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JUDGE BUSINESS SCHOOL SEMINAR
September 16, 2021

ENERGY FINANCE

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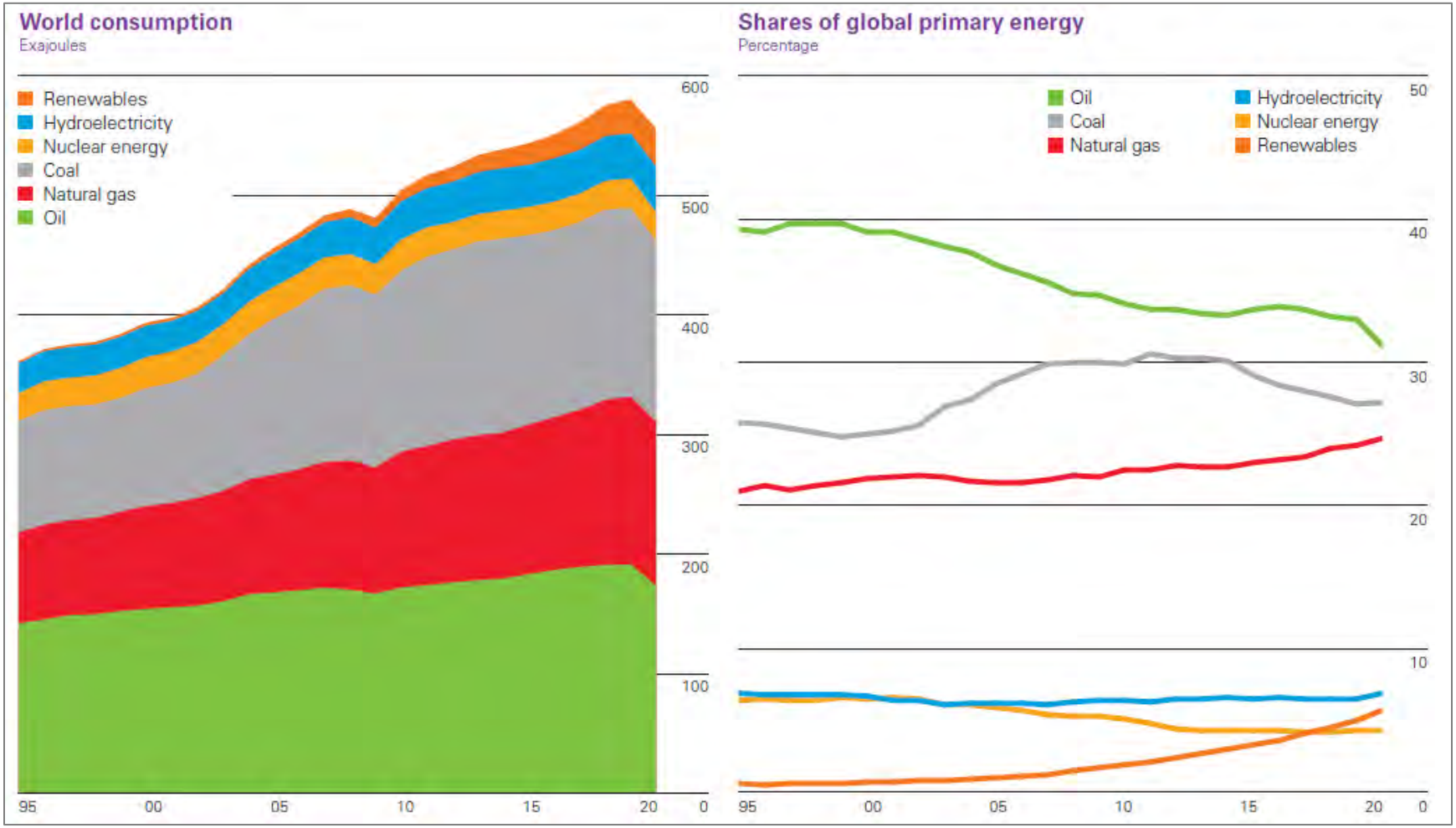
Overview Of Energy Finance

- **The "Global Energy Industry" Is The World's Largest In Terms Of Capital Investment: $1.83 Trillion In 2019**
  - Second largest nonfinancial industry in sales ($4.51 Trn)
- **Can Be Broadly Categorized Into Two Main Segments**
  - Provision of fuels for transportation;
  - Production and distribution of electricity for residential and industrial consumption
- **Describe The Financial Economics Of Global Energy Industry**
  - Focus on both physical aspects of production & distribution and capital investment required to support each segment
  - Also present academic research examining each topic
- **Then Describe SOEs' Role In Energy Production & Distribution**

Global Primary Energy Demand And Supply

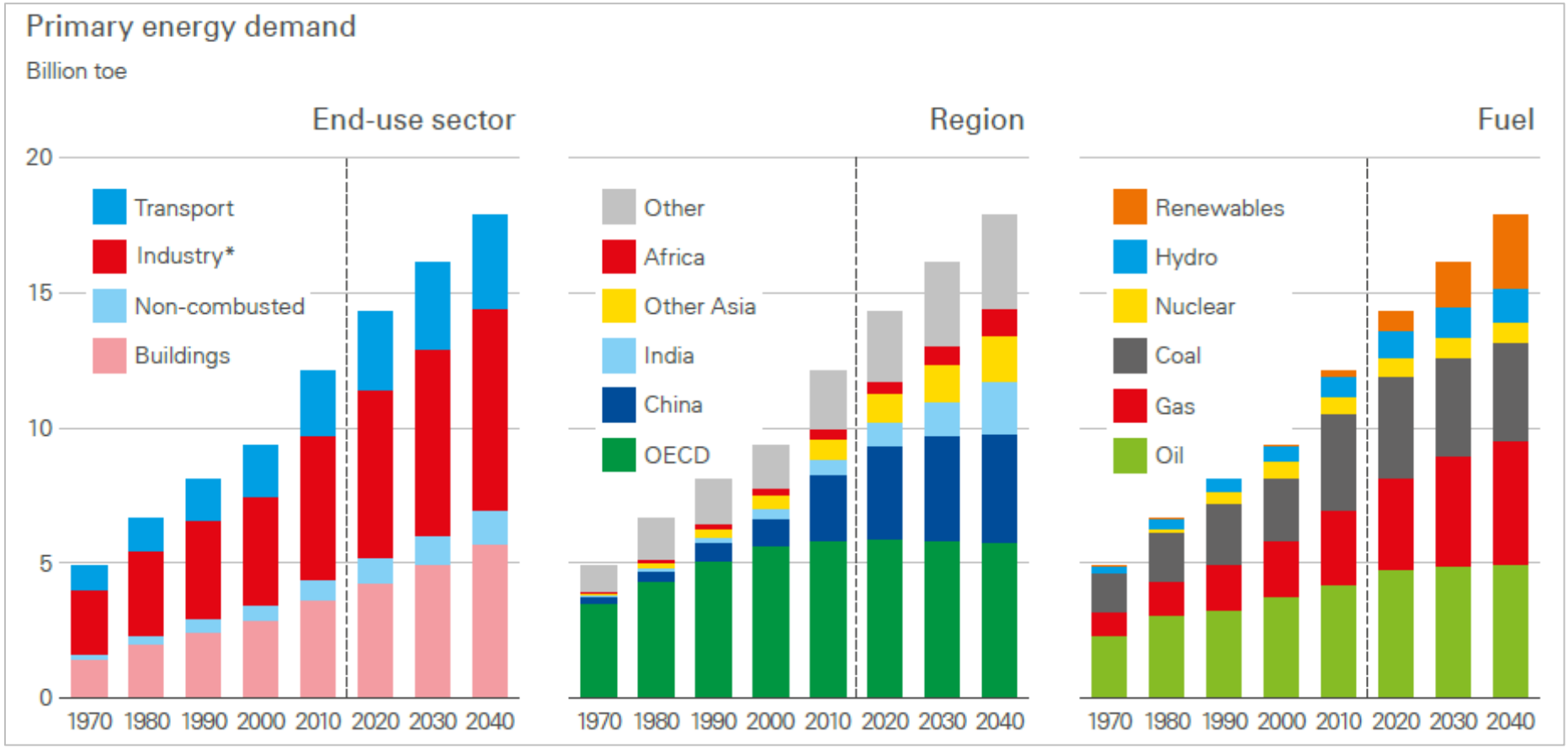
Global Energy Industry Has Sales Of $4.51 Trillion; Provides 3,181 KwH/Yr to Every Person

Figure 1. Overview of Global Primary Energy Consumption by Fuel Source, 1996-2020



Source: BP. (2021). Statistical Review of World Energy 2021, 70th Edition. London, UK.

Figure 2. Global Primary Energy Demand, 1970-2018 and Forecast to 2040



BP. (2019). Statistical Review of World Energy 2019, 68th Edition. London, UK

Table 1. Fuel Shares of Global Primary Energy and Approximate Sector Sales Revenue, 2019

Energy Source	Consumption (exajoules)*	Annual Change (exajoules)	Share of Primary Energy	Approximate 2019 Sales Revenue (US$Bn)
Oil	193.0	1.6	33.1%	$2,227.8
Natural Gas	141.5	2.8	24.2%	$799.9
Coal	157.9	-0.9	27.0%	$351.1
Hydro	37.6	3.2	5.0%	$487.3
Renewables	29.0	0.3	6.4%	$324.5
Nuclear	24.9	0.8	4.3%	$323.5
Total	**583.9**	**7.7**	**100.0%**	**$4,514.1**

* A joule is unit of work or energy equal to the work done by a force of one newton acting through one meter. It also equals approximately 0.7377 foot-pounds. One British Thermal Unit (BTU) equals 1.055 thousand joules (KJ). An exajoule equals one quintillion (10^{18}) joules.

Source: Authors' calculations, from multiple data sources

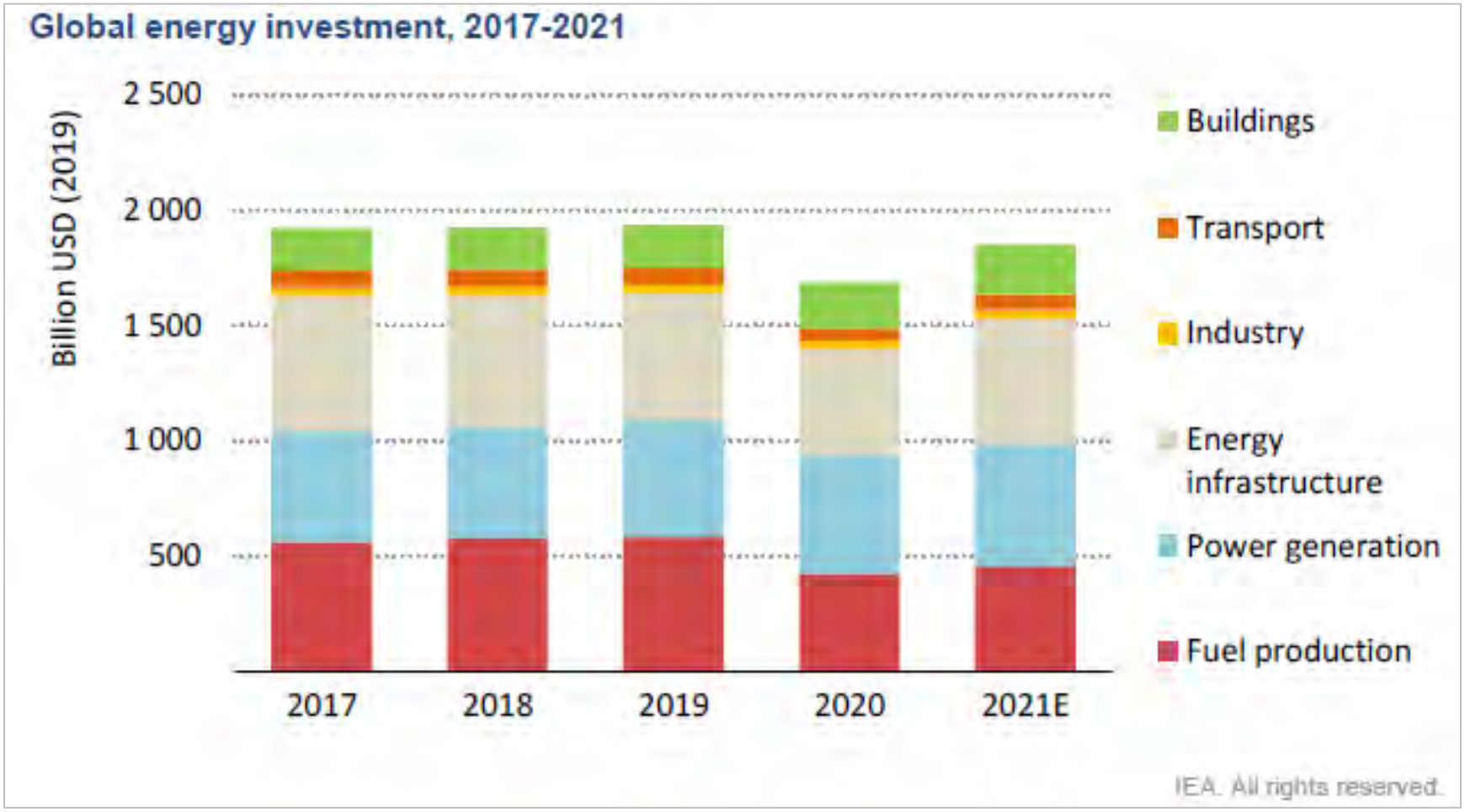
Academic Research On Energy Economics

- **Economic Research Is Vast; Only Hit Most Recent & Relevant**
  - **Cuddington and Moss** (*AER* 2002): technological change allayed sharp rise in average cost of finding gas & oil reserves over 1967-1990
  - **Barsky and Kilian** (*JEP* 2004) document impact of political events in the Middle East on oil prices and the macroceconomy
  - **Kilian** (*JEL* 2008, *AER* 2009) analyze economic effects of energy price shock, disentangle demand and supply shocks in the crude oil market
  - **Kellogg** (*AER* 2014), who shows that uncertainty about the future price of oil significantly affects Texas oil drilling activity;
  - **Arezki, Ramsey, and Sheng** (*QJE* 2017): national investment rises soon after a major oil discovery; impact on GDP (significantly positive) and employment (slightly negative) is delayed by several years

Energy Industry Capital Investment Patterns

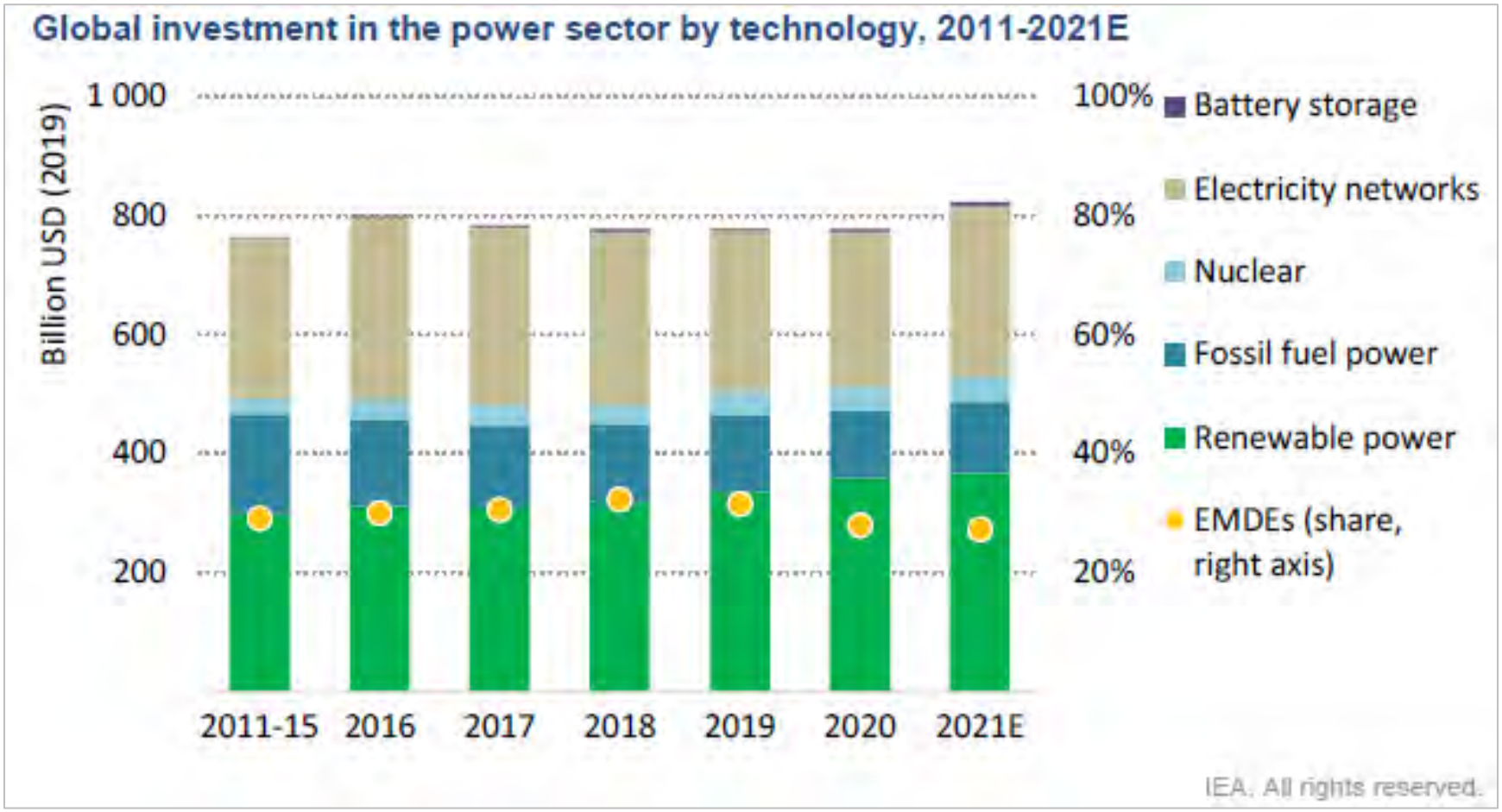
The “Global Energy Industry” Dwarfs All Others In Capex Spending, But Varies Widely By Segment

Figure 3. Energy Industry Capital Investment Spending, 2017-2021



Source: International Energy Agency (EIA). (2021). *World Energy Investment 2021*. Paris, France: IEA.

Figure 6. Global Investment in Power Sector by Technology, 2011-2021

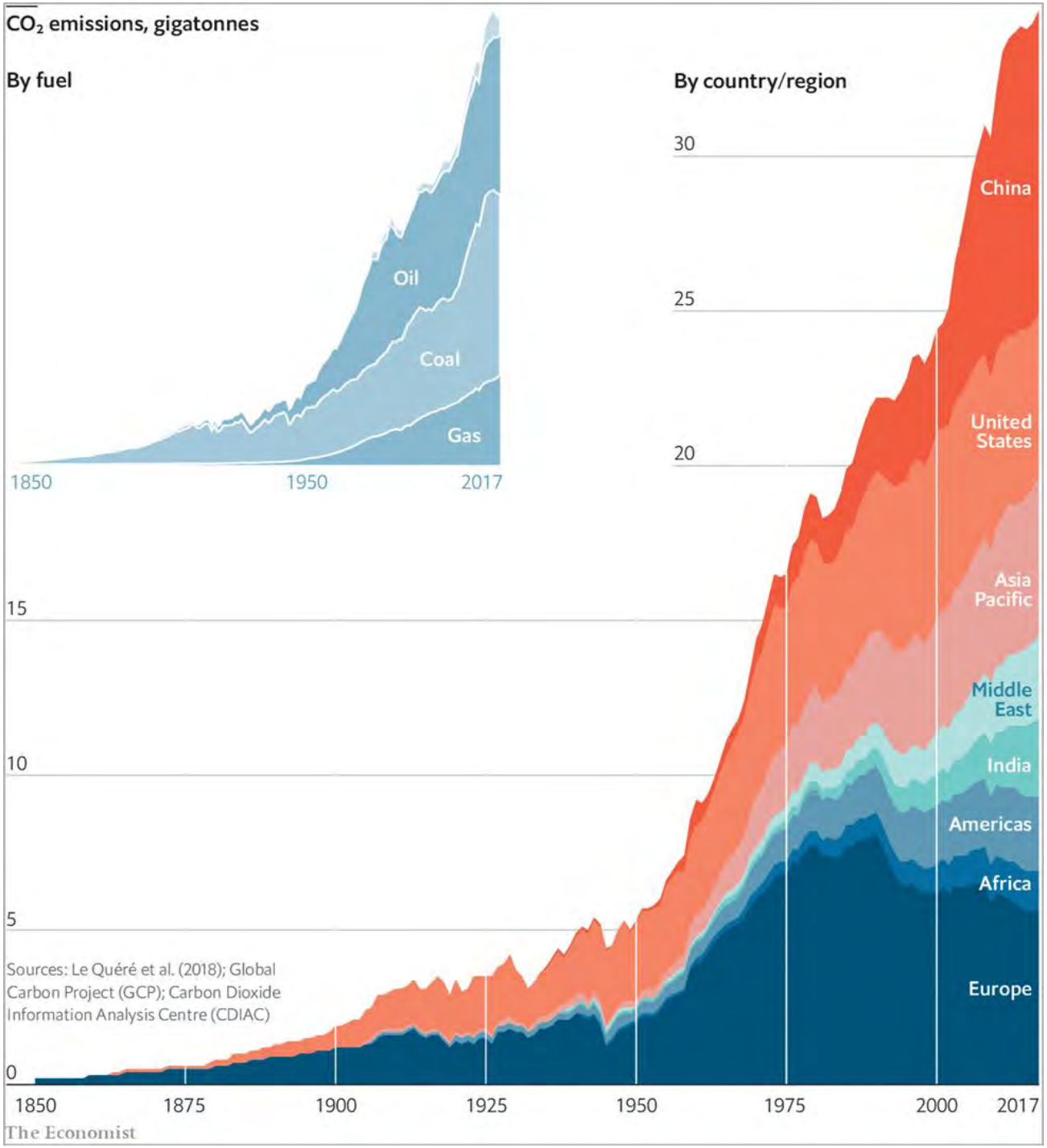


Source: International Energy Agency (EIA). (2021). *World Energy Investment 2021*. Paris, France: IEA.

The Climate Change Imperative

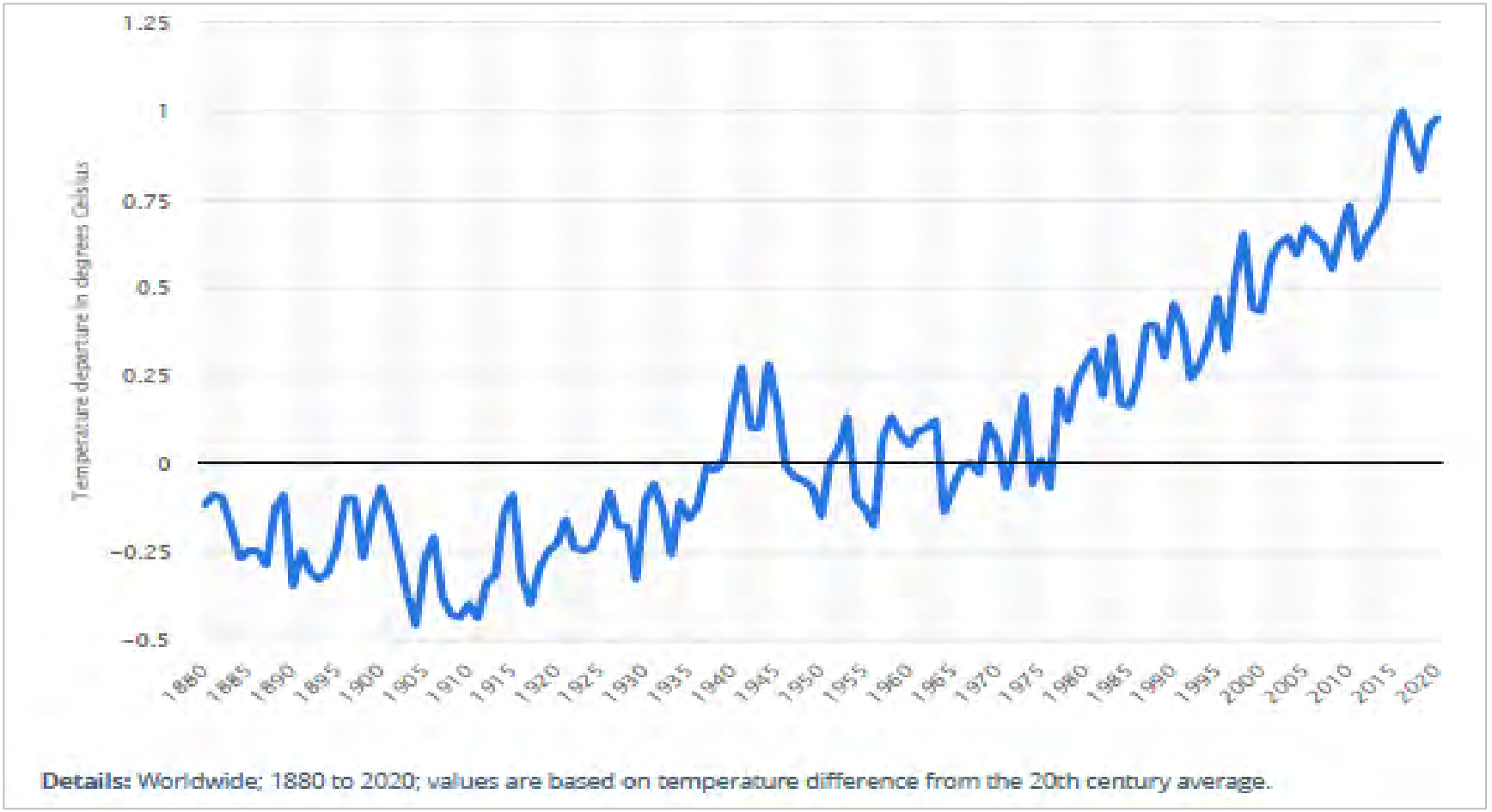
Anthropocene Climate Change Becoming Undeniable And Pressing

Figure 4. The Exponential Increase in Atmospheric Carbon Dioxide, 1850-2018



Source: *Economist*. (2019, September 21). Global warming 101. The past, present and future of climate change.

Figure 5. The Sharp Rise In Global Average Temperatures Since 1880



- **Temperatures largely stable until 1960s, then began rising rapidly**

Source: *Statista*

Climate Change Economic And Financial Research Growing Rapidly From Small Base

- **Scientific Research Began 1980s, Became Accepted Quickly**
  - Accepted within mainstream science; popular support lagged
- **Nordhaus (2008) Won Nobel Prize For His Economic Analysis Of Climate Change And Modelling Effects**
  - Convinced most economists of anthropogenic nature of change
- **Finance Came To Climate Change Research Late**
  - Andrew Karolyi lobbied by Prince Charles; led to RFS Special Issue
- **Early Research Focused On ESG, Institutional Investors**
  - Dimson, Karakaş and Li (*RFS* 2015); Ferrell, Liang and Renneboog (*JFE* 2016); McCahery, Sautner, and Starks (*JF* 2016); Riedl and Smeets (*JF* 2017); Dyck, Lins, Roth, and Wagner (*JFE* 2019); and Barber, Morse, and Yasuda (*JFE* 2021)

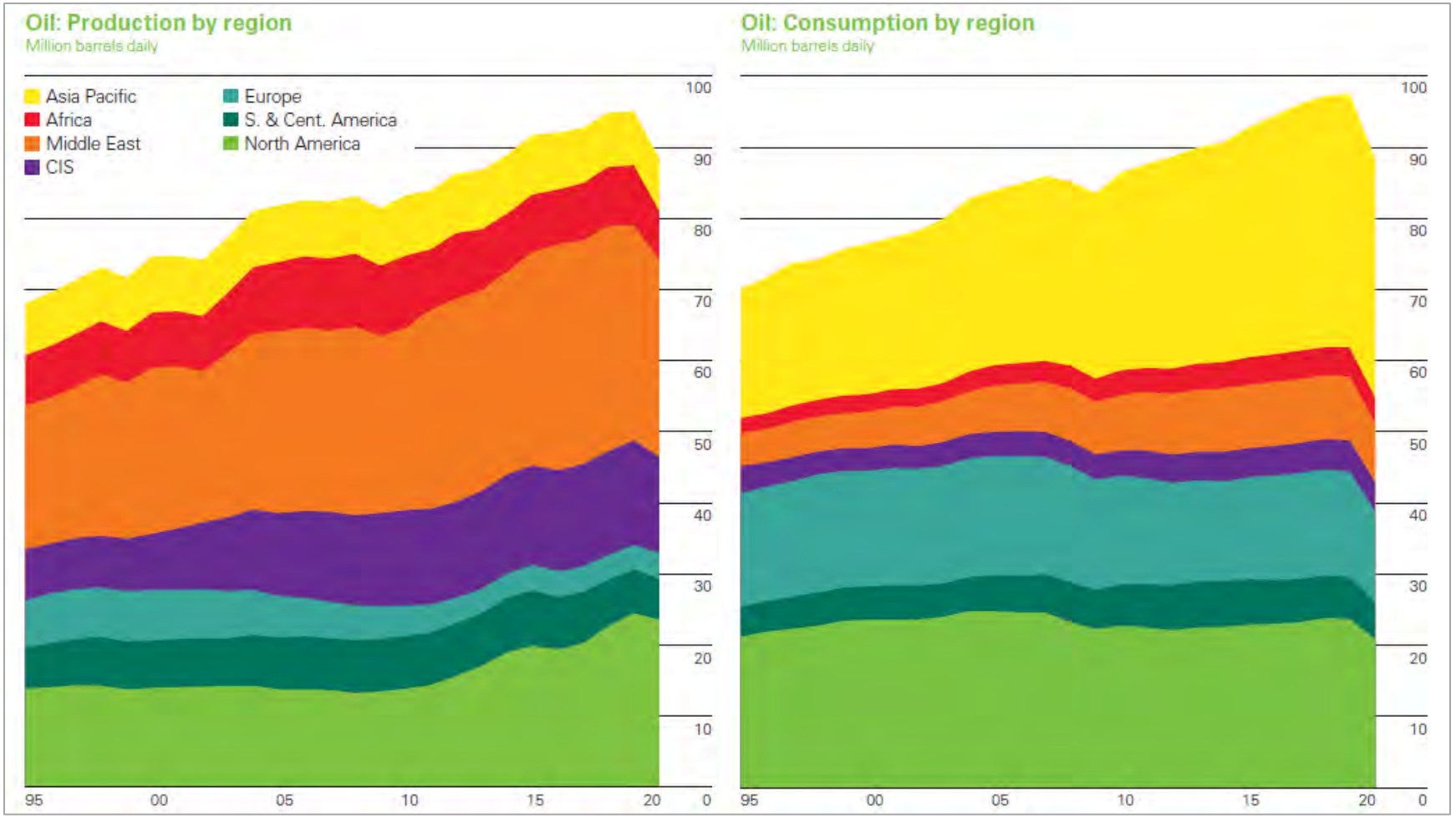
Climate Change Economic And Financial Research Growing Rapidly From Small Base

- **Climate Change Focused Finance Research Came Late 2010s**
  - Fernando, Sharfman, Uysal (*JFQA* 2017); Starks, Venkat, Zhu (*WP* 2017)
- **Most Recent (2020+) Flood Of Climate Finance Research**
  - Choi, Gao, Jiang (*RFS* 2020); Delis, de Grieff, Iosifidi, Ongena (*EBRD* 2019); Engle, Giglio, Kelly, Lee, Stroebel (*RFS* 2020); Hong, Karolyi, Schenkman (*RFS* 2020); Ilhan, Sautner, Volkov (2020); Krueger, Sautner, Starks (*RFS* 2020); Bolton & Kacperczyk (*JFE* 2021); Megginson, Malik, and Lopez (*ARFE* 2021). Pedersen, Fitzgibbons, Pomorski (*JFE* 2021)
- **Several Papers Analyze "Choice" Versus "Voice" Decision Regarding Engagement With Portfolio Firm Executives**
  - Dimson, Karakas, Lee (*RFS* 2015); McCahery, Sautner, Starks (*JF* 2016); Dyck et al. (*JFE* 2019); Kruger, Sautner, Starks (*RFS* 2020).
  - Voice channel has been documented to be more potent

Transportation Fuels—The Awkward, Ongoing Need For Petroleum

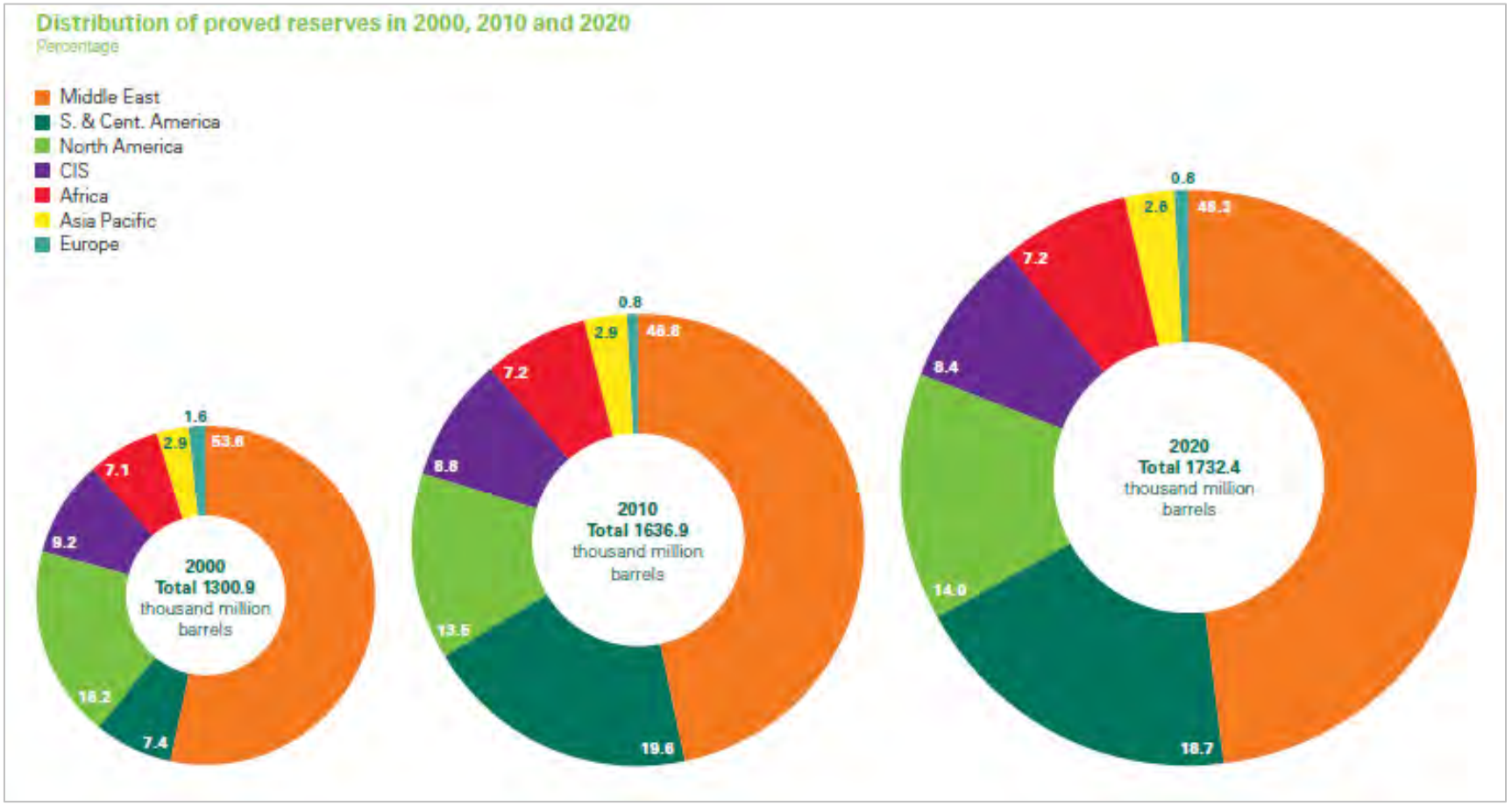
Global Oil Consumptions 100 Millions Barrels Per Day—And Growing. Few Good Substitutes As Transportation Fuels

Global Oil Production And Consumption By Region, 1996-2020



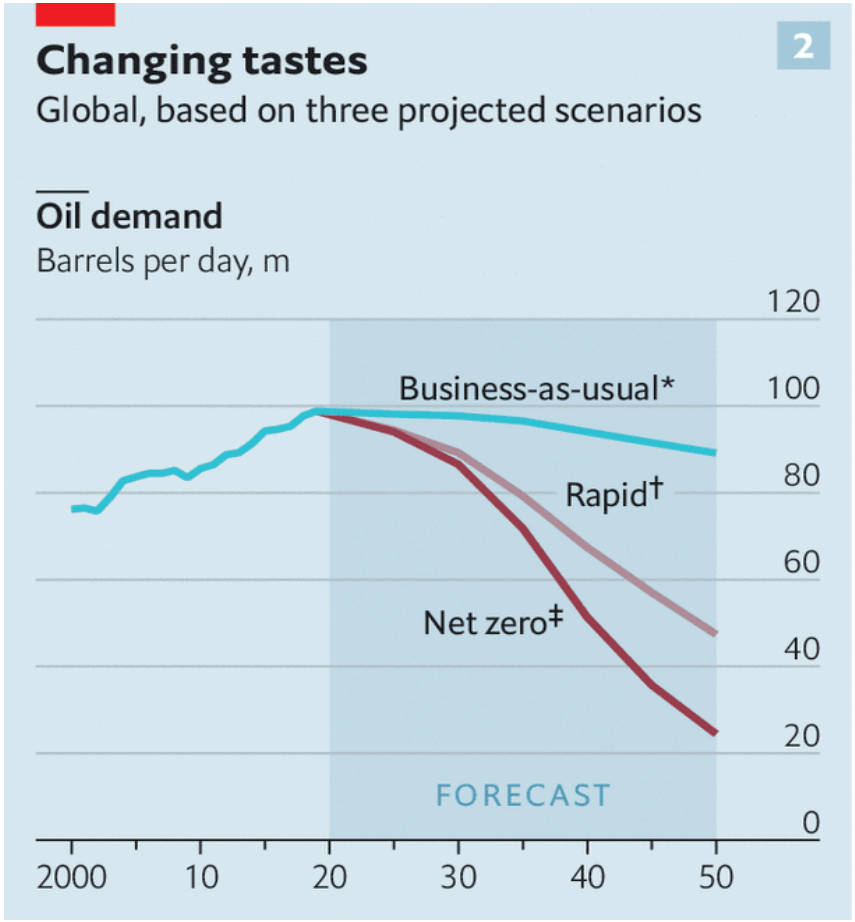
Source: BP. (2021). Statistical Review of World Energy 2021, 70th Edition. London, UK.

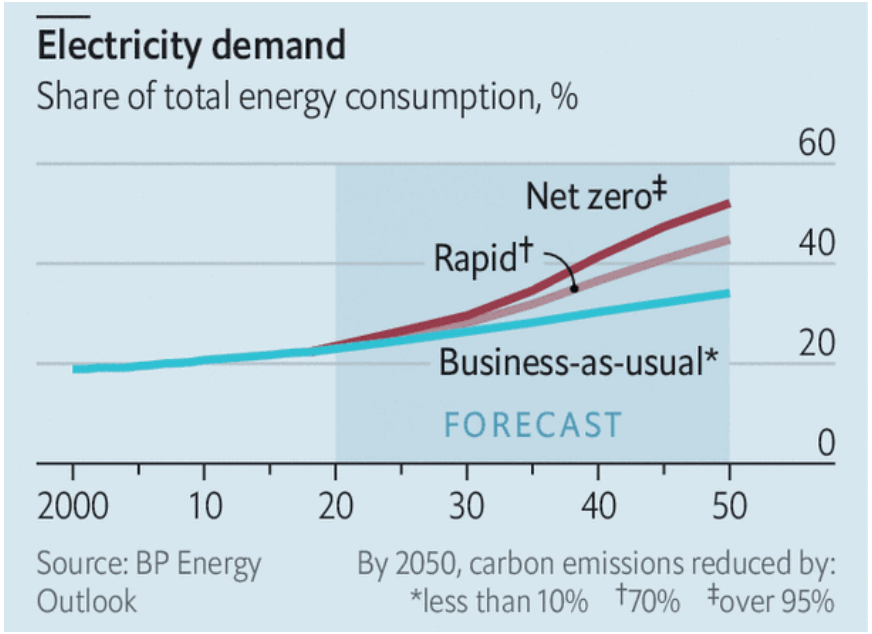
Figure 7. Proved Oil Reserves, 2000, 2010, and 2020; Total Reserves and Distribution By Region



Source: BP. (2021). Statistical Review of World Energy 2021, 70th Edition. London, UK.

Figure 8. Projecting Future Oil Demand Depends Critically on Government Policy Decisions





Source: *Economist*. (2020, September 20). The changing geopolitics of energy. America's domination of oil and gas will not cow China.

Financial Research On Petroleum Production, Investment, Pricing, Hedging & Fracking

- **Empirical Studies On Factors Influencing Oil & Product Prices**
  - Barsky & Kilian (*JEP* 2004); Buyuksahin, Lee, Moser, Robe (*EJ* 2013); Ederington, Fernando, Hoelscher, Lee, Linn (*EJ* 2019); Ederington, Fernando, Holland, Lee, and Linn (*JFQA* 2021)
- **Studies Examining Whether Prices Respond Symmetrically To Upside & Downside Supply Shocks, Similar Political Events**
  - Radchenko (*EE* 2005), Yang and Ye (*Rand* 2008), Tappata (*Rand* 2009), Balaguer and Ripollés (*EE* 2016)
- **Studies Of Investment Levels & Frictions, Oil & Gas Industry**
  - Gilje (*RFS* 2016); Gilje & Taillard (*JF* 2016); Gilje, Loutskina, Murphy (*JF* 2020); Tsyplakov (*JFE* 2008); Kellogg (*AER* 2014)

Financial Research On Petroleum Production, Investment, Pricing, Hedging & Fracking

- **Studies Assessing Political, Economic, Financial Impacts Of Major Hydrocarbon Discoveries**
  - Radchenko (*EE* 2005), Yang and Ye (*Rand* 2008), Tappata (*Rand* 2009), Balaguer and Ripollés (*EE* 2016)
  - Sabet & Heaney (*EE* 2016); Arezki, Ramey, and Sheng (*QJE* 2017); Tsui (*EJ* 2010) [Personal favorite]
- **Studies Of Investment Levels & Frictions, Oil & Gas Industry**
  - Gilje (*RFS* 2016); Gilje & Taillard (*JF* 2016); Gilje, Loutskina, Murphy (*JF* 2020); Tsyplakov (*JFE* 2008); Kellogg (*AER* 2014)
- **Institutional Investors And Commodity Trading Returns**
  - Oil as commodity: Singleton (*MS* 2014); Basak & Pavlova (*JF* 2016)
  - Futures trading strategies: Gorton & Rouwenhorst (*FAJ* 2006); Tang & Xiong (*FAJ* 2012); Christoffferson, Jacobs, Pan (*RFS* 2021)

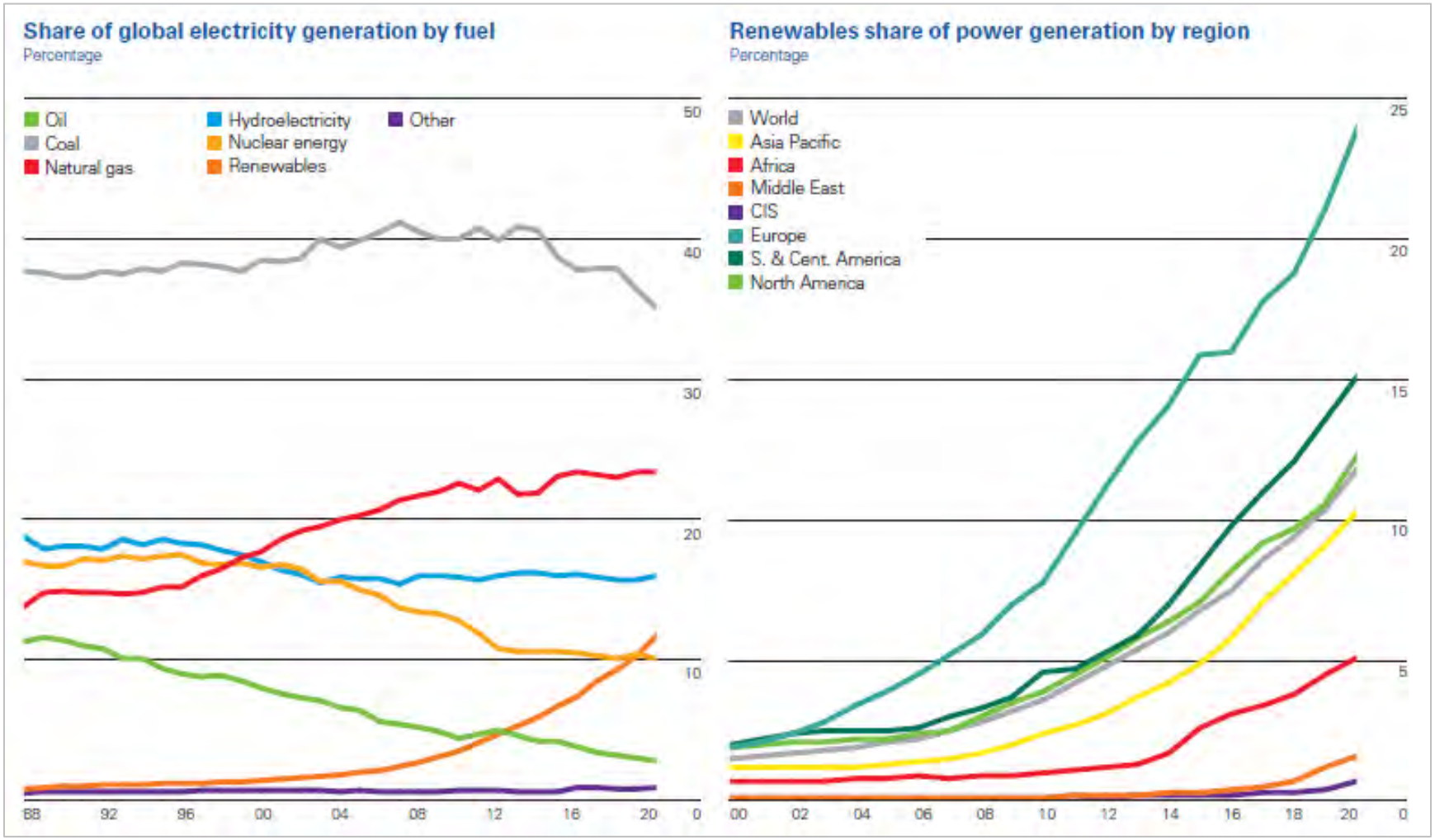
Financial Research On Petroleum Production, Investment, Pricing, Hedging & Fracking

- **Impact Of The Fracking Revolution**
  - Lake, et al (2013); Wiseman (2011). Gilje, Ready, and Roussanov (2015) assess long term economic impact
  - Mansur, and Sacerdote, (2017): During Great Recession, new oil and gas extraction increased U.S. employment by725,000 and 0.5 ppt decrease in unemployment rate
  - Pierce (2013): Spread of fracking encouraged major investments in chemical production using natural gas as a feedstock.
  - Gilje (2019): Impact of fracking on local bank credit markets significantly increases lending activity for small banks
  - Fedaseyeu, Gilje, Strahan (2015): Hydraulic fracturing brought large wealth windfalls to local landowners

Generating Electricity By Burning Fossil Fuels

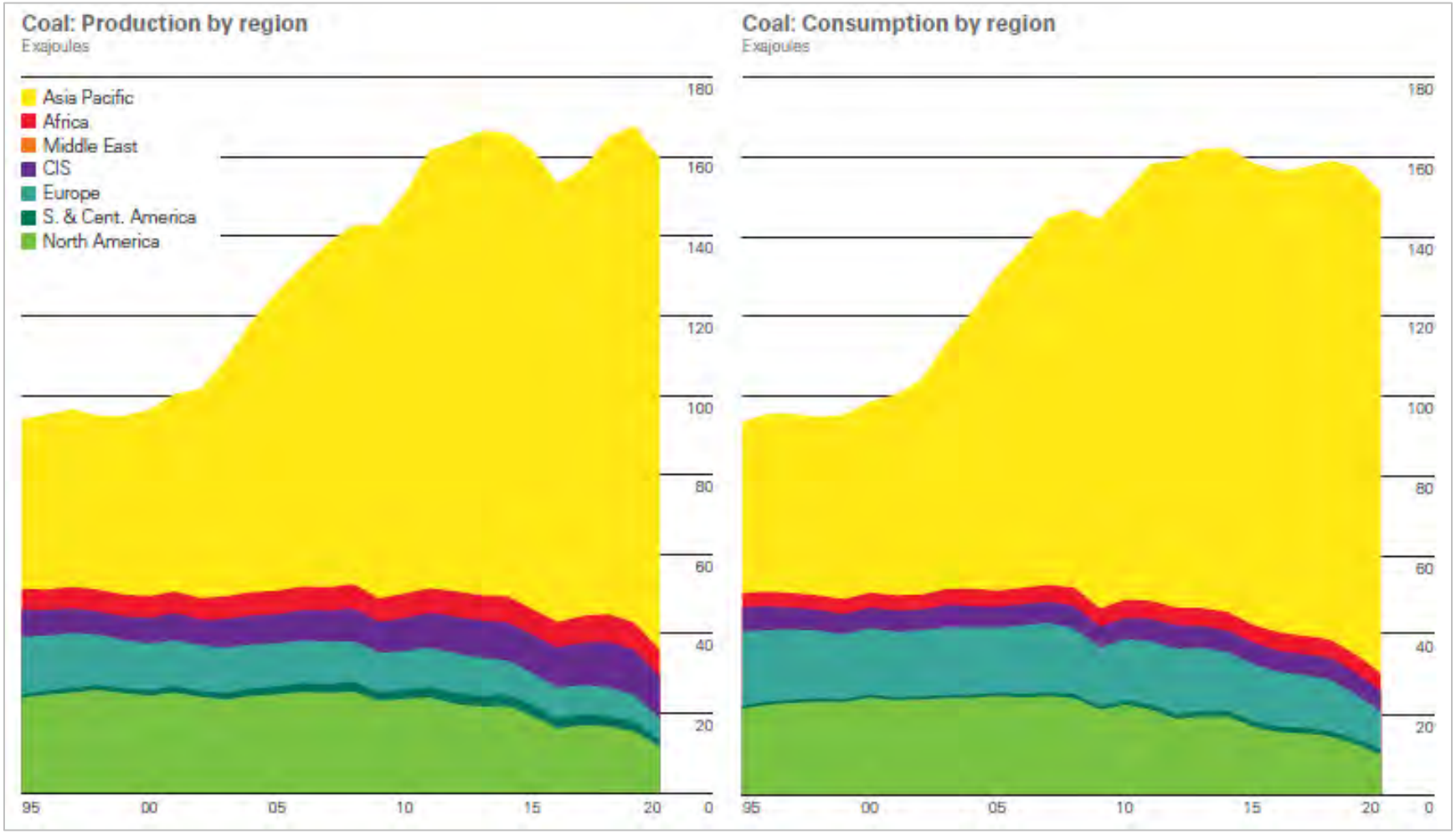
Coal Still Largest Worldwide, Natural Gas Catching Up, But Both Have Uncertain Futures

Figure 9. Share Of Global Electricity Generation By Fuel Type, 1988-2020



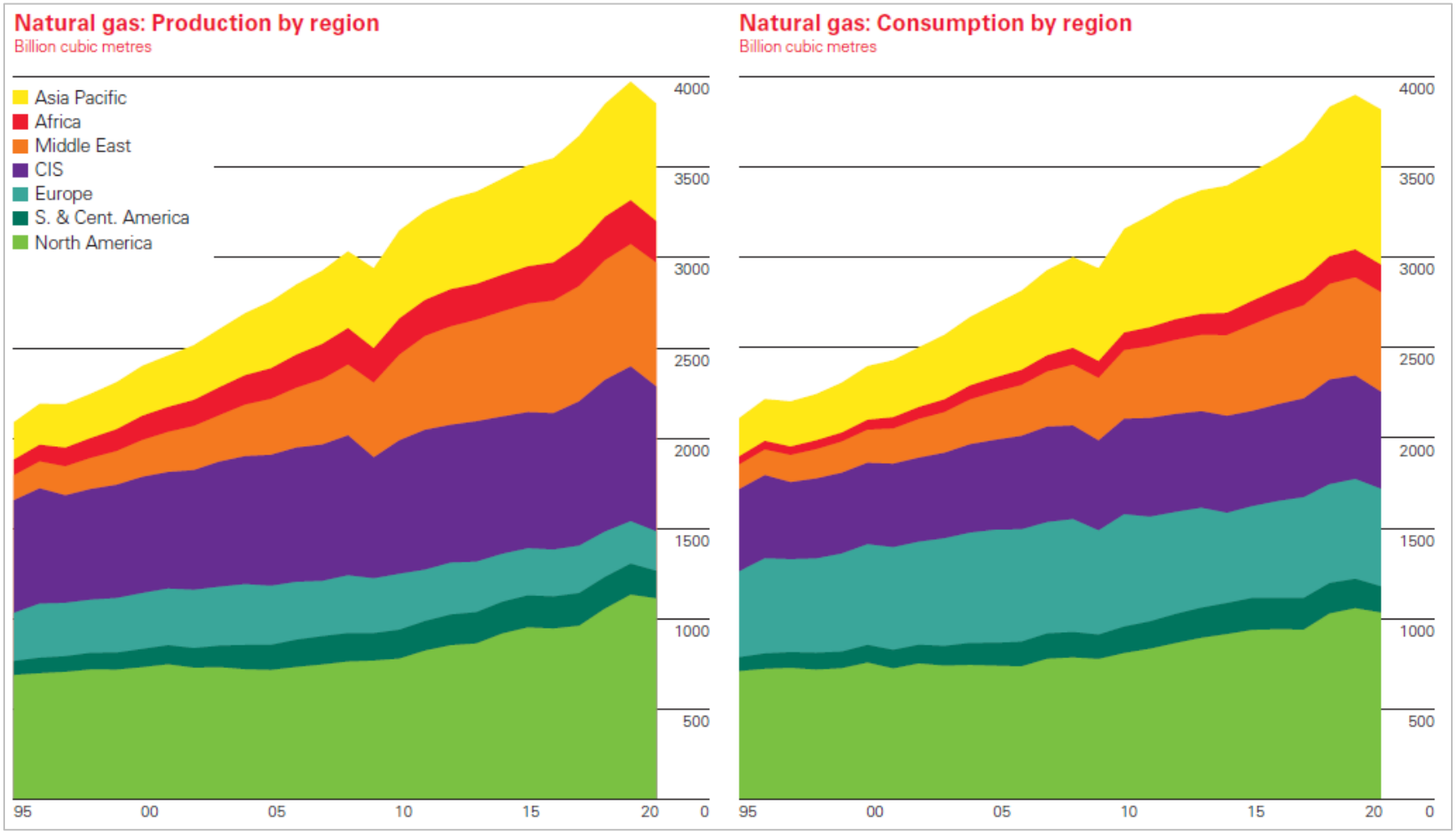
Source: BP. (2021). *Statistical Review of World Energy 2021*, 70th Edition. London, UK.

Figure 10. Coal Production & Consumption, By Region, 1995-2020



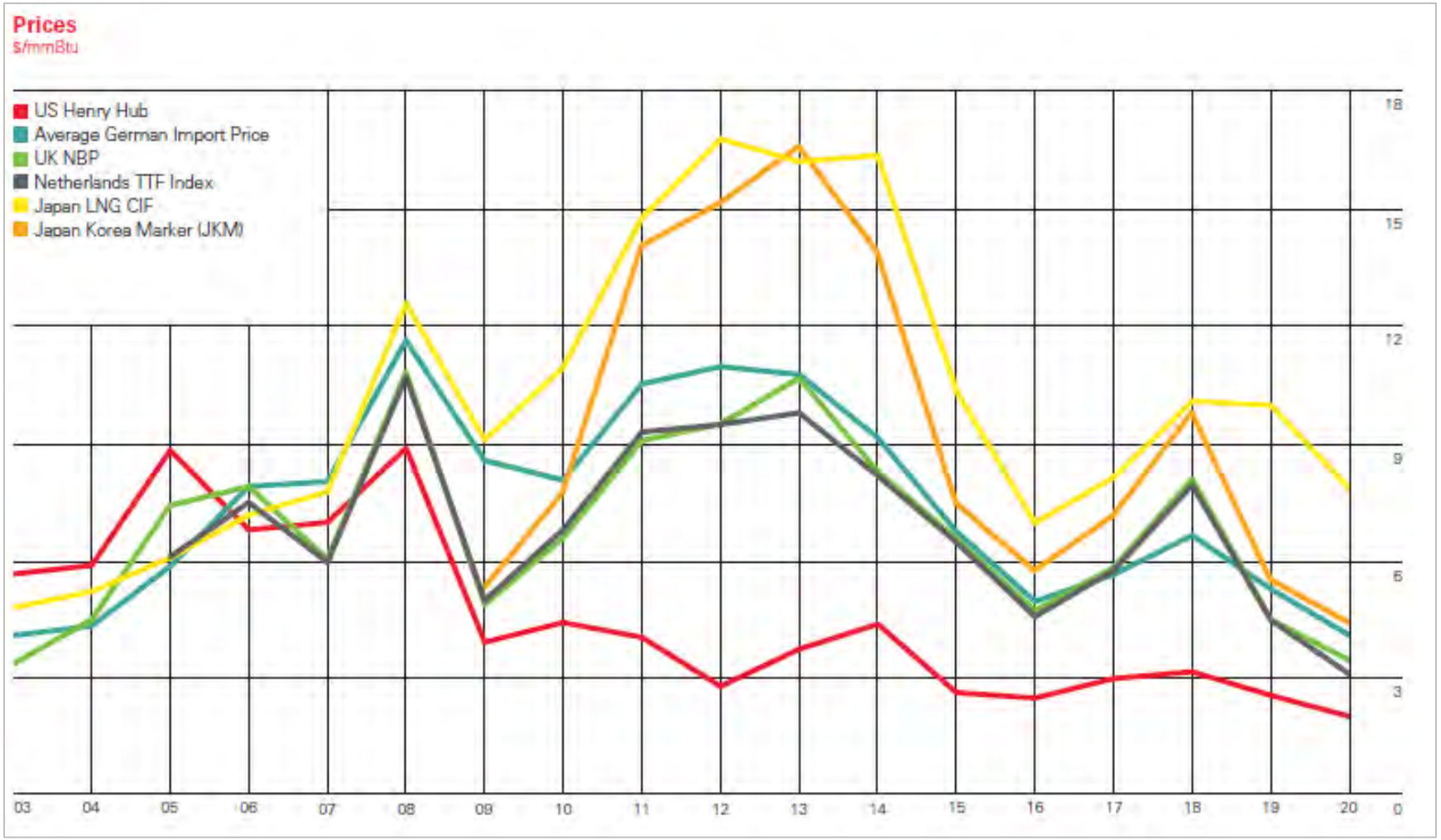
Source: BP. (2021). *Statistical Review of World Energy 2021*, 70th Edition. London, UK.

Natural Gas Production & Consumption, By Region, 1995-2020



Source: BP. (2021). *Statistical Review of World Energy 2021*, 70th Edition. London, UK.

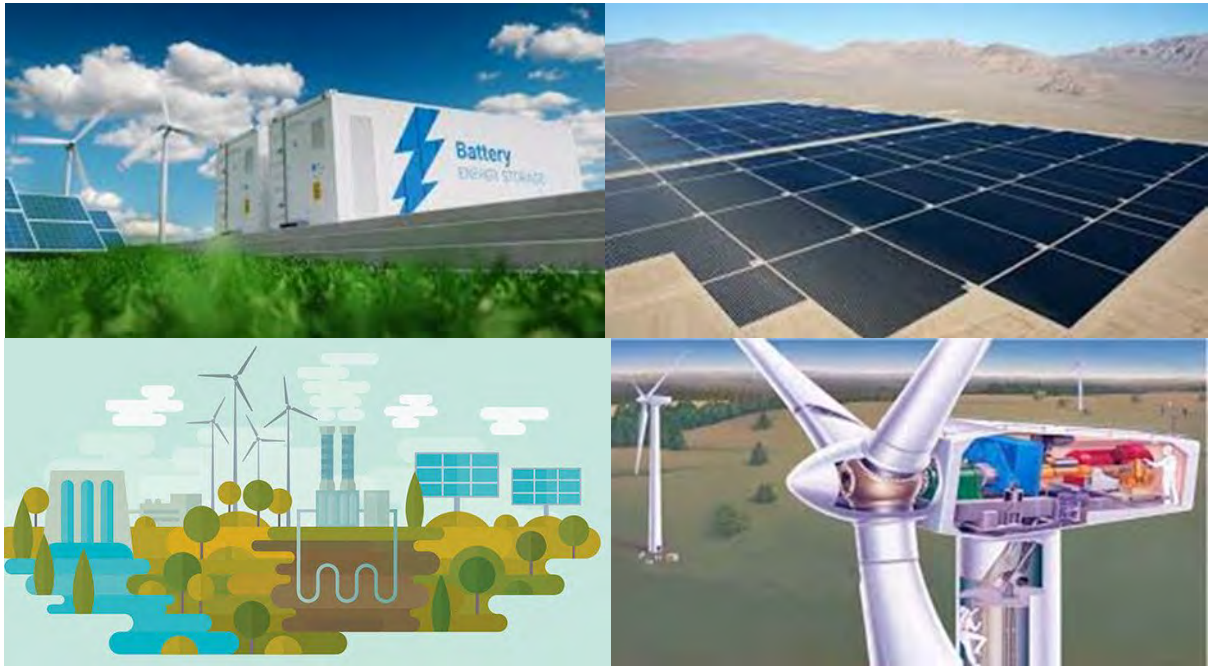
Figure 11. Distribution of Natural Gas Prices Across Global Markets, 2003-2020



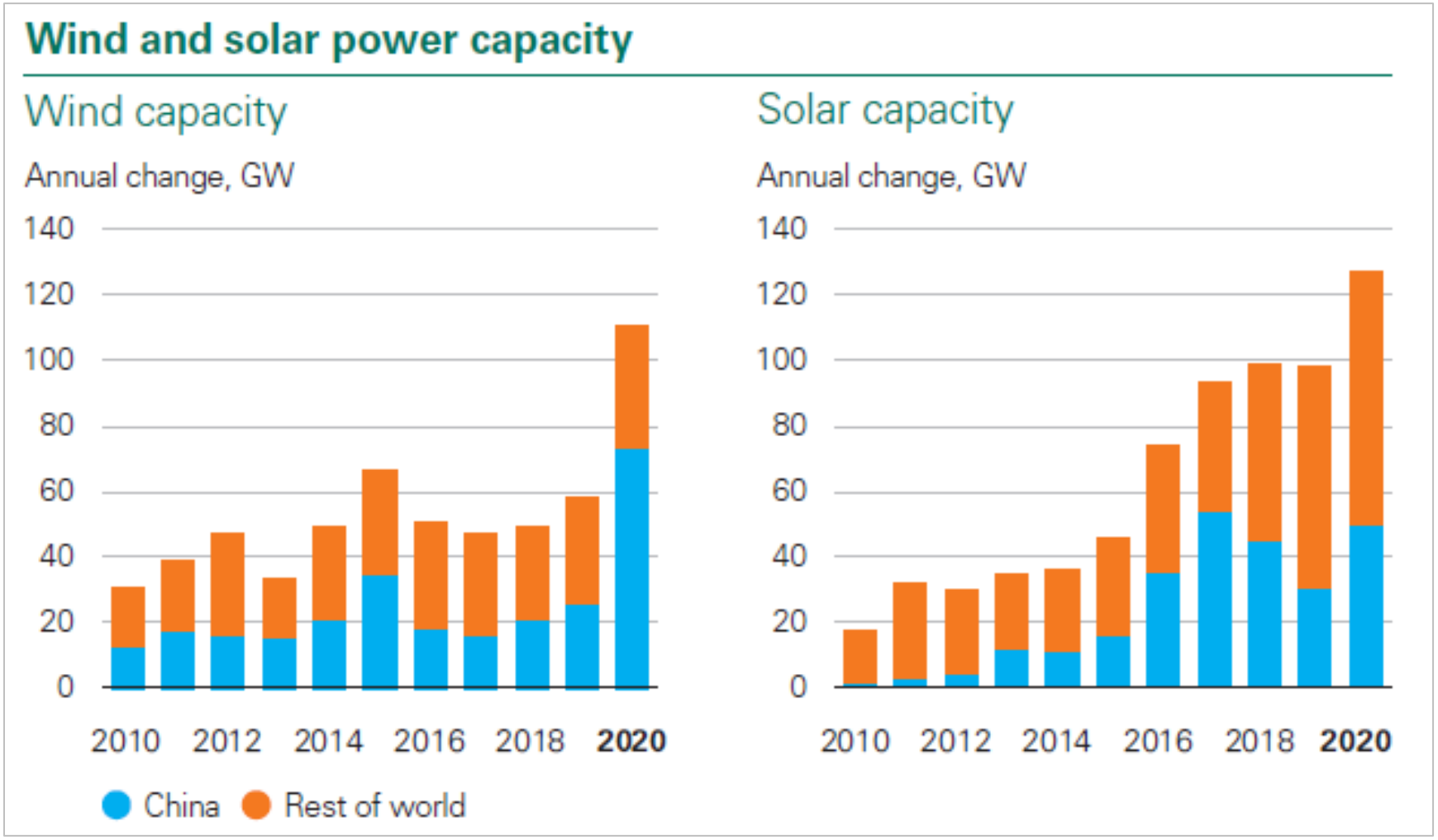
Source: BP. (2021). *Statistical Review of World Energy 2021*, 70th Edition. London, UK.

The Rise And Rise Of Renewables; Decarbonizing Rapidly But Affordably

Renewable Electric Generating Capacity Rising Very Rapidly; Cost Competitive In Many Places; Pity About The Intermittency Of Sun And Wind

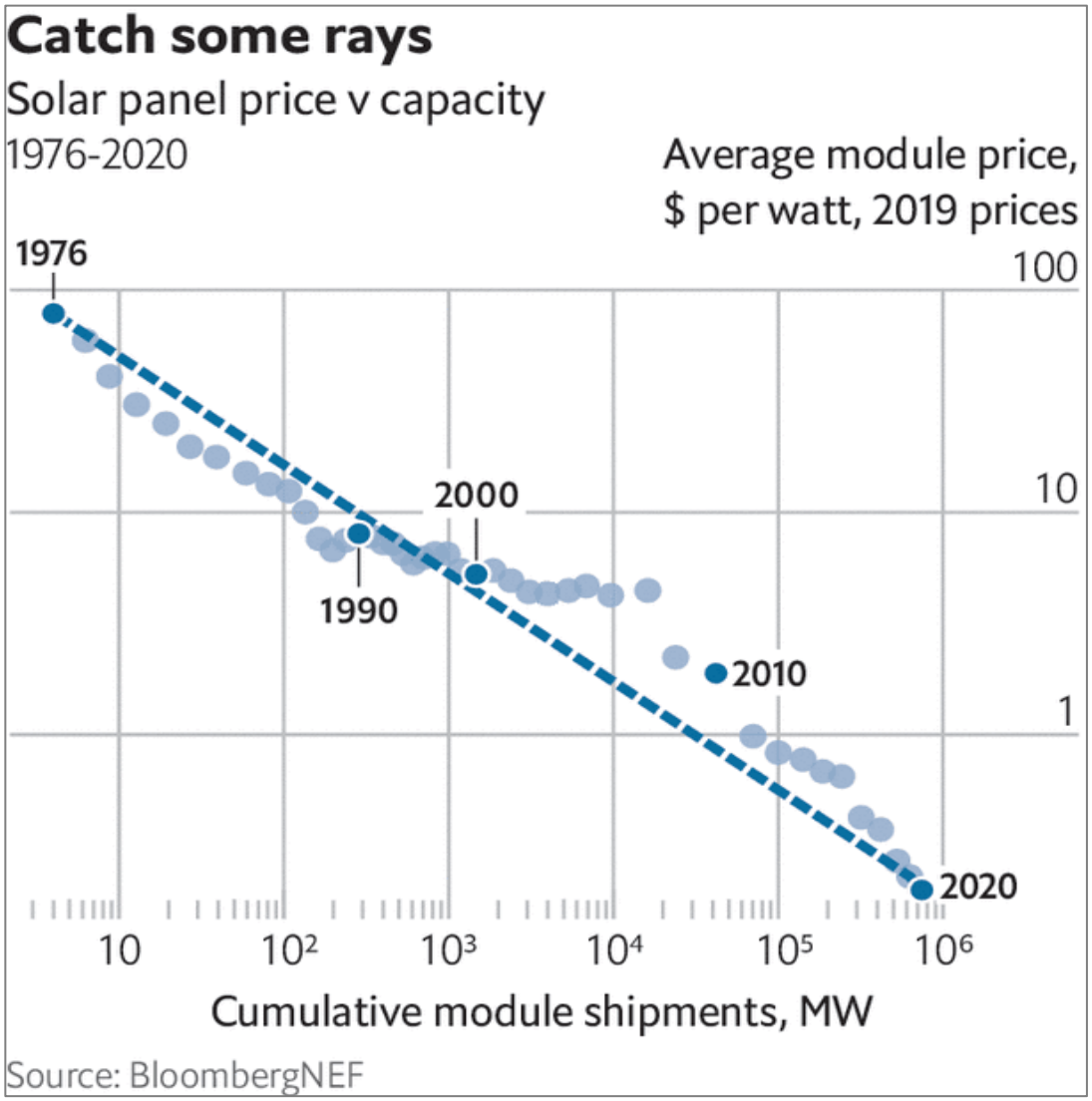


Growth Of Wind And Solar Power Generating Capacity—Mostly About China



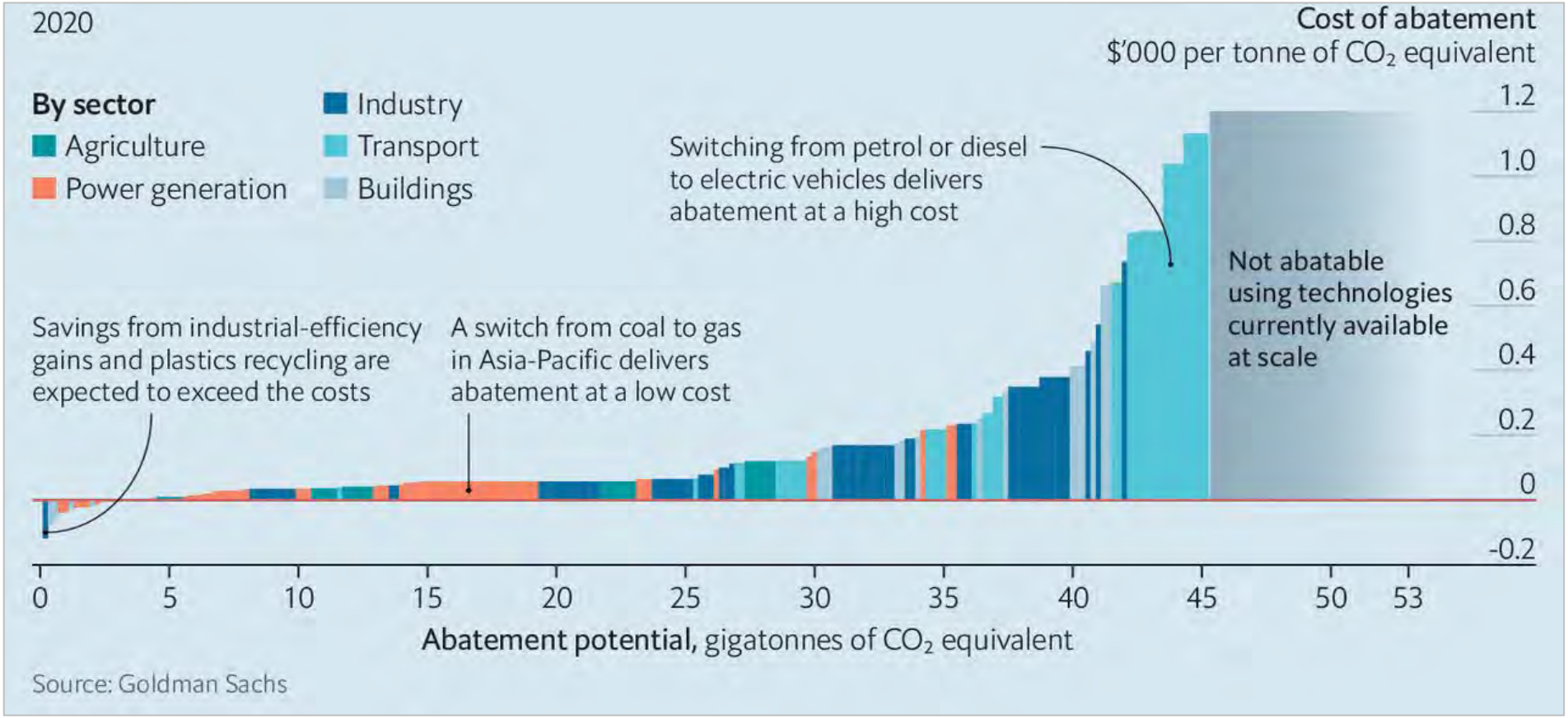
Source: BP. (2021). *Statistical Review of World Energy 2021*, 70th Edition. London, UK.

Figure 12. As Solar Panel Prices Have Fallen Installed Capacity has Increased, Both Sharply, 1976-2020



Economist. (2021, January 7). Solar power. How governments spurred the rise of solar power

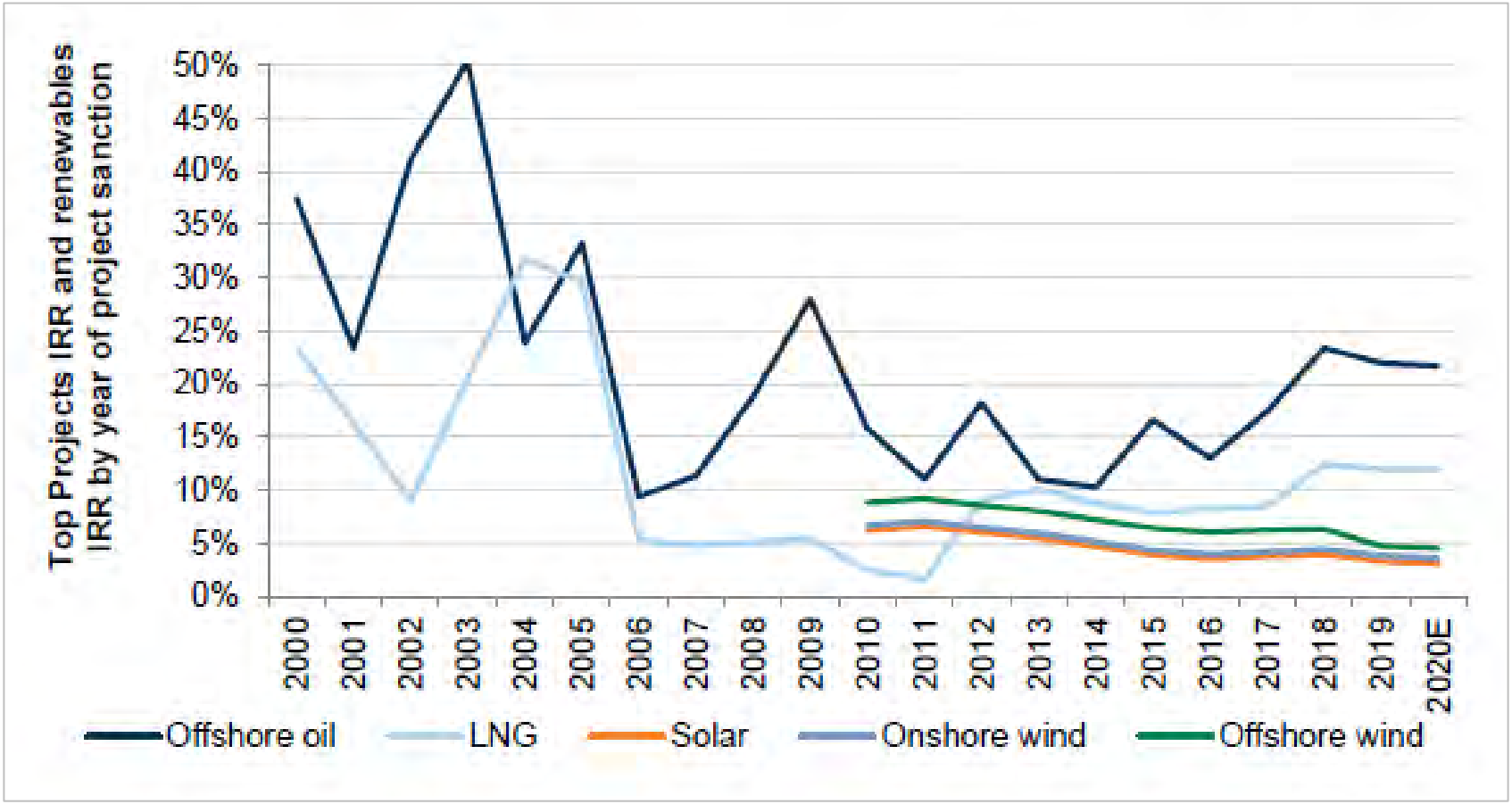
Figure 13. Abatement-Cost Curve for Global Greenhouse-Gas Emissions, 2020



- **Highest net benefit abatement strategy: Large scale shift from coal to gas in Asia-Pacific**
- **Some smaller scale abatements (industrial energy efficiency improvements) net benefits**

Source: Goldman Sachs Global Investment Research. (13 October 2020). *Carbonomics. Innovation. Deflation, and Affordable Decarbonization*, presented in Economist (27 February 2021). Giving up carbs. The cheapest way to cut carbon.

Figure 14. The Evolution Of Capital Costs For Different Energy Sectors, 2010-2020



- **Required IRR for new offshore oil projects now 22%, 5X offshore wind projects**
- **Even new LNG projects' required IRR now 12%, 3X onshore wind projects**

Source: Goldman Sachs Global Investment Research. (13 October 2020). *Carbonomics. Innovation. Deflation, and Affordable Decarbonization*.

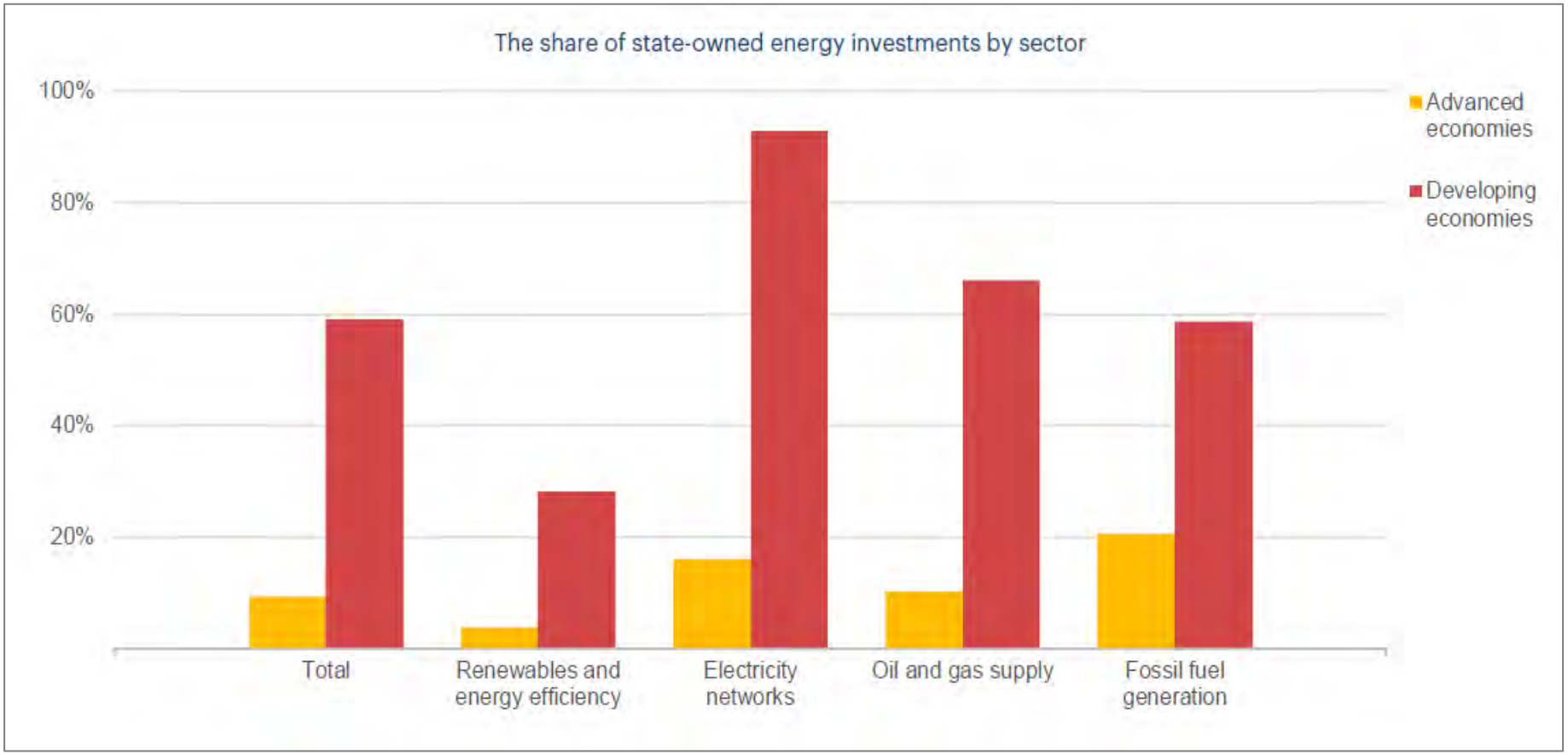
Financial Economics Research On Power Sector

- **Electricity Supply Industry (Pollitt, *JEnLit* 1997) Includes Four Sectors: Generation, Transmission, Distribution,Supply**
  - Long viewed by governments as a lead industry needing effective regulation (Pollitt, *EER* 1997; Newberry, *EER* 1997)
- **Studies Examining Determinants Of Electricity Pricing**
  - Banal-Estaňol and Micola, 2009); Aïd, Chemla, Porchet, and Touzi (2011); Becher, Mulherin, and Walkling (2012)
- **Studies Examining Whether Risk Premia And/Or Forward Premia Exist In Electricity Futures Markets**
  - Bessembinder and Lemmon (2002); Longstaff and Wang (2005); Michelfelder and Pilotte (2019)

The State's Role As Energy Provider

Government Ownership Of Energy Assets Has Fallen Sharply In OECD; Remains Very High In Developing Countries

Figure 15. The Role of State Vs Private Investors in Advanced Vs Developing Economies, By Sector



- **State ownership still very high (60% of total) in developing countries; <10% in Advanced**
- **State ownership is high in electricity networks everywhere; dominant (90%+) in DCs**

Source: International Energy Agency (EIA). (2020). *World Energy Investment 2020*. Paris, France: IEA.

Fig 16. Operational Efficiency of World's Largest National Oil Companies and Shareholder Owned Companies

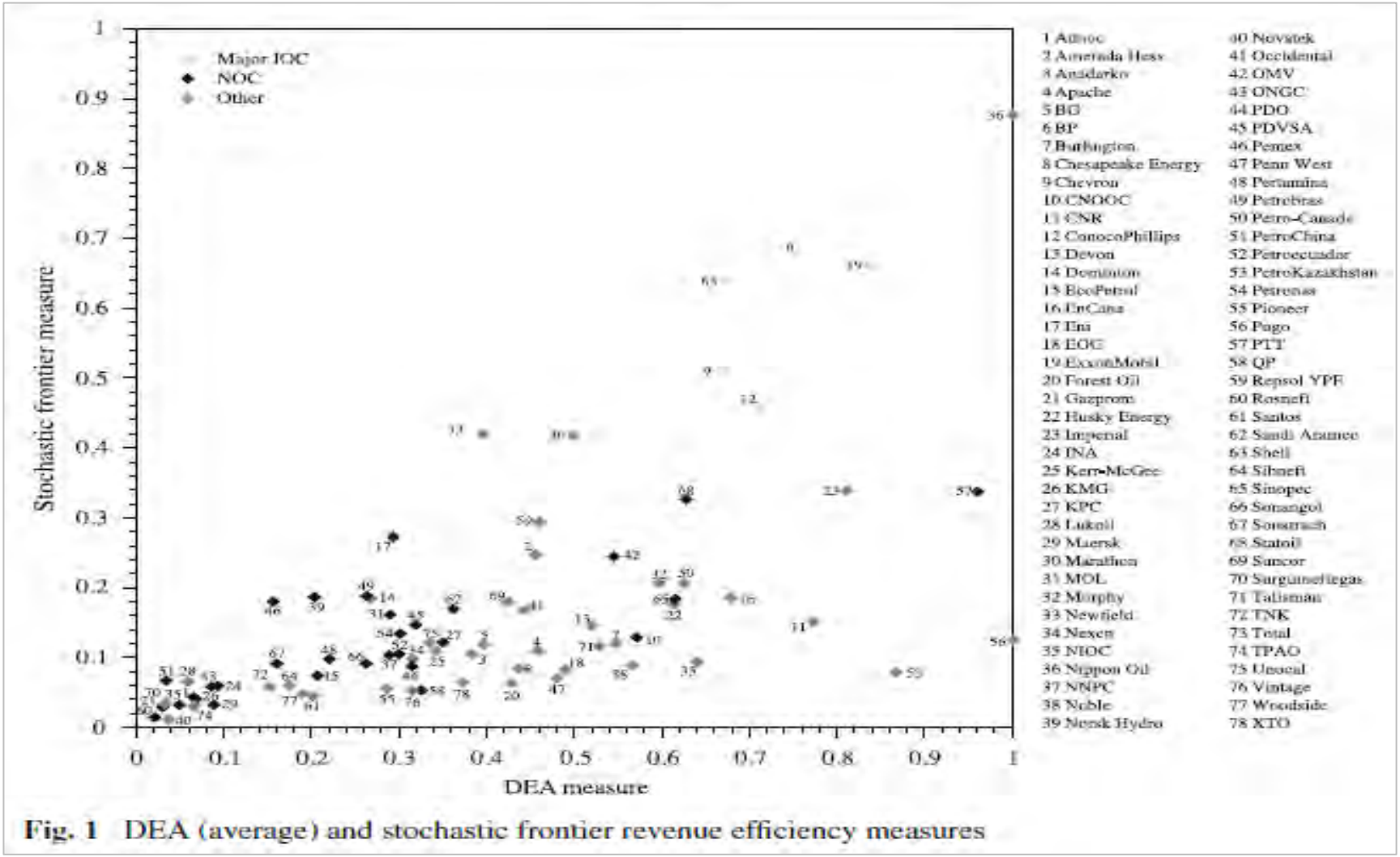


Fig. 1 DEA (average) and stochastic frontier revenue efficiency measures

Source: Stacy L. Eller, Peter R. Hartley, Kenneth B. Medlock III, 2011. Empirical evidence on the operational efficiency of national oil companies. *Empirical Economics* 40, 623-643.

Summary And Conclusions

Financing And Producing Enough Clean Energy To Transition To Low Carbon Future Will Be Immensely Difficult And Costly

Any Questions?

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