COUNCIL on FOREIGN RELATIONS

DISCUSSION PAPER

Global Energy Innovation Index

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Executive Summary

The Global Energy Innovation Index measures the contributions of thirty-nine nations to the global process of improving energy technologies. It draws on sixteen indicators covering three groups of functions that facilitate innovation: knowledge creation and diffusion, market and enterprise formation, and policy support and legitimation. The indicators are standardized, weighted, and compiled to create the main index and the Knowledge, Markets, and Policy Subindexes.

Sweden is the top-ranked contributor to global energy innovation, followed by Denmark, Finland, and Norway (see Table 1.) European nations dominate the rankings. Canada is the only nation outside of Europe to make the top ten. The United States ranks thirteenth in the index. Among other large economies, Japan ranks seventeenth, Italy twenty-first, and China twenty-ninth. The dominance of high-income countries at the top of the rankings is consistent with the concept of common but differentiated responsibilities in climate diplomacy.

Some nations score consistently across the three subindexes, but many exhibit large variations. Spain, for instance, which ranks ninth overall, comes in thirty-fourth on the Knowledge Subindex and first on the Policy Subindex. Saudi Arabia, by contrast, places third on the Knowledge Subindex and last on the Policy Subindex.

These rankings suggest that nations contribute in different ways and to different degrees to energy innovation globally. These differences are relatively stable over time and across alternative weighting schemes. National energy innovation systems, from this perspective, complement one another.

But this rosy interpretation should not be taken as an excuse for complacency. The task of energy innovation is a vital one, and all nations should be upping their games, making the strengths revealed by the index stronger and diminishing their weaknesses.

Table 1: The Rankings

Rank	Country				
1	Sweden	14	Netherlands	27	Luxembourg
2	Denmark	15	Austria	28	Greece
3	Finland	16	Australia	29	China
4	Norway	17	Japan	30	Morocco
5	United Kingdom	18	Czech Republic	31	Lithuania
6	Canada	19	United Arab Emirates	32	Chile
7	Belgium	20	Portugal	33	Poland
8	Germany	21	Italy	34	Saudi Arabia
9	Spain	22	Slovakia	35	Brazil
10	Switzerland	23	Hungary	36	Turkey
11	France	24	Ireland	37	India
12	South Korea	25	New Zealand	38	Mexico
13	United States	26	Estonia	39	Indonesia

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Introduction

"Affordable, reliable, sustainable and modern energy for all" is the United Nations' Sustainable Development Goal 7 (SDG7). The priority placed on energy by the international community reflects its central role in virtually every sphere of life: housing, transportation, commerce, industry, even culture. Although the global energy system meets many human needs, SDG7 has yet to be reached.

The energy system's predominant contribution to climate change is among its chief failings. Carbon dioxide and methane emitted by energy producers and users drive sea level rise, extreme weather, and other climatic risks, with compounding consequences for human societies and natural ecosystems. Nearly all national governments committed to reining in these emissions in Paris in 2015.

A decade later, parties to the Paris Agreement are updating these commitments as they meet in Brazil this month for the 30th Conference of the Parties (COP30). Technological innovation should play a central role in their plans. While a few technologies like solar photovoltaics and electric vehicles are on track to achieve the agreement's goals, most are not. In the International Energy Agency's Net Zero by 2050 scenario, for example, about a third of modeled emissions reductions rely on technologies that are not yet on the market.[1] Many innovations needed to combat climate change will also advance other elements of SDG7, such as accessibility and affordability.

While energy innovation is a global process, national governments are the most important contributors to it. Through their spending, taxation, and regulatory policies, as well as through the signals they send to one another and to their citizens, they can stimulate and focus financial institutions, technology developers, researchers, and other players in the energy innovation ecosystem.

But they do so to different degrees and in different ways. CFR's Global Energy Innovation Index assesses national contributions. It shines a light on achievements as well as shortcomings, with an eye toward driving the development and deployment of solutions to some of humanity's most pressing problems.[2]

The Systems Approach to Energy Innovation

The index draws on the functional theory of innovation systems. An energy innovation system consists of a complex network of actors, institutions, and resources that contribute to the generation, development, diffusion, and use of innovative energy products and services. To be effective, the system must perform a broad range of functions. Suboptimal performance of any function will slow the pace of innovation.[3]

This index is organized around groups of functions with three purposes:

- Creating and diffusing scientific and technical knowledge
- Building enterprises and markets that translate knowledge into deployable technologies
- Using public policy to support and legitimate the development and deployment of new technologies

Without the creation and diffusion of new scientific and technical knowledge, no new energy technologies will emerge and there will be nothing to scale up or legitimate. The key actors performing research, development, and demonstration (RD&D) activities include companies, government laboratories, and academic institutions. The capacity of those institutions to generate and share new knowledge is a fundamental part of each nation's contribution to the global energy innovation system.

The quality of new knowledge that individuals and institutions generate varies considerably. Most discoveries and inventions end up having little scientific or commercial value, while highly valued knowledge is ultimately recognized by and diffused through global networks of academic and professional peers. Intellectual property rights play a dual role, enabling the sharing of know-how that would otherwise remain secret, but preserving the inventor's incentive to put their invention to use by giving them exclusive rights to it.

Enterprise and market development involves a different set of actors, organizations, and institutions than knowledge creation and diffusion. Start-ups, established businesses, financial institutions, and other actors comb through new ideas and inventions, seeking the most promising options for commercial development to be further refined, tested, and scaled up. Entrepreneurs play a leading role by creating new ventures. They carry out the high-risk technological, business, and social experiments that need to be performed before innovative energy products and services can join the mainstream. These new ventures are the focal points for venture capitalists and other players within the innovation system who probe, select, and scale start-ups.

Established businesses may also identify new opportunities and assume the risks of taking untested technologies, products, and ideas to market. Both new ventures and established businesses need to engage in an iterative process of testing, validating, and refining their innovations under real-world conditions through pilot and commercial-scale demonstrations. They also need to spot niche markets and engage with potential users and early adopters in protected learning spaces in order to receive critical user feedback before introducing their innovations into larger markets.

Public policy for energy innovation involves yet another set of actors, organizations, and institutions. Public funding for RD&D performed both inside and outside of the government is crucial for scientific discovery and technological progress. The public sector plays a larger role in supporting knowledge creation for energy innovation than it does for many other sectors, in large part because markets place little value on pollution reduction.

Public policy also underpins adoption of energy innovations. New technologies and business models must be consistent with widely held values in the societies in which they will be deployed. Incumbent energy technologies are often buttressed by political, legal, and regulatory mechanisms and embedded in supportive national and regional cultures. Legitimation of energy innovations involves moving society toward new rules, regulations, routines, practices, norms, beliefs, and cultural meanings.

International collaboration can also help legitimate new energy technologies. While competition among nations and firms is typically healthy for energy innovation, it can be a deterrent if national governments fear that others may capture the gains from their investments. International collaboration can realign these incentives and make the mutual benefits of energy innovation investments more transparent. Intergovernmental organizations, global initiatives, bilateral agreements, and multilateral frameworks establish avenues for cooperation, in addition to those that emerge from the private sector.

The functions covered by these three groupings do not exhaust the possibilities for conceptualizing and understanding the energy innovation system. We have not explored the relationships between energy and other industries, for instance, or the trade-off between diversity and specialization. However, we are confident that the index covers the most essential functions of the innovation system and provides a solid basis for understanding national contributions to the global process of energy innovation.

Measuring National Energy Innovation Systems

Table 2: Indicators and Weighting

	Weight in subindex	Weight overall
Knowledge Subindex (30%)		
Number of Publications	15%	4.5%
Highly Cited Publication	30%	9%
International Co-publications	15%	4.5%
High-Quality Patents	40%	12%
Subindex total	*100%*	*30%*
Markets Subindex (40%)		
Demonstration Projects	10%	4%
Early-Stage Venture Capital Investment	15%	6%
High-Impact Clean Energy Startups	15%	6%
Successful Company Exits	15%	6%
Clean Energy Technology Exports	15%	6%
Energy Intensity Improvement	15%	6%
Clean Energy Consumption	15%	6%
Subindex total	*100%*	*40%*
Policy Subindex (30%)		
Public Investment in Low-Carbon Energy RD&D	40%	12%
Standards and Regulations	20%	6%
Effective Carbon Rates	10%	3%
National Plans and Pledges	20%	6%
International RD&D Collaboration	10%	3%
Subindex total	*100%*	*30%*
Overall total		*100%*

The index is compiled from sixteen indicators, which are listed in Table 2. This section describes each indicator briefly. Most are drawn from data published by international organizations in the open literature. A full description of the indicator scoring process and the sources from which they are drawn can be found in the appendix, which is included at the end of this report

In most cases, we have data through 2024, but in some cases, the lag is greater. Patent data, notably, lags by several years, due to the time it takes patent offices to evaluate applications and compile the data internationally. More generally, although many indicators change relatively slowly, the index is intrinsically retrospective. Changes carried out by governments elected last year, for instance, are unlikely to be reflected in it.

Although some indicators (such as adoption of regulations and standards) can be directly compared across nations, most need to be normalized to allow for cross-country comparison. Indicators that are related to economic activity (such as venture capital investment) are weighted by economic size as measured by gross domestic product (GDP). Indicators tied to human capital (such as research publications) are normalized by national population. The index therefore does not measure absolute contributions to global energy innovation, which would feature large nations more prominently.

The indicators are organized into three subindexes that correspond with the three functional groupings: knowledge, markets, and policy. The indicators within each subindex are weighted as shown in Table 2. The subindex scores are then weighted and combined to create the main index. Table 2 also displays the weight of each indicator within the index.

As Table 2 shows, the Markets Subindex is weighted most heavily in the main index, at 40 percent, while the Knowledge and Policy Subindexes are each weighted at 30 percent. Those weights reflect our judgments about the importance of the functions we seek to capture in each subindex to the overall innovation process as well as the quality of the available data. However, the index is relatively insensitive to reasonable changes in the weights of the subindexes.

KNOWLEDGE SUBINDEX

The Knowledge Subindex is made up of four indicators that measure the quantity and quality of each nation's contributions to the scientific literature that underpins energy innovation and to inventions that are sufficiently novel and useful to warrant patent protection in multiple major markets. The total number of publications in the scientific literature on topics associated with low-carbon technologies measures the overall level of effort a nation's research community is devoting to energy innovation. The number of these publications that are highly cited by other researchers measures the quality of each national community's output. The number of these publications that are coauthored with researchers from another nation measures the reach of a nation's research networks. The number of patents that are granted for the same invention in the United States, European Union, and Japan (known as "triadic patent families") indicates the quantity and quality of energy innovation carried out by a nation's businesses and individual inventors.

As shown in Table 2, high-quality patents are weighted most heavily (40 percent) in the Knowledge Subindex, because they are our only measure of the creation and diffusion of applied knowledge. We weight highly cited publications next (30 percent), since they are more likely than other publications to impact innovation. The number of publications and international co-publications are equally weighted (15 percent).

MARKETS SUBINDEX

The Markets Subindex is made up of seven indicators that gauge the degree to which a nation's entrepreneurs and businesses are developing, scaling, and exporting energy innovations, as well as the extent to which its energy users are improving efficiency and purchasing clean energy, thereby building markets for energy innovations. Participation in demonstration projects indicates a nation's commitment to supporting first-of-a-kind commercial-scale technologies. The scale of venture capital investment in cleantech start-ups measures the appetite for risk-taking on the part of a nation's financial sector. The number of high-impact start-ups measures the quality of cleantech entrepreneurship, while the number of successful start-up exits through acquisition or initial public offering provides insights into the capacity of a nation's energy innovation ecosystem to scale successful businesses. Clean energy technology exports indicate the success of a nation's innovators in penetrating foreign markets. A nation's improvement in energy intensity suggests how rapidly it is adopting energy efficiency technologies. The share of its total energy provided by clean resources signals the willingness of its users to adopt energy innovations.

As shown in Table 2, we weight all of the indicators in this subindex equally (15 percent), with the exception of demonstration projects (10 percent). The quality of our data on demonstration projects is weaker than the data for the other indicators, because the concept is ill-defined and there are no rigorous reporting processes.

POLICY SUBINDEX

The Policy Subindex is made up of five indicators that attempt to measure national governments' commitments to accelerating energy innovation. Public investment in energy RD&D drives scientific research, technological development, and demonstration projects forward. Standards and regulations for energy efficiency and renewables encourage development and adoption of technologies in these fields. Effective carbon rates (which include taxes on greenhouse gas emissions, prices on emissions set by emissions trading systems, and taxes on conventional fuels) induce innovation in low-carbon technologies by making the use of high-carbon technologies more expensive.[4] National plans and pledges indicate the trajectory of future energy innovation policies. International RD&D collaboration through the International Energy Agency and Mission Innovation encourages energy innovation among partners and globally.

As shown in Table 2, we weight public investment in low-carbon energy RD&D most heavily in the Policy Subindex (40 percent). Without such investment, knowledge creation and demonstration would depend on private and philanthropic funders and would be greatly diminished as a result. The policy function in this sense underpins the knowledge function. It also underpins the markets function through standards and regulations (weighted at 20 percent) and carbon rates (10 percent). We weight national plans and pledges at 20 percent as well, and collaboration in international RD&D forums at 10 percent.

The Index

Table 3: Index Rankings

GEII rank	Country	Subindex ranks Knowledge *Weight 30%*	Markets *Weight 40%*	Policy *Weight 30%*
1	Sweden	8	1	12
2	Denmark	1	8	10
3	Finland	6	2	6
4	Norway	7	4	5
5	United Kingdom	9	5	7
6	Canada	15	7	9
7	Belgium	20	9	4
8	Germany	19	6	11
9	Spain	34	20	1
10	Switzerland	11	16	13
11	France	32	12	2
12	South Korea	2	25	21
13	United States	29	3	15
14	Netherlands	17	18	8
15	Austria	23	19	3
16	Australia	5	21	26
17	Japan	10	23	16
18	Czech Republic	13	10	23
19	United Arab Emirates	4	36	22
20	Portugal	22	14	19
21	Italy	21	26	14
22	Slovakia	33	11	24
23	Hungary	30	13	25
24	Ireland	16	33	18
25	New Zealand	12	17	33
26	Estonia	24	15	32
27	Luxembourg	26	31	20
28	Greece	31	34	17
29	China	14	29	31
30	Morocco	18	30	28
31	Lithuania	25	28	30
32	Chile	35	24	29
33	Poland	27	22	34
34	Saudi Arabia	3	38	39
35	Brazil	38	27	27
36	Turkey	28	32	35
37	India	36	37	36
38	Mexico	39	35	37
39	Indonesia	37	39	38

Table 3 displays national rankings for the Global Energy Innovation Index and the Knowledge, Markets, and Policy Subindexes. Sweden is the top-ranked contributor, followed by three other Scandinavian nations: Denmark, Finland, and Norway. European nations dominate the rankings, capturing nine of the top ten slots. Europe's reputation as a leader in the transition to clean energy is supported by the index.[5] Only Canada breaks the trend, placing sixth.

The United States ranks thirteenth in the index, just below South Korea. The ranks of other large economies include Japan, seventeenth; Italy, twenty-first; and China, twenty-ninth. The bottom of the index is populated by large middle- and lower-income countries, including Brazil, Turkey, India, Mexico, and Indonesia. These rankings are consistent with the concept of common but differentiated responsibilities, which is a fundamental tenet of climate diplomacy that places a heavier burden for mitigating climate change on high-income countries that have emitted a disproportionate share of greenhouse gases in the past.

Most nations near the top of the rankings score consistently highly across all three subindexes. Among the top five nations, for instance, Sweden is the only one to rank outside the top ten on any subindex, with its twelfth-place ranking on the Policy Subindex. Some nations, however, exhibit large variations in rank across the subindexes. Spain ranks ninth overall, thirty-fourth on the Knowledge Subindex, and first on the Policy Subindex. Saudi Arabia, by contrast, places third on the Knowledge Subindex, second to last on the Markets Subindex, and last on the Policy Subindex.

One interpretation of these variations is that they demonstrate how national energy innovation systems may complement one another. Knowledge produced within one nation's borders may be used to found companies in another. One nation's technology exports may provide opportunities for another nation to build markets for them. Nations that lead in the Policy Subindex may provide motivation for those that are lagging. From this perspective, the global innovation system is strengthened by national diversity that reflects historical and institutional differences.

While these differences may explain the variations in the rankings across the subindexes, the potential for complementarity should not be an excuse for complacency. Top-ranked Sweden, for instance, could certainly strengthen its energy innovation policy and move up from twelfth place on that subindex. The United States, similarly, has plenty of room for improvement from its twenty-ninth-place ranking on the Knowledge Subindex.

The rankings display consistency to credible changes in the weighting scheme. We tried weighting each of the subindexes at 40 percent and 50 percent (leaving the others at 30 percent or 25 percent). In all but one case the average change in a nation's rank in the index, compared to our preferred weighting scheme, was less than one and a half places. The outlier case (in which we weighted the Knowledge Subindex at 50 percent and the other two subindexes at 25 percent) produced an average change of 2.6 ranks for each nation in the index.

We also compiled a version of the index with data from 2021. The national rankings were similar to those in 2025. Finland, Denmark, Sweden, and the United Kingdom, all of which ranked in the top five in 2025, took the top four slots in 2021. But there was also some movement: Norway moved from eleventh to fourth between 2021 and 2025, and Switzerland from tenth to fifth. The largest move was made by Spain, which rose from twenty-second in 2021 to ninth in 2025, due in large part to Spain's large and rapid increase in public investment in energy research, development, and demonstration.

Knowledge Subindex

Table 4: Knowledge Subindex Rankings

		Indicator ranks			
Knowledge subindex rank	Country	Total Clean Energy Publications	Highly Cited Publications	International Co-publications	High Quality Patents
1	Denmark	2	3	2	3
2	South Korea	10	8	10	1
3	Saudi Arabia	3	4	3	30
4	United Arab Emirates	6	2	4	29
5	Australia	9	1	1	31
6	Finland	5	5	14	7
7	Norway	1	6	11	19
8	Sweden	7	16	6	4
9	United Kingdom	13	7	5	11
10	Japan	36	35	34	2
11	Switzerland	11	15	13	5
12	New Zealand	28	10	7	24
13	Czech Republic	22	13	8	26
14	China	27	9	28	13
15	Canada	20	12	12	21
16	Ireland	15	11	26	22
17	Netherlands	16	21	18	9
18	Morocco	31	17	23	8
19	Germany	26	26	25	6
20	Belgium	17	19	29	12
21	Italy	19	20	32	20
22	Portugal	12	18	24	35
23	Austria	14	29	30	18
24	Estonia	8	37	21	16
25	Lithuania	24	14	15	37
26	Luxembourg	4	39	20	17
27	Poland	18	27	16	32
28	Turkey	30	24	17	27
29	United States	34	28	22	14
30	Hungary	25	25	19	34
31	Greece	21	22	27	33
32	France	33	32	33	10
33	Slovakia	29	23	9	37
34	Spain	23	30	37	23
35	Chile	32	34	31	15
36	India	35	33	35	25
37	Indonesia	39	31	36	37
38	Brazil	37	36	39	36
39	Mexico	38	38	38	28

The Knowledge Subindex seeks to measure national contributions to global energy innovation made through publication of research articles and patenting of inventions. Three indicators measuring publication are weighted at 60 percent in the subindex, while the remaining 40 percent is assigned to high-quality patents. Those indicators are scaled by national population or GDP to put large and small countries on a comparable footing.

As Table 4 shows, Denmark comes out on top of the Knowledge Subindex, ranking among the top three nations on all four of the indicators included in it. South Korea ranks second, leading the way in high-quality patents. Australia tops the list on two indicators, highly cited publications and international co-publications. Norway's score on number of publications is the highest for that indicator. All of these countries would have ranked at or near the top of these indicators in 2021 as well.

Saudi Arabia and the United Arab Emirates ranked third and fourth, respectively, in the Knowledge Subindex. We do not have data to compare their performance in 2021, but it is clear that these nations' recent investments in scientific capacity are paying dividends. Both ranked in the top six on all three of the publications indicators. They are in the bottom third, however, on high-quality patents, profiling similarly to Australia across the subindex components.

Finland, Sweden, the United Kingdom, and Japan round out the top ten. Japan's profile on this subindex is the mirror image of that of Saudi Arabia, the United Arab Emirates (UAE), and Australia; it ranks second in high-quality patents and near the bottom on publications. The profile of the United States resembles that of Japan, but its rank on high-quality patents is only fourteenth, leaving its subindex score in twenty-ninth place compared to Japan's tenth out of the thirty-nine countries included.

The United States dropped twelve places compared to where it would have ranked in 2021 (though the reader should bear in mind that we only have complete historical data for only thirty-one countries). The drop is particularly pronounced in highly cited publications. The Czech Republic, by contrast, shows the largest gains, moving from twenty-eighth in 2021 to thirteenth in 2025, due to growth in highly cited publications and international co-publications.

Markets Subindex

Table 5: Market Subindex Rankings

Markets subindex rank	Country	Indicator ranks: Technology Demonstration Projects	Early-Stage Venture Capital Investment	High-Impact Clean Energy Startups	Successful Company Exits	Technology Exports	Energy Intensity Improvement	Clean Energy Consumption
1	Sweden	6	1	11	1	9	11	1
2	Norway	1	10	12	6	26	30	4
3	Finland	7	5	14	2	17	35	2
4	United States	17	4	1	5	36	14	22
5	Germany	13	6	4	15	5	2	30
6	Belgium	9	16	17	10	6	4	15
7	United Kingdom	10	3	3	8	18	7	17
8	Czech Republic	28	32	30	28	3	3	9
9	Denmark	1	18	16	7	12	22	10
10	Slovakia	28	13	33	28	2	18	7
11	Portugal	4	15	33	28	35	1	13
12	Canada	11	11	2	3	20	29	16
13	Hungary	28	36	30	28	1	5	12
14	France	15	7	7	14	24	27	3
15	Switzerland	23	8	10	12	27	24	6
16	Austria	8	26	24	17	14	17	11
17	Spain	18	23	18	18	16	8	14
18	Australia	3	21	8	13	38	19	36
19	Poland	21	33	33	23	8	6	35
20	New Zealand	14	24	13	11	30	28	5
21	Japan	20	29	15	27	10	16	23
22	Netherlands	5	14	9	9	22	34	26
23	Estonia	28	1	19	4	7	39	31
24	South Korea	25	22	19	22	4	26	20
25	Chile	12	34	27	19	11	25	18
26	Italy	22	31	29	21	19	9	25
27	Brazil	26	25	23	26	32	23	8
28	China	24	9	5	24	21	32	28
29	Morocco	28	28	33	28	15	10	39
30	Lithuania	28	12	28	28	23	20	21
31	Turkey	28	37	30	28	28	15	24
32	Luxembourg	28	19	33	28	31	13	33
33	Greece	28	38	21	28	33	12	32
34	Mexico	28	35	21	28	13	21	38
35	United Arab Emirates	19	27	33	28	25	36	19
36	India	27	17	6	20	34	31	37
37	Ireland	16	20	24	16	29	33	27
38	Saudi Arabia	28	39	33	28	37	37	34
39	Indonesia	28	30	24	25	39	38	29

Table 5 displays the rankings for the Markets Subindex. These rankings attempt to capture key innovation system functions that enable the building of innovative enterprises and vibrant markets that support the rapid development and deployment of new energy technologies. The three indicators that focus on start-ups have 45 percent of the total subindex weight. Energy intensity and consumption make up 30 percent, and exports and demonstration projects, the remaining quarter.

Sweden, Norway, and Finland take the top three spots on this subindex. Sweden wins the highest score on the indicators for successful company exits and clean energy consumption with Finland placing second in both, while Norway ties with Denmark for first in demonstration projects. Three other small European nations reach the top rank on Market Subindex indicators: Estonia on early-stage venture capital investment, Hungary on clean energy technology exports, and Portugal on energy intensity improvement.

The United States ranks fourth on the Markets Subindex. It is buoyed by its top score on high-impact clean energy start-ups and top-five ranking on the other two start-up indicators. These outweigh its dismal thirty-sixth place showing on clean energy technology exports. The United Kingdom and Germany, the fifth- and sixth-ranked nations, show more consistency across the indicators.

Four European nations place among the top six in both clean energy technology exports and energy intensity improvement: Belgium, the Czech Republic, Germany, and Hungary. These rankings may reflect the shift of the industrial base of these nations away from heavy energy-intensive production. The energy intensity improvement measure also privileges nations that entered the measurement period with relatively energy-intensive or inefficient economies, since they have more room to improve than those that were already highly efficient.

Among nations for which we have complete data for 2021, Australia slipped considerably in the Markets Subindex, from seventh to twenty-first. Norway went the other direction, rising nine places. The United States rose five places, aided by a jump in the indicators for high-impact start-ups and energy intensity improvement, which offset a drop in exports.

Policy Subindex

Table 6: Policy Subindex Rankings

		Indicator ranks				
Policy subindex rank	Country	Public Investment in Low-Carbon Energy RD&D	Standards and Regulations	Effective Carbon Rates	National Plans and Pledges	International RD&D Collaboration
1	Spain	1	6	15	5	17
2	France	4	8	11	5	9
3	Austria	3	9	10	20	3
4	Belgium	5	5	17	5	20
5	Norway	2	23	4	35	13
6	Finland	6	17	8	2	17
7	United Kingdom	9	10	18	2	5
8	Netherlands	14	4	2	1	11
9	Canada	7	22	23	5	1
10	Denmark	16	2	6	2	13
11	Germany	12	1	5	12	4
12	Sweden	10	12	12	5	13
13	Switzerland	11	20	1	17	7
14	Italy	17	3	7	12	5
15	United States	ND	16	30	17	1
16	Japan	8	19	28	29	11
17	Greece	ND	25	9	12	30
18	Ireland	20	7	22	12	21
19	Portugal	13	11	13	23	24
20	Luxembourg	ND	ND	3	20	37
21	South Korea	15	13	32	33	7
22	United Arab Emirates	ND	30	ND	5	30
23	Czech Republic	19	18	19	23	25
24	Slovakia	28	15	20	12	30
25	Hungary	27	14	24	17	37
26	Australia	21	26	27	23	9
27	Brazil	18	28	36	29	22
28	Chile	22	29	26	20	29
29	Morocco	ND	36	31	5	28
30	Lithuania	23	ND	21	23	37
31	China	ND	27	33	37	13
32	Estonia	26	ND	14	29	35
33	New Zealand	29	31	25	23	22
34	Poland	25	33	16	29	30
35	Turkey	24	34	37	23	25
36	India	ND	21	35	39	19
37	Mexico	30	24	29	37	30
38	Indonesia	ND	32	34	33	35
39	Saudi Arabia	ND	35	ND	35	25

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Table 6 conveys the rankings for the Policy Subindex, which seeks to measure national governments' commitments to accelerating energy innovation. The key policies included in the subindex focus on public funding for and international cooperation in energy RD&D (which together carry 50 percent of the subindex's weight), standards and regulations for energy efficiency and renewables, effective carbon rates, and national plans and pledges.

Spain ranks first on the Policy Subindex, scoring well ahead of France, Austria, and Belgium, which take the next three places. Spain scores extremely highly in public investment in RD&D and is in the top ten in standards and regulation and pledges and plans. Its progress since 2021, when it would have ranked twenty-third in the subindex and twenty-seventh in public investment in RD&D, is very impressive.

Leadership on the other indicators is spread widely across Europe and North America, with Germany taking the top spot in standards and regulation, Switzerland ranking highest on effective carbon rates, the Netherlands leading on national plans and pledges, and Canada and the United States tying for the best score in international RD&D collaboration. Although the Scandinavian nations do not rank as highly on this subindex as the others, they are all in the top third, which contributes to their high ranks on the overall index.

The United States ranks in the middle tier of this subindex at fifteenth. Its public investment in RD&D is eighth, but it ranks thirtieth in effective carbon rates, reflecting opposition at the federal level to carbon taxes and cap-and-trade programs. (A number of states, including California, impose a price on carbon, which keeps the United States from scoring at the bottom of this measure.) Although U.S. plans and pledges score in the middle of the group, the Trump administration's pullback will certainly reduce this score in the future.

The International Energy Agency does not publish RD&D investment figures for many nonmembers, including China, India, Saudi Arabia, and the UAE. This data gap inhibits our analysis of this subindex as well as comparisons with the past. For those nations for which our data is complete, Austria stands out (along with Spain) for its rise in the rankings since 2021, while Switzerland and the Czech Republic have fallen furthest.

Conclusion

Energy innovation is a vital task for the international community. To achieve SDG7 and to mitigate the global threat of climate change, the world economy must shift toward an energy system that emits far fewer greenhouse gases. The Global Energy Innovation Index ranks nations according to their contributions to this global task.

Sweden ranks first in the index. Other Scandinavian nations also rank highly, and the top ranks are generally dominated by European nations. The picture is more varied on the Knowledge, Markets, and Policy Subindexes that go into the index, as well as the sixteen indicators that go into the subindexes. The United States, for example, ranks first on high-impact clean energy start-ups and thirty-sixth on clean energy technology exports, both of which are included in the Markets Subindex.

The index finds that nations contribute in different ways and to different degrees to energy innovation globally. These differences are relatively stable over time and across alternative weighting schemes. That suggests that national energy innovation systems complement one another. Knowledge flowing across national borders, for instance, can stimulate markets in the recipient nations. The global innovation system, in this interpretation, is strengthened by national diversity.

This rosy interpretation should not be taken as a rationale for merely maintaining the status quo. The task of energy innovation is a vital one, and all nations should be upping their games, making the strengths revealed by the index stronger and diminishing their weaknesses.

Appendix: Methodology and Sources

This appendix describes the data and methods used in CFR's Global Energy Innovation Index in detail. (Short descriptions can be found in the index report.) Our goals are to be as transparent as possible, credit the organizations whose work we draw on, and enable replication and extension by colleagues.

Sixteen indicators form the core of the index. We draw largely on data published in the open literature by other organizations. We also use a proprietary database shared by the Cleantech Group and information gathered by the research team. In many cases, the indicators measure both the level for the most recent year for which data is available and the change over the previous four years.

We standardize the indicators for direct comparison by converting them into z-scores, with the mean set to 10 and standard deviation set to 4. The scores are capped at 0 and 20 (2.5 standard deviations from the mean in either direction). This method ensures that outlier observations do not carry too much weight. A nation making an average contribution to the global energy innovation system on a given indicator receives a score of 10, while the maximum score is 20.

We then weight each indicator according to our judgment about its importance and the quality of the available data. These weights, which are laid out in Table 2 of the index report, yield the Knowledge, Markets, and Policy Subindexes as well as the full index.

KNOWLEDGE SUBINDEX

Indicator K1: Number of Publications

The primary source for this indicator is the Web of Science Core Collection, a bibliographic database maintained by Clarivate. We searched the database for key words associated with low-carbon energy technologies. (A list of the keyword searches used for each technology category is available upon request.) The addresses affiliated with the authors of each publication returned by the search were used to build country counts. If a publication included at least one author from a country, that country was credited with one publication. (In other words, we did not do fractional counting for this indicator as in Indicator K2.) Data was gathered for the years 2020 to 2024 and scaled by national population. The 2024 level was weighted at 80 percent and the rate of change since 2020 was weighted at 20 percent to create the indicator.

Indicator K2: Highly Cited Publications

This indicator uses all publications within the indicator K1 dataset that rank in the top 10 percent of each technology field by number of citations. Authorship of these publications by country was counted fractionally. This method attributes the credit for a publication to multiple contributing authors, and then aggregates by the country of each author's primary affiliation to arrive at a country attribution. For instance, for a paper with two authors from country A and one from country B, country A would receive a count of 0.67 and country B, 0.33. The total number of fractional publications is aggregated to create country totals. Data was gathered for the years 2020 to 2024 and scaled by national population. The 2024 level was weighted at 80 percent and the rate of change since 2020 was weighted at 20 percent to create the indicator.

Indicator K3: International Co-publications

This indicator uses all publications within the indicator K2 dataset that have coauthors from more than one nation. All unique countries of authors in a co-publication were each credited with one publication in our methodology. (In other words, we did not do fractional counting for this indicator as in indicator K2.) Data was gathered for the years 2020 to 2024 and scaled by national population. The 2024 level was weighted at 80 percent and the rate of change since 2020 was weighted at 20 percent to create the indicator.

Indicator K4: High-Quality Patents

The primary source for this indicator is the Organization for Economic Cooperation and Development (OECD) "patents by technology" database, restricted to the "climate change mitigation" technology domain. We collected triadic patents—that is, inventions for which applications were made in all three major patent offices: the European Union, Japan, and United States. The OECD counts patents fractionally by country and assigns them to the year of the priority date of the application (that is, when it was first applied for). Because there is a lag between the priority date and the date the patent is granted, which may be two years or more, this indicator covers an earlier period than the others. Data was gathered for the years 2016 to 2020 and scaled by GDP. The 2020 level was weighted at 80 percent and the rate of change since 2016 was weighted at 20 percent to create the indicator.

MARKETS SUBINDEX

Indicator M1: Demonstration Projects

The primary source for this indicator is the International Energy Agency (IEA) database of demonstration projects. We counted the number of completed and developing projects in each country during the 2020–24 period and scaled them by GDP. No data was found for the Czech Republic, Estonia, Greece, Hungary, Indonesia, Lithuania, Luxembourg, Mexico, Morocco, Saudi Arabia, Slovakia, or Turkey.

Indicator M2: Early-Stage Venture Capital Investment

The primary source for this indicator is the i3 database, a proprietary database shared with us by the Cleantech Group. The Cleantech Group tracks venture investments in current U.S. dollars by deal in a range of energy technology domains. We aggregated investment to the country level based on the location of the headquarters of the business receiving the investment. Because venture capital investment is volatile on an annual basis, our indicator is the average level of investment for the 2020–24 period, scaled by GDP.

Indicator M3: High-Impact Clean Energy Start-Ups

The Cleantech Group identifies and honors the most promising start-ups in the technology domains, which it tracks with several awards. These include the Global Cleantech 100, the Cleantech 50 to Watch, the APAC 25, and the Latam 25. We gathered this data for the 2021–25 period. (Note: the Latam 25 was initiated in December 2024, so no prior year data is available.) We attribute these high-impact clean energy start-up companies to the nation in which they are headquartered. The Global Cleantech 100 Awards, which are the most prominent in this group, were double-weighted relative to the others. Our indicator is the total count of weighted awards by country for the 2020–24 period, scaled by GDP. No data was found for Luxembourg, Morocco, Poland, Portugal, Saudi Arabia, Slovakia, or the United Arab Emirates.

Indicator M4: Successful Company Exits

The primary source for this indicator is the i3 database, a proprietary database shared with us by the Cleantech Group. The Cleantech Group tracks start-up exits through initial public offerings and acquisitions in a range of technology domains. Successful company exits are aggregated to the country level based on the location of the headquarters of the business. Because the number of exits is volatile on an annual basis, the exits indicator is the total number of exits for the 2020–24 period, scaled by GDP. No data was found for the Czech Republic, Greece, Hungary, Lithuania, Luxembourg, Mexico, Morocco, Portugal, Saudi Arabia, Slovakia, Turkey, or the United Arab Emirates.

Indicator M5: Clean Energy Technology Exports

The primary source for this indicator is the UN Commodity Trade Statistics Database. The methodology was drawn from a 2020 study by the International Monetary Fund that identifies a set of Harmonized System codes to the six-digit level to track clean energy technology exports. Exports comprise all such products leaving a nation's territory. Data was gathered for the years 2020 to 2024 and scaled by GDP. The 2024 level was weighted at 80 percent and the rate of change since 2020 was weighted at 20 percent to create the indicator.

Indicator M6: Energy Intensity Improvement

The primary source for this indicator is the U.S. Energy Information Administration's international energy intensity database. Energy intensity is calculated as total energy consumption per GDP using purchasing power parity. The rate of energy intensity improvement is the annual percentage change in energy intensity.

Indicator M7: Clean Energy Consumption

The primary source for this indicator is the Statistical Review of World Energy, now published by the Energy Institute and formerly published by BP. The clean energy consumption indicator is calculated as the share of a nation's total energy supply provided by nuclear energy and renewable energy. Data was gathered for the years 2020 to 2024. The 2024 level was weighted at 80 percent and the five-year rate of change was weighted at 20 percent to create the indicator.

POLICY SUBINDEX

Indicator P1: Public Investment in Low-Carbon Energy RD&D

The primary source for this indicator is the International Energy Agency's energy technology RD&D budgets database. The IEA tracks government investment in energy RD&D institutions, projects, and other activities. Low-carbon technologies include energy efficiency, carbon capture and storage, renewable energy sources, nuclear, hydrogen and fuel cells, other power and storage, and other cross-cutting technologies and research. Data was gathered for the years 2020 to 2024 and scaled by GDP. The 2024 level was weighted at 80 percent and the five-year rate of change was weighted at 20 percent to create the indicator. No data was found for China, India, Indonesia, Morocco, Saudi Arabia, or the United Arab Emirates. Greece and Luxembourg have not reported energy RD&D to the IEA since 2011 and 2012, respectively, and their government spending in energy RD&D is assumed to be zero. Data for the U.S. investments in low-carbon energy RD&D are from the Information Technology and Innovation Foundation report *Energizing Innovation in Fiscal Year 2024.*

Indicator P2: Standards and Regulations

The primary source for this indicator is the World Bank's Regulatory Indicators for Sustainable Energy (RISE) database. The RISE database uses a wide range of indicators to assess the strength of national policies and regulatory frameworks that support energy efficiency and renewable energy, on a scale of 0 to 100. Our indicator averages the RISE Energy Efficiency and Renewable Energy scores. Data was gathered for the years 2020 to 2024. The 2024 level was weighted at 80 percent and the rate of change since 2020 was weighted at 20 percent to create the indicator. No data was available for Estonia, Lithuania, or Luxembourg.

Indicator P3: Effective Carbon Rates

The primary source for this indicator is the OECD's database of effective carbon rates. This data is available for the years 2018, 2021, and 2023. The 2023 level was weighted at 80 percent and the rate of change since 2018 was weighted at 20 percent to create the indicator. No data was available for Saudi Arabia or the United Arab Emirates.

Indicator P4: National Plans and Pledges

The primary sources for this indicator are plans and pledges offered by national governments that align with the global energy goals laid out in the 28th Conference of the Parties (COP28) Global Stocktake. National commitments for renewable energy, energy efficiency, carbon capture and storage, and net-zero emissions were assessed based on inclusion in nationally determined contributions (NDCs) or long-term strategies (LTSs) available through the UN Framework Convention on Climate Change NDC Registry and LTS Portal. Nations with a net-zero emissions target receive two points if the plan is embedded in a policy document (e.g., a nationally determined contribution or long-term strategy) and one point if it is in a political pledge. We examine NDCs under the Paris Agreement to learn if they include quantified targets for energy efficiency and renewables (three points each), explicit policies for either of these technologies (two points each) or general mentions of these technologies (one point each). We also award nations one point each for endorsing these important international pledges or alliances aimed at achieving the COP28 global energy goals:

- Powering Past Coal Alliance
- Global Energy Storage and Grids Pledge
- Global Methane Pledge
- Global Cooling Pledge
- Declaration to Triple Nuclear Energy by 2050
- COP29 Hydrogen Declaration
- Carbon capture, utilization, and storage/carbon dioxide removal mentioned in NDC
- Zero Emission Vehicles Declaration
- Coalition on Phasing Out Fossil Fuel Incentives Including Subsidies

The maximum raw score on this indicator is seventeen, which would be earned if a nation has specific, credible, and quantified plans in its NDCs and has committed to all nine energy innovation pledges.

Indicator P5: International RD&D Collaboration

The primary sources for this indicator are membership and leadership in the International Energy Agency's twenty-eight clean energy Technology Collaboration Programmes and Mission Innovation's seven Missions. Participation in fossil energy programs other than for carbon capture and storage and for fusion power for which membership information was not available were excluded. A nation earns one point for membership and two points for leadership in any of these activities. The data was based on the latest available reports from the two organizations and was not scaled.

Endnotes

1. International Energy Agency, *Tracking Clean Energy Progress 2023* (Paris: International Energy Agency, July 2023) https://www.iea.org/reports/tracking-clean-energy-progress-2023; and International Energy Agency, *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach* (Paris: International Energy Agency, September 2023), https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-c-goal-in-reach/executive-summary.

2. The CFR Global Energy Innovation Index builds on two prior versions published by the Information Technology and Innovation Foundation. Colin Cunliff and David M. Hart, *Global Energy Innovation Index: National Contributions to the Global Clean Energy Innovation System* (Washington, DC: Information Technology and Innovation Foundation, August 2019), https://itif.org/publications/2019/08/26/global-energy-innovation-index-national-contributions-global-clean-energy/; and Chad A. Smith and David M. Hart, *The 2021 Global Energy Innovation Index: National Contributions to the Global Clean Energy Innovation System* (Washington, DC: Information Technology and Innovation Foundation, October 2021), https://itif.org/publications/2021/10/18/2021-global-energy-innovation-index-national-contributions-global-clean/.

3. M.P. Hekkert et al., "Functions of Innovation Systems: A New Approach for Analyzing Technological Change," *Technological Forecasting and Social Change* 74, no. 4 (2007): 413–32, https://doi.org/10.1016/j.techfore.2006.03.002; and Anna Bergek et al., "Analyzing the Functional Dynamics of Technological Innovation Systems: A Scheme of Analysis," *Research Policy* 34, no. 3 (2008): 407–29, https://doi.org/10.1016/j.respol.2007.12.003.

4. OECD, *Effective Carbon Rates 2023: Pricing Greenhouse Gas Emissions Through Taxes and Emissions Trading*, OECD Series on Carbon Pricing and Energy Taxation (Paris: OECD Publishing, 2023), https://doi.org/10.1787/b84d5b36-en.

5. Although many of its member-states are included in the index, the European Union is not. The EU as a whole is responsible for roughly 20 percent of the global total of publications, high-quality patents, early-stage venture capital investment, and high-impact clean energy startups. Those indicators, along with most others, are measured at the national level in our data. A few indicators, such as nationally determined contributions, are measured at the EU level, with all member states receiving the same value.

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