Shale oil in the refinery

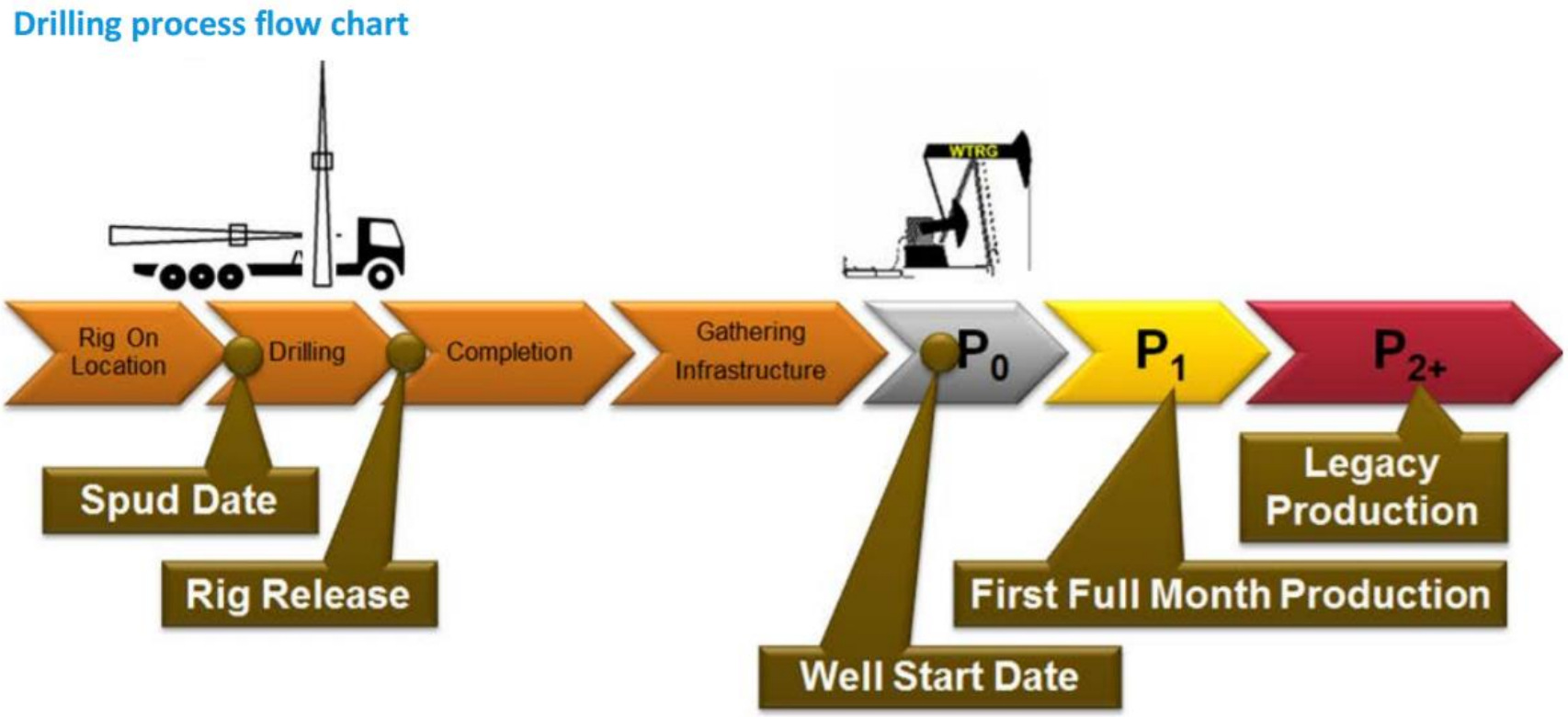
Benjámin Csorba
03. 04. 2022.
BME
Thanks to Ákos Fürcht for the basis of the slide show.

General definitions

- **Rotary rig**
  - A rotary rig rotates the drill pipe from surface to drill a new well (or sidetracking an existing one) to explore for, develop and produce oil or natural gas
- **Rotary rig count (weekly)**
  - A weekly census of the number of drilling rigs actively exploring for or developing oil or natural gas
- **Active rotary rig**
  - A rig is considered active from the moment the well is "spudded" until it reaches target depth or "TD"
- **Directional well**
  - Directional wells are typically drilled when the surface location of the well cannot be located directly above the reservoir.
  - Offshore platforms or "pad sites" on land are the most common examples. In these cases, there are a multitude of wells that start at one location, but they all intersect the reservoir at a different spot
- **Horizontal well**
  - A horizontal well is a type of directional well, when the inclination exceeds 80 degrees from vertical, or when the lower part of the well bore parallels the pay zone.
  - Horizontal wells are drilled to increase the length of the well that actually contacts the reservoir, in order to increase the productivity of the well.

Source: Baker Hughes rig count data

Drilling process flow chart

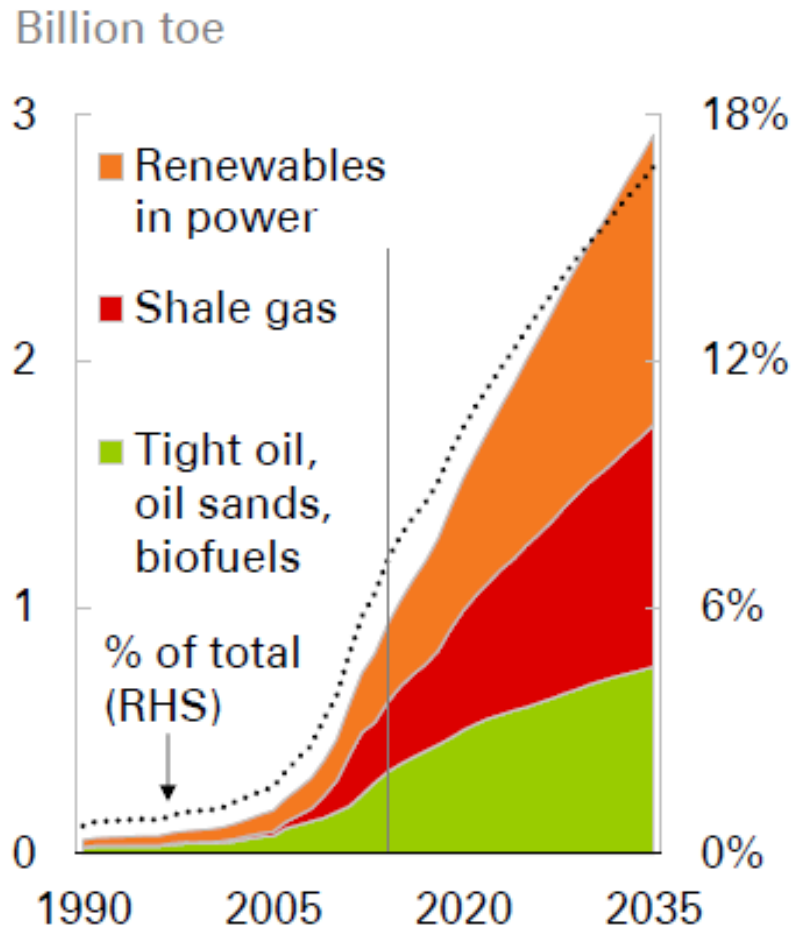


New well production (initial production): the daily production in the P1 period

Source: EIA (www.eia.gov)

Why is it important?

Prediction for 2035

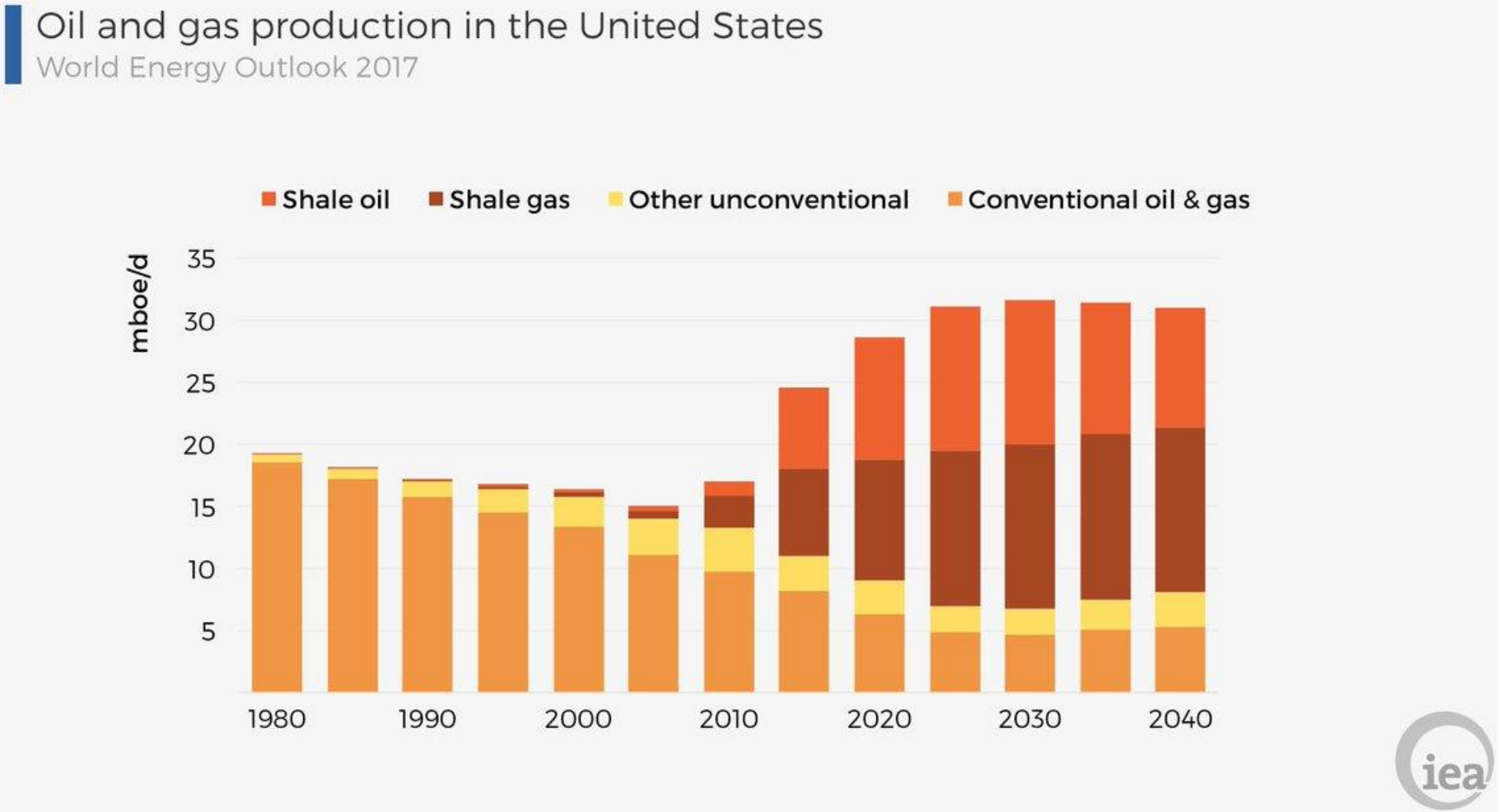


Primary energy sources

- Between 2015-2035 the non-conventional energy sources will triple
- Its increase will comprise the ~45% of the total increase
- The not used production potentials predict the restructuring of economical circumstances

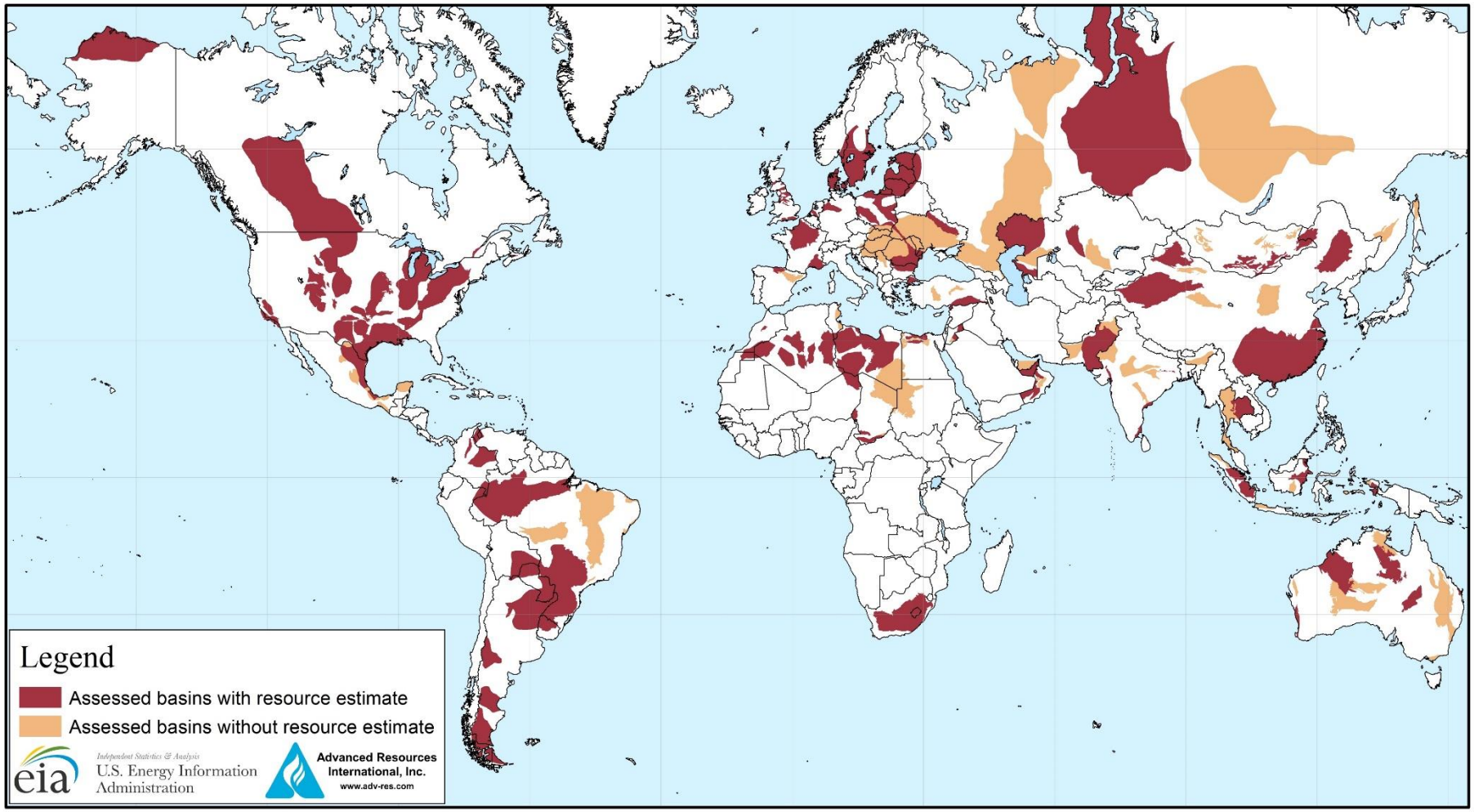
Source: BP Energy outlook 2035

Prediction for 2040



Forrás: IEA – International Energy Agency

World **shale** oil/gas **fields**



Source: EIA (www.eia.gov)

Technically recoverable shale oil reserves

Ranking	Country	bn bbl
1	Russia	75
2	USA	58
3	China	32
4	Argentina	27
5	Libya	26
6	Australia	18
7	Venezuela	13
8	Mexico	13
9	Pakistan	9
10	Canada	9
	Total	**345**

Number of shale gas wells (2012)

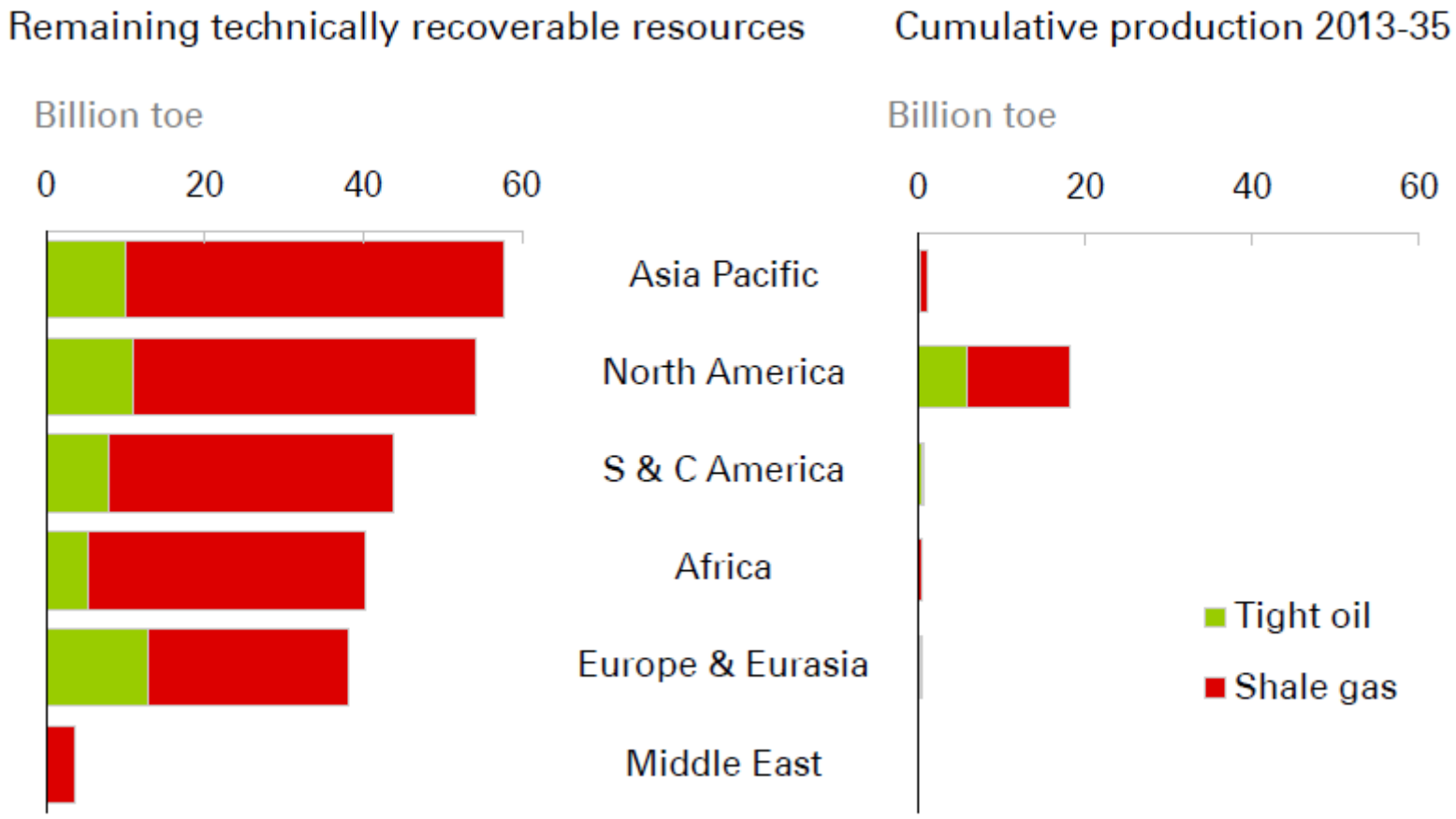
- USA: ~110 000
- Others: ~200

Energy production (2012)

- USA: 99,9%
- Others: 0,1%

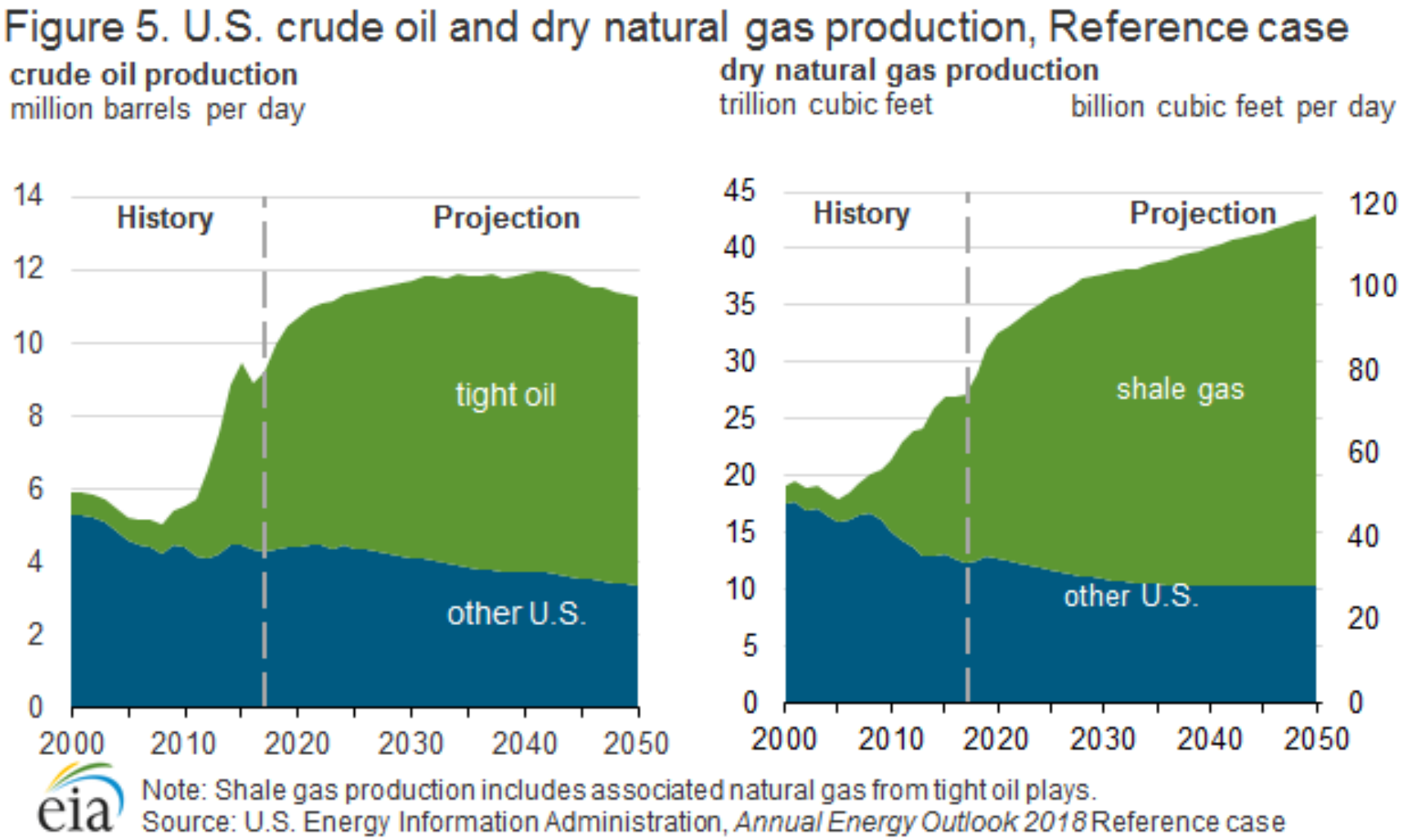
Source: EIA (www.eia.gov)

Technically recoverable shale oil reserves - 2



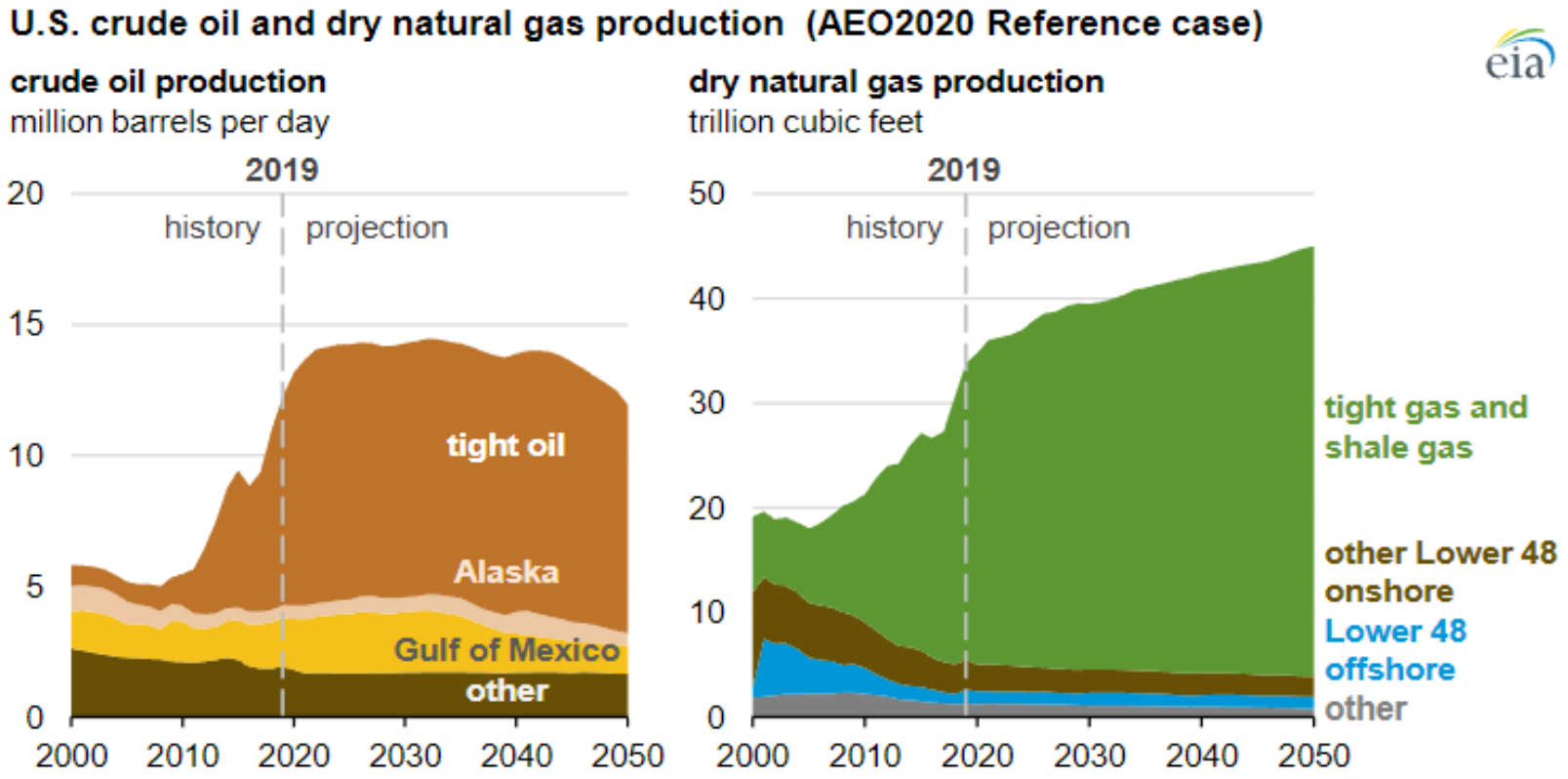
Source: Resources data © OECD/IEA 2014

Shale gas and shale oil share in total production in the US - forecast



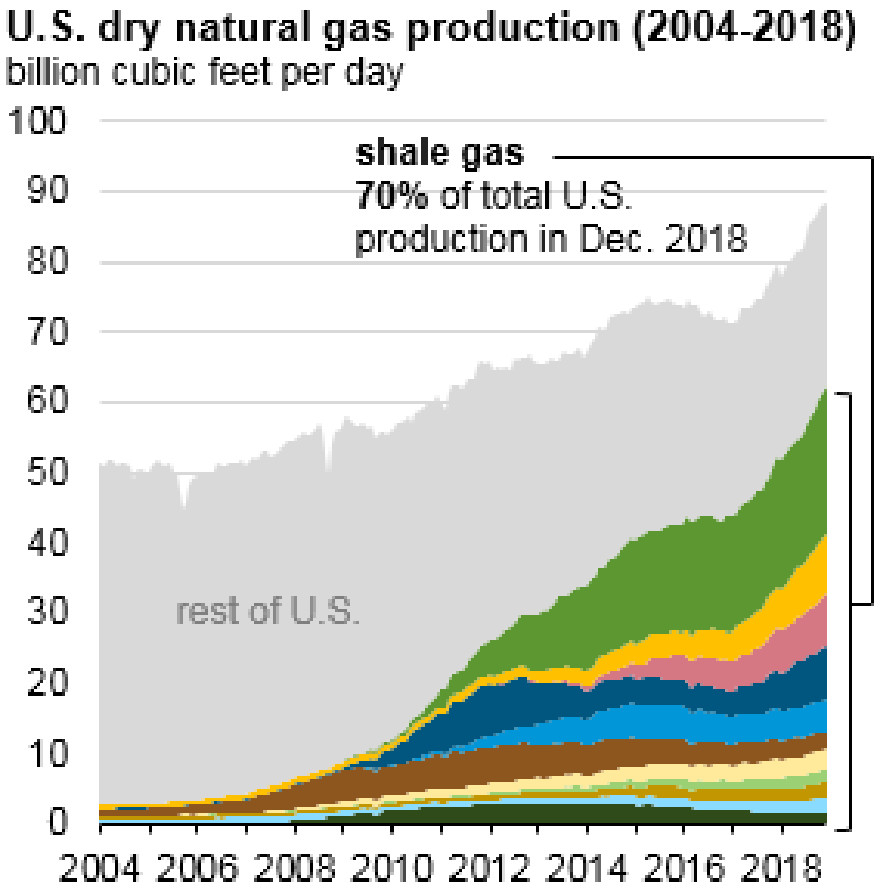
Forrás: EIA (www.eia.gov)

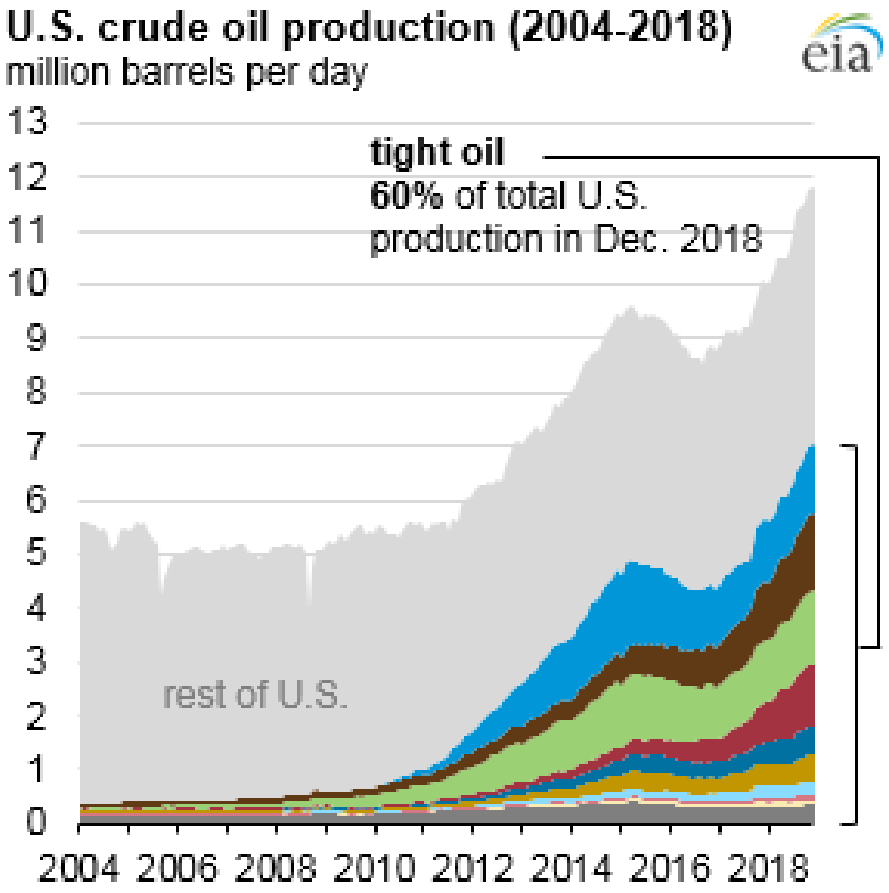
US crude oil and natural gas production by source, forecast



Source: U.S. Energy Information Administration, Annual Energy Outlook 2020

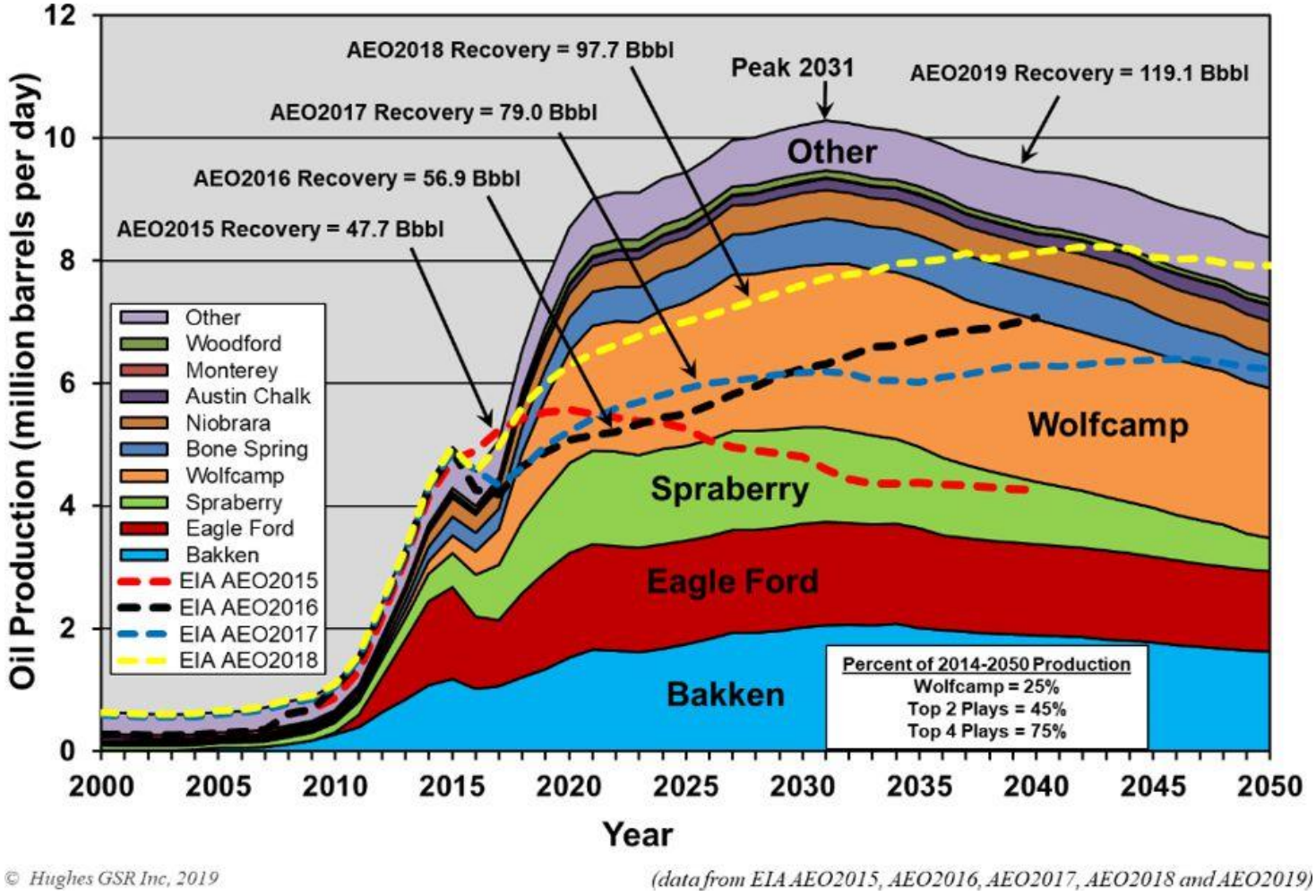
Shale gas and shale oil share of total production in the US





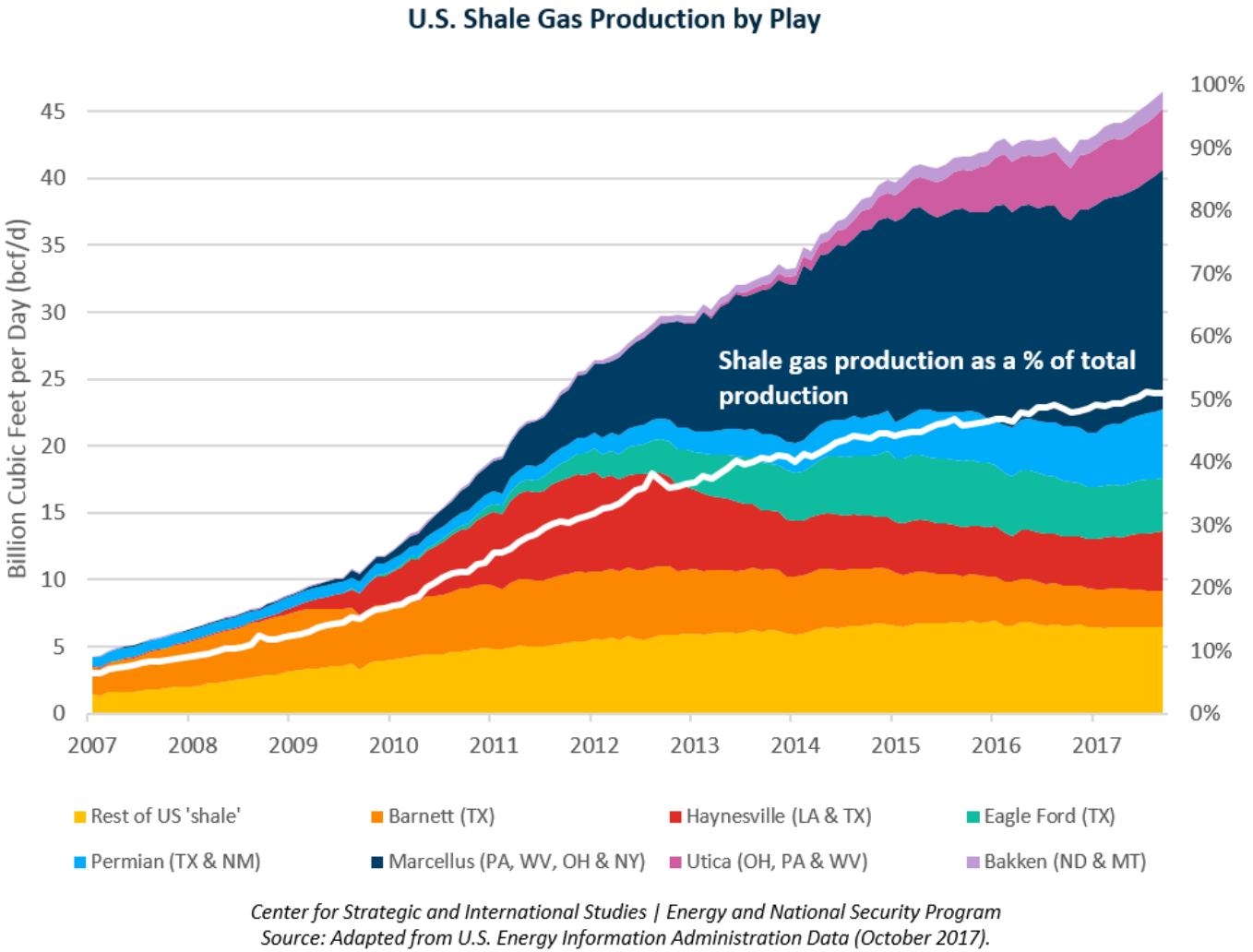
Forrás: EIA (www.eia.gov)

Past and expected future production of some fields



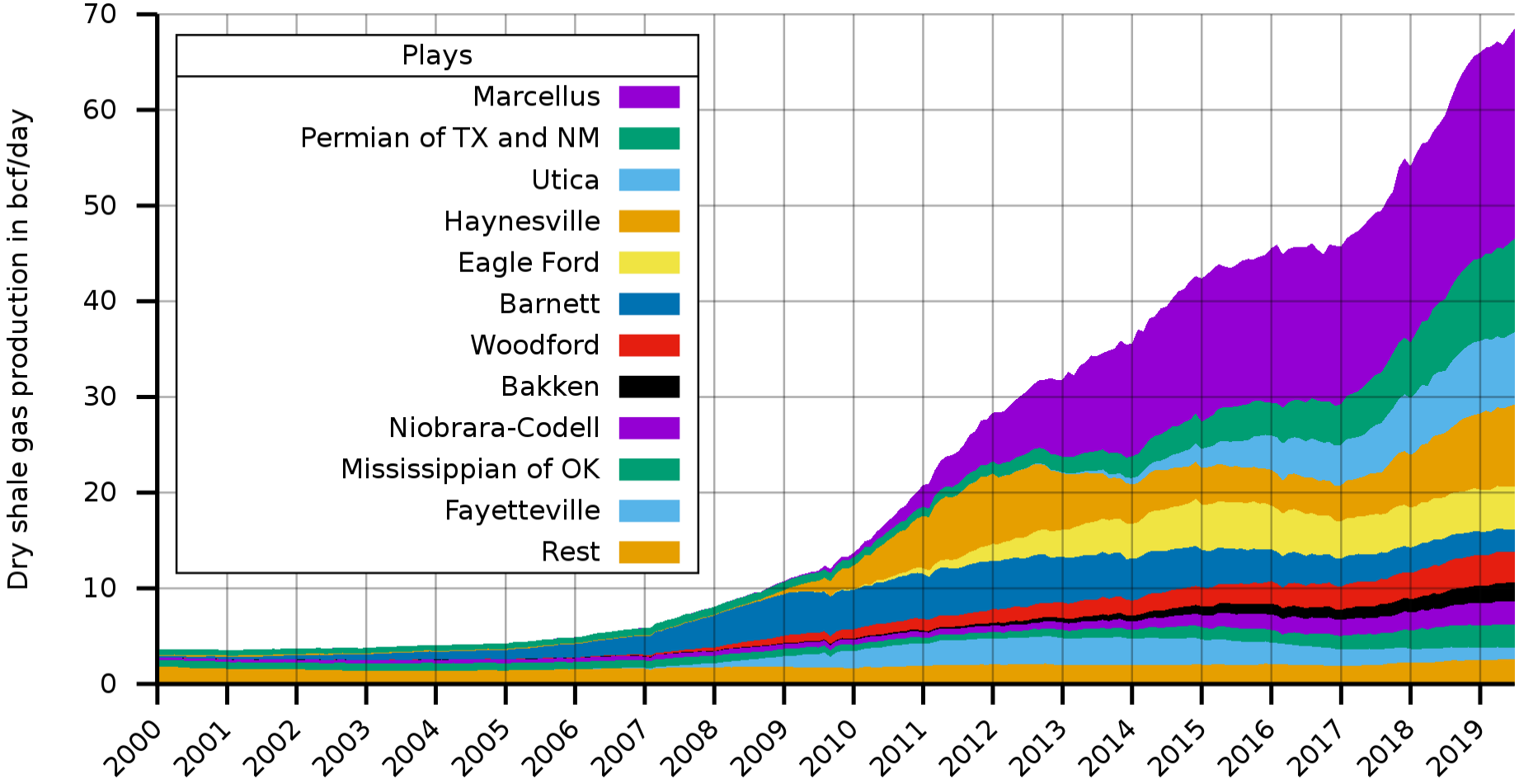
dieselnet.com

Production of some fields and the share of shale gas in total production in the US



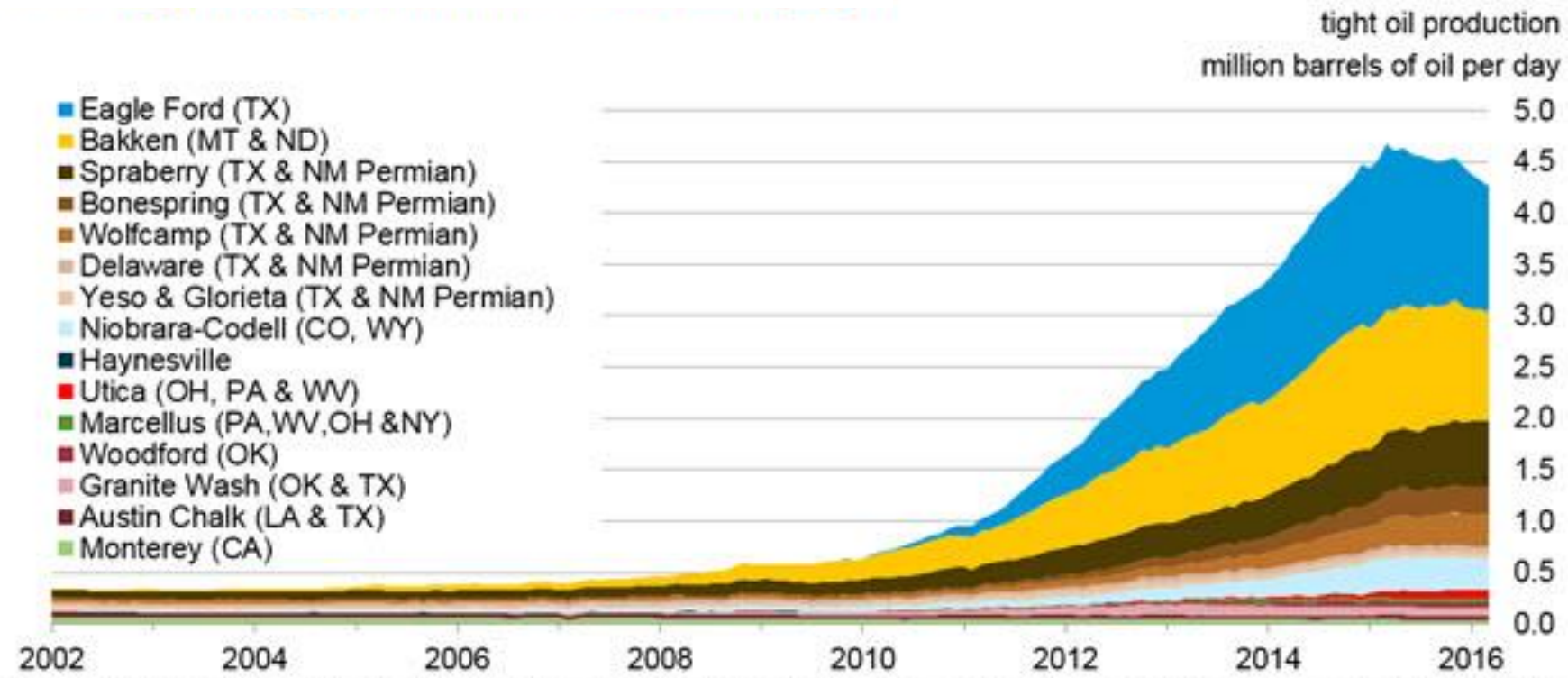
Forrás: https://www.csis.org/features/us-natural-gas-global-economy

USA shale gas production – by fields



Forrás: EIA (www.eia.gov)

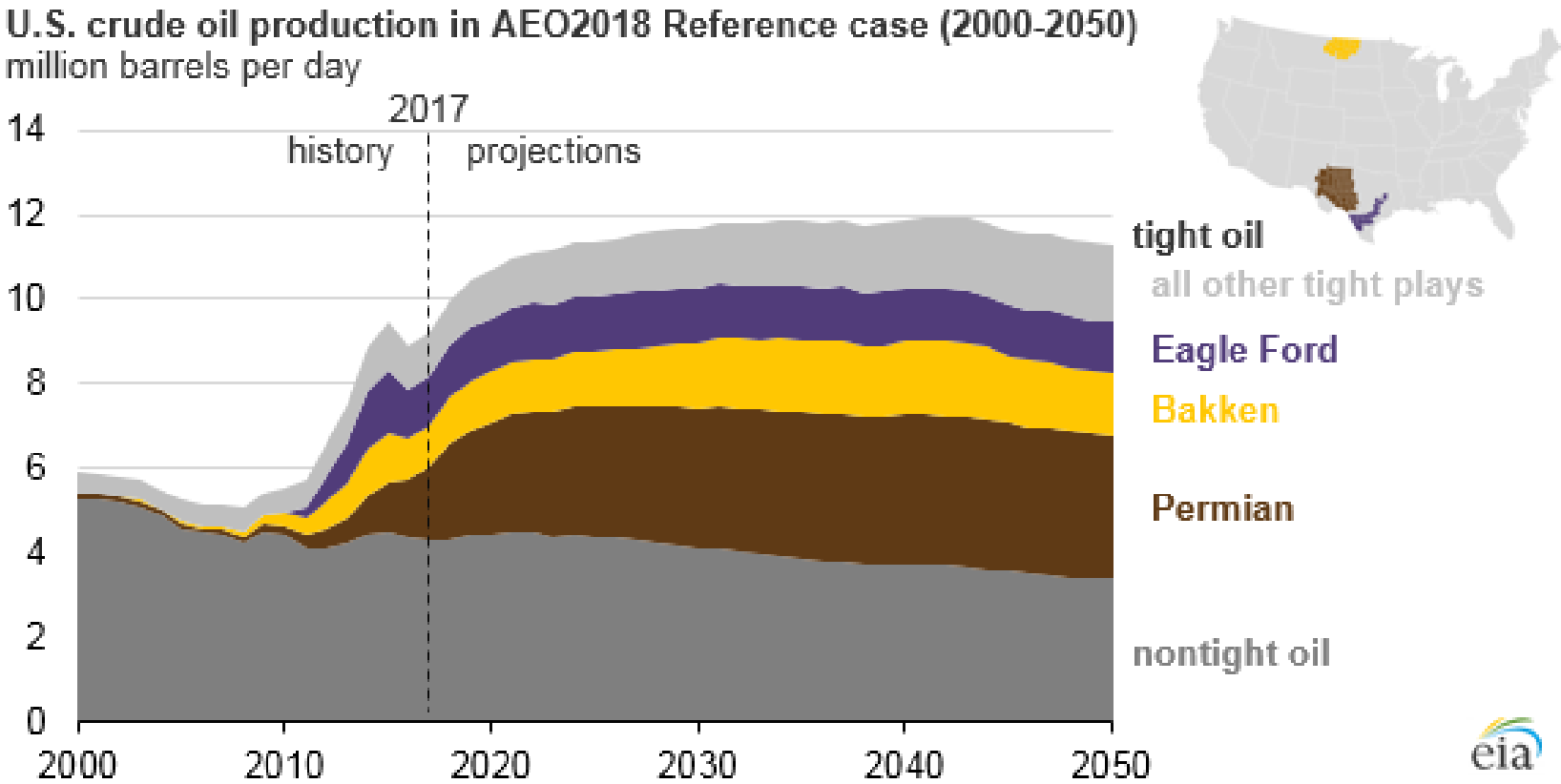
USA shale oil production – **by fields**



Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through March 2016 and represent EIA's official tight oil estimates, but are not survey data. State abbreviations indicate primary state(s).

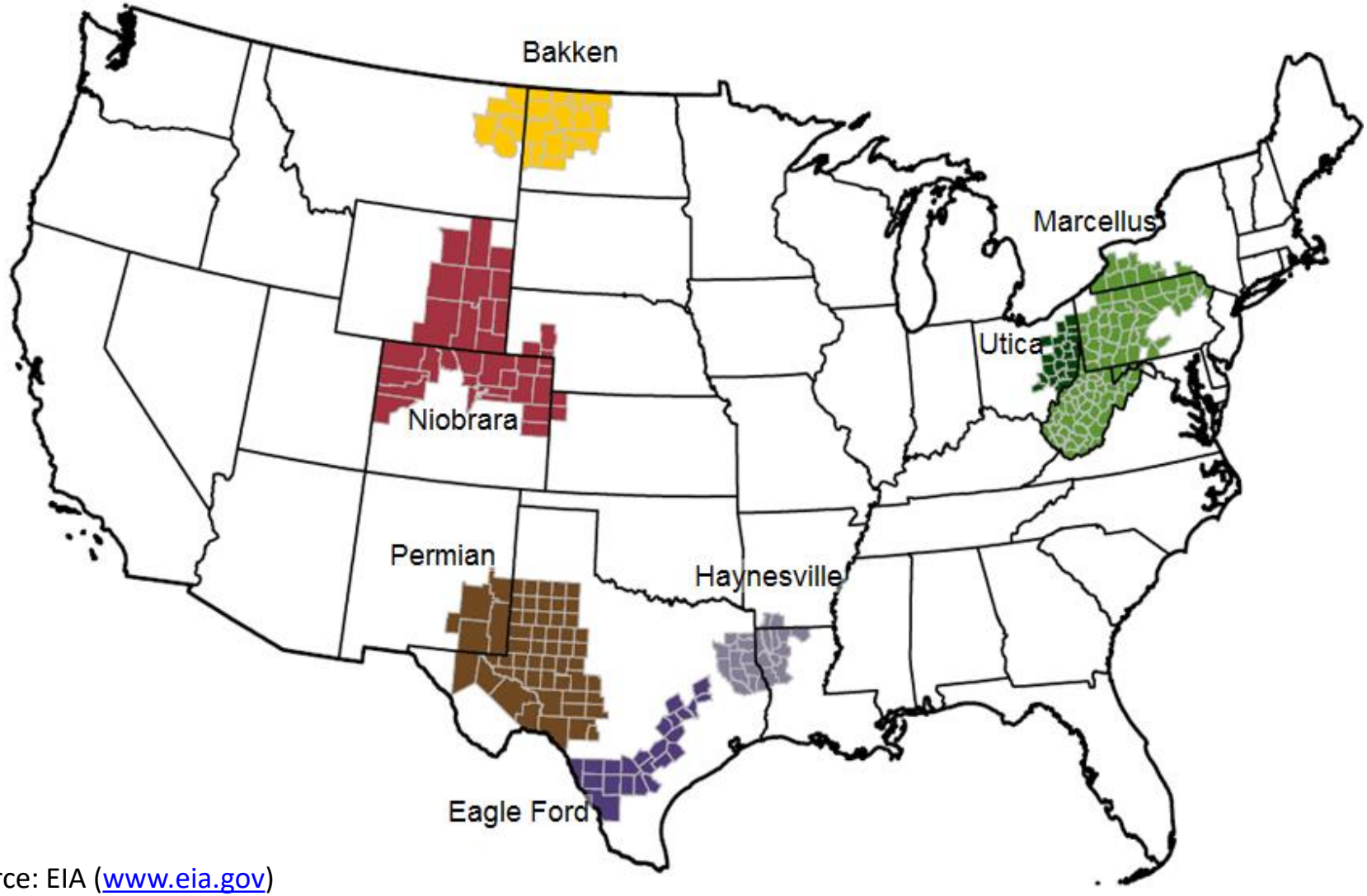
Forrás: EIA (www.eia.gov)

US crude oil production - **by fields, forecast**



Forrás: EIA (www.eia.gov)

USA shale oil/gas **fields**

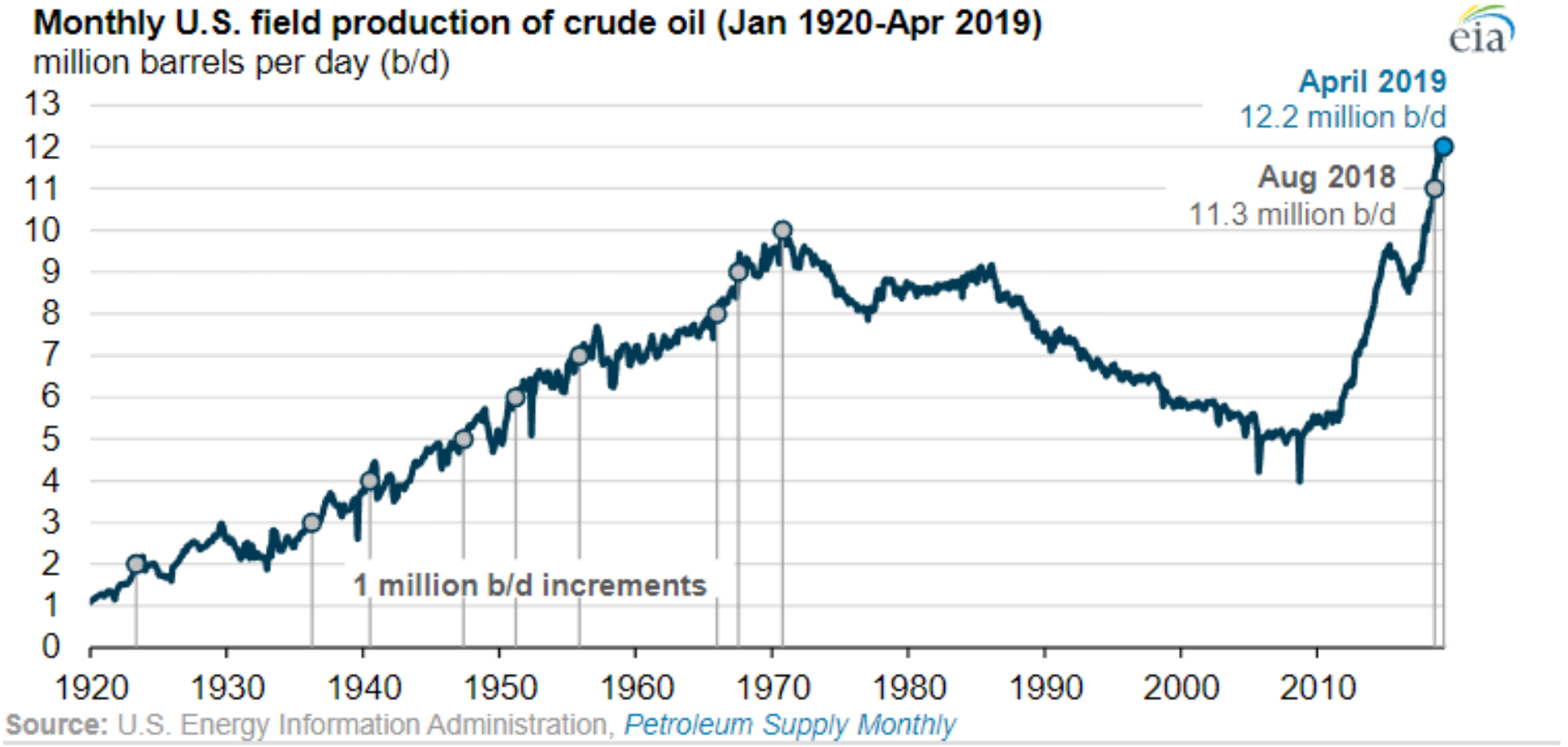


Source: EIA (www.eia.gov)

Main production data as of **2015/03**

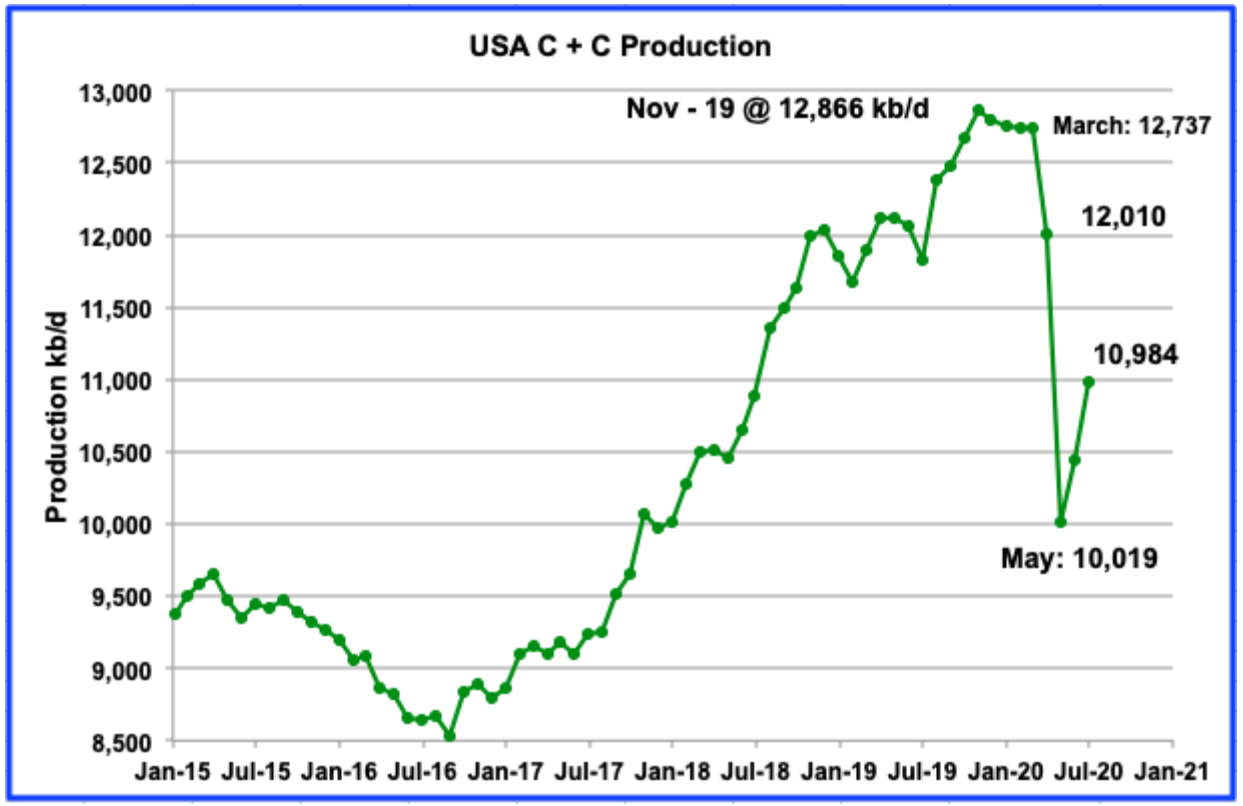
- **Texas – Permian field**
  - 2000 thbpd oil
  - 6400 mcftpd gas
- **Texas – Eagle Ford field**
  - 1700 thbpd oil
  - 7500 mcftpd gas
- **North Dakota – Bakken field**
  - 1300 thbpd oil
  - 1500 mcftpd gas
- **Pennsylvania/West Virginia – Marcellus field**
  - 60 thbpd oil
  - 16800 mcftpd gas

USA crude oil production 1859-2019



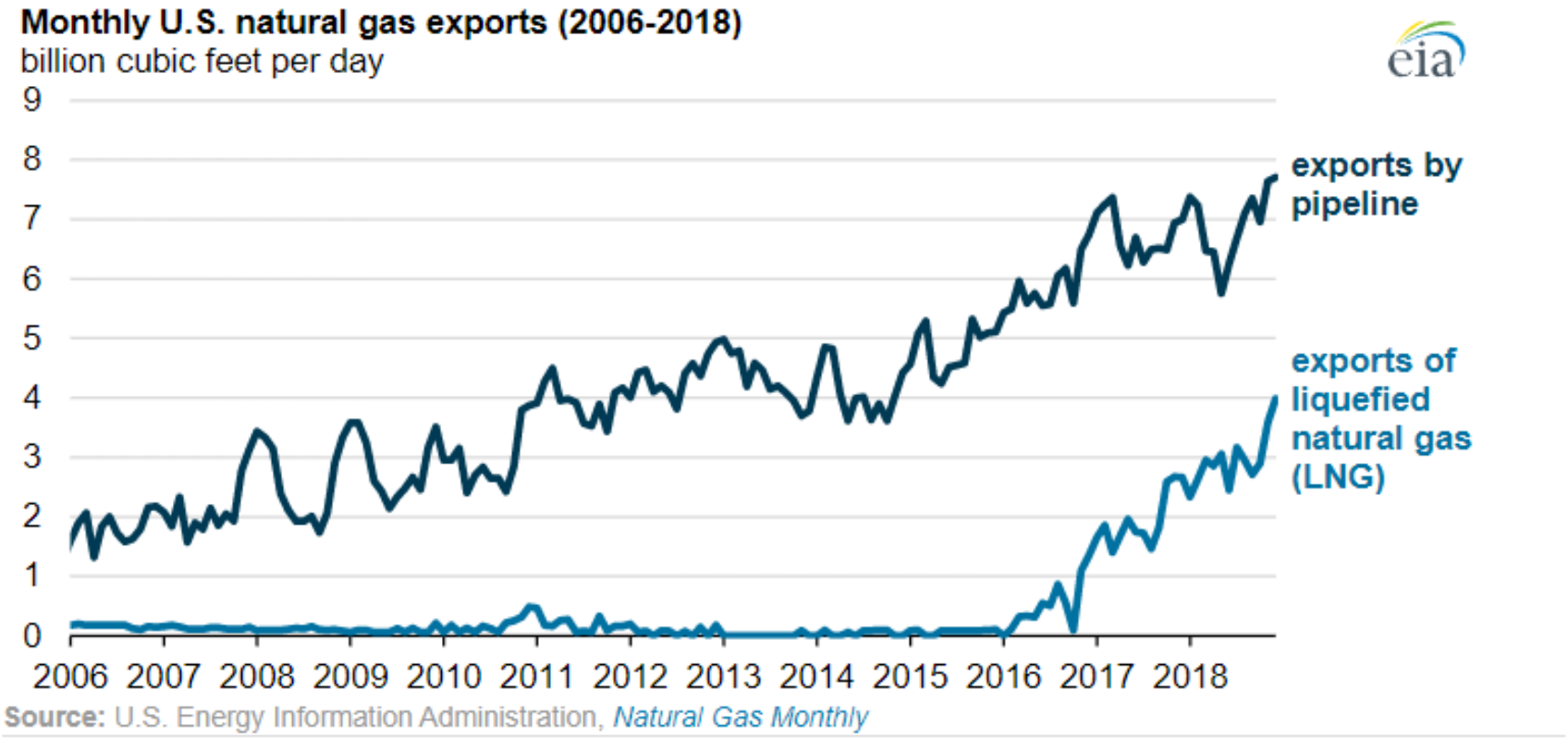
Source: EIA (www.eia.gov)

USA crude oil production 2015-



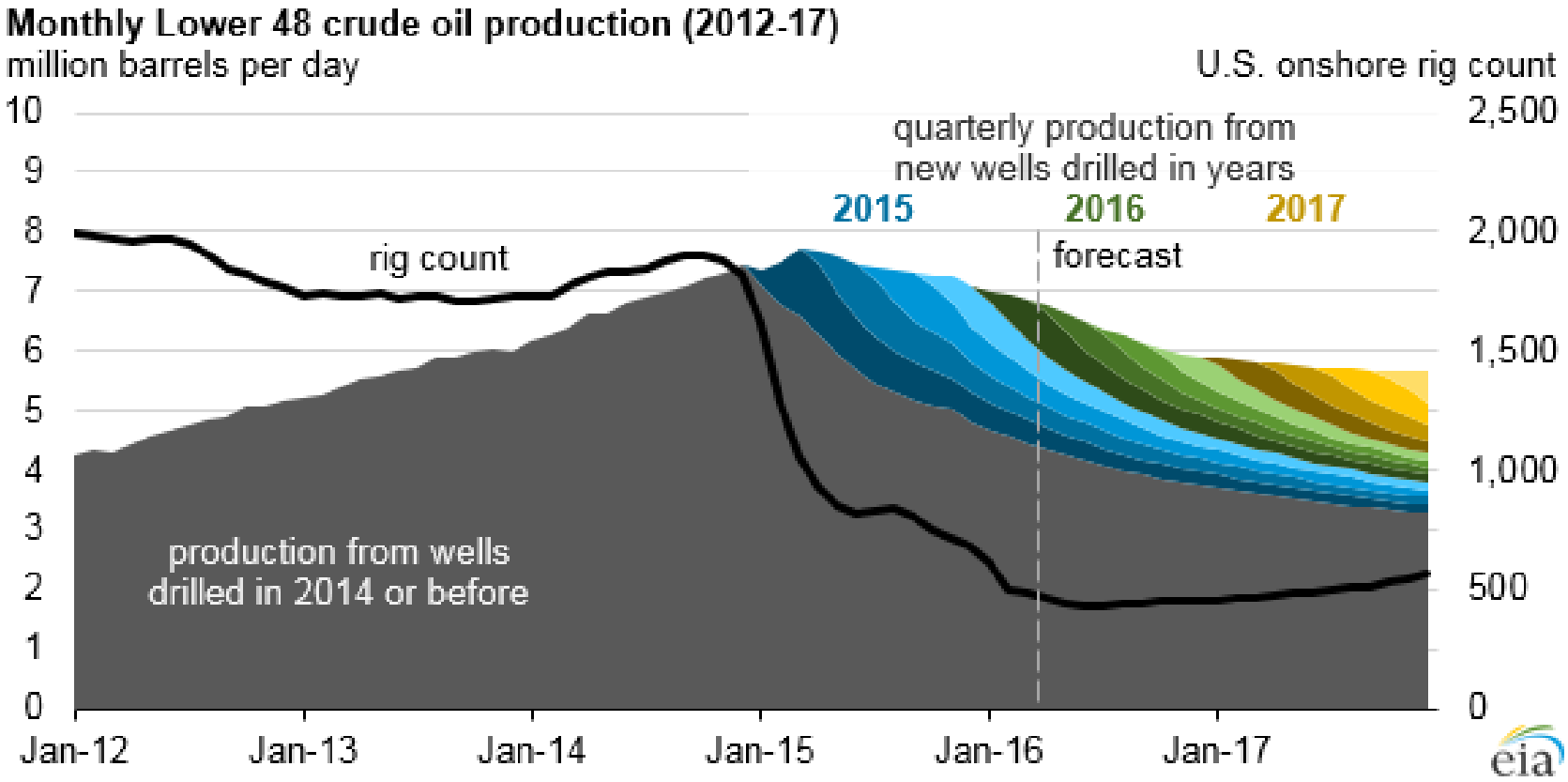
Forrás: Seeking Alpha - https://seekingalpha.com/article/4377318-u-s-july-oil-production-continues-to-rise

USA natural gas export



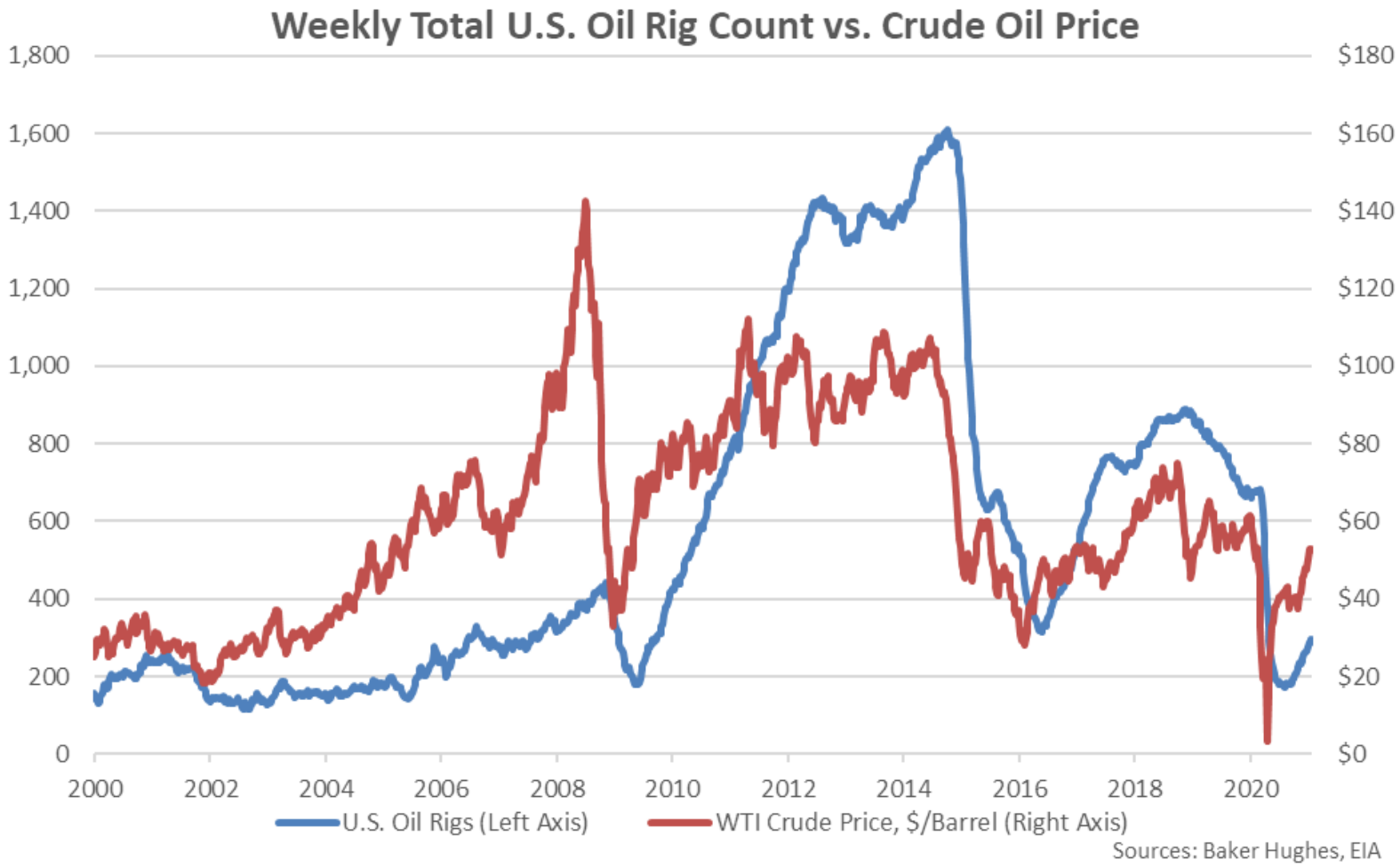
Forrás: EIA (www.eia.gov)

USA new well production 2015-



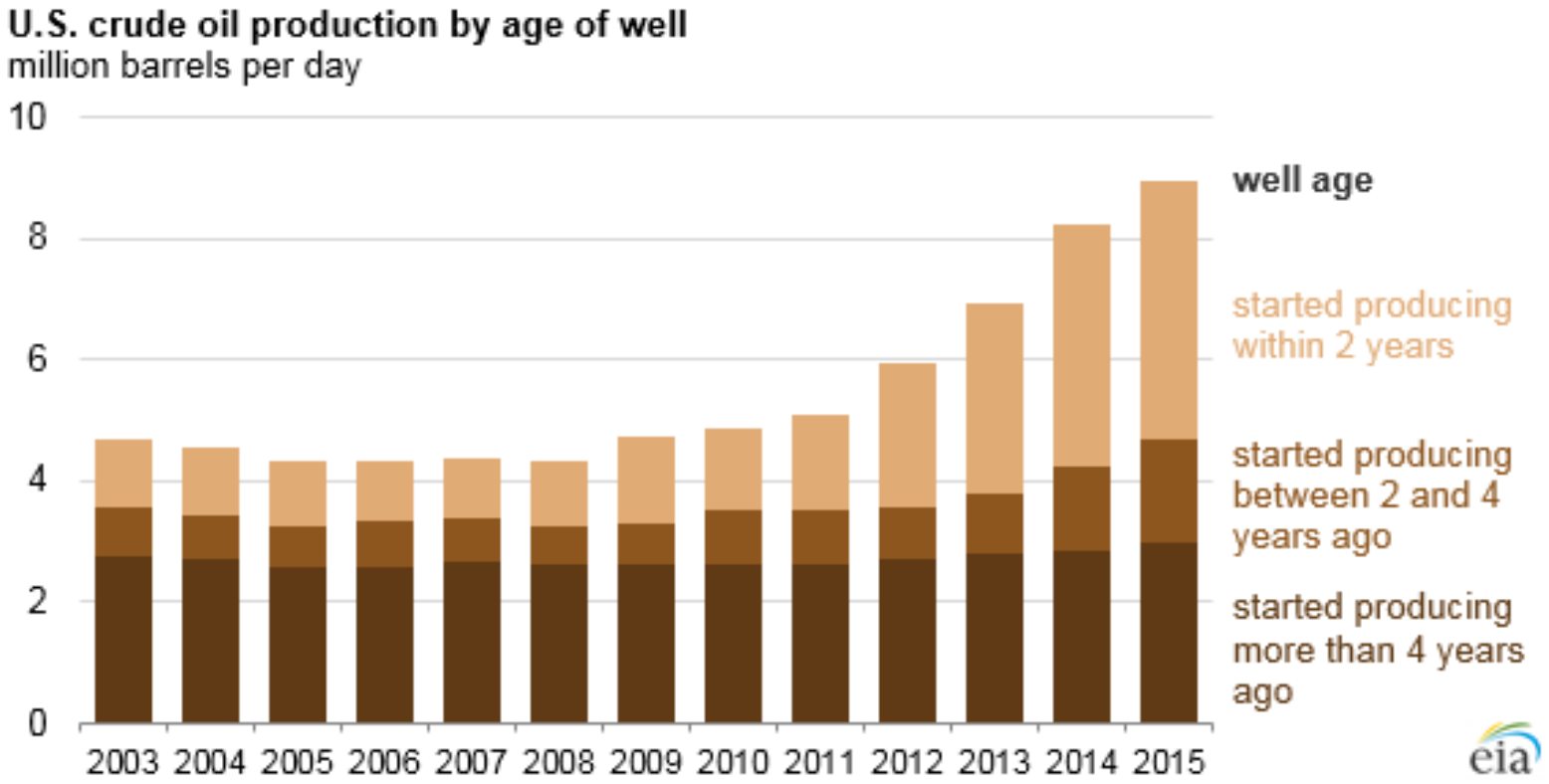
Source: EIA (www.eia.gov)

USA new rig number vs. WTI price



Forrás: Atten Babler Risk Management - https://www.attenbabler.com/index.php/2021/02/04/u-s-oil-rig-count-update-2-3-21/

Production by age of well



Source: EIA (www.eia.gov)

Consequences

Dakota Prairie Refining

- **First green-field refinery in the USA in the past 40 years** (last one in 1976)
  - Location: Dickinson, North Dakota
  - Construction started: March 2013
  - Construction finished: May 2015
  - Estimated cost: 430 m$ (original estimate: 300 m$)
  - Capacity: 20000 bpd (MOL DR: ~150000 bpd)
  - Feed: local shale oil (Bakken field)
  - Products:
    - 7000 bpd diesel fuel (final product)
    - 6500 bpd naphtha (semi-product – to other refinery)
    - 6000 bpd atmospheric residue (semi-product – to other refinery)
    - 300 bpd NGL (to local NG processing facility)
  - June 2016: due to losses (50% oil price) it was sold to Tesoro, which operates the only N-Dakota refinery

Dakota Prairie Refining (Tesoro)

USA crude oil export

- **January 2016: first batch over the past 40 years**
  - It was forbidden to export crude oil from the USA since 1975
  - Only the processed products (gasoline, diesel) export was allowed
  - Exporting company: CononcoPhillips
  - Tanker name: Theo T
  - Importing company: Vitol (trading company)
  - Destination: Marseilles (Total)

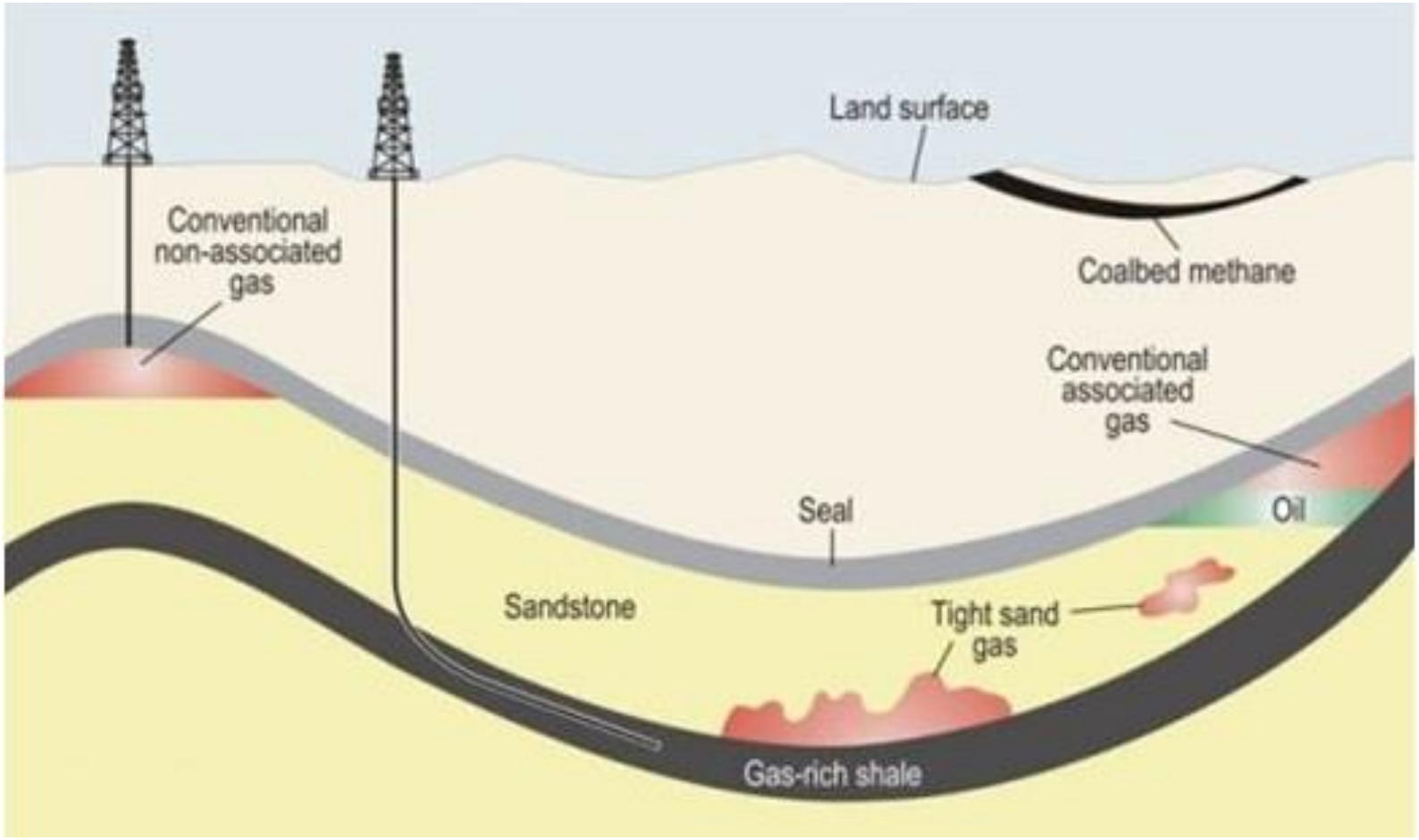
Methanol production via shale gas

- **80'-ies, 90'-ies:**
  - USA worldwide leader in methanol production 10 mt/y (mainly due to MTBE production)
- **2004:**
  - MTBE production was banned in 2002, NG prices increased: capacity dropped to only 8% (of the former peek capacity)
- **2012-2015:**
  - Shale gas revolution: NG price reduced to 1/3
  - 7 new methanol plant construction/reconstruction reported
  - The new capacities are close to the former peek

Definitions

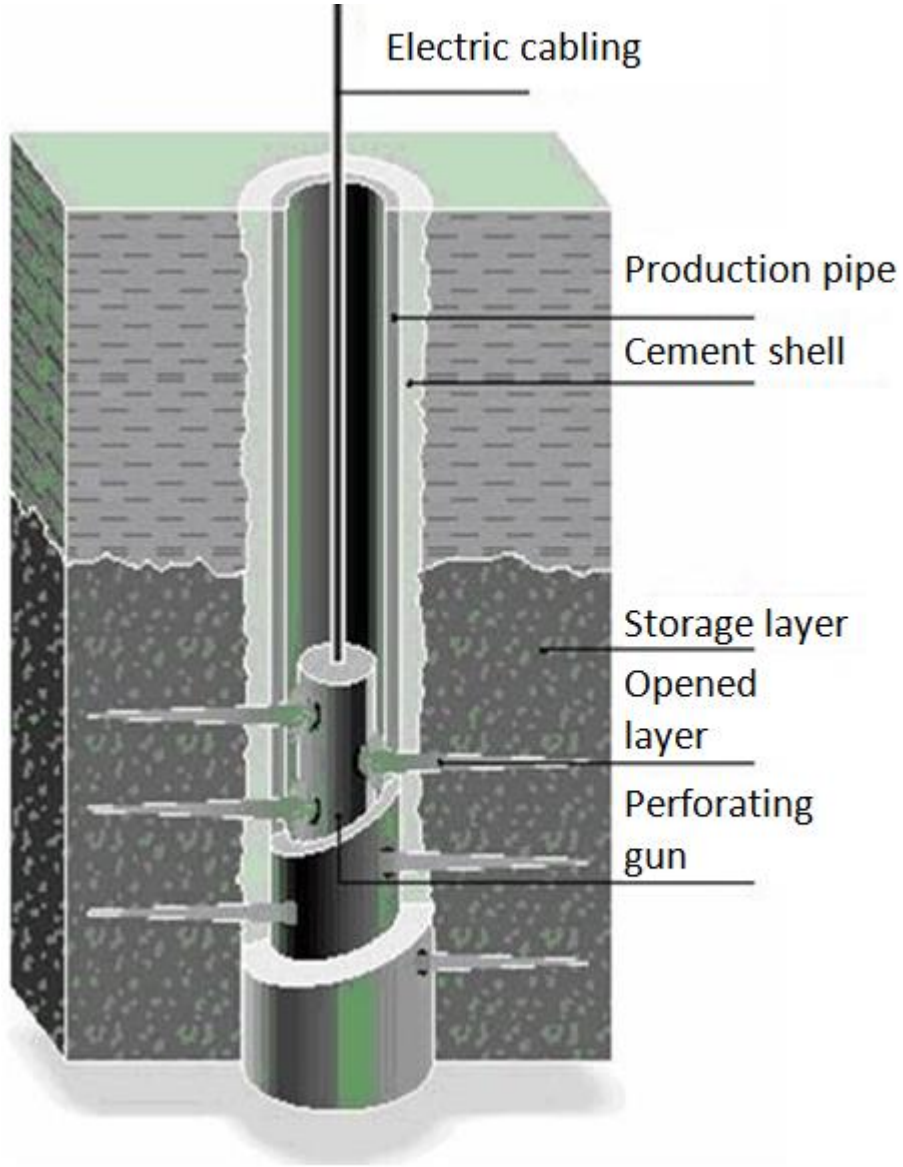
- **Mother rock**
  - Fine granular rocks, where hydrocarbon is formed and accumulated during the millions of years in the pores and channels
- **Migration**
  - The movement of the hydrocarbon formed from the higher pressure places to the typically less deep, lower pressure places
- **Capturing**
  - Accumulation of the hydrocarbon below a significantly less permeable layer (see the analogy of water impermeable layers)
- **Conventional hydrocarbon accumulation**
  - Oil and/or gas accumulated due to capturing
- **Associated natural gas**
  - Natural gas accumulated and captured together with crude oil
- **Non-associated natural gas**
  - Natural gas accumulated and captured separately from crude oil

Modes of hydrocarbon occurrences



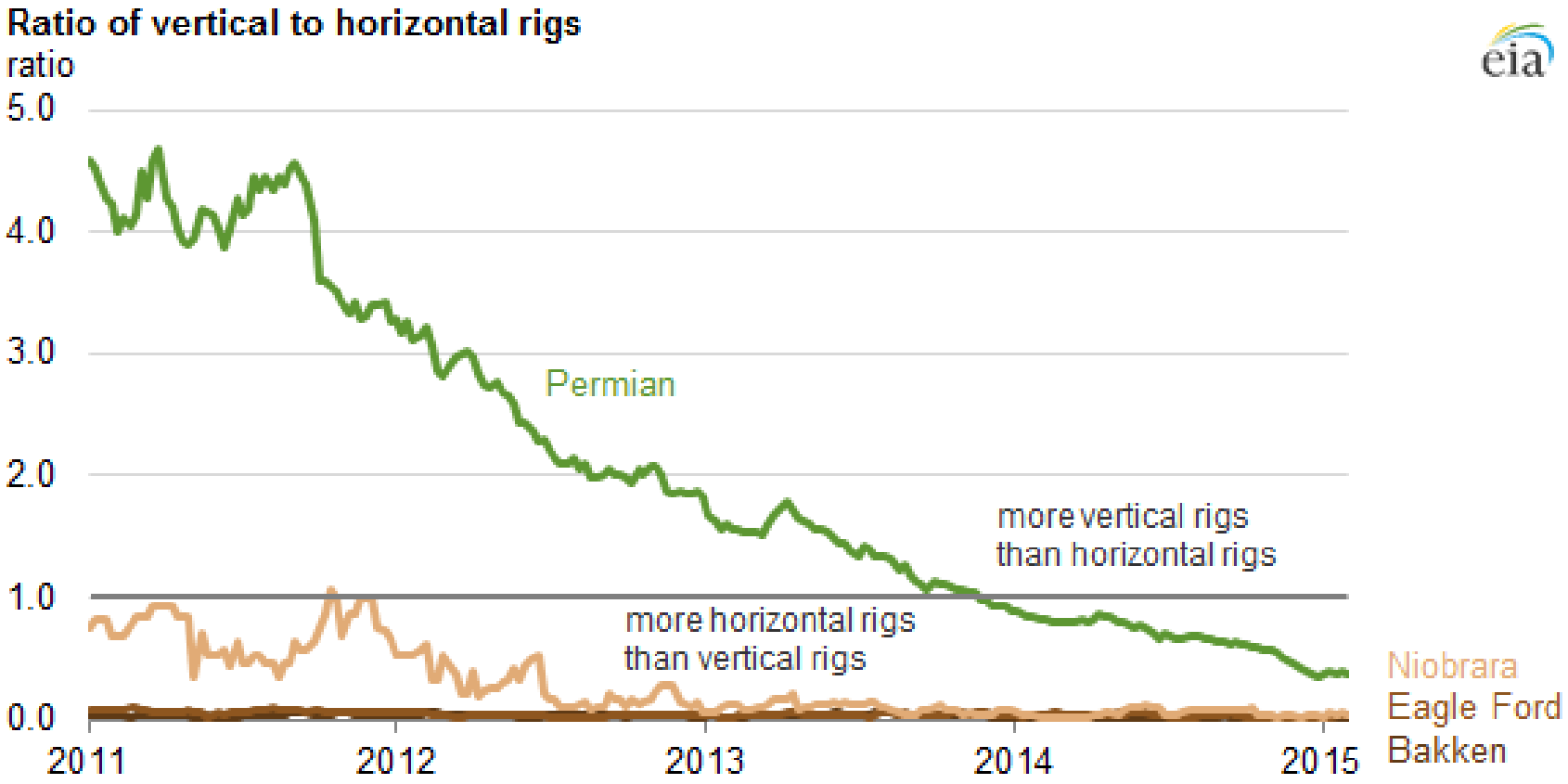
- **Non-conventional hydrocarbon occurrence**
  - Due to the tightness, compactness of the mother rock, the hydrocarbon is captured at the place of formation
- **Tight gas – sandstone and limestone gas**
  - The mother rock is sandstone or limestone
  - Production began around 1980
- **Shale gas – marl gas**
  - The mother rock is marl or shale
  - Production began around 2000 at Barnett field
- **Coalbed methane – methane captured in coal**
  - The mother rock is coal
- **Tight oil = Shale oil**
  - Generally speaking, crude oil obtained from non-conventional sources

Hydrocarbon well **layout**



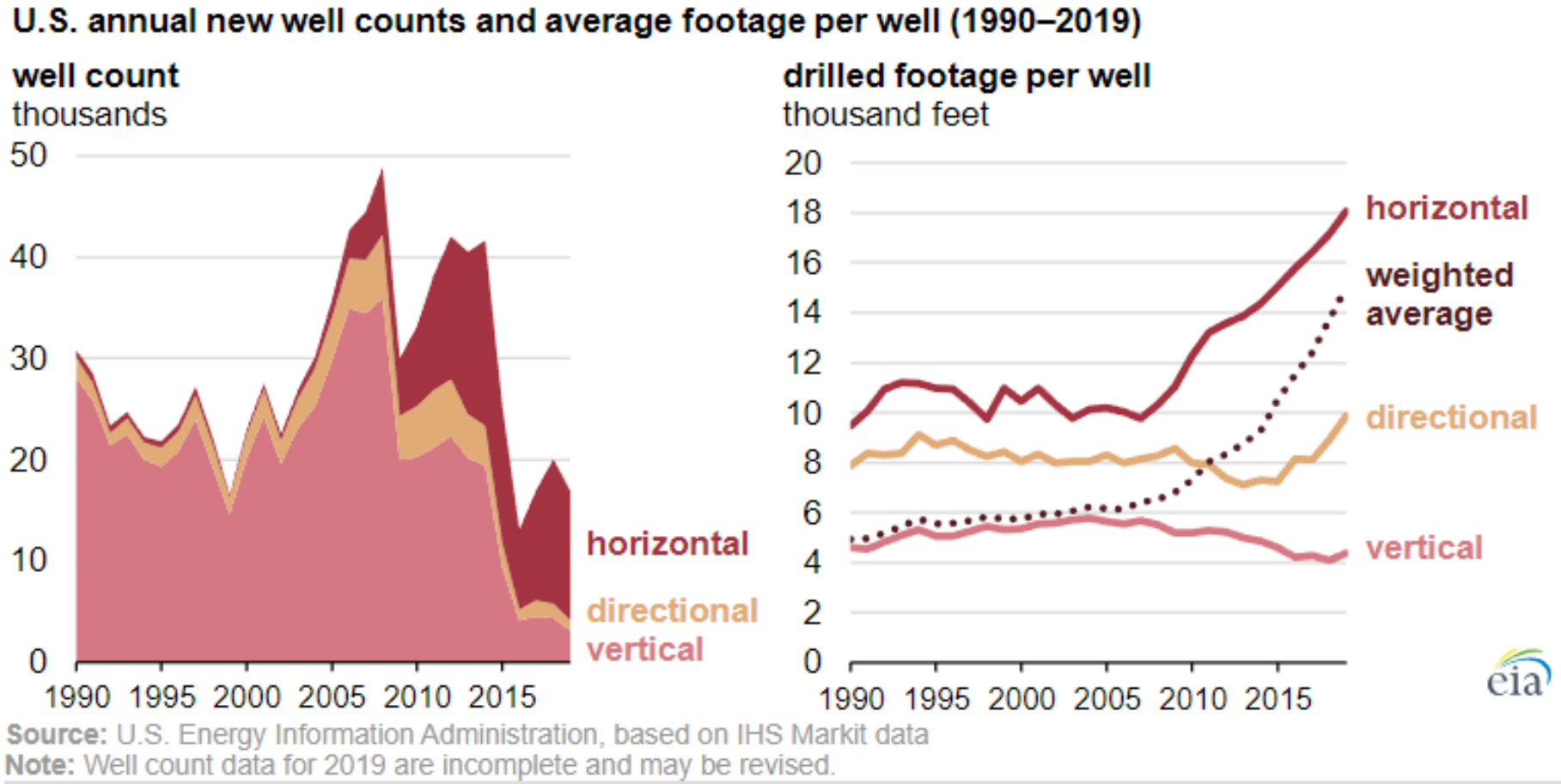
- **Horizontal drilling**
  - Drilling technology used during well drilling. It is oriented in horizontal way, according to the structures of the layers
- **Hydraulic fracturing**
  - Technology to produce artificial channel system in low permeability rocks (similar to a tree's root system)
  - Channels are formed by the use of fracturing fluid (that's why hydraulic) and are filled with artificial sand in order to prevent closing/collapse
  - Closed technology, most of the fracturing fluid is recovered.
  - The range of channel system is ~100-150 m („many" wells to be drilled, which will be depleted „soon")

Penetration of horizontal drilling



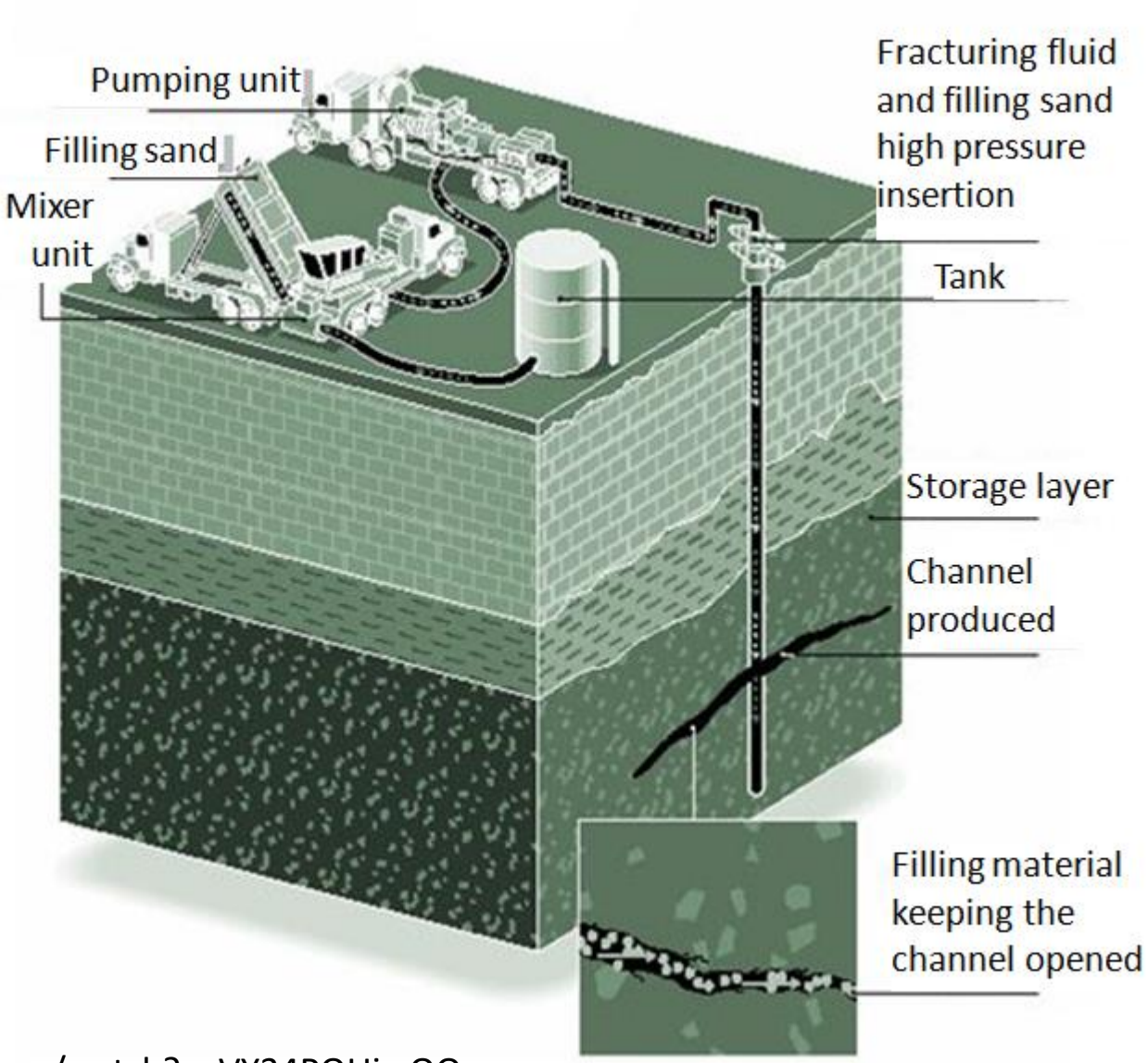
Source: EIA (www.eia.gov)

Penetration of horizontal drilling



Source: EIA (www.eia.gov)

Hydraulic fracturing



https://www.youtube.com/watch?v=VY34PQUiwOQ

Processing of shale oil

Properties of shale oil

- **Light oil**
  - Cannot be processed alone in an older refinery at the same feed rate
  - Capacity problems (under loading) will occur at the residue line (e.g. at the Delayed Coker)
  - Overloading problems will occur in the primary distillation overhead section
  - FCC heat balance will be upset, heat deficit will occur (shale oil is easy to be cracked, therefore less coke will be formed)

Properties of shale oil

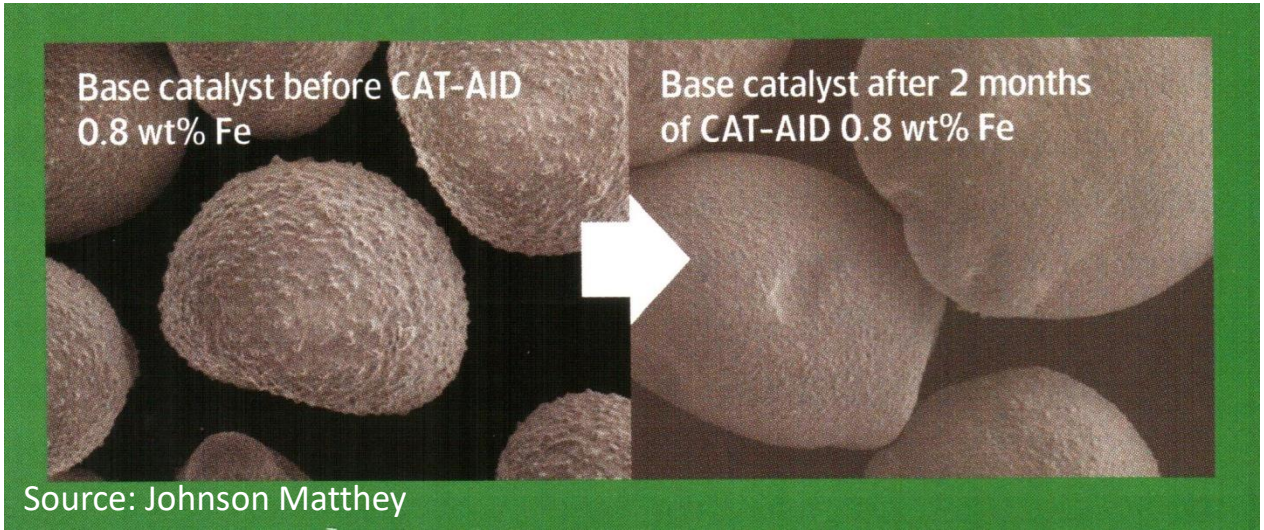
- **Paraffinic oil**
  - Incompatibility problems: mixed with asphaltenic oils, depositions, plugging may occur in the crude distillation unit heat exchanger train (the asphaltene stability is decreased, deposition affinity increases)
  - Emulsion formation problems during storage, or at the desalter: increasing the demulsifier additive, the problem may be minimised
  - Petroleum/jet quality problems may occur, which may be balanced by the cut-point modification of the fractions

Properties of shale oil

- **Alternating quality oil**
  - The quality of the shale oil may change significantly even within the same field, depending on the location of the well
  - Keeping the product qualities, require greater attention during processing the shale oil
  - Worth to equalise the quality prior to processing, by mixing the shale with other crudes
  - In the FCC, the feed contaminations change may be flexibly followed by special catalyst additives usage
  - Emulsion formation problems in the desalter: finer sized and higher amount solid contamination, than in the case of conventional crude oil. This produce danger of more pronounced corrosion and plugging problems. Increasing the demulsifier may reduce this danger.

New **contamination** components - **Iron**

- Even as corrosion products, or in naphthenate form, the iron may cause the plugging of catalyst bed, thus increasing the **reactor pressure drop** (in the Hydrotreater Unit)
- Special catalyst layers with higher pore volume are designed to capture the contamination (in the Hydrotreater Unit)
- In case of FCC catalyst, the density of the catalyst particle outer layer will increase, the accessibility of the inner surface will decrease. Due to the average density increase, fluidisation problems may occur – special additives may inhibit the formation of iron particles (e.g. Intercat CAT-AID)



Source: Johnson Matthey

New **contamination** components

- **Arsenic** – higher concentration in the shale oil
  - May be accumulated in higher concentrations in the heavy naphtha/petroleum fraction
  - Above 50 ppb will cause **activity problems** in the FCC pretreater, because it ties to the active metal centrums of the catalyst
  - Arsenic capturing catalyst layers may be used to avoid the problem (even up to 300-500 ppb level)
- **Phosphorus** – mining co-materials may increase its concentration
  - Deposits on the outer layer of the catalyst particles
  - Different pore size catalyst may be used to eliminate the problem

Literature used

- Holoda Attila: Palagázról közérthetően – nem csak környezetvédőknek, osztommagam.blog.hu, 2013.02.15
- Processing Shale Feedstocks 2014, Petroleum Technology Quaterly special edition