WOC 1
Exploration & Production of Natural Gas
SG 1.2

Assessment of Global Reserves and Resources of Natural Gas

3rd WOC-1 Meeting

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WOC-1 Leadership:
Chair: Mr. Denis Dinelli
Vice-Chair: Mr. Adif Zulkifli
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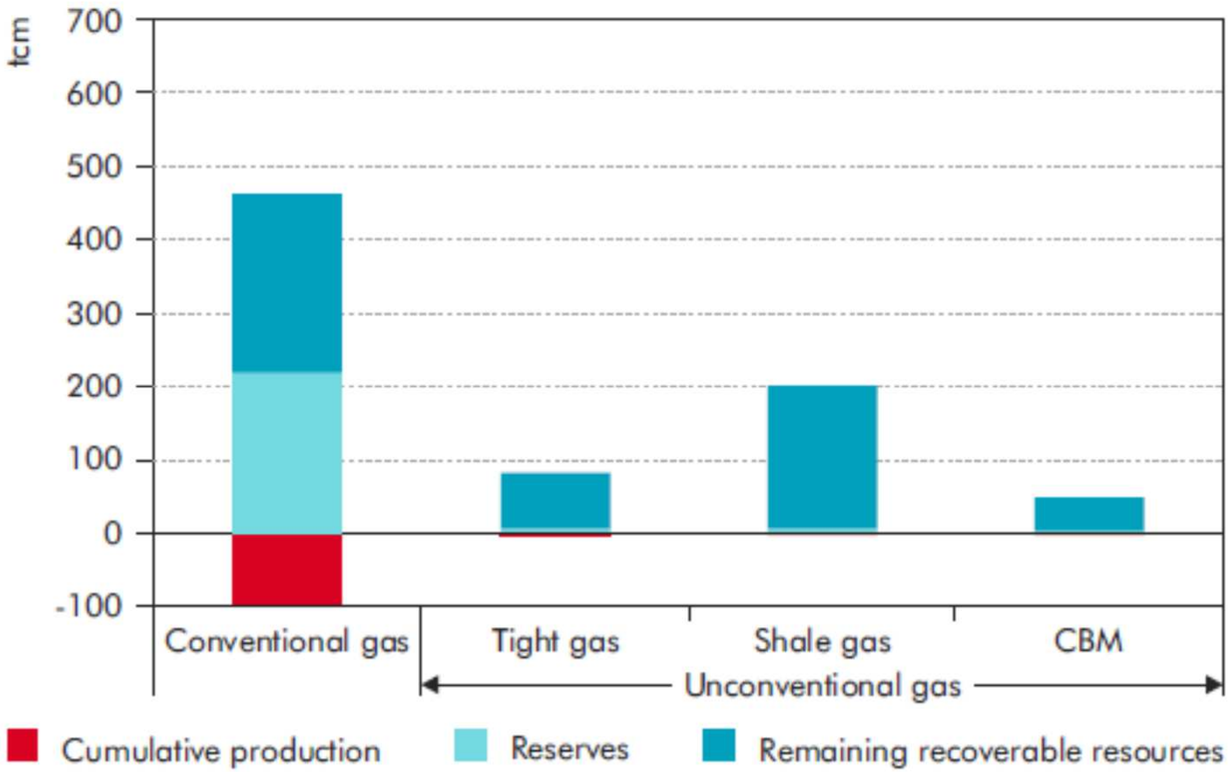
Worldwide Natural Gas Endowment

Natural Gas Resources

- The current mean assessments of conventional gas endowment quantify the ultimate recoverable resource at 475 TCM.

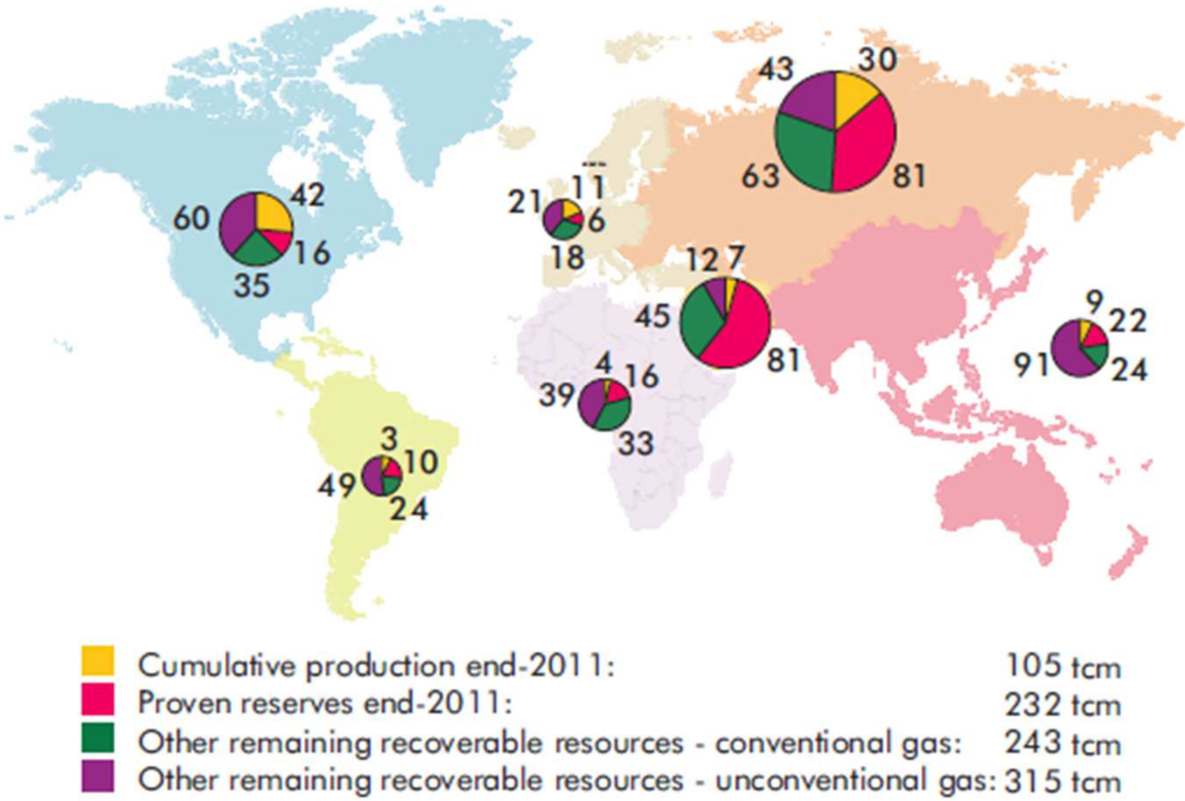
- The cumulative production is slightly above 100 TCM; consequently, the remaining recoverable resources are estimated at 400 TCM, which represents more than 100 times the current annual production.



Source: IEA, 2013

Conventional Natural Gas Reserves

Regional distribution of conventional gas



- Even though N. America has a large volume of remaining conventional resources, proven reserves base is smaller than that of the CIS and M. East.

Source: IEA, 2013

Conventional Natural Gas Reserves

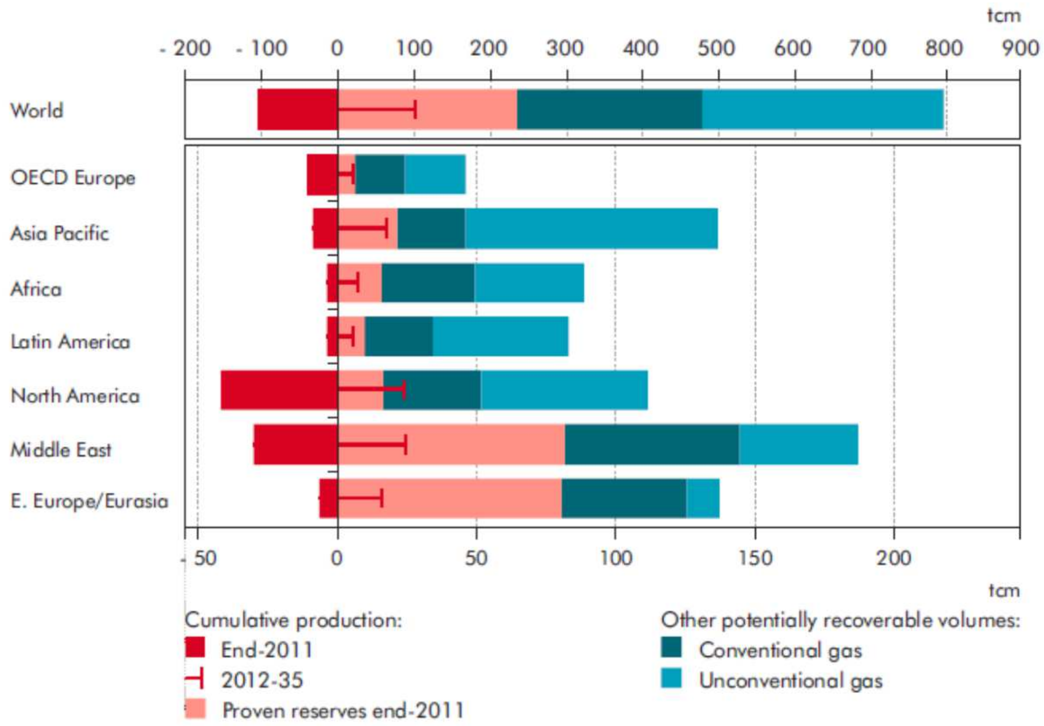
- Proven remaining reserves amount 232 TCM. There is a clear consensus among different sources about quantifications.

- World natural gas proven gas reserves are concentrated in a rather small number of large accumulations.

- Around 310 fields with reserves of more than 100 BCM/field (giants) count for around 65% of world proven reserves.

- About 12 super-giants fields (holding reserves over 1 TCM) out of 20 were developed worldwide.

- Remaining recoverable resources of conventional natural gas, including proven reserves, reserves growth and undiscovered resources, could amount to some 475 TCM



Source: IEA, 2013

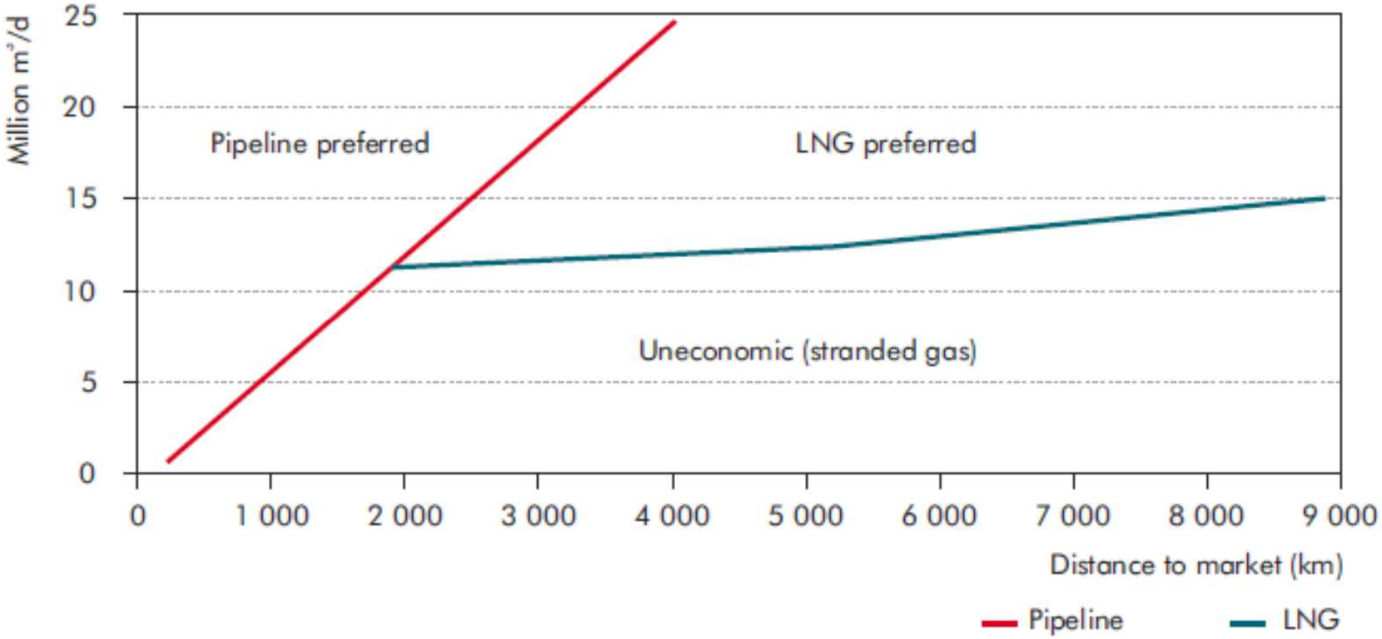
Conventional Natural Gas Reserves

- Almost three-quarters of global natural gas reserves are located in the Middle East and Eurasia. Russia, Iran and Qatar together accounted for about 55% of global natural gas reserves
- According to BP, Iran has the world's largest reserves of natural gas, and is currently the Middle East's largest natural gas producer.
- The largest production increments in the next 25 years will be coming from the Middle East (especially Iran and Qatar), North Africa and Russia.
- A significant share of the increase is expected to come from a single offshore field, which is called North Field on the Qatari side and South Pars on the Iranian side.

Source: BP / IEA, 2013

Getting Gas to Markets

- Getting gas to global markets is the central issue as major conventional reserves tend to be remote from demand centers.
- At short distance gas will be transported via pipeline, while for large gas fields, large distances can be covered through LNG.
- In some instances, neither pipeline nor LNG is cost-effective, which leaves the gas resource "stranded".



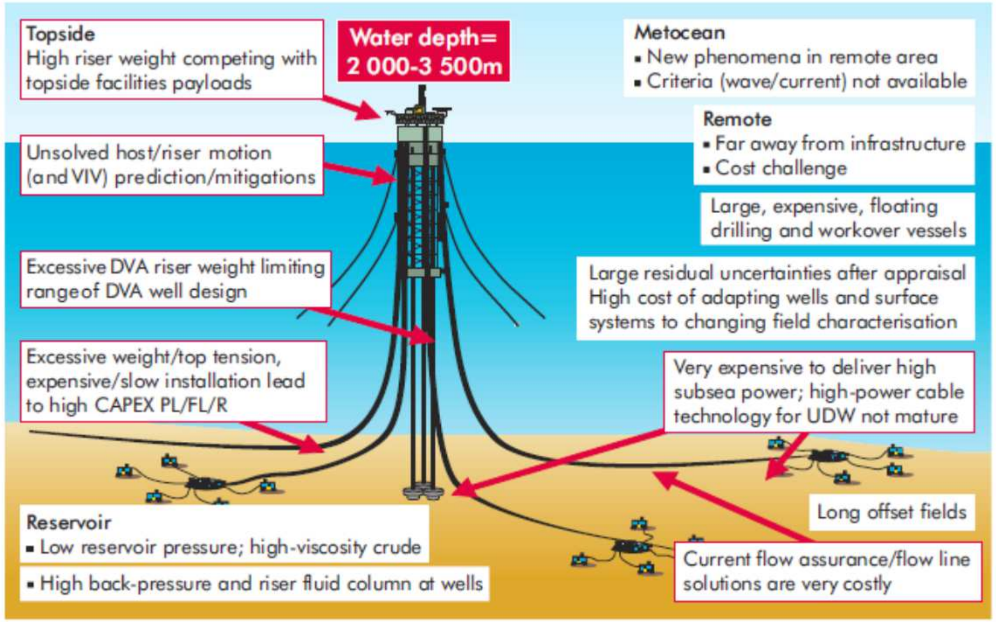
Source: IEA, 2013

Frontier Gas Resources

- Over the past decade, deepwater offshore reserves in several regions of the world and ice-prone areas of the Arctic have been considered the frontier areas for exploring and producing conventional hydrocarbons.

- More than half of all conventional oil discovered since 2000 was in deepwater offshore reservoirs and the Arctic is one of the world's largest remaining prospective areas for oil and gas.

- Developing resources in deepwater and ice-prone areas in the Arctic can be considered the most complex and expensive challenges currently facing the oil & gas industry.

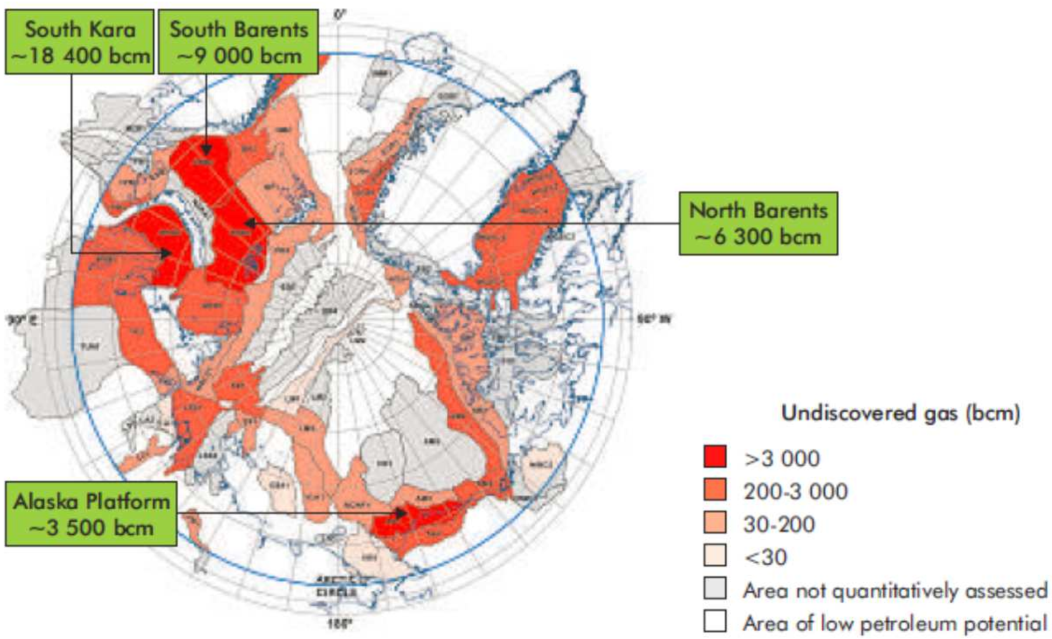


Notes: CAPEX PL/FL/R = capital expenditure on the platform, the flow lines and the riser; DVA = direct vertical access; UDW = ultra-deepwater; VIV = vortex-induced vibration.

Source: IEA, 2013

Frontier Gas Resources

- The Arctic continental shelves constitute some of the world's largest remaining prospective areas of oil and gas.
- In the late 1970s, oil production on Alaska's North Slope and natural gas production in West Siberia were the first developments to lead the way.
- Today, the exploration and production of Arctic oil and gas extend further to include a number of offshore and onshore locations in Canada, Norway, Russia and the US, and offshore Greenland.
- According to an USGS assessment, geological basins north of the Arctic Circle may contain approximately 30% of the world's global undiscovered natural gas volumes.
- Two-thirds of the undiscovered natural gas resource in the Arctic is located in just four areas: South Kara Sea, South Barents Sea, North Barents Sea and Alaska.



Source: IEA, 2013

Frontier Gas Resources - Challenges

- Exploring and producing oil and gas resources in the Arctic pose a number of challenges that go beyond current technological capabilities.

- The specific objectives of any developments in Arctic technology are:
  - to extend the drilling season;
  - protect surface drilling, production facilities and their inhabitants from ice-related dangers;
  - improve subsea exploitation technologies;
  - and increase the distance for transporting produced hydrocarbons to onshore processing facilities.

Source: IEA, 2013

Conventional, Complex Gas Projects

- An objective for SG 1.2 should be the identification of conventional, complex gas projects targeting natural gas reserves in frontier environments
  - Arctic developments
  - Deepwater gas projects
  - Remote areas / stranded gas
  - New technical challenges (e.g. sour gas)

- Complexity is not only due to any specific hurdle (e.g. drilling deeper, connecting further); but also to a combination of more than one challenge at a frontier.

- The aim is not achieving a comprehensive description of technology applications, nor an exhaustive collection of cases;

- The focus is on identifying the main technological trends that have been enabling gas developments.

- Identifying the main projects that are commercially viable up to 2020 will enable us to quantify the material impact on upstream developments and conventional supply expansion in the midterm.

Source: IEA, 2013

Unconventional Developments

Unconventional Gas Resources

- Unconventional gas is generally defined as natural gas that cannot be produced economically by using conventional technology.

- The three common types of unconventional gas are tight gas, shale gas and coal-bed methane (CBM), though methane hydrates are often included

  - Tight gas refers to natural gas trapped in sandstone or limestone formations that exhibit very low permeability and low porosity; such formations may also contain condensate
  - Shale gas refers to natural gas trapped in organic-rich rocks, dominated by shale
  - CBM refers to natural gas adsorbed onto the matrix of the coal in coal seams
  - Methane hydrates comprise methane molecules trapped in a solid lattice of water molecules under specific conditions of temperature and pressure

- Challenges relating to the production of unconventional gas are often related to the difficulty of extraction (e.g. tight gas, shale gas) and/or of the source of the gas (e.g. CBM, methane hydrates).

Source: IEA, 2013

Unconventional Gas Resources

Region	Total gas, tcm		Unconventional by type, tcm		
	Conventional	Unconventional	Tight gas	Shale gas	CBM
Eastern Europe and Eurasia	160	43	10	12	20
Middle East	132	12	8	4	0
Asia Pacific	44	93	20	57	16
OECD Americas	81	82	16	57	10
Latin America (non-OECD)	27	48	15	34	0
Africa	41	38	8	30	0.1
OECD Europe	35	22	4	17	2
World	**519**	**337**	**78**	**210**	**48**

- Global total sources of unconventional resources in place are estimated at around 340 TCM, of which shales has the largest potential with 210 TCM.
- The global distribution of unconventional gas differs markedly from that of conventional gas.

Source: IEA, 2013

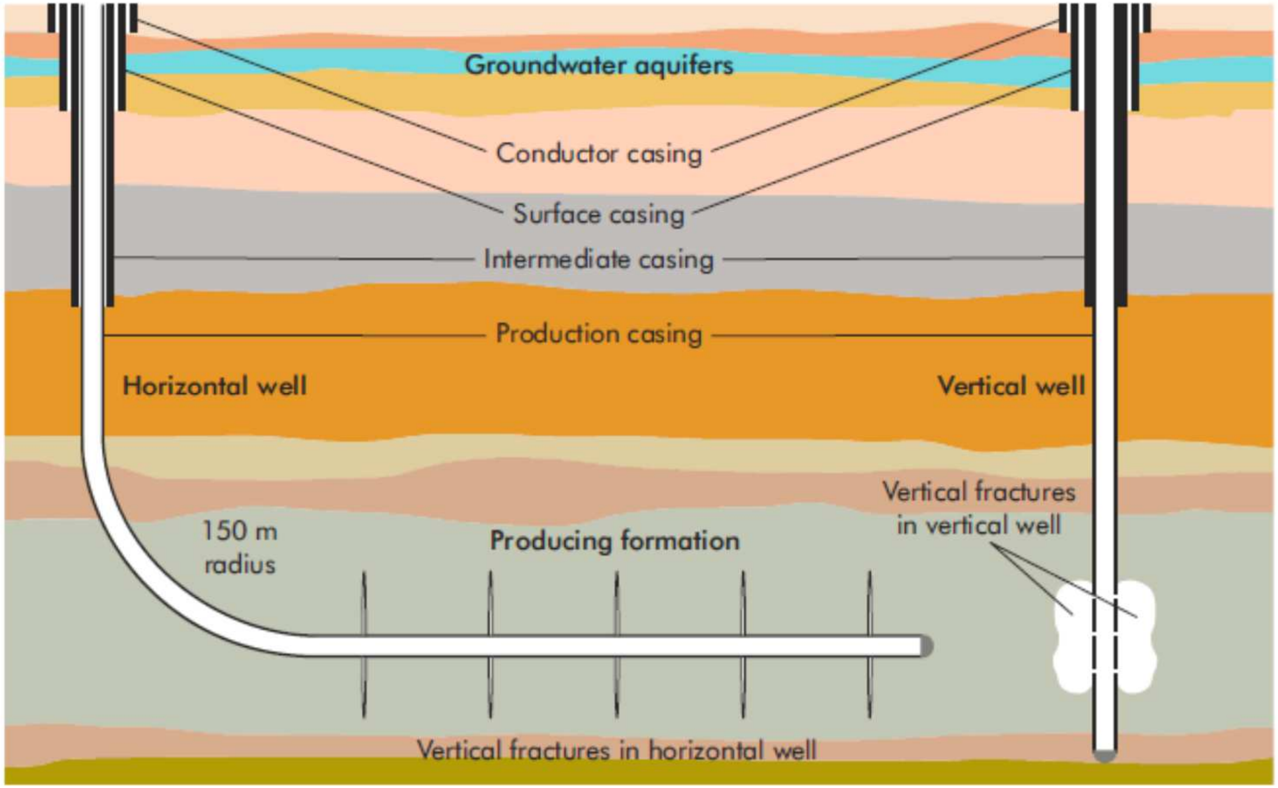
Unconventional Gas Resources

- Unconventional gas production made up almost 13% of global gas supply in 2009, which could rise to over 20% by 2035.
- Unconventional gas will significantly expand the global supply of gas. From 34% in 2011, shale gas could account for as much as 49% of natural gas production in the United States by 2035.
- Tight gas, shale gas and CBM resources are even more important for the future of domestic natural gas supplies in Canada and China, where they could account for more than 65% (Canada) and more than 80% (China) of total domestic production by 2035.
- For tight gas, shale gas and CBM, economies of scale have enabled their production to be achieved at costs broadly similar to those for production of conventional gas.

Source: IEA, 2013

Unconventional Gas Resources

- As for tight gas, connecting a large surface area of rock with the well-bore is achieved by hydraulic fracturing.
- Not only do shale plays cover much larger areas, but they also require that more wells are drilled more closely together than those of conventional resources.



Source: IEA, 2013

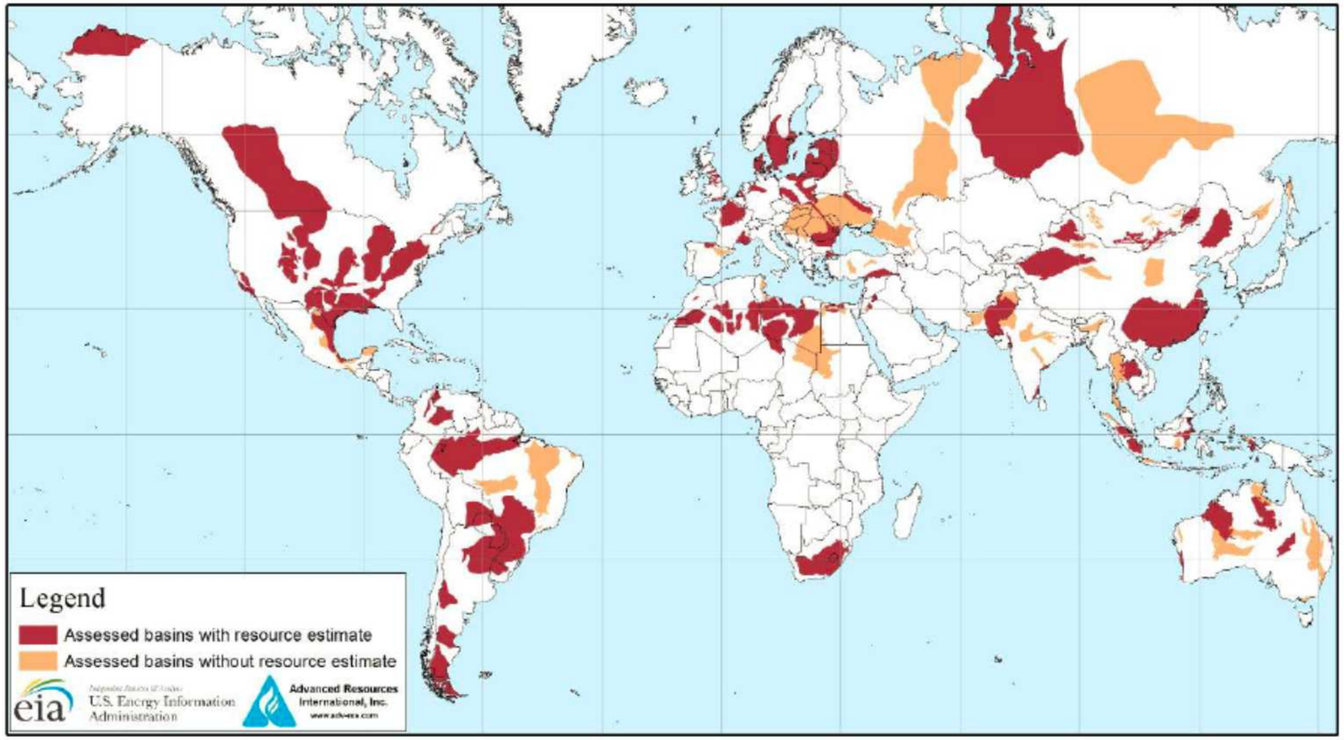
Unconventional Gas Resources

- The cost of developing and producing shale gas varies according to the particular reservoir or play.
- Current estimates of gas recovery factors vary from less than 8% to 30% of gas in place, which is significantly lower than the 60% to 80% recovery factor for conventional gas reserves.
- Testing several well designs has enabled companies to improve the ratio of cost to initial production rate, sometimes by up to 40%.
- It took more than 20 years for the annual production capacity of Barnett Shales to reach 5 BCM, but this was accomplished in just four years at the Fayetteville shale gas play.
- To reach and sustain a production plateau for shale gas usually takes several years and requires continuous drilling.
- Most of the capital costs are recovered within the first few years. This means that greenfield developments tend to be less influenced by medium-term instability in terms of both cost and price.

Source: IEA, 2013

Unconventional Gas Resources

- Outside North America, shale gas production is still negligible.
- Several companies throughout Europe are investigating shale gas prospects, for example in Austria, Poland, Sweden and the United Kingdom.
- In South America, prospects in Chile and Argentina are being reviewed and provisional assessments have been made in India and China.



Source: IEA, 2013

Unconventional Gas Resources

- EIA issued in June 2013 an update on its 2011 shale gas resource assessment.
- It assesses 137 shale formations in 41 countries outside the United States, expanding on the 69 shale formations within 32 countries considered in the prior report.
- Estimates in the updated report indicate technically recoverable resources of 7,299 trillion cubic feet of world shale gas resources.
- The new global shale gas resource estimate is 10% higher than the 2011 estimate.

- Two-thirds of the assessed, technically recoverable shale gas resource is concentrated in six countries - US, China, Argentina, Algeria, Canada and Mexico.
- The top ten countries account for over 80% of the currently assessed, technically recoverable shale gas resources of the world.

Country	Shale gas (trillion cubic feet)	
China	1,115	
Argentina	802	
Algeria	707	
U.S.[1]	665	(1,161)
Canada	573	
Mexico	545	
Australia	437	
South Africa	390	
Russia	285	
Brazil	245	
World Total	7,299	(7,795)

[1] EIA estimates used for ranking order. ARI estimates in parentheses.

Source: IEA, 2013

Prospective Future Developments Regional Focus: Argentina

Argentina has large and potentially high-quality shale gas and oil resources in four main sedimentary basins:

• Neuquén Basin: The main focus of shale exploration in Argentina, some 50 mostly vertical wells drilled since 2010 especially in Vaca Muerta formation.

• Golfo San Jorge Basin: This basin has untested but prospective, primarily shale gas resources

• Austral Basin: It contains marine-deposited black shale in the Lower Cretaceous, considered a major source rock in the basin

• Paraná Basin: Although more extensive in Brazil and Paraguay, Argentina has a small area of the Paraná Basin with Devonian black shale potential

Source: IEA, 2013

Prospective Future Developments
Regional Focus: Argentina

• Significant exploration programs and early-stage commercial production are underway in the Neuquén Basin by Apache, EOG, ExxonMobil, TOTAL, YPF, and smaller companies.

• Thick, organic-rich, marine-deposited black shales in the Los Molles and Vaca Muerta formations have been tested by approximately 50 wells to date, with mostly good results.

• Argentina has an estimated 802 Tcf of risked, shale gas in-place out of 3,244 Tcf of risked, technically recoverable shale gas resources

Shale Gas Reservoir Properties and Resources of Argentina

Basic Data	Basin/Gross Area		Neuquen (66,900 mi^2)					
	Shale Formation		Los Molles			Vaca Muerta		
	Geologic Age		M. Jurassic			U. Jurassic - L. Cretaceous		
	Depositional Environment		Marine			Marine		
Physical Extent	Prospective Area (mi^2)		2,750	2,380	8,140	4,840	3,270	3,550
	Thickness (ft)	Organically Rich	800	800	800	500	500	500
		Net	300	300	300	325	325	325
	Depth (ft)	Interval	6,500 - 9,500	9,500 - 13,000	13,000 - 16,400	3,000 - 9,000	4,500 - 9,000	5,500 - 10,000
		Average	8,000	11,500	14,500	5,000	6,500	8,000
Reservoir Properties	Reservoir Pressure		Highly Overpress.	Highly Overpress.	Highly Overpress.	Highly Overpress.	Highly Overpress.	Highly Overpress.
	Average TOC (wt. %)		2.0%	2.0%	2.0%	5.0%	5.0%	5.0%
	Thermal Maturity (% Ro)		0.85%	1.15%	2.20%	0.85%	1.15%	1.50%
	Clay Content		Low/Medium	Low/Medium	Low/Medium	Low/Medium	Low/Medium	Low/Medium
Resource	Gas Phase		Assoc. Gas	Wet Gas	Dry Gas	Assoc. Gas	Wet Gas	Dry Gas
	GIP Concentration (Bcf/mi^2)		49.3	118.0	190.1	66.1	185.9	302.9
	Risked GIP (Tcf)		67.8	140.4	773.8	192.0	364.8	645.1
	Risked Recoverable (Tcf)		8.1	35.1	232.1	23.0	91.2	193.5

Source: IEA, 2013

Methane Hydrates

• Methane (or gas) hydrates are thought to be the most abundant sources of hydrocarbon gas on earth. They are solids composed of natural gas molecules surrounded by a cage of water molecules, i.e. methane molecules held within a clathrate or lattice structure.

• One cubic meter of hydrates contains about 164 cm of methane gas at standard conditions, with an energy content that is comparable to that of bitumen and oil-sands.

• Methane hydrates can be found in permafrost Arctic regions at 200 m to 1,000 m depth or on the seabed between 500 m and 1,500 m water depth.

• The amount of natural gas in hydrate accumulations may be in the range of 1,000 – 5,000 TCM, but there is great uncertainty and some estimates are much higher.

  - It has been estimated that ocean hydrates may contain up to 120 000 TCM of methane gas in place, more than two orders of magnitude greater than worldwide conventional natural gas reserves.

• A recent US Geological Survey assessment estimated that there are 2.4 TCM of technically recoverable natural gas from hydrate deposits on the Alaskan North Slope.

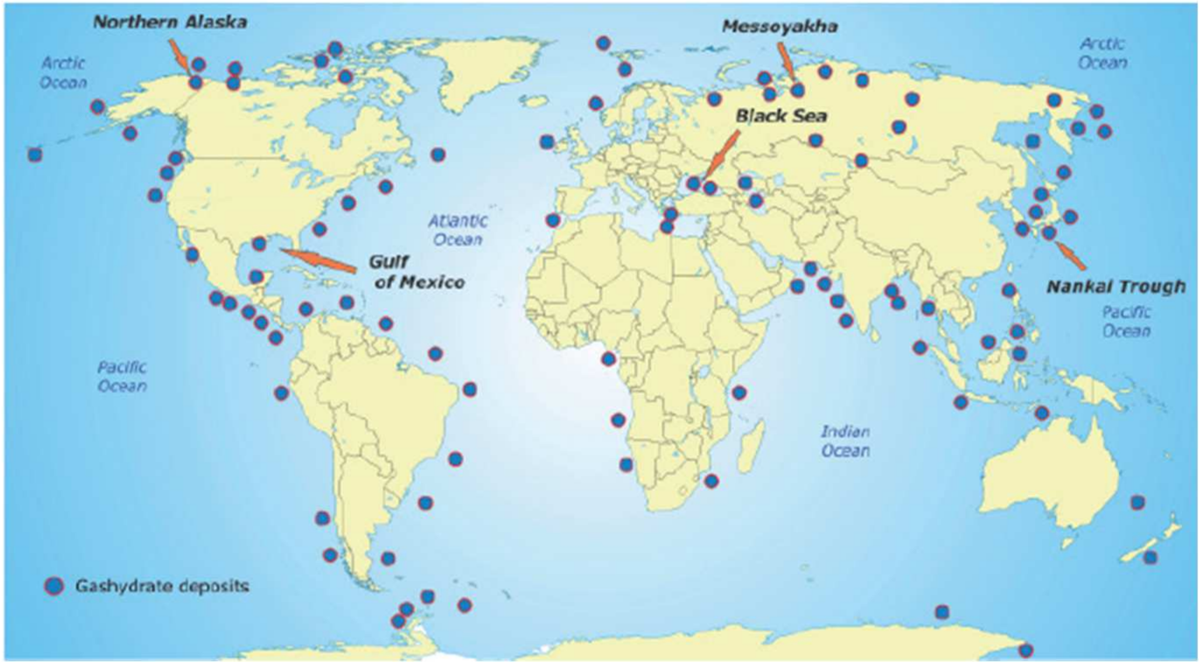
Source: IEA, 2013

Methane Hydrates

• Among unconventional natural gas sources, Methane Hydrates ranks below gas from dense rocks and coalbed methane, mainly due to economics.

• Gas hydrates are found within and under permafrost in arctic regions. They are also found within a few hundred meters of the seafloor on continental slopes and in deep seas and lakes.

Map of confirmed Methane Hydrate presence



Source: Energy Resources 2009 - BGR

Methane Hydrates: Current developments

- The development of methane hydrates still remains in the research phase with the focus on characterizing hydrates to learn more about their natural properties, to measure and monitor their production behavior and to assess techniques for their production.

- Technological innovation will be required for hydrates to be commercially exploited with minimum environmental impact. To date, there has been no commercial production of methane hydrates directly.

- Japan's government-led project has successfully extracted natural gas from methane hydrates by applying low pressure from a test vessel deployed to offshore waters as part of a two-month production test during 1Q 2013.

- Research has showed that the area near the Ise-Shima coast in central Japan alone has methane hydrate-based gas reserves equivalent to more than 10 years of the country’s current LNG consumption.

- Research to date indicates that methane hydrates could eventually be produced commercially.

Source: IEA, 2013

THANK YOU

1 - 5 June 2015
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