Testimony of David Gattie

Associate Professor of Engineering, College of Engineering

Resident Fellow, Center for International Trade and Security

University of Georgia

Before the Energy and Commerce Committee

Subcommittee on Environment and Climate Change

"Building a 100% Clean Economy: Solutions for Economy-Wide Deep Decarbonization"

U.S. House of Representatives

December 5, 2019

Summary of Testimony

I want to thank the Chairman, the Ranking Member and members of the subcommittee for the opportunity to come before you. My testimony aligns with the following points:

- America is facing two national security threats—one around climate change and the other around the U.S. nuclear power enterprise,[1,2,3]
- Climate change is global in cause and impacts, and, as carbon emissions increase globally, those impacts won't stop at U.S. borders simply because we have an aggressive domestic climate policy,
- The U.S. economy and its industrial capacity should be leveraged to innovate and deploy low- and zero-carbon technologies in developing economies where carbon emissions are of greatest concern,
- Nuclear power should be central to U.S. policy with a strategy to develop advanced reactor technologies for domestic and international deployment, and
- America must engage in climate issues globally, with national security as the overarching objective.

Global Energy, CO_2 and Renewable Energy: Magnitude and Context

Globally, energy consumption and carbon emissions are increasing (Figures 1-7, Appendices). From 2000-2018, 90% of the increase in carbon emissions originated in Asia-Pacific countries, predominantly China and India, while emissions in the U.S. declined (Figure 8; Appendices).[4] Under the most aggressive carbon policy, eliminating all U.S. emissions would reset global emissions to 2006 levels (Figure 9; Appendices). Meaning, if climate change was a threat in 2006 with U.S. emissions, climate change is a threat in 2018 without U.S. emissions.

While exponential growth in non-hydro renewables is elevating hopes that renewables are closing the gap on fossil fuels, that gap isn't closing—it's expanding.[5,6,7] (Figures 10 & 11, Appendices). For the past ten years 81.6% of global wind and 82.5% of global solar were concentrated in countries with substantial fossil fuels, nuclear and/or hydro built into their economies (Tables 1 & 2, Appendices). Meaning, traditional energy resources have provided the foundation for renewables to expand.

---

[1] Mattis, J., 2018. *Summary of the 2018 national defense strategy of the United States of America*. Department of Defense Washington United States.

[2] Coats, D. 2019. Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community. https://www.dni.gov/files/ODNI/documents/2019-ATA-SFR---SSCI.pdf

[3] U.S. Department of Defense (DOD). 2019. Report on Effects of a Changing Climate to the Department of Defense. https://media.defense.gov/2019/Jan/29/2002084200/-1/-1/1/CLIMATE-CHANGE-REPORT-2019.PDF

[4] Asia-Pacific Countries: India, Indonesia, Japan, Malaysia, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand and Vietnam.

[5] IRENA, 2019. A New World: The Geopolitics of the Energy Transformation. Global Commission on the Geopolitics of Energy Transformation. http://geopoliticsofrenewables.org/assets/geopolitics/Reports/wp-content/uploads/2019/01/Global_commission_renewable_energy_2019.pdf

[6] Roberts, D. 2019. The global transition to clean energy explained in 12 charts. Vox June 26, 2019. https://www.vox.com/energy-and-environment/2019/6/18/18681591/renewable-energy-china-solar-pv-jobs

[7] Rosane, O. 2019. America's shift from coal to renewable energy has begun. World Economic Forum July 1, 2019. https://www.weforum.org/agenda/2019/07/renewables-beat-coal-in-the-u-s-for-the-first-time-this-april

Triage and Nuclear Power

This recommends a global triage approach with resources and efforts directed toward regions where the issue is acute or emerging. In developing regions countries are at various stages of economic growth, therefore it's necessary to determine which energy technologies can be deployed effectively to sustain low-carbon economic development. One such technology is nuclear power.

Early U.S. nuclear policymakers recognized the strategic importance of America's nuclear enterprise. To them, nuclear wasn't just another energy commodity, the fate of which should be dictated by political calculus, popular opinion or market forces alone. Rather, it was central to America's foreign policy, so their approach was principled and strategic, not populist and transactional. A key objective was to create the world's most advanced nuclear technology base from which mutually beneficial global partnerships could be established within the emerging liberal international order.[8]

The 21st century is undergoing geopolitical shifts and China and Russia are leveraging state-owned nuclear enterprises as extensions of the state to establish long-term energy and technology dependencies.[9,10,11] If U.S. policy orients our technology trajectory away from nuclear, it will signal to the world that America has set aside its commitment to be a reliable partner in nuclear development, thus opening the door for China and Russia.

In Summary

Efforts to decarbonize the U.S. economy will require investment. If the return on that investment is a near-term reduction in U.S. carbon emissions, the U.S. will remain vulnerable to climate change over the long-term as global emissions increase. The U.S. cannot insulate itself from the impacts of global climate change through domestic policies targeting only the U.S. economy. Therefore, U.S. climate policy must be global and strategic, keeping in mind that if the U.S. transitions away from current energy interdependencies, those interdependencies can develop into vulnerabilities open to exploitation by energy-rich and technology-advantaged countries that don't share America's values. To that end, U.S. policy should focus on developing energy and technology relationships within developing regions, cultivated as international investment opportunities for U.S. industry and coupled to diplomatic efforts of U.S. engagement and good-will.[12,13]

Lastly, the national security implications of U.S. nuclear power can't be overstated. While nuclear has proven its value to America, its contributions remain on the horizon as economic development, climate change and national security converge into a perfect storm of 21st century global challenges that nuclear is capable of addressing.

The U.S. cannot be an energy and climate island—it isn't possible. America must engage globally and it must do so with national security as its overarching objective.

---

[8] Gattie, DK. 2019. U.S. Nuclear Power—America's Brand is at Risk. *Morning Consult*, October 29, 2019. https://morningconsult.com/opinions/us-nuclear-power-americas-brand-risk/

[9] Mattis, J., 2018. *Summary of the 2018 national defense strategy of the United States of America*. Department of Defense Washington United States.

[10] Saha, S., 2017. Russia's Nuclear Diplomacy. *Foreign Affairs*.

[11] Freeman, M. How Russia, China Use Nuclear Reactors To Win Global Influence. *Defense One*, July 13, 2018. https://www.defenseone.com/ideas/2018/07/china-and-russia-look-dominate-global-nuclear-power/149642/

[12] Gattie, D.K., 2017. Incorporating stability and resilience in energy policy for the US power sector: Recommendations for the Trump administration. *The Electricity Journal*, *30*(1), pp.47-54.

[13] Burns, W.J., 2019b. The Lost Art of American Diplomacy. *Foreign Affairs*.

<u>Note</u>

To this summary, I have appended

1. Supporting figures referenced in the summary,
2. Two commentaries, and
3. One recently-published journal article.

...ilyh...

Appendices

Figures Associated With Summary

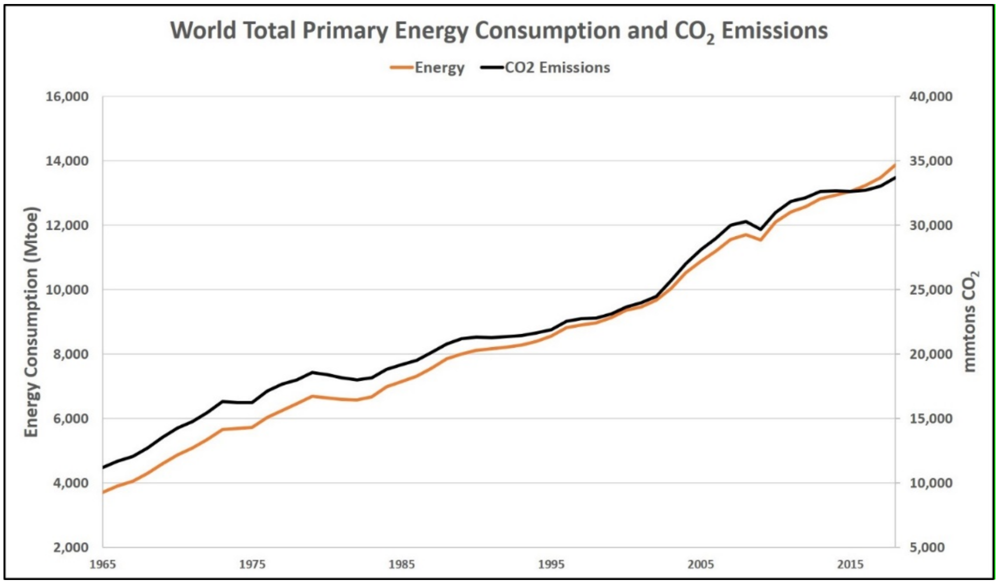


Figure 1. World total primary energy consumption and CO_2 emissions. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[14]

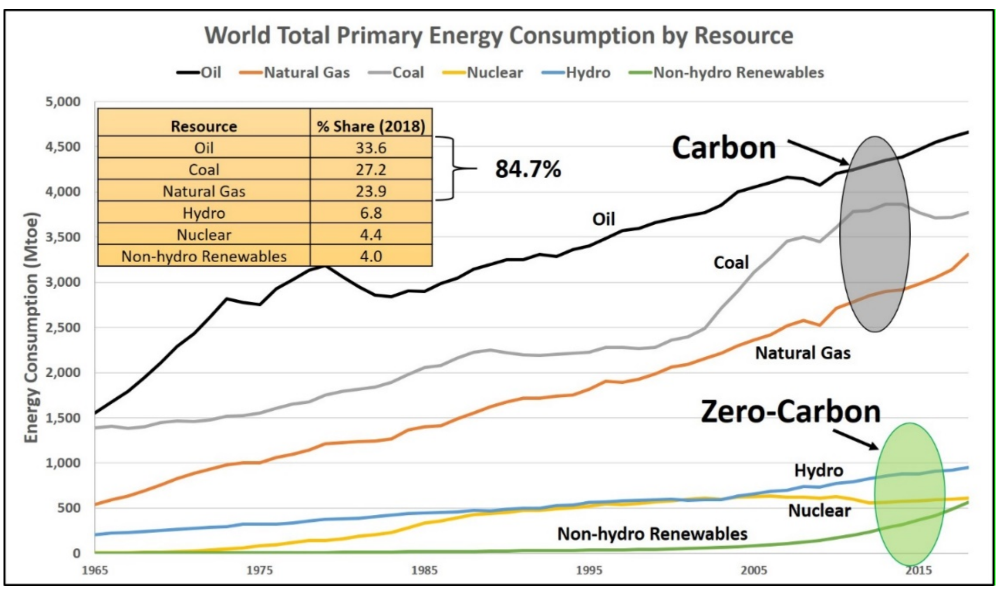


Figure 2. World total primary energy consumption by resource. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[15]

[14] Gattie, DK. 2020. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. *The Electricity Journal*, 33(1), In-Press.
[15] Ibid.

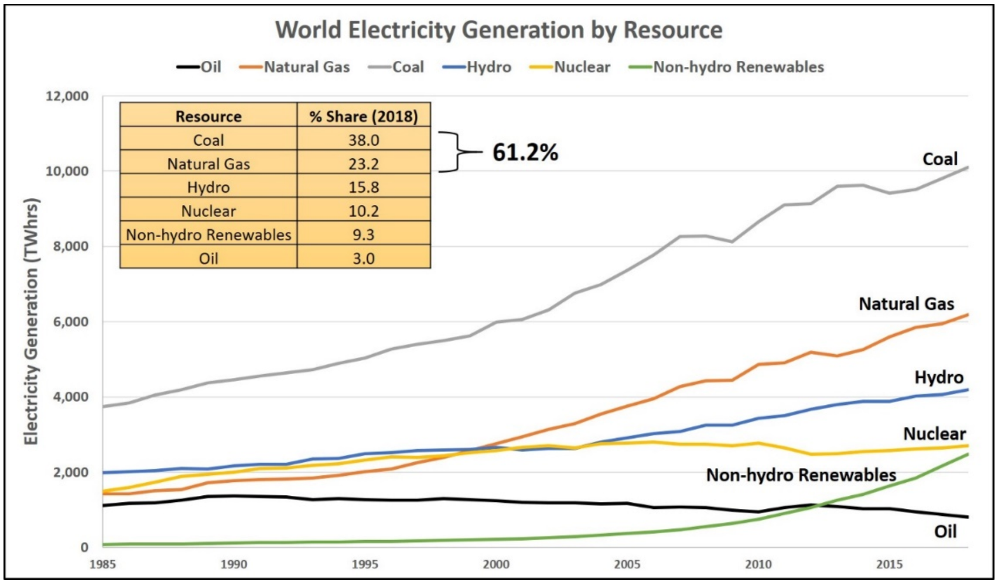


Figure 3. World electricity generation by resource. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[16]

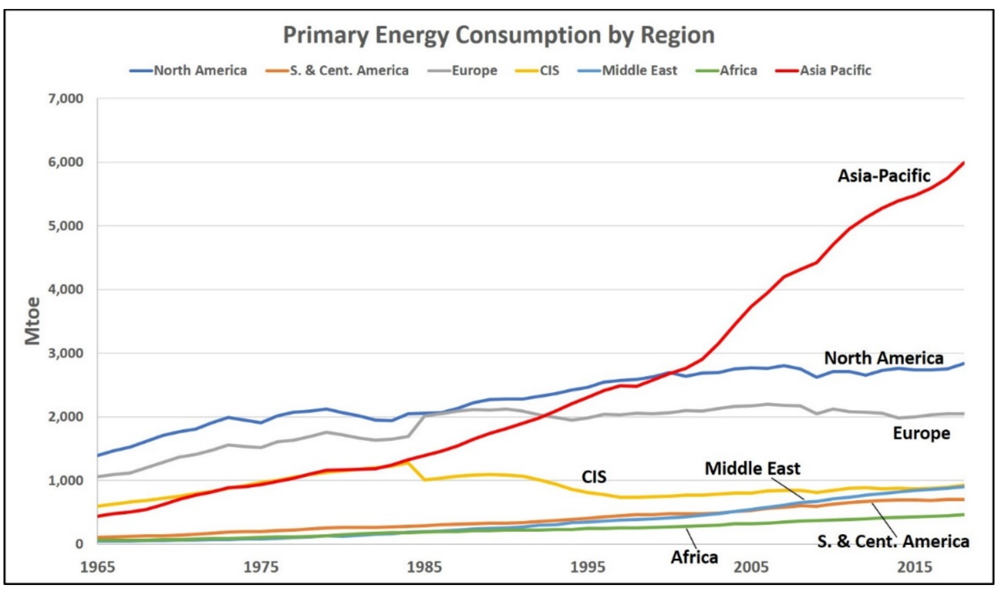


Figure 4. Primary energy consumption by region. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[17]

[16] Gattie, DK. 2020. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. *The Electricity Journal*, 33(1), In-Press.

[17] Gattie, DK. 2019. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. Presented at the *Energy Policy Research Conference*, Boise, ID. Sept. 30, 2019.

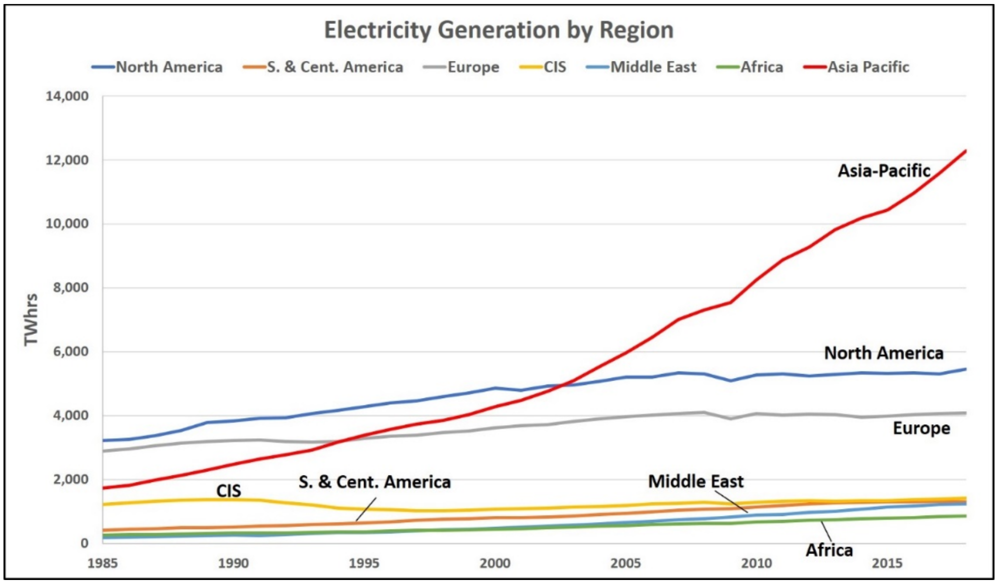


Figure 5. World electricity generation by region. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[18]

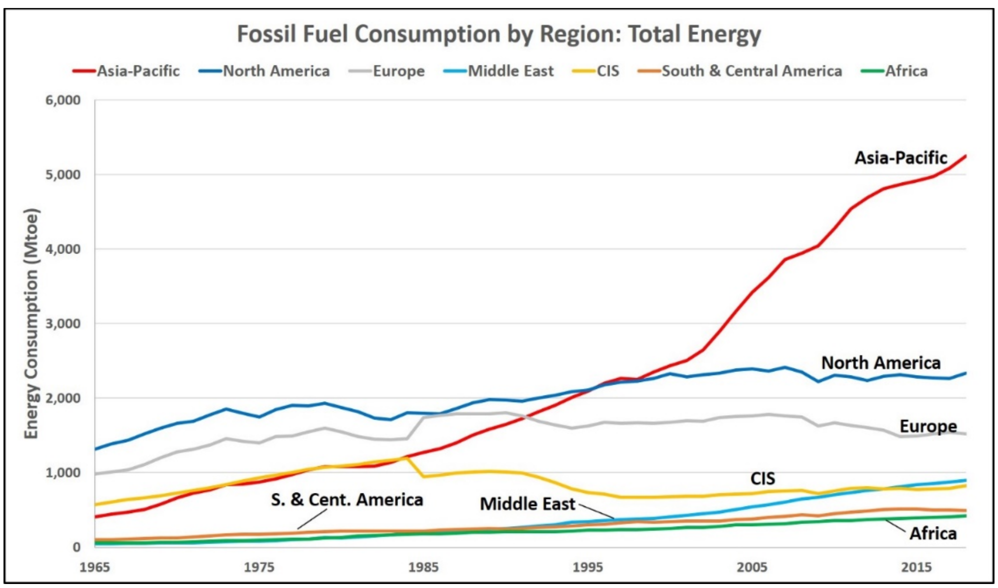


Figure 6. Fossil fuel consumption by region for total energy. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[19]

[18] Gattie, DK. 2019. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. Presented at the *Energy Policy Research Conference*, Boise, ID. Sept. 30, 2019.

[19] Gattie, DK. 2020. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. *The Electricity Journal*, 33(1), In-Press.

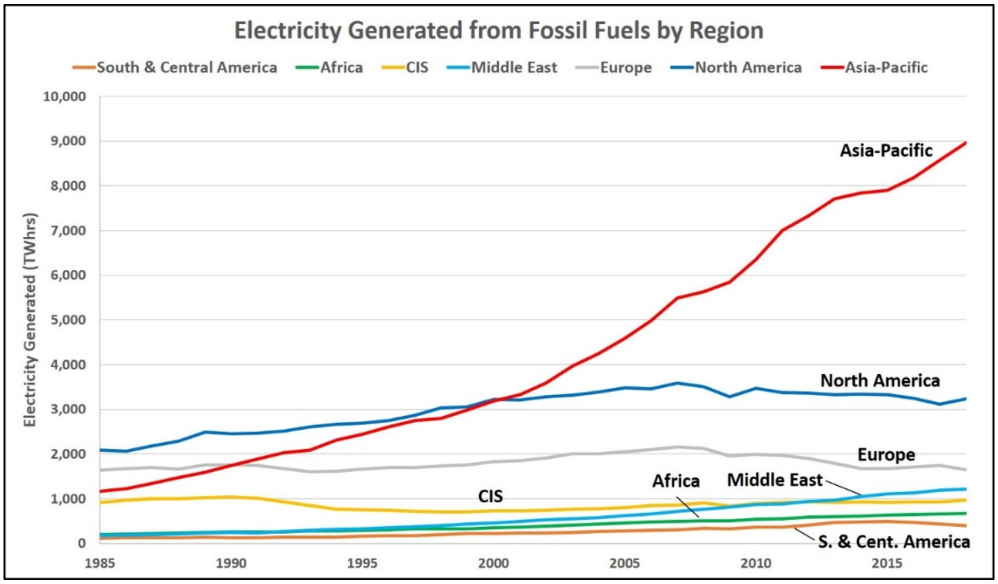


Figure 7. Electricity generated from fossil fuels, by region. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[20]

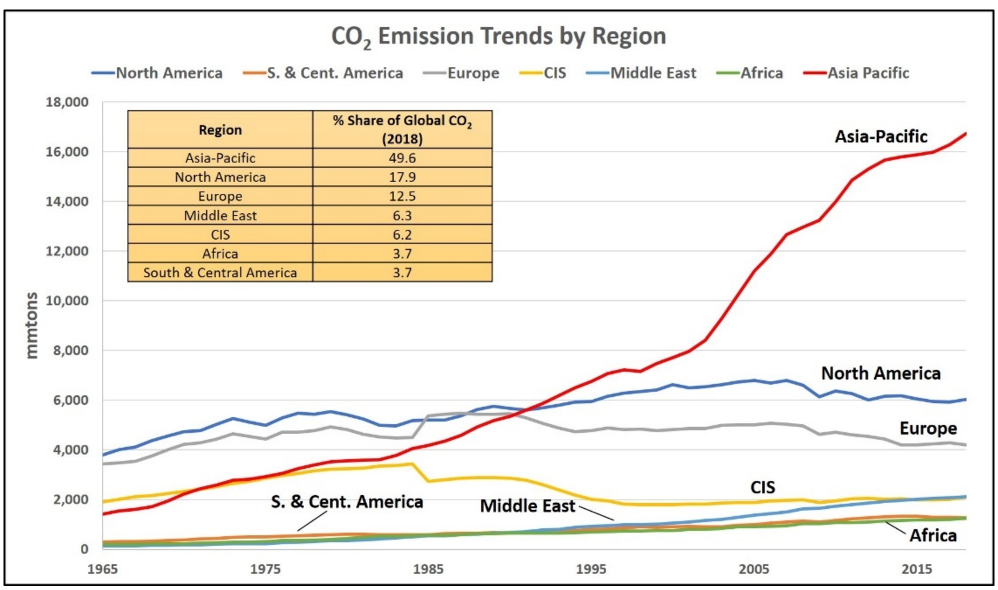


Figure 8. CO_2 emission trends by region. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[21]

---

[20] Gattie, DK. 2020. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. *The Electricity Journal*, 33(1), In-Press.
[21] Ibid.

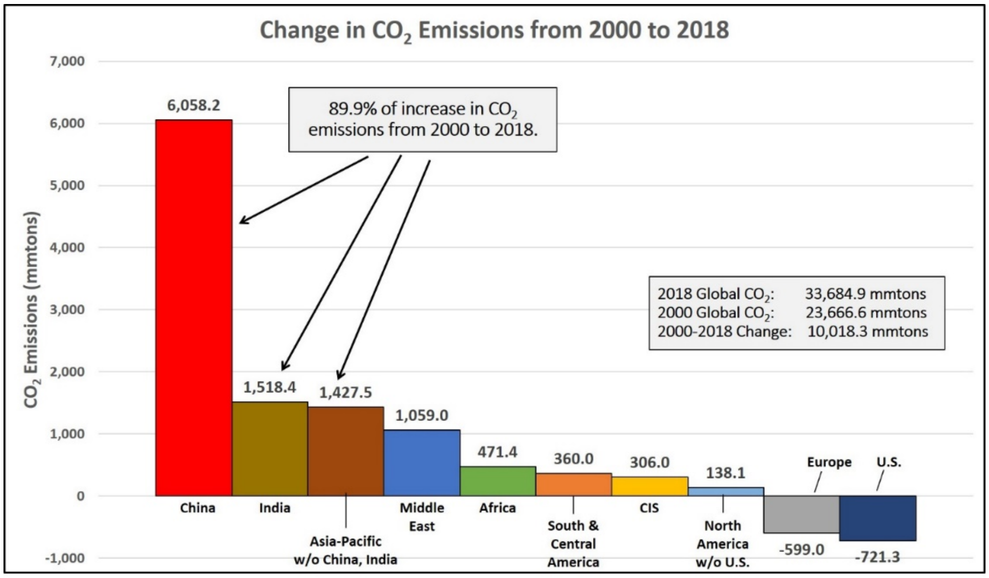


Figure 9. Change in CO_2 emissions for regions and select countries during the years 2000-2018. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[22]

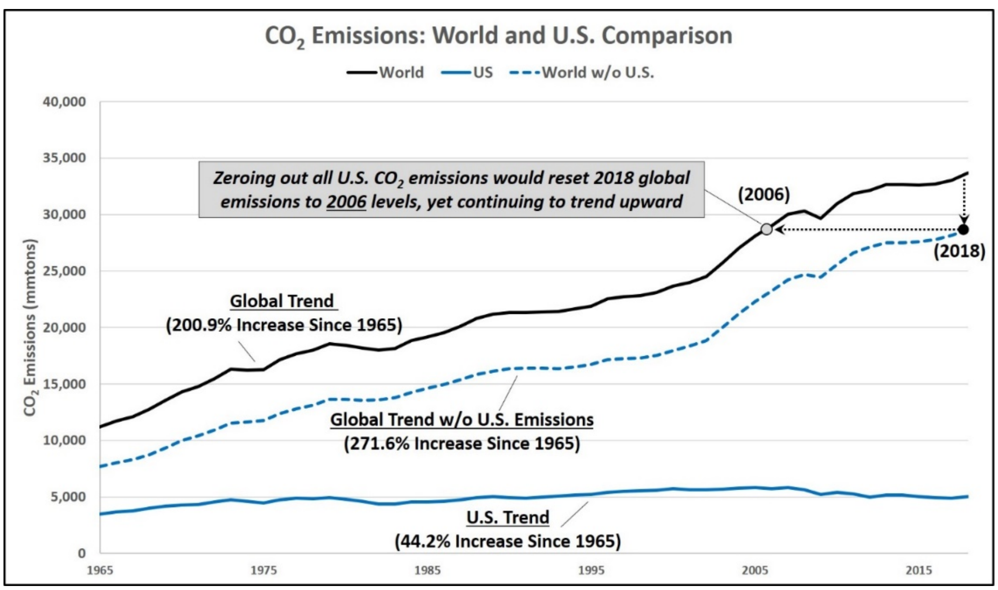


Figure 9. Comparison of CO_2 emissions for the world and the U.S. and the global impact of eliminating all U.S. CO_2 emissions. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[23]

[22] Gattie, DK. 2020. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. *The Electricity Journal*, 33(1), In-Press.
[23] Ibid.

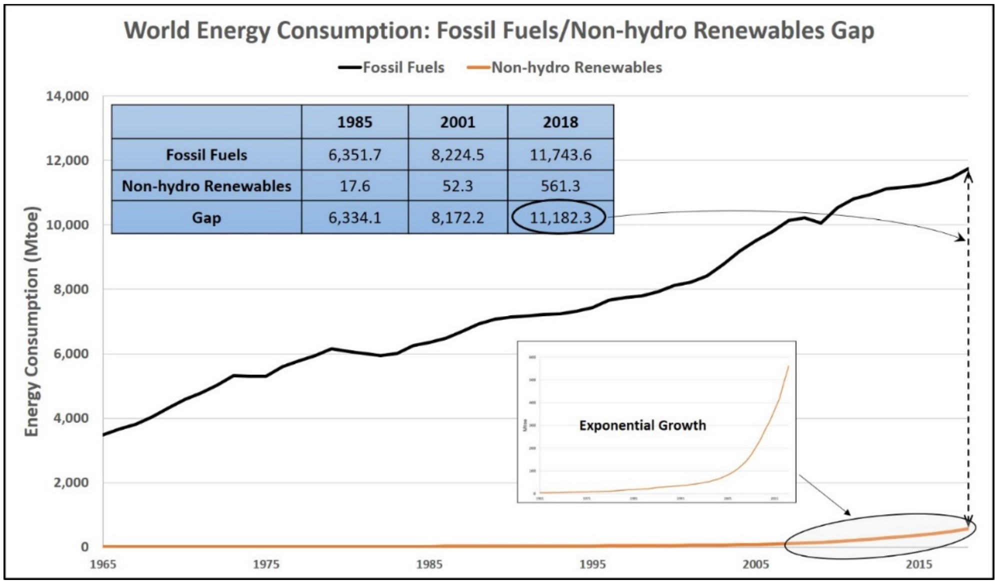


Figure 10. The fossil fuels/non-hydro renewable energy gap for world energy consumption. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[24]

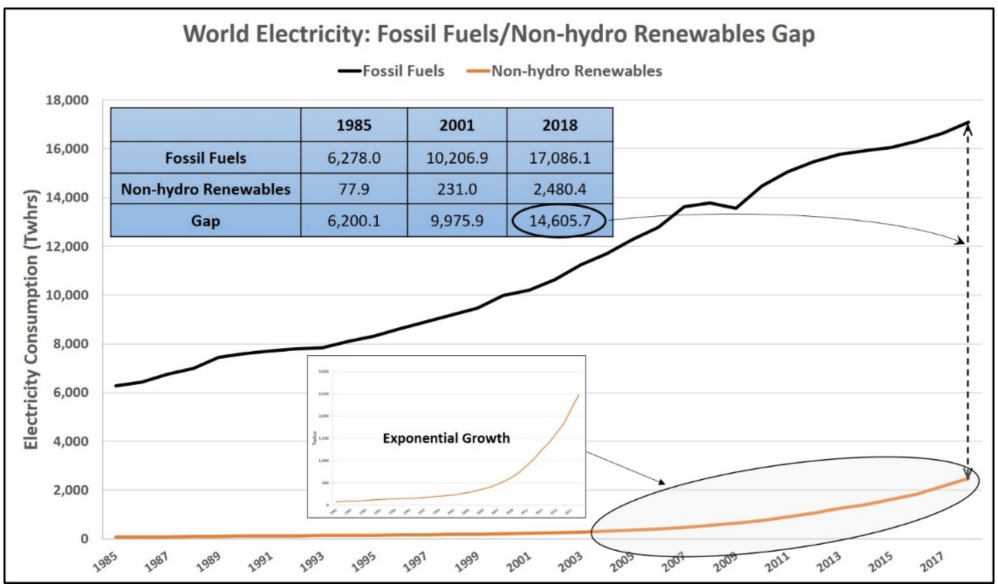


Figure 11. The fossil fuels/non-hydro renewable energy gap for world electricity. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).[25]

---

[24] Gattie, DK. 2020. U.S. energy, climate and nuclear power policy in the 21st century: The primacy of national security. *The Electricity Journal*, 33(1), In-Press.
[25] Ibid.

Country	Solar Generation		Share of In-Country Generation (2018)		GDP (2018)	
	2018 Share of World Total (%)	2017-18 Change (TWhrs)	Fossil Fuels & Nuclear (%)	Fossil Fuels, Nuclear & Hydro (%)	Current $US (millions)	Share of World Total (%)
China	30.4	59.7	74.0	90.9	13,608,152	15.9
U.S.	16.6	19.1	83.0	89.4	20,494,100	23.9
Japan	12.3	9.9	80.2	87.8	4,970,916	5.8
Germany	7.9	6.8	60.6	63.2	3,996,759	4.7
India	5.3	9.2	83.3	92.2	2,726,323	3.2
Italy	4.0	-1.1	60.1	75.9	2,073,902	2.4
UK	2.2	1.4	64.4	66.0	2,825,208	3.3
Spain	2.1	-1.8	60.6	73.4	1,426,189	1.7
Australia	2.1	3.1	81.1	87.7	1,432,195	1.7
Subtotal	**82.9**	**106.2**			**53,553,744**	**62.4**
World		*131.1*			*85,804,391*	*100*
GDP Data Source: *World Bank*						
Energy Data Source: *BP Statistical Review of World Energy 2019*						

Table 1. Countries with the greatest share of global solar generation in 2018 and over the past ten years. Solar expansion is concentrated in countries with high GDPs and that have substantial fossil fuels, nuclear and/or hydro already built into their economies as a substantial part of their electric power sector energy resource base.

Country	Wind Generation		Share of In-Country Generation (2018)		GDP (2018)	
	2018 Share of World Total (%)	2017-18 Change (TWhrs)	Fossil Fuels & Nuclear (%)	Fossil Fuels, Nuclear & Hydro (%)	Current $US (millions)	Share of World Total (%)
China	28.8	71.1	74.0	90.9	13,608,152	15.9
U.S.	21.9	20.9	83.0	89.4	20,494,100	23.9
Germany	8.8	5.9	60.6	63.2	3,996,759	4.7
India	4.7	7.7	83.3	92.2	2,726,323	3.2
UK	4.5	7.1	64.4	66.0	2,825,208	3.3
Brazil	3.8	6.1	16.3	82.2	1,868,626	2.2
Canada	2.5	3.1	33.8	93.0	1,712,510	2.0
France	2.2	3.9	72.0	83.1	2,777,535	3.2
Australia	1.3	3.1	81.1	87.7	1,432,195	1.7
Subtotal	**78.5**	**128.8**			**51,441,408**	**60.0**
World		*142.0*			*85,804,391*	*100*
GDP Data Source: *World Bank*						
Energy Data Source: *BP Statistical Review of World Energy 2019*						

Table 2. Countries with the greatest share of global wind generation in 2018 and over the past ten years. Wind expansion is concentrated in countries with high GDPs and that have substantial fossil fuels, nuclear and/or hydro already built into their economies as a substantial part of their electric power sector energy resource base.

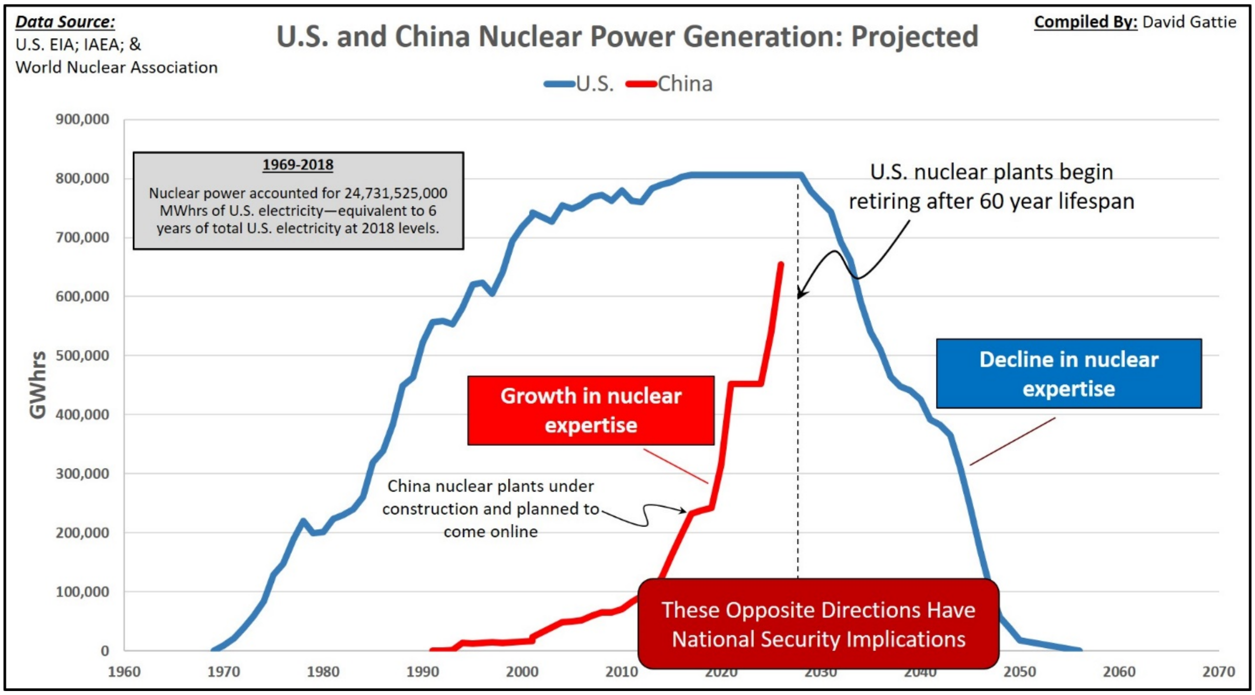


Figure 12. U.S. and China nuclear power trajectories. Data source: U.S. Energy Information Administration, International Atomic Energy Agency and World Nuclear Association. Adapted from Gattie, et al., 2018.[26]

[26] Gattie, DK, Darnell, JL and Massey, JN, 2018. The role of US nuclear power in the 21st century. *The Electricity Journal*, *31*(10), pp.1-5.

U.S. Nuclear Power—America's Brand is at Risk

David Gattie

(Published October 29, 2019 in *Morning Consult*, here)

In March 1955, the U.S. National Security Council issued a report, NSC 5507/2, entitled, "Peaceful Uses of Atomic Energy", formally setting America's civilian nuclear power policy. The objectives, stated as being *"in the interests of national security"*, can be summarized as:

a. Maintain U.S. leadership in the field,
b. Use such leadership to promote cohesion within the free world,
c. Increase progress in development and application of peaceful uses of atomic energy in free nations abroad,
d. Assure continued U.S. access to foreign uranium and thorium supplies, and
e. Prevent diversion to non-peaceful uses of fissionable materials.

Early U.S. nuclear power policymakers comprehended their moment in history and were clear-eyed and realistic as to the strategic geopolitical importance of America remaining engaged in not only an advanced domestic nuclear enterprise but also in international nuclear collaborations. In their vision of America's role in the world, nuclear power wasn't just another energy commodity, the fate of which should be dictated by political calculus, popular opinion or market forces alone. Rather, they considered nuclear power as central to America's foreign policy, so their approach to nuclear policy was principled and strategic, not populist and transactional. To that end, U.S. nuclear power policy conveyed America's commitment to, and engagement with, what was planned to be a post-war, liberal international order of allied nations committed to the shared objectives of rule of law, individual liberty, cooperative security, multilateral alliances and fair trade.

As such, U.S. civilian nuclear policy was crafted as a foreign policy/national security issue, not merely a domestic energy policy issue. And a key objective was to create the world's most advanced nuclear technology base from which mutually beneficial global partnerships could be established within the emerging liberal international order.

This strategic policy of international leadership, this promise and commitment to engage with the world in the development and deployment of safe nuclear power, was the heart of America's 20th century nuclear brand. However, that brand is at risk as public opinion on nuclear power is scattered and America is debating whether it should maintain its nuclear power enterprise or ban it altogether. Moreover, numerous U.S. nuclear plants are at risk of early closure and Georgia's Plant Vogtle is the only current nuclear construction project in the U.S.

This disposition toward U.S. nuclear power does not align with 21st century realities on at least two counts.

First, global economic development in the 20th century was dependent upon reliable electricity, and nuclear power was part of America's domestic and global response. In the 21st century, global economic development is far more complex than it was in 1955 as climate change, which is now characterized as a national security issue, is embedded in the calculus of electricity generation and economic growth. In this regard, as the U.S. debates its climate policy it should do so within the necessary global context.

From 2000-2018, global CO_2 emissions increased 10,018.3 mmtons with the Asia-Pacific region accounting for 9,004.1 mmtons—89.9% of the change. By comparison, U.S. CO_2 emissions decreased 721.3 mmtons during this period. Extending this further, if all U.S. CO_2 emissions were immediately eliminated, global emissions would be reset to 2006 levels, yet continue increasing. Meaning, U.S. climate policy focused predominantly on domestic emissions won't impact the trajectory of global CO_2 emissions. This recommends a strategic approach within a global framework wherein U.S. climate policy aligns with 21st century energy and climate realities. To that end, the U.S. can broadly impact global CO_2 emissions by upholding its original promise to collaborate on the deployment of U.S. nuclear power to support low-carbon economic growth and development in regions where carbon emissions are most acute.

Second, in the short period of time America had a monopoly on nuclear science and technology following WWII, policymakers understood the importance of projecting to the world that America's intentions for atomic energy would be grounded in principles of safe, peaceful applications of nuclear technology coupled to security and international nuclear safeguards. It was critical that the U.S. atomic energy enterprise not be a military-only endeavor, otherwise it would feed into the propaganda charges of the Soviet Union, America's 20th century great power rival, *"that the U.S. is concerned solely with the destructive uses of the atom"*. That reality must be accounted for today as China and Russia, America's 21st century great power rivals, could leverage a military-only disposition should the U.S. disengage from civilian nuclear efforts. A military-only nuclear power enterprise is not America's brand.

In all, U.S. policymakers today must bear in mind that climate policy influences energy policy, and energy policy influences the trajectory of U.S. energy technology development. If that trajectory is oriented away from nuclear power, it will signal not merely a U.S. retreat from nuclear as a domestic energy technology, it will signal to the international community that America has chosen to abandon its original principles, promises and commitments to be a trusted, reliable partner in civilian nuclear technology development. Moreover, it will signal that America is willing to abdicate its international leadership role in nuclear technology.

America's leadership and stewardship in the global nuclear ecosystem has been central in sustaining the liberal international order that has prevented great power competition from devolving into global war for the past seventy-five years. However, if America abandons its nuclear enterprise, the question must be asked: "Can the liberal international order be sustained with an illiberal, authoritarian power such as China or Russia having displaced America as the global leader in nuclear science, engineering and technology?".

America's nuclear brand is tarnished and is at risk of being competed out of existence by state-owned Chinese and Russian brands. Given the challenges and realities of the 21st century, this translates to a combined national security and global climate risk the likes of which the world has never experienced—and never should. It's also a risk that can be avoided through a recommitment to America's original nuclear power policy principles that were grounded in international engagement, collaboration and partnership.

Will the U.S. lead? Or let China and Russia dominate nuclear energy
David Gattie

(Published May 22, 2019 in The Hill, here)

On January 10, 1945, Senator Arthur Vandenberg (R-MI) gave what is commonly referred to as "the speech heard round the world". He opened with the remark: *"There are critical moments in the life of every nation which call for the straightest, the plainest, and the most courageous thinking of which we are capable. We confront such a moment now."*

Here, the once-staunch isolationist Senator Vandenberg reflected his personal reconciliation with the reality that America could no longer pursue a laissez-faire posture toward U.S. foreign policy post-WWII. The geopolitical ecology of nations was primed for change, and it was incumbent upon America to take the lead and shape that ecology into a liberal world order based on the rule of law, cooperative security, free trade, human rights and multilateral institutions.

However, it would require America to think in fundamentally different constructs. Holistic constructs of alliances, coalitions and partnerships such as the U.N., NATO and the International Atomic Energy Agency, each of which constituted an ecological whole greater than the sum of its individual parts.

The alternative was to allow an illiberal, authoritarian communist power to prey on individual war-weakened countries throughout Europe and Asia and impose its ideological will, thus creating its own ecology of nations within its sphere of influence.

The 21st century is undergoing fundamental geopolitical shifts as great power competition has re-emerged as a *central challenge to U.S. prosperity and security* with China and Russia seeking *to shape a world consistent with their authoritarian model*. And, embedded in their geopolitical strategies are state-owned nuclear power enterprises leveraged as extensions of the state to establish long-term energy and technology dependencies in emerging economies. Theirs is a top-down nuclear ecology, focused on influence and dominance, not strictly economic development or multilateral cooperation alone.

While the U.S. was the 20th century global leader in nuclear technology, it now lags China and Russia in new and planned nuclear construction and is at a financial disadvantage when competing with SOEs. This is raising concerns among many who consider U.S. leadership in nuclear technology, or the loss thereof, as a national security issue.

The issue isn't whether the U.S. has the technological capability to compete and lead—that was proven in the 20th century. The issue is, America's 20th century nuclear construct cannot compete with 21st century SOEs in China and Russia. Consequently, America's 20th century nuclear enterprise requires a new ecology if it is to meet the geopolitical challenges of the globalized 21st century and renewed great power competition.

Moreover, with the UK, South Korea, Japan and France having shown signs of political uncertainty in their respective commitments to nuclear power, the global nuclear ecosystem is potentially vulnerable to domination by a country pursuing a role of top predator. Meanwhile, the world is seeking US, Allied leadership in nuclear power—a clarion call that must be heard. At a minimum, there must be a viable non-authoritarian nuclear partner alternative committed to the rule of law, individual liberty, cooperative security, multilateral alliances and fair trade. However, while other countries waver, two countries show no signs of retreating from an aggressive nuclear power future—China and Russia. In fact, they are doubling down.

America must decide if its 20th century global nuclear leadership is worth retaining in the 21st century. If the decision is negative or one of indifference, then a post-WWI laissez-faire approach will suffice, no action is required, and global leadership will be enthusiastically pursued by an unchallenged China or Russia or a combination thereof while America gradually isolates itself within the global nuclear ecosystem.

If the decision is to retain that role, America must once again think in fundamentally different constructs—holistic constructs for a new nuclear ecology. An ecology comprised of America's top nuclear providers from various sectors of plant operation, fuel services, safety, security and project management, organized into a robust U.S. nuclear ecosystem capable of doing collectively, what the parts cannot do individually—compete with SOEs. This can then be extended to include collaborations with the UK, South Korea, Japan and France as a multilateral response to authoritarian powers offering nuclear services.

Just as technology and tactics alone are insufficient for winning battles, development of advanced U.S. nuclear technology alone is unlikely to stand up to the SOEs of China and Russia. Rather, nuclear technology must be embedded in an overall nuclear policy strategy.

America's 20th century civilian nuclear strategy was successful in part because the U.S. had a head start in nuclear technology and was arguably unrivaled globally. Moreover, private industry was allowed to drive innovation while the public sector provided appropriate support. However, the advantage of that early lead and limited rivalry has evaporated and America finds itself lagging. To that end, it's response should be to reevaluate its own nuclear ecology and reconstitute that ecology for 21st century competition, keeping the private sector in the lead with appropriate support from the public sector.

With respect to its nuclear enterprise, America needs a Vandenberg moment, where it realizes it must think in different constructs in order to align its nuclear ecology with the realities of 21st century great power competition.

That moment is now.

<u>Gattie Journal Article</u>

The following journal article goes into greater detail on the points I've briefly summarized in my opening summary. It was recently accepted for publication, and is available online at the following link:
https://www.sciencedirect.com/science/article/pii/S1040619019302957?dgcid=author

———————————————————————————————————————

U.S. Energy, Climate and Nuclear Power Policy in the 21st Century: The Primacy of National Security

David K. Gattie

University of Georgia, College of Engineering, Driftmier Engineering Center, Athens, GA, 30602
University of Georgia, School of Public and International Affairs, Center for International Trade and Security, Athens, GA, 30602

Abstract: This paper analyzes global and regional energy and CO_2 trends and concludes: 1) Domestic U.S. policies alone will not insulate the U.S. from the impacts of climate change; 2) The U.S. should triage climate change as a global threat by focusing on regions where CO_2 emissions are most acute; and 3) The U.S. civilian nuclear enterprise should be elevated in U.S. energy and climate policy in order to meet global climate and national security objectives.

1. Introduction

The U.S. climate debate is often discussed as a politically partisan issue that forces deliberations to political margins where climate policy becomes a proxy for energy policy. Proposals ranging from 100% renewable energy to resource-dominance and energy independence convey the disparity (Gattie, 2019a; Sierra Club, 2019; Smith and Walker, 2019; Bell, 2018). Given this political tension, there is no shortage of climate policy proposals, some of which focus predominantly on curbing U.S. CO_2 emissions by way of a prescribed fossil fuel divestment whereas others are oriented more toward leveraging the power of free markets (Adragna, 2018; Colman, 2019; Friedman, 2019; Nawaguna, 2019; Snow, 2019; U.S. House, 2019). Ironically, much of this tension has emerged from recent positive developments in non-hydro renewable energy and natural gas. However, what shouldn't be lost in the U.S. debate is that global climate change has been elevated to that of a U.S. national security concern for the 21st century (White House, 2015). In a January 2019 report, the Department of Defense stated explicitly that *"the effects of a changing climate are a national security issue with potential impacts to Department of Defense (DoD or the Department) missions, operational plans, and installations"* (U.S. DOD, 2019). What also shouldn't be lost in the debate is zero-carbon U.S. nuclear power and its role in both climate change and broader U.S. national security obligations.

Coal-fired power generation has been in decline in the U.S. since its 2007 peak (U.S. EIA, 2019a). During this time, the costs of solar and wind power technologies have declined allowing greater penetration of these non-hydro renewable resources into the U.S. power generation portfolio (Bogmans, 2019). From 2007 to 2018, U.S. solar expanded from 612 GWhrs to 96,147 GWhrs while wind expanded from 34,450 GWhrs to 274,952 GWhrs (U.S. EIA, 2019b). Globally, from 2007-2018, solar expanded from 7,800 GWhrs to 584,600 GWhrs and wind expanded from 170,700 GWhrs to 1,270,000 GWhrs (BP, 2019).

Meanwhile, horizontal drilling and hydraulic fracturing technologies have been unlocking abundant supplies of economically viable U.S. oil and natural gas, putting the U.S. in a global energy market position it hasn't occupied in decades (Butler, 2019; Blackwell and O'Sullivan, 2014). As a result, natural gas-fired power generation in the U.S. has expanded from 896,590 GWhrs in 2007 to 1,468,013 GWhrs in 2018 (U.S. EIA, 2019b). Globally, natural gas-fired electricity has grown from 4,277,000 GWhrs in 2007 to 6,182,800 GWhrs in 2018 (BP, 2019).

For the U.S. electric power sector, growth in solar and wind coupled with lower-carbon natural gas-fired power offsetting the loss of coal-fired power, resulted in a decline in CO_2 emissions from 2,425,000 mmtons in 2007 to 1,763,000 mmtons in 2018 (U.S. EIA, 2019c). While growth in solar and wind is leveraged by those advocating for 100% renewable energy, growth in natural gas is being leveraged by those advocating for U.S. energy dominance (Gattie, 2019a). Although solar and wind have grown exponentially and natural gas is projected to continue expanding in the electric power sector over the short-term, questions remain regarding the extent to which non-hydro renewables can displace fossil fuels (Pyper, 2018; U.S. EIA, 2019d). Moreover, the U.S. has experienced cycles of abundance and scarcity throughout its history of oil and gas dependency, so the current U.S. disposition in natural gas will eventually shift and U.S. energy and climate policy likely will have a role in the shape of that shift (Biscardini, et al., 2018; Ross, 2017).

The basic intent of U.S. climate policy is to reduce CO_2 emissions in response to a changing global climate. However, the implications of U.S. climate policy extend beyond CO_2 reduction because climate policy fundamentally influences U.S. energy policy. This, in turn, impacts the U.S. energy technology trajectory and science and engineering advancements, thus influencing America's geopolitical position and stature in the liberal world order where collaboration around energy technologies underpins 21st century international relationships.

The objectives of this paper are to analyze trends in total energy, electricity generation and CO_2 emissions at the global and regional levels and offer recommendations that address the following U.S. policy questions:

1. Do U.S. energy and climate policies that are focused predominantly around domestic objectives, have sufficient bandwidth to impact climate change as a global issue?
2. How should U.S. energy and climate policies be structured in order to have the greatest impact on CO_2 emissions at the global scale?
3. What should be the role of zero-carbon nuclear power with respect to U.S. energy and climate policy and national security?

This paper analyzes total primary energy, energy used for electricity generation and CO_2 emissions. Global and regional energy and CO_2 data are derived from BP's Statistical Review of World Energy 2019, which categorizes specific countries within each of the seven regions: North America, South and Central America, Europe, CIS (Commonwealth of Independent States), Middle East, Africa and Asia-Pacific (BP, 2019). The breakdown of regions by country is provided in the original BP Statistical Review. Some energy values are reported as Mtoe, which is million tonnes (mmtons) of oil equivalent or million metric tons of oil equivalent.

2. Global Energy, Electricity and CO_2: Magnitude, Context and Trends

As global population increases and emerging regions of the world develop and grow economically, global energy consumption and CO_2 emissions have increased commensurately. From 2000-2018, the world's primary energy consumption increased 4,507.9 Mtoe while global CO_2 emissions increased 10,018.3 mmtons—increases of 48.2% and 42.3%, respectively (Figure 1). Following a three-year span from 2013-2015, when global CO_2 emissions appeared to peak and then begin a decline, emissions increased 3.3% from 2015 to 2018.

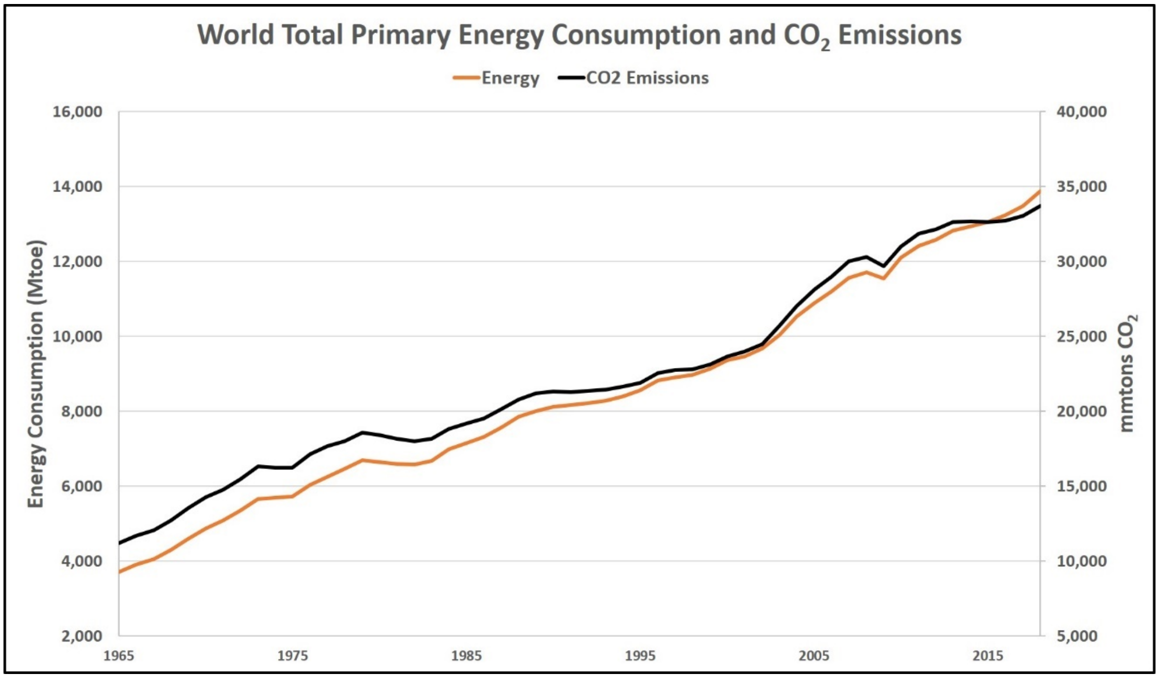
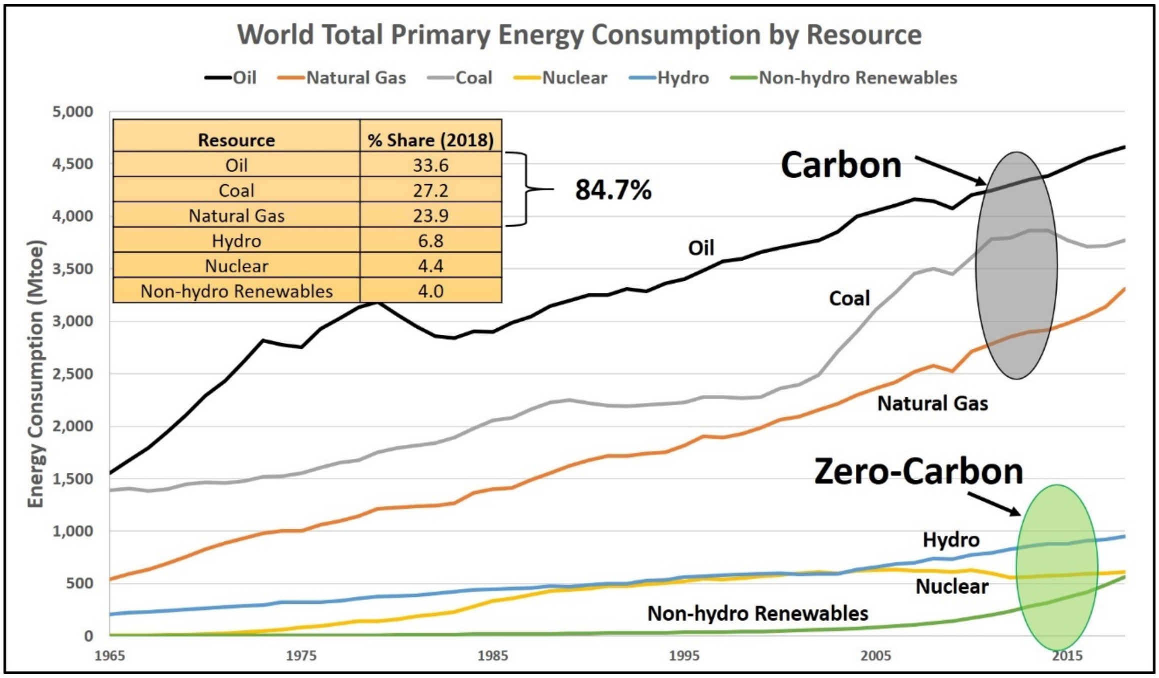


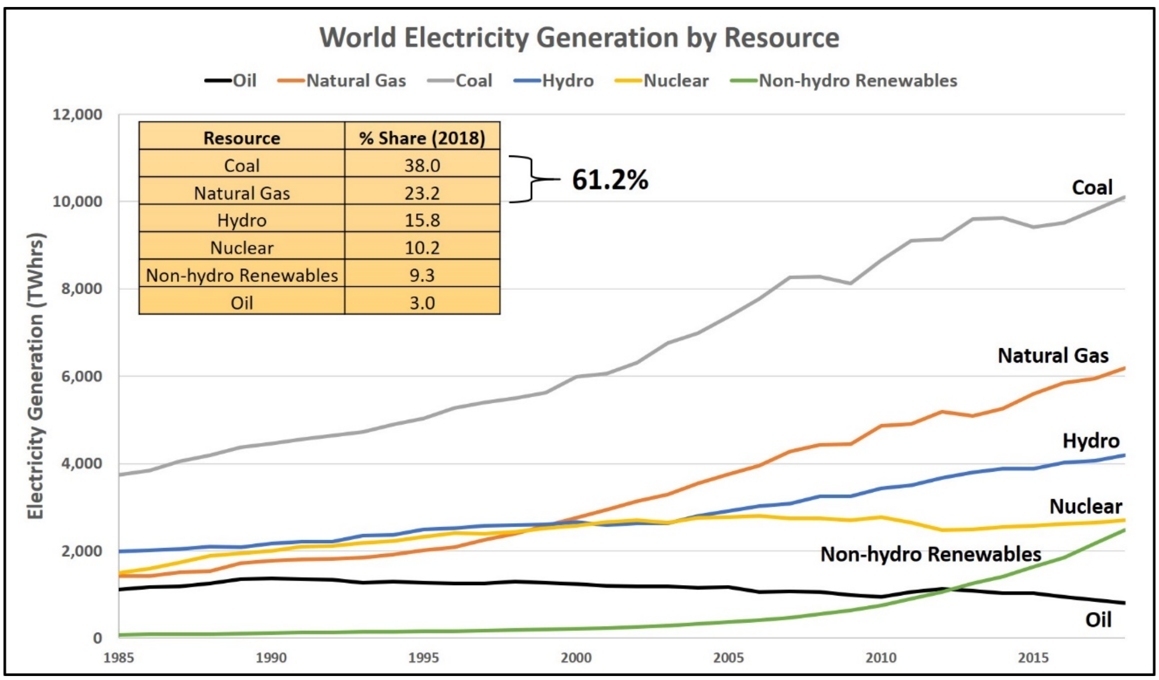
Figure 1. World total primary energy consumption and CO_2 emissions. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

Fossil fuel consumption continues trending upward, constituting 84.7% of the world's 2018 total primary energy consumption (Figure 2). Of the 15.2% zero-carbon resources, non-hydro renewables constitute 4.0%, while nuclear and hydro are 4.4% and 6.8%, respectively. Global electricity generation is also predominantly dependent on fossil fuels with 61.2% supported by coal and natural gas, 15.8% from hydro, 10.1% from nuclear and 9.3% from non-hydro renewables (Figure 3). For both total primary energy consumption and electricity generation, fossil fuel consumption continues its decadal-long trend upward, with CO_2 emissions tracking the trend.



Resource	% Share (2018)
Oil	33.6
Coal	27.2
Natural Gas	23.9
Hydro	6.8
Nuclear	4.4
Non-hydro Renewables	4.0

Figure 2. World total primary energy consumption by resource. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).



Resource	% Share (2018)
Coal	38.0
Natural Gas	23.2
Hydro	15.8
Nuclear	10.2
Non-hydro Renewables	9.3
Oil	3.0

Figure 3. World electricity generation by resource. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

2.1. Fossil Fuels and Non-hydro Renewables: The FF-NHR Gap

Since 2000, exponential growth in non-hydro renewables, particularly in power generation, is elevating the narrative that the U.S. and the world are shifting away from fossil fuels and displacing those fuels with renewable energy—particularly, solar and wind (Roberts, 2019; IRENA, 2019; Rosane, 2019). In this paper, the contention is that exponential growth in non-hydro renewables, in and of itself, isn't a sufficient indicator of a long-term trend away from fossil fuels that will impact global CO_2 emissions. Rather, a first-step indicator should be the relative increase or decrease between fossil fuels and non-hydro renewables. This is characterized here as the fossil fuel/non-hydro renewables gap—from this point forward referred to as the "FF-NHR gap" (Figure 4). If both fossil fuels and non-hydro renewables increase at the same rate and the FF-NHR gap is constant, then overall CO_2 emissions will continue to trend upward, tracking fossil fuel consumption. If non-hydro renewables increase at a faster rate than fossil fuels and the FF-NHR gap is closing, overall CO_2 emissions will continue to increase as long as fossil fuel consumption increases, although emissions per unit of total energy consumption might decrease. Even if non-hydro renewables consumption equals fossil fuel consumption and the FF-NHR gap closes entirely, if both continue to increase, overall CO_2 emissions will continue trending upward, tracking fossil fuels. Only when a decline in fossil fuels is coupled with an increase in zero-carbon energy (hydro, non-hydro renewables, and nuclear) will CO_2 emissions begin to trend downward, indicating carbon-based fossil fuels are being displaced by zero-carbon resources rather than being supplemented. While hydroelectric, nuclear, solar, wind and geothermal all are zero-carbon resources, this analysis focuses on non-hydro renewables since the exponential growth in solar and wind, in particular, is often pointed to as the most promising for renewable energy (Sylvia, 2019; Wanner, 2019; Sargent and Fanshaw, 2018; Gosens, et al., 2017; Roselund, 2019).

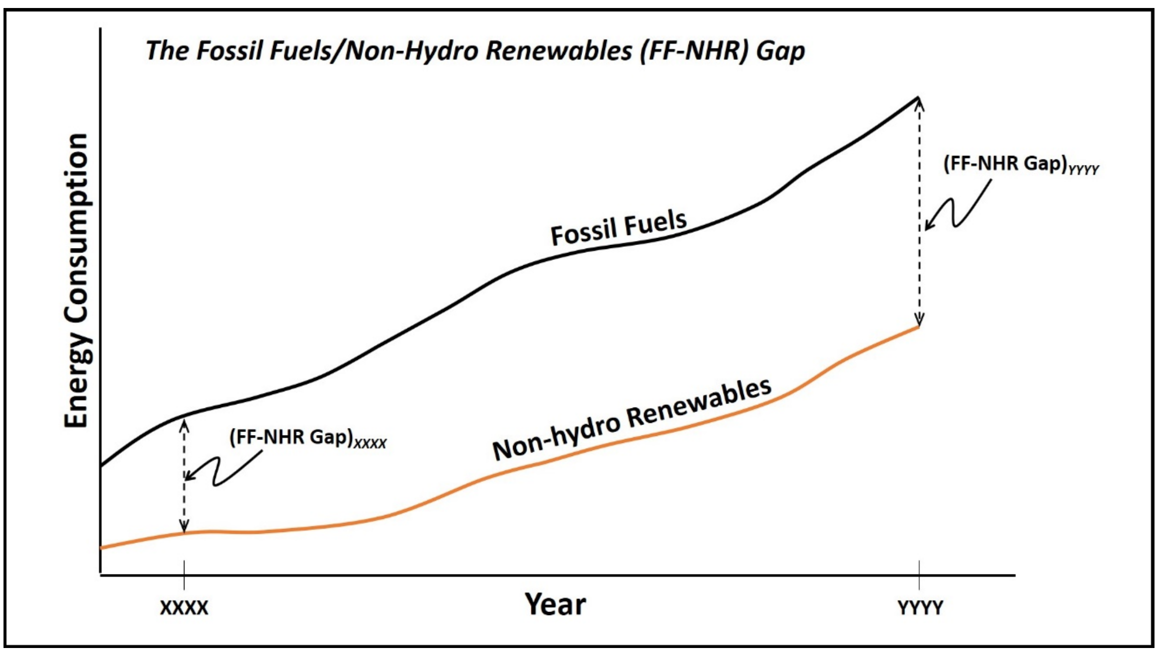


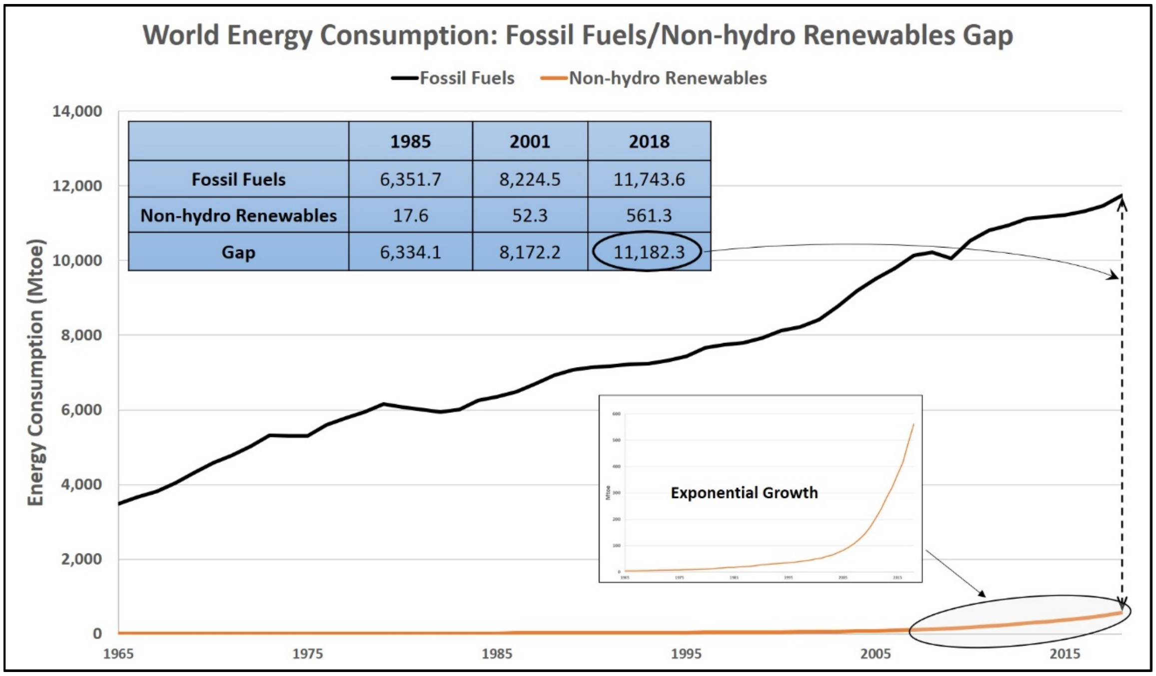
Figure 4. Graphical depiction of the fossil fuels/non-hydro renewables gap with the FF-NHR gap for year XXXX denoted as $(\text{FF-NHR})_{XXXX}$ and the FF-NHR gap for year YYYY denoted as $(\text{FF-NHR})_{YYYY}$.

2.2. The FF-NHR Gap for Total Primary Energy

Since 1985, the FF-NHR gap for global primary energy consumption has grown from 6,334.1 Mtoe in 1985 to 8,172.2 Mtoe in 2001 to 11,182.3 Mtoe in 2018 (Figure 5). The 2001 to 2018 gap increase represents a 36.8% increase even though non-hydro renewable energy grew exponentially during this period. The dominant region for fossil fuel consumption is the Asia-Pacific where consumption has increased from 2,432.8 Mtoe in 2000 to 5,246.4 Mtoe in 2018—an increase of 115.7% (Figure 6). Fossil fuels constitute 87.7% of primary energy consumption in the Asia-Pacific, and trending upward, with coal comprising 47.5% (Figure 7). In older, well-established economies fossil fuel consumption is flat, as in North America, or decreasing, as in Europe.

Of the 11,182.3 Mtoe global FF-NHR gap in 2018, Asia-Pacific countries accounted for 44.9%, North America accounted for 19.8% and Europe accounted for 12.1% (Table 1). During the period 2013-2018, the FF-NHR gap for global primary energy had a net increase of 350.0 Mtoe. The Asia-Pacific region contributed 292.0 Mtoe to this change while Europe, South and Central America and North America offset the overall increase with decreases of 103.5 Mtoe, 26.8 Mtoe and 5.3 Mtoe, respectively. The FF-NHR gap trend for the world's total primary energy consumption is increasing, not decreasing (Table 1).

A detailed comparison of the U.S., China and India, the world's top three energy consumers, indicates China was responsible for 23.7% of the world's 11,182.3 Mtoe FF-NHR gap in 2018, the U.S. for 16.4% and India for 6.4% (Table 2). Combined, China and India comprise 66.9% of the Asia-Pacific's 2018 FF-NHR gap (Tables 1 and 2). Of the 350.0 Mtoe global net increase in the FF-NHR gap during the 2013-2018 period, China was responsible for 55.9 Mtoe of the increase whereas the U.S. FF-NHR gap decreased 3.7 Mtoe. During this same period, India's FF-NHR gap had a net increase of 151.9 Mtoe, which was 2.7 times more than China's. The FF-NHR gap for the Asia-Pacific region increased from 1,266.5 Mtoe in 1985 to 2,496.9 Mtoe in 2001 to 5,021.0 Mtoe in 2018 (Figure 8). While the global FF-NHR gap from 2001 to 2018 saw a net increase of 36.8% (Figure 5), the FF-NHR gap for the Asia-Pacific region during this same period increased 101.1% even though non-hydro renewable energy grew exponentially.



	1985	2001	2018
Fossil Fuels	6,351.7	8,224.5	11,743.6
Non-hydro Renewables	17.6	52.3	561.3
Gap	6,334.1	8,172.2	11,182.3

Figure 5. The fossil fuels/non-hydro renewable energy gap for world energy consumption. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

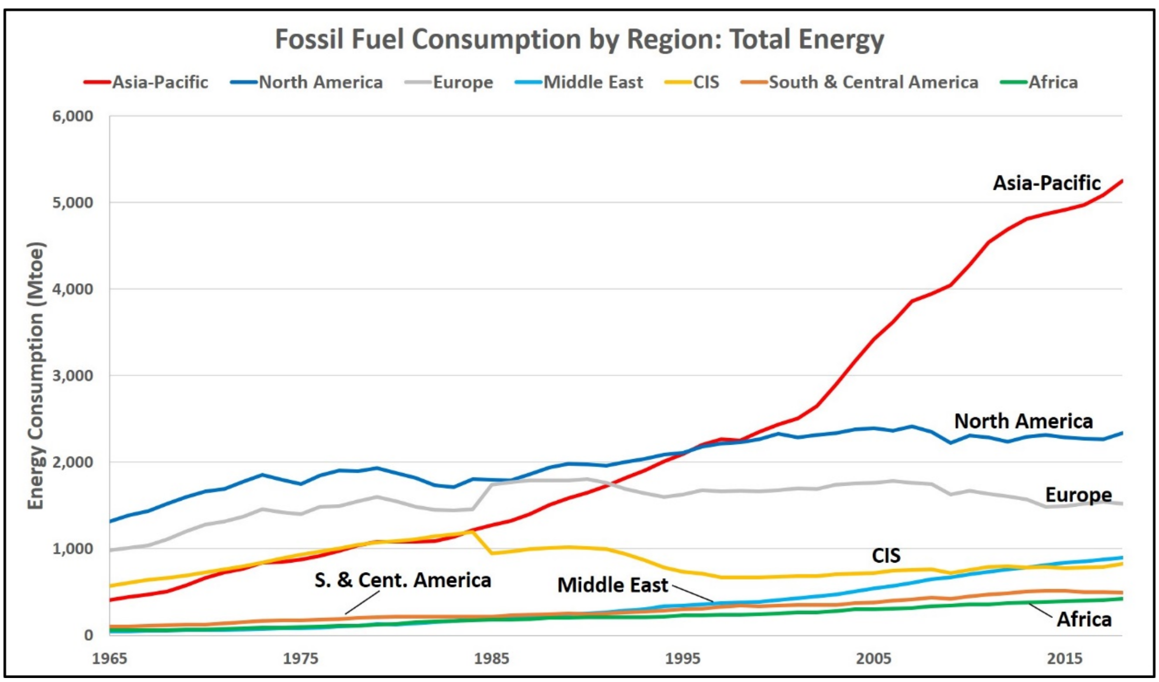


Figure 6. Fossil fuel consumption by region for total energy. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

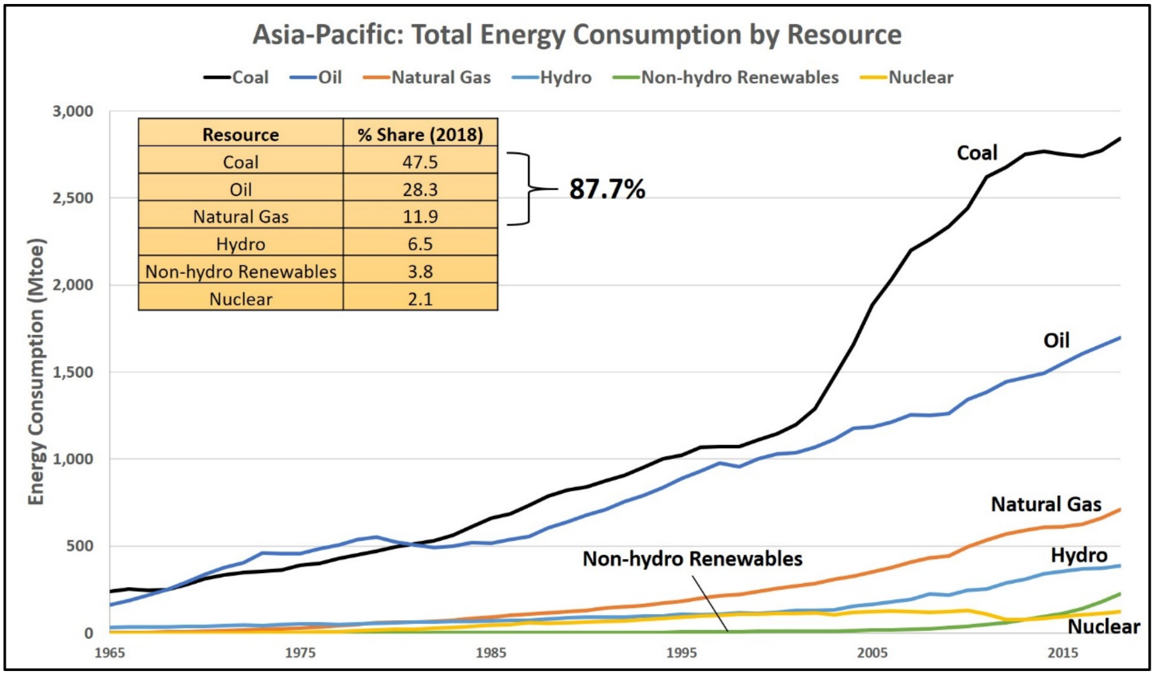


Figure 7. Total energy consumption by resource for the Asia-Pacific region. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

Fossil Fuels/Non-hydro Renewables Gap for Total Energy Consumption: By Region						
	2018				2013-2018	
Region	Fossil Fuels (Mtoe)	Non-hydro Renewables (Mtoe)	Gap (Mtoe)	Share of Global Gap (%)	Gap Change (Mtoe)	Gap Trend
Asia-Pacific	*5,246.4*	*225.4*	*5,021.0*	*44.9*	*292.0*	Increasing
North America	*2,334.9*	*118.8*	*2,216.1*	*19.8*	*-5.3*	Flat
Europe	*1,521.1*	*172.2*	*1,348.9*	*12.1*	*-103.5*	Decreasing
Middle East	*895.6*	*1.7*	*893.9*	*8.0*	*108.2*	Increasing
CIS	*827.8*	*0.6*	*827.2*	*7.4*	*46.9*	Increasing
South & Central America	*496.1*	*35.4*	*460.7*	*4.1*	*-26.8*	Decreasing
Africa	*421.7*	*7.2*	*414.5*	*3.7*	*38.6*	Increasing
World	*11,743.6*	*561.3*	*11,182.3*	*100*	*350.0*	Increasing

Table 1. Regional breakdown of the fossil fuels/non-hydro renewable energy gap for total energy consumption for 2018 and the years 2013-2018. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

Fossil Fuels/Non-hydro Renewables Gap for Total Energy Consumption: U.S., China and India						
2018					2013-2018	
Region	**Fossil Fuels (Mtoe)**	**Non-hydro Renewables (Mtoe)**	**Gap (Mtoe)**	**Share of Global Gap (%)**	**Gap Change (Mtoe)**	**Gap Trend**
China	*2,791.3*	*143.5*	*2,647.8*	*23.7*	*55.9*	Increasing
US	*1,939.3*	*103.8*	*1,835.6*	*16.4*	*-3.7*	Flat
India	*741.2*	*27.5*	*713.7*	*6.4*	*151.9*	Increasing
World	*11,743.6*	*561.3*	*11,182.3*	*100*	*350.0*	Increasing

Table 2. Breakdown of the fossil fuels/non-hydro renewable energy gap for total energy consumption for the U.S., China, and India, the world's leading energy consumers, for 2018 and the years 2013-2018. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

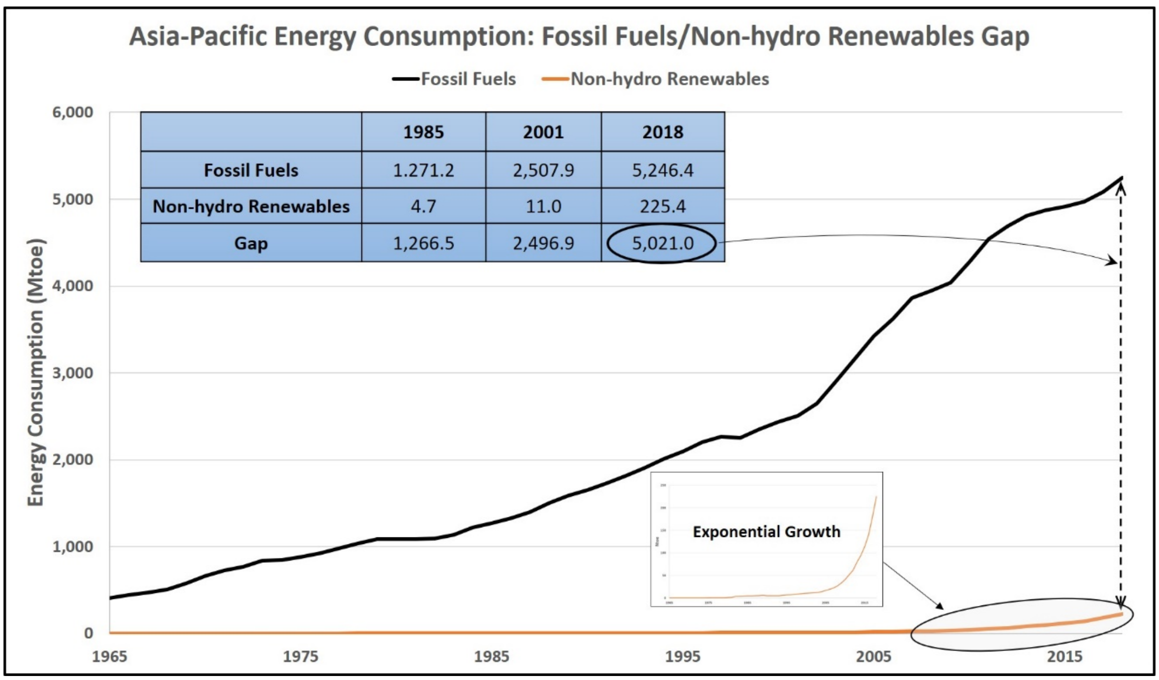


Figure 8. The fossil fuels/non-hydro renewable energy gap for Asia-Pacific total energy consumption. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

2.3. The FF-NHR Gap for Electricity

Since 1985, the FF-NHR gap for global electricity has grown from 6,200.1 TWhrs in 1985 to 9,975.9 TWhrs in 2001 to 14,605.7 TWhrs in 2018 (Figure 9). This was a 46.4% increase from 2001 to 2018 even though non-hydro renewable energy grew exponentially during this period. As with global primary energy, the dominant region for fossil fuel-based electricity is the Asia-Pacific where fossil fuel-based electricity consumption increased from 3,188.9 TWhrs in 2000 to 8,964.6 TWhrs in 2018—an increase of 181.1% (Figure 10). Fossil fuels constitute 73% of fossil fuel-based electricity in the Asia-Pacific, and trending upward, with coal comprising 59.4% of the region's power generation portfolio (Figure 11). In older, well-established economies fossil fuel-based electricity is generally flat, as in North America, or decreasing, as in Europe.

Of the 14,605.7 TWhrs global FF-NHR gap for electricity in 2018, Asia-Pacific countries accounted for 54.6% and North America accounted for 18.5% (Table 3). During the period of 2013-2018, the world's FF-NHR gap for electricity had a net increase of 88.8 TWhrs but with substantial disparity across regions. The Asia-Pacific region contributed 614.8 TWhrs to this net change while the Middle East contributed 236.1 TWhrs. Offsetting this were North America, Europe and South and Central America with net decreases of 313.6 TWhrs, 390.6 TWhrs, and 150.8 TWhrs, respectively (Table 3). The FF-NHR gap for global electricity generation is increasing, not decreasing, particularly in the Asia-Pacific region (Figure 12).

A detailed comparison of the U.S., China and India indicates China was responsible for 29.7% of the world's 14,605.7 TWhr FF-NHR gap in 2018, the U.S. for 16.4% and India for 7.8% (Table 4). Combined, China and India comprise 68.7% of Asia-Pacific's 2018 FF-NHR gap for electricity consumption. Of the 88.8 TWhr net increase in the FF-NHR gap for electricity during the 2013-2018 period, China contributed 318.9 TWhrs to the net increase whereas the U.S. FF-NHR gap had a net decrease of 294.2 TWhrs. During this same period, India's FF-NHR gap for electricity consumption had a net increase of 270.2 TWhrs. The FF-NHR gap for electricity in the Asia-Pacific region increased from 1,140.7 TWhrs in 1985 to 3,274.8 TWhrs in 2001 to 7,968.6 TWhrs in 2018 (Figure 12). The increase from 2001-2018 in the Asia-Pacific represents a 143.3% net increase compared with a 46.4% net increase in the global gap during the same period, even though non-hydro renewable energy consumption grew exponentially.

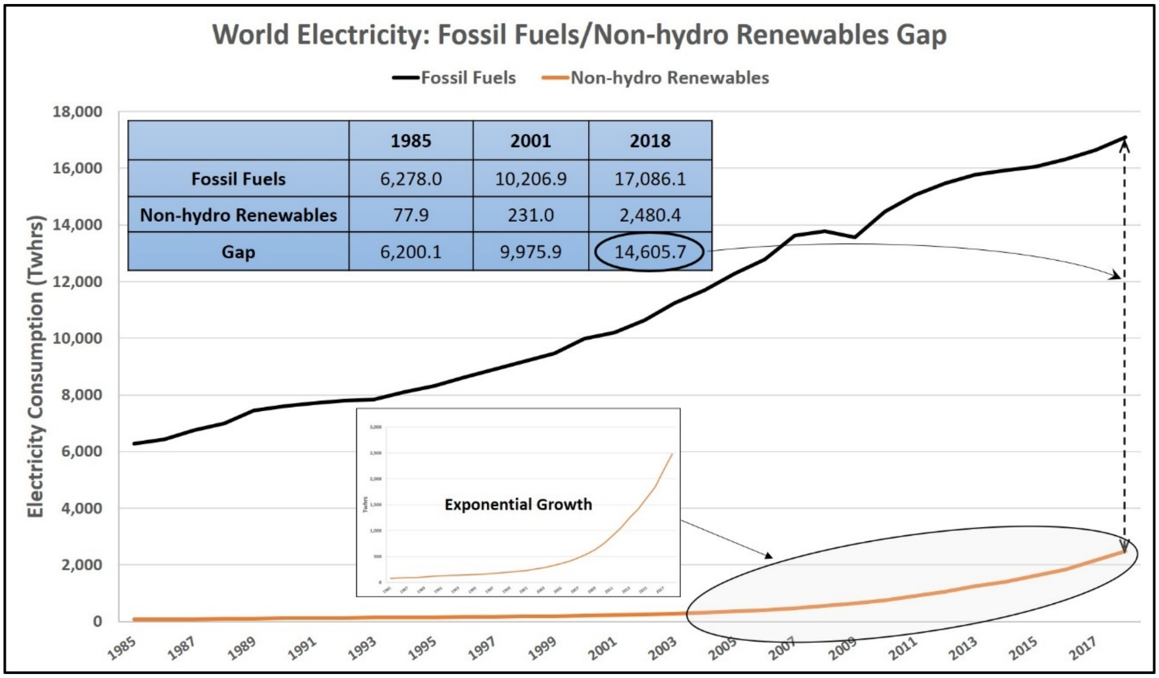


Figure 9. The fossil fuels/non-hydro renewable energy gap for world electricity. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

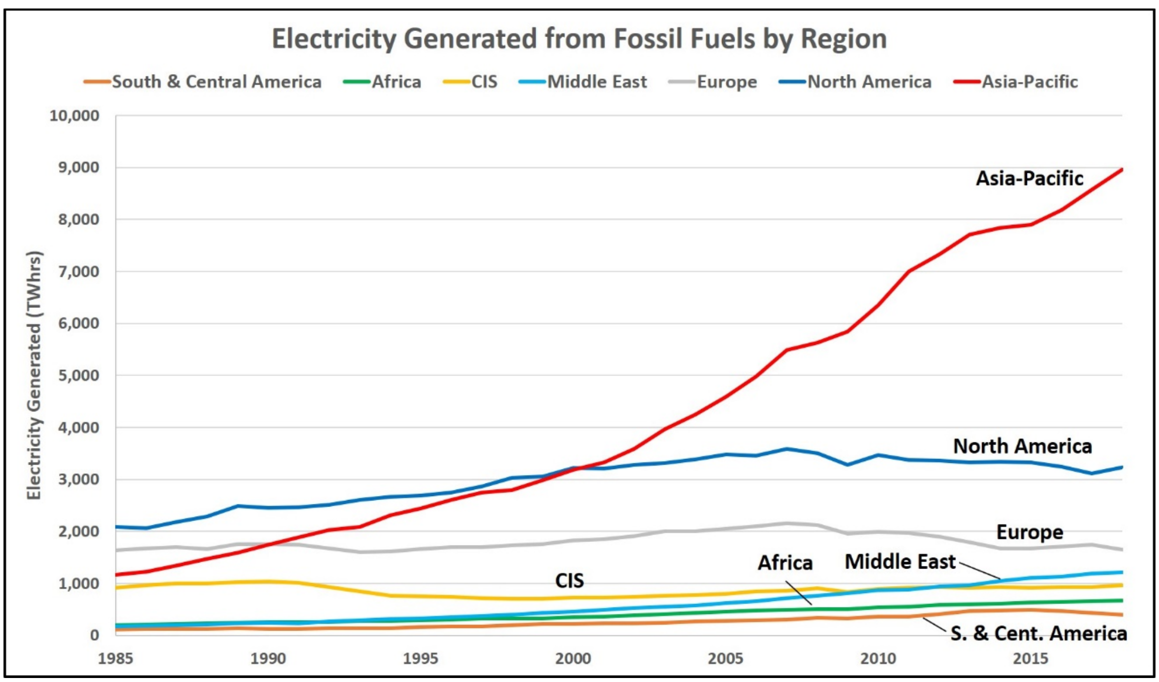


Figure 10. Electricity generated from fossil fuels, by region. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

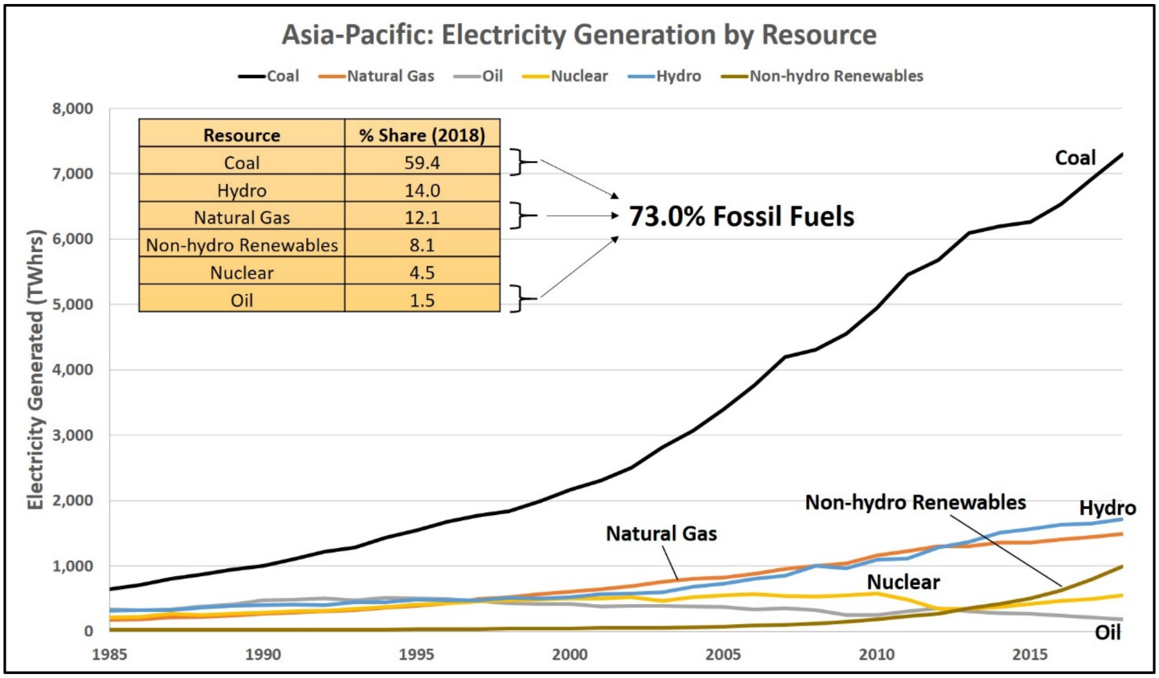


Figure 11. Asia-Pacific electricity generation by resource. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

Fossil Fuels/Non-hydro Renewables Gap for Electricity Consumption: By Region						
2018					2013-2018	
Region	Fossil Fuels (TWhrs)	Non-hydro Renewables (TWhrs)	Gap (TWhrs)	Share of Global Gap (%)	Gap Change (TWhrs)	Gap Trend
Asia-Pacific	*8,964.6*	*996.0*	*7,968.6*	*54.6*	*614.8*	Increasing
North America	*3,234.5*	*525.2*	*2,709.3*	*18.5*	*-313.6*	Decreasing
Middle East	*1,210.7*	*7.4*	*1,203.3*	*8.2*	*236.1*	Increasing
CIS	*958.7*	*2.5*	*956.2*	*6.5*	*42.8*	Increasing
Europe	*1,650.1*	*761.1*	*889.0*	*6.1*	*-390.6*	Decreasing
Africa	*672.8*	*31.9*	*640.9*	*4.4*	*50.2*	Increasing
South & Central America	*394.6*	*156.3*	*238.3*	*1.6*	*-150.8*	Decreasing
World	*17,086.1*	*2,480.4*	*14,605.7*	*100.0*	*88.8*	Increasing

Table 3. Regional breakdown of the fossil fuels/non-hydro renewable energy gap for electricity consumption for 2018 and the years 2013-2018. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

Fossil Fuels/Non-hydro Renewables Gap for Electricity Consumption: U.S., China and India						
2018					2013-2018	
Region	Fossil Fuels (TWhrs)	Non-hydro Renewables (TWhrs)	Gap (TWhrs)	Share of Global Gap (%)	Gap Change (TWhrs)	Gap Trend
China	*4,966.8*	*634.2*	*4,332.6*	*29.7*	*318.9*	Increasing
India	*1,260.7*	*121.5*	*1,139.2*	*7.8*	*270.2*	Increasing
US	*2,850.7*	*458.5*	*2,392.2*	*16.4*	*-294.2*	Decreasing
World	*17,086.1*	*2,480.4*	*14,605.7*	*100.0*	*88.8*	Increasing

Table 4. Breakdown of the fossil fuels/non-hydro renewable energy gap for electricity consumption for the U.S., China, and India, the world's leading energy consumers, during the years 2013-2018. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

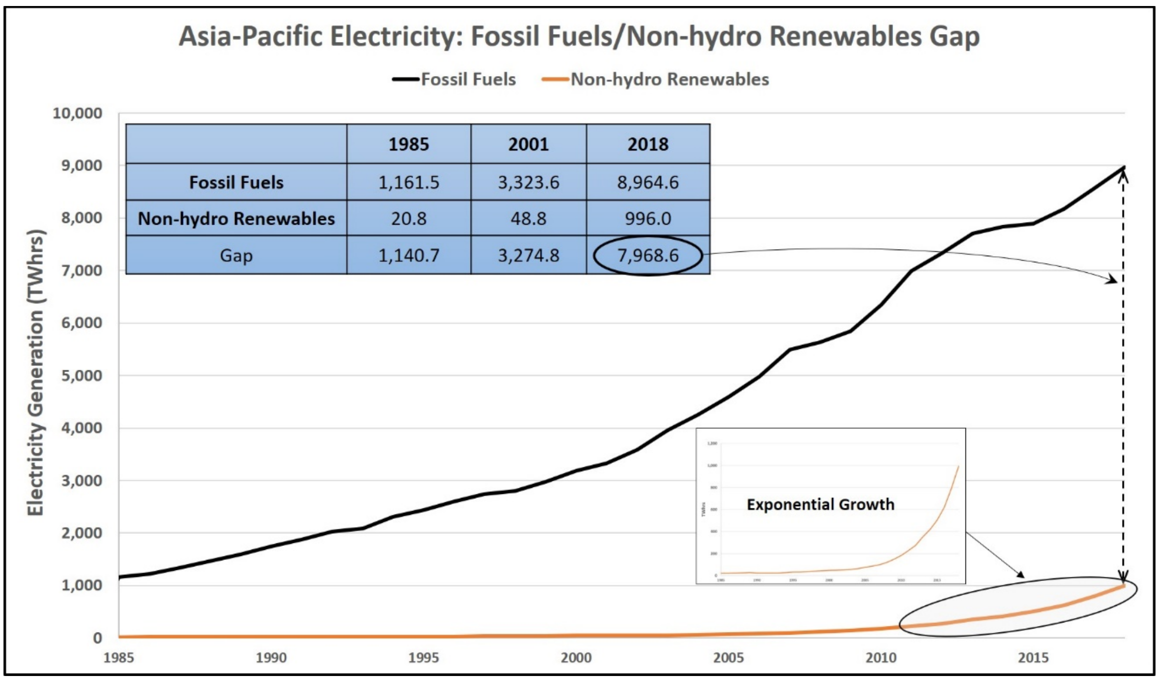
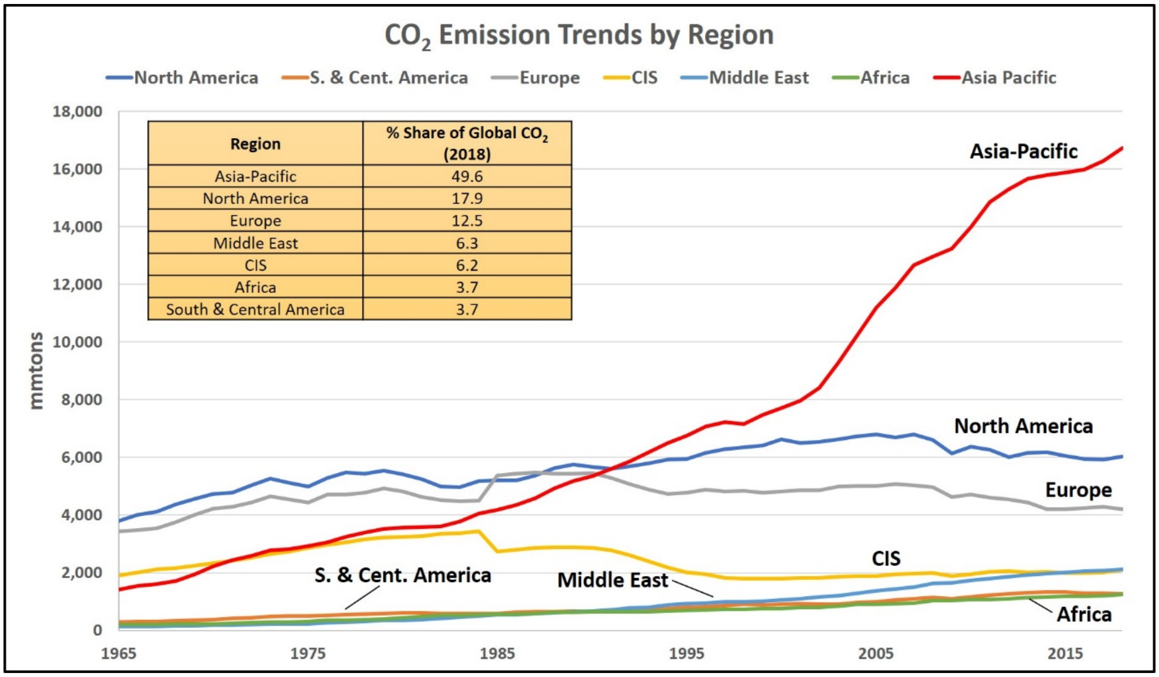


Figure 12. The fossil fuels/non-hydro renewable energy gap for Asia-Pacific electricity consumption. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

3. Discussion

At the global scale, primary energy consumption, fossil fuel consumption, total electricity generation and fossil fuel-based electricity generation are increasing. This is the trend in most regions of the world, with the general exceptions being the well-established economies of the U.S. and Europe. From 2000-2018, CO_2 emissions increased in all but two regions—those two being North America and Europe where fossil fuel consumption is flat or declining and where coal-fired power generation is shutting down and being offset by natural gas-fired power and renewables (Figure 13). Globally, during this period, CO_2 emissions increased 10,018.3 mmtons, 89.9% of which originated from Asia-Pacific countries (Figure 14). China and India accounted for 60.5% and 15.2%, respectively, while emissions in the U.S. declined by 721.3 mmtons. In the Asia-Pacific region CO_2 emissions are trending upward while in North America and Europe, emissions are trending down. At the same time, non-hydro renewable energy consumption for primary energy and electricity is growing exponentially. However, this exponential growth is not contributing to a decrease in CO_2 emissions because the FF-NHR gap is not closing—rather, that gap is increasing in most regions for primary energy consumption and electricity generation.



Region	% Share of Global CO_2 (2018)
Asia-Pacific	49.6
North America	17.9
Europe	12.5
Middle East	6.3
CIS	6.2
Africa	3.7
South & Central America	3.7

Figure 13. CO_2 emission trends by region. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

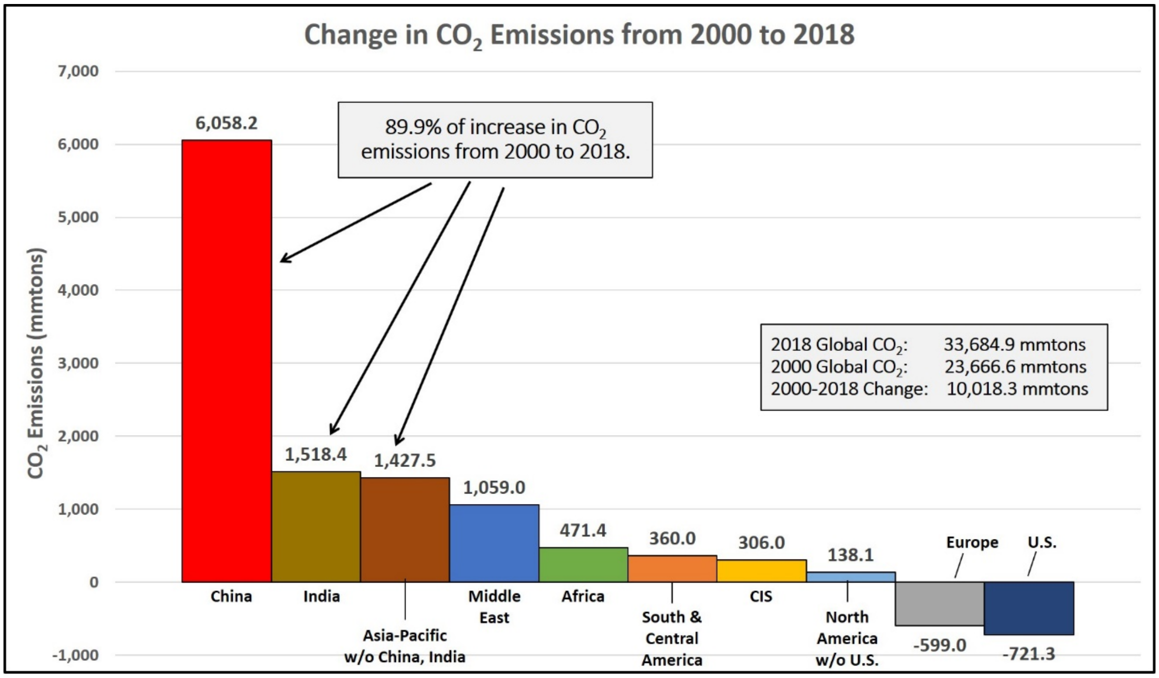


Figure 14. Change in CO_2 emissions for regions and select countries during the years 2000-2018. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

3.1. Global Climate Change and CO_2: Triaging by Region

Climate change is a global issue that, if it is to be responded to at the global scale, calls for a whole-of-nations approach. The United Nations Framework Convention on Climate Change (UNFCCC) through its Conference of the Parties (COP) and the Paris Agreement does this, although its Nationally Determined Contributions (NDC) approach is fragmented (UNFCCC, 2019; COP, 2016). In essence, the assumption is that the sum of the NDC parts (i.e., each nation meeting a nationally-determined CO_2 reduction) will be equal to or greater than the whole of the global climate challenge. However, it is already speculated that NDC pledges under the Paris Agreement won't limit global warming to 2^0C above pre-industrial levels (Greshko, 2017; UNEP, 2017; Höhne, et al., 2017). The UN Emissions Gap Report concluded: *"The NDC's that form the foundation of the Paris Agreement cover only approximately one third of the emissions reductions needed to be on a least-cost pathway for the goal of staying well below 2^oC. The gap between the reductions needed and the national pledges made in Paris is alarmingly high"*.

In the medical field, triage refers to procedures used by clinicians to prioritize prospective patients, oftentimes when vital resources for administering treatment are limited (Kipnis, 2002; Leider, et al., 2017). In disaster situations victims are often prioritized, or triaged, based on the extent of their injuries and the urgency of care needed. While the UNFCCC whole-of-nations framework is appropriate, instead of taking the NDC parts approach, the framework should be leveraged to triage the global threat of climate change by identifying those regions and countries where CO_2 is currently most acute and where CO_2 emissions are increasing and beginning to increase.

Developing regions, particularly in the Asia-Pacific, are comprised of countries at various stages of economic growth, each having different energy demands based on the maturity of their energy infrastructure and each having different domestic energy resource endowments to leverage. As such, these regions also should be triaged as to which energy technologies can be deployed appropriately in order to sustain economic development under low-carbon constraints. The rationale being that carbon reduction policies deployed with some level of success in well-developed economies may not transfer to emerging economies. One example being, energy efficiency and distributed rooftop solar in the U.S. likely can't be deployed in regions of the world where more energy is needed, not less, and where reliable, baseload electricity is needed at large scales to stand up a developing industrial base. In this case, the U.S. can propose to lead by an example that can't be followed in developing regions or the U.S. can focus on development of low- and zero-carbon technologies that can be deployed in those regions. The latter represents a regional triage approach based on CO_2 acuteness and technological triage based on which technologies can be, and should be, deployed in order to have the greatest impact on global CO_2 emissions while sustaining economic growth and development. Moreover, a compelling reason for taking a whole-of-nations triage approach is that as CO_2 emissions increase and become more urgent in developing regions, other countries around the world, where CO_2 emissions may be in decline, will be impacted nonetheless. The reality being, climate change is global in both its causes and impacts and doesn't yield to, or stop at, geographic boundaries simply because a country has an aggressive domestic energy and climate policy. Consequently, it's worth considering the impacts of any U.S. energy and climate policy focused predominantly, if not entirely, on domestic actions. That is, what would global trends look like if all U.S. fossil fuels were eliminated?

3.2. Fossil Fuel Consumption and CO_2 Emissions: World and U.S. Comparison

U.S. fossil fuel consumption increased 61.5% from 1965-2018 while global fossil fuel consumption increased 236.9% during the same period (Figure 15). More recently, U.S. fossil fuel consumption has been generally flat having decreased slightly from 2,000.3 Mtoe in 2000 to 1,939.3 Mtoe in 2018. During this same 2000-2018 period, global fossil fuel consumption for the rest of world (i.e., U.S. consumption is subtracted out as indicated by the dashed line in Figure 15), increased 60.1% from 6,122.7 Mtoe in 2000 to 9,804.2 Mtoe in 2018. Eliminating all U.S. fossil fuel consumption for the entire 1965-2018 period would produce the global trend illustrated in Figure 15. This would reduce global fossil fuel consumption for 2018 from 11,743.6 Mtoe to 9,804.2 Mtoe, resetting global fossil fuel consumption to 2006 levels—a twelve-year gain. Yet, even without U.S. fossil fuel consumption, global fossil fuel consumption would continue trending upward.

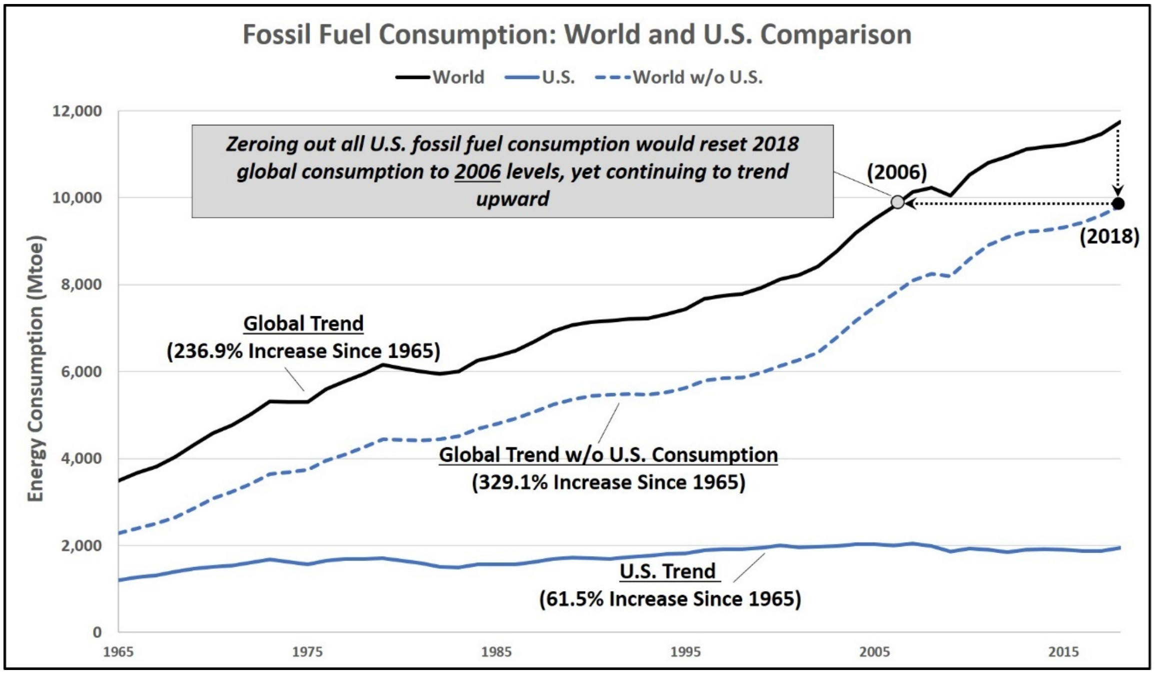


Figure 15. Comparison of total fossil fuel consumption for the world and the U.S. and the global impact of eliminating all U.S. fossil fuel consumption. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

U.S. coal consumption decreased 14.4% from 1965-2018 while global coal consumption increased 171.6% during the same period (Figure 16). More recently, U.S. coal consumption decreased 41.3% from a near all-time peak of 540.5 Mtoe in 2000 to 317.0 Mtoe in 2018. During this same 2000-2018 period, global coal consumption for the rest of world (i.e., U.S. consumption is subtracted out as indicated by the dashed line in Figure 16), increased 90.1% from 1,817.3 Mtoe in 2000 to 3,455.1 Mtoe in 2018. Eliminating all U.S. coal consumption since 1965 would produce the global trend illustrated in Figure 16. This would reduce global coal consumption for 2018 from 3,772.1 Mtoe to 3,455.1 Mtoe, resetting global coal consumption to 2009 levels—a nine-year gain. Yet, even without U.S. coal consumption, global coal consumption would continue trending upward.

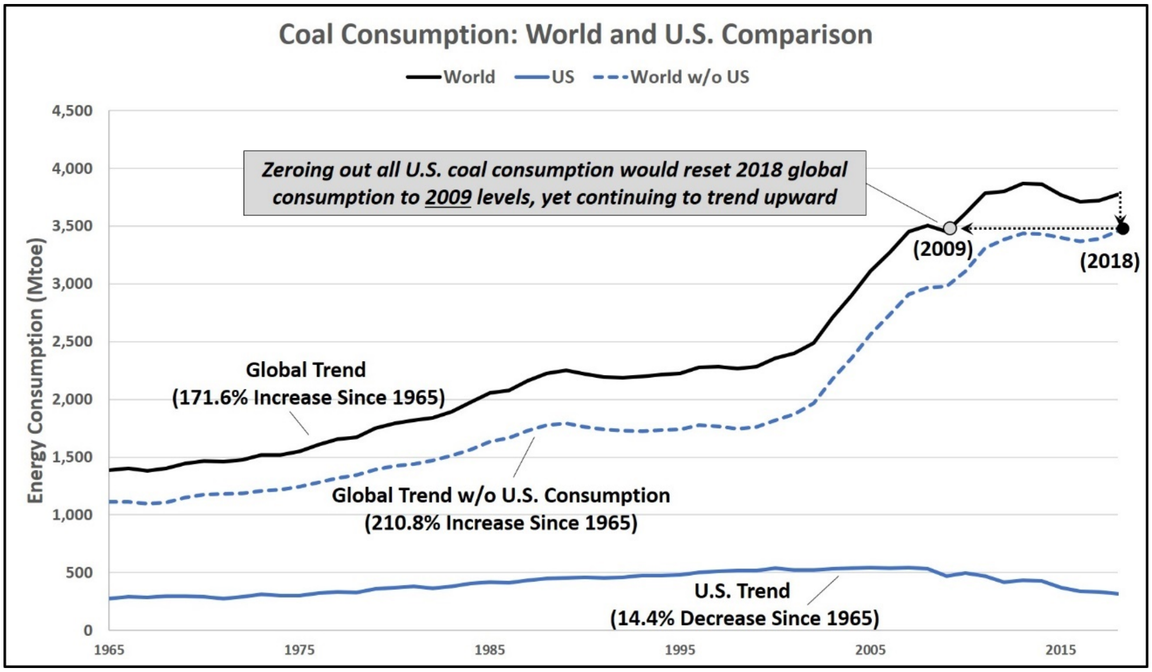


Figure 16. Comparison of coal consumption for the world and the U.S. and the global impact of eliminating all U.S. coal consumption. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

U.S. fossil fuel-based electricity increased 47.8% from 1985-2018 while global fossil fuel-based electricity increased 172.2% during the same period (Figure 17). More recently, U.S. fossil fuel-fired electricity decreased 11.4% from a peak of 3,217.5 TWhrs in 2007 to 2,850.7 TWhrs in 2018. During this same 2007-2018 period, global fossil fuel-based electricity for the rest of world (i.e., U.S. fossil fuel-based electricity is subtracted out as indicated by the dashed line in Figure 17), increased 36.9% from 10,399.9 TWhrs in 2007 to 14,235.3 TWhrs in 2018. Eliminating all U.S. fossil fuel-based electricity since 1985 would produce the global trend illustrated in Figure 17. This would reduce global fossil fuel-based electricity for 2018 from 17,086.1 TWhrs to 14,235.3 TWhrs, resetting global fossil fuel-based electricity to 2010 levels—an eight-year gain. Yet, even without U.S. fossil fuel-based electricity, global fossil fuel-based electricity would continue trending upward.

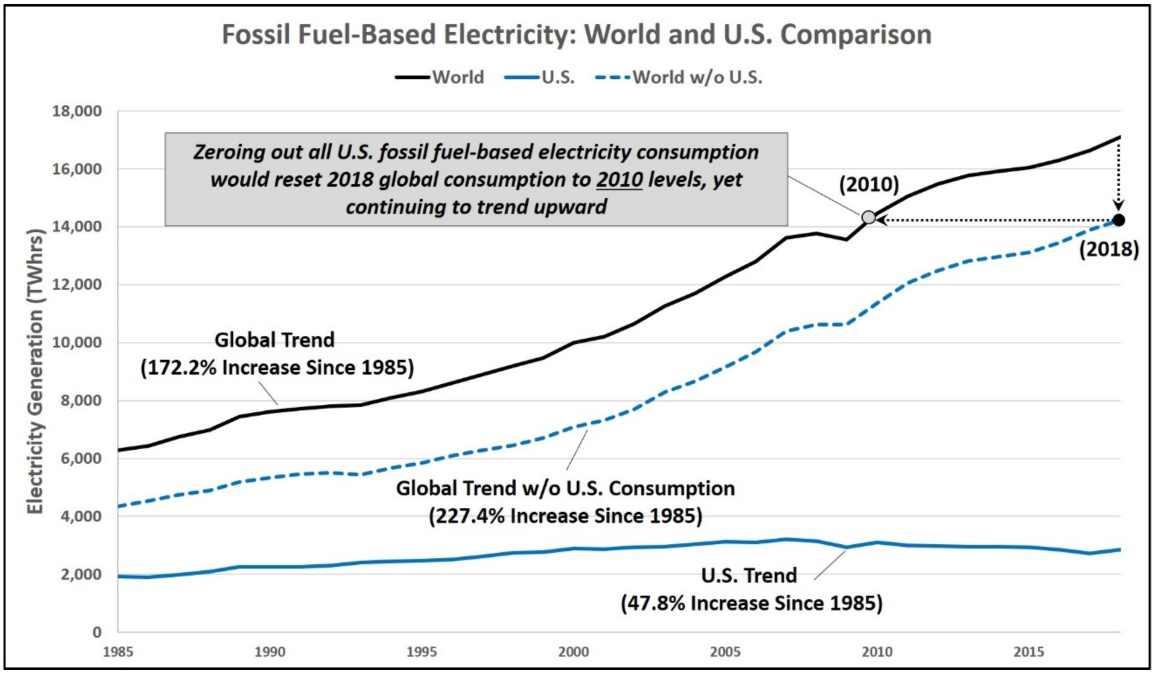


Figure 17. Comparison of fossil fuel-based electricity for the world and the U.S. and the global impact of eliminating all U.S. fossil fuel-based electricity. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

U.S. CO_2 emissions increased 44.2% from 1965-2018 while global CO_2 emissions increased 200.9% during the same period (Figure 18). More recently, U.S. CO_2 emissions decreased 13.9% from a near all-time peak of 5,828.3 mmtons in 2005 to 5,017.9 mmtons in 2018. During this same 2005-2018 period, global CO_2 emissions for the rest of world (i.e., U.S. emissions are subtracted out as indicated by the dashed line in Figure 18), increased 28.6% from 22,299.5 mmtons in 2006 to 28,667.0 mmtons in 2018. Eliminating all U.S. CO_2 emissions since 1965 would produce the global trend illustrated in Figure 18. This would reduce global CO_2 emissions for 2018 from 33,684.9 mmtons to 28,667.0 mmtons, resetting global CO_2 emissions to 2006 levels—a twelve-year gain. Yet, even without U.S. emissions, global CO_2 emissions would continue trending upward.

This raises the question as to what impact the most extreme U.S. energy and climate policy (i.e., total elimination of fossil fuels) would have on global trends in fossil fuel consumption and CO_2 emissions. It also recommends that the U.S. engage in a regional triage approach through low- and zero-carbon technology deployment in developing regions since, even without U.S. emissions, global emissions will continue increasing leaving the U.S. vulnerable to, and threatened by, global climate change. One such technology is nuclear power.

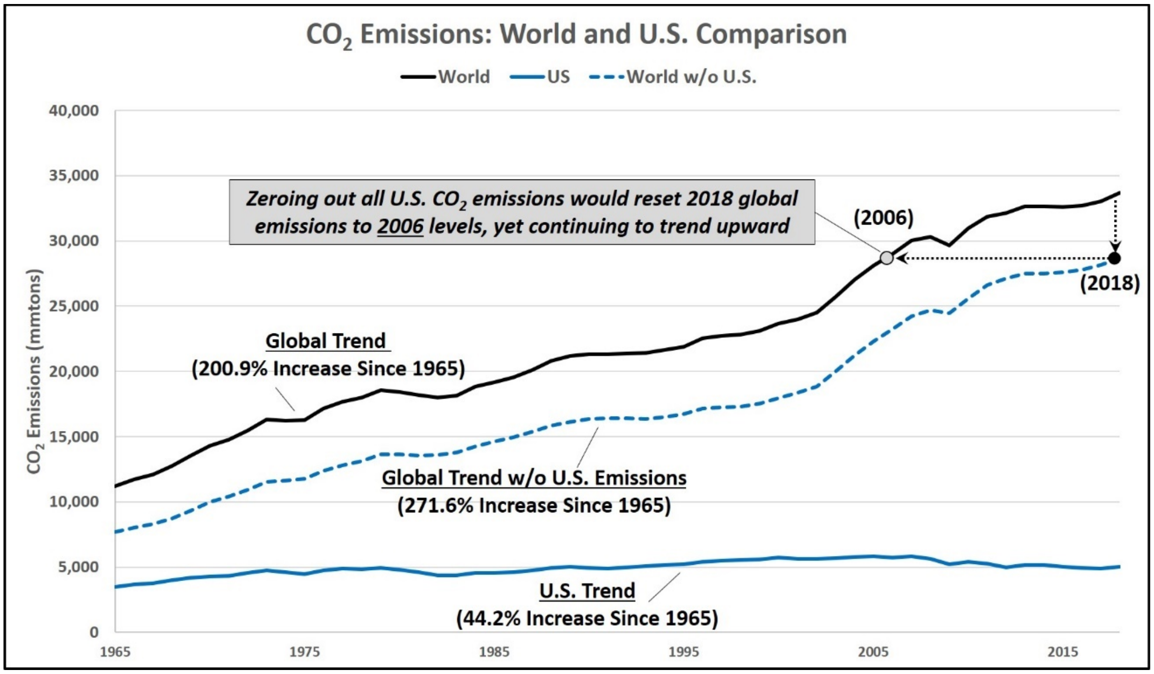


Figure 18. Comparison of CO_2 emissions for the world and the U.S. and the global impact of eliminating all U.S. CO_2 emissions. Data source: BP Statistical Review of World Energy 2019 (BP, 2019).

3.3. The Primacy of U.S. National Security: Nuclear Power and Climate Change

Civilian nuclear power is regularly in the U.S. energy and climate debate, yet with no consensus as to its place in U.S. policy. Some contend the U.S. should abandon nuclear altogether and commit to a 100% renewable energy future while others counter that, because of its highly reliable, zero-carbon benefits, global climate objectives cannot be reached without nuclear (Lifton and Oreskes, 2019; Smith and Walker, 2019; Jacobson, et al., 2015; Gattie, 2017; Gattie, 2018a; Lovins, 2017; Climate Scientists for Nuclear; Shellenberger, 2017). While nuclear energy is debated within the domestic context of U.S. energy and climate policy, America's nuclear power enterprise has a unique, high-level role of responsibility in America's broader national security context because of its civilian-military dual utility and because of America's longstanding commitment to global leadership in nuclear science, engineering and technology.

U.S. nuclear power has been central to U.S. foreign policy and national security since the Atomic Energy Act of 1946. Later revised, the Atomic Energy Act of 1954 embedded the U.S. as a committed global partner in the development and deployment of nuclear power technologies, primarily through President Eisenhower's Atoms for Peace program (Chernus, 2002). The national security objective was to establish the U.S. as the world's premier nuclear research and development enterprise and to establish a system of international control over atomic energy and the global nuclear ecosystem with the U.S. taking the lead. Consequently, nuclear science, engineering and technology were enshrined as vital elements of U.S. national security in the second half of the 20th century with U.S. nuclear power policy serving as an extension of U.S. foreign policy. Henry DeWolf Smyth, a physicist during the Manhattan Project, author of the critical report on America's wartime atomic energy program and an early member of the U.S. Atomic Energy Commission penned an article in Foreign Affairs entitled, *"Nuclear Power and Foreign Policy"* (Smyth, 1946; 1956)

In it, Smyth brought into sharp relief the importance of the U.S. being globally competitive and maintaining global leadership in nuclear research and development as a matter of foreign policy:

"At present we are in a strong position to help foreign countries obtain nuclear power. However, if we are to make our "atoms for peace" program an effective part of our foreign policy we must realize that we are in a highly competitive situation. Other countries have vigorous atomic energy programs. They have already proven their competence. They have already shown that there is no such thing as a monopoly on the laws of nature. In many instances they have more compelling domestic reasons than we have for pushing nuclear reactors as practical operating components of their national power systems. Our present commanding lead is bound to lessen. It could easily disappear if any part of our program lags seriously". (Smyth, 1956)

Smyth's contention that the U.S. nuclear program shouldn't lag other countries reflected the general consensus among not only scientists, engineers and policymakers, but also in the political arena as both parties vied for recognition as the champion of the U.S. nuclear enterprise (Gattie, 2018b). Moreover, there is an even greater need for foreign countries to obtain nuclear power in the 21st century, given the urgency of obtaining that power under carbon constraints and the existential threat of climate change.

In a report entitled *"Energy Spheres of Influence"*, Ladislaw and Tsafos (2019) point out the progress being made by China and Russia in advancing their respective nuclear enterprises and the likelihood of the nuclear industry being decidedly non-Western in a few decades:

"The United States and the West are retreating or failing to lead in other energy sectors—the nuclear industry in a few decades is likely to be decidedly non-Western. Moreover, seeing the export of nuclear goods and services as a strategic undertaking, the Russian and Chinese governments are aiding their nuclear industries financially and diplomatically as they approach new and existing markets. But China appears to be fast emerging as an aspiring leader in the global nuclear commerce after its Thirteenth Five-Year Plan identified advanced nuclear technologies as a key area for development and commercialization. Whether these changes pose a threat to the United States depends on whether you think having a vibrant nuclear industry is important. Many supporters of nuclear energy argue it is a vitally important technology we relinquish at our peril." (Ladislaw and Tsafos, 2019)

To the point of U.S. nuclear energy being a vitally important technology, many have emphasized the national security imperative of a vibrant U.S. nuclear enterprise, particularly as pertains to 21st century geopolitics (Atlantic Council, 2019; CSIS, 2013; Energy Futures Initiative 2017; Gattie, 2018a; Gattie, et al., 2018; Gattie 2019b; Graham and Mies, 2019; Lippold, 2017). The U.S. has entered a new era where energy resources and technologies (particularly fossil fuels and nuclear power) are being leveraged by revisionist powers such as China and Russia in an effort to disrupt alliances within the liberal international order established in large part by the U.S. post-World War II (McFarlane, 2019; Coats, 2019; Ladislaw and Tsafos, 2019; Hadley, 2019; Burns, 2019a; Burns, 2019b; Mattis, 2018; White House, 2017; Gattie, 2018c; Gattie, 2019b). Consequently, the U.S. is not only waging a global battle against climate change, it's also facing the global challenge of renewed great-power competition. As a result, both are converging to present unprecedented challenges for U.S. energy policy—21st century challenges that arguably are more complex and globally entangled than any in history.

In testimony before the Senate Foreign Relations Committee and in an article penned for *Foreign Affairs* (Burns, 2019a; 2019b), former U.S. Deputy Secretary of State William Burns articulated the challenges America faces in the 21st century and how those challenges will require a different approach to U.S. statecraft, particularly as pertains to energy and climate:

> *The global order that emerged after the end of the Cold War has shifted dramatically, creating unprecedented challenges for American statecraft. Great power rivalry is back, and it has brought with it complex risks and trade-offs for which we are out of practice. These challenges would be daunting in any era, but they are particularly urgent now, at a time when America's singular post-Cold War dominance is fading.*
> (Burns, 2019a)

> *The U.S. government will also have to update its diplomatic capacity when it comes to the issues that matter to twenty-first-century foreign policy—particularly technology, economics, energy, and the climate.* (Burns, 2019b)

In a triage approach to the existential threat of global climate change, as recommended in this analysis, the initial strategy for CO_2 reduction shouldn't prohibit a technology that has a proven record of addressing the magnitude and scale of the issue at hand while, instead, requiring 100% dependency on a technology with no precedent for addressing the magnitude and scale of the issue. In this case, the urgent issue is CO_2, the scale is global, the technology with a proven record is nuclear power and the one with no precedent is renewable energy technology, particularly non-hydro renewable energy. This should not be misconstrued as anti-renewable energy. Renewable energy and renewable energy technologies will be critical to a diverse energy future of low- and zero-carbon resources. Rather, the contention here is that renewable energy has limits and nuclear power cannot be dismissed offhand without taking into account the consequences.

Since 1969, nuclear power has delivered 24,731,525 GWhrs of safe and reliable zero-carbon electricity to the U.S. economy (Figure 19). Even if this level of zero-carbon power generation could be displaced by zero-carbon renewable energy, there would be no increase in climate benefits as per CO_2 reduction since zero-carbon power would be offset with zero-carbon power. However, there would be a degradation in national security as U.S. nuclear science, engineering and technology expertise fades from America's industrial DNA and its research and development complex while, at the same time, U.S. leadership in the global nuclear ecosystem is displaced by a revisionist, authoritarian power such as China or Russia. Consequently, a 100% renewable energy policy would set the U.S. on an unprecedented trajectory toward an industrial economy absent of baseload electricity while at the same time setting the international community of nations on an unprecedented trajectory toward a liberal world order without U.S. leadership in the global nuclear endeavor. It's entirely speculative as to whether the U.S. can sustain its economy with 100% renewable energy. As to whether U.S. and international security will be at greater risk with America lagging revisionist powers in nuclear science, engineering and technology and having vacated its leadership role in the global nuclear community, it would be irresponsible to gamble on such a speculative future.

4. Policy Recommendations

From this analysis, the following conclusions are drawn:

1. Fossil fuel consumption and CO_2 emissions are most acute in emerging economies and are trending up, particularly in the Asia-Pacific;
2. U.S. fossil fuel consumption and CO_2 emissions are in decline and, while eliminating all U.S. fossil fuel consumption and CO_2 emissions will provide a few years of reprieve, it will not redirect the upward trend in global fossil fuel consumption or CO_2 emissions;
3. The gap between fossil fuel consumption and non-hydro renewables (FF-NHR gap) for global primary energy consumption and electricity generation is increasing, not decreasing, therefore non-hydro renewables aren't displacing fossil fuels;
4. Because climate change is a global issue, the U.S. will be impacted by increased fossil fuel consumption and CO_2 emissions in emerging economies, regardless of U.S. climate policy, therefore a whole-of-nations triage approach is needed; and
5. Global climate change and a declining U.S. nuclear power enterprise constitute dual existential threats to U.S. national security, both of which will be exacerbated if the U.S. continues to retreat from, or abandons altogether, its nuclear power enterprise and global leadership role.

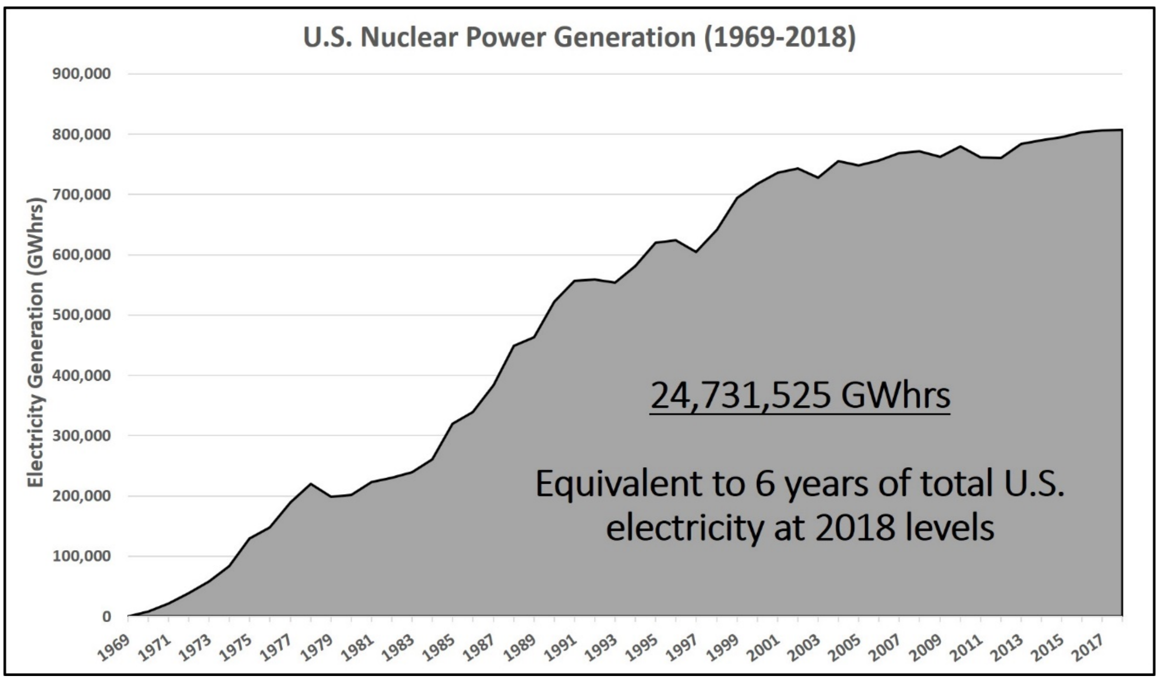


Figure 19. U.S. nuclear power generation from 1969-2018. Data source: U.S. Energy Information Administration and International Atomic Energy Agency (U.S. EIA 2019e; IAEA).

Moreover, this paper has discussed two long-term existential national security threats facing the U.S. in the 21st century: one around the issue of climate change and the other around the issue of America's nuclear power enterprise. Both have domestic and international implications, both are entangled in energy and climate issues, both are global in extent and both will require diplomacy and collaboration with certain countries and competition with others. As to the existential threat of climate change, it is contended in this paper that the U.S. cannot insulate itself from the impacts of a changing global climate through domestic energy and climate policies targeting only U.S. industries and the U.S. economy. Fossil fuel consumption, coal consumption, CO_2 emissions and fossil fuel-based electricity, while not increasing in the U.S., are increasing in other parts of the world, and the impacts will extend to the U.S. As to the existential threat of a declining nuclear power enterprise, the U.S. currently lacks the necessary political consensus to honor its longstanding foreign policy objective of positioning the U.S. as the global leader in nuclear research and development and engaging in international nuclear power partnerships. While U.S. nuclear power policy was originally crafted as an extension of U.S. foreign policy to meet the national security challenges of the 20th century, U.S. national security challenges are magnified in the 21st century by the global challenge of climate change and the strategic efforts of China and Russia to displace America as the 21st century leader in nuclear technologies (Gattie, 2019b).

In order to stand up to the magnitude and scale of these threats, U.S. energy and climate policy should be global in extent, should align with national security objectives and should be crafted as an extension of U.S. foreign policy. It is proposed here that the U.S. civilian nuclear power enterprise (research, development, deployment and international collaboration) be elevated in U.S. energy and climate policy as the central response to both threats. The following policy recommendations are now offered.

First, U.S. energy and climate policy should be both outward- and inward-oriented. Outward-oriented in that energy and climate policy should reflect the realities of climate change as a global issue that cannot be substantially impacted by domestic U.S. policies alone. As illustrated in Figure 18, if climate change was an existential threat in 2006 with U.S. CO_2 emissions included in global CO_2 emissions, then climate change is an existential threat in 2018 and beyond with U.S. CO_2 emissions removed from global emissions. Consequently, as climate change is a national security issue, U.S. energy and climate policy should align with foreign policy objectives with the U.S. taking a triage approach focused on the most acute regional sources of carbon emissions and collaborating with those regions on the deployment of low- and zero-carbon U.S. technologies that stem CO_2 emissions while supporting economic growth and regional stability. This should be cultivated as international investment opportunities for U.S. industry coupled to diplomatic efforts of U.S. good-will and a re-defined brand of U.S. energy statecraft suited to 21st challenges (Gattie, 2017; Burns 2019b).

Inward-oriented in that domestic U.S. energy and climate policy must focus on hardening U.S. energy infrastructure, reducing system vulnerabilities and increasing energy system resilience against the impacts of rising sea levels, elevated temperatures and increasingly catastrophic weather events. U.S. energy infrastructure is generally a nonpartisan issue that must be disentangled from the politics of climate change. This nonpartisanship should be leveraged in order to focus domestic U.S. policy on critical issues over which the U.S. has sovereign control (i.e., energy infrastructure), in contrast with the limited control the U.S. has over energy consumption and CO_2 emissions in other countries.

Second, U.S. nuclear power policy should be reinstituted as an extension of U.S. foreign policy with an aggressively forward-looking strategy to develop advanced reactor technologies and alternative fuels; e.g., small modular reactors, molten salt reactors and fast reactors, thorium and high-assay low-enriched uranium (HALEU) among other next-generation nuclear technologies. This aligns with outward-oriented energy and climate policies focused on the deployment of zero-carbon technologies to support economic development in emerging regions where CO_2 emissions are most acute, and it aligns with inward-oriented U.S. national security objectives of ensuring long-term, sustainable energy security. Moreover, and of unparalleled geopolitical importance, it will signal to rising, authoritative powers seeking to surpass and displace the U.S. in nuclear science, engineering and technology, that America is responding strategically to their challenge and is positioning itself to compete in civilian nuclear technology and retain its position of leadership and international nuclear collaboration.

5. Conclusion

The energy and climate challenges facing America in the 21st century are more globally dispersed and geopolitically entangled than they were in the 20th century, and it is proposed here that the overarching objective of U.S. energy and climate policy should be national security. Therefore, it's critical for U.S. policymakers to recognize and acknowledge that climate change is a growing concern due to increased carbon emissions beyond U.S. borders and that domestic energy and climate policies alone will not insulate the U.S. from its impacts. It's also critical that U.S policymakers re-examine the unique role of zero-carbon nuclear power in the context of renewed great-power competition and rising powers leveraging nuclear collaboration as an extension of geopolitical strategy. Combined, global climate change and rising powers challenging U.S. leadership in civilian nuclear power, compel 21st century America to ask itself the same question H.D. Smyth asked 20th century America in 1956: *"Are the aims of our foreign policy consistent with the aims of our domestic policy as far as nuclear power is concerned?"* (Smyth, 1956).

References

Adragna, A. 2018. Democrats go all-in on clean energy. Politico October 24, 2018. https://www.politico.com/story/2018/10/24/democrats-2018-energy-climate-change-873730

Atlantic Council. 2019. US Nuclear Energy Leadership: Innovation and the Strategic Global Challenge. Report of the Atlantic Council Task Force on US Nuclear Energy Leadership. https://www.atlanticcouncil.org/wp-content/uploads/2019/05/US_Nuclear_Energy_Leadership-.pdf

Bell, M. 2018. 'Drill, Baby, Drill' is Back in Trump Era. The Hill January 10, 2018. https://thehill.com/opinion/energy-environment/368248-drill-baby-drill-is-back-in-trump-era

Blackwill, R.D. and O'Sullivan, M.L., 2014. America's Energy Edge: The Geopolitical Consequences of the Shale Revolution. *Foreign Aff.*, *93*, p.102.

Bogmans, 2019. Falling Costs Make Wind, Solar More Affordable. IMFBlog April 26, 2019. https://blogs.imf.org/2019/04/26/falling-costs-make-wind-solar-more-affordable/

BP. 2019. BP Statistical Review of World Energy 2019.

Burns, W. 2019a. Testimony before the Senate Foreign Relations Committee. https://www.foreign.senate.gov/imo/media/doc/022719_Burns_Testimony.pdf

Burns, W.J., 2019b. The Lost Art of American Diplomacy. *Foreign Affairs*.

Butler, N. 2019. How the shale revolution is reshaping world markets. Financial Times February 25, 2019. https://www.ft.com/content/5b4cd4c6-34f7-11e9-bb0c-42459962a812

Chernus, I., 2002. *Eisenhower's atoms for peace*. Texas A&M University Press.

Climate Scientists for Nuclear. http://environmentalprogress.org/climate-scientists-for-nuclear/

Coats, D. 2019. Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community. https://www.dni.gov/files/ODNI/documents/2019-ATA-SFR---SSCI.pdf

Colman, Z. 2019. Gaetz drafting 'Green Real Deal' climate resolution. Politico March 22, 2019. https://www.politico.com/story/2019/03/22/gaetz-green-real-deal-1290463

COP, 2016. Aggregate effects of the intended nationally determined contributions: an update. Conference of the Parties https://unfccc.int/sites/default/files/resource/docs/2016/cop22/eng/02.pdf

CSIS, 2013. Restoring U.S. Leadership in Nuclear Energy: A National Security Imperative. June 14. https://www.csis.org/analysis/restoring-us-leadership-nuclear-energy .

Energy Futures Initiative, 2017. The US nuclear energy enterprise: A key national security enabler. *Energy Futures Initiative*.

Friedman, L. 2019. Bernie Sanders's 'Green New Deal': A $16 Trillion Climate Plan. NY Times August 22, 2019. https://www.nytimes.com/2019/08/22/climate/bernie-sanders-climate-change.html

Gattie, D.K., 2017. Incorporating stability and resilience in energy policy for the US power sector: Recommendations for the Trump administration. *The Electricity Journal*, *30*(1), pp.47-54.

Gattie, D.K., 2018a. A strategic policy framework for advancing US civilian nuclear power as a national security imperative. *The Electricity Journal*, *31*(1), pp.23-32.

Gattie, D.K. 2018b. Eisenhower's nuclear legacy holds steady at Vogtle. August Chronicle, December 1, 2018. https://www.augustachronicle.com/opinion/20181201/gattie-eisenhowers-nuclear-legacy-holds-steady-at-vogtle

Gattie, DK. 2018c. US nuclear power: Too strategic to fail. The Hill August 30, 2018. https://thehill.com/opinion/energy-environment/404399-us-nuclear-power-too-strategic-to-fail

Gattie, DK. 2019a. 100% Renewable Energy Isn't a Response to Climate Change—It's a Retreat. The Hill March 14, 2019. https://thehill.com/opinion/energy-environment/433992-100-renewable-energy-isnt-a-response-to-climate-change-its-a

Gattie, DK. 2019b. Will the US Lead? Or let China and Russia dominate nuclear energy. The Hill May 22, 2019. https://thehill.com/opinion/energy-environment/444944-will-the-us-lead-or-let-china-and-russia-dominate-nuclear-energy

Gattie, D.K., Darnell, J.L. and Massey, J.N., 2018. The role of US nuclear power in the 21st century. *The Electricity Journal*, *31*(10), pp.1-5.

Biscardini, G., Morrison, R., Branson, D. and Maestro, A.D. 2018. Oil and Gas Trends 2018-19: Strategy shaped by volatility. Strategy&, Pricewaterhouse Coopers. https://www.strategyand.pwc.com/gx/en/trends/2018-oil-gas-industry-trends.pdf

Gosens, J., Hedenus, F. and Sandén, B. 2017. Faster market growth of wind and PV in later adopters due to global experience build-up. Energy 131:267-278.

Graham, T. and Mies, R.W. 2019. National Security Stakes of US Nuclear Energy. The Hill May 25, 2019. https://thehill.com/opinion/national-security/445550-national-security-stakes-of-us-nuclear-energy

Greshko, J. 2017. Current Climate Pledges Aren't Enough to Stop Severe Warming. National Geographic October 31, 2017. https://www.nationalgeographic.com/news/2017/10/paris-agreement-climate-change-usa-nicaragua-policy-environment/

Hadley, S.J. 2019. Testimony before the Senate Foreign Relations Committee. https://www.foreign.senate.gov/imo/media/doc/022719_Hadley_Testimony.pdf

Höhne, N., Kuramochi, T., Warnecke, C., Röser, F., Fekete, H., Hagemann, M., Day, T., Tewari, R., Kurdziel, M., Sterl, S. and Gonzales, S., 2017. The Paris Agreement: resolving the inconsistency between global goals and national contributions. Climate Policy, 17(1), pp.16-32.

IAEA. Power Reactor Information System. U.S. Data. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US

IRENA, 2019. A New World: The Geopolitics of the Energy Transformation. Global Commission on the Geopolitics of Energy Transformation. http://geopoliticsofrenewables.org/assets/geopolitics/Reports/wp-content/uploads/2019/01/Global_commission_renewable_energy_2019.pdf

Jacobson, M.Z., Delucchi, M.A., Bazouin, G., Bauer, Z.A., Heavey, C.C., Fisher, E., Morris, S.B., Piekutowski, D.J., Vencill, T.A. and Yeskoo, T.W., 2015. 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States. *Energy & Environmental Science*, *8*(7), pp.2093-2117.

Kipnis, K., 2002. Triage and ethics. *AMA Journal of Ethics*, *4*(1).

Ladislaw, S. and Tsafos, N. 2019. Energy Spheres of Influence. Report for Center for Strategic and International Studies. https://csis-prod.s3.amazonaws.com/s3fs-public/publication/190906_LadislawTsafos_EnergySpheres_v1.pdf

Leider, J.P., DeBruin, D., Reynolds, N., Koch, A. and Seaberg, J., 2017. Ethical guidance for disaster response, specifically around crisis standards of care: a systematic review. *American journal of public health*, *107*(9), pp.e1-e9.

Lifton, R.J and Oreskes, N. 2019. The false promise of nuclear power in an age of climate change. Bulletin of the Atomic Scientists August 20, 2019. https://thebulletin.org/2019/08/the-false-promise-of-nuclear-power-in-an-age-of-climate-change/#

Lippold, K., 2017. Nuclear Energy, the Production Tax Credit, and International Security. July 31. http://www.electricreliability.org/sites/default/files/Nuclear%20Energy%2C%20The%20Production%20Tax%20Credit%2C%20and%20International%20Security.pdf .

Lovins, A.B., 2017. Do coal and nuclear generation deserve above-market prices?. *The Electricity Journal*, *30*(6), pp.22-30.

Mattis, J., 2018. *Summary of the 2018 national defense strategy of the United States of America*. Department of Defense Washington United States.

McFarlane, R. 2019. The weaponization of energy. Washington Times February 4, 2019. https://www.washingtontimes.com/news/2019/feb/4/the-weaponization-of-energy/

Nawaguna, E. 2019. This Democrat seeks GOP support with new climate action plan. Roll Call March 21, 2019. https://www.rollcall.com/news/congress/democrat-tonko-seeks-gop-support-new-climate-action-plan

Pyper, J. 2018. Fossil Fuels Won't Go Away, Even if the Energy Transition Accelerates. Greentech Media December 3, 2018. https://www.greentechmedia.com/articles/read/woodmac-fossil-fuels-wont-go-away-accelerated-energy-transition#gs.50c2p0

Roberts, D. 2019. The global transition to clean energy explained in 12 charts. Vox June 26, 2019. https://www.vox.com/energy-and-environment/2019/6/18/18681591/renewable-energy-china-solar-pv-jobs

Rosane, O. 2019. America's shift from coal to renewable energy has begun. World Economic Forum July 1, 2019. https://www.weforum.org/agenda/2019/07/renewables-beat-coal-in-the-u-s-for-the-first-time-this-april

Roselund, C. 2019. Solar grew 48x over the last 11 years. What will the next 11 bring? pv magazine March 25, 2019. https://pv-magazine-usa.com/2019/03/25/solar-grew-48x-over-the-last-11-years-what-will-the-next-11-bring/

Ross, C. 2017. The Future of Oil and Gas? Look to the Past. Forbes January 5, 2017. https://www.forbes.com/sites/uhenergy/2017/01/05/the-future-of-oil-and-gas-look-to-the-past/#7a5ae21d7457

Sargent, R. and Fanshaw, B. 2018. Renewables on the Rise 2018: A Decade of Progress Toward a Clean Energy Future. Gordon Weissman Frontier Group for Environment America Research & Policy Center. https://environmentamerica.org/sites/environment/files/reports/AME_Renewables-on-the-Rise_Jul18-Web.pdf

Shellenberger, M., 2017. The Nuclear Option: Renewables Can't Save the Planet-But Uranium Can. *Foreign Aff.*, *96*, p.159.

Sierra Club. 2019. https://www.sierraclub.org/sierra/2016-2-march-april/grapple/keep-it-ground

Smith, G. and Walker, B. 2019. Is 100% renewable energy for the US possible? Yes. Utility Dive January 30, 2019. https://www.utilitydive.com/news/is-100-renewable-energy-for-the-us-possible-yes/547135/

Smyth, H.D., 1956. Nuclear Power and Foreign Policy. *Foreign Aff.*, *35*, p.1.

Smyth, H.D.W., 1946. *Atomic energy for military purposes* (Vol. 1048). Princeton, NJ: Princeton University Press.

Snow, N. 2019. U.S. Sen. Alexander proposes 'New Manhattan Project for clean energy. Oil & Gas Journal March 27, 2019. https://www.ogj.com/general-interest/economics-markets/article/17278759/us-sen-alexander-proposes-new-manhattan-project-for-clean-energy

Sylvia, T. 2019. Solar to overtake wind in corporate renewable procurement. pv magazine August 21, 2019. https://pv-magazine-usa.com/2019/08/21/solar-to-overtake-wind-in-corporate-renewable-procurement/

UNEP. 2017. The Emissions Gap Report 2017: A UN Environment Synthesis Report.

UNFCCC, 2019. Nationally Determined Contributions (NDCs). United Nations Framework Convention on Climate Change and the Conference of the Parties. https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs#eq-1

U.S. Department of Defense (DOD). 2019. Report on Effects of a Changing Climate to the Department of Defense. https://media.defense.gov/2019/Jan/29/2002084200/-1/-1/1/CLIMATE-CHANGE-REPORT-2019.PDF

U.S. EIA. 2019a. Monthly Energy Review, August 2019. Table 6.1. Coal Overview. https://www.eia.gov/totalenergy/data/monthly/pdf/sec6_3.pdf

U.S. EIA. 2019b. Electricity Data Browser. Accessed September 22, 2019. https://www.eia.gov/electricity/data/browser/

U.S. EIA. 2019c. Monthly Energy Review, August 2019. Table 11.6 Carbon Dioxide Emissions From Energy Consumption: Electric Power Sector. https://www.eia.gov/totalenergy/data/monthly/pdf/sec11_9.pdf

U.S. EIA. 2019d. Natural gas and wind forecast to be fastest growing sources of U.S. electricity generation. Today in Energy September 17, 2019. https://www.eia.gov/todayinenergy/detail.php?id=41333

U.S. EIA. 2019e. Monthly Energy Review, August 2019. Table 8.1 Nuclear Energy Overview. https://www.eia.gov/totalenergy/data/monthly/pdf/sec8_3.pdf

U.S. House. 2019. Resolution Recognizing the duty of the Federal Government to create a Green New Deal. https://assets.documentcloud.org/documents/5729033/Green-New-Deal-FINAL.pdf

Wanner, 2019. Is exponential growth of solar PV the obvious conclusion? International Energy Agency February 6, 2019. https://www.iea.org/newsroom/news/2019/february/is-exponential-growth-of-solar-pv-the-obvious-conclusion.html

White House, 2015. Findings from Select Federal Reports: The National Security Implications of a Changing Climate. https://obamawhitehouse.archives.gov/sites/default/files/docs/National_Security_Implications_of_Changing_Climate_Final_051915.pdf

White House, 2017. National Security Strategy of the United States of America, December 2017. https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf

David K. Gattie is an Associate Professor of Engineering at the University of Georgia and a Resident Fellow with UGA's Center for International Trade and Security. He has 14 years of private industry experience as an energy services engineer and environmental engineer. His research is in the area of comprehensive energy policy and integrated energy resource planning for the power sector and his current focus is on the national security implications of U.S. nuclear power. He also serves on the Advisory Board for the Energy Policy Institute at Boise State University and on the Advocacy Council for Nuclear Matters.