described in the alternative order. This has been done as it is felt that the supply side in the oil and gas industry, in spite of the large storage capacities, it is ultimately focused on the customer demand and, as such, ends up reactive to developments on the demand side.

In this chapter there are two main points of focus: the first is to offer an overview of the uncertainties that will likely influence consumption of oil and gas products due to alternative energy and vehicle technologies; in particular, the demand for a greater variation end products is analyzed (gasoline, diesel, etc), along with the resulting dynamics of balance. The second addresses oil supply evolution by analyzing investments in E&P and refining. This gives insights into the both the past investment strategies in E&P, with a range of parameters of asset developments, as well as the investments in refining, which setup the critical infrastructure and facilities to bring the end products to market.

2.1. Demand evolution

In this section different aspects will be covered. Firstly, the demand evolution impact due to regulation, which is referred below and that has been examined in detail in section 2.4. Secondly, a detailed examination is carried out about the uncertainties in demand due to alternative energies and technologies.

2.1.1. Demand evolution impact due to regulation

Oil products demand has been growing continuously, due to their ample uses and applications, which range from fuels to special chemicals, and as a feedstock for many industries (i.e. lubricants, asphalts, basic chemicals, polymeric materials, paraffins, waxes, etc.) and consumer products (i.e. textiles, insulating and construction materials, fertilizers, adhesives, fuel additives, etc.). However, though oil product demand has been traditionally on the rise, there are several uncertainties regarding its future, which are related to the impact on transportation fuels of new environmental policies adopted in the fight against global warming.

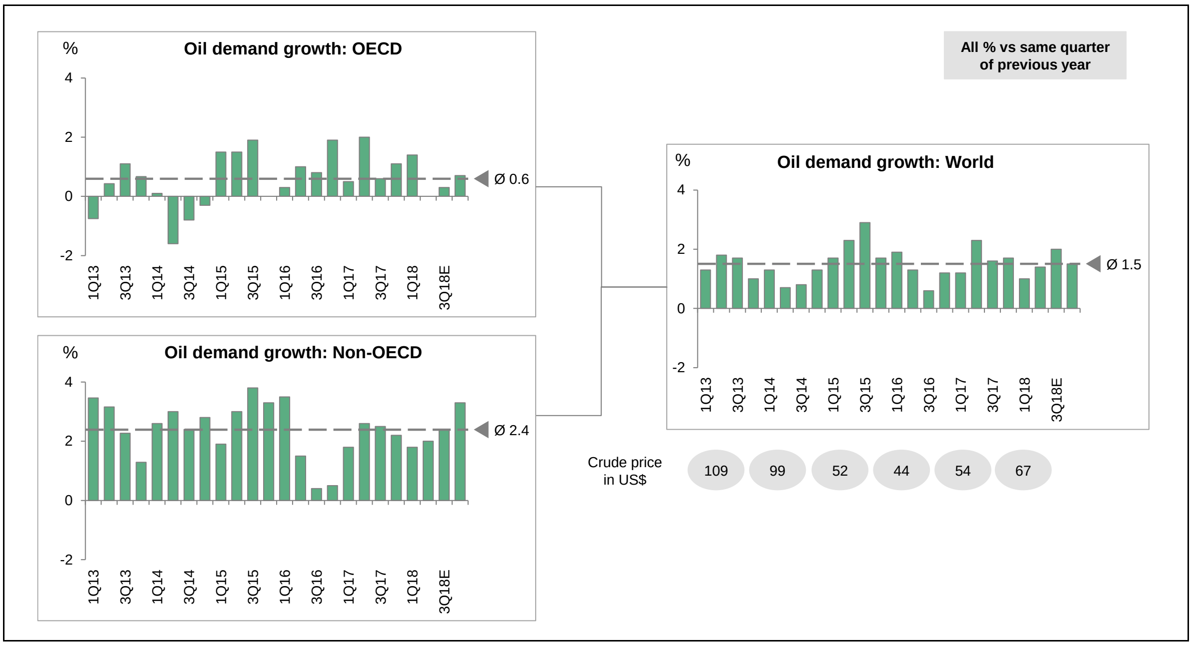
The most prominent in the last years, which will have an effect on the demand evolution, is the United Nations Paris Climate Change Conference of 2015 (COP 21) which represented one of the most ambitious agreements, since the Kyoto Protocol in 1997, to fight against global warming, by setting out a global action plan to limit world temperature to well below 2°C above pre-industrial levels.

As highlighted in Section 2.4, there are a multitude of regulations that will impact the demand side. These directly affect the consumer, like in the case of alternative energy incentives, which will be addressed in more detail in the following Subsection 3.1.2, or the producing companies. The main regulations directly affecting operators were identified in Subsection 2.4.1 as largely surrounding the topics of environmental legislation, or with a focus on the wellbeing of the human population – improved safety management of operations, transportation safety of bringing product to market, and product regulations regarding the physical properties of the petroleum products to be consumed.

2.1.2. Uncertainties in demand due to alternative energies and technologies

Commercial development of alternatives to fossil fuels for transportation, which is mainly regulatory-driven, has created real alternative markets which might capture some share of the future transportation energy mix. Thus, electric vehicles or gas-powered vehicles pose a real threat to the oil kingdom in the transportation sector.

GRAPH 13. Oil product demand growth segmentation



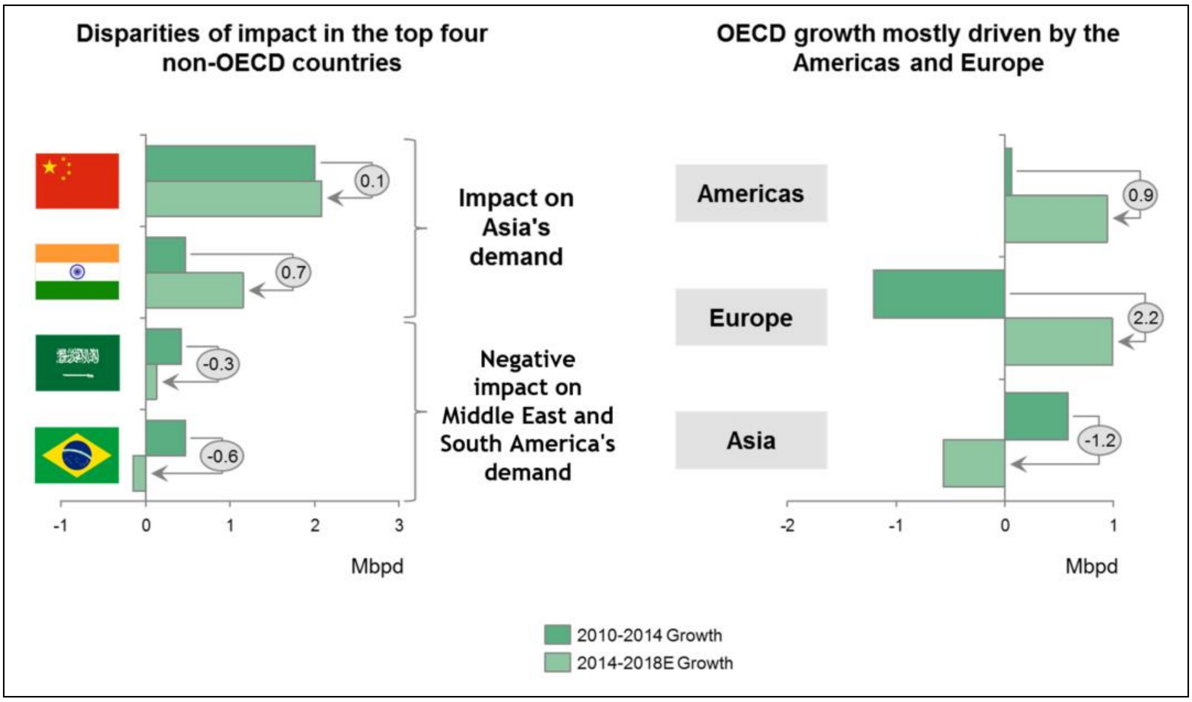
Source: IEA OMR, Bloomberg.

In the short/mid-term, global oil product demand is expected to keep growing, as developing economies - such as China or India - continue their growth paths and more people have access to personal cars. However, not all regions are following the same trend: in developed areas, such as the US or Europe, oil demand looks like it has already peaked, and could soon start to display a declining or flat trend. In other areas, growth is consistent, and there is even room to continue growing. Nevertheless, in the longer term (beyond 2025), the possibility of a peak oil demand scenario is becoming more apparent.

Oil product demand depends on different market factors, leading to great variation in its evolution in recent years. If demand growth is split into OECD and non-OECD countries, it is clear that non-OECD countries drive demand growth (see Graph 13).

Great disparities can be found either between OECD and non-OECD countries, or even within each group with regard to demand growth, as seen in Graph 14.

GRAPH 14. Disparities in oil demand growth



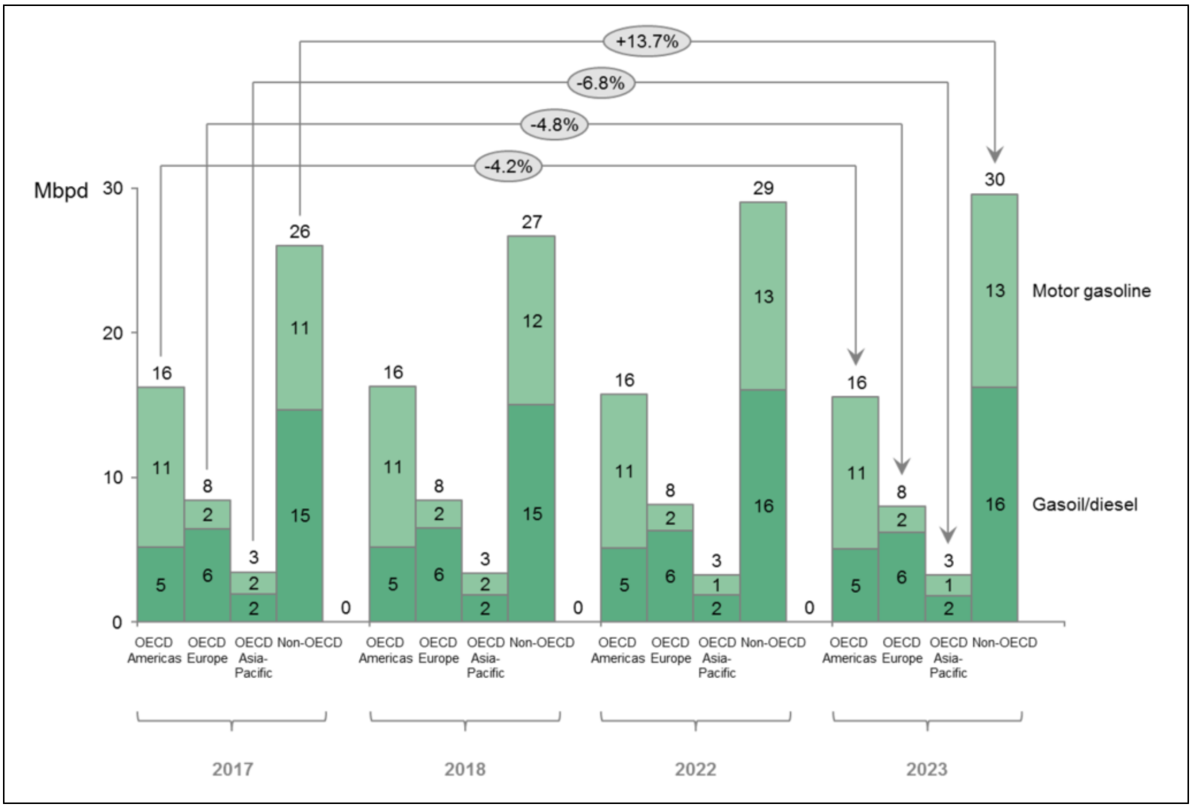
Source: IEA MTOMR.

Graph 15 shows the demand evolution by OCDE and non-OECD areas for motor gasoline and diesel; in the medium term, demand is forecasted to be driven, mainly, by non-OECD countries.

Gasoline/Naphtha demand evolution and regional balances

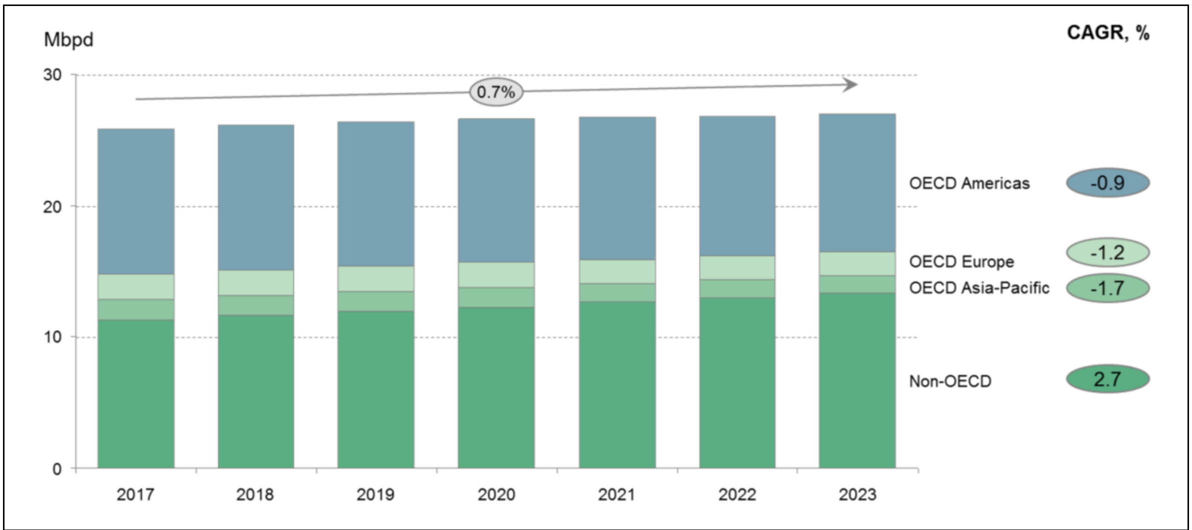
Estimated gasoline demand presents a discrete growth rate for the coming years, mainly driven by non-OECD countries demand. The increasing transportation consumption, and the economic recovery after the crisis, are the main levers for this demand growth; meanwhile, OECD Americas and Europe will show a flat demand (see Graph 16).

GRAPH 15. Final consumption segmentation



Source: IEA MTOMR.

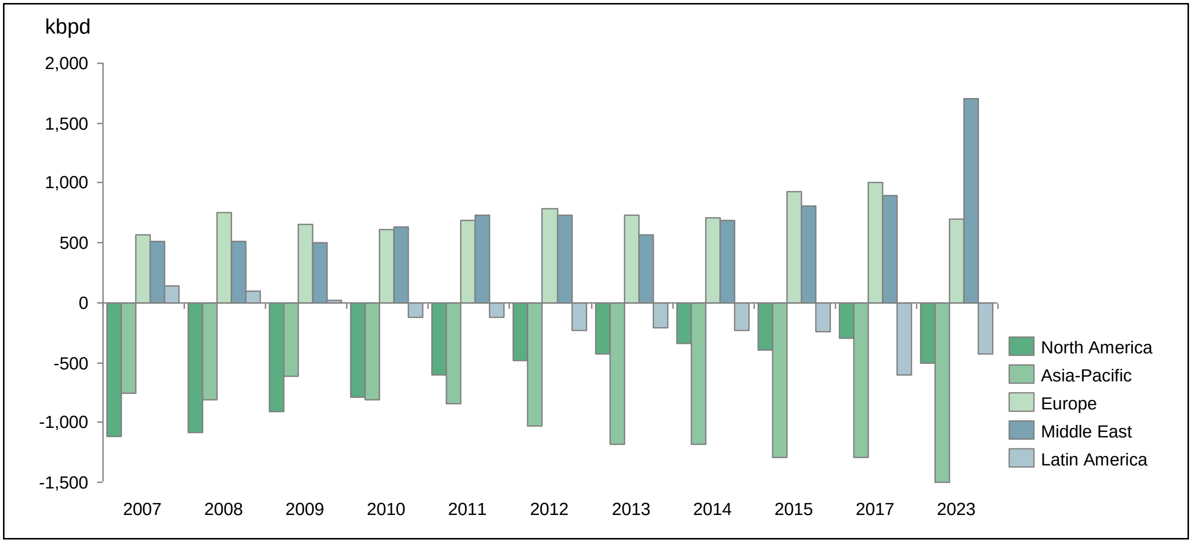
GRAPH 16. Gasoline demand evolution



Source: IEA 2018, BCG analysis.

With regard to regional balances, Europe is the world region with the strongest net naphtha/gasoline exports, with such exports reaching around one million barrels per day. However, the dieselization offsets the gasoline demand in Europe, making necessary to export the excess of gasoline produced, which is only to be surpassed by the Middle East in the coming years. In comparison, OECD Americas is gaining space, and becoming less short for the gasoline/naphtha duo (see Graph 17).

GRAPH 17. Gasoline/Naphtha regional balances

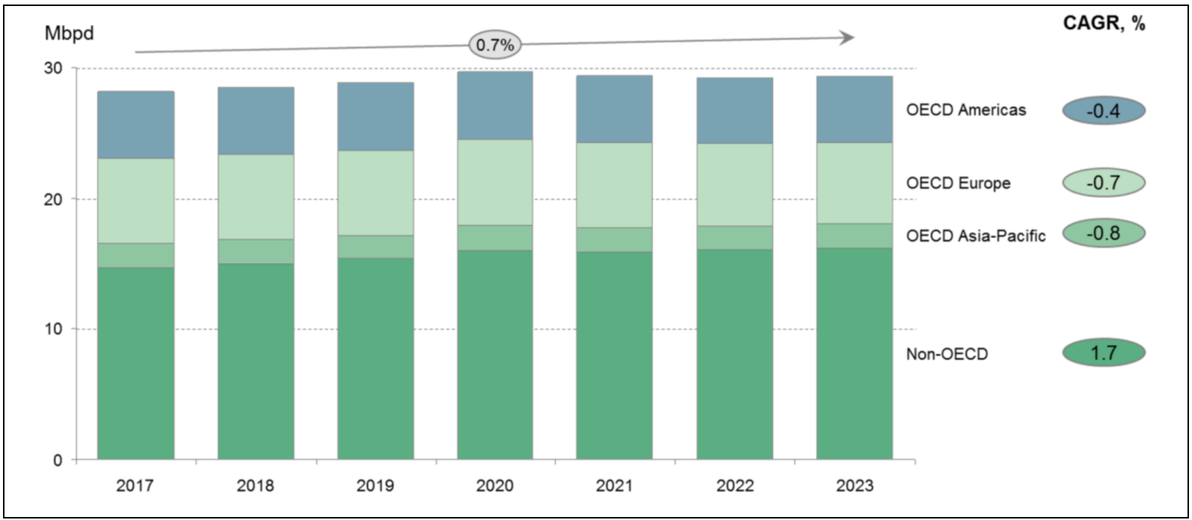


Source: IEA 2018, BCG analysis.

Diesel/Kerosene demand evolution and regional balances

In reference to diesel demand evolution, this demand is recovering pre-crisis growth rates until 2020, and the main driver for this fact is non-OECD increasing diesel demand, based on its economic recovery. The rest of the world regions show a flat or declining demand.

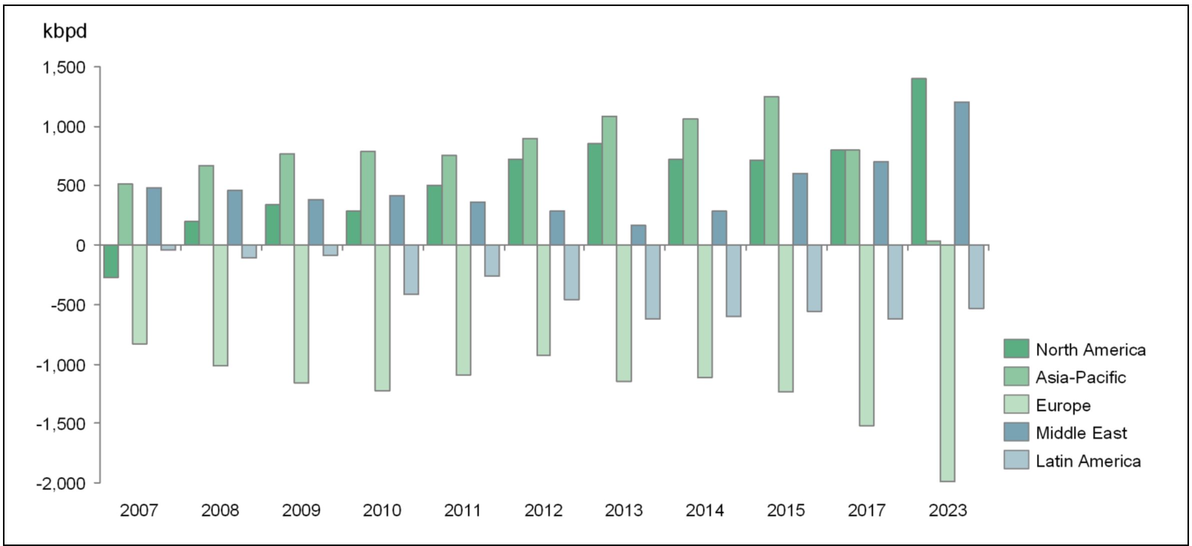
GRAPH 18. Gasoil/Kerosene demand evolution



Source: IEA 2018, BCG analysis.

In this case, regional balances are contrary to gasoline. As Europe's demand, due to past strong dieselization, is not covered with the diesel produced in the region, it is therefore necessary to import (see Graph 19).

GRAPH 19. Diesel/Kerosene regional balances



Source: IEA 2018, BCG analysis.

Meanwhile, Asia and North America are the main net kerosene/diesel exporters in the world (exports on the positive end of the graph). While in North America, diesel demand is much lower, due to weak dieselization, and presents a short position in kerosene, in Asia, the great diesel production capacity easily outpaces the demand, also being a kerosene exporter.

Other energies for transport

As a result of regulations and technological development, which have been discussed in Chapter 1, new commercial alternatives to conventional fossil fuels have been appearing for some time now (not all alternative energies for transport are covered in this chapter). In some cases, like in the use of compressed natural gas as a road transportation fuel, technology has been available and marginally used for decades, but recent decarbonization strategies, political measures to reduce dependence on oil, technological developments and standardization, have fostered the growth of the compressed natural gas (CNG) fleet; in other cases, such as the electric vehicle, battery developments and power electronics have recently increased their competitiveness (both economical and functional), driving their growth.

Following technological advances, and with countries under pressure to look for sustainable alternatives to traditional fossil fuels used in transportation, alternative energy sources have emerged. Nonetheless, the market development of alternative fuels is still held back by technological and commercial shortcomings, lack of full consumer acceptance, higher vehicle prices and lack of an adequate recharging infrastructure. The current higher cost of innovative alternative fuel applications is largely a consequence of these shortcomings. Although they have evolved and emerged as substitutes to fossil fuels, they still require targeted incentives and policies to become a viable substitute.

For this reason, governments are establishing policies to promote the use of alternative fuels in transport. For instance, in 2013, the European Commission launched the Clean Power for Transportation package, aiming to facilitate the development of a single market for alternative fuels for transport in Europe. The final Directive adopted by the European Parliament and the Council in September 2014 requires Member States to develop national policy frameworks for the market development of alternative fuels infrastructure; it foresees the use of common technical specifications for recharging and refueling stations, and it paves the way for setting up appropriate consumer information on alternative fuels, including a clear and sound price-comparison methodology.

The next sections focus on examining electric vehicles (EVs), CNG and LNG. Other alternatives such as GTL, advanced biofuels, biogas or hydrogen are only briefly discussed. The interested reader may refer to the studies mentioned in the note below. [20]

Electric vehicles

Electric vehicles are one of the main threats to oil products demand in the current environmentally-focused context. Electric vehicles can be supplied by electricity from the grid, coming increasingly from low-CO_2 energy sources, from the energy mix to the wheel. Electric vehicles "in situ" emit no pollutants and almost no noise, and thus, are more suited for urban areas. An alternative configuration is the plug-in hybrid vehicle. It combines an internal combustion engine and electric motors and can reduce fuel needs and CO_2 emissions by improving the overall energy efficiency of propulsion. However, without external recharging possibilities, this is not considered an alternative fuel technology.

Electric vehicle technology is evolving and reaching a more mature state. Nevertheless, high cost, low energy density and the heavy weight of the batteries continue to be its main obstacles. Currently, standard recharging can take a long time: between 4 and 8 hours, depending on the charging power. Improvements in battery technology - resulting in a decrease in their price - could improve their cost problem. Another relevant issue is the lack of public recharging points.

Governments are launching policies, in order to tackle these main problems and promote the surge of EV's vs. conventional vehicles. For instance, Directive

[20] For a detailed description of the regulation, the case of different countries in the use of alternative energies in transport, and some scenarios of penetration in the Basque country and Spain, see Alvarez E., and Menéndez J. (2017), Alvarez E., et al (2017), and Alvarez et al (2017).

2014/94/EU, on the deployment of alternative fuel infrastructure, launched in 2014, requires all Member States to set targets for recharging points accessible to the public, to be built by 2020, to ensure that electric vehicles can circulate at least in urban and suburban areas. Targets should ideally foresee a minimum of one recharging point per ten electric vehicles[21]. Moreover, it makes mandatory to use a common socket outlets and connecting plugs all across the EU, which will allow EU-wide mobility.

In the United States, the government has also prompted the increase in the share of electric vehicles. Former President Obama, in his 2011 State of the Union address, defined the objective of promoting the use of EVs through improvements to tax credits in current law, investments in R&D and competitive programs to encourage communities to invest in infrastructure supporting these vehicles, to reach one million EVs on the road by 2015. Previously, the United States had been fostering the share of EVs. Through the Recovery Act, they made an unprecedented investment, to build domestic manufacturing capacity and secure their position as a global leader in advanced lithium-ion battery technology. The investment included US$2.4 billion in loans to three of the world's first electric vehicle factories in Tennessee, and US$2 billion in grants to support thirty factories that produce batteries, motors, and other EV components.

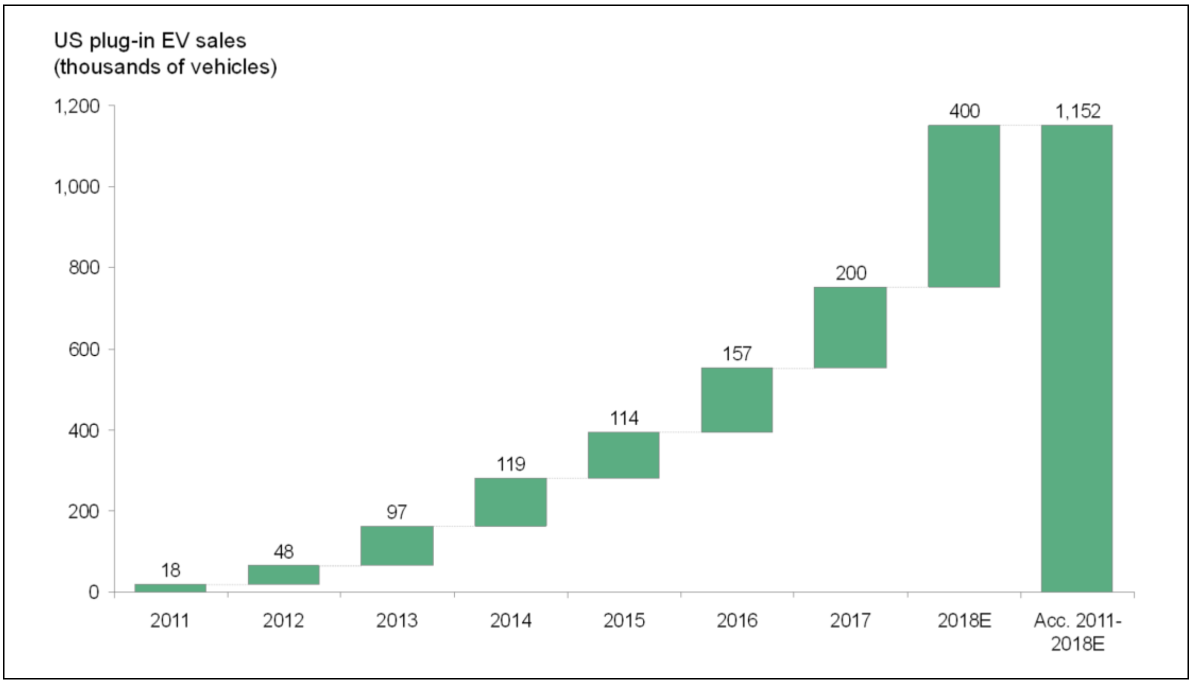
However, as can be seen in Graph 20, despite the efforts undertaken, the goal defined for 2015 of one million additional EVs on the road by then, is far from being achieved, having reached accumulated sales of around 550 thousand vehicles between 2011 and 2016. The initial goal may not be reached until 2020, according to the US Administration. The reduction in gas prices, and the high prices of EVs, estimated at around US$8,000 to US$10,000 more than equivalent-sized gasoline-powered cars with similar options, is what has daunted its increasing evolution.

Additionally, some states have their own particular directives/policies to promote the EV. For example, the state of California launched the Zero Emissions Vehicle (ZEV) Program, and signed a multistate ZEV program, a state regulation that requires automakers to sell electric cars and trucks in California and 9 states[22] on the East Coast. The objective is to ensure that automakers invest in R&D and market EVs, which generate less global warming emissions and pollution; and it was designed to result in a minimum of 1.5 million ZEV sales in California, and an additional 1.5 million ZEV sales for the states in the Northeast, by 2025.

[21] The number of the recharging points should be established, taking into account the number of electric vehicles estimated to be registered by the end of 2020 in each Member State, taking into consideration the type of cars, charging technology and available private recharging points.

[22] Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont.

GRAPH 20. US electric vehicle sales, 2011-2018E



Source: US Department of Energy, Statistics.

Compressed natural gas (CNG) and liquefied natural gas (LNG)

Compressed natural gas entails one of the forms of using natural gas in vehicles. CNG
Compressed natural gas entails one of the forms of using natural gas in vehicles. CNG
is produced by compressing natural gas to less than 1% of its volume at standard conditions. To provide an adequate driving range, CNG is stored onboard a vehicle in a compressed gaseous state, inside of cylinders at a pressure of 3,000 to 3,600 pounds per square inch (roughly equivalent to 200 - 250 bars). CNG vehicles have low pollutant emissions and have, therefore, rapidly gained ground in urban fleets of buses, utility trucks and taxis. Optimized gas-only vehicles with an engine design to operate only on gas can have greater energy efficiency than gasoline vehicles (not considering compression energy). CNG entails a clean burning transportation fuel, with lower carbon content than alternative fuels.

Liquefied natural gas, or LNG, is natural gas produced by purifying natural gas and cooling it to condensation temperature of -162°C (-260°F) to turn it into a liquid. During the process known as liquefaction, natural gas is cooled below its boiling point, removing all condensable components. The remaining natural gas is primarily methane, with small amounts of other hydrocarbons.

The first attempts to liquefy natural gas for commercial purposes date back to the beginning of the 20th century. In 1917, the first commercial natural gas liquefaction plant was built in West Virginia[23], USA, but the development of pipeline

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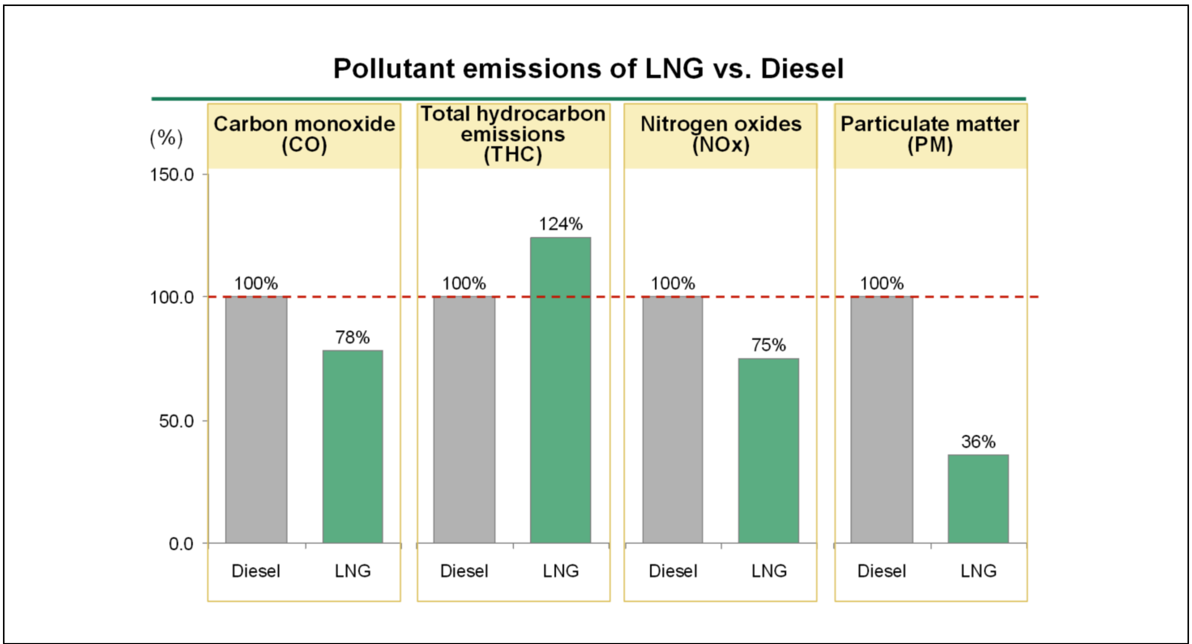
[23] Source: California Energy Commission.

transportation delayed improvement of this technology for a long time. Subsequent attempts to produce LNG were made in 1941, but production did not reach a commercial scale until the mid-1960s.

LNG offers a cost-efficient alternative to diesel for waterborne activities, like transportation, offshore services, and fisheries, as well as for ground transportation (i.e. trucks and rail). Compared to diesel, and depending on the engine type, it entails a lower level of air pollution and CO_2 emissions, and greater energy efficiency. LNG is particularly suited for long-distance road freight transportation, for which alternatives to diesel are extremely limited. LNG is suitable for trucks that require longer ranges, because liquid is more dense than gas (CNG), and therefore, more energy can be stored by volume in a given tank. LNG is typically used in heavy/medium-duty vehicles, as a more environmentally-friendly fuel compared to diesel, as stated in Graph 21. LNG is also an attractive fuel option for vessels, in particular to meet the new limits for sulfur content in marine fuels for year 2020 and in Sulfur Emission Control Areas (SECAs).

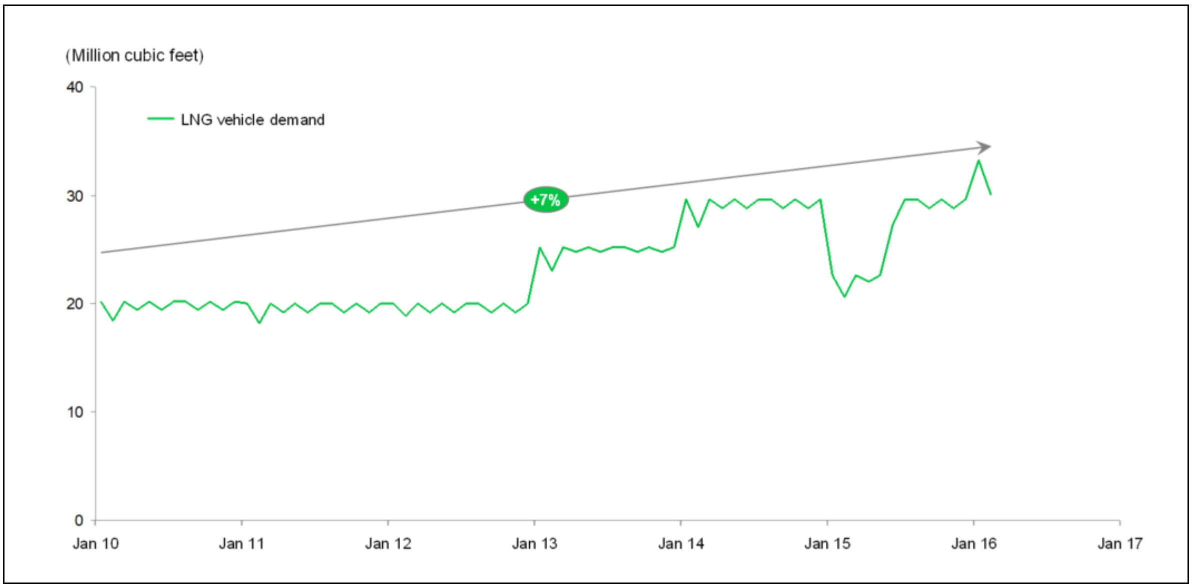
GRAPH 21. LNG represents an environmentally-friendly option to reduce emissions for heavy/medium-duty vehicles



Source: API, Liquefied Natural Gas Operations 2015. IEA 2010 The Contribution of Natural Gas Vehicles to Sustainable Transport.

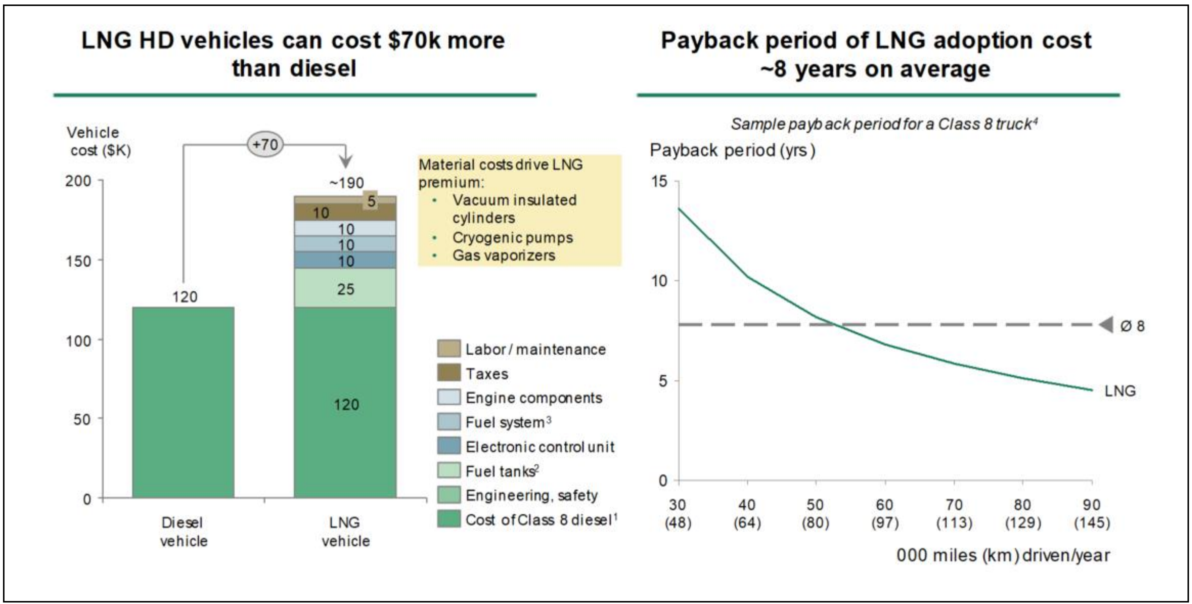
As seen in Graph 22, since 2010, US LNG Fuel Consumption has increased at 7% p.a., due to the greenhouse gas emissions standards. The first phase of medium and heavy-duty vehicle standards was implemented, starting with model year 2014, resulting in a relevant surge in LNG vehicle fuel consumption.

GRAPH 22. Demand for liquid natural gas vehicles has shown steady historical growth



Source: US Department of Energy, Statistics.

GRAPH 23. High conversion cost, limited OPEX savings expected to limit LNG adoption by fleets



Note: CNG price assumed at U.S. national average retail price of ~$2.10/GGE less 10% fleet discount; LNG price based on data on Southern California price point as of 2/2014. 1. Average class 8 tractor sleeper truck cost $123,000 ub 2012 (ACT Research). 2. Two tanks at ~$12K premium each. 3. E.g. injectors ,filters, regulators. 4. Assumes 65,000 miles/year, 7 mpg.
Source: Westport, Macquarie Capital, ACT Research, Citigroup, ANGA, Morgan Stanley research, expert interviews, BCG analysis.

However, widespread use of LNG fuel in commercial applications has been limited, because of its relatively higher production cost, as well as the need to store it in expensive cryogenic tanks. Additionally, there are a number of reasons that are hampering the demand for LNG vehicles. For instance, as seen in Graph 23, liquid natural gas trucks cost US distributors an extra US$70,000 per truck, over the cost of typical diesel trucks, which begin at about US$120,000. Moreover, the limited number of LNG fueling stations results in shippers having to incur costs when refueling, as they have to employ additional time and fuel to locate LNG fueling stations. Finally, there is a limited market for second-hand LNG trucks, hindering the recovery of the residual value of the truck.

To counter these drawbacks, governments are launching incentive programs to help transition. For example, EU Directive 2014/94/EU, launched in 2014, aims to ensure the development of a core network of refueling points for LNG at maritime and inland ports, at least by the end of 2025 and 2030, respectively. In addition, public refueling points will also be available for heavy-duty motor vehicles. Member States should ensure that refueling points are put in place within adequate distances. As an indication, the necessary average distance between refueling points should be approximately 400km. This will provide enough flexibility, since trucks can travel approximately 800km. The cost of this measure was estimated at €58M[24].

In the US, alternative fuels, like LNG, have several tax incentives and benefits. For example, The Safe, Accountable, Flexible, Efficient Transportation Equity Act provides an incentive for LNG when used for motor vehicles in particular cases. These include: on a farm for farming purposes, in certain intercity and local buses; in a school bus, exclusive use by a non-profit educational organization, and exclusive use by a state, political subdivision of a state, etc. A 50% incentive is provided to businesses, individuals, and tax-exempt entities that sell or, in some cases, use the fuel. Nonetheless, other incentives/tax credits target alternative fuel infrastructure. Namely, the Energy Policy Act (EPAct) of 2005, PL 109–58, provides for an income tax credit equal to 30% of the cost of natural gas refueling equipment, up to US$30,000 in the case of large stations and US$1,000 for home refueling appliances.

Gas to liquids (GTL)

Gas to liquids (GTL) is referred to a group of technologies capable to convert gaseous hydrocarbons (mainly natural gas) into clean liquid fuels that mix completely with petroleum fuels and, therefore, can be transported and distributed through existing infrastructure, and used by current vehicles and combustion engines without modifications.

These technologies are fundamentally based on the generation of synthesis gas, a mixture of Hydrogen (H_2) and carbon monoxide (CO), which by catalytic reactions is converted either to methanol, to gasoline range hydrocarbons or to diesel range

[24] European Commission – Memo: Clean power for transport – Frequently asked questions (January 2013).

hydrocarbons. The GTL technology utilizing the Fischer Tropsch (FT) technology is not a new technology, it comes back to the thirties of last century. It was used by Germany to produce fuel for war vehicles, ships and planes in World War II from German coal. South Africa also used this technology to produce fuels during the apartheid.

The GTL technology has the advantage of producing very clean liquid fuels but is known to be not economically feasible unless its scale is larger than about 1 million cubic meters per day (Mscmd) and, therefore, in areas where the gas natural output is inferior to that volume. In addition, when the projects being promoted by governments to develop CNG/LNG transport, distribution and refueling infrastructure the GTL large projects have lost interest, as the investment required, and their execution complexity is similar to that of a big refinery or petrochemical complex.

The cost and capacity constrains can explain why a reduced number of GTL plants are commercially operated today (according to the Energy Information Administration's *2015 Annual Energy Outlook*, only about 6% of the world's known natural gas fields are big enough to sustain a conventional, large-scale GTL plant)). Downsizing of GTL technology can provide a solution to recover smaller gas resources, stranded gas deposits or flared gas in a cost-effective way, which otherwise could not be economically recovered due to lack of transportation infrastructure.

Development of new technologies, such as microchannel reactors that allowed scale down FT reactor, and for SMR (Steam Methane Reformer) and ATR (Autothermal Reformer), GTL plant can be scaled down. Small-scale GTL plant equipment can be modularized and skid-mounted, which makes them suitable to be used in remote locations and for economical processing of smaller amounts of gas ranging from 100 to 1500 million cubic meters. The modular structure makes small GTL plants very flexible, adapted to match the size of gas resource and potentially integrated in existing facilities.

GTL technology seems to have a revival thanks to a number of companies that are investing heavily in the development of mini-GTL technologies. Although the basis for these technologies is the FT process, some of them developed innovative technologies, which are about to commercialize them. Up to date there is no one small GTL plant commercial operating, but in the last years an increasing interest in projects involving small scale GTL has evolved.

Small GTL plants could offer an environmentally friendly alternative for the warming impact of flaring associated gas, which according to Global Gas Flaring Reduction (GGFR) partnership, more than 120 Bcm of gas natural is flared every year.

Advanced biofuels and biogas

'Advanced biofuels' are those liquid fuels produced from a diversity of biomass feedstocks that do not compete with food or feed supplies, through processes that allow them to meet the quality standards and the level of sustainability criteria required by current legislation (in the UE directive 2009/28/EC in the process to be amended). Biogas refers to gas streams produced from biomass.

The term is applied to biofuels and biogas produced from ligno-cellulosic or cellulosic biomass, non-food crops and industrial and agricultural wastes and other residual biomass streams such biomass fraction of municipal wastes.

Several production processes for advanced biofuels production are being, or have been, developed, as a consequence of legal mandates for a minimum introduction in conventional transport fuels; among them the following will be mentioned: biological processes, hydrogenation of vegetable oils and thermochemical processes.

Biological Process based on cellulosic and/or ligno-cellulosic biomasses as feedstock, which through biochemical or chemical conversion steps convert their cellulose and hemicellulose components into fermentable sugars (the biochemical conversion route appears to be the cheapest option). These sugars are then fermented to ethanol or butanol followed the same steps than conventional bioethanol/butanol.

The catalytic hydrogenation of vegetable oils or animal fats is a well-known process and can produce high quality biodiesel. There are several demonstration and large scale plants in Finland, Singapore and Rotterdam. Similarly, the oils can be hydrogenated mixed with petroleum fractions in oil refineries to produce a mixture of biodiesel and diesel.[25]The HVO process could also be grouped among conventional ‘first generation’ biofuels in those production cases that use virgin vegetable oils as the feedstock.

The thermochemical route to advances biofuels includes those processes that involve thermal conversion of a ligno-cellulosic feedstocks and other solid biomass into liquid fuels, through synthesis gas from a gasification process or bio-oils by a process of pyrolysis.

Two main routes for thermochemical biofuels production are biomass to liquids and fast pyrolysis.

Biomass-to-liquids (BtL): This is a similar process to the production of liquid fuels from coal (CTL) or gas GTL (see section above). It includes biomass pretreatment, gasification at high temperature (850 ºC) to produce synthesis gas, purification of syn-gas and Fischer-Tropsch conversion and refining to biofuels.

BTL processes are favored by the development of small GTL technologies (see section above), which can be modularized and adapted to specific amount of biomass

[25]International Energy Agency, Technology Roadmap: Biofuels for Transport (2011).

feedstock available and/or supplemented by natural gas or biogas (BGTL process)to reach economic feasibility, in particular under operation with low cost feedstocks .

Fast pyrolysis: heating biomass rapidly in the absence of air at temperature within the range 400-600 and then quickly cooled to 100 ºC to obtain bio-oil and bio-char, vapors and gases; bio-oil can then be refined to biofuels.

Finally, biogas is a biofuel produced biologically from livestock, agricultural or municipal wastes, which every time is more utilized in transportation by replacing natural gas. There are thousands of biogas producing plants in Sweden and Germany, where biogas share of the total gas natural consumed in transport reaches 75% and 20%, respectively[26].

Hydrogen

Hydrogen is one of the alternative fuels for transport envisaged by some developed countries, in particular the European Union, for future development (see directive 2014/94/UE), as it offers great expectancies for efficiency improvement and greenhouse gas, and other pollutant, emissions reduction. It can also be produced from a large number of energy sources, ranging from fossils: coal, oil and natural gas, to nuclear and renewable by a good number of different processes and technologies: thermal, microbial or electrical

Currently, hydrogen is produced in millions of tons worldwide, which are used safely, mainly in oil refining and in the chemical industry. A lot of experience also exists in its transport by pipeline or in road tanks. However, in the case of extensive consumption as transport fuel, its distribution and storage, particularly on board of vehicles, presents considerable technological challenges, in terms of cost and safety.

Regarding the different hydrogen production processes (Table 8), both methane steam reforming (MSR) or gasification are mature technologies from which little improvement can be expected, but this is not the case for water electrolysis technology where improvements up to 40% can be expected. The production can take place in large centralized units followed by the distribution of hydrogen by pipeline or truck, under pressure or in liquid phase, or in small units close to the point of consumption. Scale down production is feasible (see GTL section) for both thermal and electrolytic technologies, but only in the latter case production costs are not affected

[26] Alvarez Pelegry, E et al, "Movilidad Sostenible. El papel de la electricidad y el gas natural en varios países europeos" Orkestra (2017).

TABLE 8. Hydrogen production costs by different technologies		
	Process	**Production cost of H_2 (€/kg)**
Centralized Production	Methane steam reforming (MSR) (*)	1,2
	Water Electrolysis	3,7
	Coal Gasification (**)	1,3
	Biomass Gasification	2,1
Distributed production	Methane steam reforming	2,5
	Water Electrolysis	3,7

(*) Production Cost for a production plant of 1000 t/day and natural gas price6 $/MBTU.
(**) Production Cost for a production plant of 1000 t/day and coal price 80 $/t.
Source: European Commission: World Energy Technology Outlook-2050.

Hydrogen, due to its thermophysical characteristics is difficult to store and transport, either under pressure or as a cryogenic liquid. Its heating value (120 MJ/kg) is 3 times higher than that of gasoline (43 MJ/kg), however, on a volumetric basis the situation is the opposite (8 MJ/l vs. 32 MJ/l in liquid form). The energy required for its compression to 350 bar can reach, depending on the initial pressure, up to 10% of its energy content and up to 30% for its liquefaction. The cost of transport, distribution and supply to vehicles at distances of about 50 km from the point of production is in the range of € 14 to 18/GJ very close to that of small scale production. At higher distances could be as high as € 25/GJ

Therefore, the efficient use of hydrogen in transport must be linked to highly efficient mechanical energy conversion processes, such as electric generation and power traction, which is provided by vehicles powered by fuel cells (FC). Fuel cell vehicles (FCEV) are electric vehicles in which electric power is provided by a fuel cell powered by hydrogen, which is stored in the vehicle.

The technology of FCEV has developed enough in recent years to start the commercialization of vehicles, but several barriers have yet to be overcome to make them competitive: 1) the FC cost is still high, it is due to the cost of electrodes and membrane materials; although they have been reduced in last years they are still high to compete with those of internal combustion engines; 2) efficiency improvement of the membrane and cell electrodes in operating conditions close to maximum power demand; and 3)durability: although durability of 2500 hours of operation (equivalent to about 100,000 km) has been achieved in road vehicles, at least 5000 hours are needed

Although there have been great advances in regard to these barriers in the last ten years, and that great efforts are being made in R & D, both in Europe and in the United States, but the continuity of these advances still remains to be seen. In any case, the challenges to overcome these barriers are of such magnitude that the competitiveness of hydrogen in transport and vehicles with fuel cells (FCEV) compared to conventional or alternative fuel hybrid vehicles presently is still far away.

2.2. Supply evolution

In this section, two main issues are addressed. Firstly, a look is taken at the evolution of E&P investments, which affects oil supply and oil prices, and secondly an analysis of the evolution of investments and capacity in refining is dealt with in 3.2.2.

The following subsection, related to E&P, investigate the historical spending and potential future scenarios, as well as key parameters that have led increases in prices and price determination, and the strategies that companies have taken to reduce costs. In addition, a number of investments are analyzed, taking into consideration factors such as development categorization and type of industry player, among others.

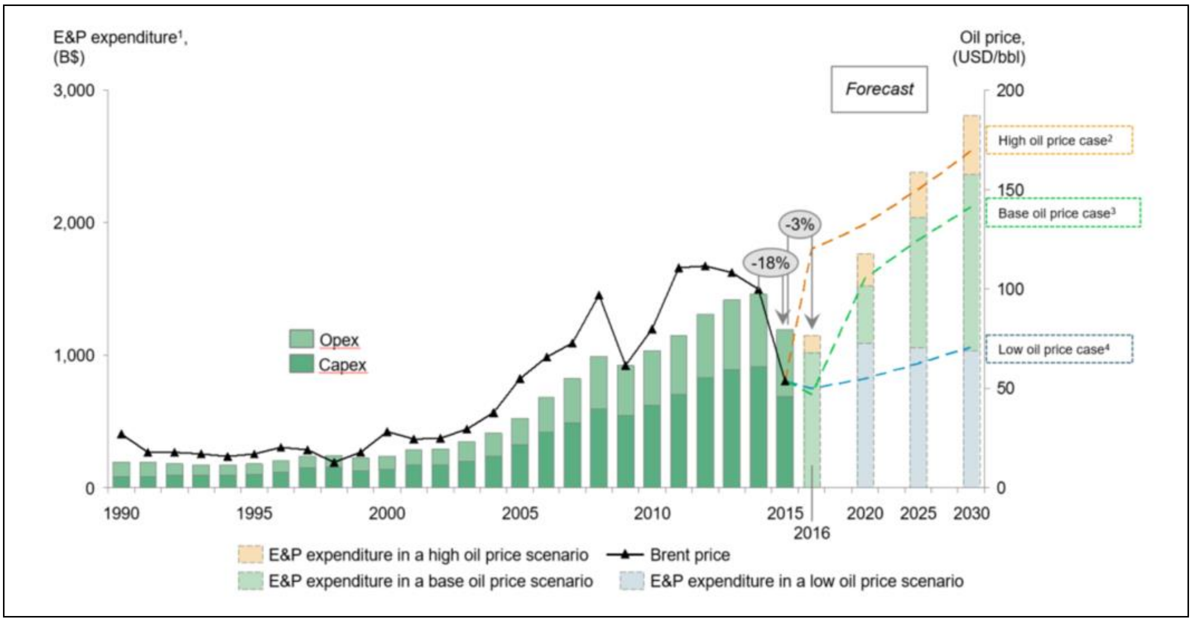
2.2.1. Evolution of investment in E&P

The sharp decline in crude oil prices that began in mid-2014, and continued until June 2017 - with oil price trading at around 50%, as compared to precrisis levels - has taken a sizable toll on much of the energy industry. O&G companies have suffered sharp reductions in revenues, and in response, they have aggressively cut costs, reduced capital spending on exploration and production, and rethought their supply chains.

However, if we take a look at the industry before the price decline in 2014, for the previous few years when crude oil traded at over US$100 per barrel, it can be seen that the upstream sector reached record investment levels, as seen in Graph 24. In fact, investment has historically been closely aligned with crude oil prices, as well as with profit margins. This means that, in principle, the recovery of investment would again be marked by the future evolution of oil prices.

While most market analysts expected oil prices to remain lower for longer, back in 2016, the deal achieved by OPEC and other major non-OPEC producers in November 2016 has tightened oil markets and recently revived prices. If this upward trend continues, global E&P spending will also start to grow, as forecasts currently suggest. Moreover, some experts predict a supply shortage in 2020, which would have an important impact on O&G prices, and on investments as well.

GRAPH 24. Historical and future E&P expenditure in three spending scenarios



Note: 1. Expenditure includes CAPEX and OPEX. All values are nominal assuming 2.5% annual inflation in the future; 2. Oil price reaches US$120/bbl in 2016 and is inflated 2.5% following years; 3. Projected oil price based on Rystad energy's Oil Market Analysis; 4. Oil price reaches US$50/bbl in 2016 and is inflated 2.5%.
Source: Rystad Energy, BCG analysis.

A trend in the industry, which stretches far back, explains why E&P producer margins have eroded over the past few years, and why E&P CAPEX investment has outgrown the increase in global production since the early 2000s. The upstream industry has been subject to increasing complexity that can be explained by four kinds of intrinsic complexity (resource, project, industry and safety) and two additional factors that further compound complexity, namely: lax cost control and government action. Each factor is examined below.

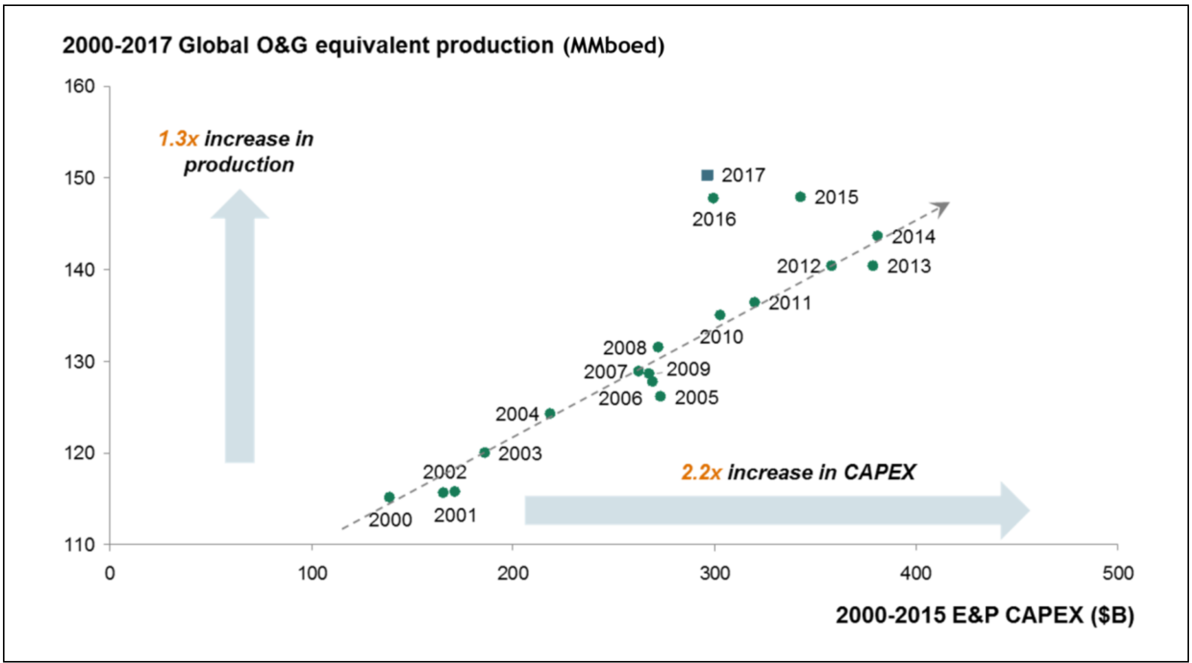
Resource complexity. The contributions of established, highly-profitable legacy oilfields to E&P company top lines have fallen, along with the fields' ongoing depletion, and there remain fewer relatively easy-to-exploit resources that remain untapped, as of yet. As a result, E&P companies have been forced to pursue larger, higher-risk projects, such as deepwater and remote developments, in an effort to enhance revenues. Such projects not only bring greater complexity, but also raise costs significantly: the industry's global finding-and-development costs rose from just over US$12 per barrel of oil equivalent in 2009, to more than US$25 in 2016. Likewise, the energy return on energy invested is lower for all of the unconventional oil production methods than for conventional fields - meaning that running operations in unconventional plays is more energy-demanding than in conventional fields, in order to produce one barrel of oil equivalent.

Project complexity. As E&P companies pursue increasingly complex resources, the development of those resources increases in complexity, as well. Projects grow larger, and the teams managing them grow larger, and incorporate more people from more companies. Such growth, in turn, increases the number of contracts and contractors, and makes the project supply chain more intricate. Nowadays, cost and time overruns are commonplace in the industry[27], which used to be the reference for large-capital project development. IHS, a research firm, conducted a survey of projects completed by major oil companies from 2005 through 2010, and which showed that a staggering 49% ran over budget and 52% missed deadlines. The median cost overrun was US$2.7 billion, and the median delay was three years and three months. Companies deployed capital to increasingly large, overly costly, and frequently delayed projects, thus eroding shareholder returns.

Industry complexity. Operators, contractors, and authorities alike have failed to create sector-wide simplification, curbing the benefits of shared learning experiences at the industry level. Each operator typically sets its own technical standards for operations and development.

Safety discipline. Prior to mid-2014, and particularly after the Deepwater Horizon oil accident back in 2010, which spilled nearly five million barrels of oil into the Gulf of Mexico and killed 11 people, there was an increase in environmental and safety concerns, and in local requirements that contributed to further industry complexity.

GRAPH 25. Relation between increases in E&P CAPEX and production



Source: Rystad Energy, BCG analysis.
Note: MMboed – Million barrels of oil equivalent per day.

Graph 25 shows the relationship between E&P CAPEX and resulting production, by year. Between 2000 and 2015, it can be seen that CAPEX more than doubled, while

[27] Based on insights derived from IHS Herold Projects' database.

gains in production only increased by a factor of 1.3. For years 2016 and 2017, it is clear that companies realigned their production strategy, scaling back investments, and ensuring the targeting of brownfield developments and top economic ranking fields.

In addition, there are two other contributing factors that led to the higher development and operation costs of O&G fields, lax cost control and government action.

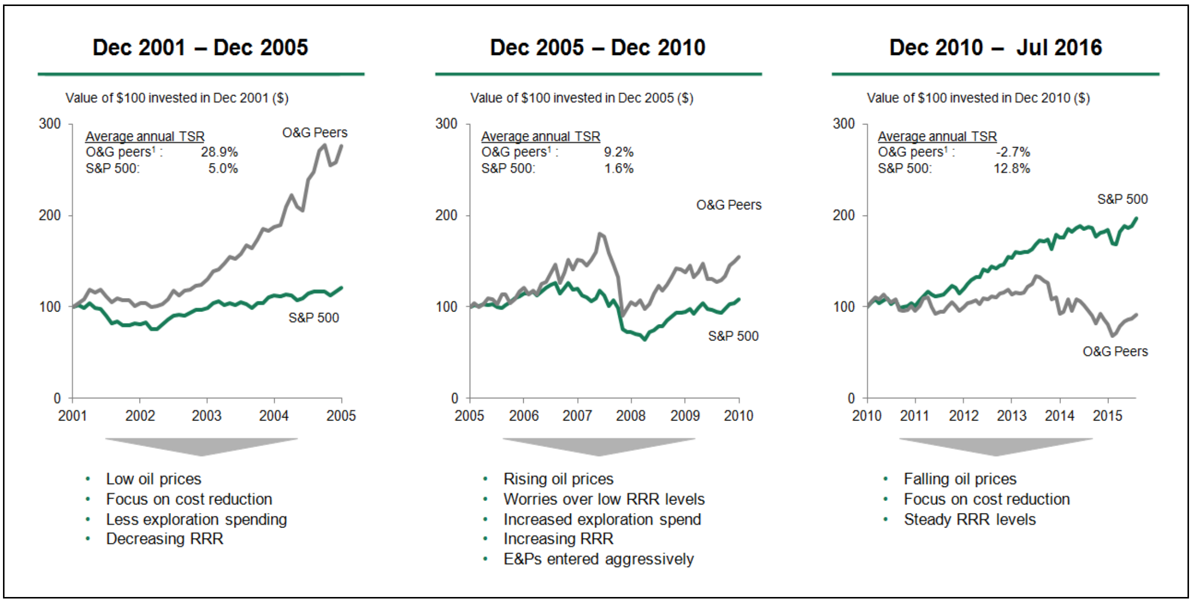
Lax cost control. In response to the high oil-price environment that prevailed until the year 2014, E&P players put a premium on growth and accelerated production. Cost control and efficiency received less attention. Many E&P companies also staffed up to meet peak growth and scale, adding many positions—such as supervisory roles and jobs in assurance. Subsequently, the companies failed to trim their headcount, as the environment was changing and their asset base was shrinking. A similar issue has also happened to contractors, who have been forced to reduce their headcounts, in order to remain competitive. E&P companies operating in some locations, such as the North Sea, have also, on occasion, foregone opportunities to reduce their logistics and infrastructure costs, by working in cooperation with one another.

Government action. E&P companies have also been saddled with higher costs, owing to government actions. For instance, many national governments insist that E&P companies use local companies in their development efforts, and meeting this requirement can - unless undertaken with extreme care - mean additional costs and inefficiencies. E&P company in-country costs for certain services in one West African country, for example, are four times those in other internationally-competitive alternatives. Government permitting-and-sanctioning processes are also often slow and cumbersome for E&P companies to navigate. And government fiscal demands on companies' revenues continue to rise, in many cases, to a degree that is inconsistent with the attractiveness of the country's resource base.

In sum, E&P companies face a headwind that continues to threaten both their revenues and their profits, with rapid increases in upstream cost, which outpaced the rise in oil prices in recent years, squeezing Free Cash Flows (FCF) and returns.

This has not always been the case, however. Historically, E&P companies had been a structurally strong value creator, favored by investors for growing and preserving long-term wealth. Global in reach, massive in scale, and able to manage complexity and mitigate risk, O&G companies generated superior shareholder returns across the business cycle. From Dec. 2001 to Dec. 2005, O&G companies created an annual Total Shareholder Return (TSR) of approximately 29%, as compared with 5% for the broad market. Similarly, from 2006 through 2010, which includes the 2008–2009 oil-price collapse, O&G companies yielded around 9% yearly to their owners, while the S&P 500 returned a mere 1.6%. Since 2011, however, the pattern of returns has eroded. From 2011 through Jul. 2016, the sector generated an annual return of approximately -2.7%, while the S&P 500 yielded nearly 13% (see Graph 26).

GRAPH 26. Total shareholder return evolution for the O&G sector



Source: Capital IQ, BCG analysis.

To protect their profitability and maintain cash returns to shareholders, E&P companies have drastically cut costs and made other adjustments to their business models, in hopes of easing the current cash-flow squeeze. The initiatives that started even before the oil price crisis of 2014 include the following: a) reduced exploration spending, b) reduced capital expenses, c) reduced operational costs, d) portfolio adjustment, e) adjustment of the operating model, f) analysis of investments in E&P, by type of development, g) slashed exploration costs, h) deferral of costly greenfield developments, i) resilience of shale production and j) offshore production. These are examined below.

Producers are scrutinizing prospects more carefully, selecting only the most promising opportunities. Companies are also keeping away from high-cost projects, such as arctic and ultra-deepwater developments. Since 2013, the 18 largest producers have cut their drilling investments in half, from $58 billion to an estimated $29 billion. Unit costs have also fallen dramatically—for example, costs for seismic and drilling services have declined 30% to 50%, or more, from 2013 to 2016—allowing operators to negotiate better terms and get more for their exploration budget.

Companies have drastically reduced capital spending, in order to preserve cash and safeguard return levels, and they have embraced greater investment discipline. In 2013, oil companies typically screened projects at $80 to $90 per barrel. In 2016, the threshold was around $60 or less. As a result, in 2015, oil companies trimmed capital budgets, cutting 2014 spending by 25%. Most projects that were in the planning phase were being postponed or canceled, and projects that were already under way were facing revisions and spending cuts. Meanwhile, producers have been able to renegotiate contracts by taking advantage of an oversupply of rigs, steel, and manpower.

As margins were shrinking, oil companies reduced operating costs as well. Such reductions typically come in waves, starting with relatively straightforward cuts in supplier expenses and procurement, which yield savings as high as 10% to 15%. In the next wave, operators increased offshore productivity through lean strategies, and they invested in improved planning, so as to reduce waste and rework, typically saving another 5% to 10%.

Some companies have reshaped their portfolios. Oil majors' traditional business model—excelling in highly-complex and costly frontier resources—has challenged the industry’s ability to generate healthy cash flows. Many transactions have been considered, but M&A activity has been modest, given the estimated US$200 billion worth of assets for sale globally, one-third of which are in North America. Sellers and buyers still disagree on valuation, but scenarios of persistently-low oil prices should lead to more transactions. Meanwhile, integrated majors are likely to continue selling off refining and marketing assets, in order to unlock the value of these businesses for investors, as their margins are buoyed by low crude oil prices and in some cases refining deficit. Companies also typically seek to be either highly diversified or very much concentrated on a few types of plays, as both strategies have proven to deliver historically higher TSR, compared to companies that remain in the middle of the diversification scale. Highly-diversified companies are typically large majors, with a long history since their inception, while highly concentrated companies are independent, with a clear example of those specialized in shale operations in North America. It has also been proven that, typically, when a company progresses towards higher diversification, it enhances company performance. The contrary movement negatively impacts company profitability and stability, except in the case of less-diversified companies becoming concentrated.

Operators that committed to cost reductions of up to 20%, have started both to simplify their operating philosophy and requirements, and to intensify supplier collaboration, so as to optimize the full value chain. Some companies undertook these measures before the 2014 price collapse. Statoil and Total, for example, adopted comprehensive rationalization efforts when the oil price was more than US$100 per barrel. Nevertheless, the scope and depth of change have not been sufficient. To restore value creation, bolder moves are needed.

Squeezed liquidity over the last three years has led E&P companies to rationalize their portfolios, for the purpose of optimizing their profitability, while reducing the cost base for the years to come. Even if uncertainty has grown, compared to the period of fairly stable oil prices between 2010 through mid-2014, several trends can easily be identified.

As previously commented, exploration is one of the segments that have been hit the hardest by the post-mid-2014 price decline. Producers are scrutinizing prospects more carefully, selecting only the most promising opportunities. As previously mentioned, companies also are keeping away from high-cost projects such as arctic and ultra-deepwater developments.

Exploration is a high-risk activity that requires high investment upfront. It is no surprise that O&G companies decided to shrink exploration expenditures, a measure to use economic resources more profitably in the short term. Exploratory budgets were cut by 30% in 2015, compared to 2014 levels, and then experienced a 24% drop in 2016. The effect of such cuts was already visible in 2016, with oil discoveries having fallen to their lowest in over 60 years. Understandably, this may lead to a severe impact in the foreseeable future, weakening global oil production.

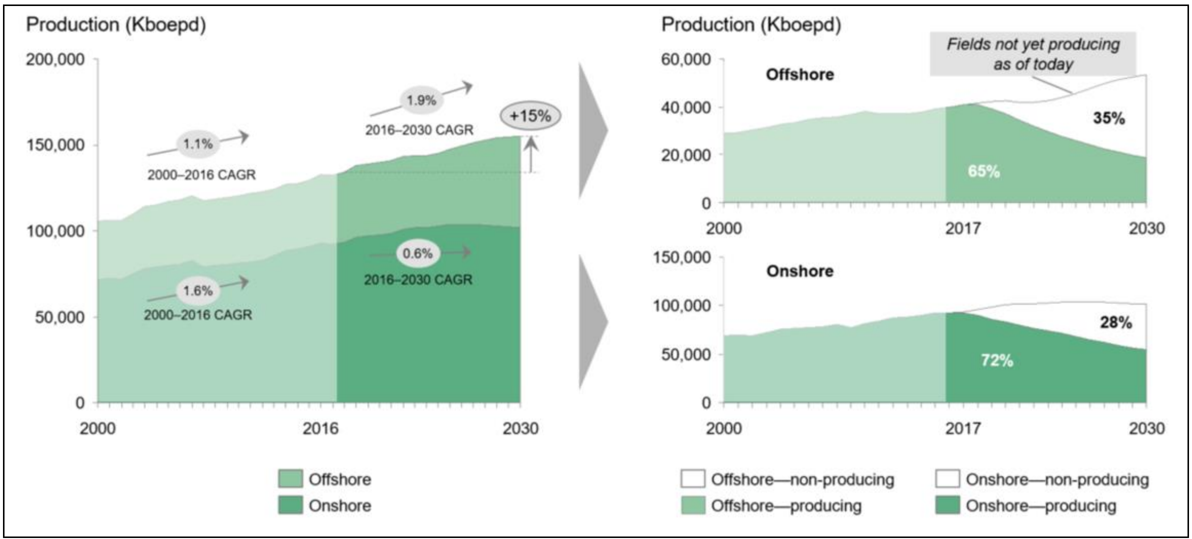
A notable share of under development and yet-to-be sanctioned fields were either delayed or canceled over the past three years. In fact, in the first quarter of 2015, more than 4 million barrels per day of combined plateau production were put on hold, due to different reasons. Projects with high production breakeven prices, or long lead times for construction, or high development costs, were deprioritized. This has led to a higher number of brownfield projects and short-cycle investments, in order to adapt to oil price uncertainty. The squeeze on companies' liquidity is to blame, as well as the perception in the industry that oil prices may remain at around US$60-80/bbl in the near future. For that reason, and in order to be cautious, companies’ future investment plans are based in this current price scenario.

America’s abundant and low-cost unconventional gas-and-oil resources have reshaped the O&G industry in recent years, and their impact has also contributed positively to other sectors, such as petrochemicals and manufacturing. During the period from 2005 through 2014, O&G combined production from unconventional resources in the US grew intensely, at an annual rate of around 25%. In 2015-2017, a period where we witnessed oil prices reaching the levels of US$25 per barrel in early 2016, and later on staying at a level around US$50 per barrel, the volumes produced from shale and tight gas plays in North America remained fairly flat, surprising a few in the industry. There are several factors that explain how operators adapted to this changing environment, demonstrating high resilience to low oil prices. On the one hand, operators refocused their drilling activity onto highly-productive basins with low breakeven prices. This measure is also called high grading. On the other hand, the sector experienced remarkable improved drilling and production efficiency, achieved by using only the most efficient rigs. On average, rigs have been drilling 25% faster now, as compared with the end of 2014.

Offshore is likely to continue to drive O&G production growth in the long term, as shown in Graph 27. However, the growth of this type of development will be particularly influenced by future oil prices, and by the ability of the industry to reduce or flex CAPEX investments, in particular for complex deep and ultra-deepwater fields. If future prices allow, however, ultra-deepwater fields are likely to grow the fastest, with Brazil and the Gulf of Mexico being the top spending regions for ultra-deepwater (UDW)[28] CAPEX.

During the 2015-2017 period, however, the offshore industry needed to adapt strongly to low oil prices, in particular in areas like the North Sea, a very mature basin with low cost control prior to the price slump. Recent deals in the North Sea, like the acquisition of Maersk Oil by Total, suggest that the region may have reached a tipping point, where margins are healthy again under current prices.

GRAPH 27. Global O&G production split by onshore/offshore



Note: Based on Rystad Base Case Scenario from 2017 onwards; Includes crude oil and natural gas only; CAGR: Compound Annual Growth Rate.
Source: Rystad UCube (October 2017); BCG analysis.

In summary, both shale and offshore are the type of development that will experience the greatest growth in the years to come. By 2030, these two types of plays could account for more than 60% of volumes for oil yet to be produced.

Analysis of investments in E&P by type of player

The E&P industry environment has witnessed an increasing number of producing players over the past decade, with many of them being independent, specialized in shale/tight resources. In fact, by the end of 2015, there were around 25% more such companies operating than in the year 2005.

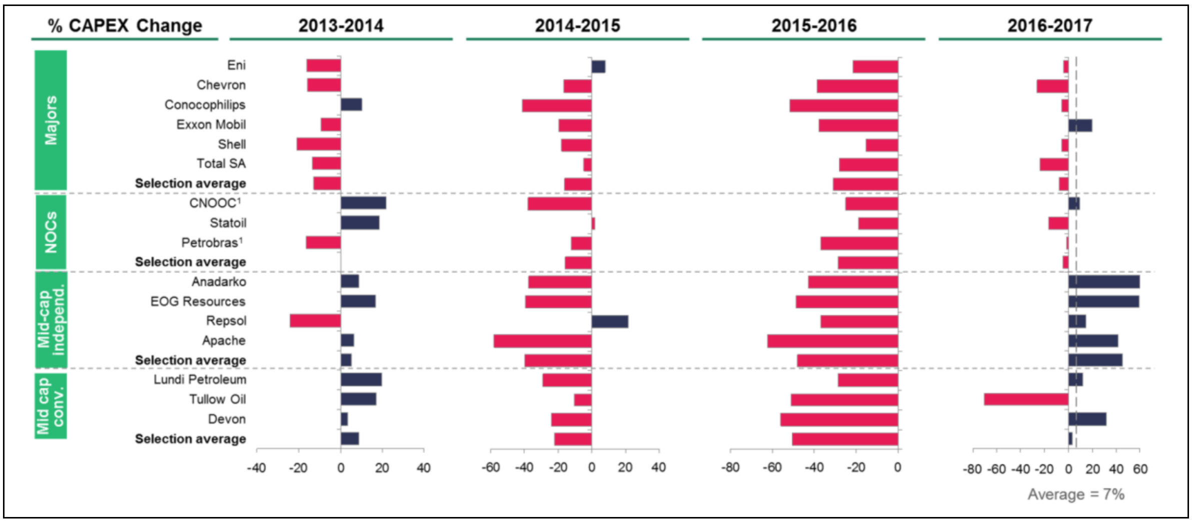
Nonetheless, the top 130 producing players alone account for 90% of global O&G production, with 50 of them being national oil companies and producing 60% (approximately) of this reduced sample. In terms of expenditure size, the

[28] UDW defined as water depths beyond 1,500 meters.

concentration of the market is even larger, with the top 30 companies spending above 50% of global E&P combined CAPEX.

The slide of crude oil prices over the past years has had a varying impact on the bottom line of each of the main company segments: Majors[29], IOCs, National Oil Companies (NOCs) and Independent companies. In Graph 28, there are a few examples for a number of representative companies, and in the case of NOCs, some for which information is publicly available.

GRAPH 28. Year-on-year CAPEX evolution by player



Note: 2017 figures are estimated, Capital expenditure is the amount of cash used by a company to invest in capital assets, such as property plant and equipment, across all the business segments.
Source: Capital IQ, BCG analysis.

Major companies are vertically integrated, meaning that they have sizeable operations in both the upstream and the downstream businesses. Historically, this has favored obtaining more stable returns for their shareholders than those obtained by pure players – typically independent ones. Likewise, these major companies show a tempered impact of the price decline in terms of the deceleration of capital investments.

On the one hand, these operators have traditionally excelled in orchestrating complex projects that are very capital intensive; during the price slump, megaprojects already in development tended not to be delayed or canceled, given the notable impact it would have in terms of contractual agreements and possible cost overruns for maintaining development for longer. However, it has been a common practice of majors not to sanction new megaprojects in deepwater, oil sands and LNG, as these long-cycle schemes require greater long-term confidence in oil prices.

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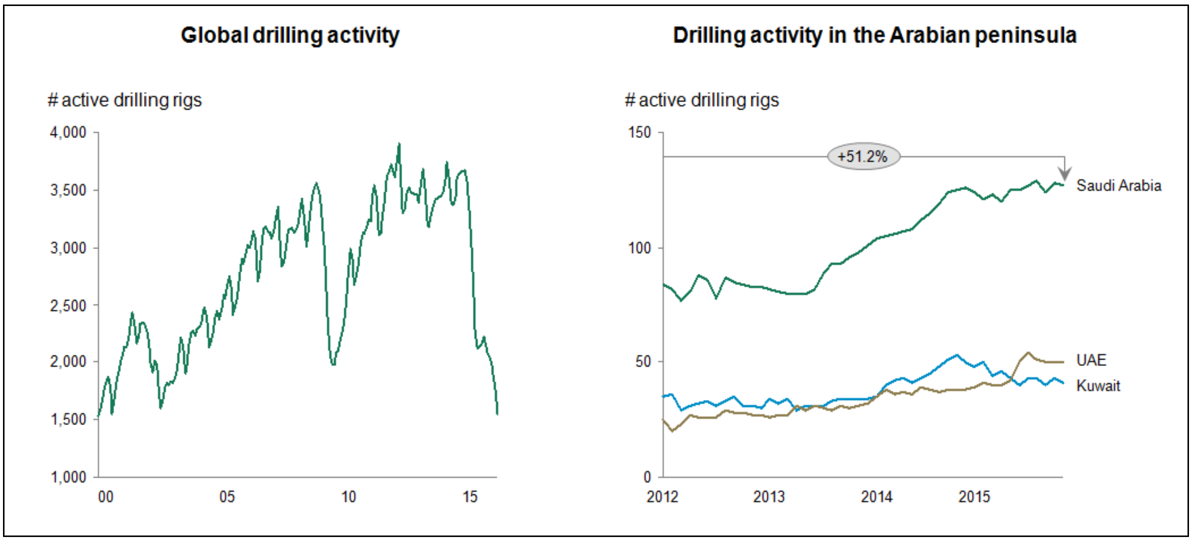
[29] "Majors" refers to the greatest integrated O&G companies, such as Exxon Mobil, Total, Shell, Chevron, BP, Conoco Phillips and ENI. By extension, along this study, at times "Majors" also refers to Integrated Oil Companies.

NOCs have been impacted differently by the dip in oil prices, depending mostly on the type of plays they develop, and on how reliant their national budgets are on O&G exports. NOCs[30] such as CNOOC[31] and Petrobras, with high exposure to offshore and deepwater operations, retrenched expenses to a higher degree than those operating cheap-to-exploit conventional oilfields.

In fact, during the past two years, certain OPEC[32] countries decided to overinvest, so as to gain market share, with near-record drilling rates to boost production (see Graph 29). Meanwhile, international drilling levels were at levels not seen since the end of 1999. In addition, it is worth noting that, considering the possibility of peak oil demand, some NOCs have decided to increase their production as long as the oil price allows for generating profits, while anticipating taxes on CO_2 emissions in the production and refining phases, in the possible future. Among company groups (Majors, NOCs, and independents), independent companies have suffered the most during the price slump, while at the same time, they could flex their operations more swiftly than NOCs or Majors. In particular, this is true for independent companies with notable exposure to shale/tight operations in North America.

GRAPH 29. Comparison of drilling activity globally and in the Arabian peninsula



Source: Baker Hughes.

After the oil price recovery in the year 2009, the American O&G industry witnessed an irrational exuberance of small independent companies that benefited from a rather stable US$100 per barrel environment, highly leveraged financially. A share of these companies could simply not survive a low-price scenario, and many filed for

[30] National Oil Companies.

[31] China National Offshore Oil Corporation.

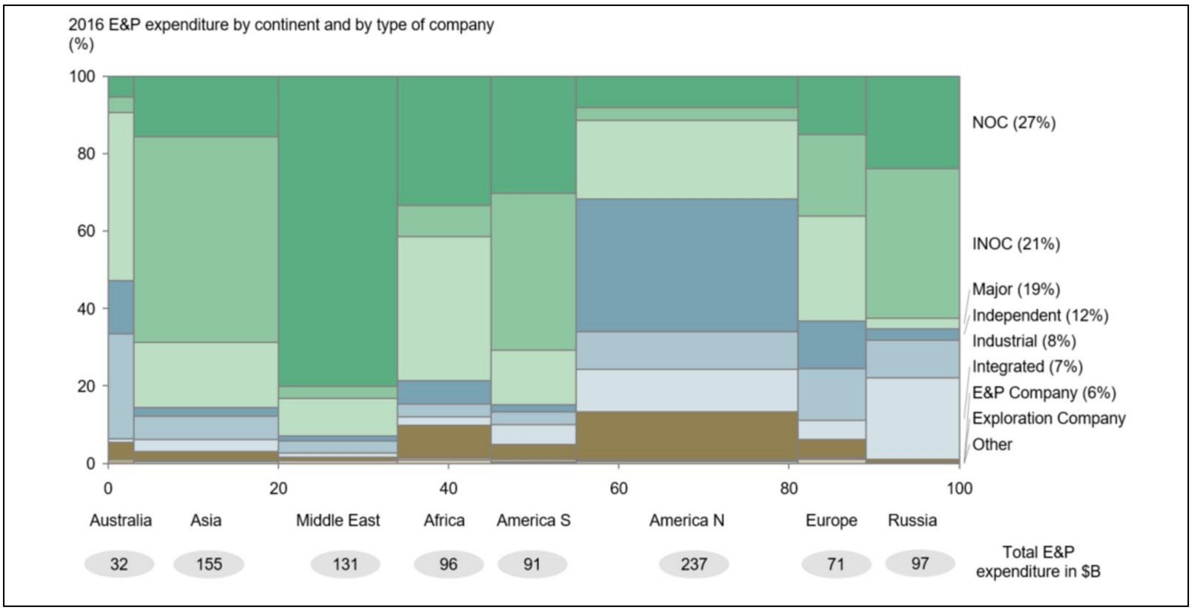
[32] Organization of Petroleum Exporting Countries.

bankruptcy. Other companies, such as Encana, started prioritizing returns over volumes, after years of having the main goal of increasing its market share, having an impact on capital investments over previous years.

Analysis of investments in E&P by other aspects

On a global scale, the E&P spending landscape is dominated by NOCs and by those national oil companies with international operations (INOCs), with around 50% of total spending in the year 2016. By region, North America shows the top spending, accounting for around 30% of global E&P expenditure, with independent companies spending roughly a third. Asia and the Middle East follow on the list of top spending regions, with 17% and 14% of global expenditure, respectively (see Graph 30).

GRAPH 30. E&P expenditure by continent and by company segment[33]



Note: Expenditure includes CAPEX and OPEX.
Source: Rystad Ucube (October 2017).

[33] Segment types can be classified as follows:

NOC – National Oil Company, e.g. Saudi Aramco (Saudi Arabia) and PDVSA (Venezuela),

INOC - (NOCSs with an international agenda, like Statoil, Petrobras, CNOOC, Gazprom, etc.),

Major – includes the 7 largest E&P companies: ExxonMobil, BP, Shell, Chevron, Total, ConocoPhillips and ENI,

Independent – includes E&P companies with more than 30 kbd production and/or more than 160 MMboe proven reserves,

Industrial – includes typically energy or oilfield service companies that have expanded into upstream, typical examples are gas companies,

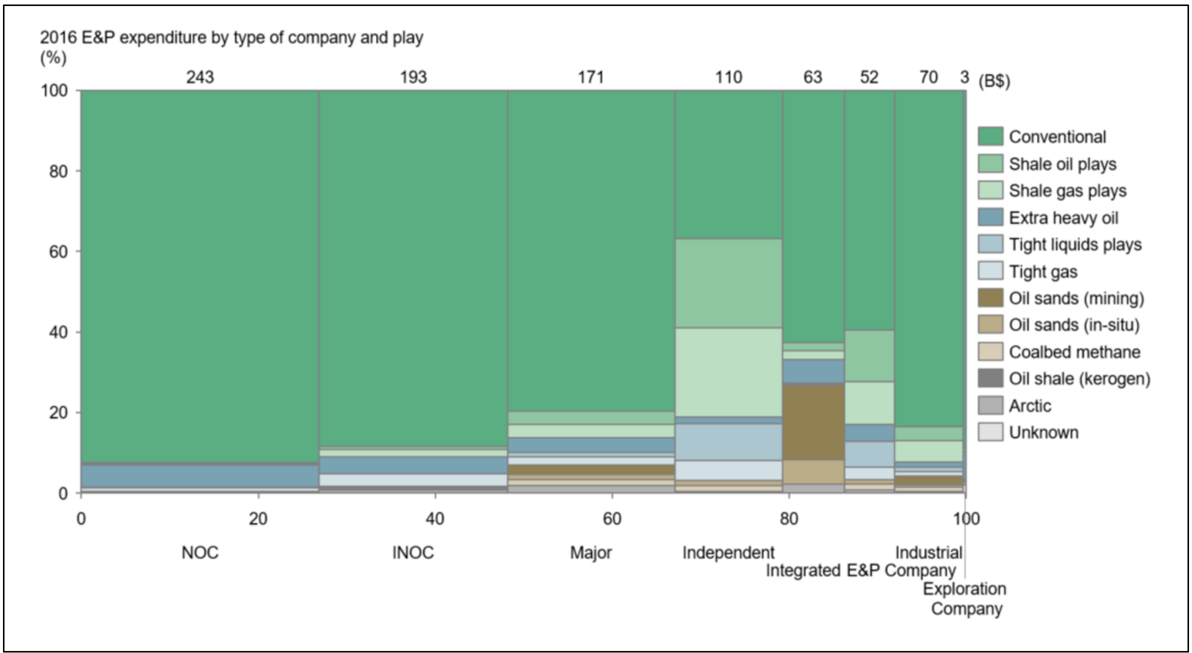
Integrated – includes companies with up-, mid-, and downstream, and minimum 100 kboed production or 480 MMboe proven reserves,

E&P Company – includes companies producing less than required to be classified as independent,

*Exploration Compan*y – companies that do not currently have production, only exploration licenses.

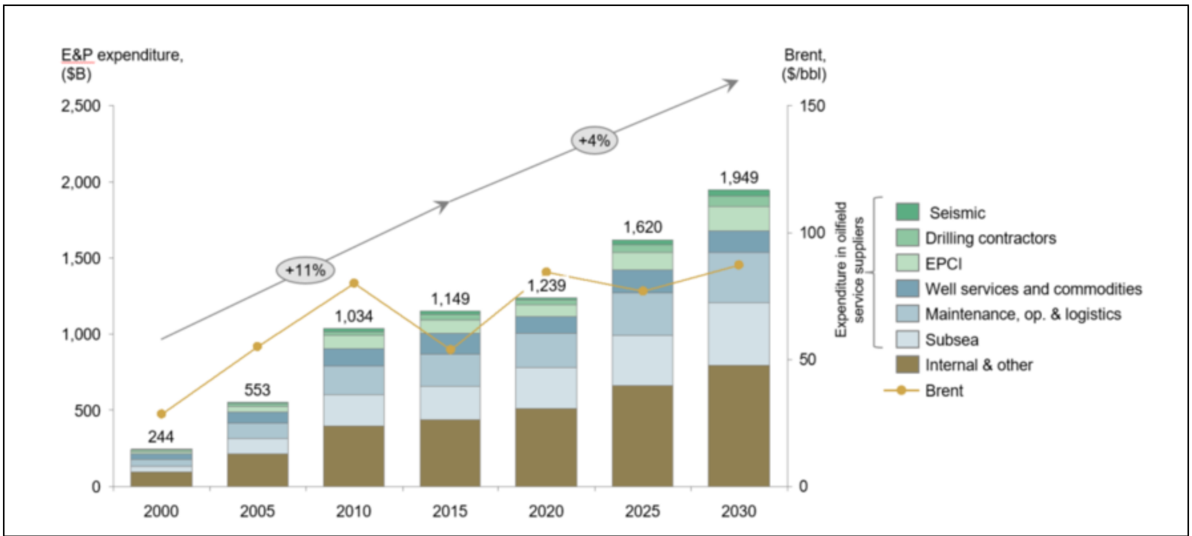
Unconventional plays are responsible for 22% of global E&P expenditure. Independent companies have the most diverse portfolios, with conventional fields representing nearly 35% of their total expenditure. At the other end of the spectrum, we have NOCs, which can still rely on easy-to-exploit resources, and with expenditure on conventional fields accounting for more than 90% (see Graph 31).

GRAPH 31. E&P expenditure by type of play and company segment



Source: Rystad Ucube (October 2017).

GRAPH 32. Global E&P expenditure 2000-2030 by activity



Note: Based on Rystad Base Case Scenario from 2018 onwards; Expenditure includes CAPEX and OPEX. All values are nominal assuming 2.5% annual inflation in the future.
Source: Rystad DCube (October 2018).

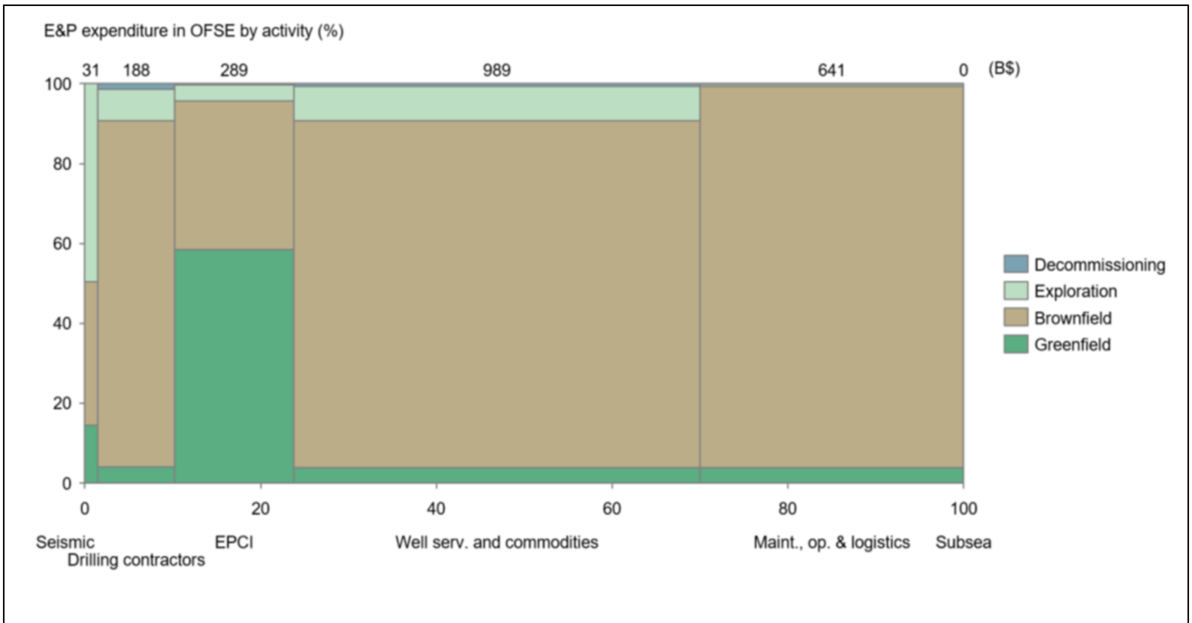
As it happens with the rest of the industry, oilfield services are going through challenging times. After seeing an almost continuous growth in E&P spending until 2014 (there was a decline in 2009), years 2015 and 2016 saw a drop in every oilfield activity.

However, predictions show slow growth in E&P expenditure in the years to come, having different rates depending on the type of oilfield activity considered. Graph 32 indicates that in the 2015-2030 period, the industry will grow at a 4% CAGR, with the highest growth from 2020 to 2030.

Investments in onshore/offshore developments have been strongly influenced by the recent low oil prices, as well. Offshore is more capital-intensive, with 20% of global fields accounting for around 35% of global expenditure. In this context, and due to the uncertainty regarding future oil price trends, onshore developments led global expenditures in 2016 with around 65% of global expenditure.

Something similar has occurred with brownfield/greenfield developments. In the current situation, oil companies are trying to avoid greenfield projects, which present higher risks and uncertainty, while they move towards brownfield projects, which are developed in a shorter term, and imply fewer risks for the investment. However, the share of brownfield and greenfield developments is highly affected by the type of activity.

GRAPH 33. E&P expenditure on onshore projects in the 2017-2021 period

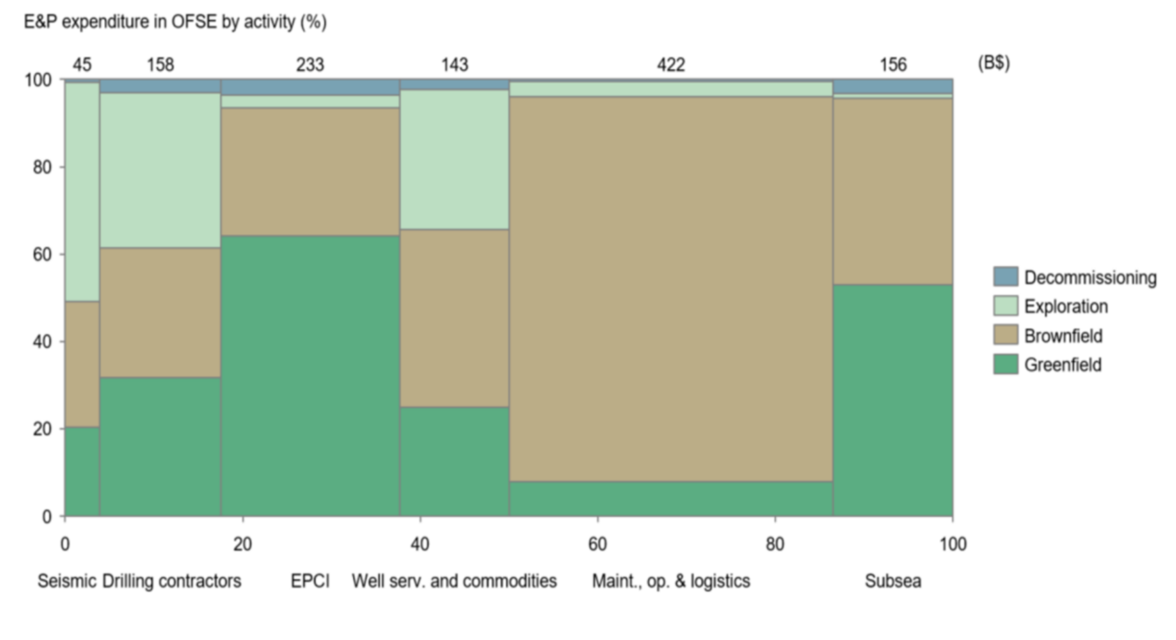


Note: Expenditure includes both CAPEX and OPEX. All values are nominal assuming 2.5% annual inflation in the future, OFSE – Oilfield Services and Equipment.
Source: Rystad DCube (October 2017).

This is particularly clear in Graphs 33 and 34, which show how, for onshore projects, most of E&P expenditure in the coming years will be in brownfield projects. This can be explained mainly by infill drilling[34], which has reduced the yearly well production decline from 5-6% to 3-4%.

It is also important to note that offshore projects are more cost-intensive than onshore projects, and thus, average project break-even prices tend to be higher, thereby affecting the investment plans of oil companies.

GRAPH 34. E&P expenditure on offshore projects in the 2017-2021 period

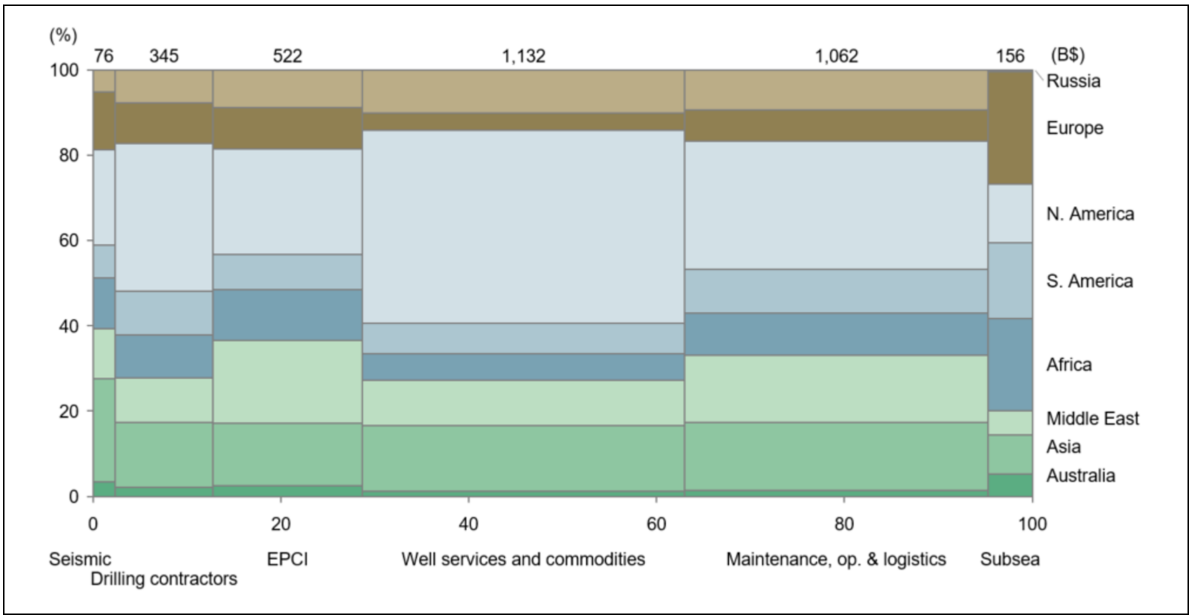


Note: Expenditure includes both CAPEX and OPEX. All values are nominal assuming 2.5% annual inflation in the future, OFSE – Oilfield Services and Equipment.
Source: Rystad DCube (October 2017).

As it is depicted in Graph 35, E&P expenditure on OFSE is not uniform around the globe. Expenditure on the different OFSE segments varies, depending on the region. For example, North America is the region spending the most money on well services and commodities (around 45% globally), while Europe represents a small share of that segment, with only 4% of global expenditure. On the other hand, Europe is leading the expenditure on subsea services (around 25%), while North America subsea expenditure represent only 15%.

[34] Infill drilling – adding new wells in an existing field within the original well patterns to accelerate recovery or to test recovery methods.

GRAPH 35. E&P expenditure on OFSE by region during the 2017-2021 period

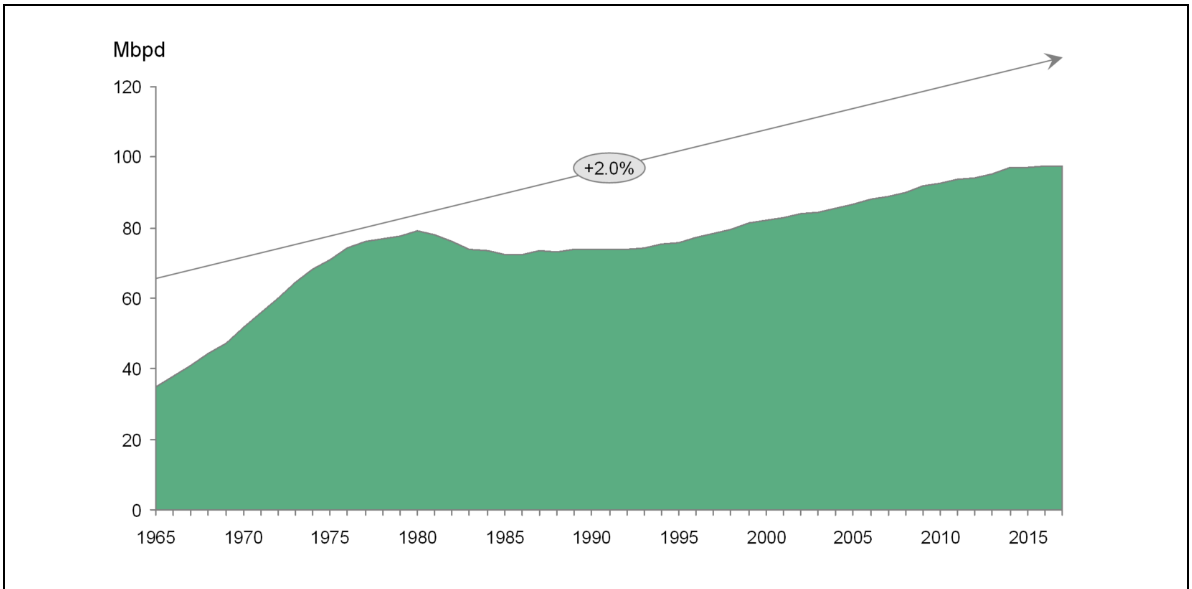


Note: Expenditure includes both CAPEX and OPEX. All values are nominal assuming 2.5% annual inflation in the future.
Source: Rystad DCube (October 2017).

2.2.2. Evolution of investments and capacity in refining

This subchapter investigates the evolution of the refining industry. The refining industry is a capital-intensive industry that has been able to cope with increasing demand for oil products, with its overall crude processing capacity growing from around 35 Mbpd in 1965 to circa 97.5 Mbpd in 2017 (i.e. increase of 2% p.a.), as shown in Graph 36.

GRAPH 36. Worldwide atmospheric distillation capacity evolution



Source: 2017 BP Statistical Review, GlobalData.

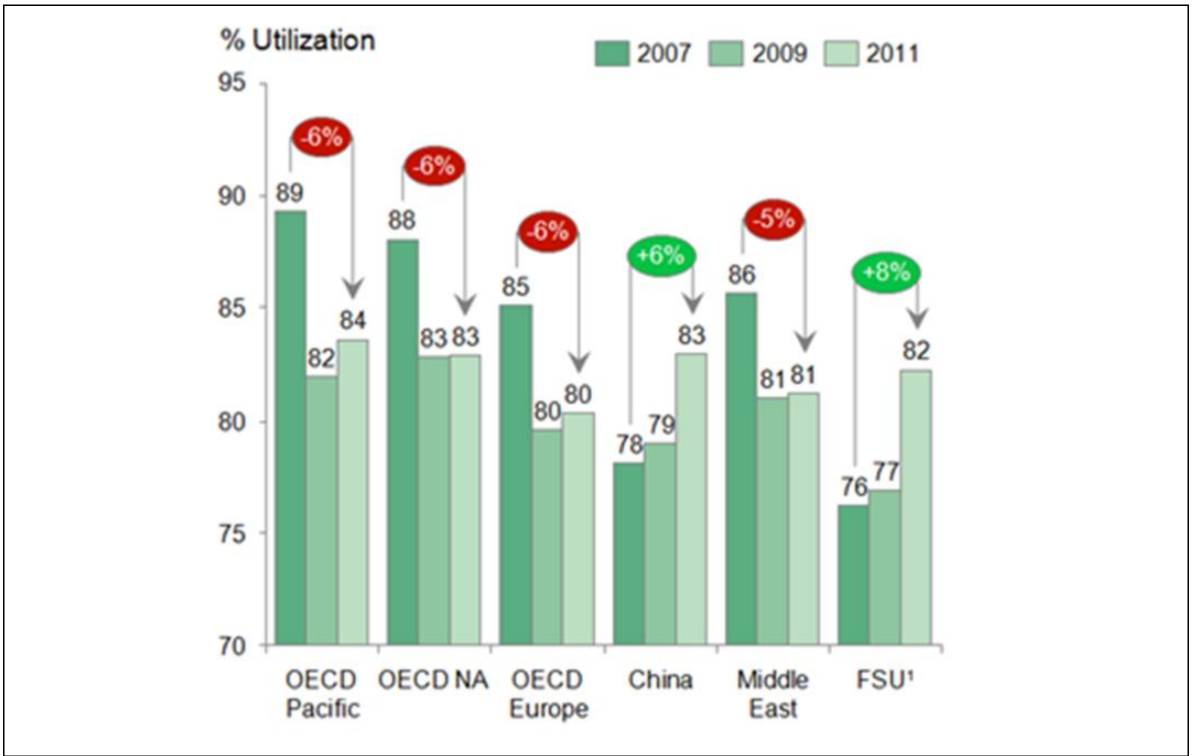
This growth trend has been followed by the different process units, but at an uneven rate. For instance, while the atmospheric distillation capacity has grown by approximately 25% over the last 20 years, newer conversion units, such as the catalytic hydrocracker and hydrotreater, have grown by around 90% and 40%, respectively, over the same period. This is explained by the popularization of the relatively recent technology, developed in the seventies to increase distillates yield from residues on new refinery projects.

The growth indicated has also been accompanied by a substantial relocation of capacity, which has shifted to Asia, driven by increasing demand, amongst other factors. While Europe that led the capacity mix share in 1965, with 38% of total capacity, its share has decreased down to 24%, and in turn, Asia-Pacific's capacity has grown from 10% to 34% over the same period.

During the economic crisis, the evolution of total capacity did not stop growing, mainly driven by countries, such as India and China; however, OECD countries, especially in Europe, reduced their refinery utilization, given the lower demand scenario and regional refinery overcapacity (see Graph 37). This refinery throughput reduction has mainly impacted less-complex refineries, especially diminishing fuel oil production in OECD countries.

Recent outlooks indicate that the medium-term trend for refining capacity additions will be well in excess of the required incremental refinery output. There is an estimated excess of 1.6 Mbpd in refinery capacity by 2022.

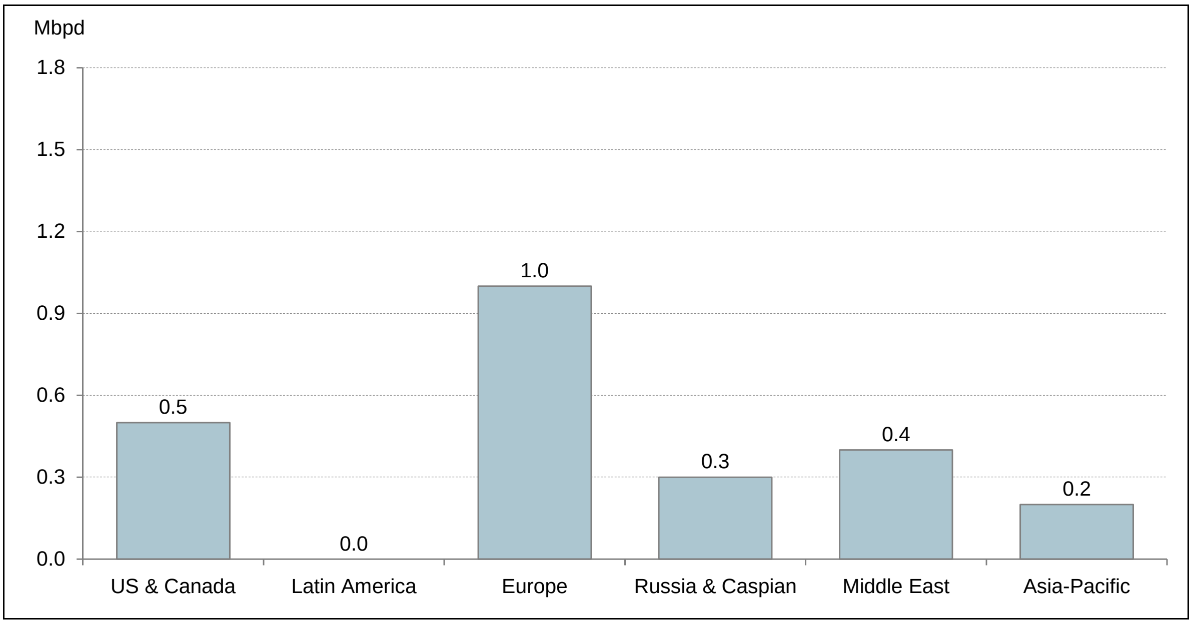
GRAPH 37. Average refinery utilization during the economic crisis, by region



Source: IEA.

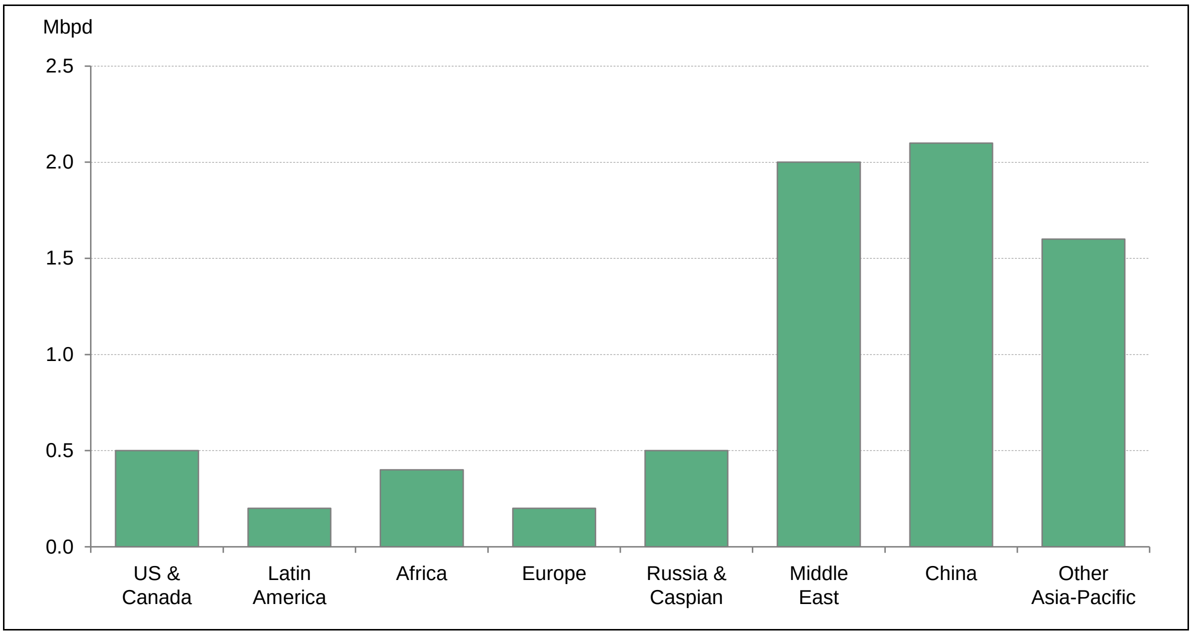
Due to this capacity surplus, Europe has been, and is expected to be, the center of refinery closure activity in the medium term (see Graph 38), with only additional European crude distillation coming from projects in Turkey and Ukraine (see Graph 38).

GRAPH 38. Expected crude distillation net capacity closures in the medium term (2017 – 2025)



Source: 2017 OPEC World Oil Outlook – Table 5.5.

GRAPH 39. Distillation capacity additions from existing projects (2017 – 2022)

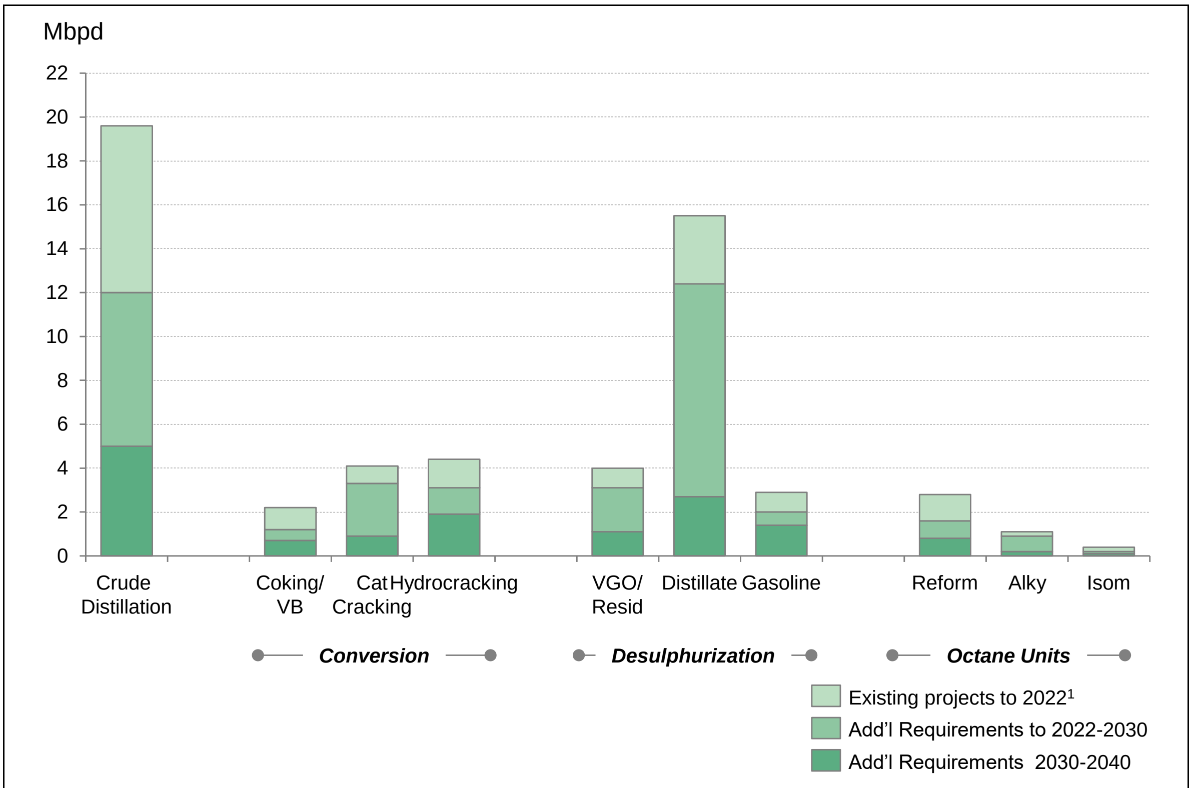


Source: 2017 OPEC World Oil Outlook – Table 5.3.

In 2016, this European capacity reduction offset new capacity additions in Asia, reducing global refinery capacity for the first time in a decade (96.5 Mbpd). The generalized reduction in throughput and utilization, across most regions in the world, is resulting in more complex marginal refinery configurations, with conversion capacity growth outperforming distillation capacity growth in recent years. Looking forward, refining capacity will deepen the current relocation trend, and will witness uneven growth between the different process units.

Regarding capacity allocation, 49% of future conversion capacity additions are expected to be developed, up to 2022, in Asia (fostered by China's and India's growth) and the Middle East (supported by a combination of growing local demand and policies in several countries, to capture added value by refining crude oil and exporting products, rather than simply exporting crude oil), see Graph 39. In Europe, refinery throughputs are projected to decline steadily and continuously. The assumed closure pipeline until 2020 has the effect of boosting utilization to approximately 83%, but thereafter, it will decline steadily to below 80% by 2035.

GRAPH 40. Global capacity requirements by process, 2016-2040



Note: Existing project exclude additions resulting from capacity creep.
Source: World Oil Outlook 2017, OPEC – Table 5.9.

The outlook for refining investment is not consistent for all types of process units (see Graph 40). As compared with a global ratio of 0.32 between conversion and distillation capacity that applies globally today, existing projects and total additions to 2040 exhibit a ratio of 0.55 conversion to distillation. All major new refinery projects comprise complex facilities designed to process "difficult" crude oils, or to produce petrochemical feedstock, resulting in high levels of secondary-processing capacity increases, and higher proportions of secondary capacity per distillation barrel, mainly due to the increasing regulation regarding sulfur content in fuels (specially the IMO regulation with a new limit of 0.5% sulfur content in marine fuels to be set in 2020), global desulfurization capacity requirements will be significant in medium term.[35]

2.3. Summary

Whilst global demand for petroleum products has grown continuously in the past, there are multiple factors which may alter this trend looking forward, some of which have become particularly relevant in the recently years. Perhaps the most significant event to take into consideration is the COP 21 agreement which sets out the urgency of reducing CO_2 levels to avoid dramatic global warming. In the outset of this chapter, it was mentioned that the factors influencing the demand side fall broadly into two categories, those directly affecting the consumer and those regulations which affect the oil and gas operator.

The chapter also highlights the disparities for demand outlook by region, for example that developed regions such as Europe already past the peak oil demand while for others like India the oil demand growth is still important. Regulations and technological developments have also played a major role in the growing alternatives to conventional fossil fuels. Price and availability remain as two primary factors that consumers look for in products, and whilst in the past petroleum has been by far the energy to fulfill both of these criteria, other alternative fuels, which are at different levels of development, such as CNG, LNG, Biofuels and hydrogen, may influence the level of demand for oil. In addition, new technologies such as electric vehicles, helped in many cases by subsidies, are in the path of becoming competitive and desirable.

The O&G industry has known for many years that easily-exploitable reserves are becoming fewer and farther away from the existing logistics infrastructure and the major oil routes, and are found in more extreme environments. As a result, projects have become more technically and commercially complex. Neglecting opportunities to improve collaborative efforts, and the need to keep impeccable safety records, means that any minor negative changes in external economic factors might erase the existing margins.

The E&P landscape has seen a dramatic reshuffling in the last four years, born out of necessity after the crash in oil prices in late 2014. The types of development being

[35] This assumes the scenario where compliance will mainly be carried out by a better quality of fuel oil, rather than by scrubbers or LNG.

targeted, and the players exploiting those resources, have shifted to react and adapt to the challenging economic environment.

In efforts to keep company cash flows positive during the downturn in oil markets, a number of new processes and strategies have been adopted. While one or two companies had already begun to implement such changes prior to the fall in prices in order to improve margins, these players and other E&P operators were not adequately prepared.

E&P CAPEX is estimated to have fallen by 18% per annum from 2014 to 2016, to around US$518 billion, recovering by some 4% the following year[36]. Companies have reduced their CAPEX significantly, delaying projects or outright cancelling them. In efforts to reduce OPEX, headcounts have been reduced globally, and companies have become more meticulous in ranking projects, and investing only in the very top projects by profitability. As a result, service companies have been hit extremely hard, with no guarantee of revenues from vertical integration. All of these factors, combined, mean that the supply surplus may well turn into a supply deficit in the near future, as production from brownfield projects declines and the investment missing from new resources kicks in.

When comparing the different types of industry players, it is evident that the independent oil companies have suffered the most, with many going into administration and liquidation. Consolidation has also been prominent among many of the larger players. By combining portfolios, companies have been able to develop economies of both scope and scale. Additionally, M&A deals between operators, oilfield service and midstream companies have been evident, with benefits possible among much of the upstream value chain. Examples of such mergers include the US$7.5 billion Total-Maersk tie-up, the General Electric and Baker Hughes merger, which creates a company with annual revenues of around US$23 billion, and the more recent agreement to merge BASF's energy unit, Wintershall, with rival DEA, creating an international company with the capability to compete with the majors.

It now remains to be seen how the industry will respond, as oil prices appear to be somewhat in a state of recovery. It is important for companies to emerge stronger, leaner and more efficient from the downturn, and not to allow cost creep as profits improve. Additionally, the E&P sector must look at other industries, outside of O&G, for take-home lessons on reducing costs.

Moving to refining, over the last 20 years atmospheric distillation capacity has grown by approximately 25% and newer conversion units such as catalytic hydrocrackers and hydrotreater, have grown 90% and 40% respectively over the same period. This growth has also been accompanied by substantial relocation of capacity, which has shifted to Asia. While Europe had 38% of total capacity in 1965, its share has decreased to 29% in recent years. During the economic crisis total capacity did not

[36] Estimation by Rystad Energy.

stop growing, driven mainly by China and India and whilst capacity utilization in Europe has been reduced.

Regarding capacity allocation of the future, 49% of future conversion capacity additions are expected to be developed up 2022 in Asia. In contrast, in Europe, refinery throughputs are projected to decline steadily.

The outlook for refining investment is not consistent for all types of process units. As compared with a global ratio of 0.32 between conversion and distillation capacity, that applies globally today, existing projects and total additions to 2040 are expected to exhibit a ratio of 0.55 conversion to distillation.

3. GENERAL STRATEGIES, RESPONSES TO SPECIFIC CHALLENGES AND BUSINESS MODELS

In this study, up to this point, a quite ample amount of information and analyses have been mentioned. The question that remains now is the following: "Taking into account the new landscape, the challenges, the objectives and priorities for players in the refining industry, which general strategies, specific responses and business models can be expected?"

To respond to this question, in this chapter, the focus is placed first upon the general challenges and general strategies, thereafter a detailed examination on the specific challenges and specific responses is carried out, and finally, a reflection on business models is presented. In order to do so, firstly, a brief review of the general challenges that participants in the industry will have to face, or those that may act as driving forces with a significant influence on the O&G industry will be provided, as well as the strategies that give response to those challenges.

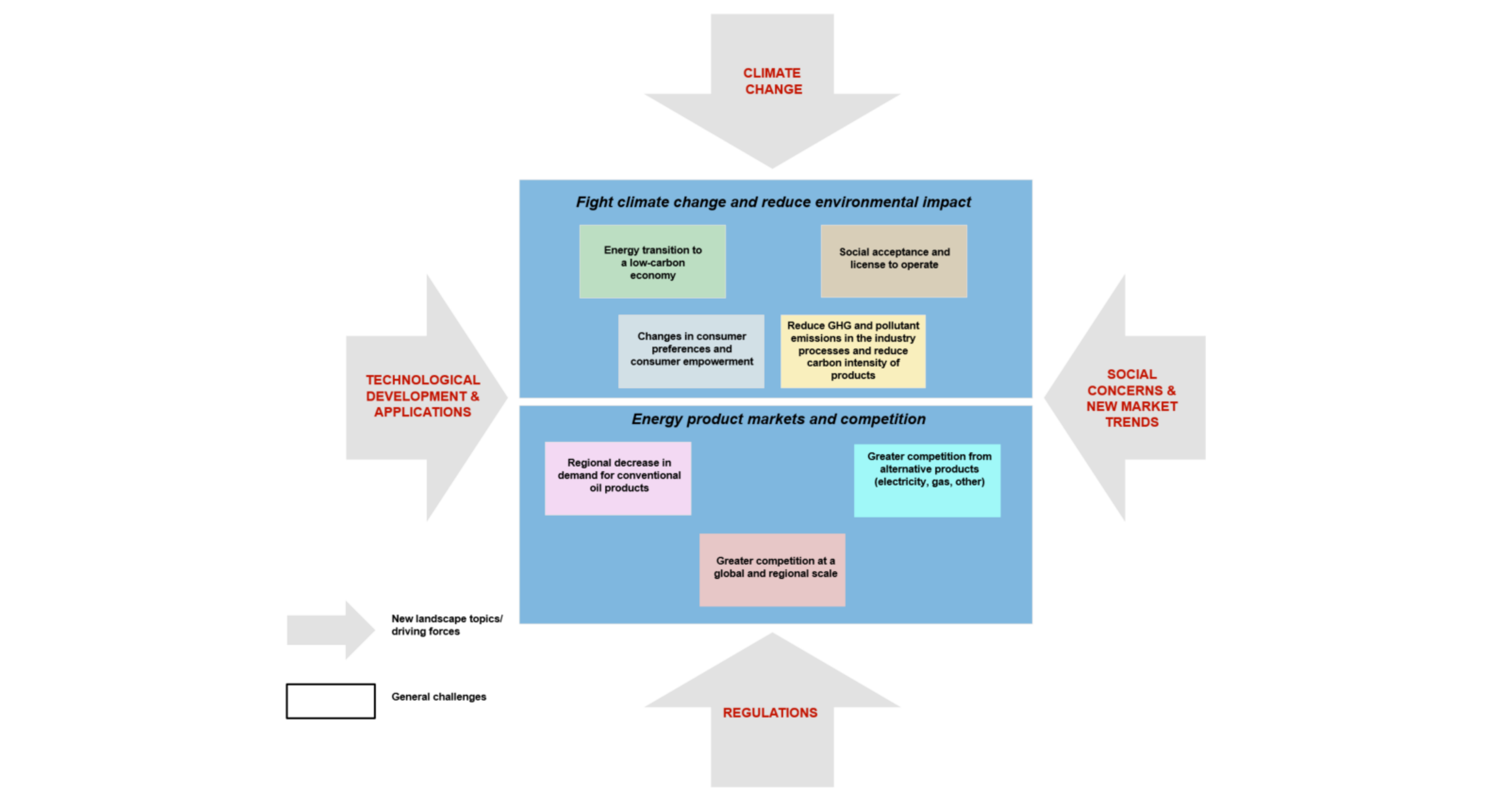
3.1. General challenges and strategies

At the beginning of this study, in Chapter 1, four main blocks of big issues that characterize the new landscape were identified, namely: climate change policies and transition to a low-carbon economy, social concerns and new market trends, technological developments and applications, and regulations. They represent the main drivers that are going to impact the oil and gas industry, sooner or later.

In the same Chapter 1, a detailed examination of these issues has been carried out, with the result of a number of specific challenges that have been expressed and specified in Tables 3, 5, 6 and 7.

As from an analytical and strategic point of view, it is clearly necessary to have a broader view of those 50 challenges (the number from the list in the aforementioned tables); an analysis of those specific challenges allows arriving at a conclusion that can be grouped into seven large themes or general challenges. These general challenges are illustrated in Figure 13 (below), and are the following: Reduce GHG and pollutant emissions in the industry processes and reduce the carbon intensity of products; Energy transition to a low-carbon economy; Changes in consumer needs and consumer empowerment; Social acceptance and license to operate; Regional decrease in demand for "conventional" oil products; Greater competition at a global and regional scale; and Greater competition from alternative products (electricity, gas, others).

FIGURE 13. An illustrative scheme of new landscape topics/driving forces and general challenges



Source: own elaboration.

These general challenges can, in turn, be associated with two main frame blocks. The first one involves fighting climate change and reducing the environmental impact, and the second one is related to energy product markets and competition (at a global or regional scale, from new entrants or new products).

The two blocks, the seven general challenges and the general strategies to deal with them can be seen in Table 9 (below).

TABLE 9. General challenges and strategies

General challenges	General strategies[37]
Fight climate change and reduce environmental impact	
• Energy transition to a low-carbon economy • Social acceptance and license to operate • Changes in consumer preferences and consumer empowerment • Reduction of GHG and pollutant emissions in industry operations and carbon-intensity products	• Enter and/or reinforce activities in the gas and electricity value chain • Enter and/or reinforce activities in renewable energies (electricity, transport, buildings) • Approach and/or reinforce activities, in order to converge with utilities towards energy companies • Reinforce integration and accelerate implementation of ICT in all business operations, from upstream to retail
Energy product markets and competition	
• Regional decrease in demand for conventional fuel oil • Greater competition at a global and regional scale • Greater competition from alternative energy products	• Improve performance results, ROA-ROCE, by maximizing value creation along the O&G value chain (full vertical integration or governance) and developing new market-demanded products[38] • Evolve to be a relevant player at a global or regional scale • Implement ICT and new technologies efficiently through the O&G chain

Source: own elaboration.

The main advantage of identifying the seven general challenges, and associating them in two main blocks, is that it allows reflecting and visualizing which might be the strategies of a broad or general nature for the industry to respond. It should be noted that, given the wide scope and the type of documents that are considered in this study, the general strategies here should be read in a flexible way, in the sense that companies may choose to react by implementing some of the strategies, though not all of them. Furthermore, it should be taken into account that there are different types of industry players, and it should be specified, when dealing with various business models (i.e. IOCs, NOCs, independent oil companies), that different type of players will choose different strategies, or a combination of them.

[37] These strategies may be developed by organic growth or M&A.

[38] For instance, distributed resources, energy efficiency, energy networks, and petrochemicals.

As can be seen in Table 9 (above), four general strategies are identified in response to the challenges of the first block, namely: Enter and or reinforce activities in the gas and electricity value chain; enter and/or reinforce activities in renewable energies; enter and/or reinforce in order to converge with utilities towards energy companies; and reinforce integration and accelerate implementation of ICT and digitalization in all business operations from upstream to refining. At the risk of simplifying, it could be said that strategies here have to do with developing companies that look to energy in an integrated way, considering non-traditional energy products of the oil industry, and at the same time, reinforcing activities in the value chain in a response to the transition to a low-carbon economy. These general strategies are illustrated in Figure 14 below.

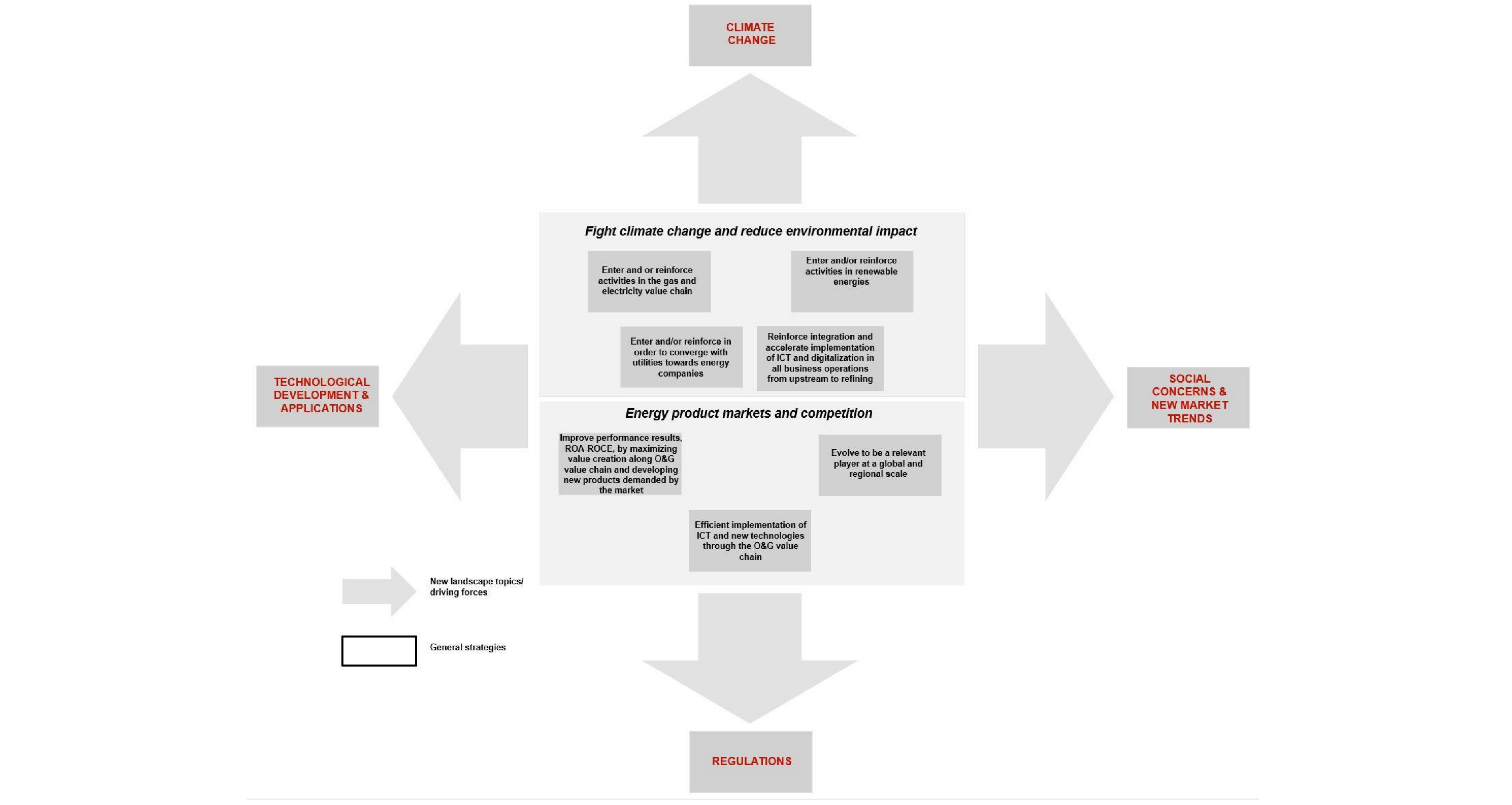
Since renewables have been increasing their share in electricity generation, and as electricity will be the final energy with the higher penetration growing in the future, it is also quite clear that electricity will become more relevant; therefore, a general strategy might have to do with becoming involved in the electricity business. In this regard, the idea of approval and/or reinforcement to converge with utilities must be appreciated. By this approach, companies will offer more energy types: oil, gas, electricity, and services. Then it can be said that companies are probably going to be present in more energy segments.

The degree to which non-traditional energy segments will feature within companies will be diverse in both scope and intensity, and cannot be expected to change dramatically overnight, even when the business strategy is implemented by acquisitions, rather than organic growth.

Furthermore, in a general consideration of the strategies must be taken into account that the energy transition and renewables will have a growing importance. However, the adaptation of the oil industry is also going to depend on the speed of the energy transition, as Fattouh, B., et al (2018)[39] has clearly shown.

[39] Fattouh, B.; Poudineh, R.; West, R. (2018) "The rise of renewables and energy transition: what adaptation strategy for oil companies and oil-exporting countries?" The Oxford Institute for Energy Studies.

FIGURE 14. An illustrative scheme of new landscape topics/driving forces and general strategies



Source: own elaboration.

Energy transition will certainly present a great challenge, but as this study shows, oil products will continue to have paramount importance; then the development and improvement of the transitional and core businesses will also be very relevant. This explains the need to reinforce activities in the O&G value chain. Thus a key factor of business models will be to reinforce control of the core businesses along the value chain. The emphasis that is put upon the general strategies with regard to non-traditional energies for the oil industry, does not mean that the core businesses shall be abandoned in the new landscape.

The second block of challenges also illustrated in Figure 14 is mainly related to energy product markets and competition. The general strategies basically have to do with a traditional approach to improve economic performance and consider company size to be consistent with a global market and with greater competition, where the strategy of ICT and digitalization is also considered relevant. In summary, three general strategies are included in this second block: Improve performance results, ROA-ROCE, by maximizing value creation along O&G value chain (full vertical integration or governance) and developing new market demanded products; evolve to be a relevant player at a global and regional scale; and efficient implementation of ICT and new technologies through the O&G chain.

3.2. Specific challenges and specific responses

After looking at the general challenges and strategies, it is convenient to summarize and complement the discussion of Chapter 1 on specific challenges (it may be noted that it is not necessary to have a complete and exhaustive correspondence of specific challenges to the general challenges identified) with specific responses. Therefore, an exercise has been carried out, the results of which are displayed in this Section 3.2, in order to revise the specific challenges seen in Chapter 1 and to identify specific responses to them. Furthermore, in this detailed analysis, a color code has been included that refers to its relationship to the general challenges.

As the reader may notice, as the work on the specific challenges and responses has enough detail to be self-explanatory, then no further explanations were considered to be included.

For sake of simplicity, the 50 specific challenges from Chapter 1, as well as the corresponding specific responses, are listed in Table 10. It should be noted that the correspondence of responses to the general or specific challenges is not unique, and that the real industry responses shall depend on the type of player and the time of implementation. Therefore, the main purpose of Table 10 is to point out the type of challenges the industry will have to face and the possible specific responses.

TABLE 10. Specific challenges and specific responses

Specific challenges	Specific responses
Energy transition to a "low-carbon economy"	
• Adapt to the implementation and growth of new mobility trends • Face potential decreased activity in refineries and lower demand for oil products, under "ceteris paribus" conditions	• Bring costs down and implement technology, by seeking the collaboration of expert service companies • Prepare in advance, by holding discussions, collaborating with regulating bodies and taking the initiative, achieving voluntary GHG reduction agreements • Anticipate and adapt commercialization and marketing strategies, as well as the refining structure, to market change • Reduce refinery operational costs and/or adjust the refinery capacity accordingly, so as to keep these profitable
Social acceptance and license to operate	
• Gain social appreciation for the industry, due to the efforts to reduce environmental impacts • Increase health and safety in operations • Develop and implement ways to produce cleaner energies and fuels • Improve the current record figures of incidents in production, transportation and refining, and inform society on them • Organize a quick global industry response (operational and financial) to any emergency that could occur • Satisfy the increasing number of stakeholder demands, complying with responsible environmental measures	• Invest in marketing initiatives, to demonstrate progress in operation health and safety, and engineering solutions to reduce/eliminate harm to the environment • Implement social responsibility measures in those countries where companies are present, as a way to contribute positively to the development of societies • Report on advances in company sustainability

(cont.)

TABLE 10. Specific challenges and specific responses (cont.)

Reduce GHG and pollutant emissions in the industry processes and reduce the carbon intensity of products	
• Reduce land occupation, energy consumption, discharges and other environmental impacts in E&P and refining • Maintain and improve efficiency and efficient incorporation of renewable energies in their activities • Implement efficient processes to reduce sulfur in fuels and adjust their properties for engine requirements to allow low NOx burning • Develop and implement ways to reduce/eliminate these hazardous components from fuels • Improve waste reuse, treatment and elimination (reinjection) processes • Reduce harmful spillages and pollutant emissions, with the goal of achieving "zero release" • Develop and implement a risk management policy	• Set up departments to ensure that regulations are known, adhered to and implemented • Invest in the assessment and development of new technologies
Regional decrease in demand for "conventional" oil products	
• Continue the optimization of oil recovery in conventional fields • Maintain cost discipline throughout the value chain, in particular in E&P • Remain competitive compared to other players in the context of a shrinking market • Contribute to preventing boom-and-bust investment cycles in E&P, as a way to reduce price volatility • Adapt strategies to reduce own reserves, in the event that the demand starts decreasing • Ensure that oil products remain competitive, resulting in the delay of transition to other energy supplies	• Achieve further technical simplification for new projects, selective screening and ranking processes, and automation • Specialize in certain resource plays, be they O&G or newer alternative energies • Plan long-term business finances, and hold possible discussions with policy makers, to ease the effect of global events on local producing costs • Invest in short-cycle projects, and even split large investment projects into phases • Adapt strategies to produce own reserves as soon as possible, in the event that demand starts decreasing

(cont.)

TABLE 10. Specific challenges and specific responses (cont.)	
Greater competition at a regional scale	
• Expand the portfolio of petroleum products, including petrochemicals • Remain competitive with a greater number of competitors, utilizing different marketing and sales strategies • Devise instruments to face the complexity in trading and futures coverage operations • Analyze and request the catalysts that best satisfy the binomial relation feedstock/expected products	• Negotiate effective partnerships and collaboration to ensure competition and shared expertise • Specialize in the market, across different energy types • Achieve integration with downstream functions, within business operations
Energy transition to a "low-carbon economy"	
Reduce GHG and pollutant emissions in the industry processes and reduce the carbon intensity of products	
• Adapt the global challenge to the regional particularities, given the different degrees of adoption by country/region • Achieve the acceptance, or at least minimize the social rejection, of fossil fuels • Effectively reduce the emission intensity, throughout the entire chain, of the fuels produced • Increase the efficiency of industry operations • Apply carbon capture and storage, and CO_2 transportation for enhanced oil production and/or underground storage of CO_2 • Ensure required investments to reduce GHG emissions are put in place • Find ways to reduce their energy products' emission intensities, such as: promoting conversion and blending • Adapt retail stations to new fuels, or create new supply points • Face decreased demand for oil products as a consequence of the irruption of alternative energies • Commingle renewables in oil fuels as part of the value offering • Contribute to the development of production facilities for biofuels (bio-refining process)	• Set internal shadow prices for greenhouse gas emissions contained in resources, when screening projects • Identify cost and market impacts of a potential carbon tax, or future regulations for reduction • Target natural gas and biogas, to potentially play a role in facilitating the broader integration of renewable electricity and/or fuels • Increase the portfolio of alternative energies in transportation • Develop further ways to utilize technologies, such as carbon capture, to counter balance emissions • Invest in renewable energies - as well as venture capital investments into new technologies in energy businesses • Rebrand companies, with particular names that indicate support for green technologies and energy (such as in the example coming from other energy companies)

(cont.)

TABLE 10. Specific challenges and specific responses (cont.)

Regional decrease in demand for "conventional" oil products	
Energy transition to a "low-carbon economy"	
• Guarantee affordable prices for consumers, while under pressure from alternative energy price reductions • Maintain crude oil and product storages capable of overcoming any global or local supply disruption • Deliver a continuous smooth product supply, as O&G projects become larger, more hazardous and more remote • Design and implement process and procedures to allow increasing operation flexibility to adapt to market and new regulation changes • Foresee potential integration of new business units, such as petrochemicals, or special non-fuel petroleum products	• Maintain stringent cost-reduction measures along the value chain, to protect operator margins, which in turn, can be passed on to the customer • Better understand the supply/demand balance, at both macro and micro levels, and develop national and private stockpiles accordingly • Introduce diversification with regard to energy offerings, in order to ensure that disruptions in O&G supply can be covered by substitutes and fuel switching
Changes in consumer preferences and consumer empowerment	
Greater competition from alternative products (electricity, gas, others)	
• Adapt commercialization and marketing strategies, and modify ad hoc the refining structure • Improve oil production and/or refining to reduce costs and draw response measures to face or adapt to a scarcity situation	• Promote the development of materials for batteries and electrochemical systems • Invest in efficient power supply infrastructure, integrating renewable energy to become part of the solution to reduce GHG emissions in transportation • Adapt commercialization and marketing strategies, and modify the refining structure

(cont.)

TABLE 10. Specific challenges and specific responses (cont.)

Reduce GHG and pollutant emissions in the industry processes and reduce the carbon intensity of products	
Energy transition to a "low-carbon economy"	
Changes in consumer preferences and consumer empowerment	
Greater competition from alternative products (electricity, gas, others)	
• Face increased competition in final demand, due to the irruption of new entrants • Envision how a company can successfully integrate these technologies, along with existing applications, within the operation management and business management systems, in order to reduce costs, minimize environmental impact, enhance safety, and improve the maintenance and availability of installations • Prepare implementation requests to service companies, with a clear objective to be reached and definition of how the results will be evaluated • Prepare knowledgeable implementation teams with their own personnel and contractors • Adapt/react to the potential new products and specifications • Remain competitive in final prices, as alternative energy-fueled vehicles become more cost efficient • Adapt and optimize refinery structures to maximizing margin and, at the same time, minimizing environmental impact	• Invest in initiatives to demonstrate progress in the health, safety and environmental care of operations • Embrace technological developments, by setting up departments within the existing business organizational model, which have a specific focus on its application for improving operations

Source: own elaboration.

3.3. A reflection on business models

Types of players and business models

In order to examine business models, it is necessary to identify the different types of players, and which business models they may have adopted or might consider implementing.

The most important players, by type of player in the industry, are as follows: a) major oil companies (i.e. ExxonMobil, Chevron, Shell, BP, Total and ConocoPhillips), b) national oil companies (i.e. Saudi Aramco, Statoil, CNPC, Petrobras, Rosneft), c) independent companies in E&P (i.e. Apache, Anadarko, Marathon Oil, etc.), d) refiners (i.e. Valero, Philips 66, Reliance Industries, etc.), e) petrochemicals (i.e. BASF, DOW, BP, Shell, Total, etc.), f) midstream operators (i.e. CLH, Enagas, Enbridge, Kinder Morgan, Trapil, etc.), g) specialized service companies (i.e. Halliburton, Baker & Hughes, Schlumberger, UOP), h) new entrants (i.e. trading houses, such as Vitol, Trafigura, Glencore; private equity: Goldman Sachs, Carlyle), i) specialized technology or new product companies (i.e. SAFT, biofuels (Cosan, Verasun, Amyris), lubricants (Q8Oils, Wolf Oil corporation),etc.)

Having identified the players this way, it will now be tried to identify the clearest or preferred business models, though in a simplified manner. In this regard, business models refer to the general trends that have been described and outlined in this study. In all cases, by considering objectives with a view to keeping a business competitive and growing, such as: 1) increase profitability and improve return on assets, 2) maintain market share, 3) reinforce core businesses (i.e. pure specialist on mature assets), 4) reinforce O&G value chain (focusing on its strong points), and 5) create/develop new businesses.

When thinking about the execution of new initiatives, the growth vector could be considered as being either Based on Technology (BoT) or Based on Know How (BoKW). While large NOCs and refiners traditionally follow proven methodologies and techniques, specialized technology companies create their niche and deliver high added-value through a BoT approach. Major IOCs and specialized service companies fall somewhere in the middle, with many years of knowledge to rely on, and with the resources to invest in technology, in order to maintain their competitive edge.

So taking into account the abovementioned objectives, the following business models may be suggested for the identified players:

TABLE 11. Types of business model by player category

Type of player	Type of business model	Main objectives
Major IOCs	- Reinforce control of the core business along the value chain and integrate operations - Expand business activity, fitting the main activity[40] - Expand business towards diversifying the energy mix offer (utilities), becoming global energy companies	1, 2, 3, 4, 5
NOCs[41]	- Reinforce control of the core business along the value chain and integrate operations - E&P and refining in existing local markets - Increase corporate activities - Expand business activity, fitting the main activity - Expand business towards diversifying the energy mix offer (utilities), becoming global energy companies	1, 2, 3
Independent companies in E&P	- Acquisitions: fields and companies in E&P – Specialization in types of upstream play or region exploited - Expand business activity, fitting the main activity	1, 2, 3
Refiners/Petchem.	- Refinery conversion investments - Expansion in other geographies - Expand business activity, fitting the main activity and diversification	1, 2, 5
Midstream operators	- Internationalization, new geographies -Integration of transportation and distribution businesses	2, 3
Specialized service companies[42]	- Specialization and diversification - Integration by M&A	2, 3, 5
Specialized technology and/or new product companies	- Create and develop products that increase added-value to those existent in the market	2, 3, 5
New entrants (Private Equity) and trading houses	- Refining business	1, 5

Source: own elaboation.

Aligned with the above points for companies adapting their business model to integration and expansion, the subsequent themes are further explored in the

[40] This also applies to some NOCs.

[41] Including previous NOCs that were later privatized (such as Gazprom).

[42] This does not include pure EPC players.

following paragraphs: vertical integration between upstream and downstream, business expansion fitting main activity, portfolio management and moving towards integrating and globalizing their energy footprint.

It is worth noting that this study does not address the organizational changes that could be required as a result of incorporating new businesses (i.e. renewables, cleaner power) into the existing organizational divisions.

Vertical integration

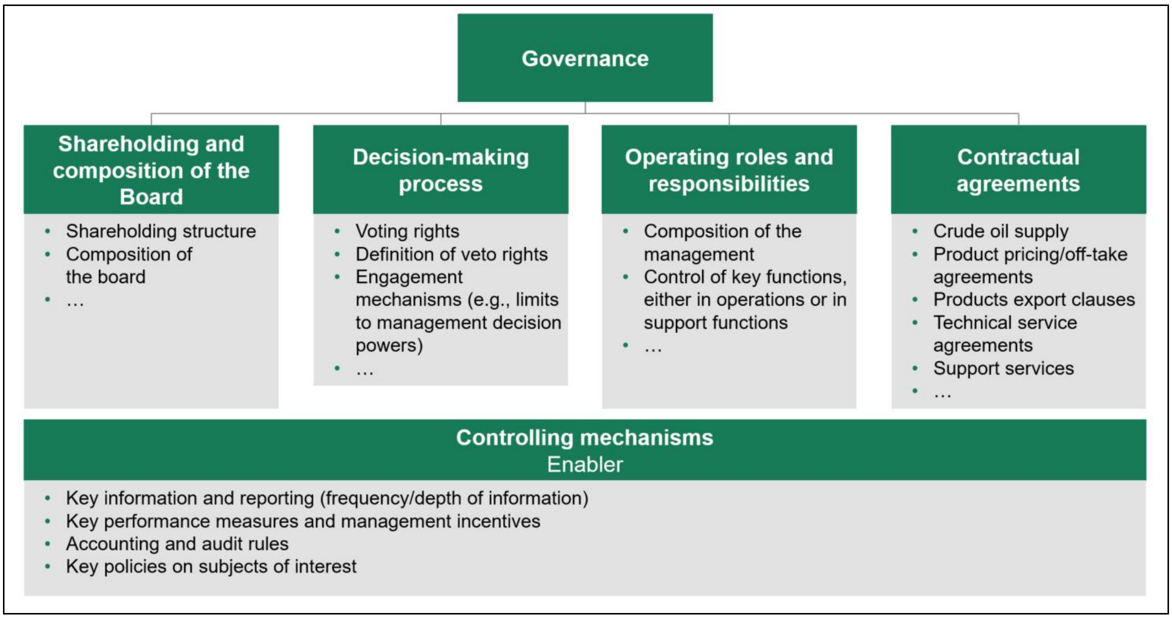
One relevant issue related to business models is the vertical integration between upstream and downstream in oil and gas, which is constantly under discussion in the industry. The key to maximizing the integration value lies in understanding and acting simultaneously in three distinct areas: a) the hard side of change, identifying and measuring the value of integration in intermediate product flows, energy networks, maintenance, logistics, etc., b) making change possible, setting up the right organization, processes and tools that will enable the company to operate with the required level of information and flexibility to make the right decisions, and c) the soft side of change, developing the right mindset and culture in the key teams to ensure that change is sustainable and embedded in the organization (i.e. making change stick).

The different fronts of O&G company integration can be expressed as follows: a) physical - synergies in terms of facilities, utilities, and infrastructure, etc.; b) hydrocarbon flows - crude oil placement, refineries optimized for crude slates, refining and petrochemical exchanges, optimized logistics, etc.; c) Process & System - integrated capital allocation, economies of scale in procurement, technology, treasury management, reduced interfaces, shared services, etc.; d) People & Culture – shared values, increased cooperation among businesses, knowledge transfer across the value chain, etc.; and e) Portfolio – higher optionality, reduced volatility, diversified risk, etc.

To highlight how the points above are applicable to a specific sector, the refining industry, strategic priorities for active players in this space have been identified, such as: increasing profitability and protecting margins, which includes developing large transformation and operational excellence programs to increase profitability, increasing the level of integration/coordination across the value chain, and developing vertical integration in adjacent countries, where value is gained, to increase netback; developing growth opportunities (trading and quality); increasing conversion capacity; minimizing raw material and energy costs; and improving size and refinery configuration. Finally, two other factors were analyzed: niche markets and products, and portfolio management.

The value from integration can be protected, even in case of the separation of selected business lines, as can be seen in Figure 15, in which different aspects of governance are considered - from shareholding and composition of the board, to contracted agreements.

FIGURE 15. Integration protection alternatives



Source: BCG experience.

Regarding the drivers for refinery/gas unit petrochemical integration are identified, among others, the following : a) premium from olefin opportunities, in relation to transportation fuels, b) stability along the value chain, flexibility to adapt to the market dynamic and prices, c) feedstock and product flexibility and availability, recovery of return streams, d) upgrading lower-value refinery streams to higher-value products, and d) expenditure and resource optimization, shared infrastructure, storage & utilities, lower logistics and energy cost, overhead and waste minimization.

Ultimately, to integrate is not the fundamental goal; rather, the objective is to maximize value creation, by: a) maximizing the synergies from integration, considering the company's starting point, context and opportunities, b) managing integration, while ensuring transparency, accountability, and management focus, c) extracting value, by separating selected entities when separation is more attractive than integration, and d) evaluating new project opportunities, considering all potential alternatives, and not only those involving the integration of current assets.

Business expansion fitting the main activity of the O&G player, by organic growth or acquisitions

For a while now, the O&G industry has been seeing changes, adapting to market new trends, trying to position – in the future – in lasting and/or profitable business segments that are somehow an extension of its original activity.

In the following table, the typical business expansions adopted, fitting the main activity of the player, are listed.

TABLE 12. Business expansions fitting main activity

Phase 1	Phase 2	Phase 3
Oil	O&G	Electricity/heat and cooling/ hydrogen
		NG and LPG production
		NG and LPG distribution and sale
		Biofuel production

Source: own elaboration.

Electricity production through a combined heat and power (CHP)/cogeneration process is not something new in the O&G industry. With regard to gas, a lot of O&G players were focused on its exploration, production and transportation, without going lower in the value chain and commercializing it to end consumers. Some Gas and Power (G&P) companies were already in the market, offering a combined product for residential and commercial usages (electricity and piped gas). With alternative energies for transportation infrastructures in development, it was just a matter of time for O&G companies to enter this segment, through their organized supply market and the lower initial investment required.

LPG is used as petrochemical feedstock, as well as for residential and other commercial applications (bottled or bulk). Autogas is also a good option to address expected product surplus in some regions, due to NG competition in heating[43].

And last, but not least, instead of closing their refinery production facilities, some O&G players are converting them to a biorefinery, taking the opportunity to use their production and storage installations. Some examples of this are the French La Mède refinery from Total SA, or the Italian Gela refinery from ENI, (see Figure 16). This allows them to produce the renewable fuels to comply with the EU mandate, to incorporate them into conventional fuels (gasoline and diesel).

Portfolio management

The changing environment faced by oil companies, whose rate of change has accelerated due to the decline in oil prices, has fostered active portfolio management in order to maintain profits and optimize the return on investment.

[43] "Research carried out in 2013, by Atlantic Consulting, compared results for 1251 models of bi-fuel vehicles, and concluded that there was an average 11% CO_2 tailpipe benefit when running on LPG, compared to the identical car running on petrol" – www.drivelpg.co.uk.

Depending on the geographical area, demand evolution, among other factors, has caused different impacts on the refining business. In Europe, for instance, capacity utilization has declined as a result of decreased demand, while in other areas, such as Asia and the Middle East, demand has led to an increase in refinery capacity. On top of all of this, it is important to note that the interests of some nations have also played a relevant role, fostering or discouraging refinery projects in their countries. A good example can be found in Middle Eastern countries, which are actively promoting new refinery projects, as a way to capture more pieces of the value chain beyond their traditional upstream businesses.

In this scenario, players are taking different positions to restructure their refining portfolios. The main actions taken by oil companies have been the following: a) Divest or reduce the refining business in some regions, mainly by companies with a presence in regions with declining demand. These companies are selectively divesting of the downstream business, reducing their participation in JV refineries, or selling their refineries, b) Relocate resources in more attractive geographies; mainly followed by international oil companies that are investing actively in new markets with high growth and good demand perspectives, c) Maintain or reinforce presence in its regional market; many oil companies, especially companies with a strong presence in their country of origin, are investing and reinforcing their portfolio. Some national oil companies in Europe and the US are focusing on their specific market.

Among the capital expenditures being planned by the oil companies that are diversifying their portfolio in new and promising markets, most of them major IOCs, the biggest investment is being located in the Middle East and Asia, with several refinery projects in the definition or construction phase. In many countries, participation in these projects usually requires being selected by the national oil company as a partner.

Independent, smaller refiners that are more attached to their regional markets, are also having limited investment activity in international projects, normally run joint ventures with other national players.

Moving towards integrating and globalizing carbon footprints

As was mentioned in other chapters, O&G companies will be strongly impacted by the enforcement of the terms of the Paris Climate Agreement, and in particular, by implementing the NDC offered by the countries/regions that have ratified it.

An analysis of the possible ways to implement NDCs shows that there are two possible procedures to arrive at compliance with the reduction targets embedded in them: 1) bottom-up, based on direct actions to achieve greenhouse gas (GHG) emission reductions, taken by O&G companies through voluntary agreements with the administration, or fostered by political measures (incentives, subsidies, fiscal, etc.), promoting investments in renewables or in other reduction processes, like carbon capture and storage; and 2) top-down, by passing legislation that sets mandatory compliance with specific targets, driving at compliance with specific NDC. This is the way adopted by the EU, which can be summarized by the following pieces of legislation: 1) establishment of an Emissions Trading Scheme (ETS), with timely the decrease of the emission cap (this affects refining and energy generation for oil production): ETS directive; 2) mandate for a minimum contribution of biofuels and other renewable fuels in the overall energy consumed by the transportation sector: renewables directive; and 3) targets for reduction of GHG emission intensity of transportation fuels/energies in is life cycle: directive on quality in transportation fuels.

Regardless of which procedure is referred to, the introduction of a minimum target for renewable energies is required. However, ICE engines fuel specifications limit the content of conventional biofuels and other bioliquids, therefore, the way to reach the mandated target, needs to promote the use of renewable electricity. Therefore, oil companies need to expand business into the electricity value chain to protect their core business as fuel suppliers, by offering renewable electricity, in order to achieve a good average GHG emission intensity for all the energy they supply.

Thus, international oil companies (IOC) are moving towards a global energy companies, with new drivers for growth and profit, re-defining what it means to be a leader in the energy industry. This is much influenced by the new landscape and general challenges, as it has been examined in Chapter 1 and this chapter.

The following Figure 16 displays a non-exhaustive overview of examples of where companies are taking actions in order to establish new ventures. In particular, the green color code highlights where companies have made significant progress, and are often establishing themselves as global leaders within the segment.

FIGURE 16. O&G player moves towards integrating and globalizing their energy footprint

	Power (overall)	RES	DER	BIO / Synthetic fuels	CCS	Advanced mobility	EE & carbon sinks
	• Acquisition of First Utility for 200M$ • Trading power in US and UK	• Investor on wind and solar projects in USA and EU	• Acquisition of Demand Response company MP2 • 60M$ finance in Sonnen (home battery solutions)	• JV with Raizen, razilian sugar cane produced 2 bn liters ethanol in 2017	• Quest CCS in Alberta; Technology Center Mongstad	• Consortium with German Government to develop 400 hydrogen fuel stations • Investing in fast charging solutions	• Small VC investments through Shell Ventures
TOTAL	• Acquisiton of Direct Energy for $1.7 bn • Acquisition of two CCGT[1] plants from KKR-Energas	• Developer of more of 400 MW of solar PV in Asia	• Owner of SunPower and Saft (battery OEM)	• Le Mede refinery, conversion to biofuel from oils	• R&D	• JV with Clean Energy Fuel for developing of NG trucks • Acquisition of PitPoint provider of clean fuels in Europe	
equinor		• Leading offshore wind industry • Funding 10M$ on solar cell research	• Investment in Convergent energy storage developer		• World leader in CCS	• Investment in ChargePoint world's largest EV charging network	
bp		• 1.5 GW of wind in US • Owner of Lightsource, PV developer	• Research on fuel cells through its New Ventures division	• JV with Bonsucro Brazilian sugarcane prod. • JV with Dupont developing Butamax	• Owner of Solida, use of CO2 for processing concrete	• Acquisition of StoreDot (20 M$) OEM batteries for use in EVs	• Research on carbon Management through its New Ventures division
REPSOL	• Buyout of Viesgo (low-emissions assets and retail business), Spanish utility	• Owns a stake in Principle Power, offshore wind platforms EPC		• Owns several refineries for co-processing HVO[2]		• 50% IBIL, operating 700 Charging points	
Chevron		• Key global player in geothermal development		• Attempts have been non-commercial	• Gorgon and Quest CCS investment totaling $1.1 bn		
eni		• PV/Wind projects in Italy, Africa and Middle East		• Primary producer of green diesel in Europe			
Exxon				• Investing in second generation biofuels (Algea) 1B$	• Participated in 1/5 of the global CCS capacity		• Development of energy efficient tyres, lubricants and plastics

Note: Gas fired combined cycle power plants; Note 2: Hydrogenated Vegetable Oil.
Source: Companies websites, Clean Energy Pipeline; BCG analysis.

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LIST OF ACRONYMS

Acronym	Term
ADR	The European Agreement concerning the International Carriage of Dangerous Goods by Road
AI	Artificial Intelligence
ARB	Reducing Air Pollution Program
ASEAN	Association of Southeast Asian Nations
BAT	Best Available Techniques
BI	Blending Index
BoKW	Based on Know How
BoT	Based on Technology
BU	Business Units
C2ES	Center for Climate and Energy solutions
CAFE	Corporate Average Fuel Economy
CAGR	Compounded Annual Growth Rate
CAPEX	Capital Expenditure
CARB	California Air Resources Board
CCR	Conradson Carbon Residue
CFD	Computational Fluid Dynamics
CI	Compression Ignition
CIF	Cost Insurance and Freight
CIS	Commonwealth of Independent States
CK	Coking
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of Parties
CSS	Carbon Capture Storage
DAFI	Directive on Alternative Fuel Infrastructures
DME	Dubai Mercantile Exchange
ECAs	Emission Control Areas
EE	Energy Efficiency
EGR	Exhaust Gar Recycle

EISA	Energy Independence and Security Act
EOR	Enhanced Oil Recovery
EPA	(U.S.) Environmental Protection Agency
EPAct	Energy Policy Act
EPC	Engineering Procurement Construction
EST	ENI Slurry Technology
ETS	Emissions Trading Systems
EU	European Union
EV	Electric Vehicles
ExpEx	Exploration Expenditure
FC	Fuel Cells
FCC	Fluid Catalytic Cracking
FCEV	Fuel Cell Electric Vehicles
FCF	Free Cash Flows
FOB	Free on Board
F-T	Fischer-Tropsch
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GTL	Gas to Liquids
HCCI	Homogeneous Charge Compression Ignition
HCK	Hydrocracking
HDS	Hydrodesulfurization
HSFO	High Sulfur Fuel Oil
HUD	Heads-up display
ICAP	International Carbon Action Partnership
ICE	Internal Combustion Engine
ICT	Information and Communication Technologies
IEA	International Energy Agency
IETA	International Emissions Trading Association
IMO	International Maritime Organization
INDC	Intended Nationally Determined Contributions
INOCS	National Oil Companies with International Operations
IOCs	International Oil Companies
IoT	Internet of Things

IVTM	Mechanical Traction Vehicles Tax
JV	Joint Venture
KM	Kilometer
KPI	Key Performance Indicator
LCFS	Low Carbon Fuel Standard
LDV	Light Duty Vehicles
LNG	Liquefied Natural Gas
LP	Linear Programming
LPG	Liquefied Petroleum Gases
LSFO	Low Sulfur Fuel Oil
LSR	Light Straight Run
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MGO	Marine Gasoil
MON	Motor Octane Number
N2O	Nitrous Oxide
NDC	National Determined Contributions
NEDC	New European Driving Cycle
NGO	Non-governmental organization
NHTSA	National Highway Traffic Safety Administration
NOC	National Oil Company
NOx	Nitrogen Oxide
NYMEX	New York Mercantile Exchange
OFSE	Oilfield Services
OPEC	Organization of the Petroleum Exporting Countries
OPEX	Operating Expenditure
OTC	Over-The-Counter
O&G	Oil and Gas
PFCs	Perfluorocarbons
PM	Particulate Matter
PNA	Polynuclear Aromatics
PSA	Production Sharing Agreement
RD&D	Research, Development and Demonstration

RED I / RED II	Renewable Energy Directive 2009/28/EC
RFS	Renewable Fuel Standard
RIN	Renewable Identification Number
ROA-ROCE	Return on Assets – Return on Capital Employed
RON	Research Octane Number
RVO	Renewable Volume Obligation
RVP	Reid Vapor Pressure
SACROC	Scurry Area Canyon Reef Operators Committee
SECA	Sulfur Emission Control Area
SGX	Singapore Exchanges
SI	Spark Ignition
SPR	Strategic Petroleum Reserve
SOX	Sulfur Oxide
STEO	International Energy Agency Short Term Energy Outlook
TANAP	Trans Anatolian Pipeline Project
TSR	Total Shareholder Return
UCO	Unconverted Oil
UIC	Underground Injection Control
UDW	Ultra-deepwater
ULSD	Ultra-low Sulfur Diesel
UNFCCC	The United Nations Framework Convention on Climate Change
VB	Visbreaking
VCR	Variable Compression Rates
VGO	Vaccum Gasoil
VR	Virtual Reality
WACC	Weighted Average Cost of Capital
ZEV	Zero Emissions Vehicle
%wt.	Percentage Weight

LIST OF UNITS

API	American Petroleum Institute crude grade	API gravity = (141.5 / Specific gravity) – 131.5
bbl	Barrel (of oil)	1 bbl = 42 US Gallons 1 bbl = 159 liters 1 bbl of oil equivalent= to 6003 scf (NG)= 170 scm (NG)
bpd	Barrels per day	1 bpd= 50 tonnes per year
Btu	British thermal unit	1 Btu = 0.293 Wh = 1,055 kJ
c/bbl	US cents per barrel	
kbpd	Thousand barrels per day	
Mbpd	Million barrels per day	
Mscf (Natural Gas)	Million standard cubic feet	1 Mscf = 23.8 toe = 167 barrels of oil equivalent
Mt	Million metric tons	
PSI	Pounds per square inch	1 PSI = 6.9 kPa = 0.068 atm
scf (Natural Gas)	Standard cubic feet (of gas) defined by energy, not a normalized volume	1 scf = 1000 BTU = 252 kcal = 293 Wh = 1,055 MJ = 0.028 scm
Scm (Natural Gas)	Standard cubic meter (of gas, also Ncm)	1 scm = 39 MJ = 10.8 kWh 1 scm = 35.315 scf 1 scm = 1.122 kg
toe	Tonnes of oil equivalent	1 toe = 1000 koe 1 toe = 1 Tonne oil equivalent (US) 1 toe = 6.85 boe 1 toe = 41.87 GJ = 11.6 MWh 1 toe = 39.68 MBtu 1 toe = 1.51 ton of coal 1 toe = 0.855 tonnes of LNG 1 toe = 1,163 Scm of NG = 41,071 Scf of NG
kWh	Kilowatt hour = 1000	1 kWh = 3.6 MJ = 860 kcal = 3,413 Btu

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