WORLD ENERGY COUNCIL
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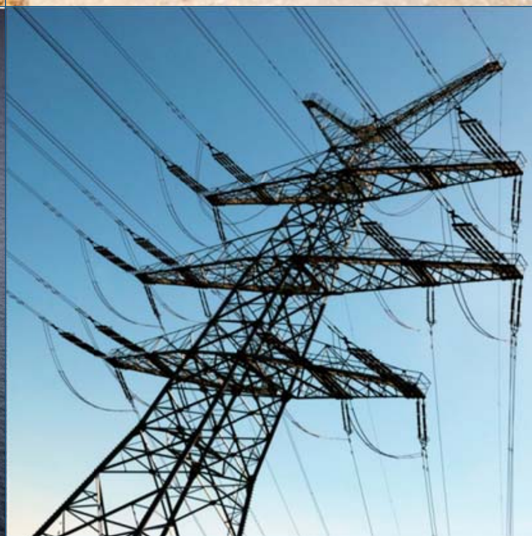
For sustainable energy.

Logistics Bottlenecks

World Energy Council



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Officers of the World Energy Council

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Executive Summary

Many of the vulnerabilities to Energy Access, Energy Security, and Environmental Sustainability result from impediments to reaching a global demand–supply balance, as well as local balances, for various energy sources and carriers. Vulnerabilities result from multiple reasons: regional imbalances of energy production and consumption, the bulky character of the majority of energy fuels, the virtual necessity of electricity consumption following its production, among others.

To detect and prioritize respective “bottlenecks” across energy carriers, they have to be measured. In this report, production, consumption, exports, and imports were measured across all major energy carriers for seven key regions of the world for three time frames—2008, 2020, and 2050. Imbalances between production and consumption form bottlenecks in each region.

From the logistics point of view, the most important types of fuel are those biggest volumes that must be transported over large distances. If fuels are ranked on that criterion, the winners are coal, oil, and gas. Although people are slowly turning to alternative energy sources—such as biofuels and nuclear energy—even in 2050, those three fuels in terms of total volume will dominate without question.

Another challenge is electricity transportation. Electricity must be consumed at its source or sent along a transmission-and-distribution network right after its production, as storage is inefficient. To make things more complicated, transmission itself is inefficient over long distances, necessitating production facilities close to end-users.

To better identify and assess possible logistics bottlenecks, a Logistics Bottlenecks Matrix was constructed, showing major bottlenecks across the energy value chain on one axis (from the manufacturing of equipment through mining and extraction to transportation and consumption) and types of fuels/electricity on the other axis.

Having prioritized energy sources and their imbalances, as well as having outlined major sources of possible imbalances, three crucial bottlenecks were identified—oil movement, natural gas and liquefied natural gas (LNG) movement, and electricity movement. Should they not be managed in 2020 and 2050 (i.e., if required energy sources and carriers are not delivered from producers to consumers), enormous damage will be done to the global economy, the full extent of which is currently immeasurable.

To manage expected key bottlenecks, significant infrastructure investments need to be made. To develop the required oil pipeline and tanker networks, gas pipelines and LNG carriers systems, as well as smart grids boosting the efficiency of electricity distribution, a total amount of about USD 900 billion will have to be spent in the 2008–2050 time frame, signifying average annual outlays of USD 21.4 billion.

Moreover, required policies and concrete actions for world leaders are described. These actions will allow for timely investments in the respective infrastructures and build bridges between the private and public sectors in various regions, so that the money which needs to be spent is spent effectively, generating desired results for companies, governments, and society.

Introduction

The Deciding the Future: Energy Policy Scenarios to 2050 study (EPS), published by the World Energy Council in 2007, indicated a number of impediments and threats to achieving access, security, and environmental sustainability of energy around the globe. Many of those threats, or vulnerabilities, which need to be overcome by the joint efforts of policymakers, companies, and societies, involve the movement of energy.

Logistics vulnerabilities are inherent to the world of energy and result for multiple reasons:

- Regional imbalances of energy production and consumption (e.g., Europe consumes much more oil than it produces);
- Low-energy density of the majority of fuels (GJ per kilogram), stressing modes of transportation (pipelines, mega-tankers, LNG carriers, etc.);
- The virtual necessity of immediate electricity consumption due to inefficient and costly technologies for storing electricity;
- Electricity transmission is inefficient over long distances.

Worth examining are the numerous points of contact between logistics bottlenecks and manufacturing bottlenecks. In fact, the energy supply chain along starts with the manufacturing of energy equipment and energy-related facilities, such as power plants

1. Energy capabilities and requirements in the mid- and long-term

A model was created to allow the measurement of expected energy capabilities and requirements of major energy carriers (oil, natural gas, LNG, uranium, biomass, biogas, and biofuels) and the movement of electricity across and through several regions (Figure 1) at relevant points in time (2020 and 2050, with 2008 as reference).

A mix of data sources [model used in EPS 2050 using data for the Lion (high cooperation and integration, high government involvement) Scenario, BP Statistical Review of World Energy, relevant reports of the International Energy Agency (IEA), among others] was used to determine current and future production, consumption and trade flows of relevant energy carriers, and electricity among the regions.

Figure 1
Division of the world into regions for the purposes of this study.

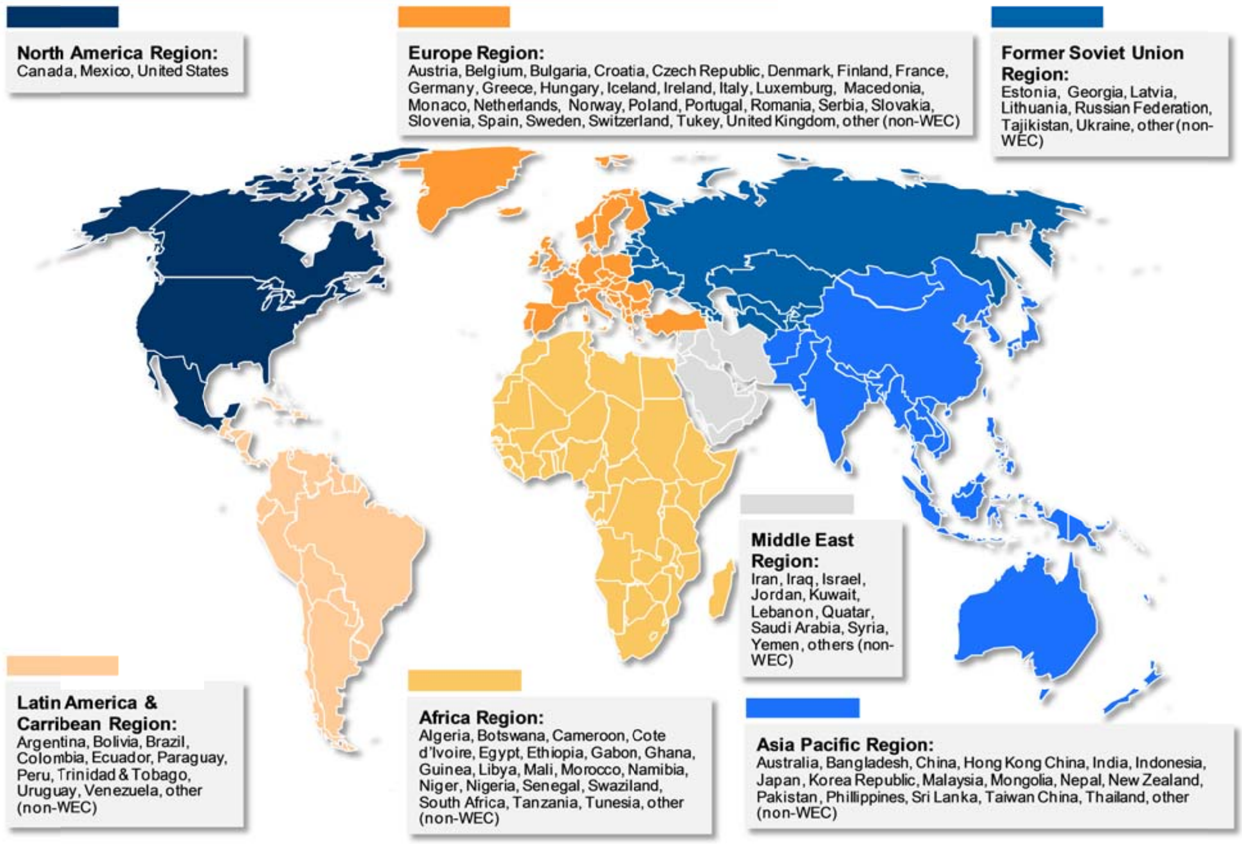
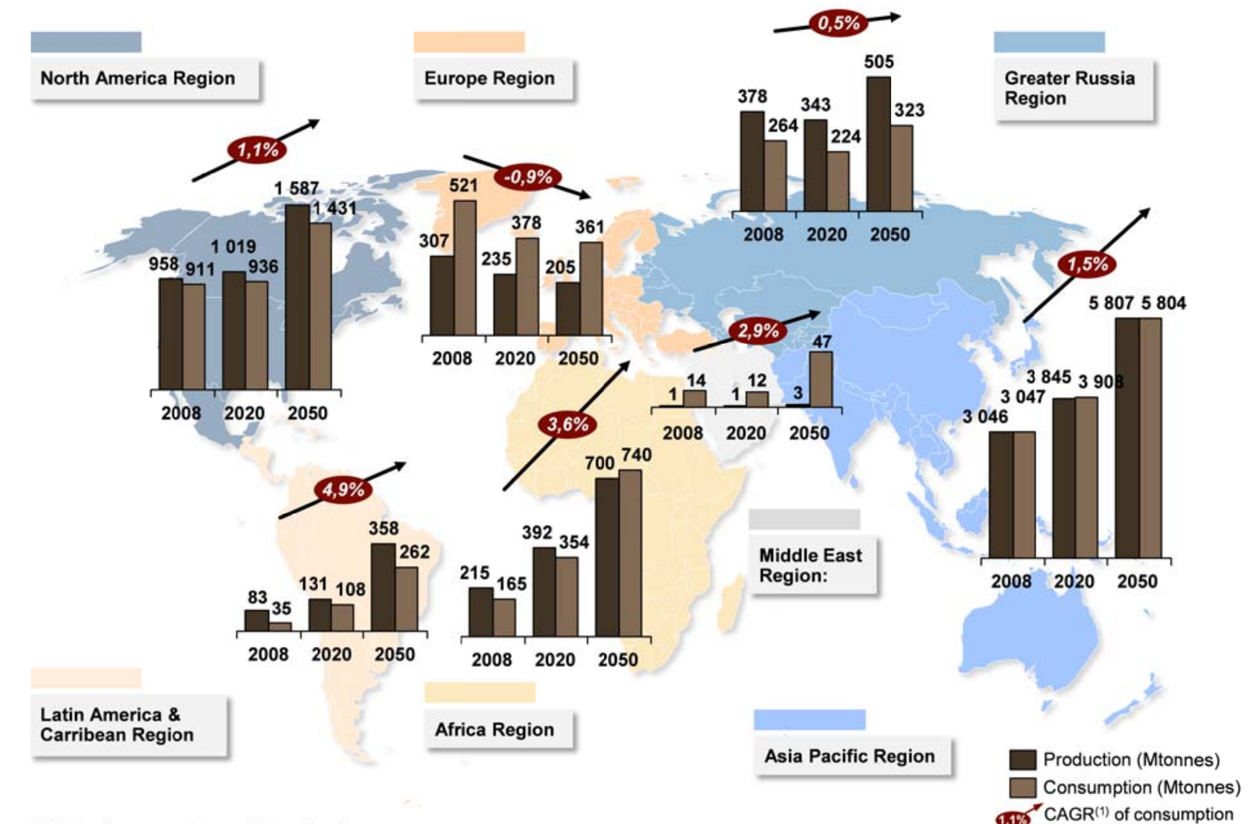


Figure 2

Growth rate in the production and consumption of coal in 2008 according to region, with projections for 2020 and 2050.

Source: EPS2050, 2009 BP Statistical Review of World Energy 2009, IEA



(1) CAGR – Compound Annual Growth rate

1.1 Coal

In 2008, the Asia Pacific region was the biggest global coal producer and consumer, both values over 3 billion tonnes—61% of the global demand-and-supply (the conversion rate for coal used throughout the study: 1 million tonnes of coal equals 27 800 TJ). Appendix 1 has the conversion factors used in this report. Other regions of the world have much lower appetites for coal, although for the past several years, coal has been the fastest growing energy carrier from a global consumption point of view (Figure 2).

Despite the high burden on the environment from burning coal and low-energy density with respect to oil or natural gas, coal is expected to keep its major role in ensuring the energy balance around the world due to its abundance and fairly even geographical spread. Global coal production is estimated to increase by 20% in 2020, with respect to 2008, and by a further 54% by 2050. The major consumer will be Asia Pacific, and only Europe and Russia are expected to decrease their coal consumption by 2020 and 2050.

1.2 Oil

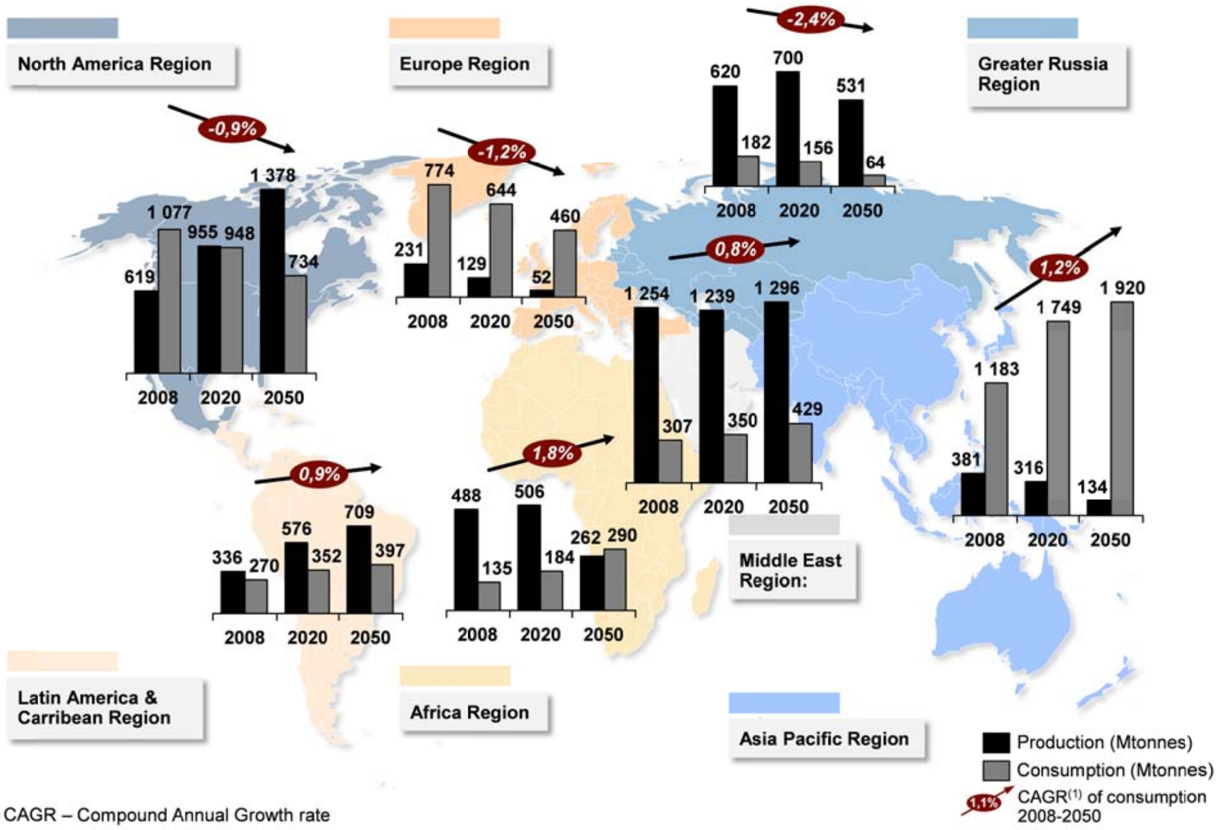
The situation in the oil market is much more complex than the coal market. Oil consumer markets are often far from producer markets and most of its reserves are limited to a few areas (Figure 3). Two-thirds of reserves are in the Middle East. There are great oil importers, such as Europe (70% of annual consumption imported) or Asia Pacific (68%), which could not function without pipelines and tankers bringing in crude and oil products from exporting countries.

By 2020, global consumption of oil will reach 4.4 billion tonnes, meaning a 12% increase from 2008 (1 million tonnes of oil equals ~ 42,000 TJ).

Figure 3

Growth rate in the production and consumption of oil in 2008 according to region, with projections for 2020 and 2050.

Source: EPS2050, 2009 BP Statistical Review of World Energy 2009, IEA



(1) CAGR – Compound Annual Growth rate

Although some regions will decrease their dependence on oil imports, that will be due primarily to expanding production rather than controlling consumption. North America, as an example, will switch from importing 43% of oil consumed in 2008 to a break-even in 2020, but mainly thanks to expanding production by 54% rather than cutting consumption by 12% (according to the EPS 2050 model).

1.3 Natural gas and liquefied natural gas (LNG)

Natural gas is much less convenient to transport than oil. Expensive pipelines are needed or liquefaction/re-gasification terminals must be constructed next to harbours. Hence, only 12% of gas produced in 2008 was exported to other regions, while the same indicator for oil was 48% [1 billion cubic meters (bcm) of gas equals 36,000 TJ; see Appendix 1 for the conversion table].

Discovered reserves of natural gas are much more abundant than oil, and already a shift toward gas is observed on the global markets. By 2020, global production is expected to increase by 39%, and from 2020 to 2050, another 41%, according to the EPS 2050 model.

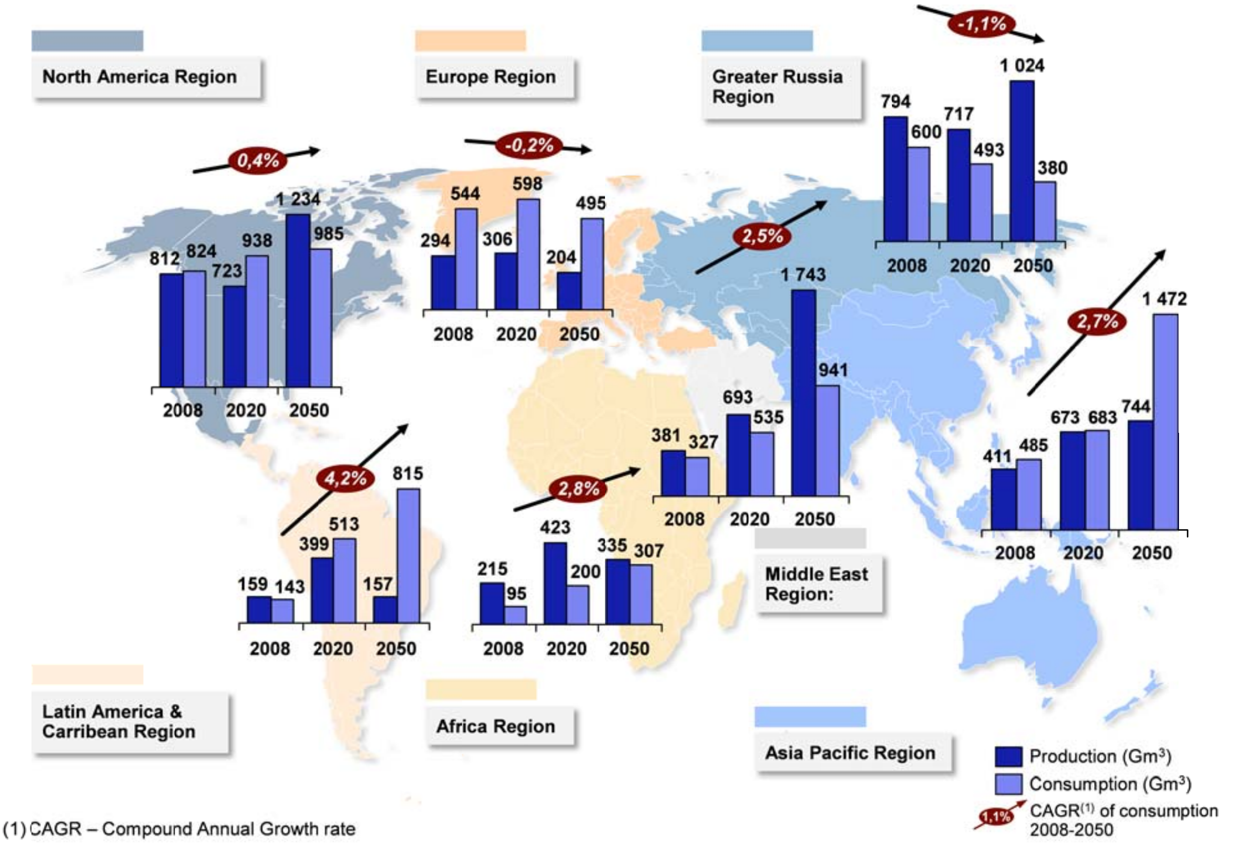
1.4 Uranium

Uranium ore reserves, an energy source for nuclear power plants, are concentrated in just a few regions—six countries (Canada, Kazakhstan, Australia, Namibia, Russia, and Niger). Together, they are responsible for over 80% of global production. Although most uranium used in nuclear power plants has to be imported, it is the most energy dense and therefore efficient fuel in the world (around 2,250 TJ from one tonne of uranium).The total volume of uranium that has to be transported is insignificant when compared with oil and coal (1 tonne of uranium equals 546 TJ; see Appendix 1 for the conversion table). Therefore,

Figure 4

Growth rate in the production and consumption of natural gas in 2008 according to region, with projections for 2020 and 2050.

Source: EPS 2050, 2009 BP Statistical Review of World Energy 2009, IEA



uranium will be not included in further parts of the study.

1.5 Biomass and biogas

To lower the global carbon footprint and save diminishing energy resources, biomass, biogas, biofuels, and other renewable energy fuels are being looked at by more and more governments. Entrepreneurs are being given green certificates, tax incentives, and other regulatory support.

From the logistics point of view, both biogas and biomass are still insignificant. As for biogas, its global production in 2008 equalled 33.1 million cubic meters (same conversion rate to TJ as natural gas). That was just 1.1% of natural gas production. Biomass is a local energy source—less than 1% of global production is expected to be either exported or imported. For these reasons, neither biomass nor biogas will be treated preferentially in further parts of the study.

1.6 Electricity

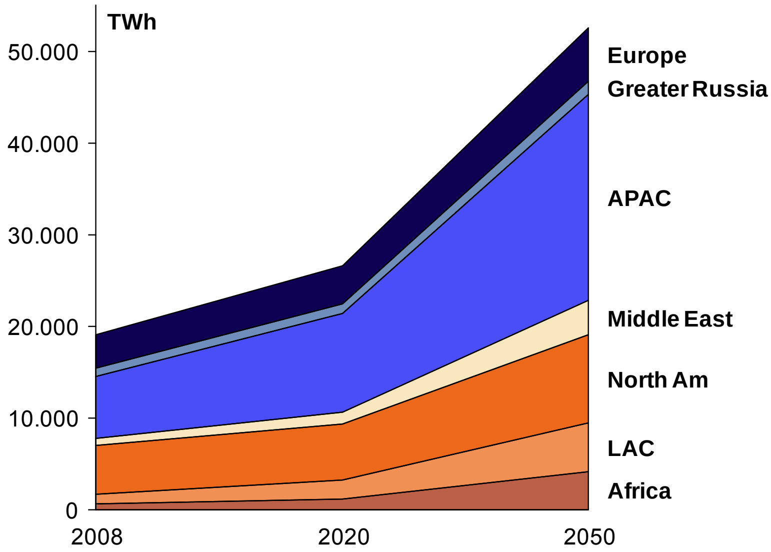
After having mined, processed, and transported energy products, different types of energy are received per se—be it fuel for cars and other vehicles, heat for our houses and workplaces, or electricity for our tools, appliances, and other necessities of living. Regardless of the form of energy, there is no doubt electricity is fundamental to everyday activities and lies at the heart of technological progress for countries and whole regions. There is a high correlation between GDP per capita and electricity consumption per capita throughout the world.

Electricity, after being produced in power plants and sent along transmission lines to a distribution grid, has to be consumed on the spot—otherwise it is wasted, putting a premium on "just in time" production. Storing electricity is both expensive and inefficient, as is its very long-distance transportation. At the end of 2007, transmission and distribution losses in U.S., for example, were

Figure 5

Projected electricity consumption across regions in 2008, 2020, and 2050.

Source: EPS 2050 model



estimated at 6.5% (U.S. Energy Information Administration). Hence, electricity usage has many restrictions and imbalances around the globe.

Currently, electricity production and consumption are concentrated in the most developed regions of the world. Europe, with just over 9% of the global population, consumes 24% of the world's electricity. North America, with 5%, consumes 28%. On the other extreme, Africa's 14% of the world's inhabitants must do with just 3% of the electricity (1 TWh of electricity equals 3,600 TJ; see Appendix 1 for the conversion table).

Not surprisingly, the demand for electricity will increase for all regions in both the 2008–2020 and 2020–2050 time frames (Figure 5). Growth will be driven especially by emerging markets. The Asia Pacific region is projected to increase electricity consumption between 2008 and 2020 by 60%, Africa by 86%, and Latin America by 87% (EPS 2050 model).

2. Energy trade: closing the gaps between requirements and capabilities

The fragile supply–demand balance across energy carriers can only be achieved today thanks to the transportation of respective energy carriers from net-exporting countries (where production exceeds consumption, assuming no significant stock level changes) to net-importing countries. Major trade flows are presented per fuel type with a forward look to 2020 and 2050.

2.1 Coal

In 2008, the global production of coal reached almost 5 billion of tonnes, 14% of which was exported to other regions (Figures 6 and 7). Coal reserves are spread fairly evenly around the globe. As a result, most coal-consuming countries do without long-distance coal transportation, with Europe as the biggest exception (imports 73% of the region's consumption).

Figure 6

Exports and imports of coal in 2008 according to region, with projections for 2020 and 2050.

Source: EPS 2050, 2009 BP Statistical Review of World Energy 2009, IEA

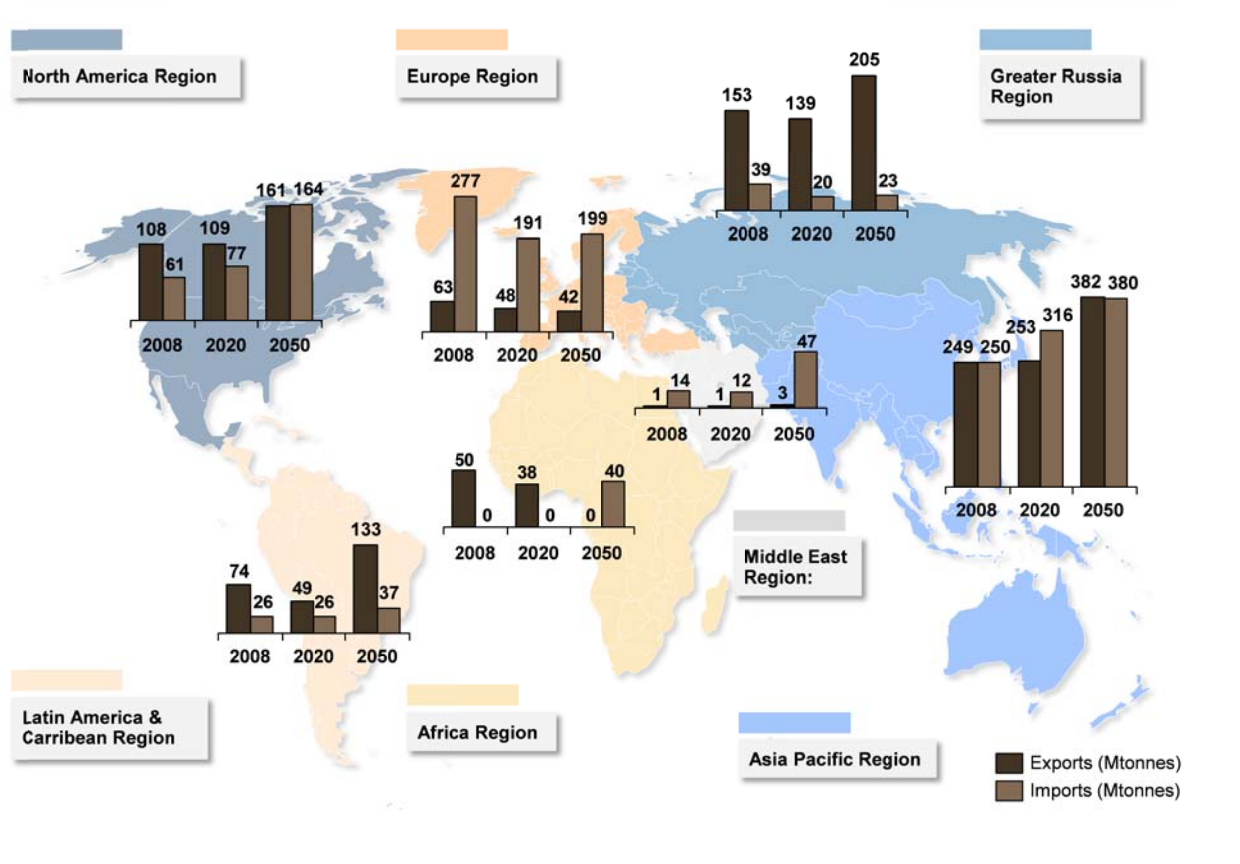
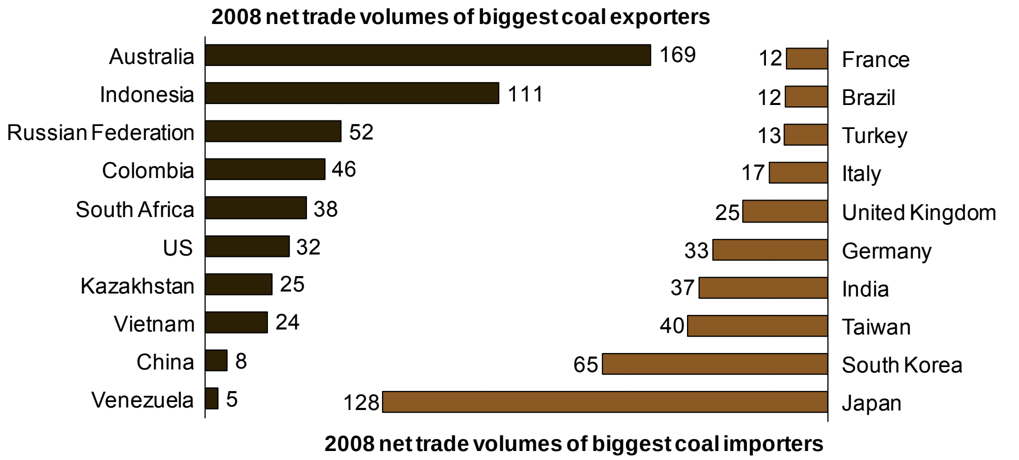


Figure 7

The world's largest net-exporters and importers of coal in 2008 and their net trade volumes in million tonnes.

Source: EPS 2050, 2009 BP Statistical Review of World Energy 2009, IEA



Over the next decade, the biggest coal-consuming regions will exploit their own coal reserves rather than pursue long-distance imports. By 2020, although global coal consumption will grow by 19% with respect to 2008, coal exports are projected to decline by 9%, to 637 million tonnes.

The 2050 time frame will change this picture. Coal exports will start growing (by 39% to 926 million tonnes with respect to 2008), with all regions increasing nominal imports and some even turning from net-exporters to importers (Africa). Asia Pacific will remain the biggest coal exporter and

Figure 8

Exports and imports of oil in 2008, according to region, with projections for 2020 and 2050.

Source: EPS 2050, 2009 BP Statistical Review of World Energy 2009, IEA

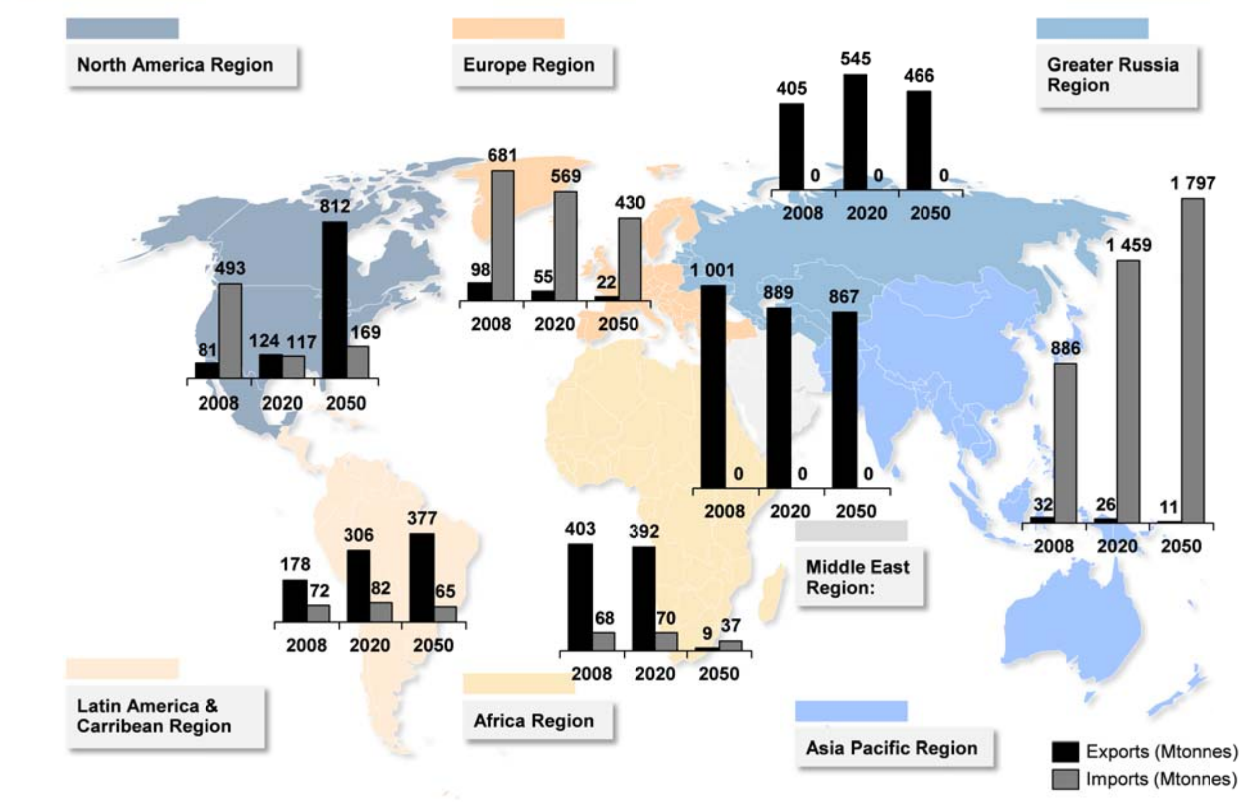
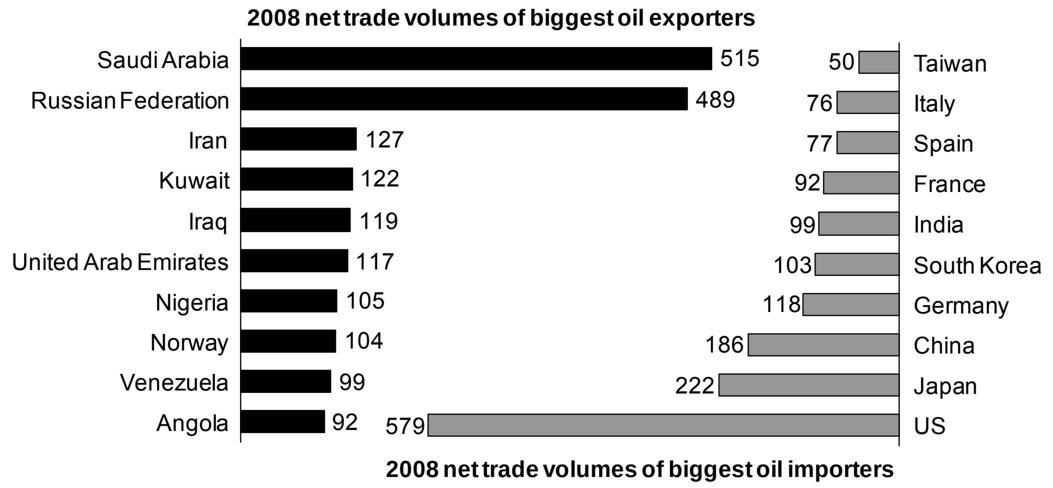


Figure 9

The world's largest oil net-exporters and importers in 2008 and their net-trade volumes in million tonnes.

Source: EPS 2050, 2009 BP Statistical Review of World Energy 2009, IEA



importer with global shares of 41% and 43%, respectively (according to the EPS 2050 WEC model).

2.2 Oil

For many years, global supply–demand in the oil market has been anything but balanced. Few countries hold the majority of reserves, while most of oil "heavy users" are vulnerable and dependent on supplier countries, often from other regions. In 2008, out of around 3.9 billion tonnes of oil produced, as much as 2.2 billion were exported to other regions, accounting for 56% of total production (Figures 8 and 9).

Toward 2020, most of the heavy oil importers will struggle to curb their dependence, or at least replace long-distance suppliers with closer ones to some extent. One reason is that large reserves of oil are located in geopolitically turbulent areas, which places higher risks on them as import sources. Another reason, thanks to successful research and development, is that previously unavailable oil fields in net-importing countries are now feasible alternatives to imports (heavy oil in Venezuela and oil sands in Canada).

In the 2020–2050 time frame, global demand for oil will remain difficult to curb—and so will be its transportation needs. It is projected that 58.8% of oil refined in 2050 will be exported to other regions of the world—a higher share than either in 2008 or 2020.

2.3 Natural gas and liquefied natural gas (LNG)

The transportation of natural gas, vital for today's economy, is a challenge much more difficult to overcome than arguably any other fuel. It needs to be compressed and pumped in large quantities to create sufficient pressure in gas pipelines. If transported by sea, it must be liquefied and then re-gasified at the destination.

As a result, only 11.5% of natural gas extracted in 2008 was exported to other regions of the globe (Figure 10). Most of those relatively scarce trade flows occurred via gas pipelines linking gas fields in former Soviet countries and Europe (44% of global exports). Other significant flow was directed from North Africa to southern Europe—86 bcm represented around one-fourth of global exports (Figure 11).

By 2020, the world will be demanding much higher accessibility and portability of natural gas. Not only will gas exports grow by 86%, according to our projections, but also their share in global

Figure 10

Exports and imports of natural gas in 2008 according to region, with projections for 2020 and 2050.

Source: EPS 2050, 2009 BP Statistical Review of World Energy 2009, IEA

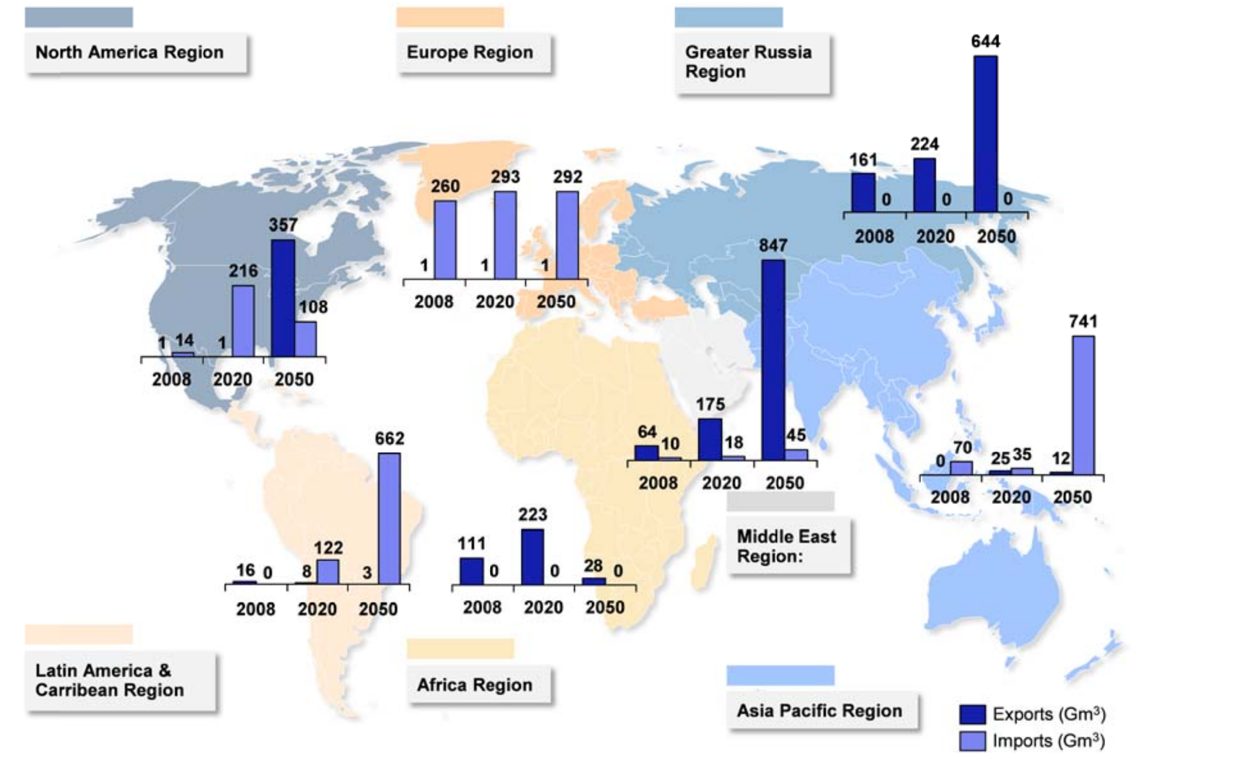
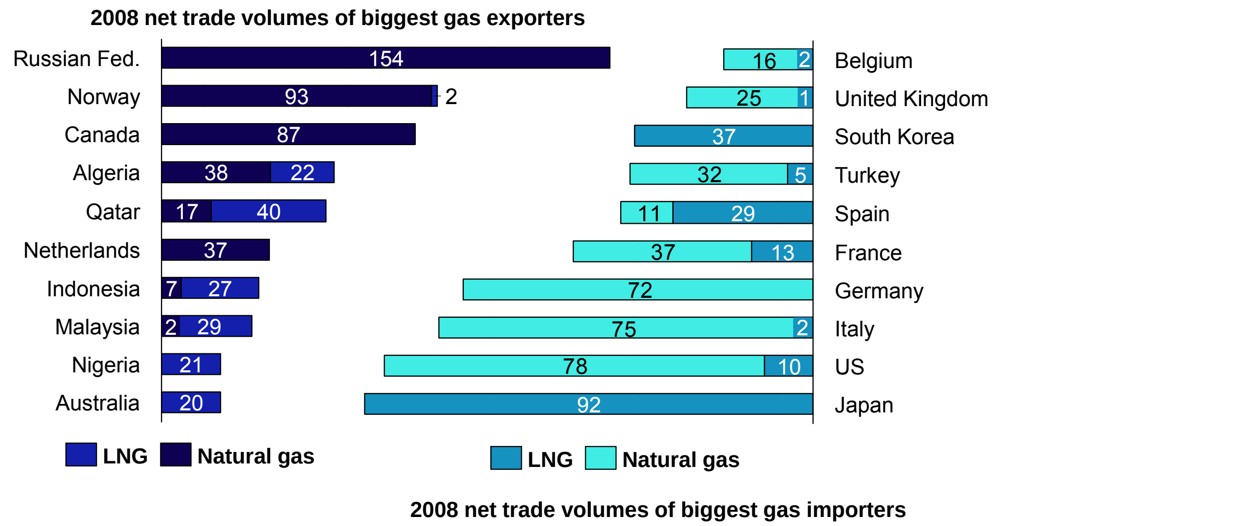


Figure 11

The world's largest natural gas and LNG net-exporters and importers in 2008 and their net-trade volumes in billion cubic meters.

Source: EPS 2050, 2009 BP Statistical Review of World Energy 2009, IEA



production is bound to increase by 45%, signifying the highest raise across all energy carriers. Between 2008 and 2020, former Soviet countries will grow their exports by 39%, Africa by 102%, and the Middle East by as much as 225%.

By 2050, global natural gas exports are expected to almost triple with respect to 2020, and share of exports in the world's production—more than double—will reach 34.8%. The quantity of gas moved will not be as large as oil (58.2% of output is now exported to other regions), but nonetheless will increase enormously compared to the present.

3. Largest logistics bottlenecks across the energy supply chain and energy carriers

Assessing major expected trade flows across regions and energy carriers is vital to show which carriers will really “matter” when it comes to transportation over the long distances to meet energy demand in the future. Equally important is mapping and evaluating potential bottlenecks in a sustainable energy supply. A structure based primarily on an energy supply chain is used here, from extraction of the respective fuel types through their transportation and storage to consumption (Figure 12). These steps need to be adjusted for electricity bottlenecks. Transmission grids (high-voltage) and distribution grids (mid- and low-voltage) as well as storage are most important.

Bottlenecks can be assigned to respective energy sources or to the carriers themselves, as described previously. For segmentation purposes, energy sources can be divided into three basic types—solid (coal, uranium, and solid biomass), liquid (oil and biofuels), and gas (natural gas and biogas).

Placing successive steps of a logistics supply chain on one axis and energy sources and carriers on the other one leads to a matrix of logistics bottlenecks. This matrix, in turn, can be populated with respective logistics risks that may disturb the energy supply–demand balance.

A detailed discussion of all identified logistics bottlenecks would take extensive space; besides, it is difficult to prioritize them to show major challenges to the demand–supply equilibrium over the long term. Therefore, Appendix 2 shows details according to the segmentation described above and is only summarized below, followed with an overview of critical gaps where the biggest bottlenecks appear.

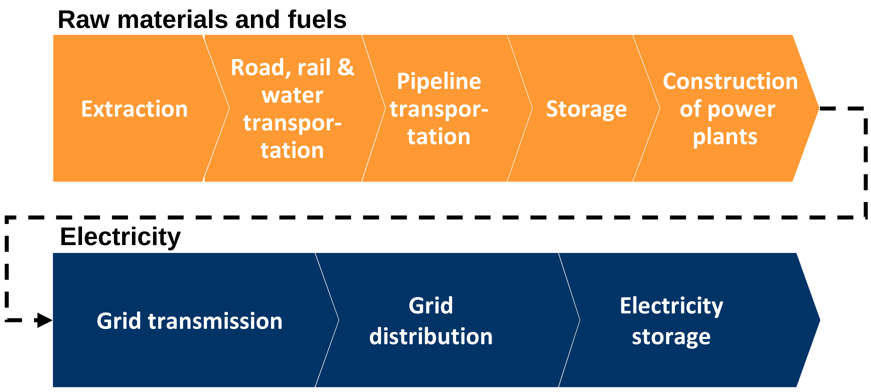
3.1 Bottlenecks across the supply chain steps related to energy sources

A variety of logistics bottlenecks is related to energy sources. Some are universal for all their types (e.g., capacity shortage for manufacturing of energy-related equipment), but more are source-specific. For some solid fuels, for example biomass, compromising agricultural areas is an issue, as growing populations require increasingly higher food production

Liquid fuels, i.e., oil and biofuels, have their problems. In the case of biofuels, many challenges result from a rather complex supply chain—both biodiesel (from oil crops) and bioethanol (from sugar and starch crops) require growing crops first, then processing them to obtain the final product, which in case of bioethanol, has to be additionally blended in refineries or depots with gasoline. Moreover, due to pressure on agricultural areas, EU countries are already debating decreasing minimum obligatory shares of bioethanol in car fuel. Oil logistics bottlenecks will be discussed in detail in the study.

Most of transportation bottlenecks related to gas energy carriers are related to their inherent characteristics—volatility and flammability. Vulnerabilities related to natural gas and LNG will be discussed in the study. As for biogas, an important logistics issue that can restrict its growth is low average production capacity of biogas facilities. Fuelled with organic waste, rarely do biogas-fired power plants (or combined heat and

Figure 12
Potential bottlenecks across the steps of an energy supply chain with conversion to electricity.



power plants) have access to high amounts of fuel. Therefore, their potential output will be limited due to lack of economies of scale.

3.2 Bottlenecks across the supply chain steps related to energy carriers

When discussing energy accessibility, people relate primarily to electricity, which arguably has biggest impact on their lives. After being produced in power plants, electricity is transported via high-, mid-, and low-voltage grids to end consumers—households, industry, institutions, and so forth. It may also be stored for later use. Transportation bottlenecks are detailed in later chapters of the study. Critical gaps are identified where the biggest vulnerabilities appear (based on the Vulnerabilities Matrix).

Although all logistics bottlenecks deserve attention and concrete actions from investors and policymakers to ensure a stable supply of respective energy carriers and electricity, they still can be prioritised to show critical gaps, which the world must manage; otherwise, exporting countries will not realize potential sales and the economic growth of importers will be hampered without energy to fuel it.

Three bottlenecks —oil transportation, gas transportation, and efficient-electricity systems—require the most effort to ensure a supply–demand balance in the 2050 time frame. They will be detailed and measured, and a management plan will be proposed.

3.3 Crude oil transportation

Since its first commercial use in the 1850s, the variety of applications for crude oil has steadily expanded. Crude oil is reasonably portable and its reserves around the globe are uneven. The Middle East countries and Russia hold between them a little less than two-thirds of global reserves as of 2008. Both mid- and long-distance transportation are required to satisfy the growing hunger for oil. In 2008, 56% of extracted oil was already being transported to other regions. Such an amount has and will result in an array of logistics challenges to handle.

3.3.1 Major bottlenecks

Between 2008 and 2050, global oil exports are projected to increase by 17%. This growth may not seem extraordinarily high, but nonetheless investors and politicians will struggle to ensure a sustainable supply. That will happen due to three reasons:

Table 1
The world's major oil pipelines and their 2008 through-put.

Direction	Pipeline(s)	Capacity (1,000 bbl/day)	Through-put (million tonnes)*
CIS→Europe	Friendship (Russia–CEE and Western Europe)	1,300	58.5
CIS→APAC	Kazakhstan–China	120	5.4
Middle East→APAC	Kirkuk–Ceyhan (Iraq–Turkey)	1,500	67.5

*Assumed 20,000 bbl in 1 million tonnes crude and 90% average utilization of pipelines.

1. Oil exports higher by 17% from 2008 to 2050 is still a large growth, equalling 368 million tonnes—close to the oil consumption of France, Germany, Italy, and Spain together in 2008.

2. Along with shifting demand–supply patterns, oil trade routes will change. For example, European crude imports are projected to shrink from 681 million tonnes in 2008 to a mere 430 million tonnes in 2050, signifying that some exporters (like Russia and surrounding countries) will have to find new markets for their products. This means higher investment needs than those resulting from a volume increase of pure exports.

3. Apart from the economic issues likely to happen, social, political, and environmental tensions that may create more logistics bottlenecks for oil are also very important.

Having those three sources of potential supply bottlenecks in mind, a list of them may be put forward:

- Postponing investment decisions (for example new rigs) due to price volatility of crude.
- An insufficient number of ships.
- Terrorist attacks on ships.
- Hijacking ships (e.g., pirates near Somalia).
- Terrorist attacks on pipelines.
- Pipelines used as a tool in political blackmail.
- Congestion management (especially in agglomerations).
- Sinking oil platforms (often cheaper than towing it and disposing of it on land).

3.3.2. Necessary capacities

Equally important to identifying oil transportation bottlenecks is actually sizing them, i.e., defining the investment gap that will cover necessary amounts of crude to regions which will need them in the 2020 and 2050 time frames.

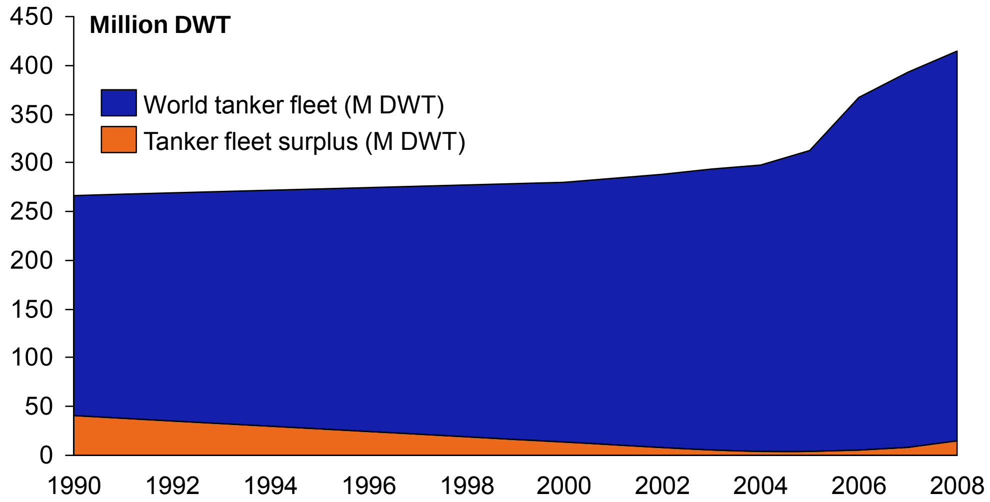
Logistics infrastructure in 2008

In 2008, global extra-regional exports of crude amounted to 2,197 million tonnes, the vast majority of which was transported via oil pipelines and oil tankers. Table 1 lists crucial cross-regional pipeline logistics routes along with their capacities and 2008 transportation volumes.

As for land transportation, there are additionally significant extra-regional volumes of crude transported via rail from CIS to APAC (specifically, from Russia to China)—amounting to around 9 million tonnes annually (179 tsd barrels per day). All in all, oil pipelines used for transportation between regions accounted for a mere 6.4% of global exports (140 million tonnes) in 2008. The rest was transported via tankers, although it must be noted that loading in most ports would be impossible without pipelines connected to oil fields.

Oil tankers transported the remainder of cross-regional crude flows, 2,061 million tonnes. Crude oil together with petroleum products are major

Figure 13
Capacity development of the global tanker fleet and capacity surplus in the 1990–2008 period.
Source: Review of the maritime transport 2009, United Nations Conference on trade and development, Geneva



maritime transport commodities, accounting for 34% of total transports via the sea in 2008. At the end of the year, the tonnage of tanker fleet reached 414 million dead-weight tonnes.[1] Utilization of global tankers reached 96.5% and has been rising over last 20 years, with exception of last financial crisis temporarily curbing oil demand across all regions (Figure 13).

Apart from investments in enhancing the total capacity of oil tankers, maintaining such a large fleet in operational condition required scraping some ships and replacing them with new ones. In 2008, 202 vessels were demolished, totalling 5.5 million DWT (1.3% of total capacity).

Capacity requirements between 2008–2050

Between 2008 and 2050, significant investments in oil movement infrastructure will be required to maintain the supply–demand balance. They will result from increasing demand in most regions and from changing demand–supply patterns around the globe (e.g., regions shifting from net-exporters to net-importers).

Existing oil pipelines will continue to operate in the foreseeable future—first, because there will be demand from Europe for Russian crude (Friendship pipeline) and from APAC for Middle East oil (Dorytol pipeline). However, increasing demand, especially from emerging Asian economies, such as China and India, will urge neighbouring net-exporters to lay additional pipelines, which are at the moment the cheapest means of crude transportation. Table 2 lists planned pipelines investments for the 2008–2020 time frame.

Between 2008 and 2020, all major currently planned investments in increasing crude pipeline capacity will be realized among the CIS, Europe, APAC, and the Middle East. It comes as no surprise—they are relatively close and urgently require new transport routes to reach clients for their crude (CIS and Middle East) or to ensure supply for domestic markets (Europe and APAC).

Altogether, four significant projects are planned, with a combined length of around 9,000 kilometres and an annual through-put of 175 million tonnes of crude. From this amount, 50 million tonnes from the Neka–Jask pipeline should be subtracted; it will

[1] Dead-weight tonnage (DWT) determines how much weight a particular ship can safely carry. DWT contains weights of cargo, fuel, ballast water, fresh water, provisions, crew, and passengers; 1 DWT equals 1 tonne of payload.

Table 2

Major planned oil pipelines 2008–2020.

Direction	Pipeline(s)	Length (km)	Capacity (1,000 bbl/day)	Target annual through-put (million tonnes)
CIS→Europe/APAC	Trans-Caspian Oil transportation system (Kazakhstan–Turkey/Mediterranean	700+ shuttle tankers	1,200	60
CIS→APAC	Kazakhstan–China extension	960	n/a	15*
	East Siberia–Pacific (Russia–China)	5,857	1,000	50
CIS→Middle East	Neka–Jask pipeline (Kazakhstan–Iran)	1,550	1,000	50

*Only surplus through-put.

be more of a transit route from the Caspian Sea to the Persian Gulf. Summing up the remaining 125 million tonnes of annual capacity with 131 million tonnes from existing pipelines (assuming Russia will give up current rail transportation once the East Siberia–Pacific pipeline is ready), that leaves 256 million tonnes of crude, which may be transported via pipelines in 2020 on an extra-regional scale.

Because few companies or governments are announcing oil-pipeline development plans further out than 2020, sizing additional pipeline capacities from 2020 to 2050 requires further assumptions.

Looking at the projected global oil trade from a demand–supply perspective, in the 2008–2020 time frame, out of 141 additional million tonnes of crude to be exported by countries worldwide, 125 million tonnes will likely be exported to customers in other regions via pipelines. Thus, 89% of incremental global exports in that period can be assigned to oil pipelines. Assuming that this share remains unchanged through 2050, then out of 226.9 million tonnes of projected incremental extra-regional oil exports, 201.3 million tonnes will require additional pipeline capacity and 25.6 million tonnes of additional tanker capacity (Figure 14).

Figure 14

Projected required capacities for oil pipelines and tankers for extra-regional crude exports in the 2008–2050 time frame.

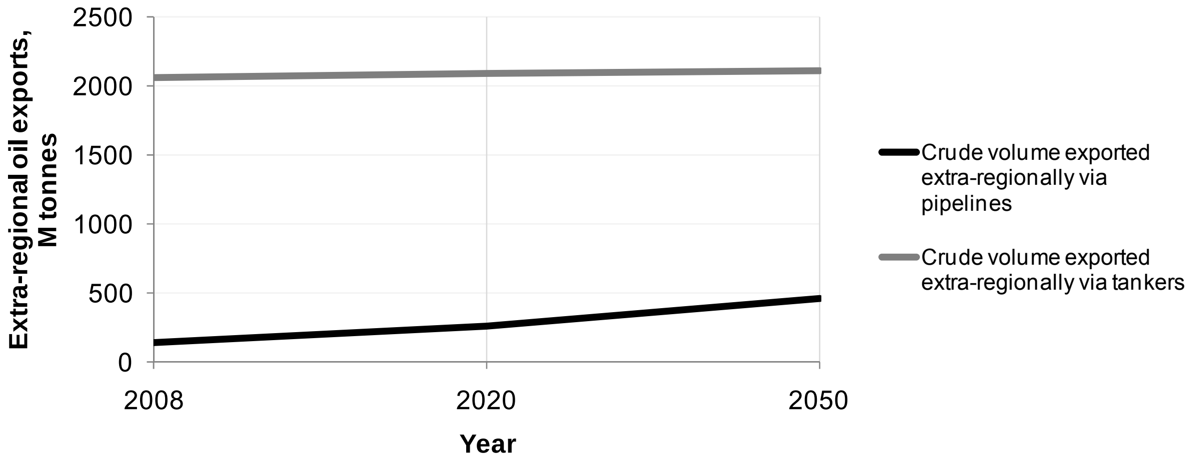


Table 3
The world's major gas pipelines and their 2008 through-put.

Direction	Pipeline(s)	Length (km)	Through-put (bcm)
CIS→Europe	Yamal–Europe	4,196	33
	Druzhba	2,750	30
CIS→APAC	Central Asia–China (Turkmenistan/ Kazakhstan–China)	1,833	40
	South Caucasus Pipeline (Azerbaijan–Turkey)	692	8.8
CIS→Middle East	Korpeje–Kordkuy (Turkmenistan–Iran)	200	8
APAC→Europe	Turkey–Greece	210	7
Middle East→CIS	Iran–Armenia	140	2.3
Middle East→APAC	Iran–Turkey	2,577	11
Africa→Europe	Maghreb–Europe (Algeria–Spain)	1,620	12
	Greenstream (Libya–Italy)	540	11
	Medgaz (Algeria–Spain)	757	8
	Trans-Mediterranean (Algeria–Italy)	2,560	30.2
Africa→Middle East	Arab gas pipeline (Egypt–Lebanon)	992	10.3

3.4. Gas transportation

The transportation of natural gas is arguably even more challenging than oil. Gas is highly flammable and ethereal. The smallest leak in a pipeline may lead to losing large amounts of this valuable resource, not to mention creating an extraordinary risk for fire or explosions. Long-distance gas transportation is equally, if not more, problematic. It has to be cooled down to less than -162 degrees Celsius to liquefy it and its volume compressed more than 600-fold. So its trade value must justify its transportation cost.

3.4.1. Major bottlenecks

Long-distance natural gas transportation is projected to rise rapidly via pipelines and LNG carriers. In 2008, global extra-regional exports of gas amounted to 353.5 bcm—11.5% of the world's production. In 2020, this volume is projected to increase to 657.3 bcm (16.7% of global production), and to as much as 1,892.7 bcm (34.8% of global production) in 2050!

To ensure this growth, numerous logistics bottlenecks concerning natural gas must be addressed:

- Sub-optimal investments in pipeline systems, partly due to geopolitical pressures (Nord Stream, South Stream, and Nabucco).
- Adjustments of local laws and regulations to avoid obstruction of network investments (e.g., right of way).

Table 4

Global extra-regional routes of LNG transportation in 2008 (in bcm). Orange boxes indicate intra-regional flows and are presented for information only.

Source: BP Statistical Review of World Energy, 2009

		Origin					
		North America	LAC	Europe	Middle East	Africa	APAC
Destination	North America	-	8.75	0.56	0.18	4.06	
	LAC		1.61			0.08	
	Europe		5.03	1.21	8.06	40.99	
	Asia Pacific	0.97	1.97	0.42	53.78	17.05	85.69

- Threat of terrorist attacks on pipelines and LNG tankers.
- Other LNG transportation challenges (distance from production unit to end-consumers, costs incurred, and infrastructure required to compress/decompress natural gas).

3.4.2. Necessary capacities

To assess necessary capacities, as in case of oil, the gas exports in 2008 may be split into two streams: gas pipelines and LNG carriers. Analogically to crude, the current infrastructure and needs for its further development to satisfy global demand are described.

Logistics infrastructure in 2008

In 2008, extra-regional exports of gas amounted to 353.5 bcm, transported by both gas pipelines, and LNG tankers. Gas pipelines moved around 60% of this volume, 211.6 bcm, between regions. Table 3 shows the division of that volume among respective pipelines. Altogether, 13 trans-regional gas pipelines have a total estimated through-put of 211.6 bcm.

As for infrastructure associated with LNG, at the end of 2008, there were 309 LNG carriers worldwide, with total capacity of 43.2 bcm of gas. They transported 141.9 bcm of LNG following routes shown in Table 4. Altogether, 353.5 bcm of natural gas exported in 2008 between regions were transported via LNG carriers (roughly 40%) and 60% via pipelines.

Capacity requirements between 2008 and 2050

The demand for natural gas, being a much cleaner fuel than oil and thus more widely accepted, will grow significantly over the coming years. The resulting extra-regional exports are projected to grow almost exponentially—by 86% from 2008 to 2020 and by another 188% in the 2020–2050 time frame! Beyond any doubt, that will require tremendous investment to make sure exporting markets have a platform to reach their customers.

To accommodate such growth, exporters are already building their capacities of existing pipelines and laying new ones. Table 5 lists planned gas pipelines, their length, diameter, and annual targeted through-put.

Should all started and announced projects be completed, 398.5 bcm of pipeline capacity would be added between 2008 and 2020. That is not likely to happen, however, for one simple reason—Europe will not need that much gas. At the end of 2008, 63 bcm of gas were imported by Europe from CIS via the Druzhba and Yamal–Europe pipelines, plus 68 bcm from Africa and Turkey. In 2008–2020, incremental European gas imports are projected at 33.2 bcm. Even assuming that all of that will be imported via gas pipelines, there is still a huge gap

Table 5

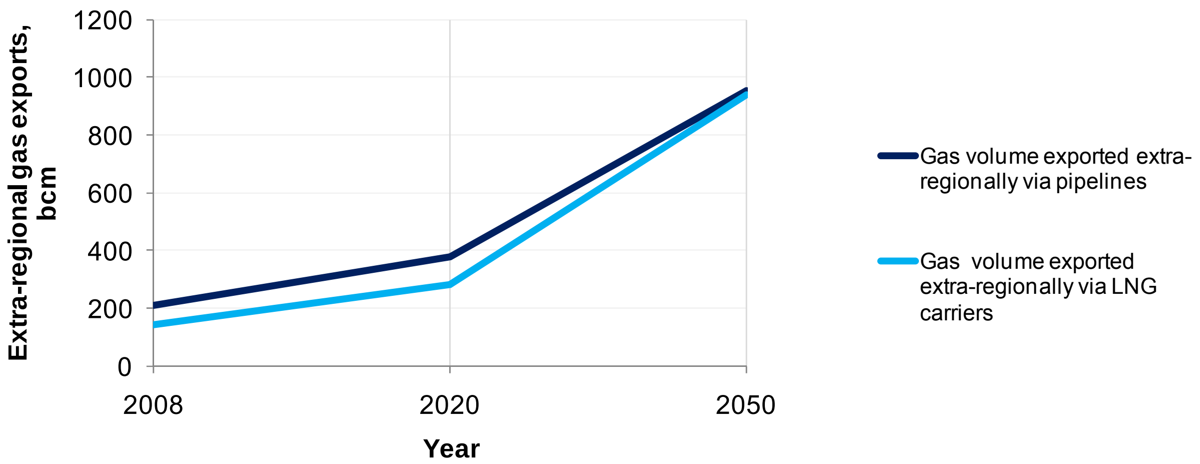
The world's major planned gas pipelines.

Direction	Pipeline(s)	Length (km)	Diameter (inches)	Target annual through-put (bcm/year)
CIS→APAC	Central Asia–China enhancement (Turkmenistan–China)	1,833	42	15*
	Altai Gas Pipeline (Russia–China)	2,800	56	30
	South Caucasus Pipeline (Azerbaijan–Turkey)	692	42	11.2*
	Trans-Afghanistan Pipeline (Turkmenistan–India)	1,680	56	33
	Blue Stream (Russia–Turkey)	1,213	24–55	16
CIS→Middle East	Azerbaijan–Iran	200		6.57
	Arab gas pipeline, Phase 2 (Turkey–Syria)	62	36	
	Azerbaijan–Syria		90	1
CIS→Europe	Nabucco	3,300		31
	Nord Stream	1,222	36	55
	White Stream (Georgia–EU pipeline)	2,100	48	32
	South Stream (Russia–EU)	900	42	63
Middle East→APAC	Qatar–Turkey pipeline	2,500	28	20
	Oman–India pipeline	1,100 (subsea)	42	26.5
	Iran–Pakistan pipeline	900	42	7.8
	Pars pipeline (Iran–Turkey	1,740	-	37
Africa→Europe	GALSI (Algeria–Italy)	865	22–48	8
APAC→Europe	Turkey–Greece	210	36	5*
Africa→ Middle East	Arab gas pipeline (Egypt–Jordan)	1,200	36	0.5

*Only surplus through-put.

Figure 15

Projected required capacities for gas pipelines and LNG carriers in extra-regional gas exports in the 2008–2050 time frame.



of 161.2 bcm between announced new pipelines to Europe (in total, 194 bcm) and the abovementioned projected import increase. Such a discrepancy stems from political reasons—some projected pipelines will substitute for current ones (e.g., the Nord Stream is an alternative to the Druzhba or Yamal pipes). The others will substitute each other (like the South Stream supported by Russia versus Nabucco or White Stream supported by politicians and investors willing to decrease the current European dependence on Russian gas).

Of the announced incremental investments in gas pipelines to Europe, potentially capable of transferring 194 bcm of gas, only 33.2 bcm of additional gas inflows are about to materialize. That leaves 237.8 bcm of global incremental gas exports via pipelines. (Other planned pipeline investments are all assumed to be realized.) From the remaining list, some of the projects are competing for the same gas—for example, the South Caucasus Pipeline (Azerbaijan–Turkey) and Blue Stream (Russia–Turkey). Taking that into account, a 30% correction factor representing shares of projects not likely to be completed because other options were substituted can be assumed. This leaves 166.4 bcm as likely incremental gas pipeline throughput between 2008 and 2020.

The remainder of necessary exports will have to be transported by LNG tankers, if at all. It would amount to 137.3 bcm (difference between additional exports of 303.8 bcm in 2008–2020 and 166.4 bcm assumed to be transported via new pipelines).

Between 2020 and 2050, as in case of oil, there are no available projections for the development of transportation infrastructure for natural gas. Incremental gas exports from 2020 to 2050 have been estimated at 1,235.5 bcm. To see how they might be split between gas pipelines and the LNG fleet, the world map with additional gas demand and supply divided among the regions, is illustrative. In case of Europe, imports are projected to stay at a constant level between 2020 and 2050. In APAC, however, gas imports are likely to increase by 719 bcm. Assuming 80% of that amount to be transported via pipelines calculates to 575.2 bcm. Remaining incremental capacity (660.3 bcm) will be transported via LNG carriers (Figure 15).

3.5 Electricity systems

The process of the generation and distribution of electricity has always been a struggle to increase efficiency, i.e., the ratio of output (power supplied to end-customers) to input (energy value of the fuels used to generate electricity). According to the McKinsey Global Institute, in 2003, only 37% of energy used in power generation process reached customers, the rest being lost in transmission.

Table 6
Status of implementation of smart grids in selected countries.
Source: From Policy To Implementation: The Status of Europe's Smart Metering Market, Cap Gemini 2009 and Smart Meters Gaining U.S. Foothold, www.sustainablebusiness.com

Country	Status
Denmark	Smart meters being introduced on a large scale; around 30% of meters are being replaced with smart meters
Finland	All major utilities are implementing smart meters on a large scale; 20% of the population already have a smart meter installed
Ireland	Implementing a two-way communication system with the customers of an innovative electricity pre-payment service
Italy	Arguably the best developed smart meter network in the world—27 million meters have been replaced with AMR devices by 2006; plans to reach 95% of consumers by the end of 2011
Sweden	Some smart grid functions implemented nationwide with a project to install meters that collect payments monthly was finished in 2009; around 1 million advanced meter readers now being implemented by Vattenfall and E.ON
U.S.	Smart meters now represent 4.7% of installed meters in U.S.; President Obama's administration made large-scale implementation of smart meters a top priority in the energy sector, introducing a large-scale stimulus plan worth in total USD 4.5 billion for this purpose in January 2009

Looking ahead to 2020 and 2050, the energy sector must achieve much higher efficiency to be able to satisfy increasing demand, especially from emerging economies, while consuming scarce energy resources.

3.5.1 Major bottlenecks

Major bottlenecks to increasing the efficiency of electricity systems can be divided into two groups: those related to power generation and those related to power distribution. The former results in manufacturing bottlenecks (for example, replacing standard, coal-fuelled power turbines with modern ones based on Integrated Gasification Combined Cycle, IGCC). The latter results in logistics bottlenecks. For example:

- Inability to accurately assess the required amount of electricity in the network, resulting in the distribution of excessive quantities of power.
- One-way communication in the network, from electricity providers to customers, losing information potentially helpful in production planning (switch-off plans in factories, holidays of private users).
- Problems with the distribution of electricity generated from renewable sources (wind and solar) and the production planning of such intermittent resources restrains their contribution to the total volume of such energy in the network.
- Few trans-national grid connections, enabling potential price reductions (arbitrage)
- Increasing overall network security (local blackouts), and increasing the stability of local networks near borders.
- Limited capabilities in assessing sources of power loss along the grid, resulting from technical issues or energy theft.

3.5.2. Necessary capacities

All inefficiencies embedded in today's electricity transmission and distribution processes may be decreased—and some of them eliminated—thanks to smart grid systems. “Smart grid” is a colloquialism for a set of tools, both software and hardware, enabling power companies to increase the efficiency of electricity distribution by improving information capture throughout the network. Hardware elements of smart grids contain, first of all, automated meter readers (AMRs) that measure in real-time the consumption of electricity by various points in the network (at end-users and at crucial network points, such as transformers). Telecommunications and data-storage infrastructure is required to handle, analyse, and store enormous amounts of data gathered via AMRs (from SIM cards to servers). The software elements of smart grids comprise programs used by operators to monitor network utilization, as well as programs for end-users (web-based CRM software) to monitor energy consumption in households.

Necessary capacities with respect to electricity distribution should indicate when respective regions of the globe could develop their own smart grid systems. Table 6 reflects the current status of smart-grid implementation in countries most advanced in this area.

From the current status of smart-meter implementation around the world, it can be argued that Europe and North America are two regions with the highest potential for the widespread use of smart meters by 2020. This argument is supported by ABI Research, which argues that the EU and North America will have the highest numbers of AMRs by 2014—the former being projected to have installed 115 million smart meters, and the latter 45 million units.

Other regions of the world, it can be assumed, are more likely to finish their deployment by 2050, although some are already actively pursuing smart power networks. An exception may be Middle East, which has not yet started large-scale implementation of AMRs, but due to a comparatively low number of citizens and large financial reserves, they could complete the whole process in a few years.

4. Infrastructure investments required to manage key logistics bottlenecks

In this section, a top-down cost assessment of required investments in the global development of smart grids is proposed.

4.1 Necessary investments in oil transportation

Having assessed the required capacities for the oil infrastructure in the 2020 and 2050 time frames, the projected actual investments needed, can be calculated should those capacities be addressed. To do this, it is necessary to assess relevant price benchmarks for each means of transportation.

4.1.1 Relevant price benchmarks

As for oil pipelines, required investments in developing the transportation infrastructure may be projected primarily based on an average cost of constructing a pipeline capable of delivering 1 million tonnes of crude from producer markets to consumer markets. To quantify this benchmark, a closer look on cost evaluation of selected pipeline projects was taken.

An average cost per 1 million tonnes of crude oil through-put as the average for the current and planned pipelines is calculated in Table 7 and this yields an estimated cost of USD 45.6 million per million tonnes.

In case of oil tankers, it will be easier to project investments in developing the fleet with respect to required capacity measured in DWT. A benchmark cost of 1-million DWT of tanker capacity can be derived. Although generally the price of tankers depend on their capacity, it is not linear—thanks to economies of scale, great ships cost much less per 1-million DWT than small vessels. Table 8 summarizes the estimated cost per 1 million DWT depending on type (class) of tanker.

Measured as the average from Table 8's calculated prices per 1-million DWT capacity of various tanker types depending on size, an average price per 1-million DWT of capacity at USD 666.3 million is estimated.

Table 7
Cost evaluation of selected, planned oil pipeline projects .

Pipeline(s)	Annual through-put target (million tonnes)	Projected cost of the pipeline	Pipeline(s)
Trans-Caspian oil transportation system (Kazakhstan–Turkey/Mediterranean	60	4,000	66.7
East Siberia–Pacific (Russia–China)	50	600	30
Neka–Jask pipeline (Kazakhstan–Iran)	50	2,000	40

Table 8
Average price of oil tankers per 1-million DWT depending on type of vessel.

Tanker class	Average size (in DWT)	Price of a new vessel (USD million)	Price per million DWT (USD million)
Product tanker	35,000	43	1,229
Panamax	70,000	50.5	721
Aframax	100,000	58	580
Suezmax	160,000	89	556
Very Large Crude Carrier	260,000	120	462
Ultra Large Crude Carrier	435,000	196	450

4.1.2 Evaluation of investments required in the 2008–2020 time frame

Multiplying additional through-put resulting from planned investments in oil pipelines with the price benchmark of cost per 1 million tonne of target crude through-put yields the projected investment outlay necessary to close the demand gap for crude oil transported via oil pipelines.

USD 5.7 billion
investments in pipelines 2008–2020
=
125 million tonnes
through-put of planned pipelines
x
USD 45.6 million/million tonnes
price benchmark–average cost of a pipeline per 1 million tonnes

In the case of oil tankers, required investments should include both outlays for developing the fleet to cover additional demand as well as replacing obsolete vessels. As outlined previously, in 2008, the global tanker fleet transported 2,061 million tonnes of oil using ships with 414 million DWT. This signifies 1 million DWT of the global tanker fleet's capacity were used to transport 5 million tonnes of crude. If, as calculated previously, extra-regional oil exports using tankers will increase by 15.9 million tonnes in the 2008–2020 period, that will require an additional 3.2 M DWT tanker capacity. Multiplying this by the price benchmark of USD 666.3 million per 1 million DWT (average tanker construction cost), demands USD 2.1 billion to fill this demand.

On top of that, required outlays to keep the global fleet operational, scrapping no-longer-viable vessels and replacing them with new ones, must be added. In 2008, the tonnage of scraped vessels reached 5.5 million DWT. Assume this rate remains stable from 2008 to 2020. That would mean a cumulative replacement tonnage of 66 million DWT—equalling USD 43.9 billion of investment costs.

Total required investments in the 2008–2020 time frame may be calculated as follows:

USD 56 billion
investments in tankers 2008–2020
=
USD 2.1 billion
new tankers required
x
USD 43.9 billion
fleet replacement cost

Summing up, required investments in oil pipelines and tankers yield USD 51.7 billion necessary to cover logistics aspects of meeting extra-regional demand for oil in the 2008–2020 time frame.

4.1.3 Evaluation of investments required in the 2020–2050 time frame

Incremental crude transport volumes in the 2020–2050 time frame have already been derived. Using the same methodology and price benchmarks as in the 2008–2020 time frame (investment unit costs will most probably in fact rise), the required capital expenditures (CAPEX) can be easily calculated.

For oil pipelines, the following equation summarizes projected costs:

USD 9.2 billion
investments in pipelines 2020–2050
=
201.3 million tonnes
through-put of planned pipelines
x
USD 45.6 million/million tonnes
price benchmark–average cost of a pipeline per 1 million tonnes

As for oil tankers, once again investment outlays in 2020–2050 will consist of two components—a new fleet to cover incremental oil exports (25.6 million tonnes equalling 5.1 million DWT) and a replacement fleet to cover for scraped vessels (166.3 million DWT calculated as follows: 417.2 million DWT of operational tankers fleet in 2020 x the 1.3% annual replacement rate times 30 years in the assessed period). Utilizing the price benchmark of USD 666.3 million per 1-million DWT additional tanker capacity, the sum of new fleet outlays in 2020–2050 can be estimated at USD 3.4 billion, and replacing scrapped ships at USD 110.8 billion. Altogether, required investments in oil infrastructure will amount to USD 123.4 billion.

USD 114.2 billion
investments in tankers 2020–2050
=
USD 3.4 billion
new tankers required
x
USD 110.8 billion
fleet replacement cost

4.2 Necessary investments in gas transportation

To derive the necessary investment outlays for required transportation infrastructure, a similar methodology as for oil from relevant price benchmarks and required capacities to money (CAPEX) spending necessary may be assumed.

4.2.1 Relevant price benchmarks

In case of pipeline gas transportation, a benchmark cost of laying a pipeline for 1 bcm is required. This cost can be estimated based on expert evaluation of the total cost of some pipeline projects planned for the coming years (Table 9).

The average weighed cost of gas pipeline construction per 1 bcm of through-put target from six evaluated projects was calculated to USD 330.8 million/1 bcm.

The second benchmark is the cost of LNG-fleet construction per 1 bcm of LNG carried. Different sources quote various costs, but assume a rather

Table 9
Cost evaluation of selected planned gas pipeline projects.

Pipeline(s)	Annual through-put target (bcm)	Projected cost of the pipeline (USD million)	Cost per 1 bcm of through-put target (USD million)
Nabucco	31	10,600	341.9
Iran–Pakistan gas pipeline	7.8	3,200	410.3
Central Asia–China pipeline expansion	15	7,300	486.7
Trans-Afghanistan pipeline	33	7,600	230.3
South Stream	63	21,500	341.3
GALSI	8	2,000	250.0

conservative cost by the Review of Maritime Transportation that estimates a 150 million-cubic-meter LNG tanker costing USD 245 million in 2008. Because costs of LNG-carrier construction have dropped by 45% since the mid-80s, according to the U.S. Energy Information Administration, efficiency increase needs to be built in. Assuming another 40% efficiency increase as an average between 2008 and 2050 yields USD 147 million for a 150 million-cubic-meter carrier, which, extrapolated to a 1-bcm capacity, gives the cost benchmark 980 M USD per 1 bcm LNG tanker capacity.

4.2.2 Evaluation of investments required in the 2008–2020 time frame

Having calculated necessary cost benchmarks and required capacities for gas pipelines and LNG tankers, the projected necessary investments for the 2008–2020 time frame can be derived.

In case of pipelines, essential CAPEX outlays will be the product of planned cumulative through-put and the price benchmark—average cost of a gas pipeline per 1 bcm.

USD 55.1 billion
investments in pipelines 2008–2020
=
166.4 bcm
through-put of planned pipelines
x
USD 330.8 million/1 bcm
price benchmark–average cost of a pipeline per 1 bcm

As for LNG tankers, a part of the fleet operating in 2008 will become obsolete and have to be replaced sometime between 2008 and 2020. Assuming the same rate of scraped fleet (1.32% per year) fleet replacement will be assumed to be the same. In 12 years from 2008 to 2020, 15.8% of the global fleet is likely to be replaced at a cost of USD 6.7 billion (12 years □ 1.36% replacement rate □ 43.2 bcm of global fleet capacity □ USD 980 million cost benchmark per 1 bcm). In case of a new fleet, tankers with a total capacity of 41.8 bcm will be required (if 43.2 bcm capacity was sufficient in 2008 to transport 141.9 bcm LNG, then an 85-bcm capacity should be enough in 2020 to transport 279.2 bcm of LNG, indicating required incremental capacity of 41.8 bcm).

Total required investments in the global LNG fleet in 2008–2020 may be calculated as follows:

USD 47.7 billion
investments in tankers 2008–2020
=
USD 41.0 billion
new tankers required
x
USD 6.7 billion
fleet replacement cost

4.2.3 Evaluation of investments required in the 2020–2050 time frame

For oil tankers, the same price benchmark applies to calculate the necessary investments, multiplied by the projected 2020–2050 additional pipeline through-put.

USD 190.3 billion
investments in pipelines 2020–2050
=
575.2 bcm
through-put of planned pipelines
x
USD 330.8 million/1 bcm
price benchmark–average cost of a pipeline per 1 bcm

Necessary investments in the LNG fleet will be very high to compensate for planned exports growth. Expanding the fleet to cover projected incremental 660.3 bcm exports will cost USD 197 million (same logic as before). On top of that, USD 13.3 billion will be needed to cover the part of the fleet that becomes obsolete during this time (30 years x 1.36% replacement rate x 85 bcm of global fleet capacity in 2020 x USD 980 million cost benchmark per 1 bcm). All in all, necessary investments will amount to USD 210.3 billion.

USD 210.3 billion
investments in tankers 2020–2050
=
USD 197.0 billion
new tankers required
x
USD 13.3 billion
fleet replacement cost

4.3. Necessary investments in efficient electricity systems

Investments in efficient electricity systems, in order to achieve sustainable energy systems, will require smart grids around the globe on a national level utilizing interconnectivity options with neighbouring countries (trans-national connections like today's Market Coupling in Benelux and Germany and Nord Pool in Scandinavia). Based on the experience from the most advanced markets in smart-grid deployment and on an assumed implementation pace in the respective regions, an investment projection may be constructed.

4.3.1 Relevant price benchmarks

Italy is the most advanced market in the world with respect to smart grids. From 2001 to 2006, 80% of end-users were linked to a smart network and their meters replaced with two-way automated meter readers (AMRs). The project cost was estimated at a total of USD 3 billion. Considering the annual consumption of electricity in Italy of 317.9 TWh (2008 consumption according to the International Energy Agency), the average cost of a smart grid per 1 TWh of consumption amounted to USD 11.8 million (total cost of USD 3 billion/(80% of customers x 317.9 TWh total consumption).

Target benchmark cost of installing smart-grid solutions per 1 TWh of electricity consumption should incorporate expected diminishing hardware costs (AMRs should be less and less costly to produce) and scale effects. For the purposes of this study, it has been assumed that the average cost of smart-grid components will be average 50%

Table 10
Projected progress and estimated costs in smart-grid implementation from 2008 to 2020.

	Percentage of end-users with AMRs		Energy consumption (TWh)		Estimated cost of smart-grid deployment (USD million)
	2008	2020	2008	2020	2008–2020
Europe	10%	80%	3,633.3	4,110.4	16,970.5
North America	3%	80%	5,283.4	6,180.6	28,069.3
South America	0%	10%	1,075.0	2,014.3	1,188.1
APAC	0%	10%	6,734.6	10,749.6	6,340.2
Africa	0%	10%	643.7	1,194.2	704.3
USSR	0%	10%	946.8	1,048.5	618.4
Middle East	0%	50%	742.3	1,266.7	3,735.6
TOTAL			**19,059.0**	**26,564.3**	**57,626.4**

Table 11
Projected progress and estimated costs in smart-grid implementation from 2020 to 2050.

	Percentage of end-users with AMRs		Energy consumption (TWh)		Estimated cost of smart-grid deployment (USD million)
	2020	2050	2020	2020	2020-2050
Europe	80%	95%	4,110.4	5,766.5	5,101.7
North America	80%	95%	6,180.6	9,535.4	8,436.1
South America	10%	80%	2,014.3	5,312.3	21,932.7
APAC	10%	80%	10,749.6	22,482.9	92,824.3
Africa	10%	80%	1,194.2	4,170.9	17,220.2
USSR	10%	80%	1,048.5	1,463.5	6,042.2
Middle East	50%	95%	1,266.7	3,758.8	9,976.4
TOTAL			**26,564.3**	**52,490.4**	**161,533.7**

lower in 2008–2050 period than it was in case of Italy. Hence, the value of benchmark cost of installing smart-grid solutions per 1 TWh of electricity consumption has been finally calculated at USD 5.90 million.

4.3.2 Evaluation of investments required in the 2008–2020 time frame

As discussed previously, Europe and North America are most likely to introduce smart grids on a wide scale before 2020 (Table 10). Current progress of implementation in Europe (which may be measured as a share of the AMRs in the total number of meters in the region) can be estimated at around 10%, whereas in North America, it is around 3% (highest in U.S., lowest in Mexico). Apart from several pilot projects, other regions have yet to start full-scale implementation projects.

Both Europe and North America have the means and determination to install AMRs at 80% crucial consumption point by 2020. The Middle East can easily reach 50% implementation—this region by 2020 will reach consumption levels of 1,266.7 TWh, just over 20% of the consumption in North America. Other regions will most probably have started large-scale implementation programs by then, allowing them to reach 10% implementation. To reach the assumed implementation status, USD 57.6 billion of investments in smart grids is required.

4.3.3 Evaluation of investments required in the 2020–2050 time frame

The year 2050 may see nearly full emplacement of smart meters worldwide (Table 11). By then, Europe, North America, and the Middle East should reach 95% coverage, whereas other regions may install smart meters for 80% of the population. Reaching these assumed implementation levels by 2050 requires investing over USD 161.5 billion.

5. Necessary policies

Multi-million dollar investments are a necessary but not exclusive condition to bring about the infrastructure required to ensure a balanced energy supply–demand and manage key logistics bottlenecks. Equally important are necessary policies that support the timely development of necessary infrastructure without excessive costs.

5.1 Necessary policies in oil transportation

Apart from enhancing pipeline capacities and developing a dense network of oil tankers, the following steps are recommended to ensure a constant supply of oil on a global scale:

Recommendations for policymakers

- Granting legal rights-of-way for oil pipelines (mostly at the national level) to prevent blockage for economic reasons (selling the ground at economically-justified prices;
- International cooperation to reduce piracy on oil tankers ; unless pirates are pressured on land and sea, oil tankers will have to choose suboptimal routes, and in extreme cases be unable to serve some customers
- Introducing stimulus packages for oil-tanker producers (long-term tanker leasing contracts, dockyard infrastructure adapted to producing oil tankers, incentivizing the replacement of obsolete fleet).

Recommendations for industry

- Intensifying RD&D activities aimed at increasing oil demand–supply balance, i.e., increasing production in importing regions
- Develop additional pipeline infrastructure (cheapest oil transportation mode) and pursue economies of scale in the market for tankers.

5.2 Necessary policies in gas transportation

As seen over the past few years, political tensions and power games in natural-gas transportation could obscure the primary objective, which should be providing sufficient quantities from net-exporting to net-importing countries at affordable prices. Every so often, natural gas is treated as a political tool to increase influence over a particular importing region or to obtain ownership over distribution assets in targeted economies.

To prevent it and allow for undisturbed access to this natural gas, strict policies should be supported by both policymakers and companies:

Recommendations for policymakers

- Granting legal rights-of-way for gas pipelines (also mostly at the national level
- Incentivizing projects with the most positive economic impact and ensuring highest energy interconnectivity (like the Trans-European Energy Network programme)
- Providing incentive packages to increase cross-border trade of natural gas (especially

via pipelines), such as decreasing transit fees, and signing long-term legally-binding contracts.

- Cutting price subsidies gradually for gas where they are too high to encourage energy efficiency (especially in net-exporting countries), and enforcing much stricter controls over gas consumption and potential losses (tends to be laxer in countries with abundant gas).

Recommendations for industry

- Increasing regional partnerships through joint infrastructure investments (sharing natural gas storage facilities, and sharing costs of laying pipelines), which also may decrease per-unit investment costs.
- RD&D investments in liquefaction and re-gasification technologies – any process efficiency increases will have a large impact in the face of rapid projected growth in LNG transportation
- Increasing LNG transportation efficiency, e.g. through economies of scale in LNG carriers (transportation using the largest carriers results in a cost reduction of20-30%)

5.3 Necessary policies in electricity transmission

A set of regulations and incentives ensuring proper management of electricity transmission should focus on promoting increased energy efficiency and regional cooperation. We recommend adapting following principles by policymakers and industry:

Recommendations for policymakers

- Developing financial vehicles by utilities and governments (especially regulators) to ensure the timely deployment of smart grid networks. International cooperation by governments to incentivise deployment of trans-system network connections, e.g., the EU list of supported electricity infrastructure projects as part of the Trans European Network.
- Support the introduction of third-party access (TPA). This functions well in EU countries but on much too low a scale outside the European Union. TPA ensures de-monopolization of regional electricity markets, opens options to buy electricity from any market player.
- Supporting international projects to build “energy bridges” between countries—to ensure electricity price convergence and create power pools to decrease the risk of blackouts; an example is the Scandinavian Nord Pool
- Creating stimulus packages for operators of power plants and distribution infrastructures. The focus should be on increasing productivity, efficiency, and reliability of energy assets. Elements of a possible incentive system can be found in EU climate directives (red certificates for combined heat and power production, CO_2 allowances for modernization of production infrastructure, and planned white certificates for increasing energy efficiency).

Recommendations for industry

- International cooperation in developing common standards for smart-grid networks; joint efforts could diminish required outlays for developing standards and increase interoperability between national power networks.
- Investments in large-scale smart-grid systems even without strong incentives from governments, thereby decreasing energy losses and delivering extra value to customers (through more accurate information and billing and extended services package) should be encouraged.

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Appendix 1. Conversion rates used in the study

Table 1
Conversion rates used in the study

	Study unit	Terajoules (10^{12} J)
Electricity	1 TWh	9.3
Gas	1 bcm	37.5
Oil	1 million tonnes	41.7
Uranium	1 tonne	0.44
Coal	1 million tonnes	27.79

Appendix 2.
Matrix of logistics bottlenecks

Table 1

		Raw materials / fuels					Electricity		
		Extraction	**Road / rail / water transportation**	**Pipeline transportation**	**Storage**	**Construction & fitting of energy-related facilities**	**Grid transmission**	**Grid distribution**	**Electricity storage**
Raw materials / fuels - solid	**Coal**	• Security concerns esp. In underground mines	• Lack of proper infrastructure (ports for loading / offloading coal)			• Balancing necessity of increased generation from biomass / co-generation with affordability for end-customer			
	Nuclear				• No wide recycling of nuclear waste (high costs?)	• NIMBY issue when constructing a plant (need of better social education)			
	Solid biomass	• Compromising agricultural areas for needs of energy sector (biomass)				• Need to build power plant / CHP close to biomass sources			
Raw materials / fuels - liquid	**Oil**	• Postponing investment decisions (e.g. in new rigs) due to price volatility of crude	• Insufficient number of ships • Terrorist attacks on ships • Ships' hijacking (e.g. pirates near Somalia)	• Terrorist attacks on pipelines • Pipelines used as a tool in political blackmails					
	Biofuels	• Compromising agricultural areas for needs of energy sector (biofuels)							

Table 1

		Raw materials / fuels					Electricity		
		Extraction	Road / rail / water transportation	Pipeline transportation	Storage	Construction & fitting of energy-related facilities	Grid transmission	Grid distribution	Electricity storage
Raw materials / fuels - gas	Natural gas			• Investment shortage in international pipeline linkages • Investment decisions driven by politics rather than economic factors • Need of adjustment of local laws / regulations to avoid obstruction of network investments (e.g. Law of road) • Pipelines used as a tool in political blackmails	• Storage security esp. Against terrorists attacks • High dependence on gas in energy portfolio of many countries (e.g. Romania, Italy)	• Low level of investment security (e.g. in Russia)			
	Biogas								
	LNG		• Insufficient number of ships • Terrorist attacks on ships • Ships' hijacking (e.g. pirates near Somalia)		• Terrorist attacks (esp. LNG terminals / silos in port cities)				
	Hydrogen								

Table 1

		Raw materials / fuels					Electricity		
		Extraction	Road / rail / water transportation	Pipeline transportation	Storage	Construction & fitting of energy-related facilities	Grid transmission	Grid distribution	Electricity storage
Renewables	General renewables								
	Wind	• Generation volume very hard to predict / model - may disturb distribution network				• Manufacturing capacity shortage for windmills (esp. Some parts e.g. rotor blades)		• Disruption of distribution network (volatility of generation from wind)	• Insufficient electricity storage possibilities (may lead to network disruptions / overloads)
	Solar				• Very high generation costs limiting usage in many countries (e.g. in Africa, Asia)	• Inefficient long distance transportation (esp. needed e.g. in Mediterranean)			
	Hydro	• Threat of terrorist attacks on dams				• Further development of hydro energy limited in some countries (best sites already in use)			
Electricity	Electricity					• Electricity generation capacity gap likely in most countries - need to speed up generation investments • No proper fiscal policy incentivizing investments in generation capacity	• Transmission inefficiency (esp. Long distance) - including energy losses • No proper fiscal policy incentivizing investments in transmission network • Insufficient interconnections between national grids dangerous in case of blackouts etc. • Imbalanced national networks (generation assets far from consumption)	• Distribution inefficiency including energy losses • No proper fiscal policy incentivizing investments in distribution network • Liberalization of EU electricity distribution too slow in some countries - quality of services less likely to improve	• Electricity storage inefficient and insufficient (electricity consumed "on spot") • Slow R&D progress on technologies enabling electricity storage (e.g. fuel cells)

Appendix 3. Oil refining

Importance of refining in the oil value chain

Discussions about the oil and gas business tend to take place in the media only when accidents or crises are catalysing the public's attention, but are otherwise left to the experts. This is now clearly not in the interest of the industry, because it brings attention only to the negative aspects of the business and ignores its contribution to the general well-being and to the health of the economy. In fact energy is the driver of any type of economy and oil has still a fundamental contribution as "energy producer".

Oil per se is not of much use as an energy source: it needs to be converted in different products before it can be used. Refining is the step that converts crude oil into different types of fuels and feeds for the petrochemical sector.

It is this centrality of the oil sector to the economic system of developed countries that explains why it is so often invoked to explain global geo-political balances and energy security issues. What instead is not discussed is how the well-being of the oil sector is crucial to the welfare of a country. All OECD countries are large importers of crude oil but, apart from providing employment opportunities for many skilled workers, a competitive refining sector produces advanced fuels, meeting increasingly tougher environmental standards and cheap raw materials for the chemical industry. It also requires advanced research in several disciplines, develops and spreads around sophisticated technologies and contributes large amounts of indirect taxes to the public coffers!

It is important to ensure the viability of the refining sector because, given the current proportion of energy products derived from oil and the complex and extensive logistics infrastructure in place to move oil and fuels, the process to replace fossil fuels and oil with other energy sources will be gradual and slow. All international studies forecasting energy consumption indicate that fossil fuels (oil, coal and gas) will still be the main source for a few more decades, so it is each country's vital interest to safeguard its existing refining business.

Scale, cyclicality and other main characteristics of the business

The refining business has some intrinsic characteristics that it developed in its history and now define its structure. It is impossible to understand how it reacts to the impacts from the recent financial crisis without recognizing that:

- it requires huge investments because of economies of scale;
- its assets lie preferably close to demand;
- once a plant configuration has been fixed, it is relatively inflexible in adjusting the ratio between gasoline and diesel, as well as the crude type;
- in the '60s - '80s most EU refiners invested heavily in cat-crackers (which are yielding mainly gasoline) in order to supply internal

market and growing demand from the US market. Over the last few years, instead, new investments in Europe tended to be in hydrocracking capacity, in order to meet the increased internal demand of diesel, while in the US they mainly went into coking.

The recent difficulties of the refining sector can be explained by the combination of two effects: those related to global economic changes (mainly the growing importance, for both demand and supply, of developing countries, where very significant oil resources are located) and those specific to the financial crisis. We will examine the two separately, because the effects of the crisis are transitory, while the others are long-term trends.

Among the "structural", long-term trends, we highlight:

- The decoupling of oil and fuels prices, that have started to be controlled by different drivers:
    - fuel prices reflect mainly the supply/demand balance in the served markets;
    - oil prices are now distorted by financial considerations (because oil, as commodities in general, is now a financial investment class whose attractiveness to global money flows is largely uncorrelated with demand of the physical).

As a consequence, refining margins have become more volatile.

- The divergence of growth rates between OECD and developing countries, with the OECD almost flat and developing countries showing markedly higher rates
    - local demand grows with population and income per capita;
    - less stringent environmental constraints which facilitate low-cost production of less sophisticated products;
    - subsidies are often provided for fuels in order to sustain demand and speed up development of the country;
    - availability of Western technologies allows more competitive (more efficient and large-scale) investments.

All this results in different supply/demand balances between the countries, with a diffused overcapacity in the OECD and difficulties to export excess fuels from developed economies to the countries with strong demand.

- The demand growth for energy products in emerging economies will slow down somewhat because of:
    - income inequality (since wealth concentrates into fewer hands);
    - phasing-out of subsidies;
    - congestion and pollution;
    - widespread availability of more efficient technology reducing unit energy consumption.

- The availability in developing countries of capital to invest. For the refining sector this has meant huge investments outside the OECD area.
- The changing structure of the refining business in OECD countries: IOCs have tended to focus on upstream investments rather than on the downstream, so a growing number of refineries in the world is now operated by independents or NOCs.

Unique features of this last crisis compared to previous cycles

Refining has traditionally been a cyclic business, plagued by alternating phases of under and over-capacity expansion. In the report we will look at what makes the crisis of the last two years different from past cycles.

This last one started as a financial crisis in the USA: the sudden lack of liquidity from the banking system immediately led to (among other things) a drop in consumption that in turn caused a drop in production across all economic sectors among developed countries. The economic recession took on some specific characteristics in the downstream sector, because of changes occurring in the energy business. In brief, on a global scale:

- the crisis and economic recession, hitting an already mature market resulted in a contraction of demand for fuels. This has in turn, because of the inflexibility of supply, led to depressed refining margins;
- there are some factors that in OECD countries are contributing to dampen fuels demand growth:
  - increasing demand for biofuels, sustained by mandatory requirements;
  - increasing availability of other (e.g. LPG, methane);
  - improving engine performance standards and adoption of stricter efficiency standards (e.g. CAFE standards in the US);
  - improved extraction technology and new large discoveries of shale gas in the USA is likely to dampen consumption of oil based fuels in the coming years;
  - lower fuels demand in the USA has dampened gasoline exports to the US, a mainstay of the European refining balance;
  - the continuing shift in the transportation sector from gasoline to diesel puts pressure on all the plants without an hydrocracker;
  - legislation to limit greenhouse gases emissions, particularly by OECD countries, further impact the already weak competitiveness of local refiners. Given its proximity to the Middle East, in the EU the adoption of the new ETS mechanism for CO_2 emission permits can significantly improve the competitiveness of imports. This phenomenon is known as “carbon leakage”.

- The investments by NOCs in local refining capacity bring at the same time reduced demand in the Middle East and increasing exports into developed countries fuel markets
- The reduced economic attractiveness of the downstream business is gradually pushing IOCs (International Oil Companies) to focus more on E&P.

In the past the reaction of developed countries to cyclical downturns in refining were (also sharp) reductions in capacity, closing, transforming in depots. This is still likely to happen again, but with some new twists:

- Assets dismissed by IOCs are often taken over by NOCs, eager to increase their penetration into developed economies
- Some refiners are trying to develop technologies allowing more flexibility in adjusting the ratio of diesel and gasoline in the conversion process
- EU refiners are hoping that improved performance of Internal Combustion Engines will reduce motorists' preference for diesel over gasoline. In the meanwhile, they are wishing for a termination by local legislators of the tax advantages granted years ago to diesel.

Medium-long term consequences for the refining business

It is important to understand how the refining industry will re-balance in order to supply:

- increasing demand from the BRIC (Brazil Russia India China) countries;
- the diesel deficit in Europe

while reducing gasoline exports to the USA, and which countries and companies will have to reduce their ambitions in the downstream business.

This report is an attempt to estimate the new trade balances in fuels, by macro-basin, for the years to come. It will look at the sudden global swing from under to over-capacity brought about by the economic crisis and the macro-changes described above and assess their impact along the various steps of the global oil value chain, focusing on those specific to refining operations.

World Evolution of the Demand

The economic crisis, the spread of the biofuels and energy efficiency are the main factors influencing the world demand. In particular:

- the economic crisis will bring, by 2020, a contraction of the consumption estimated between 2 and 5 Mbpd (present estimation around 100÷103 Mbpd versus an estimation prior to the crisis of 105 Mbpd);
- at 2020 biofuels contribution is estimated to be around 3 Mbpd (2.2÷2.6 ethanol e 0.6÷0.7 biodiesel);
- the effect of the measures introduced in North America (CAFE Standards) in matters of energy efficiency will have a growing impact on the reduction of the petroleum products.

The areas that will grow more than others in terms of demand and refining capacities are Asia and the Middle East.

Europe will have to face - from both political and industrial point of view - the problem of structural gasoline surplus which, on the long run, will have to find its outlet not only in the North American market but also in other consuming areas (mainly Asia).

Two scenarios are here illustrated (High and Low) based on the projections of two primary energy consultants (Wood Mackenzie and Parpinelli). These two scenarios do not appear to be so different, at least in the big numbers, and this is because there is a substantial agreement on the assumptions made by the consultants.

We try to synthesize them below:

- refined products will remain key for the transport sector at least up to 2020;
- the economic crisis, which began at the end of 2008 and it is not completely overcome yet, had an impact on demand growth, not only changing the growth rates, but also decreasing the starting point (demand in 2009);
- the growing spread of biofuels, supported in the OECD countries by laws and regulations, is eroding the consumptions of gasoline and diesel;
- there is renewed attention to energy efficiency, not only in Europe, but also in the US (CAFE standards).

Demand Outlook

The economic crisis will bring a contraction in consumptions, and by 2020, the overall results in both scenarios will be

- contraction of consumption is estimated between 2 and 5 Mbpd (present estimation around 100÷103 Mbpd versus an estimation prior to the crisis of 105 Mbpd). To 2020 consumption growth is expected between 1.4% (Low scenario) and 1.9% (High scenario) vs. 1.6% expected before the crisis;
- break-through technologies to increase efficiency in transport (reduction of consumption) or greater energy efficiency affect the demand;
- a reduction of gasoline demand in Europe and in the US;
- growth in the demand of middle distillates worldwide;
- Europe and Asia are confirmed as major consumer of diesel due to the dieselization of the fleet and strong growth in transport business especially in Asia;
- consumption of biofuels will reach approx. 3 Mbpd (2.2÷2.6 ethanol e 0.6÷0.7 biodiesel);
- in North America gasoline will continue to be requested (43% of world total in both scenarios) from the United States but will tend to gradually decrease;
- Europe will face an increasing structural surplus capacity, particularly on gasoline,

Figure 1

Low Scenario – Demand Evolution

Source: eni's elaboration on Parpinelli data

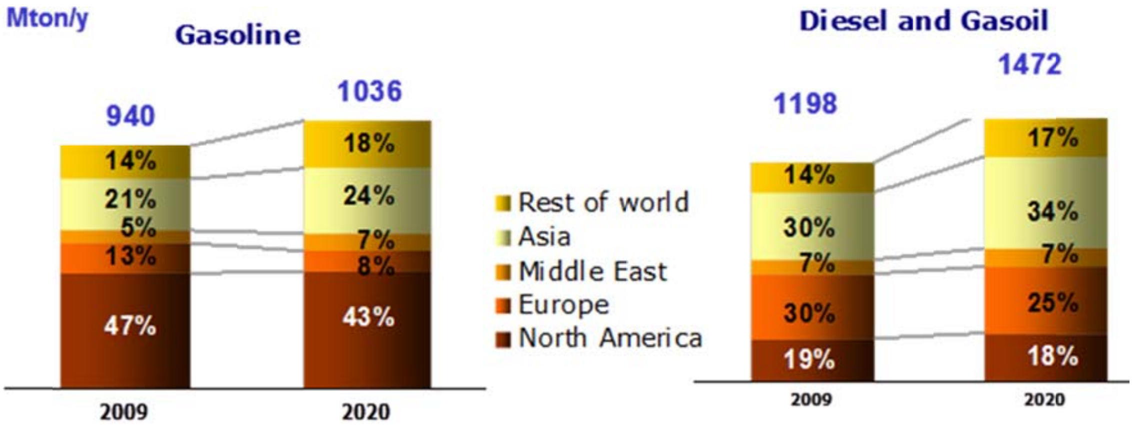
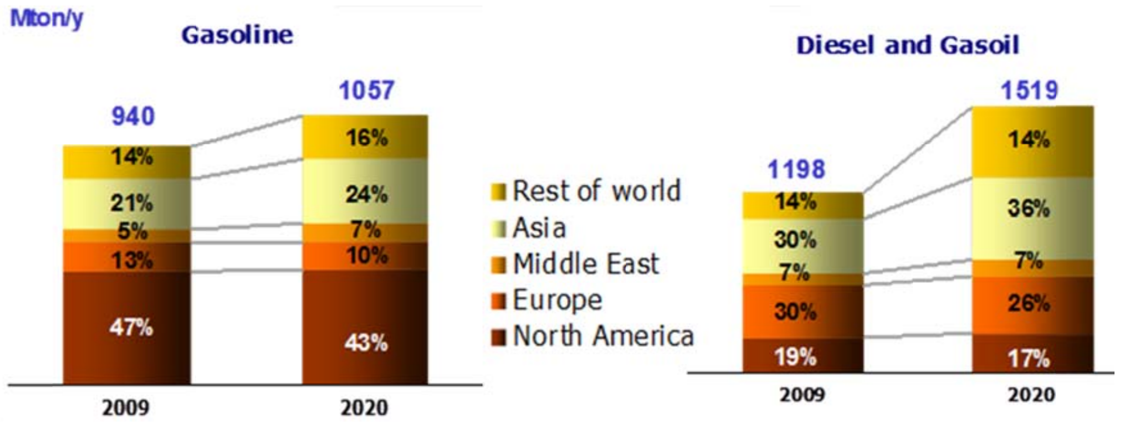


Figure 2

High Scenario – Demand Evolution

Source: eni's elaboration on Wood Mackenzie data



exacerbated by the gradual reduction of the deficit in North America.

It can be noticed a lower growth in gasoline demand in Europe and in the US and a slower increase in the consumption of middle distillates in Asia, comparing the Low scenario with the High scenario.

Supply Outlook - New Refining Capacity

In the High Scenario 9.1 Mbbl/d of new refining capacity (deriving from new refineries or expansions) are projected between 2009 and 2015, while in the Low Scenario 9.9 Mbbl/d. In both cases projects have been cancelled and delayed. The Low scenario forecasts a smoother scheduling of new refineries over time in comparison to the High scenario, while the difference is due mainly to expansions for which the Low scenario forecasts almost 1 Mbbl/d of refining capacity in excess of the High scenario.

In recent years a clear shift can be seen in the trend of global refining capacity: the center of gravity of additional capacity is moving eastward, in line with the new map of world consumption.

In both scenarios capacity developments between 2010 and 2020 are mostly projected in Asia and Middle East, with an incidence of almost 70% with respect to the world total.

Figure 3

Low Scenario – New Refining Capacity

Source: eni's elaboration on Parpinelli data

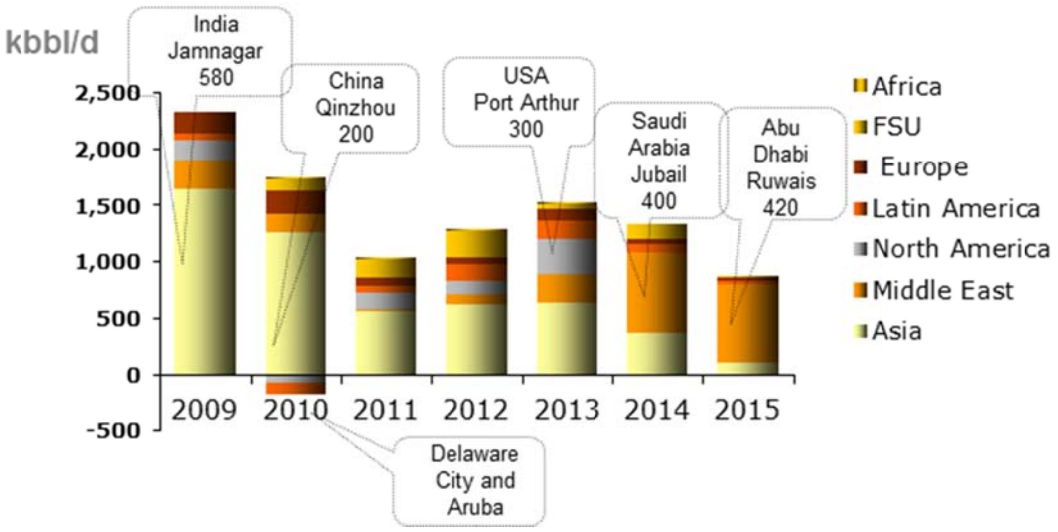
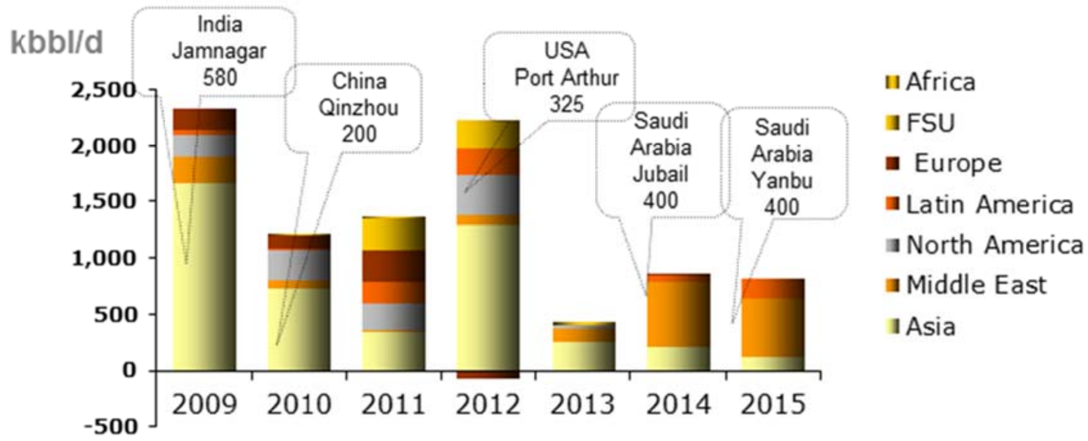


Figure 4

High Scenario – New Refining Capacity

Source: eni's elaboration on Wood Mackenzie data



Refined Products: Global supply / demand scenario

Looking at the different products the Low scenario and the High scenario tend to diverge: according to the Low scenario in 2020 the world will have a big surplus of gasoline.

The global supply-demand balance shows a surplus of refined products in the recent years. In the long term (after 2015), the global balance points out a shortage of products (with the exception of gasoline in the Low scenario) as the increased demand is not adequately satisfied by new refining capacity. This unbalance is probably due to a limited visibility on possible additional expansion projects.

On the other hand there are new products entering the market: reference is made mainly to biofuels (ethanol, ETBE and biodiesel) that compensate (it would be better to say over-compensate) the imbalance for gasoline and diesel. This is evident both in the Low scenario and in the High scenario.

Figure 5
Low Scenario – Refined Products Supply/Demand Balance 2020
Source: eni's elaboration on Parpinelli data

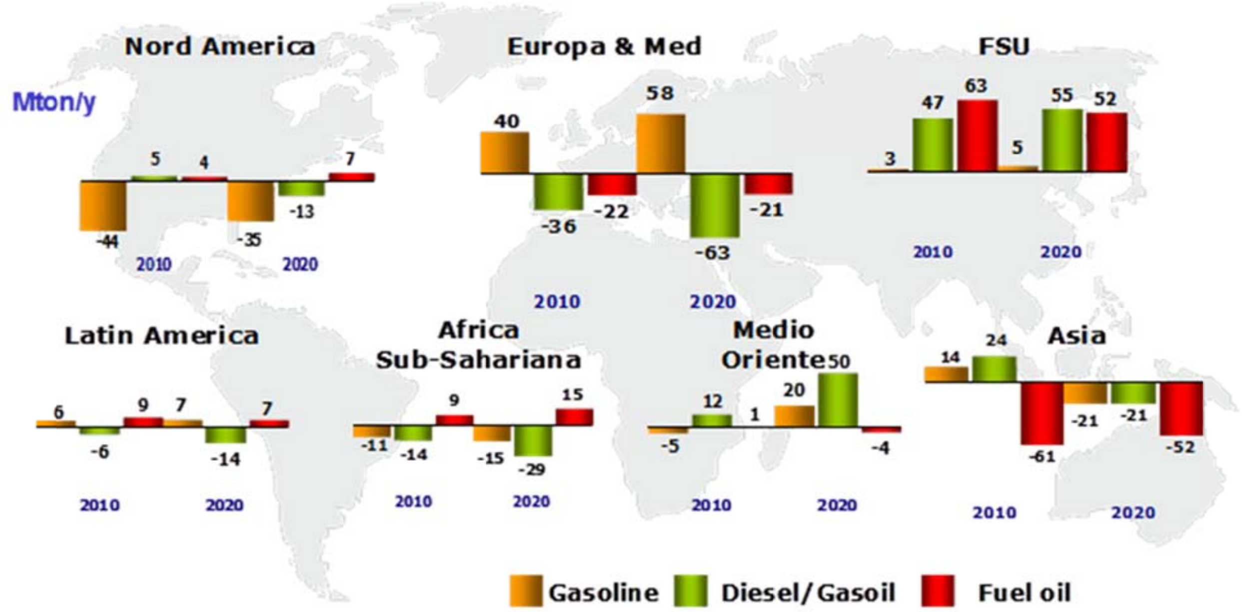


Figure 6
Low Scenario - Global Supply/Demand Balance at 2020
Source: eni's elaboration on Parpinelli data

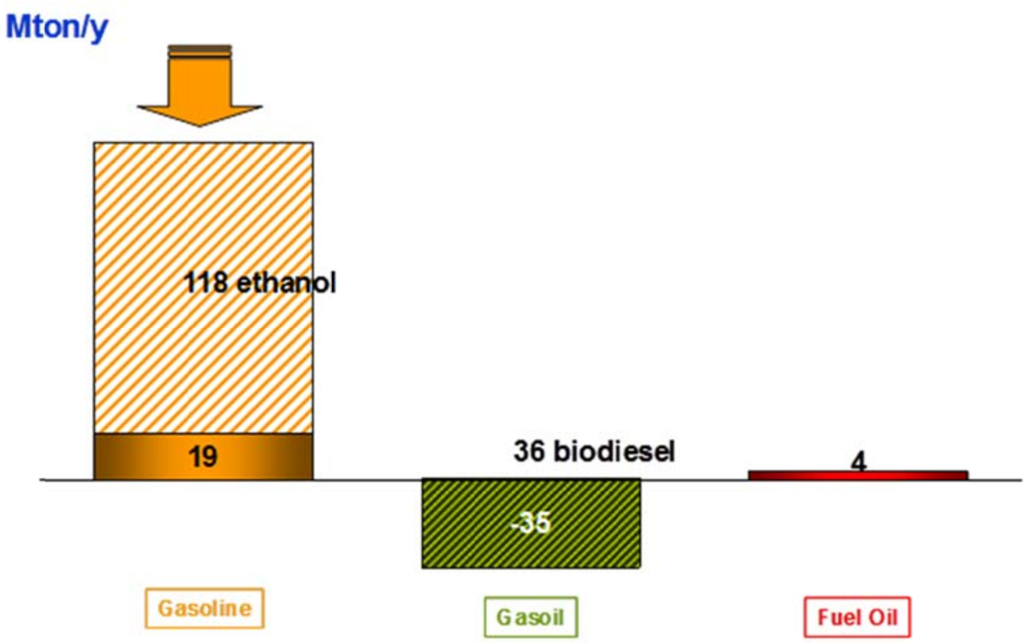


Figure 7

High Scenario – Refined Products Supply/Demand Balance 2020

Source: eni's elaboration on Wood Mackenzie data

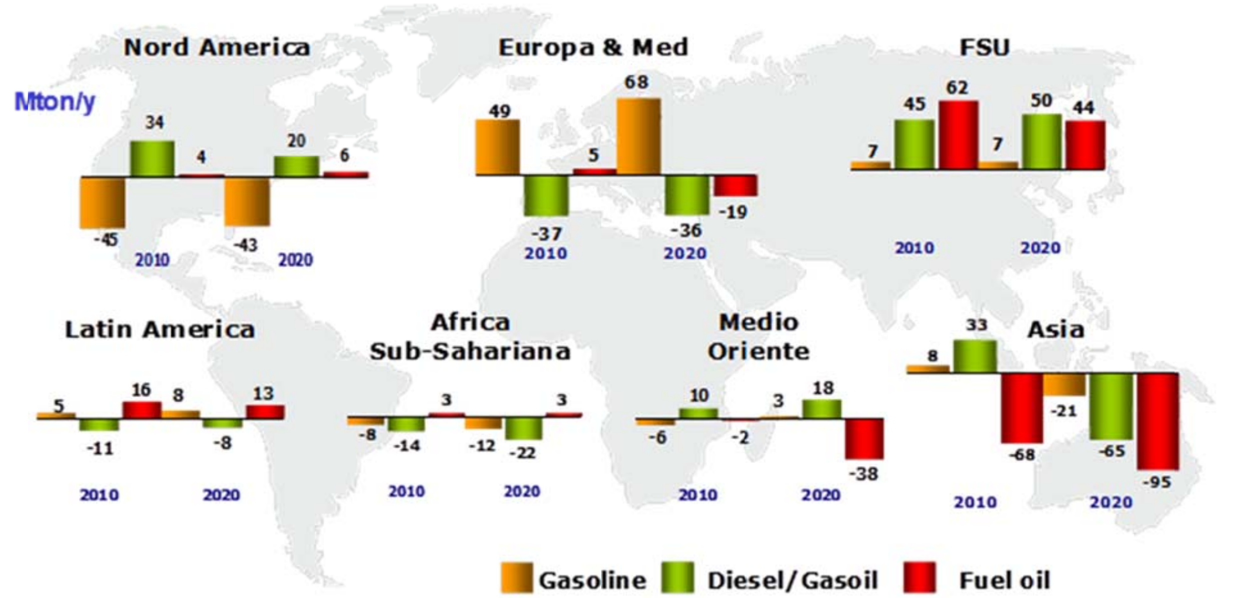


Figure 8

High Scenario - Global Supply/Demand Balance at 2020

Source: eni's elaboration on Wood Mackenzie data

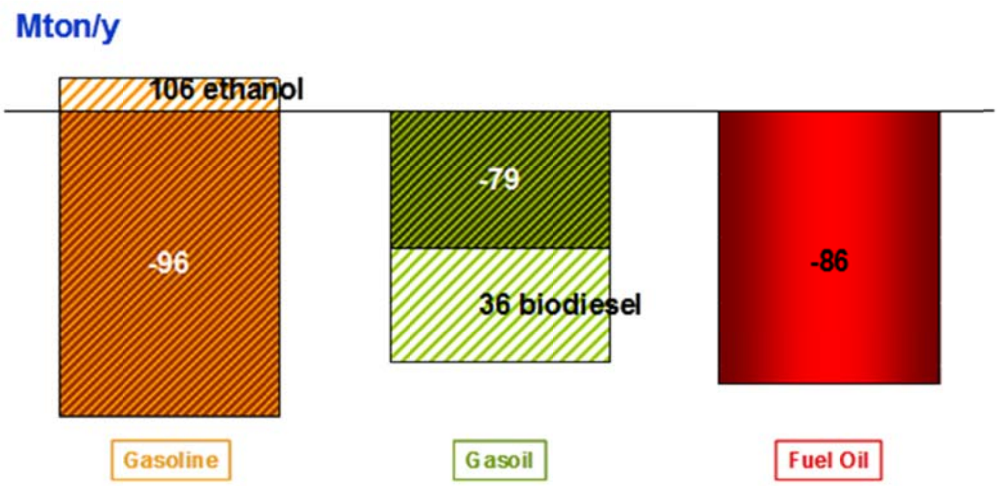
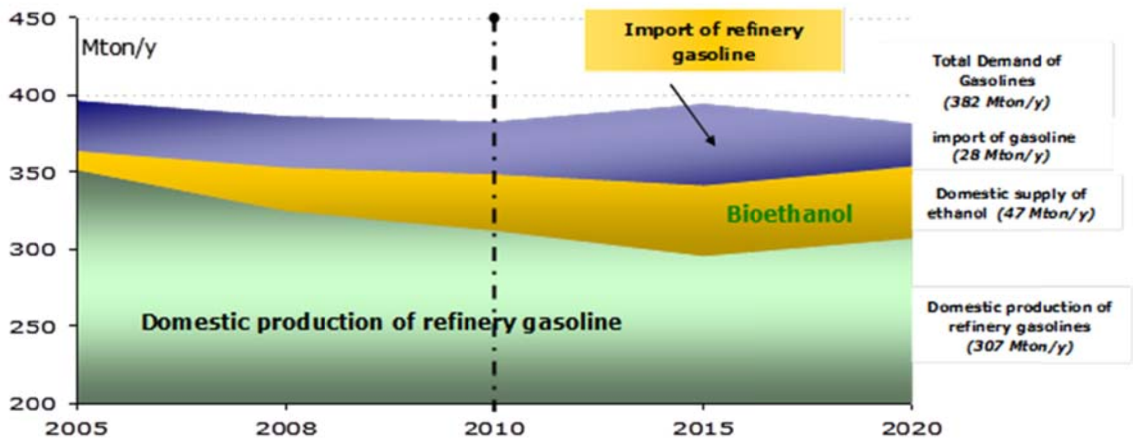


Figure 9
Gasoline Demand in the USA
Source: eni's elaboration on Wood Mackenzie data



Gasoline

Although gasoline deficit remains almost steady in North America, it will be harder to place the increasing surplus from Europe.

In 2020, a gradual reduction in imports of gasoline in the US is projected, mainly because of the "going green" policy carried out by the US administration, with its three primary goals:

- increased engine efficiency standards, anticipating to year 2016 the goals of the CAFE standards
- tax credits to facilitate the registration of 1 million hybrid vehicles by 2015 and the purchase of cars using LPG
- progressive penetration of bioethanol, with estimated growth rates around 6% per year in the Low scenario and 4.2% per year in the High scenario in the period 2010-2020.

At global level we have completely different situations at 2020 in the two scenarios:

- in the Low scenario there is a surplus of fossil gasoline of 19 mln ton/y, which is further worsened by 118 mln ton/y of ethanol;
- in the High scenario there is a deficit in fossil gasoline of 96 mln ton/y, more than compensated by ethanol for 106 mln ton/y.

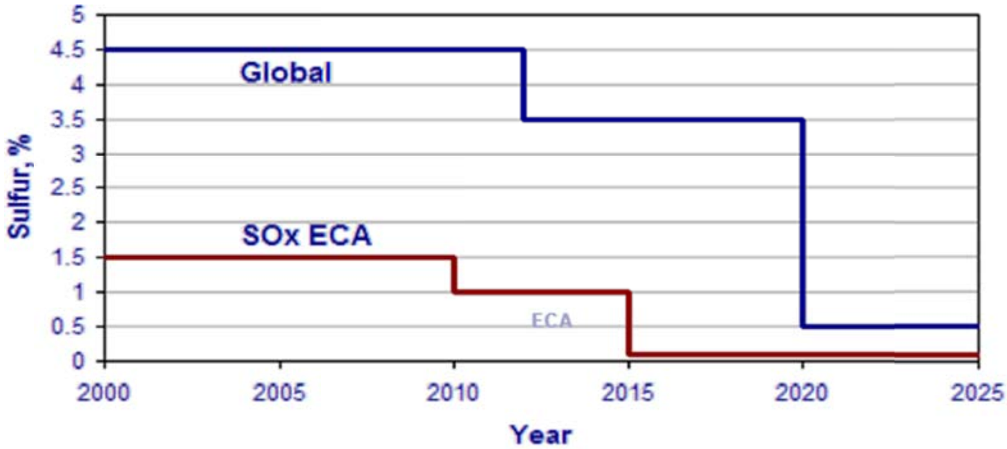
Europe, which for years has been exporting its surplus towards the US, would need to take appropriate measures on the industrial (closing refining capacity and trying to improve diesel yields) and political (pro gasoline tax policy) side.

In that context, and with particular reference to Asia, why not consider it a good market for the surplus of European gasoline to replace the now declining US consumption? In fact, penetrate such a market and redirect the flow of traditional exports is complicated for at least two reasons: firstly because European products are high quality and reduced climate environmental impact is not required (and therefore not competitive) in countries without stringent environmental constraints, and secondly because Asian countries are heavily investing in new refining capacity with the intent to reduce an increasing dependence on supplies from abroad. Consider also another critical aspect that strongly connect Asian and European markets, exacerbating the condition of the latter: the greater demand for diesel needed to cover domestic consumption in emerging countries can subtract large amounts of product mostly from Russia, the main supplier of Europe.

Diesel

Also with regard to Gasoil the two scenarios are not in agreement about the supply-demand balance at 2020, because in the Low scenario global deficit of diesel (35 mln ton/y) is more than balanced by biodiesel (+36 mln ton/y), while in the High scenario deficit of diesel is 79 mln ton/y and biodiesel is only 36 mln ton/y, leading to a total deficit of 43 mln ton/y. The High scenario moreover

Figure 10
Legislative Impact on Fuel Oils
Source: EPA, Wood Mackenzie, International Maritime Organization (IMO)
ECA = Emission Control Area, SECA = SOx Emission Control Area



does not take into account the new IMO regulations about bunker fuel (while the Low scenario does), which could reduce of about 40% the deficit of Fuel Oil and increase of the same amount Gasoil demand.

Fuel Oil

The International Maritime Organization (IMO), the UN agency in charge of improving safety and preventing pollution from ships, in order to reduce emissions by vessel traffic issued the MARPOL (MARine POLlution) regulation. In October 2008 a significative amendment to MARPOL Annex VI was approved, aimed at reducing even further emissions from ships. The main changes to MARPOL Annex VI will see a progressive reduction in sulphur oxide (SOx) emissions from ships, with the global sulphur cap in bunker reduced initially to 3.50% (from the current 4.50%), effective from 1 January 2012; then progressively to 0.50 %, effective from 1 January 2020, subject to a "sustainability review" to be completed no later than 2018, that could delay the enforcement at 2025.

The limits applicable in Sulphur Emission Control Areas (SECAs, currently Baltic Sea, North Sea and English Channel) have been reduced to 1.00%, beginning on 1 July 2010 (from the current 1.50 %); being further reduced to 0.10 %, effective from 1 January 2015.

Recently even United States and Canada requested the definition of an ECA (Emission Control Area) that could come into effect from 2012.

This could bring to switching fuel oil demand towards middle distillates, with an impact of in the order of 200 mln ton/y.

In this contest the role of new deep conversion projects should be very important in order to decrease fuel oil production.

Conclusions

Main Oil System Challenges

For the on-going years the whole Oil System should reiterate its strategy, objectives and commitments to overcome the structural challenges affecting the refining industry in the World and in Europe and USA in particular, by:

- continue to adjust its refining base in response to shrinking demand in Europe (gasoline/diesel fuel imbalance); and USA (gasoline demand);
- address the impact of the restructuring of its activities in affected regions;
- comply with severe regulations, i.e. in the European Union, especially those concerning the environment
- implement a significant capital expenditure program in Asia and in Middle East, as

forecast for 2015, that should offer an appropriate answer to the growing demand expected till 2020

How to cope with challenges

In the meantime the Oil Companies should be committed that the long term viability of the industry depends not only on a necessary reduction of the refining capacity, but also on restoring its competitiveness. In order to achieve this, it would be appropriate to:

- encourage flexibility and rationalization of unbalanced refining assets through fiscal measures, optimization of remediation liabilities and cooperation agreements between suffering operators;
- challenge the more stringent requirements on biofuel blending;
- review the tax distortions on fuel mix and in general on refining activities;
- try to reduce the differences in environmental laws and regulations between Europe and Asia/Middle East
- impose involvement of Oil Companies in the European Union legislative process.

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