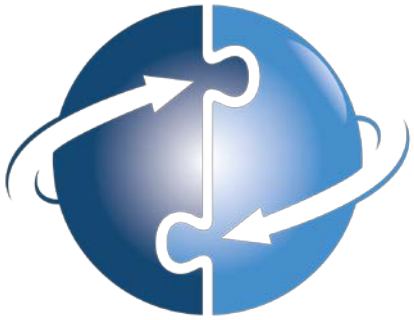
Building Common Energy Security



ENERGY FUTURES INITIATIVE

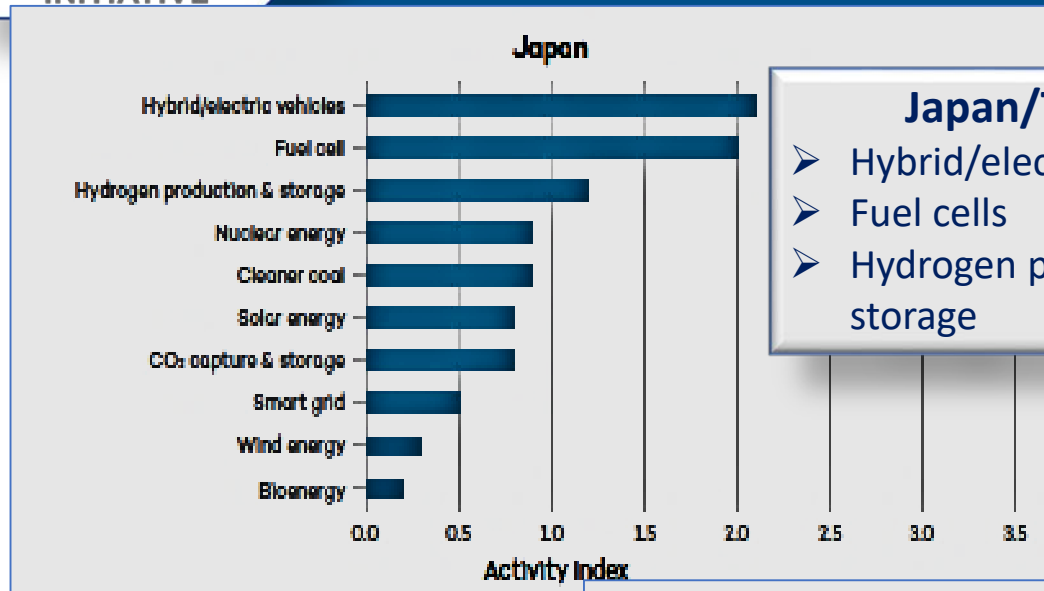
Melanie Kenderdine
Principal, Energy Futures Initiative
Paris, France
October 17, 2019

Science, Data Sending Alarms, Urgent Action Needed

- 9 of 10 warmest years on record between 2005-2016
- Arctic warming 2-3x faster than global average; its sea ice is declining at a rate of 12.8 percent per decade
- Sea levels (global average) have risen 7-8 inches since 1900; could reach 1-4 feet by 2100
- In May 2019, atmospheric CO_2 concentration reached 415 ppm, the highest level in at least 800,000 yrs.
- At the current rate of warming of 0.2°C per decade, the planet will likely reach the lower target of 1.5°C by as early as 2030

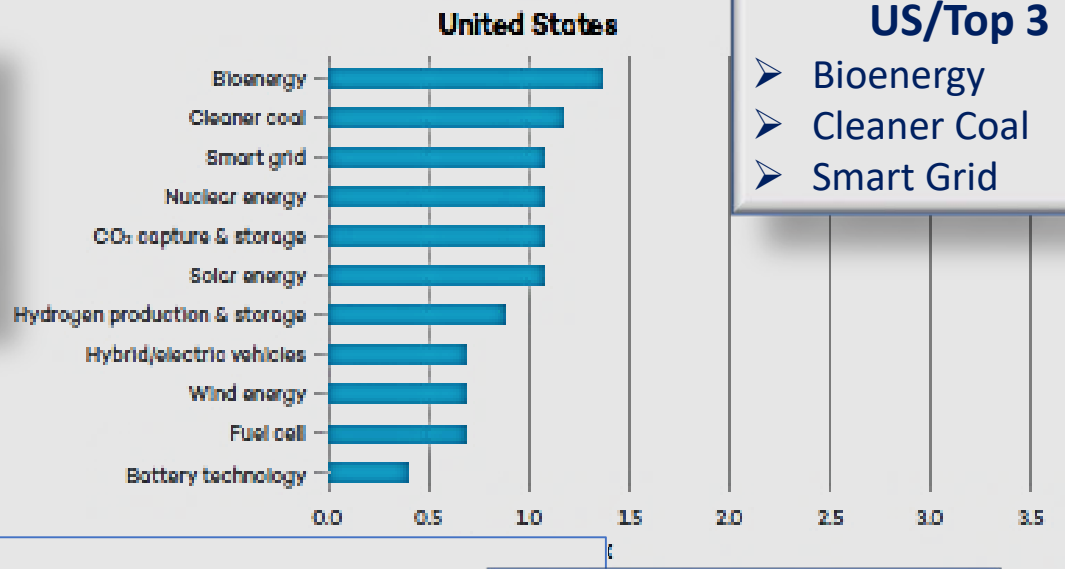
- According to the IPCC, "…On land, impacts on biodiversity and ecosystems, including species loss and extinction, are projected to be lower at 1.5°C of global warming compared to 2°C"
- An increase of 2° C in global average temperatures means that 37% of the world's population will experience extreme heat, compared to 14% at 1.5°
- As of 2018, 2/3rds of the major emitting countries were not on track to meet their targets
- In 2018, US CO_2 emissions from fossil fuel combustion rose 2.7%

Japan/US/EU Patent Activity Index for Select Electricity Technologies



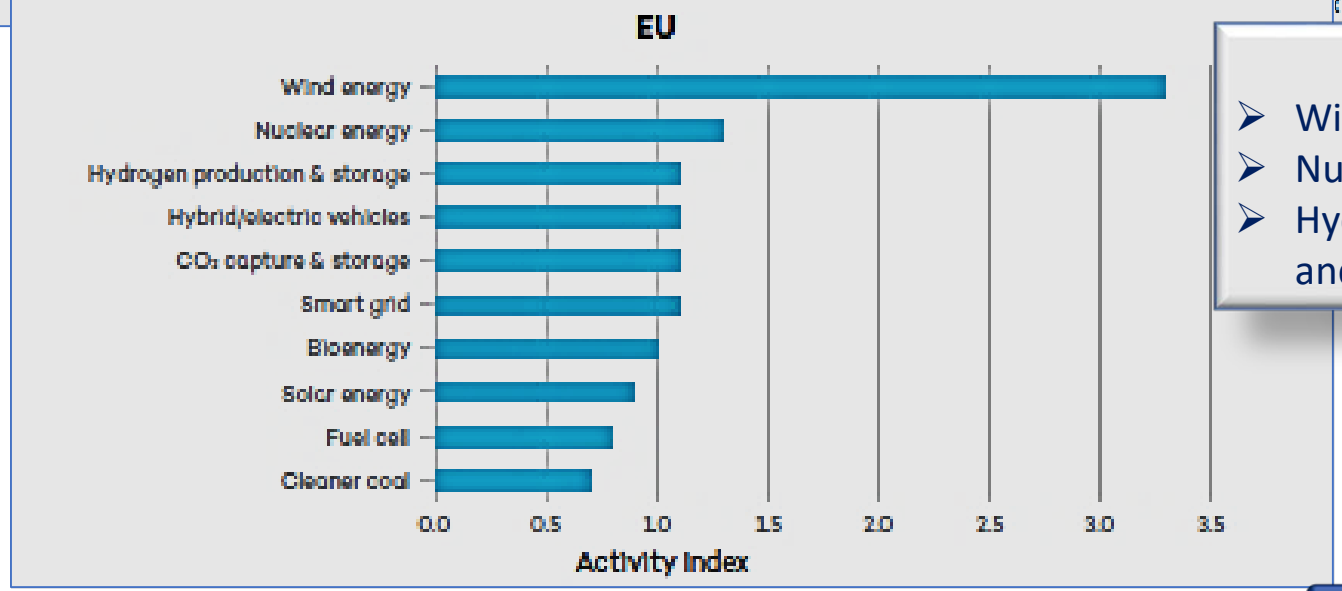
Japan/Top 3

- Hybrid/electric vehicles
- Fuel cells
- Hydrogen production & storage



US/Top 3

- Bioenergy
- Cleaner Coal
- Smart Grid



EU/Top 3

- Wind energy
- Nuclear energy
- Hydrogen production and storage

A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area.

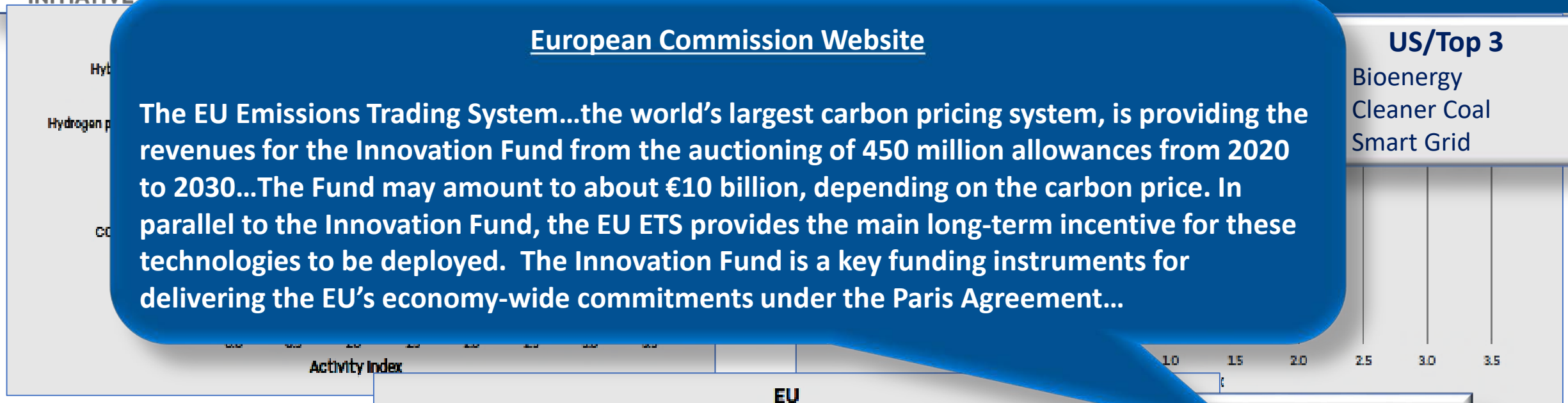
Source: NSF Website, accessed Mat 26, 2018

Japan/US/EU Patent Activity Index for Select Electricity Technologies

ENERGY FUTURES INITIATIVE

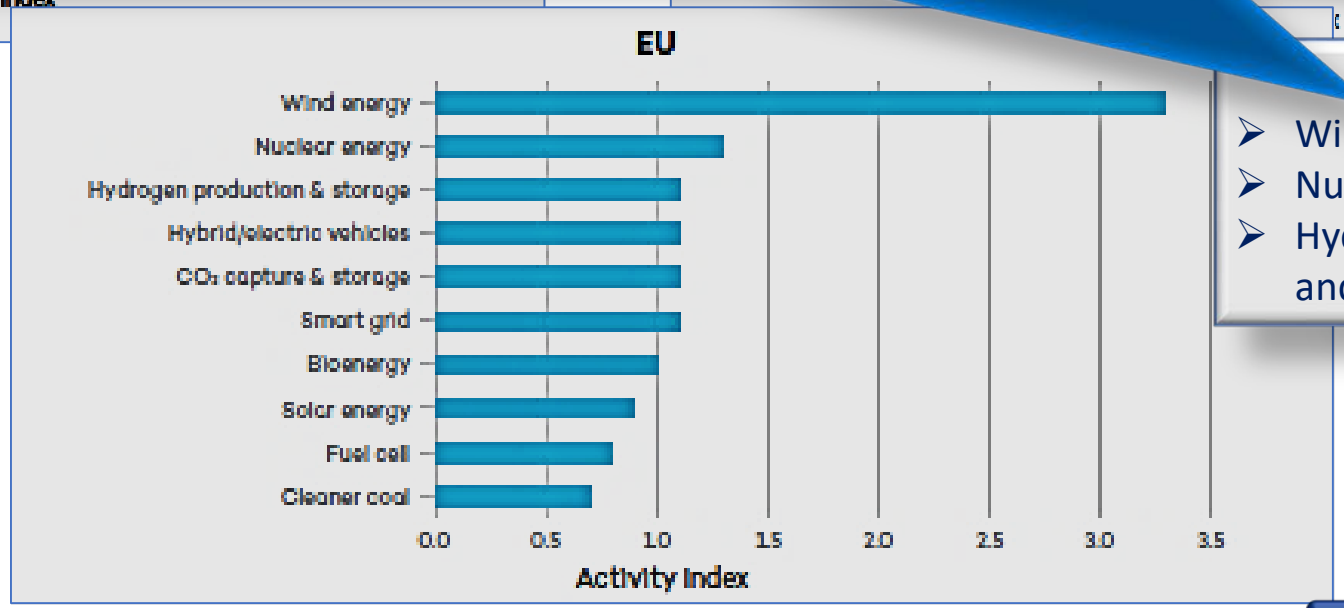
European Commission Website

The EU Emissions Trading System…the world's largest carbon pricing system, is providing the revenues for the Innovation Fund from the auctioning of 450 million allowances from 2020 to 2030…The Fund may amount to about €10 billion, depending on the carbon price. In parallel to the Innovation Fund, the EU ETS provides the main long-term incentive for these technologies to be deployed. The Innovation Fund is a key funding instruments for delivering the EU's economy-wide commitments under the Paris Agreement…



US/Top 3

Bioenergy
Cleaner Coal
Smart Grid



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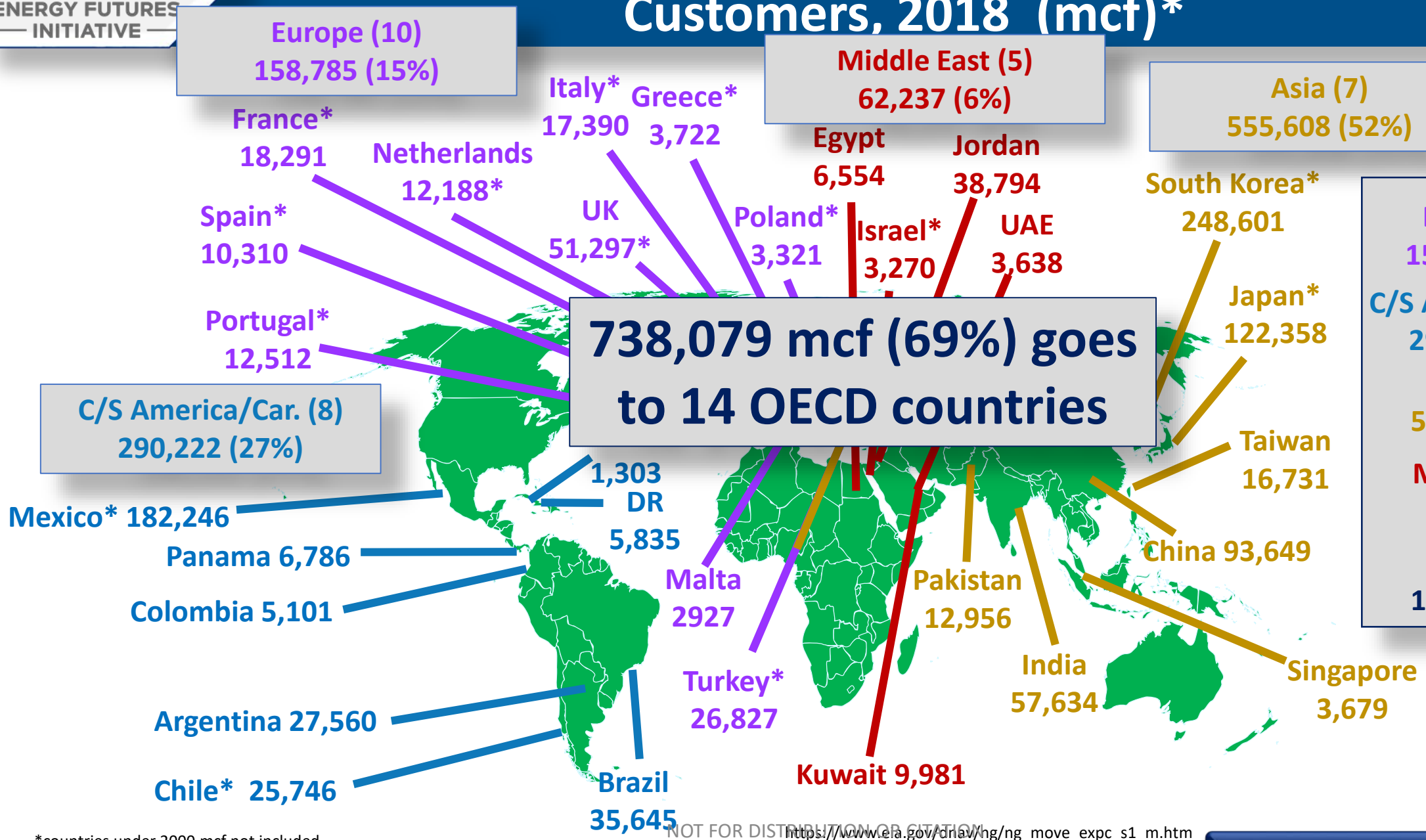
Source: NSF Website, accessed Mat 26, 2018

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

ENERGY FUTURES INITIATIVE

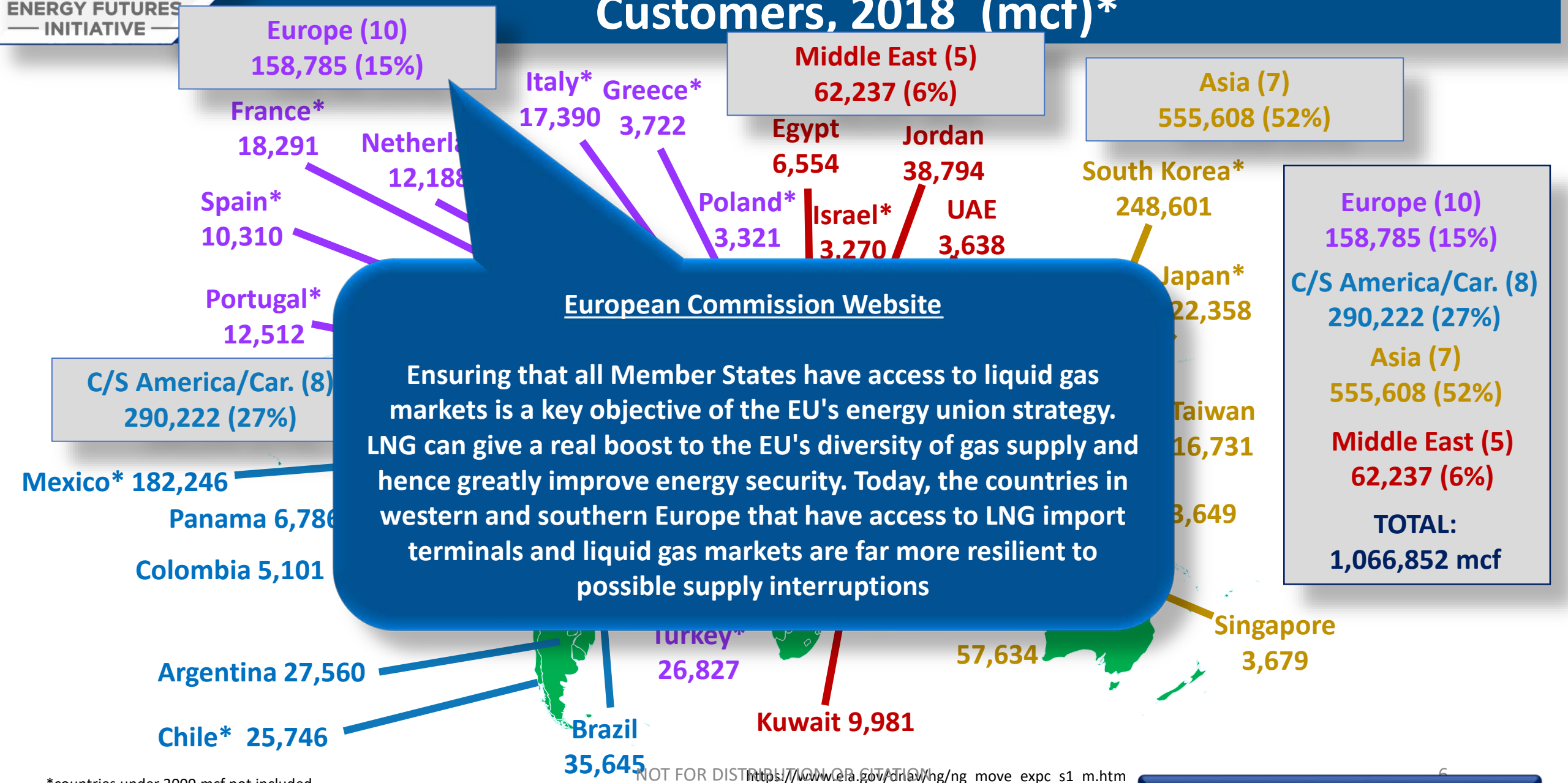


*countries under 2000 mcf not included

https://www.eia.gov/dnav/ng/ng_move_expc_s1_m.htm

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

ENERGY FUTURES INITIATIVE



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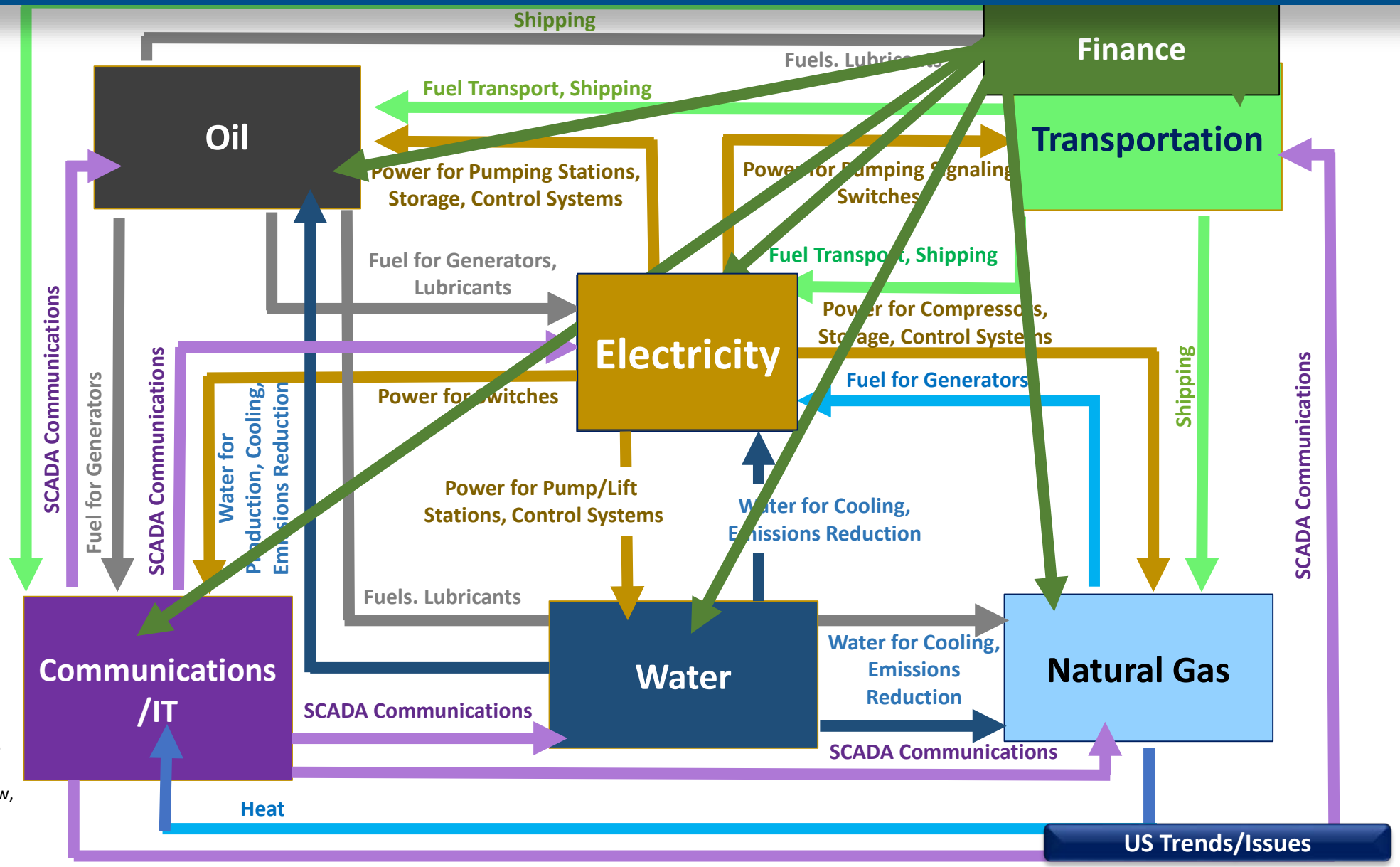
Electricity and Lifeline Network Interdependencies



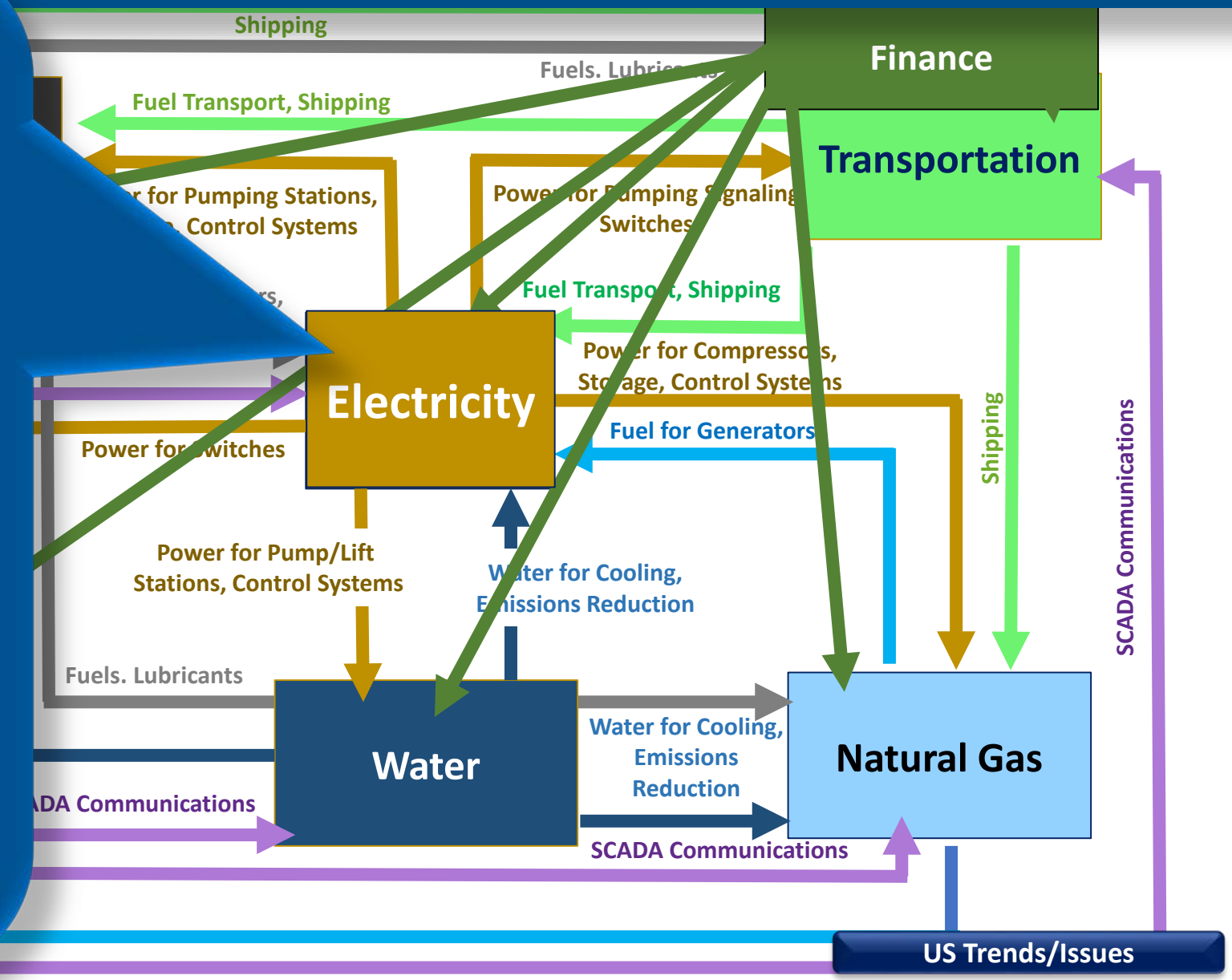
Source: Modified from the Second Installment of the Quadrennial Energy Review, Transforming the Nation's Electricity Systems, 2017

Electricity and Lifeline Network Interdependencies

European Commission Website

…the energy sector presents certain particularities that require …attention

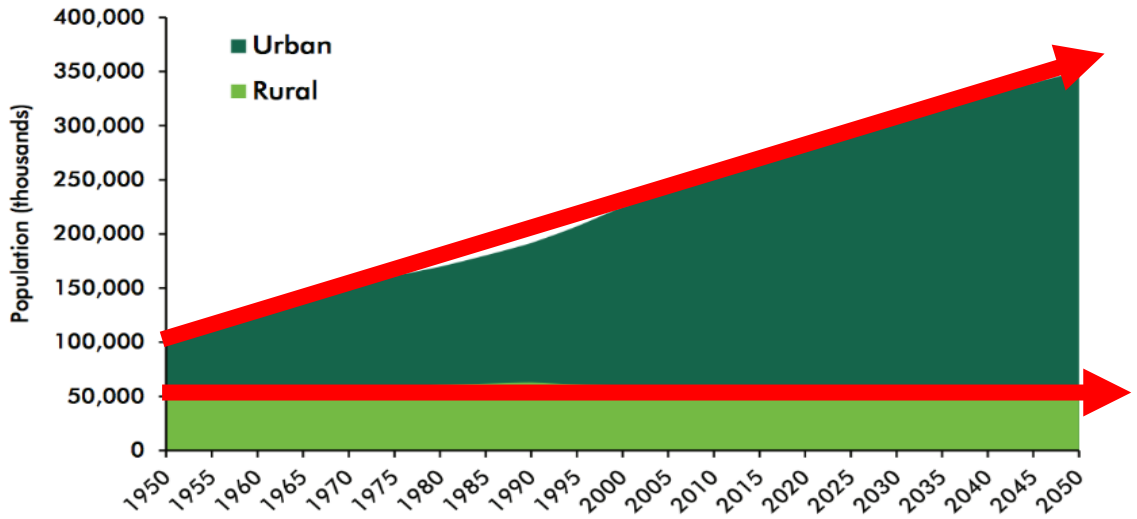
- *real-time requirements* - some energy systems need to react so fast that standard security measures …can simply not be introduced
- *cascading effects* - electricity grids and gas pipelines are strongly interconnected … An outage in one country might trigger blackouts or shortages of supply in other areas
- *combined legacy systems with new technologies* - [legacy systems need] to interact with the most recent state-of-the-art equipment for automation and control, such as smart meters or connected appliances



US and Global Urbanization Trends

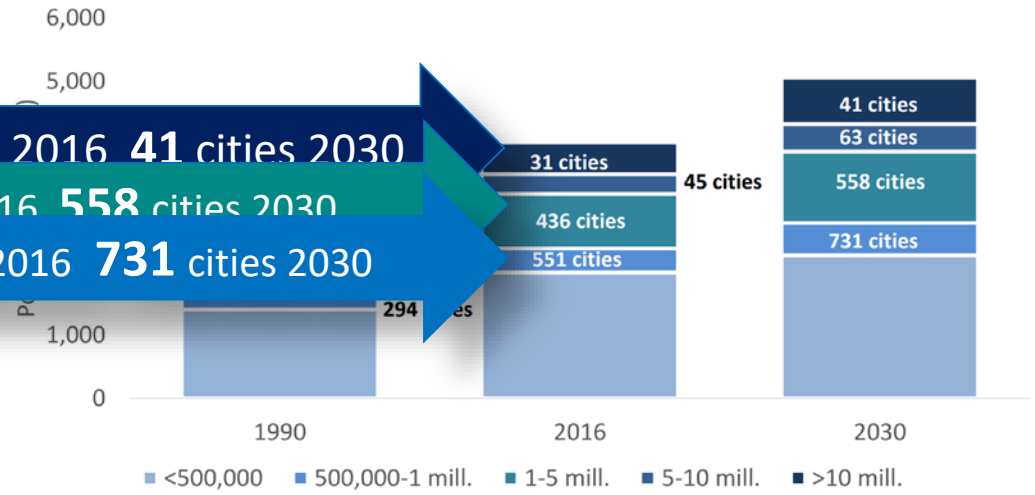
Between 2016 and 2030, the population in all city size classes is projected to increase, while the rural population is projected to decline slightly. While rural areas were home to more than 45 per cent of the world's population in 2016, that proportion is expected to fall to 40 percent by 2030.

US population, 1950-2050



While the number of urban residents in the 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.

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



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

US and Global Urbanization Trends

US population, 1950-2050

European Commission Website

The European Commission has…been increasing its focus on urban issues…by 2020 it is estimated that almost 80% of EU citizens will be living in cities…the Commission should develop …a set of criteria to assess the environmental performance of cities

Smart grids deployment: increase deployment of smart grids to help integrate renewable energy and allow consumers to better regulate their energy consumption

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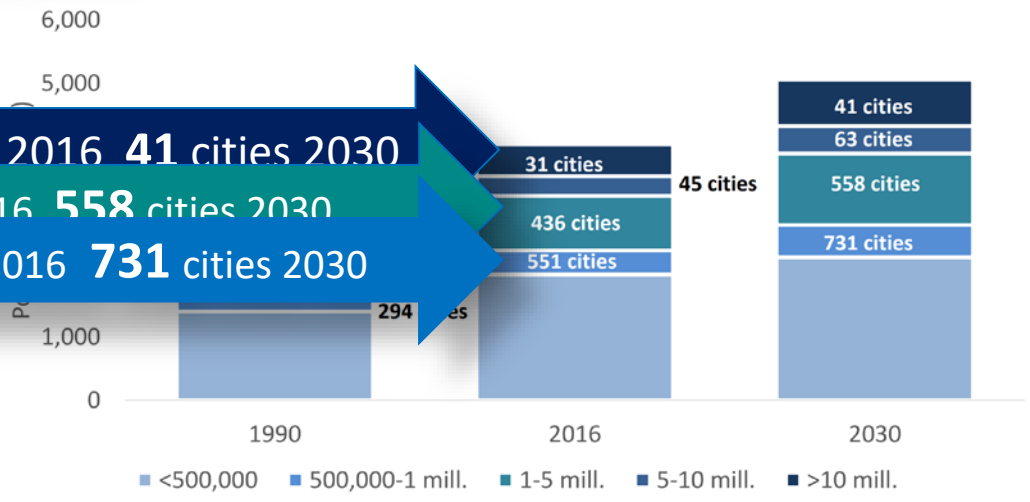


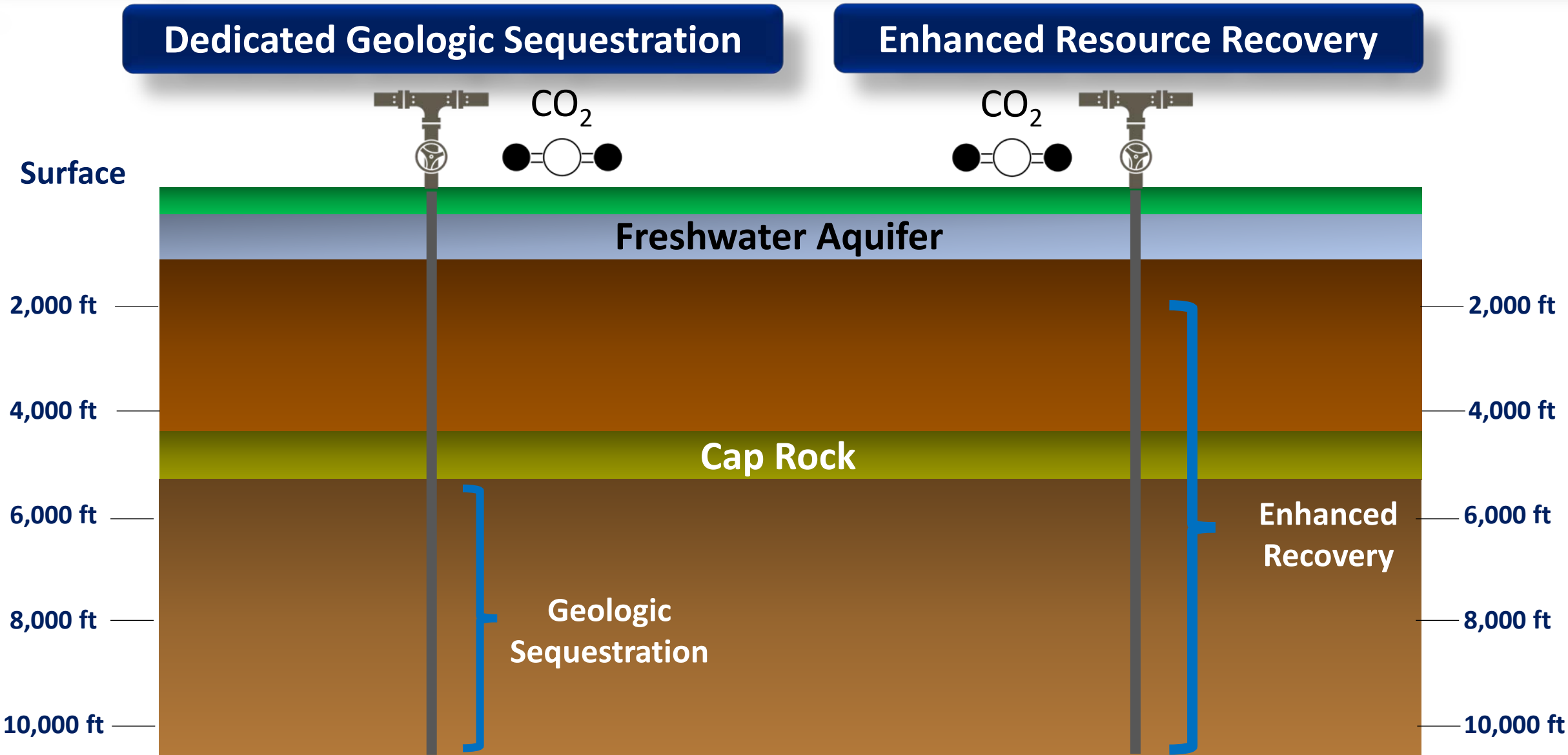
Source: United Nations, Department of Economic and Social Affairs, Population Division (2014): World Urbanization Prospects: The 2014 Revision.

>10M **31** cities 2016 **41** cities 2030

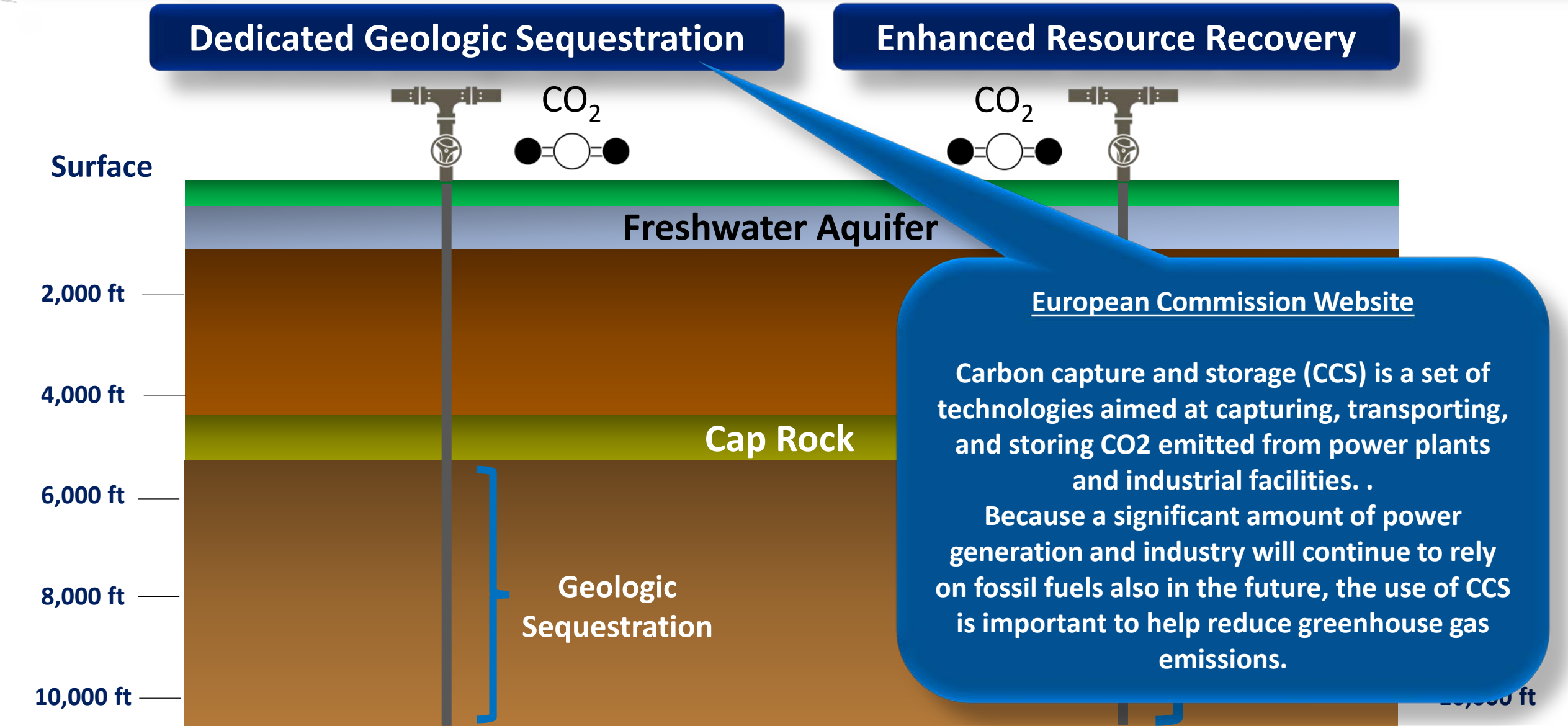
1-5M **326** cities 2016 **558** cities 2030

500k-1M **551** cities 2016 **731** cities 2030

Geology of Sequestration, Enhanced Resource Recovery



Geology of Sequestration, Enhanced Resource Recovery



Modernized Definition of Energy Security: G-7 Energy Security Principles, Adopted by Leaders in Brussels, 2014

European Commission Website

Priority gas corridors

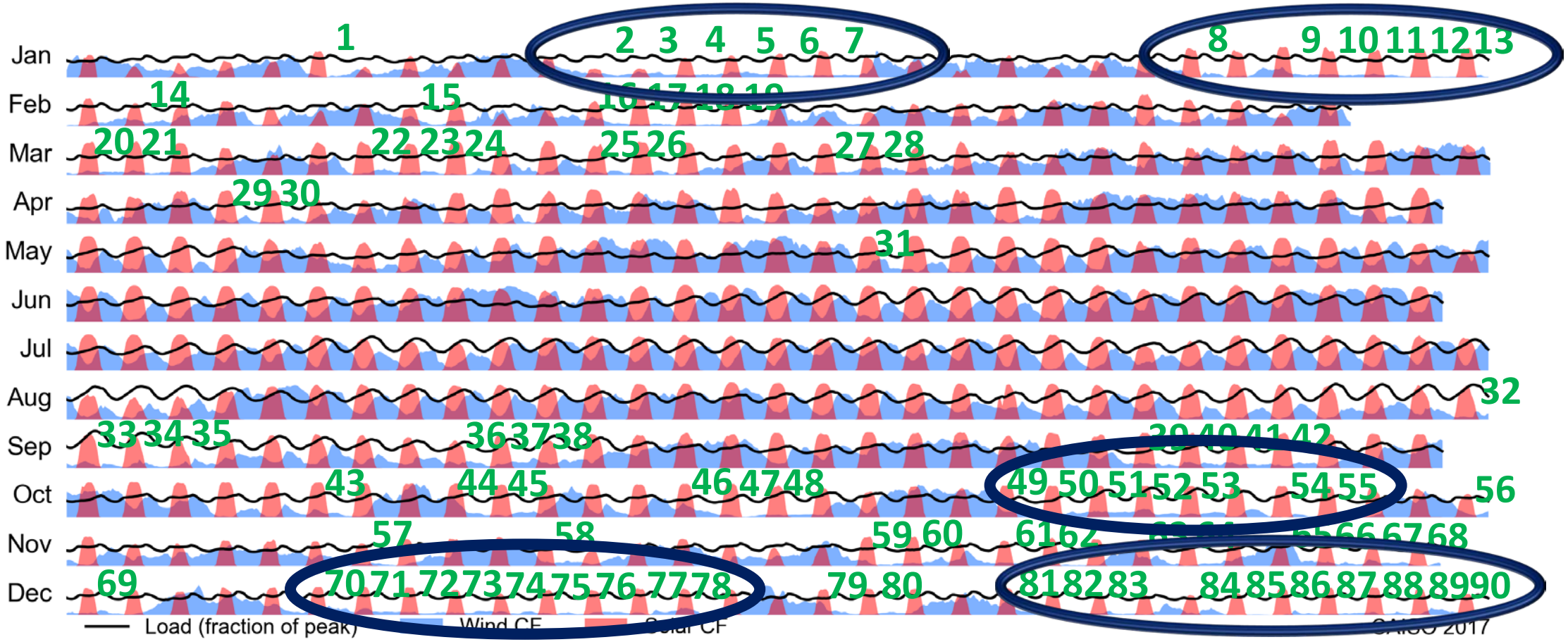
- **North-south gas interconnections in Western Europe to further diversify routes of supply**
- **North-south gas interconnections in central eastern and south eastern for enhancing diversification and security of gas supply.**
- **Southern Gas Corridor to enhance diversification of gas supply.**
- **Baltic Energy Market Interconnection Plan in gas to end the isolation of the three Baltic States and Finland,**

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

G7 Initiative for Energy Security, May, 2014

Challenges with Integrating Intermittent Renewables

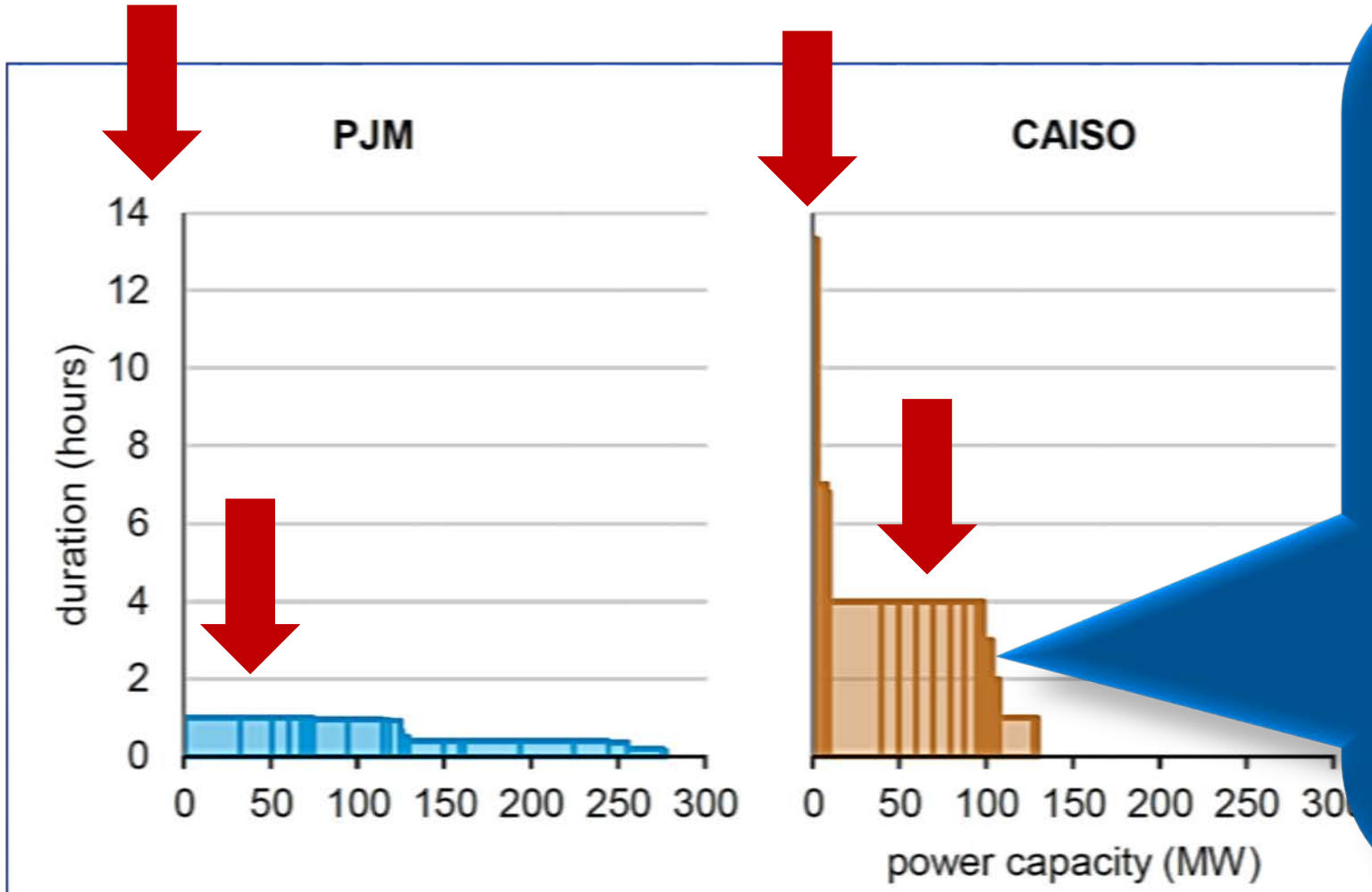
Over the course of a year large-scale dependence on both wind and solar will result in significant periods requiring very large-scale back-up options



Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

Source: CAISO data, EFI analysis

Challenges with Integrating Intermittent Renewables



European Commission Website

In December 2018, the new revised Renewables Energy Directive (2018/2001) entered into force – establishing a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023.
The new directive is part of the Clean Energy for All Europeans Package , aimed at establishing a new stable legislative framework which will facilitate the clean energy transition and help the EU to meet its Paris Agreement commitments on reducing greenhouse gas emissions.

Source: EIA, 2018

Metals Demand for Low Carbon Technologies

Light Emitting Diodes (11)

Al

Wind (10)

CCS (8)

Chr
Indi

Iron (cast), Nickel

Silver, Zinc

In 2017, UNEP calculated that **low carbon technologies will need over 600 million metric tonnes more metal resources in a 2° C scenario compared to a 6° C scenario where fossil fuel use continues on its current path.**

(It also concluded that the 2° scenario would save more than 200 million cubic meters of water …)

Metals Demand for Low Carbon Technologies

Light Emitting Diodes (11)
Aluminum, Chromium, Copper, Indium, Iron (cast), Lead, Manganese, Molybdenum, Nickel, Silver, Zinc

Wind (10)
Aluminum, Chromium, Copper, Indium, Iron (cast), Iron (magnet), Lead, Manganese, Molybdenum, Neodymium (proxy for rare earths), Nickel, Steel (engineering)

CCS (8)
Aluminum, Chromium, Cobalt, Copper, Indium, Manganese, Molybdenum, Nickel

Nuclear Power (8)
Chromium, Cobalt, Copper, Indium, Lead, Molybdenum, Nickel, Silver

Concentrating Solar (3)
Aluminum, Iron (cast), Silver

Electric Vehicles (6)
Cobalt, Copper, Manganese, Neodymium (proxy for rare earths), Nickel, Silver

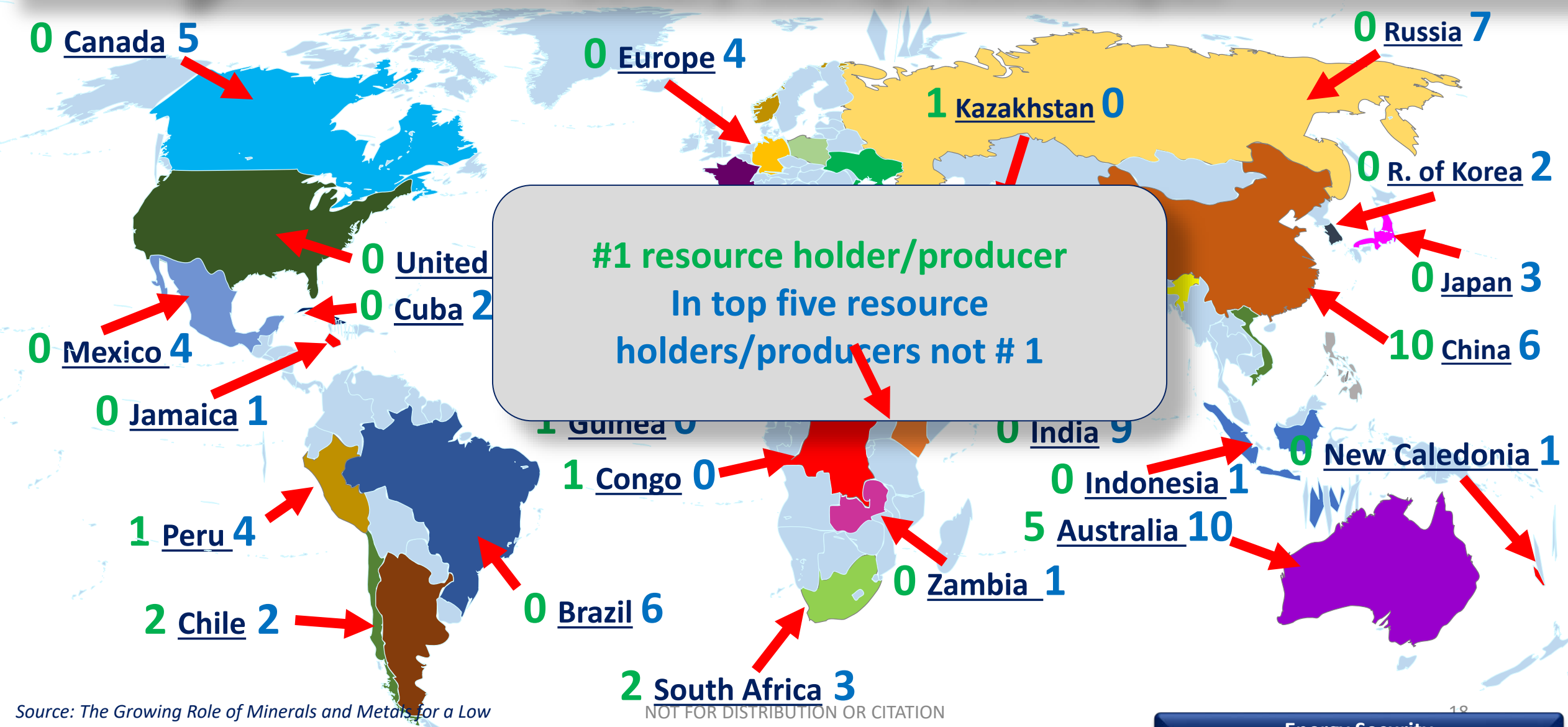
Energy Storage
Aluminum, Cobalt, Lithium, Iron (cast), Nickel

Electric Motors (3)
Aluminum, Copper, Iron (magnet)

Solar PV (6)
Aluminum, Copper, Indium, Nickel, Silver, Zinc

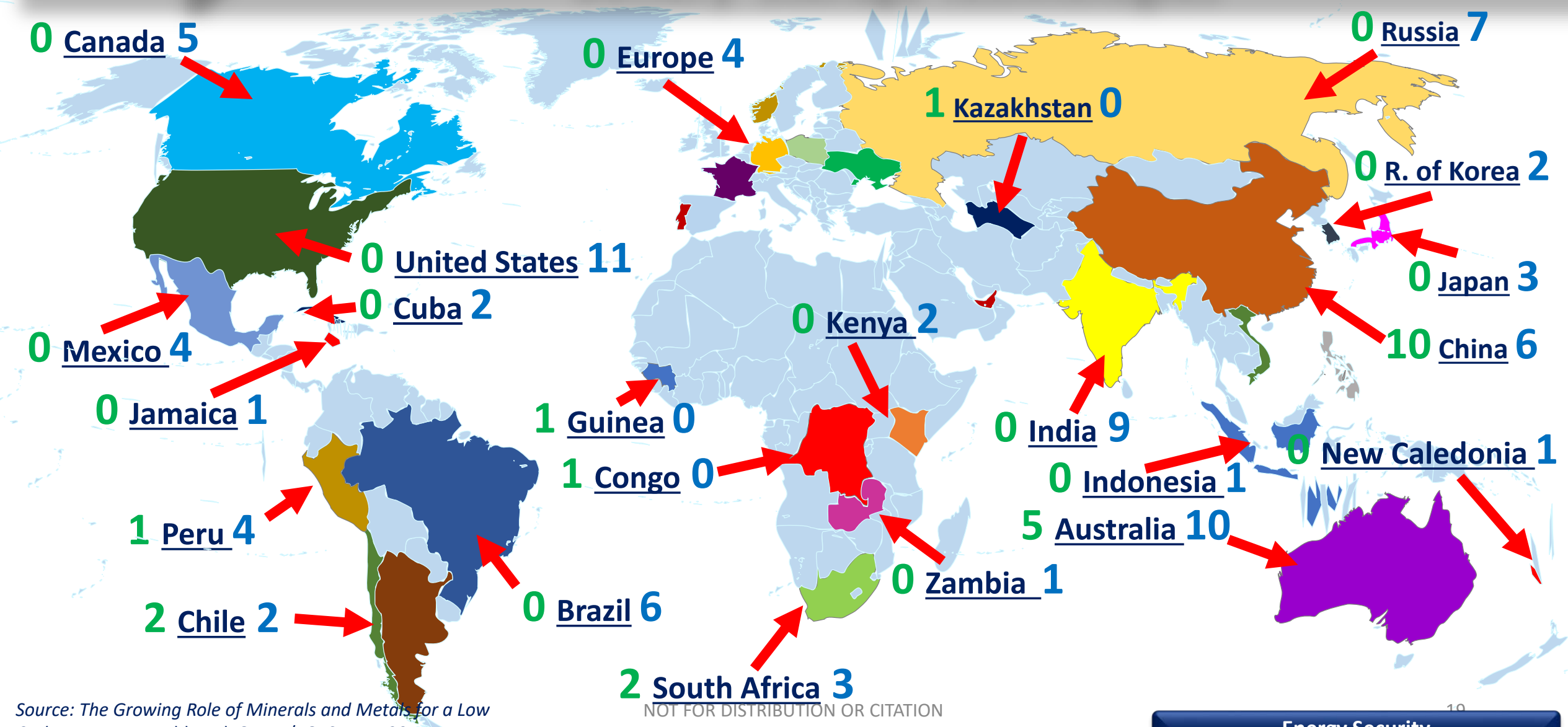
Better Meets Reality,
March, 2019

Select Metals, Minerals and Processes for Wind, Solar and Battery Storage Technologies



Source: The Growing Role of Minerals and Metals for a Low Carbon Future, World Bank Group/EGPS, June 2017

Select Metals, Minerals and Processes for Wind, Solar and Battery Storage Technologies



Source: The Growing Role of Minerals and Metals for a Low Carbon Future, World Bank Group/EGPS, June 2017

Select Metals, Minerals and Processes, #1/Top Five for Asia/Australia

Asia Top 5/#1 in --

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

11 Number One's

Source: The Growing Role of Minerals and Metals for a Low Carbon Future, World Bank Group/EGPS, June 2017

Australia/New Caledonia Top 5/#1 in –

Aluminum Smelter Capacity
Aluminum Refinery Production
Bauxite
Cobalt
Copper
Crude Iron Ore
Reserves/Iron Content
Lead
Lithium
Manganese
Nickel (Australia, New Caledonia)
Rare Earths
Silver
Titanium
Zinc

5 Number One's

Lithium, Cobalt, Nickel Production/Reserves

ENERGY FUTURES INITIATIVE

Meeting the Clean Energy Ministerial's target of 30 million electric vehicle sales by 2030 would require 314 kt/yr. of cobalt, almost three times the 2017 level for all uses. At those rates, reserves would last 23 years.

Carbonbrief.org

Lithium Production/Reserves (metric tons)

	Mine production 2017	Mine production 2018e	Reserves[6]
United States	W	W	35,000
Argentina	5,700	6,200	2,000,000
Australia	40,000	51,000	[7]2,700,000
Brazil	200	600	54,000
Chile	14,200	16,000	8,000,000
China	6,800	8,000	1,000,000
Portugal	800	800	60,000
Namibia	—	500	NA
Zimbabwe	800	1,600	70,000
World total (rounded)	[8]69,000	[8]85,000	14,000,000

Cobalt Production/Reserves (metric tons)

	Mine production 2017	Mine production 2018e	Reserves[7]
United States	640	500	38,000
Australia	5,030	4,700	[8]1,200,000
Canada	3,870	3,800	250,000
China	3,100	3,100	80,000
Congo (Kinshasa)	73,000	90,000	3,400,000
Cuba	5,000	4,900	500,000
Madagascar	3,500	3,500	140,000
Morocco	2,200	2,300	17,000
Papua New Guinea	3,310	3,200	56,000
Philippines	4,600	4,600	280,000
Russia	5,900	5,900	250,000
South Africa	2,300	2,200	24,000
Other countries	7,650	7,000	640,000
World total (rounded)	120,000	140,000	6,900,000

Nickel (metric tons)

	Mine production 2017	Mine production 2018e	Reserves[8]
United States	22,100	19,000	110,000
Australia	179,000	170,000	[9]19,000,000
Brazil	78,600	80,000	11,000,000
Canada	214,000	160,000	2,700,000
China	103,000	110,000	2,800,000
Colombia	45,500	43,000	440,000
Cuba	52,800	53,000	5,500,000
Finland	34,600	46,000	NA
Guatemala	53,700	49,000	1,800,000
Indonesia	345,000	560,000	21,000,000
Madagascar	41,700	39,000	1,600,000
New Caledonia[10]	215,000	210,000	—
Philippines	366,000	340,000	4,800,000
Russia	214,000	210,000	7,600,000
South Africa	48,400	44,000	3,700,000
Other countries	146,000	180,000	6,500,000
World total (rounded)	2,160,000	2,300,000	89,000,000

Source: USGS, 2019

Tesla's global supply manager for battery metals, told a closed-door Washington conference of miners, regulators and lawmakers that the automaker sees a shortage of key EV minerals coming in the near future…Tesla will continue to focus more on nickel, part of a plan by Chief Executive Elon Musk to use less cobalt in battery cathodes.

Electrek, May, 2019

Conclusions: World Bank Study & Mine

Cobalt Mining in Democratic Republic of Congo

Conclusions: World Bank Study & Mine

US should –

- *Increase its diplomatic and investment focus on Western Hemisphere and Africa*
- *Protect supply chains for minerals/metals needed for wind, solar and batteries*
- *Support new domestic mining activities for key minerals/metals*
- *Support innovation in mining efficiency and in earth abundant materials for wind, solar and batteries*
- *Use renewable energy for electricity needed in mining operation*
- *Promote humane mining conditions around the world*

Conclusions: World Bank Study & Mine

"It would be reasonable to expect that all low-carbon energy systems are more likely than not to be more metal intensive than high-carbon systems. In fact, **all literature examining material and metals implications for supplying clean technologies agree strongly that building these technologies will result in considerably more material-intensive demand than would traditional fossil fuel mechanisms.**

…Simply put, a green technology future is materially intensive and, if not properly managed, could bely the efforts and policies of supplying countries to meet their objectives of meeting climate and related Sustainable Development Goals. It also carries potentially significant impacts for local ecosystems, water systems, and communities."

The Growing Role of Minerals and Metals for a Low Carbon Future, World Bank Group/EGPS, June 2017