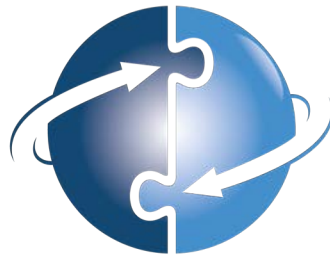


Advancing the Landscape of Clean Energy Innovation

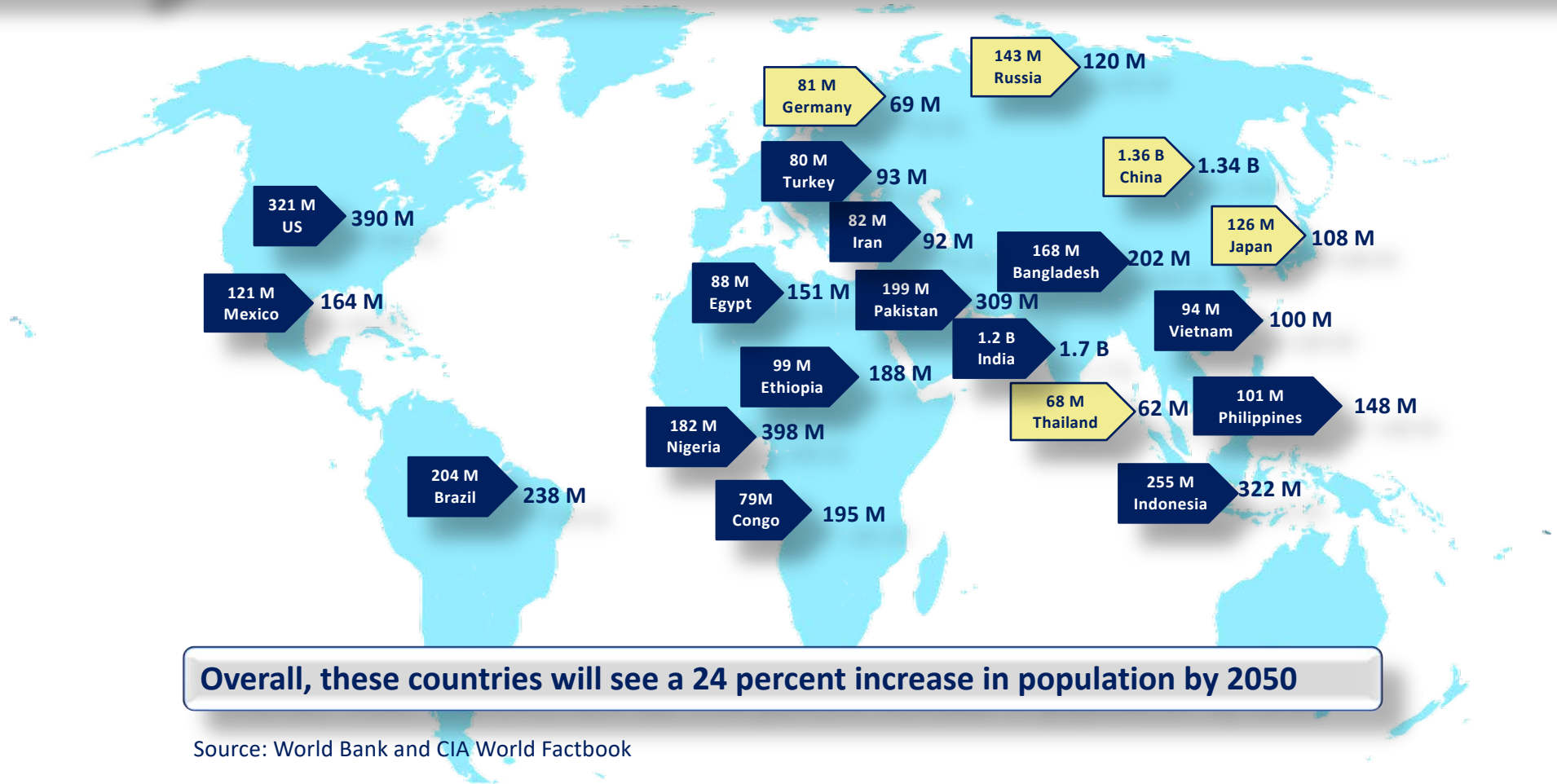


ENERGY FUTURES — **INITIATIVE** —

Melanie Kenderdine
Principal, Energy Futures Initiative
Changing Definitions of Energy Security
Global Change Forum
Cambridge, MA
March 29, 2019



20 Most Populous Countries in 2015, Populations in 2050



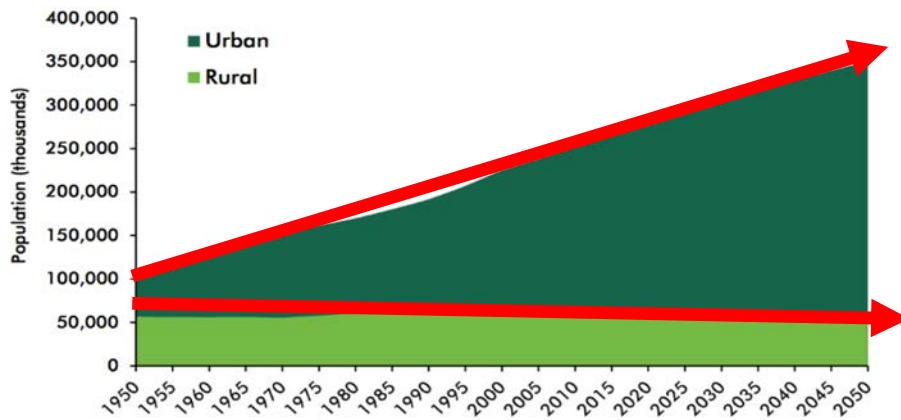
Overall, these countries will see a 24 percent increase in population by 2050

Source: World Bank and CIA World Factbook



US and Global Urbanization Trends

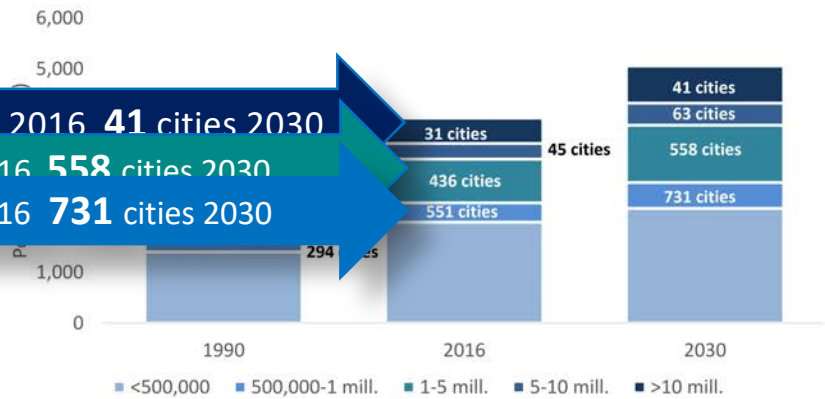
US population, 1950-2050



Between 2016 and 2030, the population in all city size classes is projected to increase, while the rural population is projected to decline slightly. While rural areas were home to more than 45 per cent of the world's population in 2016, that proportion is expected to fall to 40 percent by 2030.

Global urban population by size class of settlement, 1990-2030

>10M 31 cities 2016 41 cities 2030
1-5M 326 cities 2016 558 cities 2030
500k-1M 551 cities 2016 731 cities 2030



While the number of urban residents in the U.S. has increased approximately 500 percent since 1910, the number of rural residents has only increased by 19 percent. The southern, western, and coastal areas of the U.S. continue to see greatest population increases.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2014): World Urbanization Prospects: The 2014 Revision.



Electricity and Lifeline Network Interdependencies

Shipping

Alert (TA18-074A) March 15, 2018

Russian Government Cyber Activity Targeting Energy and Other Critical Infrastructure Sectors

Systems Affected

- Domain Controllers
- File Servers
- Email Servers

“This joint Technical Alert (TA) is the result of analytic efforts between the Department of Homeland Security (DHS) and the Federal Bureau of Investigation (FBI). This alert provides information on **Russian government actions targeting U.S. Government entities as well as organizations in the energy, nuclear, commercial facilities, water, aviation, and critical manufacturing sectors.**

DHS and FBI characterize this activity as a multi-stage intrusion campaign by Russian government cyber actors who targeted small commercial facilities’ networks where they staged malware, conducted spear phishing, and gained remote access into energy sector networks. **After obtaining access, the Russian government cyber actors conducted network reconnaissance, moved laterally, and collected information pertaining to Industrial Control Systems (ICS).”**

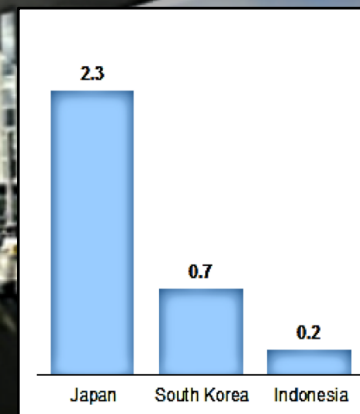


ENERGY FUTURES
INITIATIVE

Significant Global LNG Volumes by 2025

“Only 23 of the existing 421 LNG vessel fleet could pass through the canal. Now, nearly 90% of all LNG vessels can pass through the canal....a typical trip from Sabine Pass to Japan is roughly 16,000 nautical miles without the canal and 9,133 nautical miles using the canal. That’s a saving of 42%..”

ADI Analytics

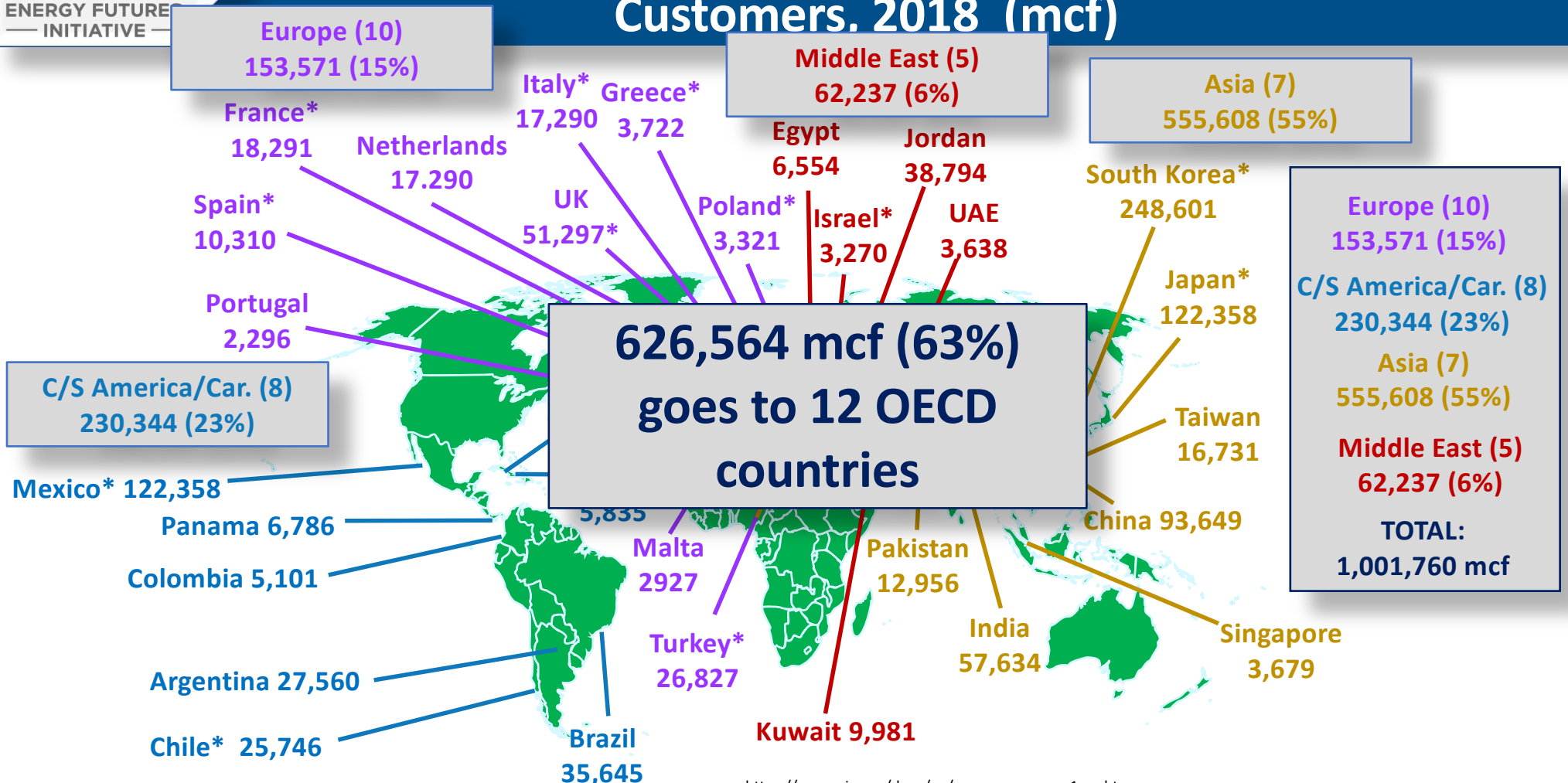


US LNG Volumes to Asia through Panama Canal by 2020 expected to exceed 3 bcf/d. EIA

Source: BP Statistical Review

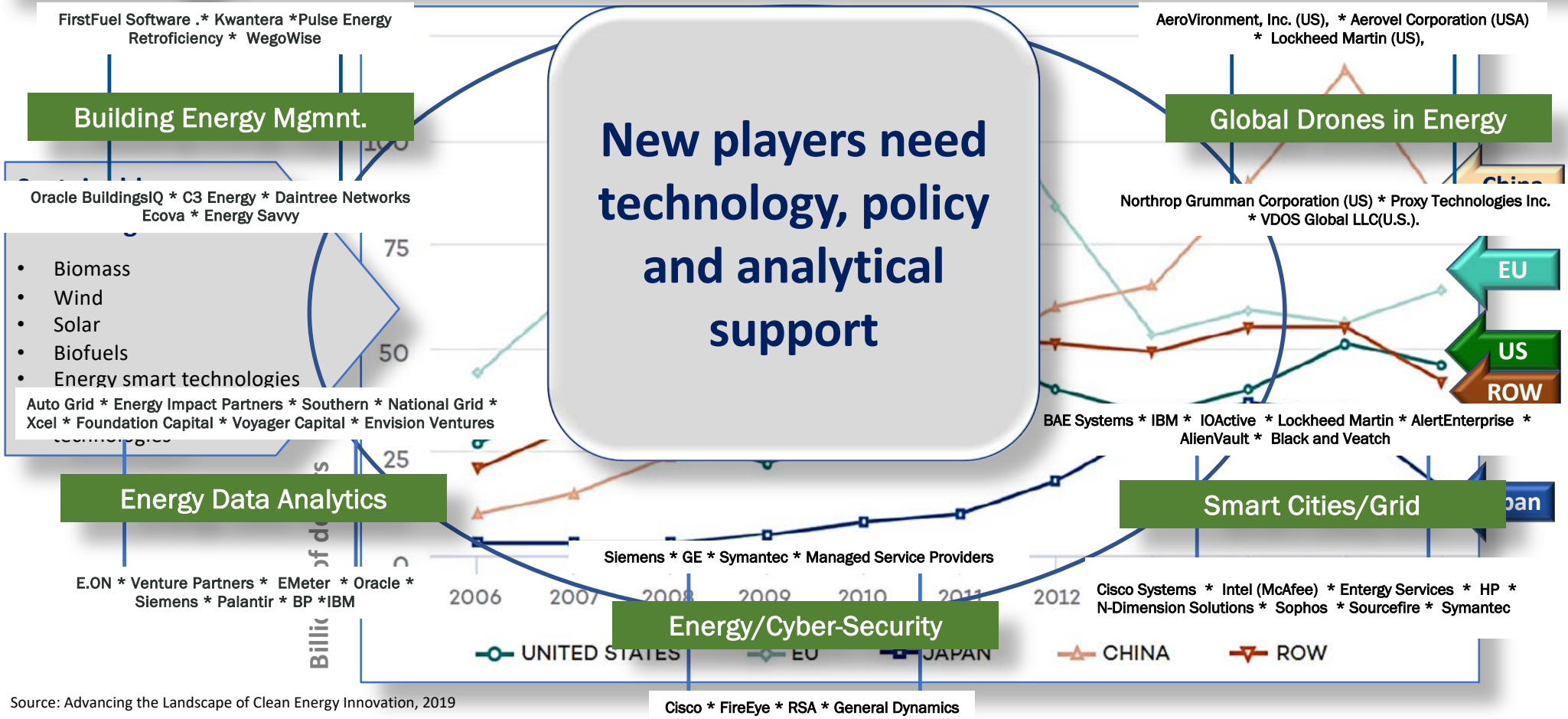
* Plants under construction

US LNG Export Growth and Large-volume Customers. 2018 (mcf)



https://www.eia.gov/dnav/ng/ng_move_expc_s1_m.htm
NOT FOR DISTRIBUTION OR CITATION

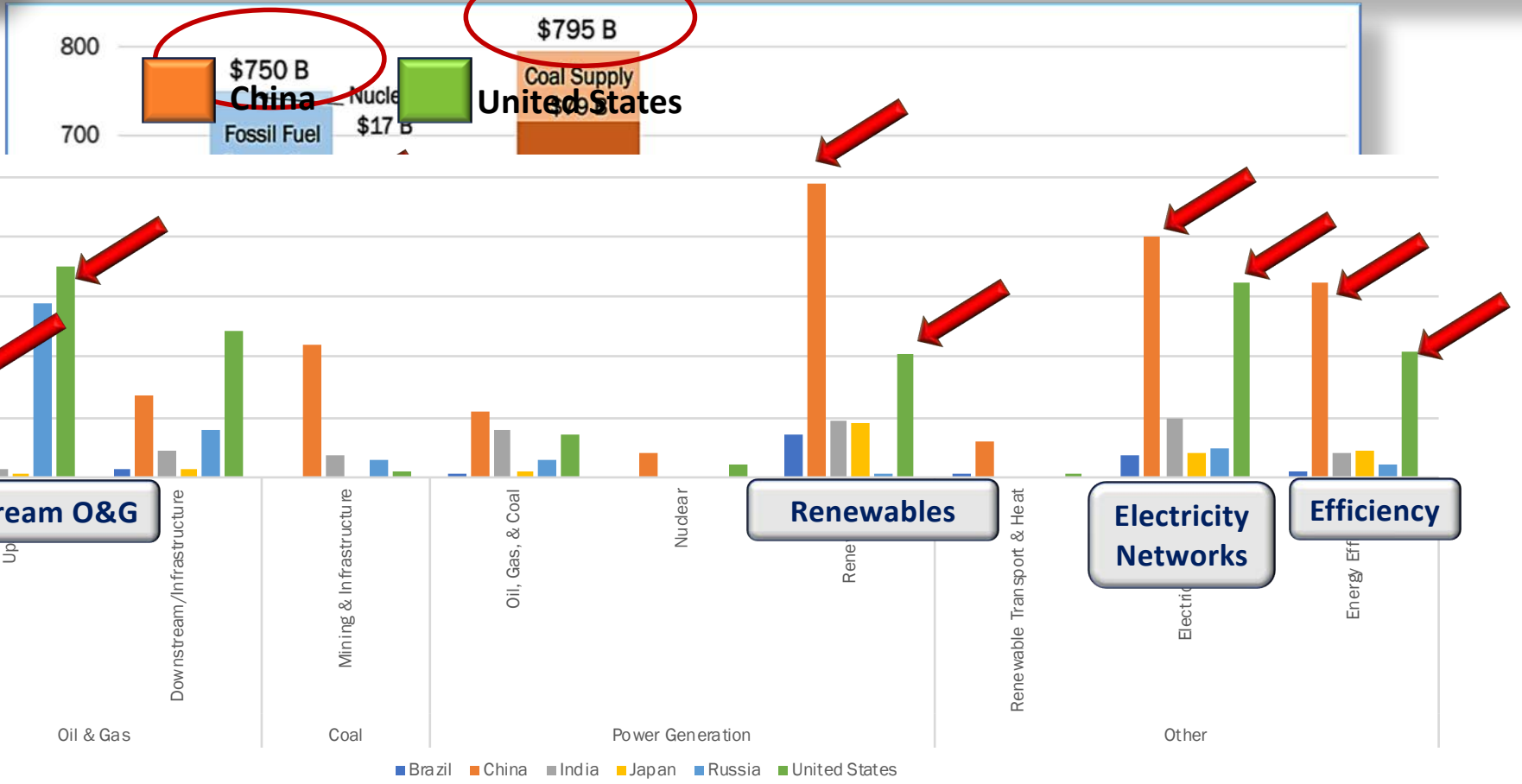
Later-stage Private Investment in Sustainable Technologies by Selected Region or Country, 2006-2016



Source: Advancing the Landscape of Clean Energy Innovation, 2019



Global Energy Investment, 2017





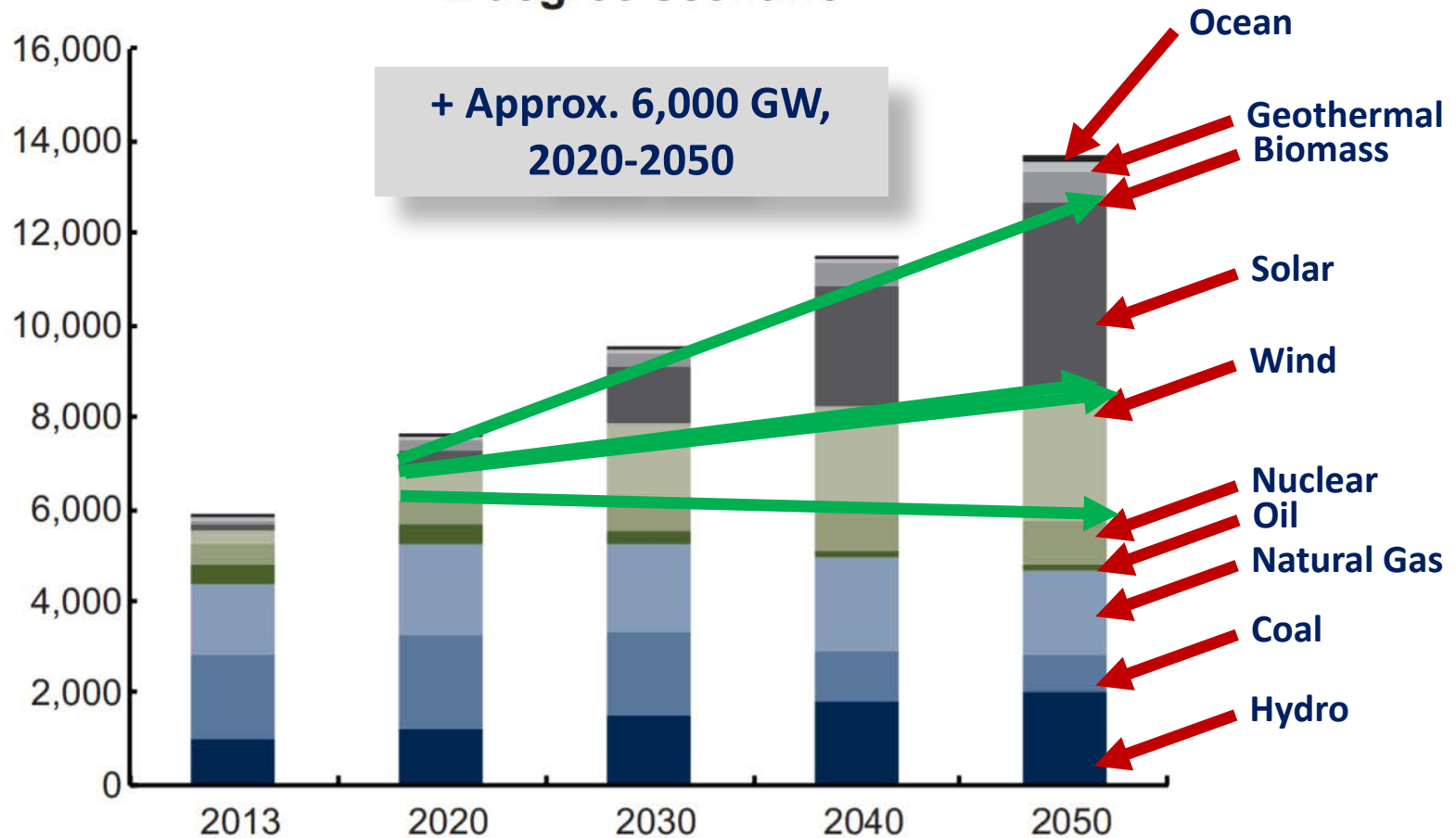
Energy Security for the 21st Century

- ◆ *Flexible, transparent and competitive energy markets, including gas markets, should be developed.*
- ◆ *Infrastructure modernization will improve energy system resilience. Promoting supply and demand policies will help withstand systemic shocks.*
- ◆ *Energy fuels, sources and routes should be diversified and development of indigenous sources of energy supply should be encouraged.*
- ◆ *Reducing our greenhouse gas emissions and accelerating the transition to a low carbon economy are key contributors to enduring energy security.*
- ◆ *Energy efficiency in demand and supply, and demand response management should be enhanced.*
- ◆ *Deployment of clean and sustainable energy technologies and continued investment in research and innovation should be promoted.*
- ◆ *Emergency response systems, including reserves and fuel substitution for importing countries, should be put in place to manage major energy disruptions.*



IEA Technology Scenarios for Electricity Installed Capacity (GW)

2 degree scenario





US Non-fuel Mineral Import Dependence, USGS, 2017

MAJOR IMPORT SOURCES OF NONFUEL MINERAL COMMODITIES FOR WHICH THE UNITED STATES WAS GREATER THAN 50% NET IMPORT RELIANT IN 2018

Commodity	Percent	Major import sources (2014-17) ²
ARSENIC (trioxide)	100	Morocco, China, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, Vietnam, South Africa, China
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	China, Canada, Republic of Korea, Taiwan
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA (sheet, natural)	100	China, Brazil, Belgium, Austria
NEPHELINE SYENITE	100	Canada
NIOBIUM (columbium)	100	Brazil, Canada, Russia, Germany
RARE EARTHS (compounds and metals) ³	100	China, Estonia, France, Japan
RUBIDIUM	100	Canada
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	Brazil, Rwanda, Australia, Congo (Kinshasa)
THORIUM	100	India, United Kingdom
VANADIUM	100	Austria, Canada, Republic of Korea, Russia
GEMSTONES	99	India, Israel, Belgium, South Africa
BISMUTH	96	China, Belgium, Mexico, Republic of Korea
YTTRIUM	>95	China, Estonia, Japan, Republic of Korea
POTASH	92	Canada, Russia, Belarus, Israel
TITANIUM MINERAL CONCENTRATES	91	South Africa, Australia, Canada, Mozambique

Electronics
Solar PV

Sensors

LEDs
Power plants,
desalination plants

60°

80°



ENERGY FUTURES INITIATIVE

Median Metals Demand for Supplying Solar Photovoltaic Technologies Through 2050

Aluminum Sm

Indium

ant

Metals/Minerals In Top Five of Global Resource Holders

Solar PV

US **2** China **8 (9)**

Wind Generation

US **1** China **6 (9)**

Battery Storage TOP FIVE

US **0** China **7 (7)**

% Resource found in Top 5 Countries

% China*

% US*

* Denotes one of top 5

■ 2D

■ 4D

Aluminum Copper Indium Iron Lead Molybdenum Nickel Silver Zinc



ENERGY FUTURE
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Select Metals, Minerals and Processes, #1 & Top Five

Asia Top 5/#1 in --

- Aluminum Smelter Capacity (China)
- Aluminum Refinery Production (China)
- Bauxite (Vietnam)
- Cadmium (China)
- Chromium (Kazakhstan, India)
- Cobalt (Philippines)
- Indium (China, Japan, R. of Korea)
- Pig Iron (China)
- Raw Steel (China)
- Iron Ore (China, India)
- Lead (China)
- Lithium (China)
- Manganese (India)
- Molybdenum (China)
- Silicon Production (China)
- Silver
- Titanium (China, India)
- Zinc (China)

10 Number Ones

South America Top 5/#1 in --

Australia Top 5/#1 in --

- Aluminum Smelter Capacity
- Aluminum Refinery Production
- Bauxite
- Cobalt
- Copper
- Indium (Canada)
- Crude Ore
- Mineral Iron Content
- Lead
- Lithium
- Manganese
- Nickel
- Silver
- Zinc

5 Number One's

3 Number One's

0 Canada

0 Mexico

7
Area 2

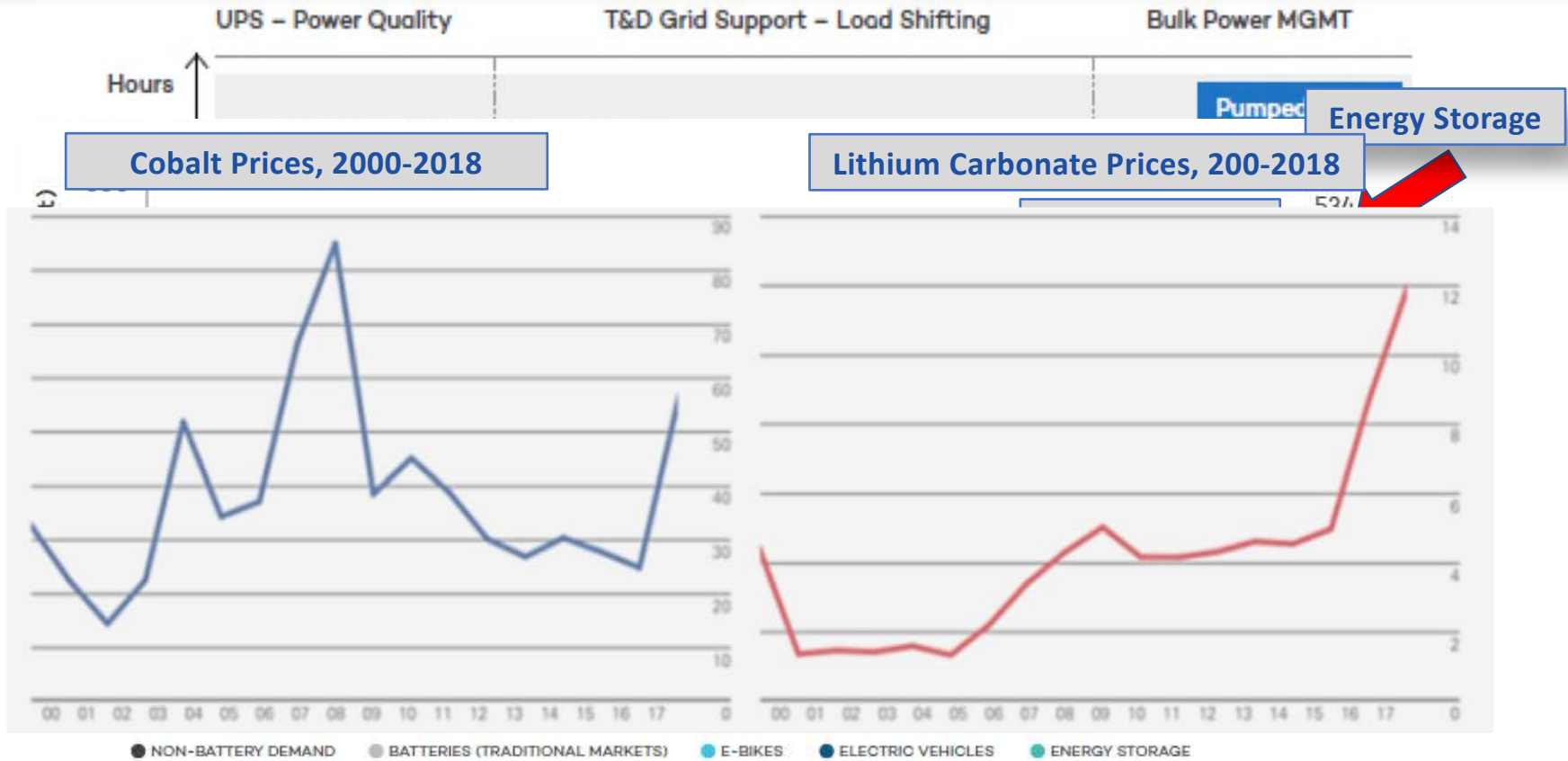
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ENERGY FUTURES INITIATIVE

Lithium Demand by End Use Application, 2013-2025





Conclusions: World Bank Study, Mine

US should –

- *Increase its diplomatic and investment focus on Western Hemisphere and Africa*
- *Protect LNG supply chains, especially for our allies*
- *Protect supply chains for minerals/metals needed for wind, solar and batteries*
- *Support new domestic mining activities for key minerals/metals*
- *Support innovation in earth abundant materials for wind, solar and batteries*
- *Promoted humane mining conditions around the world*
- *Develop rules of engagement for cyber-attacks*