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The transition away from hydrocarbons

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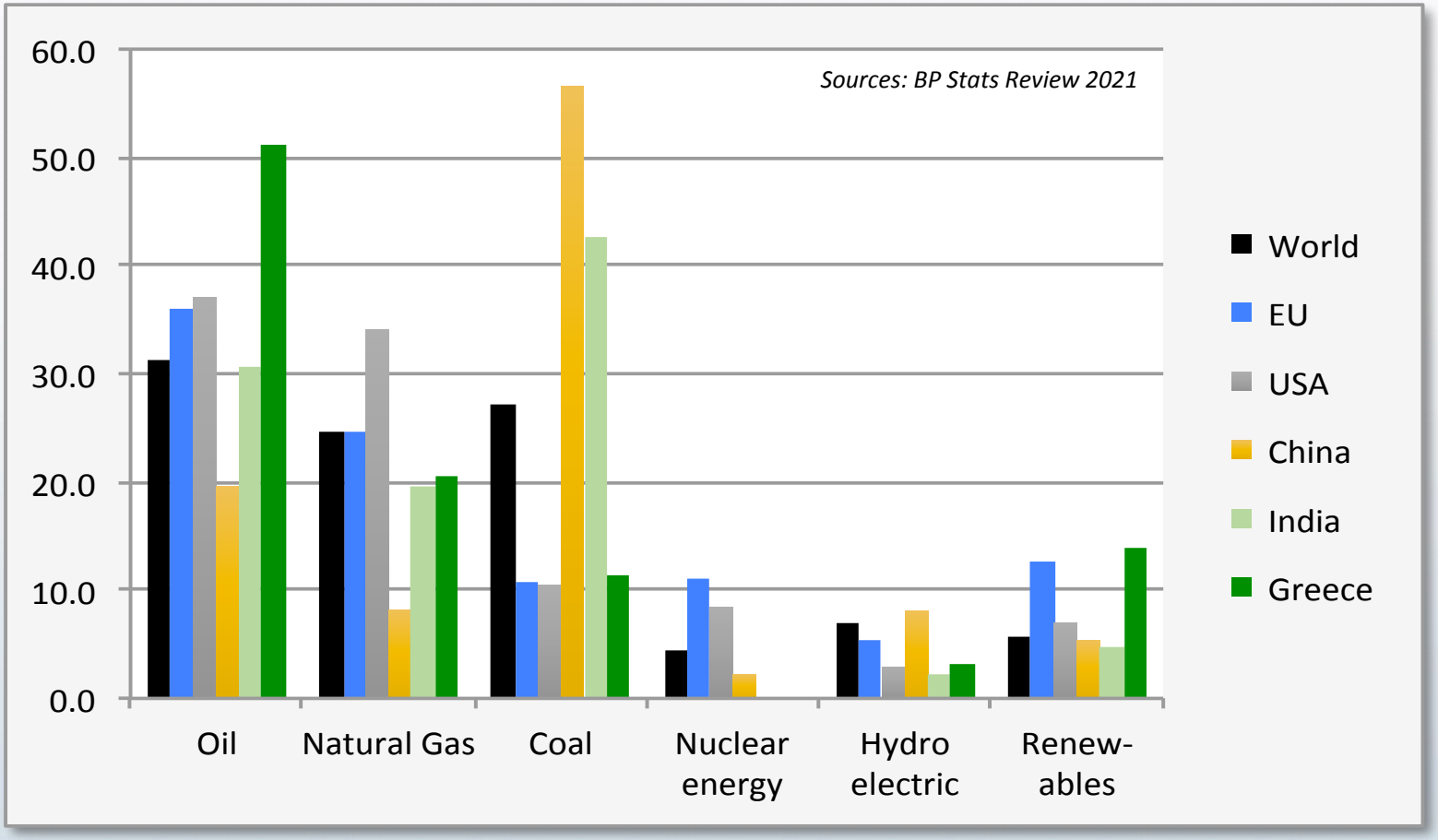
" With the ***depletion of fossil fuels*** I think it very likely that automobiles powered by internal combustion engines will be with us for ***at most a few decades longer***. "

— **Carl Sagan, eminent planetary scientist and astrophysicist, in his book *Broca's Brain [1974]***

Setting the scene

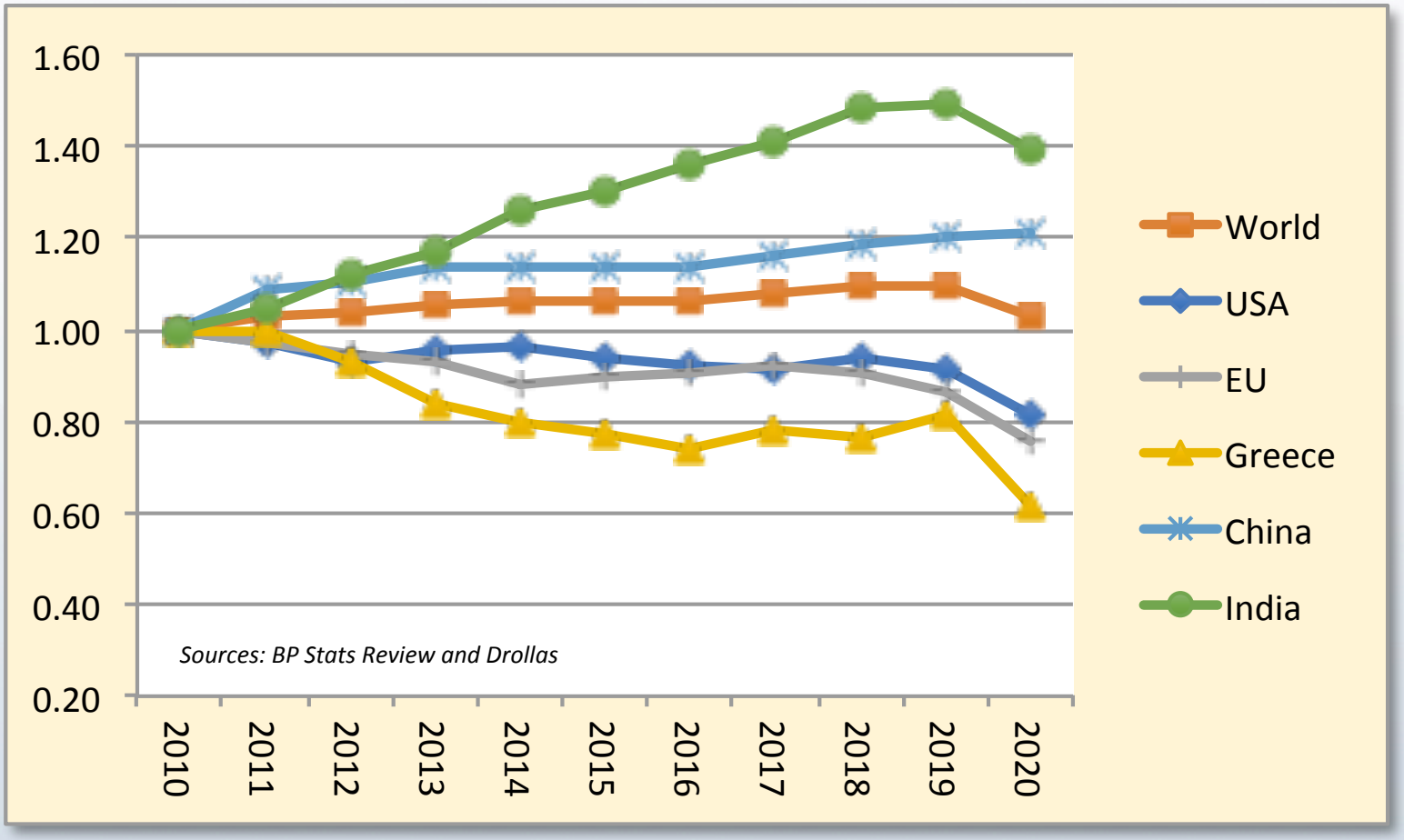
- When I was completing my studies in the mid-1970s, the main concerns were about the onset of an ice age and the depletion of oil and natural gas resources, hence Carl Sagan's remark. In the event neither concern ended up having any validity.
- By the 1990s mankind's preoccupations had shifted in the diametrically opposite direction, fearing an increase in CO_2 and its impact on mean global temperature.
- Whether achieving **Net Zero CO_2** emissions in Europe by 2050 is really necessary is a moot point, as is the wider issue of whether CO_2 drives global temperature rises in the first place. These doubts are usually not discussed, all important as they may be.
- My worries today have more to do with **[a]** the speed of the transition away from fossil fuels (83% of global primary energy in 2020), **[b]** which countries will bear the main burden of such a global concern and **[c]** at what overall cost.
- As has been often touched upon, relying solely on wind and solar power to drive motor transport, space heating and industrial needs requires backing up, either by natural gas, nuclear power or battery power. For air and sea transport, renewable liquid fuels are the only viable long-term alternatives to fossil fuels.

Shares in primary energy — 2020



- At 31% in 2020, the world's dependence on oil exceeded all other sources of energy; moreover, the share of hydrocarbons in primary energy weighed in at 83.1%.
- Greece has the highest dependence on oil (51%) in Europe, because of its heavy use of oil for space heating alongside the more traditional usage of oil for transport. Its gas and hydro shares are below the EU average, but its renewables share exceeds the EU average.

CO_2 emissions [index 2010=1] 2010 – 2020



- Last year was an unusual year due to the adverse impact of Covid-19 on most economies, resulting in much reduced economic activity and CO_2 emissions with it — apart from China, that is.
- Both the US and the European Union have achieved around 20% reductions in CO_2 emissions since 2010, the former by an increase in the use of cheap natural gas as a result of the shale gas revolution and the latter by concerted governmental efforts.

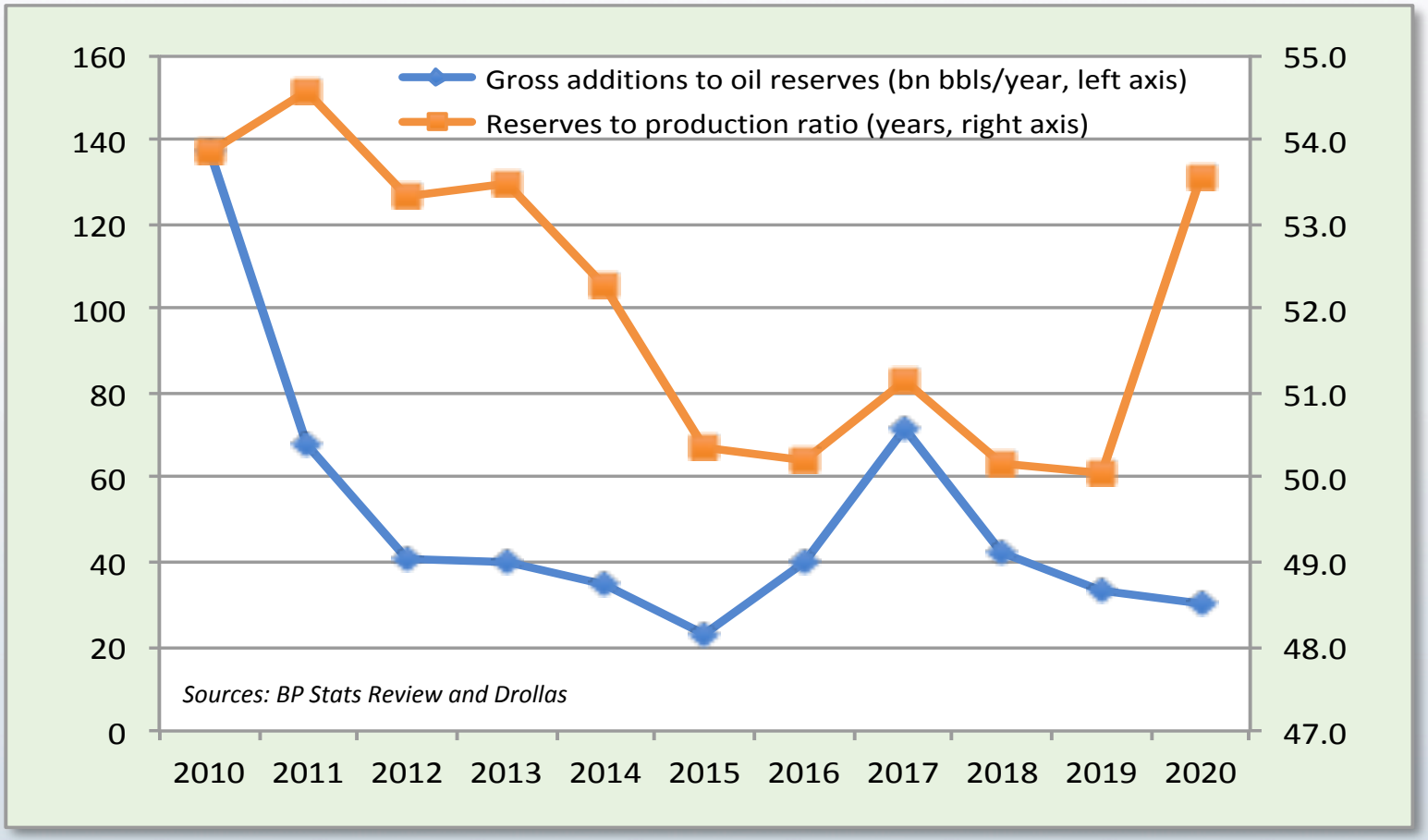
Primary energy consumption per capita - 2020 in gigajoules per head

Source: BP Stats Review

	2000	2020	% pa
USA	337.7	265.2	-1.2
OECD	192.7	159.1	-1.0
non-OECD	33.2	52.8	2.3
EU	150.7	125.2	-0.9
WORLD	64.2	71.4	0.5
Africa	14.2	13.9	-0.1
Asia-Pacif	32.5	59.6	3.0

- Since 2000 the world as a whole has been consuming increasing amounts of energy per head at a rate of 0.5% per annum, led by the Asia-Pacific region (3.0%).
- Africa's consumption per head is 20% of the global average, while the Asia-Pacific area's energy usage per capita is still 37% of the OECD average.

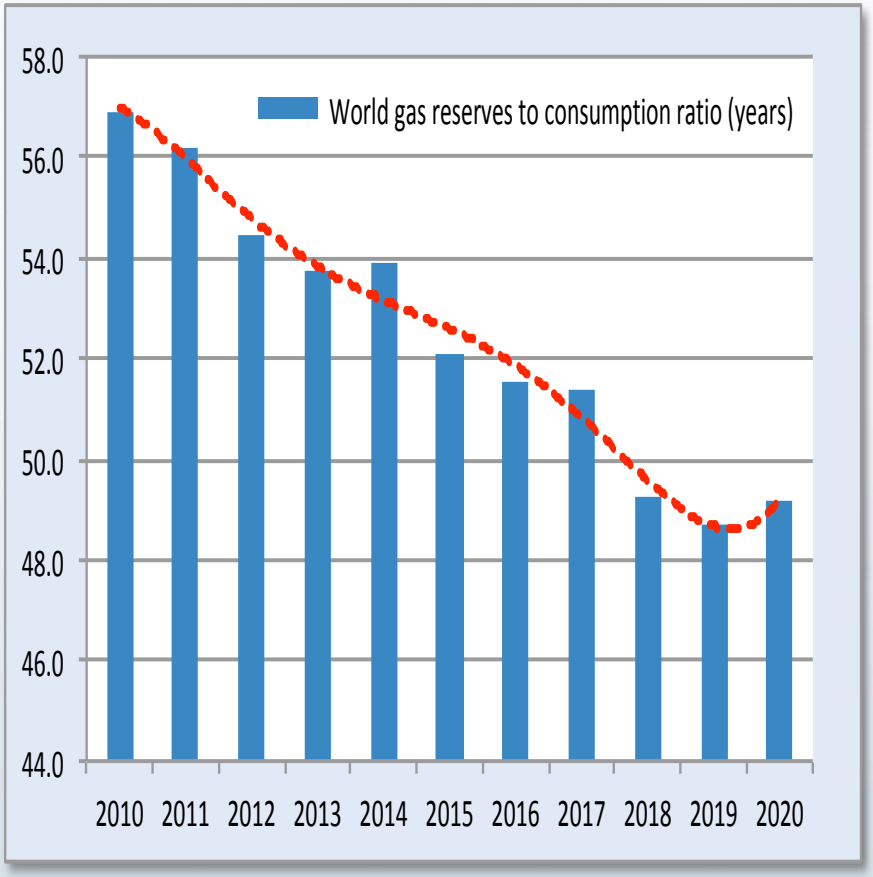
Oil discoveries and Reserves-to-Production ratios

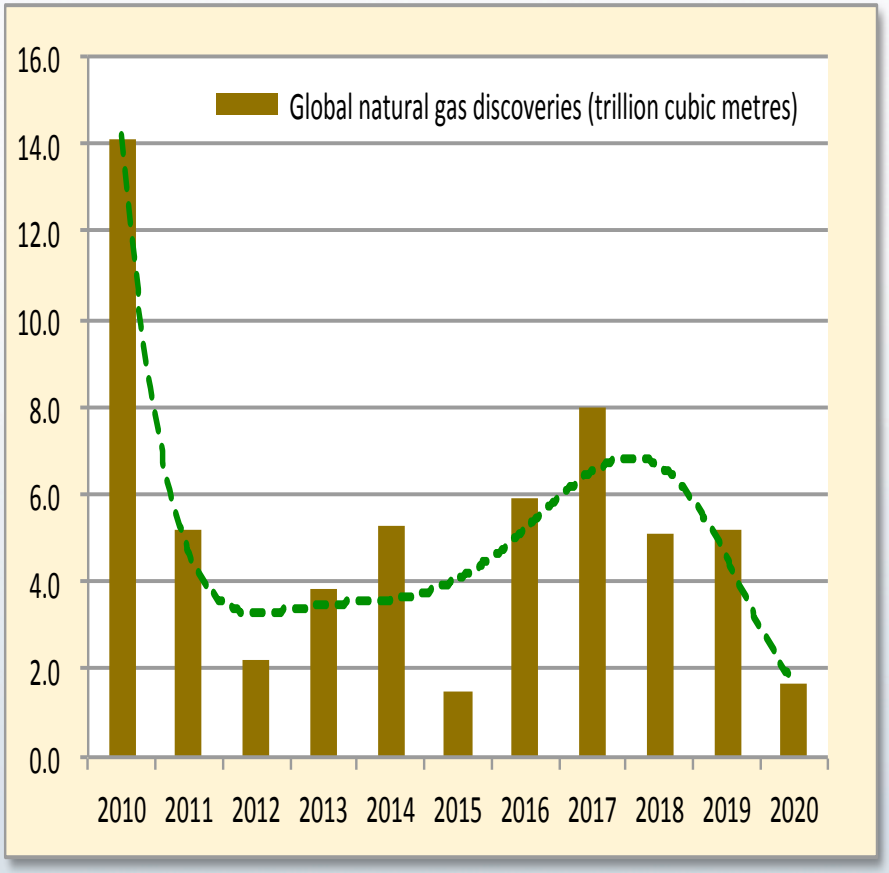


- To transition away from hydrocarbons in less than 30 years is a tall order indeed, leaving aside the vast cost measured in many trillions of Dollars. My concern is that pressure from the advocates of climate change is already causing many investors to shun investment in upstream oil and gas, down from $900bn in 2014 to $350bn a year. This will eventually lead to higher prices.
- Gross additions to global oil reserves (from wildcat discoveries and extensions/revisions to existing oilfields) have declined considerably over the last ten years, as indeed has the world's reserves-to-production ratio [note 2020 was exceptional due to the collapse in oil output].

Natural gas: the last ten years

Sources: BP Stats Review and Drollas





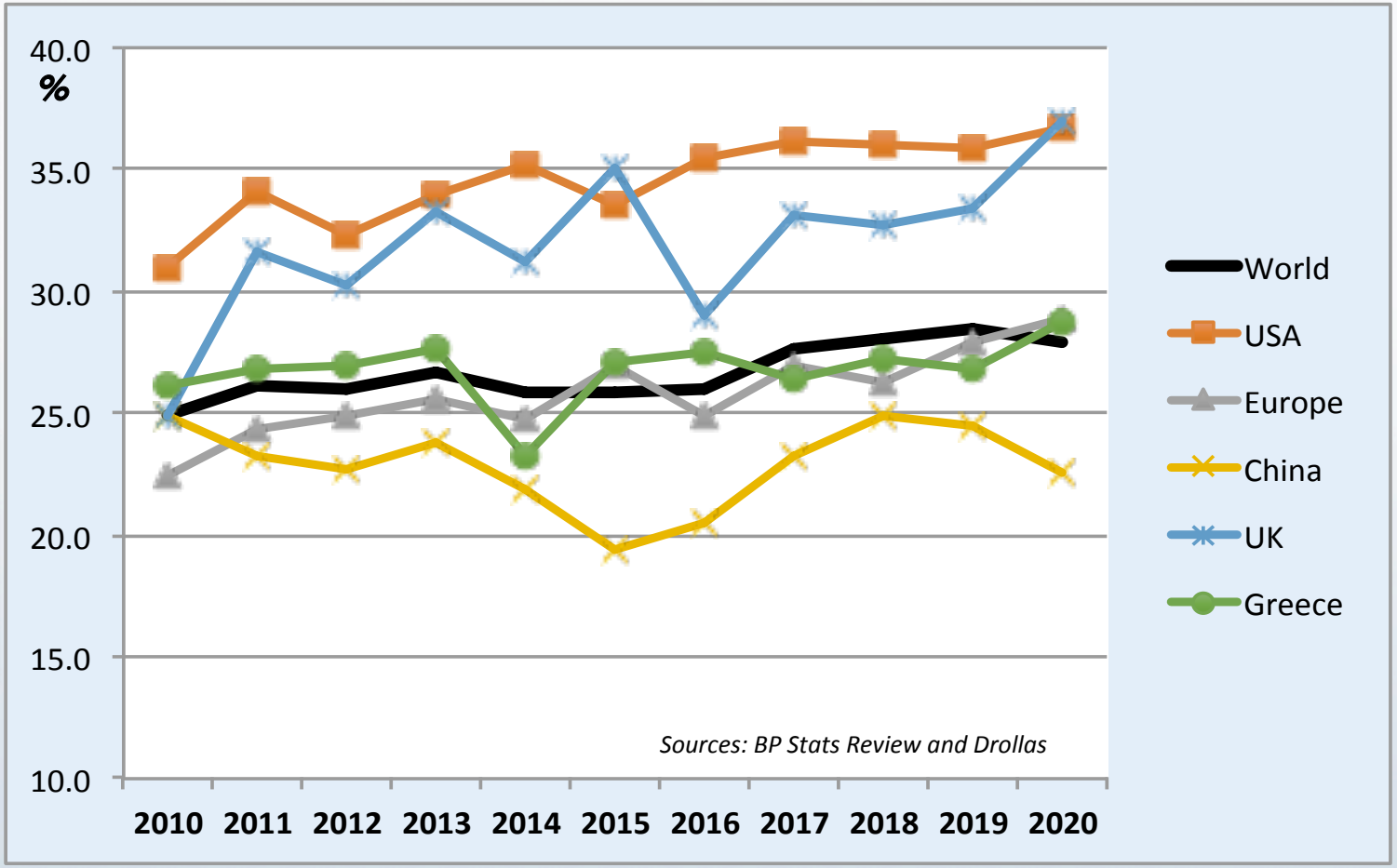
The amount of cover provided by global natural gas reserves has declined considerably over the last ten years, from 57 to 49 years. The key reason for this is the drop in gross natural gas discoveries, including wild cat wells, extensions to known reserves and revisions to existing gas fields. The role played by gas prices and chance discoveries in driving growth in gas reserves, and recent investor reluctance to finance gas developments as before, have all contributed to the drop in gas reserves' cover.

Wind power – important considerations

- Wind is a fluctuating stream of low-density energy. The Betz limit caps the energy that can be extracted from a moving fluid. Wind turbines are already effective machines in extracting wind energy.
- The problem is the wind itself, which is unreliable. As the British science writer Matt Ridley wrote, *"Mankind stopped using it [wind power] for mission-critical transport and mechanical power long ago, for sound reasons. It's just not very good"*.
- The turbines' propellers appear to turn lazily, but their blade tip speeds average around 240 kms/hour, hence the large number of birds and bats killed by them.
- A 2-MW turbine weighs about 250 tonnes and its manufacture requires 150 tonnes of coal to make the steel structure and the cement base. The rare earths for the magnets generate epic pollution, but out of sight in far-away places like Mongolia.
- Wind farms require space: each turbine needs to be at least 7 rotor diameters away. For GE's 2-MW turbine (with a rotor diameter of 127 meters) each turbine needs to be almost 900 meters away.
- Each turbine has a life cycle of around 20 years, needing 15 years for payback. Operation and maintenance costs can be significant.

Annual average wind power load factors

The key considerations affecting the load factors are wind conditions in the various locations, the maintenance periods involved and the number and duration of the wind turbines' breakdowns.



Wind is an unreliable resource, because it is a fluctuating stream of low-density energy. A wind turbine's rateable capacity is never fully used, because the wind either is not blowing, or it blows too much and the turbine has to be switched off; some time (typically 15 days per annum) must also be set aside for maintenance. The load factor measures electricity generated as a percentage of rateable generating capacity.

Concluding remarks

- For the EU to achieve net zero emissions of CO_2, a number of key current areas of fossil fuel usage need to be replaced with renewable energy — **motor transport**, **space heating**, **process heat for industrial applications, and liquid fuels for air and sea transport**.
- To use wind power to supply electricity for large EV fleets, tens of thousands of additional wind generators will be needed, costing many billions of Euros and needing a lot of space and infrastructure expenditure (for access roads, transmission lines, substations, etc…). The main problem with wind turbines is that wind is an unreliable source of low-density energy.
- Because of this, gas-fired or other power systems need to be available as back-up and/or extensive storage systems developed, increasing considerably the cost of wind power. It would be cheaper in the long run to develop nuclear power more extensively and to retain considerable gas-fired generating capacity.
- Activist investors are shunning hydrocarbons, which will have two undesirable results during the transition period: **[A]** their prices will be higher than otherwise would have been the case, causing general inflation and fuel poverty for the vulnerable, and **[B]** global dependence on oil and gas production in geopolitically volatile regions will rise.