Geopolitics, Development, and the Energy Transition

Center For Science and Technology

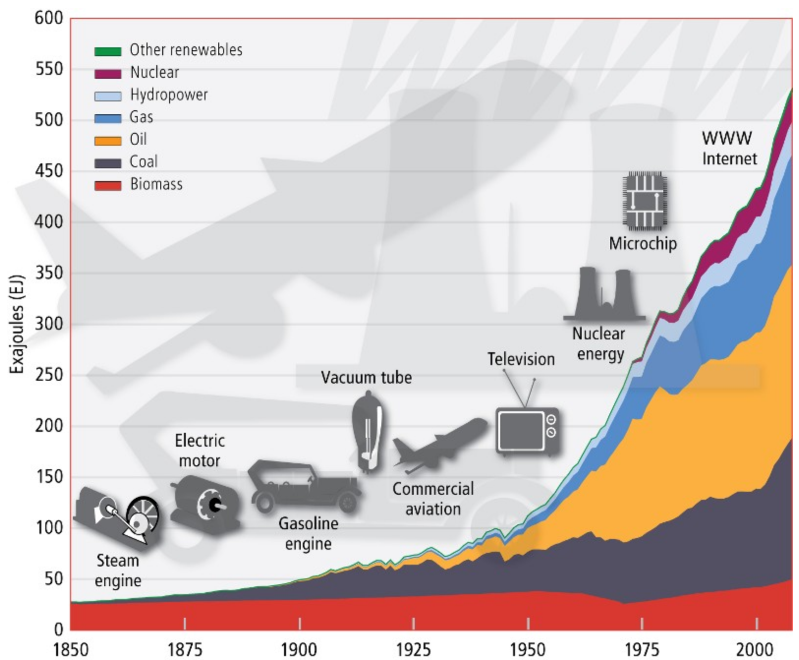
February 6, 2019

Morgan D. Bazilian, Ph.D.

Director, The Payne Institute, and Professor of Public Policy

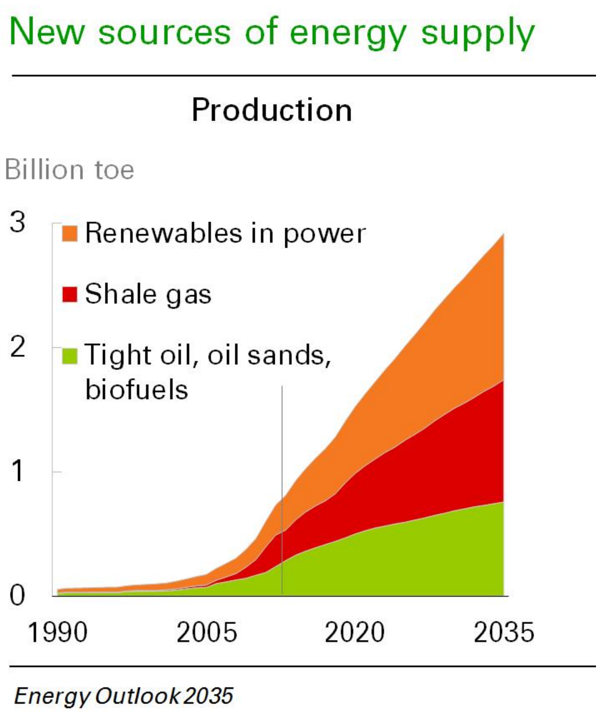
Of policy curves, triangles, and asymmetry

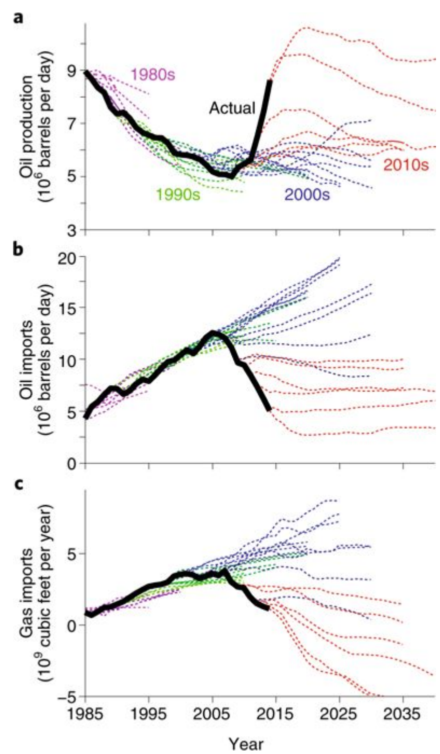
Of non-linearity



IIASA, Nakicenovic

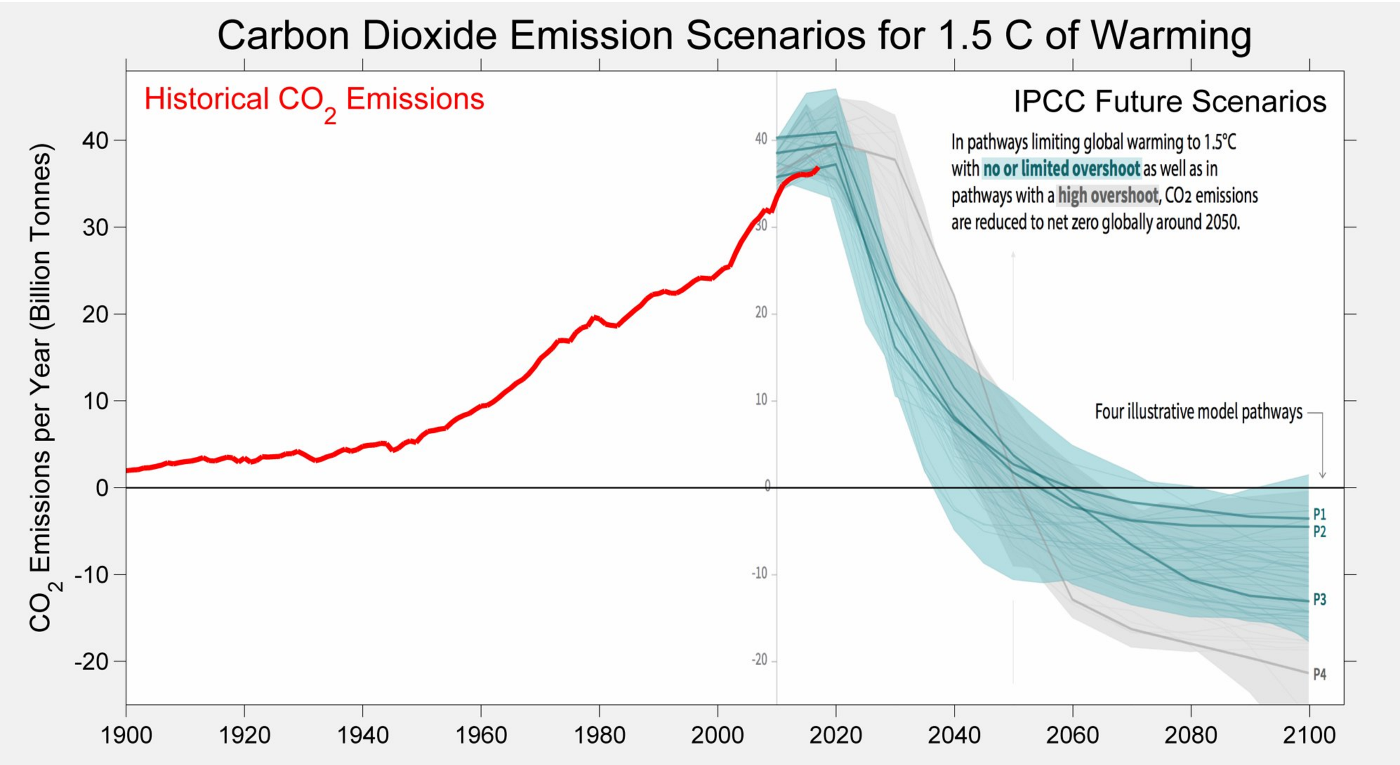
Tough for policy and regulations to keep up with curves like this





BP, Davis, S. Nature, 2018

Curves



Carbon Dioxide Emission Scenarios for 1.5 C of Warming
Historical CO2 Emissions
IPCC Future Scenarios
In pathways limiting global warming to 1.5°C with no or limited overshoot as well as in pathways with a high overshoot, CO2 emissions are reduced to net zero globally around 2050.
Four illustrative model pathways
P1
P2
P3
P4
CO2 Emissions per Year (Billion Tonnes)
40
30
20
10
0
-10
-20
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100

Policy making is more than analysis


The American Interest

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ISSOUF SANOGO/AFP/Getty Images

CASE BY CASE

Teaching Public Policy

FRANCIS FUKUYAMA

Local context is all too often lacking in the prevailing economics-centered approach to public policy education.

In my previous post, I noted how public policy education needs to shift its focus from training policy analysts to training leaders who are capable of actually

Among the many problems with the current economics-centered approach to public policy education is the lack of appreciation for local context. Modern economics aspires to be context-free: it seeks universal rules of human behavior that can be mathematized in abstract models.

(At least) seven contours

While the climate change impacts of the transition are being well-monitored, less so are other energy-related considerations.

(1) institutional shifts in the influence and membership of multilateral organizations like the Organization of Petroleum Exporting Countries (OPEC) and the International Energy Agency (IEA);

(2) the accelerating growth of trade in natural gas either through new international pipelines or via a rapidly expanding market for liquefied natural gas (LNG);

(3) the supply chain of cutting-edge clean edge technologies and their trade;

(4) issues of cybersecurity that are growing in importance with the rise of interconnected systems and new forms of metering and system operations;

(5) the changing landscape for conflict and other minerals due to these changes in technologies and their deployment in large numbers;

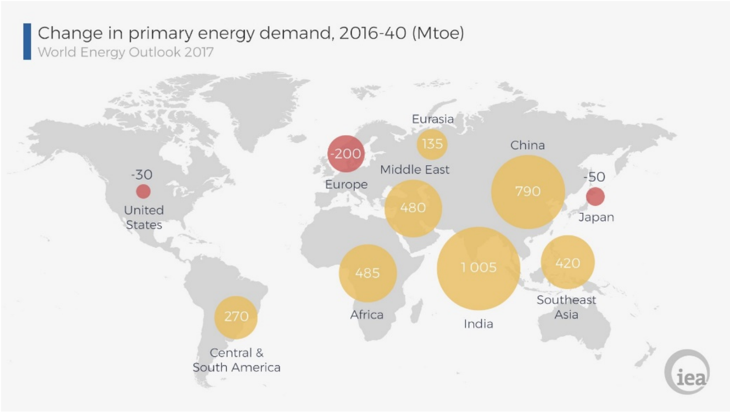
(6) the growing regional power interconnection in electricity grids from the Belt and Road to East Africa; and

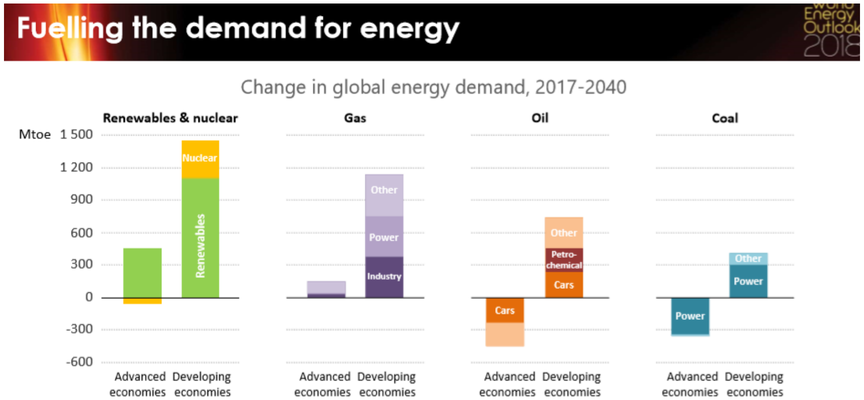
(7) Lingering energy poverty and the demand for provision of quality and affordable energy services to billions of people and businesses. It is clear that these areas go well beyond technology.

(We provide thematic lens here, while traditional IR would focus more on State-level interactions)

The rest (most) of the world

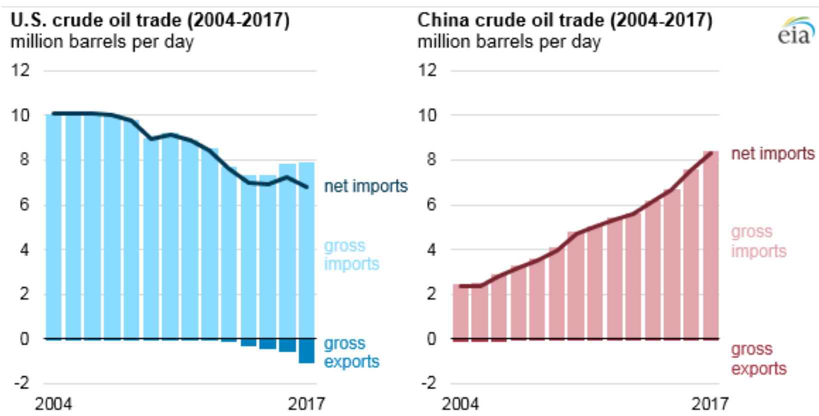
The energy transition is largely a developing country story

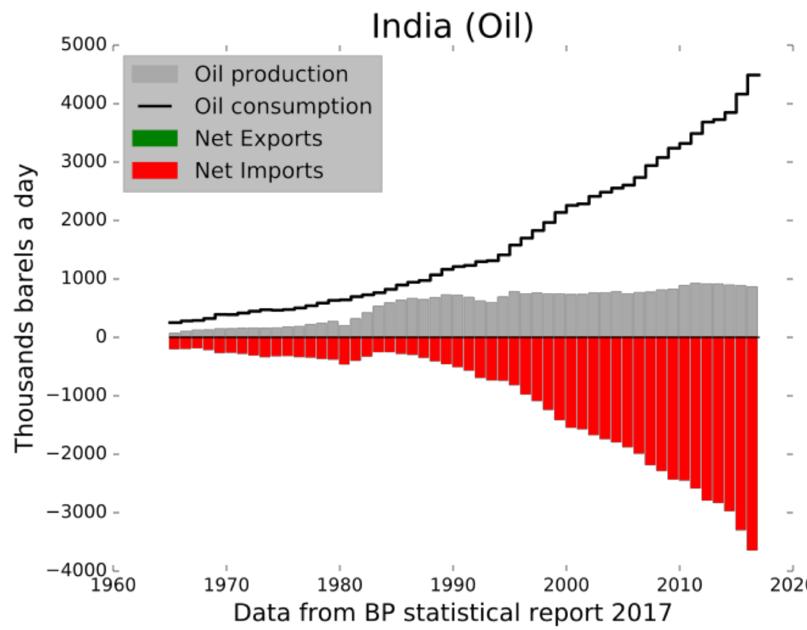




IEA WEO 2017

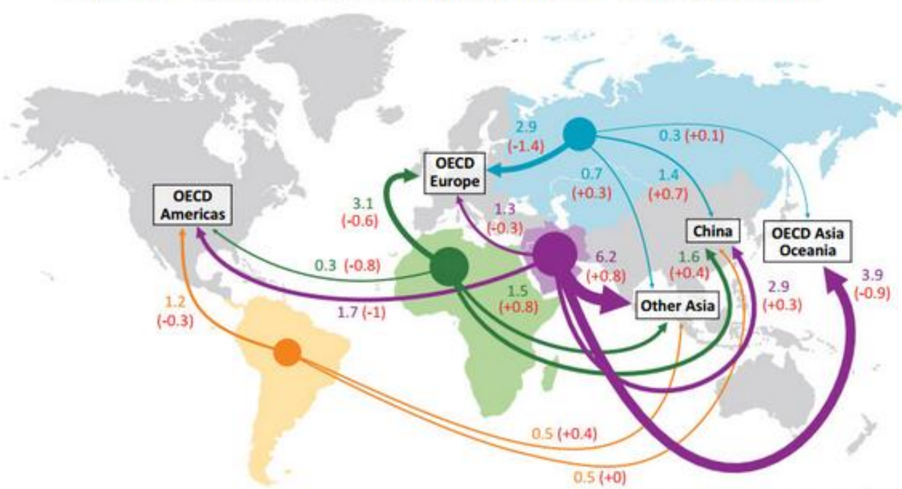
Changing demand/priorities





Changing trade maps for oil and gas

Figure 1.4 Crude exports in 2018 and growth over 2012-18 for key trade routes

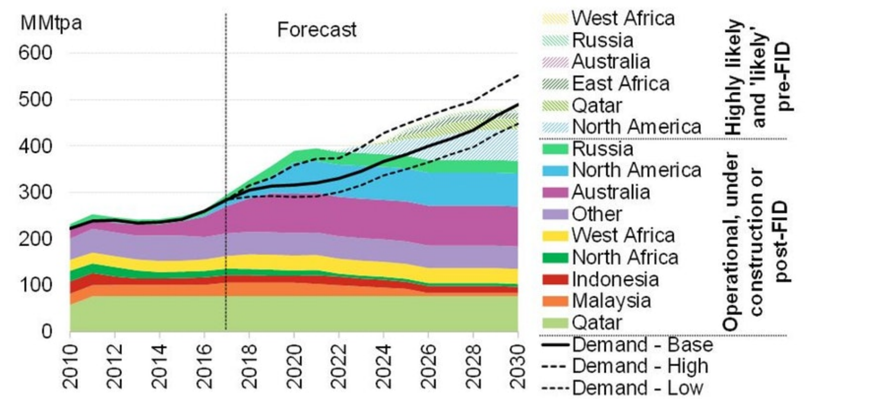


Red numbers in brackets denote growth in period 2012-18

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: IEA, 2013a.

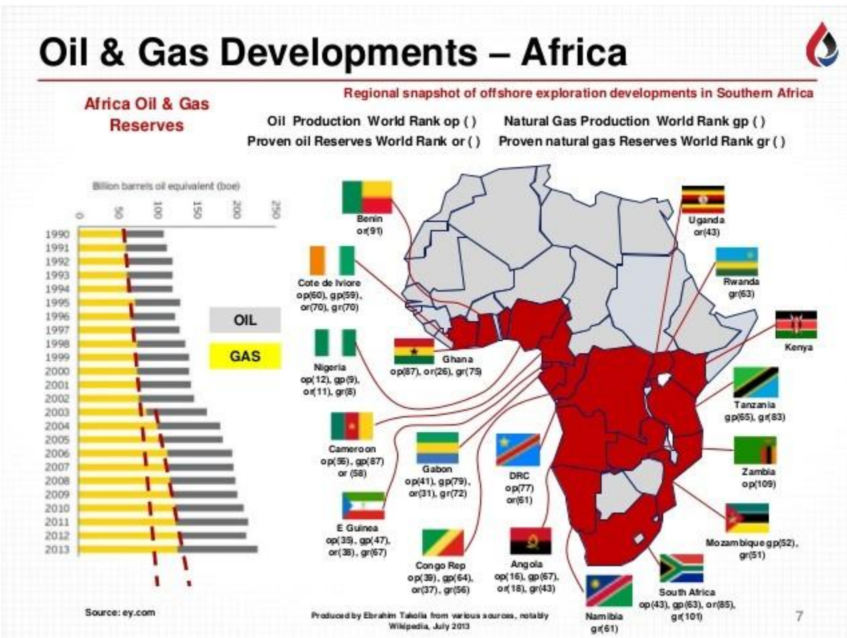
Global LNG demand and supply capacity

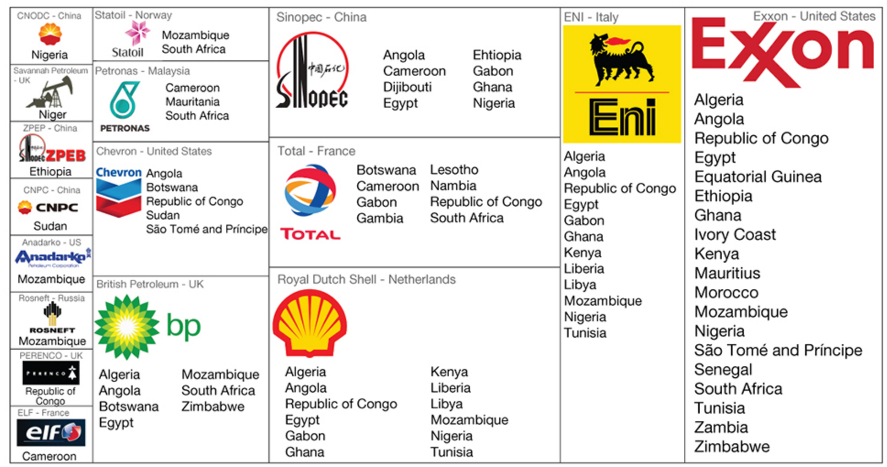


Note: 'Highly-likely' and 'likely' pre-FID projects are included on this chart. The likelihood of a project being built by 2030 is assessed based on the project's regulatory stage, project size, infrastructures, developers' financial strength, offtake contracts, and sovereign risks.

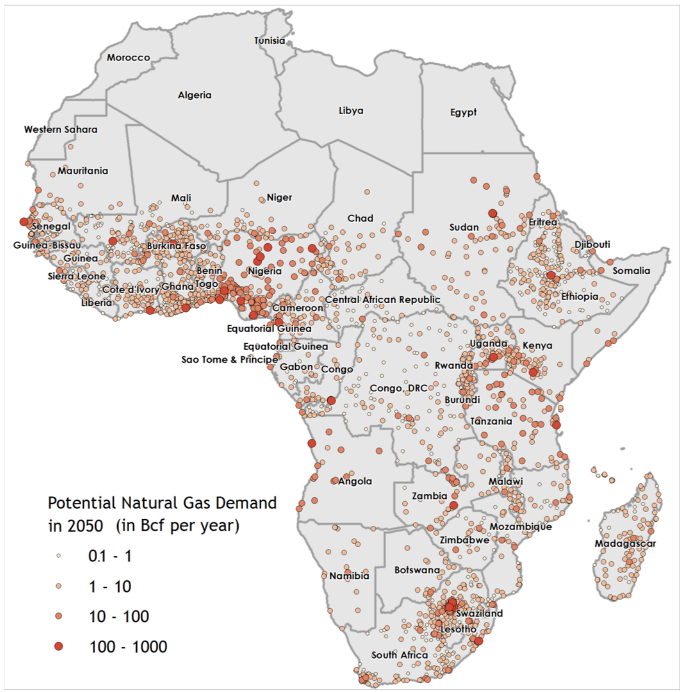
Source: Bloomberg New Energy Finance, Poten & Partners, customs data.

Opportunity





Natural gas and development?



Estimated potential natural gas demand in sub-Saharan Africa by 2050.

Energy Research & Social Science

Volume 39, May 2018, Pages 74-77

Perspective

Signalling, governance, and goals: Reorienting the United States Power Africa initiative

Todd Moss [a, b], Morgan Bazilian [c, d, e]

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https://doi.org/10.1016/j.erss.2017.11.001

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Abstract

Power Africa, the United States' effort to boost electrification on the continent launched in 2013, has made an impressive start. Progress toward generation and connections goals are on track. The initiative has catalyzed significant private sector investment, built a diverse portfolio, and embraced a range of technologies including natural gas. Nevertheless, Power Africa faces political and institutional hurdles that threaten its continued success and perhaps its very survival.

Flaring and planning

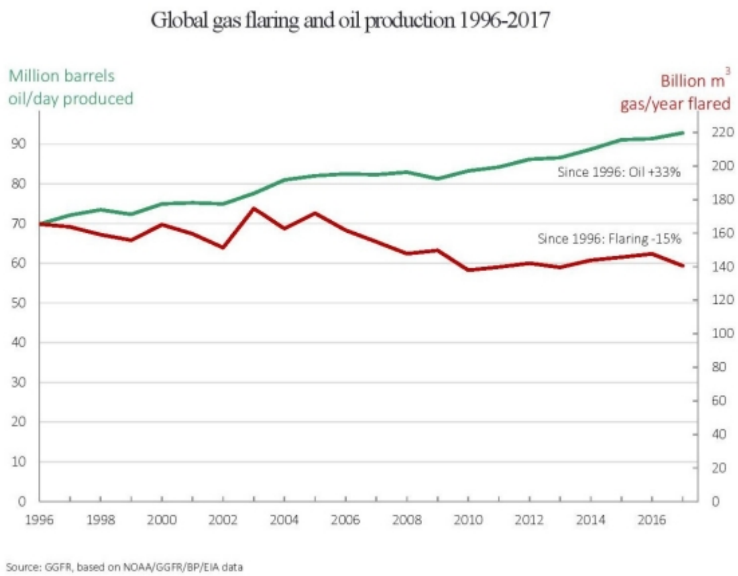
Governments, oil companies, and development institutions around the world are encouraged to endorse the "Zero Routine Flaring by 2030" Initiative.

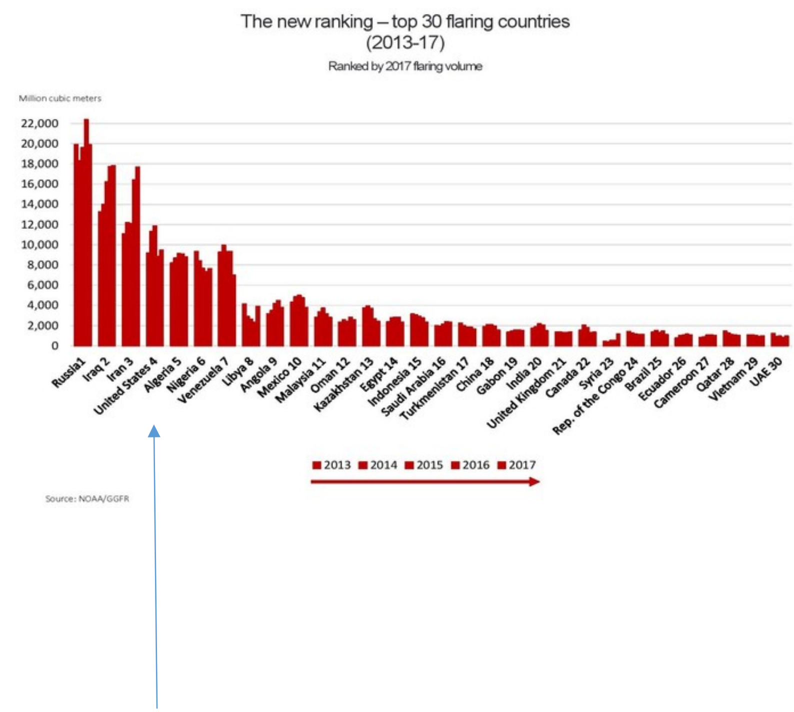
USA has endorsed.

About 140 billion cubic meters annually. Enough to produce 750 billion kWh power

More than the entire power consumption on the African continent currently

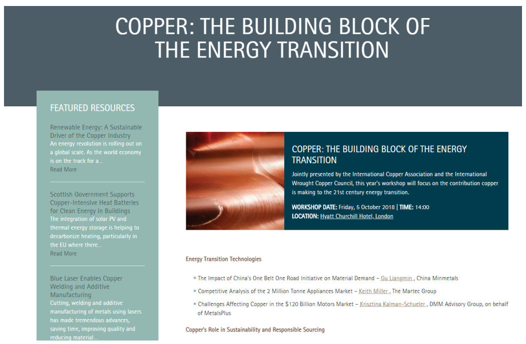
#4

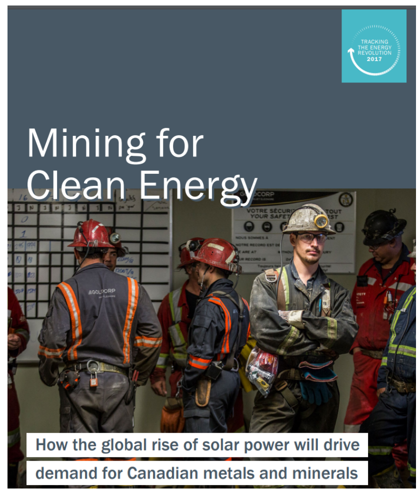

Global gas flaring and oil production 1996-2017
Million barrels oil/day produced
Billion m³ gas/year flared
Since 1996: Oil +33%
Since 1996: Flaring -15%
Source: GGFR, based on NOAA/GGFR/BP/EIA data


The new ranking – top 30 flaring countries (2013-17)
Ranked by 2017 flaring volume
Million cubic meters
Russia1
Iraq 2
Iran 3
United States 4
Algeria 5
Nigeria 6
Venezuela 7
Libya 8
Angola 9
Mexico 10
Malaysia 11
Oman 12
Kazakhstan 13
Egypt 14
Indonesia 15
Saudi Arabia 16
Turkmenistan 17
China 18
Gabon 19
India 20
United Kingdom 21
Canada 22
Syria 23
Rep. of the Congo 24
Brazil 25
Ecuador 26
Cameroon 27
Qatar 28
Vietnam 29
UAE 30
2013 2014 2015 2016 2017
Source: NOAA/GGFR

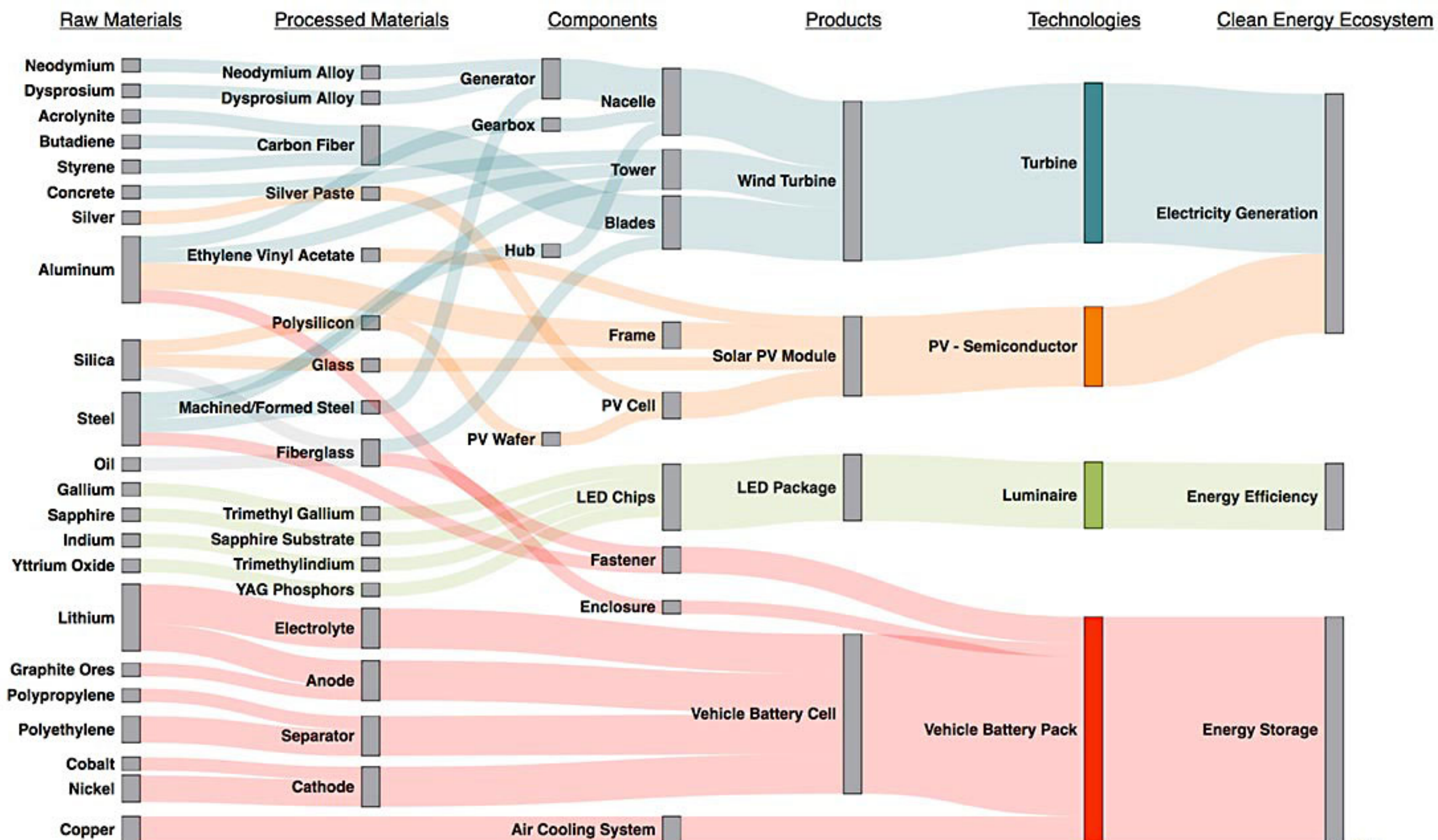
Minerals and metals

Movements and Memes





ICA, 2018



Raw Materials
Processed Materials
Components
Products
Technologies
Clean Energy Ecosystem
Neodymium
Dysprosium
Acrolynite
Butadiene
Styrene
Concrete
Silver
Aluminum
Silica
Steel
Oil
Gallium
Sapphire
Indium
Yttrium Oxide
Lithium
Graphite Ores
Polypropylene
Polyethylene
Cobalt
Nickel
Copper
Neodymium Alloy
Dysprosium Alloy
Carbon Fiber
Silver Paste
Ethylene Vinyl Acetate
Polysilicon
Glass
Machined/Formed Steel
Fiberglass
Trimethyl Gallium
Sapphire Substrate
Trimethylindium
YAG Phosphors
Electrolyte
Anode
Separator
Cathode
Generator
Gearbox
Hub
PV Wafer
Nacelle
Tower
Blades
Frame
PV Cell
LED Chips
Fastener
Enclosure
Air Cooling System
Wind Turbine
Solar PV Module
LED Package
Vehicle Battery Cell
Turbine
PV - Semiconductor
Luminaire
Vehicle Battery Pack
Electricity Generation
Energy Efficiency
Energy Storage

USA “Critical” materials

- Aluminum (bauxite), used in almost all sectors of the economy
- Antimony, used in batteries and flame retardants
- Arsenic, used in lumber preservatives, pesticides, and semi-conductors
- Barite, used in cement and petroleum industries
- Beryllium, used as an alloying agent in aerospace and defense industries
- Bismuth, used in medical and atomic research
- Cesium, used in research and development
- Chromium, used primarily in stainless steel and other alloys
- Cobalt, used in rechargeable batteries and superalloys
- Fluorspar, used in the manufacture of aluminum, gasoline, and uranium fuel
- Gallium, used for integrated circuits and optical devices like LEDs
- Germanium, used for fiber optics and night vision applications
- Graphite (natural), used for lubricants, batteries, and fuel cells
- Hafnium, used for nuclear control rods, alloys, and high-temperature ceramics
- Helium, used for MRIs, lifting agent, and research
- Indium, mostly used in LCD screens
- Lithium, used primarily for batteries
- Magnesium, used in furnace linings for manufacturing steel and ceramics
- Manganese, used in steelmaking
- Niobium, used mostly in steel alloys
- Platinum group metals, used for catalytic agents
- Potash, primarily used as a fertilizer
- Rare earth elements group, primarily used in batteries and electronics
- Rhenium, used for lead-free gasoline and superalloys
- Rubidium, used for research and development in electronics
- Scandium, used for alloys and fuel cells
- Strontium, used for pyrotechnics and ceramic magnets
- Tantalum, used in electronic components, mostly capacitors
- Tellurium, used in steelmaking and solar cells
- Tin, used as protective coatings and alloys for steel
- Titanium, overwhelmingly used as a white pigment or metal alloys
- Tungsten, primarily used to make wear-resistant metals
- Uranium, mostly used for nuclear fuel
- Vanadium, primarily used for titanium alloys
- Zirconium, used in the high-temperature ceramics industries

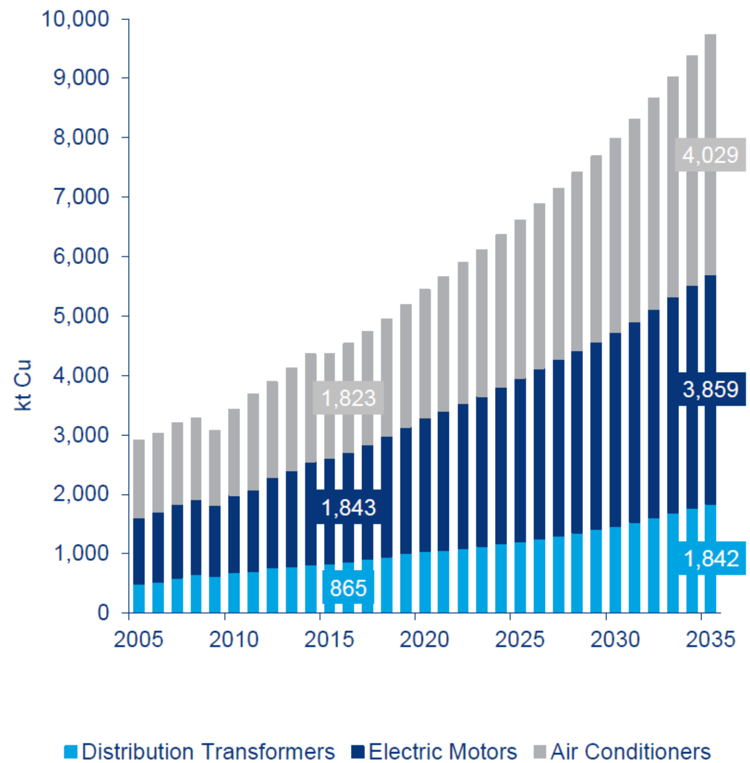
Under the Executive Order, these commodities qualify as “critical minerals” because each has been identified as a non-fuel mineral or mineral material that is essential to the economic and national security of the United States, that has a supply chain vulnerable to disruption, and that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economy or national security.

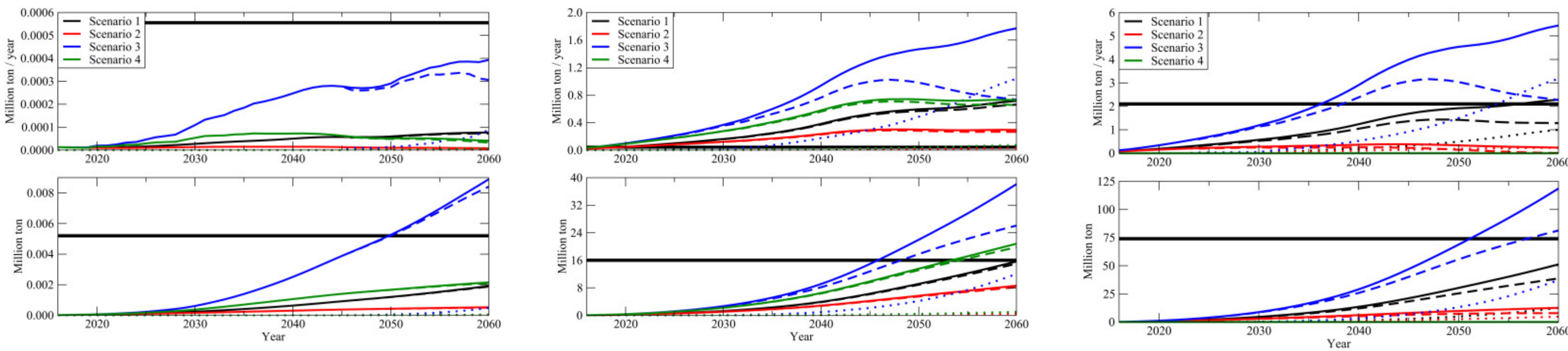
Copper demand in energy efficiency sectors almost doubles from 4.7 Mt in 2017 to reach 9.7 Mt by 2035

Distribution Transformers

Electric motors

Air Conditioners

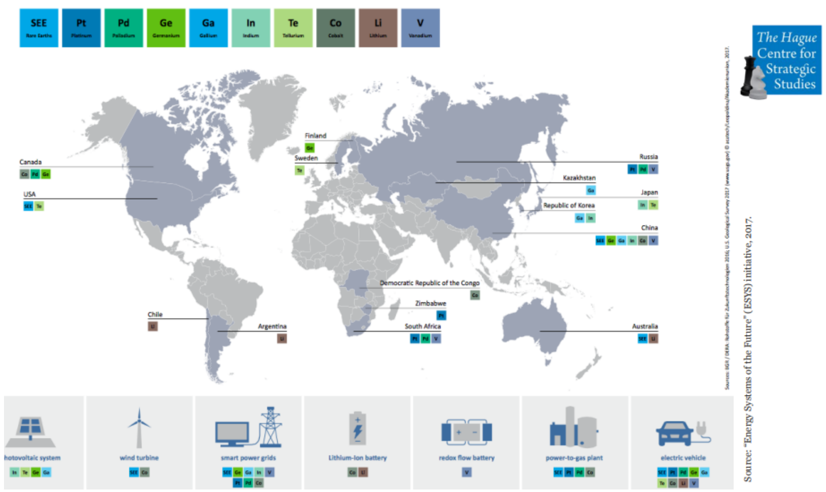


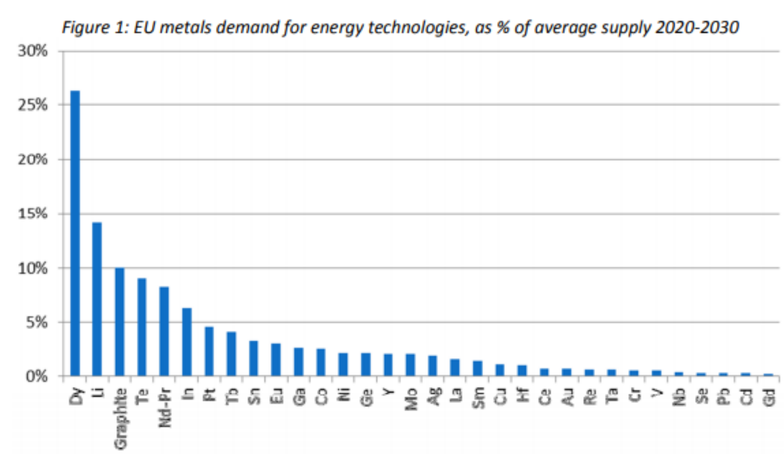


Tellurium; Lithium; and Nickel

https://www.sciencedirect.com/science/article/pii/S0301421518302726#f0020

Europe also looking at these issues…





And China and Japan……

Web Exclusive

The Chinese Investment that Could Boost Chile's Lithium Boom – and Help Climate Change, Too

BY JORGE HEINE AND ANDERS BEAL | NOVEMBER 7, 2018

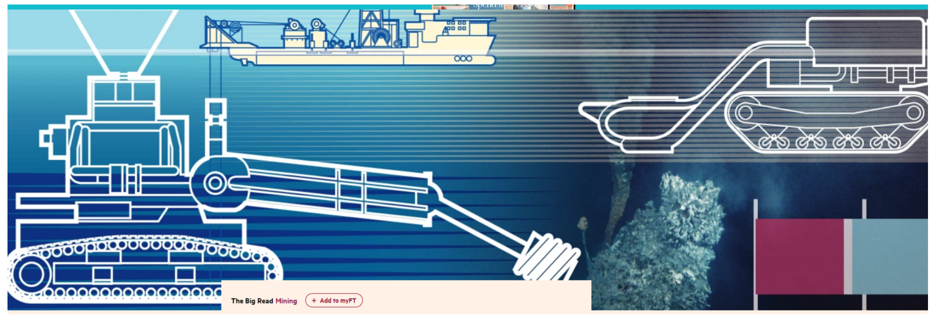
A Chinese firm wants to invest billions, but has met resistance.

Workers take samples of salt brine in the Salar de Atacama, Chile.
Oliver Llaneza Hesse/Construction Photography/Avalon/Getty Images

18

Such are the riches to be found in them, that the Andes mountains have been described as a gigantic open pit mine.

Something similar can be said of the Atacama Desert in Northern Chile, the driest in the world and home to several coveted global commodities. The previous century saw interest in its nitrates, and more recently the Atacama has been touted as an exceptional source of solar energy, capable of generating all of Chile's electricity needs and more. Now, lithium, which has been called the



The Big Read Mining + Add to myFT

Electric vehicles spur race to mine deep sea riches

Miners want to tap subsea cobalt deposits for green technologies, but environmentalists worry

Critical Materials Institute
AN ENERGY INNOVATION HUB

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About CMI

The next CMI webinar on October 30 will feature John Ormerod of Magnet Applications, Inc. He will present "Rare Earth Magnets: Yesterday, Today, and Tomorrow." There is no fee to register for a CMI webinar; registration is required to receive a link to the webinar. Link to registration page: https://mines.zoom.us/webinar/register/WN_V-

CMI Highlights

The Federal Laboratories Consortium honored an acid-free dissolution rare-earth magnet recycling process developed by CMI researchers at Ames Laboratory with a 2018 Notable Technology Development Award. Link

CMI in the News

- Ames Laboratory: Critical Materials Institute takes major step toward printed anisotropic magnets
- ISU College of Engineering News: Alex King receives international Acta Materialia Hollomon Materials & Society Award
- Federal Laboratory Consortium: Acid-free dissolution rare-earth magnet recycling process
- Ames Laboratory: Rare-earth magnet recycling tech wins innovation award
- Resource World Magazine: Specialty Metals Report
- CleanTech Alliance: Showcase recap: Recycling electronic devices

Georgetown Journal of International Affairs

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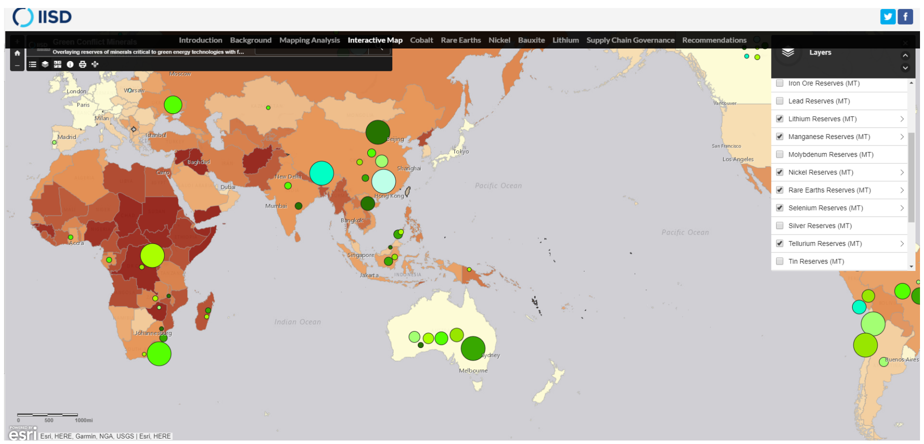
Table 2
Cobalt production and reserves (metric tons) (Drexhage et al., 2017 based on USGS, 2016).

Country	Mine production	Reserves
Congo (Kinshasa)	63,000	3,400,000
Australia	6000	1,100,000
Cuba	4200	500,000
Zambia	2800	270,000
Philippines	4600	250,000
Russia	6300	250,000
Canada	6300	240,000
New Caledonia	3300	200,000
Madagascar	3600	130,000
China	7200	80,000
Brazil	2600	78,000
South Africa	2800	31,000
Other countries	7700	633,000
Total	120,400	7,162,000

Minerals and conflict



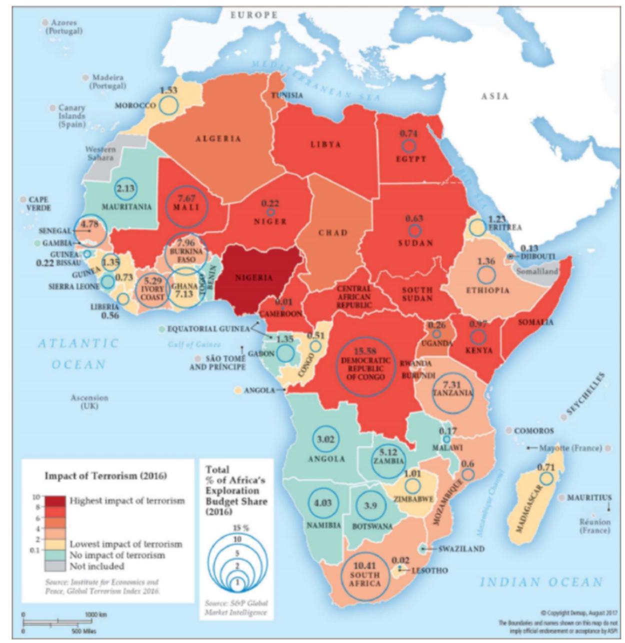
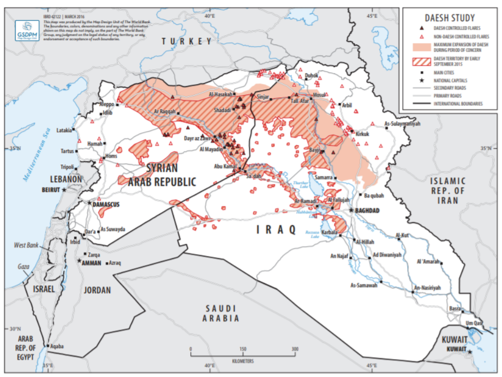


Fig. 3. Mining exploration budget and terrorism impact (Sharland et al., 2017).

Energy and conflict

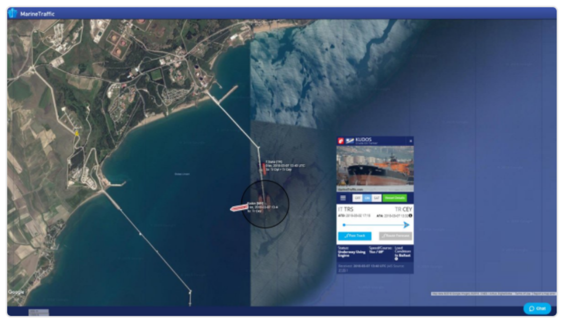
New ways to monitor geopolitics

Figure 1: Iraq and Syria Oil Production, Fields, and Daesh Control, March 2016



TankerTrackers.com @TankerTrackers · Mar 7

KUDOS has now arrived at the KRG berth in the port of Ceyhan, Turkey. She last departed Ceyhan on December 11th with 424K barrels to Croatia. Was only half full. #OOTT



World Bank, 2017; Tanktrackers on Twitter

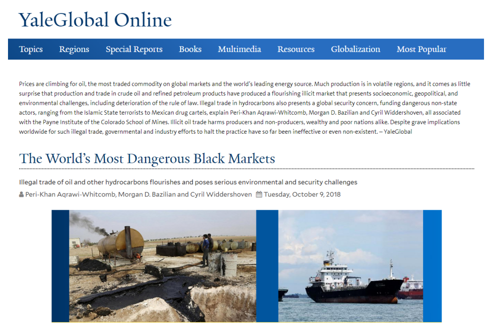
Energy and peace


FOREIGN AFFAIRS HOW MINI-GRIDS CAN POWER DISASTER RECOVERY
Amy Myers Jaffe, Lindsay Iversen, and Morgan D. Bazilian
SIGN IN SUBSCRIBE
ALVIN BAEZ / REUTERS
SNAPSHOT November 9, 2017 Puerto Rico Energy

How Mini-Grids Can Power Disaster Recovery

New Energy Technologies and the Future of Humanitarian Aid

By *Amy Myers Jaffe*, *Lindsay Iversen*, and *Morgan D. Bazilian*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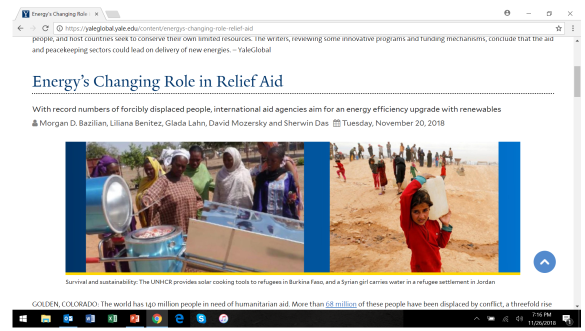
The World's Most Dangerous Black Markets

Illegal trade of oil and other hydrocarbons flourishes and poses serious environmental and security challenges

Peri-Khan Aqrawi-Whitcomb, Morgan D. Bazilian and Cyril Widdershoven Tuesday, October 9, 2018


Energy's Changing Role in Relief Aid

With record numbers of forcibly displaced people, international aid agencies aim for an energy efficiency upgrade with renewables

Morgan D. Bazilian, Liliana Benitez, Glada Lahn, David Mozersky and Sherwin Das Tuesday, November 20, 2018

Survival and sustainability: The UNHCR provides solar cooking tools to refugees in Burkina Faso, and a Syrian girl carries water in a refugee settlement in Jordan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The Peace Dividends of Energy Infrastructure – North Korea, Iran and Beyond

By Morgan D. Bazilian and Saleem H. Ali · 23 August 2018 CONFLICT AND SECURITY

Morgan D. Bazilian and Saleem H. Ali explore the possibilities of using pipelines, or other energy infrastructure, as a basis for peace.


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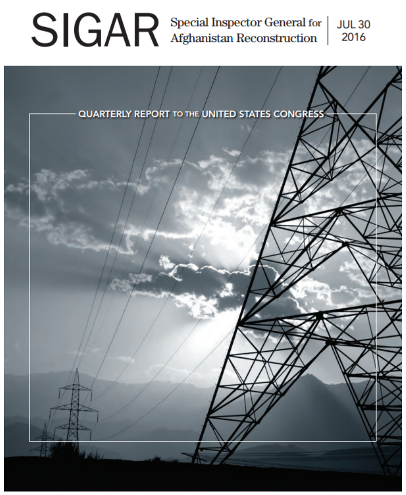
Much Ado About Nord Stream 2: Pipeline Politics and European Energy Security

By Alex Gilbert and Morgan D. Bazilian · 26 September 2018 CLIMATE CHANGE, ENERGY AND SUSTAINABILITY

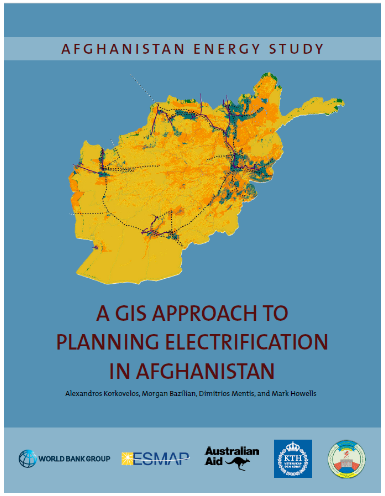
Alex Gilbert and Morgan D. Bazilian explore how the USA can support European energy security.



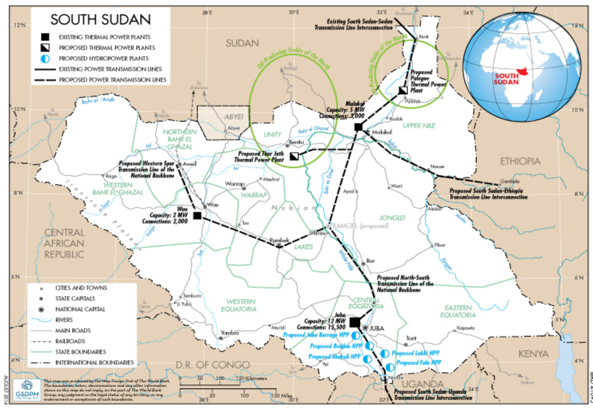
"In fragile and conflict-afflicted country settings, power system planning cannot ignore the inherent risks. . . . Such risks can, for example, manifest in projects being delayed, abandoned, or coming in at very high costs. Security issues can thus significantly hamper, or make infeasible, the delivery of power system master plans."

—*"Considering Power System Planning in Fragile and Conflict States"*

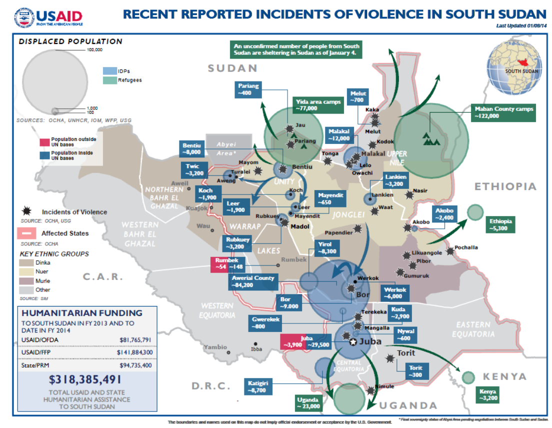
Source: Morgan Bazilian and Debrabrata Chattopadhyay, "Considering Power System Planning in Fragile and Conflict States," *Cambridge Working Papers in Economics*, 11/3/2015, p. 2.



South Sudan

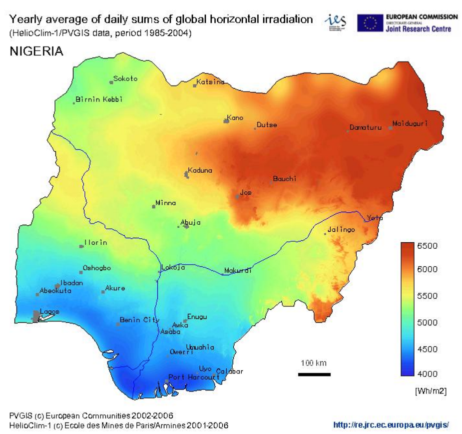


Assumption

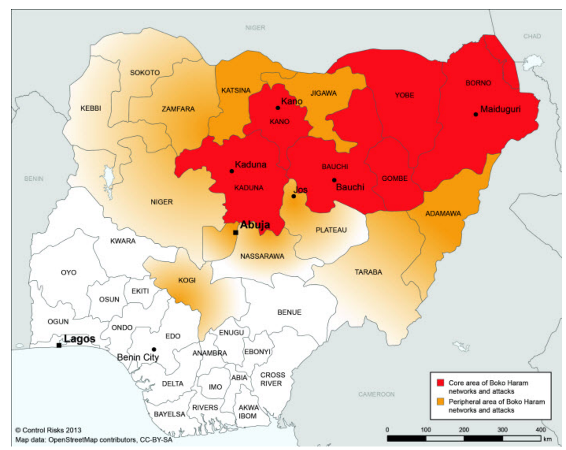


Reality

Nigeria - Solar



Assumption

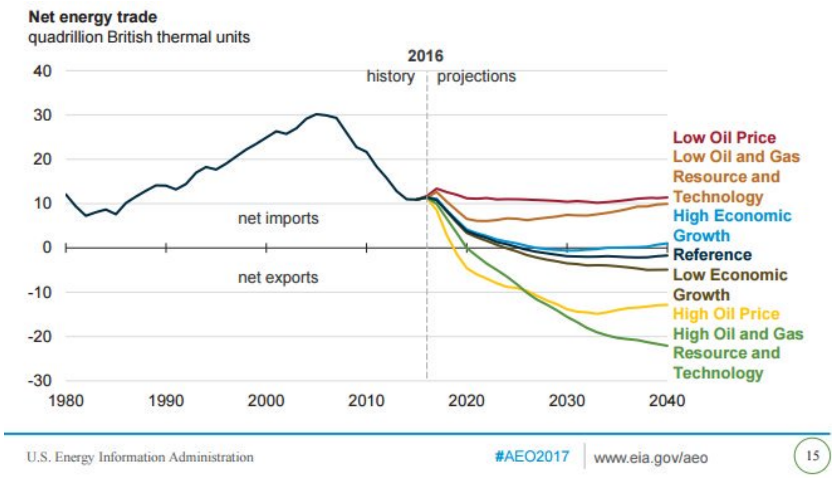


Reality

A bit on security and independence

Analogies in oil and gas security

- Independence is the wrong framing. The world is interrelated and growing more so.
- Energy security "measured" through various metrics: HHI, governance; import dependency; reliability, etc.
- Consider and model:
  - Diversification of sources of supply (various fuels and technologies)
  - Diversification of supply chains
  - Resilience or the ability to handle shocks and recover from failures
  - Reducing energy demand to ease the burden on infrastructure
  - Redundancy in case failures occur
  - Distributing timely information to markets.
- Apply sophisticated metrics to critical or security of minerals and metals



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