



# Economics for Energy Annual Lecture

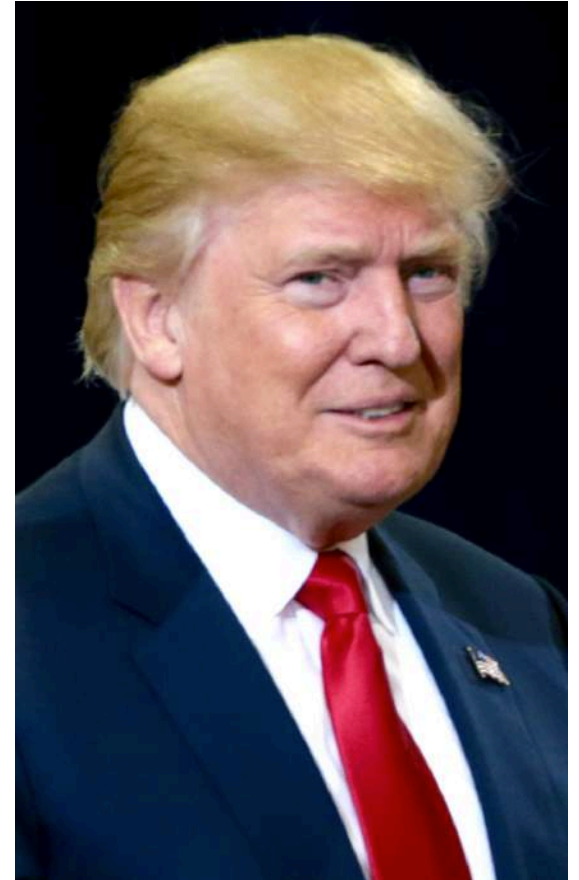


*View of Pudong, Shanghai (1983)*  
上海浦东 (1983年)



*View of Pudong, Shanghai*  
上海浦东





# ENERGY TECHNOLOGY AND GEOPOLITICS -- EIGHT TRENDS



# SUMMER OLYMPICS 2008 OPENING CEREMONY



***AUGUST 8, 2008 – 8:08pm***

# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.
- 8.

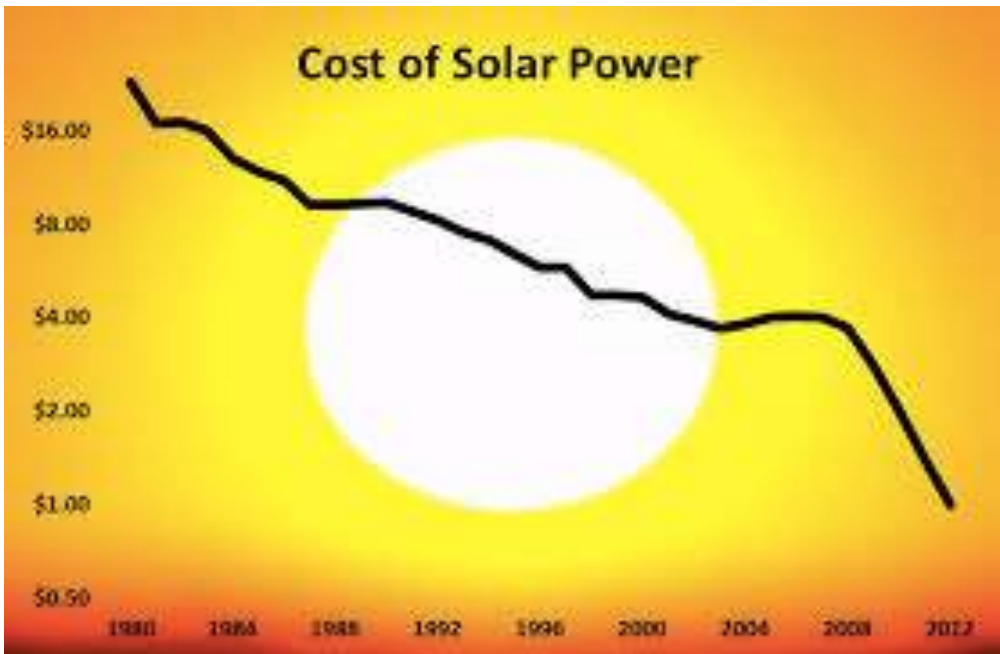


# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

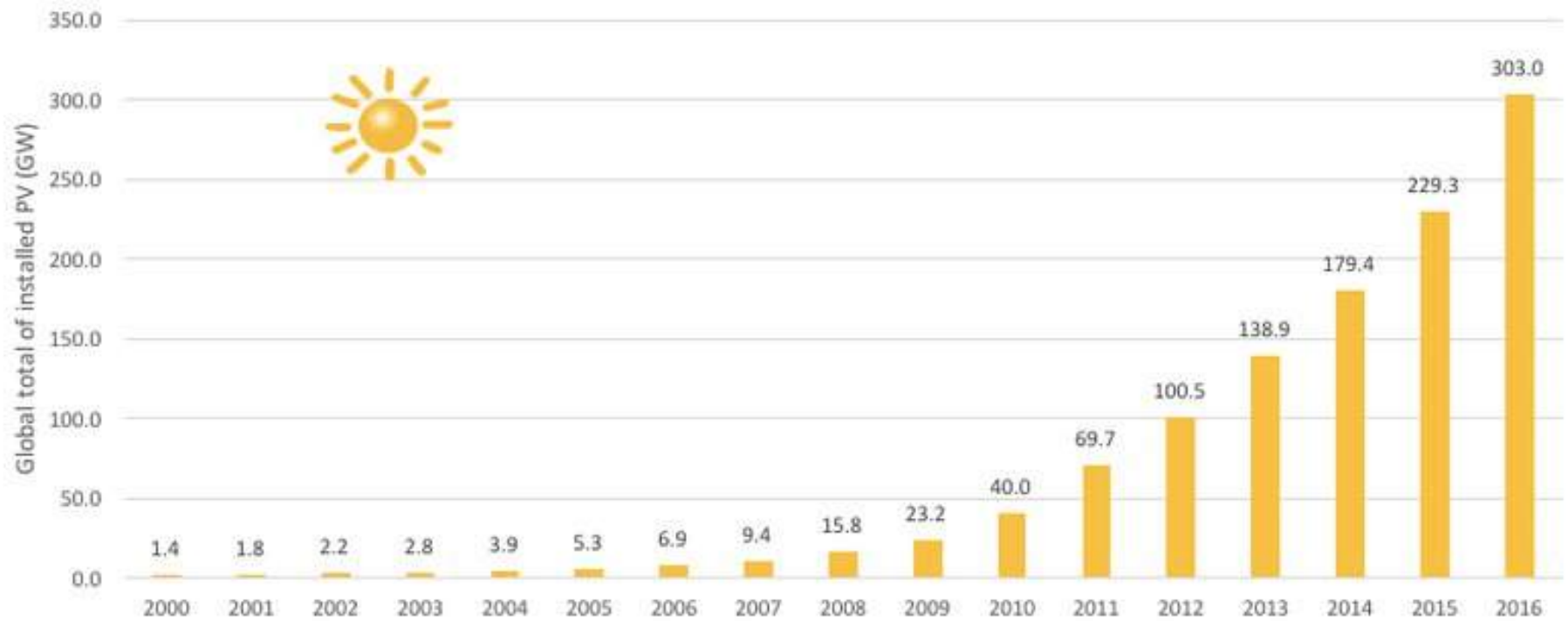
## ***1. Renewable Energy Revolution***

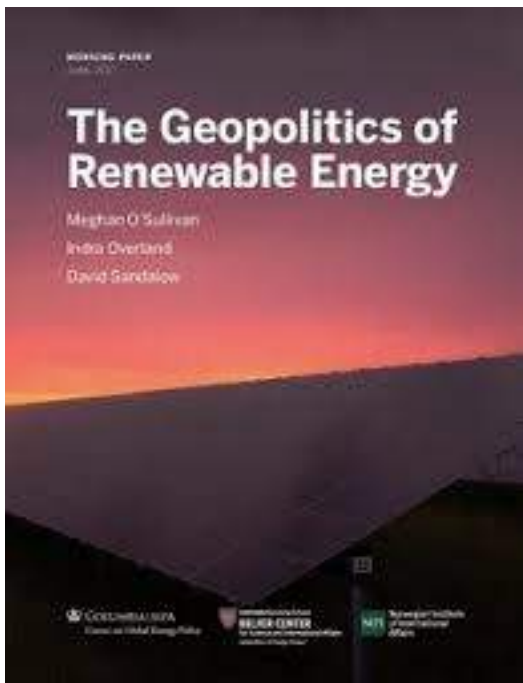






## Cumulative installed solar PV globally





- Cartelization of key minerals
- Distributed generation/energy security
- Transnational electric grids/energy security
- Reduced poverty
- Reduced oil and gas revenues
- Avoided climate change

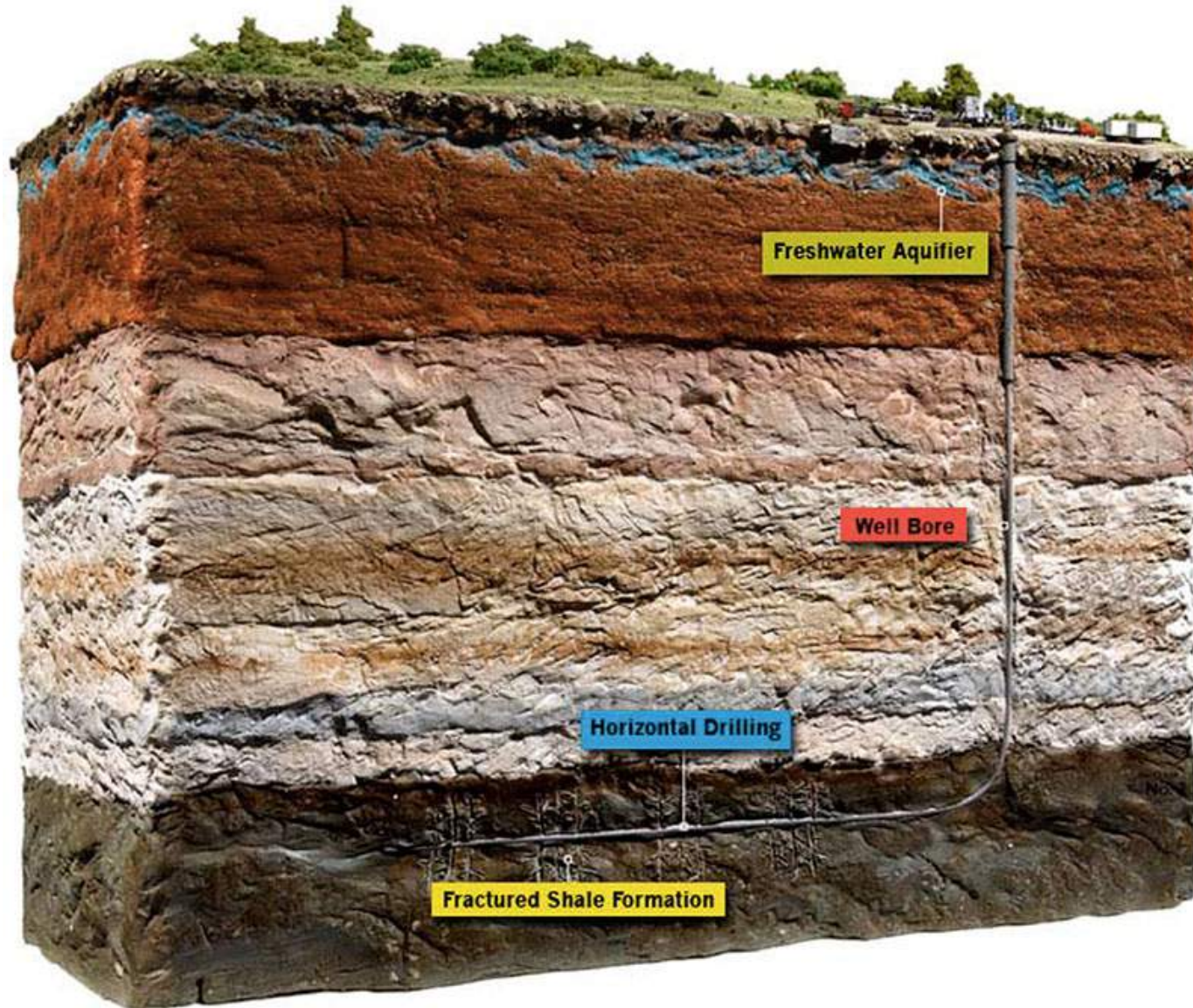
	EIA IEO2016		BPEO2016		IEA WEO2016	
Year	Share of Fossil Fuels	Share of Renewables (defined as "other" than liquids, gas, coal and nuclear)	Share of Fossil Fuels	Share of Renewables	Share of Fossil Fuels	Share of Renewables
2014		11.95%		9.22%	81.01%	14.16%
2015	83.25%	12.19%	85.43%	9.57%		
2016	82.62%	12.66%				
2020	81.26%	13.83%	83.01%	11.41%	79.04%	15.50%
2025	80.21%	14.66%	80.96%	13.28%	77.72%	16.50%
2030	79.33%	15.07%	79.10%	14.92%	76.34%	17.47%
2035	78.73%	15.61%	77.19%	16.65%	75.16%	18.41%
2040	78.24%	16.12%			74.04%	19.34%

# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

1. Renewable Energy Revolution
- 2. *Shale Revolution***

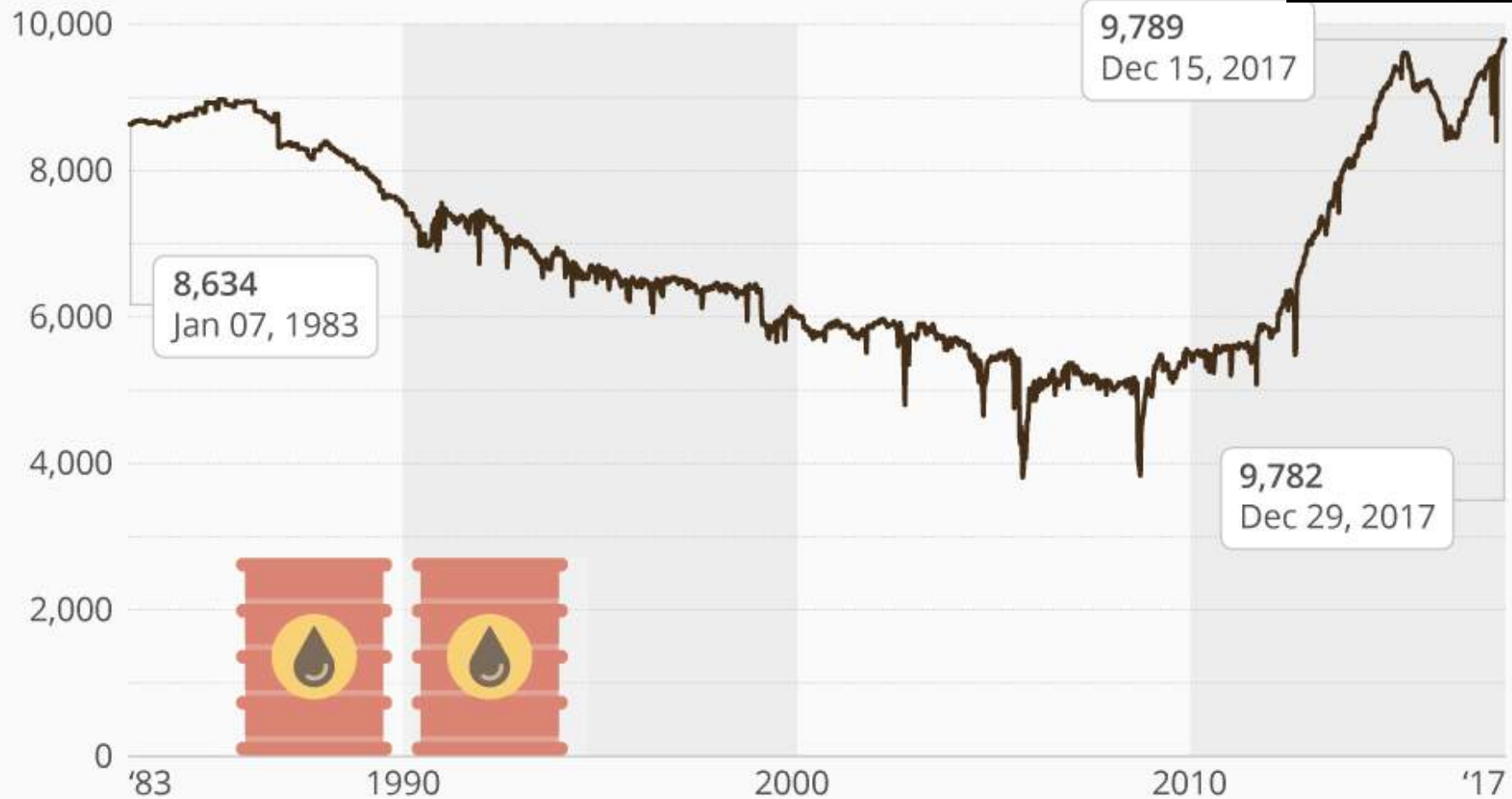


# Hydraulic fracturing



# U.S. Oil Production Heading for New Highs

Weekly U.S. field production of crude oil (thousand barrels per day)

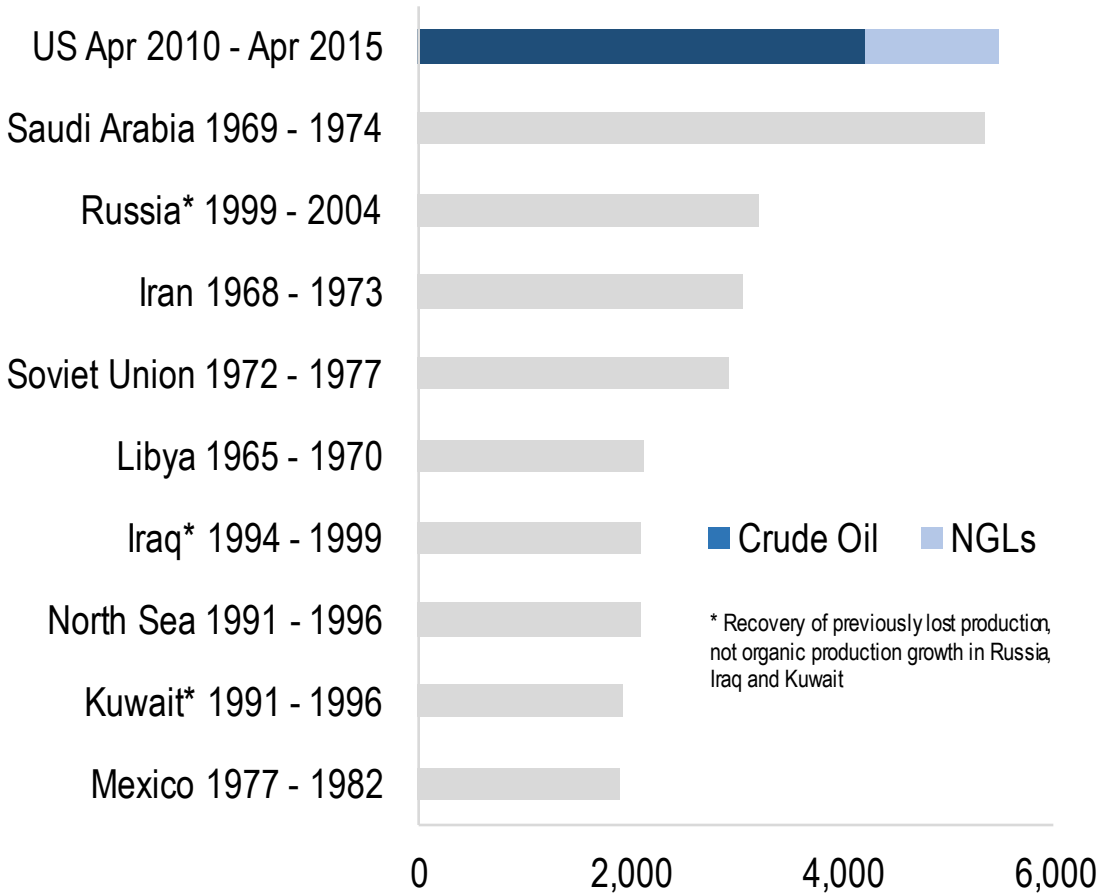


@StatistaCharts Source: U.S. Energy Information Administration



# Oil Production Growth

(thousand barrels per day)



\* Recovery of previously lost production, not organic production growth in Russia, Iraq and Kuwait

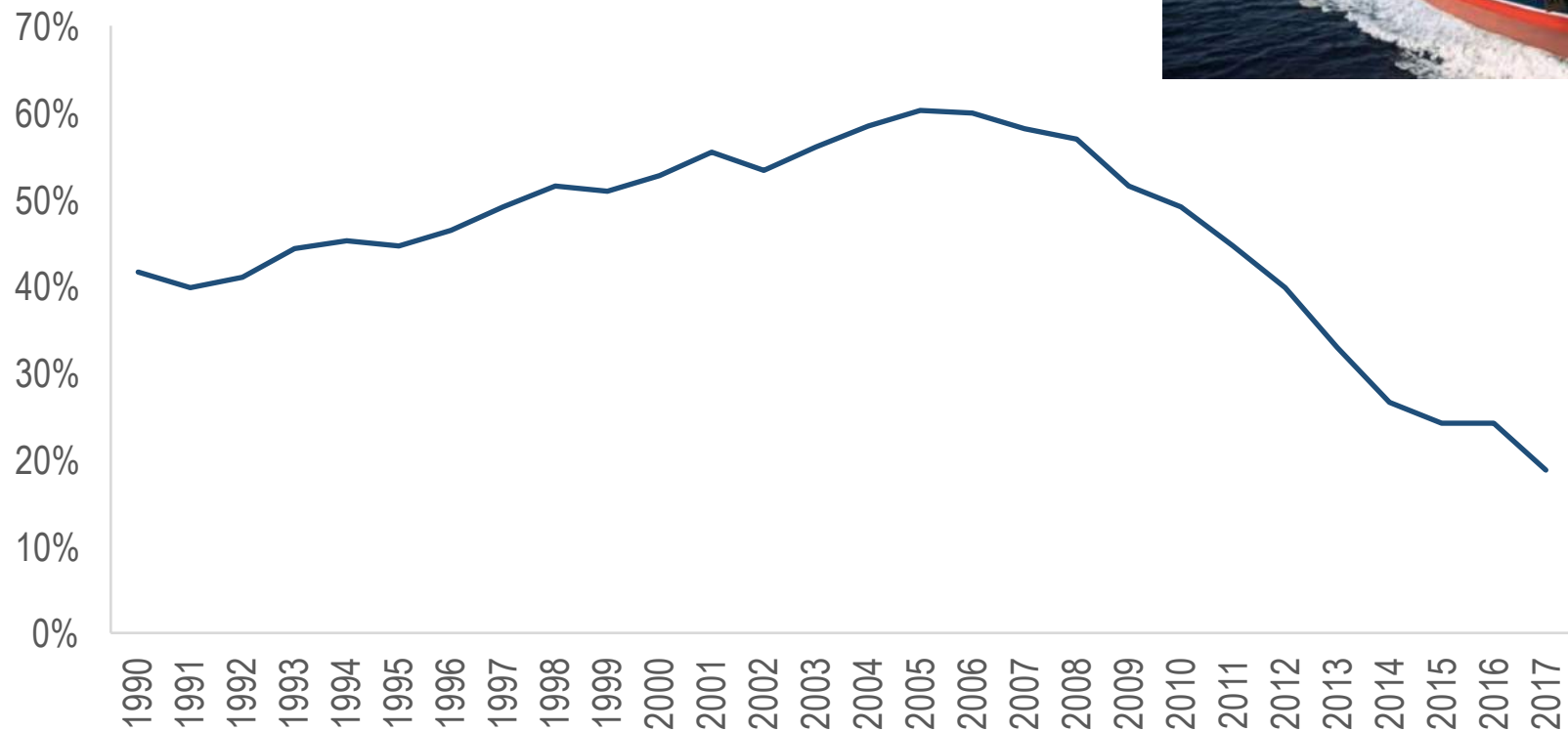
Source: BP Statistical Review, EIA





# US Oil Imports

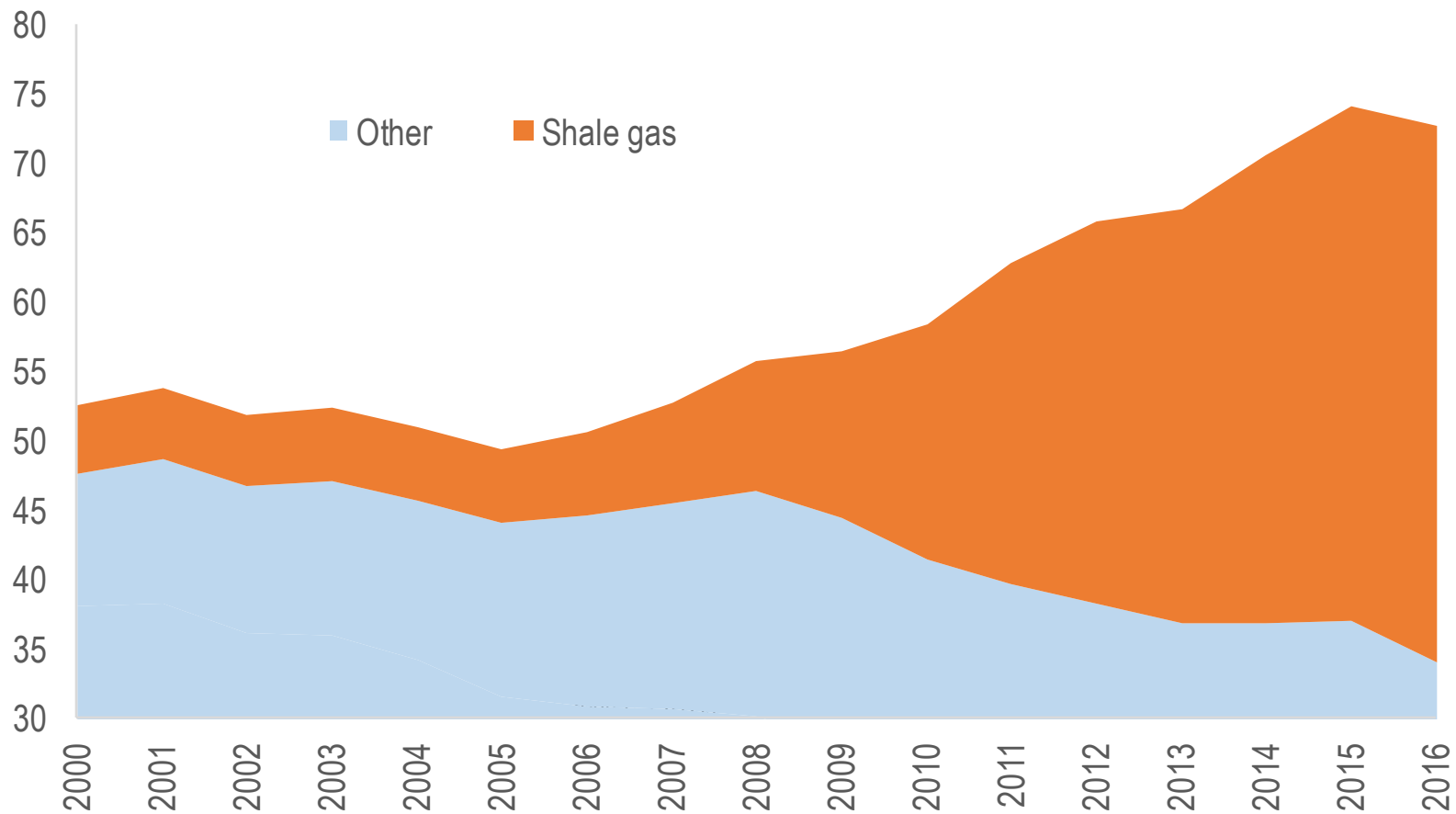
(percent of total consumption)



# US Natural Gas Production 2000-2016

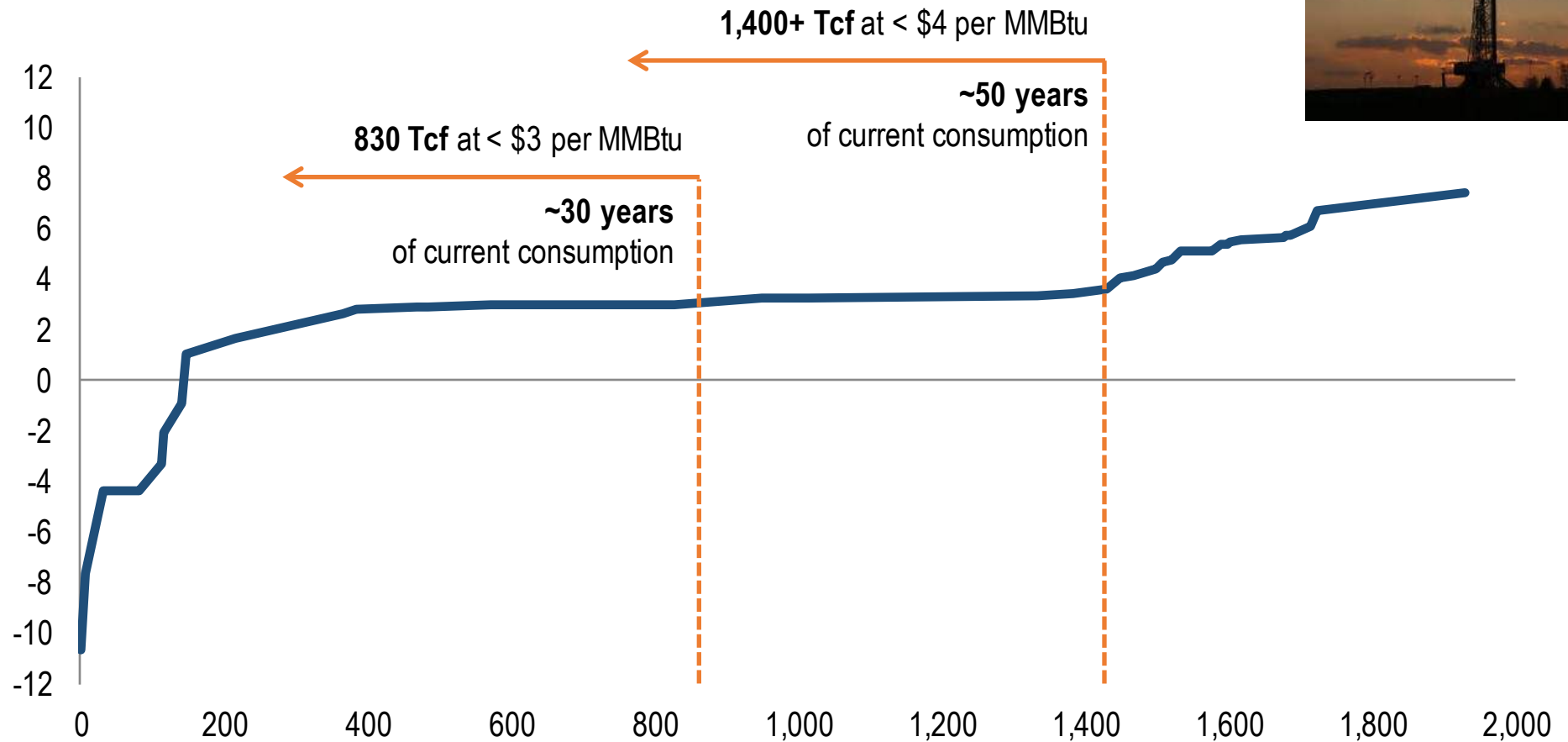


**US Dry Gas Production**  
Bcf/day



# US Shale Gas Resource Is Huge

**US Natural Gas Supply Curve, Henry Hub Breakeven Price**  
Trillion cubic feet, \$ per MMBtu



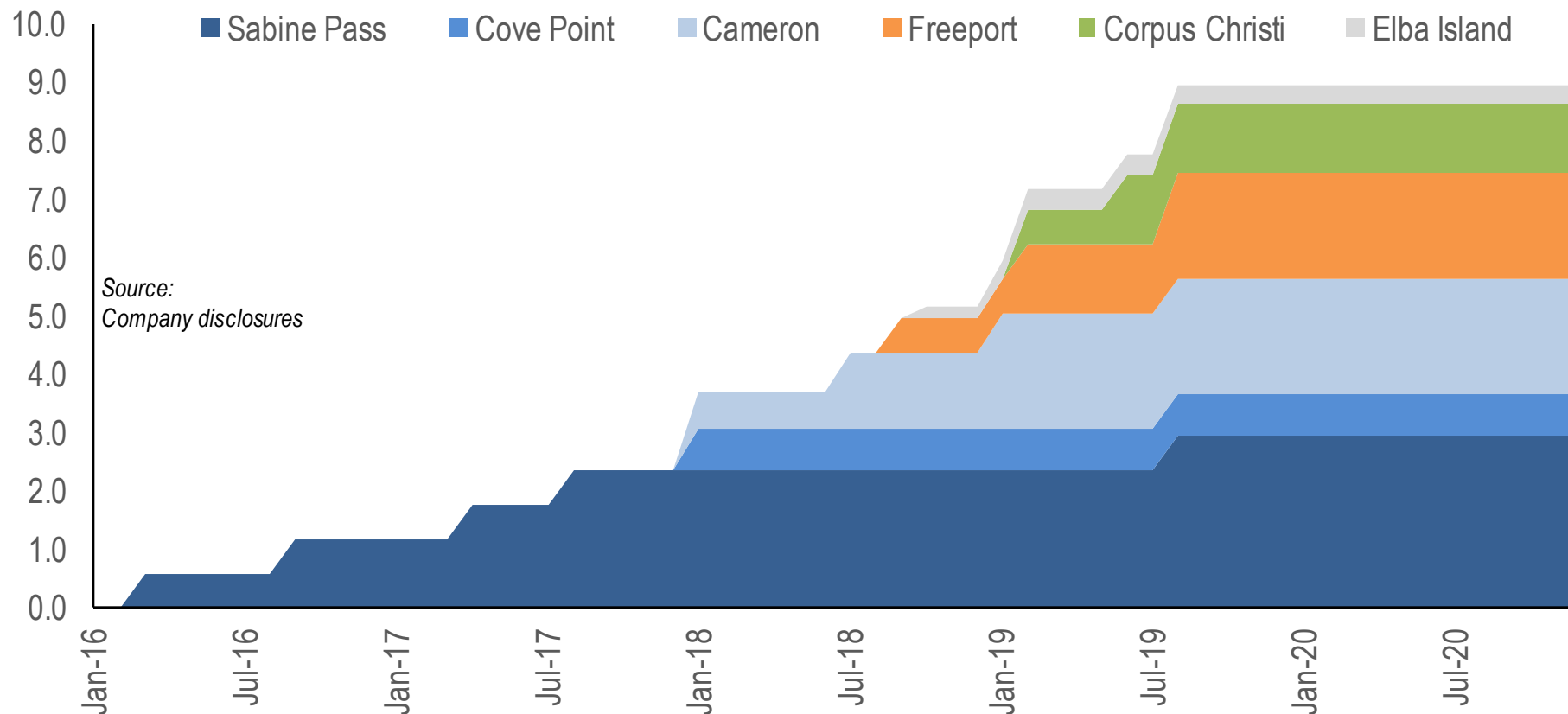
Source: IHS



# US LNG Export Capacity Growing

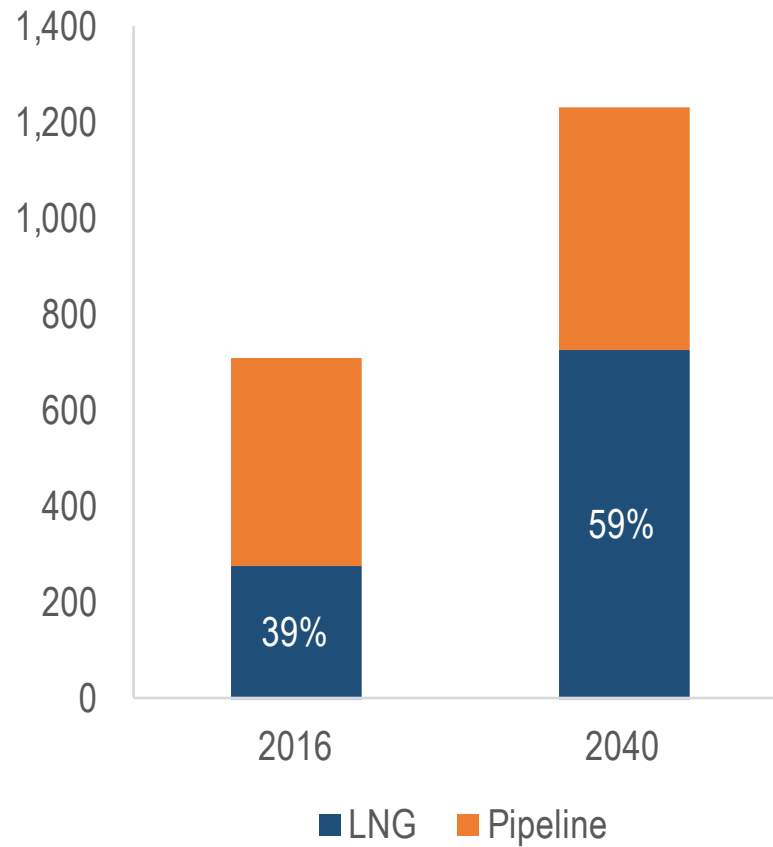
US LNG Export Capacity Under Construction, Commissioning, and in Operation

Bcf per day



# A Changing Global Gas Order

**Global Gas Trade by Mode**  
Billion cubic meters

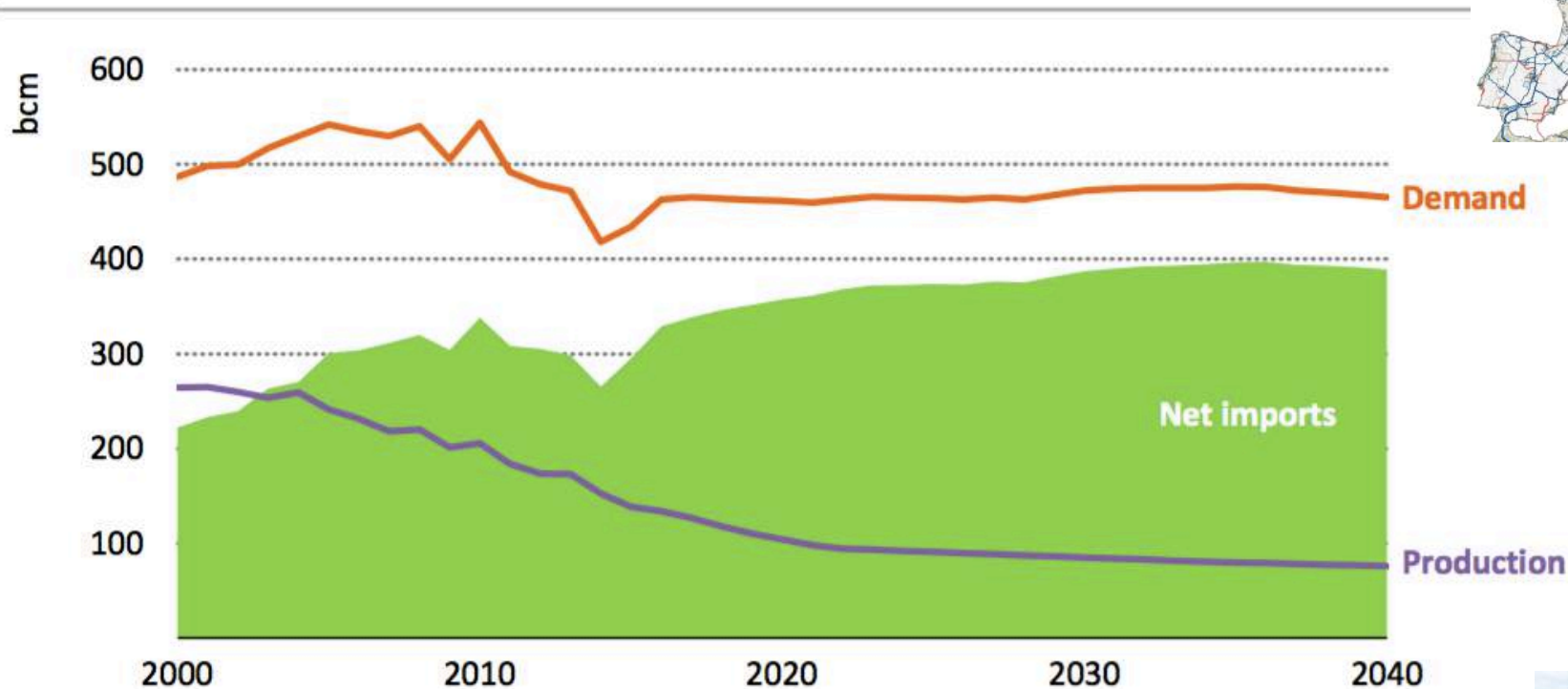


Source: IEA WEO 2017



# European Gas Imports Projected to Grow

**Figure 8.9** ▷ Natural gas balance of the European Union in the New Policies Scenario



*Even with a flat demand outlook, the European Union's gas imports increase to 2040 as domestic output continues to decline*



Source: IEA WEO 2017



# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

1. Renewable Energy Revolution
2. Shale Revolution
- 3. *Rise of China***



*View of Pudong, Shanghai (1983)*  
上海浦东 (1983年)

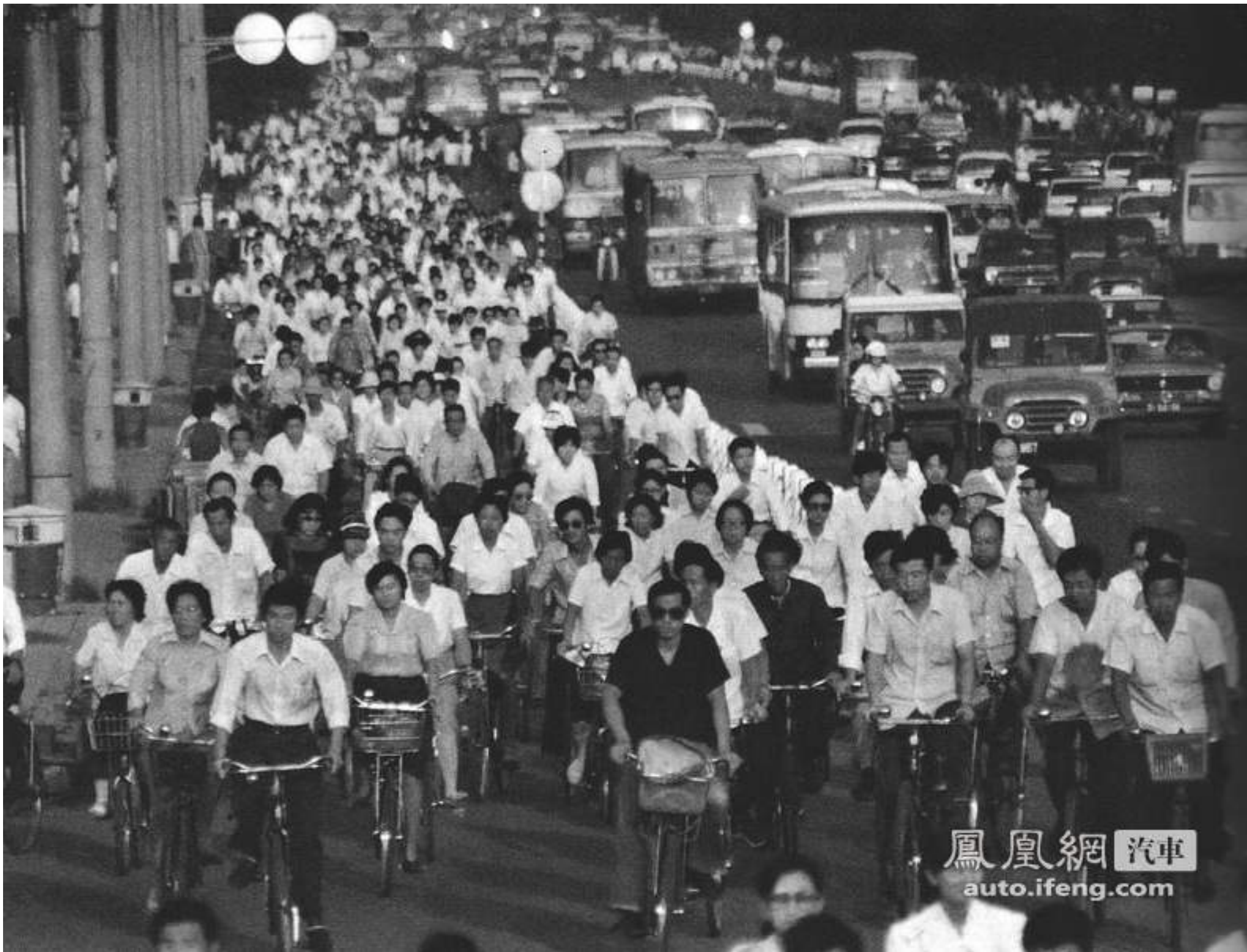




*View of Pudong, Shanghai*  
上海浦东

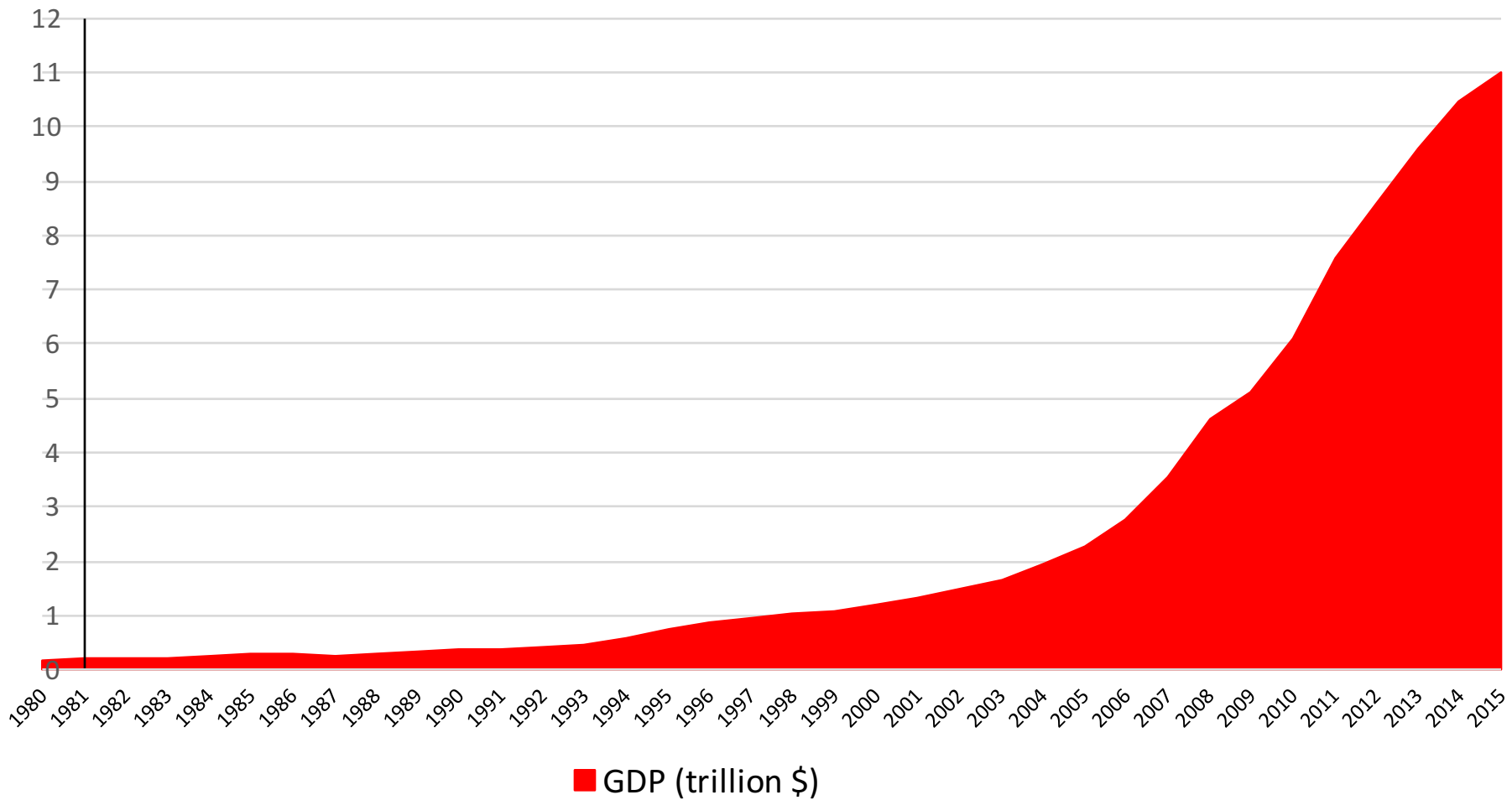








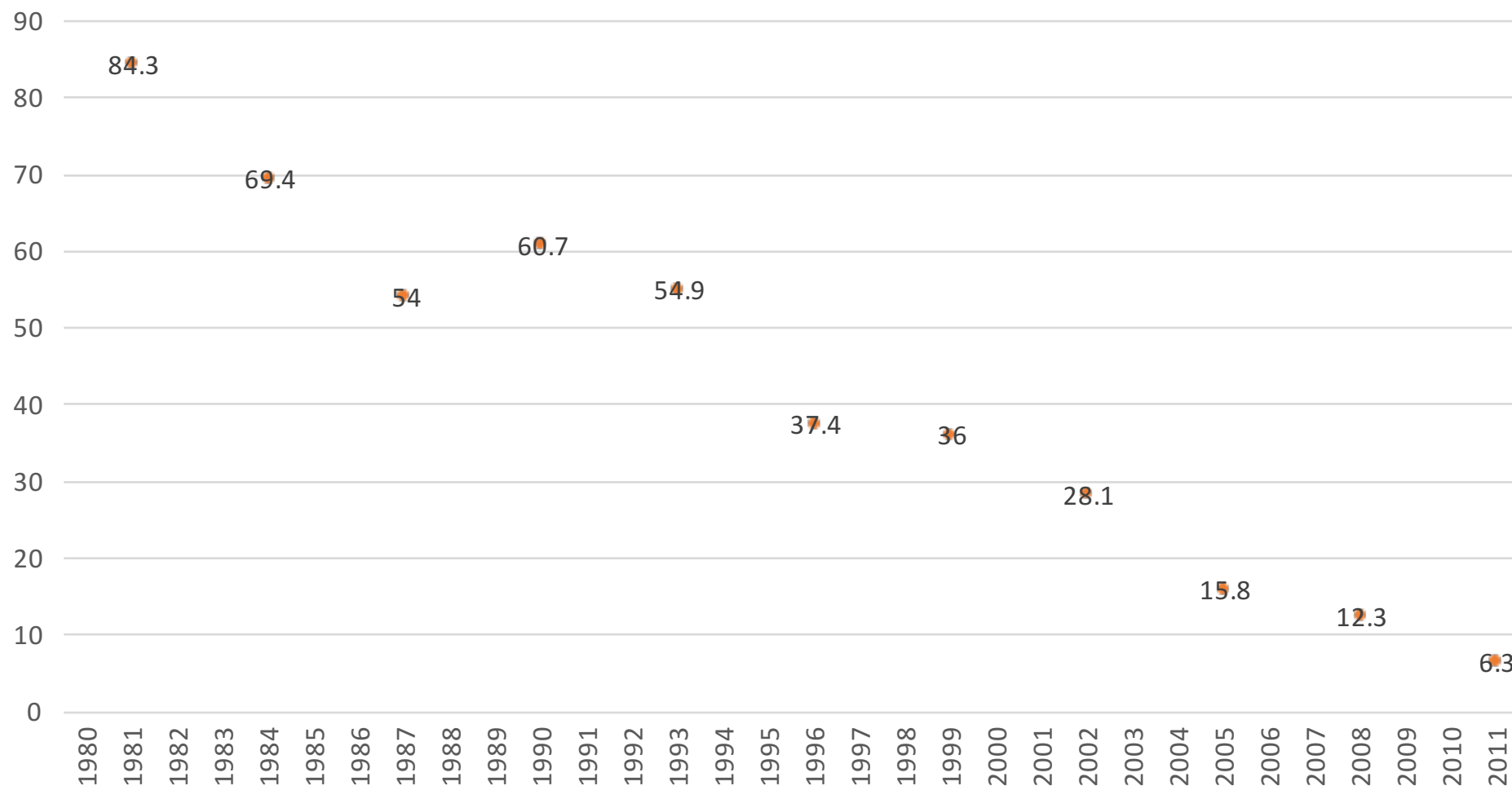
# China GDP 1980-2015



Source: World Bank Group



# China – Percent of Population Living on Less Than \$1.25 Per Day 1980-2013



Source: World Bank Group

# Tiananmen Square, Beijing

北京，天安门



Beijing Marathon October 2014  
北京马拉松，2014年10月

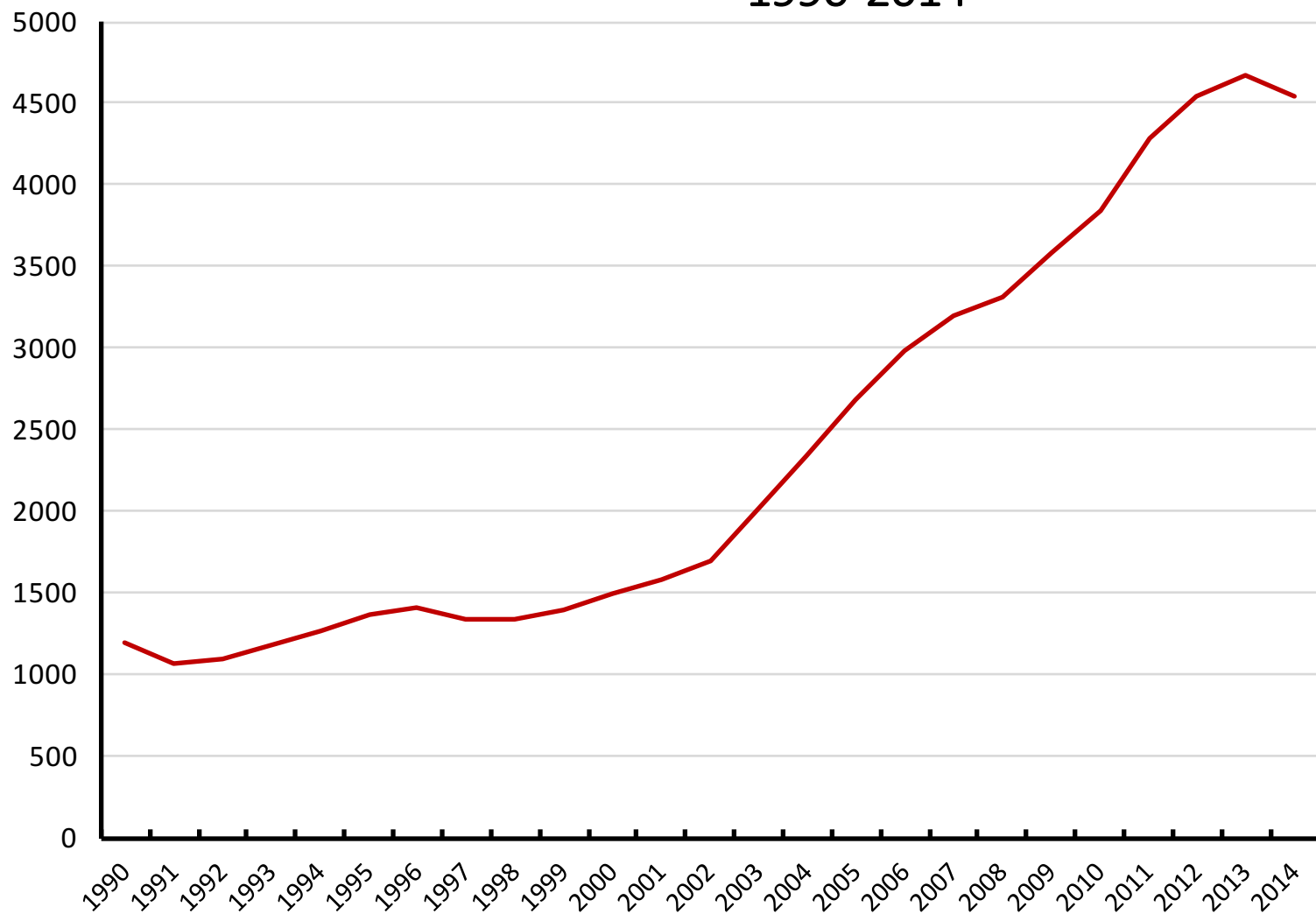






# Chinese Coal Consumption

1990-2014

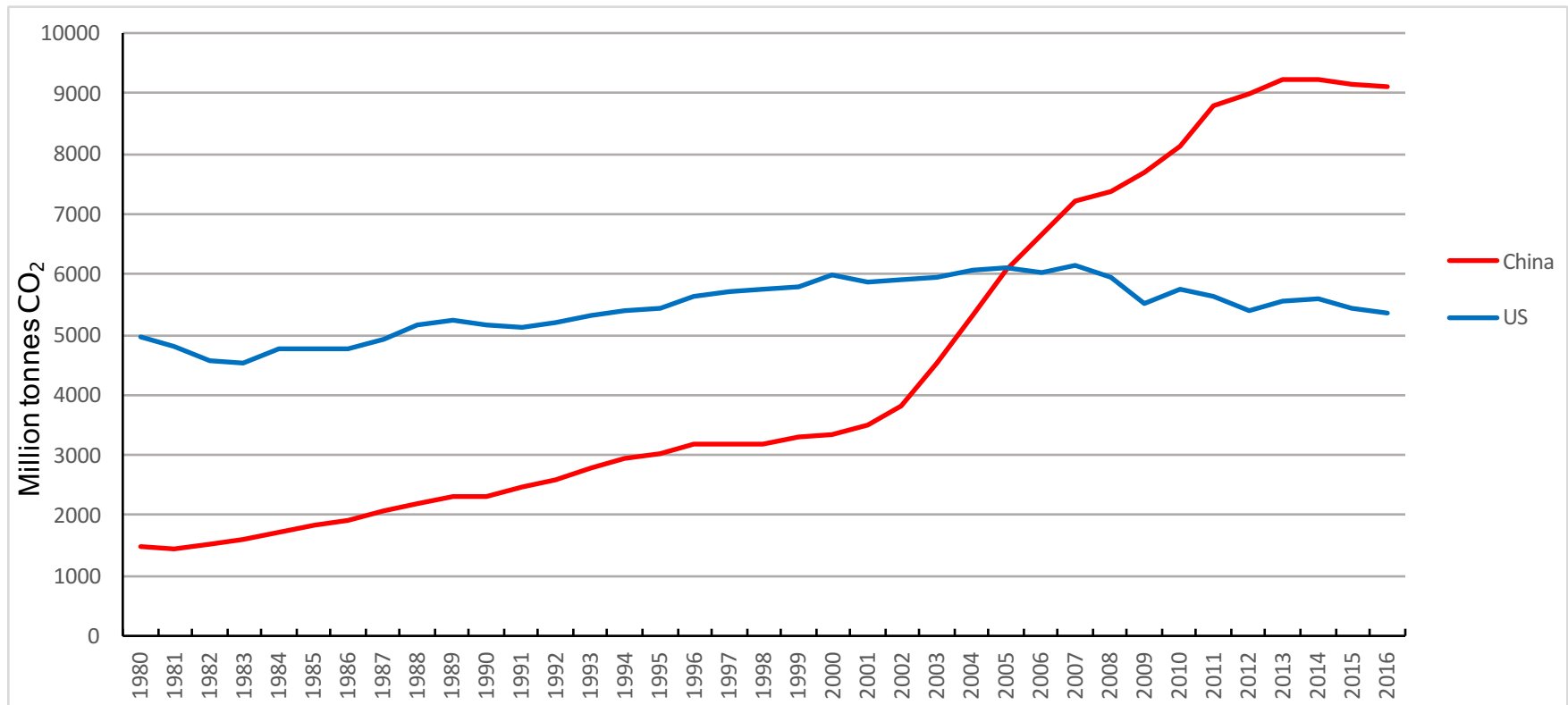


- million short tons

Source: U.S. Energy Information Administration



# CO<sub>2</sub> Emissions (1980-2016)

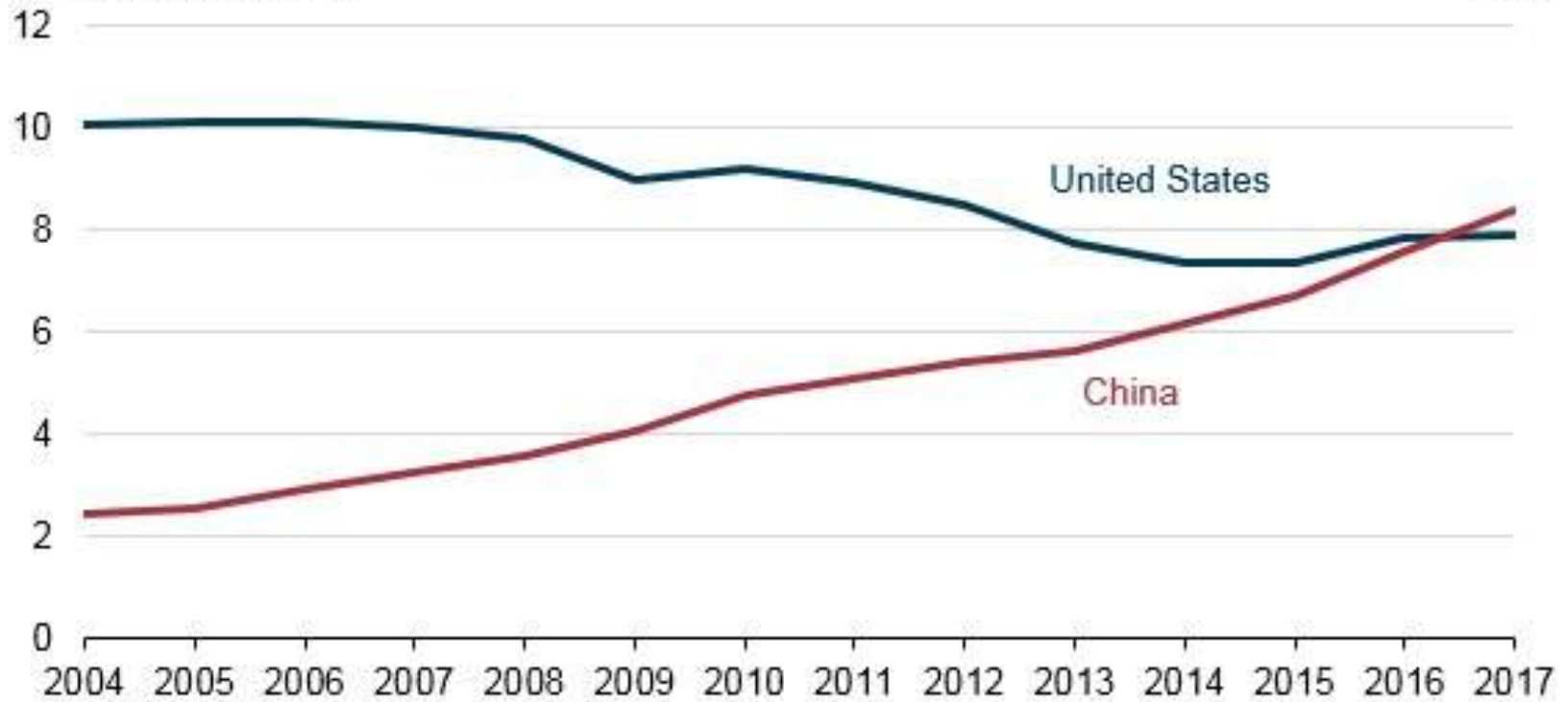


Source: BP Statistical Review of World Energy 2017

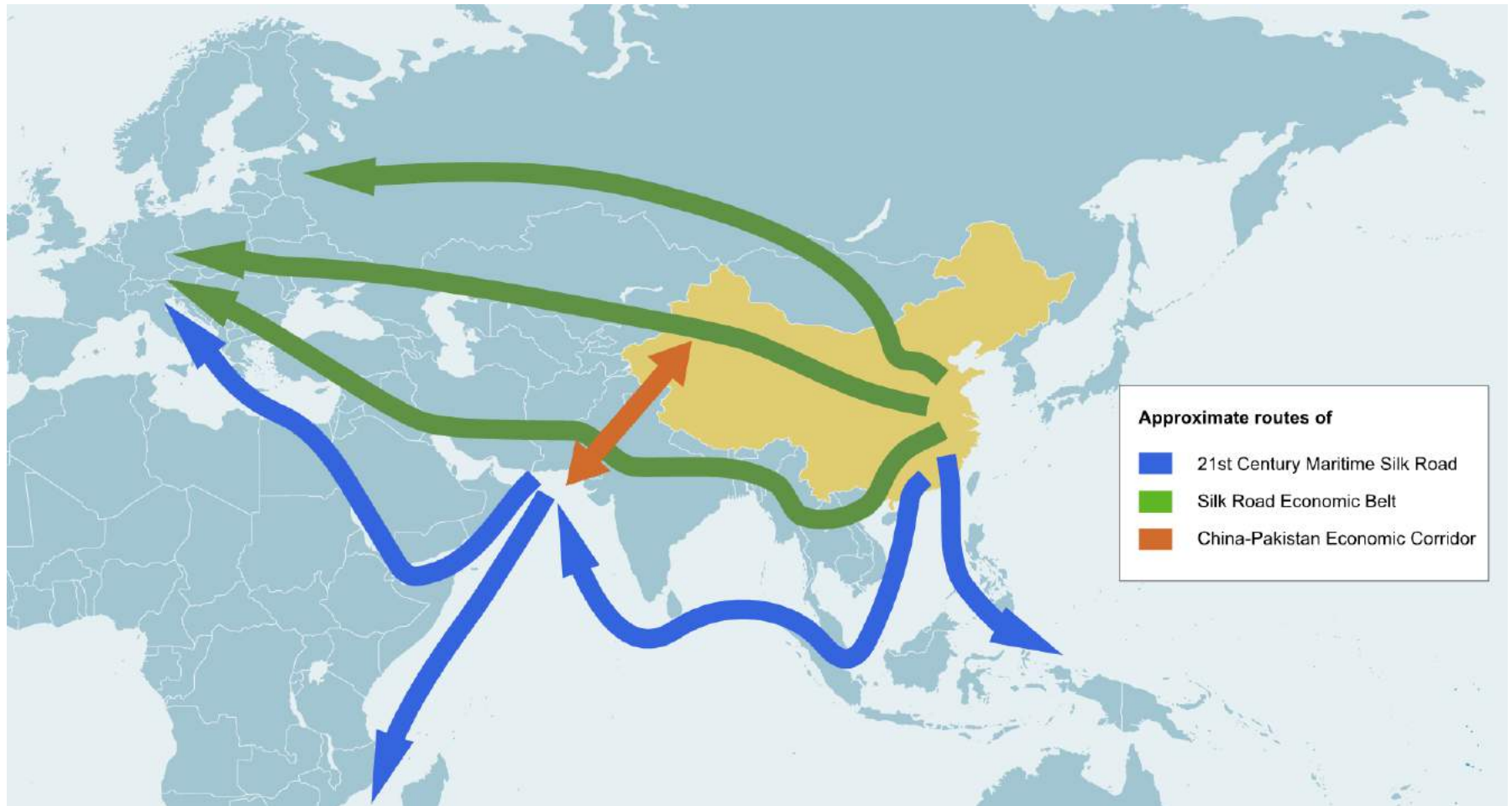
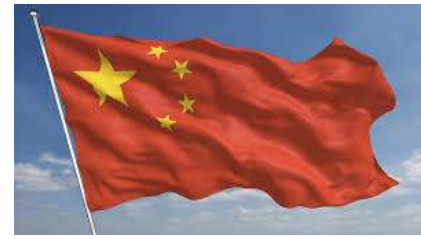
# Oil Imports



Annual U.S. and China gross crude oil imports (2004-2017)  
million barrels per day



# Belt and Road Initiative



# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

1. Renewable Energy Revolution
2. Shale Revolution
3. Rise of China

## ***4. Attack on Globalization***





# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

1. Renewable Energy Revolution
2. Shale Revolution
3. Rise of China
4. Attack on Globalization
- 5. *Saudi-Russia Rapprochement***







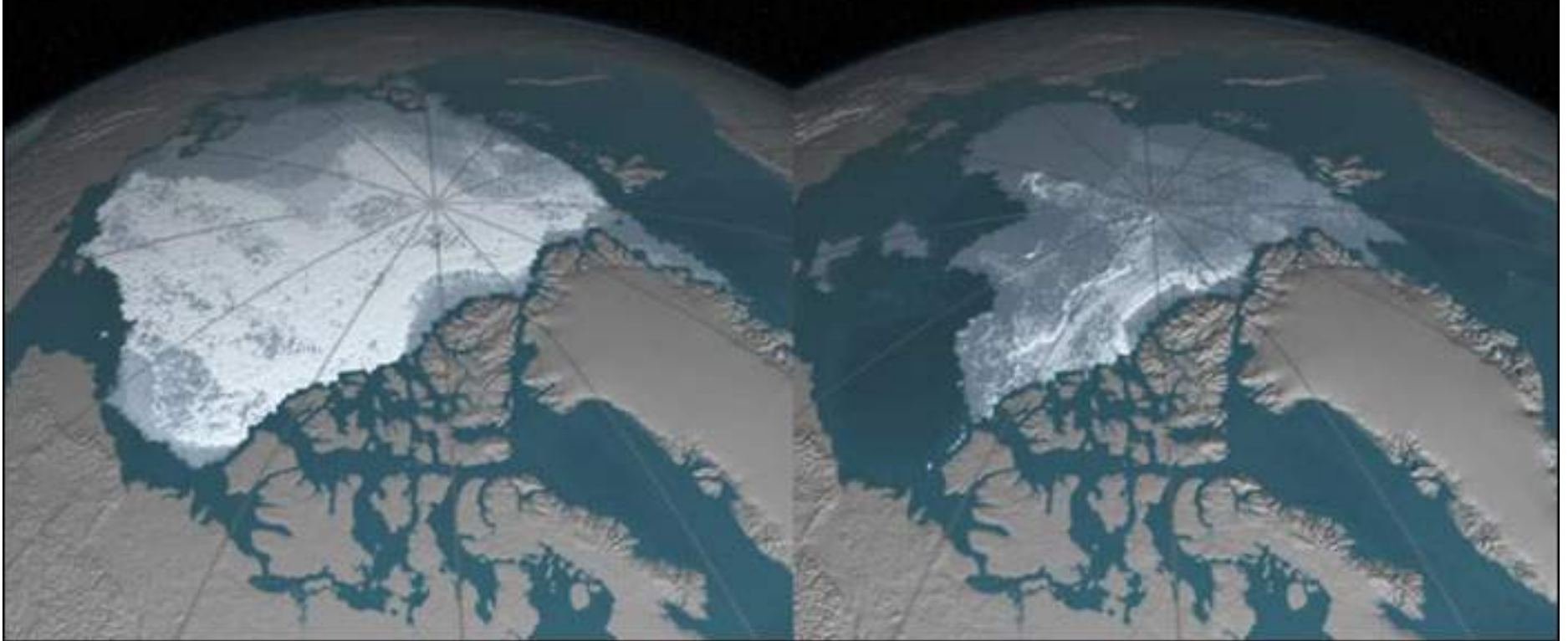
# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

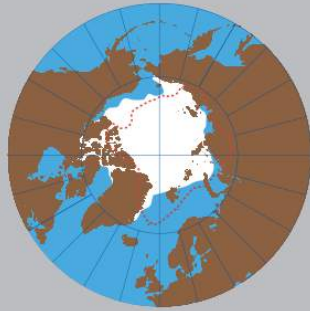
1. Renewable Energy Revolution
2. Shale Revolution
3. Rise of China
4. Attack on Globalization
5. Saudi-Russia Rapprochement
- 6. *Melting Arctic***



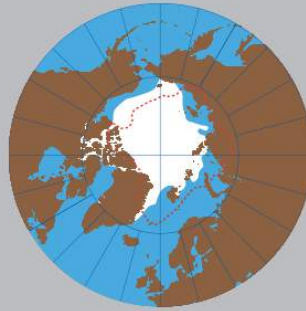
Sep 1984

Sep 2016

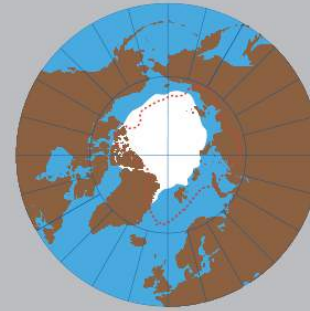




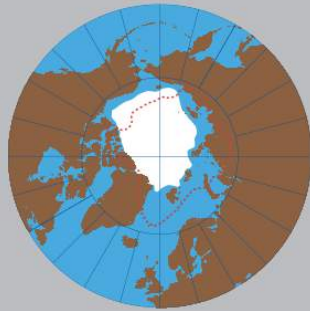
1979: 2.78 MILLION SQ. MI.



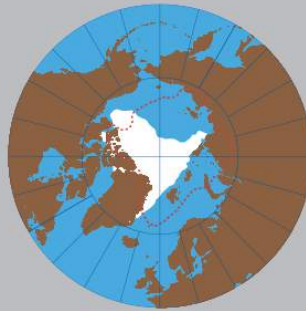
1982: 2.89 MILLION SQ. MI.



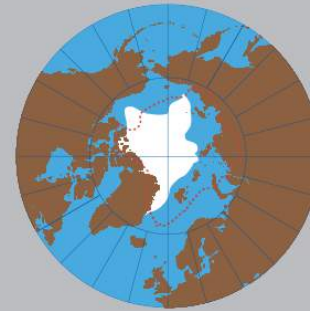
2000: 2.43 MILLION SQ. MI.



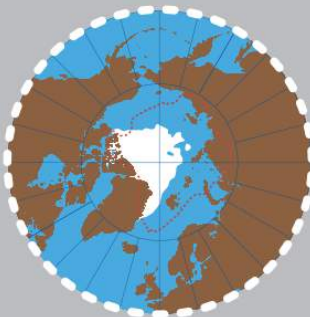
2006: 2.27 MILLION SQ. MI.



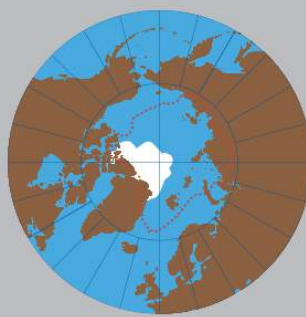
2007: 1.61 MILLION SQ. MI.



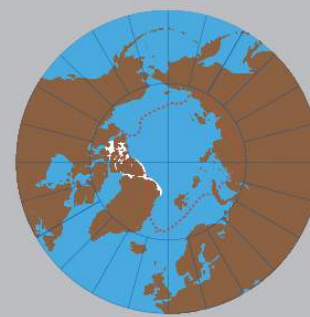
2011: 4.3 MILLION SQ. MI.



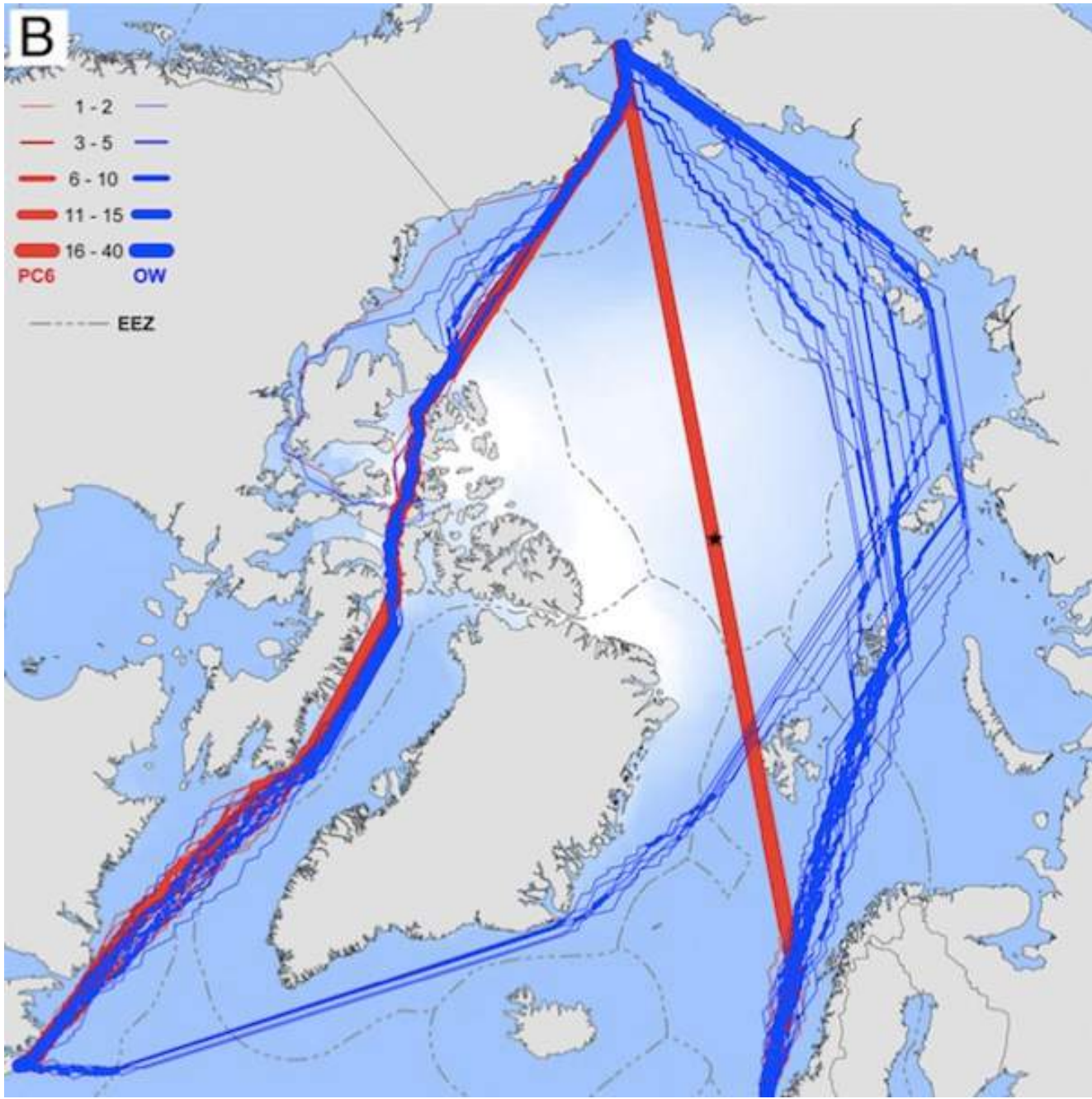
SUMMER 2012: 1.32 MILLION SQ. MI.



2015-2025



2025-2035: ARCTIC OCEAN  
COULD BE ICE-FREE IN SUMMER





# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

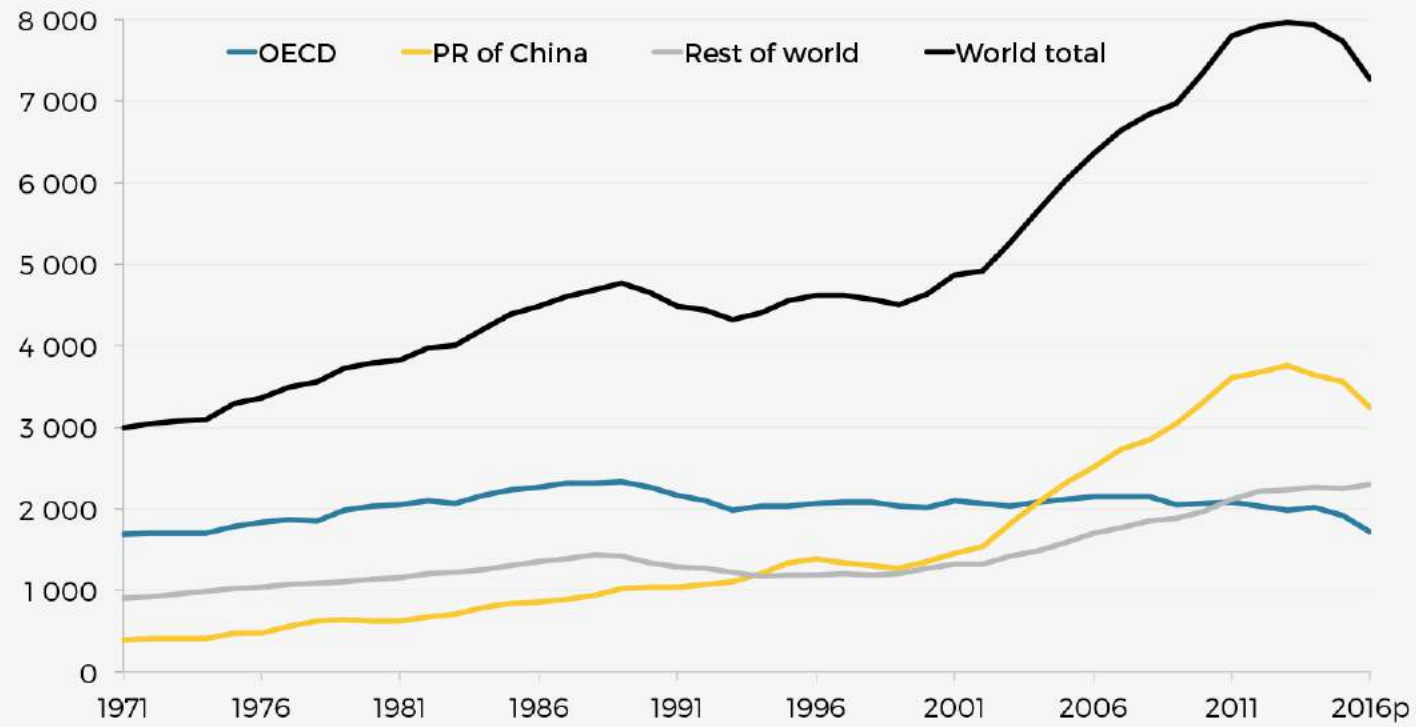
1. Renewable Energy Revolution
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5. Saudi-Russia Rapprochement
6. Melting Arctic
7. ***Coal – Plateau or Long Decline?***





## World total coal production (Mt)

Coal Information 2017

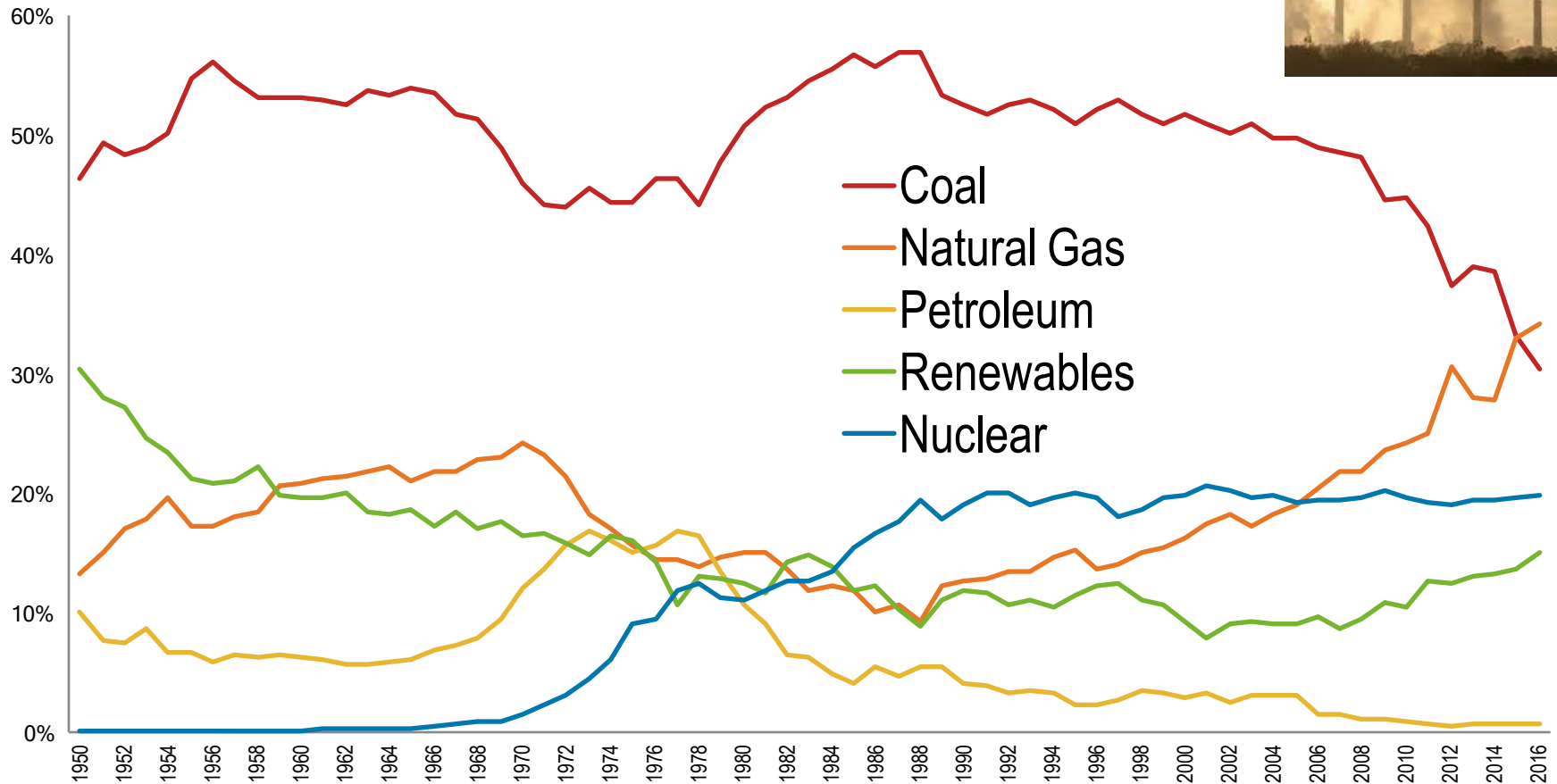




# US Power Generation by Fuel 1950-2016



Percent of Total

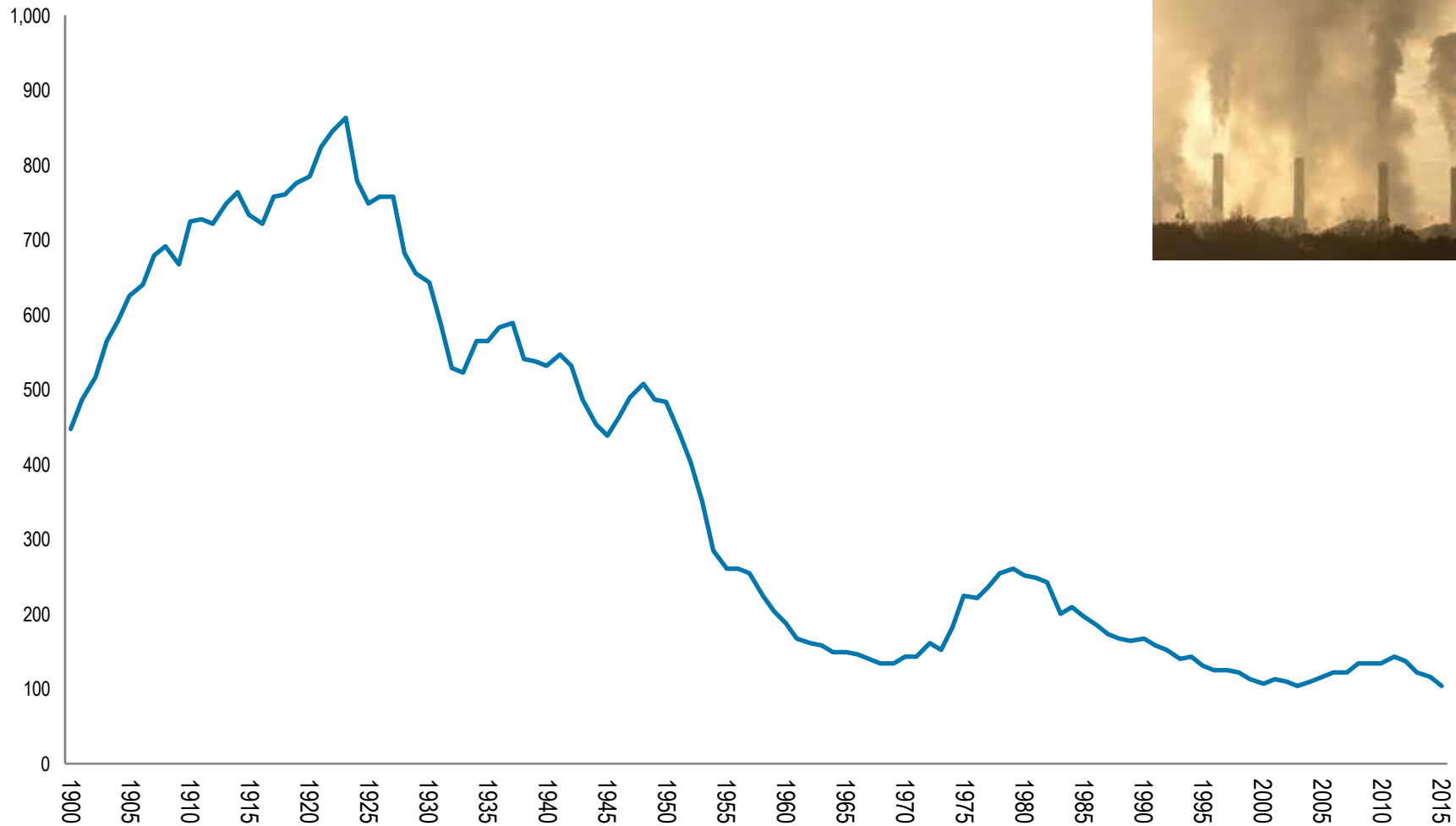


Source: Figure 11, EIA



# U.S. Coal Mining Employment 1900-2015

Thousand Miners

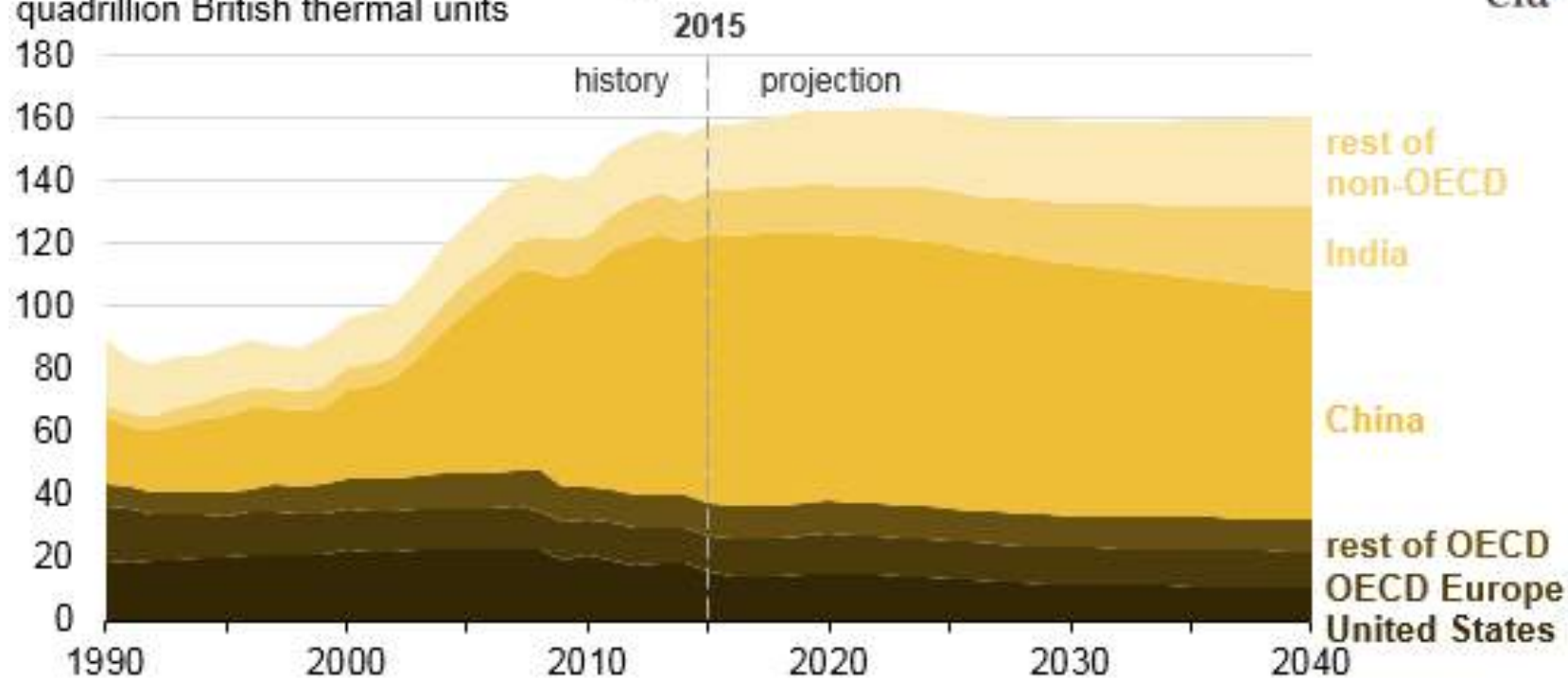


Source: Figure 2, Mine Safety and Health Administration, includes office workers starting in 1973



### World coal consumption (1990-2040)

quadrillion British thermal units



# MIAMI



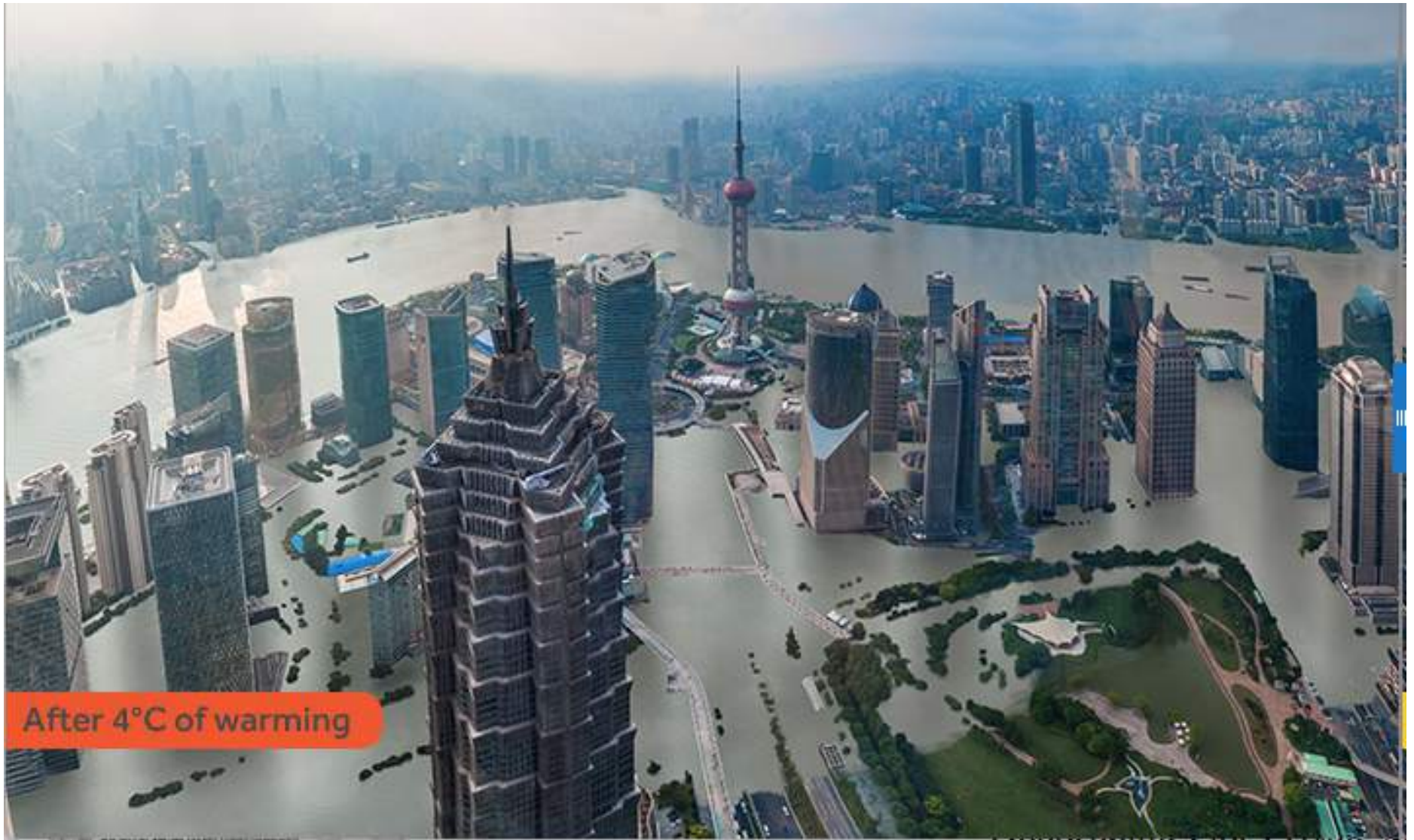
# MIAMI



After 4°C of warming



After 2°C of warming



After 4°C of warming





# ENERGY TECHNOLOGY AND GEOPOLITCS -- EIGHT TRENDS

1. Renewable Energy Revolution
2. Shale Revolution
3. Rise of China
4. Attack on Globalization
5. Saudi-Russia Rapprochement
6. Melting Arctic
7. Coal – Plateau or Long Decline?
- 8. *Transportation Revolution***



# TRANSPORTATION REVOLUTION

- Ride Sharing
- Electric Vehicles
- Autonomy







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*View of Pudong, Shanghai (1983)*  
上海浦东 (1983年)



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