

The High Cost of Fear

Understanding the Costs and Causes of South Korea's
Proposed Nuclear Energy Phase-Out



By Michael Shellenberger, Mark Nelson, Madi Czerwinski,
Michael Light, John Lindberg, and Minshu Deng

August 2017



**ENVIRONMENTAL
PROGRESS**

NATURE AND PROSPERITY FOR ALL



Cover photo credit: Kenneth Lu/Flickr

Table of Contents

Executive Summary

About the Authors

Introduction

I. South Korea's Proposed Nuclear Phase-out

- A. Political Reform and Democratization
- B. Challenges and Opportunities
 - 1. Methodology
 - 2. Findings

II. Understanding Anti-Nuclear Fear

- A. Why Prosperity Breeds Paranoia
- B. Why Environmentalists Turned Against Nuclear in the 1970s
- C. Foreign Funding and Misinformation in South Korea
- D. The Truth About Fukushima
- E. Fukushima as Panic
- F. Hying Earthquake and Corruption Fears

III. Lessons and Recommendations

- A. Lessons Learned
- B. Recommendations

IV. Appendix A: Environmental Progress Donors

V. Appendix B: Open Letter to President Moon from Climate Scientists and Conservationists

VI. Appendix C: "Why I Changed My Mind about Nuclear Power" by Michael Shellenberger. *Chosun Ilbo*. July 21, 2017.

VII. Appendix D: Supplementary Charts and Figures

Executive Summary

“The High Cost of Fear” uses publicly available data, the best-available peer-reviewed scientific research and simple methods to calculate economic and environmental impacts of a nuclear phase-out in South Korea.

We find a nuclear phase-out would:

- Cost at least \$10 billion per year for additional natural gas purchases alone, the equivalent of 343,000 salaries of jobs paying South Korea’s per capita annual average salary of \$29,125;
- Almost all of the cost would be in the form of payments for fuel, thereby reducing South Korea’s trade surplus;
- Require a significant increase in fossil fuel use given South Korea’s lack of renewable energy resources;
- Increase premature deaths from air pollution by replacing nuclear plants instead of coal plants with natural gas;
- Damage and perhaps destroy South Korea’s lucrative nuclear export business;
- If measured against the average U.S. car mileage, it would increase carbon emissions the equivalent of adding 1500 - 2700 million U.S. cars to the road, an amount that would prevent South Korea from achieving its Paris climate commitments.

“High Cost” also examines the historical and sociological drivers of the proposed nuclear phase-out and finds:

- Anti-nuclear misinformation stems from well-funded foreign organizations, particularly Greenpeace and Friends of the Earth, which oppose cheap and abundant energy;
- Arrogance and fear of public panic by the nuclear industry were primary causes of the Fukushima accident and its aftermath;
- Anti-nuclear attitudes and concerns are reflected in a lack of South Korean trust in industry and government, as well as a lack of understanding of nuclear and radiation;
- Anti-nuclear advocates used Fukushima to exaggerate the seriousness of South Korea's 2014 paperwork falsification scandal, which demonstrated the

independence of South Korea's regulator, as well as the 2016 earthquake, which was 350,000 times less powerful than the 2011 earthquake that resulted in the tsunami and meltdowns.

"High Cost" points to the following lessons to be learned from the backlash to nuclear in South Korea and other nations:

- No nation — even energy-poor ones, like South Korea and France — is immune to the war on nuclear, which is the ultimate factor driving the decline of nuclear energy globally;
- The nuclear industry, governments, and the UN IAEA are unable to protect and expand nuclear energy — in South Korea and in much of the rest of the world — for cultural, pecuniary and institutional reasons;
- A new vision, new institutions and new leadership are required to save and expand nuclear;
- Nuclear's radical vision and foundational moral purpose must be revitalized as atomic humanism;
- New institutions — such as science associations, universities, private philanthropies and NGOs — must be supported to defend nuclear and engage the public;
- Nations must overcome fears by standing up to nuclear fear-mongering and learning from successful efforts to reduce public fears.

About the Authors



Michael Shellenberger is a *Time Magazine* "Hero of the Environment" and Green Book Award-winning author and policy expert.

Michael is co-author of visionary books and essays including "The Death of Environmentalism;" *Break Through, An Ecomodernist Manifesto*; "Evolve;" and *Love Your Monsters*, and has been featured in publications ranging from *Scientific American* to *Nature Energy* and *PLOS Biology* to the *New York Times*, *Washington Post* and *Wall Street Journal*.

Michael made the intertwined moral and scientific case for energy and environmental justice in "An Ecomodernist Manifesto," written with 17 other leading scholars and scientists, in "Why Energy Transitions are the Key to Environmental Progress," coauthored with Rachel Pritzker and in the TEDx talk, "How Humans Save Nature."

Michael is a leading pro-nuclear environmentalist. He was featured in "Pandora's Promise," an award-winning film about environmentalists who changed their minds about nuclear, appeared on "The Colbert Report," and debated nuclear on CNN's "Crossfire" with Ralph Nader and at UCLA with Mark Jacobsen. His 2016 TED talk is on "How Fear of Nuclear Hurts the Environment."

Michael's 2007 book with Ted Nordhaus, *Break Through*, was called "prescient" by *Time* and "the best thing to happen to environmentalism since Rachel Carson's *Silent Spring*" by *Wired Magazine*. Michael is co-founder and Senior Fellow at Breakthrough Institute, where he was president from 2003 - 2015 and is an advisor to MIT's "Future of Nuclear Energy" task force.

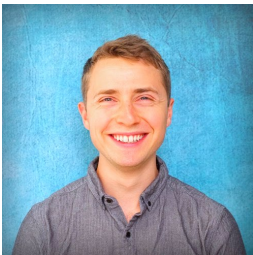
Michael has been an environmental and social justice advocate for over 25 years. In the 1990s Michael helped save an old-growth redwood forest and helped force Nike to improve factory conditions in Asia. In the 2000s, Michael advocated for and helped realize an expansion of federal investment in renewables and energy efficiency.



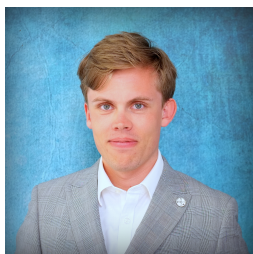
Mark Nelson, Senior Analyst, Environmental Progress. Mark created and manages EP's Energy Progress Tracker, the most comprehensive review of nuclear power plants planned, under construction and at-risk of premature closure around the world.



Madison Czerwinski, Senior Researcher, Environmental Progress. Madi oversees EP's historical, qualitative and quantitative research into the factors driving the construction and cancellation of nuclear power plants.



Michael Light, Senior Researcher, Environmental Progress. Michael is an investigative journalist and reporter who oversees EP's reporting and publications strategy.



John Lindberg, Research Fellow, Environmental Progress. John is an expert on radiation and European energy politics. He spent three years as a policy adviser in the Scottish Parliament, and extensively researches public acceptance and perceptions of nuclear energy.



Minshu Deng, Executive Vice President, Environmental Progress. An environmental scientist and science writer, Minshu oversees all of EP's research, engagement and advocacy efforts.

Introduction

Over the next several months, South Koreans will debate whether to phase out domestic nuclear energy. As an independent, not-for-profit organization, Environmental Progress (EP) is publishing this report to support public engagement and understanding of a proposed nuclear phase-out.¹

EP views nuclear energy as essential to achieving our mission to lift all humans out of poverty while reversing humankind's negative environmental impact. Our view of nuclear's environmental benefits is shared by the United Nations Intergovernmental Panel on Climate Change (IPCC)², the International Energy Agency (IEA)³, top conservation leaders and the world's leading climate scientists.⁴ But whatever decision South Korea makes, we hope it is informed by a strong understanding of basic energy realities.

EP and I have more than a passing interest in South Korea. My wife is Korean-American and I have come to respect the difficult climb out of poverty made by her parents and other Koreans. Cheap nuclear energy was a critical driver of that climb out of poverty. Today, South Korea is one of the few nations in the world that has mastered the art of cost-effective nuclear plant construction – a potentially lucrative export industry that was aided by South Korea's successful bid for the construction of a new nuclear plant in the United Arab Emirates.

I travelled to South Korea last April and again in July to interview more than two dozen individuals, often at length, including students, taxi drivers, industry executives, university professors, public opinion researchers, safety regulators, journalists and diplomats about what they thought of the proposal to phase out nuclear.

¹ EP is entirely supported by individuals and foundations with no interest in our research. In service to transparency, we publicly list all our donors on our website: "Why, What & How." <http://www.environmentalprogress.org/why-what-how/>

² In its 2014 report, the IPCC concluded, "Achieving deep cuts [in greenhouse gas (GHG) emissions] will require more intensive use of low-GHG technologies such as renewable energy, nuclear energy, and CCS [carbon capture & storage]."

³ In a January 2015 news release, the IEA identified nuclear power as "a critical element in limiting greenhouse gas emissions." See "Taking a fresh look at the future of nuclear power" (2015). Available at: <https://www.iea.org/newsroom/news/2015/january/taking-a-fresh-look-at-the-future-of-nuclear-power.html>

⁴ EP has over the last several years supported a growing number of climate scientists to advocate for nuclear energy including James Hansen, Kerry Emanuel, Ken Caldeira, Pushker Kharecha and Tom Wigley among others.

The vast majority of non-experts said they knew little of the nuclear phase-out proposal. Several repeated misinformation about nuclear accidents, waste and renewables, while others asked me my opinion, including why I thought the government was seeking a nuclear phase-out.⁵

As such, this report sets out to do three things:

1. Calculate, quantify and better specify likely economic and environmental impacts of a nuclear phase-out.
2. Understand why South Korean leaders are pursuing a solution that will result in more expensive energy, more air pollution and fewer jobs and/or lower salaries.
3. Draw lessons from the anti-nuclear backlash and offer recommendations for addressing it.

In the end, gaining an understanding of our fears is inevitably a process of understanding ourselves – one that holds the promise of freeing all of us from irrational and self-destructive impulses. We hope this report contributes to that goal of collective liberation. We all have much to gain, or lose.

– Michael Shellenberger, President

⁵ For discussion see Shellenberger, M. 2017. "Greenpeace's Dirty War on Clean Energy, Part I: South Korea Version." Available at: <http://www.environmentalprogress.org/big-news/2017/7/25/greenpeaces-dirty-war-on-clean-energy-part-i-south-korean-version>

I. South Korea's Proposed Nuclear Energy Phase-out

A. Political Reform and Democratization

Since the end of the Korean civil war in 1953, South Korea has alternated between periods of democratic reform and a reversion to tradition. In 1987, South Koreans approved through national referendum a new constitution that allowed direct elections, including that of the president. Even so, successive South Korean governments have left a significant amount of policymaking to government experts, kept electricity production in the hands of the state-owned utility and contracted with well-connected *chaebol* firms.

With the election of President Moon Jae-in, South Korea has entered a new era of democratization and reform. With the older regime discredited by a major corruption scandal involving Korea's *chaebol* corporate conglomerates and former President Park Geun-hye, Moon was elected on a broad mandate to end corruption and open up the government and economy to new entrants. Since taking office, Moon has overseen a broad reform agenda that includes public involvement in key decisions, including the future of South Korean energy.

Shortly after taking office, President Moon temporarily halted construction of two nuclear reactors, Shin Kori-5 and Shin Kori-6, near Ulsan, which had been authorized by the previous government. A citizen's jury selected by newly elected President Moon will decide whether to permanently halt construction Shin Kori-5 and Shin Kori-6. That decision is widely viewed within South Korea and abroad as a kind of referendum on South Korea's energy future.

The South Korean backlash against nuclear began with the 2011 accident at Fukushima Daiichi in Japan. There, three reactors melted down triggering hydrogen gas explosions and the release of radioactive particles. A total of 164,865 people were evacuated⁶ resulting in the deaths of more than 1,600 people.⁷

Support for nuclear energy among Koreans was relatively high until Fukushima. In 2010, 71 percent of the public said nuclear energy was safe, but in 2011 only 35

⁶ Kunii et al. 2016. "Severe Psychological Distress of Evacuees in Evacuation Zone Caused by the Fukushima Daiichi Nuclear Power Plant Accident: The Fukushima Health Management Survey." *PLoS ONE* 11(7)

⁷ 2014. "Fukushima stress deaths top 3/11 toll." *The Japan Times*. Available at: <http://www.japantimes.co.jp/news/2014/02/20/national/post-quake-illnesses-kill-more-in-fukushima-than-2011-disaster/>

percent did.⁸ In 2009, 51 percent of respondents said they favored building more nuclear plants. By 2015, that number had dropped to 30 percent.⁹

Between 2012 and 2014, paperwork certifying the quality of parts used in several nuclear plants was discovered to be falsified, undermining public confidence in the state-owned nuclear plants. Government officials then discovered that documents of tests on components at 20 reactors had been forged. Eventually, thousands of forged documents were uncovered,¹⁰ resulting in 100 indictments of employees including the Vice President of KEPCO.^{11,12}

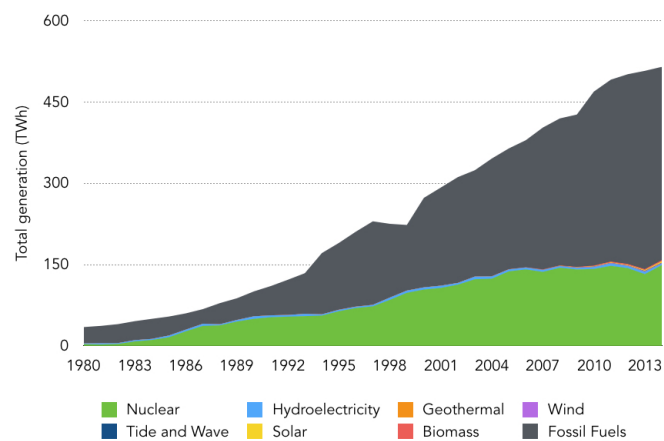
Finally, in 2016, an earthquake off the coast of North Gyeongsang Province surprised citizens by breaking the historical record for largest earthquake in the country and thus undermined the credibility of government experts while frightening local residents.

In response, President Moon campaigned for the phase-out of both nuclear power and coal plants – and for the transition toward renewables like solar and wind, as well as greater energy efficiency.

B. Challenges and Opportunities

In 2014, fossil fuels accounted for 69 percent of South Korea's

South Korea's electricity mix, 1980 - 2014



Source: U.S. Energy Information Administration

⁸ Cho, M. 7 Jan, 2013. "South Korea to Expand Nuclear Energy despite Growing Safety Fears." *Reuters*. Available at: www.reuters.com/article/us-nuclear-korea-idUSBRE90704D20130108.

⁹ Dalton, T. and Cha, M. 2016. "South Korea's Nuclear Energy Future." *The Diplomat*. Available at: thediplomat.com/2016/02/south-koreas-nuclear-energy-future/.

¹⁰ "CFSI (Counterfeit, Fraudulent, Suspect Item) Investigation." Korea Institute of Nuclear Safety. Available at: www.kins.re.kr/en/ourwork/cfsi.jsp.

¹¹ July, 2017. "Nuclear Power in South Korea. World Nuclear Association." World Nuclear Association. Available at: www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx.

¹² Sang-Hun Cho. August 3, 2013. "Scandal in South Korea Over Nuclear Revelations." *The New York Times*. Available at: <http://www.nytimes.com/2013/08/04/world/asia/scandal-in-south-korea-over-nuclear-revelations.html?mcubz=0>.

electricity mix. And the share of South Korea's electricity coming from fossil fuels has been steadily on the rise since 1980, while the share of electricity from clean sources has been declining since the 1990s. Over the last decade, South Korea has already seen its reliance on coal increase to 40 percent as nuclear's contribution to its electricity mix fell from 40 percent to 30 percent.¹³

Nuclear power currently accounts for 96 percent of clean electricity. Solar and wind, by contrast, provide just one and 0.35 percent, respectively, of South Korea's electricity.

While South Korea is committed to generating more of its electricity from solar and wind, geography, cost and reliability pose significant barriers. South Korean solar resources are poor, and land scarce. KEPCO's own figures indicate that the current cost of electricity produced from wind and solar is 2.3 times more expensive than nuclear, after including nuclear decommissioning and spent fuel management. Moreover, since solar and wind in South Korea generate electricity at just 10 to 30 percent of their rated capacity over the course of a year, even a vast fleet would require the burning of coal or natural gas in the times of the day or seasons when the sun isn't shining or the wind isn't blowing.

In response to these challenges, advocates of a nuclear phase-out point to the large deployment of renewables in places like California and Germany, which are phasing out their nuclear plants; to Japan's significant reduction of energy consumption through energy efficiency; and to the rapidly declining cost of lithium batteries for storage.

But each example raises more challenges than it answers. Both Germany and California have seen their emissions rise in recent years, despite deploying record-levels of solar and wind, since both require the increased use of coal or natural gas as their nuclear plants closed and economic growth occurred off-grid with cheap liquid fossil fuels. Japan indeed reduced its overall electricity consumption but saw its fossil fuel combustion and emissions rise significantly since shuttering its nuclear plants.

And while lithium batteries have become cheaper, they are unable to store large quantities of electricity over several months except at extreme cost. In addition, lithium batteries would help coal or nuclear plants run more constantly, increasing the

¹³Harris, B., and Buseong, K. 2017. "South Korea joins ranks of world's most polluted countries." *Financial Times*. Available at: www.ft.com/content/b49a9878-141b-11e7-80f4-13e067d5072c.

demand for their operation; if nuclear plants were removed while batteries were added to the grid, coal consumption would increase.¹⁴

C. Economic and Environmental Costs of a Nuclear Phase-Out

1. Methodology

Environmental Progress has made a set of simple, easy-to-reproduce economic and environmental calculations without use of any modeling. We chose this method for several reasons.

First, simpler calculations make obvious the basic assumptions and are easier to replicate. Because claims made by private-sector energy promoters are often exaggerated, policymakers, journalists and the public are rightly skeptical of economic and environmental claims. As such, we have created calculations that any South Korean citizen with a basic understanding of arithmetic can complete.

Second, no modeling is required to understand the broad impact a given set of policies would have on the economy and the environment. While some econometric studies are useful for calculating impacts on jobs, too often they rely on unwarranted assumptions that are often hidden behind unnecessary complexity.

Third, and finally, modeling too often creates a feeling of "false precision," which serves to both mask uncertainties and distract from well-established facts, such as that replacing nuclear with fossil fuels and renewables *must* increase pollution, and that raising energy prices *must* result in slower growth, lower wages and/or job loss.

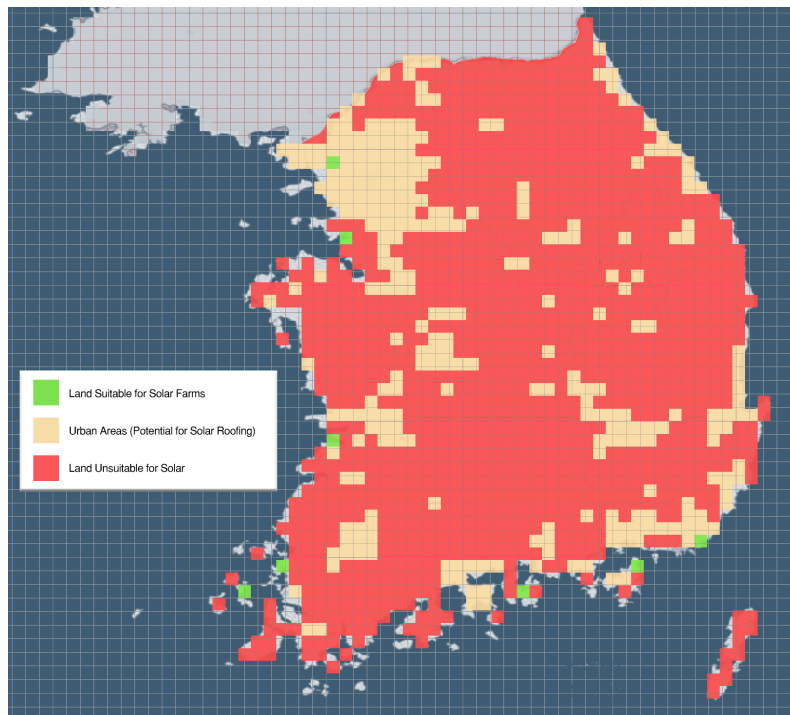
2. Findings

1. Coal and natural gas, not solar and wind, are the most likely replacements for nuclear.

Replacing nuclear with solar and wind would require a prohibitively large amount of land and investment to be feasible. For South Korea to replace all of its nuclear plants with solar, it would need to build 6,400 solar farms the size of one of the country's largest, Sinan, which would cost around \$400 billion and cover an area seven times

¹⁴ For an example of this effect in the U.S., see Hittinger, E., and Azevedo, I. January 28, 2015. "Bulk Energy Storage Increases United States Electricity System Emissions." *Environmental Science and Technology*, 49 (5). p. 3203-3210. Available at: <http://pubs.acs.org/doi/abs/10.1021/es505027p>.

larger than Seoul.^{15,16} To do the same with wind¹⁷ would require \$170 billion and cover an area 19 times larger than Seoul.



¹⁵ When referring to solar farms, a Sinan Solar Farm equivalent is used, with 24 MW capacity, 35,000 MWh generation and 670,000 m² area based on information from Conergy, Sinan's builder, in a report [http://asia.conergy.com/wp-content/uploads/2016/05/SinAn_LR.pdf]. For the construction of these future solar projects, similar costs as estimated for the U.S. are assumed, with an overnight capital cost of \$2,388 USD per kW capacity, from the US Energy Information Administration (EIA) [https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf]. Compared to these costs for the U.S., South Korean labor is likely to be cheaper but land more expensive. Overall 2016 solar electricity generation data [<http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>].

¹⁶ When using this information to quantify replacing current Korean nuclear electricity, the nuclear capacity data refers to currently operating and under-construction reactors from IAEA's Power Reactor Information System database [<https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=KR>] in addition to the Shin Kori units 5 and 6. An 87 percent capacity factor [<https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=KR>] was used for the South Korean nuclear fleet referenced. The area of Seoul used for comparison was assumed to be 605.2 km².

¹⁷ When referring to wind turbines, a 5MW equivalent is used, assuming a 27.6 percent capacity factor [<http://www.mdpi.com/journal/energies>]. For the construction of these wind turbines we assumed a capital overnight cost of \$1,861 USD per kilowatt-electric of capacity [https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf]. The required land area per 5MW wind turbine in Korea is calculated using average wind speeds of approximately 6 m/s in South Korea [<http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>].

The map of South Korea above shows the general suitability of the country's land for vast increases of solar panel areas, based on land use.¹⁸ Only eight out of the more than 1,000 ten kilometer-by-ten kilometer squares is predominantly suitable for extremely large solar projects. Of course, solar farms can be and in fact are today built in areas designated on this map as "unsuitable", but these farms in South Korea today require the loss of fertile farmland or cutting down of wooded areas. The country's largest current farm, Yeongwol, is cut directly into formerly forested mountaintops in Gangwon province.¹⁹ A substantial area of South Korea is considered urban land and thus could integrate solar energy production with rooftop panels, but urban solar generally has much low capacity factors than utility-scale solar.

Replacing Korea's nuclear electricity would require either:



*5MW turbine, 25% capacity factor
 †5inAn solar farm equivalents

Sources: Conergy, RVO, IAEA

Wind power expansion would experience different but comparable space constraints. Kima et. al. (2014) find that land where the "minimum feasibility for building wind is

¹⁸ The data, obtained from the Land and Water Division of Food and Agriculture Organization, divided land into eight major categories: forest, grasslands, shrubs, agriculture, urban land, wetlands, sparsely vegetated areas and bare areas. Most of these categories were further divided based on livestock density, agricultural activity and government protection. Each square in the grid represents a 10 KM by 10 KM area of land. Forests, wetlands and agricultural land are in this map deemed unsuitable sites for large contiguous solar farms, as construction would require significant ecological damage or loss of food production capability. Any protected land or land with moderate or high livestock density is removed from the possibility of solar expansion for the same two reasons. Any grasslands, shrubby land, sparsely vegetated areas or bare areas that are unmanaged or have low livestock density are left as possible solar-farm-suitable land. Urban land is denoted in orange. Uncolored areas, particularly on small islands and the coast, did not have land use data available and are not included in this analysis.

¹⁹ See the location in satellite imagery on Google Maps [<https://goo.gl/maps/vzaudDweSK72>]

assured" only constitutes about 20 percent of the total area of South Korea.²⁰ The authors find that wind power plants on this land would correspond to a theoretical potential of only 41 GW of capacity, and this is calculated based on weak environmental regulations, which, they note, if strengthened would further limit this theoretical capacity. Additionally, the areas of South Korea that experience the greatest wind power density are relatively far from the most dense clusters of power substations. The need for further transmission lines would further increase both land consumption and the visual presence of a large wind turbine capacity expansion.

Currently, rural opposition to wind and solar farms is considered a limiting factor by the South Korean government in expanding beyond current low installed capacity of wind and solar. And the high cost of electricity storage and maintaining back-up fossil energy generation would add up significantly only after the initial stages of expansion are surpassed.

The recent experience of Germany underscores the unreliability of national solar and wind fleets. Germany installed 1.5 GW (3.9 percent) more solar panel capacity but got 1.2 TWh (3 percent) less electricity from solar in 2016 because it was less sunny than in 2015. And Germany installed 5 GW (11 percent) more wind turbine capacity but electricity from wind decreased 1.4 TWh (2 percent) because it was less windy than 2015.²¹

In recognition of these realities, President Moon has already called for importing Russian gas through a new pipeline he hopes to build through North Korea, and importing liquified natural gas (LNG) from the United States.^{22,23}

²⁰ Kima, H., Kanga, Y., Hwanga, H., & Yuna, C. 2014. "Evaluation of Inland Wind Resource Potential of South Korea According to Environmental Conservation Value Assessment." *Energy Procedia* 57, p. 773 - 781.

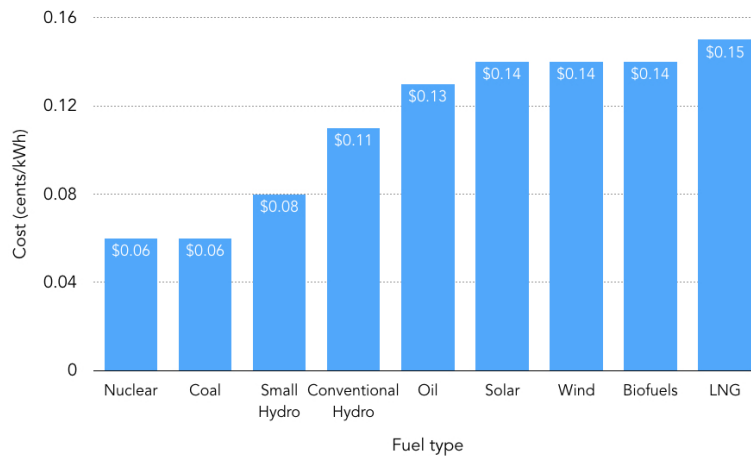
²¹ Nelson, M. and Deng, M. June 17, 2017. "Germany." Available at: <http://www.environmentalprogress.org/germany/>.

²² Adams, R. 2017. "Moon Jae-in Making Friends By Importing More Gas." *Forbes*. Available at: <https://www.forbes.com/sites/rodadams/2017/07/12/geopolitical-advantages-of-moon-jae-in-plan-to-increase-south-koreas-natural-gas-consumption/#78686ec014df>.

²³ Collins, R. 2017. "South Korea Is Very, Very Interested in U.S. Natural Gas." *Bloomberg*. Available at: <https://www.bloomberg.com/news/articles/2017-06-30/south-korea-is-very-very-interested-in-america-s-natural-gas>.

2. Replacing nuclear with natural gas would cost \$10 - \$15 billion annually, immediately, with long-term losses higher and unknown.

Average Cost of Korean Electricity by Fuel Type, 2015



Source and notes: KHNP Korea Electric Power Statistics. Values converted from South Korean Wons to US Dollars using a conversion factor of 0.00089. The 2015 average includes the cost of decommissioning and spent fuel management which was not included prior to 2015.

Replacing South Korea’s nuclear plants with natural gas would require a \$27 billion up-front investment in natural gas combustion turbine plants and \$10.3 billion per year at current low LNG prices to pay for gas imports.^{24,25,26}

²⁴ For cost of imported natural gas, the price of imported liquefied natural gas in Japan in 2016 is used. The figure comes from BP Statistical Review 2017, and is \$6.94 per million BTU (British Thermal Unit) [<http://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-natural-gas.pdf>]. The U.S. Energy Information Agency’s outlook for the assumed heat rate of new combined-cycle gas turbines of 6,600 BTU per kWh is followed [<https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=KR>].

²⁵ Korean nuclear energy generation to be replaced with natural gas derived from the capacity of currently operating and under-construction reactors from IAEA’s Power Reactor Information System database in addition to the Shin Kori units 5 and 6, whose work has presently been halted by the new administration, assuming an 88 percent capacity factor for all plants in line with the average of the last five years of Korean nuclear plant capacity factors [<https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=KR>].

²⁶ The overnight capital cost to build replacement natural gas turbine plants assumes a capital cost of \$923 USD per kilowatt-electric of capacity [https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf], under the conservative assumption that new Combined Cycle Gas Turbine (CCGT) plants will have the same 87 percent capacity factor [<https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=KR>] of the nuclear plants being replaced. All nuclear capacity is replaced one-to-one by natural gas turbine capacity is assumed, with nuclear capacity including all Korean operating and under-construction reactors in addition to Shin Kori Units 5 and 6.

If that \$10 billion were instead spent on direct job creation to reduce youth unemployment – currently the highest among all age groups at 10 percent – the number of unemployed South Koreans between the ages of 15 - 29 could be reduced from 980,000 to 640,000 with salaries at the national average.²⁷ Even if the overhead cost of administering the new jobs was 50% of the amount of average salary, this would amount to an unemployment reduction from 980,000 to 751,000.

However the actual economic value lost or created by using gas or nuclear would be higher given the indirect impact of electricity costs on jobs and the loss of a valuable export industry. A study from the Institute of Energy Economics, Japan, found that the net GDP increase from producing electricity from Japan's idle nuclear reactors instead of from imported fossil fuels was 50 percent higher than the cost alone paid for the imported fossil fuels.²⁸ As such, the immediate marginal cost to the economy of replacing nuclear with natural gas could be closer to \$15 billion annually. This number does not include long-term structural changes and losses that would accompany the closure of the nuclear manufacturing and servicing sectors, merely the unavoidable direct fuel substitution costs.

There are uncertainties about which South Koreans would be most harmed by a phase-out of nuclear, and by how much. What is certain, however, is that increases in the cost of electricity and the burning of more fossil fuels would result from a nuclear phase-out.

A large body of economic scholarship finds that any increase in electricity prices in South Korea will result in slower economic growth. One study by two South Korean economists found “a long run bidirectional causal relationship between energy and GDP, and short run unidirectional causality running from energy to GDP.”²⁹ Another study found that from 1970 to 2002, the “increase in electricity consumption directly affects economic growth.” The researcher concluded, “electricity now constitutes a

²⁷ Statistics Korea records age 15-29 unemployment rate of 9.8 percent in 2016 [http://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx_cd=1495]. With a 15-29 population of 10 million, about 980,000 youth are unemployed [<http://databank.worldbank.org/data/reports.aspx?source=population-estimates-and-projections&Type=TABLE&preview=on#>]. OECD Stats gives the Korean average salary in 2016 as \$29,125. [<https://stats.oecd.org/>]

²⁸ M. Aoshima et al. 2017. “Economic and Energy Outlook of Japan Through FY 2018”. *Institute of Energy Economics, Japan (IEEJ)* . Available at: <http://eneken.ieej.or.jp/en/press/press170725.pdf>

²⁹ Oh, W., and Lee, K. 2004. “Causal relationship between energy consumption and GDP revisited: the case of Korea 1970-1999.” *Energy economics*, 26(1), p. 51-59.

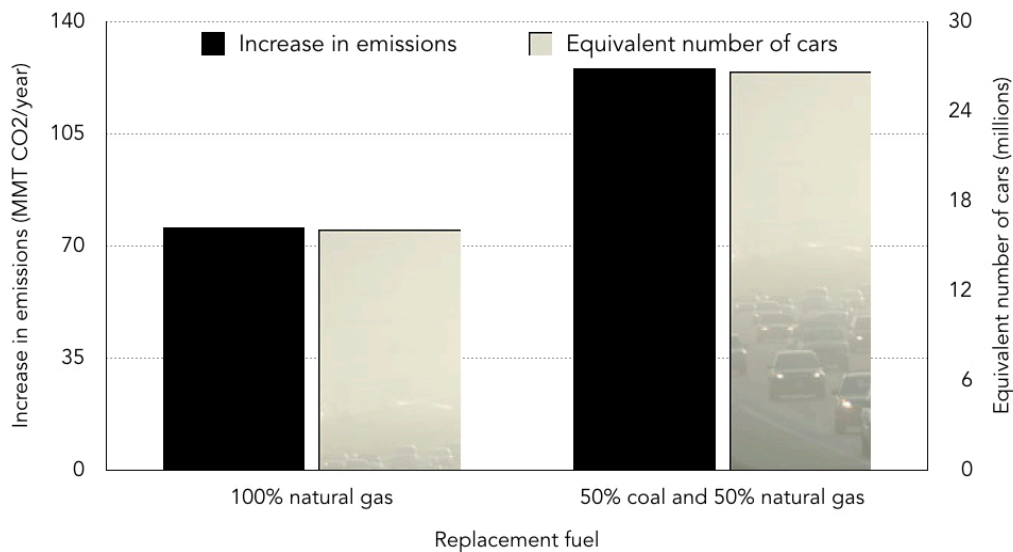
critical factor in sustaining the well-being of the Korean people as well as the nation's economic growth."³⁰

3. Replacing nuclear with natural gas would export at least \$10 billion annually of South Korean wealth abroad compared to keeping nuclear.

Nuclear has been disproportionately responsible for South Korea's development because most of the costs paid for its energy production stays inside the country, in contrast to fossil fuel purchases which strictly benefit other countries and reduce South Korea's trade surplus.

In addition, thanks to its aggressive drive for technology independence and local

Nuclear closure would increase emissions the equivalent of adding 27 million cars to road



Sources and notes: Increase in emissions calculated based on estimated annual generation of all South Korean nuclear reactors using a capacity factor of 0.92. Emissions factors are calculated based on values from the U.S. Energy Information Administration. Calculations of cars added to the road assume an average emissions per passenger vehicle of 4.7 metric tons CO₂ per year, as per the U.S. Environmental Protection Agency. Calculations involving coal emissions factors assume all coal is bituminous.

production of parts and systems for its nuclear sector, South Korea's industries are complementary to the nuclear sector which in turn provides stable, cheap electricity to run those industries.

³⁰ Yoo, S. H. 2005. "Electricity consumption and economic growth: evidence from Korea." *Energy Policy*, 33(12), p. 1627-1632.

South Korea still imports 97 percent of its energy at a cost of \$94 billion annually.³¹ Although public figures for South Korea's nuclear fuel importing costs are not available, published uranium metal, conversion, and enrichment costs³² suggest the cost of imported nuclear fuel and services amount to about half a percent of that total – around \$500 million.³³ The rest of the nuclear sector's needs are provided by South Korean technology, manufacturing and employees.

As such, when South Korea imports coal and natural gas, it is effectively sending most of the fuel costs as profit outside of the country, to American, Canadian, Australian, Qatari, and Russian coal and gas producers. Since South Korea does not produce natural gas, and currently spends about \$500 million importing uranium and services for nuclear fuel per year, the switch would result in a \$10 billion annual reduction in the nation's trade balance.

4. A domestic nuclear phase-out would undermine South Korea's nuclear export ambitions.

South Korea is today a world leader in the export of nuclear technology, with a current \$20 billion contract to build four reactors in the United Arab Emirates. South Korea is one of the few countries in the world that avoids significant delays in new reactor construction, thanks in large part to a workforce with accumulated experiences from continuously building new domestic plants since the 1980s.

If South Korea goes forward with phasing nuclear plants out domestically, Korean companies will be unable to retain construction capabilities. Existing domestic manufacturing capacities of Korean suppliers like KEPCO and Doosan Heavy Industries will be reduced for lack of demand.

³¹ The Observatory of Economic Complexity. (n.d.). Available at: <http://atlas.media.mit.edu/en/profile/country/kor/>

³² Cameco: Uranium Price. (n.d.). Retrieved August 17, 2017. Available at: <https://www.cameco.com/invest/markets/uranium-price>.

³³ The estimated cost of imported uranium for Korean reactors is based on the U.S. Energy Information Administration's (EIA) information about uranium usage for American nuclear reactors. From EIA's figures of 45 million pounds of U₃O₈-equivalent yearly average load in U.S. nuclear reactors in 2015 and 2016, and average 2015-2016 yearly generation of 801.5 TWh, we estimate a consumption of 25.5 tonnes of U₃O₈-equivalent per TWh of nuclear electricity generated in Light Water Reactors. Long term U₃O₈ price as of June 2017 is taken from Cameco. In addition, it is assumed that 800 SWUs is required per tonne of uranium feed, with conversion, enrichment, and natural uranium costs as of July 2017.

We can find no evidence of a nation growing its nuclear export capabilities without maintaining a robust nuclear sector at home. Sweden,³⁴ Germany³⁵ and the United States all saw their shares of the nuclear export market reduced to nonexistence after cutting their domestic nuclear construction programs—Germany's exit from nuclear will cost the country an estimated \$2.15 trillion by 2030 in energy costs while its reactor exports drop to zero.³⁶ No American-owned reactor company has successfully sold and then completed a reactor in a foreign nation since the halt of American reactor expansion in the 1980s. General Electric has sold but not completed two reactors in Taiwan since that time.³⁷

Although KEPCO has earned a reputation for building nuclear power plants, both domestically and abroad, on time and on budget, without a domestic supply chain and, equally importantly, the trust of foreign nations, South Korea will not remain competitive in the global nuclear export market.³⁸

KEPCO is today in the midst of bidding for one of the largest nuclear construction contracts in the world, for three APR1400 reactors at Moorside in the United Kingdom. The contract could be worth \$22 billion provided KEPCO agreed to build the reactors for two-thirds the per-kilowatt cost of EDF's Hinkley Point C. However, KEPCO's ability to complete the project was called into question after President Moon's election, amidst his calls for the domestic nuclear phase-out.³⁹

5. Replacing nuclear plants with natural gas could threaten electrical grid security, stability and reliability.

The recent shutdown of nuclear reactors in Japan and Taiwan has resulted in energy insecurity and grid unreliability. Economists at Japan's leading energy economics

³⁴ World Nuclear Association. June, 2017. "Country Profiles: Sweden." Available at: <http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/sweden.aspx>.

³⁵ Dempsey, J. September 18, 2011. "Siemens Abandoning Nuclear Power Business." *The New York Times*. Available at: <http://www.nytimes.com/2011/09/19/business/global/19iht-siemens19.html>.

³⁶ Steitz, Christoph. January 17, 2012. "Siemens puts cost of nuclear exit at 1.7 trillion euros." *Reuters*. Available at: <http://www.reuters.com/article/us-siemens-energy-idUSTRE80G10920120117>.

³⁷ Environmental Progress analysis of IAEA Power Reactor Information System. Available at: <https://www.iaea.org/PRIS/home.aspx>.

³⁸ Nguyen, Viet Phuong. August 12, 2017. "Lights Out for South Korea's Nuclear Export Ambitions." *The Diplomat*. Available at: <http://thediplomat.com/2017/08/lights-out-for-south-koreas-nuclear-export-ambitions/>.

³⁹ Ward, Andrew. June 28, 2017. "Kepco confirms talks on joining Moorside nuclear project." *Financial Times*. Available at: <https://www.ft.com/content/c4417b54-5c03-11e7-9bc8-8055f264aa8b>.

research organization have priced the direct, immediate link between nuclear plants staying offline and loss of GDP, finding that losing four reactors of the size of South Korea's standard design will lead to \$1.8 billion of increased fossil fuel expenditures for next year alone, and the loss of \$2.7 billion dollars of GDP.⁴⁰ While identifying an exact number is impossible and would create "false precision," some rough estimates are possible.

On 15 August 2017, a mistake at a natural gas plant in Taiwan caused 4.2GW of power to be lost in the country's north, leading to grid failure that affected six million homes and 151 manufacturing companies.⁴¹ Had the Taiwanese government not decided to keep nuclear plants offline in preparation for future decommissioning, 4.8GW of power from three nuclear plants would have been available in the same part of the country as the gas plant failure and prevented the resulting five-hour outage that disrupted both residential electricity access and shut down assembly lines. The incident occurred in the late afternoon, meaning that increased solar energy would not have avoided the blackout.

A transition from nuclear to fossil fuels in South Korea could have similar effects to those observed in Taiwan, but also present reliability concerns unique to the Korean peninsula. Should President Moon's proposed LNG pipeline through North Korea be completed, thereby increasing South Korea's reliance on Russian imports of the fuel, Moscow may gain the kind of leverage it now uses to pressure Ukraine and the rest of Europe for political gain.⁴²

6. Replacing nuclear plants will increase pollution-related illnesses and deaths.

The removal of nuclear plants from the grid would extend the life of coal plants by using limited resources for more expensive natural gas to replace nuclear instead of coal. While many Koreans blame China for Seoul's poor air quality, up to 70 percent of South Korea's PM 2.5 comes from within the country.⁴³ And research shows that Korea's coal-fired power plants, along with diesel-powered vehicles, are to blame for

⁴⁰ M. Aoshima et al. 2017. Economic and Energy Outlook of Japan Through FY 2018. Institute of Energy Economics, Japan (IEEJ) . Available at: <http://eneken.ieej.or.jp/en/press/press170725.pdf>.

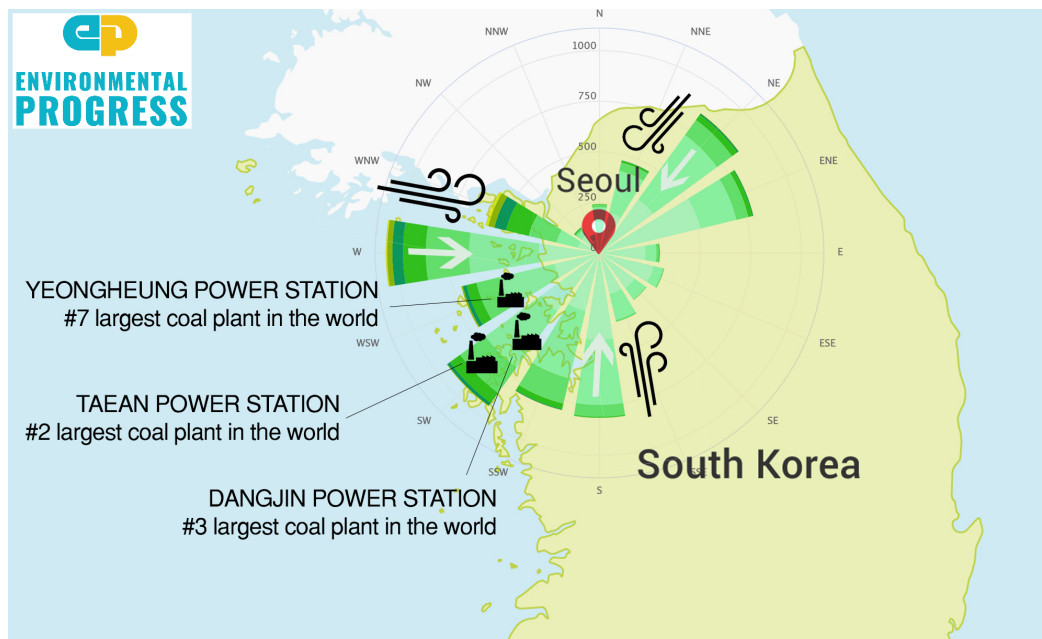
⁴¹ Yu, Jess Macy. August 17, 2017. "Taiwan power outage affected 151 companies, caused \$3 million in damages." *Reuters*. Available at: <http://www.reuters.com/article/us-taiwan-power-outages-idUSKCN1AX0S3?il=0>.

⁴² Henderson, N. 13 October, 2016. "Can America Stop Putin Standing on Europe's Gas Pipe?." *Newsweek*. Available at: <http://www.newsweek.com/can-america-stop-putin-standing-europe-gas-pipe-507287>.

⁴³ South Korea Ministry of Environment. 2016. 미세먼지 발생원 [Fine dust source]. Available at: http://issue.korea.kr/me/finedust/?content_id=46.

the majority of PM 2.5, fine particulate matter, which is the deadliest form of air pollution.

South Korea and Seoul in particular have some of the worst air quality in the world. Yale researchers found that one out of every seven days of the year the air was



"unhealthy for sensitive groups" such as children, the elderly and sick. Three of the world's 10 largest coal plants are located immediately to the city's southwest,⁴⁴ putting over half of South Korea's population in the direct path of prevailing winds⁴⁵ that carry the plants' pollution. None of these plants is set to close under the Moon administration's current energy policy, which has prioritized closing smaller plants.

Today, over 50 percent of all South Koreans are exposed to unsafe levels of air pollution, according to an international study published by Yale University last year.⁴⁶ As such, Seoul's pollution is five times worse than that in Los Angeles.⁴⁷

⁴⁴ Sourcewatch. "Top Ten Largest Coal Plants in the World." http://www.sourcewatch.org/index.php/Top_ten_largest_coal_plants_in_the_world.

⁴⁵ https://www.meteoblue.com/en/weather/forecast/modelclimate/seoul_republic-of-korea_1835848.

⁴⁶ Hsu, A. et al. 2016. "2016 Environmental Performance Index". New Haven, CT: Yale University. Available at: http://epi.yale.edu/sites/default/files/2016EPI_Full_Report_opt.pdf.

⁴⁷ Hu, E. 2016. "Korea's Air Is Dirty, But It's Not All Close-Neighbor China's Fault." *NPR Morning Edition*. Available at: <http://www.npr.org/sections/parallels/2016/06/03/478796463/koreas-air-is-dirty-but-its-not-all-close-neighbor-chinas-fault>.

A separate study found that by 2060 South Korea will have the most deaths from air pollution among the world's wealthiest countries.⁴⁸ And the economic cost of South Korea's air pollution is \$9 billion every year.⁴⁹

7. A nuclear phase-out would increase carbon emissions and prevent South Korea from achieving its Paris climate change targets.

Given the intermittency of solar and wind, and South Korea's land scarcity, replacing the nation's nuclear plants would require a significant increase in coal and/or natural gas, which would increase air pollution in Seoul and prevent South Korea from meeting its Paris climate commitment.

Replacing South Korea's remaining nuclear plants with natural gas would produce carbon pollution the equivalent of adding 27 million U.S. cars to the road.

South Korea has promised to mitigate 314.7 million metric tons of carbon dioxide equivalent by 2030 as part of the 2015 Paris Climate Accord.⁵⁰ Given the high cost of natural gas and renewables though, if South Korea proceeds to replace its nuclear plants, it would likely do so with a mix of coal, natural gas and oil. This would *increase* emissions an amount equivalent to 52 percent of the *reductions* below business-as-usual as required under the Paris Agreement.

The Paris Agreement requires South Korean emissions reductions greater than all of the emissions from the country's electricity. However, a nuclear closure would increase South Korean emissions the equivalent of adding 27 million U.S. cars to the road and greatly hinder any progress towards Paris commitments.⁵¹ The more nuclear

⁴⁸ OECD. 2016. "The Economic Consequences of Outdoor Air Pollution". *OECD Publishing*, Paris. Available at: <http://dx.doi.org/10.1787/9789264257474-en>.

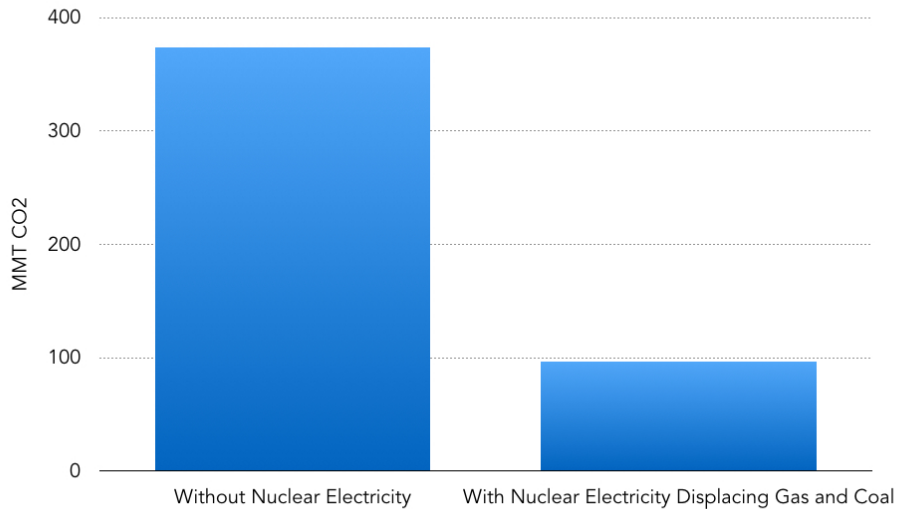
⁴⁹ Harris, B., and Buseong, K. 2017. "South Korea joins ranks of world's most polluted countries." *Financial Times*. Available at: www.ft.com/content/b49a9878-141b-11e7-80f4-13e067d5072c.

⁵⁰ The South Korean Paris climate agreement goals, as well as the nation's 2030 Business As Usual emissions, were stated in the government's Intended Nationally Determined Contributions (INDC) submission to the UN's Framework Convention on Climate Change [(March 2016) Submission by the Republic of Korea: Intended Nationally Determined Contribution. NDC Registry.].

⁵¹ Increase in emissions calculated based on estimated annual generation of all South Korean nuclear reactors using a capacity factor of 0.92. Emissions factors are calculated based on values from the U.S. Energy Information Administration. Calculations of cars added to the road assume an average emissions per passenger vehicle of 4.7 metric tons CO₂ per year, as per the US Environmental Protection Agency. Calculations involving coal emissions factors assume all coal is bituminous.

power that South Korea loses, the more difficult it would become to meet its emissions targets.

Paris climate agreement emissions goals



Source: IAEA, NDC Registry, KEPCO

Moreover, the expansion of renewable energy would require vast amounts of land area and harm the natural environment. Phasing out South Korea’s fossil fuels would require about 7 nuclear power plants or about 9,400 solar farms the size one of South Korea’s largest solar farms. Replacing Korea’s 2016 fossil fuel electricity *and* nuclear electricity would require either about 40,000 wind turbines or 14,000 large solar farms.⁵²

⁵² Korean fossil fuel emissions from the 2016 electricity generation data was calculated by assuming coal, natural gas, and oil emission factors of 900, 370 and 750 grams of carbon dioxide per kilowatt-hour respectively. A weighted, combined emission factor was created using KEPCO 2016 electricity generation data to determine the overall emission increase due to replacing the current nuclear electricity with these fossil fuels if fossil fuel proportions remain constant under nuclear phase-out.

II. The Origins of Anti-Nuclear Fear

A. Why Prosperity Breeds Paranoia

When the Korean civil war came to an end in 1953, the energy-poor nation was forced to look abroad for resources to power its rebuilding and development. It did so primarily with coal and nuclear energy. South Korea "indigenized" Western nuclear technologies and in the process developed its own standard – one it has proved capable of building quickly and efficiently. Cheap, reliable electricity was critical for South Korea to see its per capita GDP rise from \$1,050 in 1977 to \$6,642 in 1990 to \$27,538 in 2016⁵³ – one of the fastest increases in world history.

Today, economists, historians and sociologists broadly agree that South Korea's prosperity was also a result of several critical cultural and institutional factors including protectionist and state-directed industrial policies; strong family ties; a high cultural, familial and national emphasis on higher education; and a strong emphasis on manufacturing for export.^{54,55,56} Like Japan before it and China after, South Korea has gradually risen up the manufacturing food chain from manufacturing simple, low-value goods to more complex, high-value ones including cars, ships, electronics and appliances.^{57,58,59,60}

According to the Economic Complexity Index (ECI), South Korea has the 3rd most-complex economy in the world. Its top industries are those that have a demand for high amounts of absolutely reliable energy, such as integrated circuits, chemicals, and

⁵³ GDP per Capita (Current US\$), South Korea. The World Bank, data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=KR.

⁵⁴ Yi, K. 1976. *A New History of Korea*. Harvard University Press. p. 165. ISBN 9780674615762.

⁵⁵ Lee, Kenneth B. 1997. *Korea and East Asia: The Story of a Phoenix*. Greenwood Publishing Group. p. 72. ISBN 9780275958237.

⁵⁶ Seth, M.J. 2010. *A History of Korea: From Antiquity to the Present*. Rowman & Littlefield Publishers. p. 443. ISBN 9780742567177.

⁵⁷ Chang, H. 2002. *Kicking Away the Ladder: Development Strategy in Historical Perspective*. Anthem Press. ISBN 9781843310273.

⁵⁸ Chang, H. 2002. *Globalization, Economic Development, and the Role of the State (essay collection)*. Zed Books. ISBN 9781842771433.

⁵⁹ Chang, H. and Shin, J. 2003. *Restructuring Korea Inc.* Routledge. ISBN 9781134469383.

⁶⁰ Chang, H. and Jeong, S. 2004. *Kwe-Do Nan-Ma Hankook-Kyungje*. Bookie, Seoul. ISBN 9788985989831.

automobile manufacturing. South Korea's economic success consists of importing raw fuels, metals, and parts, and then transforming these inputs in some of the most complex and organized industrial processes. Almost totally free from natural energy resources, and with a high population density, South Korea's prosperity is highly dependent on its reliable and cheap electricity.

Around the world, rising prosperity sharply reduces many of the risks of poverty, from hunger to violence to infectious disease, allowing populations to worry and even become paranoid about risks that would have seemed trivial in an earlier era, such as a nuclear meltdown. Evidence for this comes from the fact that there was little public concern and no anti-nuclear backlash after either the 1957 accident at Windscale, Britain or the Fermi-I accident in Michigan in 1966, even though both were far more serious than the 1979 Three Mile Island meltdown.⁶¹

Indeed, over the last two decades, and well-before Fukushima, rising prosperity has also brought greater dissatisfaction with South Korea's chaebol system and the source of energy most associated with it: nuclear power. As such, South Korea is following the same pattern as the United States and Europe, which began to turn against nuclear power in the 1970s.

Since the 1960s, social scientists have documented how individuals who express the greatest fear of nuclear are those who express nostalgia for the agrarian past and claim to favor the decentralization of food and energy production, and dislike and do not trust the government, military, scientific and industrial establishments with their larger centralized bureaucracies.⁶² President Moon, environmental activists, and others thus have used Fukushima, the paperwork scandal and the earthquake as part of a larger effort to discredit the *ancient regime*.

While the South Korean experience is unique, it holds many similarities to the backlash to nuclear that occurred in the 1970s in Europe and the United States. Understanding what is different and what is similar may help reveal underlying economic or non-cultural factors behind anti-nuclear ideology.

⁶¹ Goldschmidt, B. 1982. "The Atomic Complex: A Worldwide Political History of Nuclear Energy." *American Nuclear Society*. ISBN: 9780894485510.

⁶²Notably, while anti-nuclear ideology often sits on the left, it can as often sit on the political right. Indeed, extreme libertarianism and extreme egalitarianism often merge in the rejection of large institutions, and both are characterized by what one historian identified as a "paranoid style" of politics.

For discussion, see Douglas, M. and Wildavsky, A., 1982. *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers*. Berkeley: University of California Press.

B. Why Environmentalists Turned Against Nuclear in the 1970s

Public fear of nuclear energy appears natural but has been deliberately promoted since the early 1960s in the United States and Europe to advance what often appears to be unrelated political agendas, such as the subsidization of renewable energy. This history has been well-documented in a series of academic and non-academic texts, including Thomas Wellock's *Critical Masses: Opposition to Nuclear Power in California (1958-1978)*, Christian Joppke's *Mobilizing Against Nuclear Energy: A Comparison of Germany and the United States*, and Robert Wyss' *The Man Who Built the Sierra Club: A Life of David Brower*.^{63,64,65}

Until the early 1970s, environmentalists in the United States and much of Europe were in favor of nuclear power. "Nuclear energy is the only practical alternative that we have to destroying the environment with oil and coal," said famed nature photographer, Ansel Adams, a board member at one of America's largest and oldest environmental groups, the Sierra Club.⁶⁶

The need for nuclear was clear. For example, air pollution in Ohio's cities was so bad that people had to turn on their car headlights during the day to see through the smoke.⁶⁷ On particularly bad days, people had to brush soot off their cars, and re-wash clothes they had hung out to dry. Policymakers agreed something had to be done, and so Ohio's electric utilities sought to build eight reactors across four different nuclear power plants, which do not emit harmful air pollution.⁶⁸

Public health studies concluded that nuclear plants were far safer than coal because they generated no air or water pollution. A study published in 1973 by researchers at

⁶³ Wellock, T. 1998. "Critical Masses: Opposition to Nuclear Power in California, 1958-1978." *University of Wisconsin Press*. ISBN: 9780299158545 p. 85.

⁶⁴ Joppke, C. 1993. "Mobilizing Against Nuclear Energy: A Comparison of Germany and the United States." *University of California Press, Ltd*. ISBN: 0502078136.

⁶⁵ Wyss, R. 2016. "The Man Who Built the Sierra Club: A Life of David Brower." *Columbia University Press*. ISBN: 9780231541312.

⁶⁶ Adams, A. Playboy Magazine interview. May 1983.

⁶⁷ Ohio Environmental Protection Agency, 2012. "Ohio EPA Celebrating 40 Years: Air Quality." Available at: <http://www.epa.ohio.gov/40YearsandMovingForward/AirPollutants.aspx>

⁶⁸ Nunnelee, E. 1985. "Historical Profile of U.S. Nuclear Power Development." *Atomic Industrial Forum, Inc*.

Carnegie Mellon University found that nuclear power generation poses significantly less of a health hazard than coal-fired generation per megawatt of power generated. The researchers concluded that the lower risks of nuclear compared to coal applied to both fuel extraction and power generation processes.⁶⁹

Meanwhile, news stories on the estimated health impacts of coal were featured on the front page of the *New York Times*:

“According to a Congressional estimate made public last month, the number of deaths attributable to pollutants from coal combustion, using 1975 as a base, is 48,120 a year. Should the use of coal rise dramatically over the next decade, as expected, that number was calculated to rise to 55,835.”⁷⁰

The ideologically-motivated backlash to nuclear began in California in the mid-sixties. It was back then that a handful of Sierra Club activists feared “overpopulation” and rising migration into California would destroy the state’s scenic character.

Anti-humanists influenced by the discredited British economist Thomas Malthus attacked nuclear for being a source of inexhaustible, cheap and reliable power. “If a doubling of the state’s population in the next 20 years is to be encouraged by providing the power resources for this growth,” wrote David Brower, Executive Director of the Sierra Club, “the state’s scenic character will be destroyed. More power plants create more industry, that in turn invites greater population density.”⁷¹

The primary fear was not accidents, waste or weapons but rather too many people and over-consumption. “Giving society cheap and abundant energy would be the equivalent of giving an idiot child a machine gun,” said a prominent conservationist. “It’d be little short of disastrous for us to discover a source of cheap, clean and abundant energy because of what we would do with it,” wrote another.⁷²

And, in 1974 – against the wishes of Ansel Adams and the older generation of pro-nuclear conservationists – the Sierra Club began an effort to deliberately alarm the public about nuclear. “Our campaign stressing the hazards of nuclear power will

⁶⁹ Lave, L. B., and Freeburg, L. C. 1973. “Health effects of electricity generation from coal, oil, and nuclear fuel.” *Nuclear safety*, 14(5), p. 409.

⁷⁰ Lyons, R. D. 1979. “Public Fears Over Nuclear Hazards Are Increasing.” *The New York Times*.

⁷¹ Wellock, T. 1998. “Critical Masses: Opposition to Nuclear Power in California, 1958-1978.” *University of Wisconsin Press*. ISBN: 9780299158545 p. 85.

⁷² *Ibid*, p. 88.

supply a rationale for increasing regulation," the executive director wrote in an internal memo to the board of directors, "and add to the cost of the industry..."⁷³

Adherents to these anti-humanistic views acknowledged that they had to frighten the public in order to succeed. "If you're trying to get people aroused about what is going on," said one anti-nuclear leader who was a professor at University of California, Berkeley, "you use the most emotional issue you can find." When asked if he worried about nuclear accidents another anti-nuclear leader replied, "No, I really didn't care because there are too many people anyway."⁷⁴

Anti-nuclear activists especially turned to fictional films to frighten the public. Twelve days before a meltdown at Three Mile Island in Pennsylvania in 1979, Hollywood nuclear disaster movie "China Syndrome" was released in theaters. The accident framed journalist and public perceptions of the accident as catastrophic, even though the most radiation someone standing right at the plant gate received was one-sixth of a chest x-ray.⁷⁵ And the film hammered home the idea that neither the government nor the nuclear industry could be trusted to protect public safety.

And in 2006, a popular 1987 German children's novel – "Die Wolke" – about a nuclear disaster was made into a film, and may have contributed to the cultural climate that led to Germany's decision to close all of its nuclear plants in wake of the Fukushima accident. Like "Pandora" and "China Syndrome," the book and movie depicted a nuclear accident occurring alongside a breakdown of social order and lack of governance.

C. Foreign Funding for Misinformation in South Korea

In 1970, the former Executive Director of the Sierra Club left to found Friends of the Earth, whose top priority was to stop the spread of nuclear energy to poor and developing nations like South Korea, often partnering with Greenpeace.⁷⁶ This effort extends to South Korea. Seeking to exploit the Fukushima accident, Greenpeace

⁷³ Wellock, T. 1998. "Critical Masses: Opposition to Nuclear Power in California, 1958-1978." *University of Wisconsin Press*. ISBN: 9780299158545 p. 85.

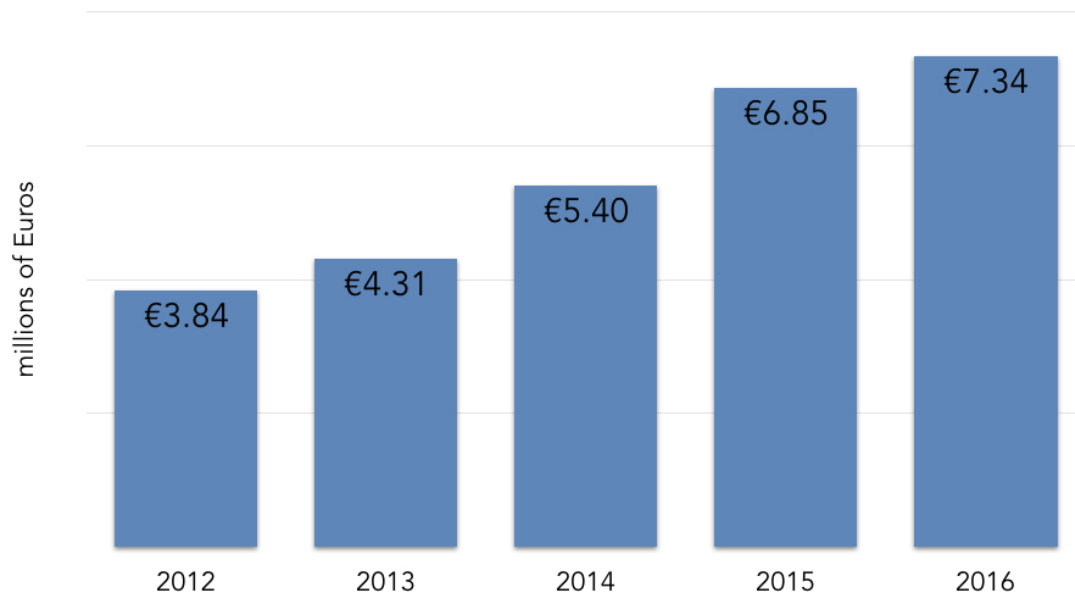
⁷⁴ *Ibid*, p. 83.

⁷⁵ U.S. Nuclear Regulatory Commission, 2013. *Backgrounder on the Three Mile Island Accident*. [Online]. Available at: <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html>.

⁷⁶ Gibson, D. 2002. "Environmentalism: Ideology and Power." *Nova Publishers*. ISBN: 9781590331491 pp. 65.

flooded their East Asian offices and allies with funding, increasing the amount spent there from €3.8 million in 2012 to €7.3 million in 2016.^{77,78}

Direct Funding Given by Greenpeace International to Greenpeace East Asia



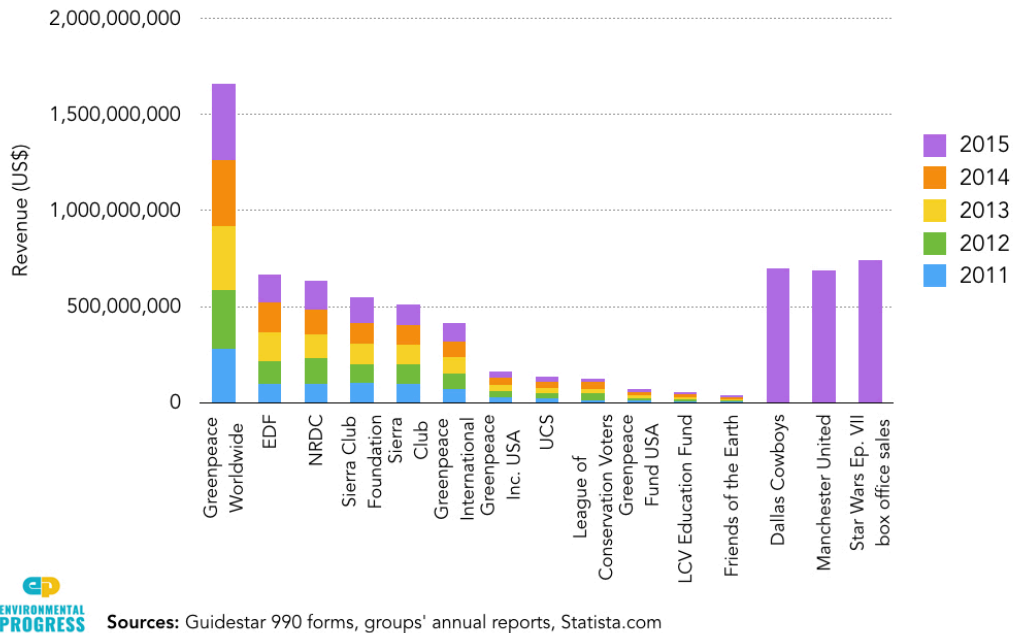
Sources: <http://www.greenpeace.org/international/Global/international/publications/greenpeace/2017/Combined-2016-Yearend-Report.pdf>; <http://www.greenpeace.org/international/Global/international/publications/greenpeace/2016/Combined-2015-Yearend-Report-final.pdf>; <http://www.greenpeace.org/international/Global/international/publications/greenpeace/2015/Combined-2014-Yearend-Report-final.pdf>; <http://www.greenpeace.org/international/Global/international/publications/greenpeace/2014/GPI-Combined-Financial-Statements-2013.pdf>.

The 2016 South Korean “Pandora” terrifyingly depicts a meltdown and hydrogen gas explosion at a Korean nuclear plant, along with many scenes of public panic and the kind of evacuation that resulted in the deaths of 1,600 people in Japan. “Pandora” contains graphic scenes of workers suffering radiation poisoning, a hapless president overwhelmed by shadowy forces, and nostalgic reveries about life when Korea’s small southern towns were dominated by farming, fishing and tourism. The film’s

⁷⁷ Stitching Greenpeace Council and Related Entities Draft Annual Financial Statements 2016. 2016. Greenpeace International. Available at: www.greenpeace.org/international/Global/international/publications/greenpeace/2017/Combined-2016-Yearend-Report.pdf.

⁷⁸Greenpeace International Annual Report 2012. 2013. Greenpeace International. Available at: <http://www.greenpeace.org/international/Global/international/publications/greenpeace/2014/GPI-Combined-Financial-Statements-2013.pdf>.

Annual Revenue for Anti-Nuclear Groups



sophisticated special effects and computer-generated images are equal to anything made by Hollywood.

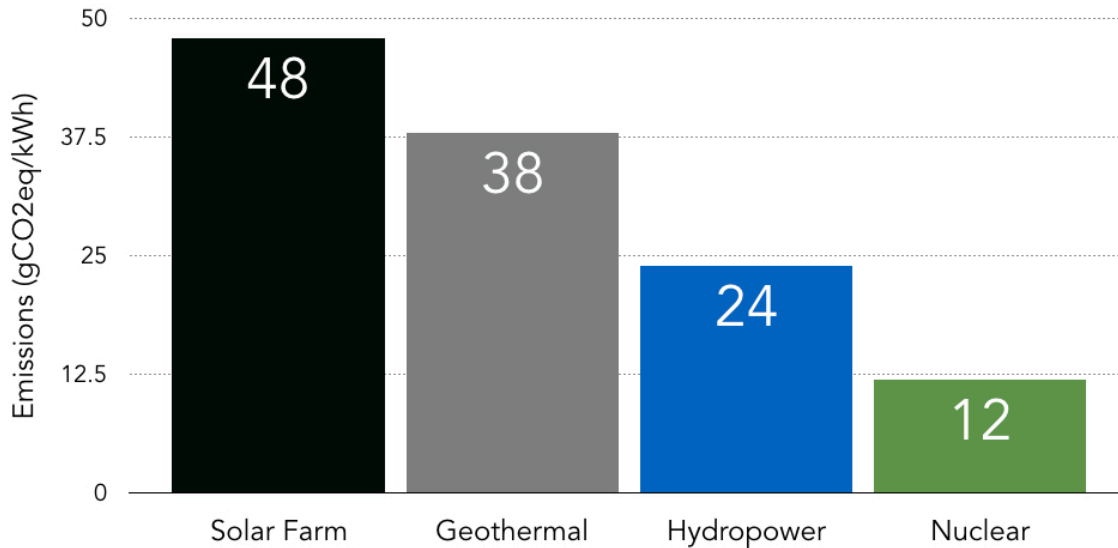
Over five million Koreans, nearly one-fifth of the voting population, viewed “Pandora,” whose release was timed perfectly to influence the nation’s presidential elections.⁷⁹ Greenpeace worked with “Pandora”’s filmmakers to organize screenings with actors from the films, and protests, and filed a large class action lawsuit to halt the construction of new reactors, Kori-5 and Kori-6.

Anti-nuclear advocacy is a big business. Greenpeace International’s annual budget is nearly \$400 million, Friends of the Earth’s worldwide budget is \$12 million, and the Sierra Club’s is well over \$100 million.⁸⁰ Each of the organizations has hundreds of millions of dollars in their bank and stock accounts.

⁷⁹ Greenpeace. 2017. “Concern and hope coexist.” Available at: <http://www.greenpeace.org/korea/news/feature-story/3/2017/nuke-pandora-gv/>.

⁸⁰ Financial information for Sierra Club, Friends of the Earth and Greenpeace was pulled from Guidestar 990 forms and the groups' annual reports. The revenues of the Dallas Cowboys, Manchester United and Star Wars were found on Statista.com.

Solar Produces 4 Times More Pollution Than Nuclear



Source: Intergovernmental Panel on Climate Change (IPCC) 2014

Annex III Table A III.2 :: Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wisser, 2014. "Annex III: Technology-specific cost and performance parameters." In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.



Most anti-nuclear groups receive funding from fossil fuel and renewable energy interests. The Sierra Club⁸¹ famously took \$26 million from natural gas interests and only repudiated it after a few of its members took the story to the media.⁸² And many board members and donors of anti-nuclear groups NRDC⁸³ and ELPC⁸⁴ stand to benefit directly from closing nuclear plants and replacing them with fossil fuels and renewables.

Anti-nuclear efforts seek to frighten people and deny nuclear's well-documented environmental benefits. On July 12, 2017, Korea's KBS News reported that Greenpeace leader Jennifer Morgan claimed that "to make fuels for nuclear plants,

⁸¹ <http://www.environmentalprogress.org/sierra-club/>.

⁸² Mokhiber, R, 2012. "The Sierra Club Took Millions From Fracking Industry." Available at: <https://www.counterpunch.org/2012/02/03/the-sierra-club-took-millions-from-fracking-industry/>.

⁸³ <http://www.environmentalprogress.org/nrdc/>.

⁸⁴ <http://www.environmentalprogress.org/elpc/>.

we have to go through the whole process of uranium mining, transporting, and disposing. Considering this fact, there will be a lot of carbon emissions.”⁸⁵

In fact, according to the IPCC, nuclear energy produces four times less carbon pollution per unit of energy than solar farms, 3.4 times less than solar roofs, three times less than geothermal, and half as much as hydroelectric dams.⁸⁶

Second, Greenpeace’s Morgan told the Korean Herald that Apple, Google and Facebook have committed to sourcing 100 percent of their electricity from renewables.⁸⁷ In reality, Google has said it will consider obtaining some of its electricity from nuclear energy,⁸⁸ and in 2011, two top Google engineers published a startlingly honest account about the company’s failed renewable energy effort.⁸⁹

The two Google engineers concluded, “Trying to combat climate change exclusively with today’s renewable energy technologies simply won’t work; we need a fundamentally different approach.” They called instead for a climate program where the “bulk of resources” is dedicated “to proven technologies” including nuclear.

⁸⁵ Greenpeace Secretary General. 2017. “Korea, energy too inefficient.” *KBS News*. Available at <http://news.kbs.co.kr/news/view.do?ncd=3514678&ref=A>.

⁸⁶ Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014. “Annex III: Technology-specific cost and performance parameters.” *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, U.S..

⁸⁷ The Korea Herald, Jul 13 2017. “Greenpeace encourages South Korea to aim higher at 100% renewable.” Available at: <http://www.koreaherald.com/view.php?ud=20170713000909>.

⁸⁸ Vaughan, A. Dec 6 2016. “Google to be powered 100% by renewable energy from 2017.” *The Guardian*. Available at: <https://www.theguardian.com/environment/2016/dec/06/google-powered-100-renewable-energy-2017>.

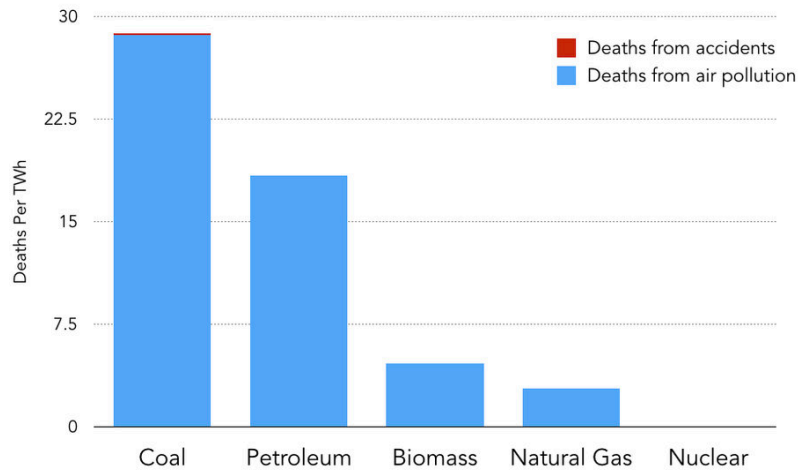
⁸⁹ In 2011, the company decided that [Google’s renewable energy program] RE<C was not on track to meet its target and shut down the initiative. The two of us, who worked as engineers on the internal RE<C projects, were then forced to reexamine our assumptions.

Fork, D., Koningstein, R. 18 November, 2014. “What It Would Really Take to Reverse Climate Change.” *IEEE Spectrum*. <http://spectrum.ieee.org/energy/renewables/what-it-would-really-take-to-reverse-climate-change>.

Third, Greenpeace's Senior Climate & Energy Campaigner at Greenpeace East Asia in Seoul, Daul Jang, claimed, "Nuclear and coal are clearly two of the most unsafe and polluting energy resources."⁹⁰

In truth, according to every major scientific study since the 1970s, *nuclear plants are the safest way to make reliable electricity* – precisely because they emit no air or water pollution.⁹¹

Nuclear is already the safest way to make reliable electricity.



Source: Markandya, A., & Wilkinson, P. 2007. Electricity generation and health. *The Lancet*, 370(9591), 979-990.

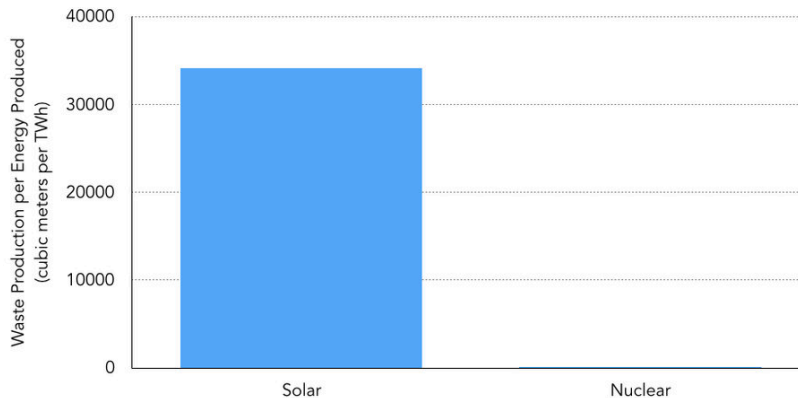
Fourth, Greenpeace and other anti-nuclear groups criticize nuclear "waste" when every other form of waste from energy production – from coal and natural gas to solar panels and wind turbines – produce more toxic waste that poses a far greater threat to humans and the natural environment.

⁹⁰ Greenpeace, June 19 2017. "South Korean President vows to phase out nuclear and coal." Available at <http://www.greenpeace.org/international/en/press/releases/2017/South-Korean-President-vows-to-phase-out-nuclear-and-coal---Greenpeace/>.

⁹¹ Markandya, A., & Wilkinson, P. 2007. "Electricity generation and health." *The Lancet*, 370(9591), 979-990.

For instance, solar panels are unsafe for landfills due to their toxic components⁹². As a result, solar PV usage results in 300 times more⁹³ toxic waste compared to nuclear when producing the same amount of electricity.⁹⁴ Mining and manufacturing impacts

Solar panels produce ~300x more waste than nuclear reactors when providing the same amount of energy.



Sources and Notes:

US GAO, http://www.gao.gov/key_issues/disposal_of_highlevel_nuclear_waste/issue_summary
 World Nuclear Association, <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx>
<http://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-archive/reactor-archive-december-2015.aspx>
 IAEA, <https://www.iaea.org/PRIS/home.aspx>
 BP, <http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>



Solar panels specifications vary. Panel specifications were standardized according to TrinaSolar's Duomax Dual Glass 60-Cell Module: http://static.trinasolar.com/sites/default/files/PS-M-0474%20%20Datasheet_Duomax_PEG5_XX_US_Feb_2017_A.pdf

from wind power contribute to the growth⁹⁵ of an uninhabitable swamp in China, known as Baotou Lake.⁹⁶ And the most urgent waste crisis facing the world today is global warming – the result of carbon dioxide waste emitted by fossil fuels and biomass.

⁹² Silicon Valley Toxics Coalition, 2009. "Toward a Just and Sustainable Solar Energy Industry." Available at: http://svtc.org/wp-content/uploads/Silicon_Valley_Toxics_Coalition_-_Toward_a_Just_and_Sust.pdf.

⁹³ Desai, J., Nelson, M. June 21 2017. "Are we headed for a solar waste crisis?" Available at: <http://www.environmentalprogress.org/big-news/2017/6/21/are-we-headed-for-a-solar-waste-crisis>.

⁹⁴ This calculation assumes that solar panels last 25 years and that a 1 GW reactor produces 27 tonnes of waste annually. Capacity factors for solar PV and nuclear are derived from the 2016 BP Statistical Review of World Energy and IAEA PRIS and are assumed to remain constant over the 25 year period calculated. Solar panel specifications were standardized according to TrinaSolar's Duomax Dual Glass 60-Cell Module.

⁹⁵ Institute for Energy Research. 2013. "Big Wind's Dirty Little Secret: Toxic Lakes and Radioactive Waste." Available at: <http://instituteforenergyresearch.org/analysis/big-winds-dirty-little-secret-rare-earth-minerals/>.

⁹⁶ The Daily Mail, Jan 26 2011. "In China, the true cost of Britain's clean, green wind power experiment: Pollution on a disastrous scale." Available at: <http://www.dailymail.co.uk/home/moslive/article-1350811/In-China-true-cost-Britains-clean-green-wind-power-experiment-Pollution-disastrous-scale.html>.

All of humankind's previous energy transitions, from wood fuels and coal to natural gas and uranium, resulted in what's known as "dematerialization." In other words, the newer fuels produced the same amount of energy while using far less "matter" or natural resources. By contrast, a transition from fossil fuels to solar, wind, biomass or hydro-electricity would require re-materialization – the use of more natural resources – since sunlight, wind, organic matter and water are all far less energy-dense than oil or gas. Basic physics predicts that that re-materialization would significantly increase the environmental effects of generating energy.

Because of its high energy density, uranium's mining impacts are minuscule compared to coal, oil and natural gas. Few material input mean very small amounts of waste output. And, as conservationists from California to Germany have learned, trying to replace nuclear with solar and wind requires 100 to 700 times more land.

Anti-nuclear groups have for 40 years proposed significant reductions in per capita energy consumption, but during that time, *per capita* energy consumption rose in developed and developing nations alike, and for good reason: higher levels of energy consumption allow vastly improved standards of living, and the continuing technological advances that reduce environmental impact.

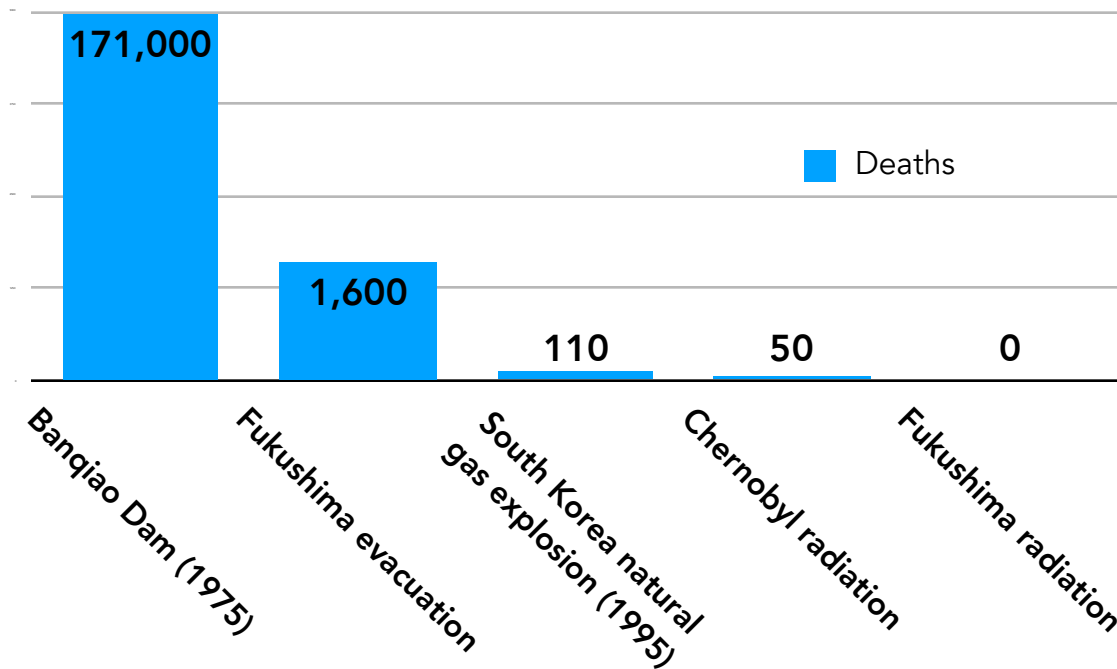
Rising rates of energy consumption are allowing for many forms of dematerialization unimaginable just 10 years ago. Smart phones require modestly more energy to manufacture and operate than older cell phones, but by obviating the need for physical newspapers, books, magazines, cameras, watches, alarm clocks, GPS systems, maps, letters, calendars, address books and stereos. And fertilizers and tractors have dramatically increased agricultural yields and allowed poorer soils to return to grasslands, wetlands and forests, and allowed wildlife to return.

D. The Truth About Fukushima

Fukushima is the proximate cause of South Korea's anti-nuclear backlash, but more than six years after the accident, the science is unequivocal: nobody has gotten sick much less died from the radiation that escaped from three meltdowns followed by three hydrogen gas explosions. And there will be no increase in cancer rates.⁹⁷

⁹⁷ The World Health Organization (WHO) concluded that, "for the general population inside and outside of Japan, the predicted risks are low and no observable increases in cancer rates above baseline rates are anticipated." World Health Organization, 2013. "Global report on Fukushima nuclear accident details health risks." Available at: http://www.who.int/mediacentre/news/releases/2013/fukushima_report_20130228/en/.

Deaths from energy accidents & energy panics



By contrast, the panicked and unnecessarily large over-evacuation took the lives of 1,650 people⁹⁸, most of whom would have lived had the Japanese government followed normal protocols and order residents to “shelter-in-place.”⁹⁹ In 2013, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) concluded that the vast majority of the Fukushima evacuation zone is safe and nearly

⁹⁸ 2014. “Fukushima stress deaths top 3/11 toll.” *The Japan Times*. Available at: <https://www.japantimes.co.jp/news/2014/02/20/national/post-quake-illnesses-kill-more-in-fukushima-than-2011-disaster/#.WZR2d1GGNhE>.

⁹⁹ International Atomic Energy Agency. 2015. *The Fukushima Daiichi Accident*. IAEA: Vienna.

all residents could have returned long ago – indeed, most should never have left.^{100, 101}

There is no evidence of any harm from low doses of radiation and even applying the debunked linear no-threshold (LNT) measure,^{102,103,104,105} the lifetime dose of 150 mSv increases the risk of fatal cancer risk by less than one percent.¹⁰⁶

Even following LNT, more lives would have been saved sheltering-in-place than evacuating. "By avoiding what would have been an average cumulative exposure of 16 mSv," writes radiation expert George Johnson, "the number of cancer deaths prevented was perhaps 160, or 10 percent of the total who died in the evacuation itself."¹⁰⁷

Fukushima and Chernobyl both show that the impacts of nuclear meltdowns on public health is far lower than was predicted in the 1950s. In 1957, in a study for the US Atomic Energy Commission, researchers with Brookhaven National Labs estimated a nuclear meltdown's worse case scenario would be 3,400 immediate deaths from

¹⁰⁰ UNSCEAR calculated radiation doses within the 20-kilometer evacuation zone in the first year after the accident. The highest was in Tomioka township, at 51 mSv, which on the one hand is 25 times higher than areas of Seoul, but still far below many regions of the planet where natural radiation can be up to 200 mSv a year without any increases of cancer. See Ghiassi-nejad, M. et al. 2002. "Very high background radiation areas of Ramsar, Iran: preliminary biological studies." *Health Physics*, 82(1), pp. 87-93.

¹⁰¹ Even more dramatically is the fact that an 80-year lifetime dose – the dose someone who was five years old during the accident would receive by the time she turned 85 – would be just two to three times the first-year dose. That's because radiation levels drop rapidly from weather and radioactive decay. That means the highest dose residents would have received had they lived their whole lives in the evacuation zone was about 100-150 mSv in the most contaminated townships – about the same lifetime background dose of a typical American (2.4 mSv per year). See UNSCEAR. 2014. "SOURCES, EFFECTS AND RISKS OF IONIZING RADIATION." *UNSCEAR 2013 Report*. Volume I. REPORT TO THE GENERAL ASSEMBLY SCIENTIFIC ANNEX A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami." p. 209, pp. C 154.

¹⁰² Calabrese, E. J. 2017. "The threshold vs LNT showdown: Dose rate findings exposed flaws in the LNT model part 1. The Russell-Muller debate." *Environmental Research*, Volume 154, pp. 435-451.

¹⁰³ Calabrese, E. J. and O'Connor, M. K. 2014. "Estimating Risk of Low Radiation Doses – A Critical Review of the BEIR VII Report and its Use of the Linear No-Threshold (LNT) Hypothesis." *Radiation Research*, Volume 182, p. 463-474.

¹⁰⁴ Jaworowski, Z. 2010. "Observations on the Chernobyl Disaster and LNT." *Dose-Response*, Volume 8, p. 148-171.

¹⁰⁵ Socol, Y. et al. 2014. "Commentary: Ethical Issues of Current Health-Protection Policies in Low-Dose Ionizing Radiation". *Dose-Response*, Volume 12, p. 342-348.

¹⁰⁶ Insurance Information Institute. 2015. Mortality Risk. Available at: <http://www.iii.org/fact-statistic/mortality-risk>.

¹⁰⁷ Johnson, G. 2015. "When Radiation Isn't the Real Risk." *The New York Times*. Available at: https://www.nytimes.com/2015/09/22/science/when-radiation-isnt-the-real-risk.html?_r=0.

Acute Radiation Syndrome (ARS) and 43,000 fatal cancers over 50 years – a report that was attacked as too conservative by anti-nuclear groups.¹⁰⁸

But the worst nuclear accident in history, Chernobyl, whose reactor was unshielded and on fire for 14 days, only resulted in the deaths of 28 firefighters, according to the World Health Organization (WHO), “due to [acute radiation syndrome] ARS. [Others] have since died but their deaths could not necessarily be attributed to radiation exposure.” WHO notes that “There may be up to 4,000 additional cancer deaths among the three highest exposed groups over their lifetime,”¹⁰⁹ but population-wide studies and cohort studies show no increase in cancer rates beyond the children affected by highly treatable thyroid cancer – for which there is only a one percent mortality rate.¹¹⁰

As such, even in the worst case scenario – Chernobyl – two orders of magnitude fewer people died from ARS, and one order of magnitude fewer people will die prematurely from cancer, than predicted by Brookhaven.

The real damage is caused by anti-nuclear fear-mongering. The WHO concludes that Fukushima residents have suffered psychological impacts similar to those experienced by residents near Chernobyl – most tragically by children.¹¹¹

E. Fukushima as Panic

On March 3, 2011, a tsunami swept across northern Japan quickly killing an estimated 15,000 individuals, mostly by drowning. This traumatic event undermined public confidence in the ability of the government to protect its people.

This loss of trust quickly extended to the Fukushima Daiichi nuclear accident, which resulted in the melting of three reactors, three hydrogen explosions, and the

¹⁰⁸ U.S. Atomic Energy Commission. 1957. “Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants.” *United States Energy Research and Development Administration*: Oak Ridge, TN.

¹⁰⁹ World Health Organization. 2005. “Chernobyl: the true scale of the accident.” Available at: <http://www.who.int/mediacentre/news/releases/2005/pr38/en/>.

¹¹⁰ United Nations Scientific Committee on the Effects of Atomic Radiation. 2008. “Sources and Effects of Ionizing Radiation, Volume II, Scientific Annexes C, D, and E.”

¹¹¹ World Health Organization. 2015. “Fukushima Five Years On.” Available at: http://www.who.int/ionizing_radiation/a_e/fukushima/faqs-fukushima/en/.

evacuation of 164,865 individuals. Less than 50,000 of them have returned, despite it being safe for all but a very small number of individuals to return.¹¹²

There have been two major independent studies of the Fukushima accident. The first was instigated by the Japanese Diet and led by Dr. Kiyoshi Kurokawa,¹¹³ and the second by the Rebuild Japan Foundation and led by journalist Yoichi Funabashi.¹¹⁴ Both reports conclude the Japanese nuclear industry and government both overconfident in their ability to prevent an accident, and deeply fearful of frightening the public. The two combined to prevent industry and government from implementing adequate safeguards including disaster preparedness.

Exaggerated fears of radiation – and fears by industry and government officials of public fears – led officials to withhold information from the public, and not to prepare for a nuclear accident. “I think we were afraid of a panic,” said an assistant to the prime minister. Government paternalism resulted in officials failing to conduct routine disaster preparedness out of obligation to deliver “peace of mind.”¹¹⁵ And fears of public fears led the industry and government to not upgrade nuclear plants for “fear that any safety improvement would provoke criticism that existing safety provisions and regulations were inadequate...”¹¹⁶

The reports put heavy emphasis on the “micro-management meddling” by former Prime Minister Naoto Kan.¹¹⁷ Kan ordered the operator to reduce the amount of water used for cooling the reactors, delayed venting and expanded the size of the evacuation. “The Prime Minister’s consequential decision to go to the site and give directions not only took the time of the on-site operators, but caused a disruption in the planned chain of command for the nuclear power company, the regulatory agencies, and the Prime Minister’s office,” the Diet investigation concluded.¹¹⁸ After

¹¹² Kunii et al. 2016. “Severe Psychological Distress of Evacuees in Evacuation Zone Caused by the Fukushima Daiichi Nuclear Power Plant Accident: The Fukushima Health Management Survey.” *PLoS ONE* 11(7), e0158821.

¹¹³ Kurokawa, K., et al. 2012. “The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission.” *The National Diet of Japan*: Tokyo.

¹¹⁴ Independent Investigation Commission on the Fukushima Nuclear Accident, 2014. “The Fukushima Daiichi Nuclear Power Station Disaster: Investigating the Myth and Reality”. *Routledge*: London.

¹¹⁵ Funabashi. 2015, p. 79.

¹¹⁶ Funabashi et al. 2015, p. 182.

¹¹⁷ Funabashi, Y. 2015. “Anatomy of the Yoshida Testimony,” *Rebuild Japan*.

¹¹⁸ Kurokawa, K., et al. 2011. “The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission.” *The National Diet of Japan*: Tokyo.

the accident, Kan accused Tepco leadership of proposing to abandon the plant, but Kurokawa et al. rejected this accusation as unfounded, and concluded there was never a plan by plant management nor Tepco headquarter to abandon the plant.¹¹⁹

Funabashi and others describe Kan's behavior as an instance of "elite panic" – when government officials panic in fear of public panic.¹²⁰ "The government basically panicked," explained independent radiation expert and medical doctor, Dr. Mohan Doss. "When you evacuate a hospital intensive care unit, you cannot take patients to a high school and expect them to survive. It was the fear of radiation that ended up killing people."¹²¹

In addition to being an elite panic, Fukushima was also a "moral panic," meaning that the panic was not an instinctual response to fear but rather reflected anxieties broader than the accident itself. Moral panics involve superstitious fears, widespread societal consensus, and the identification of scapegoats.¹²²

Some examples of moral panic include the killing of women healers in 17th century North America for being alleged "witches;" the violence directed toward European Jewry blamed for the Black Death in the 15th Century; and the mass killing of six thousand ethnic Koreans blamed for the 1923 Kanto earthquake. After World War II, many Japanese shunned fellow citizens as "contaminated" for being exposed to radiation from the bombings of Hiroshima and Nagasaki – an eerie foreshadowing of the shunning of Fukushima residents forced to evacuate.¹²³

F. Hying Earthquake and Corruption Fears

Just as past anti-nuclear panics in the United States, Europe and Japan had their origins in declining public confidence in government, South Korea's proposed nuclear phase-out is as much a manifestation of growing dissatisfaction with the Korean chaebol system as it is a reaction to Fukushima.

¹¹⁹ Ibid.

¹²⁰ Funabashi. 2016, p.48.

¹²¹ Johnson, G. 2015. "When Radiation Isn't the Real Risk." *The New York Times*. Available at: https://www.nytimes.com/2015/09/22/science/when-radiation-isnt-the-real-risk.html?_r=0.

¹²² Thompson, W. E. and Gibbs, J. C. 2016. "Deviance and Deviants: A Sociological Approach."

¹²³ Cleveland, K. 2014. "'SIGNIFICANT BREAKING WORSE': The Fukushima Nuclear Crisis as a Moral Panic." *Critical Asian Studies*, 46(3). p. 509-539.

Meltdowns do not in themselves frighten people. What's required is an active effort to make people scared or worried. Evidence for this can be seen with both the document falsification scandal and the earthquake.

The 2014 paperwork scandal demonstrated the independence of the Korean safety regulator, which insisted on the shutdown of reactors even when they were desperately needed to supply electricity during a hot summer. Some reactors equipped with parts involved in the scandal were immediately shut down by the regulator until the affected parts could be stripped out and replaced.¹²⁴ Parts that had been falsely certified were ultimately replaced at a cost in the hundreds of thousands of dollars, and the suppliers as well as senior executives were held accountable.

The Gyeongju earthquake on September 12, 2016 was the most powerful ever recorded in South Korea – but at a rating of 5.4M_w,¹²⁵ it was 350,000 times less powerful¹²⁶ than the Tohoku earthquake in 2011 which caused the tsunami that killed 15,000 people and led to the Fukushima meltdowns.

Moreover, Korea's nuclear plants are designed to withstand earthquakes 250 times more powerful than Gyeongju, while Korean schools, apartment buildings, and other vital infrastructure are not. Korean experts believe that the Gyeongju earthquake was close to the theoretical limit for the power of earthquakes in Korea, as the Yangsan Fault that produced it is unlike the types of faults that produce powerful earthquakes in Japan.¹²⁷

Although anti-nuclear activists seized upon Gyeongju as evidence in support of shutting down Korea's nuclear fleet, nuclear power plants are in reality the most earthquake-resistant buildings in the country.¹²⁸ Moreover, while anti-nuclear misinformation has suggested that the Tohoku earthquake damaged the Fukushima nuclear plants, the truth is that all of Japan's nuclear plants survived the earthquake,

¹²⁴ Korea Institute of Nuclear Safety. "CFSI (Counterfeit, Fraudulent, Suspect Item) Investigation." Available at: www.kins.re.kr/en/ourwork/cfsi.jsp.

¹²⁵ U.S. Geological Survey. "Earthquake Hazards Program." <https://earthquake.usgs.gov/earthquakes/>. Accessed on August 22, 2017.

¹²⁶ U.S. Geological Survey. "How much bigger is a magnitude 8.7 earthquake than a magnitude 5.8 earthquake?" https://earthquake.usgs.gov/learn/topics/how_much_bigger.php. Accessed on August 22, 2017.

¹²⁷ Jung, L.H. 2016. "S. Korea Still Presumed Safe from Major Earthquakes: Experts." *The Korea Herald*, www.koreaherald.com/view.php?ud=20160913000002.

¹²⁸ Chung, J. 2016. "South Korea's Biggest Earthquake Triggers Nuclear Safety Concerns." *Reuters*. Available at: www.reuters.com/article/us-southkorea-nuclear-quake-idUSKCN11J0R2.

but were damaged instead through insufficient protection from the following tsunami.¹²⁹

¹²⁹ World Nuclear Association, "Earthquakes and Seismic Protection for Japanese Nuclear Plants", <http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/appendices/earthquakes-and-seismic-protection-for-japanese-1.aspx>

III. Lessons Learned and Recommendations

A. Lessons Learned

1. No nation is immune from the war on nuclear.

The underlying cause of nuclear energy's decline is public fear and distrust. Despite being the safest way to make electricity, nuclear is perceived to be the most dangerous. Exaggerated fears of radiation preceded Fukushima in both Japan and South Korea. What changed after Fukushima was the loss of public trust that governments could prevent an accident.

Anti-nuclear misinformation comes not from marginal sources but rather large, heavily-funded NGOs like Greenpeace and FOE, which have long been funding activities in South Korea, including lawsuits, protests and propaganda efforts like those associated with the disaster film "Pandora."

For decades, nuclear industry officials believed South Korea – like France – would be immune from largely Western anti-nuclear efforts due to the country's lack of energy resources. That belief now appears to have been an episode of wishful thinking. Today, both South Korea and France have leaders who – with the tide of public opinion behind them – are seeking to close nuclear plants.

As explained in the sections above, the meltdowns at Fukushima, in conjunction with the paper falsification, or "cable scandals," that uncovered widespread forgery in the nuclear regime, eroded the public's trust in nuclear energy. Greenpeace took advantage of these events by reciting the imminent danger of safety issues at the nuclear plants, even going so far as breaking into the restricted areas of the Kori plant.

The day of the 2016 earthquake, Greenpeace filed a lawsuit against the government, claiming it was attempting to suppress the criticisms of its policies. Months later, "Pandora" was released into theaters. President Moon's announced nuclear phase-out in 2017 was widely praised, given that public opinion of nuclear was so entrenched in fear.

Greenpeace's strategy, while effective, was not of its own creation. Anti-nuclear groups in the U.S. had been taking advantage of these tactics decades earlier. Less than two weeks before Three Mile Island, the disaster film "China Syndrome" hit

theaters in the United States, its leading lady a prominent anti-nuclear activist. Although released before the accident, the effect was the same: a spreading fear of nuclear power. The possibility of a nuclear moratorium was discussed in presidential campaigns and soon after, the Sierra Club, NRDC, and EDF participated in filing a lawsuit to ensure this would become a reality. In 1983, the Supreme Court upheld the constitutionality of California's nuclear moratorium, leading to other states following suit.

Though the lawsuits in these two cases were fundamentally different in nature, these actions at the judicial level brought legitimacy to the fear-mongering these so-called environmental groups were promoting. Legal action was not used in isolation at the federal level, either. The Sierra Club filed a lawsuit against the proposed Davis-Besse nuclear power plant in Ohio, and though the plant eventually came to fruition, the resistance to it led to the cancellation of two of the three planned reactors.

2. The nuclear industry, governments, and the UN's IAEA cannot be relied upon to save nuclear energy.

The nuclear industry inside Korea and around the world repeatedly ignored warnings of declining public trust. In 2015, the South Korean nuclear establishment moved "forward [with building new nuclear plants] despite safety concerns"¹³⁰ – the public sentiment at the time was that the government could simply force its will upon South Korea. A nuclear industry analyst predicted shortly thereafter that, "Rising national concerns about nuclear safety and decreasing support for building new power plants, coupled with general distrust of government, pose a critical challenge to Korea's nuclear future."¹³¹

And yet, no industry, governmental or inter-governmental institution stepped forward to engage public concerns, even though much of what South Koreans interviewed said they want is more information about the operation, regulation and maintenance of the plants.¹³²

¹³⁰ Cho, M. 2013. "South Korea to expand nuclear energy despite growing safety fears." *Reuters*. Available at: <http://www.reuters.com/article/us-nuclear-korea-idUSBRE90704D20130108>.

¹³¹ Dalton, Toby, and Minkyong Cha. 23 Feb. 2016 "South Korea's Nuclear Energy Future." *The Diplomat*, thediplomat.com/2016/02/south-koreas-nuclear-energy-future/.

¹³² Based on more than two dozen interviews conducted with residents near nuclear plants as well as residents of Seoul by Michael Shellenberger in April and July, 2017.

History is repeating itself. Before in the United States, Europe, and Japan, the nuclear industry, government regulators, and IAEA all failed to properly engage and address public concerns, for psychological, sociological and financial reasons.

As such, nuclear energy supporters and advocates must move forward assuming that the industry, governments and inter-governmental institutions like IAEA cannot be relied upon to protect and expand nuclear energy. New social actors including new leaders and new institutions are required.

3. A new vision, new institutions and new leadership are required to save and expand nuclear.

Over the last decade, a growing group of climate, environmental and health scientists in Europe and the U.S. has successfully advocated for nuclear energy to address air pollution, resource scarcity and climate change. The most concrete manifestation of their work was the continued operation of nuclear plants in Illinois and New York. Today, around the world, there is growing recognition of nuclear power's environmental benefits.

Supporters of nuclear must show their support for nuclear publicly. Public statements such as those by South Korean university professors, open letters from climate scientists, public talks, debates, rallies and demonstrations all show that people concerned about the public interest believe strongly in the importance of nuclear energy for creating a better world. Of special importance is highlighting the lives saved by nuclear power replacing fossil fuels – and the real harms caused by anti-nuclear fear-mongering.

B. Recommendations

1. Revitalize nuclear's radical vision and foundational moral purpose: atomic humanism.

Around the world, nuclear energy was created and promoted by humanists seeking to achieve a radical vision: lift *all* poor nations out of poverty. In his 1953 "Atoms for Peace" speech, President Dwight Eisenhower declared that "a special purpose" of nuclear energy was to provide power to "electricity-starved" nations. And in the 1960s, South Korean leaders sought to use nuclear energy for similar reasons.

But rising prosperity and the war on nuclear have led many South Koreans and others around the world to conclude that nuclear energy is unnecessary for the older economic reasons or for newer environmental ones.

What's needed is atomic humanism – a reaffirmation of nuclear energy's transcendent moral purpose – and a grassroots, civil society effort to rescue humankind's most important environmental technology from anti-humanists.¹³³

Only nuclear energy can lift all humans out of poverty while reducing humankind's environmental impact and increasing energy security. Fossil fuels can lift humans out of poverty but at a high environmental cost. Renewables are unreliable, expensive, and bring with them large environmental impacts.

And only nuclear energy can facilitate humankind's transition to a zero-pollution, high energy civilization. Most major energy transitions were driven by revolutions in transportation. We moved from wood to coal through the use of railroads. Similarly, trains and ships drove the transition from coal to oil.

The next great transportation revolution may be with electric cars or hydrogen-fueled, super-sonic jets. Whatever the final carrier fuel, a massive expansion of the power sector will be required to replace petroleum. And a similarly large expansion will be required to replace natural gas used for cooking and heating. Only nuclear can provide sufficiently large enough quantities of cheap and clean electricity to generate the requisite electricity and hydrogen.

2. New institutions such as science associations, universities, private philanthropies and NGOs must defend nuclear and engage the public.

Rising democratization must be embraced by advocates of nuclear who should take advantage of South Korea's proposed nuclear phase-out to engage with and educate the public about energy choices. Our interviews found significant desire among ordinary South Koreans for more information, not just about nuclear but energy in general.

Philanthropies, universities and NGOs should initiate a national dialogue and university "teach-ins" that involve a wide segment of Korean society, including both pro- and anti-nuclear voices, including Greenpeace and Friends of the Earth. The

¹³³ Shellenberger, M. 2017. "Atomic Humanism as Radical Innovation: Michael Shellenberger's Keynote to American Nuclear Society." Available at: <http://www.environmentalprogress.org/big-news/2017/6/12/atomic-humanism-as-radical-innovation-2017-keynote-address-to-the-american-nuclear-society>.

older paternalistic and authoritarian top-down model, where decision-makers and experts make decisions without public involvement, have been rejected by publics around the world, including in South Korea. The sooner pro-nuclear advocates embrace democratic decision-making and public engagement, the more time the public will have to learn the truth about nuclear and other technologies.

These new institutions and voices must put the public good – both cheap energy and clean energy – over private financial gain. They must recognize the human, not just technological side, to the backlash against nuclear. And they must be leaders in opening up energy decision-making to new social actors rather than clinging to older, paternalistic habits.

3. Overcome fears by standing up to nuclear fear-mongering and learning from successful efforts to reduce paranoia such as with vaccines.

New research finds that phobias can be overcome indirectly, including through media, and provides possibilities for overcoming “radiophobia,” or fear of nuclear energy. Traditionally it was thought that the only way to overcome a phobia was through “direct extinction” – confronting the phobia directly, such as when someone afraid of elevators practices getting in one. But new research finds that people can overcome their phobias simply by watching others overcome theirs, a process known as “vicarious extinction.” In fact, vicarious extinction can work better than direct extinction, in part because it effectively blocks the return of conditioned fear.¹³⁴ This research suggests that people might overcome their fears of nuclear energy by watching others overcome theirs, perhaps as part of a television or on-line documentary.

Another promising approach is the one taken by vaccines advocates. Public support for vaccination grew after World War II thanks to better public understanding of the science behind vaccinations, and direct experience with infectious disease, particularly polio.¹³⁵ But as trust in government declined, and memories of the horrors of polio faded, vaccination rates declined and disease outbreaks occurred with greater frequency. Civil society efforts by parents of children with weakened immune system along with physicians associations involved the stigmatization of

¹³⁴ Golkar, A., Selbing, I., Flygare, O., Öhman, A., & Olsson, A. 2013. "Other People as Means to a Safe End: Vicarious Extinction Blocks the Return of Learned Fear." *Psychological Science*. DOI: 0956797613489890.

¹³⁵ Poland, G. & Jacobson, R. 2011. "The Age-Old Struggle against the Antivaccinationists." *The New England Journal of Medicine*, vol. 364. p.97-99.

parents who did not vaccinate their children, leading to the California legislature and governor effectively requiring all public school students to be vaccinated.¹³⁶

¹³⁶ Boghani, P. 2015. "California Approves Strict New Vaccine Requirements for Children." *Frontline*. <http://www.pbs.org/wgbh/frontline/article/california-approves-strict-new-vaccine-requirements-for-children/>.

Appendix A: Environmental Progress Donors



Frank Batten Jr.

Frank is the co-founder of the Weather Channel and owns media company Landmark Media Enterprises.



Steve and Michele Kirsch Foundation

Steve and Michele Kirsch are philanthropists who are blazing a new trail for charitable giving and political advocacy throughout the high-tech community, particularly Silicon Valley.



Gary Kahanak

Gary currently serves as Viridian's NW Arkansas Regional Office Director for Residential Services.



Ross Koningstein

Ross is an advisor to Google Ventures and a generalist engineer at Google.



Rachel Pritzker

Rachel Pritzker is founder and president of the Pritzker Innovation Fund, which supports the development and advancement of paradigm-shifting ideas.



Roland Pritzker

Roland Pritzker is Chairman of the Pritzker Innovation Fund as well as an entrepreneur, musician, race car driver, private equity investor and philanthropist.



Carl Wurtz

Carl is the president and owner of Hyperoptix Design, a web development firm.



Jim Swartz

Jim is a philanthropist, the co-founder of American venture capital firm Accel, and has been the lead director of more than 50 successful companies.

Appendix B: Open Letter to President Moon

July 5, 2017

Honorable President Moon Jae-in
The Blue House
Seoul, South Korea

Dear President Moon,

We are writing as scientists and conservationists to urge you to consider the climate and environmental impacts of a nuclear energy phase-out in South Korea.

Over the last 20 years, South Korea has earned a global reputation for its ability to build well-tested and cost-effective nuclear plants. South Korea is the only nation where the cost of nuclear plant construction has declined over time. And in United Arab Emirates, South Korean firm Kepco has proven it can build cost-effective nuclear power plants abroad just as it can at home.

There is a strong consensus among climate policy experts that an expansion of nuclear energy will be required to significantly reduce carbon emissions and improve air quality. The Intergovernmental Panel on Climate Change, the International Energy Agency, and dozens of climate scientists and energy experts have affirmed the importance of nuclear energy to climate mitigation.

A phase-out of nuclear plants by South Korea domestically would profoundly undermine efforts by Kepco to compete for new nuclear construction contracts abroad. Buyer nations would rightly question why they should buy nuclear plants from a nation phasing out its nuclear. And a domestic nuclear phase-out would atrophy the workforces and supply chains needed for South Korea's global construction efforts.

Solar and wind are not alternatives to nuclear. In 2016, solar and wind provided 1 and 0.35 percent of South Korea's electricity, respectively. For South Korea to replace all of its nuclear plants with solar, it would need to build 4,400 solar farms the size of one of South Korea's largest solar farms, Sinan Solar Farm, which would cover an area 5 times larger than Seoul. To do the same with wind would cover an area 14.5 times larger than Seoul.

The intermittent nature of solar and wind and the lack of inexpensive grid-scale storage require the continued operation of fossil fuel power plants. As a result, every time nuclear plants close they are replaced almost entirely by fossil fuels, which has resulted in higher emissions from Germany to California to Japan.

Given the intermittency of solar and wind and South Korea's land scarcity, replacing the nation's nuclear plants would require a significant increase in coal and/or natural gas, which would prevent South Korea from meeting its commitments under the Paris climate agreement, and would increase air pollution in Seoul.

The high cost of replacing closing nuclear plants would be better spent on technological innovation to make South Korean nuclear plants even safer and cheaper. Replacing nuclear with natural gas would require \$23 billion as up-front investment in new plants, and \$10 billion per year to pay for gas imports.

Instead of phasing out nuclear, we encourage you to lead an effort to both make nuclear even safer and more cost-economical than it already is through the development and demonstration of accident-tolerant fuels and new plant designs.

The planet needs a vibrant South Korean nuclear industry, and the South Korean nuclear industry needs you as a strong ally and champion. If South Korea withdraws from nuclear the world risks losing a valuable supplier of cheap and abundant energy needed to lift humankind out of poverty and solve the climate crisis.

We support the call by 240 South Korean professors and strongly encourage you to deliberate with a wide range of energy and environmental scientists and experts on these questions before making any final decisions.

We are grateful for your consideration of these ideas, and look forward to your response.

Sincerely,

James Hansen, Climate Scientist, Earth Institute, Columbia University

Kerry Emanuel, Professor of Atmospheric Science, Massachusetts Institute of Technology

Pushker Kharecha, Columbia University, NASA

Richard Rhodes, Pulitzer Prize recipient, author of *Nuclear Renewal* and *The Making of the Atomic Bomb*

Stewart Brand, Editor of the Whole Earth Catalog

Robert Coward, President, American Nuclear Society

Ben Heard, Executive Director, Bright New World

Andrew Klein, Immediate Past President, American Nuclear Society

Steve McCormick, Former CEO, The Nature Conservancy

Michelle Marvier, Professor, Environmental Studies and Sciences, Santa Clara University

Richard Muller, Professor of Physics, UC Berkeley, Co-Founder, Berkeley Earth

Peter H. Raven, President Emeritus, Missouri Botanical Garden. Winner of the National Medal of Science, 2001

Paul Robbins, Director, Nelson Institute for Environmental Studies, University of Wisconsin-Madison

Mark Lynas, author of *Six Degrees*

Chris Dickman, Conservation Scientist, University of Sydney

David Dudgeon, Chair of Ecology & Biodiversity, School of Biological Sciences, The University of Hong Kong, China

Erle C. Ellis, Ph.D, Professor, Geography & Environmental Systems, University of Maryland

Christopher Foreman, author of *The Promise & Peril of Environmental Justice*, School of Public Policy, University of Maryland

Norris McDonald, President, Environmental Hope and Justice

Nobuo Tanaka, Sasakawa Peace Foundation

Gwyneth Cravens, author of *Power to Save the World*

Wolfgang Denk, European Director, Energy for Humanity

Kirsty Gogan, Executive Director, Energy for Humanity

Joshua S. Goldstein, Prof. Emeritus of International Relations, American University

Steven Hayward, Senior Resident Scholar, Institute of Governmental Studies, UC Berkeley

Joe Lassiter, Professor, Harvard Business School

David Lea, Professor, Earth Science, University of California

Martin Lewis, Department of Geography, Stanford University

Elizabeth Muller, Founder and Executive Director, Berkeley Earth

Stephen Pinker, Cognitive Scientist, Harvard University

Samir Saran, Vice President, Observer Research Foundation, Delhi, India

Jeff Terry, Professor of Physics, Illinois Institute of Technology

Barrett Walker, Alex C. Walker Foundation

Tom Wigley, Climate and Energy Scientist, National Center for Atmospheric Research, Boulder, Colorado

Michael Shellenberger, Time Magazine "Hero of the Environment," President, Environmental Progress

[1] Intergovernmental Panel on Climate Change (IPCC) 2014. Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wisner, 2014. "Annex III: Technology-specific cost and performance parameters." In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R., et al]

Appendix C: Why I Changed My Mind about Nuclear Power, by Michael Shellenberger

그릇된 공포에 에너지의 미래를 맡기려는가

특별기고



마이클 셸렌버거
美 환경진보 대표

'완벽한 안전'은 허상일 뿐
원전 백지화로 가기보다는
안전기술 개발과 규제 강화로
위험 낮추는 게 바른 방향
정부는 국민 불안 해소 위해
투명성 높이는 노력 기울여야

나는 최근 서울을 방문해 미국 내 에너지 전문가 그룹의 서명을 담은 공개서한을 청와대에 전달했다. 서한의 요지는 간단 명료하다. 한국의 반영과 환경보호를 위해 원전은 필수 불가결하다는 것이다.

나는 인생 대부분을 반핵(反核) 운동에 바쳤다. 주위의 환경운동가들은 내게 '원자력은 공포'라는 편견을 심어줬다. 1979년 미국 펜실베이니아주(州) 트리마일 섬(TMI) 원전 사고가 나기 12일 전에 반핵 영화인 '차이나 신드롬'이 개봉했다. 영화는 성공했고 이후 미국 최고의 록 그룹들이 전국을 순회하며 반핵 콘서트를 열었다. 탈핵(脫核)은 시대의 유행어이자 코드가 됐다. 버섯구름이 그려진 당시 포스터가 아직도 기억에 생생하다.

반핵 행동가였던 나는 핵폐기물 저장소가 캘리포니아에 들어서는 것을 막았고 신재생에너지도 입을 꾸준히 주장했다. 오바마 전 대통령이 2008년 대선 공약으로 "향후 10년간 재생에너지에 1500억달러를 투자하겠다"고 약속했을 때 최고의 성취감을 느꼈다. 태양광발전으로 대기오염과 지구온난화를 극복할 수 있을 거라 생각했다.

하지만 내 생각이 바뀌기까지 그 후 오랜 시간이 걸리지 않았다. 신재생에너지는 안정적인 에너지원(源)이 아니다. 신재생에너지의 에너지 밀도는 화석연료와 우라늄보다 턱없이 낮다. 게다가 발전을 위해 넓은 땅과 막대한 천연자원이 필요하다. 원전 1기(基)와 같은 양의 전기를 생산하기 위해 태양광 설비단지(Solar Farm)는 원전의 150배, 풍력발전소는 750배의 땅이 필요하다. 태양광

발전을 하기 좋은 사막 지대가 많은 내 고향 캘리포니아에서조차 "땅이 부족하다"는 얘기가 나온다. 한국 내 원전을 태양광으로 모두 대체하려면 서울 면적의 5배 넘는 공간이 필요하다. 한국의 전체 발전량에서 태양광(1%)과 풍력(0.3%)이 차지하는 비중이 아예서 미미하지 않을 수 있는 대목이다.

탈원전과 함께 한국이 지난 60년간 쌓아올린 원자력 기술은 중국에 유출될 것이다. 이미 중국은 한국 원전 기술자들에게 러브콜을 보내고 있다. 원전 산업의 공급 사슬이 무너지면 아랍에미리트(UAE) 원전 수출과 같은 기술 및 운영 노하우 수출을 더 이상 기대할 수 없다. 한국 대통령이 "삼성·현대·LG가 안전하지 않다"고 선언한다면 어느 누가 그들이 만든 제품을 사려 하겠는가? 이후 원전을 지으려면 중국 또는 러시아를 찾아야 한다. 자유 진영 국가들이 가장 우려하는 상황이다.

2011년 후쿠시마 사태 이후 원전에 대한 한국인의 두려움을 이해한다. 하지만 원자력을 화석연료나 천연가스로 대체할 수는 없다. 석탄은 대기오염의 주범이고 천연가스는 가격이 비싸다. 원자력을 천연가스로 모두 대체하려면 연간 100억달러가 든다. 발전소를 짓는 데만도 200억달러 이상이 필요하다.

결국 필요한 것은 더 나은 규제와 기술의 혁신이다. 지난 40년 동안 원전이 가장 안정적으로 전기를 공급해왔다는 사실은 자명하다. 원전에 대한 그릇된 공포와 미신을 타파해야 한다. 반핵 단체들이 원전 공포를 조장하는 데에는 금전적인 이유가

있다. 석유와 천연가스 공급자 중 일부는 반핵 활동을 하는 시민단체(NGO)에 운영비를 지원한다. 미국 내 주요 반핵 단체들은 모두 메이지 석유회사에서 연간 100만달러가 넘는 후원금을 받았다.

완벽한 안전은 허상(虛想)이다. '위험 제로' 달성에 도달했던 일본 정부와 원전 업계는 정작 최악의 상황이 닥쳤을 때 제대로 대처하지 못했다. 한국 정부는 탈핵(脫核)으로 100% 안전한 사회를 이루고 싶어하는 듯하다. 하지만 그 어떤 기술도 완벽하지 않다. 허투루 수천명이 자동차 사고와 의료 과실로 죽는다. 그렇다고 자동차와 병원을 없앨 수는 없는 노릇 아닌가.

이번 방한 때 한국인 수십명과 만나 그들의 생각을 들었다. 원전 근처에 사는 주민도 만났다. 반핵을 주장하는 이들조차 "무엇으로 원전을 대체할 것인가엔 의문이 있다"고 말했다. 또 다른 주민들은 "탈원전보다 원전이 제대로 유지·관리되고 있는지가 더 궁금하다"고 했다.

한국에서 원전이 살아남기 위해서는 투명성 제고가 필요하다. 한국 원전업계는 대중이 느끼는 공포를 더 진지하게 받아들이고 원전에 대한 우려를 불식시키는 데 총력을 기울여야 한다. 공공사업의 초기 단계부터 시민이 활발히 참여하는 '공공의 관여(public involvement)'는 비단 한국뿐만 아니라 전 세계를 위해서도 필요한 일이다. 한국의 원전 산업이 세계에서 차지하는 비중이 그만큼 크기 때문이다. 한국 정부는 조금 더 시간을 가지고 이 문제를 숙고하기 바란다. 그릇된 공포가 가장 소중한 에너지원을 파괴하는 것보다 비극적인 일은 없다.

July 21, 2017

Last week I traveled to Seoul to deliver an open letter signed by some of the world's most prestigious climate and environmental scientists urging President Moon Jae-in to reconsider South Korea's phase-out of nuclear energy. My reason? To communicate the message that the world needs a South Korean nuclear power to achieve prosperity and environmental protection for all.

If South Korea closes its nuclear plants, no nation will buy Korean nuclear plants, just as nobody would buy a Hyundai or LG appliance if the president of South Korea declared them unsafe. And nations seeking nuclear power will have only China and Russia to buy reactors from – an outcome that is rightly feared by liberals and conservatives alike around the world.

For most of my life, I opposed nuclear energy. As a child raised by liberal peace activists, I was taught to fear it. In 1979, when I was seven, the anti-nuclear Hollywood blockbuster "China Syndrome" was released just 12 days before one of the reactors at Three Mile Island nuclear plant in Pennsylvania melted down. Over the next year, America's biggest rock stars toured the country performing at "No Nukes" concerts. I still remember the No Nukes poster hanging in our local food cooperative depicting a mushroom cloud.

In my 20s I worked on anti-nuclear causes. I helped to block a radioactive waste storage facility in California, and promoted solar and wind. Our most successful effort was winning a \$150 billion investment by the Obama administration in solar, wind, and electric cars. I believed that we could eliminate air pollution and solve global warming through innovations with renewable sources of energy.

But almost immediately afterwards my colleagues and I started to notice some big problems with renewables. First, they are incredibly unreliable, generating power only 20 to 30 percent of the time. And despite the hype, there is no battery revolution forthcoming. The only way to store large amounts of electricity is through what's called "pumped storage." These are essentially large hydroelectric dams that pump water uphill during times of excess electricity and then release the water over the turbines when electricity is needed. Lithium batteries are wonderful for our cell phones and laptop computers but are extremely expensive and have very short lives.

Second, renewable fuels – whether water, sunlight, wind, or wood – require huge amounts of land and natural resources. On average, a solar farm must cover an area 150 times larger than nuclear to generate the same quantity of electricity as a nuclear plant; wind farms must cover an area 750 times larger. The reason is easy to understand: renewable fuels are energy-diffuse, meaning that there is very little energy per unit of mass compared to both fossil fuels and uranium. The energy density of the fuel in large measure determines its environmental impact.

If low energy density of solar is a problem in my home state of California, where we have large deserts available for solar farms, imagine how much more of a problem it is in South Korea, which has far more people per square kilometer. This reality goes a long way to explaining why South Korea gets just 1 percent and 0.3 percent of its electricity from solar and wind, respectively.

Indeed, replacing all of South Korea's nuclear plants with solar would require covering an area five times the size of Seoul; replacing them with wind turbines would

require covering an area 15 times larger. And none of that considers the land that would be required for pumped hydro storage – something South Korea also lacks.

The Korean nuclear plants represent 60 years of investment that will likely go to the Chinese if South Korea abandons them. The Chinese are already courting Koreans with job offers and promises of high wages and benefits. Ultimately, a phase-out means that South Korea would not be able to sustain its supply chain, and therefore would not be able to export the plant technology or operate and supply the plant it has just finished building in the United Arab Emirates.

As a result, South Korea would need to use coal or natural gas to replace its nuclear. Coal already contributes to serious air pollution in Seoul, while natural gas is expensive. The annual cost of replacing all of South Korea's nuclear plants with natural gas would be \$10 billion on top of a one-time cost of roughly \$20 billion to build new natural gas plants.

It is understandable that South Koreans are afraid of nuclear energy given the 2011 accident at Fukushima, but the solution is better regulation, better technology and public involvement, not substituting fossil fuels for nuclear.

As hard as it may be to believe, the scientific evidence is overwhelming – and has been for 40 years – proving that nuclear energy is the safest way to make reliable electricity. That's because while air pollution kills seven million people per year, hardly anybody is harmed during even the worst nuclear accidents.

Far more deadly is fear and panic. The tsunami that hit the coast of Japan in 2011 instantly killed about 15,000 people, many of who could have survived had Japan been better prepared.

Still traumatized by that event, Japan's Prime Minister inappropriately involved himself in managing the meltdowns at Fukushima in ways that created great harm, according to both independent investigations of the accident. Instead of sheltering-in-place as is often done in response to natural disasters like typhoons, the Prime Minister ordered an evacuation that resulted in the unnecessary deaths of hundreds of sick and elderly people.

Of course, fear and panic serve powerful financial interests. Should we be surprised that natural gas companies fund many of the anti-nuclear groups that spread misinformation about nuclear? The anti-nuclear group Friends of the Earth – which has representatives in South Korea – received its initial funding from a wealthy oil

man, while Greenpeace receives over \$350 million per year from anonymous sources. All three of the largest anti-nuclear groups in the United States have budgets over \$100 million per year and receive funding from oil, gas, solar and wind investors, or are invested in oil and gas, and renewable energy companies.

Nothing is more dangerous than the myth of perfect safety. The Japanese nuclear industry and government promoted the idea of perfect safety and the consequence was a failure to prepare for the worst. Now, many people in South Korea seem to want perfect safety from non-nuclear energy sources, whether it be natural gas, coal, solar or wind. But why? From what other technology do we demand perfect safety? Thousands of people die every year from car accidents, hospital medical errors, and simply falling down stairwells. The solution is not to ban cars, hospitals and stairwells but rather for the society to improve the technologies and demand greater public involvement and engagement in guaranteeing their safe use.

When I visited South Korea for the first time last April, and again last week, I interviewed dozens of ordinary people, including those in Busan who live near nuclear power plants, about their opinions about nuclear. While some said they just wanted to ban the technology outright, many more had questions about what would replace it. And more often than not the people who live near the plants said they just wanted to better understand what was happening in the plants, and wanted to know that they were being well-maintained and regulated.

Clearly, trust is lacking, and something needs to change for South Korea's nuclear program to survive, and the proposal to phase out nuclear energy should come as a wake-up call to South Korean nuclear industry, which has done an expert job of building plants but a poor job of seriously engaging public concerns. Simply put, the nuclear industry and governments must do a better job taking seriously – and addressing – public concerns and fears.

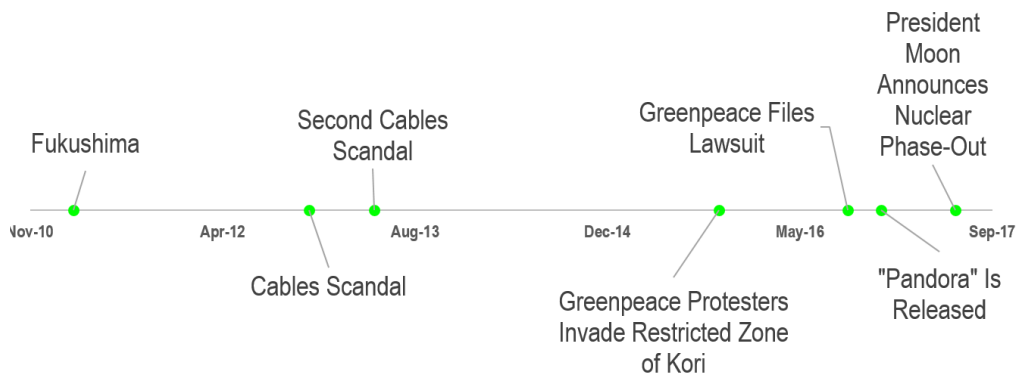
But it is also the responsibility of any people – whether South Korean, American or Japanese – to seek to understand our choices and their consequences for ourselves, our children and our planet.

Given how important their nuclear energy sector is to the world, I encourage the South Korean people to take the time needed to properly deliberate and weigh these questions. Nothing would be more tragic – not just for the South Korean people but also for the planet and the human race as a whole – than to allow fear and panic to destroy that which is most precious.

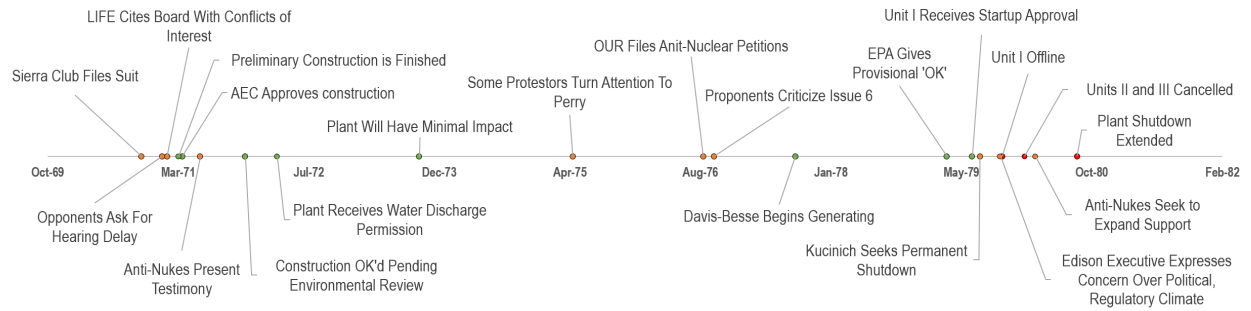
Appendix D: Supplementary Figures



The timeline of events leading up to the United States Supreme Court's decision to allow for states to place moratoriums on the construction of nuclear power. Included is the debut of the nuclear disaster film "China Syndrome," the accident at Three Mile Island nuclear power station, and the involvement of anti-nuclear NGOs in legal proceedings.



The timeline of events leading up to President Moon's announcement of South Korea's nuclear phase-out. Included is the nuclear meltdown at Fukushima in Japan, scandals involving forged nuclear documents at South Korean plants, the release of the nuclear disaster film "Pandora," and the opposition tactics of Greenpeace.



This timeline was constructed as part of EP's historical analysis of nuclear power plant construction and cancellation. It includes events related to the progress of, opposition against, and regulatory burden on the Davis-Besse nuclear power plant in Ohio. Unit I of this power plant went into commercial operation, but units II and III were cancelled.