# Oil and natural gas
# Peak Oil and ERoEI

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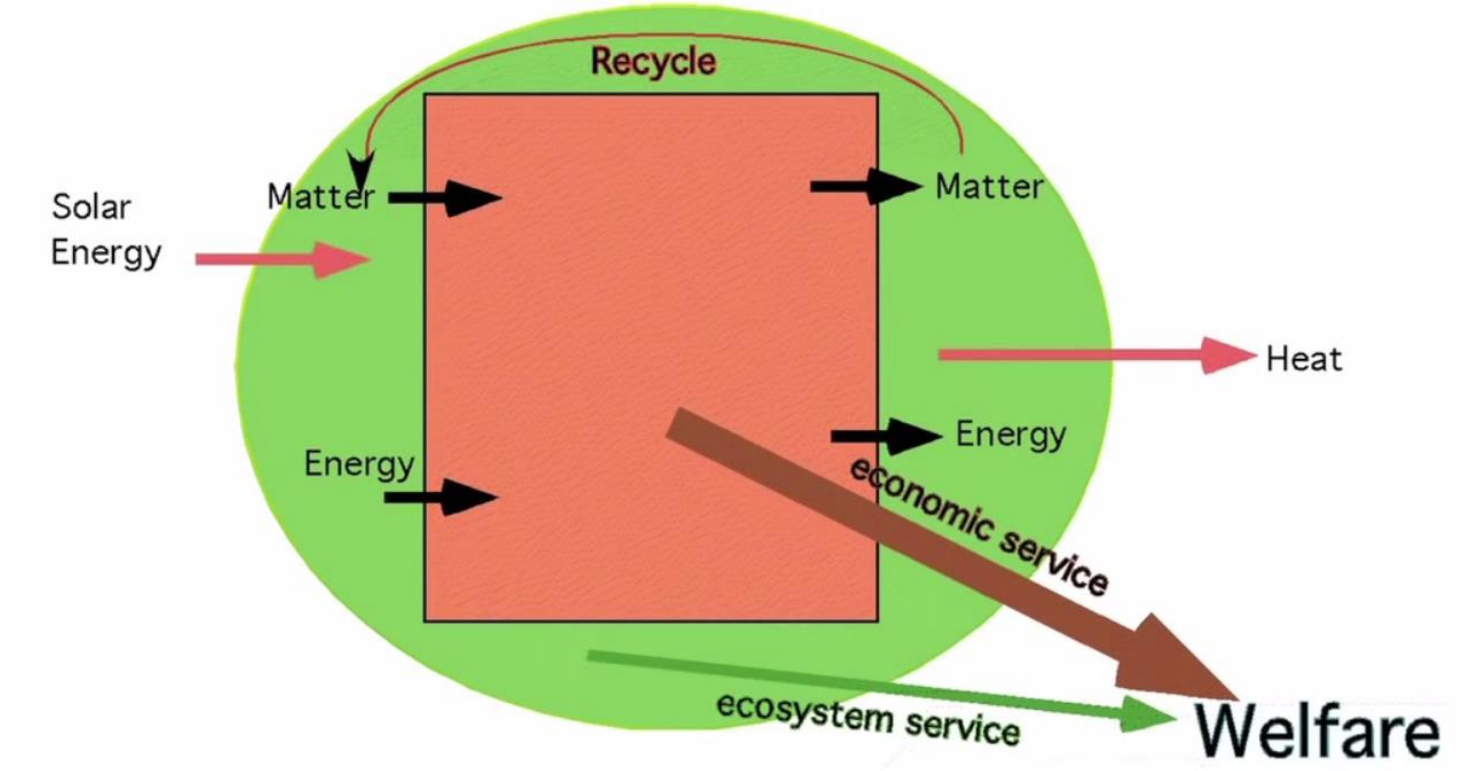
# Modern 7bn people world

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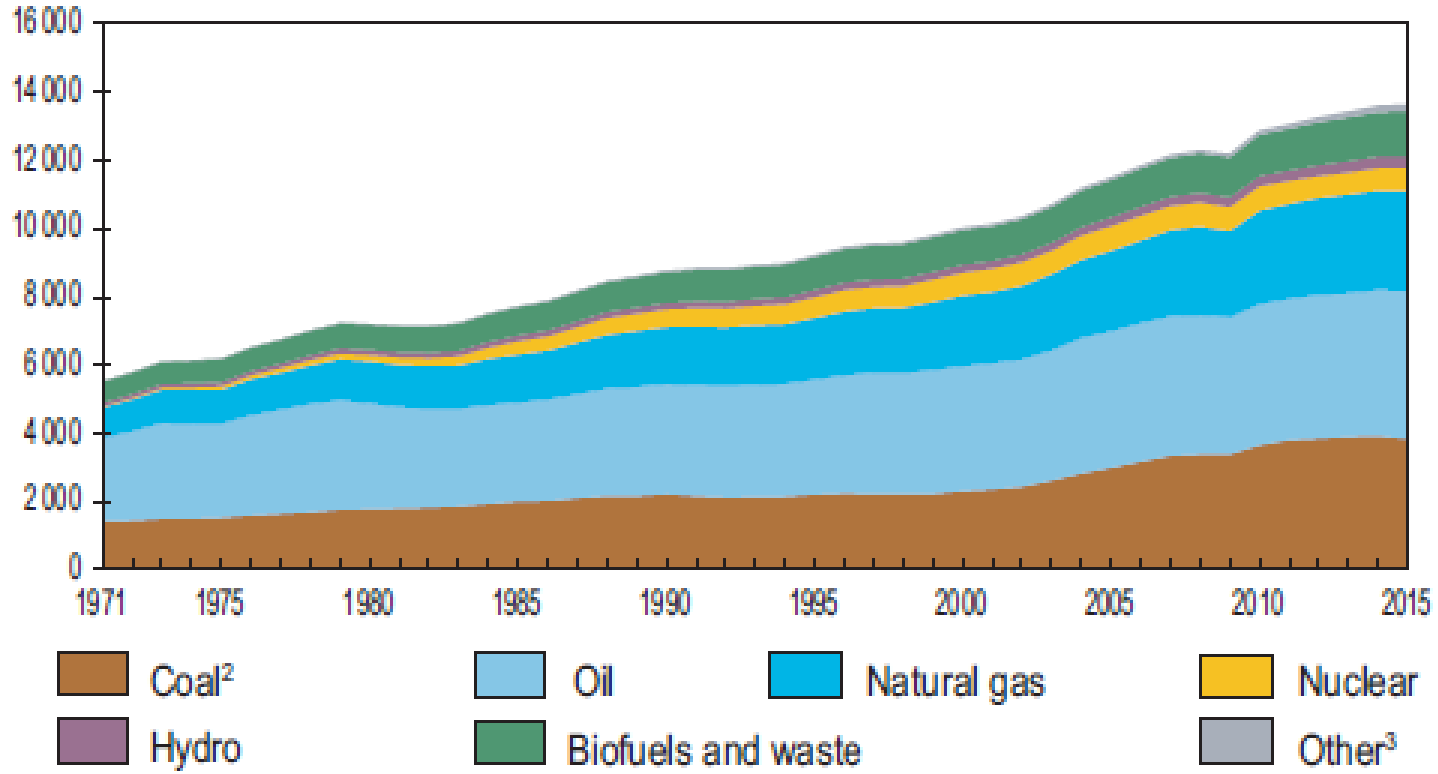
# World total primary energy supply by fuel (1971 – 2015)




*Note: Peat and oil shale aggregated with coal.*

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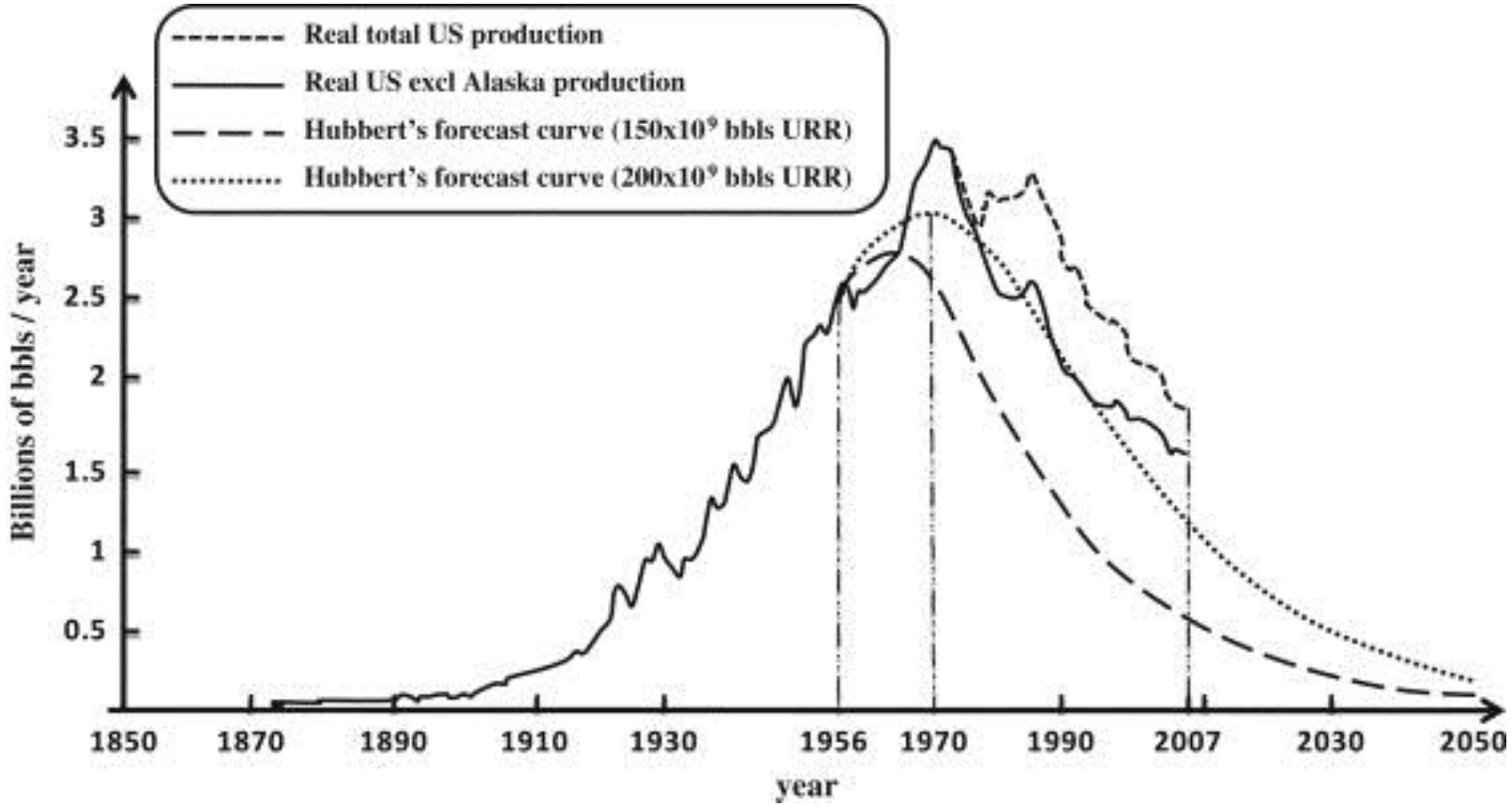
# Peak Oil

- 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“.

# Peak Oil concept

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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) |

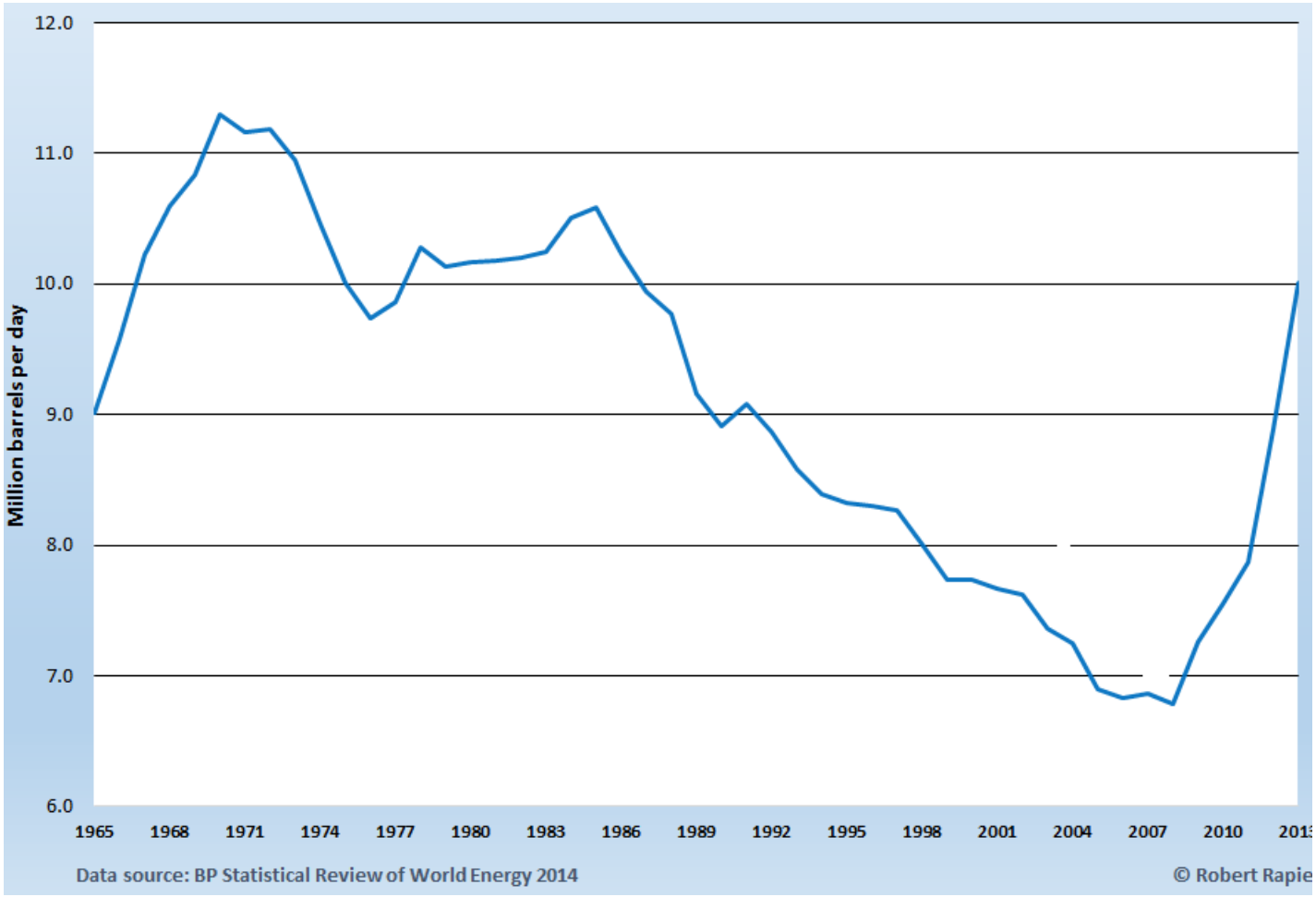
# Was Hubbert right?

- 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.

# US oil production since 1965

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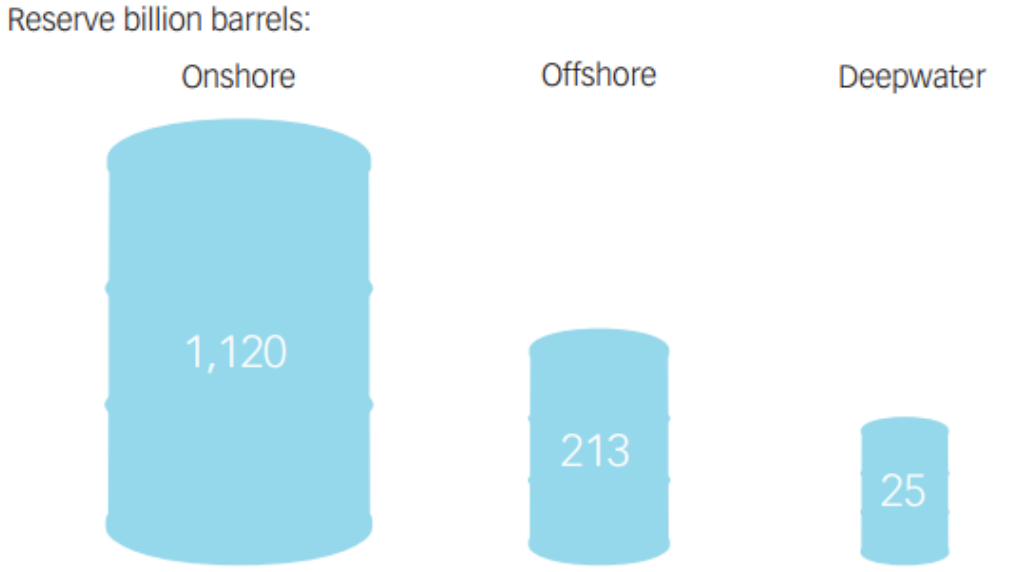
# New areas of exploration – deep waters

- 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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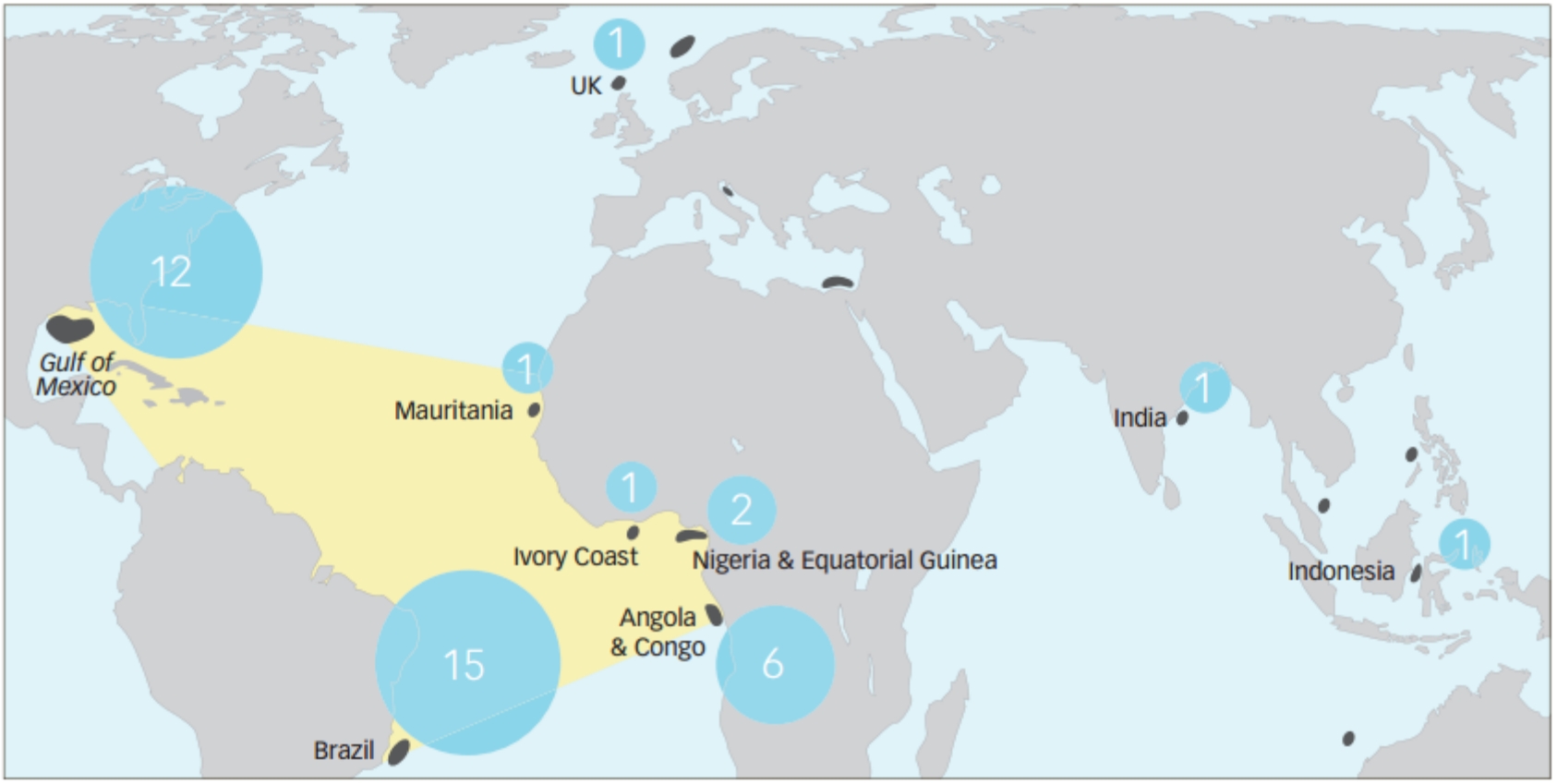
# Location of deepwater drilling oil fields




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

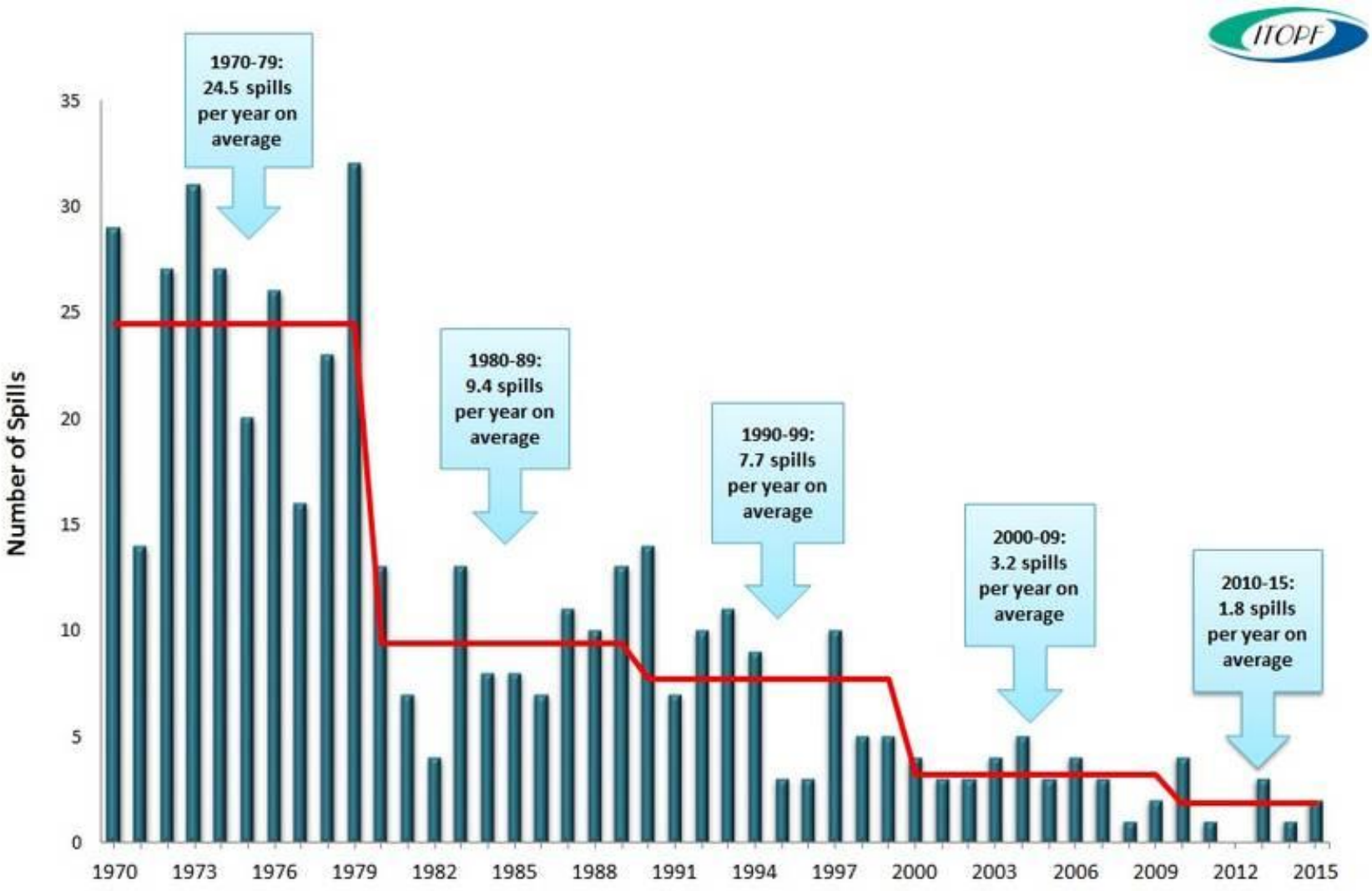
| Date of Incident | Location | Incident and Spillage Details (Estimated figures) | Insured loss ($) |
|---|---|---|---|
| 28.1.69 - 12.2.69 | Santa Barbara, California | 80,000 - 100,000 barrels | Not available |
| 3.6.79 - 23.3.80 | Ixtoc Well, Mexico | 3.3 million barrels | 22,000,000 |
| 22.4.77- 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

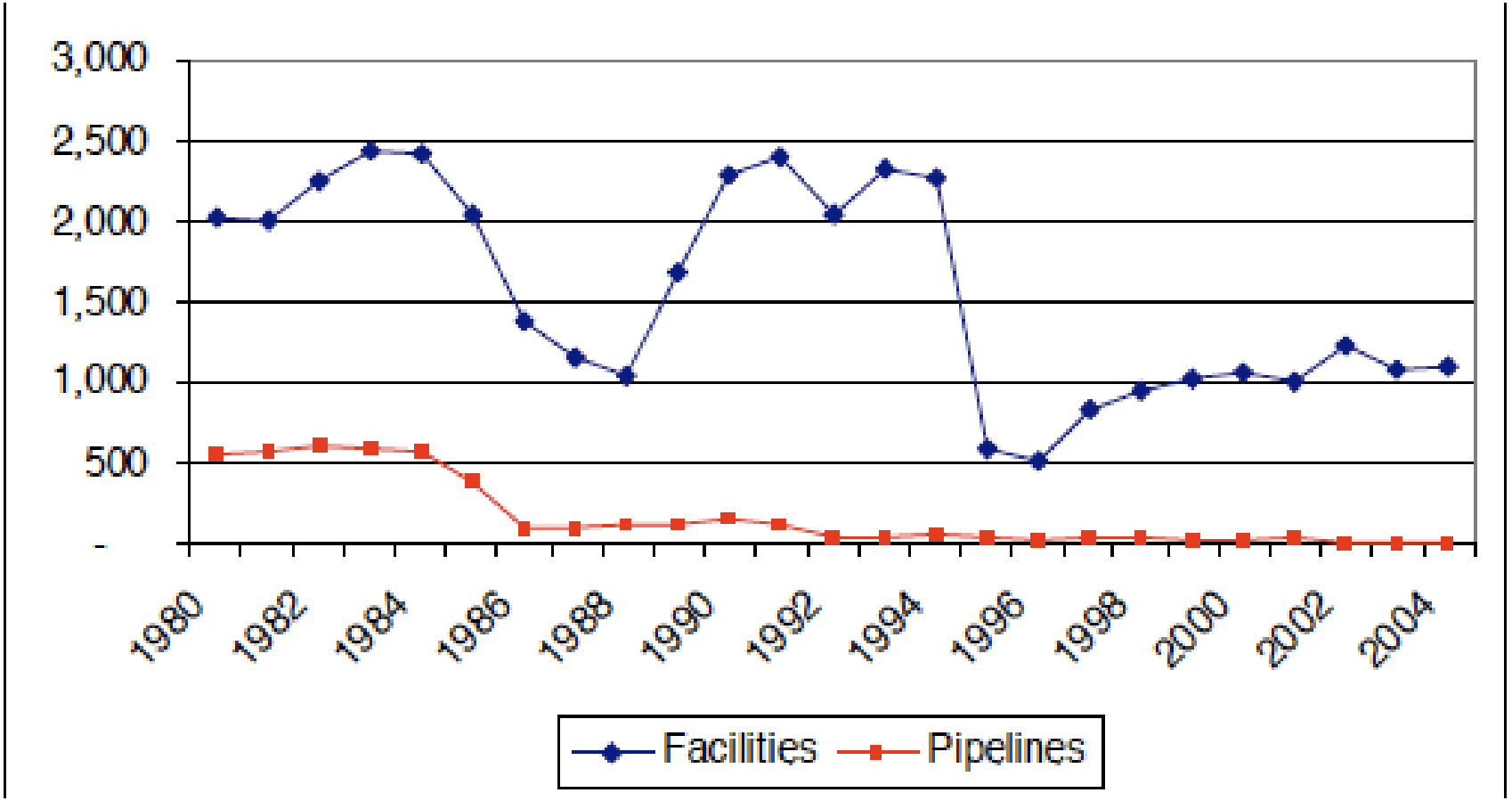
# Transport of oil

- 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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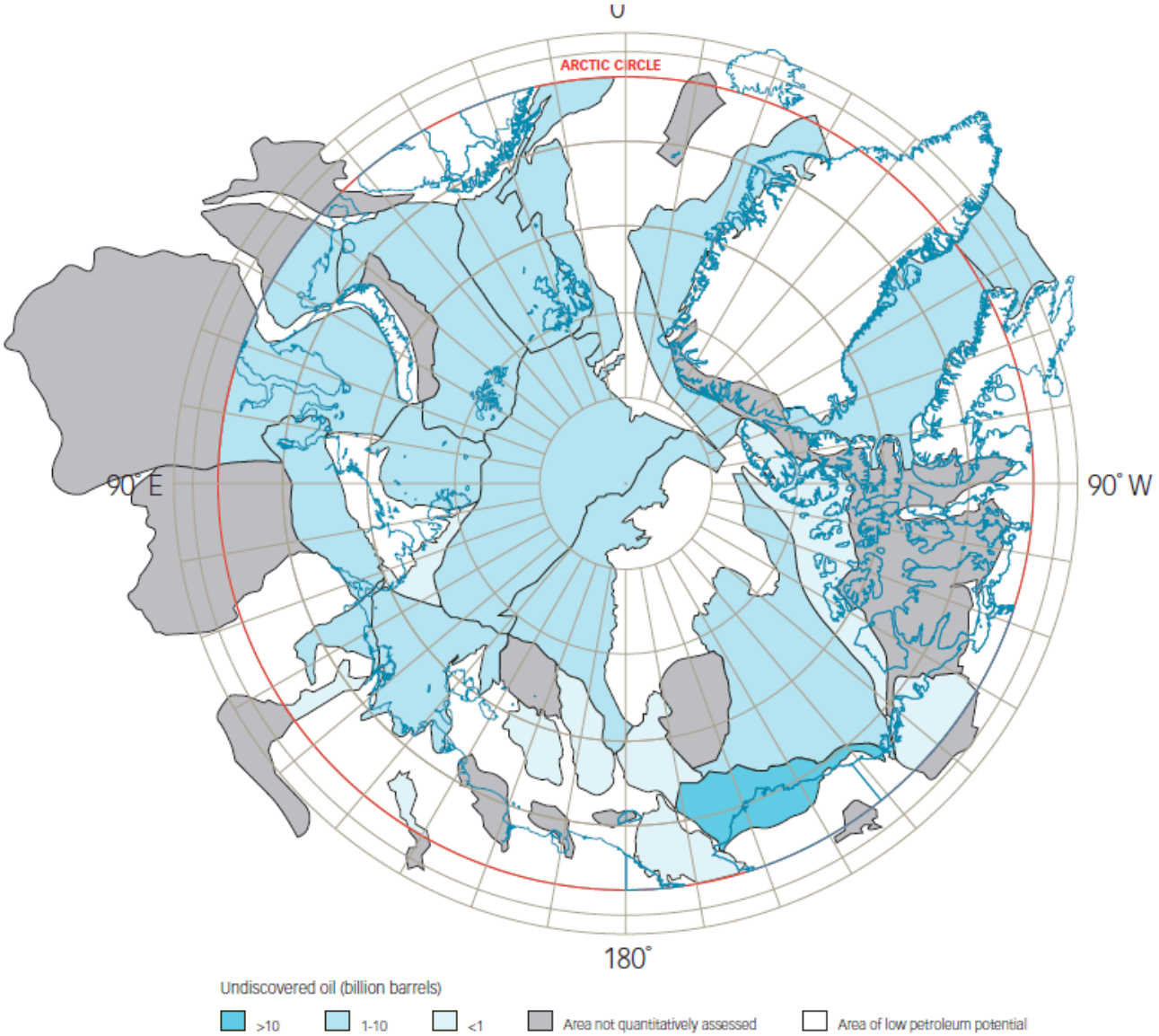
# New areas of exploration – Arctic regions

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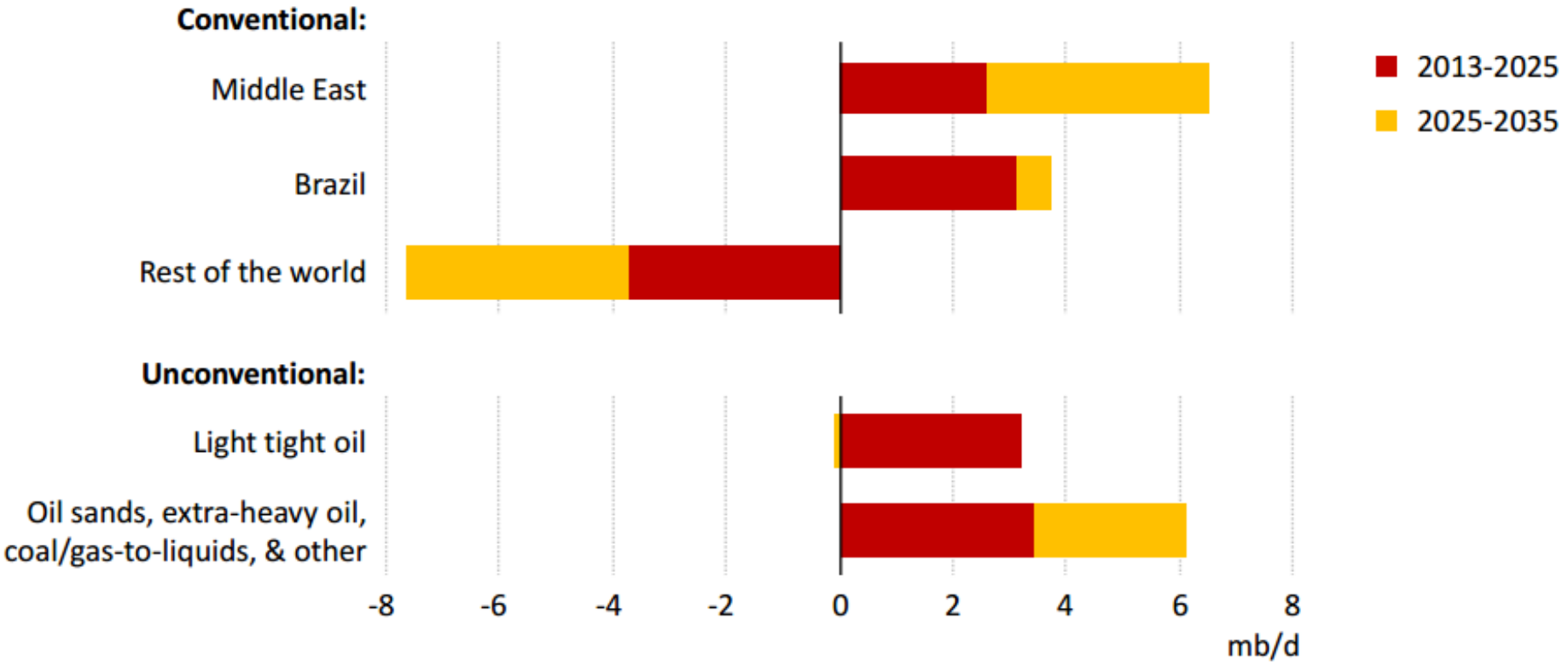
Source: Map courtesy of the U.S. Geological Survey

# 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.

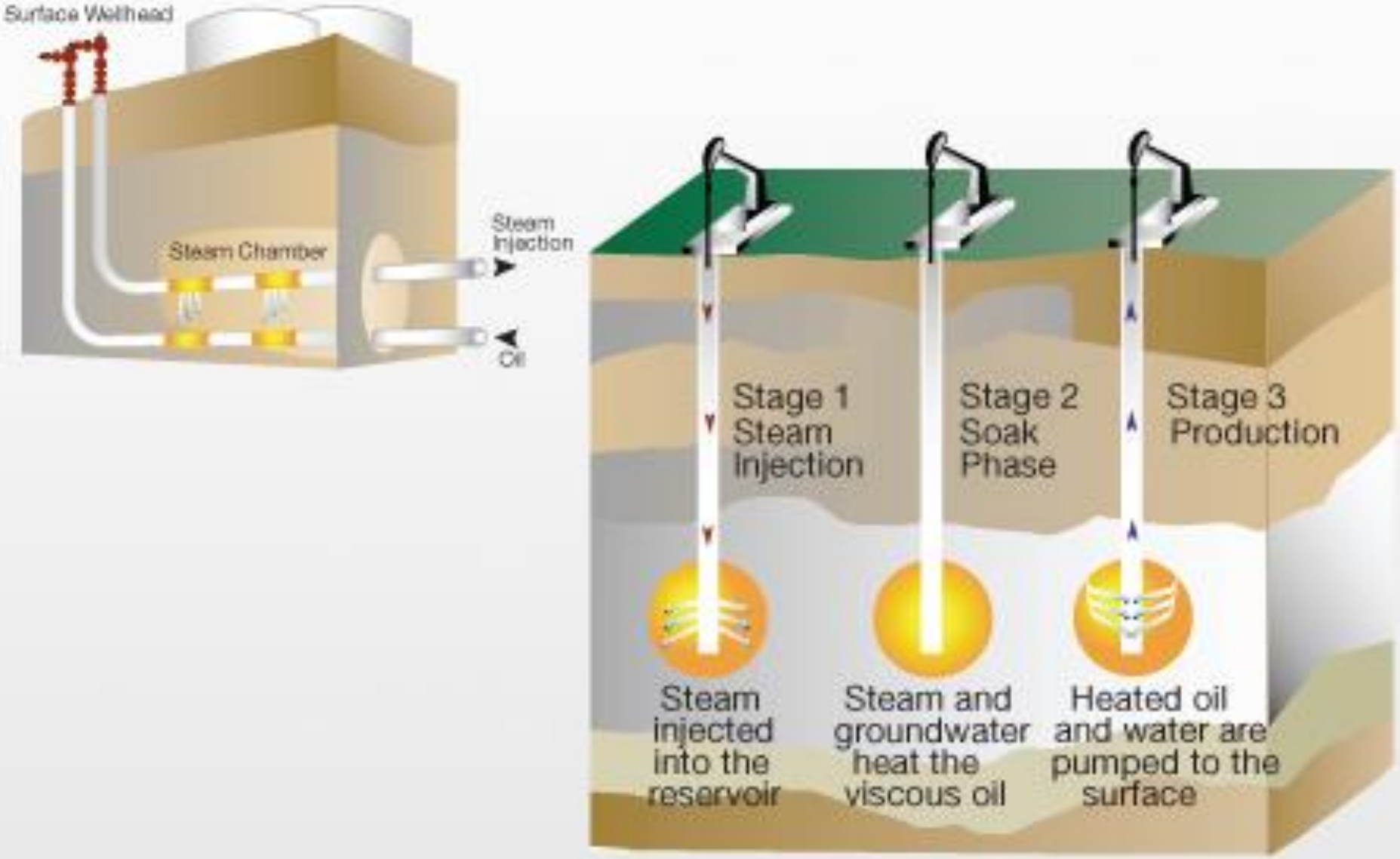
- Conventional oil: mineral oil consisting of a mixture of hydrocarbons of natural origin, exists in liquid form under normal surface temperatures and pressure.
- Unconventional oil: to be extracted non-conventional technology is needed, in natural state (without heating or diluting) couldn´t be extracted.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

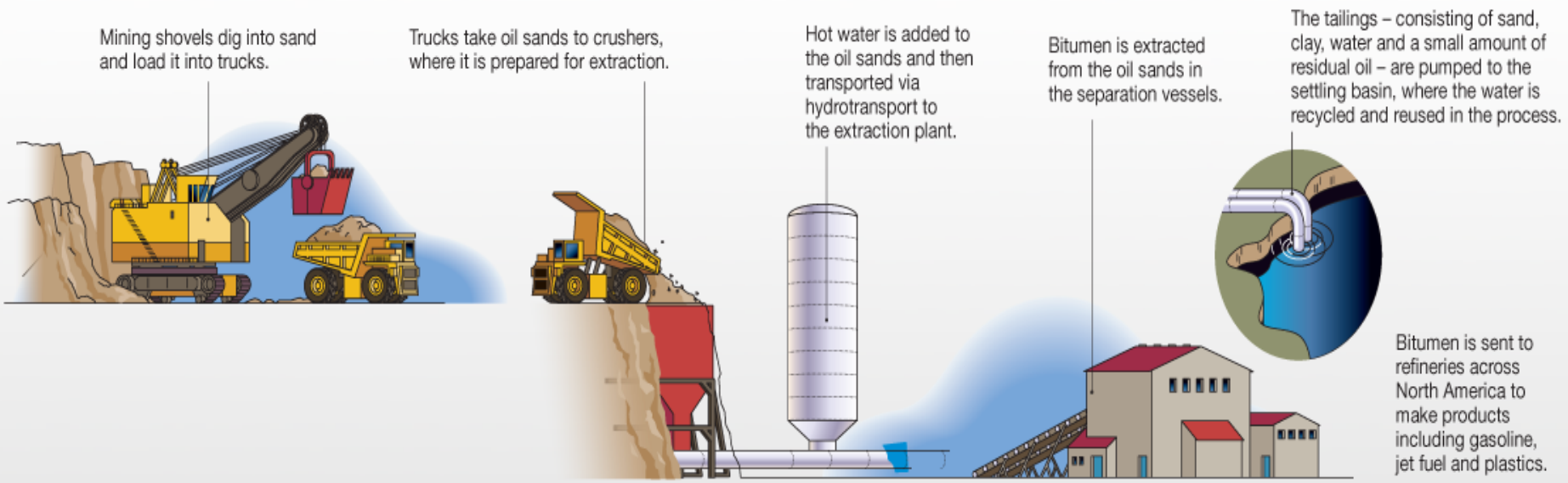
# Producing techniques: in-situ mining

- 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

# Peak Oil theory disproved?

= Peak oil might by postponed.

= Technology and strict regulation could limit accidents.

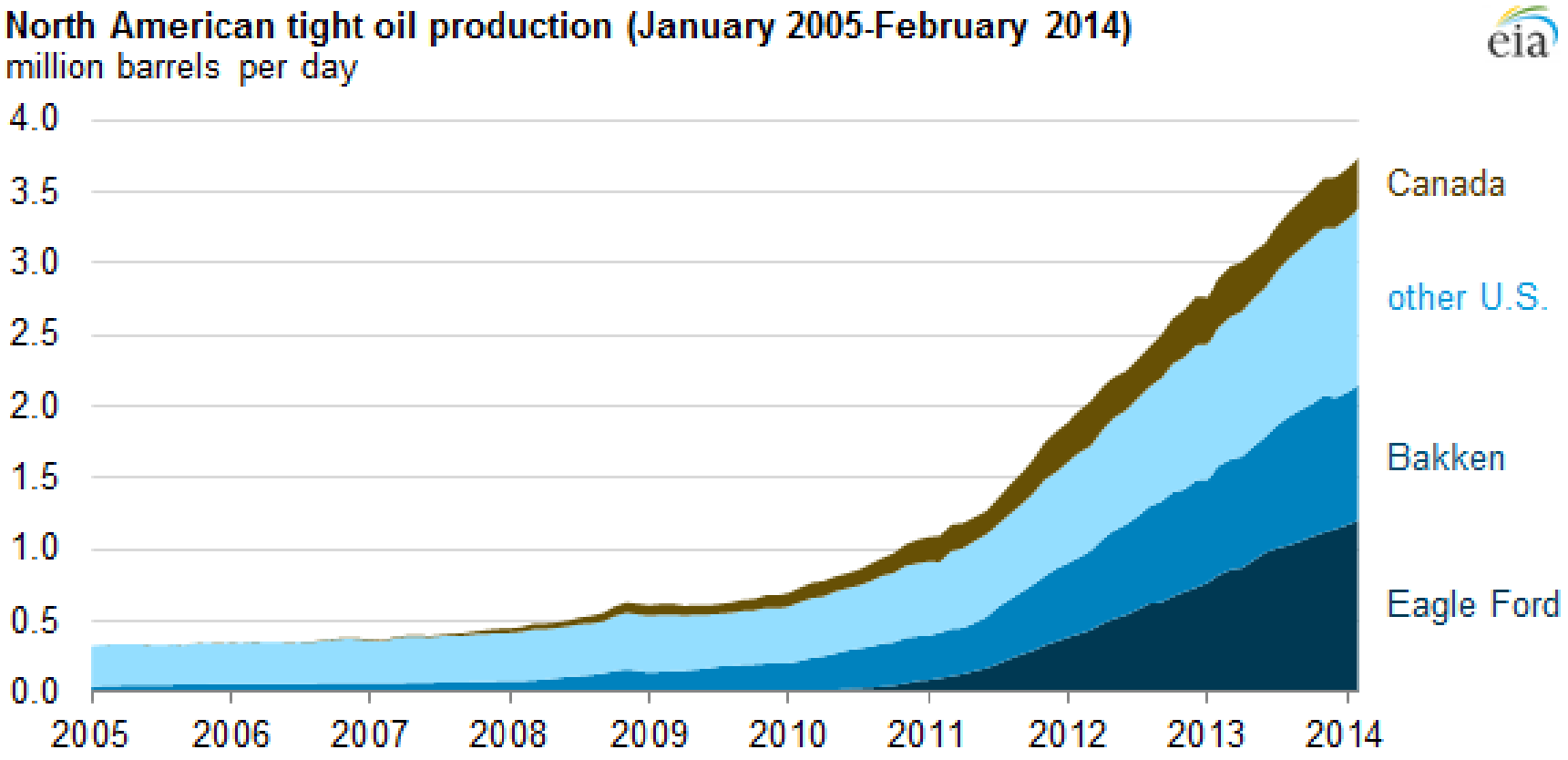
= New sources of oil and natural gas consumes more environmental services (water, land etc.)

= And their low ERoEI requires even more intense production.

= Still physical limits of production

= Demand Peak Oil?

# Peak Oil theory disproved?

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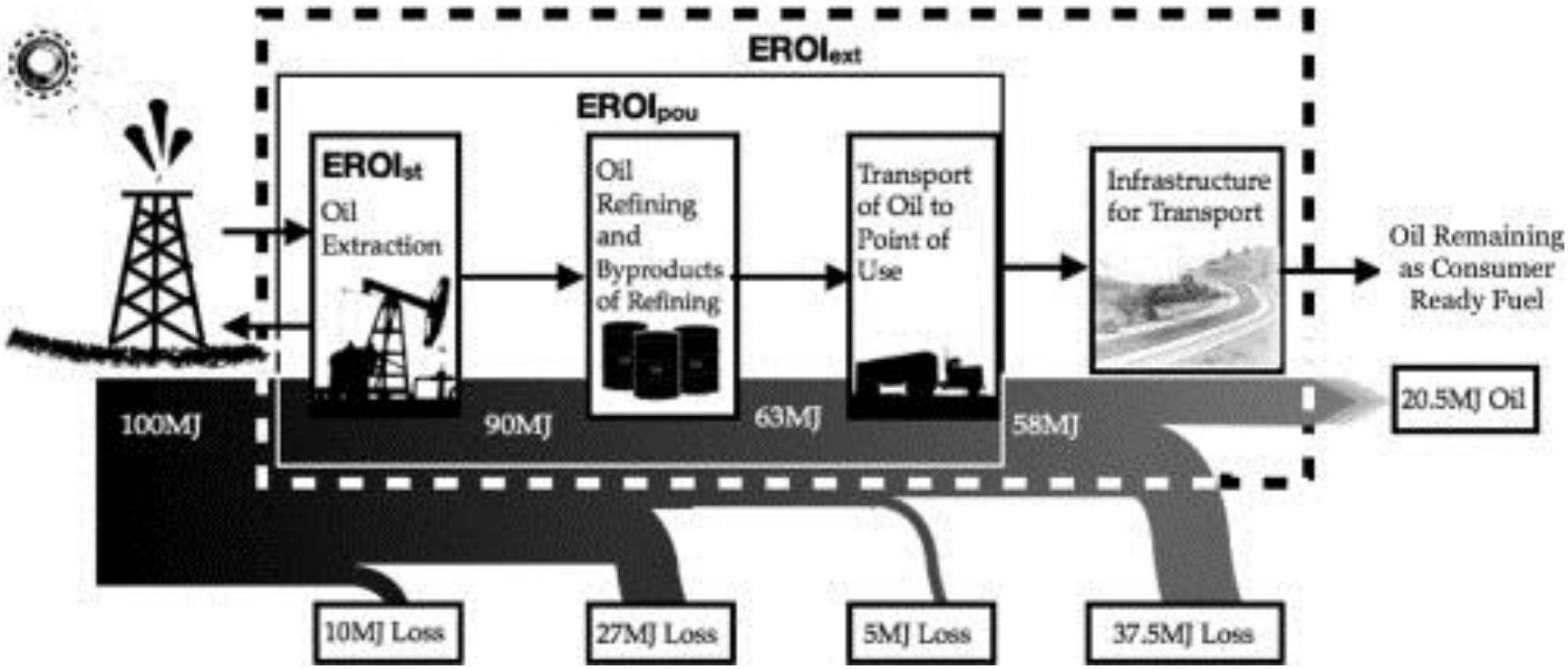
# ERoEI

- 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

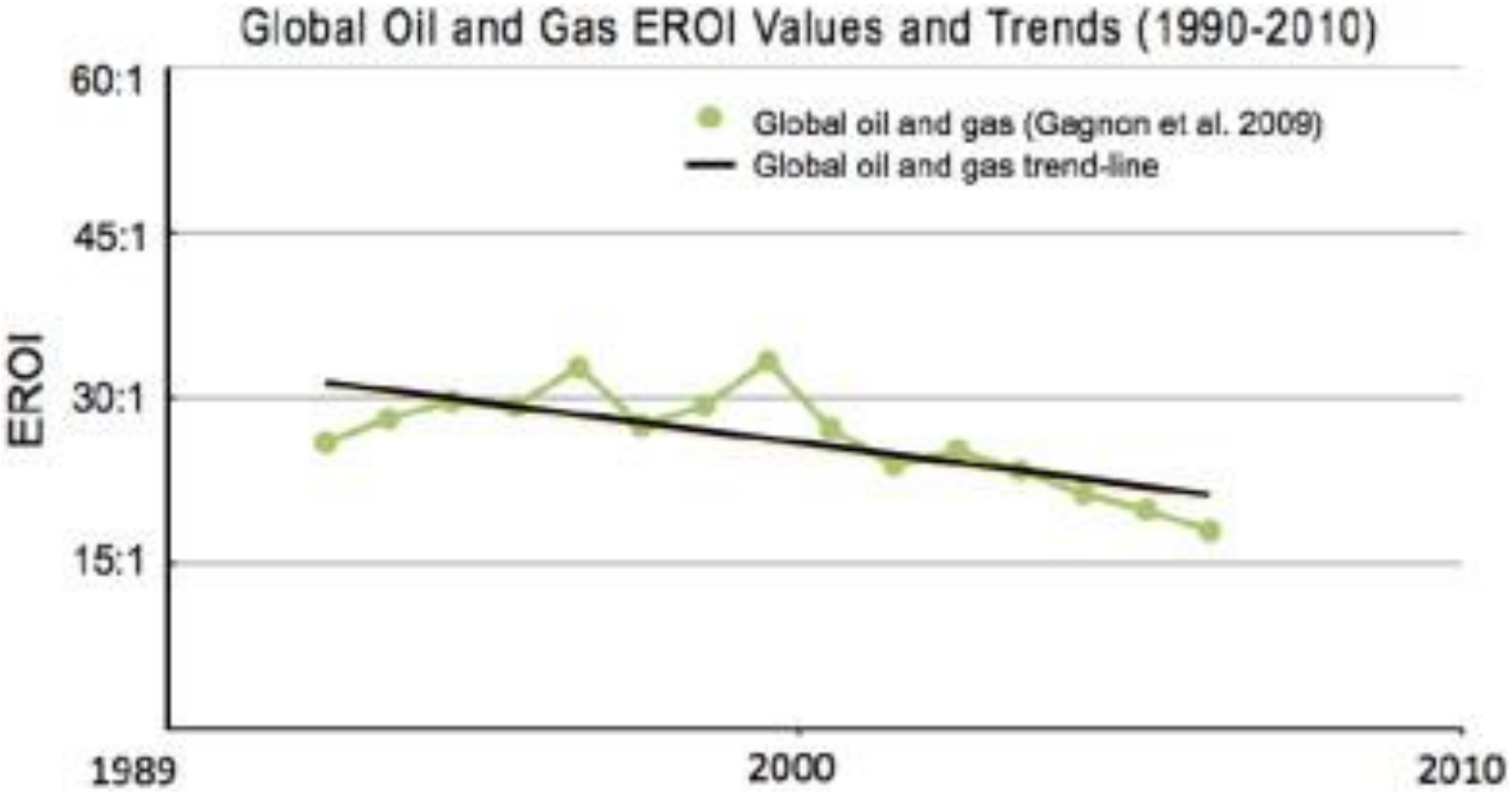
- Standard ERoEI – divides the energy output for a project (region, country) by the sum of the direct and indirect energy used to generate that output.
- Point of use ERoEI – includes additionally the costs associated with refining and transporting the fuel
- Extended ERoEI – considers the energy required 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.

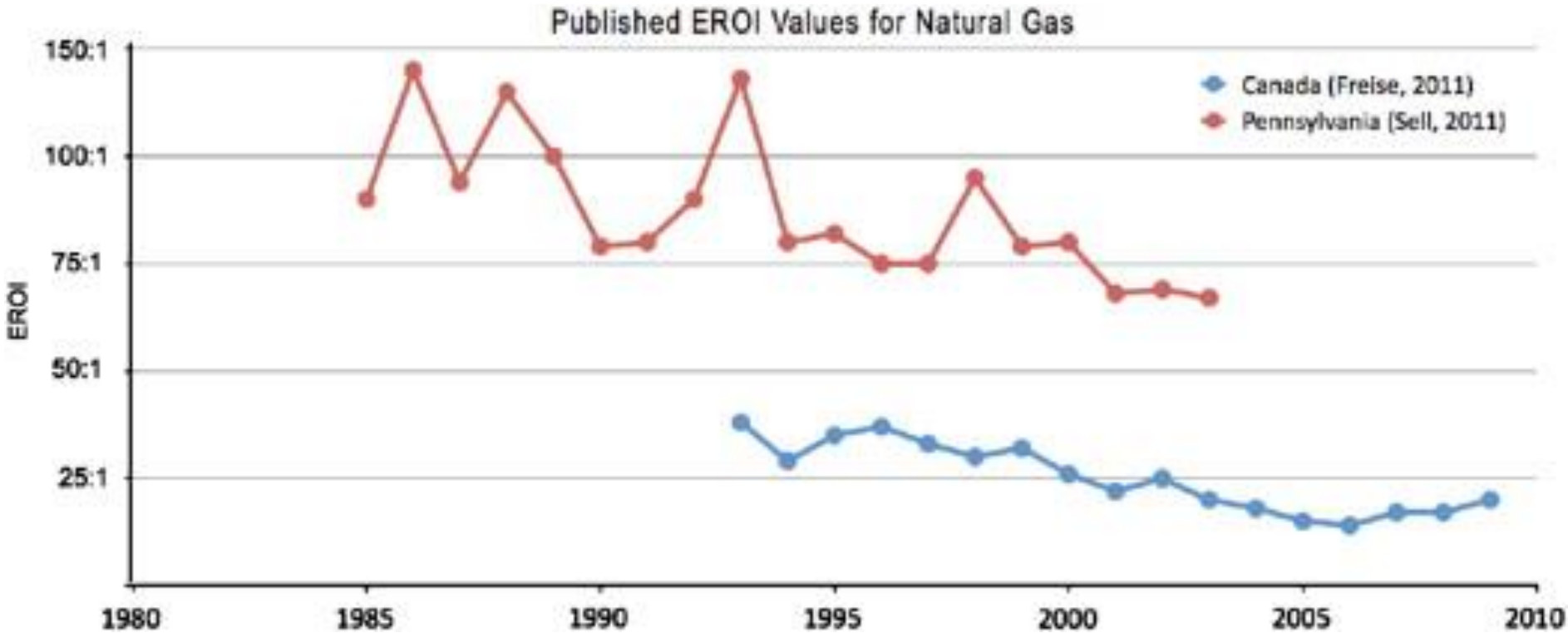
# ERoEI


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 |


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?

- Still lot of resources to be utilized – (energy) peak is not the imminent threat.
- However, environmental costs of production of fossil fuels are not static. Each additional barrel of oil and cubic metre of gas is more (not less) environmentaly demanding.
- Moreover, production needs to grow faster than consumption due to the ERoEI of new reserves.

# Sources


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