POSTGRADUATE STUDIES –

OIL BUSINESS DURING THE GAS REVOLUTION

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MBA Class

24th of April, 2015

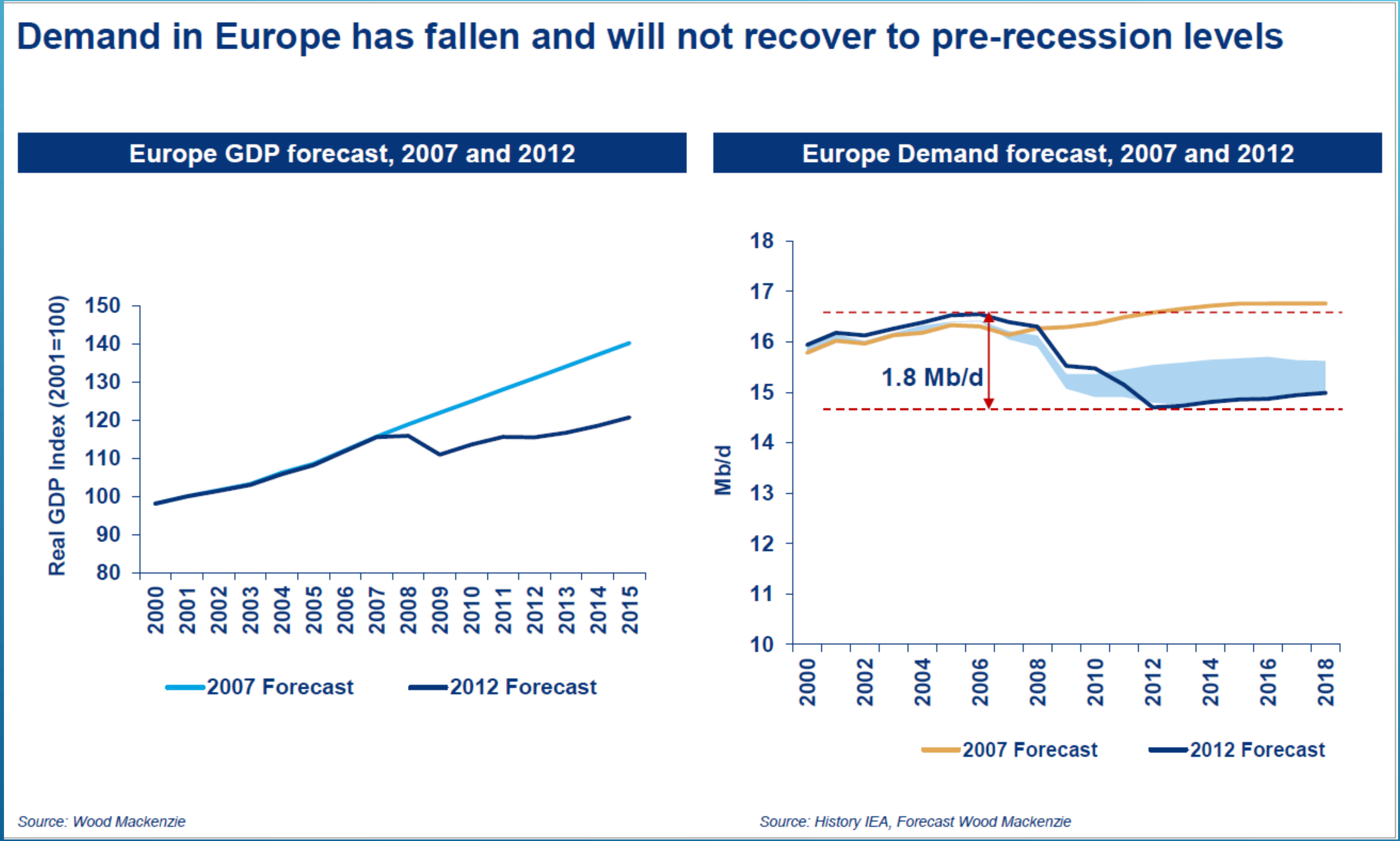
AGENDA

- Overall view
- Oil industry converted into oil & gas industry
- Dynamics of technology shifts
- NLG, LNG, LPG
- GTL

OVERALL VIEW

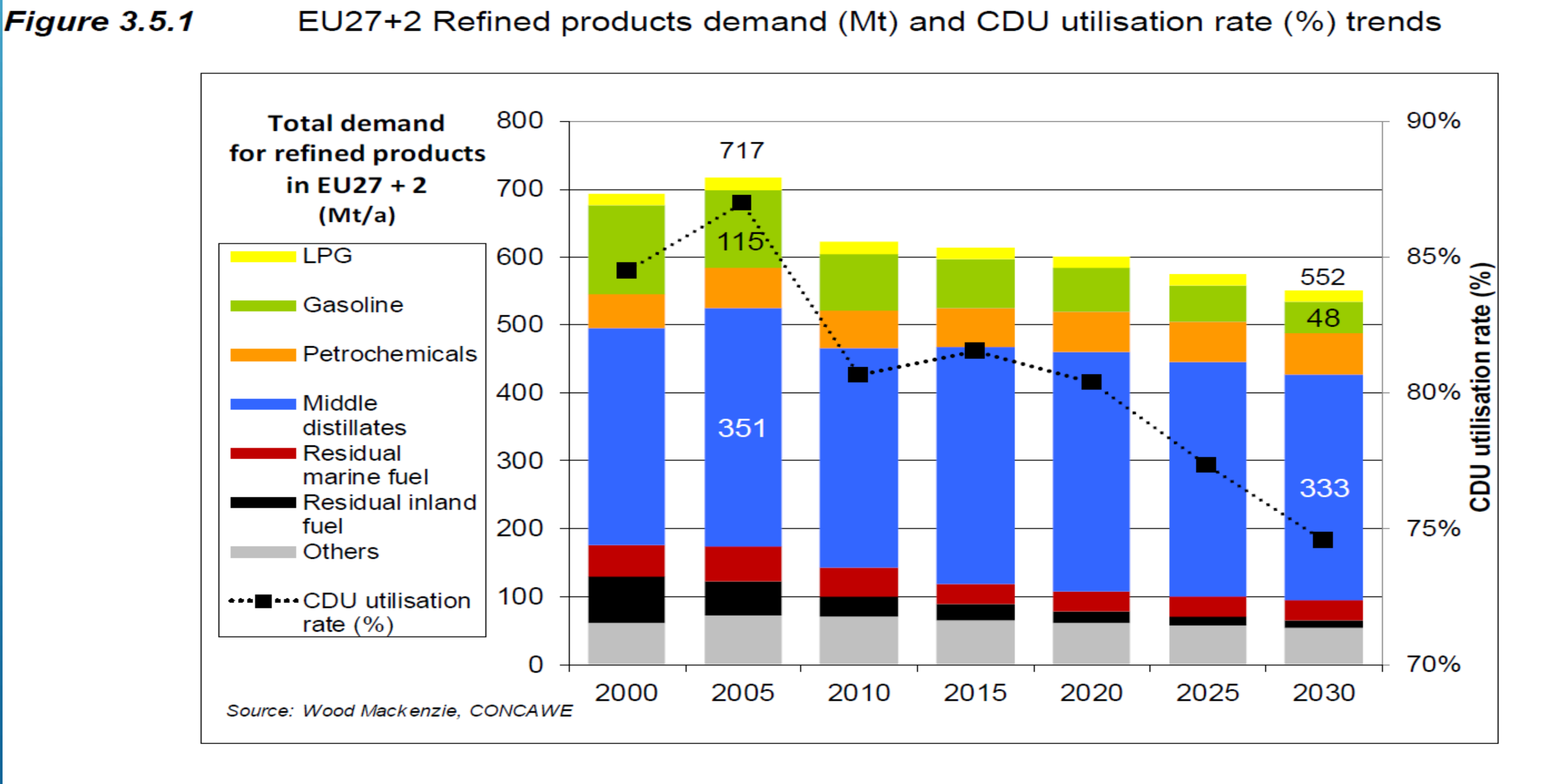
- Refining as a mature business
- Downstream as a poor cousin of upstream
- Complexity of the refining business – joint product issue
- Refining as an energy consumer

FALLING DEMAND FOR OIL BASED PRODUCTS



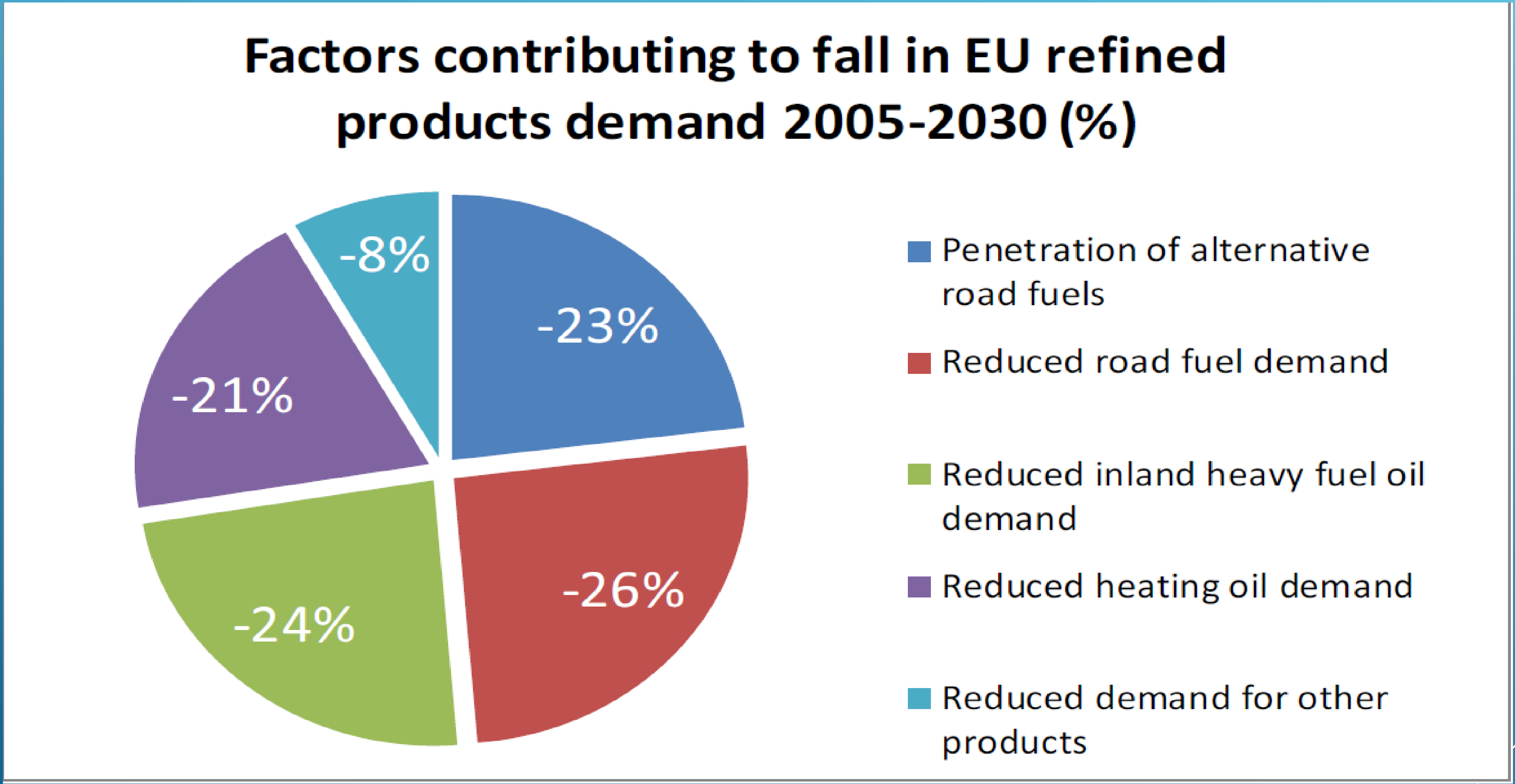
Steve Cooper, „Crude Oil in Europe: Production, Trade and Refining Outllok", WoodMckenzie, London, 2013, p. 14.

EVOLUTION OF THE EUROPEAN DEMAND SIDE – CUTTING ON EDGES



„Oil refining EU in 2020, with perspectives to 2030", Concawe Report 1/2013, p. 21.

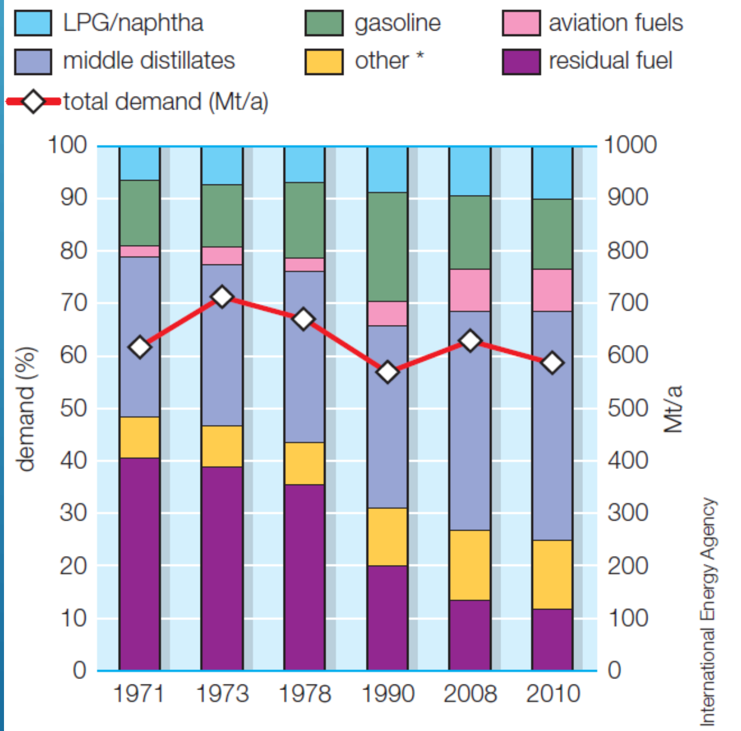
EVOLUTION OF THE EUROPEAN DEMAND SIDE – GASOLINE TO DIESEL



„Oil refining EU in 2020, with perspectives to 2030", Concawe Report 1/2013, p. 19.

EVOLUTION OF THE EUROPEAN DEMAND SIDE – GASOLINE TO DIESEL

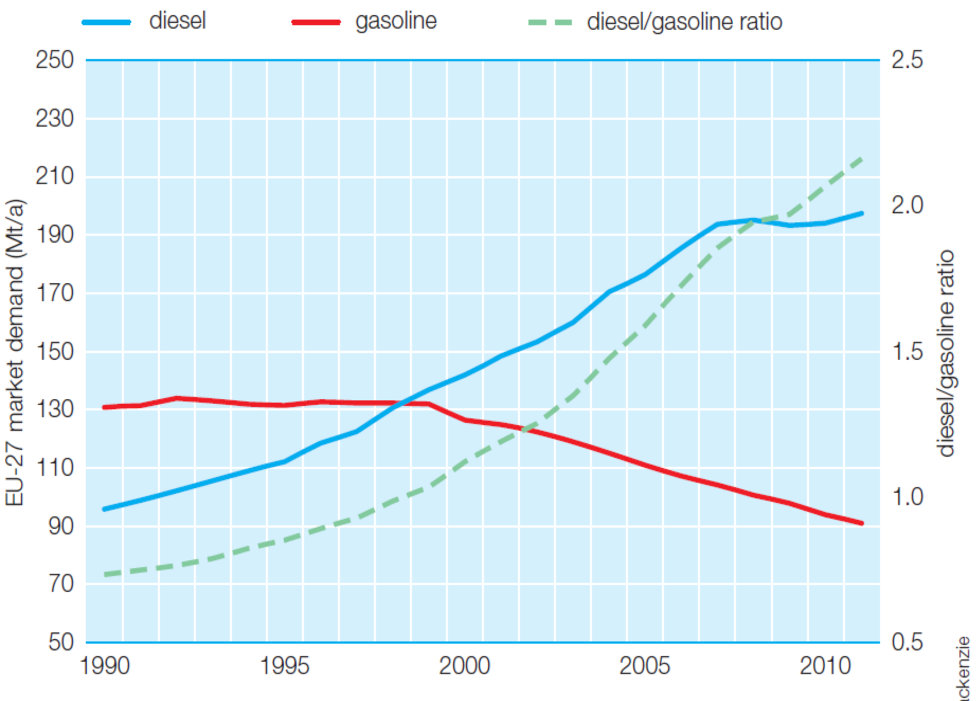
Figure 1 The evolution of petroleum product demand in what was to become the EU-15 over the past 40 years



* The 'other' category mostly consists of speciality products such as lube oils, bitumens, solvents, etc.

Source: International Energy Agency

Figure 2 The diesel to gasoline ratio in EU-27 countries, 1990–2011



Above: the high uptake of diesel passenger cars and strong road freight growth have caused the diesel to gasoline ratio in EU-27 countries to triple over the past two decades.

Source: Wood Mackenzie

„The evolution of oil refining in Europe", Concawe Review, vol. 22/1, 2013, p. 32.

EVOLUTION OF THE EUROPEAN DEMAND SIDE – FUEL QUALITY

Table 1 The quality requirements of EU road fuels have been fundamentally changed in the past two decades

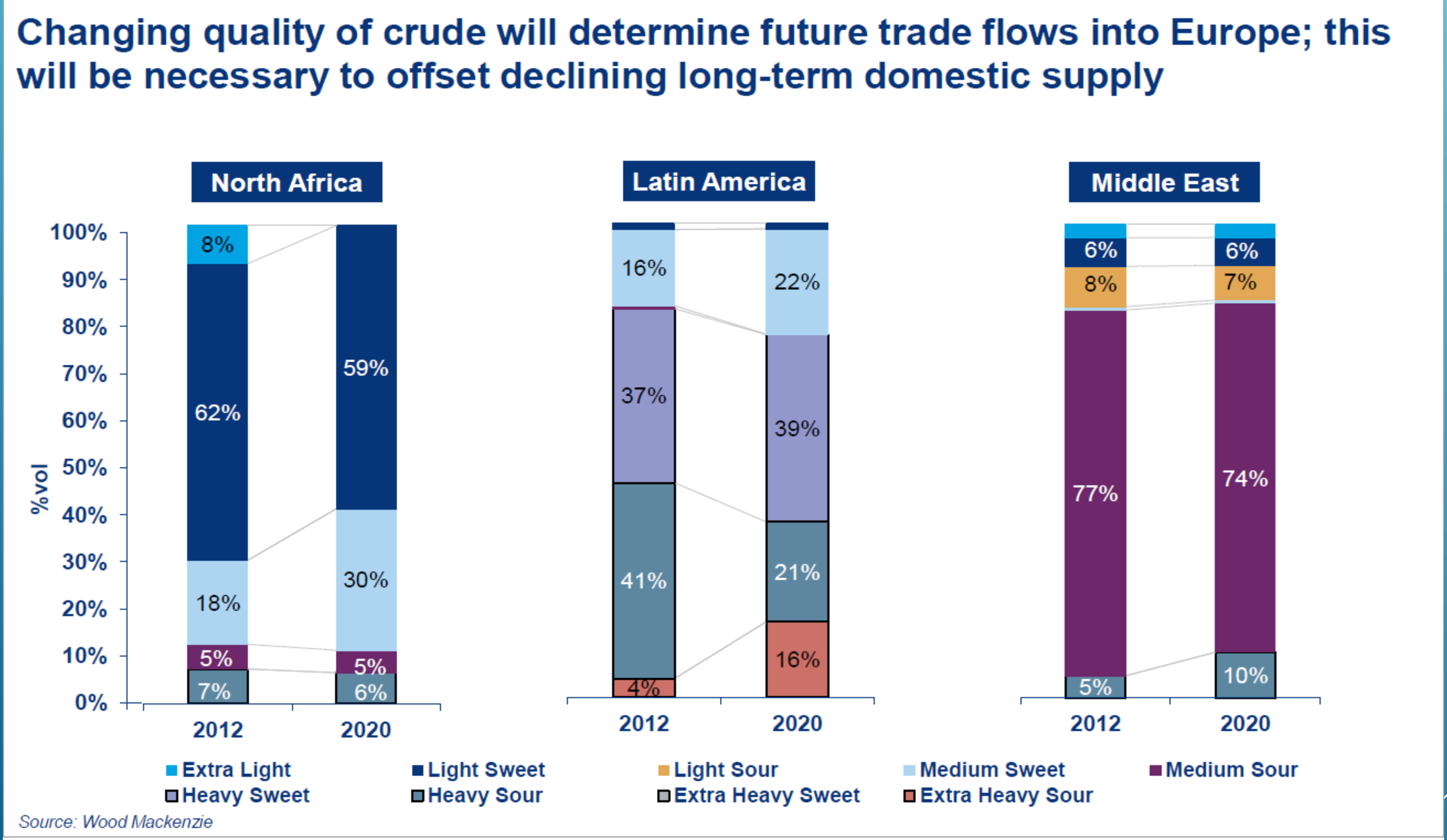
		Year	1994	1995	1996	2000	2005	2009
Unleaded gasoline (standard grade)						**EN228**		
Sulphur	ppm m/m	max	1000	500		150	50/10	10
Benzene	% v/v	max	5			1		
Aromatics	% v/v	max	Not specified			42	35	
Olefins	% v/v	max	Not specified			18		
Oxygen	% m/m	max	2.5[a]			2.7		
Vapour pressure (summer)	kPa	max	up to 80			60[b]		
Diesel (standard grade)						**EN590**		
Cetane Index		min	46					
Cetane Number		min	49			51		
Sulphur	ppm m/m	max	2000		500	350	50/50	10
Density	kg/m	min	820					
		max	860			845		
T95	degrees C	max	370			360		
Polyaromatic hydrocarbons	% m/m	max	Not specified			11		
Lubricity	µm @ 60°C	max	Not specified		460			

[a] Up to 3.7% at Member State discretion. Individual limits apply to specific compounds.

[b] 70 kPa maximum allowed in Member States with arctic or severe winter conditions.

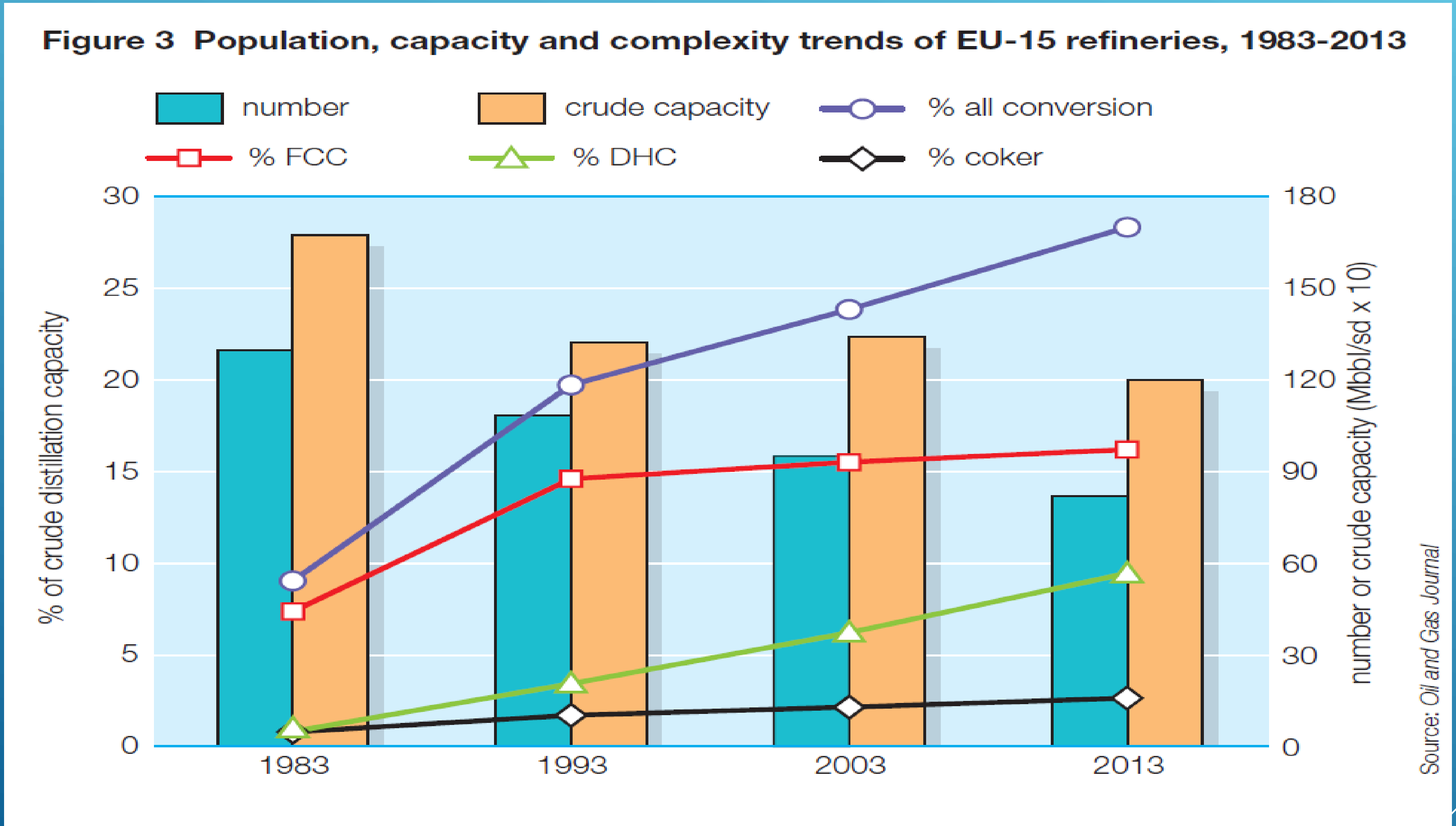
„The evolution of oil refining in Europe", Concawe Review, vol. 22/1, 2013, p. 33.

EVOLUTION OF THE CRUDE SUPPLY AROUND EUROPE



Steve Cooper, „Crude Oil in Europe: Production, Trade and Refining Outllok", WoodMckenzie, London, 2013, p. 12.

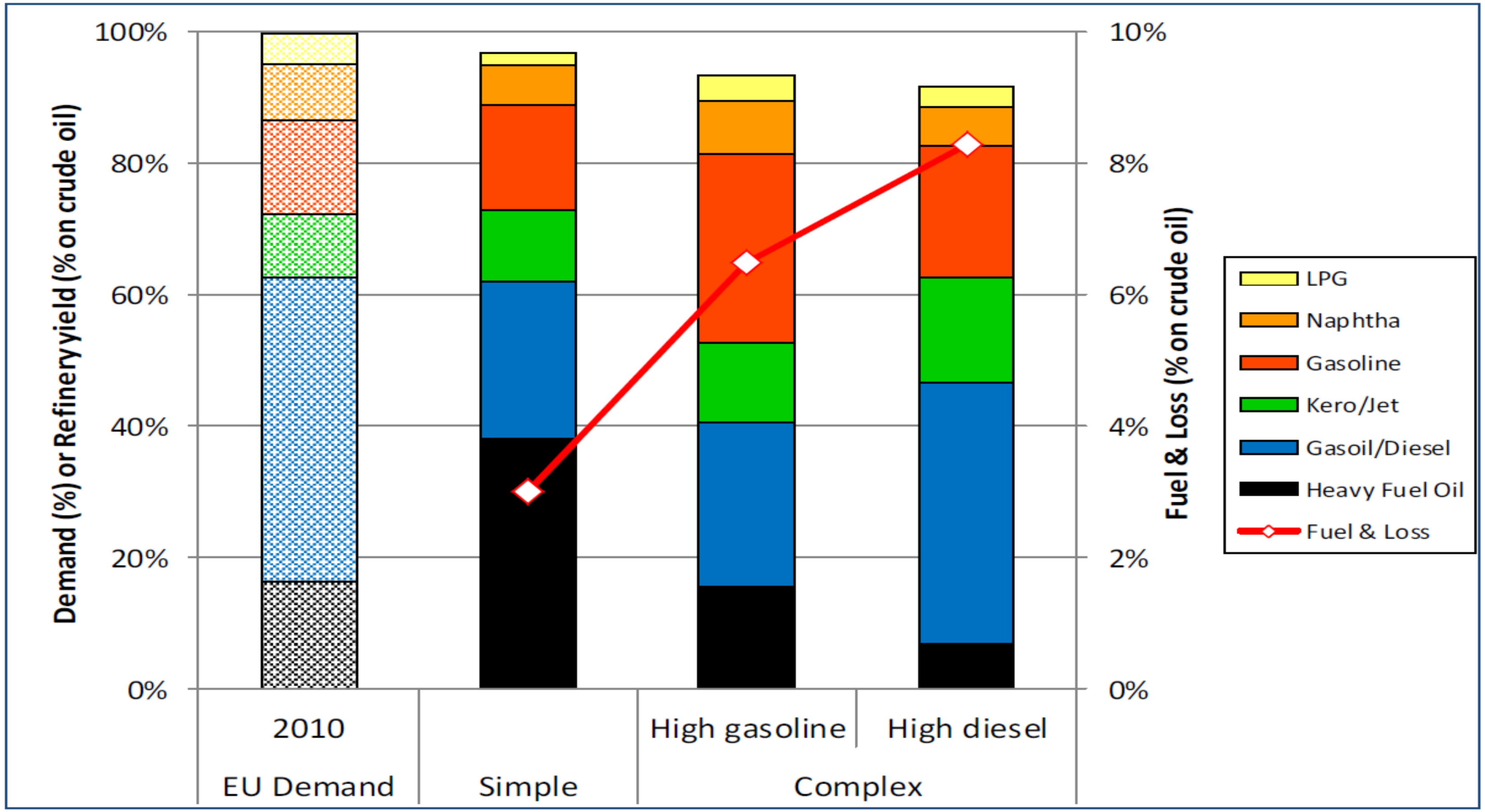
THE EUROPEAN REFINERIES – EVOLUTION OF CAPACITY



„The evolution of oil refining in Europe", Concawe Review, vol. 22/1, 2013, p. 34.

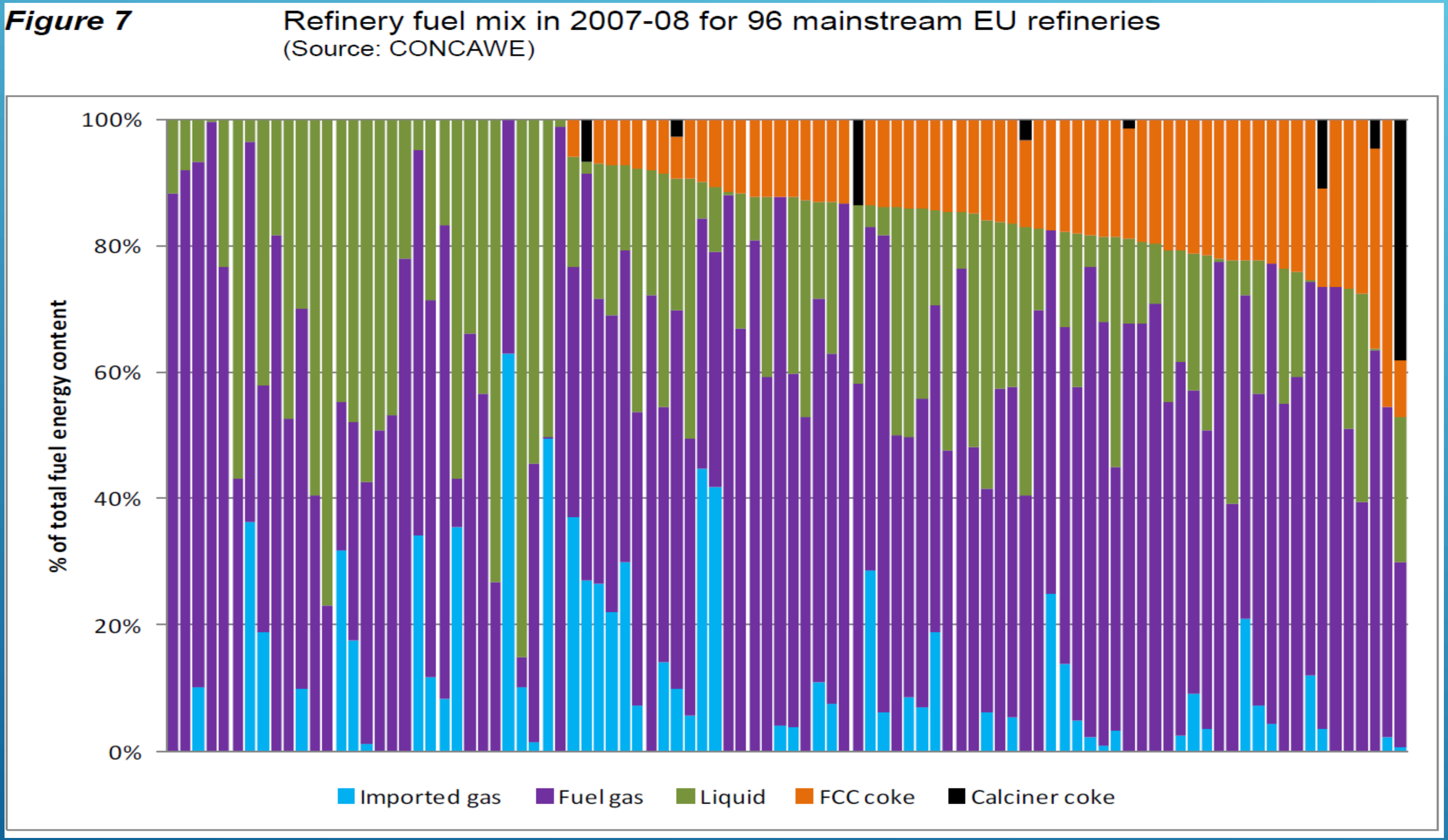
REFINERIES AS ENERGY CONSUMERS

Figure 3 Typical EU refinery fuel consumption as % of yield in simple and complex refineries



„EU Refinery Energy Systems and Efficiency", Concawe report no 3/2012, p. 4.

NATURAL GAS AS A KEY EXTERNAL ENERGY SOURCE FOR REFINERIES



„EU Refinery Energy Systems and Efficiency", Concawe report no 3/2012, p. 11.

CONCLUSIONS

- Refining in Europe - a mature business with declining demand
- Key pressures, beyond falling demand:
  - Diesel/Gasoline ratio forcing conversion up
  - growing energy costs pushing conversion costs up
  - both driven by EU policies
- Majors leaving the business
- Independents too weak to hold pressure
- NOCs ready to step in

OIL BUSINESS CONVERTED INTO “O&G”

- Natural gas technical challenges
- Gas based market products
- Oil & gas majors

ATTRACTIVENESS OF NATURAL GAS VS CRUDE OIL

- It is more difficult to bring to markets:
  - Through more complex logistic systems (Kandyoti, 2012)
  - Through conversion to LNG, LPG or GTL
- Deposits are more dispersed and “safe” countries possess bigger share in reserves

EXPANSION OF OIL BUSINESS INTO GAS

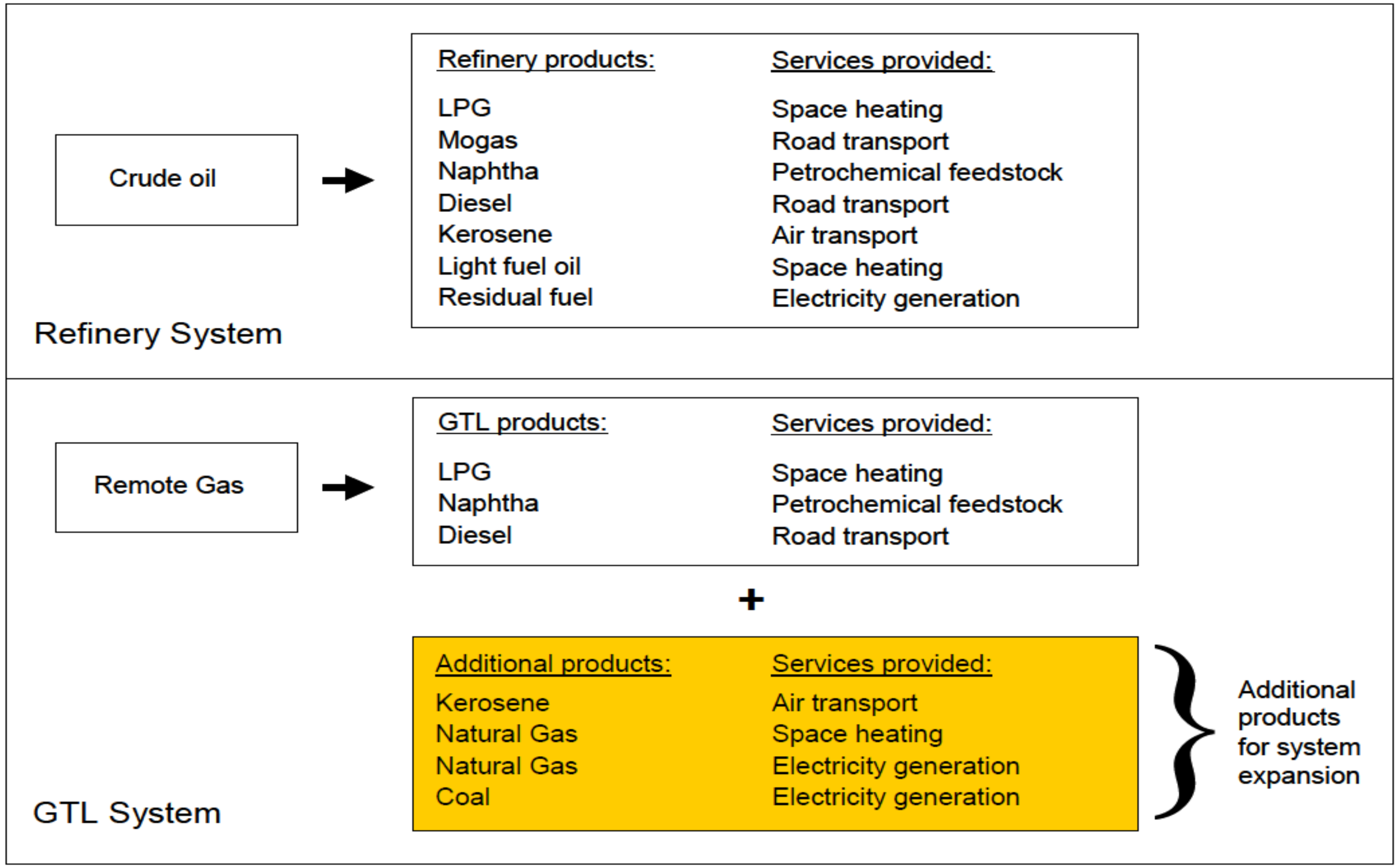
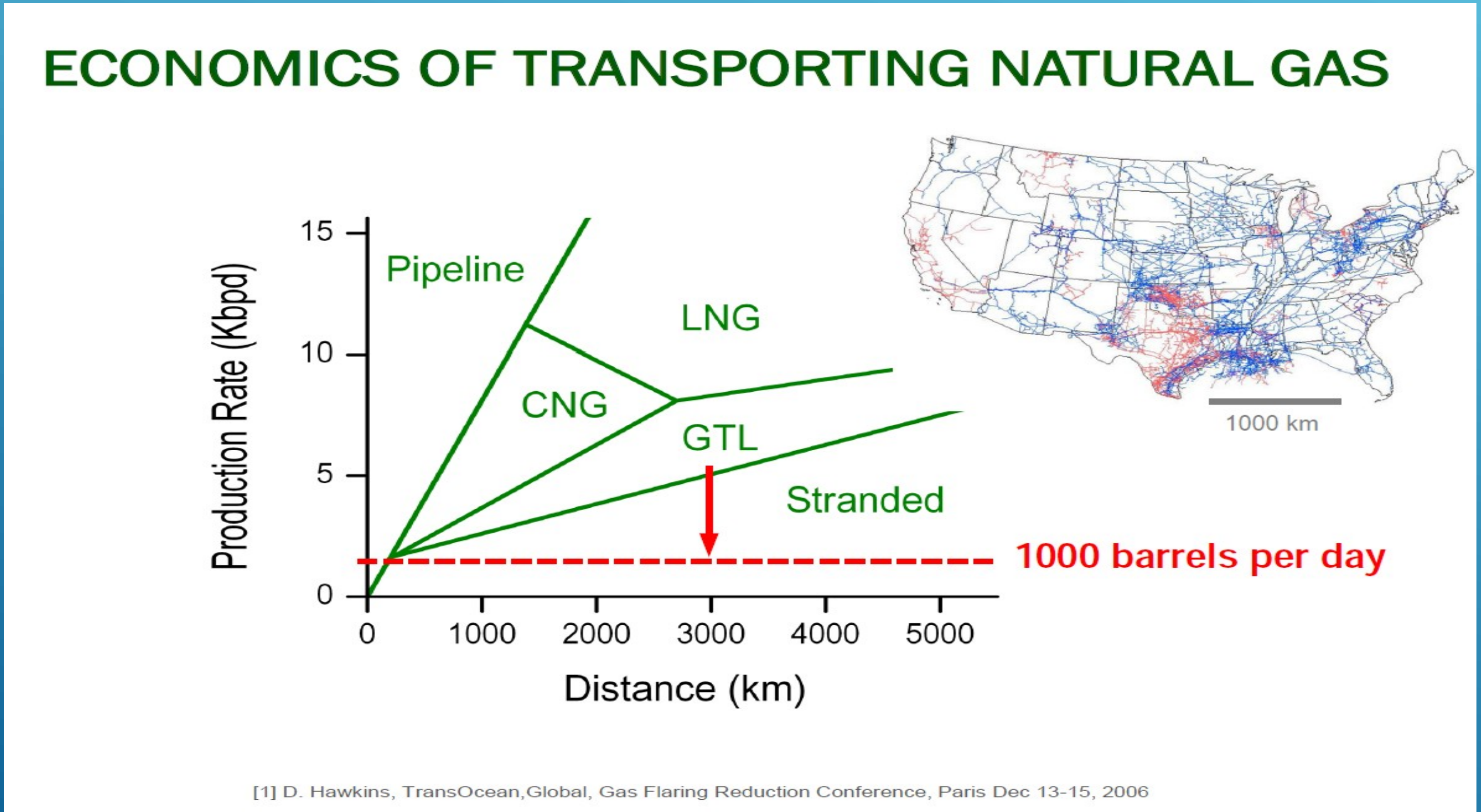


Figure 1: Illustration of the systems studied (Source: modified from PwC, Sasol Chevron study)

Five Winds International 2004: *Gas to liquids. Life cycle assessment synthesis report*. page. 13

LOGISTIC IS THE KEY ISSUE



OIL & GAS MAJORS

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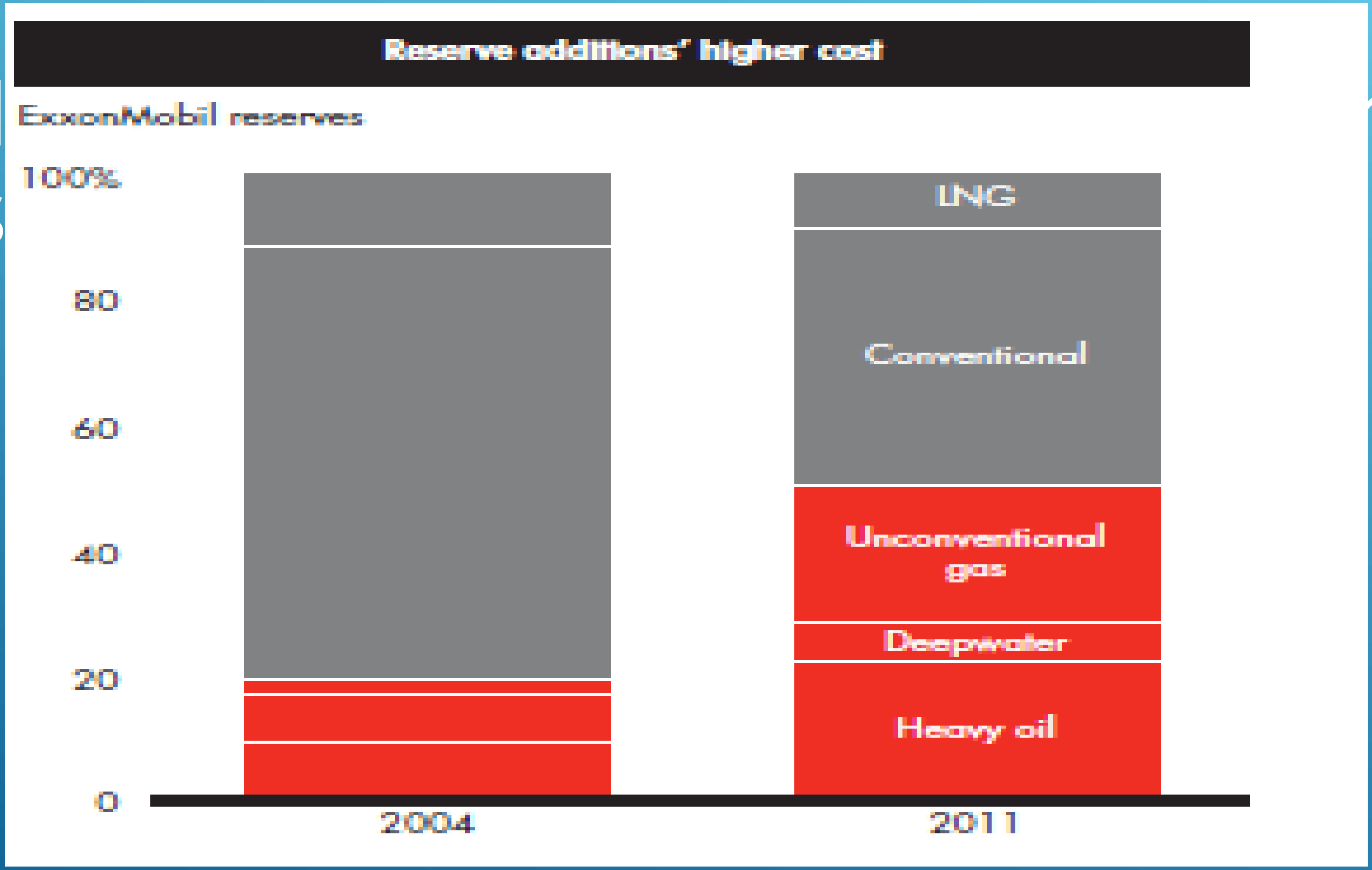


GAS TAKEOVERS SURPASSING OIL TAKEOVERS

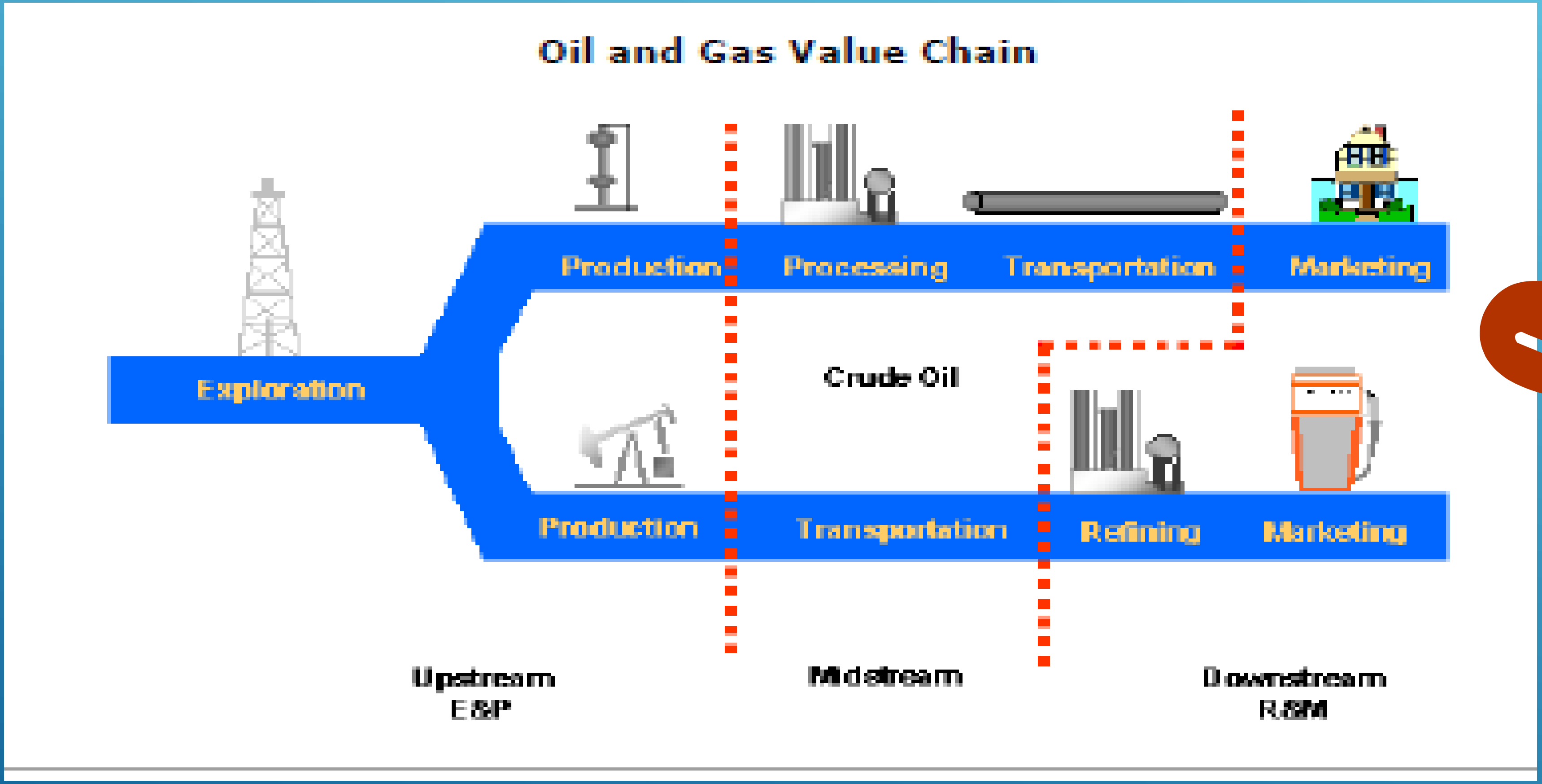
- Mega buyouts now regard natural gas: Exxon buying XTO Energy for 41 bn USD (2009/2010) and Shell to make 70 bn USD bid for British Gas (2015). The former was driven by shale gas, the latter by LNG

- The purchase of BG is also a reminder that the oil majors are really oil and natural gas majors. BG will give Shell major LNG positions in Australia, and to a lesser extent in East Africa. By 2018, Shell will have twice the liquefaction capacity as ExxonMobil. *Oilprice Newsletter, 2015.04.11*

DYNAMICS OF TECHNOLOGY SHIFTS

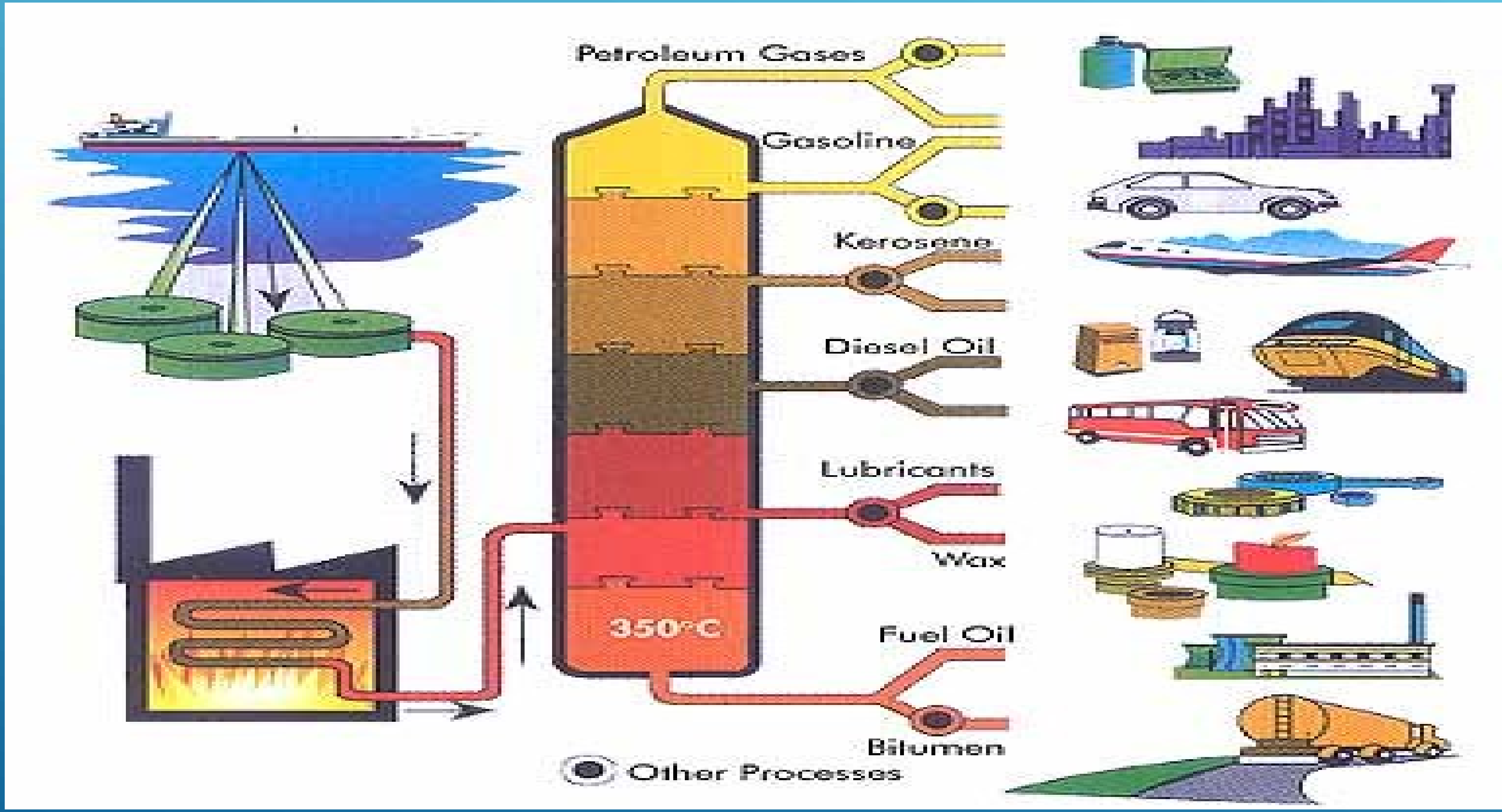
- Innovation in Upstream
- Breakthrough downstream innovations
- Research & Development
- Oil is natural but money made on it are anthropogenic

AT FIRST GLANCE OIL IS A VERY SIMPLE BUSINESS (…)



It’s, after all, about converting crude in a field into a fuel in an engine.

(…) BUT MORE DEEPER INSIGHT REVILES SOME COMPLEXITY (…)



(…) CONTINUING DOWN TO THAT LEVEL

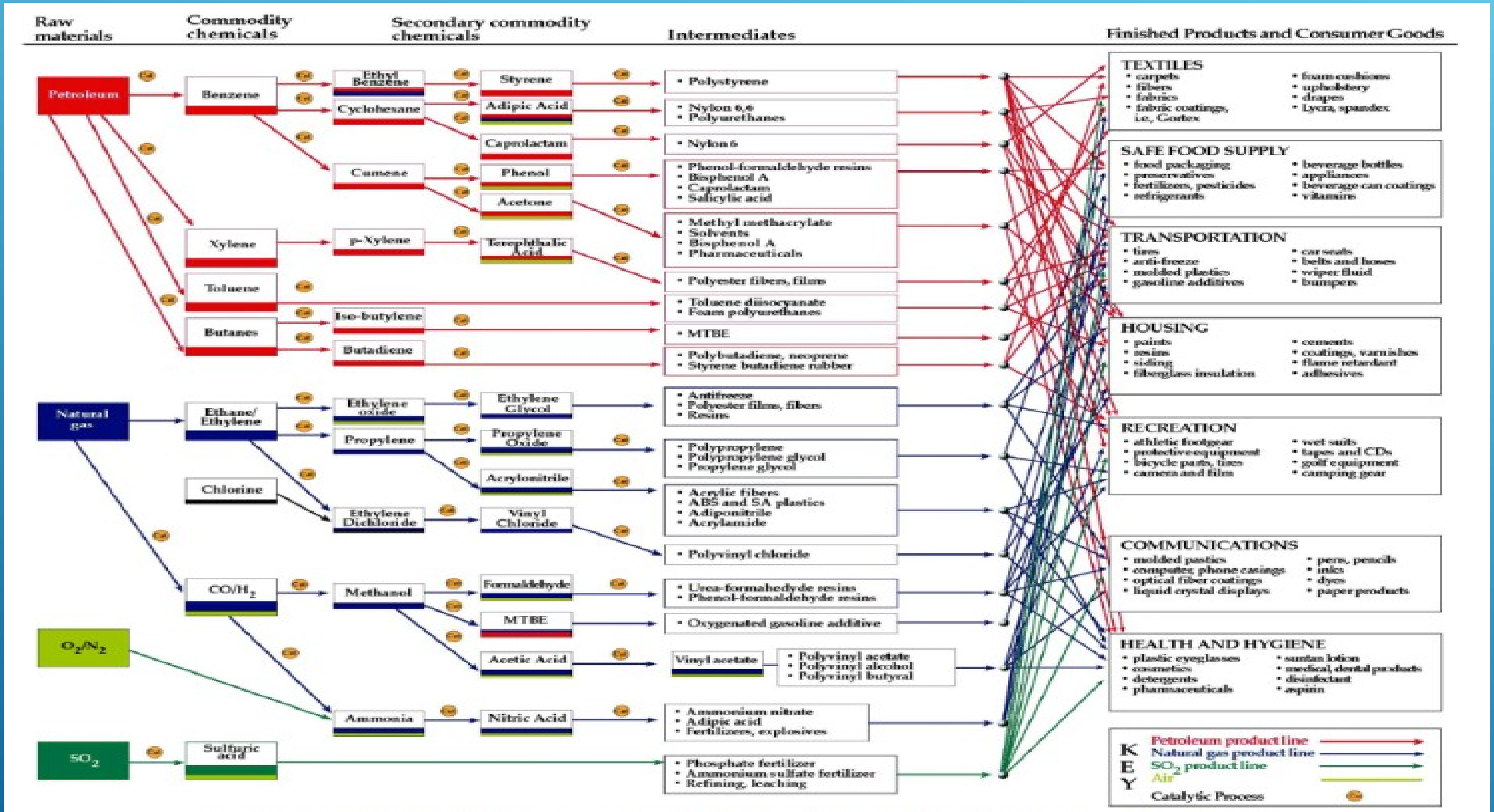


Figure 2 – An Example of a Flow-Chart for Products from Petroleum-based Feedstocks

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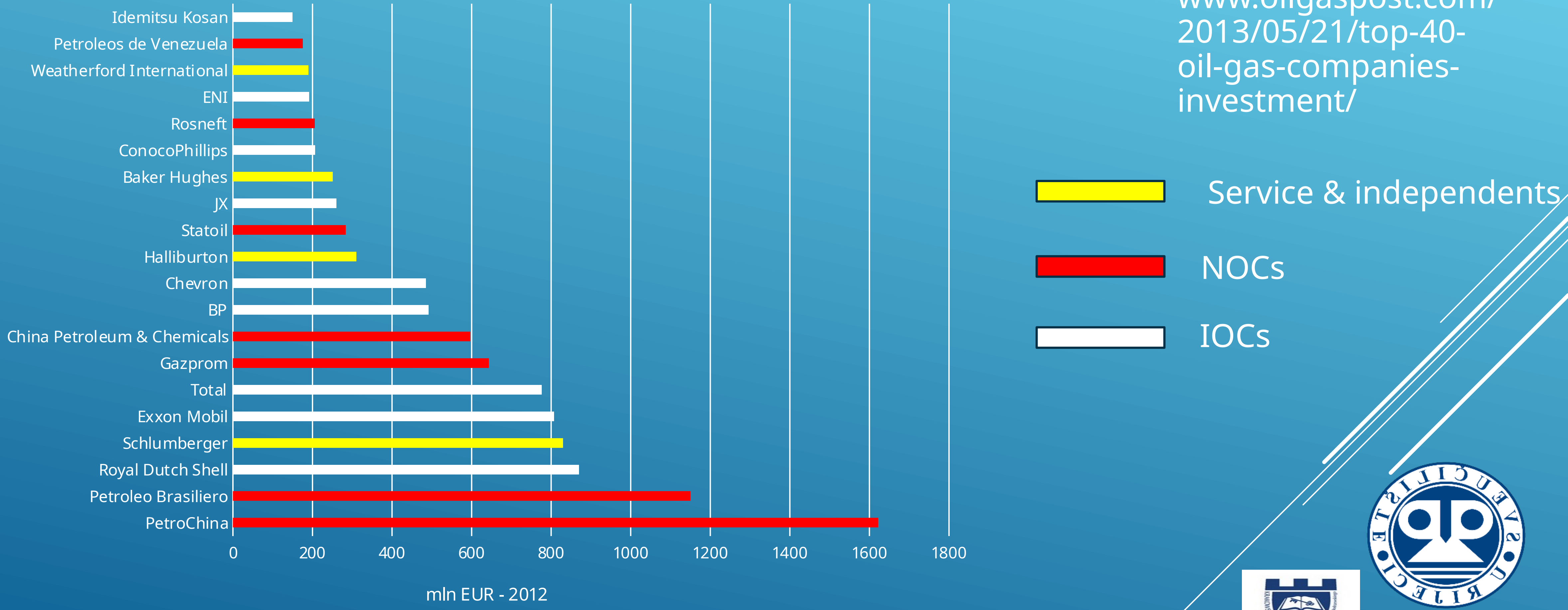
http://denmarkusmgreentour.wordpress.com/page/2/

R&D EXPENDITURES OF OIL & GAS INDUSTRY

http://www.oilgaspost.com/2013/05/21/top-40-oil-gas-companies-investment/



UPSTREAM INNOVATION

- „For the upstream exploration and production (E&P) industry, the story of the last decade has been one of remarkable resilience, extraordinary innovation (...)”:
- Increasing application of computing methods in seismic analyses
- Horizontal drilling (initiated at commercial scale in 80s)
- Sophisticated reservoir modelling and simulating
- Hydraulic fracturing

Kibsgaard Paal, „A decade of upstream technology innovation” in: „Addressing Global Energy Challenges” World Petroleum Council, 2013, page 74.

BREAKTHROUGH DOWNSTREAM INNOVATIONS: HYDROCRACKING

- Hydrocracking (eg. Converting heavy, long hydrocarbon strings into short light ones) was first patented in Russia in 1881
- Todays hydrocracking units are based on catalytic processes developed 1942-1947. These were first processes capable, at commercial scale, to change natural product structure as defined by crude
- There would be no diesel revolution without hydrocracking

BREAKTHROUGH DOWNSTREAM INNOVATIONS: GTL

- Origins of GTL technology can be traced to pre II World War period.
- Its first commercial debut after a long period in Shell's Bintulu GTL plant in Malaysia in the early 1990s.
- The Pearl Gas to Liquids (GTL) joint venture project of Shell and Qatar Petroleum - the world's largest GTL plant and in fact one of the biggest refineries though with a natural gas as a feedstock, started 2011/2012
- Consequences remain to be seen but definitely will be far going

BREAKTHROUGH DOWNSTREAM INNOVATIONS: SUMMARY

- Both Hydrocracking and GTL share some common properties:
  - inward process orientation;
  - customers needs definition developed without customers;
  - no new products as a direct result;
  - huge capital expenditures.

CUSTOMER RELATED INNOVATIONS

- Often developed outside industry (petrochemicals by IG Farben, Dow, ICI)
- Promoted by niche players
- Not obviously linked to the refinery business
- Relatively low volume
- Possible if focus of R&D is redirected from internal processes to customer needs

UNATTRACTIVENESS OF CUSTOMER RELATED INNOVATIONS FOR OIL MAJORS

- Low volumes:
  - even if margins per unit are high overall margins are low;
  - oil products are joint products – almost any change in one specification requires at least some alternations across the portfolio;
- Cost of managing risk is very high since applications are made in businesses distant from Oil & Gas: mechanical industries, pharmacy and food, packaging.

CUSTOMER ORIENTED INNOVATION – VGO SOLVENT EXTRACTION CASE

- Traditionally part of VGO has been converted into two external products: base oil Gr. I and waxes;
- Starting from 90s base oil Gr. I has been gradually replaced by Gr II and Gr III base oils which are derived from hydrocracking residue;
- Official reason: Gr II and III have many functional advantages over Gr. I (which is true, by the way)
- Real reason: the only way to increase Diesel output, all other things equal, is to divert VGO from solvent extraction to hydrocracking – consequently Gr I has to disappear;
- Proof: the other external products obtained from the solvent extraction are waxes – they in turn can not be obtained from hydrocracking – customers got informed: you will have less waxes and they will be more expensive. Any problem with that. Oh it’s your problem !!!

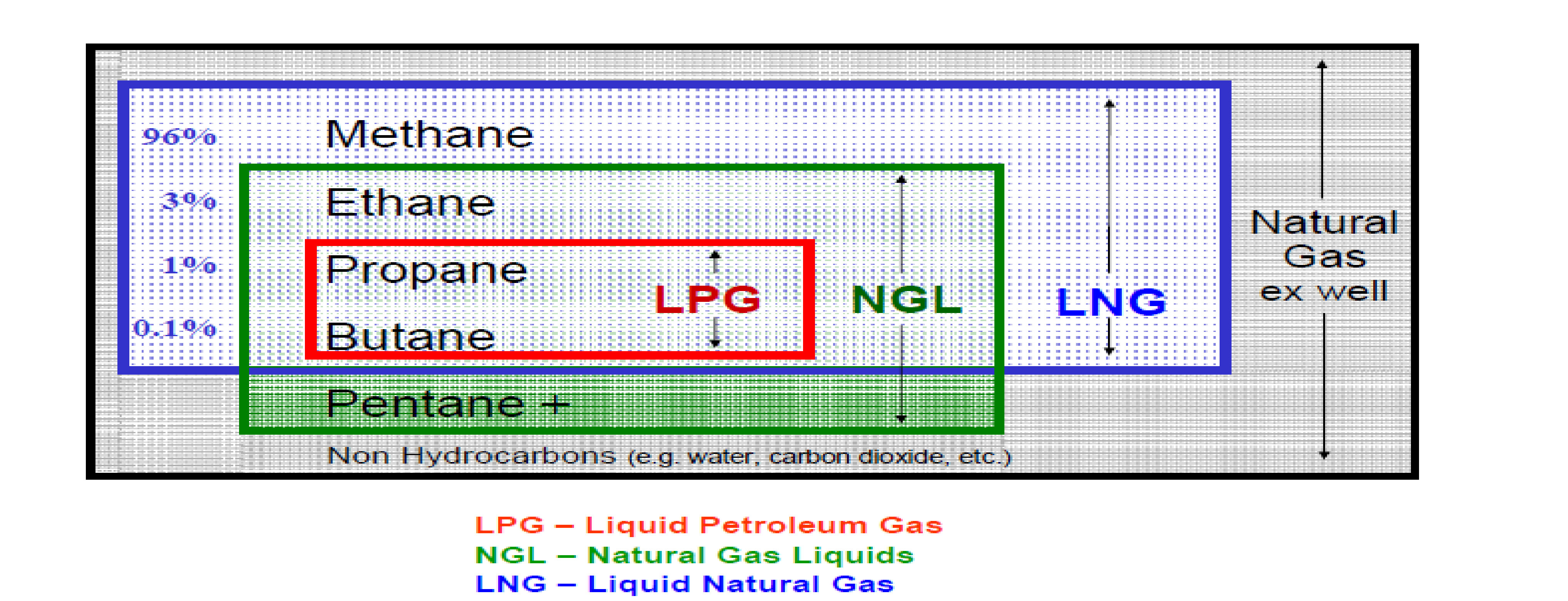
CONCLUSIONS

- R&D in case of Oil Majors is a supplementary internally oriented activity – such is this business
- Product innovations are not on the top of priority lists
- Majors are very good in networking and taking advantages of various alliances
- NOCs have made heavy investments in R&D – results remain to be seen

LPG, LNG, NLG

- LNG – a logistic solution
- LPG and CNG – leap forward transportation fuels
- GTL (discussed separately) – bringing gas to refinery business

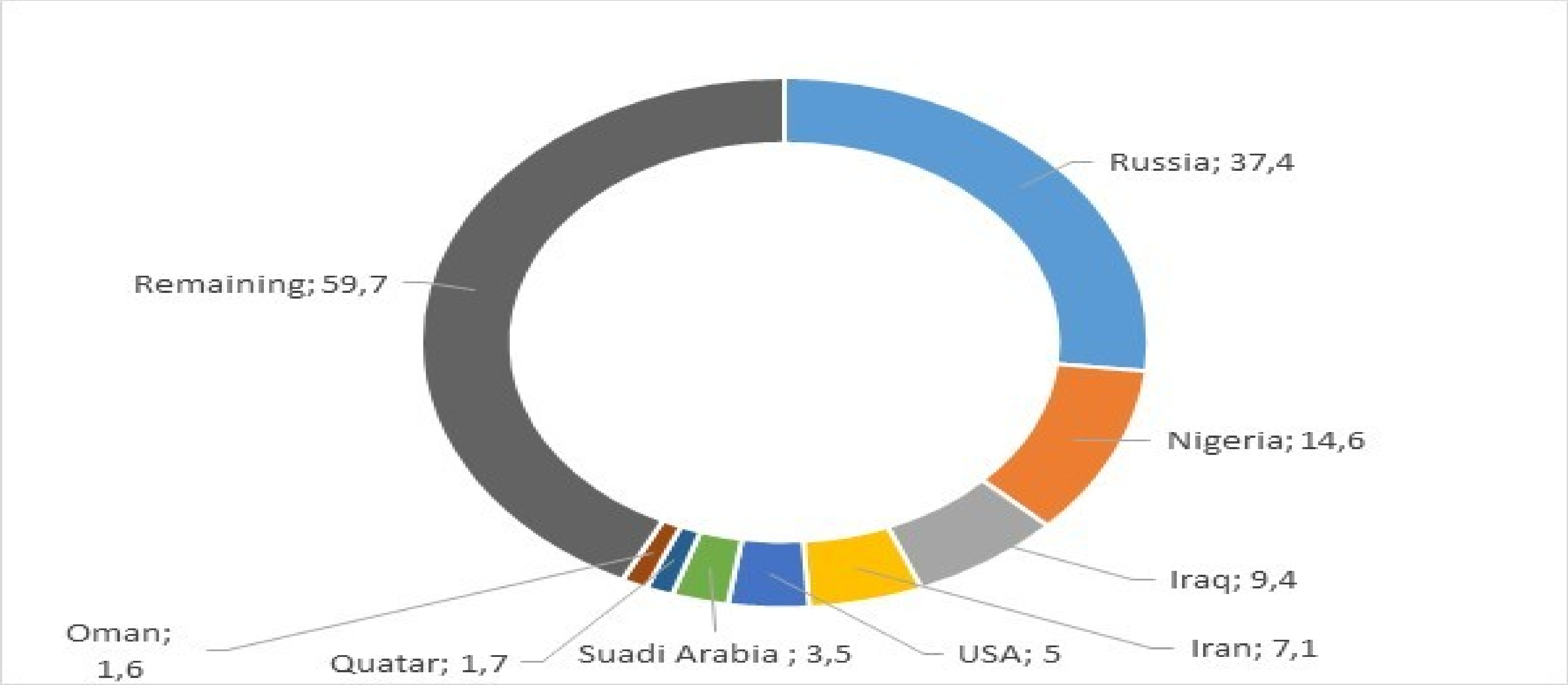
KEY VOCABULARY



- CNG: Compressed Natural Gas used for transportation competing with LPG
- NGL and LNG used as competing mode of movement

ABUNDANT GAS SUPPLY BASE IN SOME DISTANT PLACES

Volumes of gas flared in bcm, 2011.



LNG TECHNOLOGY

- The first LNG plant was built in Arzew, Algeria in 1964 and had a capacity of 400 kT annually.
- The first shipment to Japan, opening East Asian market for LNG occurred in 1969.
- Durr Charles et al. *LNG technology for the commercially minded*. Gastech 2005.

LNG TECHNOLOGY

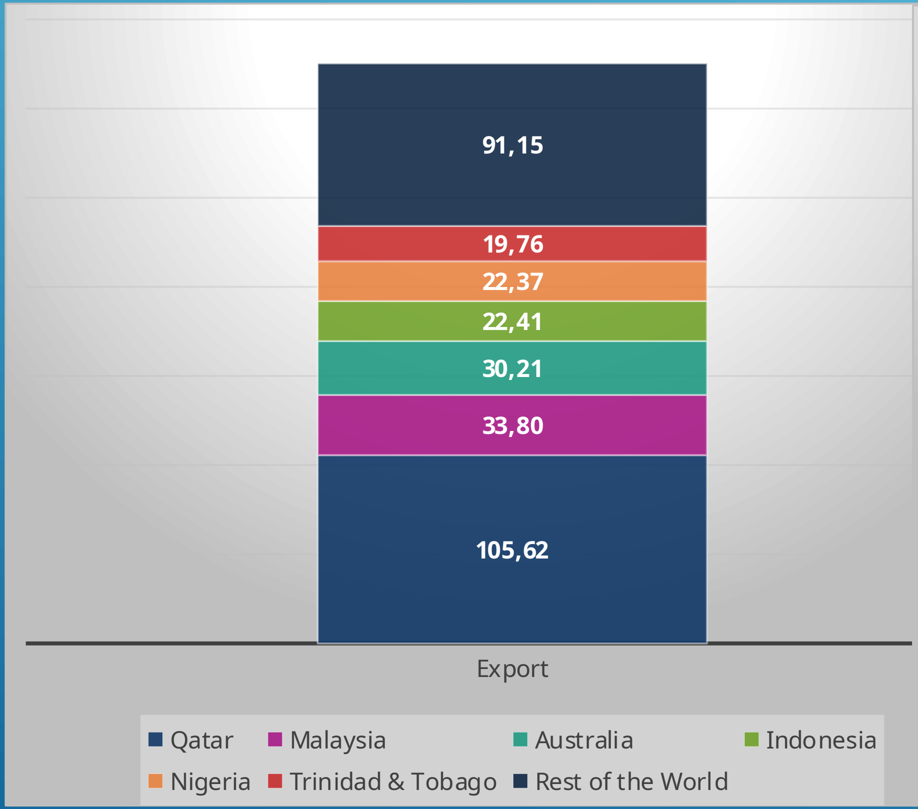
- LNG technology is based on chilling natural gas down to -160 C what reduces the volume by a factor of roughly 600. This volume reduction forms the key advantage for transportation over long distances especially where marine transportation can be used (where pipelines in turn become more expensive).
- However, the low temperature creates a substantial disadvantage:
  - Firstly reducing the temperature of the gas to -160 C requires energy. Typically about 10% of the natural gas delivered to a LNG plant must be burned to provide the energy needed for cooling down.
  - Secondly the refrigeration machinery is expensive as low temperature of processing requires special materials.
  - Thirdly LNG must be stored in tanks made of aluminum, stainless and high nickel steel, or other more expensive specialized materials. In case of natural gas pipelines operating at ambient temperature can be made of carbon steel materials.
- Durr Charles et al. *LNG technology for the commercially minded*. Gastech 2005.

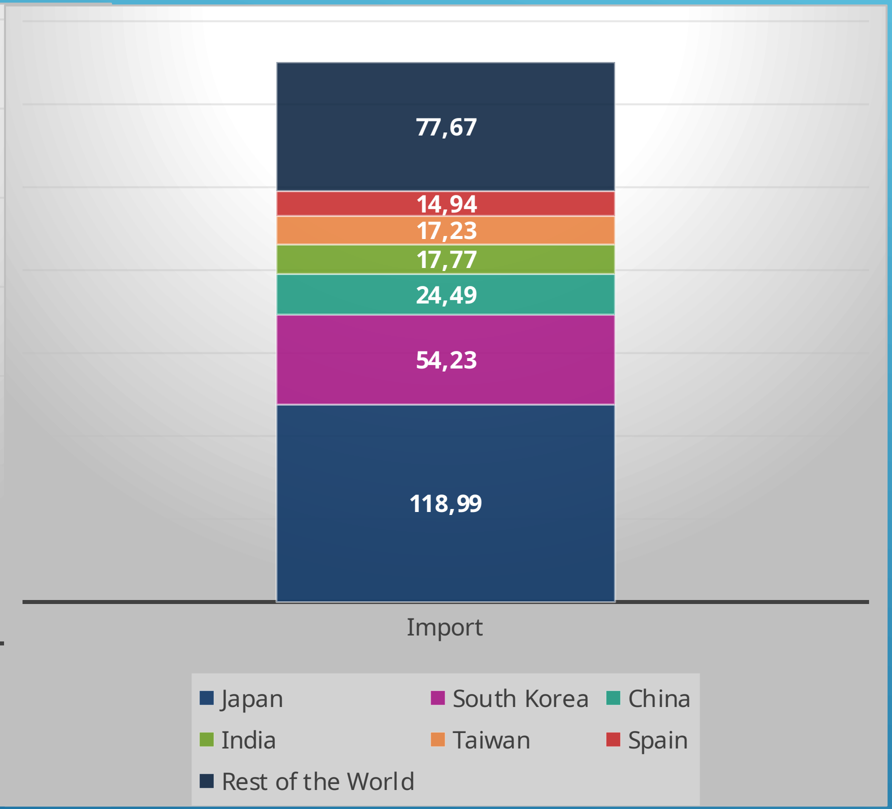
LNG MARKET GLOBALIZATION

- The globalization of natural gas is leading to product specification problems related to “gas interchangeability.”
- Traditionally gas was produced for a local market to meet its respective specifications resulting from equipment and appliances designed for that local specification.
- The key LNG markets: European, Pacific Rim, UK and US are characterized by wide differences in the specifications. This invoking interchangeability problem.
- Typically the gas can come from two sources: associated with oil and non-associated. Associated gas has a high concentration of heavy components and must have propane and butane (also known as liquid petroleum gas, LPG). At some point gas has to be conditioned to final customers’ specifications. Although gas interchangeability is important from gas marketing and technology perspectives, the cost of providing interchangeability is relatively low.
- It looks like the industry is heading in a direction of conditioning the gas at the receiving end. This provides the receiving terminal with flexibility on supply side. Durr Charles et al. *LNG technology for the commercially minded*. Gastech 2005.
- The most fundamental obstacle for LNG growth is the high transportation costs. EIA estimates that liquefaction and forwarding costs from US Gulf Coast to Japan surpass 8 USD/MMBtu thu being twice more than purchasing cost at point of origin Houser, loc. 2454).

LNG TRADE GLOBALLY

LNG trade in bcm equivalent below accounts for less than 10 % of natural gas consumption





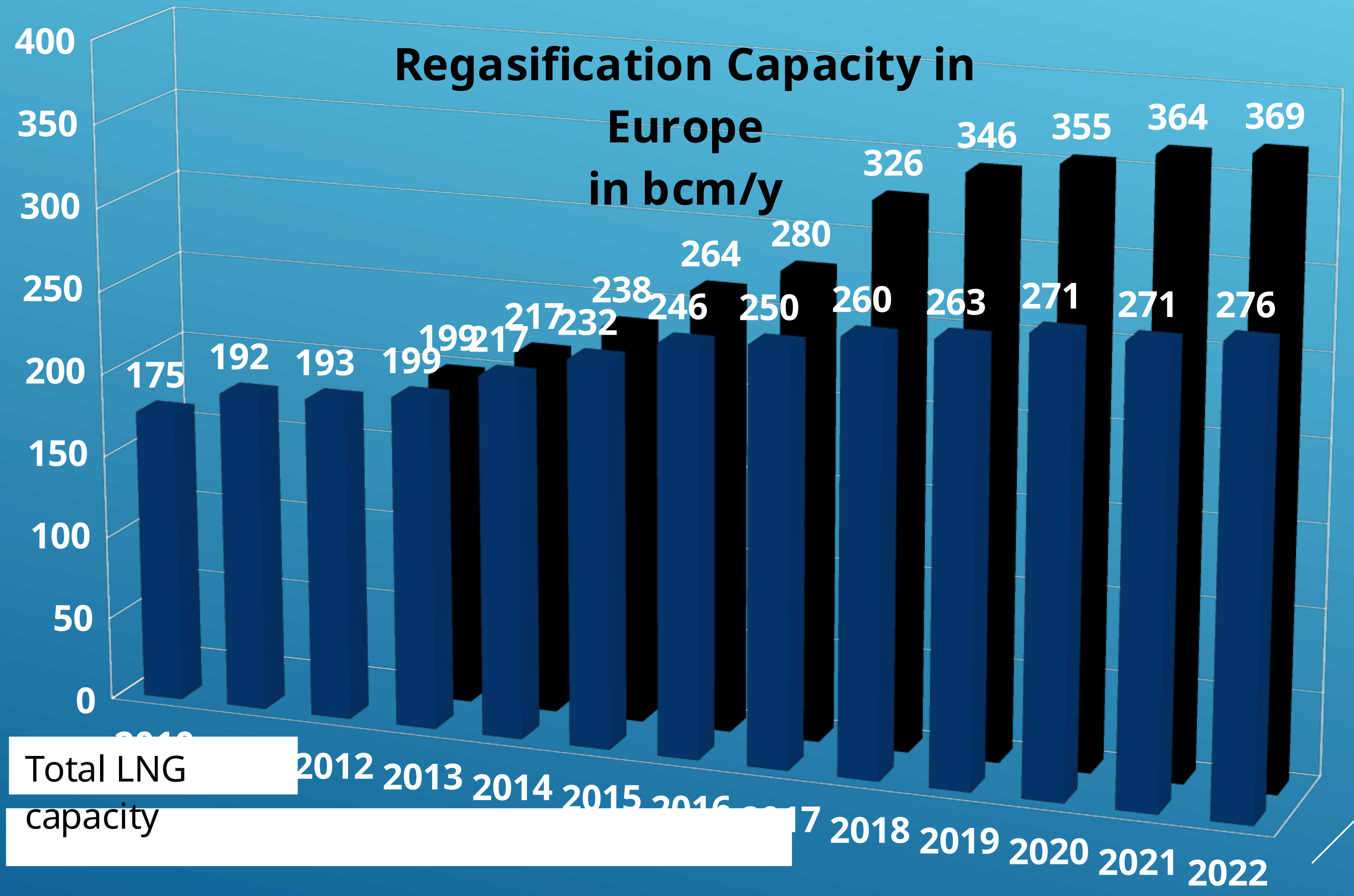
It has been estimated that a LPG terminal with all infrastructure and tankers for 8,4 bcm/year would cost 4 bn USD. *(Kandiyoti, p. 15)*

STATUS OF THE US LNG PLANTS

Magnalia project presentation

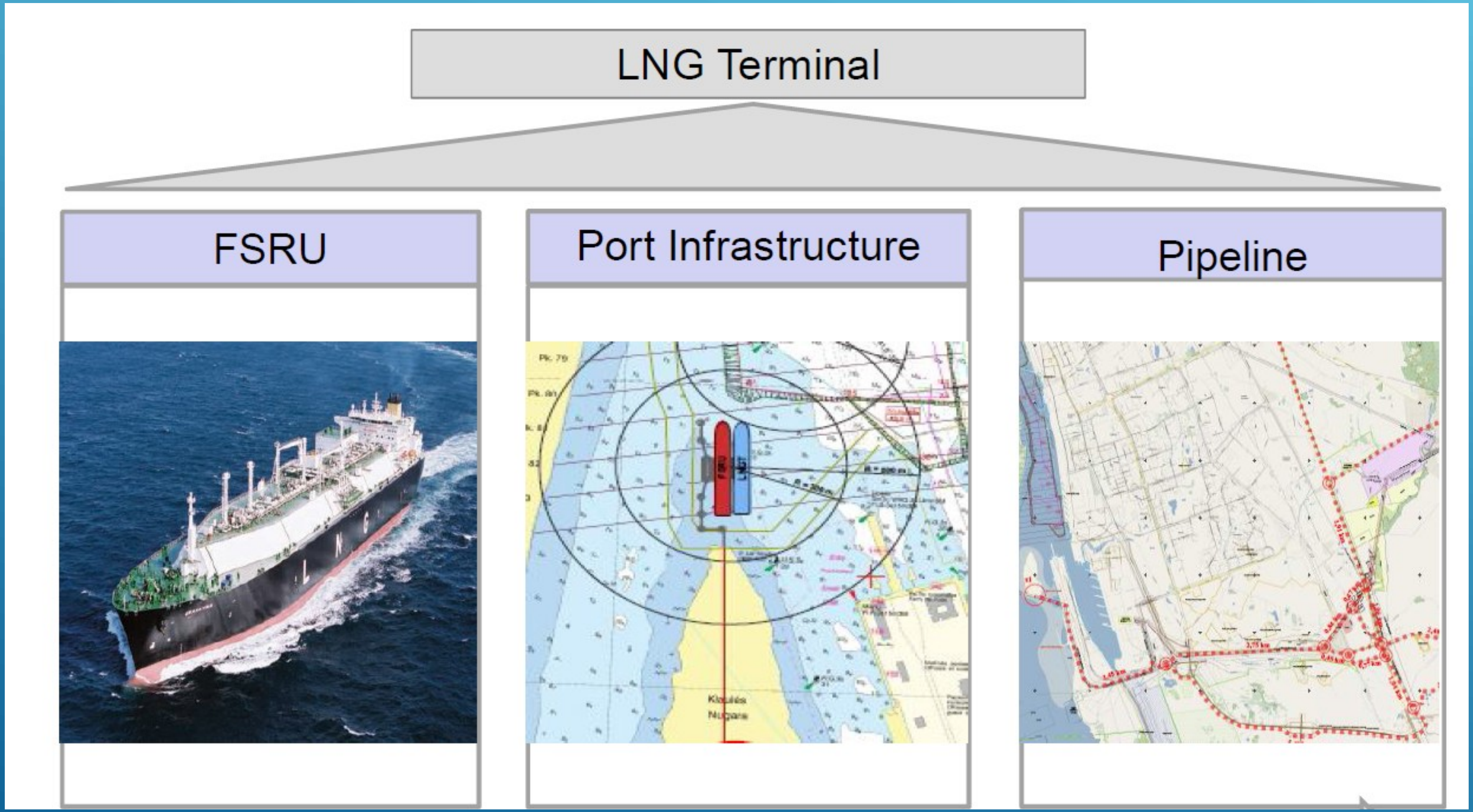
Project (Company)	Location	Sponsor	Capacity mtpa	Offtake mtpa	FTA Approval	Non-FTA Approval	Non-FTA Approval mtpa	First LNG Proposed	FERC Status	FERC 'filing' Date
Sabine Pass	Louisiana	Cheniere Energy	27	19.8	Y	Y	16.9	2015	Approved, Apr-12	Dec-11
Freeport LNG	Texas	Freeport	13.2	13.2	Y	Y	13.8	2017/18	Filing	Aug-12
Lake Charles	Louisiana	Southern Union (BG)	15	15	Y	Y	15.3	2018	Pre-filing	Mar-12
Cove Point	Maryland	Dominion Resources	5.3	4.6	Y	Y	5.9	2017/18	Filing	Apr-13
Cameron LNG, LLC	Louisiana	Sempra Energy	13.5	12.3	Y	Y	13	2017/18	Filing	Dec-12
Jordan Cove	Oregon	Veresen	6	-	Y	N	-	2017/18	Filing	May-13
Oregon LNG	Oregon	LNG Development Co	9	-	Y	N	-	2018	Filing	Jun-13
Corpus Christi	Texas	Cheniere Energy	13.5	-	Y	N	-	2018	Filing	Jun-13
Lavaca Bay FLNG	Texas	Excelerate Energy	4.4	-	Y	N	-	2018	Filing	Feb-14
Magnolia LNG	***Louisiana***	***Liquefied Natural Gas Ltd***	***8***	***-***	***Y***	***N***	***-***	***2018***	***Pre-filing***	***Mar-13***
Southern LNG	Georgia	Southern LNG/Kinder Morgan	2.5	2.5	Y	N	-	tbc	Pre-filing	Dec-12
Gulf LNG	Mississippi	GE Energy & Kinder Morgan	11.5	-	N	N	-	tbc	Pre-filing	Dec-12
Golden Pass	Texas	Exxon Mobil / Qatar Petroleum	15.6	-	Y	N	-	tbc	Pre-filing	Dec-12
CE FLNG	Louisiana	CE FLNG	8.2	-	Y	N	-	tbc	Pre-filing	Apr-13
Gulf Coast LNG	Texas	M S Smith	13.2	-	Y	N	-	tbc	n/a	-
Carib Energy	TBC	Crowley Maritime	0.3	-	Y	N	-	tbc	n/a	-
Main Pass Energy Hub	Louisiana	Freeport-McMoran Energy	24	-	Y	N	-	tbc	n/a	-
Pangea LNG	Texas	Pangea LNG Holdings	8.4	-	Y	N	-	tbc	n/a	-
Waller LNG	Louisiana	Waller LNG Services	1.2	-	Y	N	-	tbc	n/a	-
Gasfin LNG	Louisiana	Gasfin Development	1.5	-	Y	N	-	tbc	n/a	-
Venture Global LNG	Texas	Venture Global	5.1	-	Y	N	-	tbc	n/a	-
Eos & Barca LNG	Texas	Eos & Barca	24.5	-	Y	N		tbc	n/a	-
Total			**230.9**	**67.4**			**64.9**			

LNG CAPACITY IN EUROPE



Source GLE NG

KLAIPEDA LNG PROJECT



Designed for 4bcm annual capacity to meet 100 % of Lithuanian demand.
FSRU may function also as LNG carrier.
Opened in Dec. 2014
Created by politics.

LPG ON CROSSROADS OF CRUDE AND GAS

- LPG is derived either from crude-oil refining or from natural-gas production. At present, more than 60% of global LPG comes from natural gas processing plants.
- LPG is generally refrigerated for large-scale bulk storage and seaborne transportation as a liquid, but it is transported and stored locally in pressurized tanks or bottles (cylinders) (WLPGA 2014).

LPG DIRECT GASOLINE COMPETITOR?

- Has more than 1,000 applications: apart from transportation, it is used in commercial business, industry, farming as well as for domestic heating and cooking.
- By far the biggest consumer is chemical industry with 40 million tonnes per year in US and Saudi Arabia.
- Personal vehicles is the best known and one of the fastest growing sectors, representing almost 9% and 22.87 million tonnes of global LPG consumption worldwide (2010). (WLPGA, 2014)

LPG GLOBAL MARKET

- Total LPG production was 280 million tonnes and only 1/3 of that was traded internationally.
- Asia-Pacific, North America and Middle East count as both producers and consumers with the former being net importer while the latter two running surpluses.
- Shale gas revolution will impact LPG.

GTL TECHNOLOGY

- Historical background of crude oil substitutes based on gases
- Description and key products of GTL technology
- Competitive position of natural gas as feedstock for refinery business
- Conclusions – Will gas substitute crude oil as a primary refining feedstock?

FISHER - TROPSCH

- Two German engineers Fisher and Tropsch successfully developed and patented the process based on a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons in 1925.
- The process was due to German military needs during the II World War . The first plants began operation in 1938, followed by eight other to reach maximum capacity of 570,000 th. Mg year of oil products equivalent, meeting up to 15% of total German needs.

1945 -2010 PERIOD

- After the II World War Fisher – Tropsch synthesis attracted an enormous amount of research and development effort to such extend that a special web-side named www.fischer-topsch.org was created with an aim to collect a comprehensive bibliography of literature, including books, journal articles, conference presentations and government reports as well as related patents.

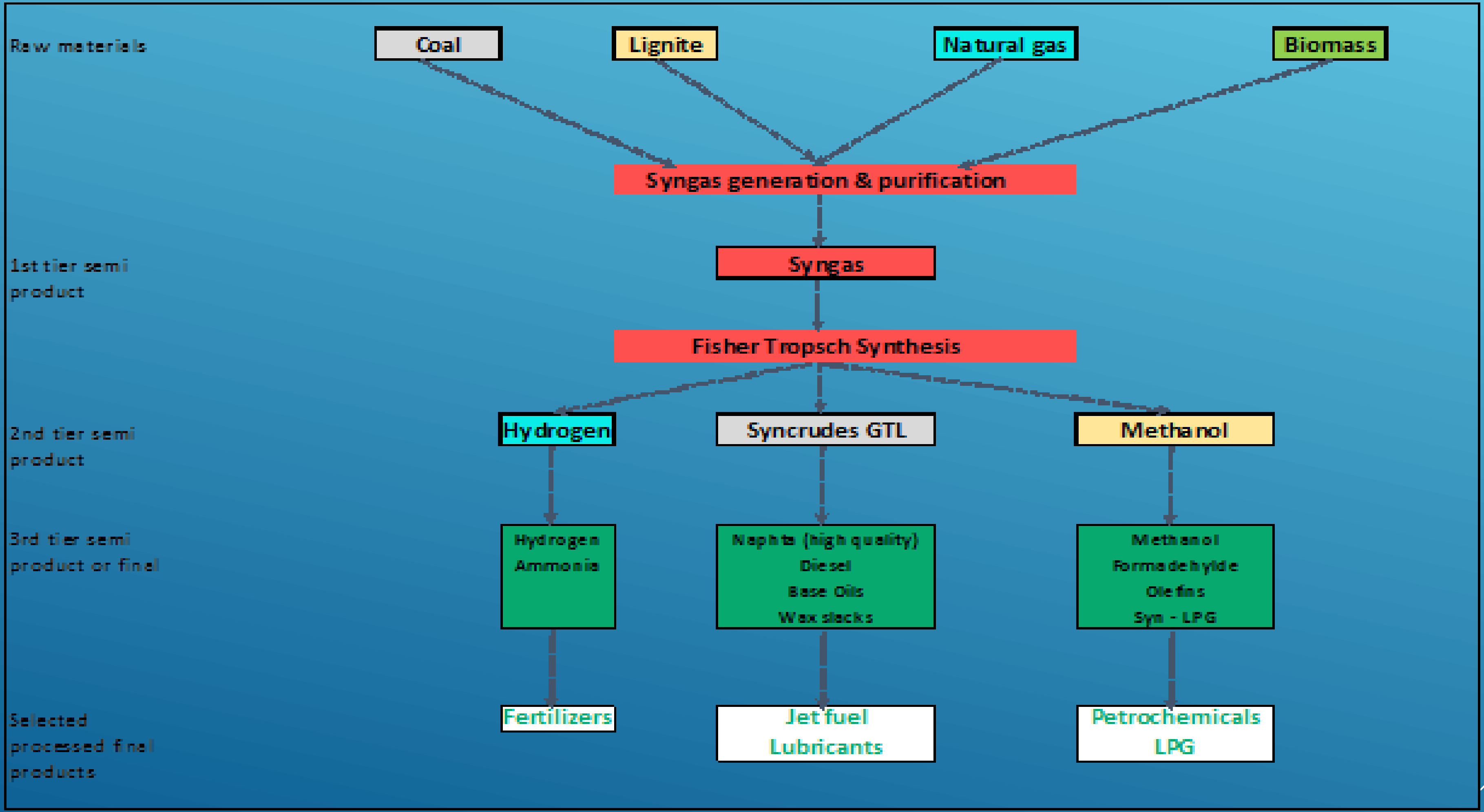
- The popularity of German achievements among academics for a long time had not been matched by their practical application.
- The only country expressing a real interest in a development of Fischer Tropsch technology was Republic of South Africa (RSA) – a country boycotted widely due to its apartheid policy, having extensive coal resources and virtually no oil fields – therefore constituting ideal premises for the technology development. The company in charge for the effort to redevelop Fischer –Tropsch technology was Sasol whose first commercial plant was opened in 1952 in Sasolburg, 40 miles south of Johannesburg.

GTL REINVENTED

Operator	Location	Commencing year	Nameplate capacity (bbl/d)	Construction costs (USD 1 000 K)
Shell	Bintulu/Malasya	1993	12,000	1,500
Sasol	Sasolburg/RSA	1994	5,600	n/a
Shell	Bintulu/Malasya	2006	2,700	n/a
Sasol/Chevron	Oryx/	2006	34,000	1,500
Shell	**Pearl/ Qatar**	**2011**	**140,000**	**20,000**
Chevron	Escravos/Nigeria		34,000	10,000
Source: Based on (EIA 2013, p. 9)				

- Three plants in the United States—in Lake Charles, Louisiana; Karns City, Pennsylvania; and Ashtabula, Ohio—are proposed. Of these, only the Lake Charles facility is a large-scale GTL plant.

GTL VALUE CHAIN



GTL R&D

- Research and development trends have to address the following challenges :
  - capital cost reduction as, even by energy and refinery standards Fischer – Tropsch is a very capital intensive technology;
  - expanding feedstock base through development of efficient least-cost gasification technologies for biomass, coal etc.;
  - improving selectivity and catalyst lifetime.
- GTL is still a nascent technology with potential for improvements

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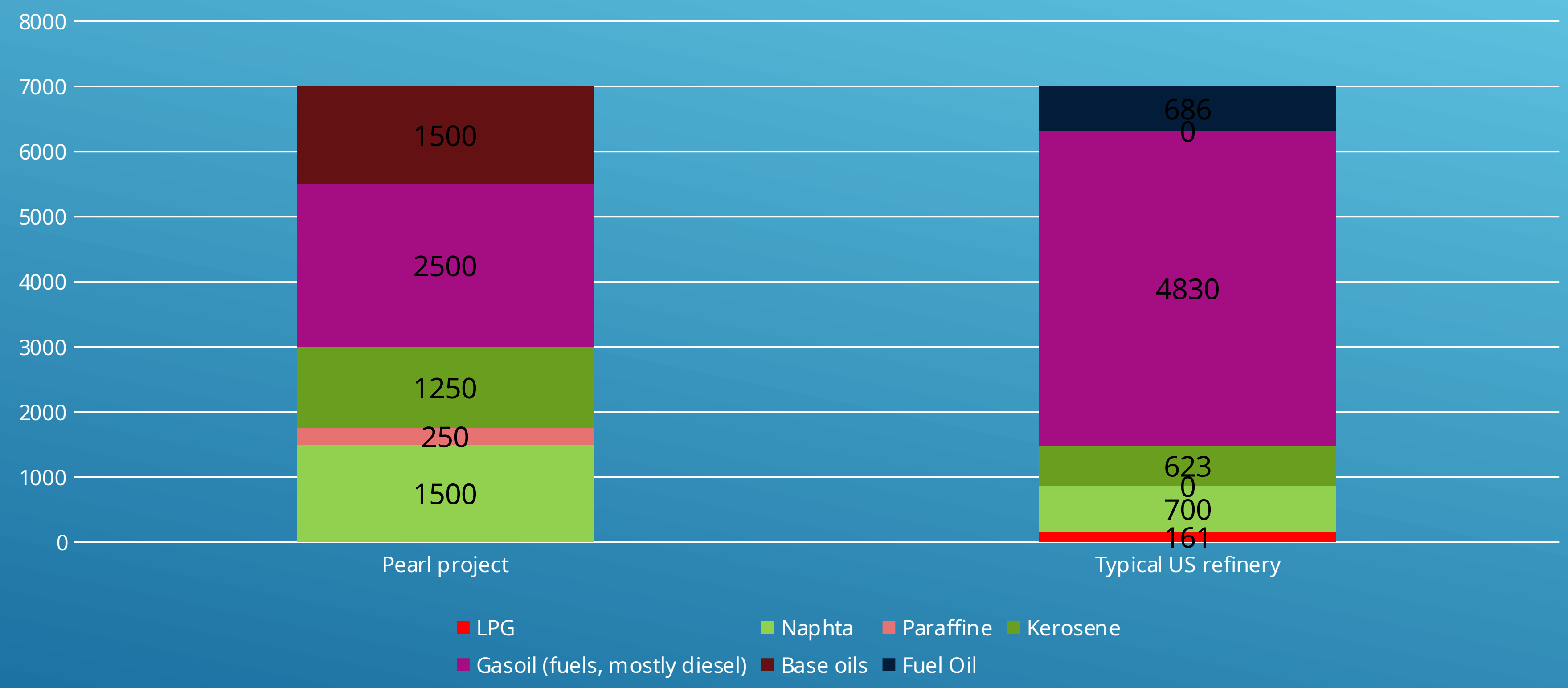
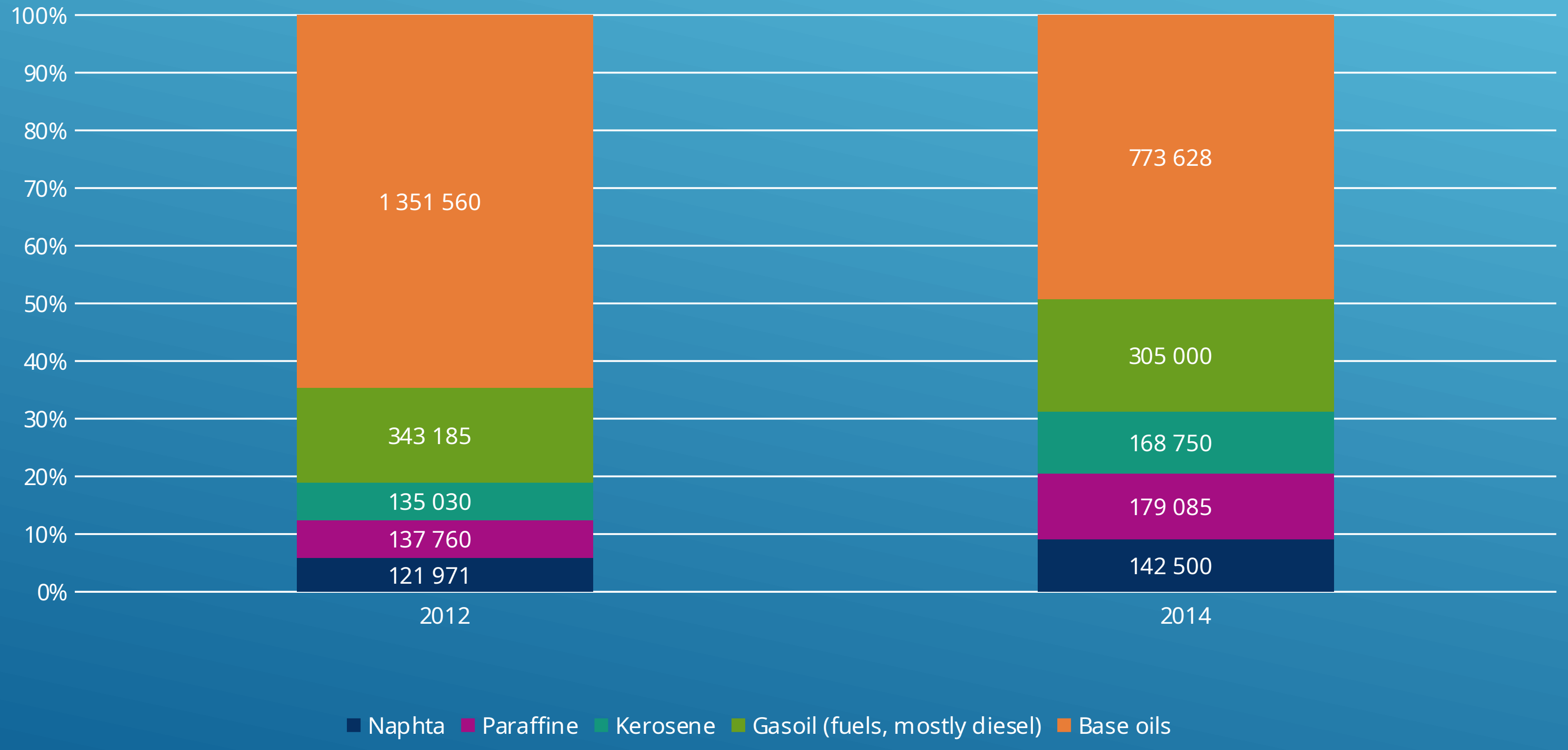
GTL PRODUCT SLATE



GTL exchanges 2 300 kT generic fuel for 1 500 kT Group III base oils and additional 800 kT naphta

PEARL VALUE DRIVERS

- Share in total premium over the crude equivalent value (own estimates, k USD)



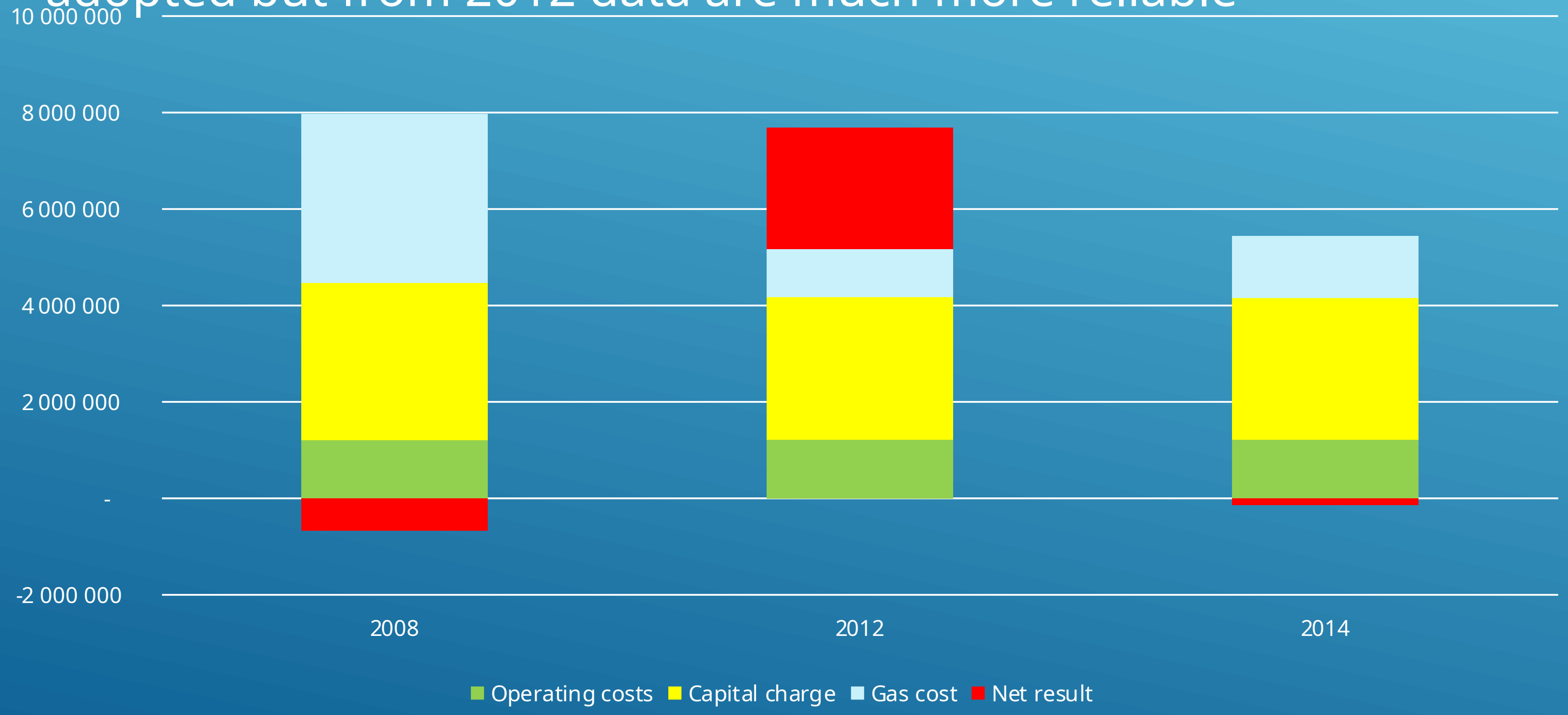
PEARL'S MISFORTUNES

- Cheap crude oil.
- Cheap Group III base oils.
- Attractive LNG.
- Capital overspendings.

Not given for ever but second and third seem to be structural.

PEARL ECONOMICS

- Key economic factor based on own estimates (k USD)
- Most probably for 2008 real Quatar prices were much below quotations adopted but from 2012 data are much more reliable



GTL ALTERNATIVE OPTIONS

- Mini plants:
  - The University of Oxford came with a very active catalyst capable to work only with small quantities. In a similar environment the Pacific North West Laboratory in the USA invented a new type of chemical reactor. These two inventions seem to offer a clear advantage of small scale GTL installation oriented towards diesel productions.
  - Claims are made that the cost of such product can be as low as 70 % of traditionally obtained diesel

- Units built into existing refineries. Synergies:
  - the potential availability of CO_2,
  - the use of a hydrocracker for upgrading (with potential of up to 75 % reduction in investment expenditures),
  - the availability of existing utilities, offsites and services.

CONCLUSIONS

- Full scale GTL natural gas based plants still under question mark.
- Crude-gas spread a key factor determining GTL future.
- GTL, as a nascent technology, still has potential for (revolutionary) improvements.
- Three paths for GTL development are clear:
  - Bio based GTL.
  - Micro GTL.
  - Refineries built-in GTL installations.