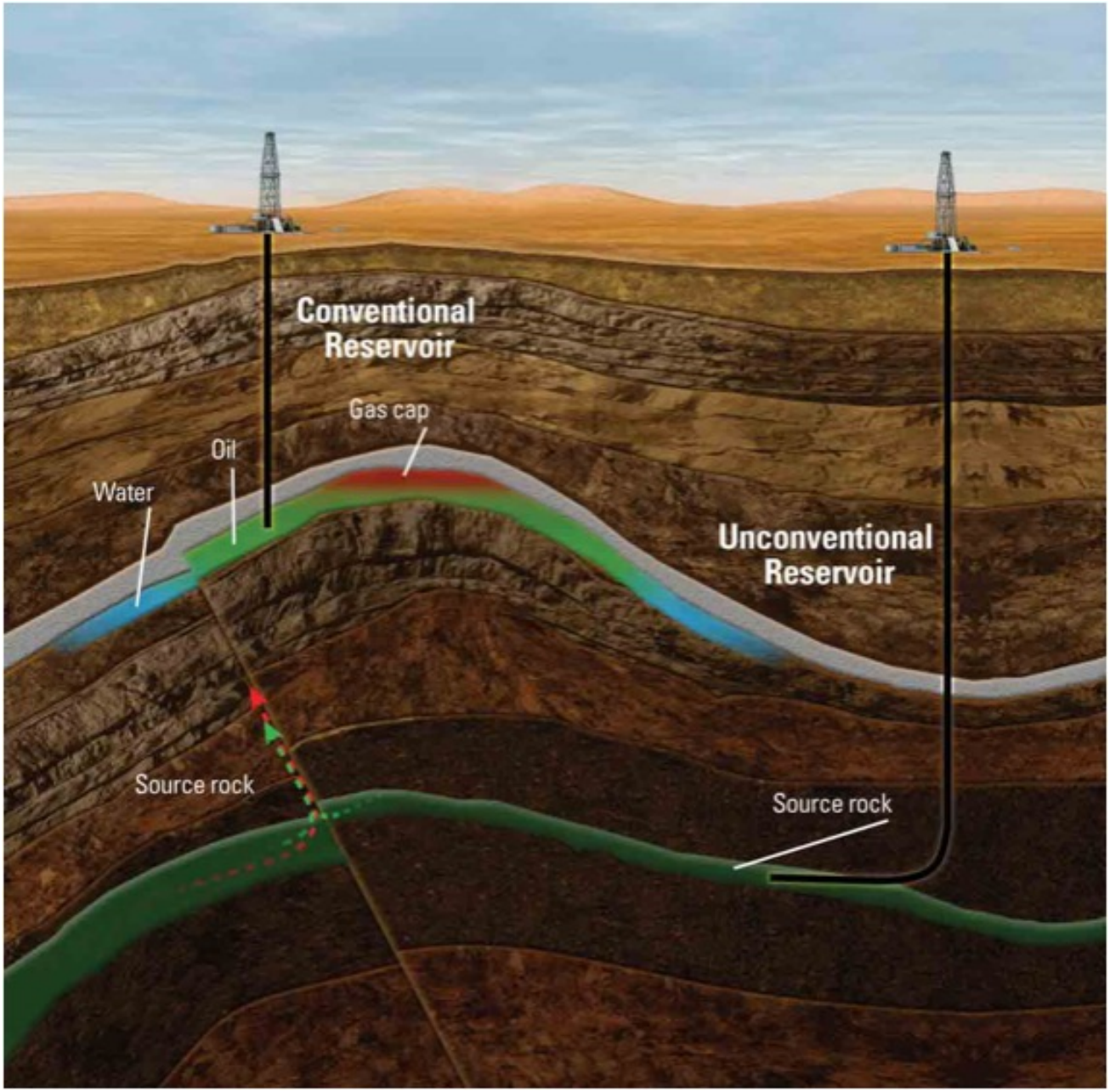
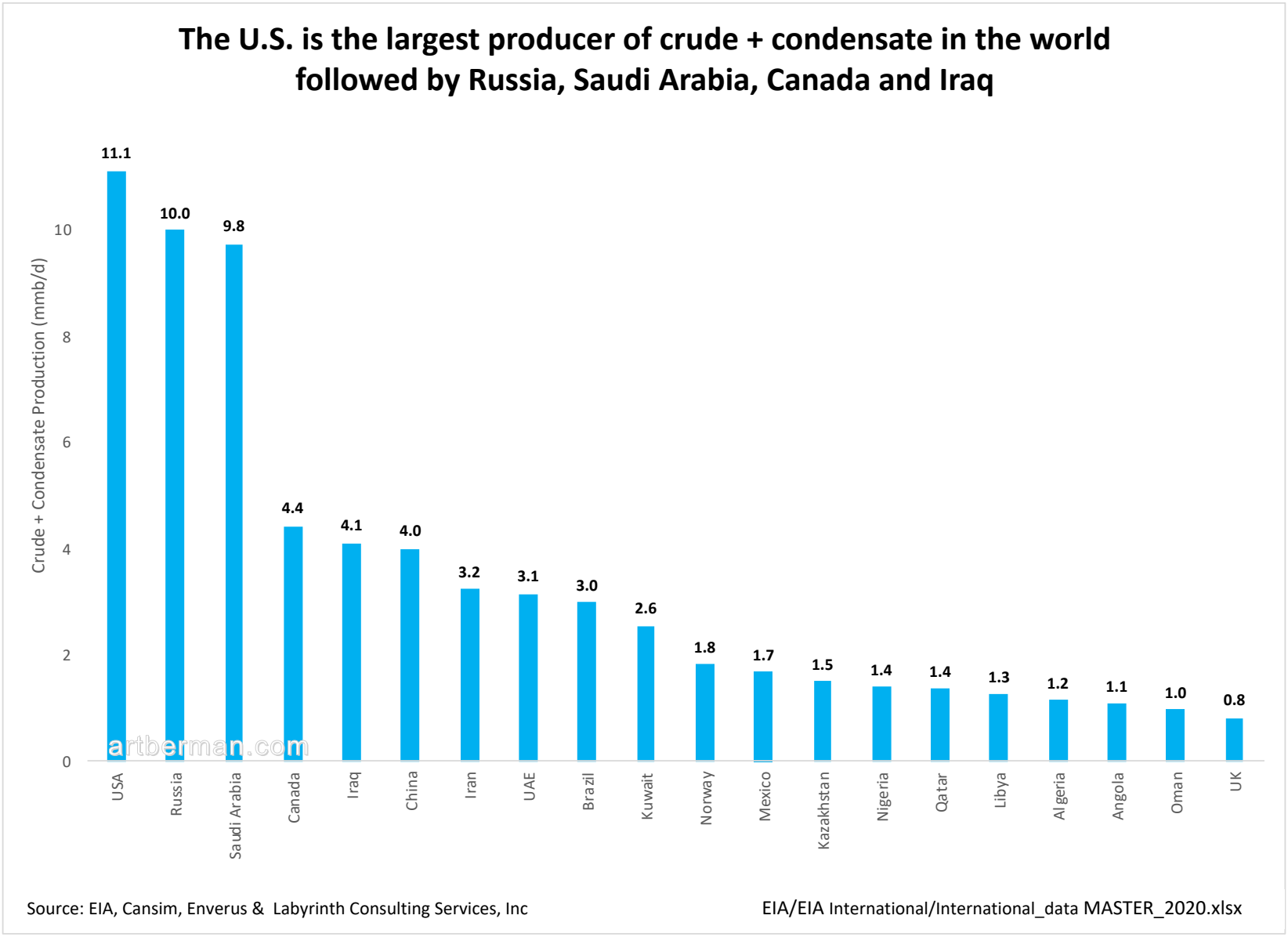
Art Berman

Oil Essentials: scarcity or abundance and the energy transition

Oil Basics


Conventional Reservoir
Gas cap
Oil
Water
Unconventional Reservoir
Source rock
Source rock

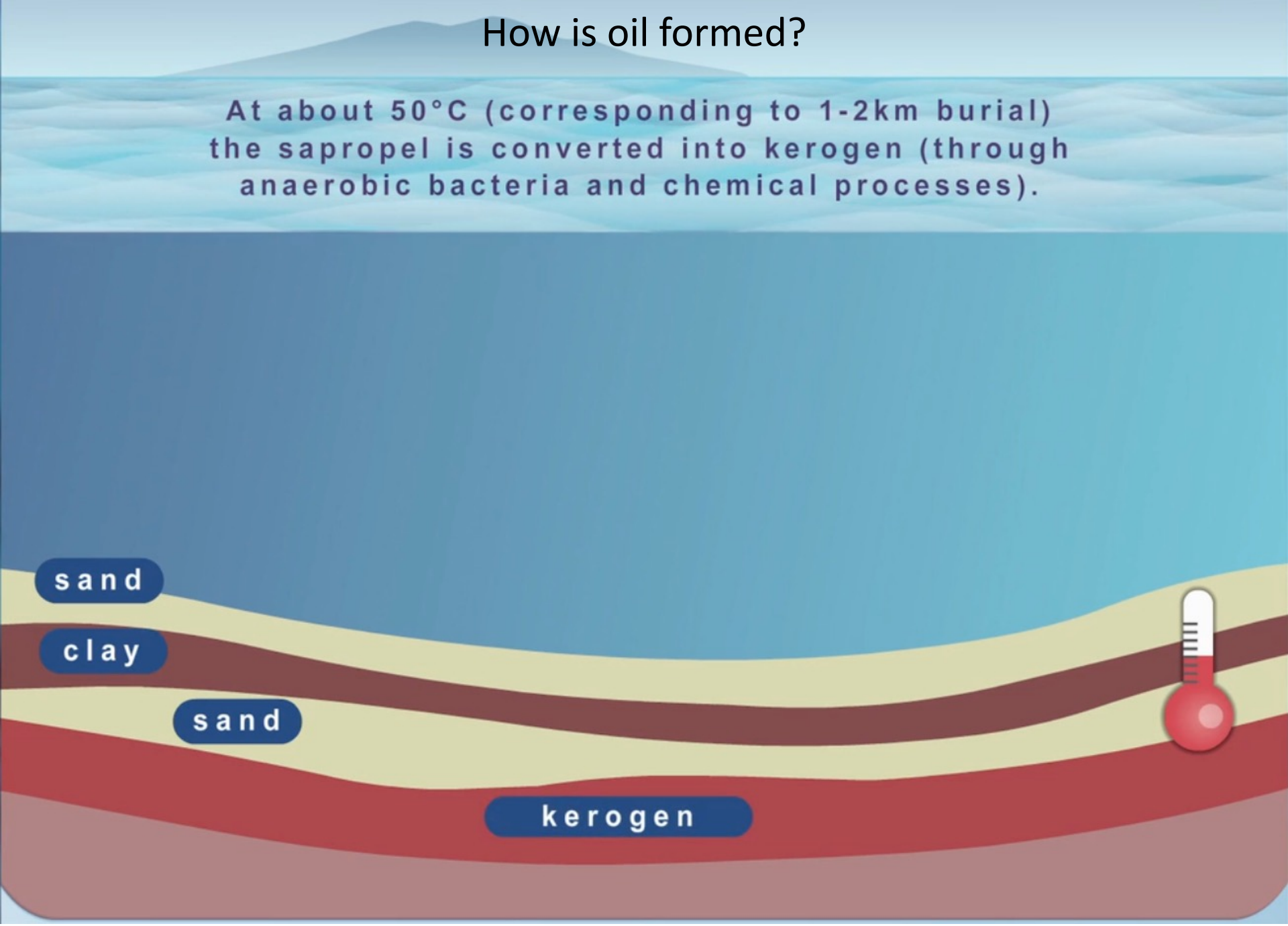
The U.S. is the largest producer of crude oil and condensate in the world
Followed by Russia, Saudi Arabia, Canada and Iraq



How is oil formed?

https://www.sciencelearn.org.nz/videos/800-oil-formation

How is oil formed?



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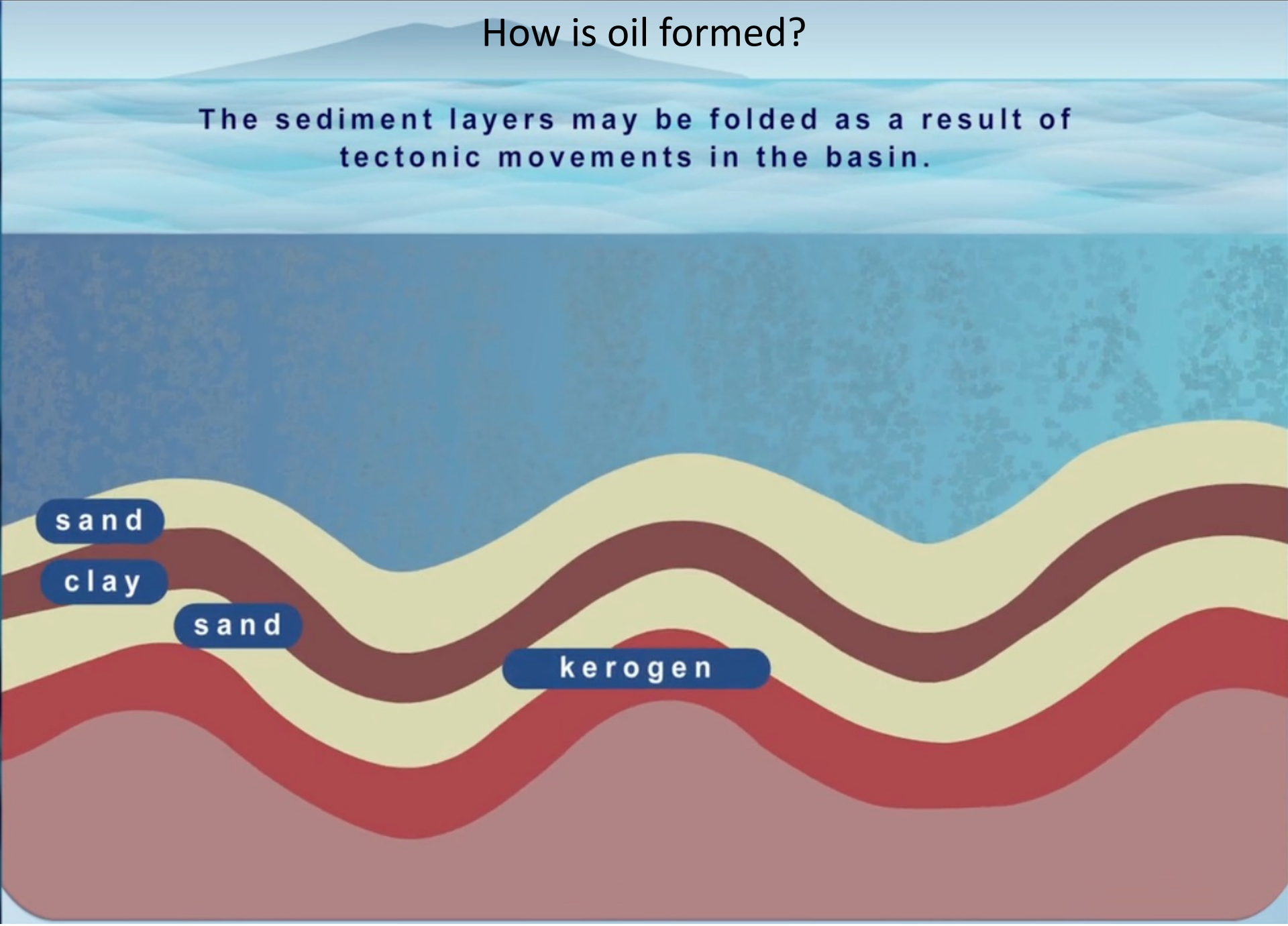

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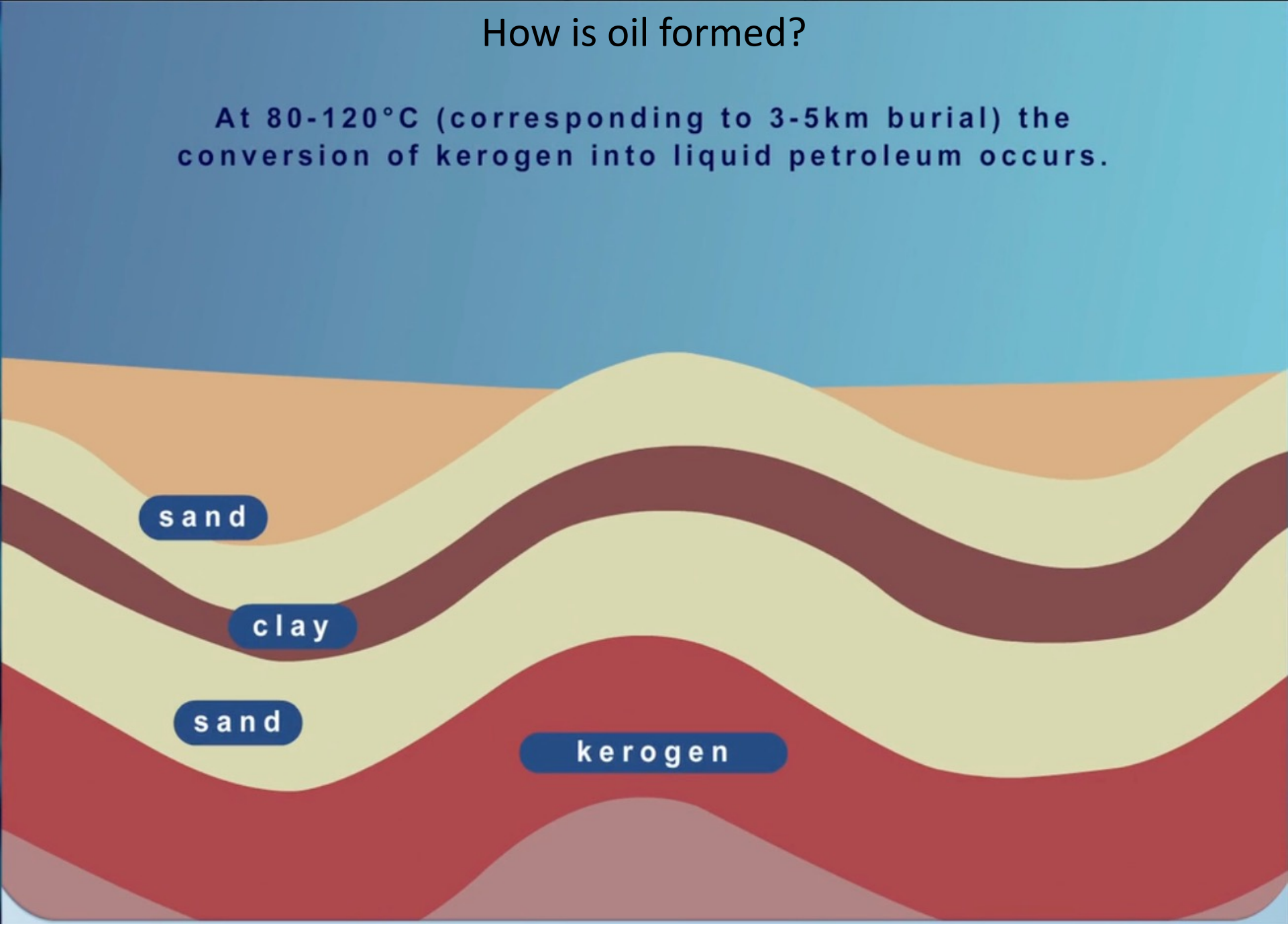

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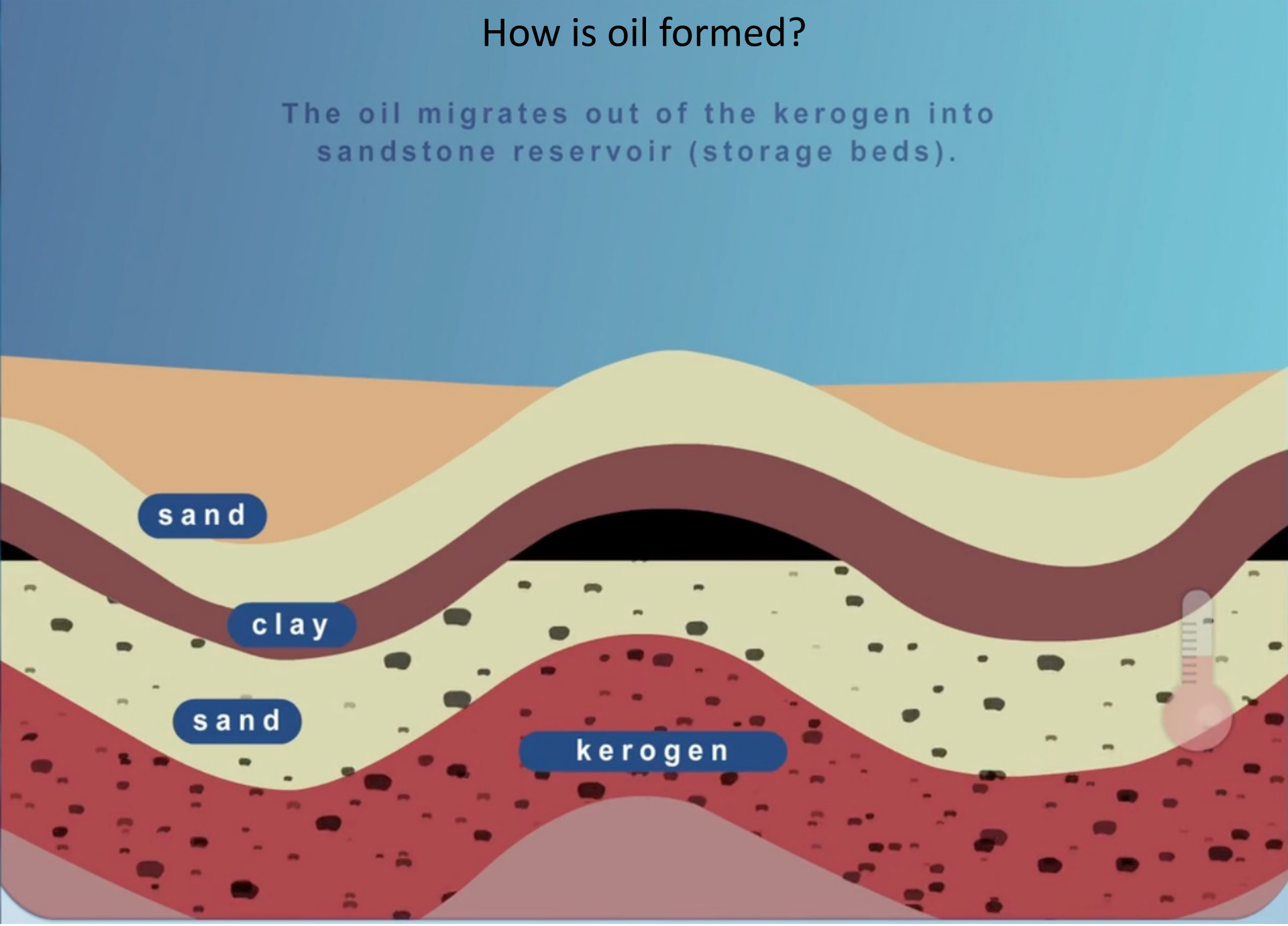

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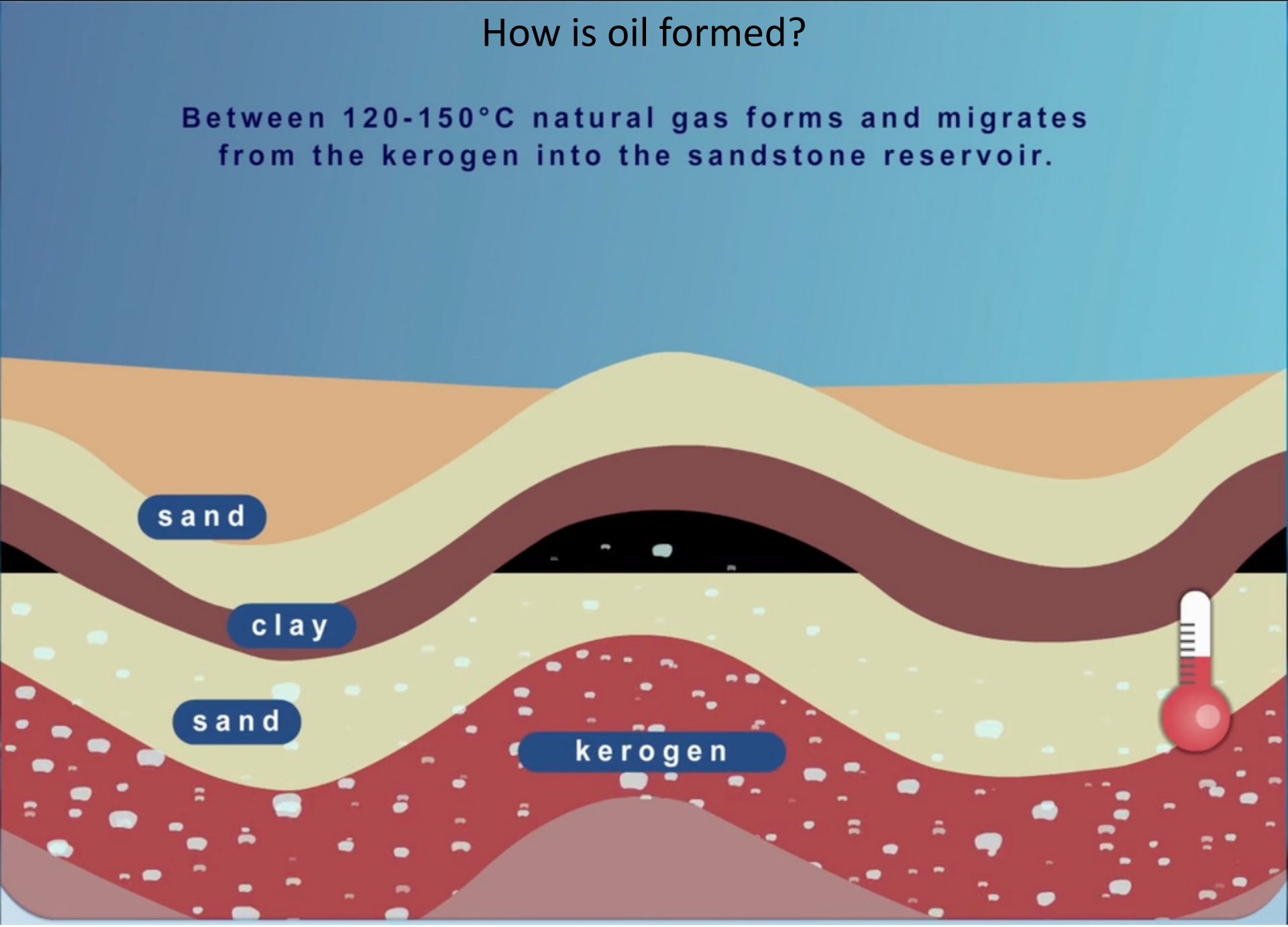
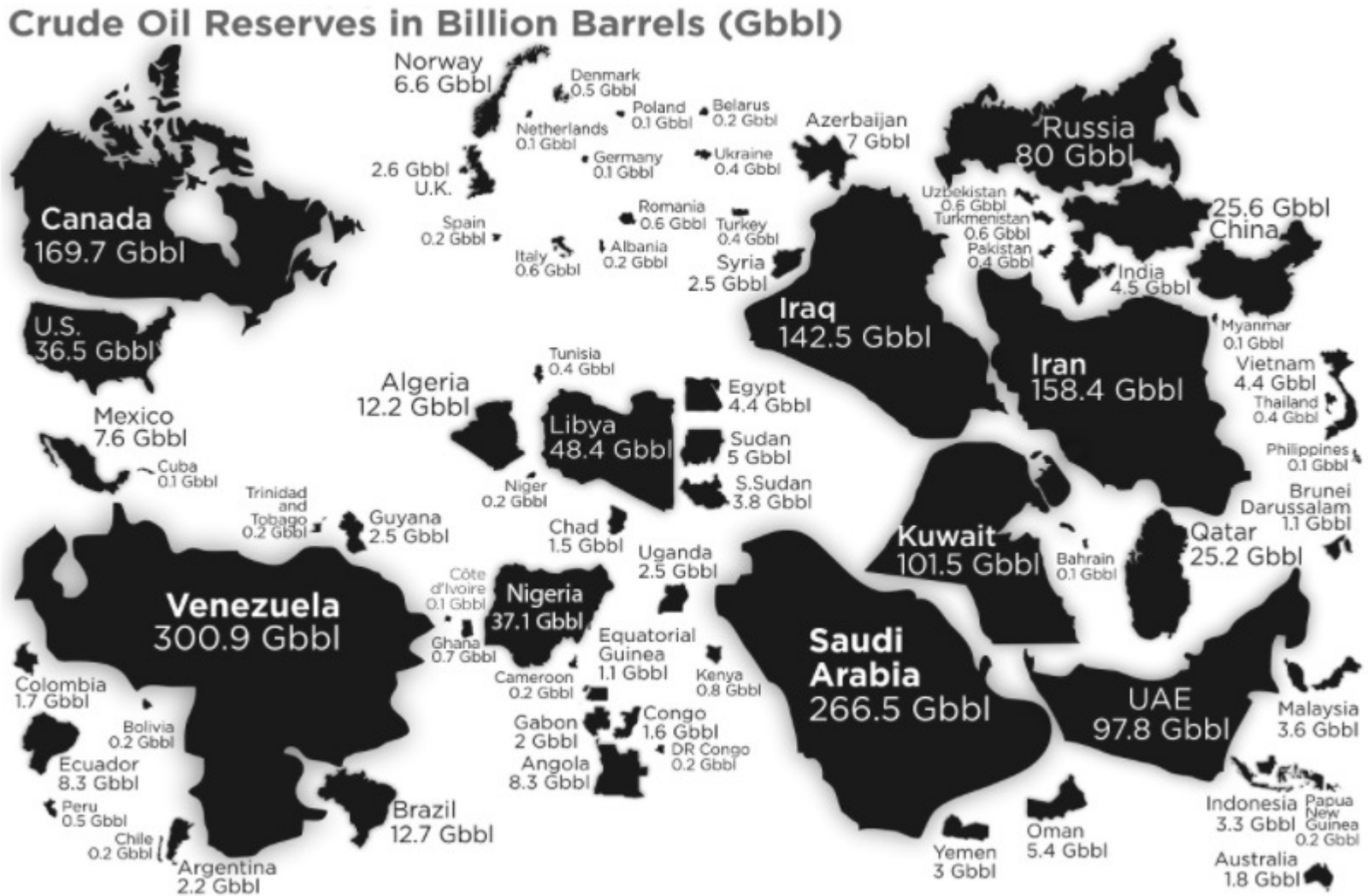


How is oil formed?

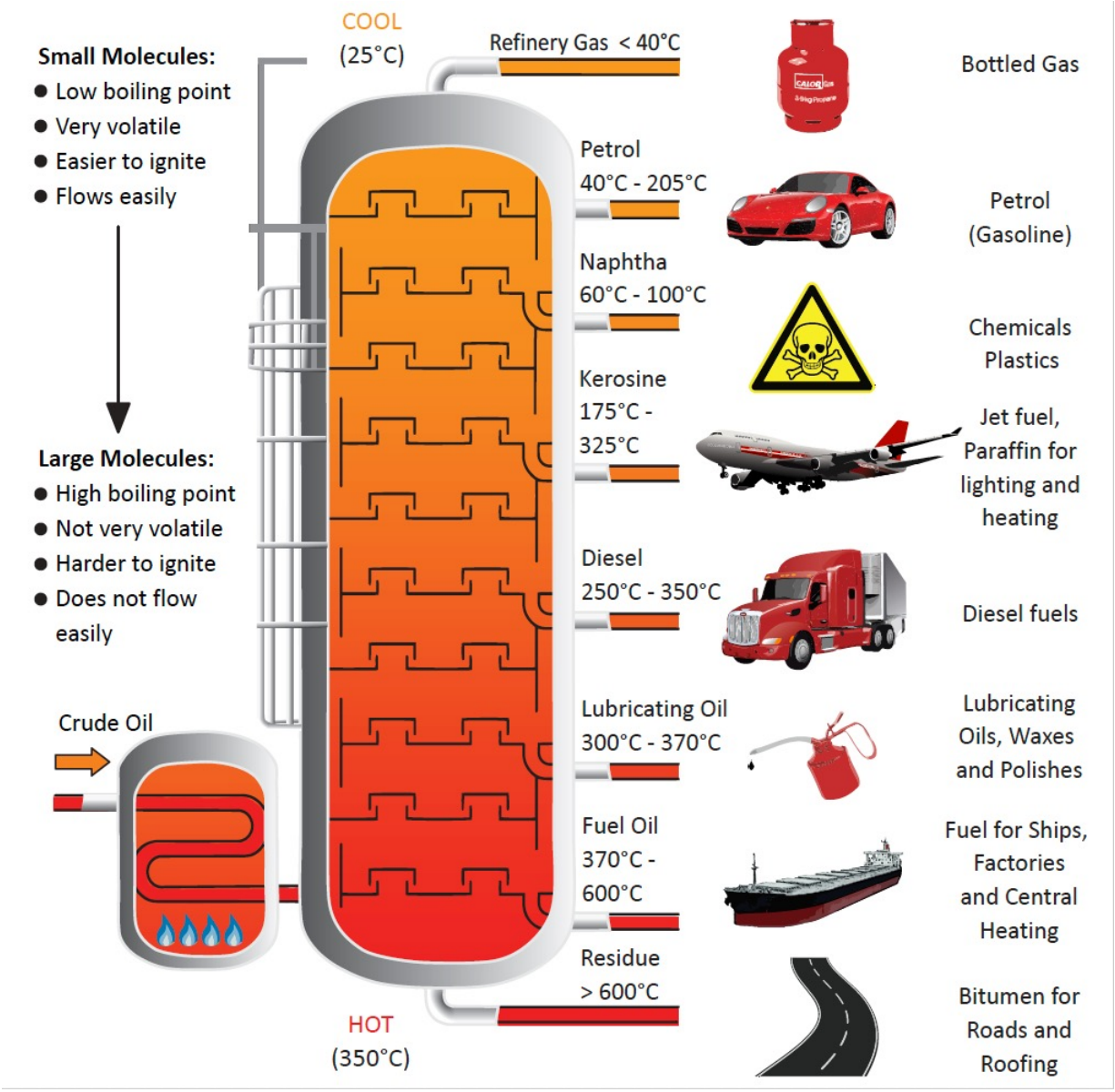
An oil or gas field forms when the liquid or gas moves through the pores and spaces of permeable rock and collects within the pore spaces under an impermeable trap.

Where is oil found?



https://www.visualcapitalist.com/map-countries-most-oil-reserves/

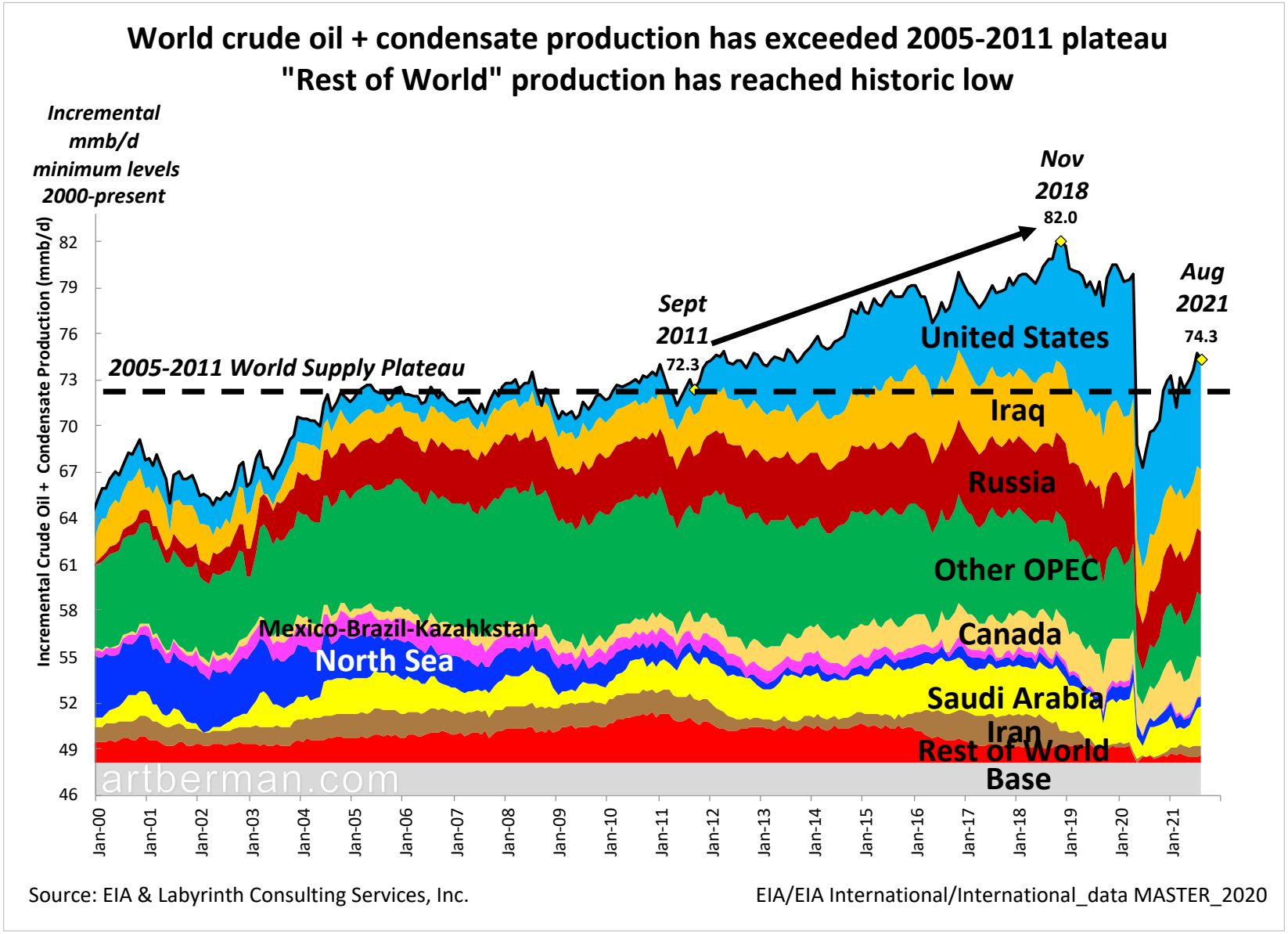
What is made from oil?



http://science-resources.co.uk/downloads/Fractioning_Column_A3.pdf

What is depletion?

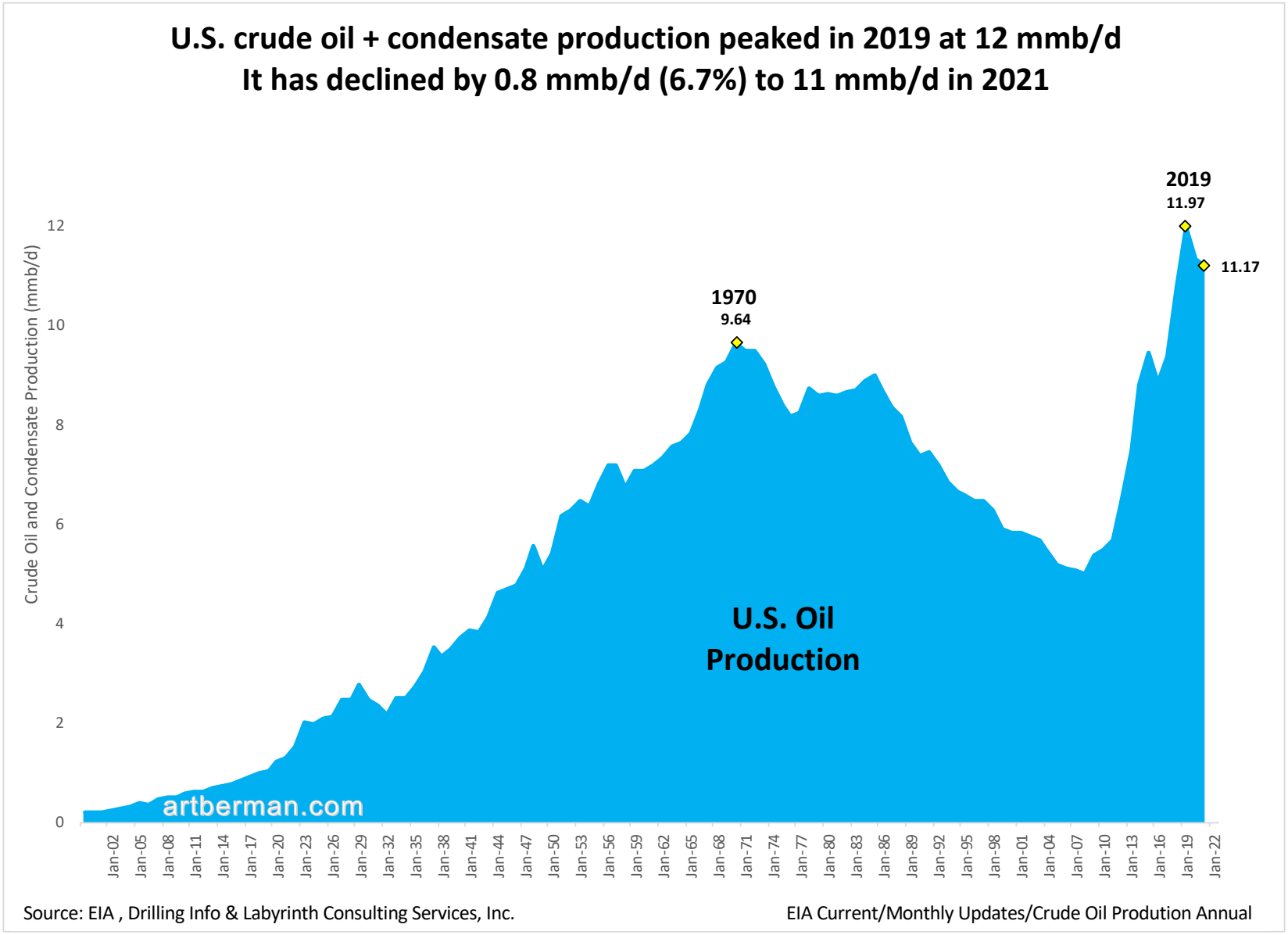
Most of world oil production growth has been from the United States since about 2010



Source: EIA & Labyrinth Consulting Services, Inc.

EIA/EIA International/International_data MASTER_2020

Impressive growth in U.S. oil production from 5 mmb/d in 2008 To 12 mmb/d in 2019



Source: EIA , Drilling Info & Labyrinth Consulting Services, Inc.

EIA Current/Monthly Updates/Crude Oil Prodution Annual

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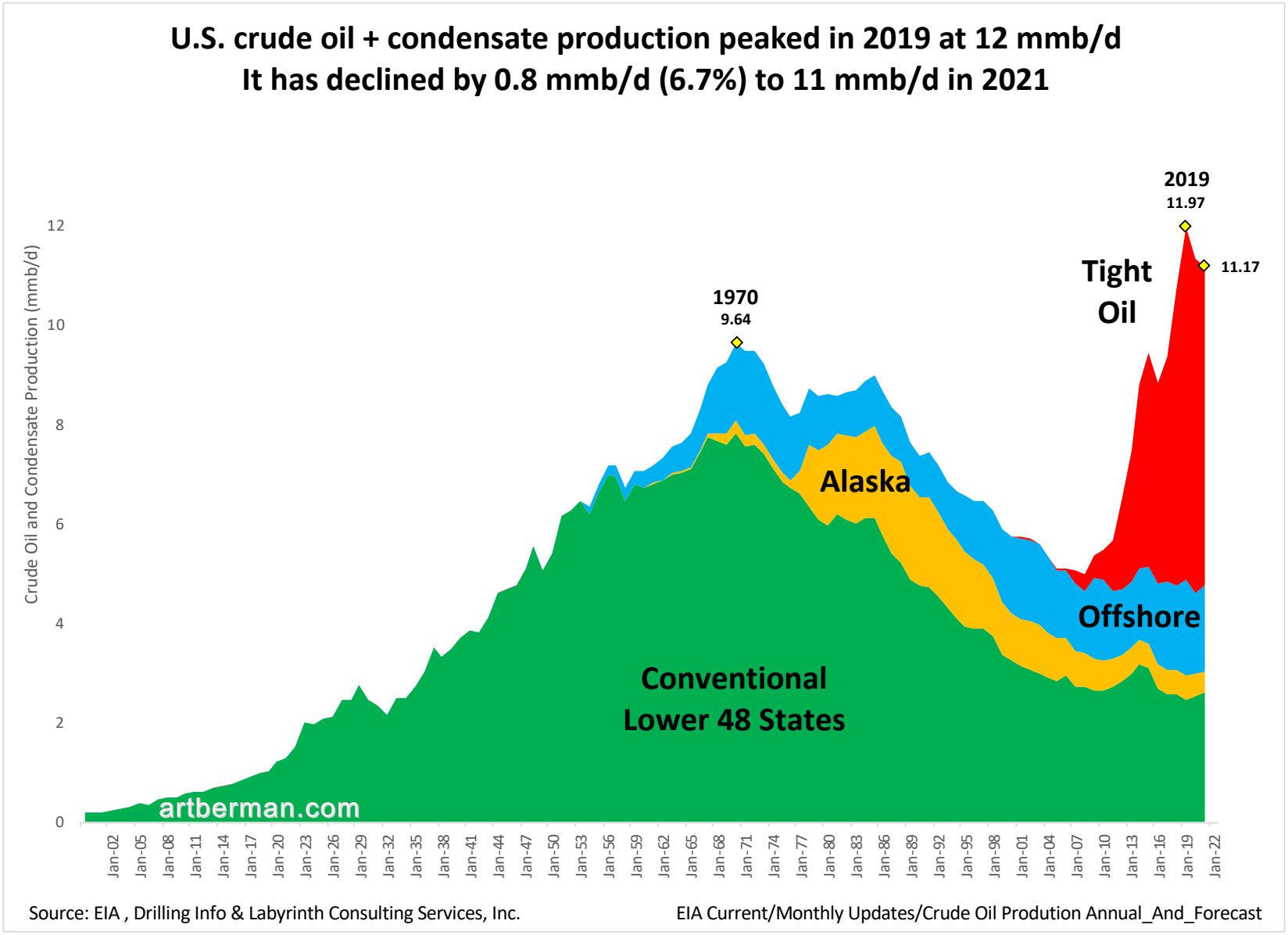
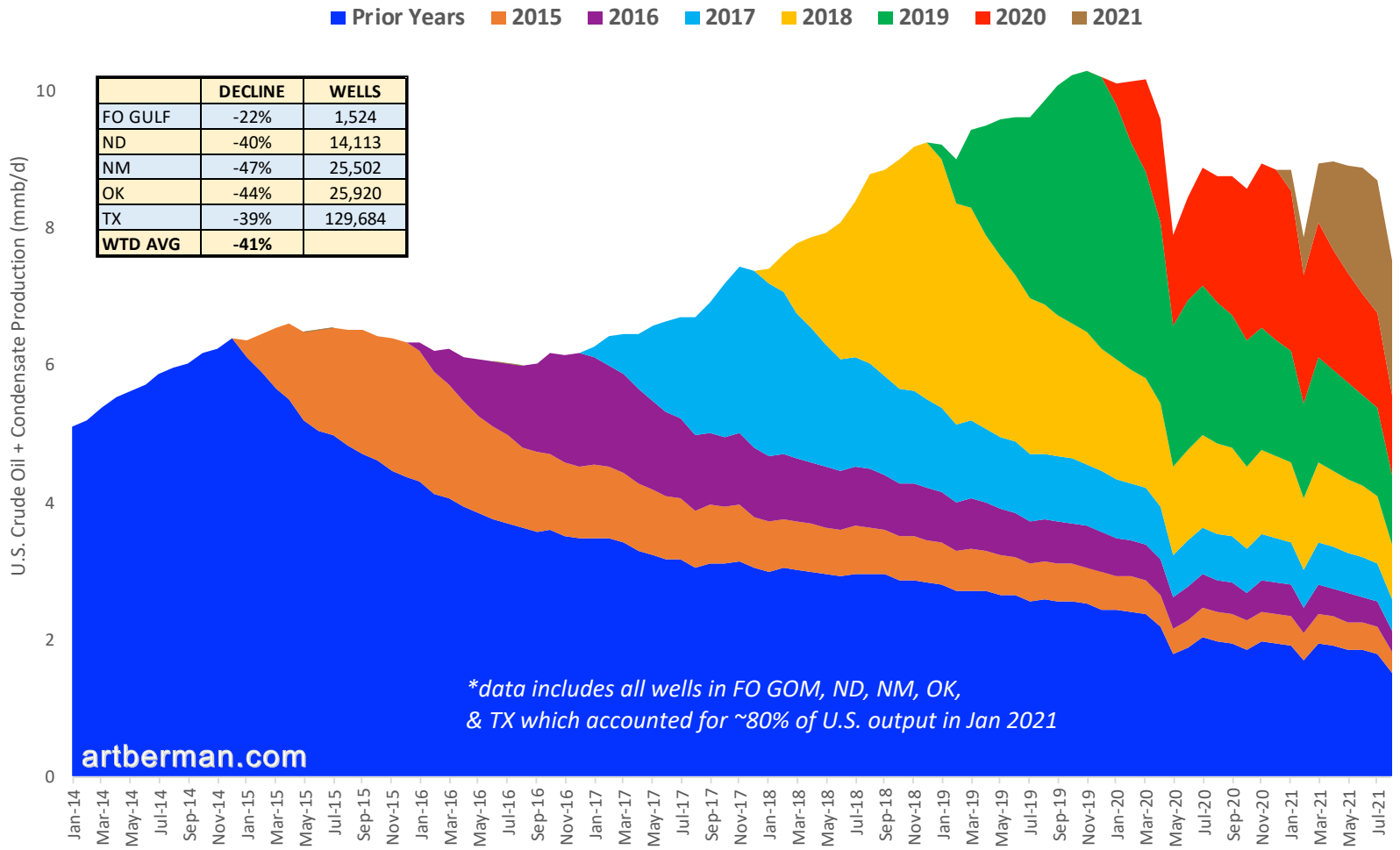


Source: EIA , Drilling Info & Labyrinth Consulting Services, Inc.

EIA Current/Monthly Updates/Crude Oil Prodution Annual_And_Forecast

High decline rates mean that increasing levels of drilling needed to prevent production levels from falling

The U.S. oil production base decline was 41% per year in 2020
Ouput would fall almost 5 mmb/d in a year if no new wells were drilled

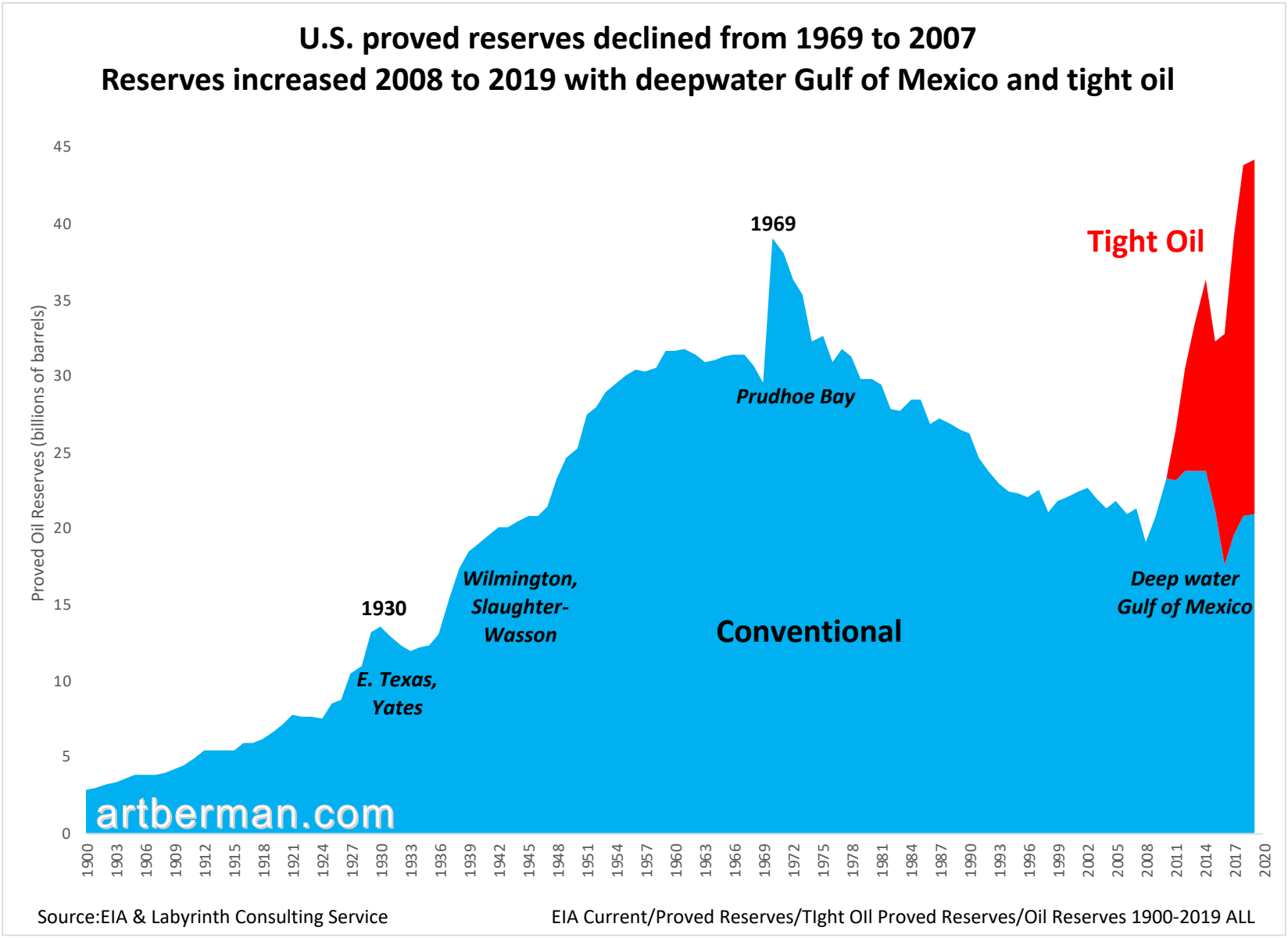


	DECLINE	WELLS
FO GULF	-22%	1,524
ND	-40%	14,113
NM	-47%	25,502
OK	-44%	25,920
TX	-39%	129,684
WTD AVG	**-41%**	

Source Enverus & Labyrinth Consulting Services, Inc.

Oil & Gas Supply/TX-ND-NM-OK-FO/FO-ND-NM-OK-TX Merged Vintaged CUM 1980-2020 OCT 2021

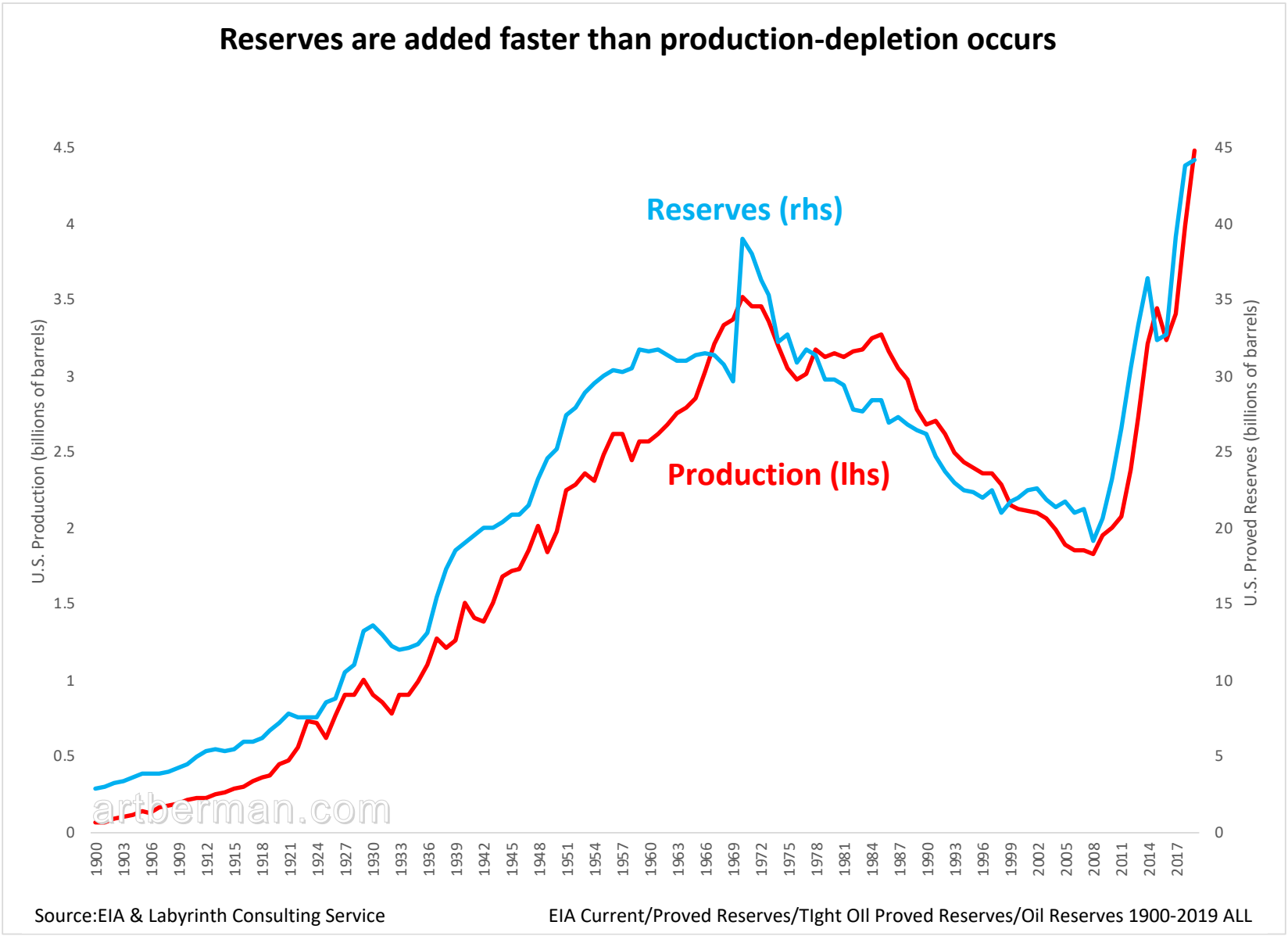
Decline and depletion are not necessarily the same thing
Depletion is about reduction of proved reserves



Source:EIA & Labyrinth Consulting Service

EIA Current/Proved Reserves/TIght OIl Proved Reserves/Oil Reserves 1900-2019 ALL

Reserves are added faster than production-depletion occurs



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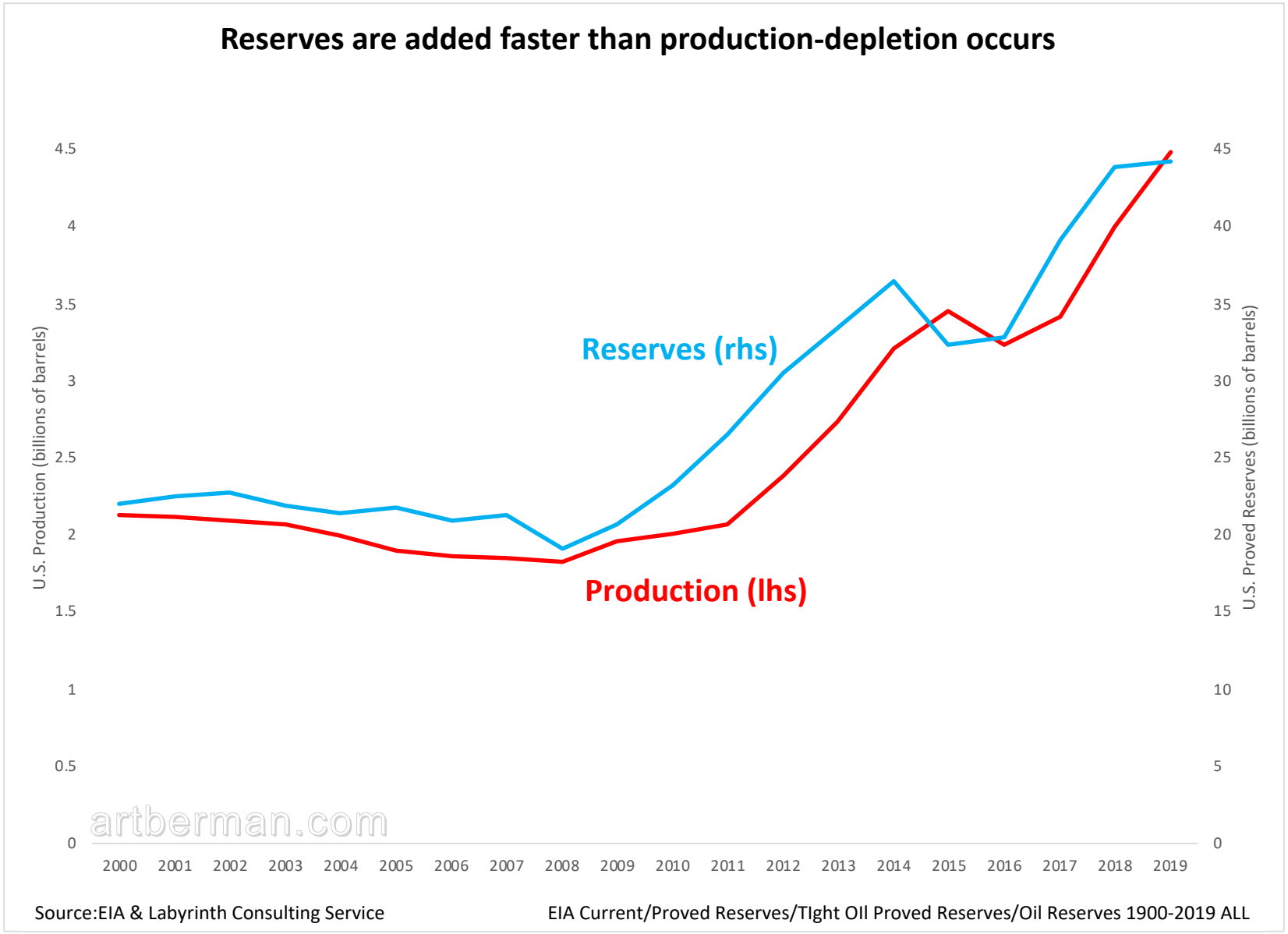
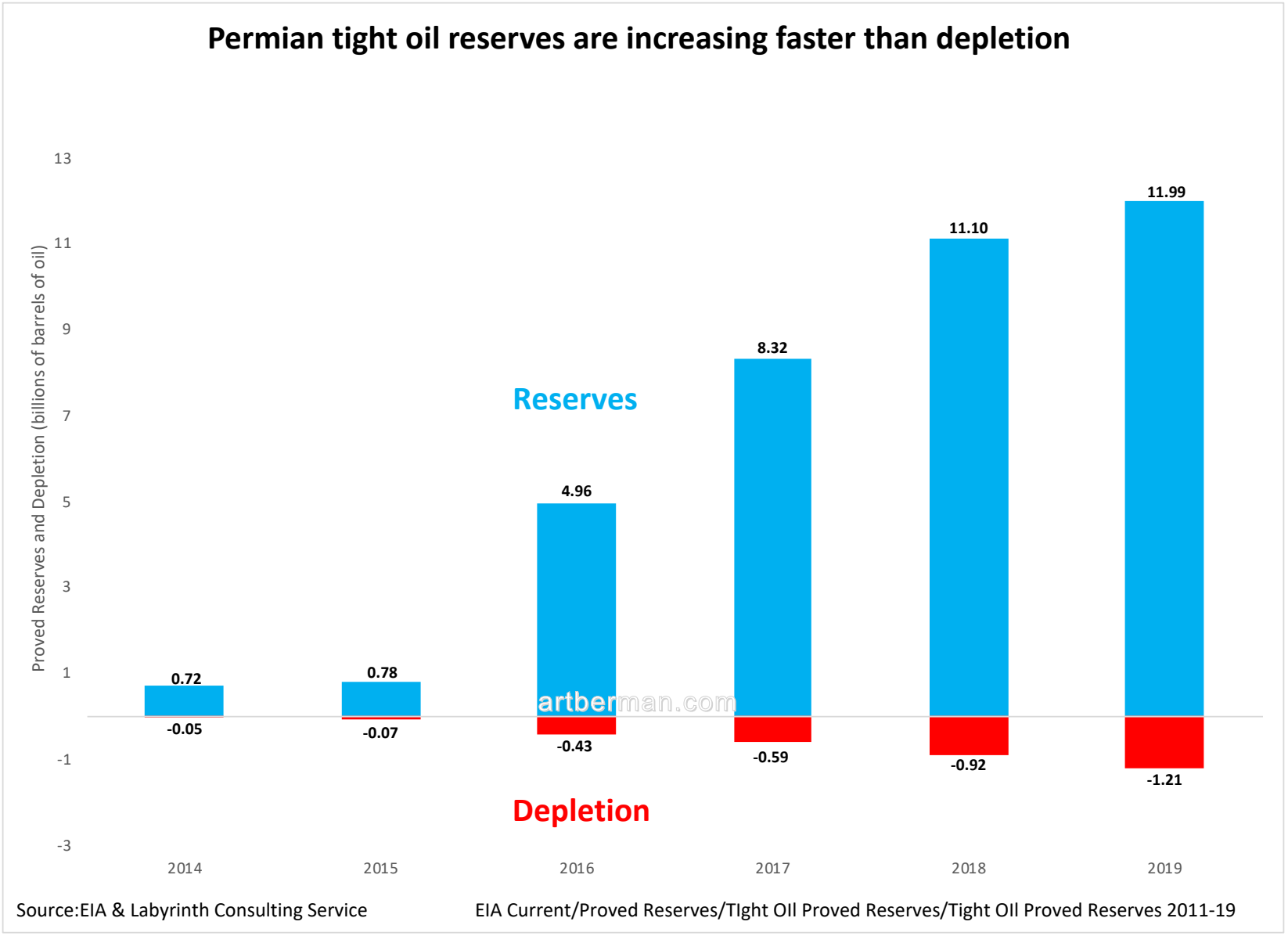
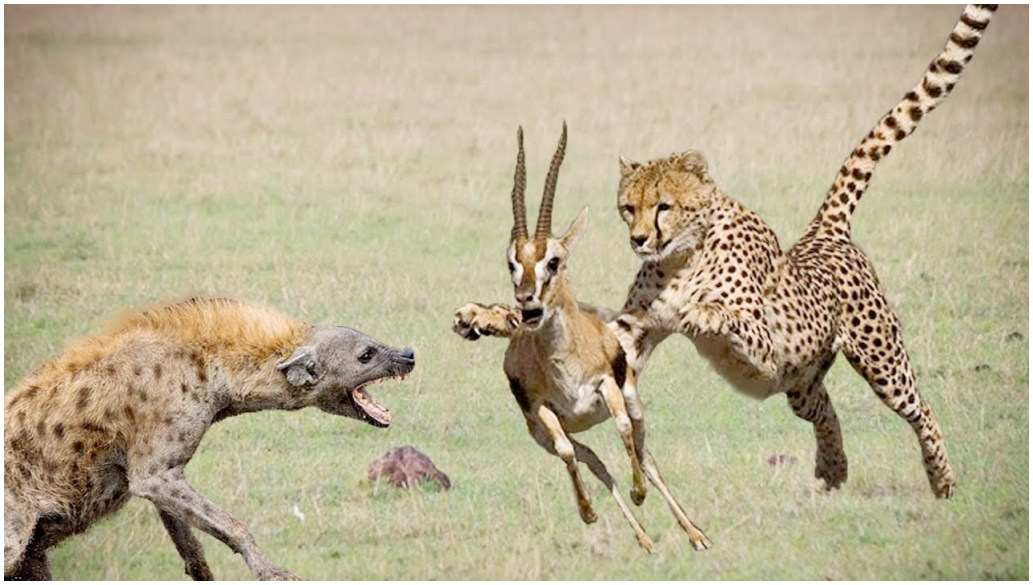


Permian reserves are increasing faster than depletion

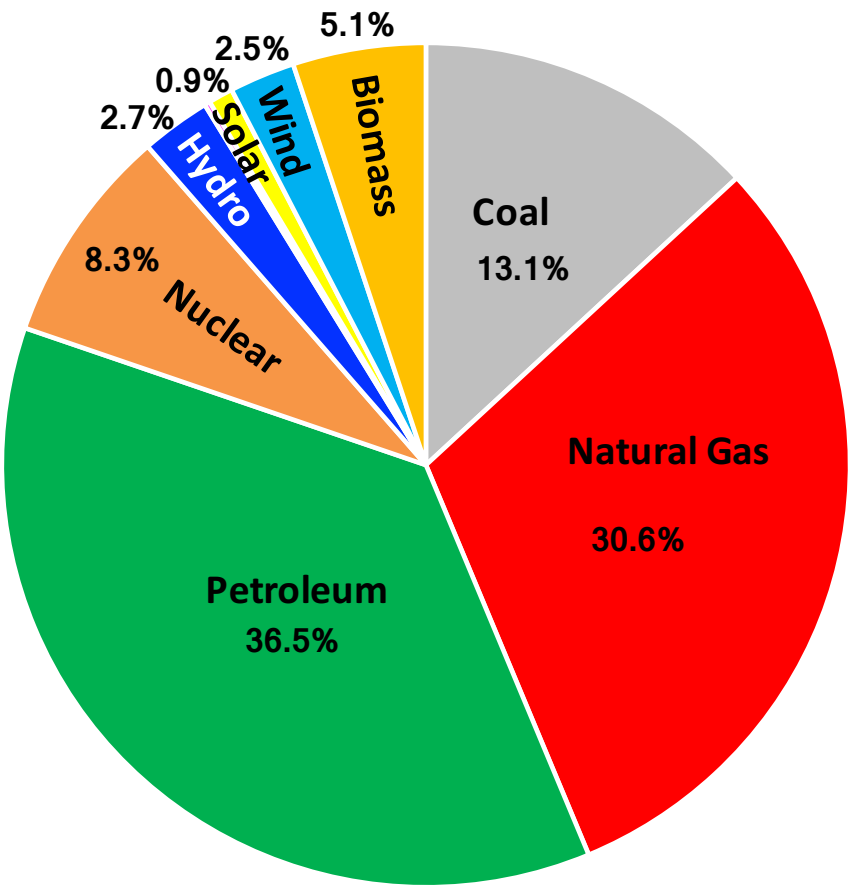


“Energy is and always will be the currency of life”
–Nate Hagens



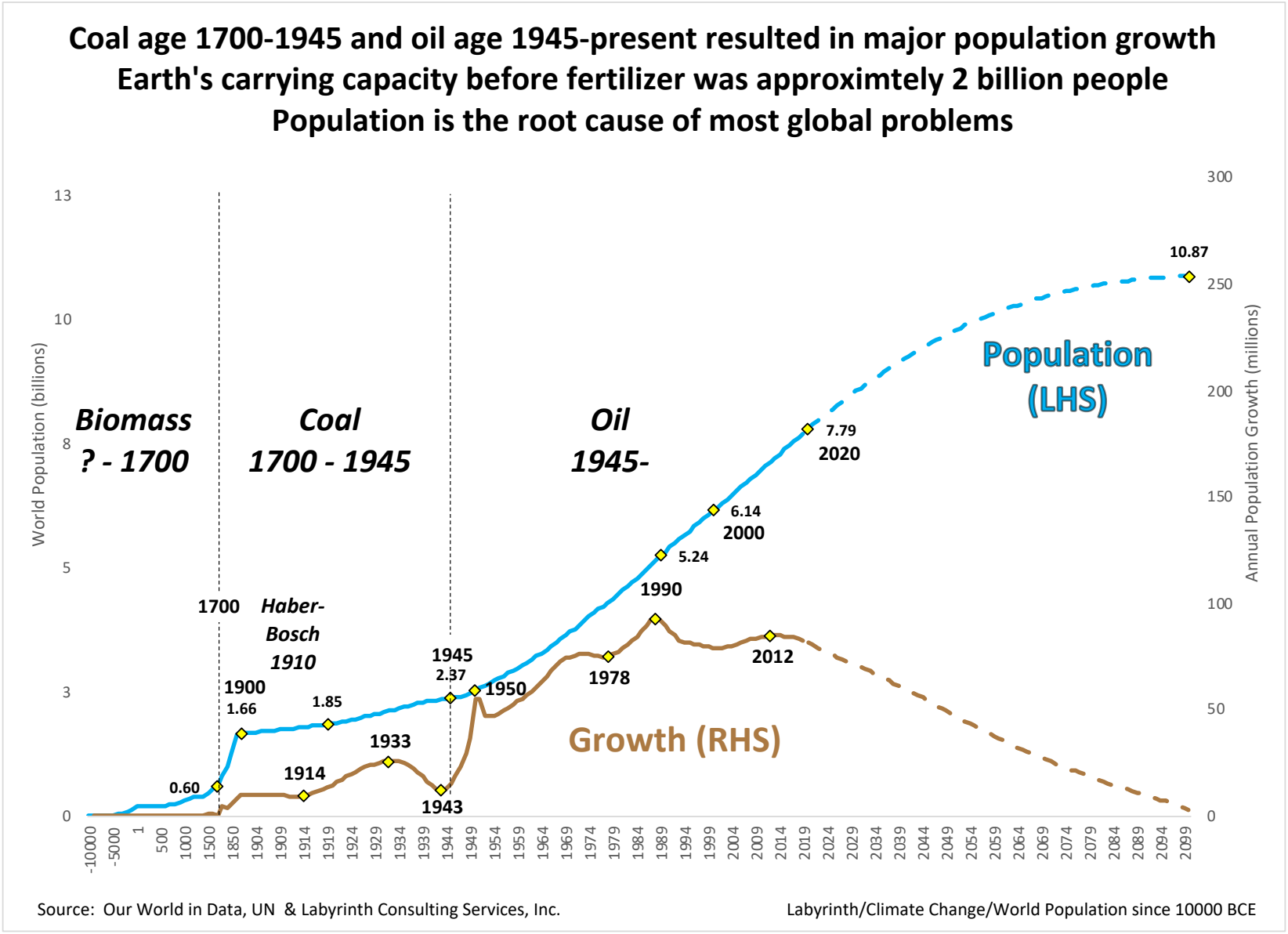
- Any movement, activity or event in nature requires energy
- Human society runs on energy
  - Work requires energy—joules/calories.
  - Subsistence: energy intake = energy expenditure.
  - Surplus: energy intake > energy expenditure.
  - If I accumulate excess energy such as grain, I may choose to have you do some of my work in exchange for some of that energy.
- Money is a call on work
  - Today, most work is done by oil, natural gas and coal.
  - Energy is the economy. Money is a call on energy. Debt is a lien on future energy.
- No species has never gone from a higher- to a lower-density energy source.

The truth about the energy mix is that fossil energy dominates
Little has changed over the last 50 years



- The world economy is 79% dependent on fossil energy. Substitution cannot happen fast enough to both reduce emissions & maintain economic growth.
- Fossil fuels cannot be abandoned because production of non-fossil energy requires substantial carbon use.
- Electric vehicles, solar panels & wind turbines made of metal & minerals that require fossil energy for mining, transport, manufacturing & distribution. Diesel is the principal fuel for mining and for shipping raw materials to manufacturing plants.
- Equipment change: 1.6 bn cars & trucks. Less than 1% of those—8.5 million—are electric. What happens to all of those vehicles that run on gasoline or diesel?

High energy density coal moved world population from 0.5 to almost 2 billion
Fertilizer and oil resulted in population increase to almost 8 billion by 2020



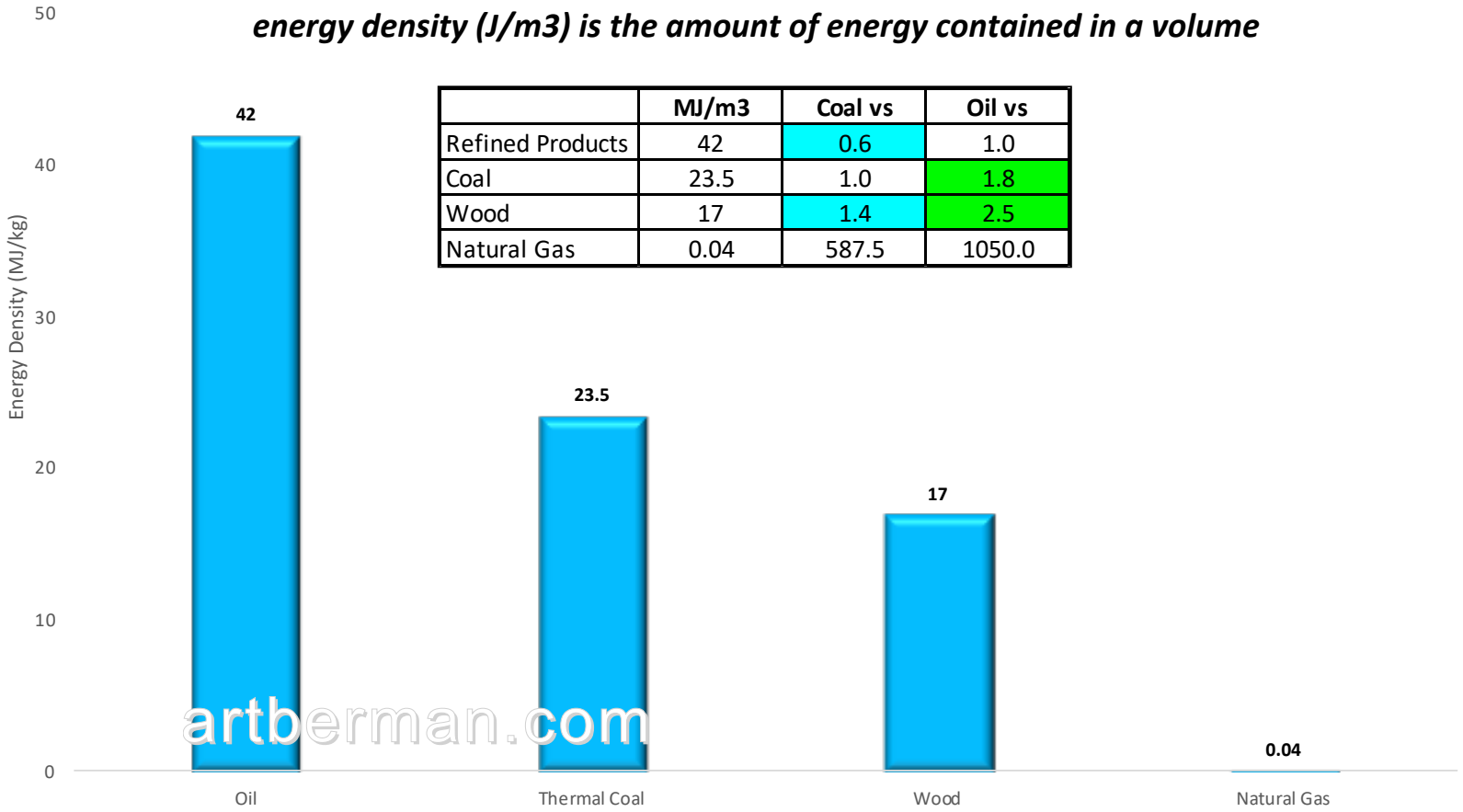
Energy density: amount of energy contained in a volume
Not all energy sources are equal

Energy density explains why we prefer coal over wood and oil over coal
Coal has 1.4 times times as much energy as wood
Oil has 1.8 times more energy than coal and 2.5 more energy than wood

energy (J) is the potential to do work

energy density (J/m3) is the amount of energy contained in a volume

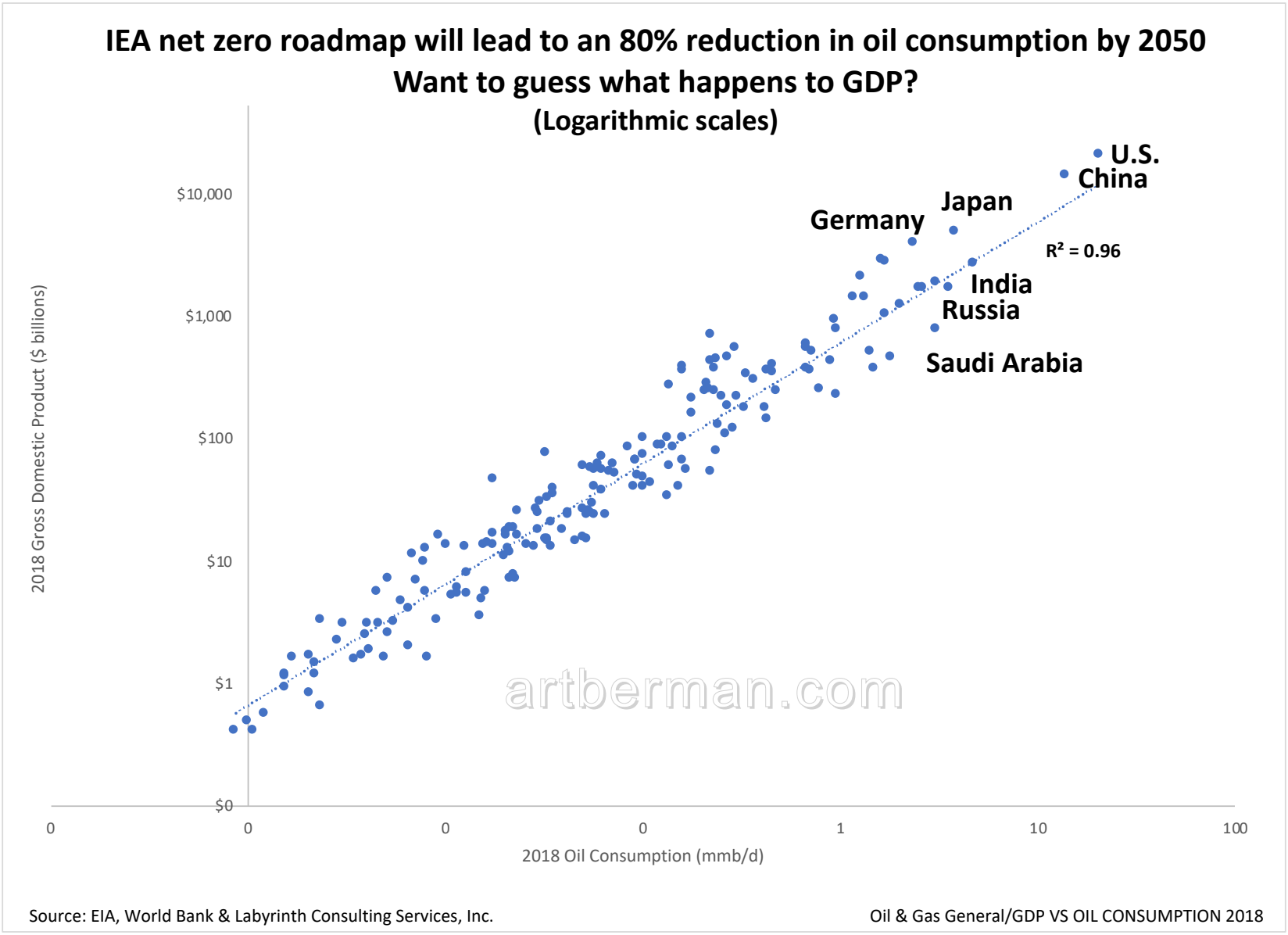
	MJ/m3	Coal vs	Oil vs
Refined Products	42	0.6	1.0
Coal	23.5	1.0	1.8
Wood	17	1.4	2.5
Natural Gas	0.04	587.5	1050.0



Source: Layton (2008) & Labyrinth Consulting Services, Inc.

EIA/Energy Density/Energy Density Comparison

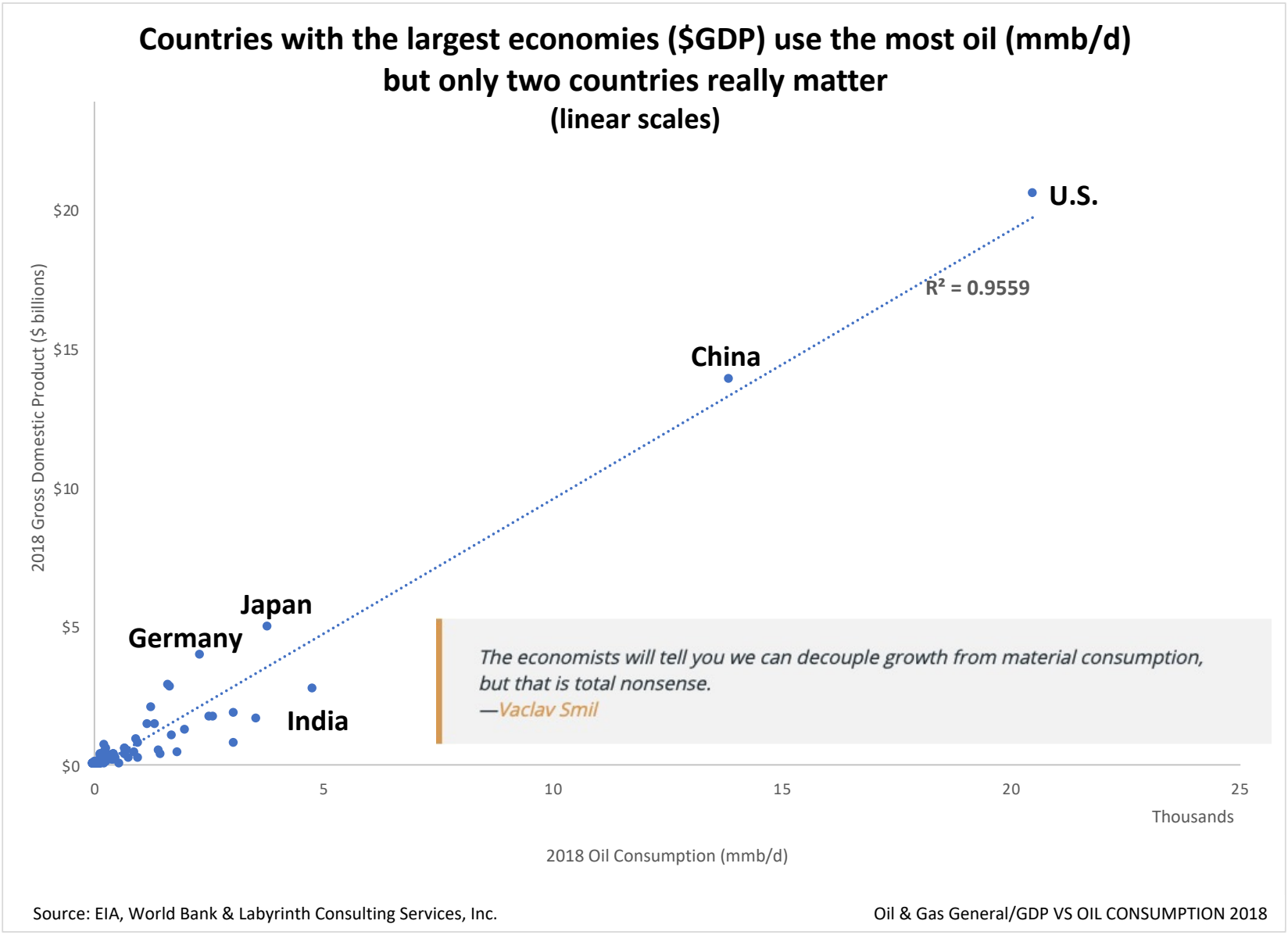
Oil consumption and GDP are an almost perfect correlation



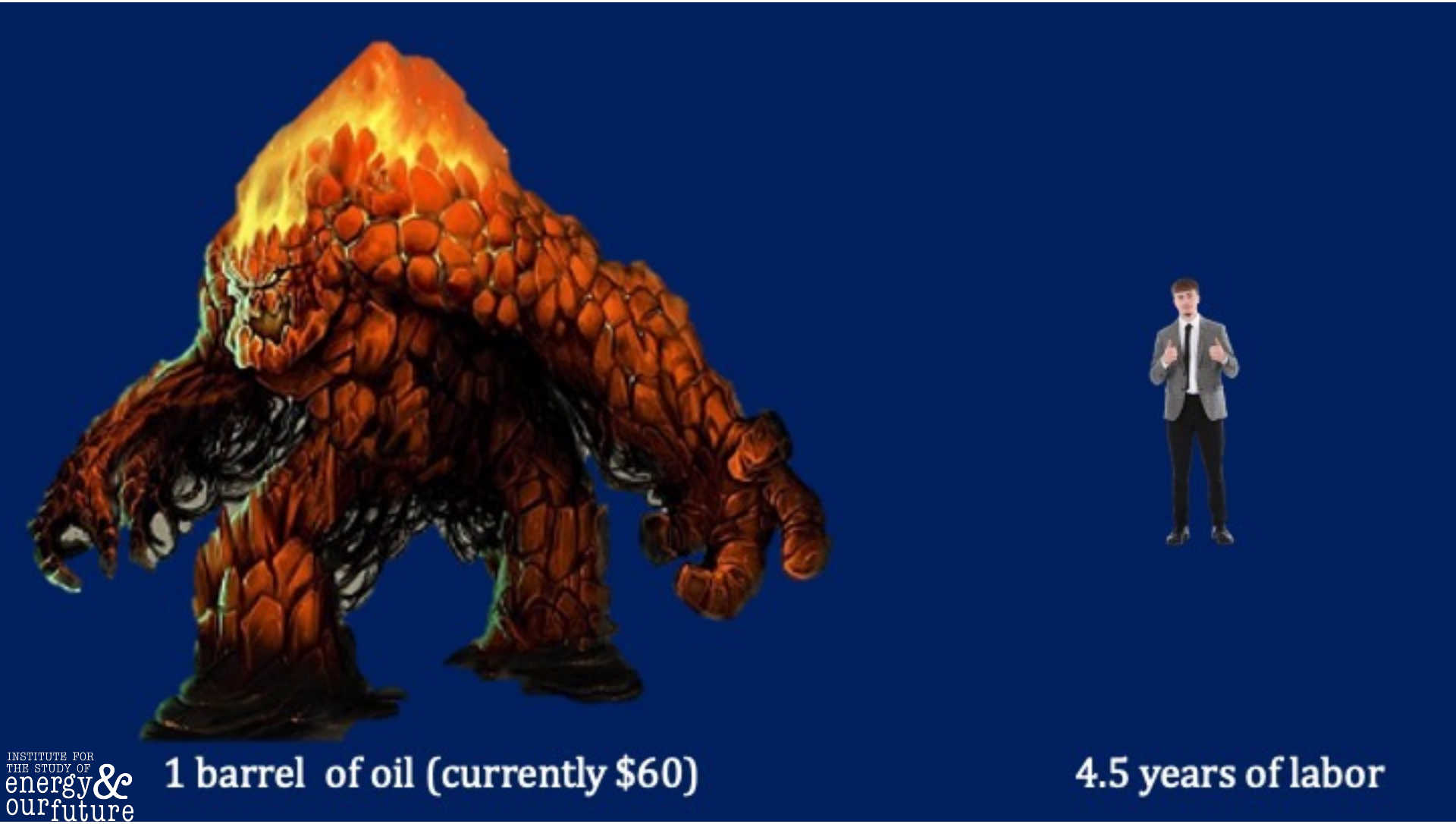
Source: EIA, World Bank & Labyrinth Consulting Services, Inc.

Oil & Gas General/GDP VS OIL CONSUMPTION 2018

A linear scale reveals why U.S. and China are leading world economies



The myth of human progress through ingenuity and free markets
The truth is it's mostly because 1 barrel of oil contains 4.5 years of human labor



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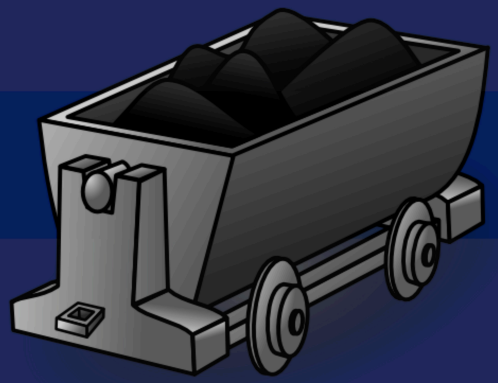


=

X ~500,000,000,000!

- **We should think about energy as workers**
- **Cost ≠ price ≠ value**

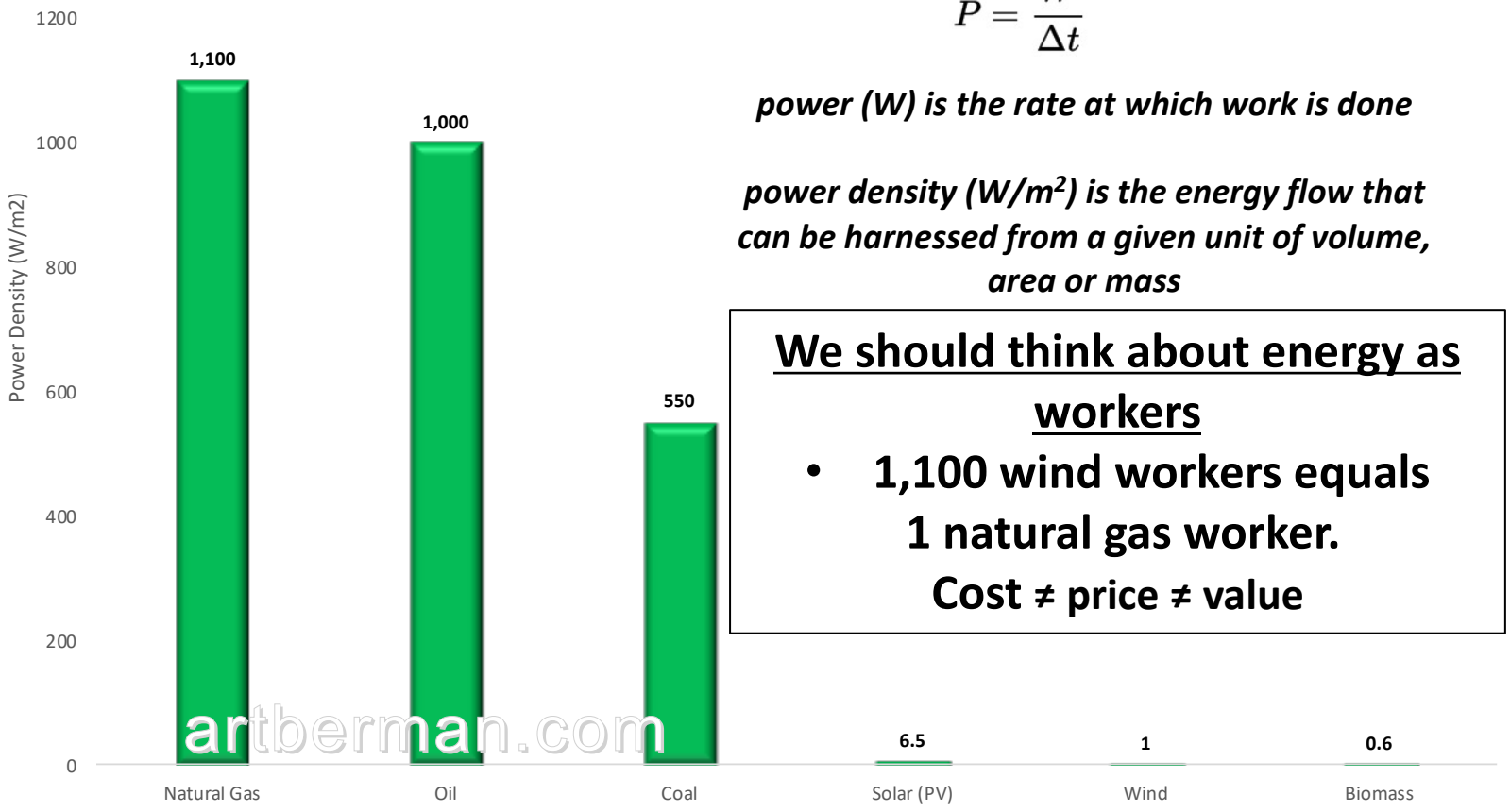
INSTITUTE FOR THE STUDY OF energy & our future

1 barrel of oil =5.7 million BTU or 1,760 kWh. 1 human does 0.6kWh per work day, x250 days per year. 1 barrel=11 years of work *0.45 efficiency = 4.8 years. World uses 100 billion boe per year. 100 billion *4.8 =480,000,000,000

Economics for the Future: Beyond the Superorganism, Hagens 2020

Power density: how much energy can be converted to power from a volume
Natural gas has 200 times more power density than solar and 1000 times more power density than wind

Solar PV has 0.6% the power density of natural gas and wind has 0.1%
Solar requires 200 times larger source area to deliver the same power as gas
Wind requires 1000 times larger source area to deliver the same power as gas



$$P = \frac{W}{\Delta t}$$

power (W) is the rate at which work is done

power density (W/m^2) is the energy flow that can be harnessed from a given unit of volume, area or mass

We should think about energy as workers

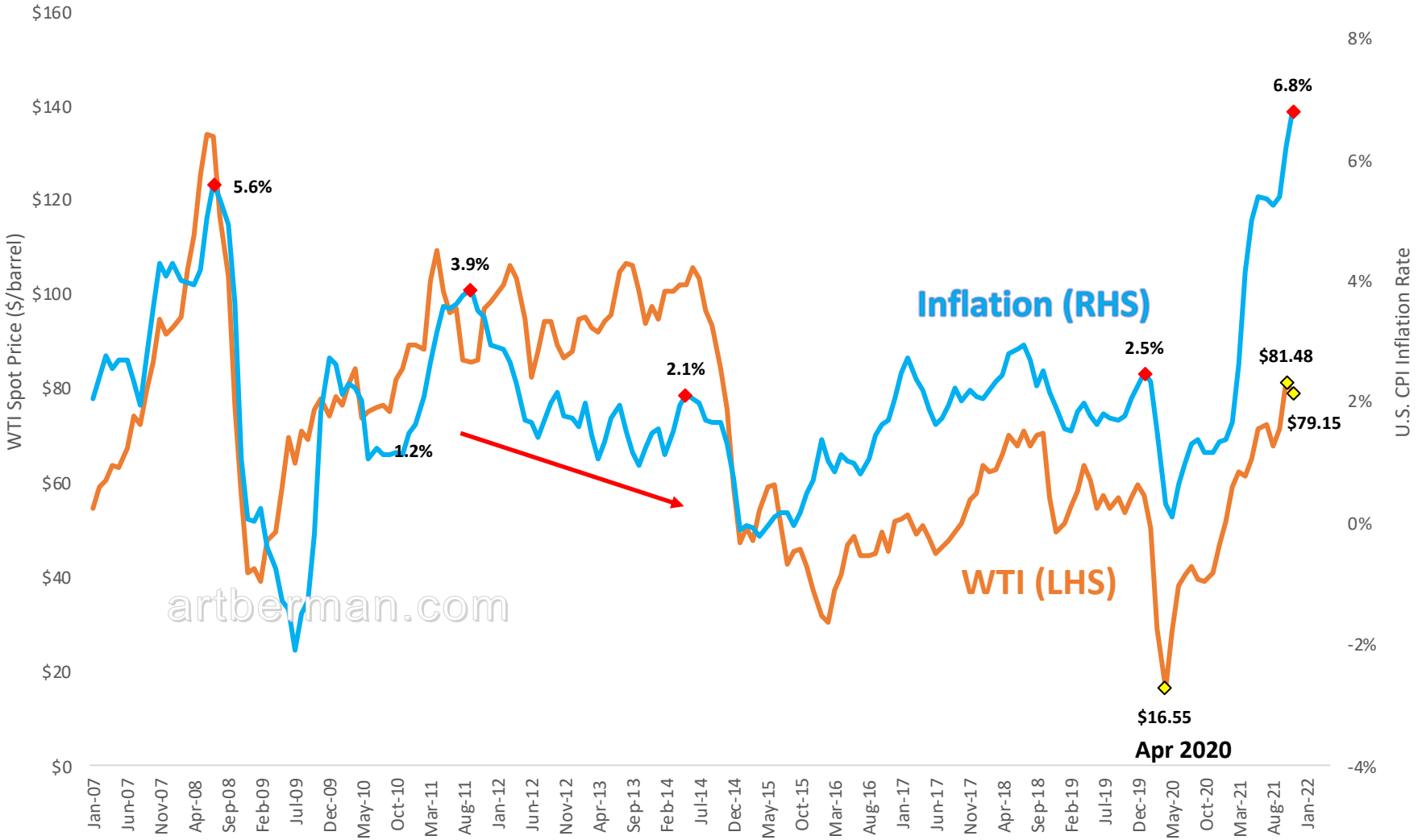
- **1,100 wind workers equals 1 natural gas worker.**

Cost ≠ price ≠ value

Source: Smil (2011), Layton (2008) & Labyrinth Consulting Services, Inc.

EIA/Energy Density/Energy Density Comparison

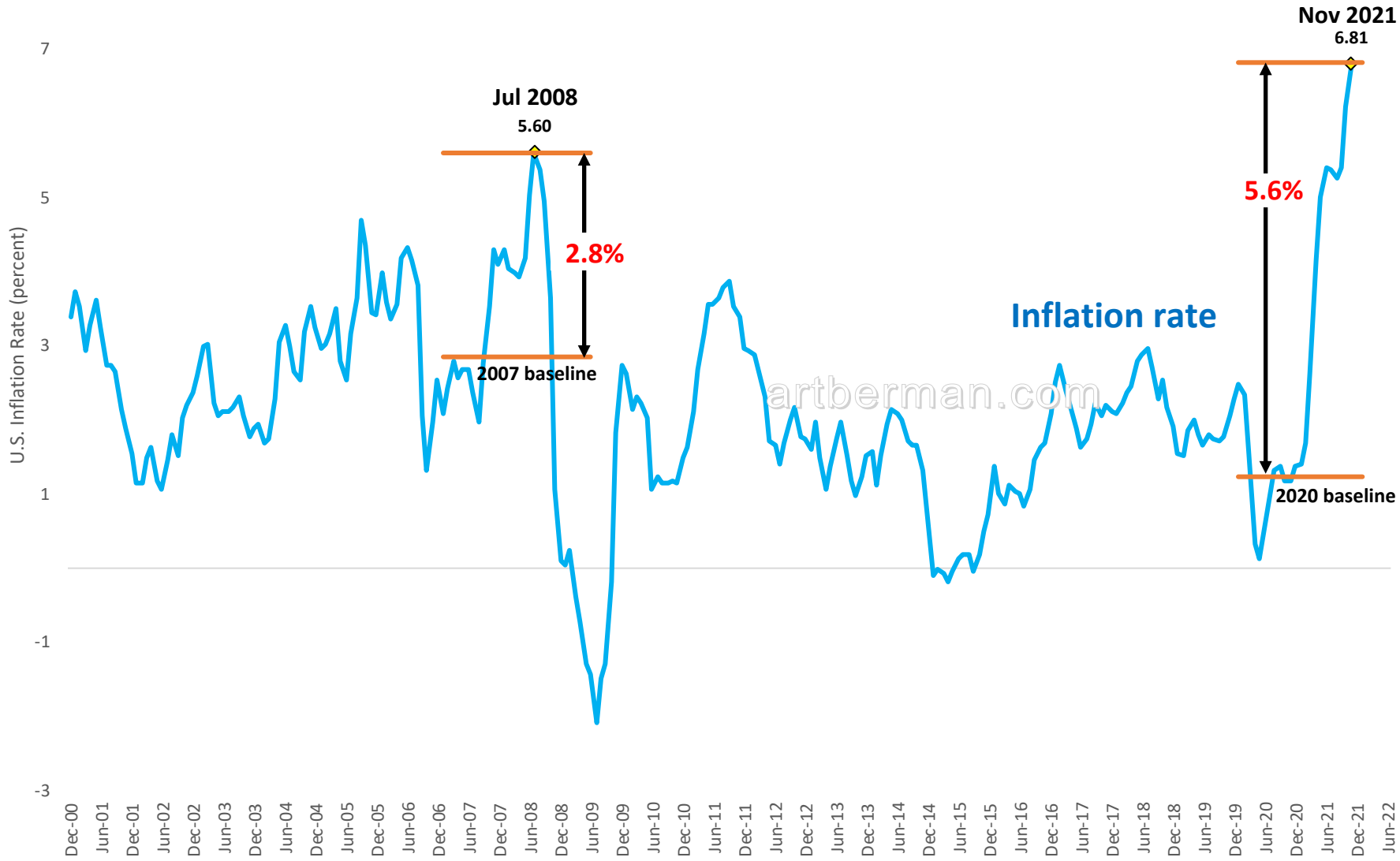
Higher oil price is the leading cause of inflation
November U.S. inflation rose from 6.2% to 6.8%
WTI price decreased slightly from $81.48 to $79.15



Source: OECD, EIA & Labyrinth Consulting Services, Inc

Oil & Gas General/CPI INFLATION OECD_DP_LIVE

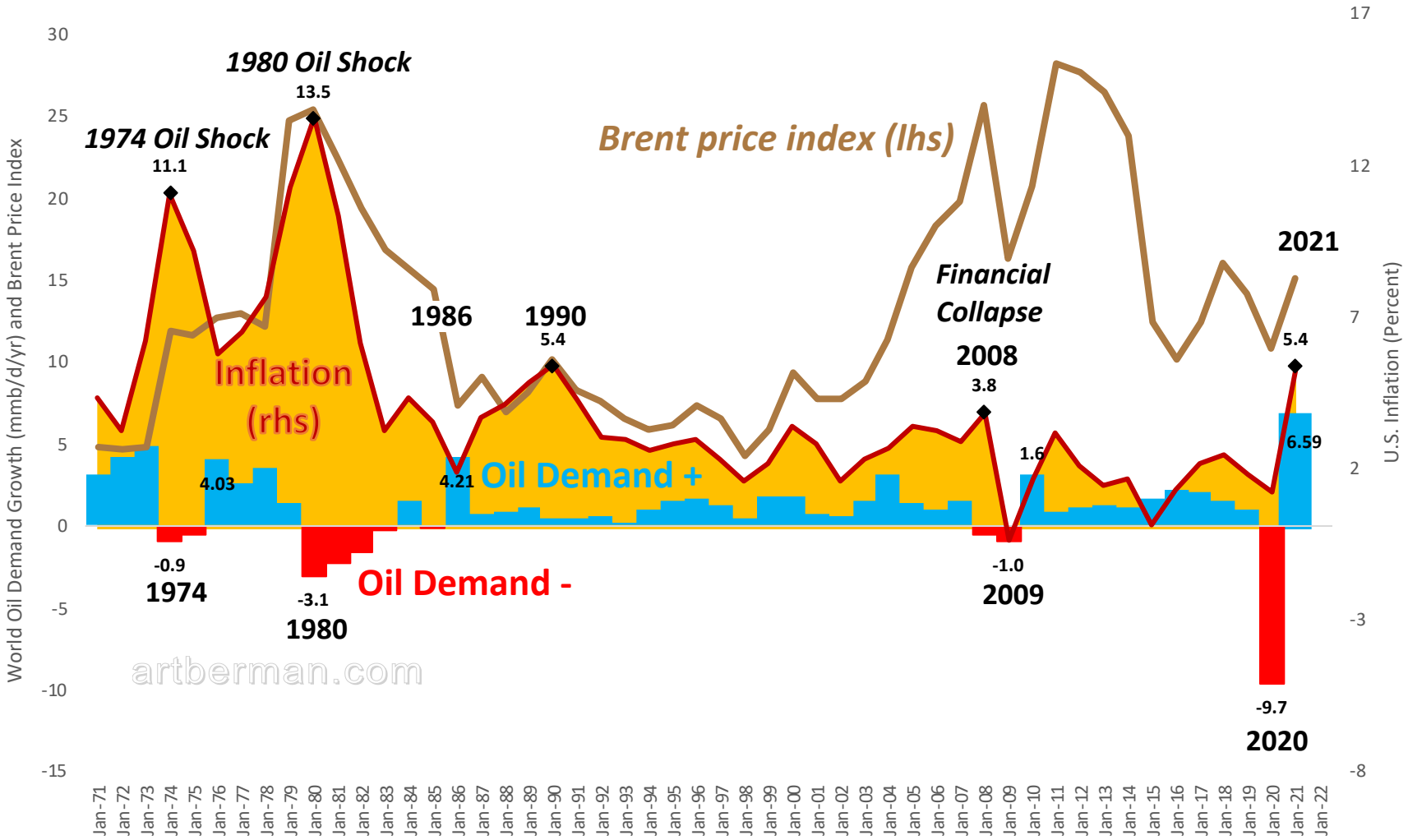
November U.S. inflation rate of 6.8% was +5.6% more than 2020 baseline
July 2008 rate of 5.6% was 2.8% more than 2007 baseline



Source: OECD & Labyrinth Consulting Services, Inc.

Oil & Gas General/DP_LIVE_OECD_

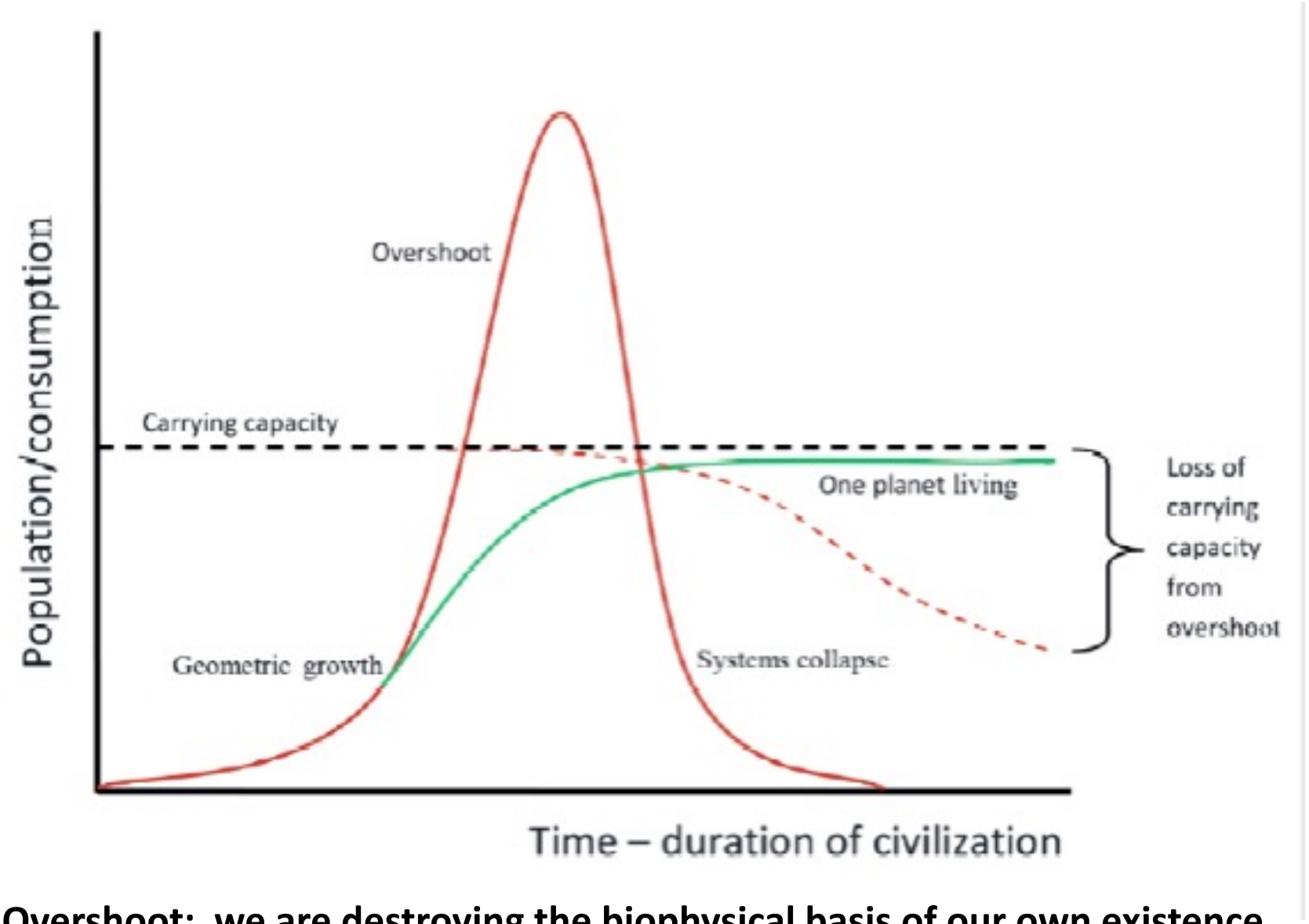
Factors causing oil demand destruction are poorly understood
2021 oil demand growth is highest ever and annual inflation rate is highest since 1990



Source: IEA, OPEC, US Federal Reserve Bank, & Labyrinth Consulting Services, Inc

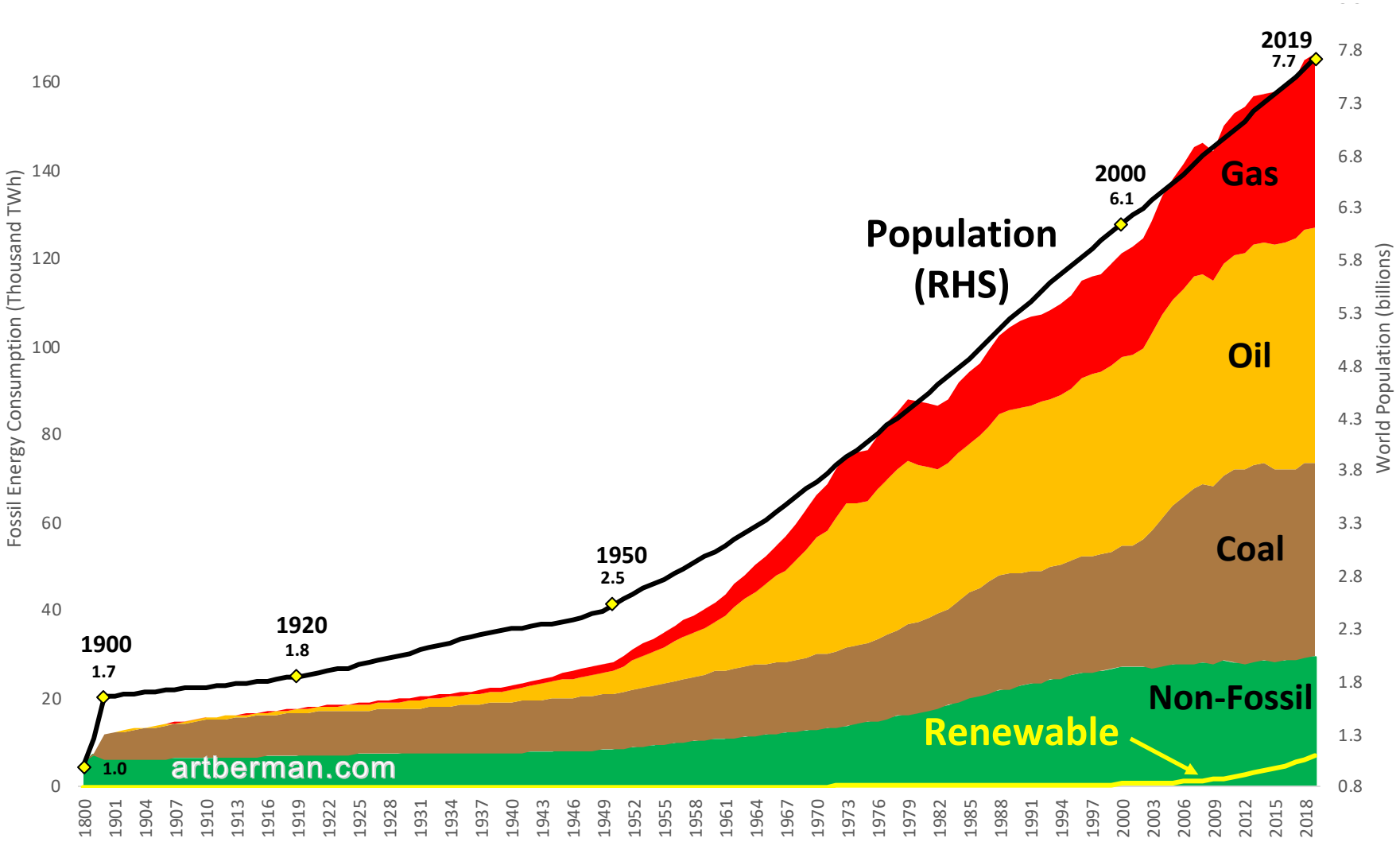
Oil & Gas General/Inflation Annual Master

Renewable energy promoters claim that we can replace our energy needs without fossil fuels but that does not address ecological overshoot



Overshoot: we are destroying the biophysical basis of our own existence

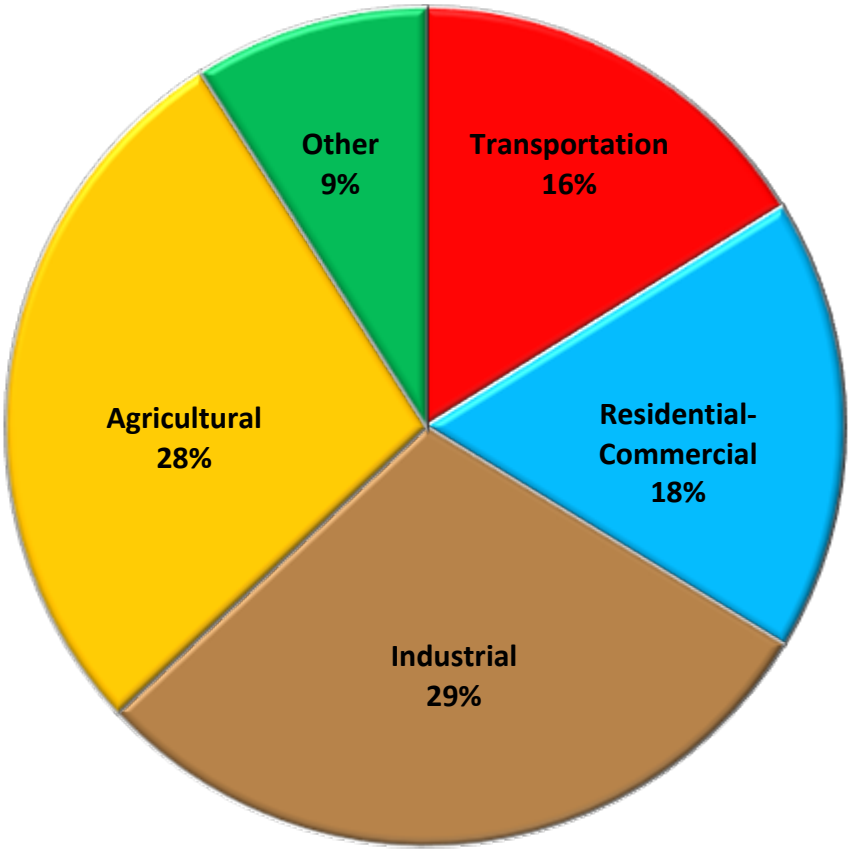
Non-fossil energy sources only capable of supporting population of ~2 billion today
Tripling that capacity only supports ~6.0 of 9.8 billion projected 2050 population



Source: Our World in Data, UN & Labyrinth Consulting Services, Inc.

Labyrinth/Climate Change/World Population since 10000 BCE

Electric vehicles will reduce emissions much less than expected

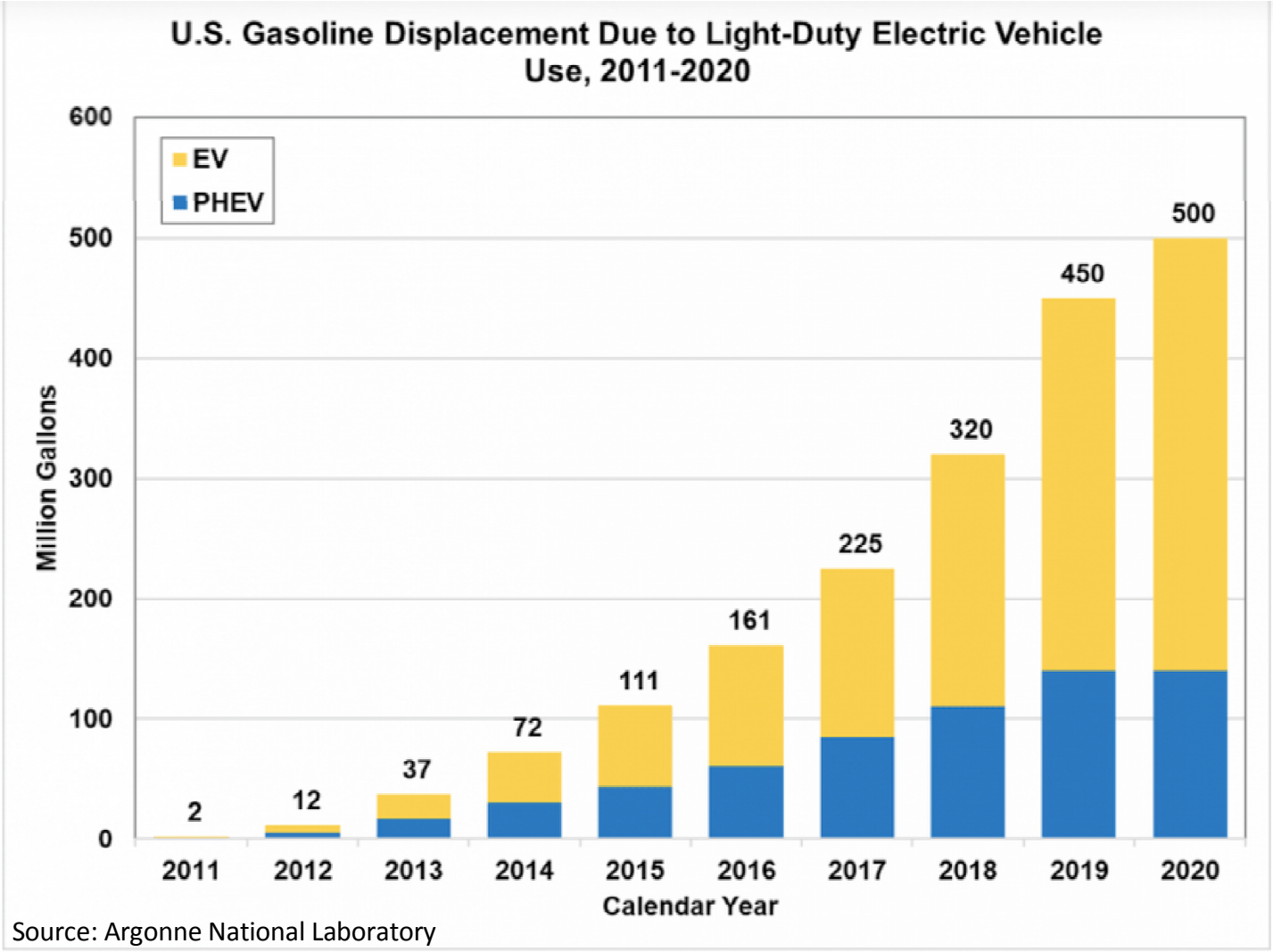


- Transportation sector accounted for only 16% of global greenhouse gas emissions in 2020.
- Less than half of ICEs (78 mm) were for automotive use. Agriculture, manufacturing, power generation, forestry and construction accounted for the other 53%.

Source: World Resources Institute, Our World in Data & Labyrinth Consulting Services, Inc.

Labyrinth/Climate Change/Global GHG Emissions by Sector

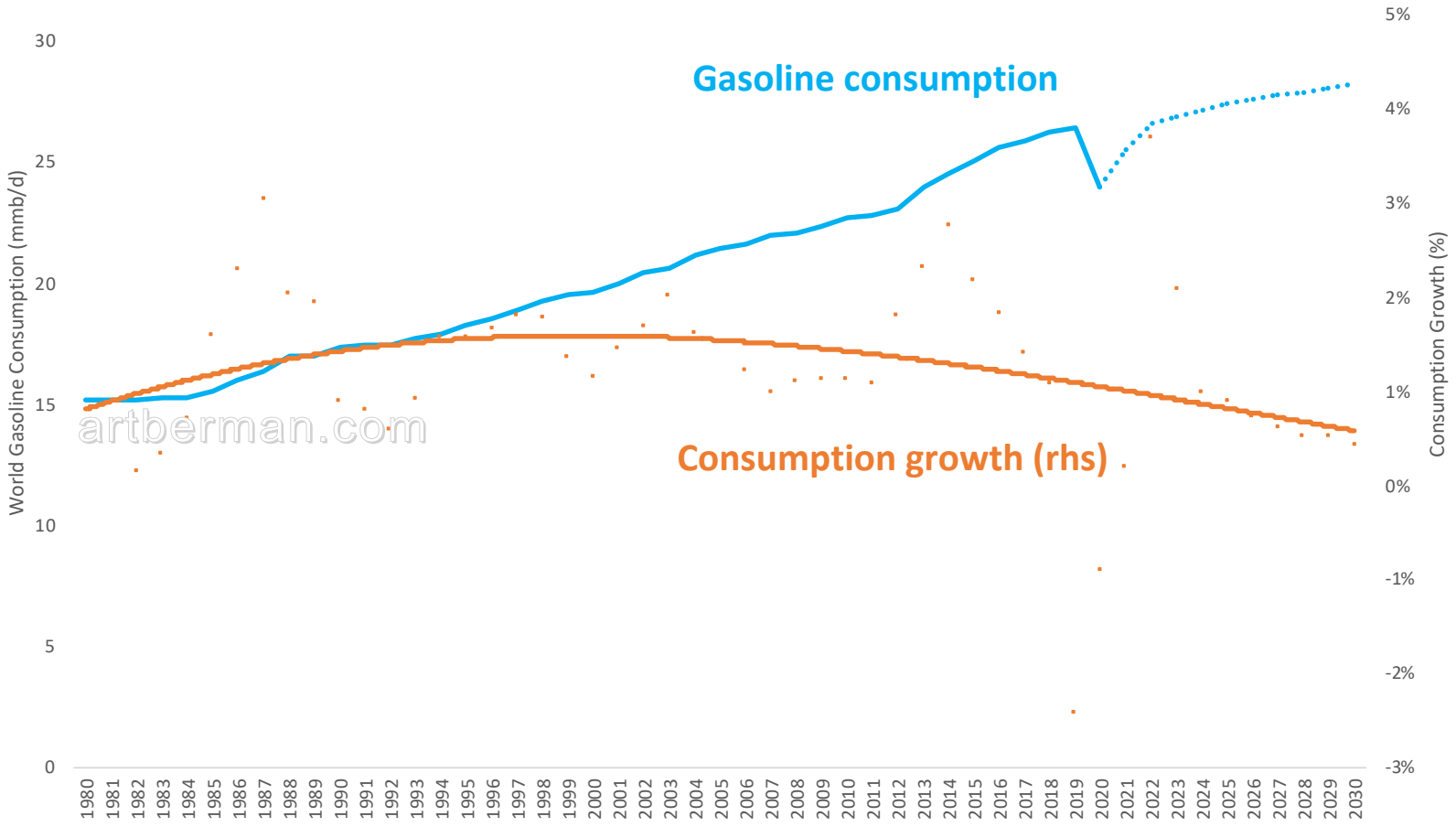
Experts believe that electric vehicles have reduced consumption of gasoline by 500 million gallons per year



Source: Argonne National Laboratory

Gasoline consumption decline began long before electric vehicles

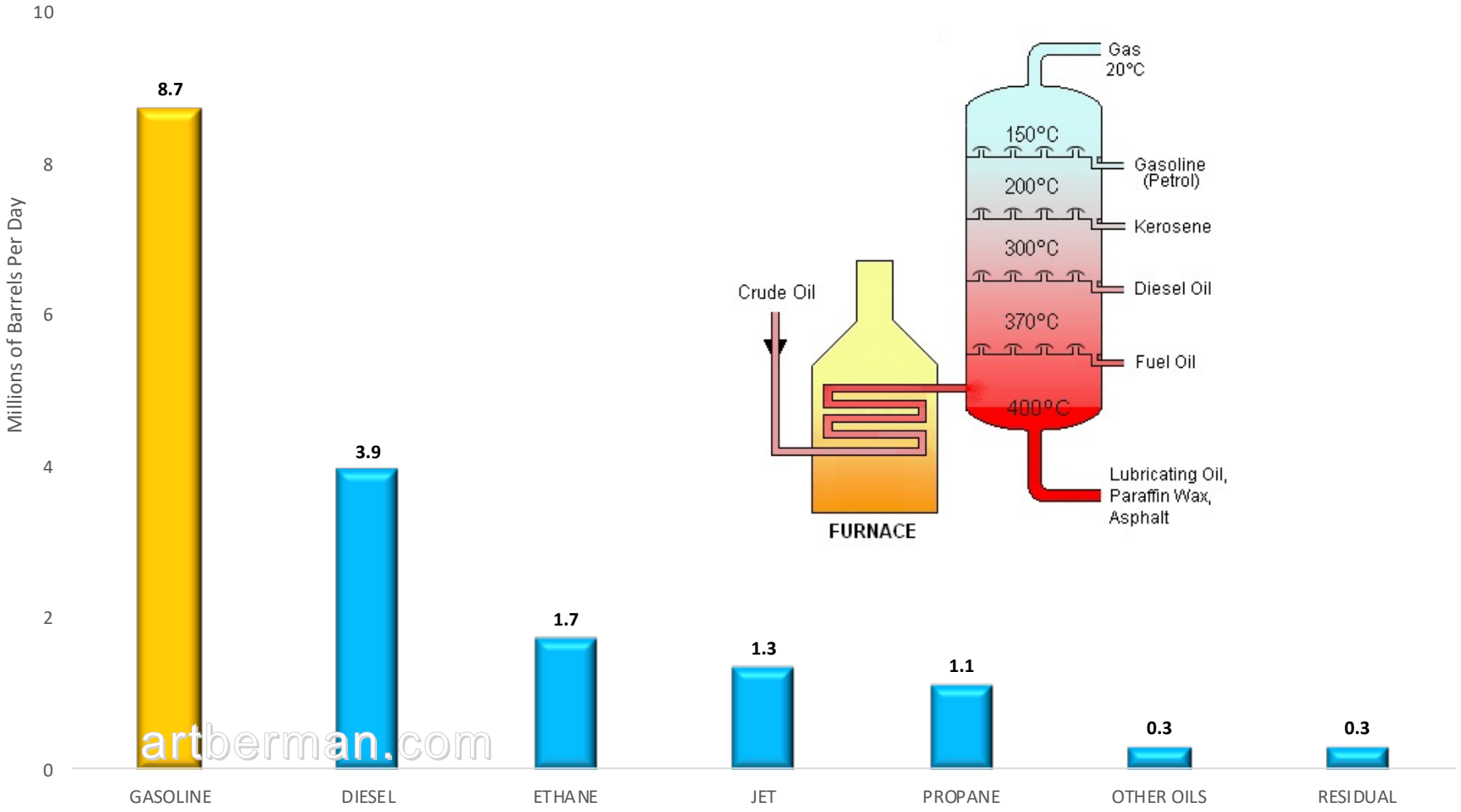
Claims that EVs have reduced world gasoline consumption are hard to demonstrate
Decline in world gasoline consumption growth began long before EVs
and gasoline must be produced to refine diesel, jet fuel, ethane for plastics, etc.



Source: EIA & Labyrinth Consulting Services, Inc.

EIA International/International Consumption

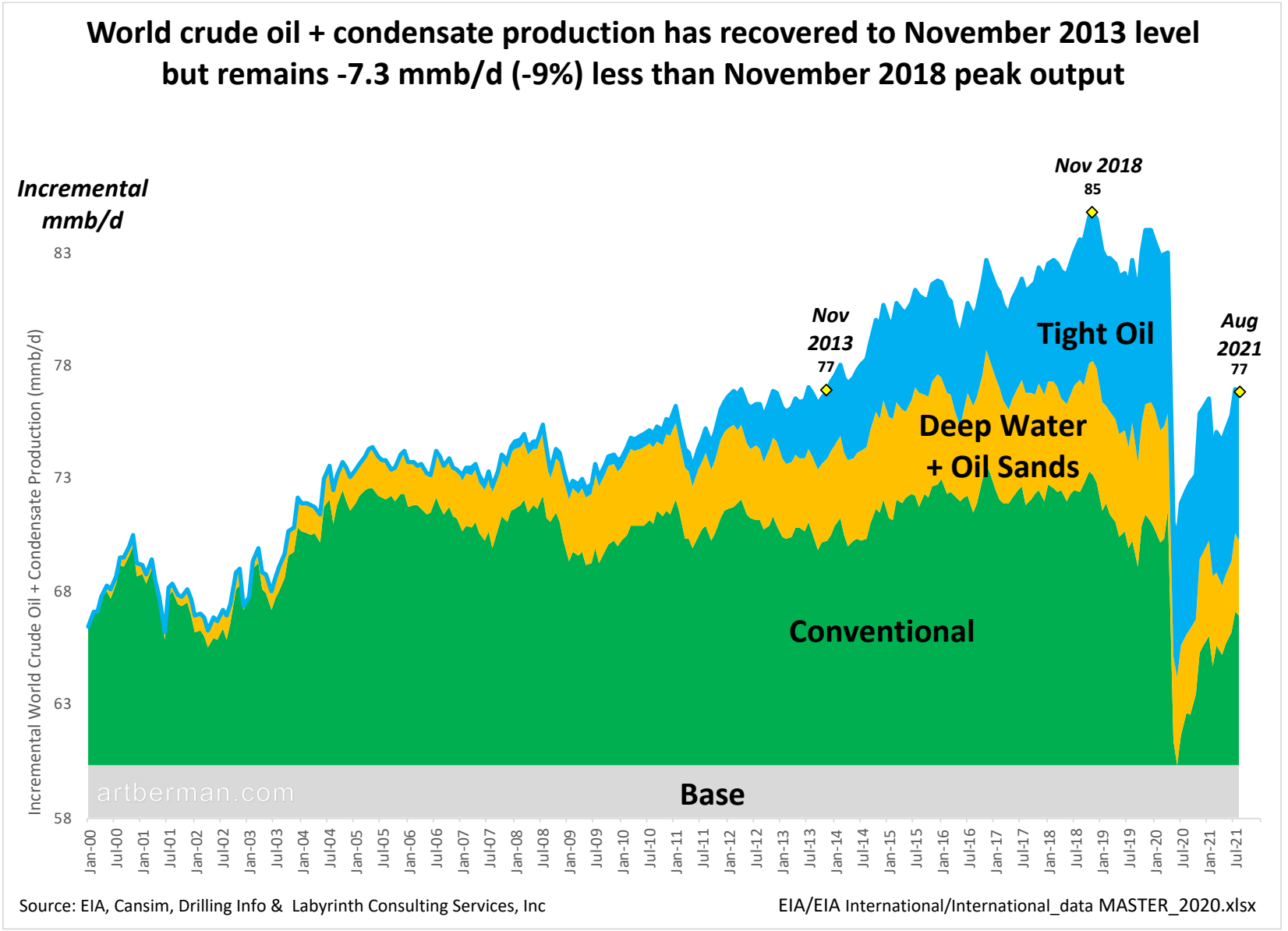
Gasoline accounts for 45% of U.S. refined products in 2021
If U.S. consumes *less* gasoline because of EVs, it will still be produced
Cannot produce diesel, jet fuel, ethane or propane *without also producing gasoline*



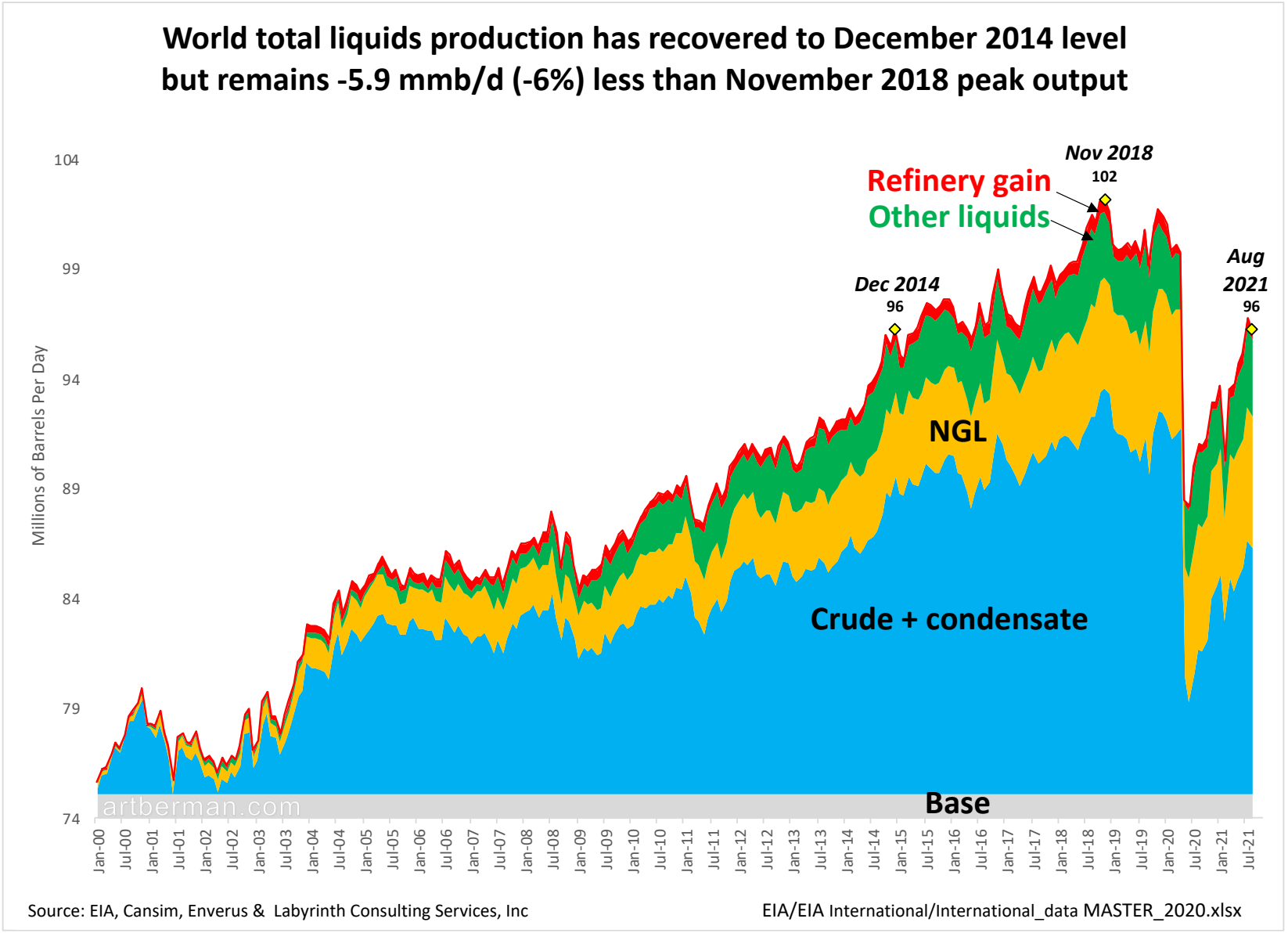
Source: EIA & Labyrinth Consulting Services, Inc.

EIA Current/Monthly Updates/U.S. Product Supplied Master

World crude + condensate production is 9% less than 2018 peak level



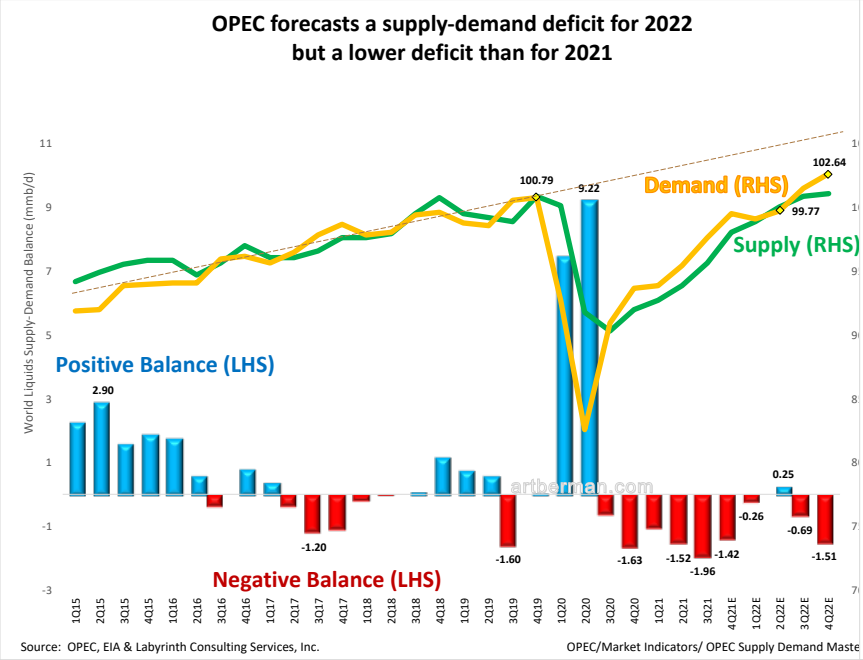
World liquids production is 6% less than 2018 peak level

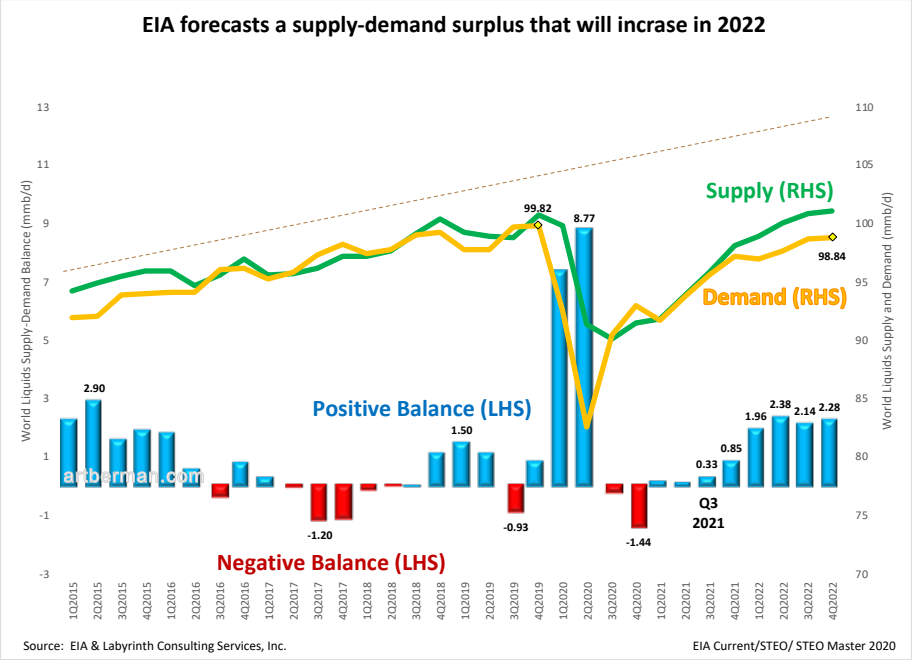


Source: EIA, Cansim, Enverus & Labyrinth Consulting Services, Inc

EIA/EIA International/International_data MASTER_2020.xlsx

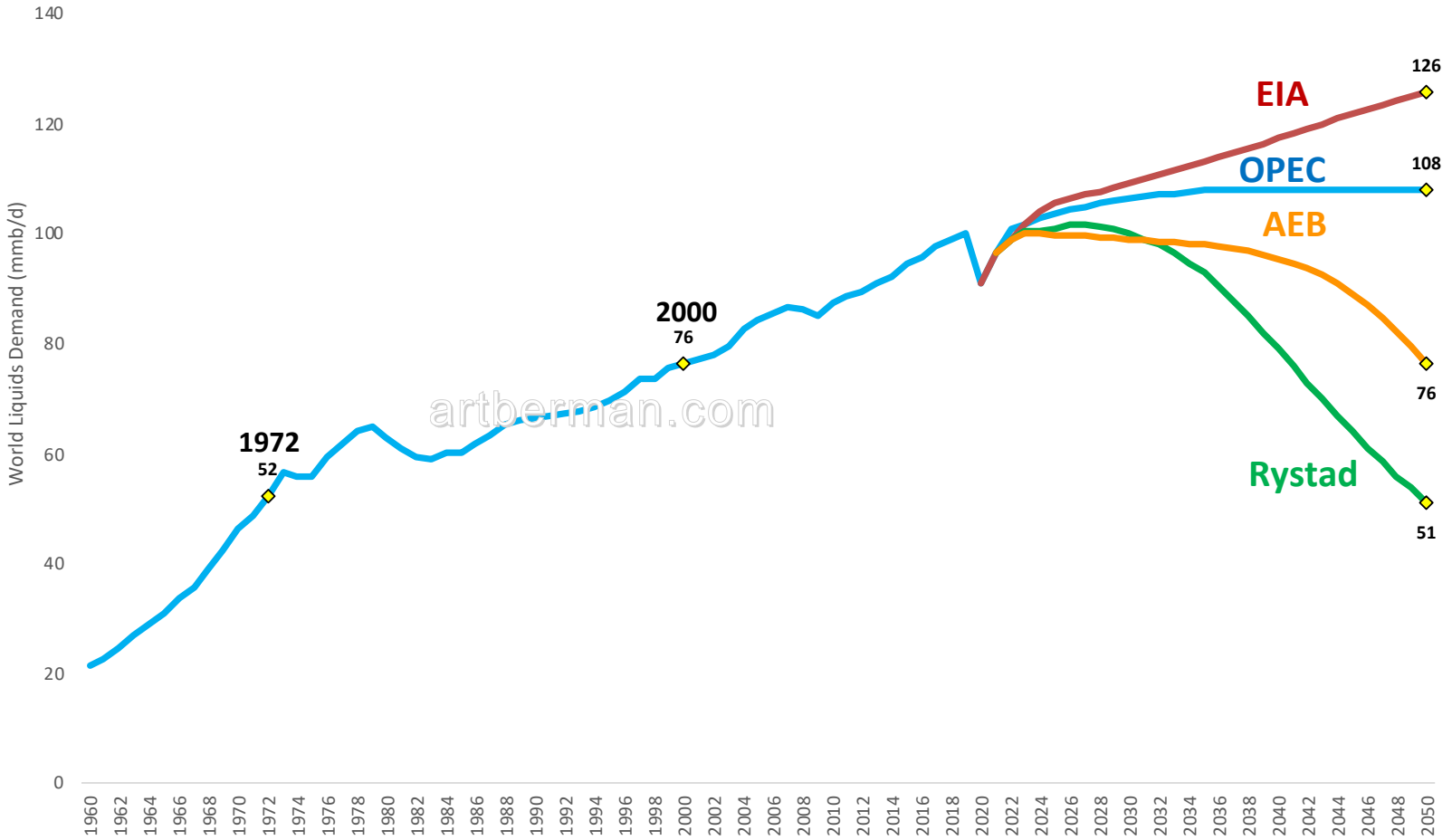
Concerns about a supply shortfall may be misplaced
Demand growth has shifted downward from long-term trend
Pessimistic supply forecasts still project lower S-D deficits than in 2021





Peak demand forecasts apparently not a factor for those calling for structural supply deficits

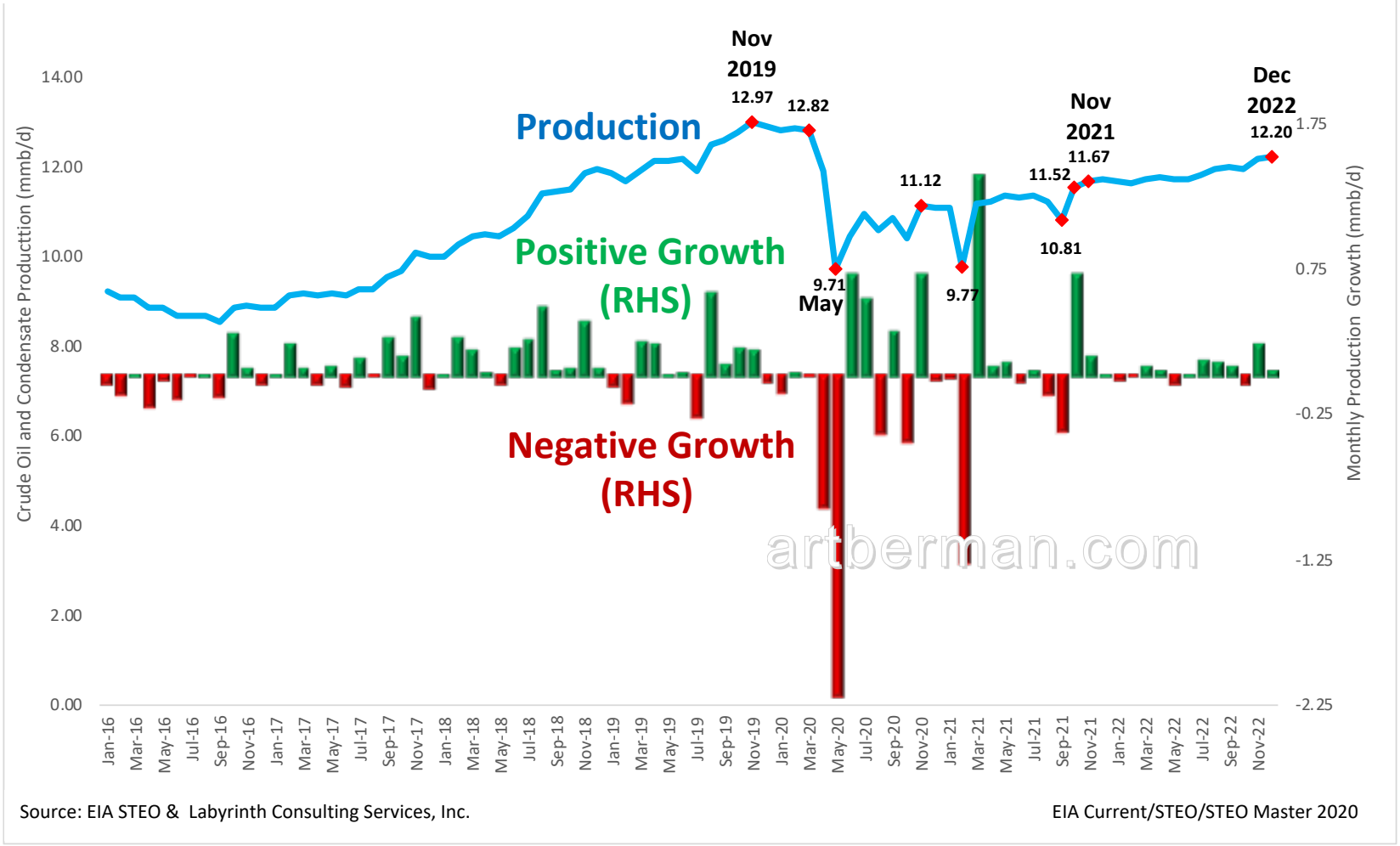
Four forecasts for future oil demand show range of uncertainty
EIA is unrealistic for continuous growth & OPEC for flat trajectory
AEB puts 2050 demand back to 2000 level, Rystad to 1972



Source: OPEC, EIA, Rystad Energy & Labyrinth Consulting Services, OPEC/Annual Statistical Bulletin 2021/ASB2021_all/T47 ANNUAL DEMAND & FORECAST

U.S. production peaked in 2019
Forecasts do not suggest return to that level by late 2022

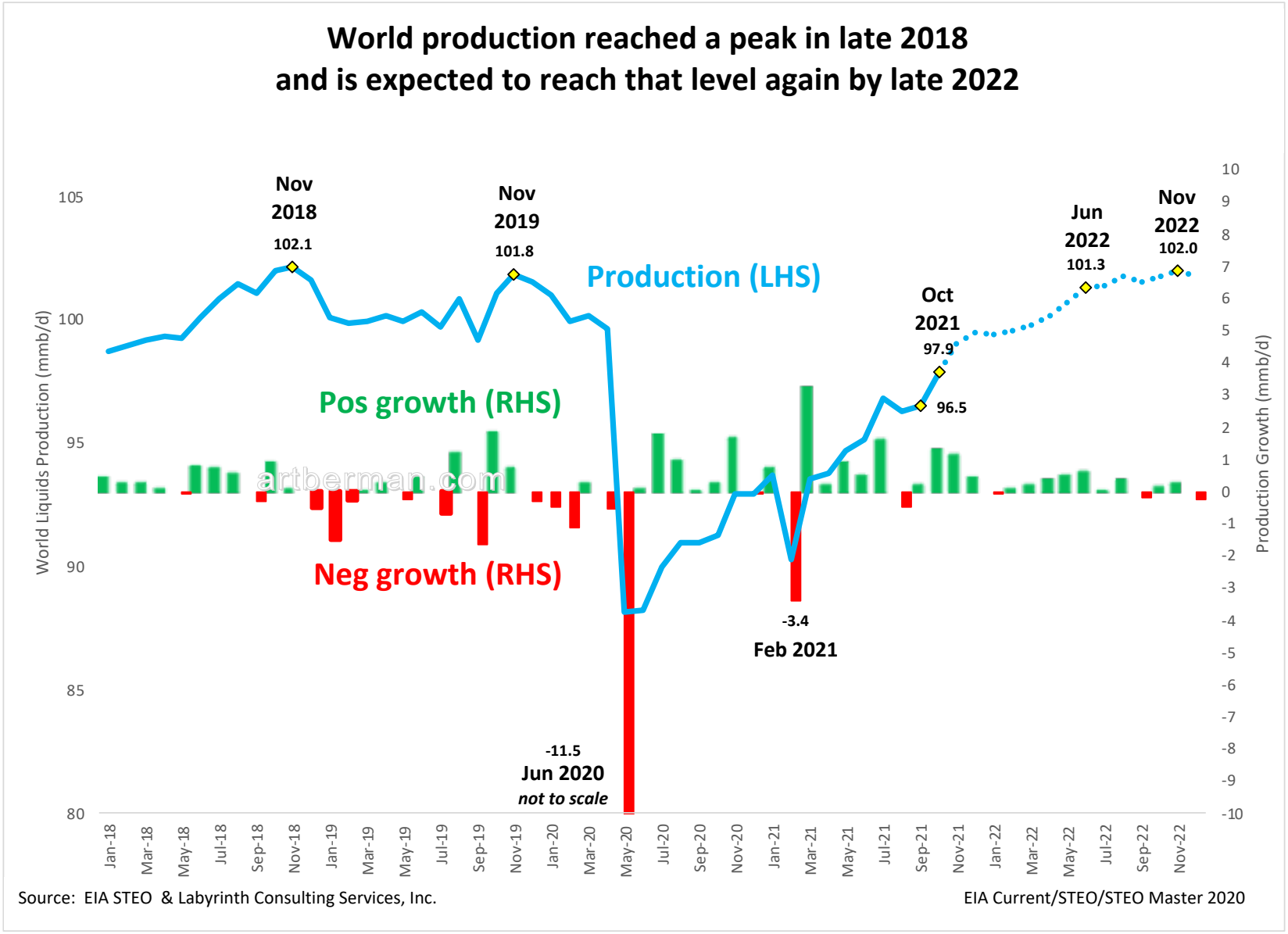
U.S. oil output reached almost 13 mmb/d in late 2019
and is not expected to reach that level in 2022



Source: EIA STEO & Labyrinth Consulting Services, Inc.

EIA Current/STEO/STEO Master 2020

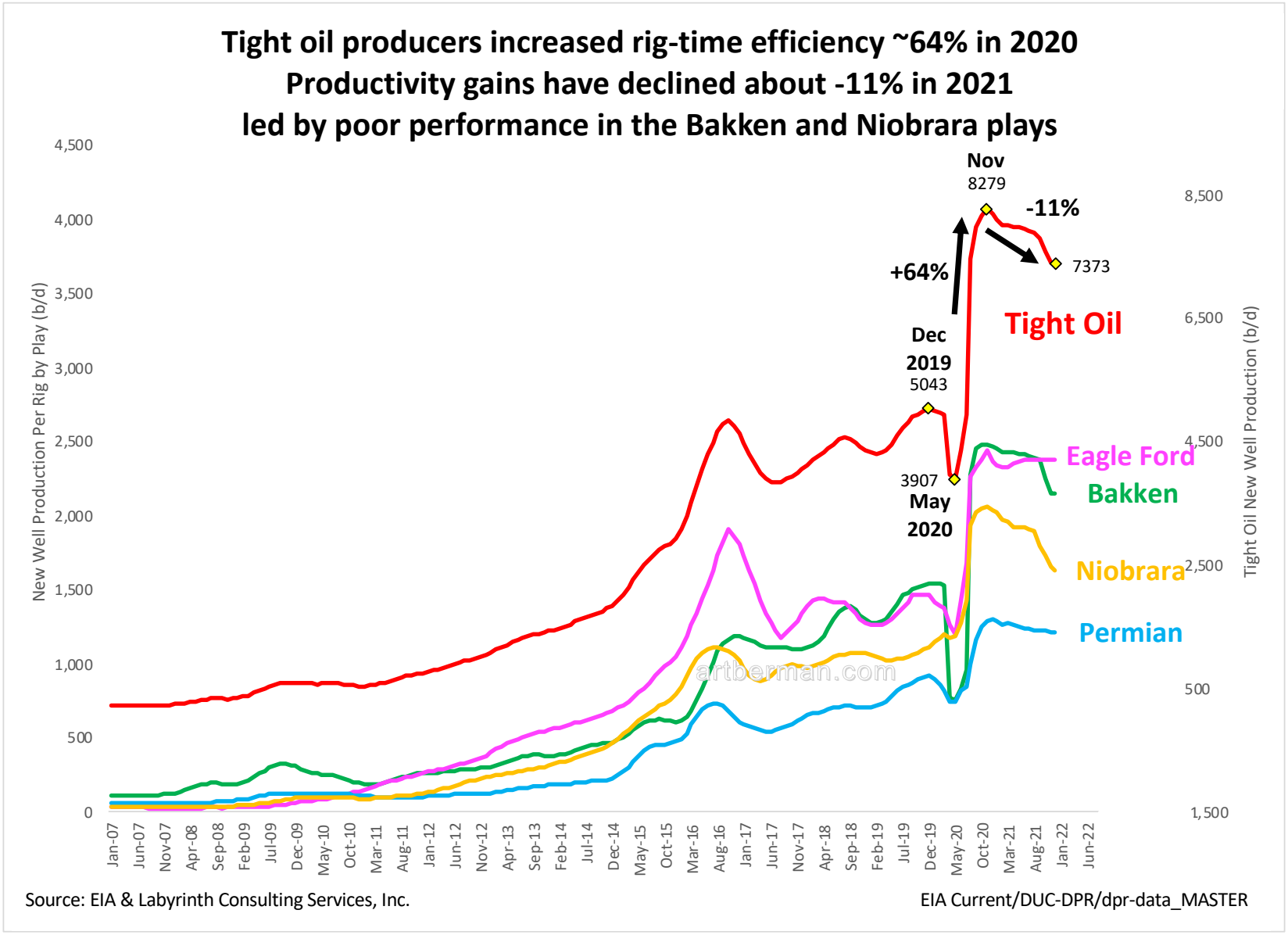
World production peaked in 2018
but some forecasts suggest return to that level by late 2022



Source: EIA STEO & Labyrinth Consulting Services, Inc.

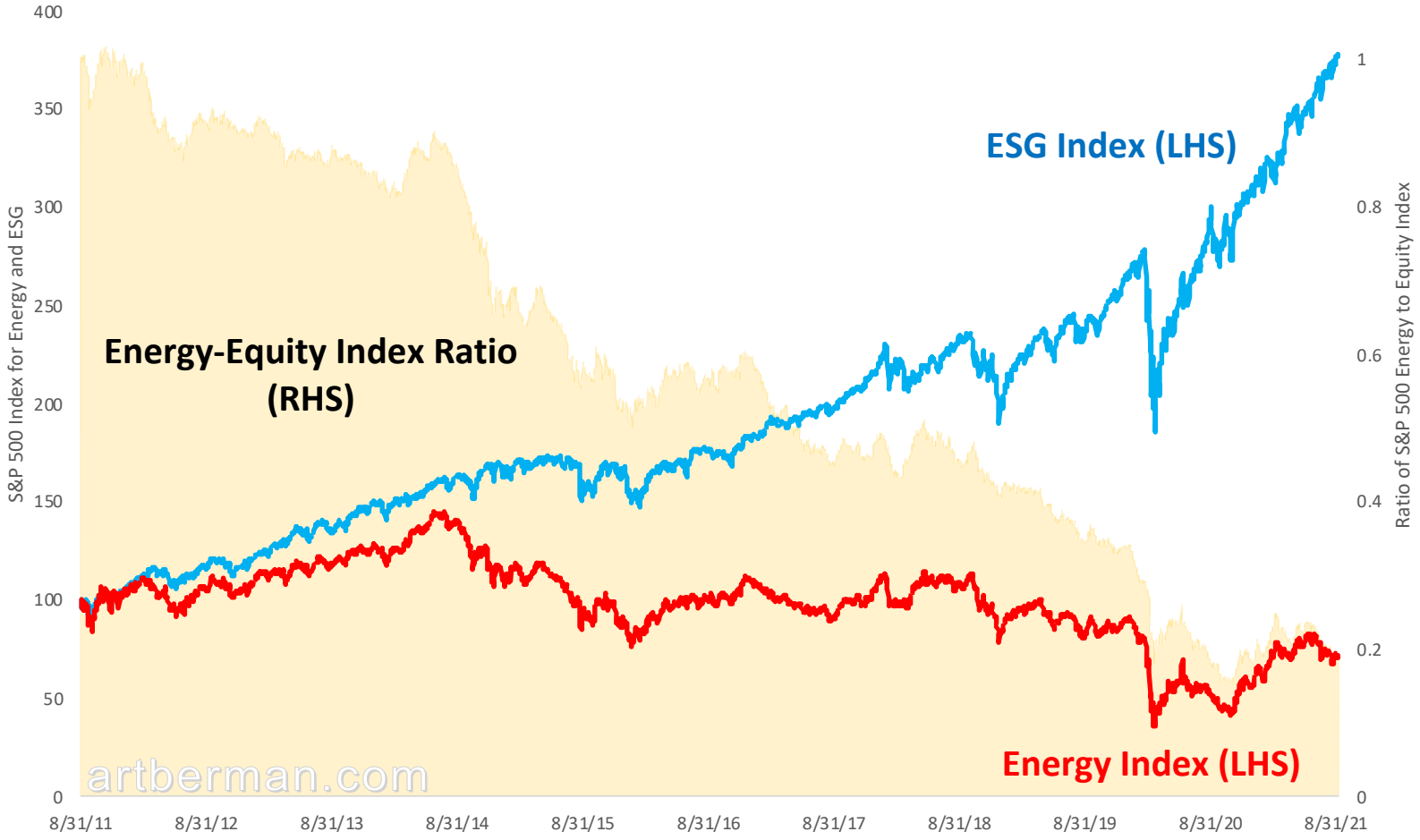
EIA Current/STEO/STEO Master 2020

Oil producers have found ways of improving efficiency with technology



Investors and Credit Markets Are Shorting Energy
Investors believe there are better returns outside of energy

Energy sector performance has fallen by about 50% since 2014
while ESG sector performance has increased 140%
ESG has out-performed equities by about 1.5% while energy has under-performed



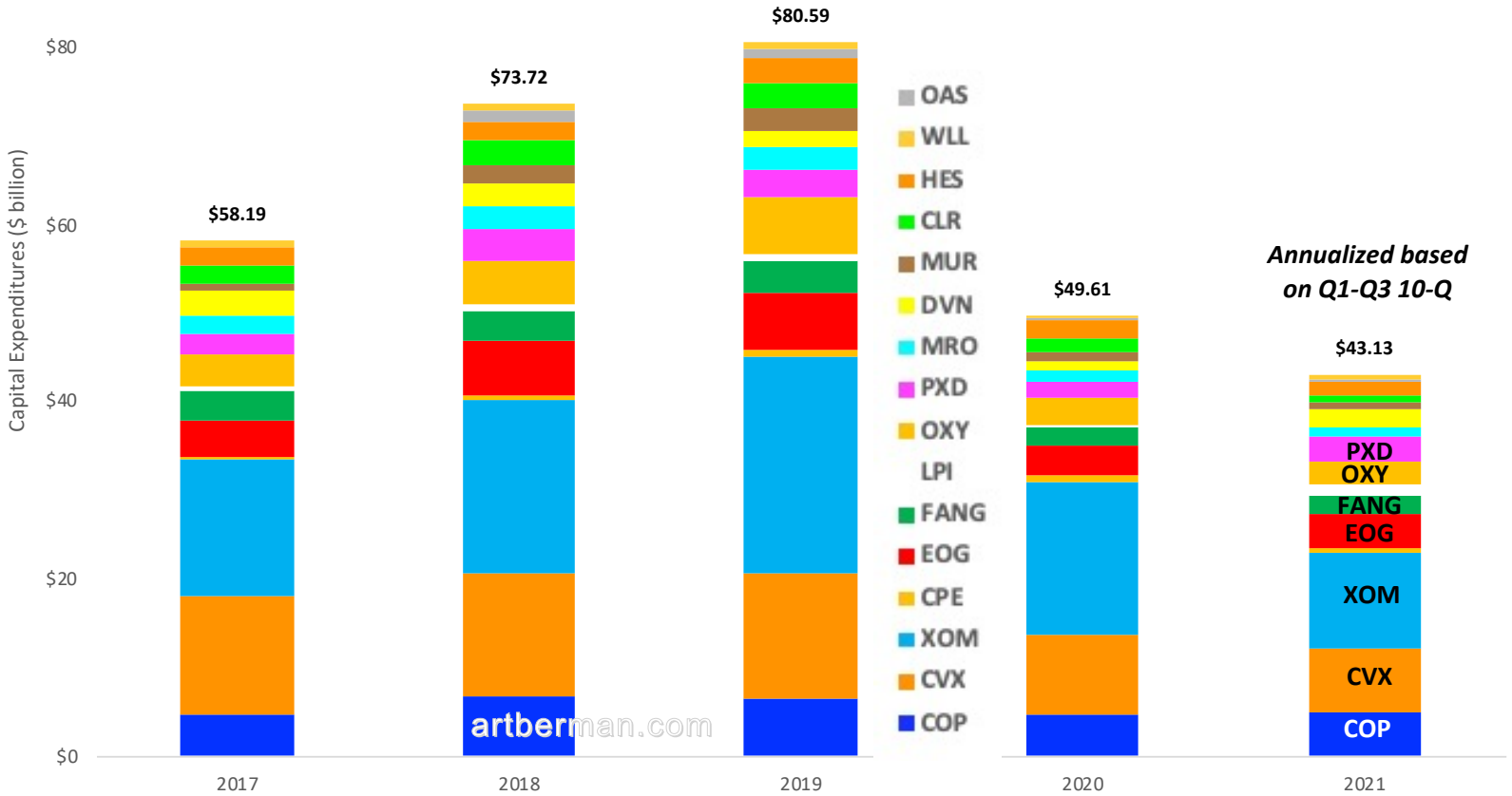
Source: S&P Dow Jones Indices & Labyrinth Consulting Services, Inc.

Oil and Gas General/S&P 500 Energy_ESG_Total S&P PerfmormanceComparison

Shale companies have free cash flow for the first time in the history of tight oil plays

That is largely because they aren't spending much capex

2021 sampled E&P capex -13% less than in 2020 & -46% less than in 2019
2021-2019: COP -24%, CVX -49%, XOM -56%, EOG -41%, FANG -46%, OXY -59%, CLR -75%

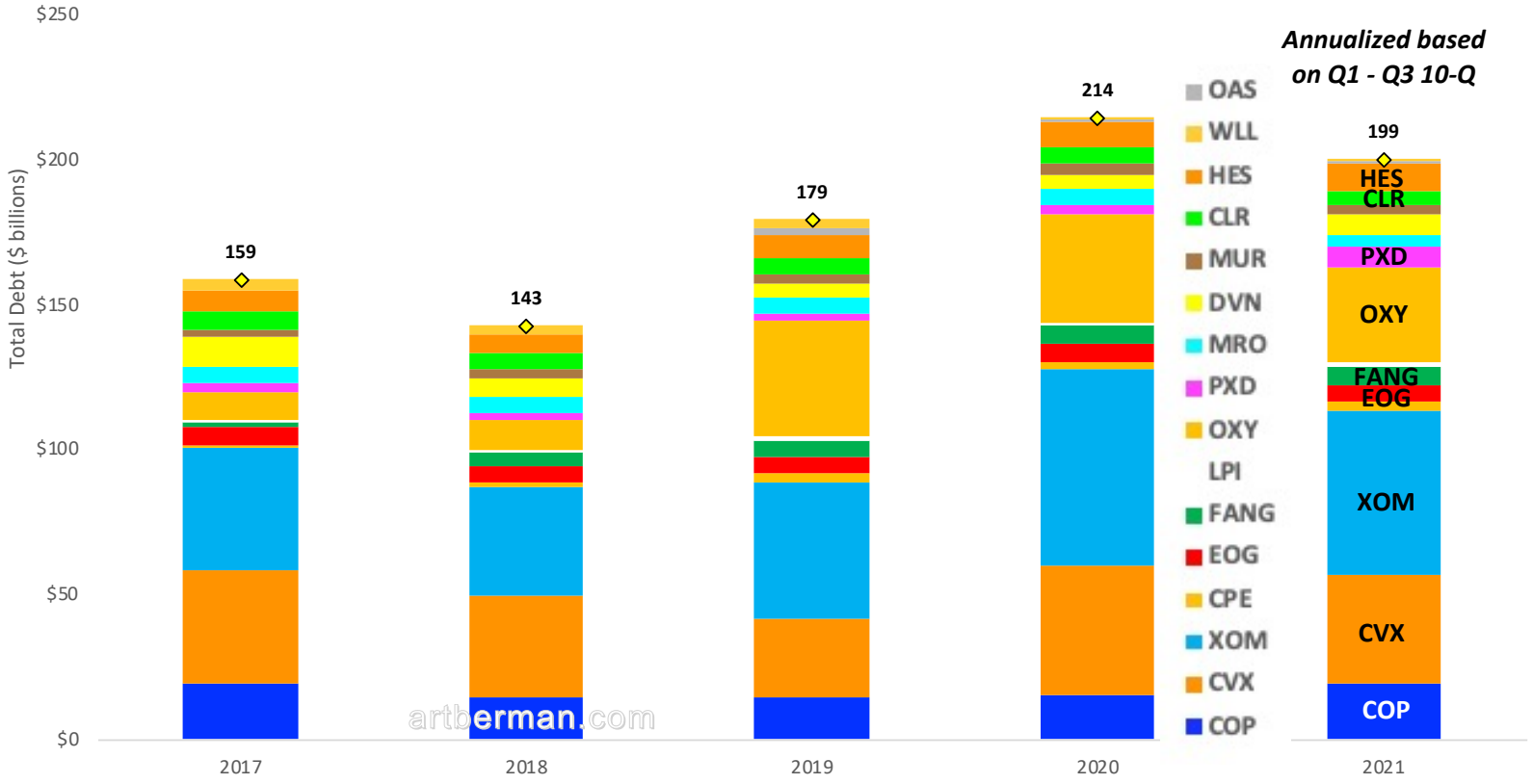


Source: Yahoo Finance & Labyrinth Consulting Services, Inc.

Oil & Gas Supply/Sampled E&Ps/Sampled E&Ps FINANCIAL

Debt remains high but is more acceptable because of cash flow

Debt has fallen about -7% in 2021 from record 2020 levels
but is +11% more than in 2019 and +39% more than in 2018
COP, FANG, PXD and DVN took on substantial debt for acquisitions in 2020-2021



Source: Yahoo Finance, EIA & Labyrinth Consulting Services, Inc.

Oil & Gas Supply/Sampled E&Ps/Sampled E&Ps FINANCIAL