Oil and natural gas
Peak Oil and ERoEI

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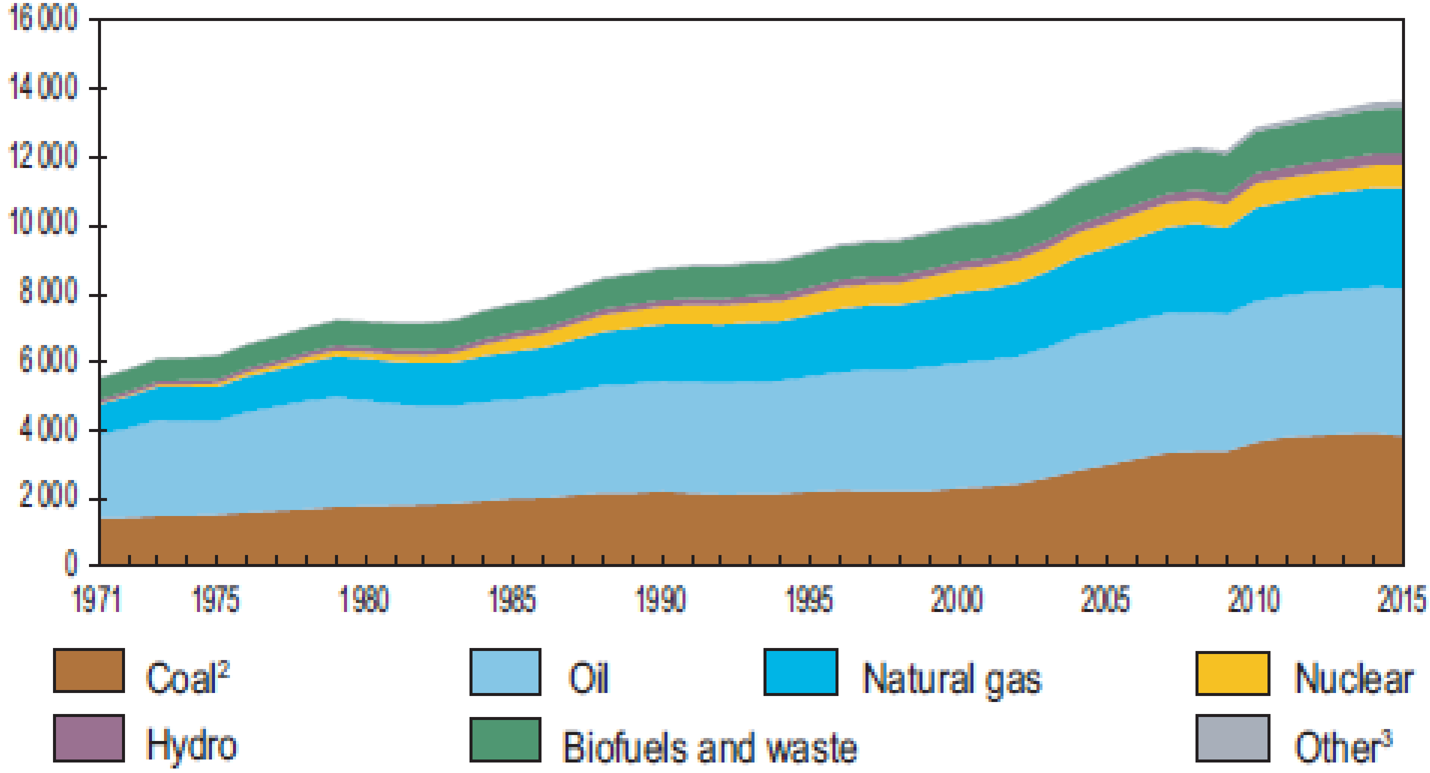
World total primary energy supply by fuel



Note: Peat and oil shale aggregated with coal.

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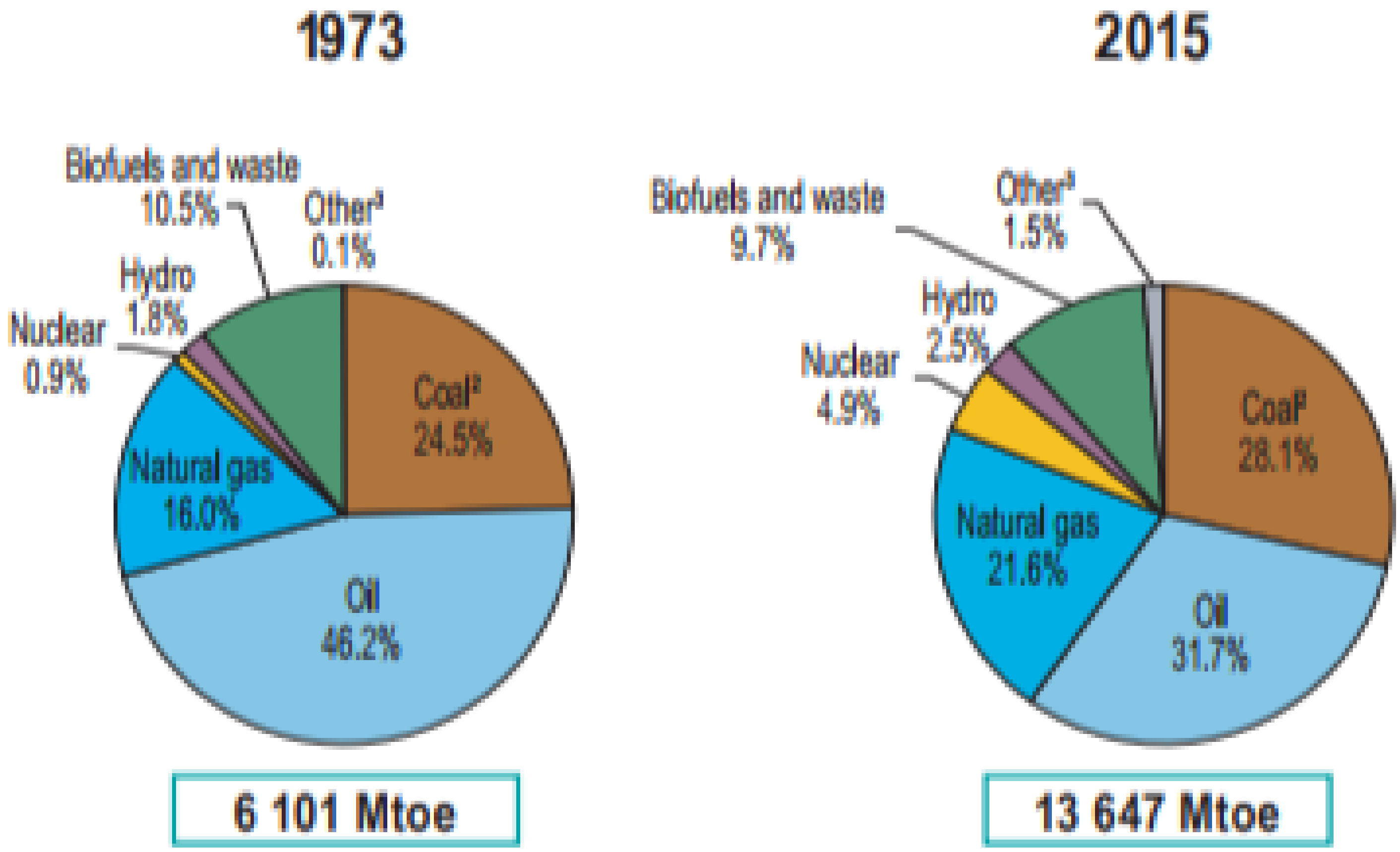
World total primary energy supply by fuel



Note: Peat and oil shale aggregated with coal.

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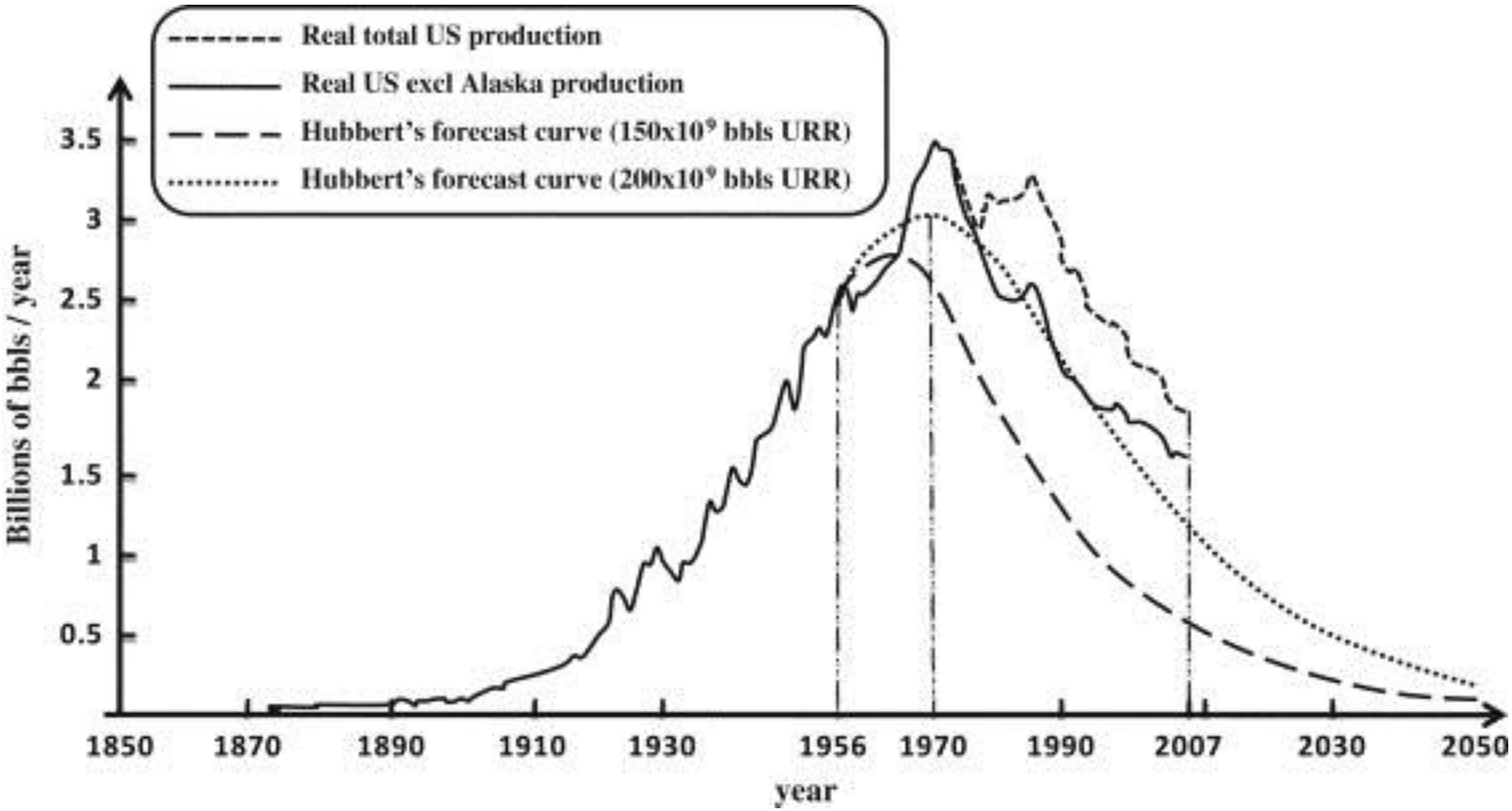
Peak Oil

- A point in time when the maximum rate of extraction is reached and only decline in production is expected.
- Based on Marion King Hubbert´s (1903-1989) models (Shell, US Gelogical Survey).
- Presentation in San Antonio in 1956 predicting U.S. oil peak for 1970.
- Concept is being criticized for „Malthusian perspective“.

Oil (gas) peak



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„Early peak“ predictions

Peak oil date	Source and date of forecast
2006–2007	Bakhtiari (2004)
2006 on	Simmons (2006)
After 2007	Skrebowski (2004)
Soon after 2007	World Energy Council (2007)
2009–2031	Sorrell et al. (2009)
Before 2010	Goodstein (2004)
Around 2010	Campbell (2005)
Possibly 2010	Klare (2004)
2010	Aleklett et al. (2010)
After 2010	Skrebowski (2005)
2006–2017	Hiro (2007)
Soon after 2010	De Margerie, C., Total S.A. (Walt, 2010)
2008–2012	De Almeida and Silva (2009)
2012–2017	Koppelaar, 2005 and Koppelaar, 2006
2008–2018	Robelius (2007)
2014	Nashawi et al. (2010)
2015	Shell (2008)

„Late peak“ predictions

Peak oil date	Source and date of forecast
Not before 2017	CERA (2008)
After 2020	Hayward, T., BP (Macalister, 2010)
After 2020	CERA (Jackson and Esser, 2004)
2020 or beyond 2035	IEA (2010)
2020 (for oil and gas)	Shell (2011)
2025 or later	Davis (2003)
2035	CERA (Jackson, 2006)
Not before 2035	EIA (2010)
No visible peak	Maugeri (2012)
No peak but 54.2 years of global production	BP (2012)
‘Peak oil theories have been abandoned’	Mountains Scenario
‘Oil demand …reaching a long plateau in the 2040s’	Oceans Scenario (Shell, 2013)

Was Hubbert right?

- Easily accessible oil and gas deposits are being depleted.
- Decreasing discovery rate (fields ´too big to miss´).
- But predicted peak repeatedly increased and postponed.
- How to explain this contradiction?

Was Hubbert right?

- Economic perspective – „oil reserves are the amount of oil that is minable at today´s prices using existing technology“ (proven, probable and possible reserves).
- E&P in extreme conditions.
- New techniques of extraction (unconventional oil and gas).
- Increasing recovery rate - from 22% in 80s to 35% today.

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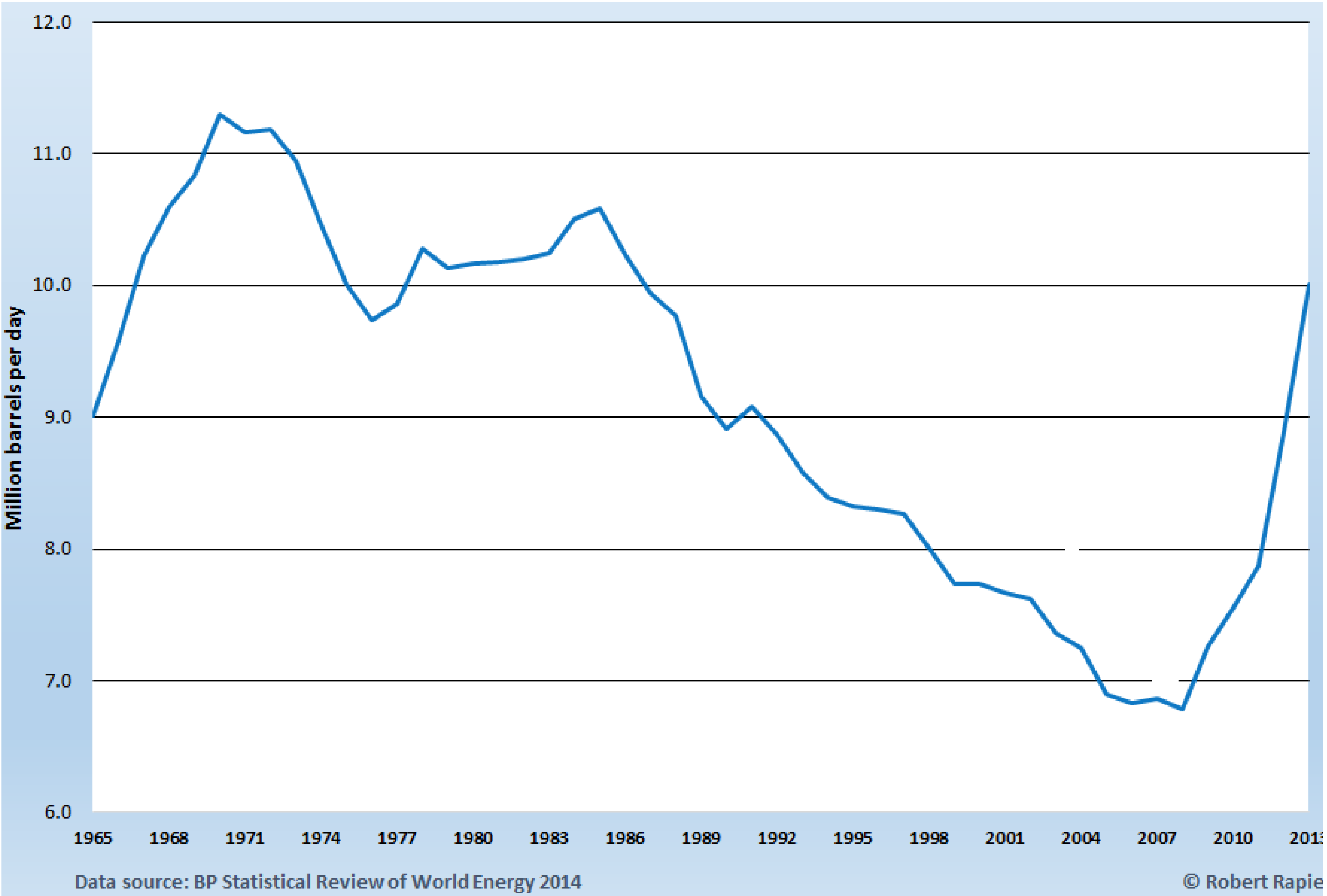
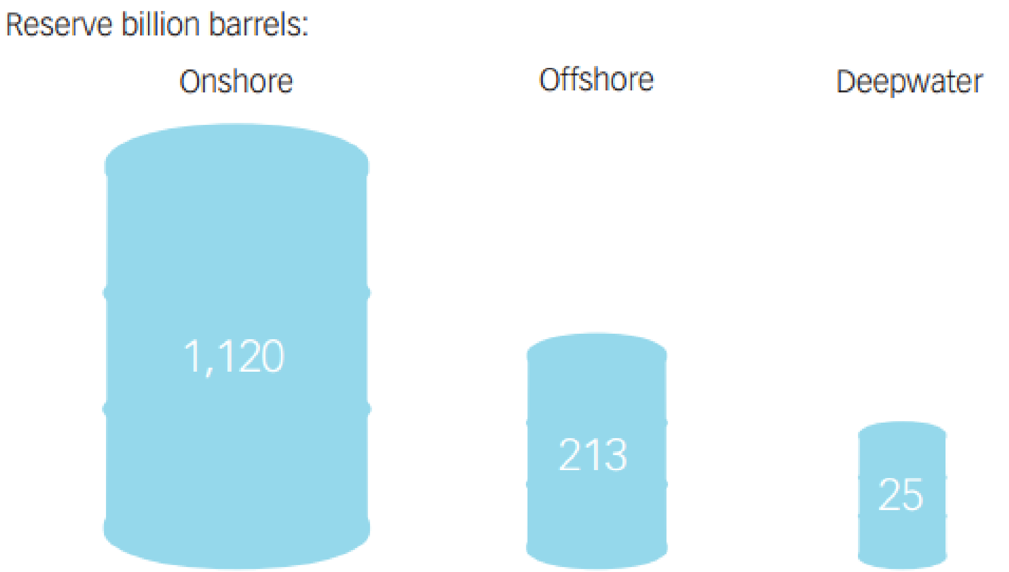
US oil production since 1965



New areas of exploration – deep waters

- Wells drilled in excess of 1000 feet as deep (first in 1975), 5000 and more (1986) as ultra-deep.
- Gulf of Mexico, Brazil, West Africa.



Note: Figures are a representative sample of the world's major oilfields in billion of barrels.

Source: World Energy Outlook 2010 © OECD/International Energy Agency 2010

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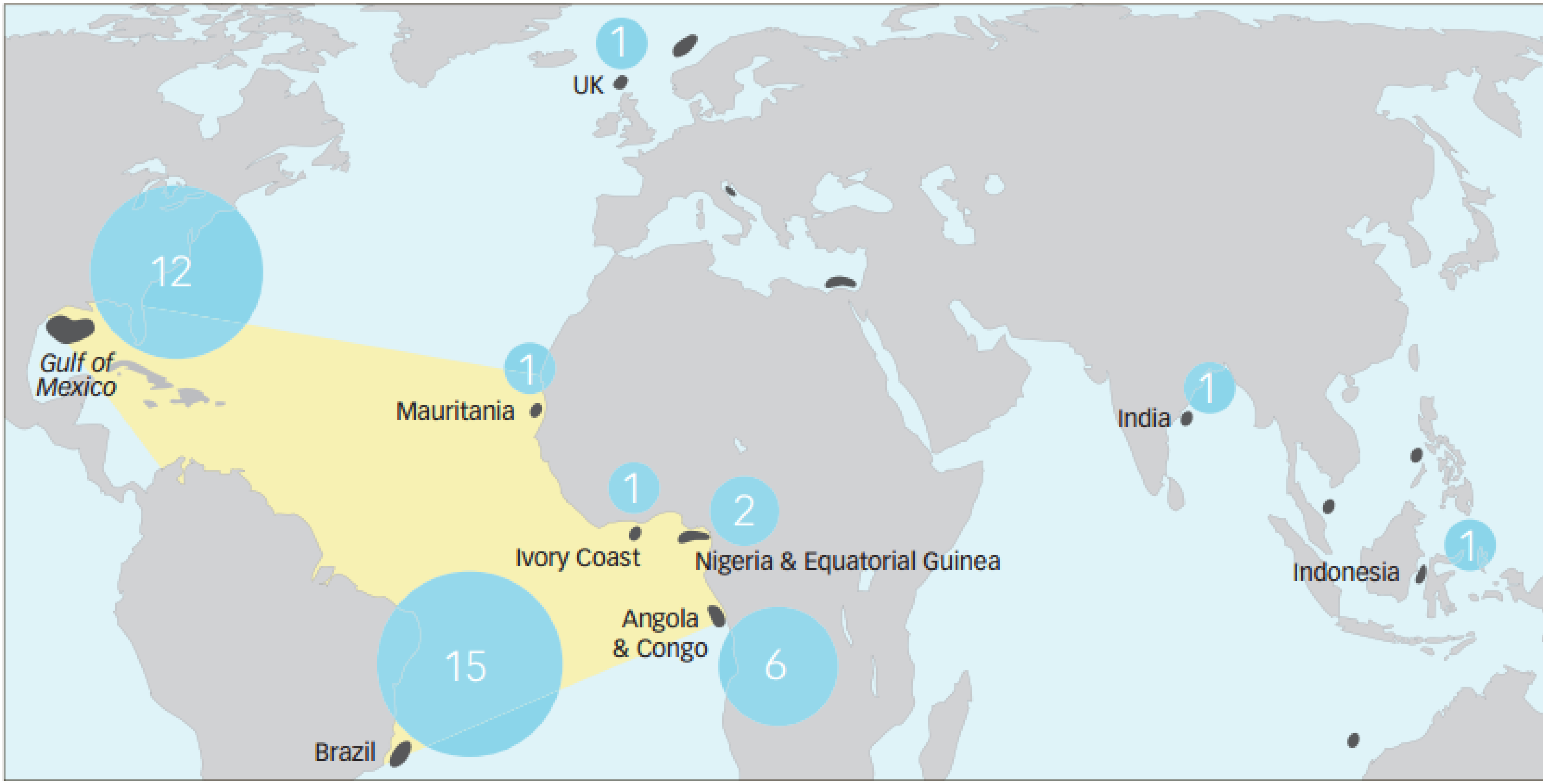
Location of deepwater drilling oil fields



Deepwater development areas

"Golden Triangle"

Number of deepwater oil fields below 400m

Source: Petroleum Economist

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New areas of exploration – deep waters

Traditional onshore drilling.

- Limited impacts – considerable experience, physically limited possibility of spillage.
- Impacts similar to mining operations in non-energy industry – land use, water and air pollution, dust, noise, transportation damages of habitats.
- Long history of regulation in the EU and USA.

New areas of exploration – deep waters

Offshore drilling

- Complicated technology and hostile environment increase the risk of accidents and their impact.
- Oil spillages in the water (1m3 = spillage up to 1km2).
- Increase in a number of off-shore installations accompanied by more stringent regulation (2010 Gulf of Mexico - Directive 2013/30/EU on safety of offshore oil and gas operations).

High profile oil spills from offshore blowouts

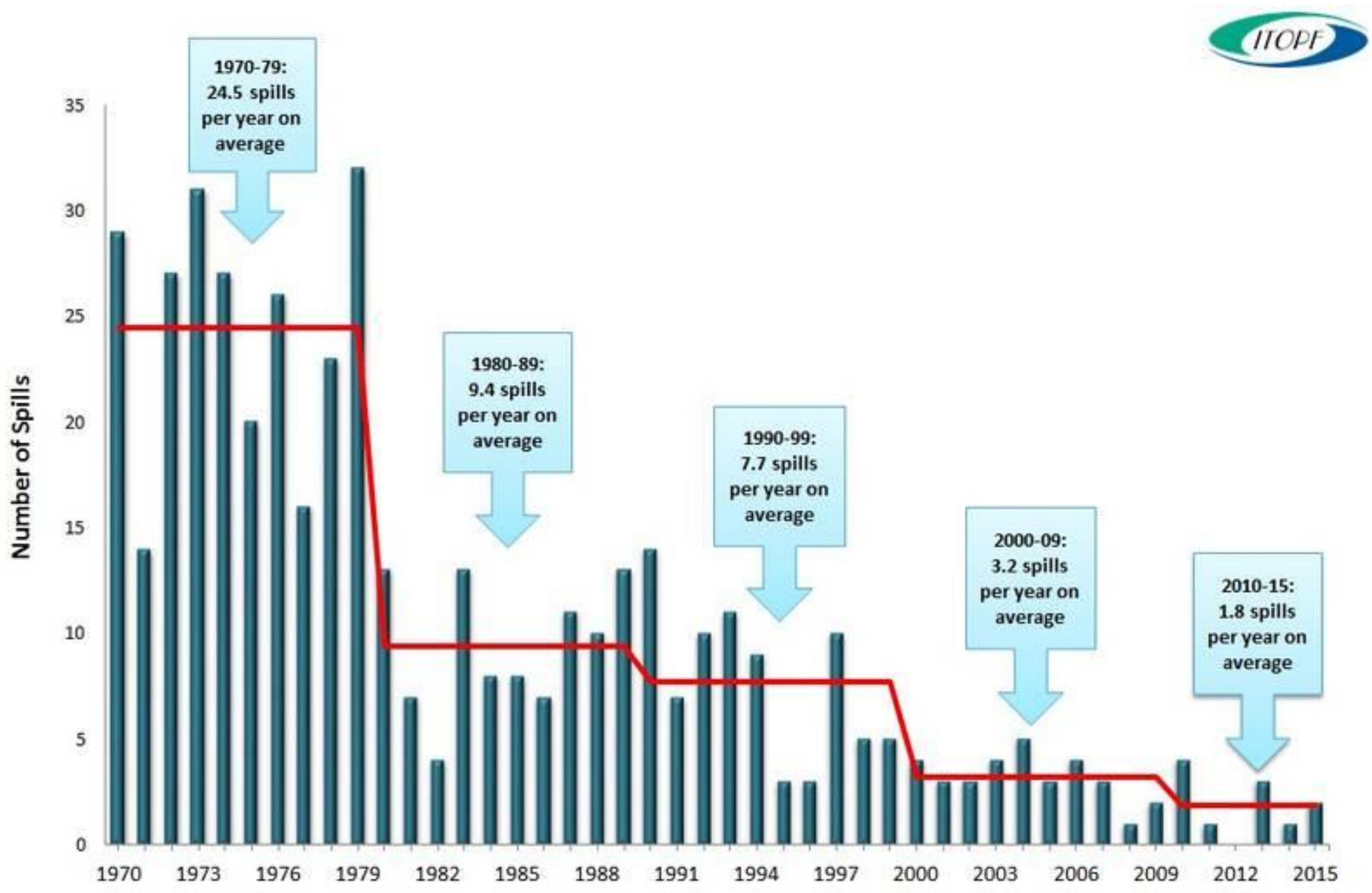
Date of Incident	Location	Incident and Spillage Details (Estimated figures)	Insured loss ($)
28.1.69 - 12.2.69	Santa Barbara, California	80,000 - 100,000 barrels	Not available
3.6.79 - 23.3.80	Ixtoc Well, Mexico	3.3 million barrels	22,000,000
22.4.77- 30.4.77	Ekofisk Norwegian Sector, North Sea	202,381 barrels	6,887,000
1980	Funiwa Niger Delta, Nigeria	200,000 barrels	53,554,000
2.10.80 - 10.10.80	Arabian Gulf	100,000 barrels	1,300,000
21.8.09 - 3.11.09	Timor Sea, Australia/ Indonesia	28,800 barrels of condensate oil	425,000,000
20.4.10 - 15.7.10	Gulf of Mexico	4.9 million barrels, plus 11 fatalities and 17 injuries	2,560,000,000

Adapted from Willis Energy Loss Database and American Petroleum Institute Analysis of US Oil Spillage 2009

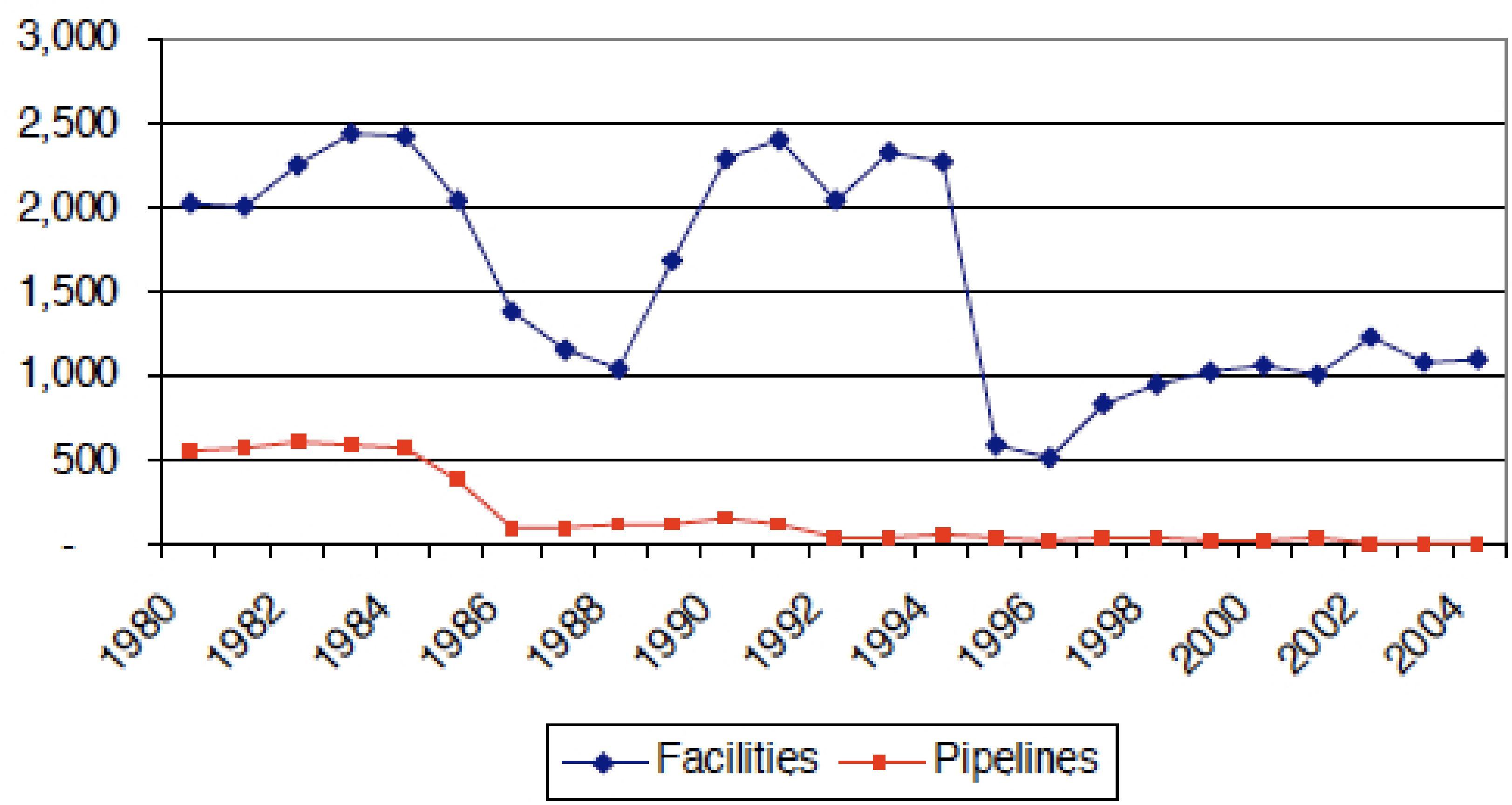
Transport of oil

- One of the biggest threats in ship transportation – oil spill. Intentional (terorism, piracy) and unintentional (accident, collision,, running ashore, failure of the ship) accidents.
- Risk is significantly higher in highly frequent areas – in 1995-2005 in Turkish Straits 269 accidents.
- To stop VLCC or ULCC tanker 14 minutes and 3km are needed.
- In 70s there were 25,2 leaks annually, in 80s 9,3 leaks, in 90s 7,8 and after 2000 3,4 leaks annually.
- But with increasing capacity of tankers the oil spills are more severe with increasing environmental impacts.

Oil spills during the maritime transport of oil



Annual number of spills to U.S. waters from facilities and pipelines, 1980 - 2004



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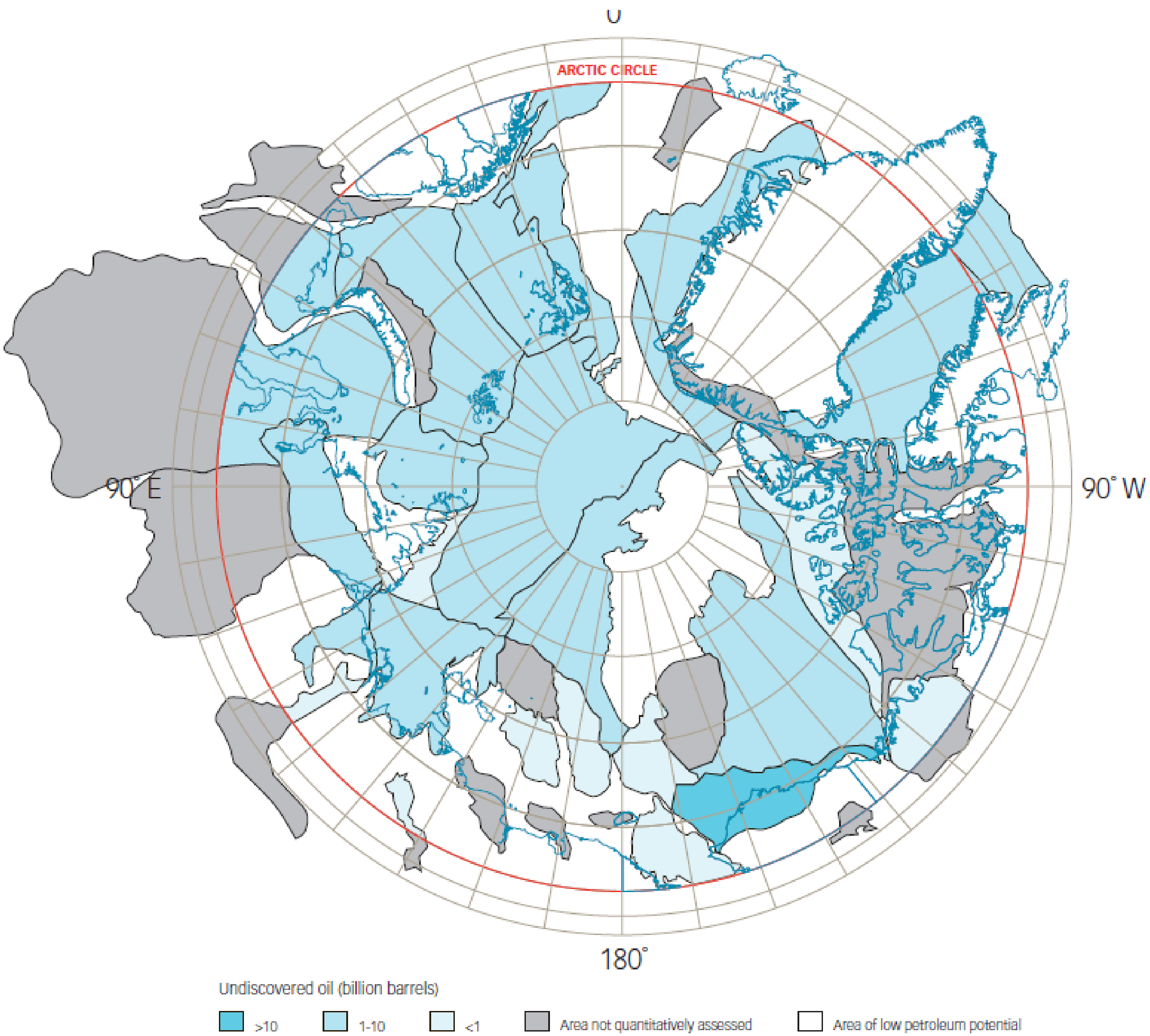
New areas of exploration – Arctic regions



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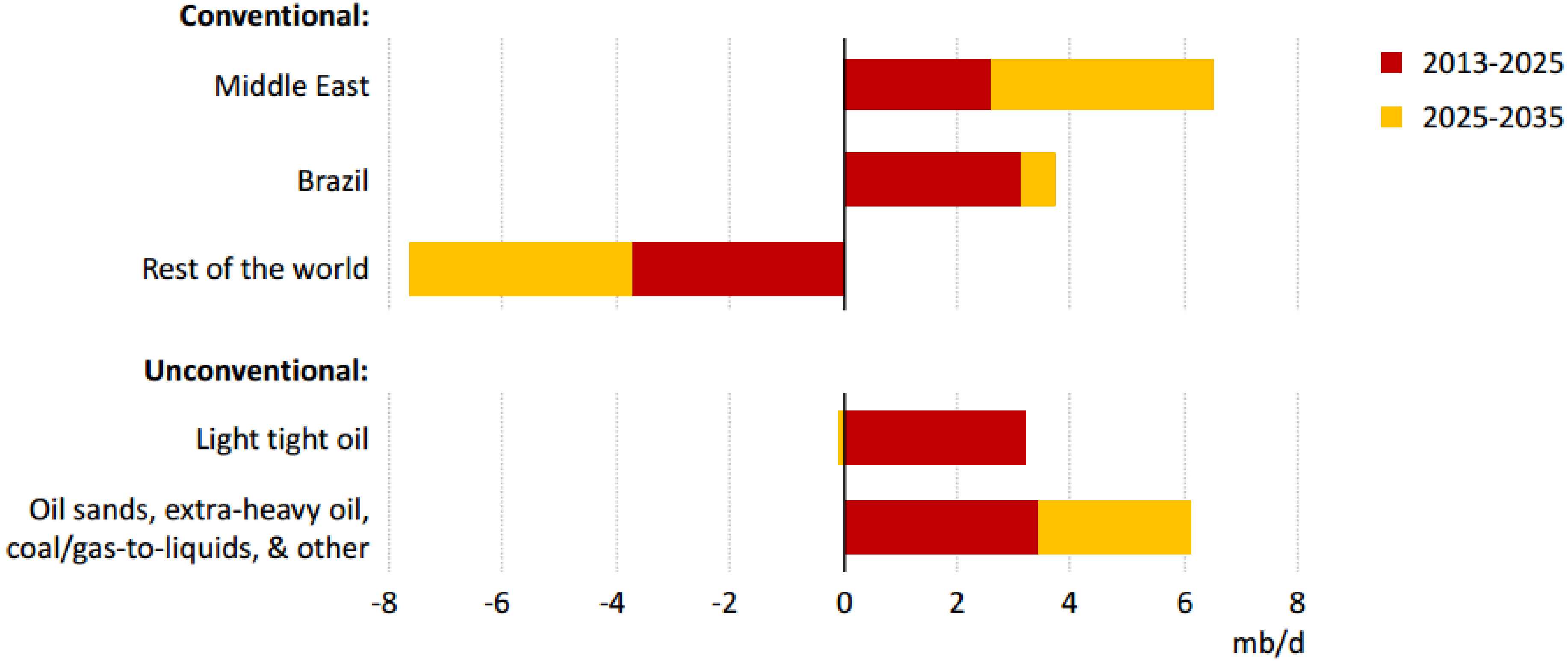
Source: Map courtesy of the U.S. Geological Survey

Contributions to global oil production growth



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Unconventional sources - oil

Produced or extracted using techniques other than the conventional (oil well) methods.

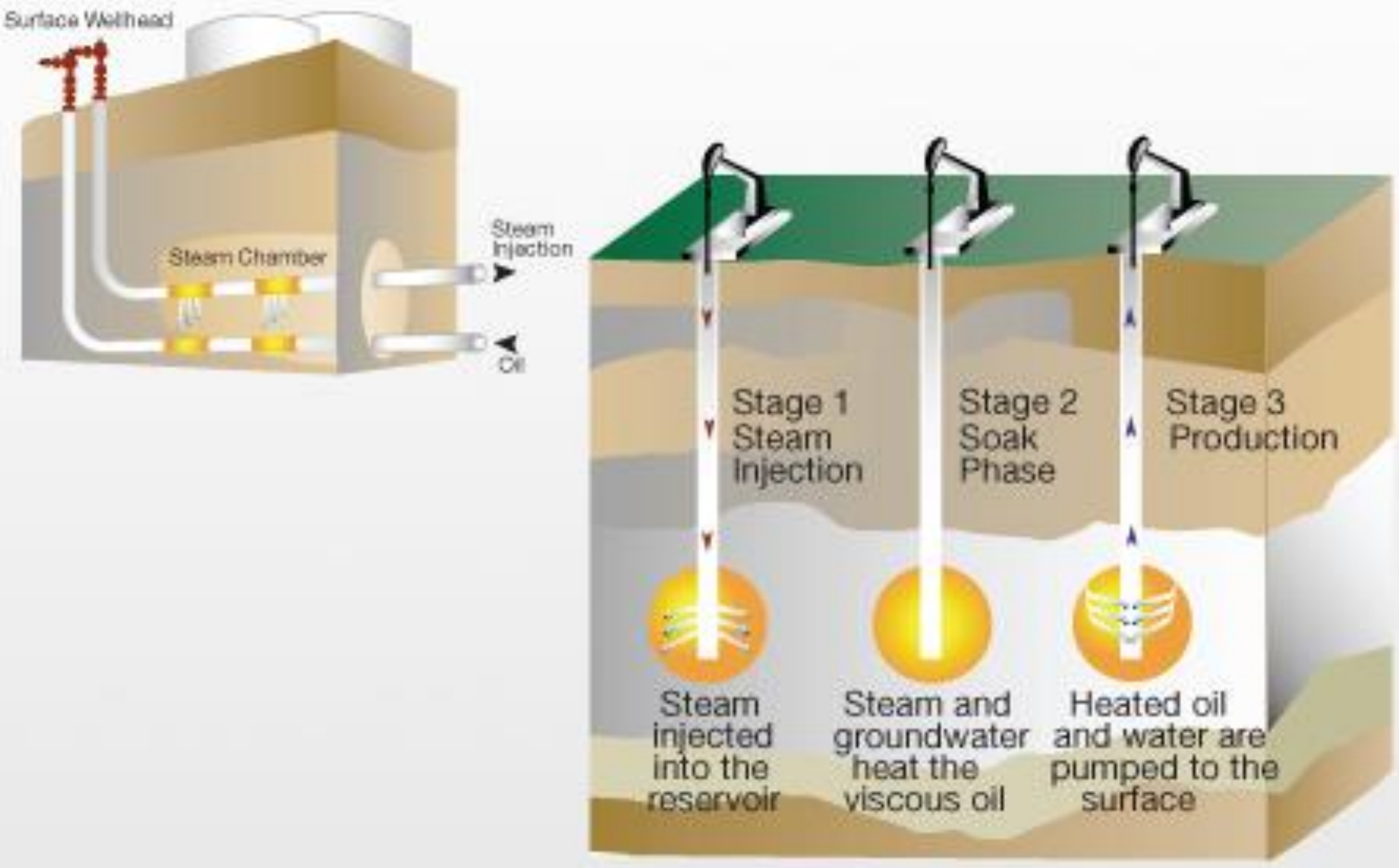
- Conventional oil: mineral oil consisting of a mixture of hydrocarbons of natural origin, exists in liquid form under normal surface temperatures and pressure.
- Unconventional oil: to be extracted non-conventional technology is needed, in natural state (without heating or diluting) couldn´t be extracted.
- Oil sands, tight oil, oil shale, oil produced from coal…

Oil sands, tight oil, oil shale...

- Consistency – extremely dense and viscous, almost solid.
- High level of sulphur and metals (nickel, vanadium).
- Venezuela – Orinoco Belt (1200 bn. barrels = approximately equal the world´s reserves of lighter oil, 200 billion barrels technically recoverable)
- Alberta, Canada – reserves of 1700 -250 bn. barrels (11 % of world oil reserves, 3rd on the world), 99 % oil sands. Export around 2 mil. barrels/day.

Producing techniques: in-situ mining

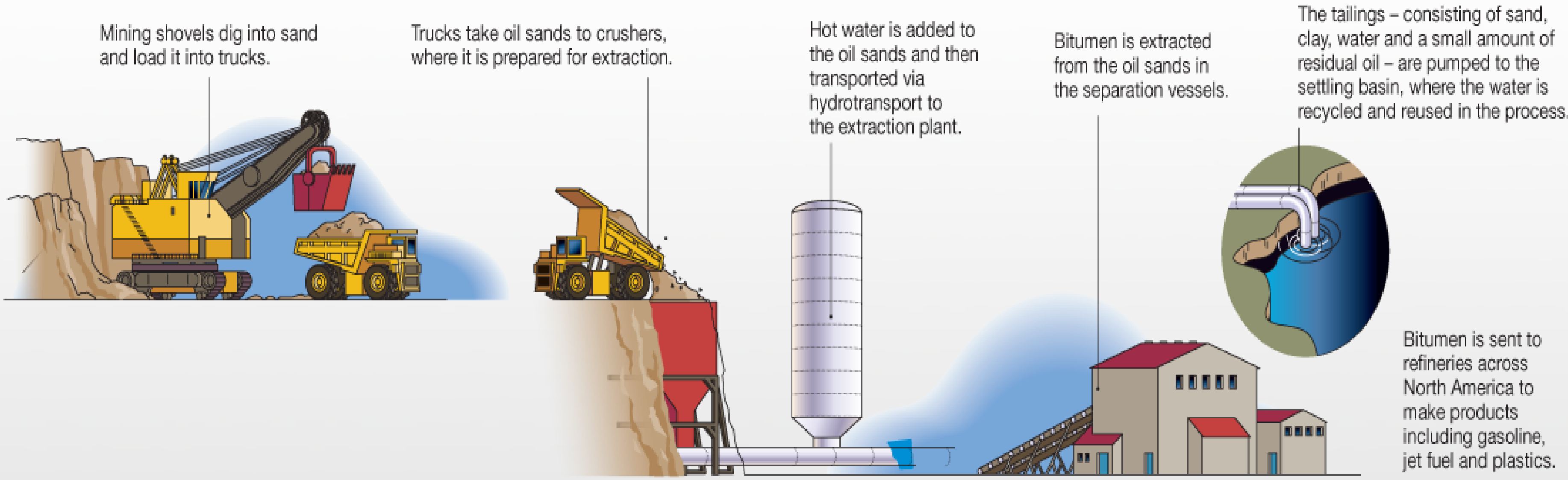
- Injecting hot fluids (or steam) into the rock formation, shale oil is recovered through vertical wells.
- Increased water and energy (natural gas) consumption. 2-4 barrels of water/1 barrel of oil, 70-90% could be recycled.



Surface Wellhead
Steam Chamber
Steam Injection
Oil
Stage 1 Steam Injection
Stage 2 Soak Phase
Stage 3 Production
Steam injected into the reservoir
Steam and groundwater heat the viscous oil
Heated oil and water are pumped to the surface

Producing techniques – open pit mining

- Open pit (ex-situ) mining (max 70m) (oil sand-bitumen, also shale oil).
- Excavation, when sand is cooped out by power shovels, carried away, then hot water is used to separate bitumen from the sand. Then it is refined.
- 8-10 barrels of water/1 barrel of oil, 40 – 70% could be recycled. About 2 (but up to 4) tons of material/1 barrel of oil.
- 1,5x more GHG then in case of conventional crude oil.
    - http://www.youtube.com/watch?v=YkwoRivP17A



Mining shovels dig into sand and load it into trucks.
Trucks take oil sands to crushers, where it is prepared for extraction.
Hot water is added to the oil sands and then transported via hydrotransport to the extraction plant.
Bitumen is extracted from the oil sands in the separation vessels.
The tailings – consisting of sand, clay, water and a small amount of residual oil – are pumped to the settling basin, where the water is recycled and reused in the process.
Bitumen is sent to refineries across North America to make products including gasoline, jet fuel and plastics.

Shale gas

- Natural gas (= clean fuel) trapped within shale formations.
- Fracking – combination of horizontal drilling and hydraulic fracturing.
- High consumption of water, 0,5-2% of injected liquid represents added chemicals.
- One well – 280 000 hl of water.
- 2-4 hectares/1 drilling pad (= up to 30 wells), 3-6km between pads.
- Transport – one well/700-2000 trucks (during installation one car every 4 minutes).
- Methane leackages, earthquakes.

- https://www.youtube.com/watch?v=Ag9GUogWEa0

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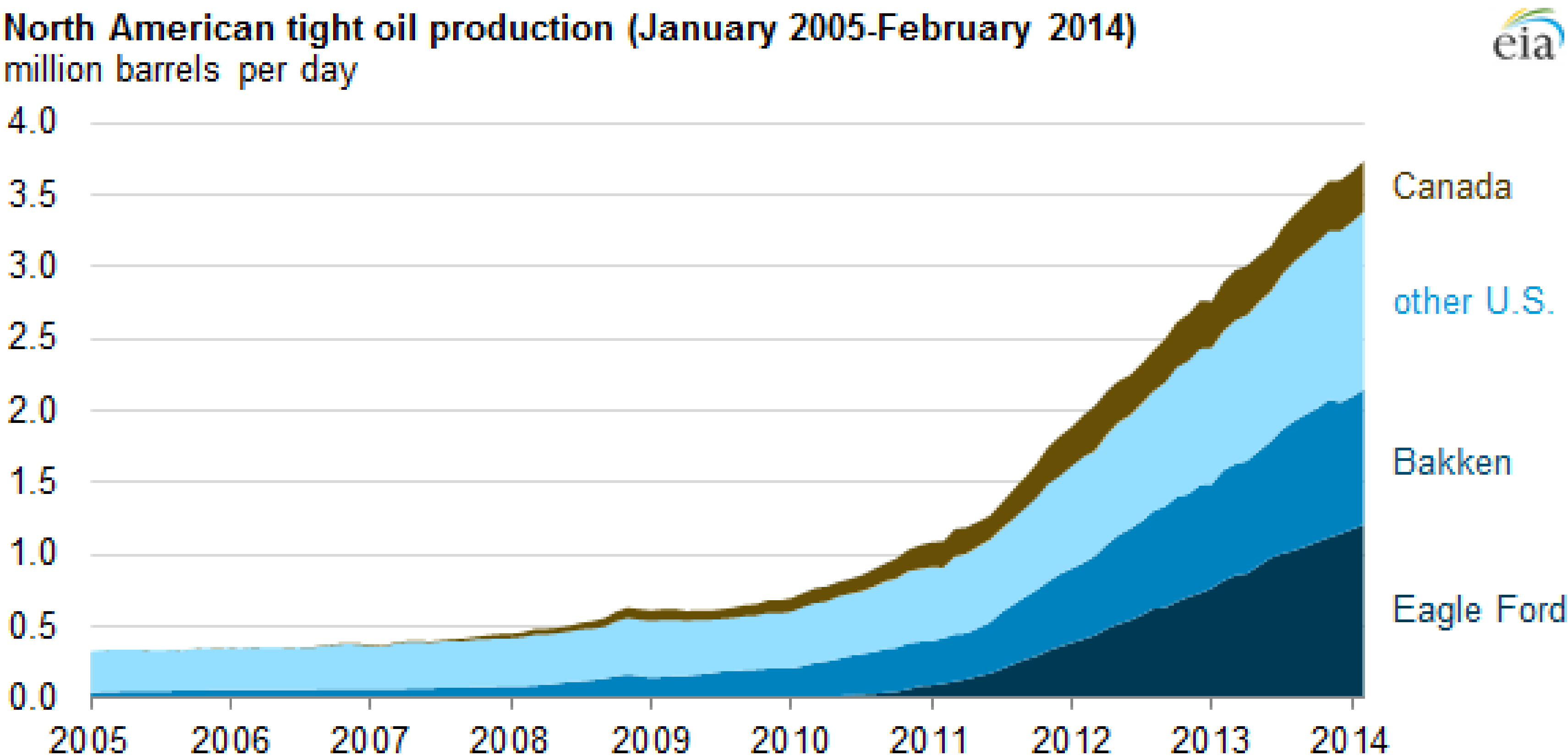
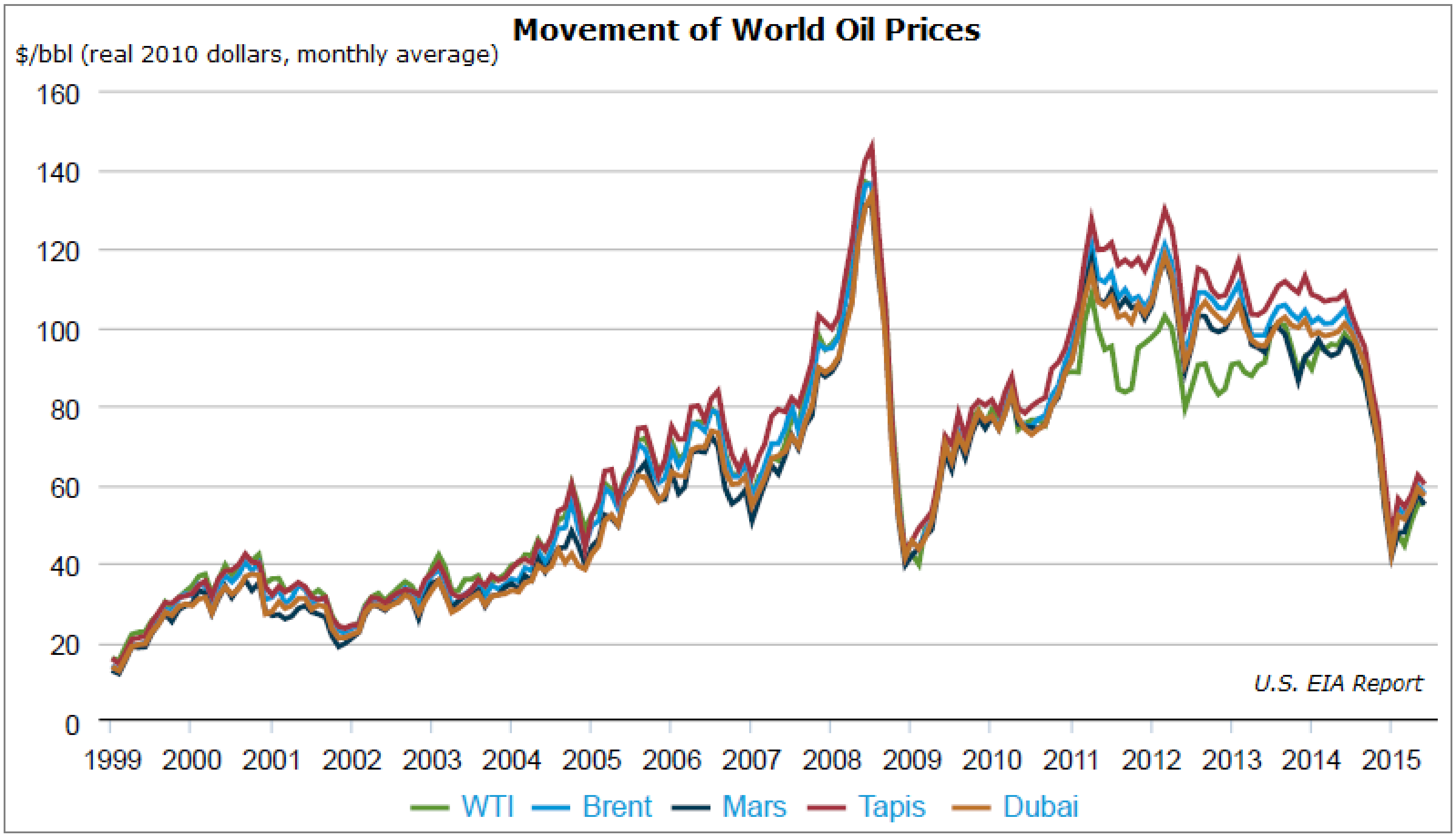
Peak Oil theory disproved?

- Peak oil might by postponed.
- Technology and strict regulation could limit accidents.
- New sources of oil and natural gas consumes more environmental services (water, land etc.)
- And their low ERoEI requires even more intense production.

Peak Oil theory disproved?



Peak Oil theory disproved?



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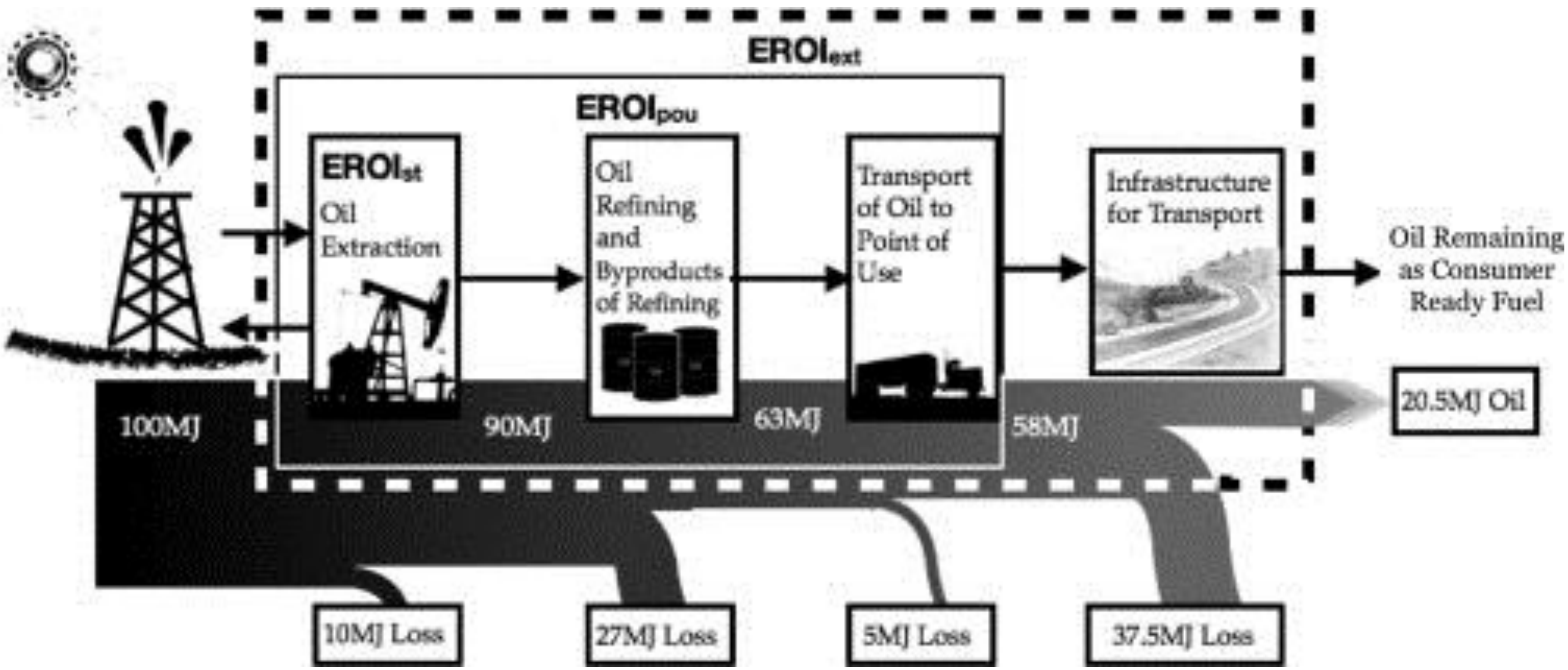
ERoEI

- Energy returned on energy invested – ratio of the amount of usable energy delivered from a particular energy resource to the amount of energy used to obtain that energy resource.
- Less then one – energy sink, net energy loss.

ERoEI

- Standard ERoEI – divides the energy output for a project (region, country) by the sum of the direct and indirect energy used to generate that output.
- Point of use ERoEI – includes additionally the costs associated with refining and transporting the fuel
- Extended ERoEI – considers the energy required not only to get but also to use a unit of energy.
- Societal ERoEI – all gains from fuels and all costs of obtaining these fuels.

ERoEI



EROIext
EROIpou
EROIst
Oil Extraction
Oil Refining and Byproducts of Refining
Transport of Oil to Point of Use
Infrastructure for Transport
Oil Remaining as Consumer Ready Fuel
100MJ
90MJ
63MJ
58MJ
20.5MJ Oil
10MJ Loss
27MJ Loss
5MJ Loss
37.5MJ Loss

EROEI of different sources of energy

Oil in the beginning of oil business	100
Oil in Texas around 1930	60
Oil in the Middle East	30
Other oil	10-35
Natural gas	20
High quality coal	10-20
Low quality coal	4-10
Water power plants	10-40
Wind power plants	5-10
Shale oil	5
PV power plants	2-5
Nuclear energy	4-5
Oil sands	max. 3
Shale oil	max. 1,5
Biofuels (in Europe)	0,9 - 4

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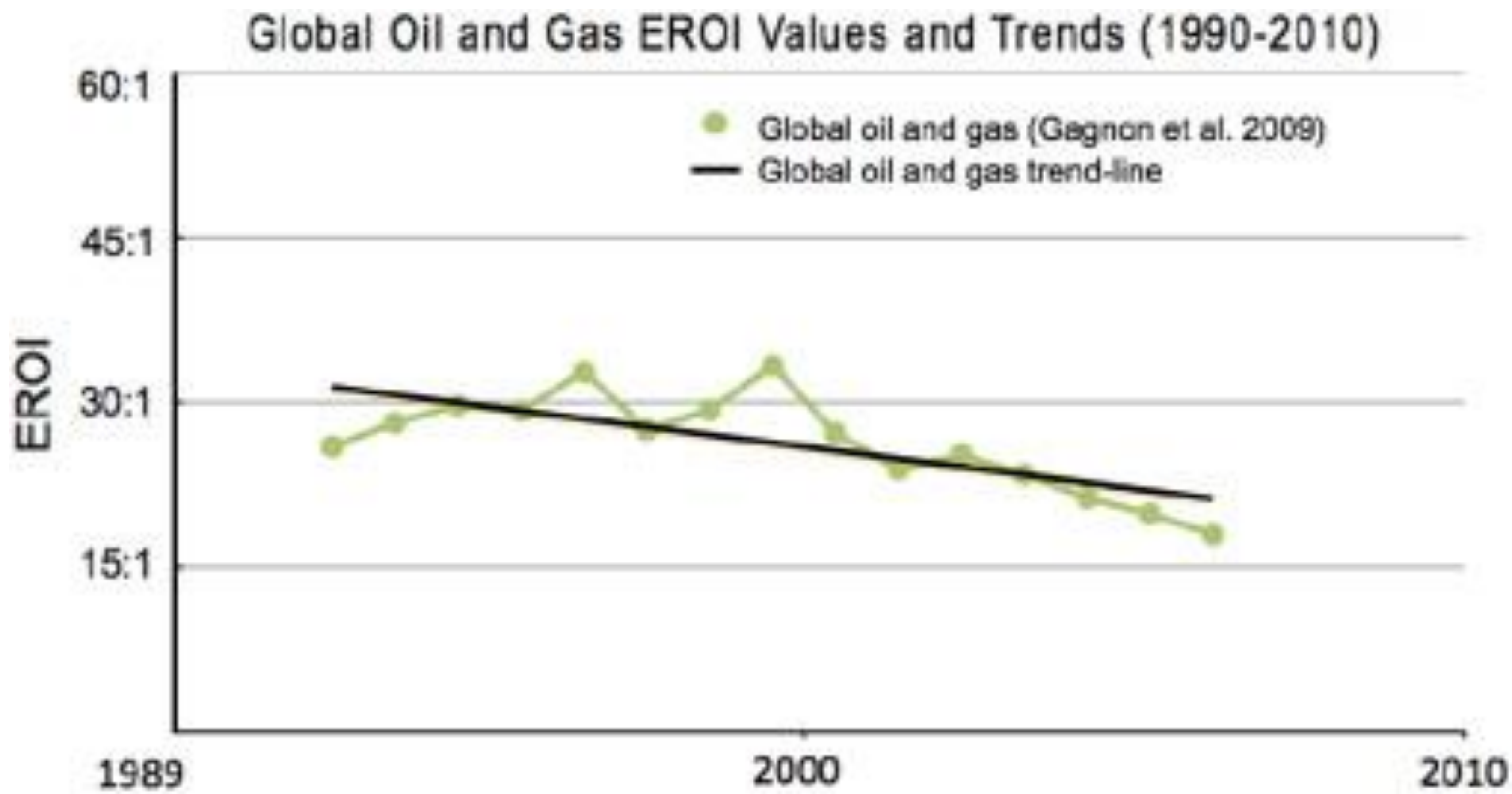
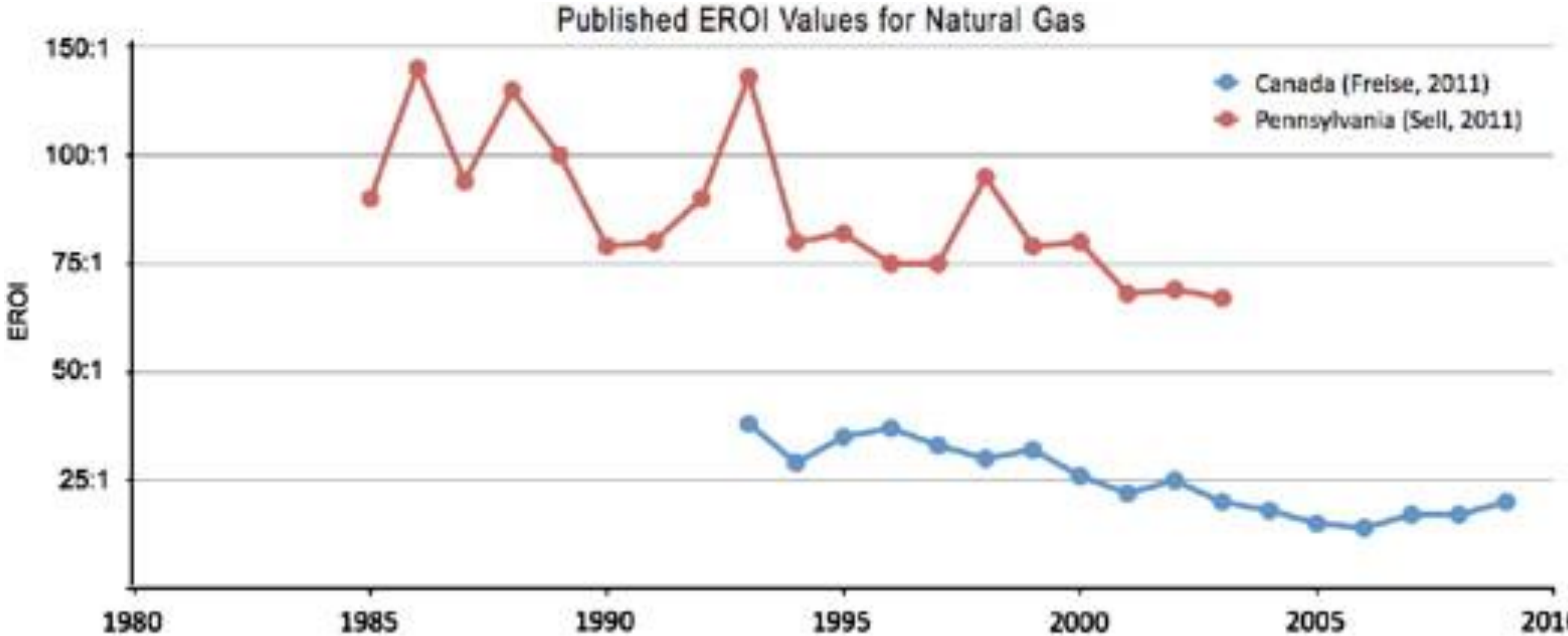

Global Oil and Gas EROI Values and Trends (1990-2010)
60:1
45:1
30:1
15:1
EROI
Global oil and gas (Gagnon et al. 2009)
Global oil and gas trend-line
1989
2000
2010



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Future of fossil fuels?

- Environmental cost of consumption of fossil fuels is not static.
- Production needs to grow faster than consumption due to the ERoEI + each new barrel of oil and cubic metre of gas is more (not less) environmentaly demanding.

Sources

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