

IPAA
March, 2021

CRITICAL THINKING FOR EQUITABLE ENERGY



Scott W. Tinker





Environment

And

Energy

And

Economy

Climate Change

Education

Energy

Gender Equality

Healthcare

Housing

Hunger

Immigration

Land, Air, Water

Population

War

WE WANT ENERGY TO BE

CHEAP

RELIABLE

CLEAN

ENERGY

Economy

Energy

Environment

CHEAP

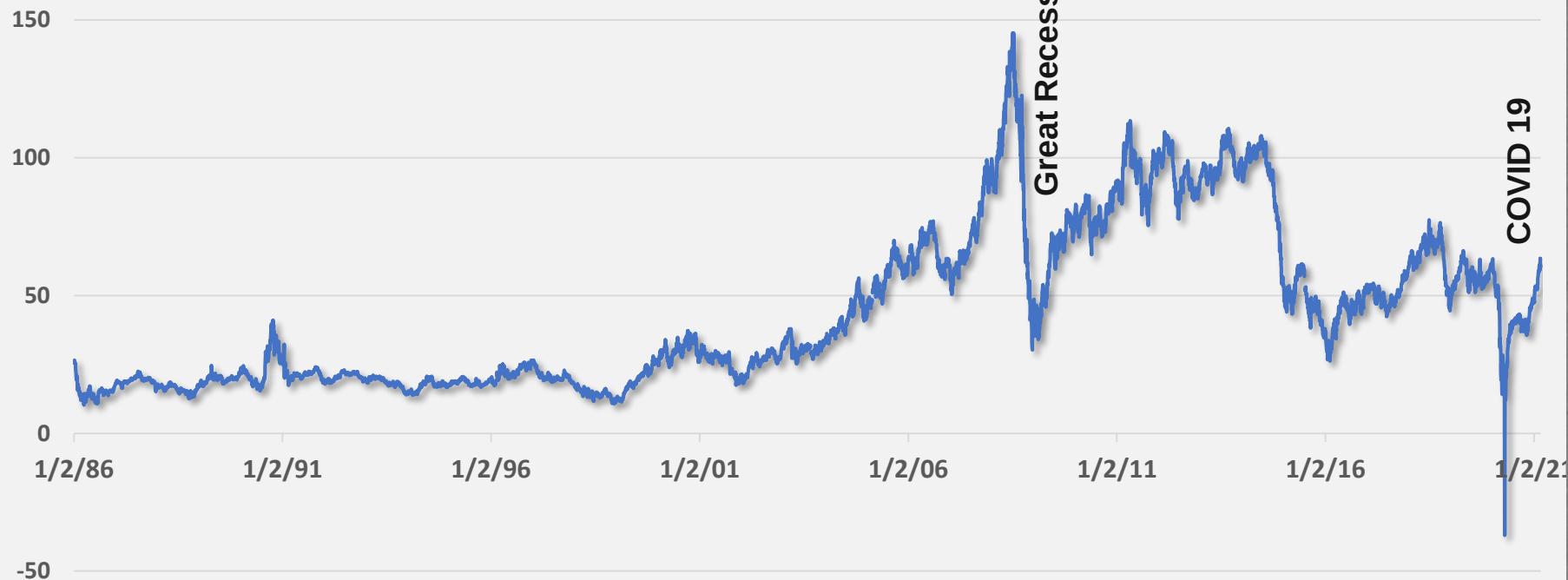
✓ PRICE VOLATILITY

✓ AFFORDABLE TO THE CUSTOMER

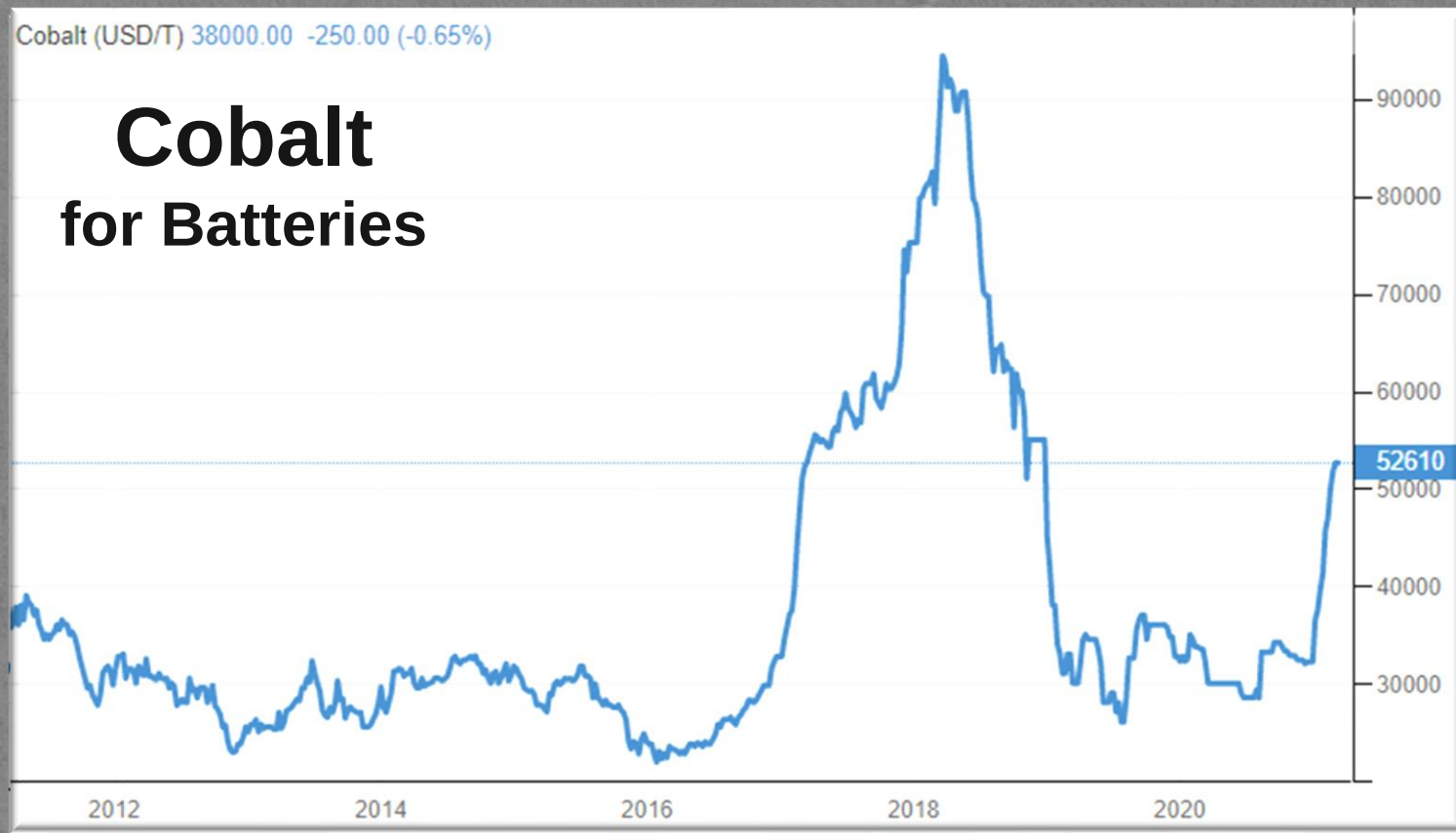
VOLATILITY

WTI Spot Price

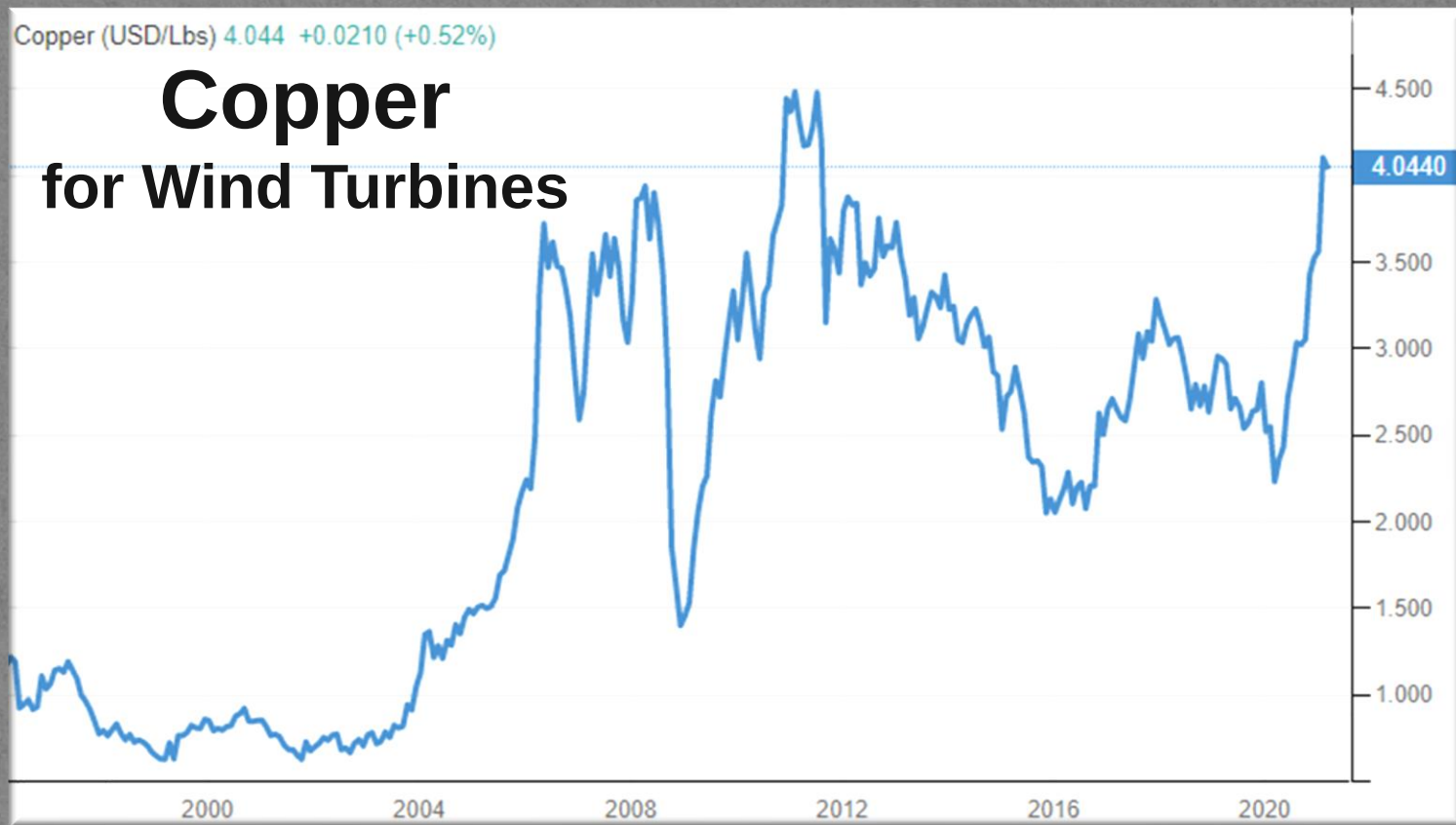
Dollars per Barrel



VOLATILITY



VOLATILITY



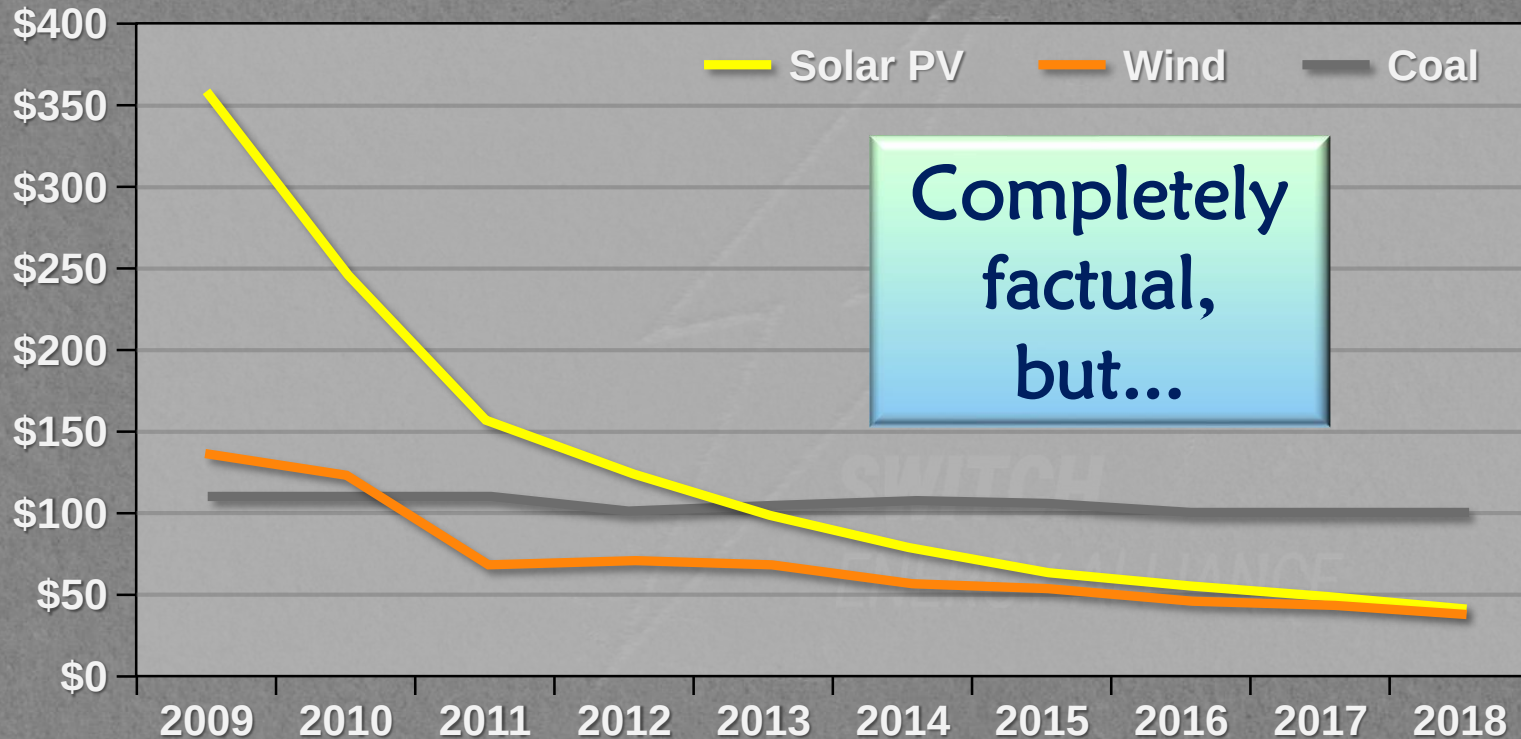
CHEAP

✓ PRICE VOLATILITY

✓ AFFORDABLE TO THE CUSTOMER

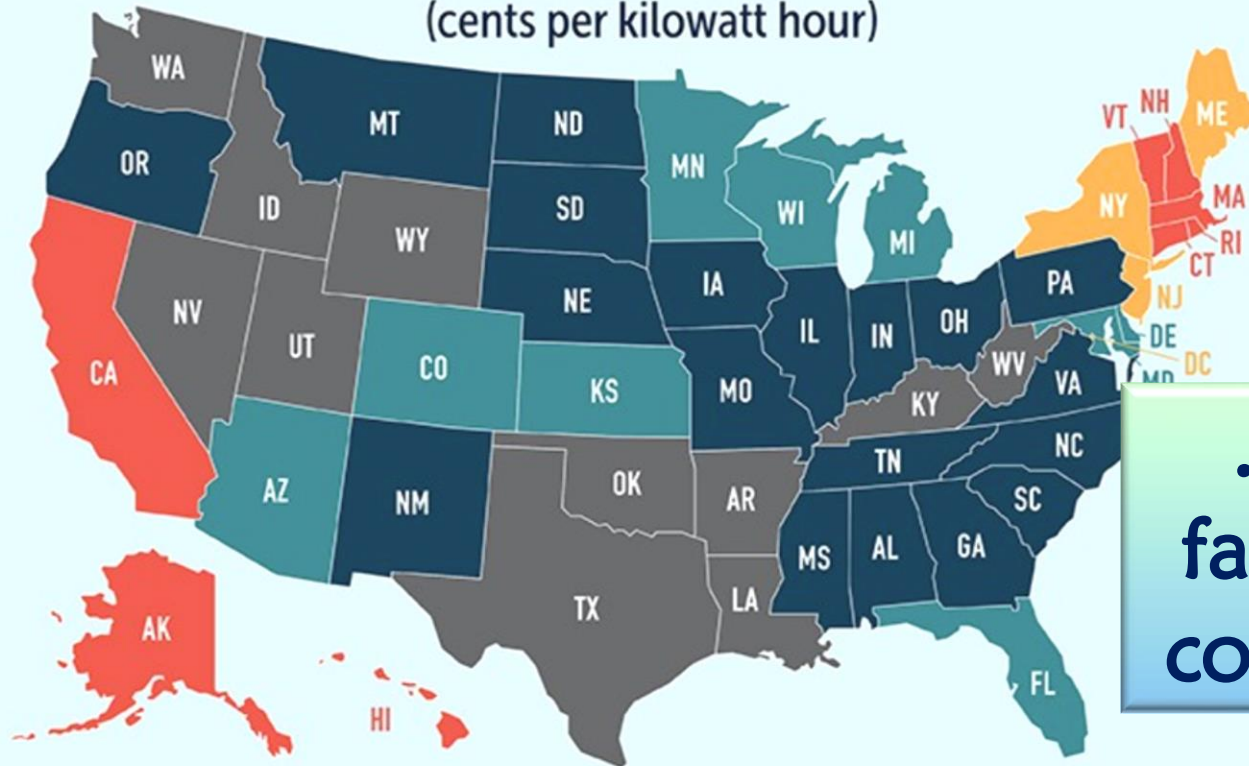
LCOE of Utility-Scale Generation

Mean LCOE \$/MWh



2019 U.S. Average Electricity Retail Prices

(cents per kilowatt hour)



...not
factually
complete

<https://www.globalenergyinstitute.org/average-electricity-retail-prices-map#>

COST OF INTERMITTENCY

Requires Backup to be Reliable

- ✓ Load Following Plants: *Cost*
- ✓ Storage: *Scale*
- ✓ Renewable Dispersion: *Area of Access*
- ✓ Combining Sources: *Timing*

COST OF INTERMITTENCY

Intermittent Solar and Wind require expensive backup to make them **Reliable**, and that makes them more expensive to the Consumer (“CCOE”).

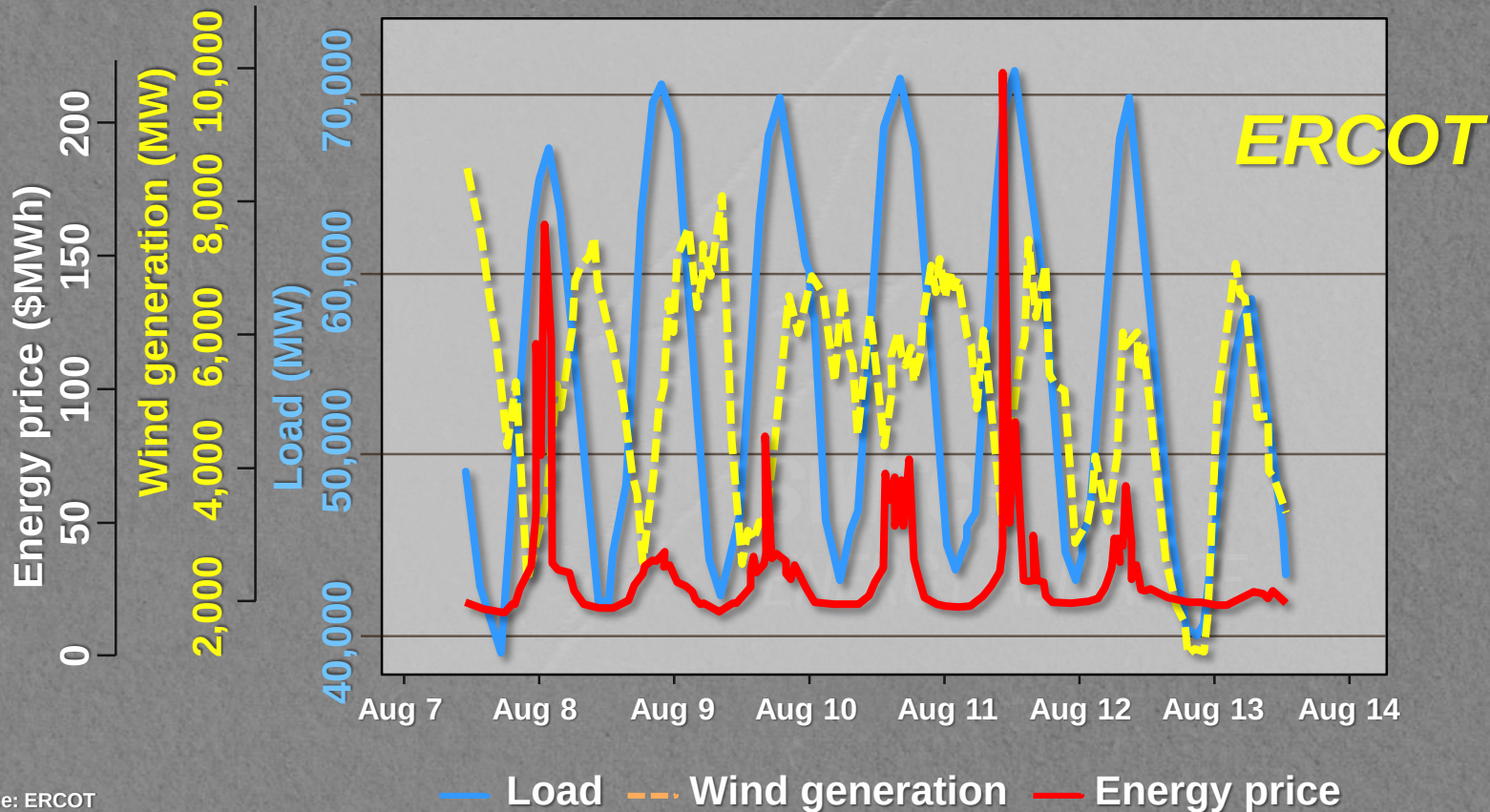
RELIABLE

✓ INTERMITTENT

✓ AVAILABLE 24/7/365 (AT WHAT COST?)

The Demand Curve

Load, Wind Generation, and Energy Prices



The Demand Curve

Load, Wind Generation, and Energy Prices

Balancing demand and supply requires a *portfolio* of generation options in order to be **Reliable**.

RELIABLE

✓ INTERMITTENT

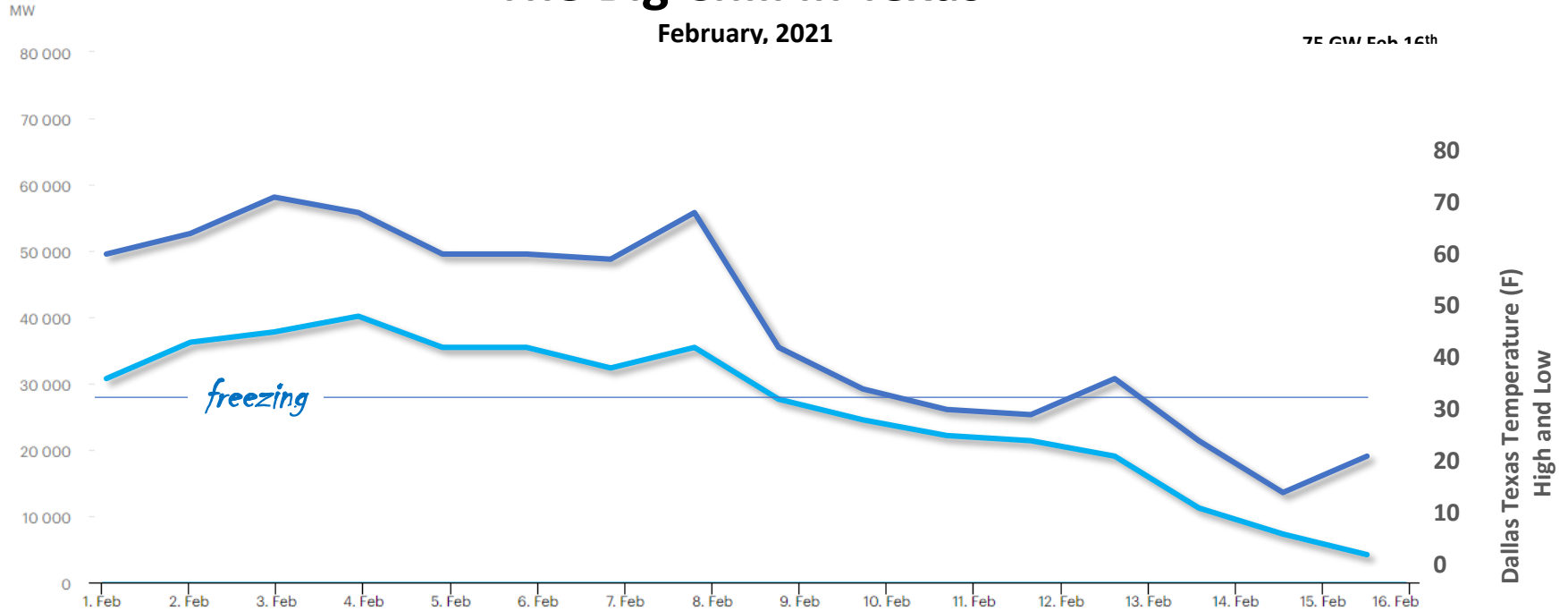
✓ AVAILABLE 24/7/365 (AT WHAT COST?)

The Big Chill in Texas

Tinker, 2021

February, 2021

75 GW Feb 16th



Electricity Graph, IEA

Temperature Data: <https://www.accuweather.com/en/us/dallas/75202/february-weather/351194>

¹ U.S. Energy Information Administration ERCOT demand forecast peak of 75 GW

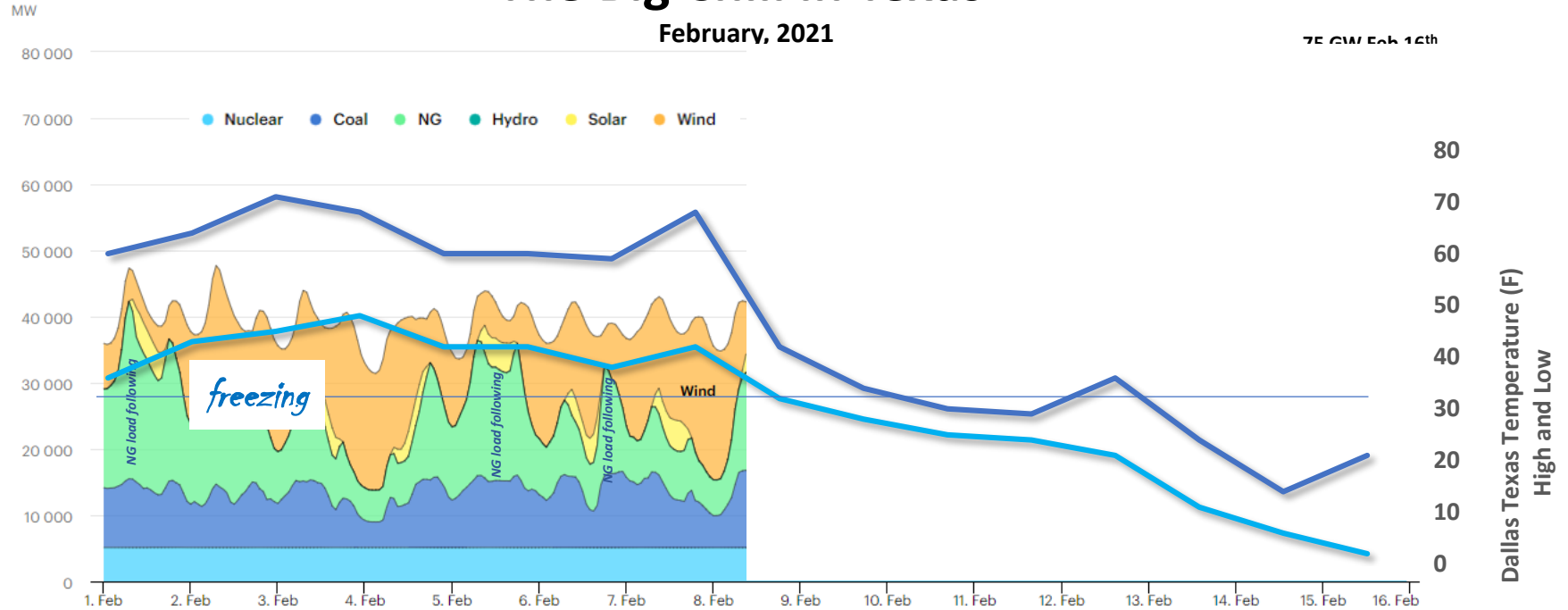
² North American Electric Reliability Corp. [predicted](#) winter extreme weather event demand peak in ERCOT

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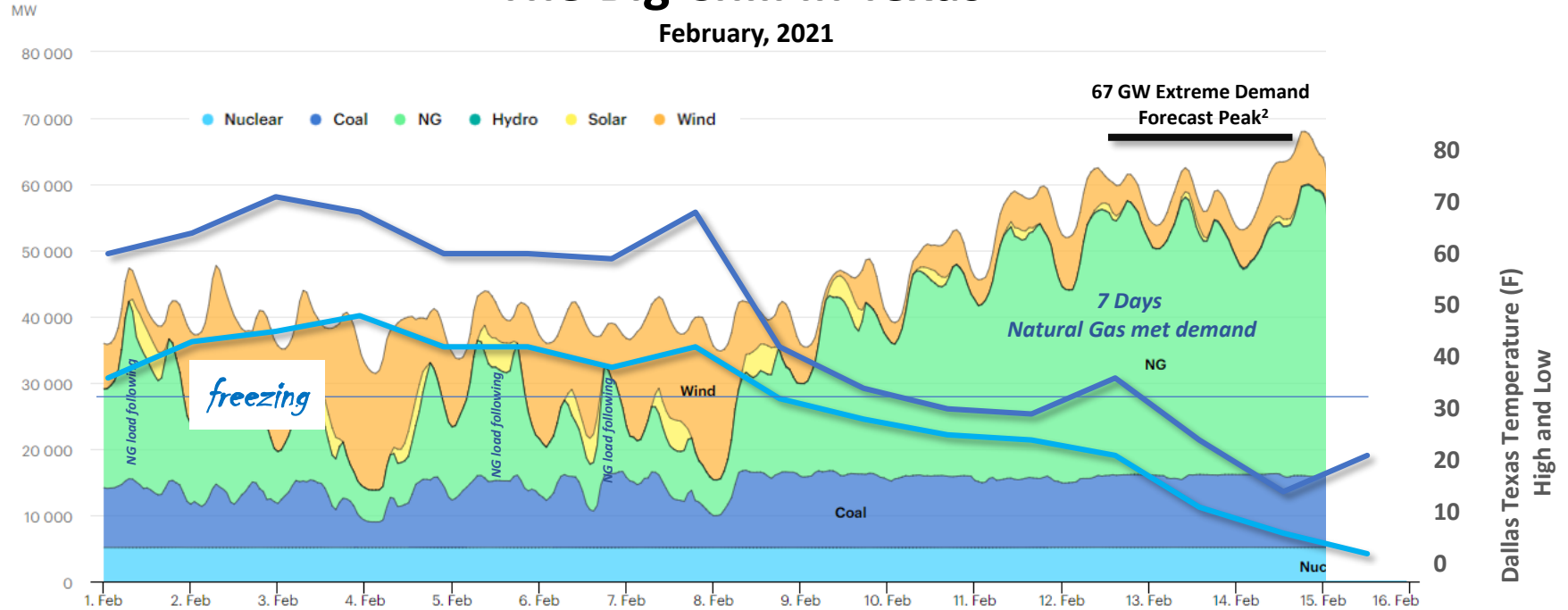
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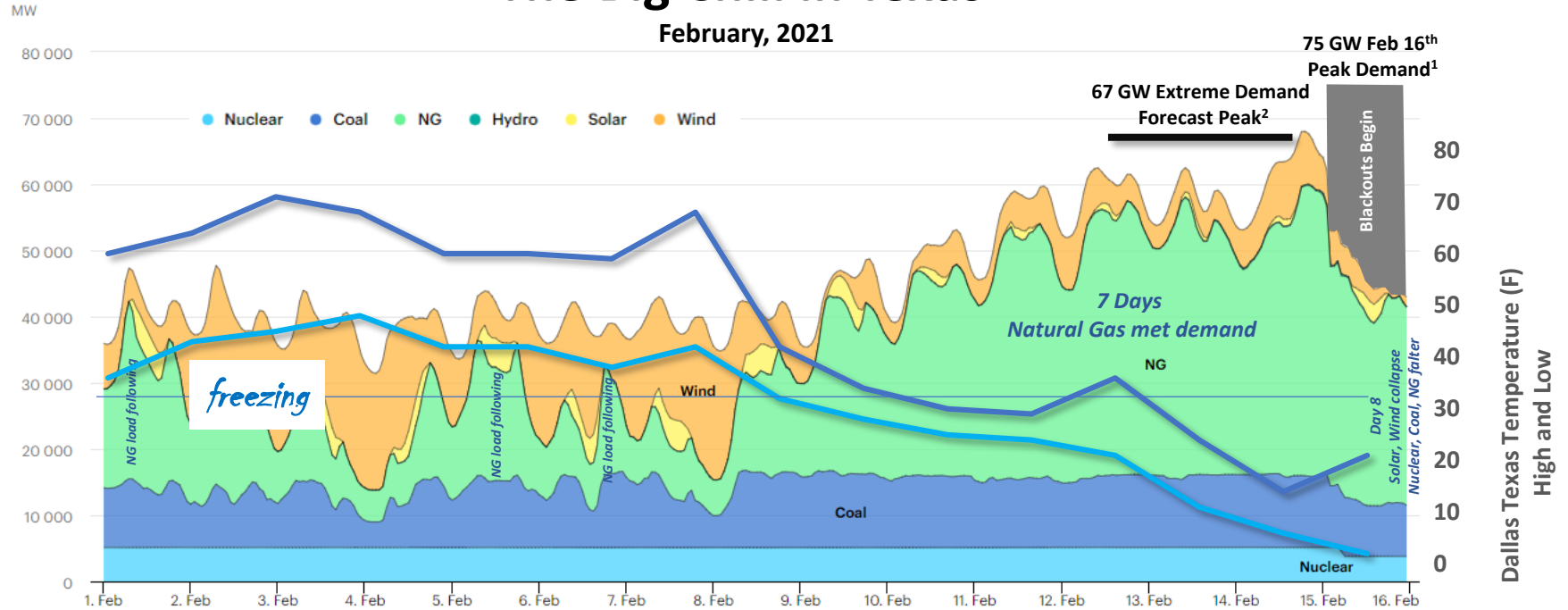
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"Natural gas is the culprit"

"Solar and wind tanked"

"Isolated grid"

"ERCOT and planning"

"Energy market vs. Capacity market"

"Resiliency of equipment"

"Cost to upgrade"

"Climate change"

Unlimited supply of Finger Pointing!

Should the freeze Event cause permanent change?

CLEAN

- ✓ CO₂ EMISSIONS
- ✓ LOCAL AIR

~2.6 Billion people cook indoors with wood, dung, charcoal and other biomass. Smoke kills ~ 3 million/year



CLEAN

- ✓ CO₂ EMISSIONS
- ✓ LOCAL AIR
- ✓ LAND
- ✓ WATER



Poor economies have
poor air, land and water.



STAGE OF ECONOMY

CHEAP *EMERGING*

RELIABLE *DEVELOPING*

CLEAN *DEVELOPED*



Global Income

<\$1000/yr

LOW INCOME LEVEL
\$995 or less a year



100 1,000 10,000
People per square mile

EMERGING

\$1k to \$4k/yr

LOWER MIDDLE
\$996 to \$3,945



100 1,000 10,000
People per square mile

DEVELOPING

\$4k to \$12k/yr

UPPER MIDDLE
\$3,946 to \$12,195

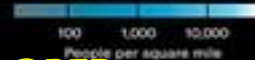


100 1,000 10,000
People per square mile

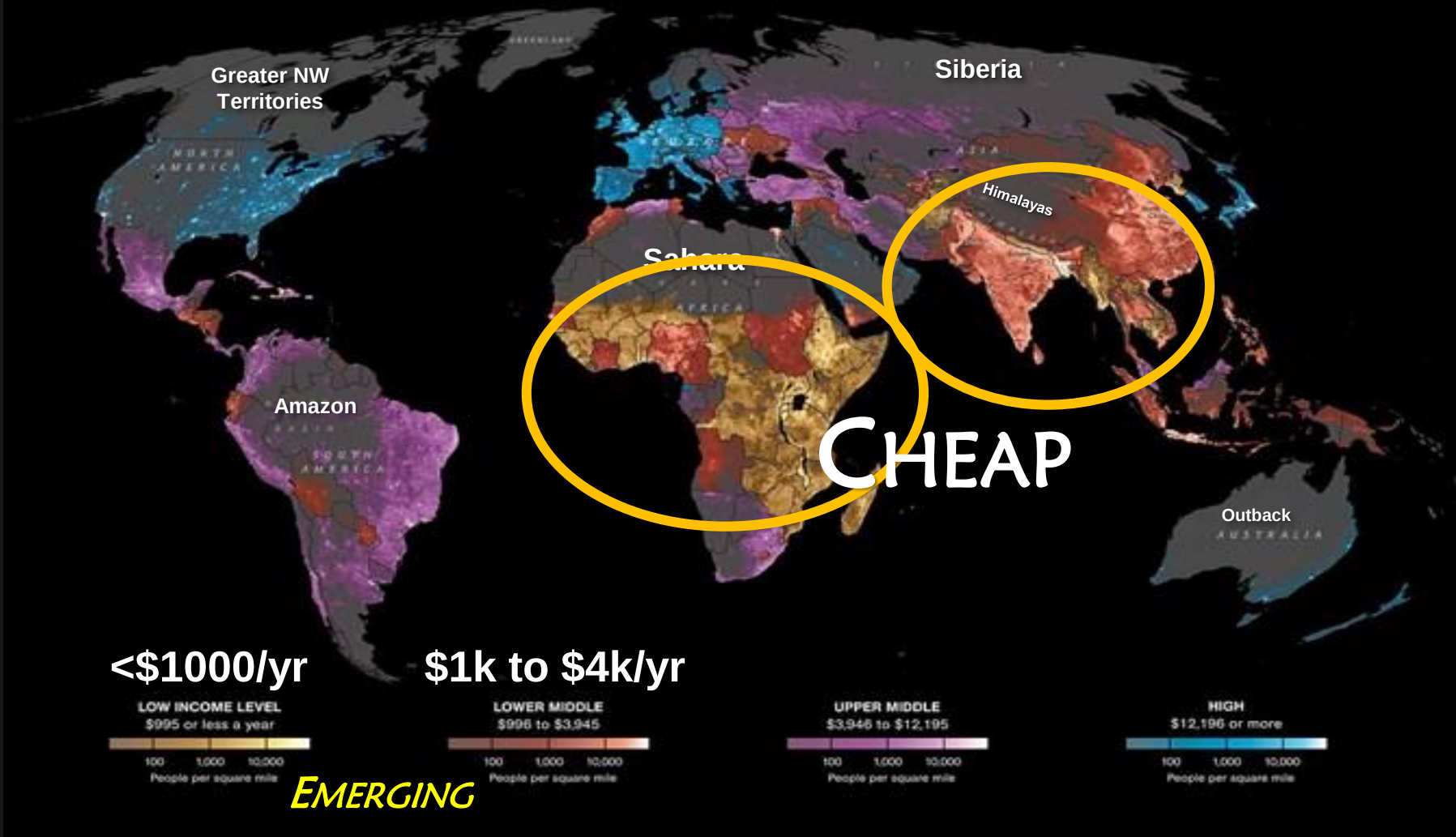
DEVELOPED

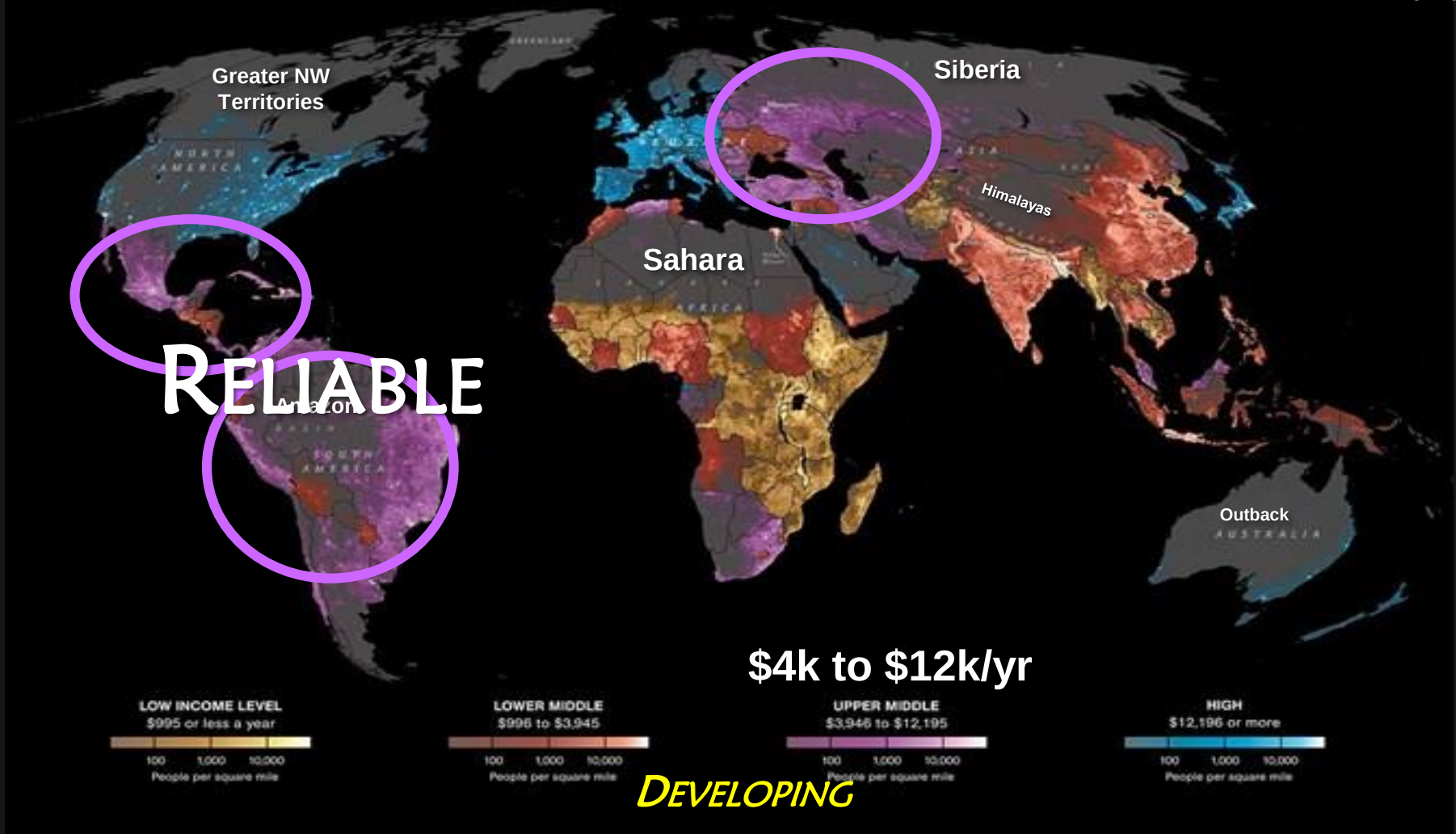
>\$12,000/yr

HIGH
\$12,196 or more

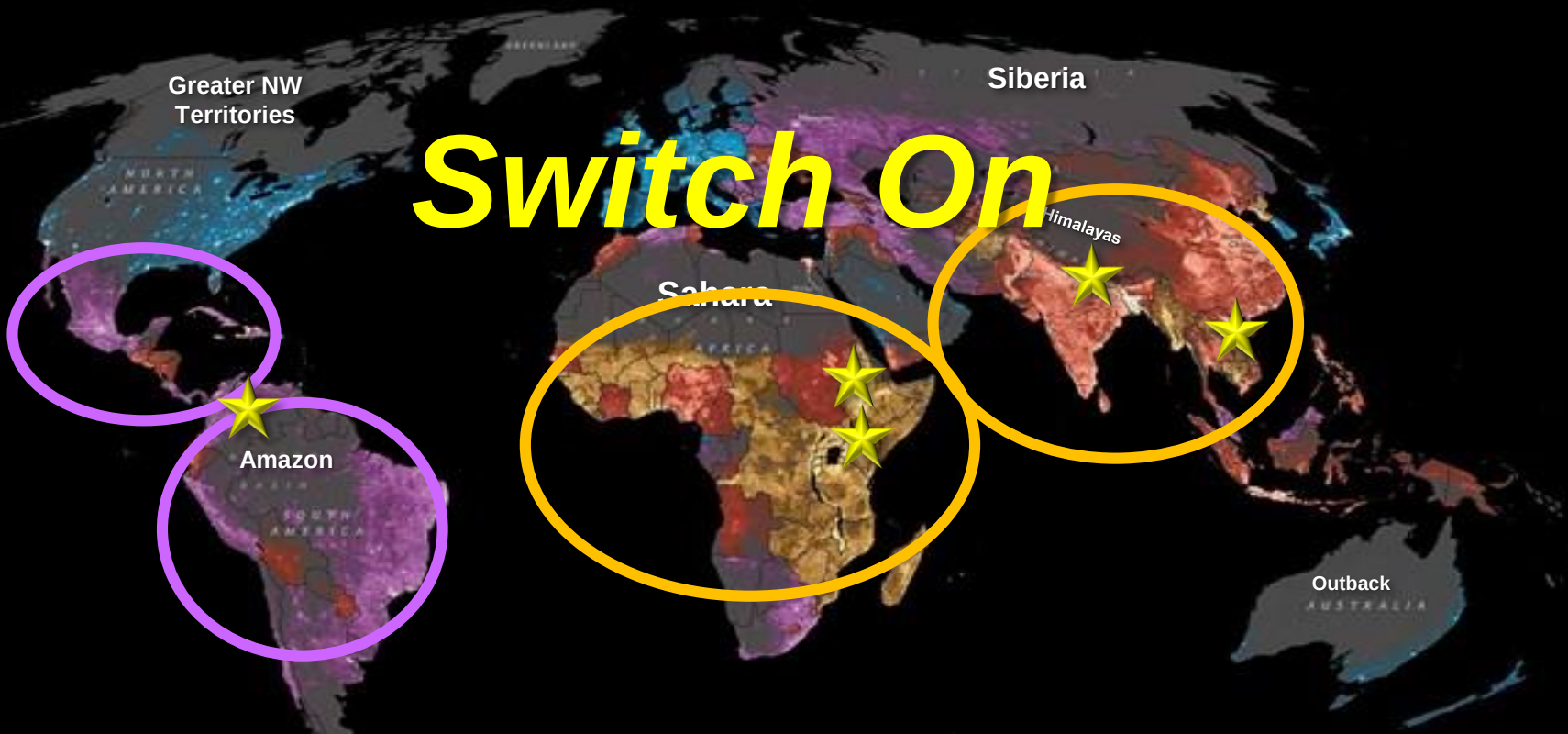


100 1,000 10,000
People per square mile





Switch On



<\$1000/yr

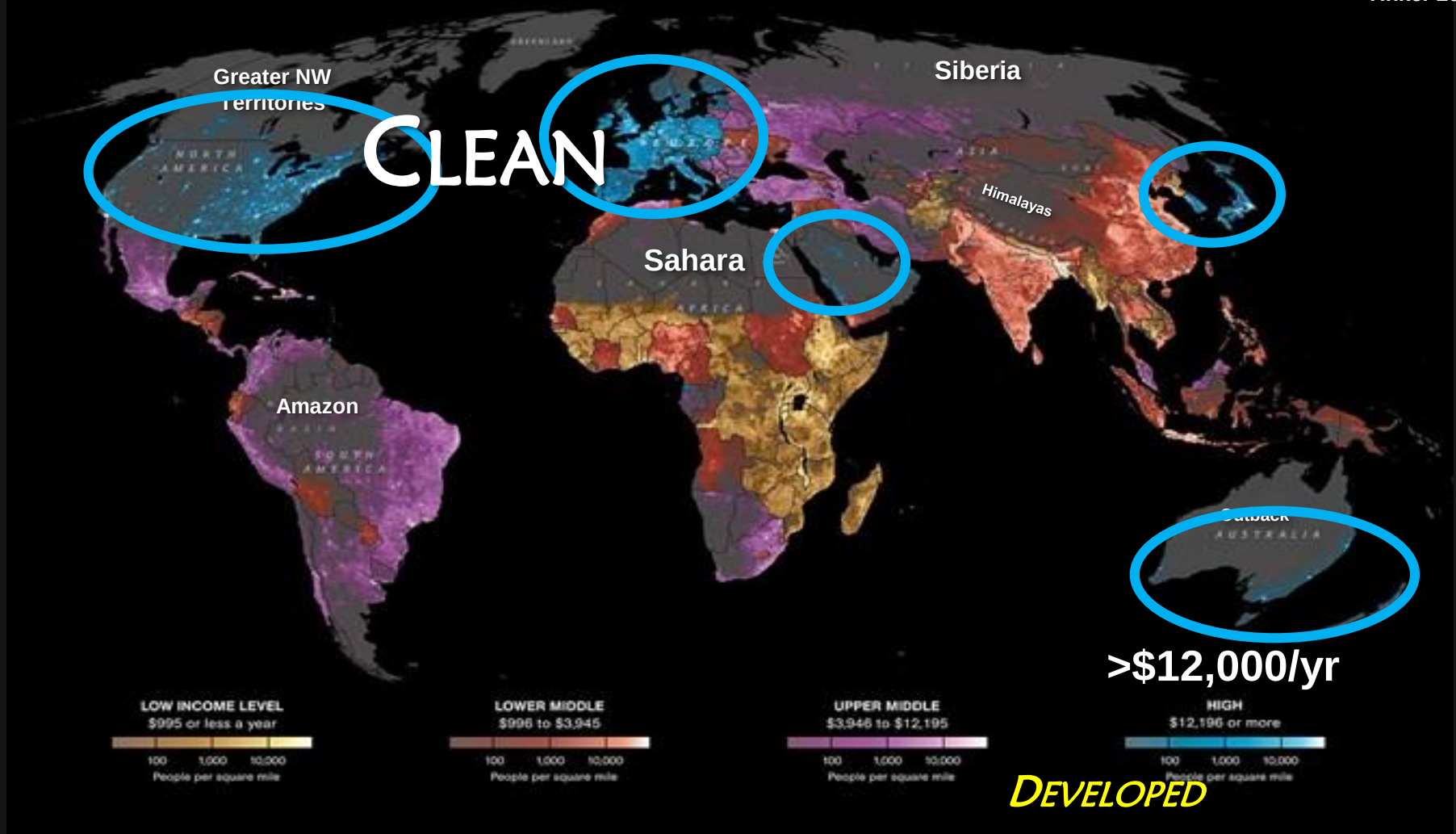
\$1k to \$4k/yr

\$4k to \$12k/yr



EMERGING

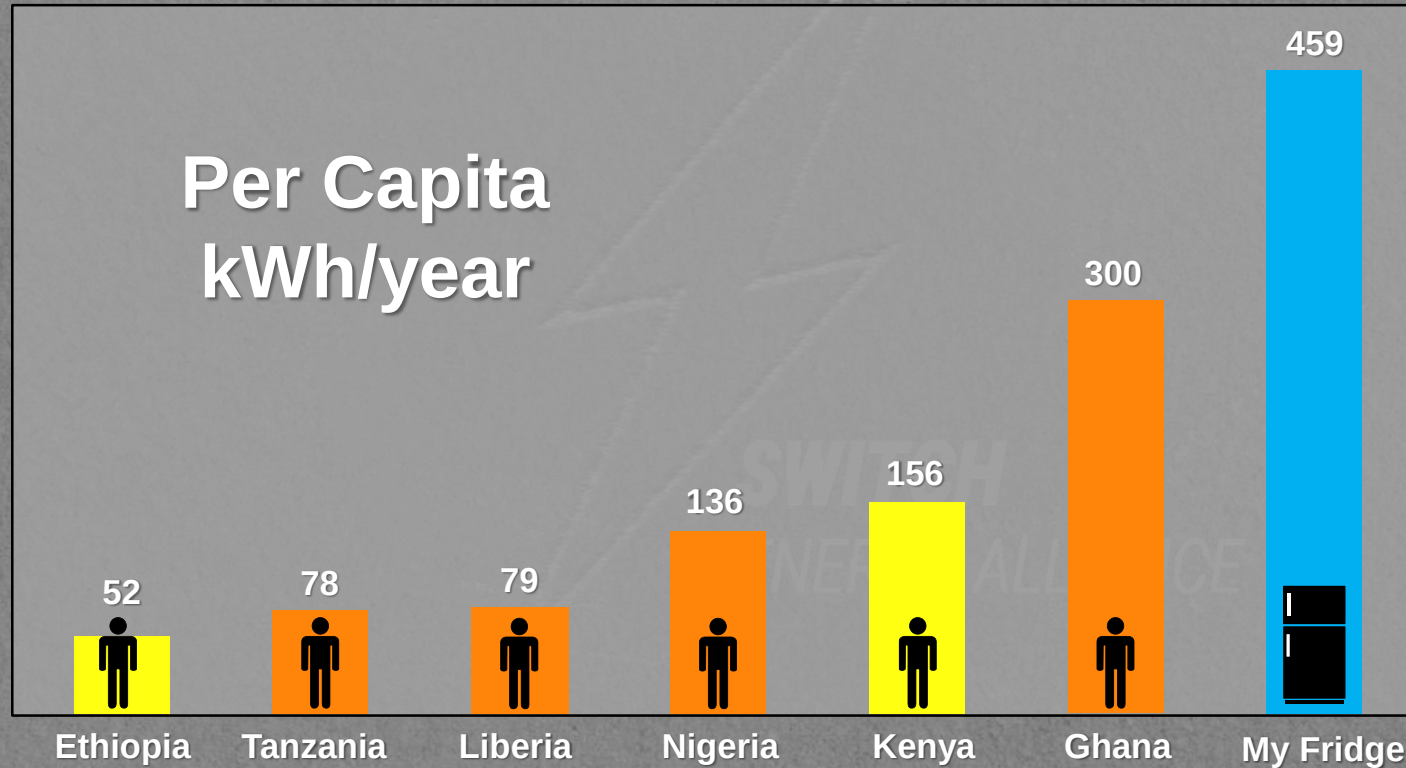
DEVELOPING



A world map at night, with city lights glowing in yellow and orange against a dark blue background. The map is centered on the Atlantic Ocean, showing North and South America on the left and Europe, Africa, and Asia on the right.

What does
“little to no energy”
mean?

Annual Energy Consumption



Economic Poverty and Energy Poverty

Circles sized by
total population

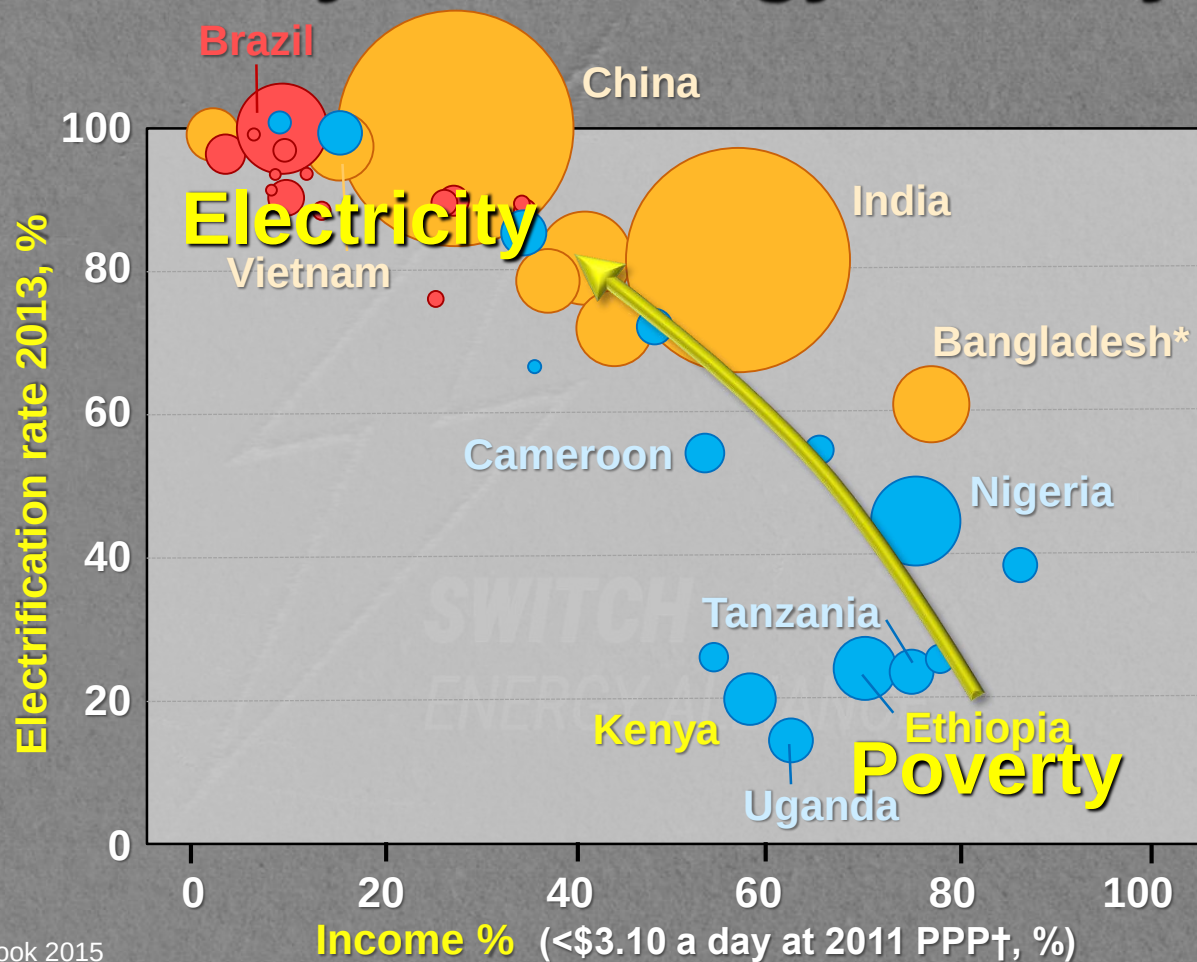
● Africa

● Asia

● Latin America

* Bangladesh uses
2005 PPP and \$2
a day poverty line

† Purchasing power
parity





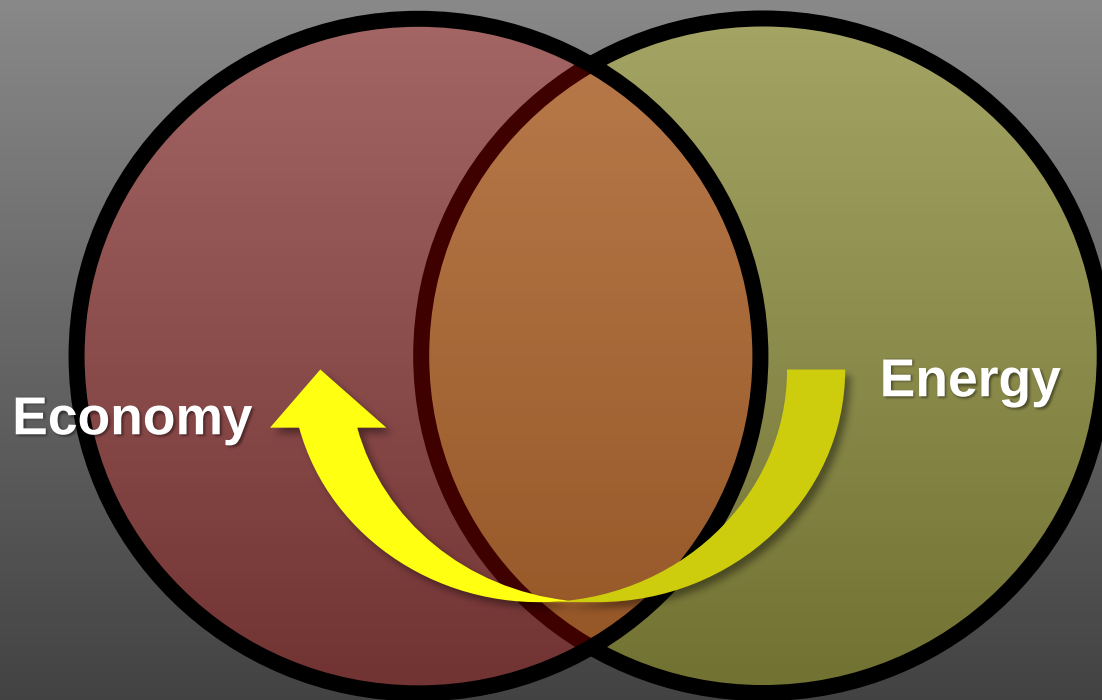
***It's Time to
Power the
People***

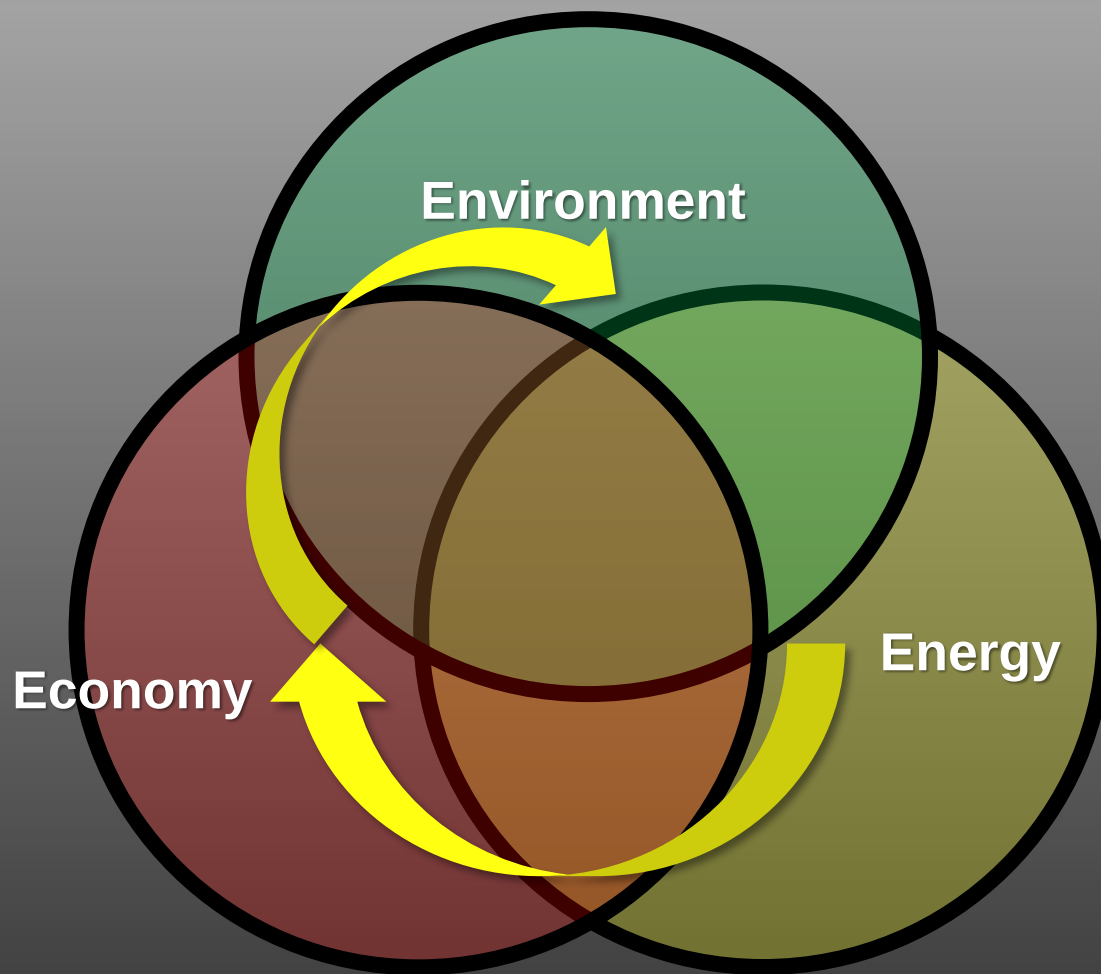
EQUITABLE

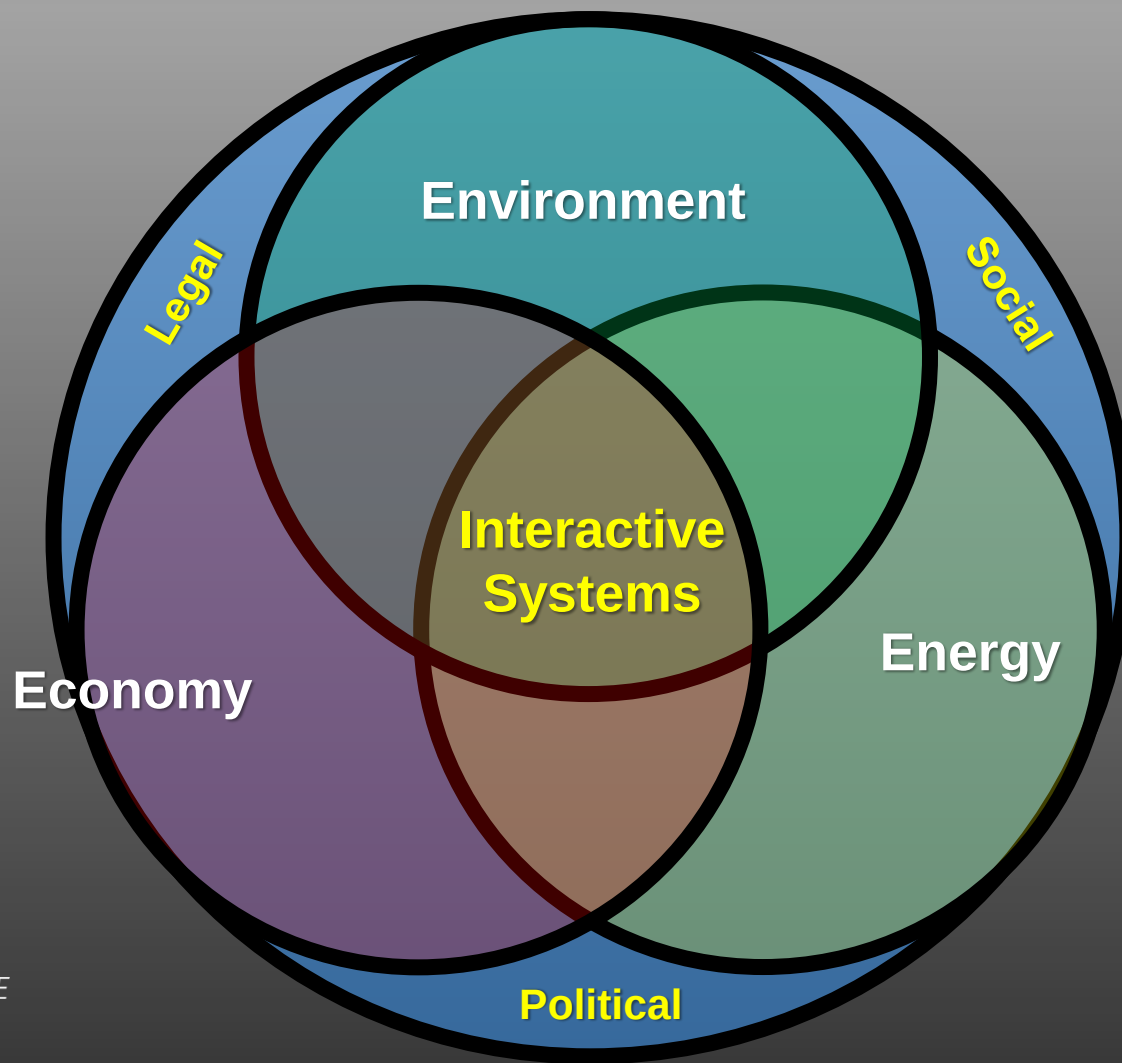
ACCESS TO AFFORDABLE AND RELIABLE
ENERGY, WHICH UNDERPIN A HEALTHY
ECONOMY AND A CLEAN
ENVIRONMENT.

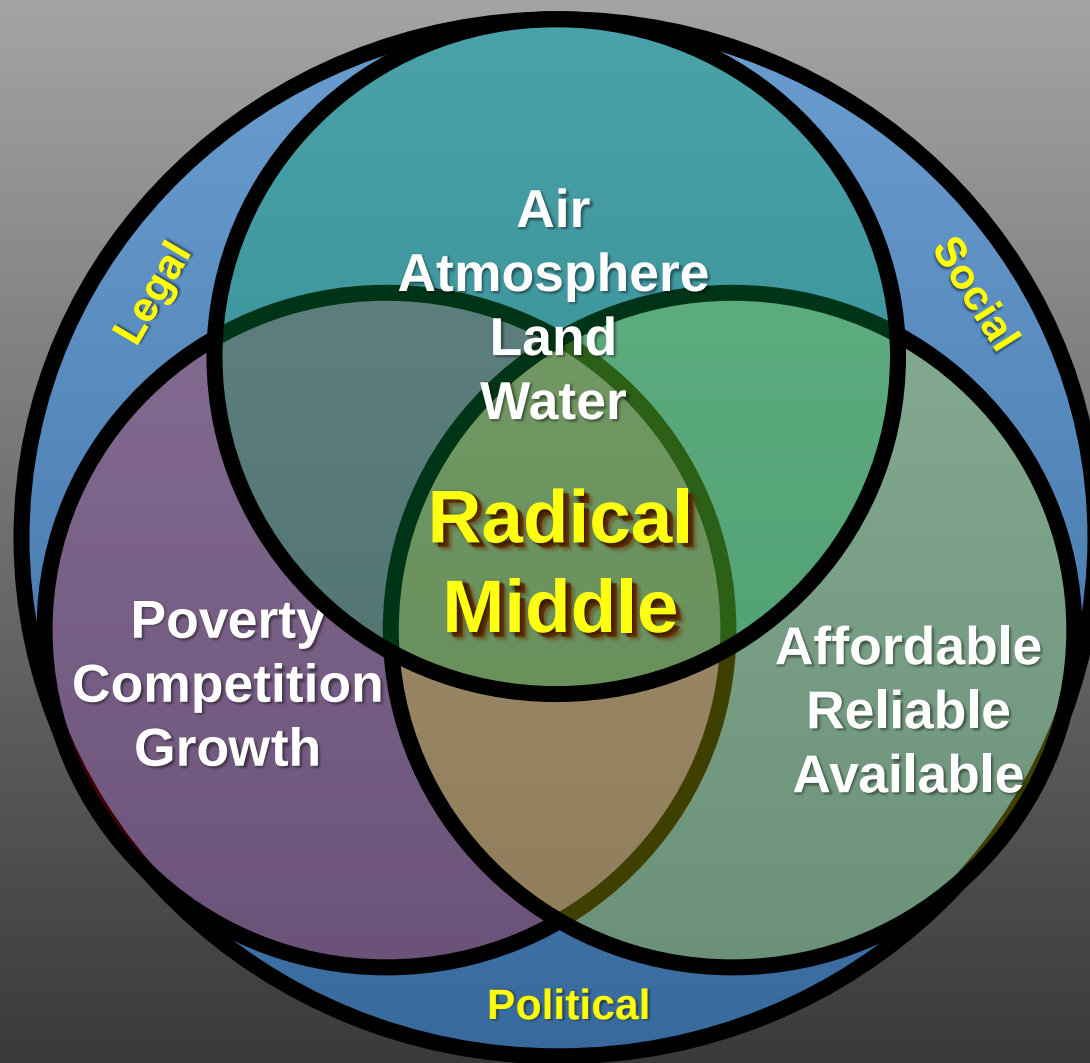
EQUITABLE

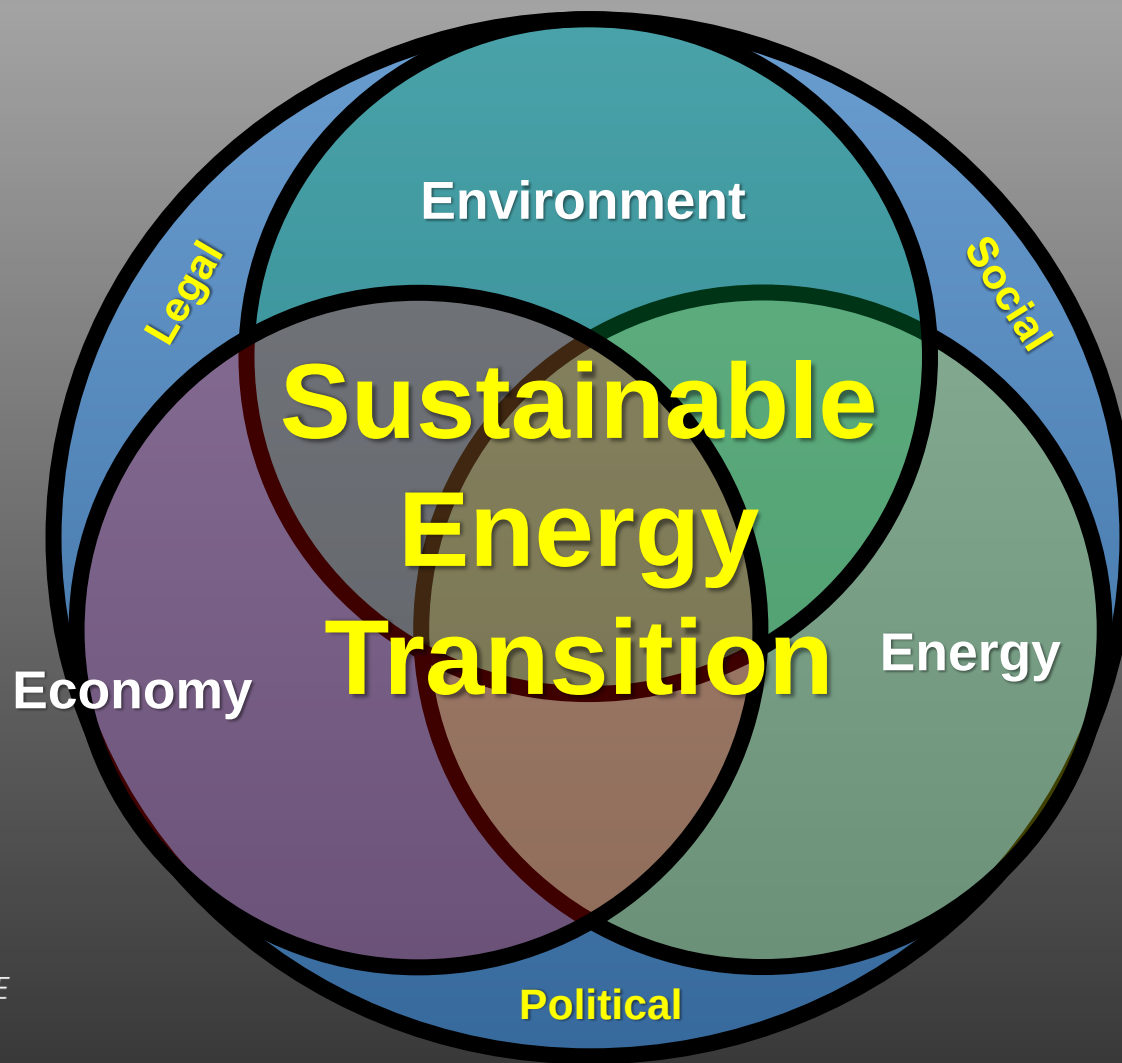
ACCESS TO AFFORDABLE AND RELIABLE
ENERGY, WHICH UNDERPIN A HEALTHY
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ENVIRONMENT.











TRANSITIONS

ECONOMIC WEALTH

SCALE

TECHNOLOGY

ACCESS

RELIABILITY

ENERGY DENSITY

PUBLIC OPINION

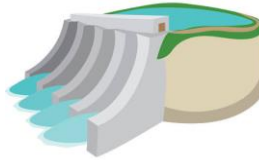
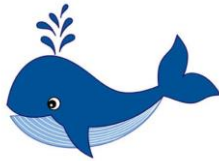
NATURAL EVENTS

ENERGY TRANSITION

~1000 AD



~1500 AD

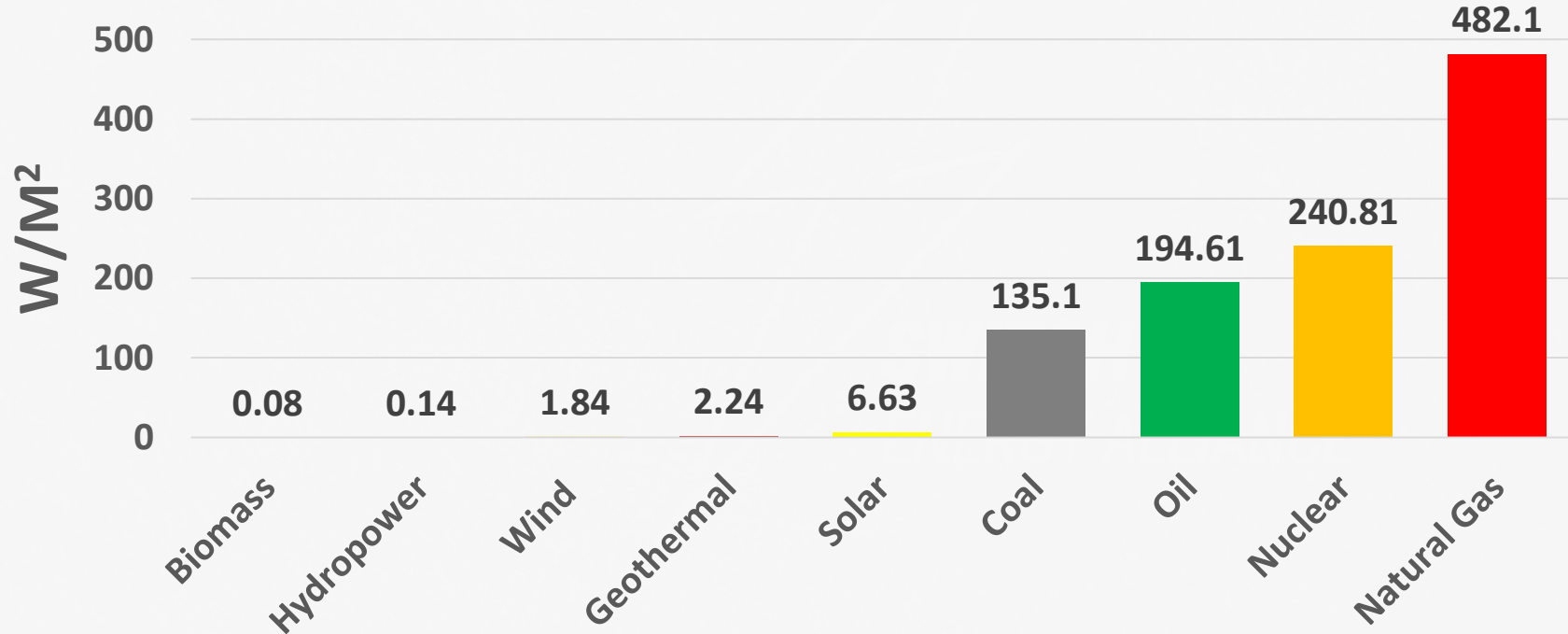


~2000 AD



ENERGY TRANSITION

Surface Power Density



ENERGY TRANSITION

~1000 AD

~1500 AD

~2000 AD

C HC CH₄ H U Th

Higher Density →

Lower Carbon →

ENERGY TRANSITION

~1000 AD

~1500 AD

~2000 AD



Lower Density

Lower Carbon



Will be a Challenge

HIGH DENSITY



Coal

HIGH DENSITY



Oil

VCE

HIGH DENSITY



Gas

VCE

HIGH DENSITY



Nuclear

CE

Environmental Impact

Coal, Oil, Natural Gas

- Mining and Manufacturing *Land, Water, Emissions*
- Drilling and Completion: *Land, Water*
- Water Handling: *Recycling, Disposal, Earthquakes*
- Transportation: *Pipelines, Trucks, Ships, Rail*
- Refining and Petrochemicals: *Emissions*
- Combustion: *Vehicle and Power Plant Emissions*

Wed., Mar. 10

Tue., Mar. 9

Mon., Mar. 8

Fri., Mar. 5

Edition Archive

SEARCH:

go!

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LAW

Big Tobacco had to pay \$206B. Is Big Oil next?

Maxine Joselow, E&E News reporter • Published: Wednesday, March 10, 2021



Cities and states look to past litigation against Big Tobacco as they push lawsuits against Big Oil. Claudine Hellmuth/E&E News (illustration); Freepik (photos)

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- Drilli
- Water
- Tran
- Refin
- Com

issions

makes

ons

LOW DENSITY

Polysilicon Plant



Solar

LOW DENSITY



Wind



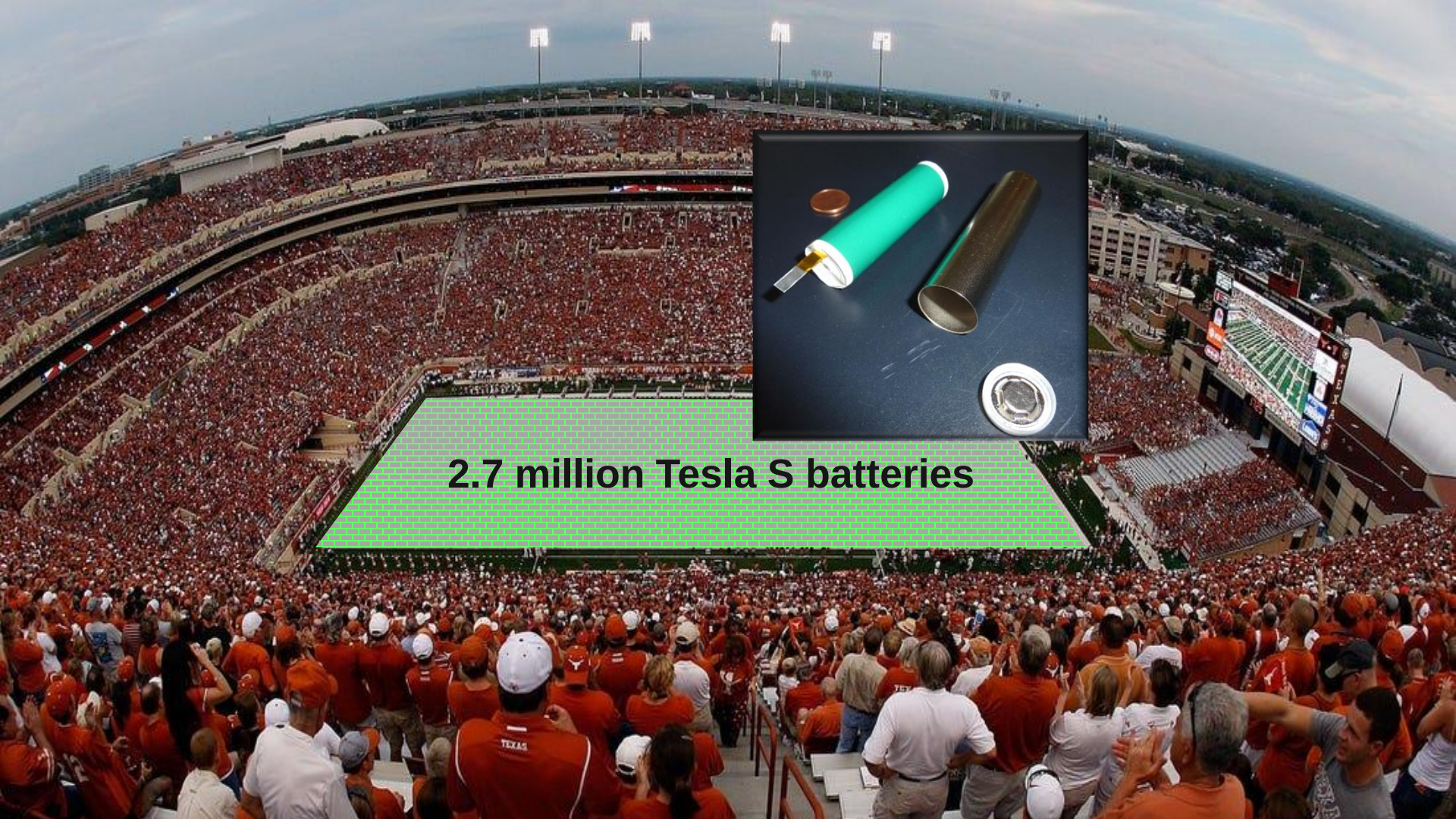
TESLA



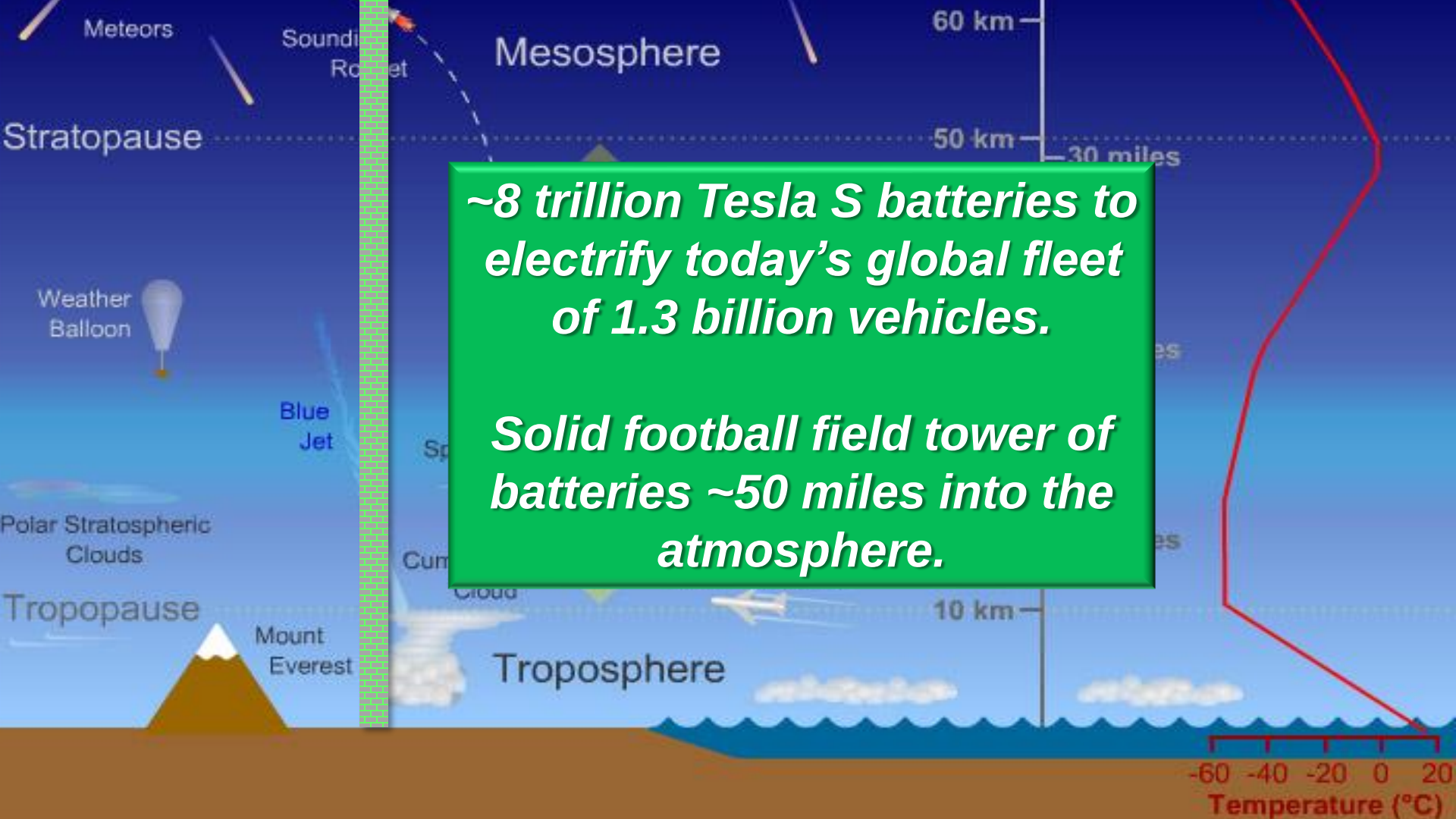
~7000 Lithium-Ion
Batteries in One Tesla S



Lithium mine



2.7 million Tesla S batteries



ENERGY STORAGE

It's time to get serious about recycling lithium-ion batteries

A projected surge in electric-vehicle sales means that researchers must think about conserving natural resources and addressing battery end-of-life issues

by *Mitch Jacoby*

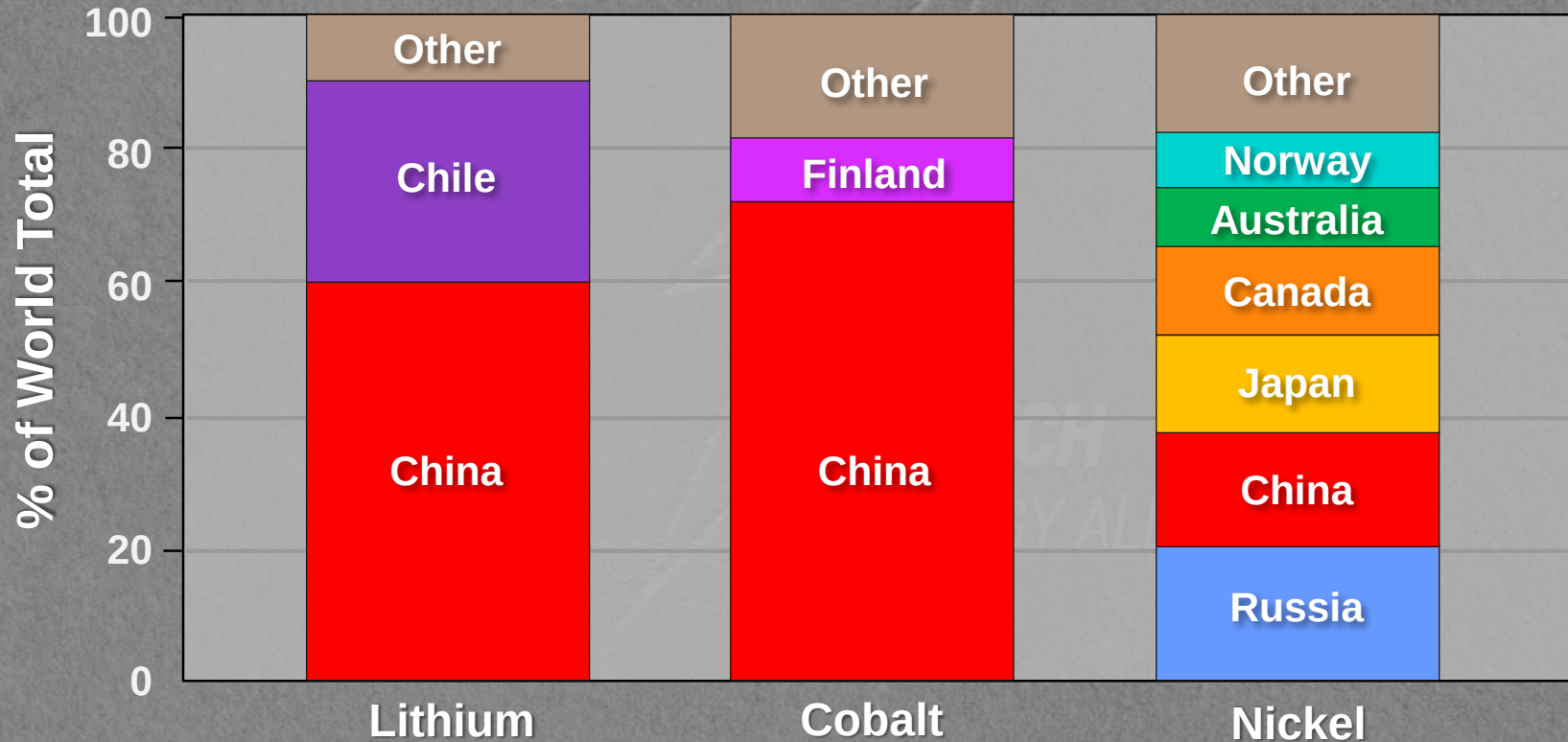
JULY 14, 2019 | APPEARED IN **VOLUME 97, ISSUE 28**

“a multimillion-metric-ton heap of Li-ion batteries that could end up in the trash ...but because of technical, economic and other factors, *less than 5% are recycled today.*”

IN BRIEF

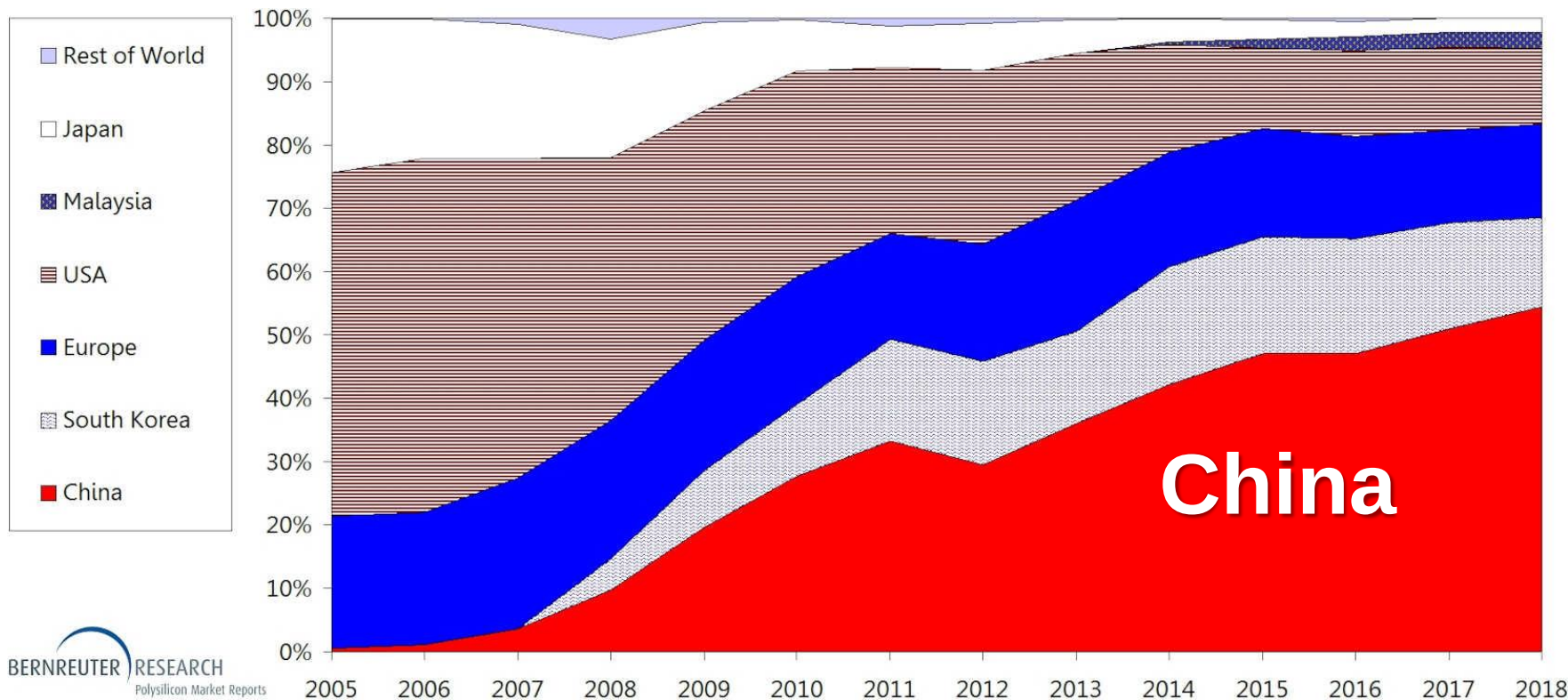
Lithium-ion batteries have made portable electronics ubiquitous, and they are about to do the same for electric vehicles. That success story is setting the world on track to generate **a multimillion-metric-ton heap of used Li-ion batteries** that could end up in the trash. The batteries are valuable and recyclable, but because of technical, economic, and other factors, less than 5% are recycled today. The enormity of the impending spent-battery situation is driving researchers to search for cost-effective, environmentally sustainable strategies for dealing with the vast stockpile of Li-ion batteries looming on the horizon.

CAPACITY OF MINERAL REFINERIES BY COUNTRY 2020

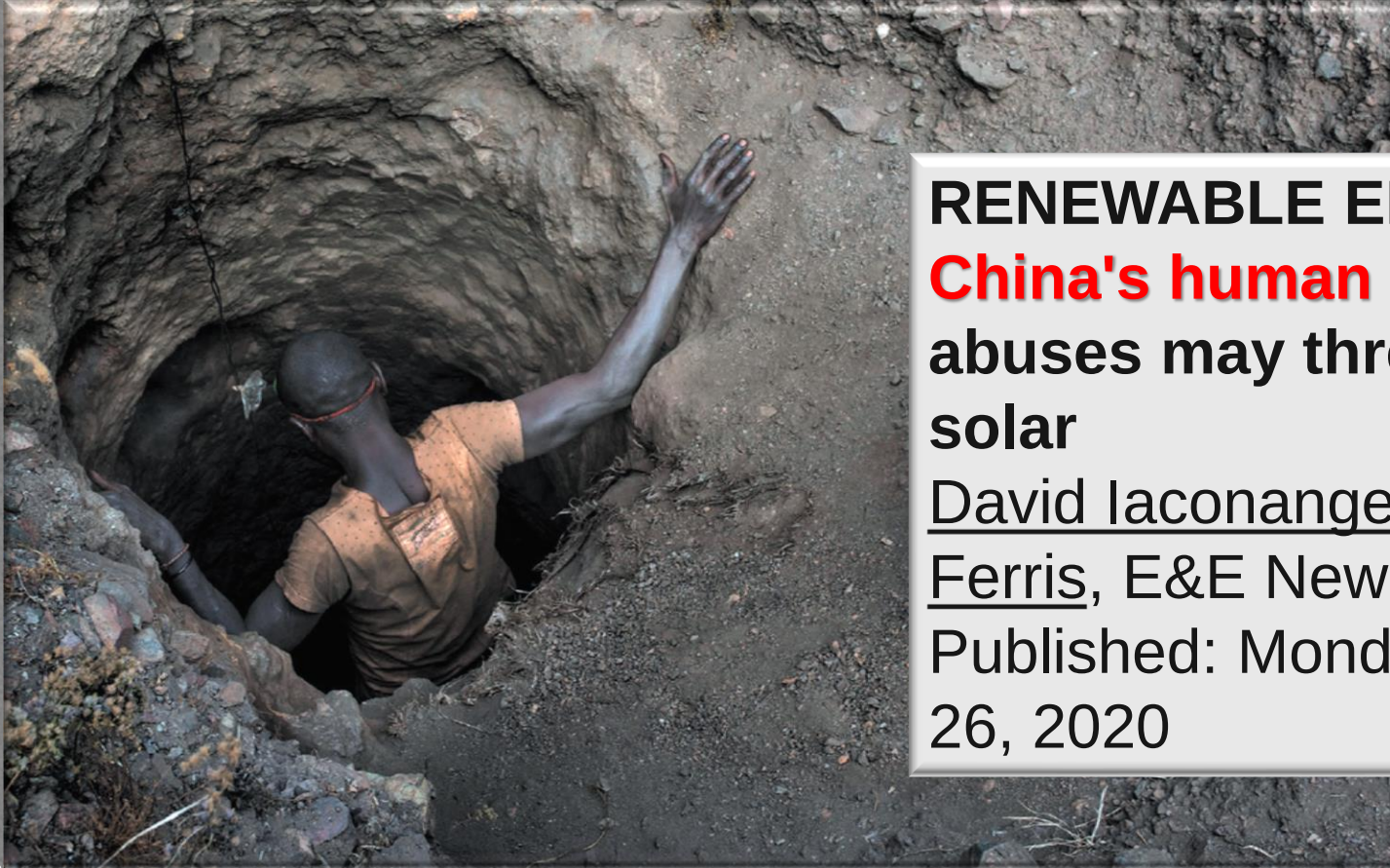


CAPACITY OF MINERAL REFINERIES BY COUNTRY

Polysilicon Production



HUMAN RIGHTS ABUSES



RENEWABLE ENERGY
China's human rights
abuses may threaten U.S.
solar

David Iaconangelo and David Ferris, E&E News reporters
Published: Monday, October
26, 2020

Environmental Impact

Renewables and Batteries

- Mining and Processing *Land, Water, Emissions*
- Manufacturing: *Turbines, Panels, Batteries*
- Production: *Land for “Farms”*
- Transmission: *Electricity*
- Disposal: *Landfill*

Environmental Impact

Renewables and Batteries

All forms of energy require
non-renewable earth
resources, manufacturing, and
landfill disposal.

Wed., Mar. 10

Tue., Mar. 9

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Fri., Mar. 5

Edition Archive

SEARCH:

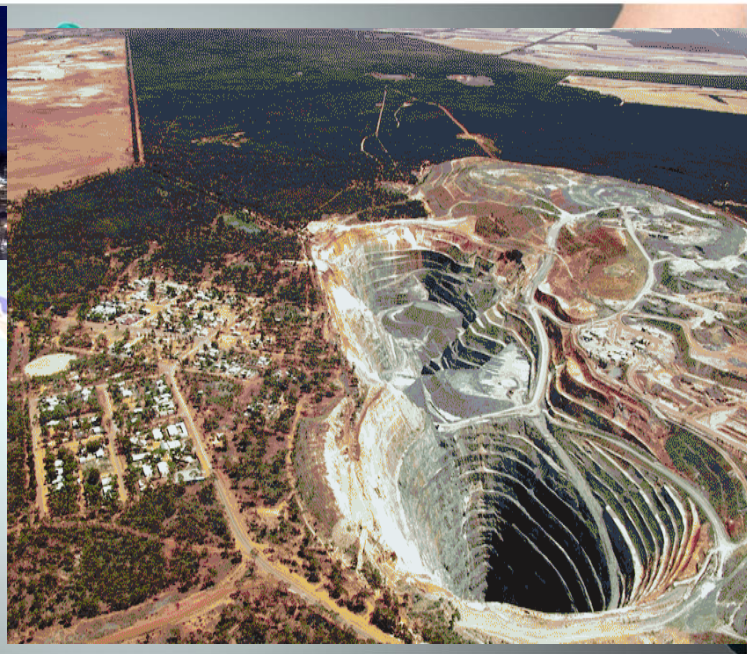
go!

<< Back to table of contents.

LAW

Big Tobacco had to pay \$206B. Are Big Renewables Next?

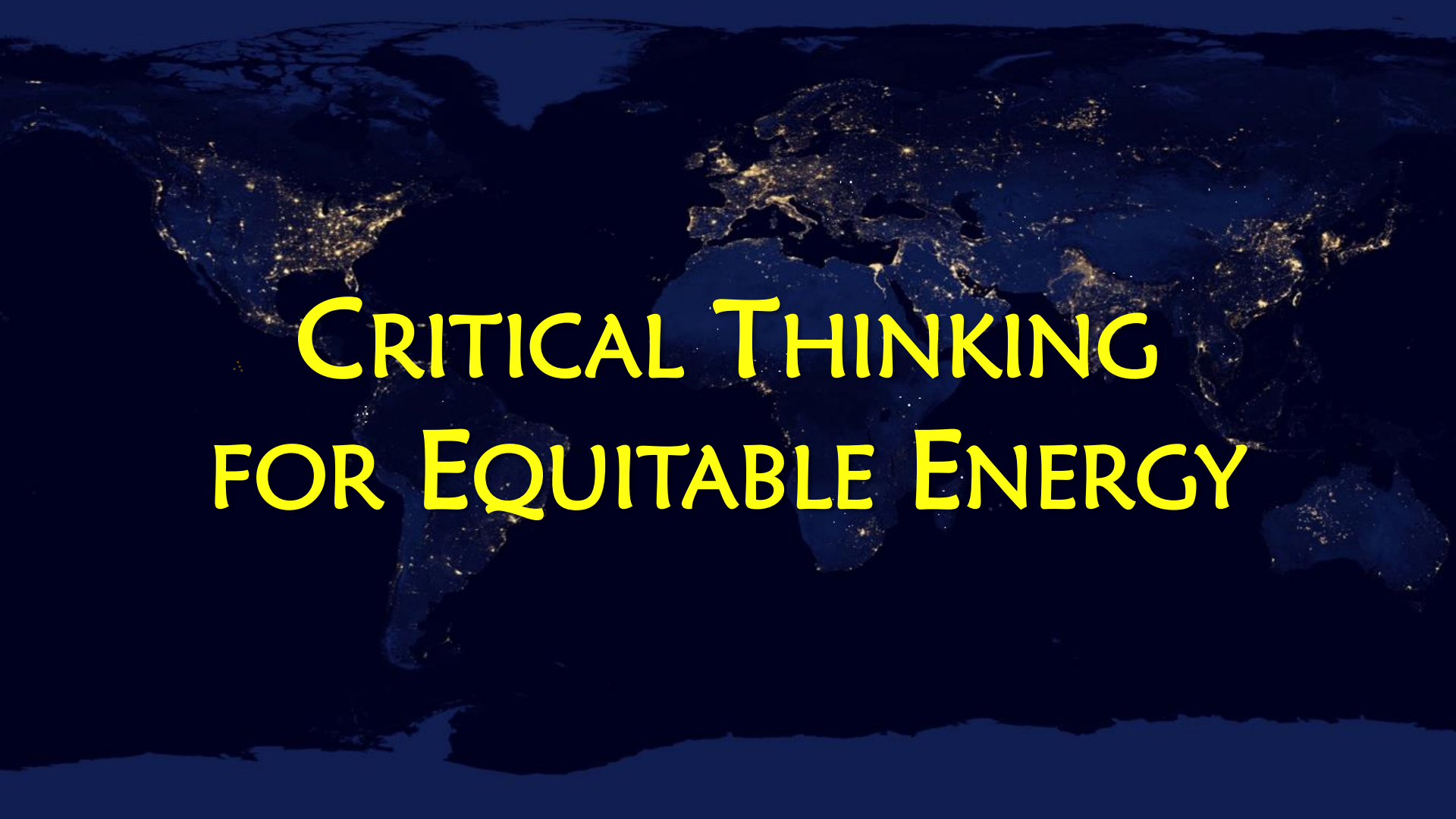
Author of the future



Cities and states look to past litigation against Big Tobacco as they push lawsuits against Big Oil. Claudine Hellmuth/E&E News (illustration), Freepik (photos)

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- Pro
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sions

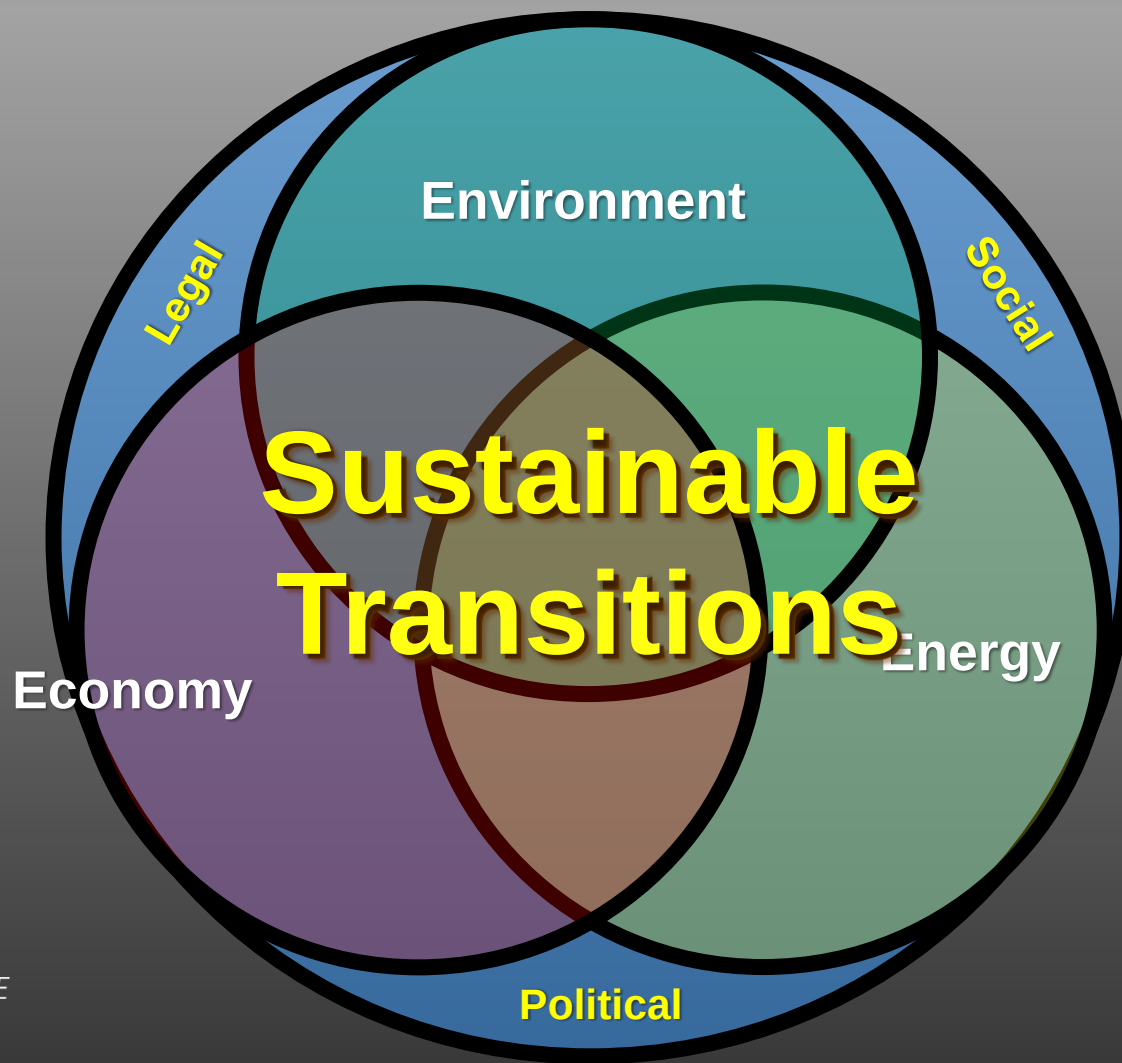
A world map at night, showing the continents in dark blue and the oceans in a lighter blue. Numerous small, bright yellow and orange dots represent city lights, concentrated in North America, Europe, and East Asia. The map is centered on the Atlantic Ocean.

CRITICAL THINKING FOR EQUITABLE ENERGY



It is the mark of an
educated mind to be
able to entertain a
thought without
accepting it.

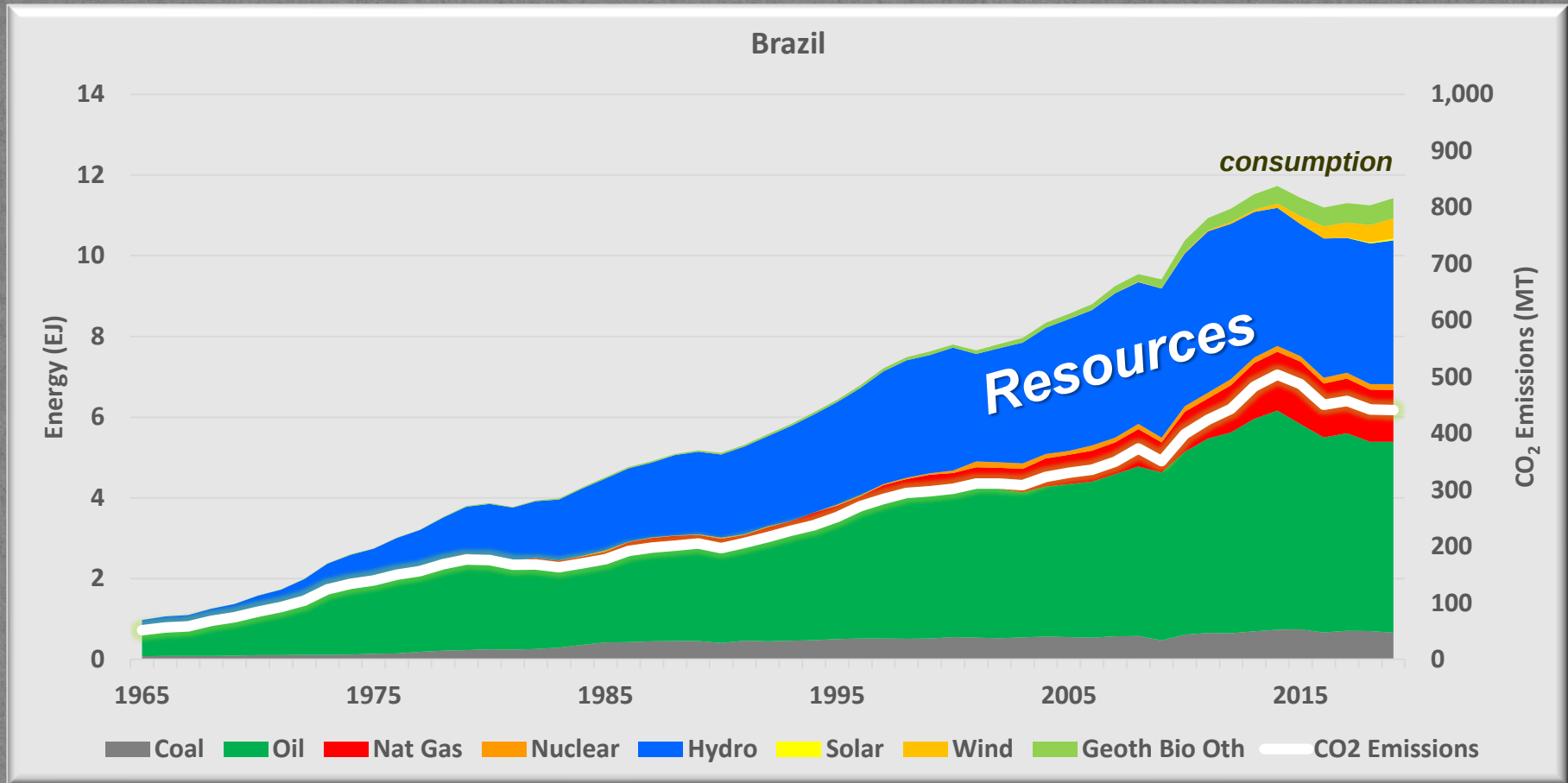
...Aristotle



ENERGY TRANSITIONS

<u>Type</u>	<u>Drivers</u>	<u>Duration</u>
Event	Nature, Economy, Technology	Unpredictable
Resource	Power Density, Scale, Access	Sustained
Policy	Public Opinion, Energy Security	Cyclic

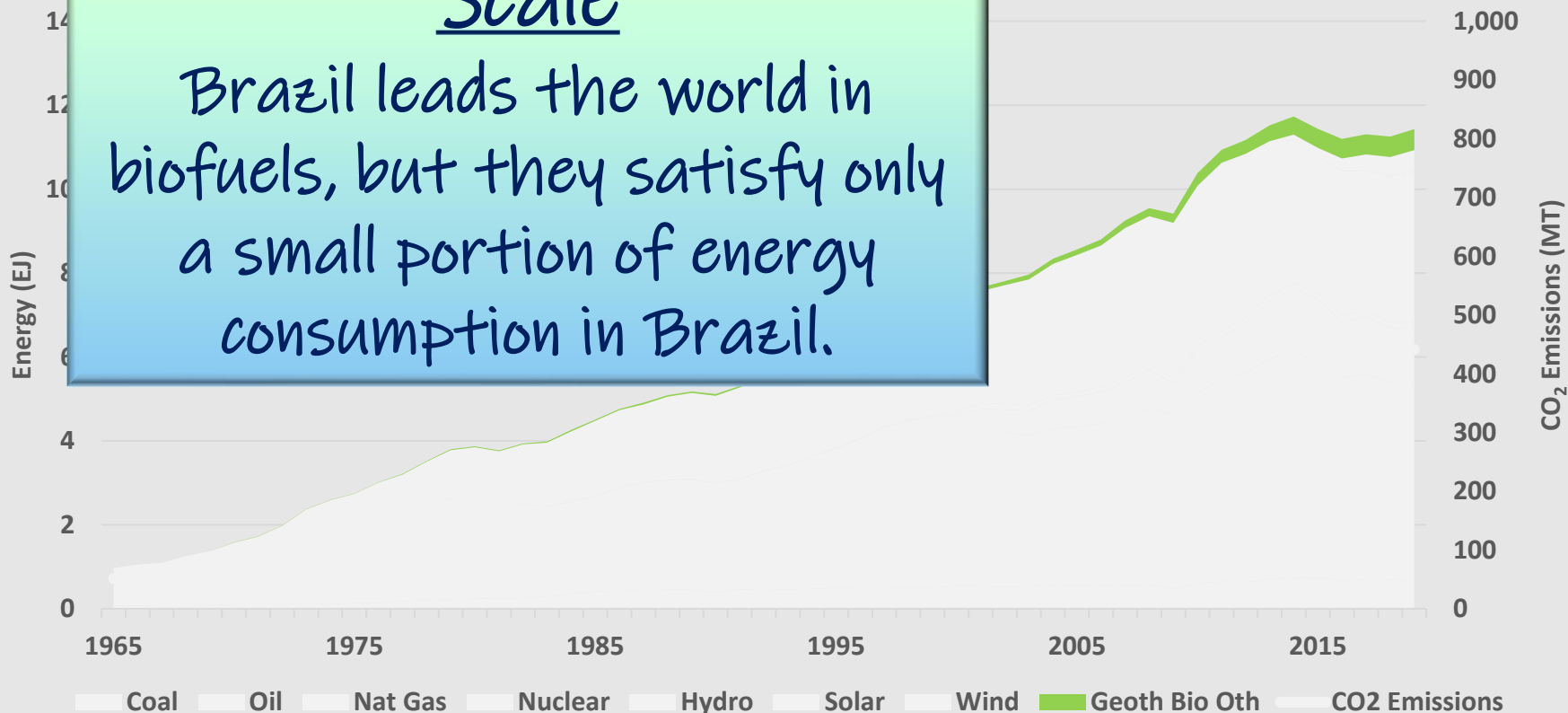
BRAZIL ENERGY TRANSITION



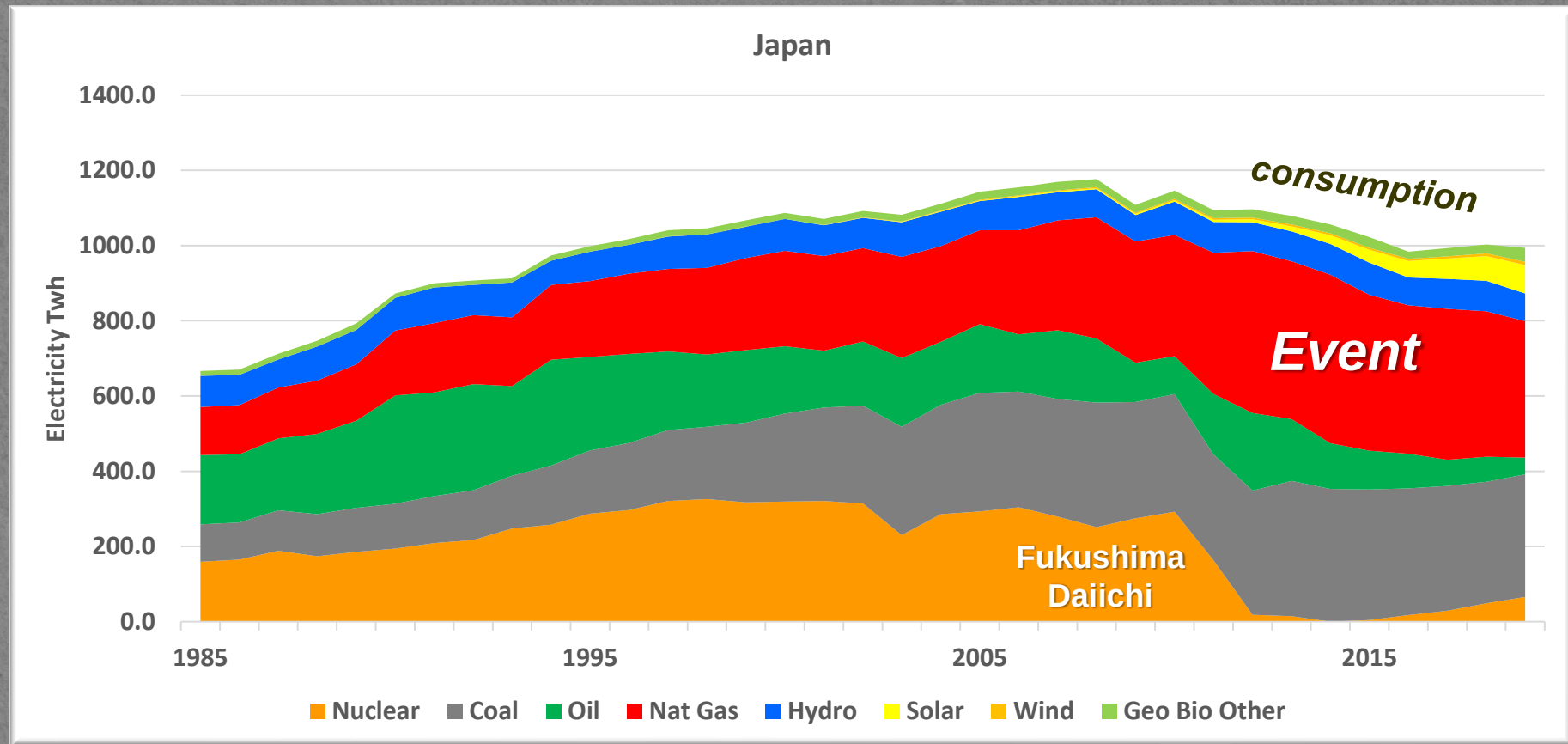
BRAZIL ENERGY TRANSITION

Scale

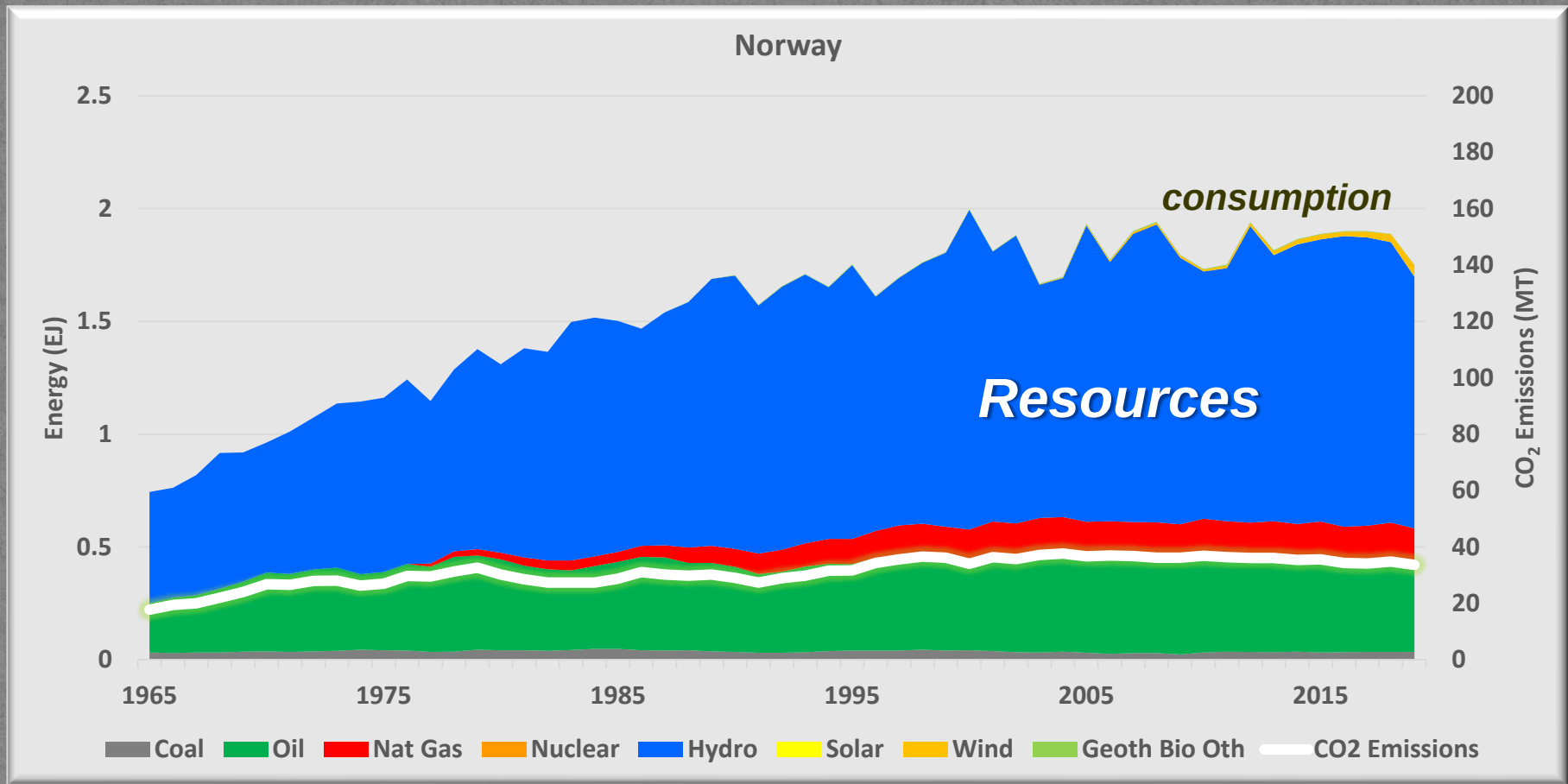
Brazil leads the world in biofuels, but they satisfy only a small portion of energy consumption in Brazil.



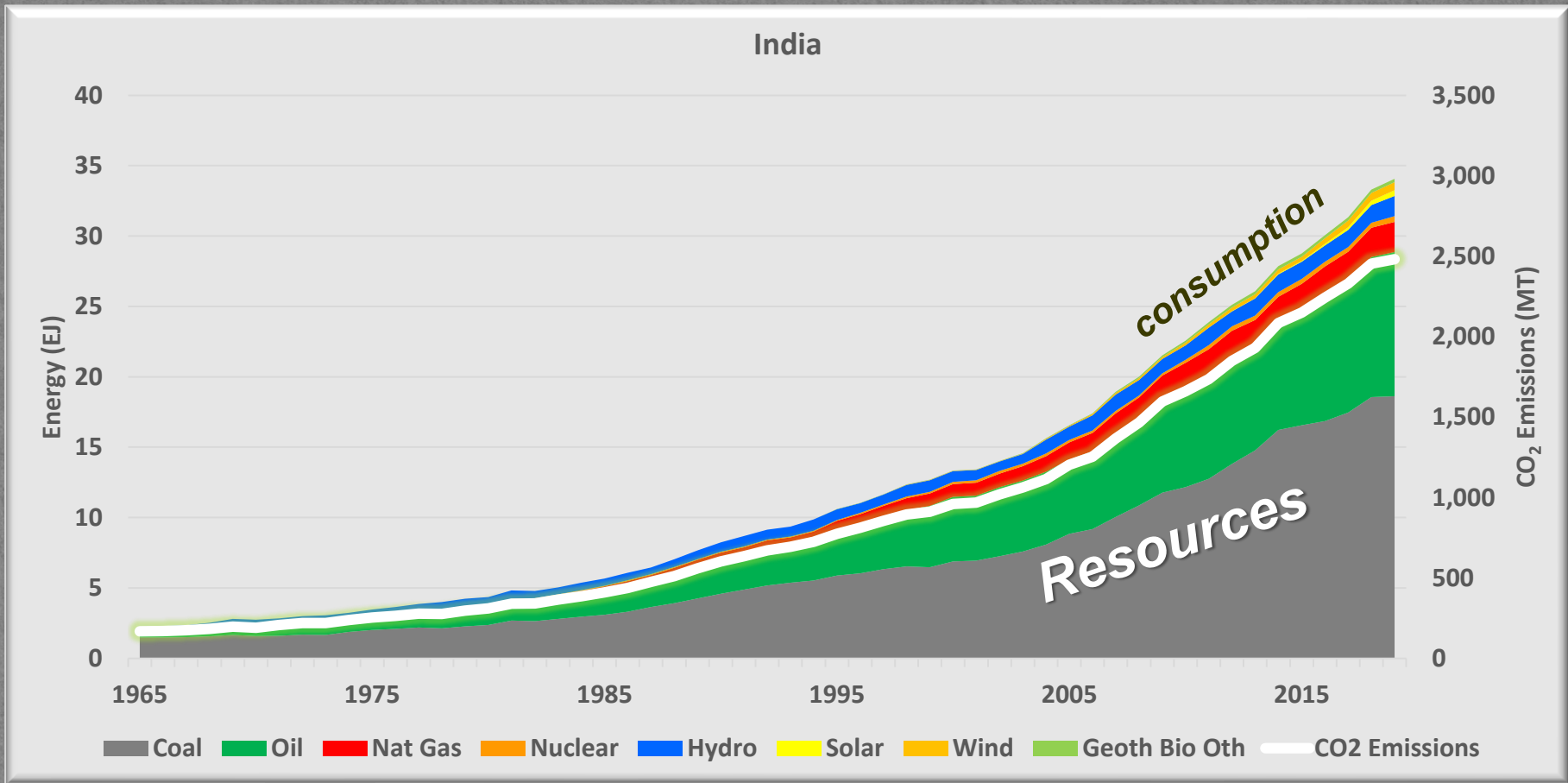
JAPAN ELECTRICITY GENERATION



NORWAY ENERGY TRANSITION

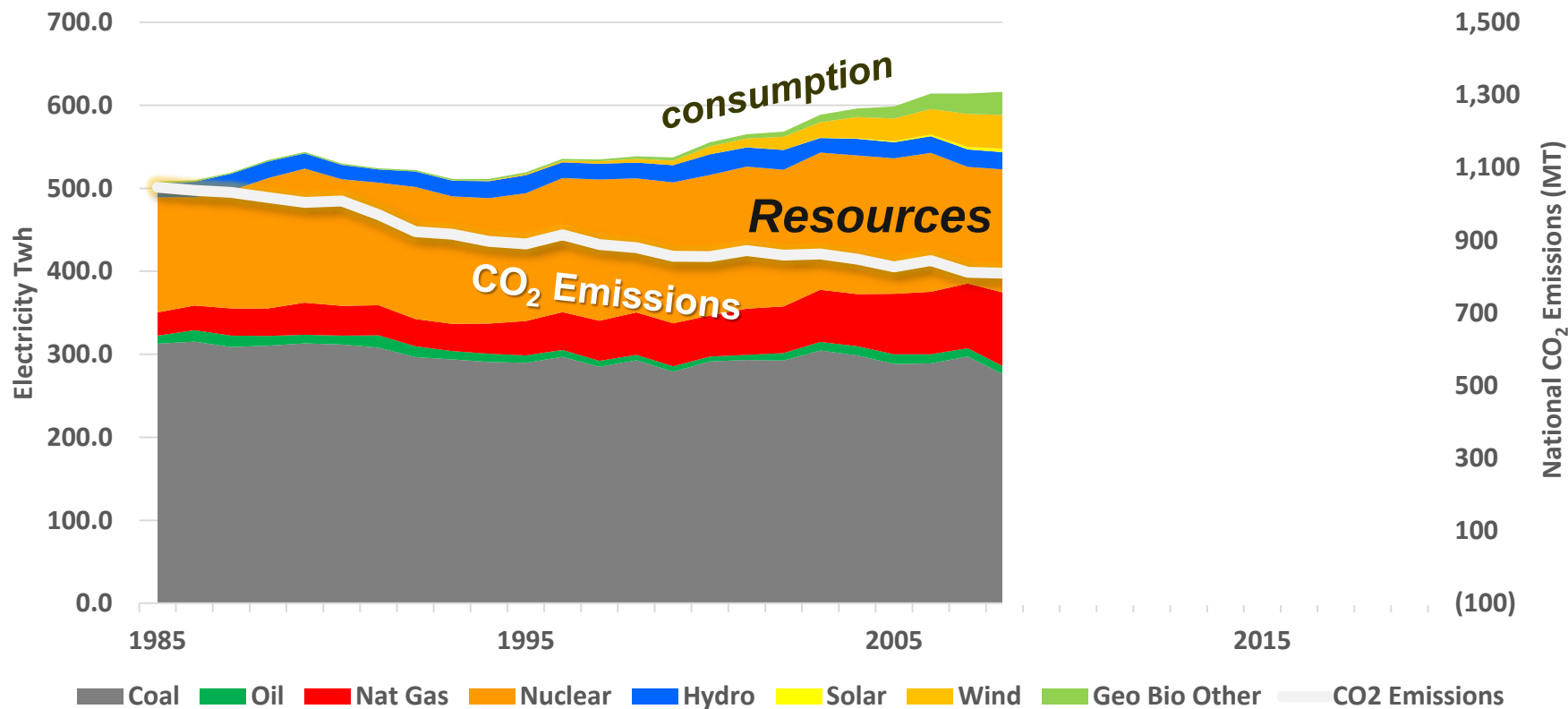


INDIA ENERGY TRANSITION



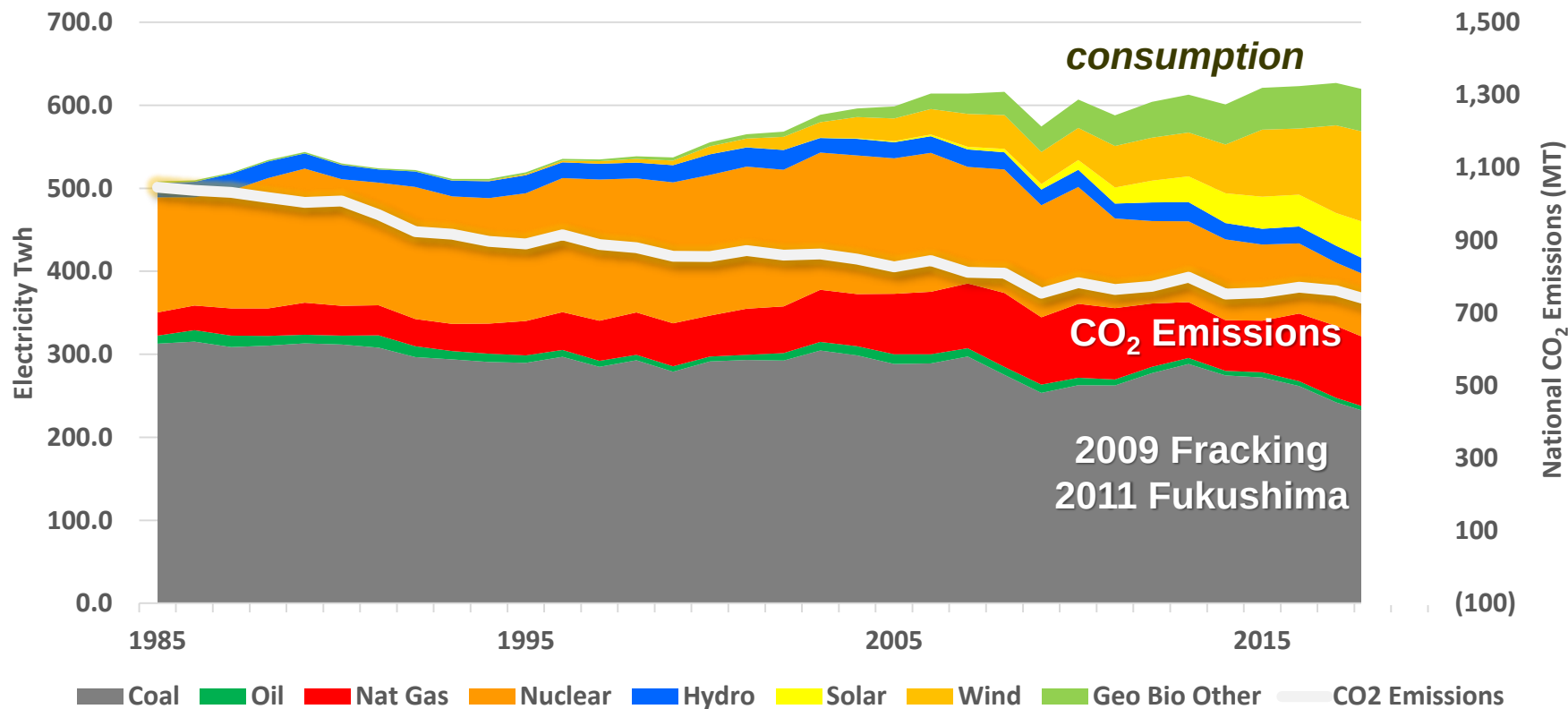
GERMAN ELECTRICITY TRANSITION

Germany Electricity



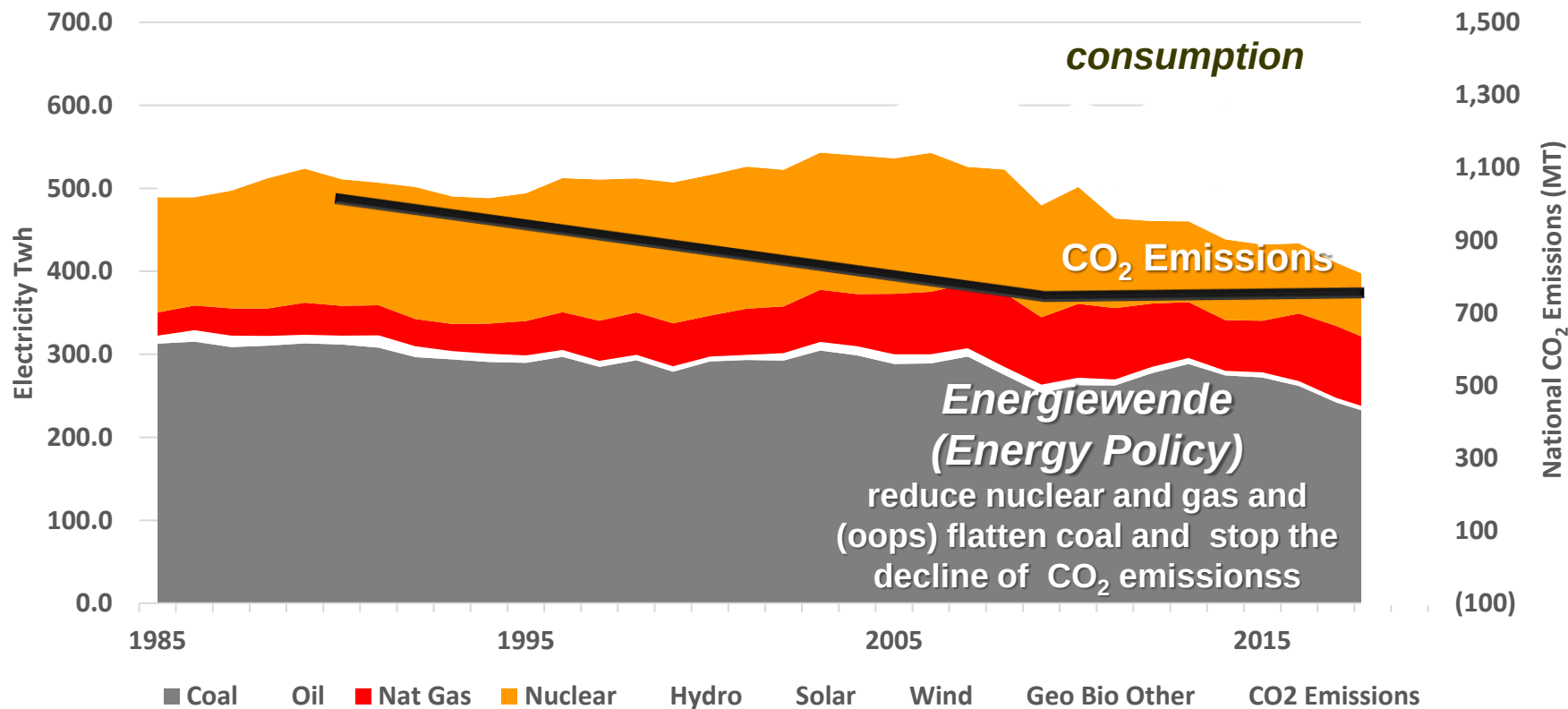
GERMAN ELECTRICITY TRANSITION

Germany Electricity



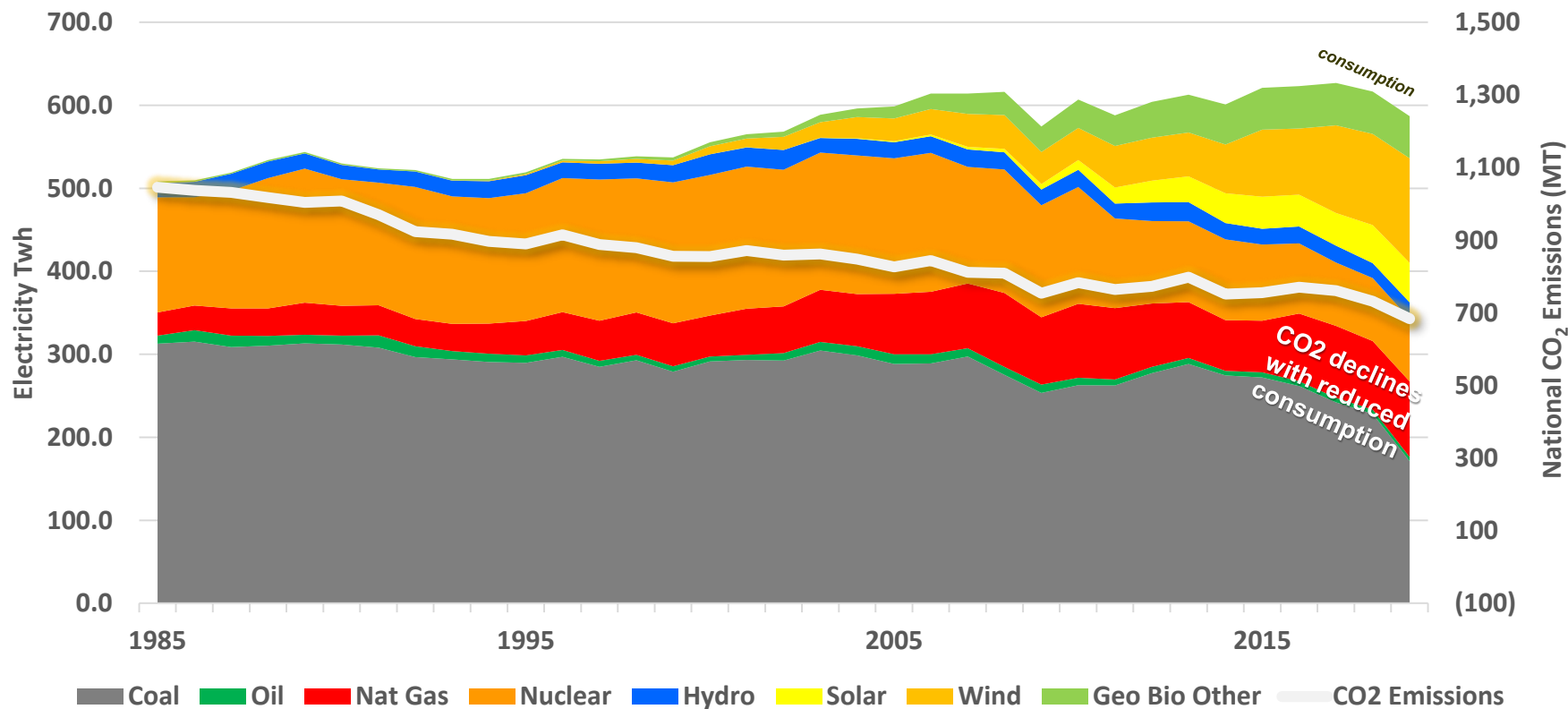
GERMAN ELECTRICITY TRANSITION

Germany Electricity

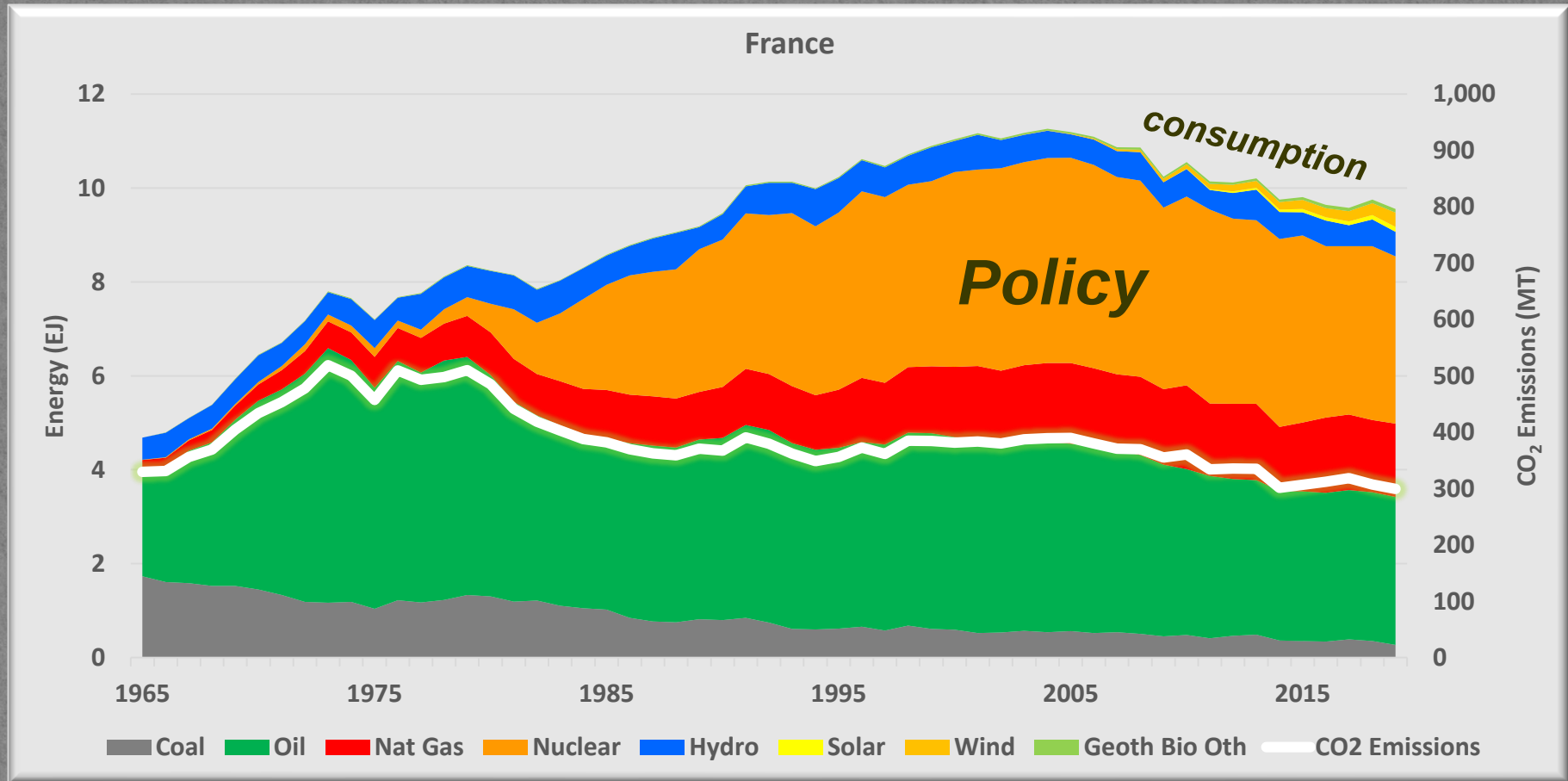


GERMAN ELECTRICITY TRANSITION

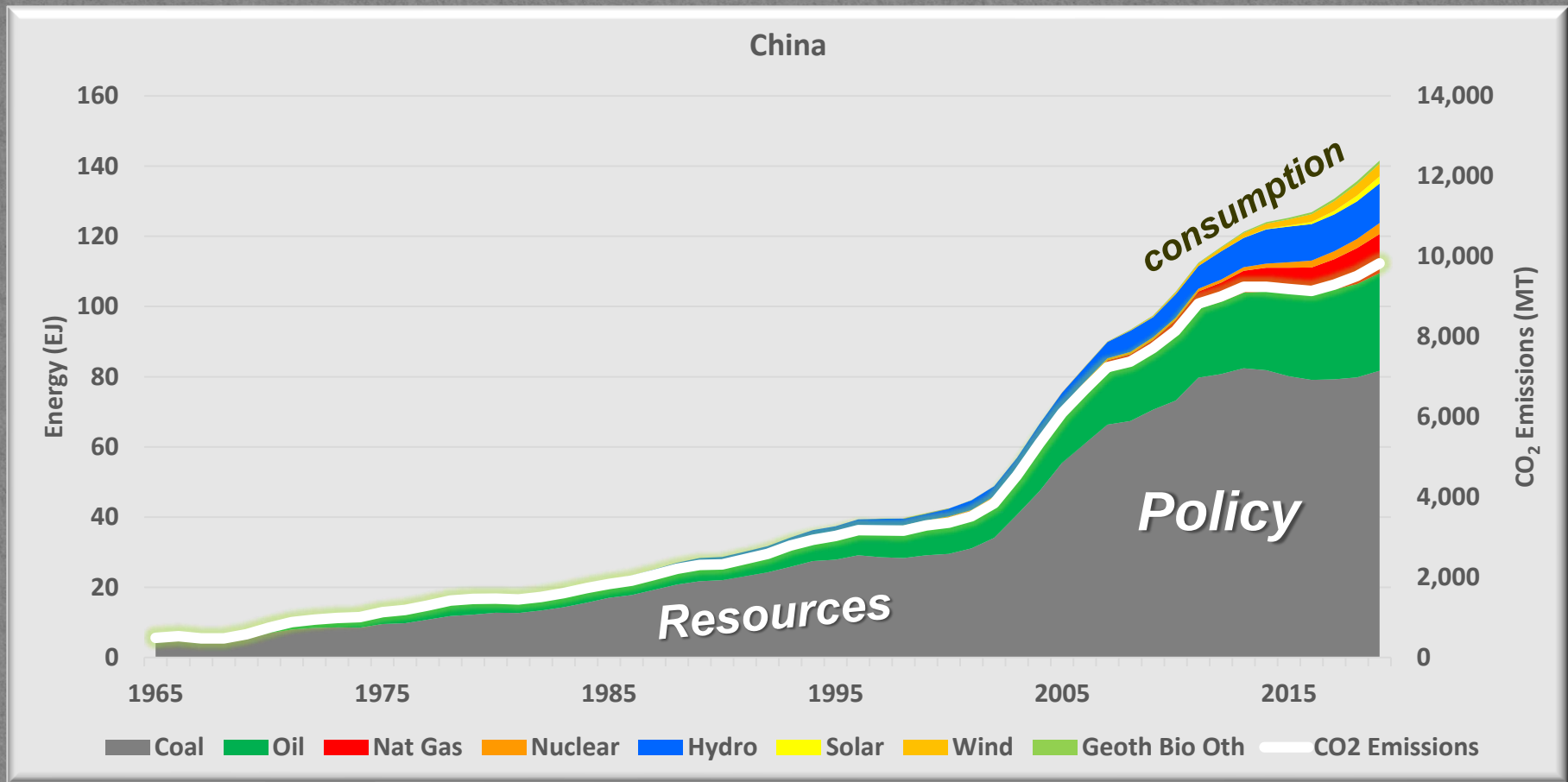
Germany Electricity



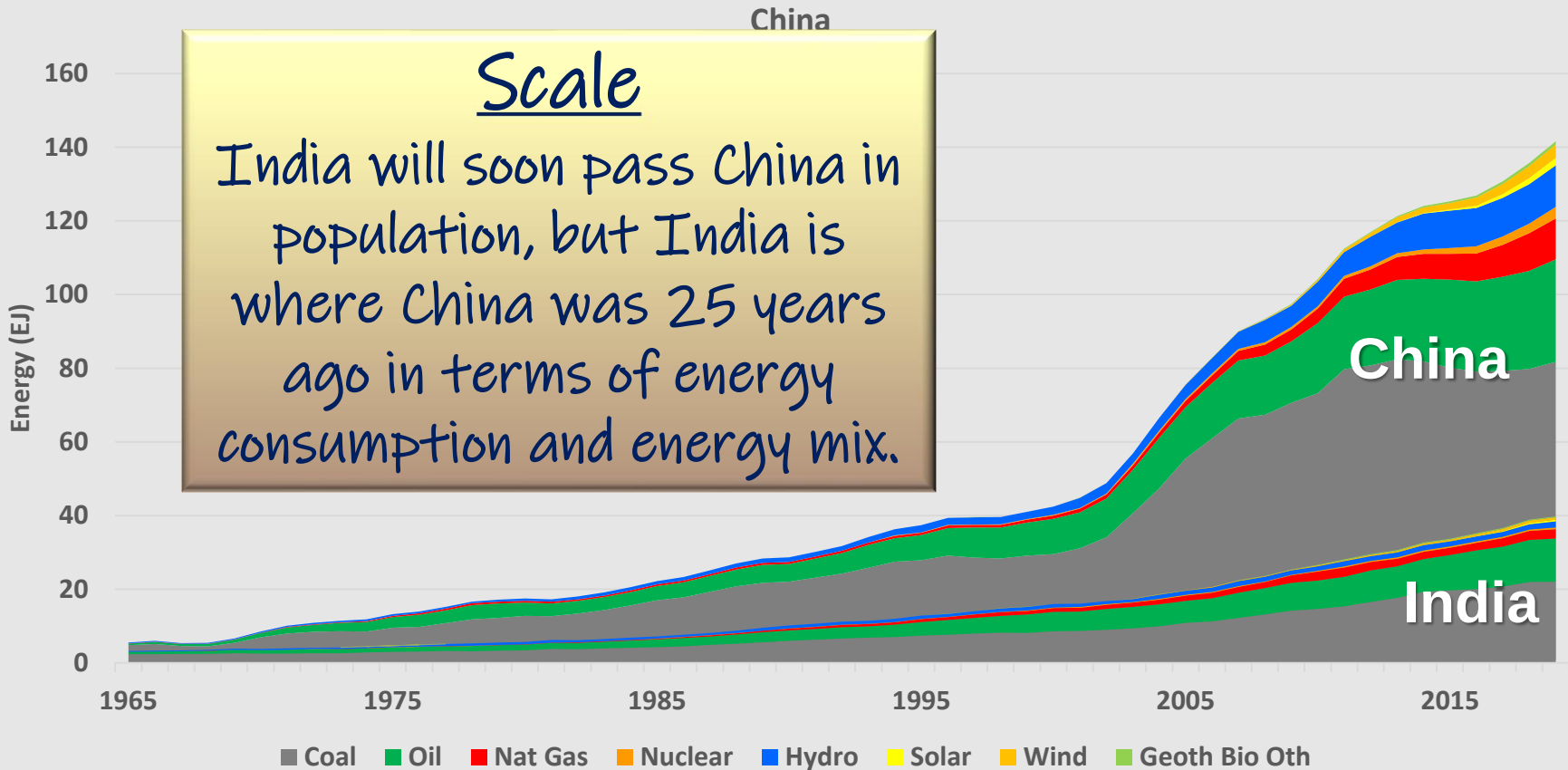
FRANCE ENERGY TRANSITION



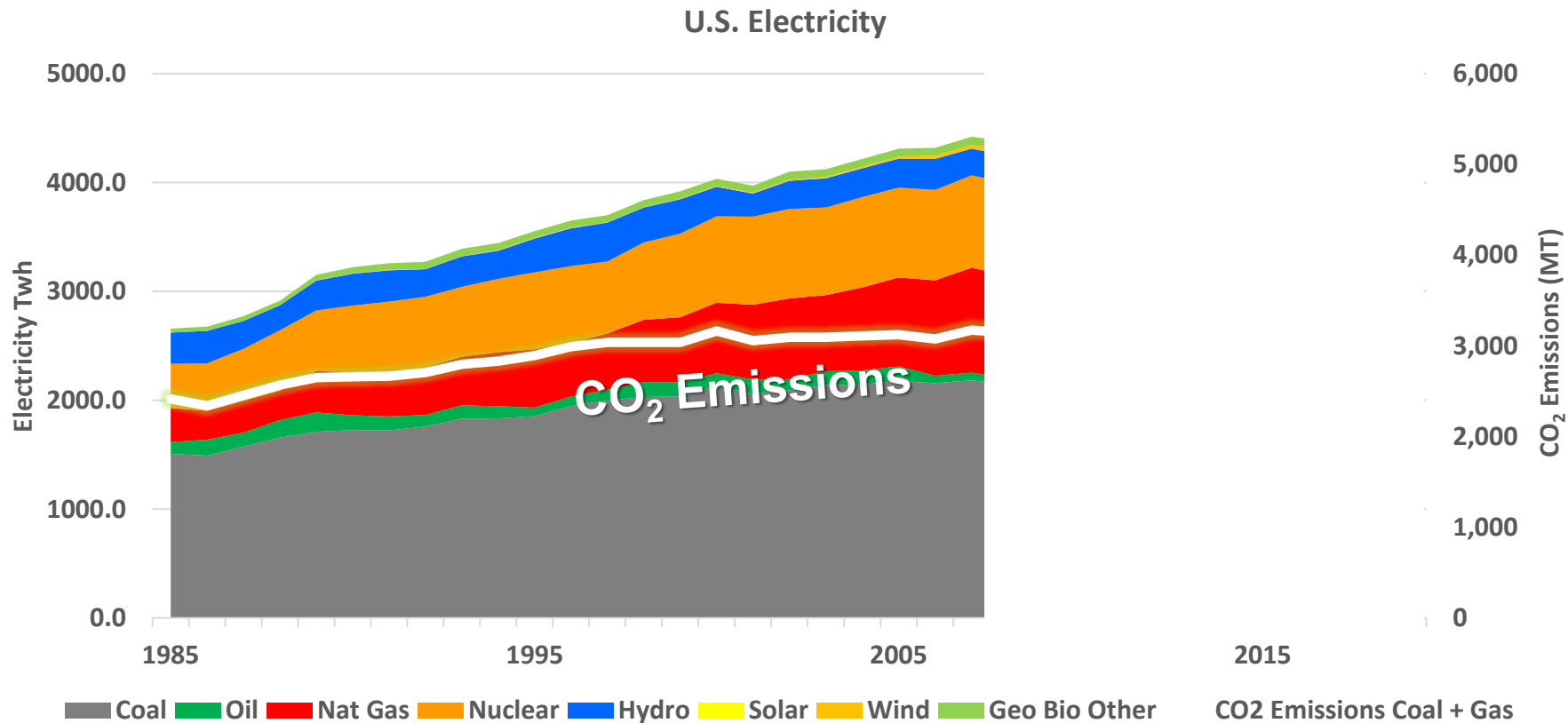
CHINA ENERGY TRANSITION



CHINA V. INDIA

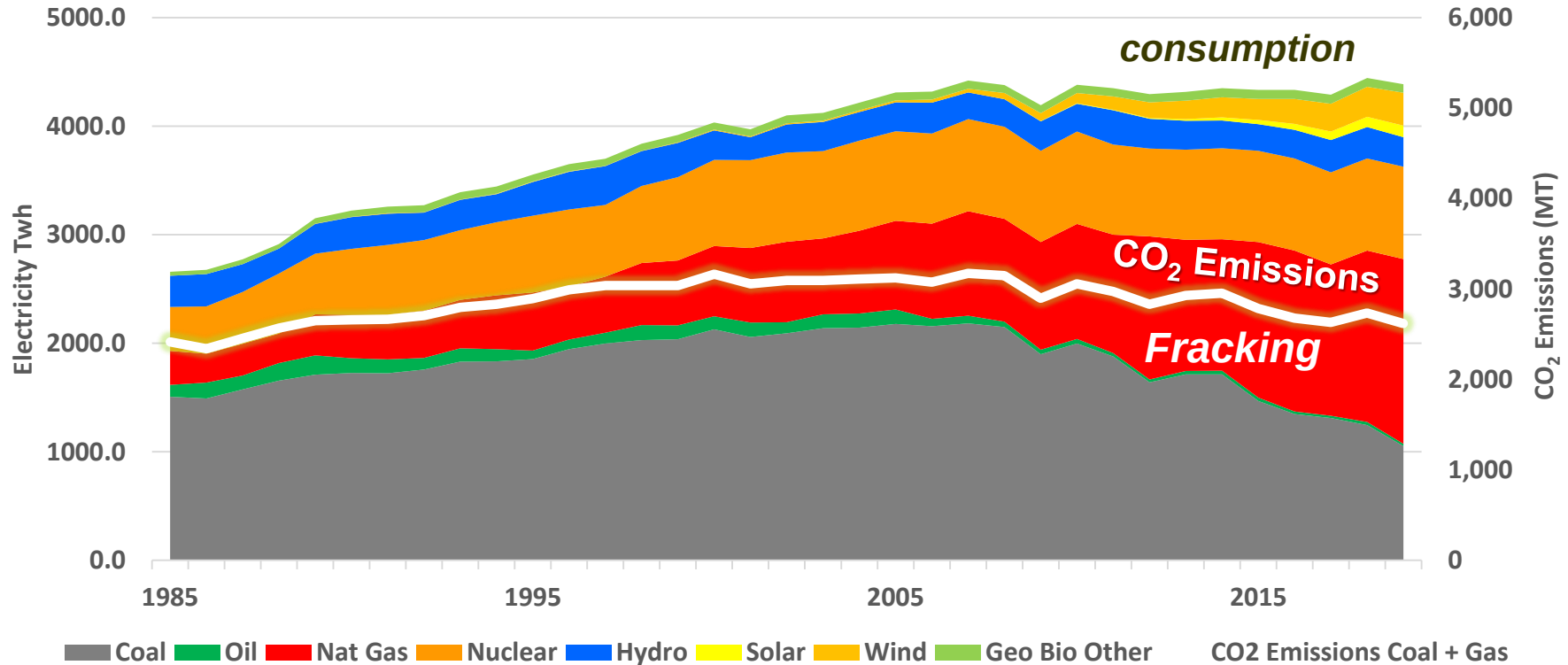


U.S. ELECTRICITY TRANSITION



U.S. ELECTRICITY TRANSITION

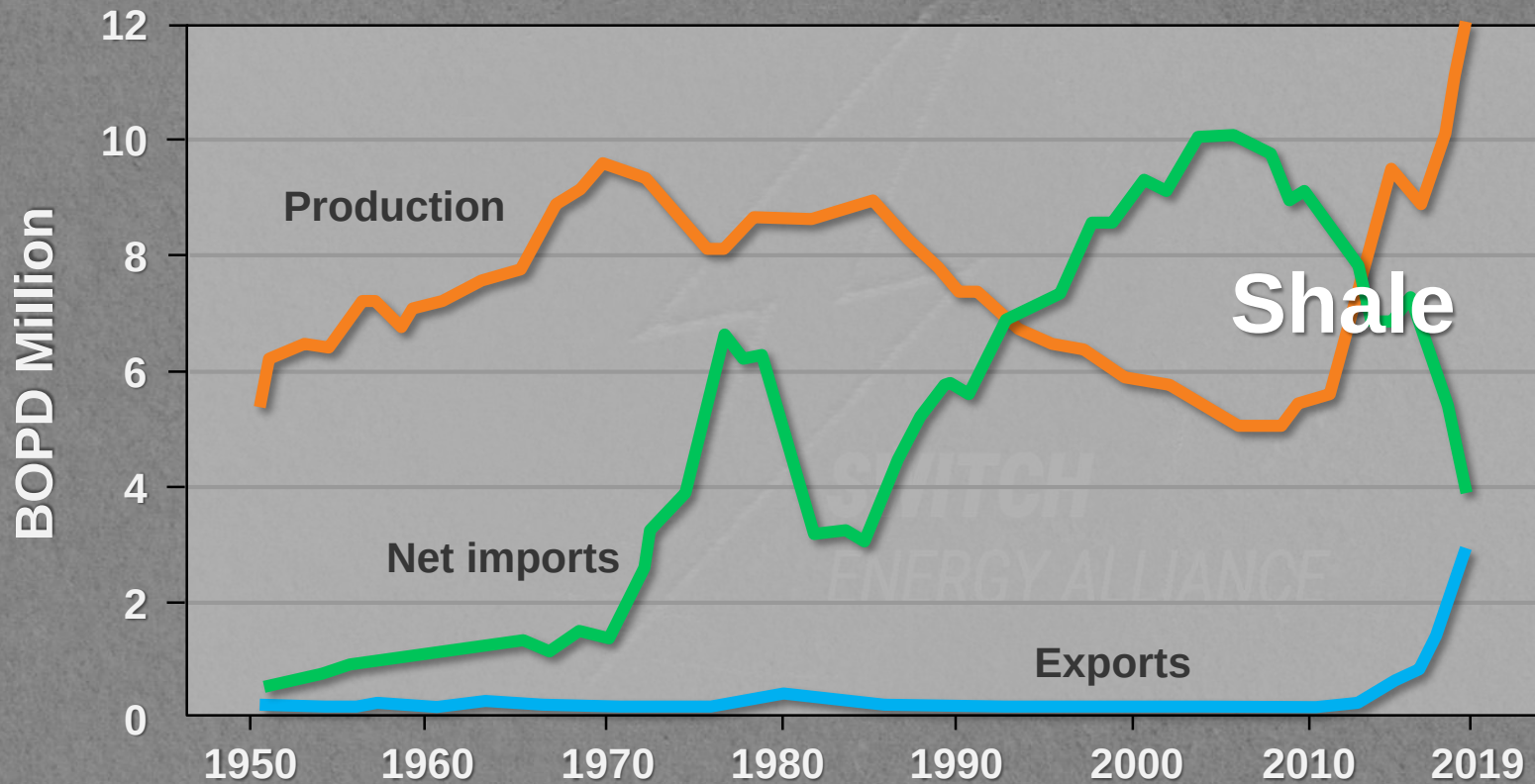
U.S. Electricity

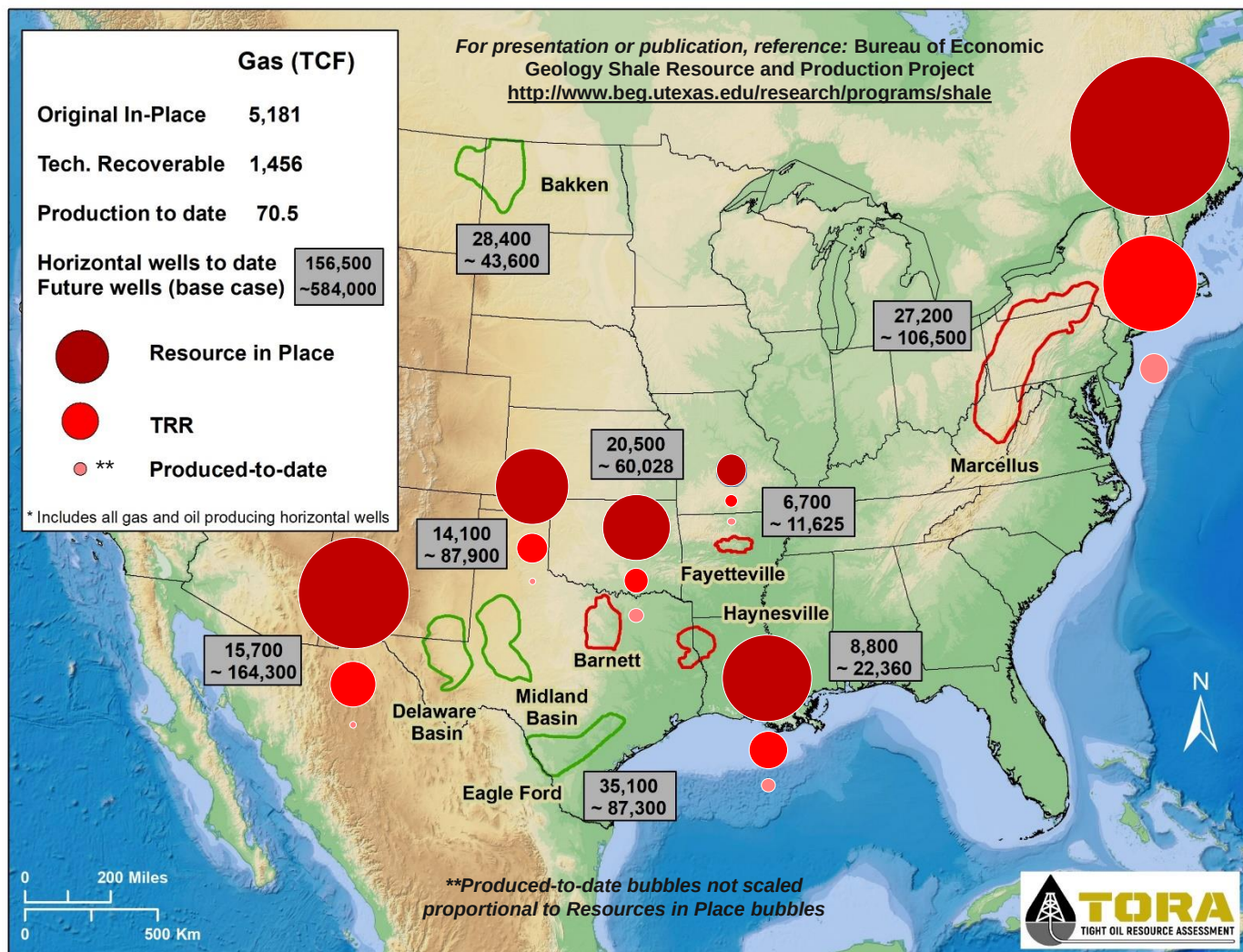


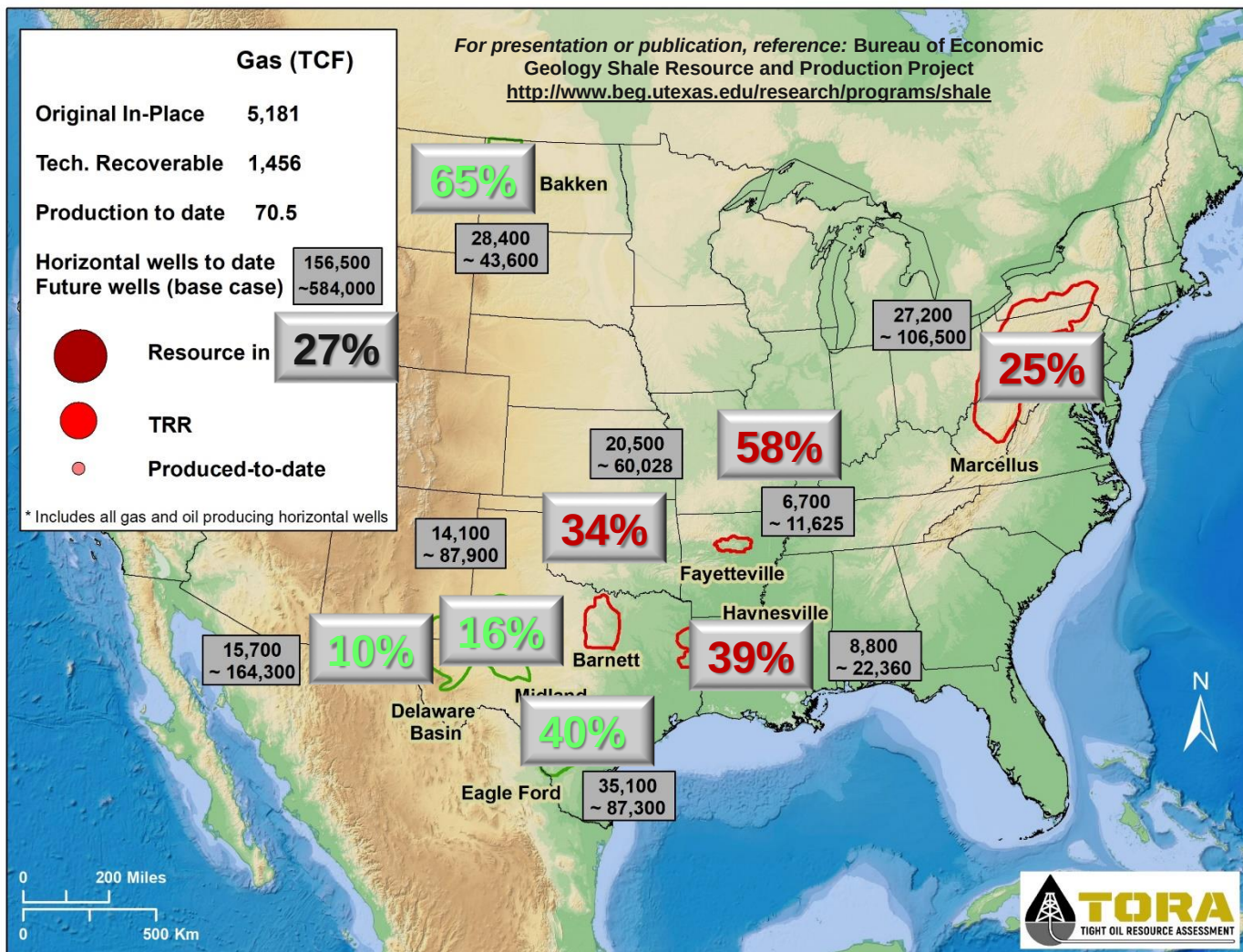
U.S. ELECTRICITY TRANSITION

The proposed 2015 Clean Power Plan (CPP) CO₂ emission reduction goals were met in 2020 (!), one decade ahead of schedule, without the CPP.

United States Crude Oil







Gas (TCF)

Original In-Place 5,181

Tech. Recoverable 1,456

Production to date 70.5

For presentation or publication, reference: Bureau of Economic
Geology Shale Resource and Production Project
<http://www.beg.utexas.edu/research/programs/shale>

65%

Bakken

28,400

27,200
~ 106,500

Resource in 27%

Produced-to-date

~ 60,028

Marcellus

6,700

11,625

Havnesville

15,700

10%

16%

Barnett

39%

8,800

23,360

Eagle Ford

35,100

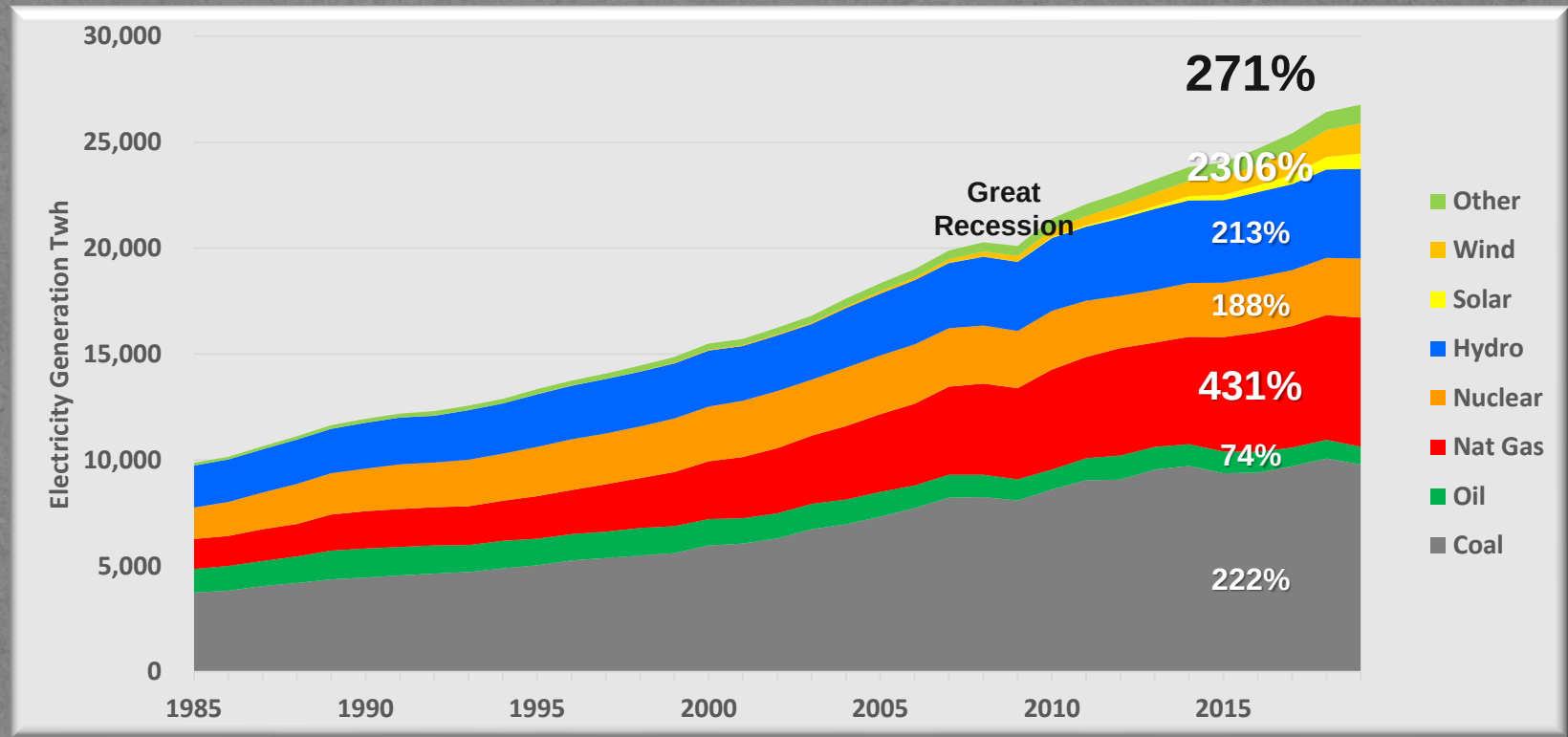
~ 87,300

0 200 Miles
0 500 Km



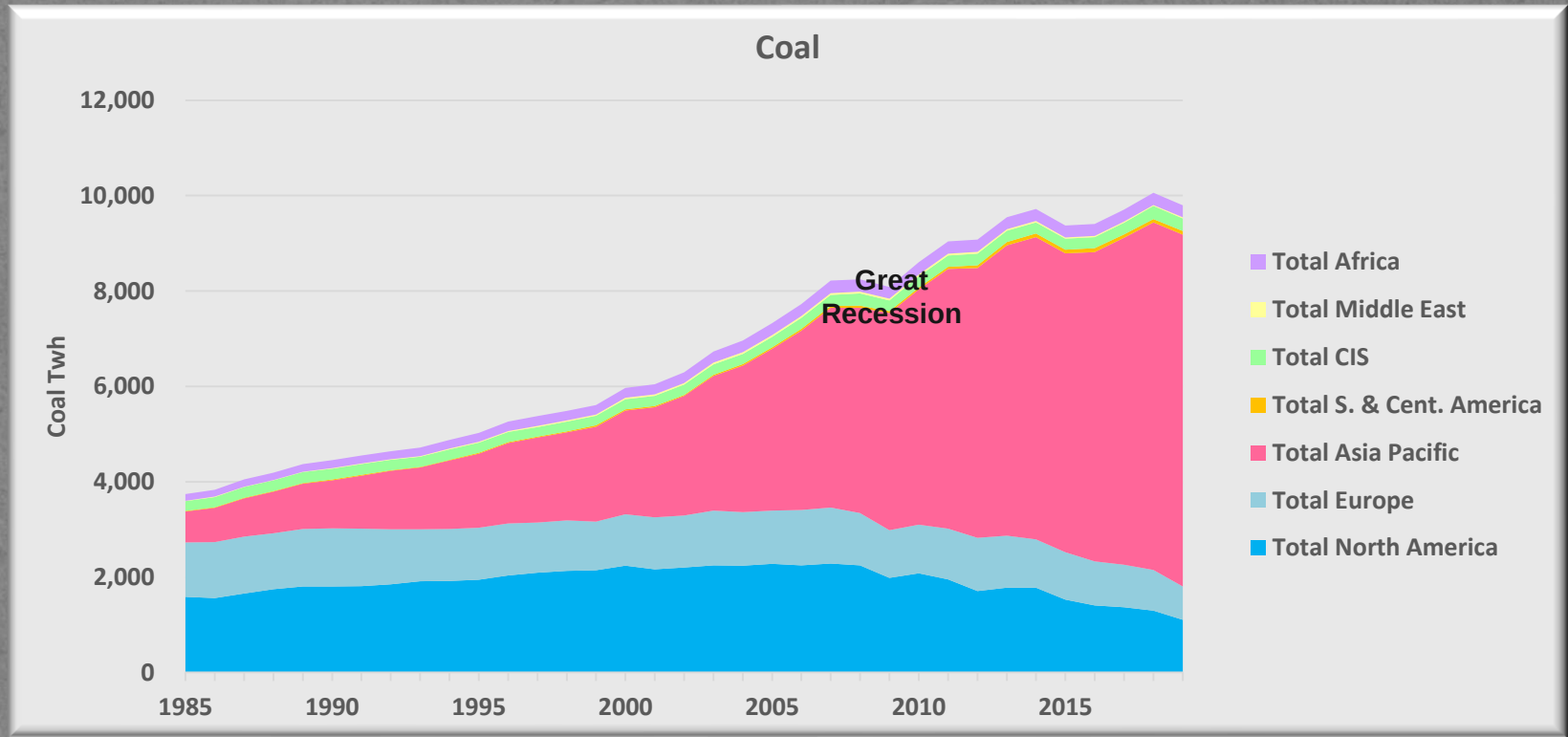
*Recovery to date of <5% of
TR natural gas and <8% of
TR oil leaves a tremendous
remaining resource.*

GLOBAL ELECTRICITY GENERATION BY SOURCE



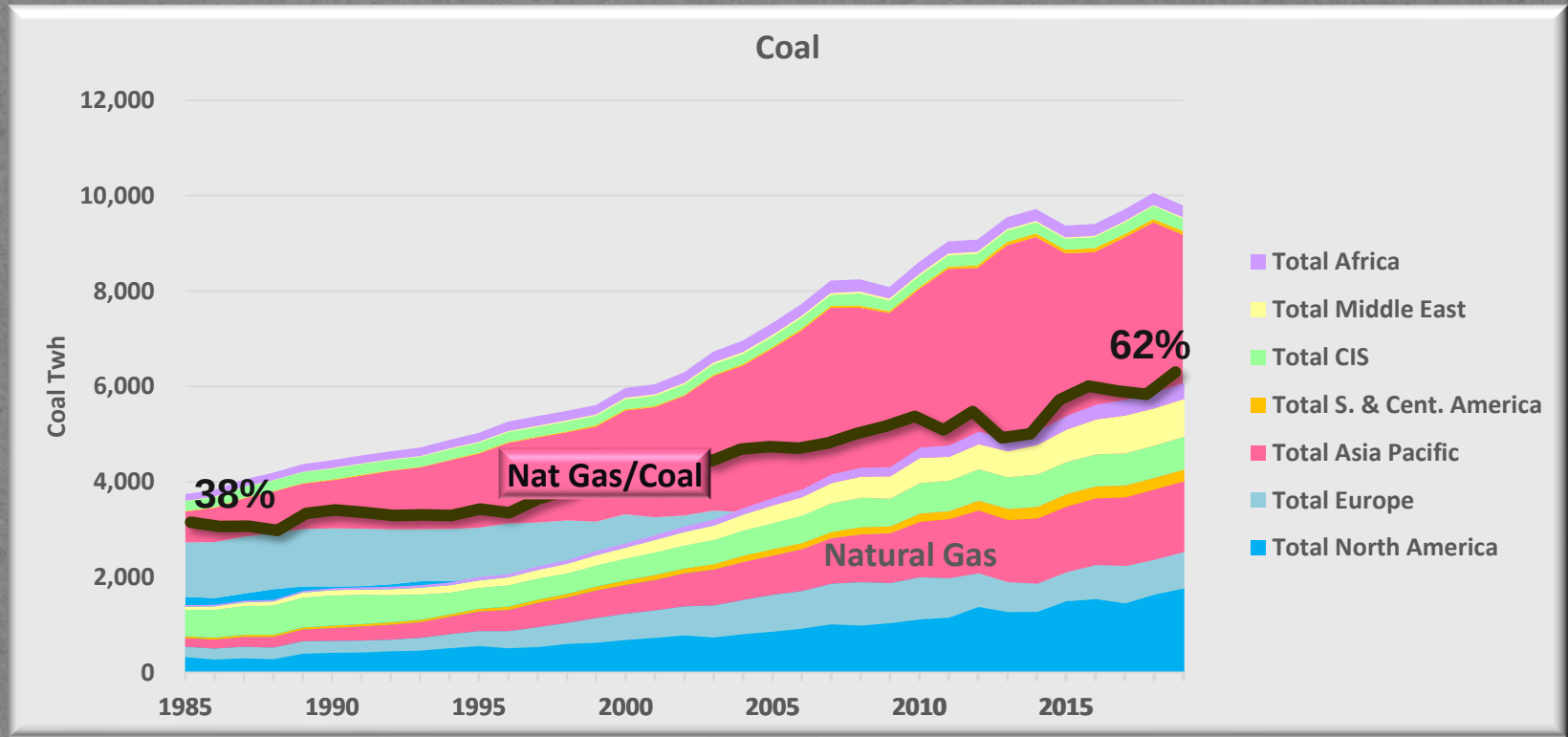
GLOBAL ELECTRICITY GENERATION

COAL V. NATURAL GAS



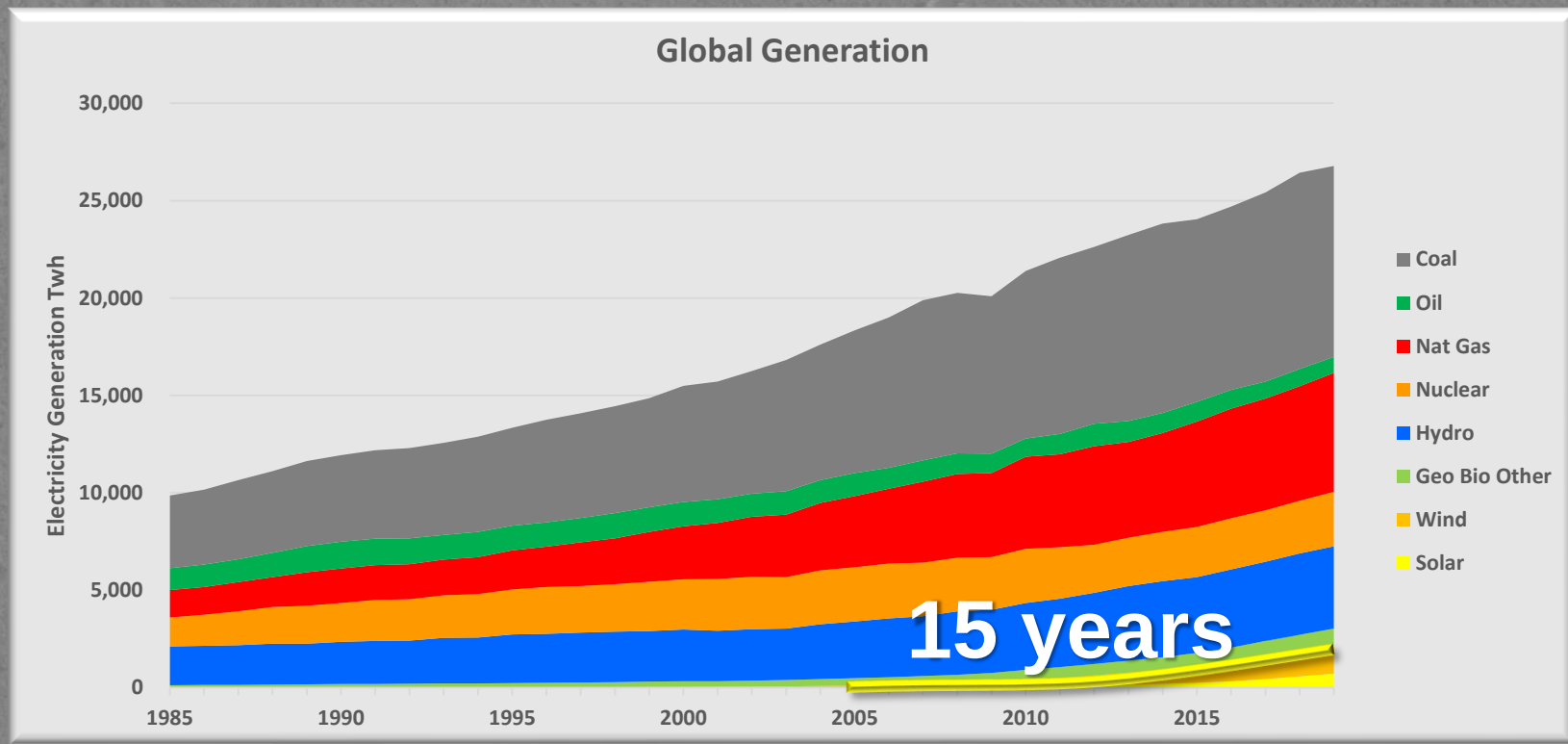
GLOBAL ELECTRICITY GENERATION

COAL V. NATURAL GAS



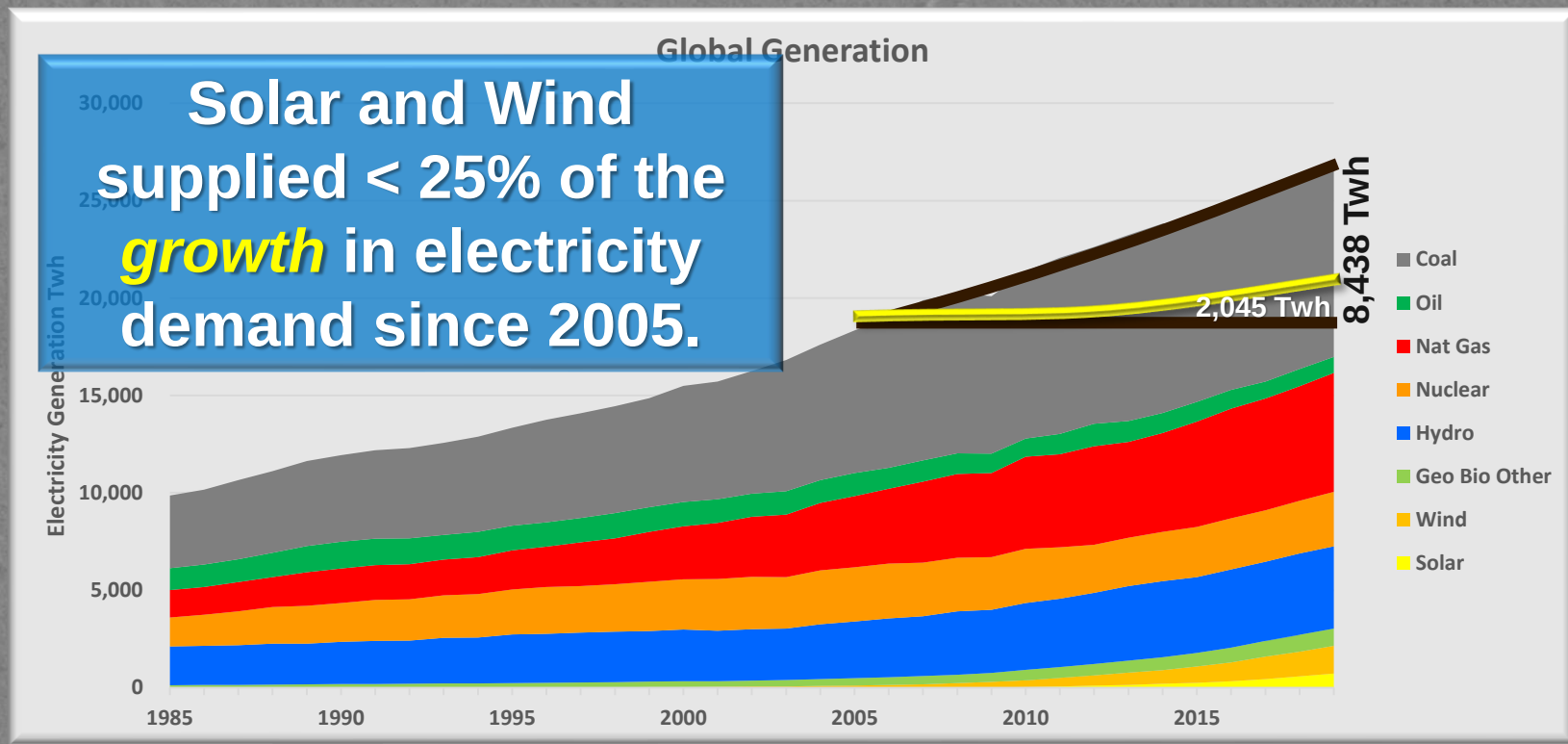
GLOBAL ELECTRICITY V. SOLAR AND WIND

BY SOURCE

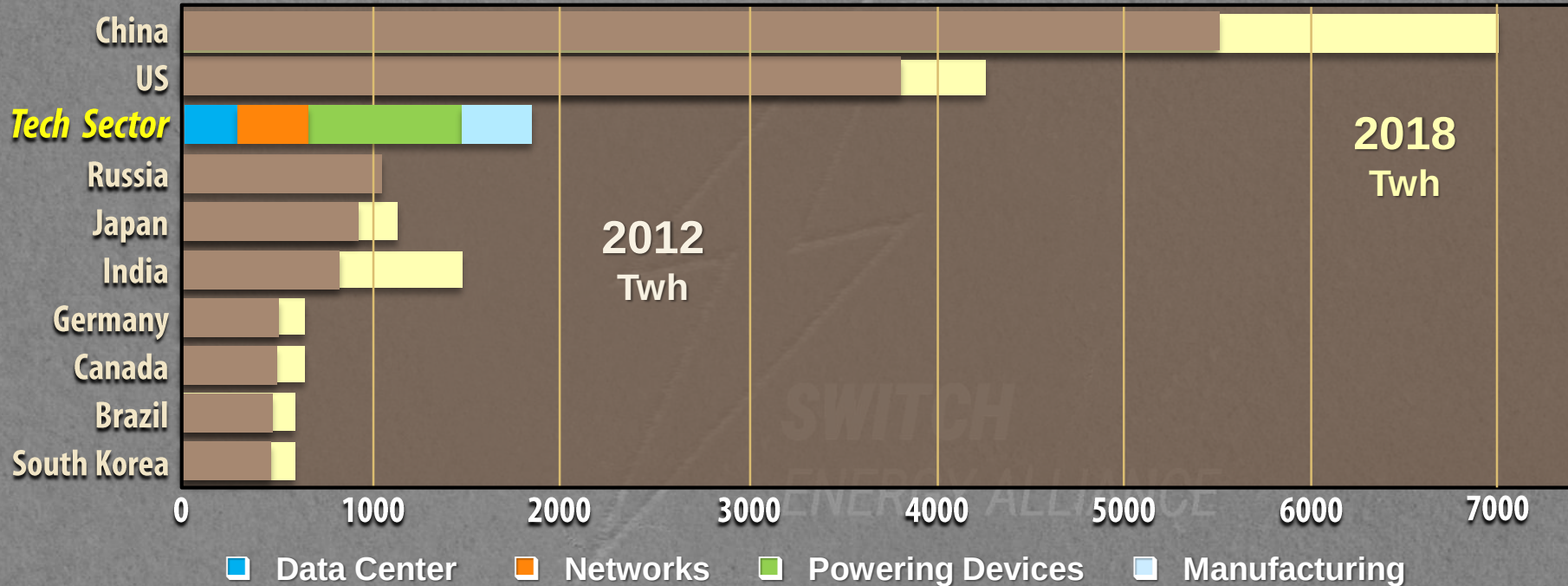


GLOBAL ELECTRICITY V. SOLAR AND WIND

BY SOURCE

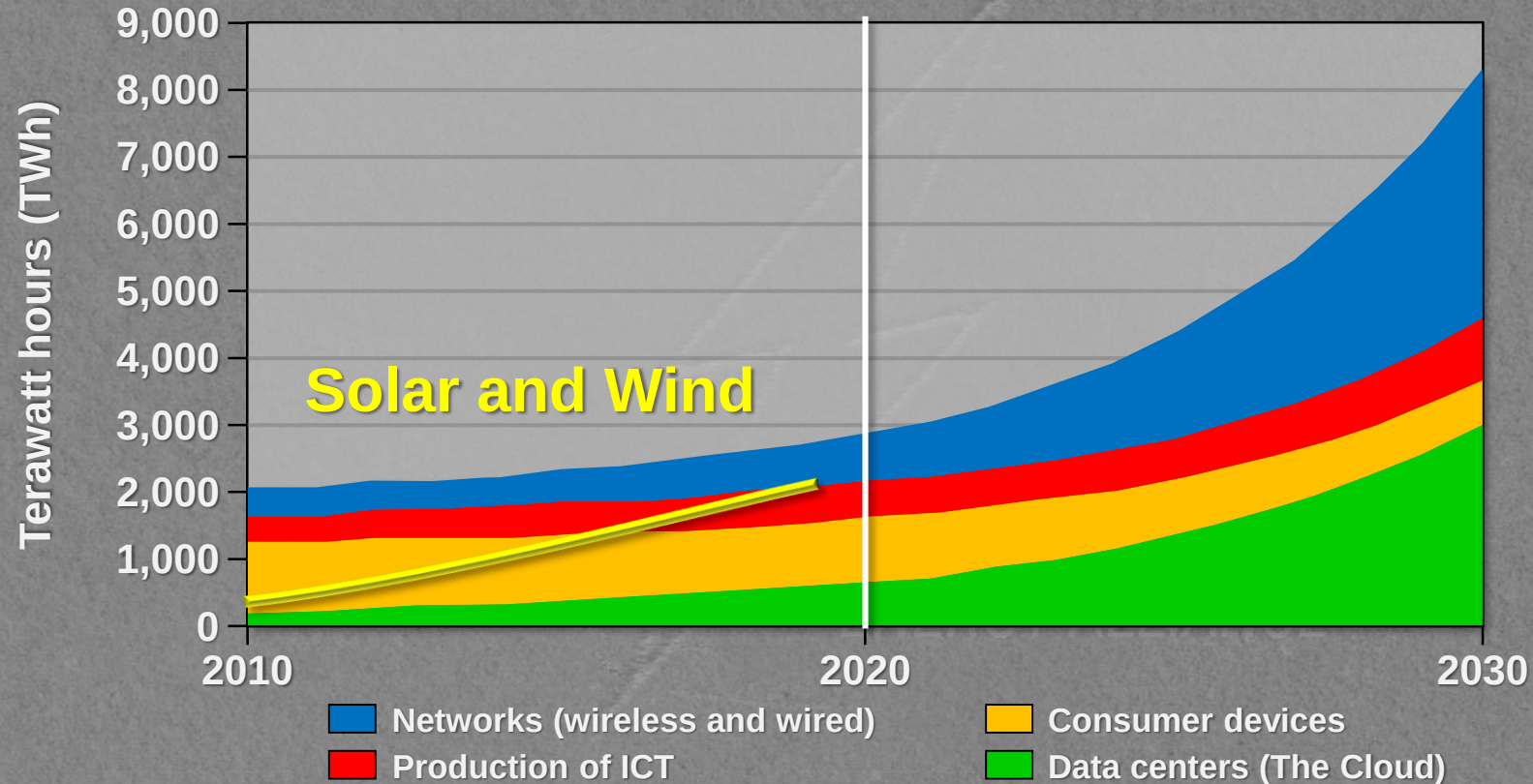


Electricity Use



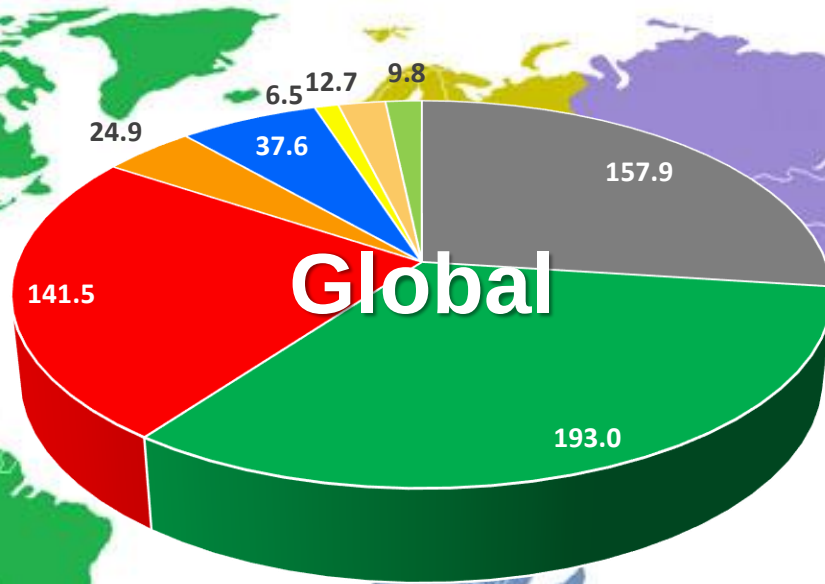
Source: Emerging Trends in Electricity Consumption for Consumer ICT, Peter Corcoran and Andres Andrae (2013) and CIA World Factbook. China/Russia/Canada figures are from 2014. BP Statistical Review 2019

TECH SECTOR ELECTRICITY



The Global Energy Transition

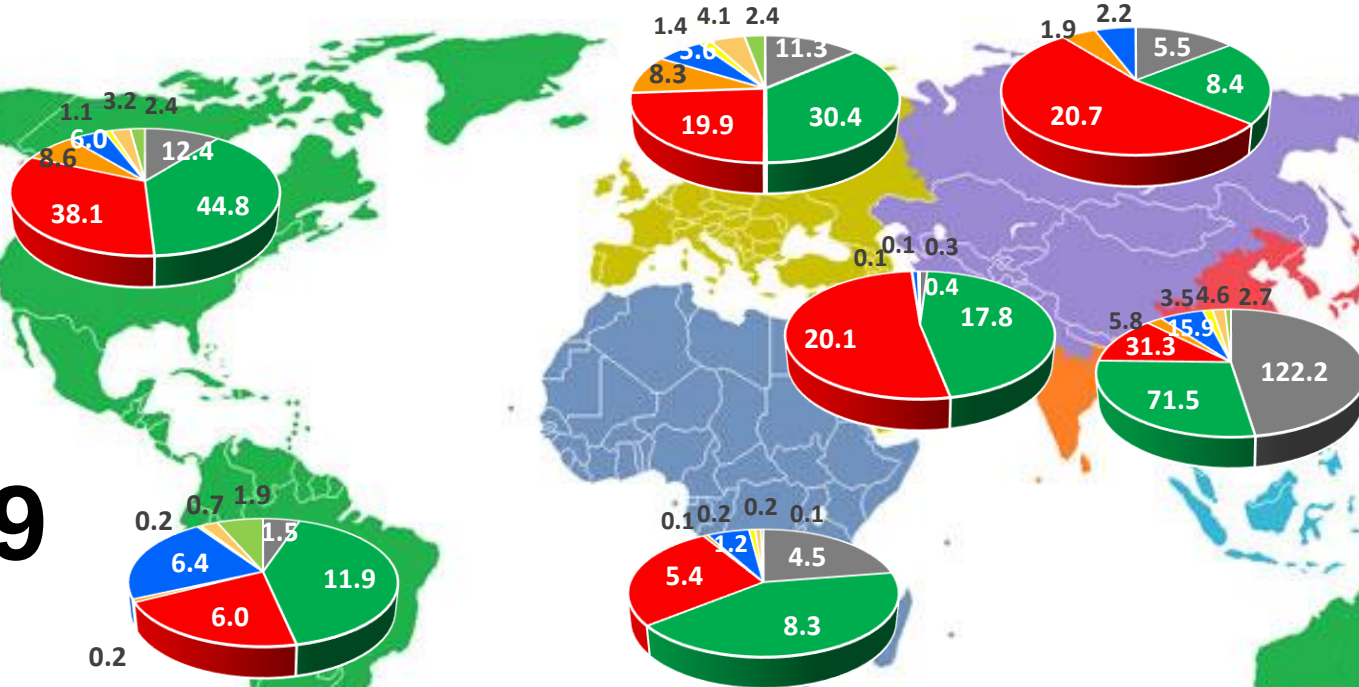
2019



Global Population
Each map color ~ 1.1 billion people
(1 EJ ~ 1 Tcf)

The Global Energy Transition

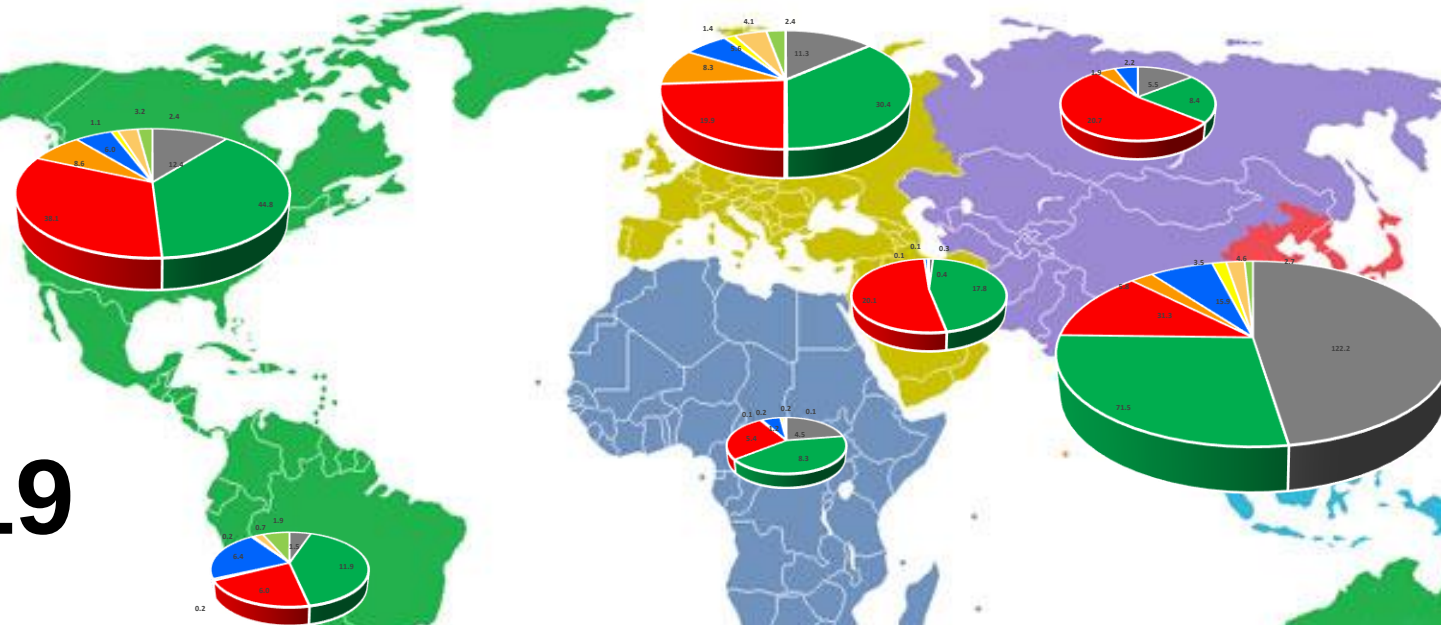
2019



Global Population
 Each map color ~ 1.1 billion people
(1 EJ ~ 1 Tcf)

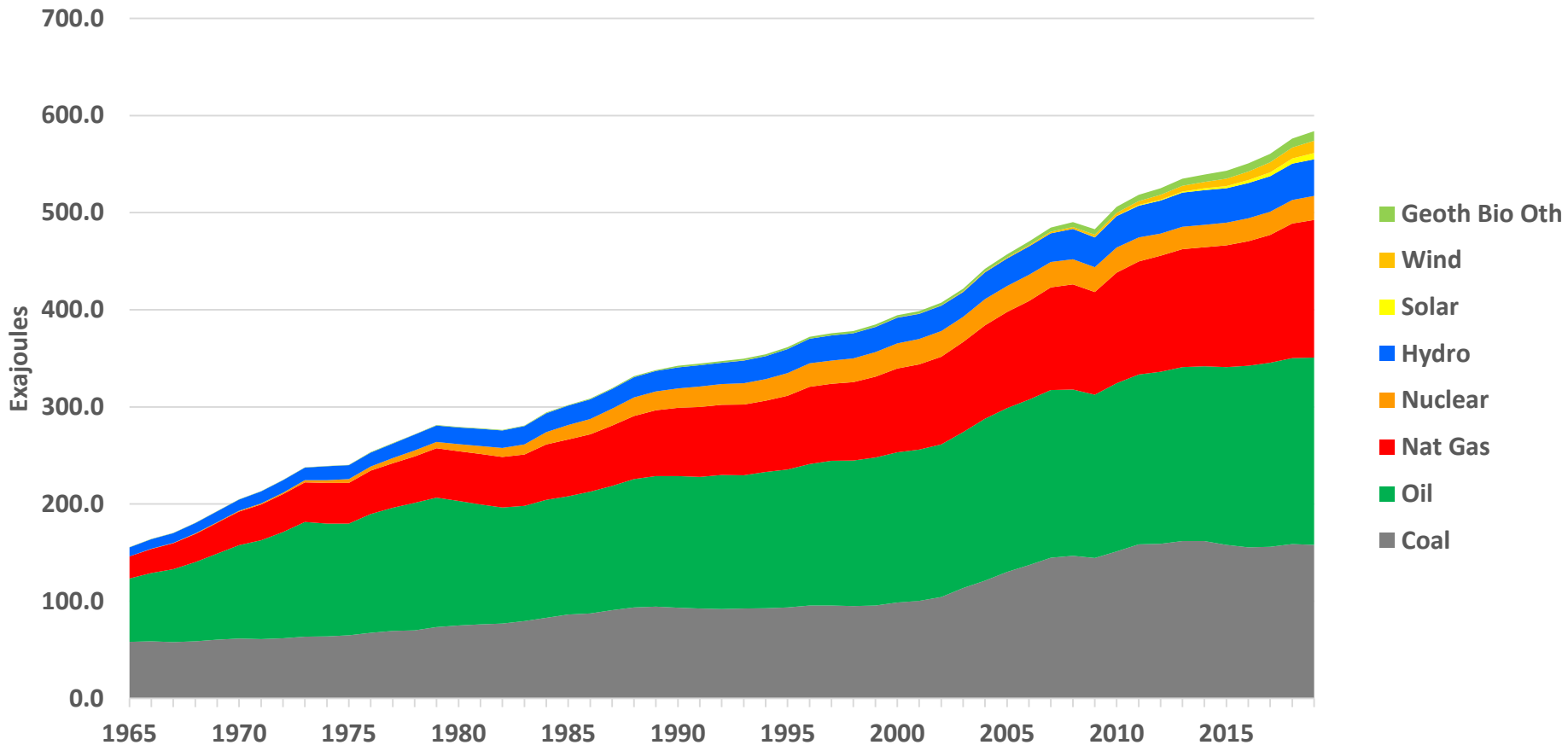
The Global Energy Transition

2019

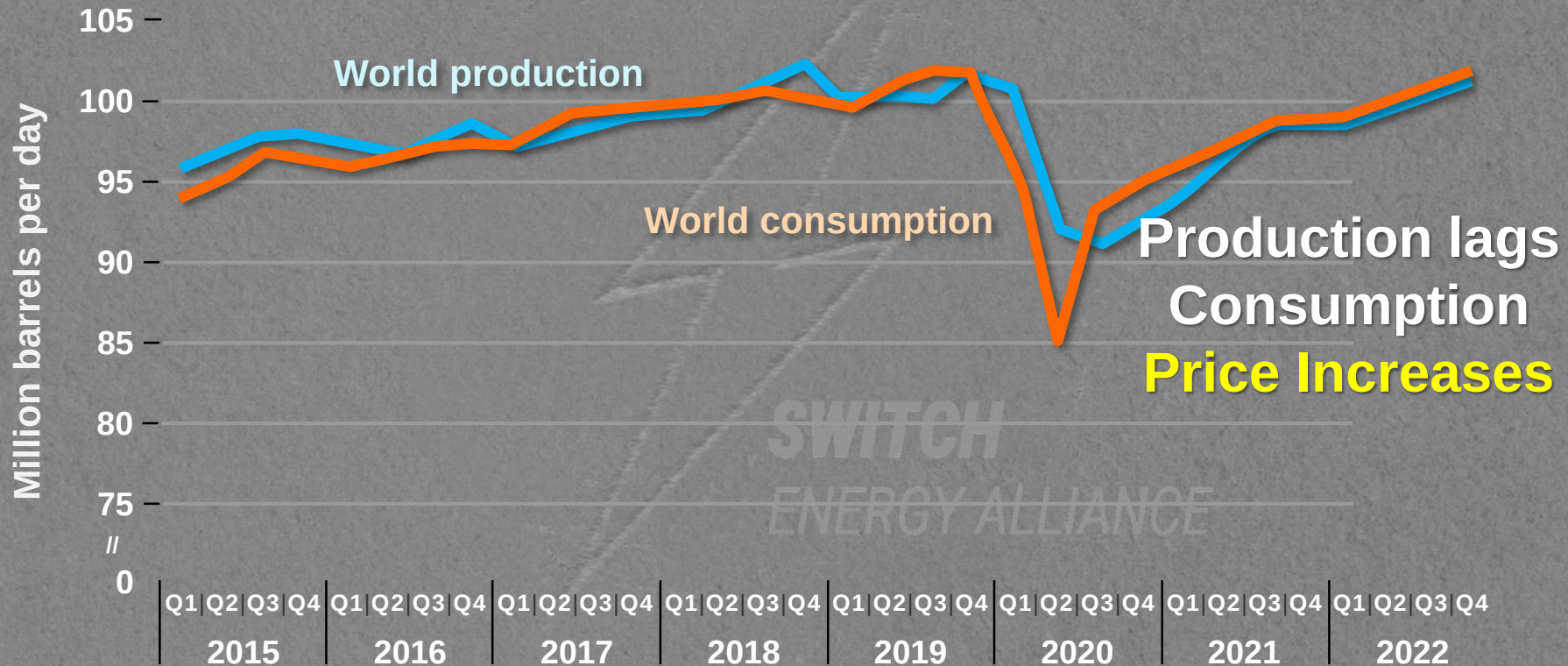


Global Population
 Each map color ~ 1.1 billion people
(1 EJ ~ 1 Tcf)

The Global Energy Transition



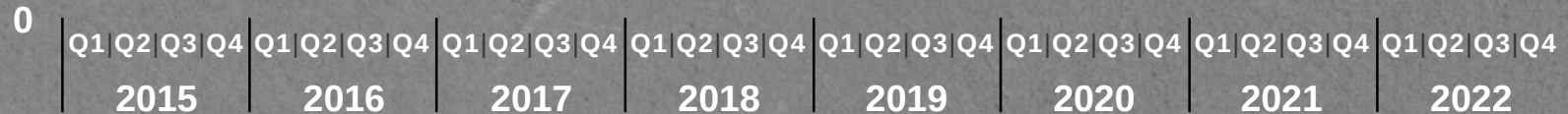
World Oil Production/Consumption



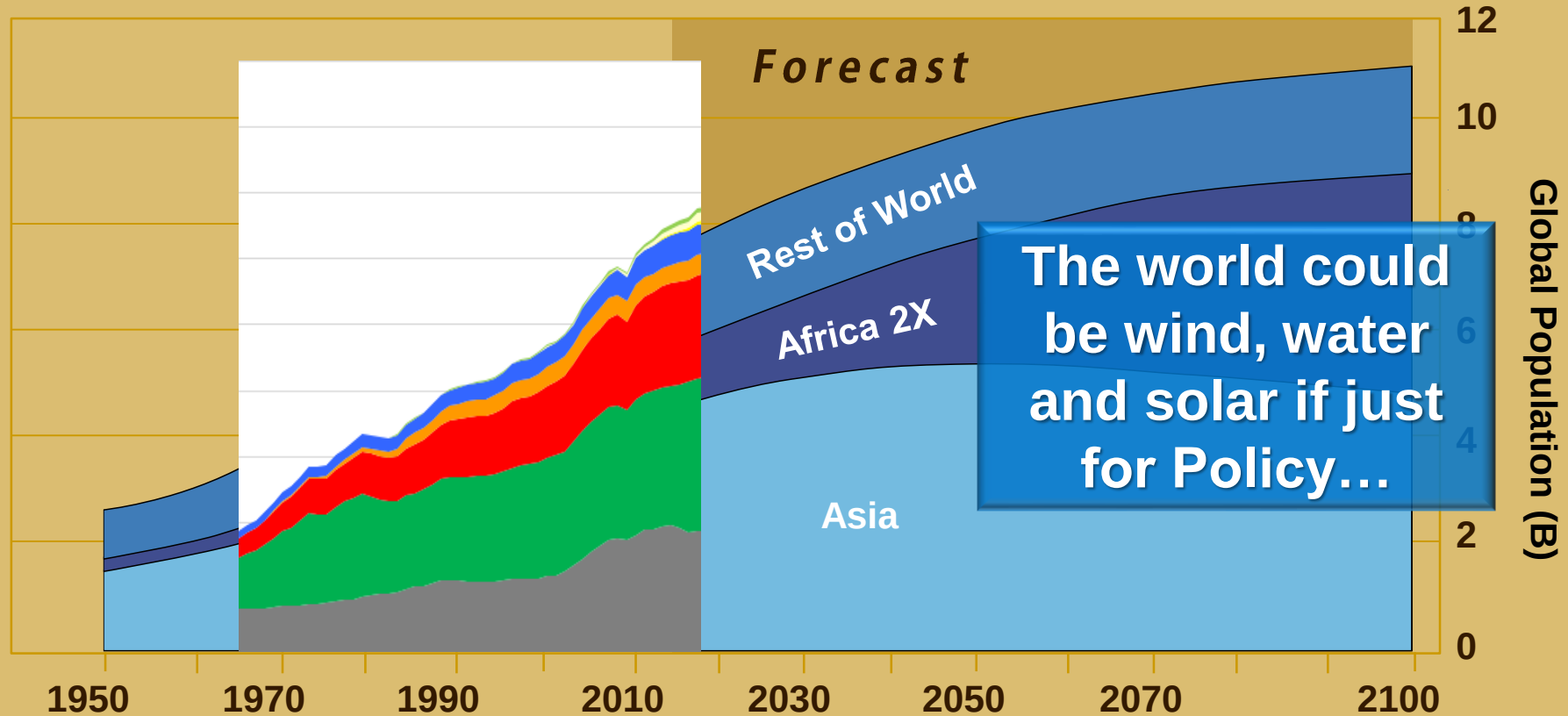
World Oil Production/Consumption

Million barrels per day

COVID-19 will change some work behaviors in developed nations, but will not have a lasting impact on the global economy or energy mix.



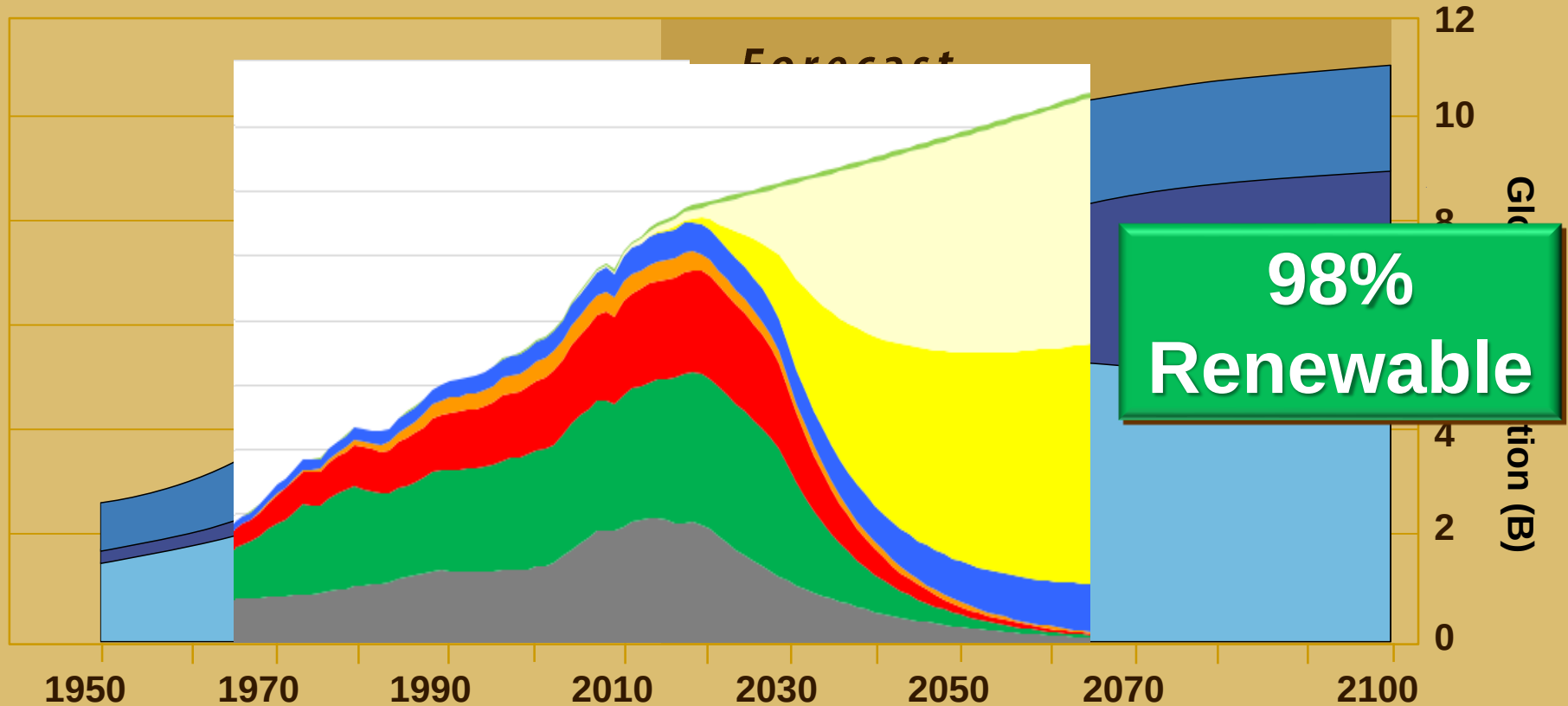
GLOBAL ENERGY TRANSITION RATE



Data: BP Statistical View of World Energy (2020). Analysis Tinker

Source: Population Data from the UN

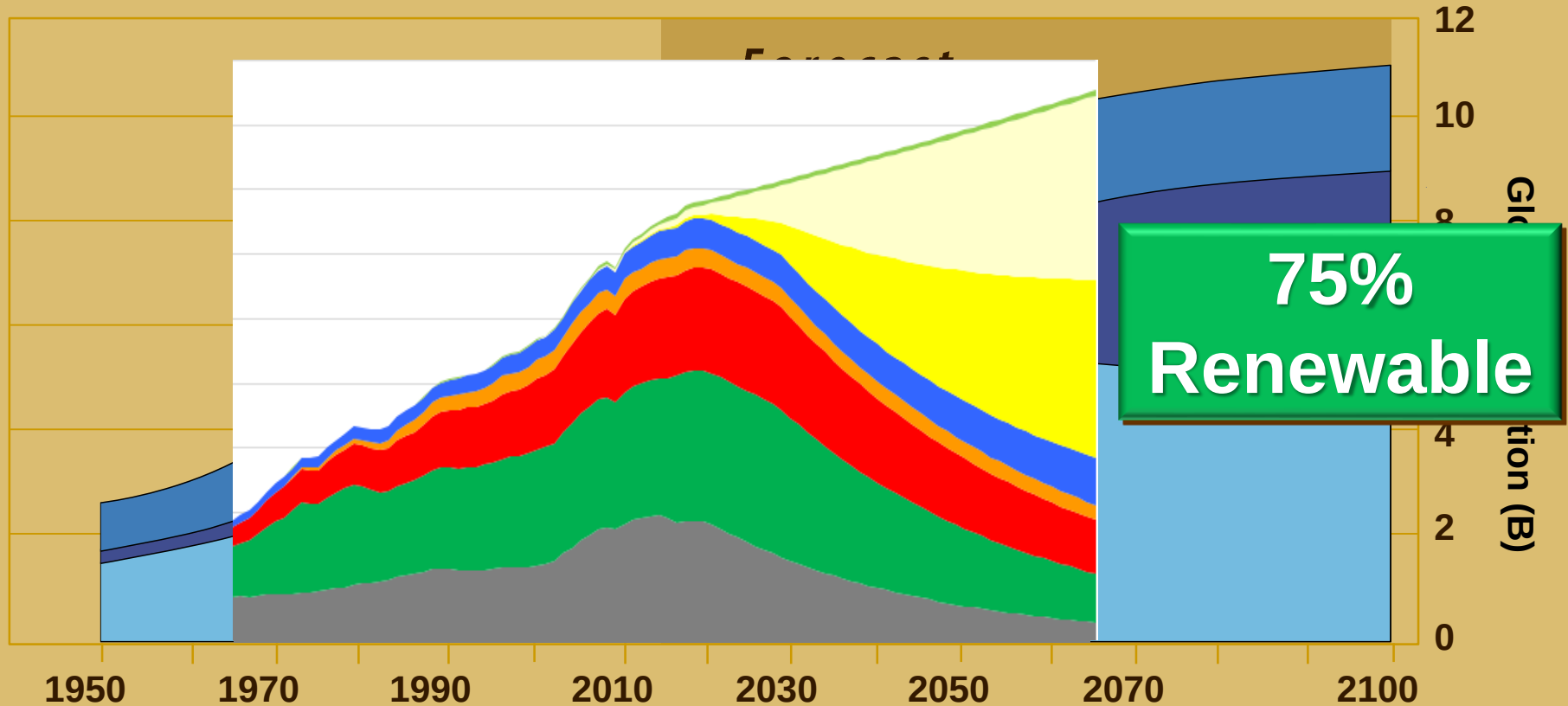
GLOBAL ENERGY TRANSITION RATE



Data: BP Statistical View of World Energy (2020). Analysis Tinker

Source: Population Data from the UN

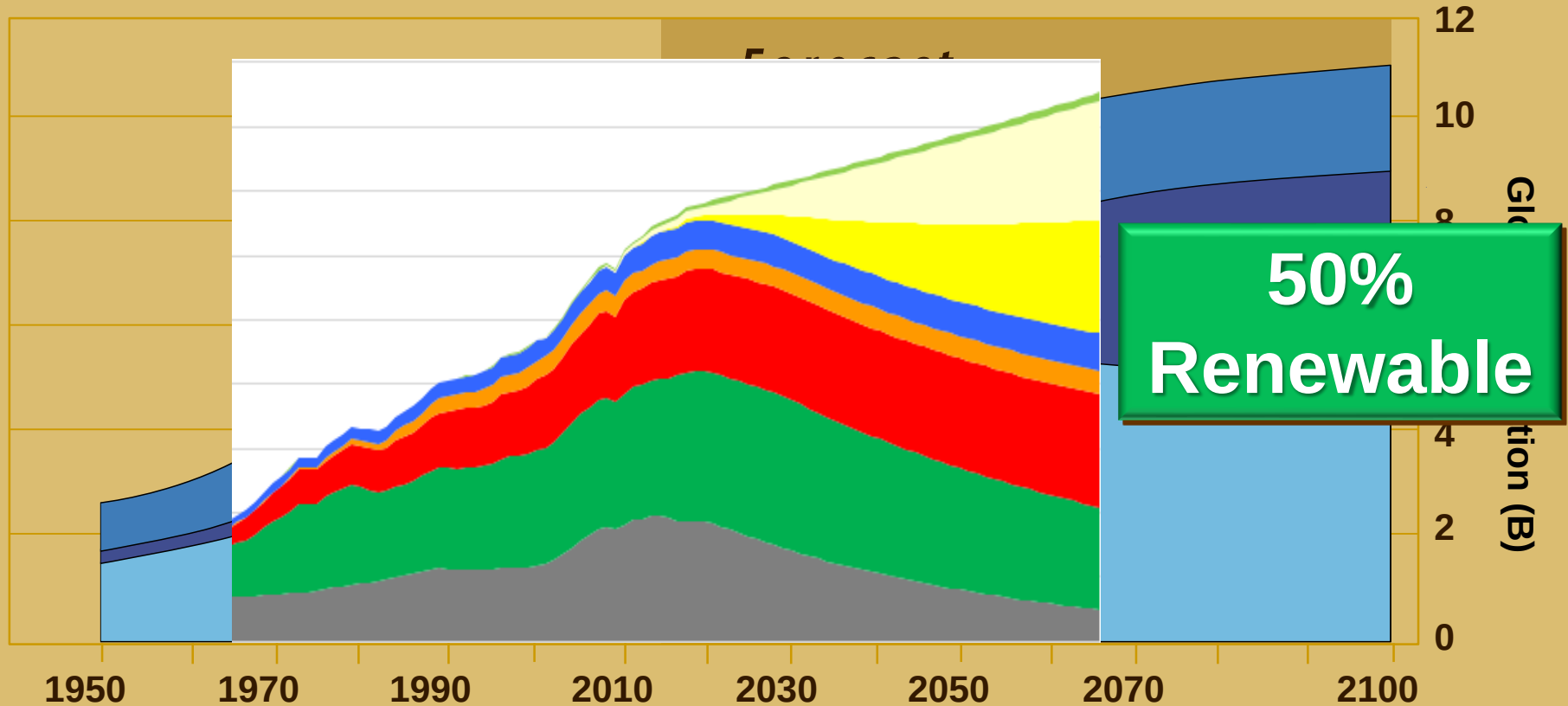
GLOBAL ENERGY TRANSITION RATE



Data: BP Statistical View of World Energy (2020). Analysis Tinker

Source: Population Data from the UN

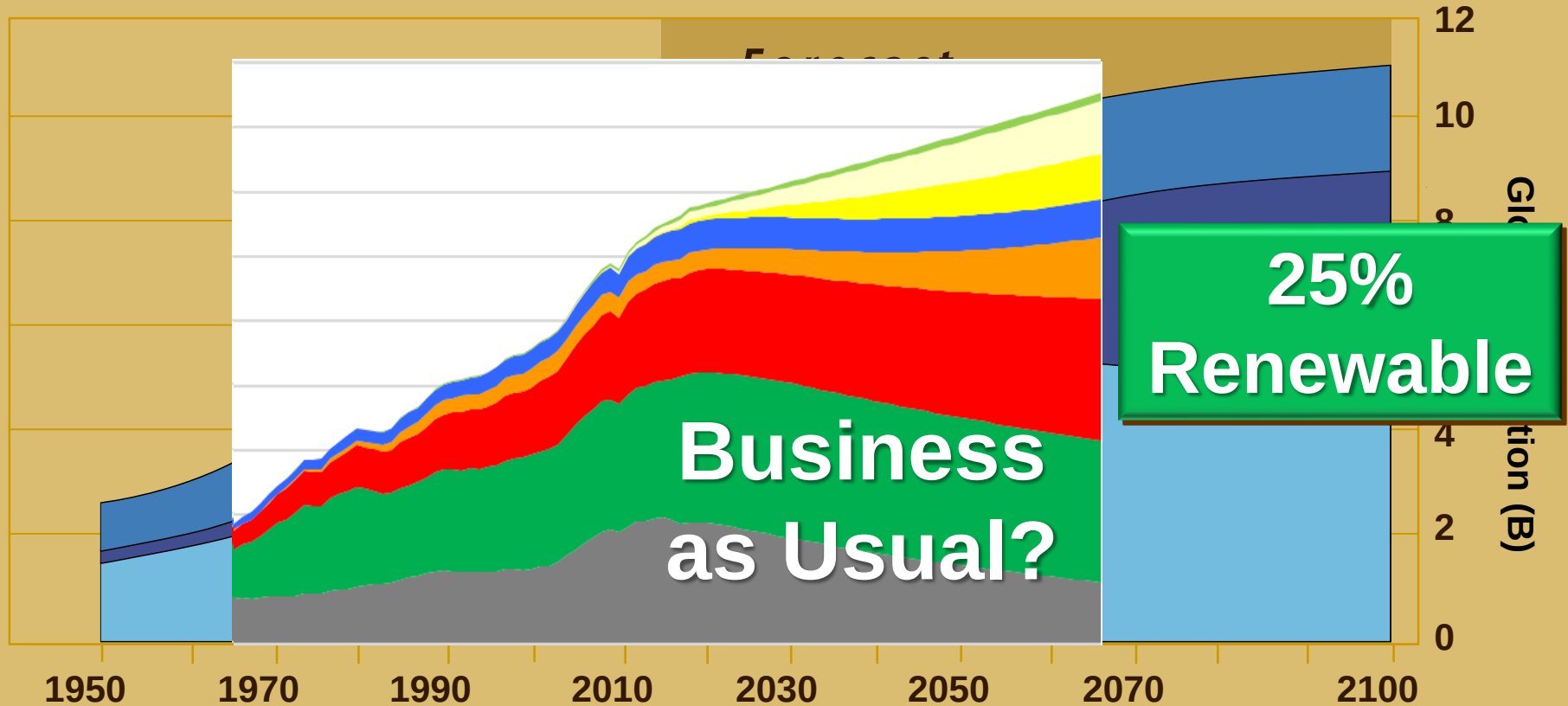
GLOBAL ENERGY TRANSITION RATE



Data: BP Statistical View of World Energy (2020). Analysis Tinker

Source: Population Data from the UN

GLOBAL ENERGY TRANSITION RATE

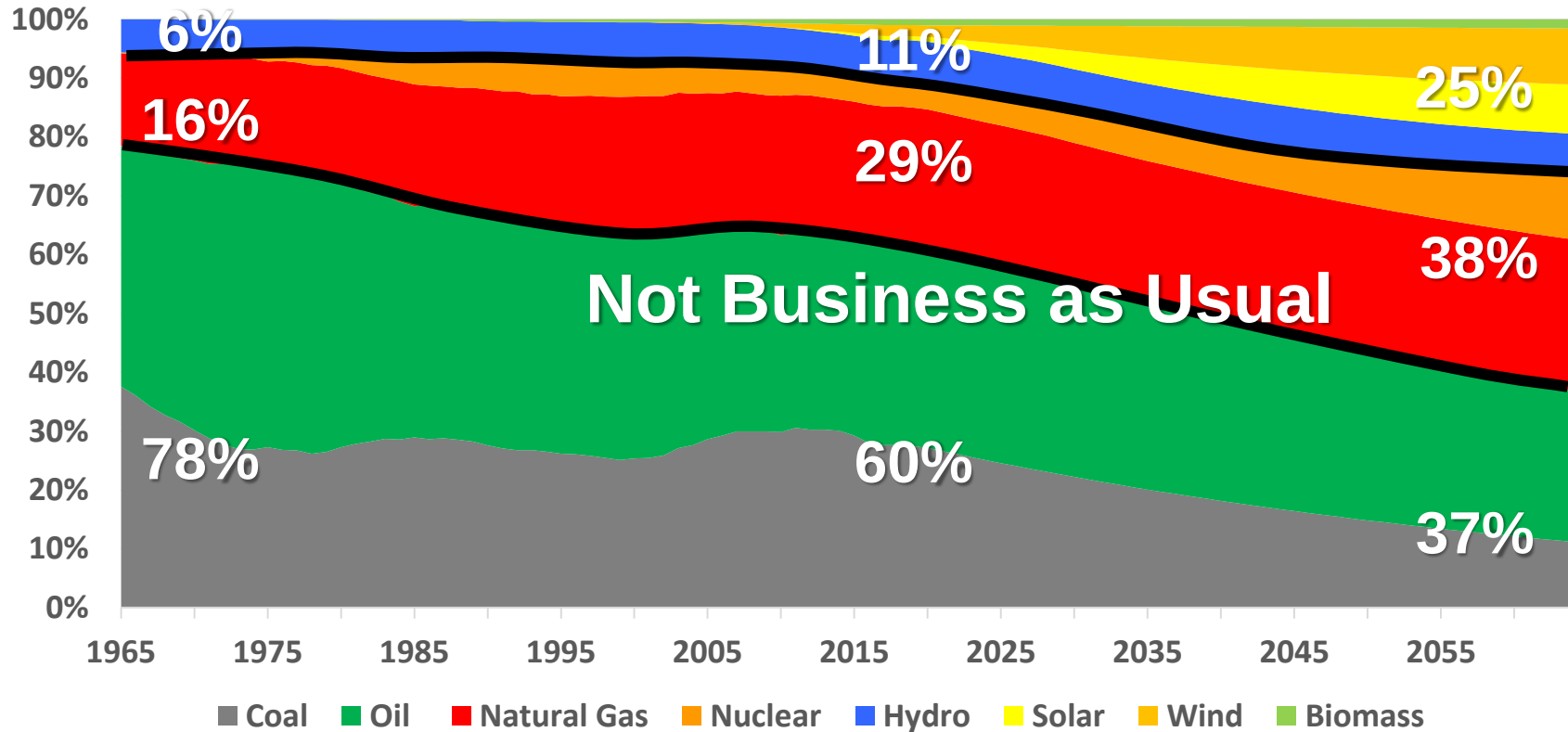


Data: BP Statistical View of World Energy (2020). Analysis Tinker

Source: Population Data from the UN

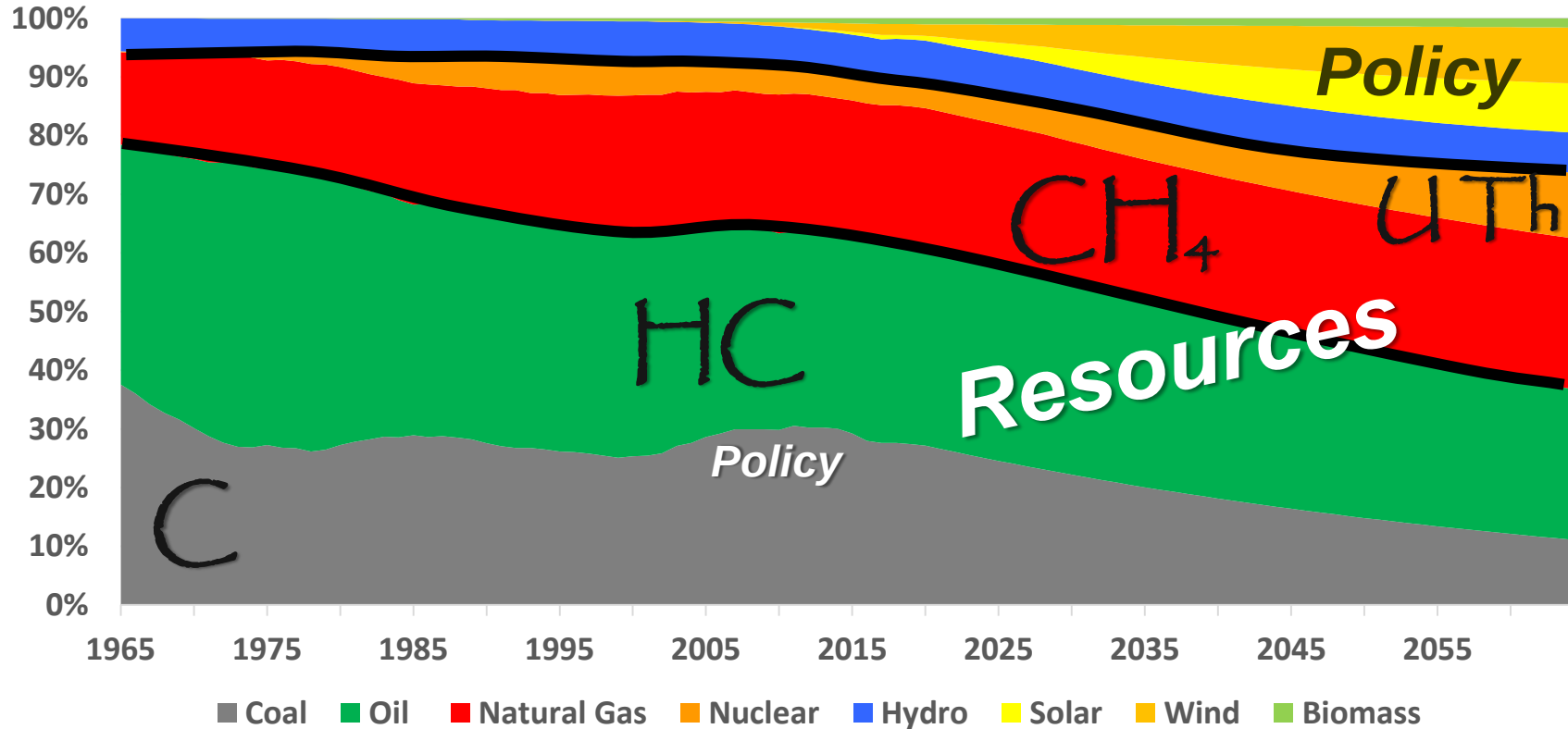
GLOBAL ENERGY TRANSITION

25% Renewable



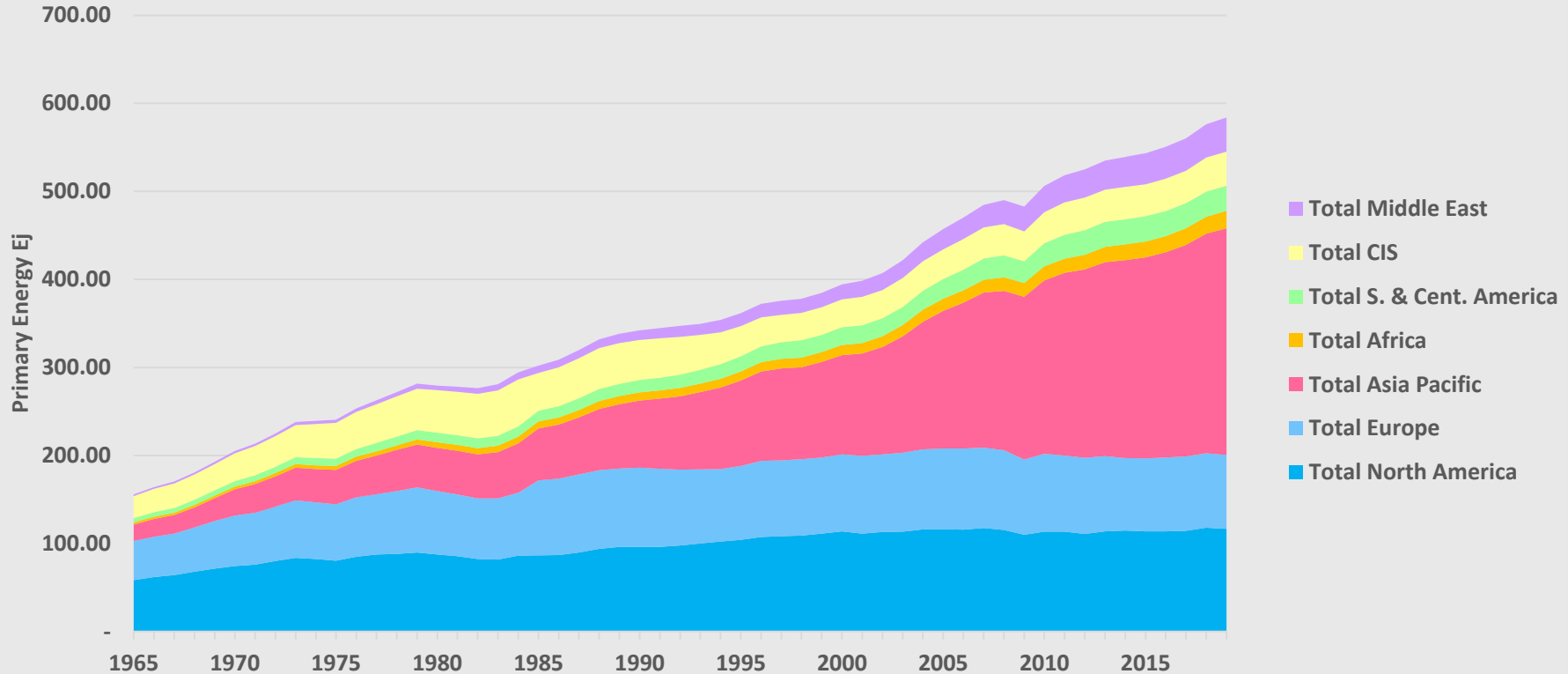
GLOBAL ENERGY TRANSITION

25% Renewable

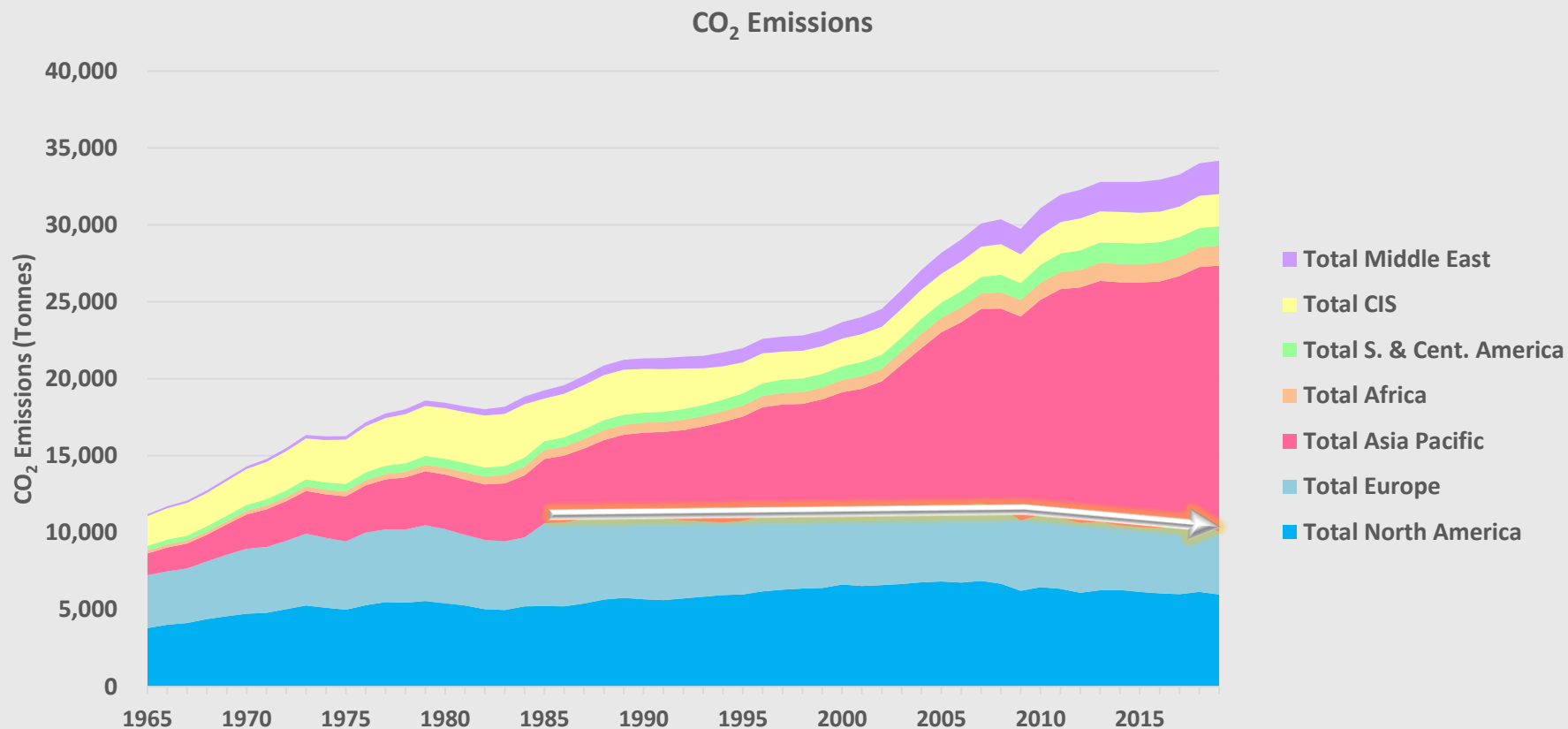


GLOBAL ENERGY BY REGION

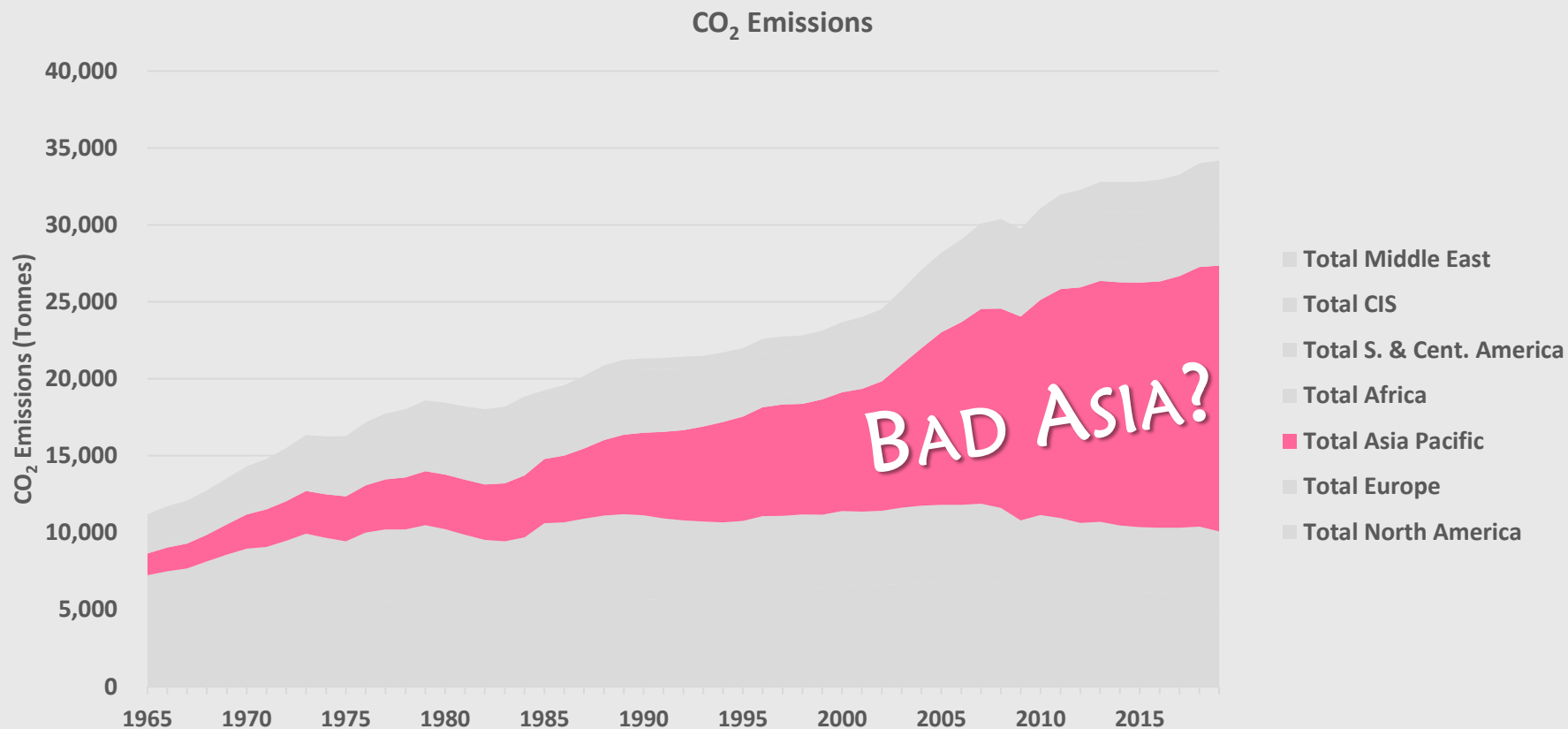
Global Energy Consumption by Region



GLOBAL ANTHROPOGENIC CO₂ EMISSIONS

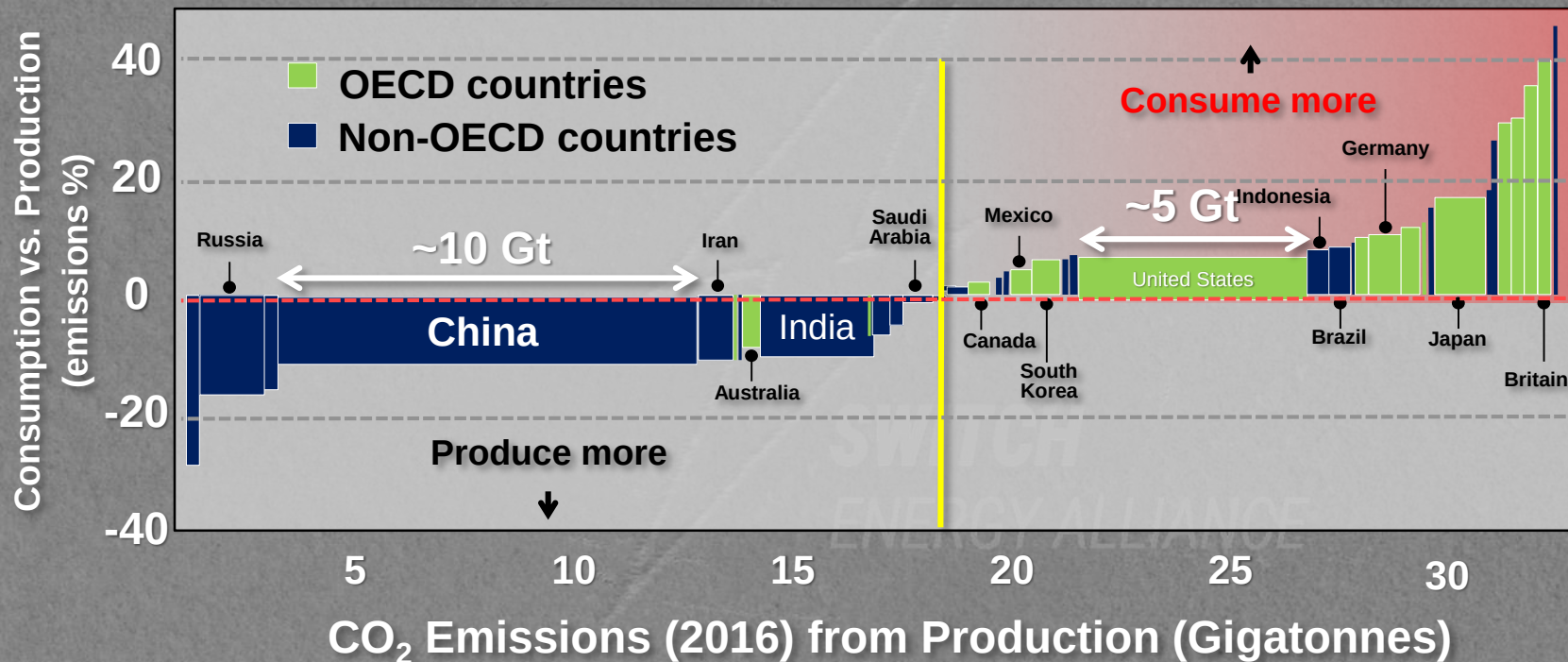


GLOBAL ANTHROPOGENIC CO₂ EMISSIONS

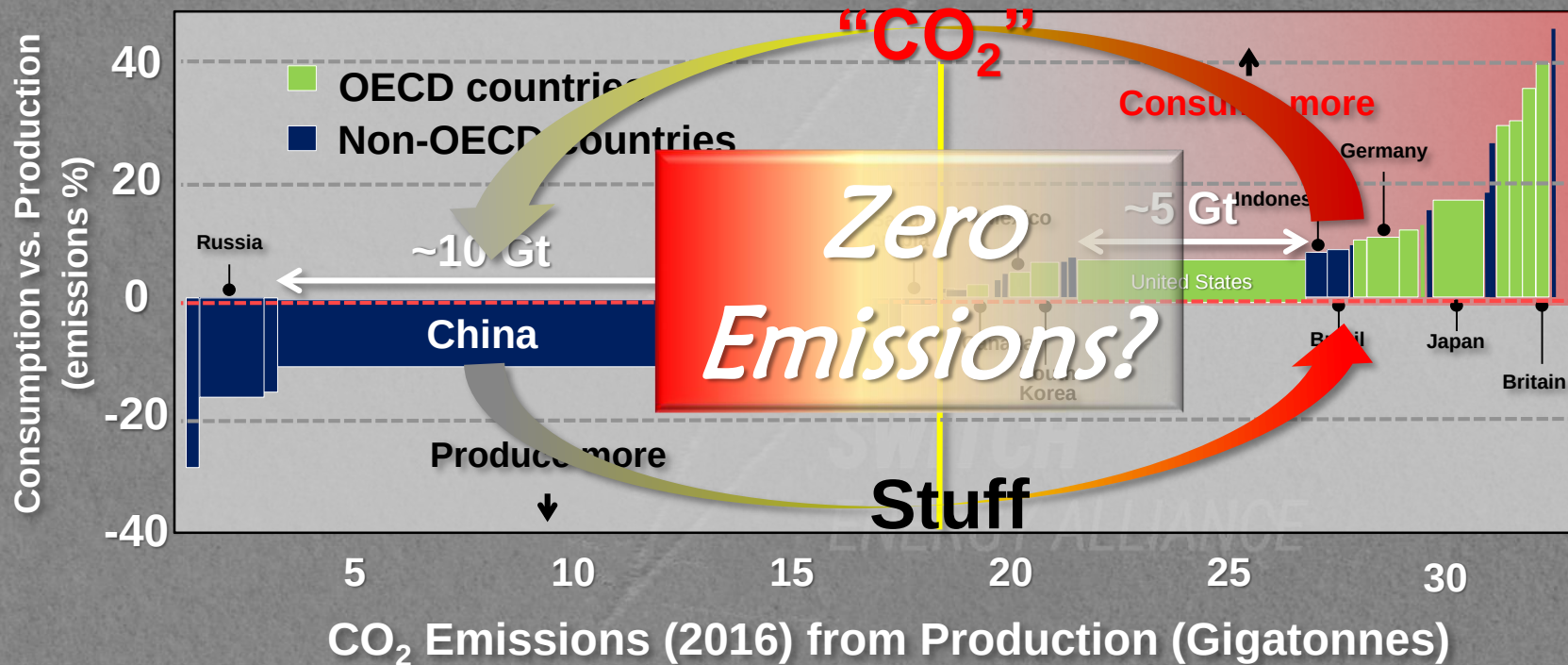


CO₂ Emissions

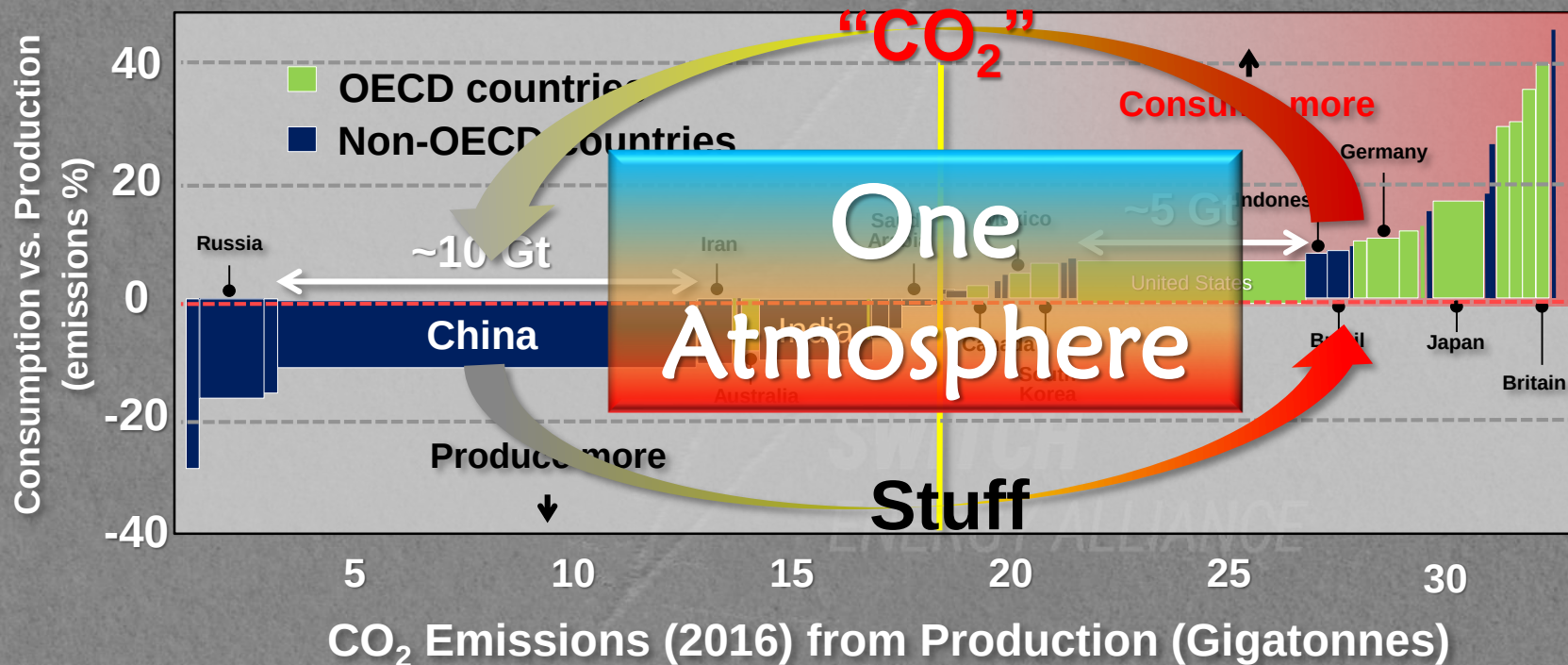
Consumption vs. Production



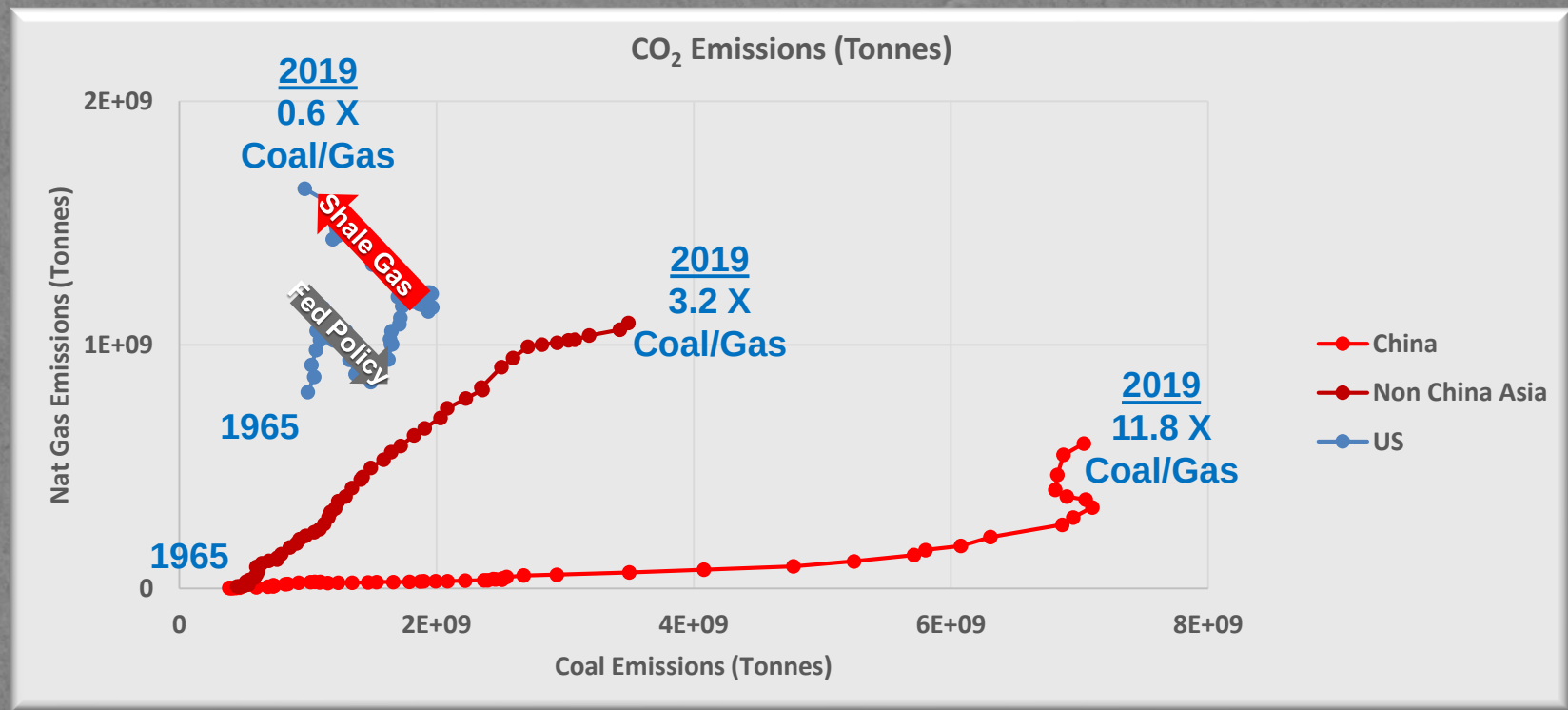
CO₂ Emissions Consumption vs. Production



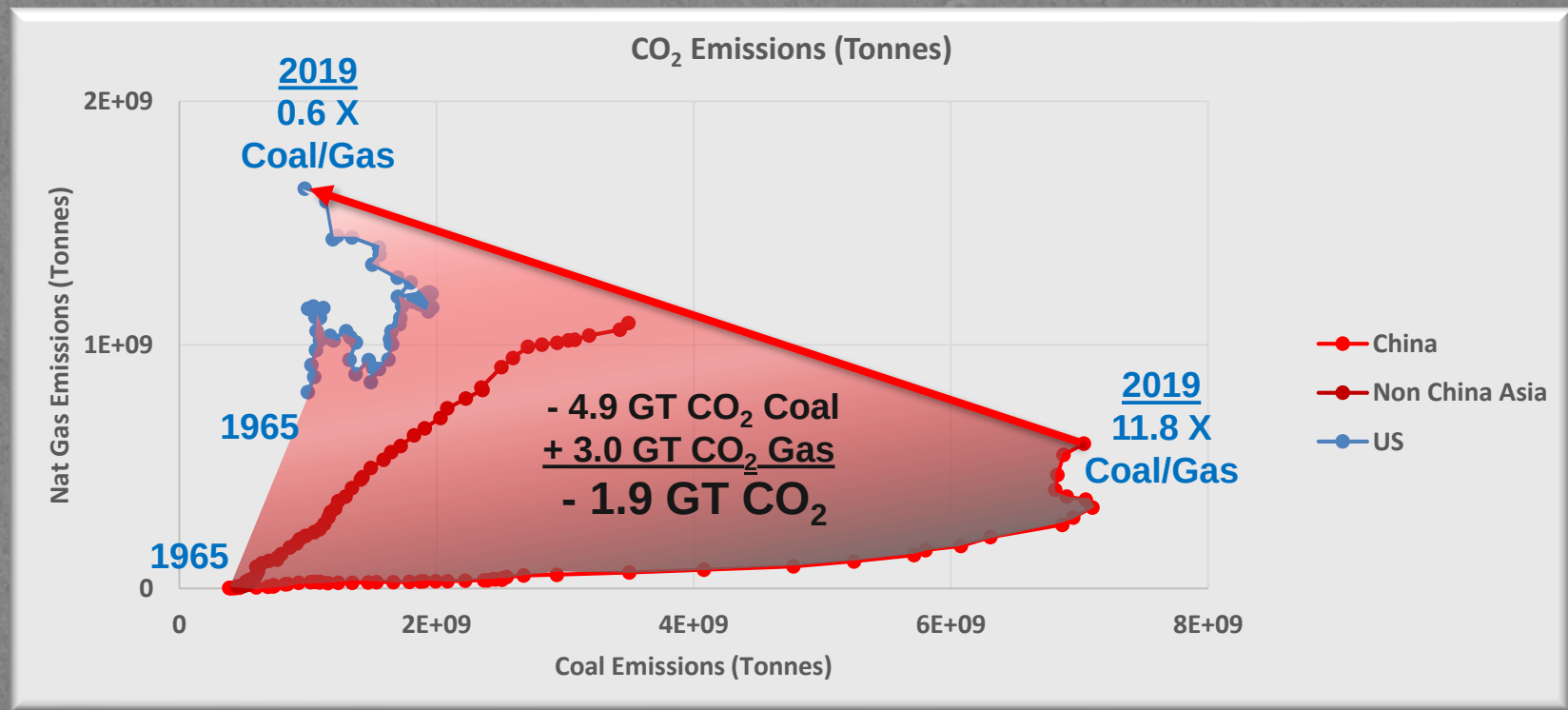
CO₂ Emissions Consumption vs. Production

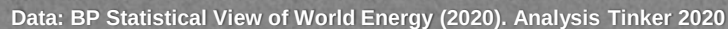


COAL TO GAS CO₂ EMISSIONS REDUCTIONS

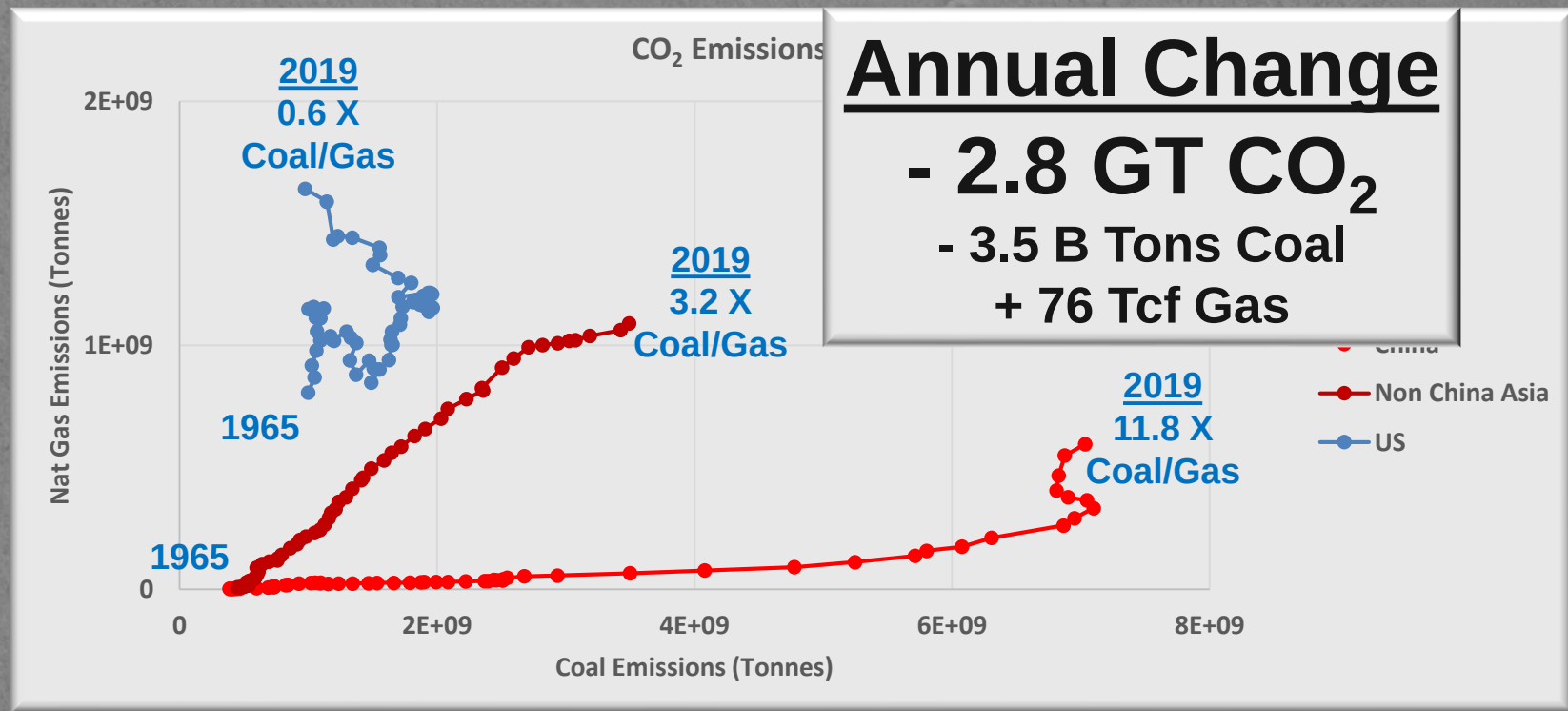


COAL TO GAS CO₂ EMISSIONS REDUCTIONS





COAL TO GAS CO₂ EMISSIONS REDUCTIONS

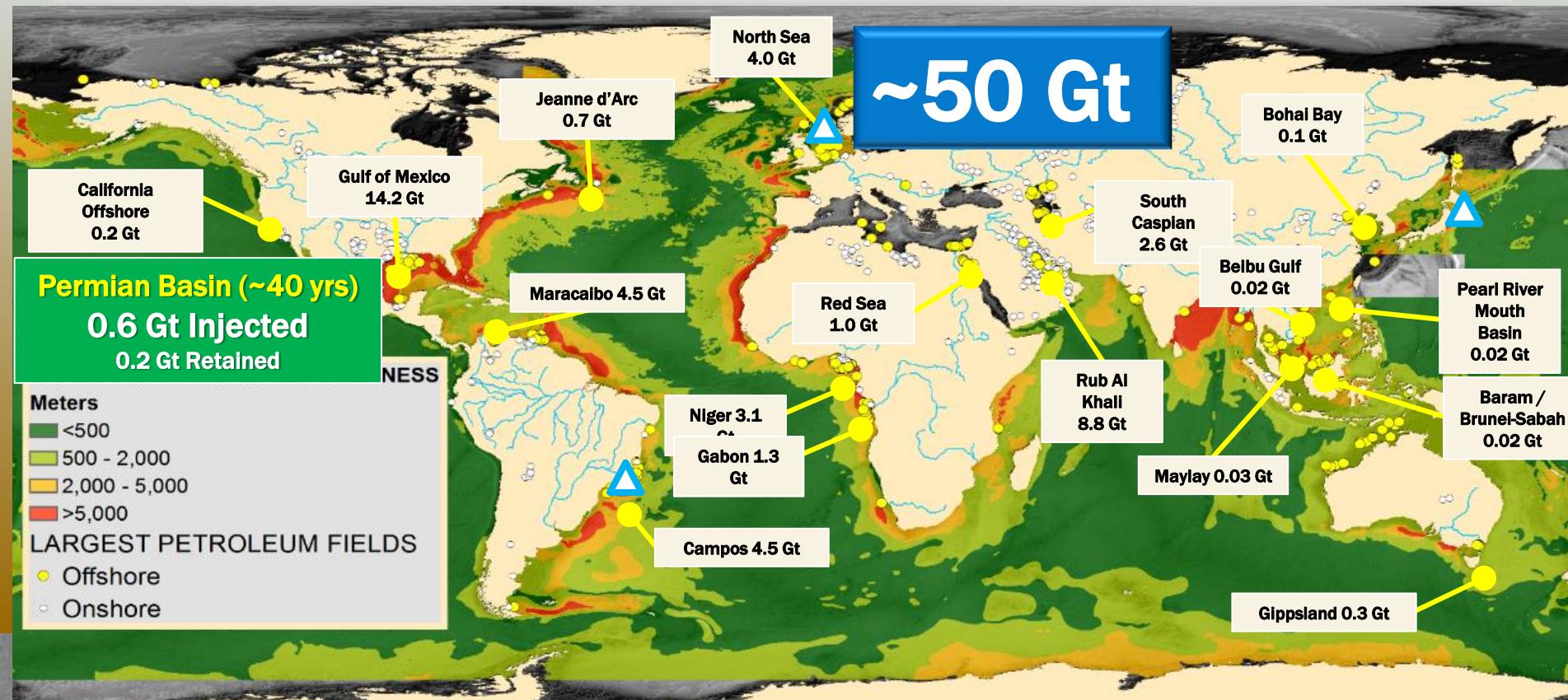


REDUCING CO₂

- Natural Gas, w/CCUS
- Nuclear
- Coal w/CCUS
- Geothermal and Hydro
- Centralized Wind
- Distributed Renewable

Efficiency and Conservation

Offshore Margins and Potential Use of CO₂ for EOR

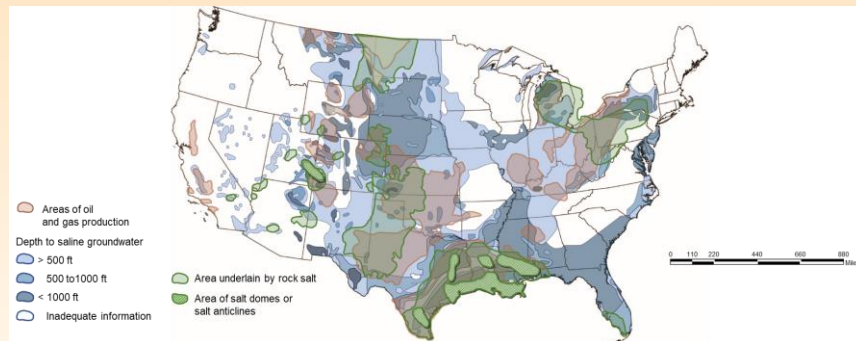


Large-Scale Hydrogen Utilization

Geological Storage

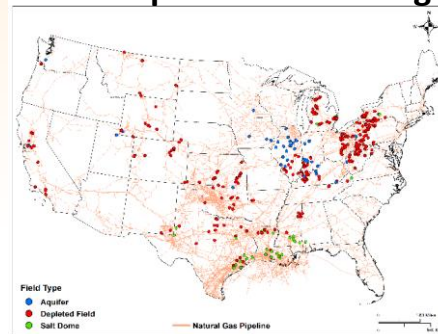
- Development of large-scale hydrogen markets for industrial use, power, and heavy transportation will require a large number of high capacity geological storage sites (> 1000 tonnes)
- Salt caverns, depleted fields and aquifers are the best candidates, but H₂ storage in depleted fields and aquifers is untested
- Bureau's research is to characterize potential sites and conduct research to determine suitability and model large-scale H₂ infrastructure development scenarios.

Areas of Potential Aquifer, Depleted Field and Salt Storage



US Natural Gas Pipeline and Geological Storage

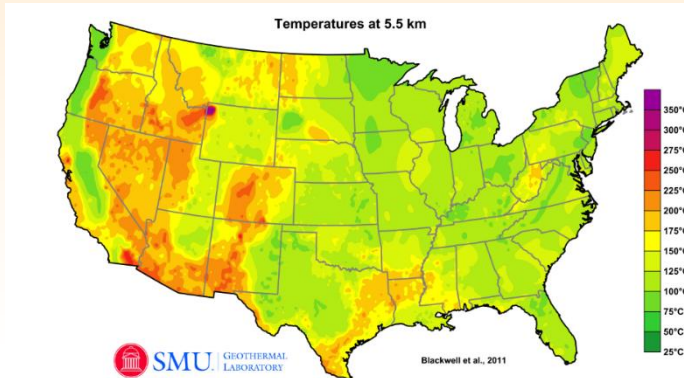
Current
US Natural Gas
Storage
Capacity
4250 Bcf



Current
H₂ Storage
~ 6 Bcf
(3 sites in
Texas)

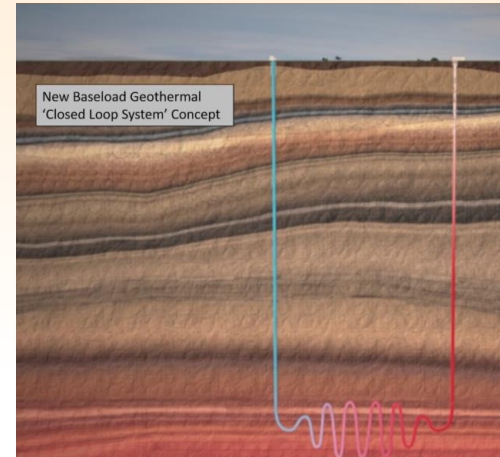
The Potential of Geothermal

- **Background:** Geothermal energy; clean, dispatchable electricity generated from the heat of the Earth, has been a small part of the US and world energy picture for a hundred years
 - Advances in technology, particularly from the Oil & Gas industry are making geothermal power a nearer-term reality
 - Deep closed loop systems and variants break the geographic constraint of going where nature concentrates the resource

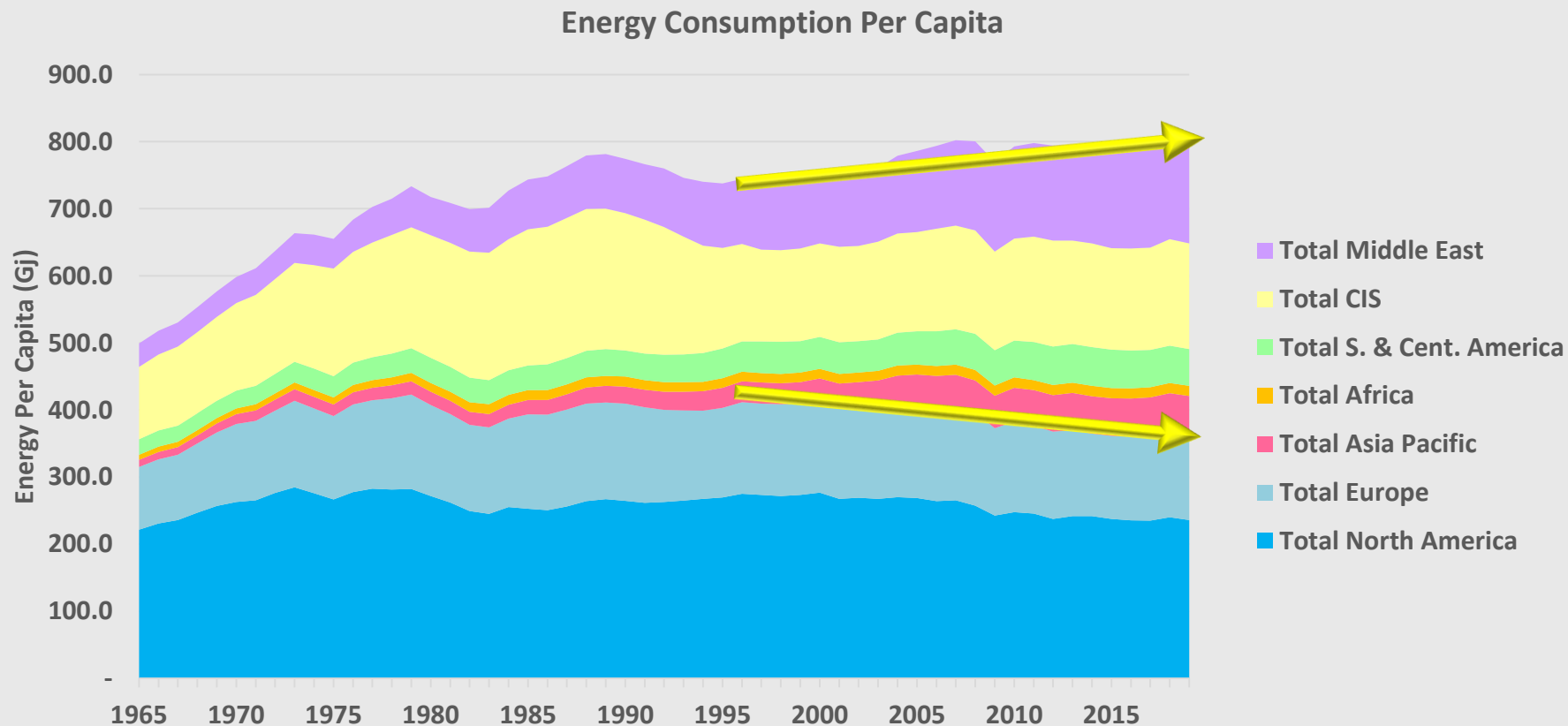


← Current best estimate of temperature at 5.5 km depth in the lower 48 states. Current technology can generate economically viable power from ~150°C fluids (yellow, orange, red).

One style of closed loop system→



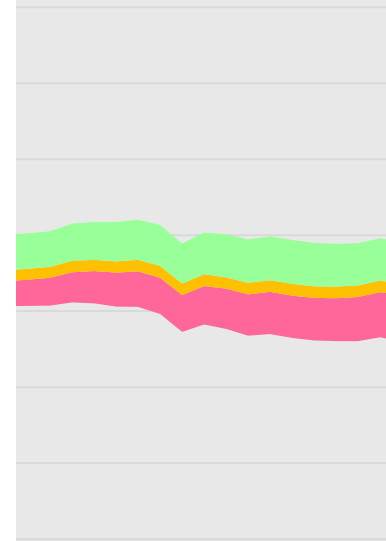
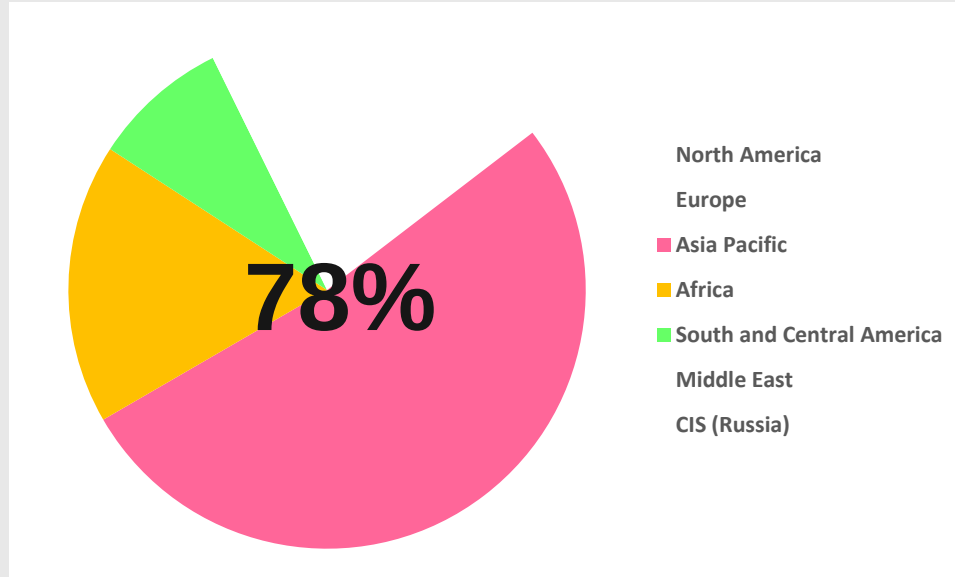
GLOBAL ENERGY DEMAND/CAPITA



GLOBAL ENERGY DEMAND/CAPITA

Global Energy Consumption Per Capita

900.0



Total Middle East

Total CIS

Total S. & Cent. America

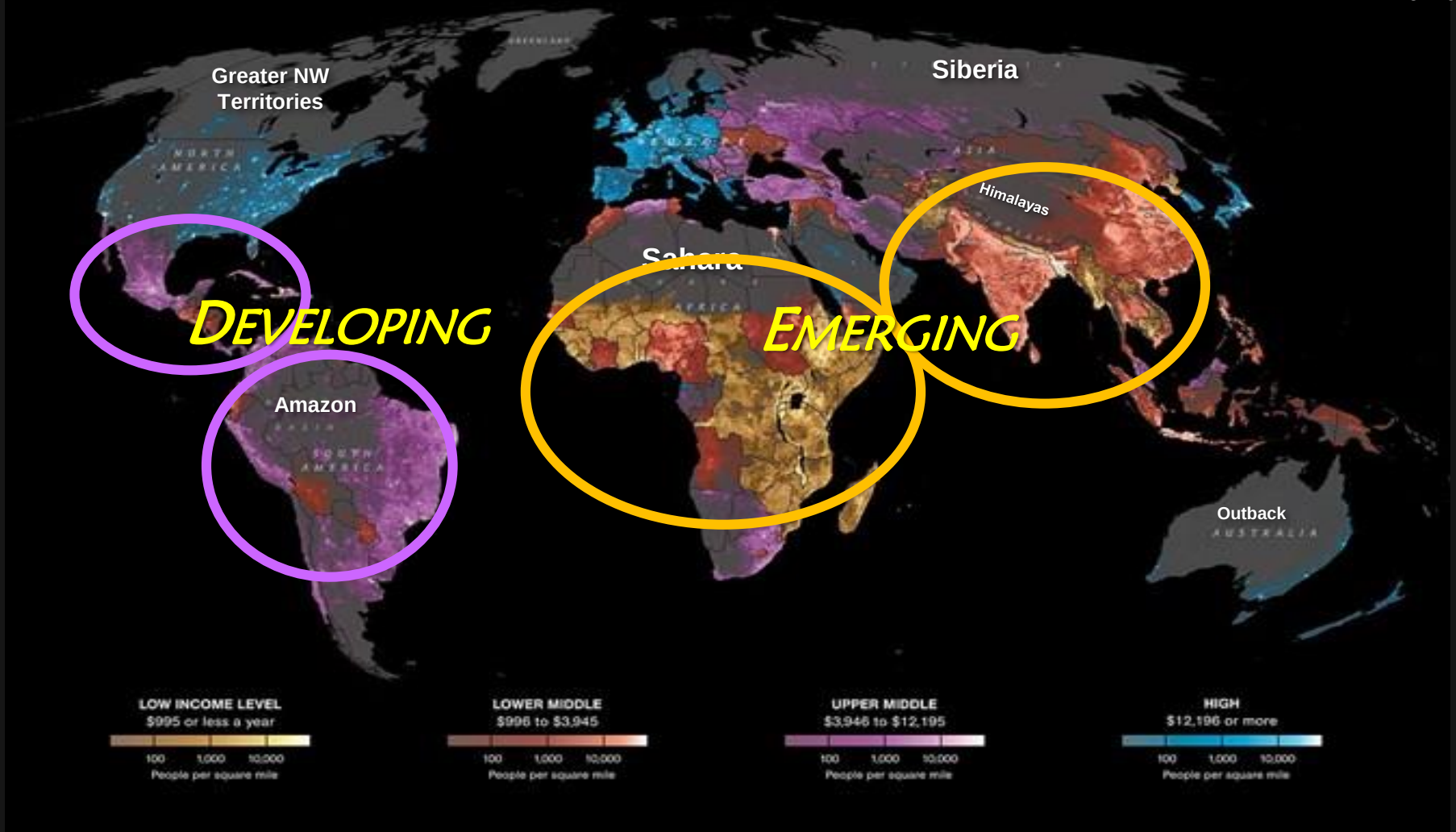
Total Africa

Total Asia Pacific

Total Europe

Total North America

1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015



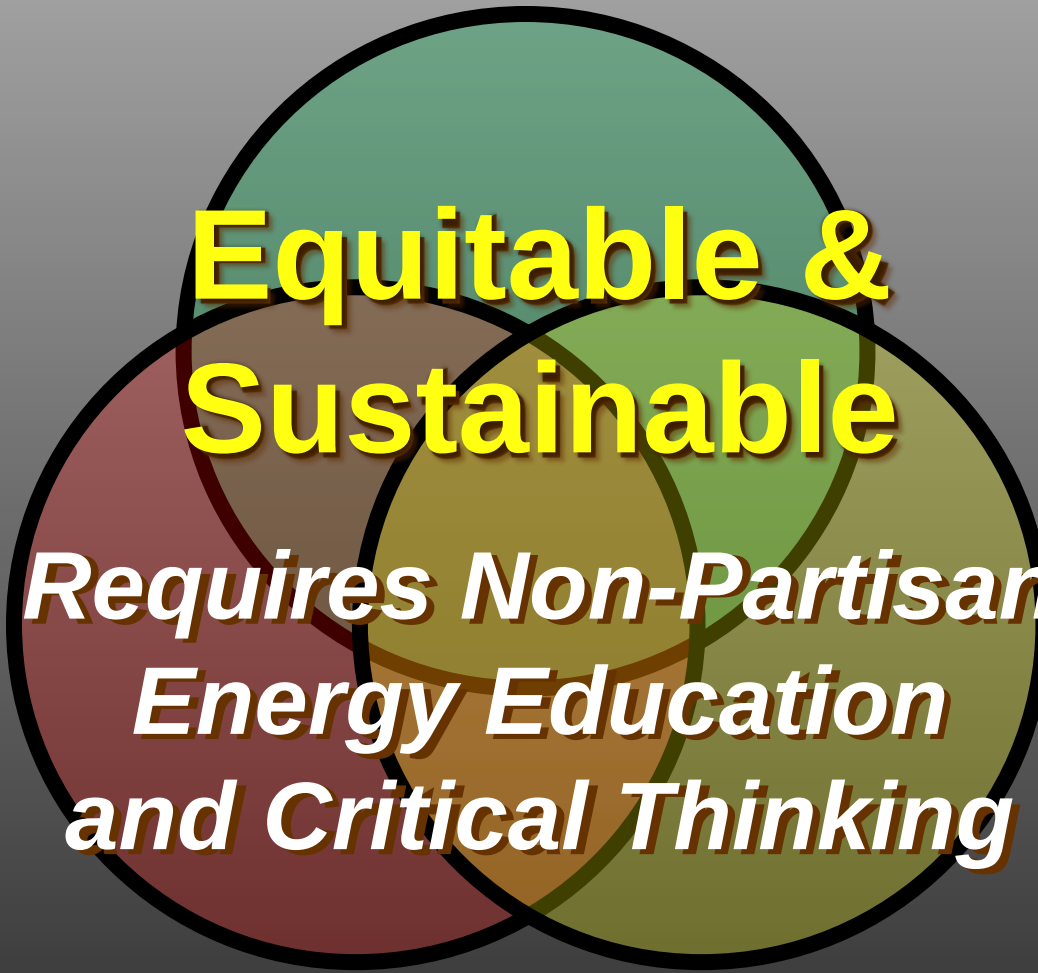
**Reduce Impacts of ALL Energy
Atmosphere, Air, Land and Water**
Environment

**Radical
Middle**

Economy

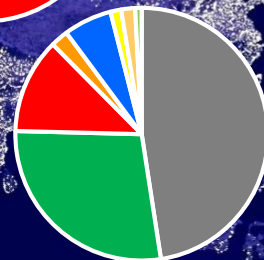
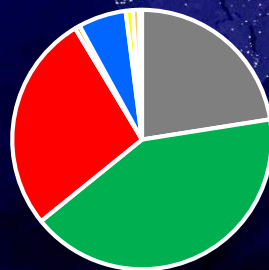
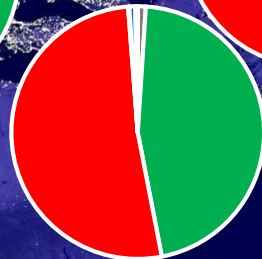
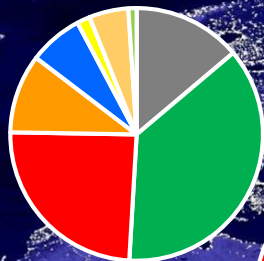
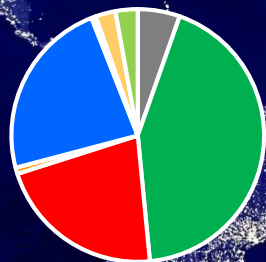
**End Energy Poverty
Build Global Economy**

Energy
**Affordable
Reliable
Available**

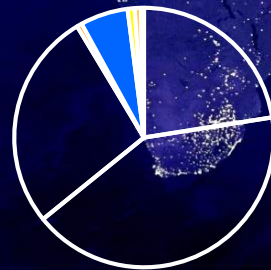
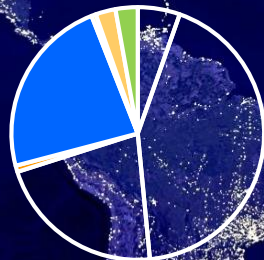


Equitable & Sustainable

***Requires Non-Partisan
Energy Education
and Critical Thinking***



**Eliminate
Coal, Oil, Gas
and Nuclear**





The past, not the future...

**Equitable energy
impacts...**

***Hunger, Clothing,
Shelter, Clean Water***

***Immigration
and Migration***

***Environmental
Investment***

***Climate
Adaptation &
Mitigation***

***Population
Growth***

***Rights and Empowerment
of Women***

***Education and
Health Care***

A world map with a dark blue background, where landmasses are outlined in a lighter blue. The map is covered with numerous small, bright yellow and white dots representing city lights, with a high concentration in North America and Europe. A semi-transparent yellow rectangular box is centered horizontally across the middle of the map.

Equitable energy...

Changes the World!



BUREAU OF
ECONOMIC
GEOLOGY

*Where Energy, Environment
and Economy Converge*

- TORA
- MSRL
- CISR
- GCCC (CCUS)
- Geothermal
- RCRL
- QCL
- STARR
- AWE
- Hydrogen

Switch Energy Alliance

Inspire an Energy Educated Future

<https://Switchon.org>

- Instagram @doctinker
- Watch Films & Presentations
- Download Slide Decks
- Switch Classroom



For financial interests of Scott Tinker see

<http://www.beg.utexas.edu/people/scott-tinker>

Thank you

