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The Impact of Merging Climate and Trade Policy on Global Demand for Nuclear Energy

BY GEORGE DAVID BANKS

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COVER: The Kori No. 4 reactor of state-run utility Korea Electric Power Corp (KEPCO) is seen in Ulsan, about 410 km (255 miles) southeast of Seoul. Source: REUTERS/Lee Jae-Won

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The **Global Energy Center** promotes energy security by working alongside government, industry, civil society, and public stakeholders to devise pragmatic solutions to the geopolitical, sustainability, and economic challenges of the changing global energy landscape.

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EXECUTIVE SUMMARY

A growing number of countries are embracing ambitious commitments to reducing greenhouse gas (GHG) emissions in the near-term. To prevent emissions and job leakage to countries with less stringent regulatory regimes, several Western governments are exploring trade mechanisms that would charge a fee or tax at the border on goods made more carbon intensively than their own. Growing interest across Group of Seven (G7) countries to explore this option creates opportunities to reach a common approach to climate and trade policy making.

If the G7 were to reach a deal, the grouping would account for about 40 percent of global imports and yield substantial market power, enough to create a *de facto* international carbon price. This development would promote investments in low-carbon technologies, likely including nuclear energy, especially in emerging economies that wish to protect and bolster their export competitiveness. At the same time, these governments would be less inclined to build out unabated fossil fuel infrastructure.

The consequences of pricing embodied carbon in trade flows would also impact developed countries that are phasing down or out their civil nuclear programs. If shuttered nuclear plants are replaced in part by unabated fossil fuels, those economies would also experience a reduction in their export competitiveness. Countries that are greatly dependent on exports as a percentage of their economy—for example, Germany and South Korea—would be particularly vulnerable to these impacts.

- G7 countries should encourage global investments in low-carbon technologies, including commercial nuclear energy, particularly in developing countries that export carbon-intensive products.
- Western economies that are phasing down or out their civil nuclear programs should realize that their export competitiveness would deteriorate if at least some of that generation were to be replaced by unabated fossil fuels.
- Emerging economies should reconsider investments in unabated fossil fuel infrastructure.

Global forecasts for commercial nuclear power have not factored in the emergence of trade mechanisms that tax carbon intensity. Policy makers who manage proliferation risks should take particular notice as these trade mechanisms would likely increase demand for civil nuclear reactors, further strengthening the power of a potential monopoly controlled by China and/or Russia over supply chains related to civil nuclear technologies and services.

INTRODUCTION

Governments are increasingly pledging to meet mid-to-late century net zero targets for reducing greenhouse gas (GHG) emissions, with one hundred and forty countries, which account for 90 percent of global emissions, either formally adopting or announcing such a goal as of November 2021.[1] Nonetheless, the near-term reduction pledges made so far are not on track to meet the main goal of the Paris Agreement, which seeks to limit global warming to well below 2 degrees Celsius compared to pre-industrial levels.[2]

Despite Beijing's pledge to achieve net zero emissions by 2060, China's emissions trajectory between now and 2030 alone threatens to undermine the world's climate change mitigation efforts. The global carbon budget associated with the 2-degree-Celsius target will be exhausted around 2045, assuming current emissions trends.[3] Cumulative Chinese carbon pollution between now and then, fueled in part by consumer demand in the United States and elsewhere, will consume at least 30 percent of that budget, even if Beijing makes good on its promise to peak before 2030 and cuts annual emissions thereafter to achieve net zero in another thirty years.[4]

Between now and mid-century, China and developing economies are forecasted to account for over 100 percent of the expected increase in global carbon dioxide (CO_2) emissions.[5] However, even if all Organisation for Economic Cooperation and Development (OECD) countries reached the target of net zero by 2050, it would still be insufficient to cover non-OECD emissions growth. Thus, it is becoming clearer that the pledge-based structure of the Paris Agreement, while necessary for international climate cooperation, is not sufficient to meet global emissions goals; increased bilateral, regional, and plurilateral cooperation is needed to reinforce efforts to accelerate the deployment of low-carbon technologies and systems to avoid forecasted emissions growth, particularly in the developing world.

While the United States and other developed economies have backed low-carbon financing programs through multilateral development banks and their export credit agencies to support climate change mitigation in poor countries, those efforts will fall far short of the financing that is needed for the global clean energy transition, eespecially for technologies

1 "Climate Action Tracker," accessed November 16, 2021, https://climateactiontracker.org/global/cat-net-zero-target-evaluations/.

2 IPCC (Intergovernmental Panel on Climate Change), *Climate Change 2021: The Physical Science Basis*, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, https://www.ipcc.ch/assessment-report/ar6/; EIA (US Energy Information Administration), "International Energy Outlook 2019," accessed on August 3, 2022, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=10-IEO2019&region=0-0&cases=Reference&start=2010&end=2050&f=A&linechart=Reference-d080819.11-10-IEO2019~Reference-d080819.25-10-IEO2019~Reference-d080819.26-10-IEO2019&ctype=linechart&sourcekey=0; Ida Sognnaes et al., "A Multi-Model Analysis of Long-Term Emissions and Warming Implications of Current Mitigation Efforts," *Nature Climate Change* 11 (December 2021), https://doi.org/10.1038/s41558-021-01206-3; and UN Environment Programme, *Emissions Gap Report* 2021, October 26, 2021, https://www.unep.org/resources/emissions-gap-report-2021.

3 Mercator Research Institute on Global Commons and Climate Change, "That's How Fast the Carbon Clock Is Ticking," accessed April 14, 2021, https://www.mcc-berlin.net/en/research/co2-budget.html.

4 Assuming only a 3 percent annual growth increase between now and 2030 and an annual reduction of half a gigaton of emissions thereafter, an overly optimistic scenario, in this author's opinion.

5 While developed countries are cutting their emissions, the emissions growth from China and the developing world is expected to be larger than the total change in emissions. See EIA, "International Energy."

like nuclear energy with high capital costs. The World Bank estimates that developing economies will need to spend roughly 4.5 percent of their national income to achieve their economic development goals in a manner that squares with the 2-degree-Celsius target.[6] The related infrastructure financing gap is massive, on a scale of many trillion dollars per year, according to several studies.[7]

The financing gap is unlikely to be filled through conventional international aid and financing programs. Previous pledges by richer economies have failed to materialize[8] and there is little expectation for a shift in spending priorities, such as defense.[9] This challenge is compounded by the fact that poor countries are unwilling or unable to pay the "green premium" for energy infrastructure, unlike much of the developed world.[10]

Designing a commercialization pathway for nuclear energy technologies that works in poor countries requires cutting their costs compared to conventional fossil fuel technologies. Crucially, it also depends on the creation of an international market, most likely through trade policy, that rewards carbon-efficient infrastructure investments and taps the vast financial resources managed by the private sector and state-owned enterprises.

6 World Bank, *Beyond the Gap: How Countries Can Afford the Infrastructure They Need While Protecting the Planet*, February 19, 2019, https://www.worldbank.org/en/topic/publicprivatepartnerships/publication/beyond-the-gap---how-countries-can-afford-the-infrastructure-they-need-while-protecting-the-planet.

7 "Forecasting Infrastructure Needs and Gaps," Global Infrastructure Hub, accessed on August 3, 2022, https://outlook.gihub.org/; and UNDP (United Nations Development Programme), *Financing the 2030 Agenda*, January 26, 2018, https://www.undp.org/publications/financing-2030-agenda.

8 See Jocelyn Timperley, "The Broken $100-Billion Dollar Promise of Climate Finance – and How to Fix It," *Nature*, October 20, 2021, https://www.nature.com/articles/d41586-021-02846-3.

9 Stockholm International Peace Research Institute (SIPRI), "World Military Spending Rises to Almost $2 Trillion in 2020," April 26, 2021, https://sipri.org/media/press-release/2021/world-military-spending-rises-almost-2-trillion-2020.

10 Bill Gates, "Here's a Formula That Explains Where We Need to Invest in Climate Innovation," *Time 2030*, January 22, 2021, https://time.com/5930098/bill-gates-climate-change/.

THE IMPORTANCE OF TRADE POLICY IN CLOSING THE CARBON LOOPHOLE

Generally, countries that adopt carbon regulations are concerned about emissions and job leakage because policies that impose additional costs create an economic incentive for offshoring jobs to economies with less stringent regulations. This shift in economic activity frequently results in the regulated economy importing the embodied carbon that it offshored if its demand for those products has not fallen.

Consequently, many regulated economies are not actually reducing emissions at the level to which they have committed. When accounting for net emissions imported, for example, pollution from carbon in the United States is approximately 10 percent higher than official reports, which are based on emissions generated within US territory.[11] In the European Union (EU) and the United Kingdom, accounting for overall consumption drives emissions up about 30 percent and 40 percent, respectively, which negates, in some cases, all reductions reported since 1990, which is the common European baseline.[12] Closing this “carbon loophole” likely requires the creation of a trade mechanism that addresses the imbalance between the import or export of embodied emissions, thus making any given country’s regulatory regime more effective in its contribution to global climate change mitigation.[13]

Momentum is gathering in the EU, the United States, and other developed economies to address this challenge by adopting a policy known as a carbon border adjustment mechanism (CBAM). EU and US policy makers have separately introduced legislation to impose carbon fees or taxes on imported goods, largely from energy-intensive manufacturing sectors, which would consider the GHGs emitted in their production.

Last year, the EU proposed a CBAM that would require most importers to pay a carbon fee or tariff at the EU border on carbon-intensive products, such as steel and aluminum.[14] This charge would equalize the carbon price facing EU domestic products and imports, thus leveling the playing field for European firms in the home market and removing the incentive for those regulated companies to move production overseas. Because the United States does not have an explicit price on carbon, US lawmakers have expressed an interest in exploring a different track to define the border fee or tariff, using the implicit price produced by domestic carbon-related policies or measuring the embodied carbon in imports and comparing that to US production.[15]

11 Buy Clean, “The Carbon Loophole in Climate Policy,” September 2018, https://www.climateworks.org/wp-content/uploads/2018/09/Carbon-Loophole-in-Climate-Policy-Final.pdf.

12 Renilde Becqué et al., “Europe’s Carbon Loophole,” Climate Works Foundation, September 2017, https://www.climateworks.org/wp-content/uploads/2017/09/EU-carbon-loophole_final-draft-for-consultation.pdf; Richard Partington, “Britain Now G7’s Biggest Net Importer of CO_2 Emissions per Capita, Says ONS,” *Guardian*, October 21, 2019, https://www.theguardian.com/uk-news/2019/oct/21/britain-is-g7s-biggest-net-importer-of-co2-emissions-per-capita-says-ons.

13 The “carbon loophole” refers to the embodied GHG emissions tied to the production of goods that are imported from a relatively unregulated economy to an economy with more stringent regulation.

14 European Commission, “Carbon Border Adjustment Mechanism: Questions and Answers,” July 14, 2021, https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661.

15 Chris Coons, "Sen. Coons, Rep. Peters introduce legislation to support U.S. workers and international climate cooperation", press release, July 19, 2021, https://www.coons.senate.gov/news/press-releases/sen-coons-rep-peters-introduce-legislation-to-support-us-workers-and-international-climate-cooperation; and Josh Siegel, “Congress Is Eyeing a Bipartisan Climate Trade Policy – Thanks to Trump,” *Politico*, February 24, 2022, https://www.politico.com/news/2022/02/24/congress-is-eyeing-a-bipartisan-climate-trade-policy-thanks-to-trump-00009490.

People walk on the bank of the Huangpu river near a coal-fired power plant in Shanghai, China. Source: REUTERS/Aly Song

EU policy making and growing interest in the United States have spurred conversations in other developed economies. Canada, for instance, is exploring the adoption of a CBAM as part of its larger climate change mitigation strategy,[16] and Japan's Ministry of Economy, Trade, and Industry (METI) and Ministry of the Environment have convened expert advisory panels to identify a potential CBAM policy design.[17]

Importantly, a key goal in EU and US policy making circles is the desire to form a carbon club with other countries. In June 2022, Germany, which currently holds the Group of Seven (G7) presidency, gained the backing of G7 leaders for the creation of "an open and cooperative international Climate Club" by the end of the year with an initial focus on reaching "a common understanding of assessing ways to compare the effectiveness as well as the economic impacts" of different mitigation policies.[18]

If the G7 were to ultimately agree to a common climate and trade approach (i.e., a tariff or fee at the border on imports), the club, particularly if it were expanded to include a critical mass of other likeminded economies like Australia and South Korea, would create a *de facto* global carbon price. This grouping would account for more than 40 percent of worldwide imports, giving the club significant leverage over global markets.[19] While this initiative would likely take a number of years to complete because of its complexity, it is clear that there is growing momentum to explore such an arrangement among key economies.

16 Government of Canada, "Exploring Border Carbon Adjustments for Canada," modified August 5, 2021, https://www.canada.ca/en/department-finance/programs/consultations/2021/border-carbon-adjustments/exploring-border-carbon-adjustments-canada.html. Canada is particularly vulnerable to BCA policy design in the United States with more than 75 percent of its exports from energy-intensive, trade-exposed sectors being shipped to its southern neighbor.

17 Shiho Takezawa, "Japan Mulls Carbon Border Tax for Polluters, Nikkei Says," *Bloomberg Tax*, February 10, 2021, https://news.bloombergtax.com/daily-tax-report-international/japan-mulls-carbon-border-tax-for-biggest-polluters-nikkei-says.

18 G7, "G7 Statement on Carbon Club," June 28, 2022, https://www.g7germany.de/resource/blob/974430/2057926/2a7cd9f10213a481924492942dd660a1/2022-06-28-g7-climate-club-data.pdf?download=1.

19 Eurostat, "International Trade in Goods," accessed August 3, 2022, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_in_goods#The_three_largest_global_players_for_international_trade:_EU.2C_China_and_the_USA.

THE IMPORTANCE OF COMMERCIAL NUCLEAR ENERGY IN REDUCING GLOBAL EMISSIONS

Nuclear energy plays a critical role in global climate change mitigation. When the entire fuel life cycle is considered, nuclear is among the most climate-friendly sources of electricity, emitting one hundred times less carbon per megawatt-hour than coal and fifty times less than natural gas.[20] In addition, a study conducted by the United Nations Economic Commission for Europe found that nuclear energy's life cycle CO_2 emissions are lower than any other low-carbon technology.[21]

According to the Nuclear Energy Institute, nuclear power plants in the United States save more than 470 million metric tons of CO_2 emissions annually that would otherwise come from fossil fuels.[22] Globally, the use of nuclear energy has cut

Table 1: Importance of commercial nuclear in selected major economics

Major economy	Near-term reduction target (2030)	Net-zero target	Nuclear electricity production (billion kWh)		Percent electricity production	
			2019	2020	2010	2020
Canada	40% -45% below 2005	2050	94.9	92.2	15.1	14.6
China	Growth target util 2030	2060	330.1	344.7	1.8	4.9
France	40% below 1990	2050	70.6	70.6	74.1	70.6
Germany	65% below 1990	2045	71.1	60.9	28.4	11.3
India	Growth target	2070	40.7	40.4	2.9	3.3
Japan	46% below 2013	2050	65.7	43	29.2	5.1
Republic of Korea	40% below 2018	2050	138.8	152.6	32.2	29.6
Russia	30% below 1990	2060	195.5	201.8	17.1	20.6
United Kingdom	78% below 1990 by 2035	2050	51	45.9	15.7	14.5
United States	50%-52% below 2005	2050	809.4	789.9	19.6	19.7

Data taken from World Nuclear Association at https://www.world-nuclear.org/information-library/facts-and-figures/nuclear-generation-by-country.aspx

20 Union of Concerned Scientists, "Benefits of Renewable Energy Use," updated December 20, 2017, https://www.ucsusa.org/clean-energy/renewable-energy/public-benefits-of-renewable-power#.XBZsrxNKh24.

21 United Nations Economic Commission for Europe (UNECE), *Carbon Neutrality in the UNECE Region: Integrated Life-Cycle Assessment of Electricity Sources*, 2022, https://unece.org/sites/default/files/2021-10/LCA-2.pdf.

22 Nuclear Energy Institute, "Climate," accessed August 3, 2022, https://www.nei.org/advantages/climate.

CO_2 emissions by more than 60 gigatons over the past fifty years, which is equivalent to about two years of worldwide carbon pollution.[23] While this number may seem trivial at first glance, it is very meaningful when the remaining global carbon budget for meeting the 2-degree-Celsius target is considered (roughly twenty-five years plus). If the world were to replace all coal and natural gas power with nuclear energy or another zero-emissions technology, global CO_2 emissions would fall by 22.6 gigatons.

Globally, there are approximately 445 nuclear power reactors operating in more than thirty countries, with a total capacity of about 400 gigawatts of electrical output.[24] In 2020, these reactors supplied about 10 percent of the world's electricity.[25] Currently, approximately fifty power reactors are being built in nineteen countries, largely in China, India, Russia, and the United Arab Emirates.[26] Developing economies tend to invest in commercial nuclear programs to supply pollution-free electricity and improve economic and energy security. For the major economies, which account for roughly 80 percent of global GHG emissions, nuclear power plays a crucial role for most in meeting electricity demand and helps provide a pathway to achieving increasingly ambitious climate targets.[27]

Civil nuclear power also offers opportunities to decarbonize energy-intensive sectors of the economy, such as transportation and manufacturing. Demand for hydrogen, for example, is rapidly growing in the industrial sector to lower carbon intensity of production. Nuclear energy, which operates at a very high capacity, is well positioned to fill this need. According to a French government study, the cost of producing green hydrogen (i.e., hydrogen produced by zero-carbon technologies) from nuclear and hydropower is four times less than making it with electricity generated by solar and wind.[28] Coupling the high-temperature thermal heat from nuclear reactors with electrolysis (i.e., chemical decomposition produced by passing an electric current through a liquid or solution containing ions) can reduce carbon emissions, potentially all the way to zero. Advances in this area may lay the groundwork for future technology "advancements in electric vehicles, biofuel upgrades, and synthetic fuel production."[29]

Unfortunately, the expansion of nuclear power in the global energy mix faces strong headwinds in several major economies that also rank as the largest emitters of GHGs. After the damage to the Fukushima nuclear plant during the tsunami in March 2011, public opinion toward nuclear energy shifted, especially in the developed world, resulting in new nuclear projects being canceled or the announcement of nuclear phasedown or phaseout plans, which in turn resulted in carbon pollution growth. In Germany, for instance, its nuclear phaseout plans have resulted in CO^2 emissions growth of 36.3 metric tons per year, or a 13 percent increase in emissions above what would have happened without the anti-nuclear policy.[30]

Recent polling has suggested that publics are more willing to consider building new nuclear plants to combat climate change or prolonging their operation to address energy security concerns.[31] However, the assumption that nuclear power can easily be swapped out for other low-carbon sources appears widespread.[32] According to a poll commissioned by the BBC after the Fukushima disaster, for example, most publics backed re-

23 International Energy Agency (IEA), *Nuclear Power in a Clean Energy System*, May 2019, https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

24 World Nuclear Association, "Plans for New Reactors Worldwide," updated November 2021, https://world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx.

25 Ibid.

26 Ibid.

27 Jan Strupczewski and Gavin Jones, "G20 Leaders Struggling to Toughen Climate Goals, Draft Shows," Reuters, October 30, 2021, https://www.reuters.com/business/environment/g20-leaders-try-cap-global-warming-15-degrees-draft-2021-10-30/.

28 French National Assembly, "Modes of Production for Hydrogen," Scientific Notes of the Office, Note No. 25, April 2021, https://www2.assemblee-nationale.fr/content/download/342294/3355536/version/3/file/_OPECST_2021_0032_note_hydrogene.pdf.

29 IAEA (International Atomic Energy Agency), *Climate Change and Nuclear Power 2020*, September 2020, https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1911_web.pdf.

30 Stephen Jarvis, Olivier Deschenes, and Akshaya Jha, "The Private and External Costs of Germany's Nuclear Phase-Out," NBER Working Paper Series, Working Paper 26598, December 2019, https://www.nber.org/system/files/working_papers/w26598/w26598.pdf.

31 Cary Funk and Meg Hefferon, "U.S. Public Views on Climate and Energy," Pew Research Center, November 25, 2019, https://www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and-energy/; Nikolaus J. Kurmayer, "German Pro-Nuclear Activists Make Rare Appearance in Berlin," *EurActiv*, November 15, 2021, https://www.euractiv.com/section/energy-environment/news/german-pro-nuclear-activists-make-rare-appearance-in-berlin/; Matthew Smith, "What Role Should Nuclear Play in Britain's Climate Change Strategy," YouGov, October 18, 2021, https://yougov.co.uk/topics/politics/articles-reports/2021/10/18/what-role-should-nuclear-play-britains-climate-cha; Aaron Patrick, "Half of Left-Wing Voters Support Nuclear Power," *Financial Review*, March 29, 2021, https://www.afr.com/companies/energy/half-of-left-wing-voters-support-nuclear-power-20210326-p57eci; and Rebecca Staudenmaier, "Ukraine War Sparks Major Shift in Germany's Energy Opinions," DW, April 7, 2022, https://www.dw.com/en/ukraine-war-sparks-major-shift-in-germanys-energy-opinions/a-61401277.

32 International Atomic Energy Agency, *Global Public Opinion on Nuclear Issues and the IAEA: Final Report from 18 Countries*, consultant report by GlobeScan Incorporated, October 2005, http://large.stanford.edu/courses/2015/ph241/llanos1/docs/globescan.pdf.

placing nuclear energy with renewables and improvements in energy efficiency.[33] Lost on the public, however, is the number of positive attributes that nuclear energy provides relative to other low-carbon technologies, including the amount of land needed to replace a nuclear power plant's generating capacity with renewables. Nuclear energy requires about 12 acres per megawatt (MW) produced, compared to 43.5 for solar and 70.6 for wind power.[34]

For countries with limited land mass and dense populations like South Korea, which ranks the highest of the major economies with robust civil nuclear fleets, this physical constraint to fuel switching poses a significant challenge.[35] Even for larger countries with more available land, policy makers that place a priority on climate change mitigation often ignore the fact that the fastest growth of low-carbon power sources historically has occurred during the build-out of commercial nuclear programs.[36]

While the Russian invasion of Ukraine has generated increased support in Europe for nuclear energy, it remains to be seen if it will have a longstanding impact on public views, particularly in Germany where opposing nuclear energy helps define political identity.[37] Changes in trade policy and its pricing of embodied carbon in trade flows, however, may have a greater impact on government policy as these are likely to influence political elites and industry leaders who, until now, have been on the sidelines of the political debate over nuclear energy. As discussed previously, shutting down civil nuclear plants, in practice, has resulted in emissions growth, thus resulting in greater carbon intensity of industrial production.

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33 Richard Black, "Nuclear Power 'Gets Little Public Support Worldwide,'" BBC News, November 25, 2011, https://www.bbc.com/news/science-environment-15864806. Also see Globe Scan, "Opposition to Nuclear Energy Grows: Global Poll," November 25, 2011, https://globescan.com/opposition-to-nuclear-energy-grows-global-poll/.

34 In general, one MW can power as many as one thousand homes. See Landon Stevens, *The Footprint of Energy: Land Use of U.S. Electricity Production*, Strata, June 2017, https://docs.wind-watch.org/US-footprints-Strata-2017.pdf.

35 Statistics Times, "List of Countries by Population Density," accessed August 3, 2022, https://statisticstimes.com/demographics/countries-by-population-density.php.

36 Junji Cao et al., "China-U.S. Cooperation to Advance Nuclear Power," *Science* 353 (6299) (August 5, 2016): 547–548, http://science.sciencemag.org/content/353/6299/547.

37 Charlie Campbell, "As Putin Threatens Nuclear Disaster, Europe Learns to Embrace Nuclear Energy Again," *Time*, April 21, 2022, https://time.com/6169164/ukraine-nuclear-energy-europe/.

THE IMPACT OF CLIMATE AND TRADE POLICY ON THE DEMAND FOR COMMERCIAL NUCLEAR ENERGY

A carbon club's adoption of a common climate and trade policy to close the carbon loophole would make developing exports produced with unabated fossil fuels less competitive in that market. This initiative should encourage countries with a greater role for state planning in power generation to increase investments in low-carbon electricity. While the need for renewable energy should increase in those economies, the baseload power attributes of civil nuclear plants (e.g., reliability and affordability) should result in greater demand for commercial nuclear technologies or other sources of firm, clean power. Likewise, those countries would weigh the cost to their competitiveness of continued investments in conventional fossil energy, which would likely reduce demand for carbon-intensive energy infrastructure.

Merging climate and trade policy, however, would not only affect the competitiveness of developing country exports. A *de facto* international carbon price is likely to negatively impact exports from a developed economy that is phasing out or down (formally or informally) its civil nuclear program if shuttered plants are partly replaced by fossil fuel generation. Replacing zero-carbon nuclear reactors with natural gas or coal-fired generation would cause higher pollution from the power sector, as well as an increase in the industrial sector's

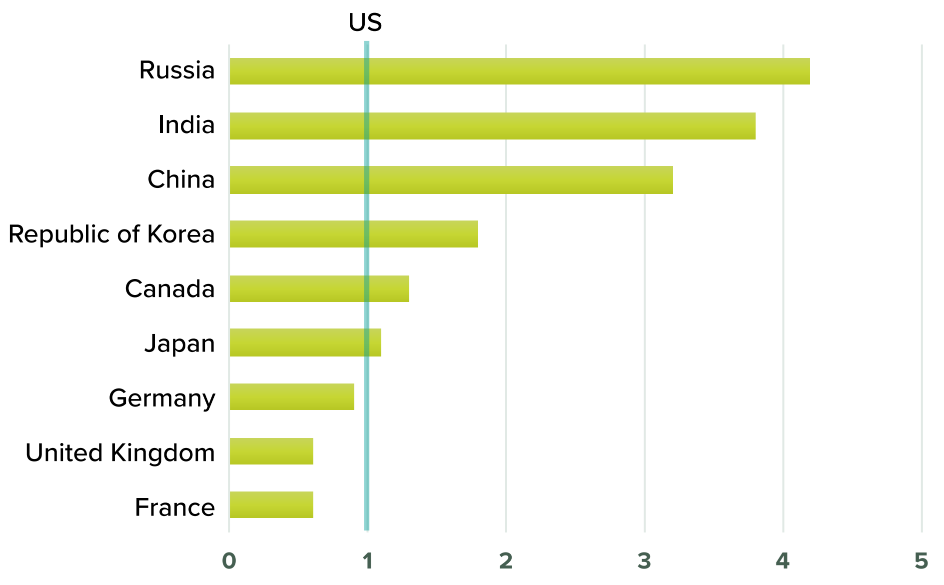
Table 2: Importance of exports to selected major economies and the potential impact of climate and trade policy on competitiveness

Major economy	Exports of goods and services (percentage of GDP)	Likely impact of current civil nuclear policy on export competitiveness*		
		Negative	Positive	Unknown
Germany	43.8	●		
Republic of Korea	36.9			●
Canada	29.0			●
France	28.0	●		
United Kingdom	27.4			●
Russia	25.5		●	
China	18.5		●	
India	18.1		●	
Japan	17.6			●
United States	11.7			●

Data taken from World Bank at https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS.

* If civil nuclear power is at least partly replaced by power generation that results in higher life cycle emissions.

Table 3: Carbon advantage of the US economy, relative to selected major economies (US = 1.0)



indirect emissions from the electricity required to make products. Any growth in the carbon intensity of a manufactured good would reduce its competitiveness in countries that price carbon internally or at the border.

Because no country has yet imposed a CBAM or BCA, the impact of this emerging policy, perhaps through a carbon club, on industrial and power sector policy making has been mostly ignored and, in practice, is largely unknown. In particular, heavy manufacturing interests in industrialized countries with nuclear phaseout or phasedown policies have failed to grasp what it could mean for their competitiveness in a global market that taxes carbon intensity if their host country eliminates or reduces the share of nuclear energy and replaces it, at least in part, with fossil fuels.

Moreover, policy makers in the United States and elsewhere who are concerned about nuclear supply chains and associated proliferation risks have likely underestimated the global demand for commercial nuclear power and the related challenge of addressing the problems generated by a potential Chinese and/or Russian monopoly on the supply chain of nuclear technologies and services. They do not appreciate that a *de facto* international price on carbon would change the economics for the global expansion of commercial nuclear programs.

Most major economies' policies pertaining to existing commercial nuclear programs would either bolster or undermine the attractiveness of their exports as climate and trade policy making becomes more integrated. In the case of China, India, and Russia, if investments in nuclear power were to result in an increase in the percentage of overall electricity generation, there would be an improvement in their overall carbon efficiency.

Interestingly, the major economies most vulnerable to carbon border adjustments because of the economic importance of their exports, particularly Germany and South Korea,[38] are pursuing or have in the past embraced formal, government-backed policies that would phase out or down their commercial nuclear programs. Barring breakthroughs in carbon capture, utilization, and storage (CCUS) that would abate fossil fuel emissions, or in energy storage innovation that would enable increased grid penetration for renewables, nuclear power is likely to be replaced by a mix of fossil fuels and renewables

38 We give South Korea a negative score because the country's nuclear energy policy has become politicized with one major party pushing for its phase out. However, Yoon Suk-yeol, the newly elected president of South Korea, has pledged to scrap the nuclear policy of his predecessor. See Christian Davies, "South Korea Signals Nuclear U-Turn as Global Energy Crisis Looms," *Financial Times*, April 13, 2022, https://www.ft.com/content/6329e02a-d3e9-4812-9062-d5fda8ad7c61.

in those economies, thus resulting in GHG emissions growth in the power sector or an increase in high-emission electricity imports, as in the case of Germany. Moreover, if a climate-informed trade policy results in countries being accountable for the GHG emissions they consume, importing fossil-fuel power to make up for the electricity lost from nuclear shutdowns would reduce carbon efficiency and negatively affect export competitiveness.

The impact of new trade policies remains to be seen for Canada, Japan, the United Kingdom, and the United States. While government support in those economies remains for their respective programs, public policy hurdles must be addressed in each for the role of nuclear in their energy mixes to at least remain the same. These challenges are not simple to address as they range from public opposition in the case of Japan to structural flaws in market designs in Canada, the United Kingdom, and the United States.

As a quick reference for US policy makers on how foreign civil nuclear policy making could directly impact US exports, Table 3 shows the current carbon efficiency of selected major economies, relative to the United States. Countries that score less than 1.0 have a carbon advantage over the United States, and those that are higher are less efficient.[39]

For the sake of convenience, we will assume that the United States maintains its share of nuclear energy in its electricity mix as other countries implement their current set of policies on civil nuclear energy. In this case, France and Germany, both of which currently enjoy a carbon advantage over US production, would see their lead vis-à-vis the United States erode. As Table 2 suggests, the major economies with the most ambitious current civil nuclear programs (China, India, and Russia) are the least competitive with US production at this time, but that handicap could be at least partially mitigated with the relative build out of their respective nuclear power programs.

CONCLUSION

Economies with ambitious GHG emissions reduction commitments in the near term are looking to create trade mechanisms that prevent emissions and job leakage to countries with less stringent climate regulatory regimes. Growing support across G7 countries for such measures is highly likely to provide opportunities for collaboration in designing a common approach to climate and trade policy making. The enactment of a plurilateral agreement among the G7 and likeminded economies—accounting for at least 40 percent of global imports—would generate a *de facto* international price on carbon.

In order to encourage investments in nuclear energy globally:

- G7 countries should encourage global investments in low-carbon technologies, including commercial nuclear energy, particularly in developing countries that export carbon-intensive products.
- Western economies that are phasing down or out their civil nuclear programs (as an official policy or as a result of market forces) should come to terms with the fact that their export competitiveness would deteriorate if at least some of that generation were to be replaced by unabated fossil fuels. This scenario should be especially worrisome to those that are greatly dependent on exports as a percentage of their economy (e.g., Germany and South Korea). In the case of Germany, which remains committed to a nuclear phase-down and supports pricing embodied carbon in trade flows, it appears that the country's manufacturing base may not have connected these dots.
- Emerging economies should think twice about investments in unabated fossil fuel infrastructure.

At the same time, global forecasts for commercial nuclear power have not factored in the likely merger of climate and trade policy. Policy makers in the energy and nonproliferation space have likely underestimated the global demand for commercial nuclear power and the proliferation risks that could emerge. The United States and its allies should consider the national security implications of increased global demand for nuclear power in the context of a potential Chinese and/or Russian monopoly on supply chains related to civil nuclear technologies and services.

39 An index of 3.2 for the purpose of this table means that China's economy on average requires 3.2 times as much CO_2 emissions to produce its output than the United States. See Catrina Rorke and Greg Bertelsen, "America's Carbon Advantage," Climate Leadership Council, September 2020, https://clcouncil.org/reports/americas-carbon-advantage.pdf.

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