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King Abdullah Petroleum Studies and Research Center

Commentary

Understanding the Dynamics of the Renewable Energy Transition: Country Performance and Potential

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Renewable energy (RE) is a vital stream of the global energy transition toward sustainable alternatives

Renewable energy (RE) is a vital stream of the global energy transition toward sustainable alternatives. Various mitigation strategies, such as enhancing energy efficiency, utilizing fuel switching, deploying nuclear power and adopting carbon capture, have been developed. Of these, RE has captured the most attention globally, especially in the power sector. Despite this global trend, however, RE penetration differs significantly across countries. Some countries, such as Denmark, generate half of their power from renewable resources. In contrast, many others, such as Russia, are generating less than 1% of their power from renewable resources as of 2018. These data facts raise the important question of whether this heterogeneity in RE penetration reflects countries' potentials. In other words, to what extent countries truly utilize their RE opportunities. To shed light on this critical question, we present a comprehensive analysis of country-specific transition gaps. We define the transition gap as the difference between a country's RE transition potential and its performance. Measuring these transition gaps can help policymakers recognize their countries' transition opportunities.

The RE transition is a complex, multifactor and long-term process

The RE transition is a complex, multifactor and long-term process. Several domestic and global factors affect countries' motivations to increase their use of RE (e.g., Bourcet [2020]; Darmani et al. [2014]; Sener, Sharp, and Anctil [2018]). Focusing on the key determinants, Yilmaz (2021a) identifies 45 indicators in seven main areas to construct a composite index, the RE transition potential index (RETPI). These seven main areas are *economic factors, financial development, human capital, energy access, energy security, environmental sustainability and institutional infrastructure*. The RETPI is a powerful tool for assessing a country's RE transition potential given its standing on the key indicators over the past three decades.

In this study, we use RETPI scores to measure countries' RE transition potentials. Among different proxies for the RE transition performance in the literature (e.g., Bourcet [2020]), we focus on modern RE technologies. Specifically, we employ the share of non-hydroelectric RE (NhRE), which includes solar, wind and geothermal resources,[1] in total electricity generation.[2]

The findings of our country-specific comparative analysis indicate significant transition gaps. A considerable number of countries underperform their potentials, whereas some countries overperform. Among European countries with the highest transition potentials, Germany, Ireland and the United Kingdom are overperformers. In contrast, Finland, Sweden, Norway, Austria and Switzerland underperform despite their high potential. Denmark is an exceptional overperforming Nordic country. Its NhRE share in electricity generation, 48%, is one of the highest globally as of 2018. Fossil-fuel-rich countries in Central Asia, such as Russia, Kazakhstan, Azerbaijan, Turkmenistan and Uzbekistan, significantly underperform their potentials, with NhRE shares below 1%.

The countries in East Asia and the Pacific with the most potential, such as Hong Kong and Singapore, have surprisingly low transition performances. Their NhRE shares remain below 1% as of 2018, with almost full dependence on traditional fossil fuels for electricity production. Additionally, Japan and Australia are far from achieving their full potential. New Zealand is a pioneering country in the Pacific, leading the regional transition with an

outstanding performance. South Asian countries, such as India, Pakistan and Bangladesh, have moderate-to-low transition potentials based on their RETPI scores in 2018. However, their transition performances generally rank higher than their potentials do.

Countries in the Middle East and North Africa generally have average transition potentials, with the United Arab Emirates (UAE) and Israel ranking the highest. The region's resource-rich economies with higher transition potentials mostly underperform. In contrast, the region's lower-income economies perform well. For instance, the NhRE shares in electricity generation in Jordan and Morocco range from 10% to 18%. Sub-Saharan African nations have the lowest transition potentials globally, although this region has some exceptional high performers. For instance, Kenya has one of best RE transition performances in the world, with an approximately 50% share of NhRE in electricity generation. The Republic of Congo and Mauritania are also high performers in the region.

The only two countries in the North America region, the United States and Canada, are among those with the highest RE transition potentials globally. However, both countries underperform their potentials. Countries in Latin America and the Caribbean generally have moderate-to-low transition potentials, and most of them overperform. In particular, Chile and Brazil have the highest transition potentials in this region, along with Costa Rica, Uruguay and El Salvador. These countries are remarkable examples of overperformers, with NhRE shares that are much higher than the world average.

Notably, several concerning issues associated with RE technologies may discourage countries from reaching their potentials. Some important issues include the reliability of mineral supplies, manufacturing processes, recycling, storage and geographic specificities. Environmental damage is also associated with RE technologies (e.g., wind turbines, solar panels and batteries) (IEA 2021).[3] Because these important issues are not directly captured in the RETPI's construction, they may impact the transition gaps calculated in this study.

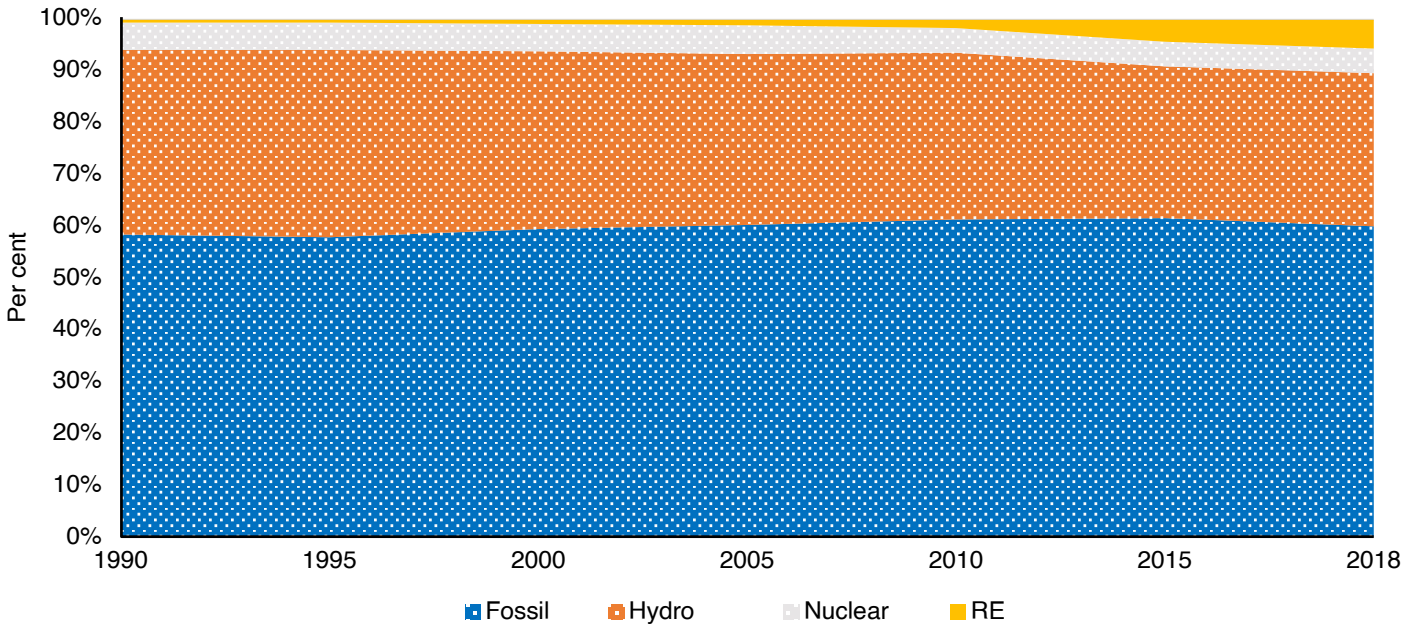
1. Trends Over the Last Three Decades

RE Transition Performance Trends

The global RE transition, proxied by the NhRE (i.e., solar, wind and geothermal) share in electricity generation, has significantly accelerated over the last decade (Figure 1). The NhRE share has increased almost nine times since 1990, as Figure 2 shows. In contrast, electricity generation from traditional fuels (i.e., oil, gas and coal), nuclear and hydropower resources has steadily declined over the last three decades. Despite this decline, however, these energy sources still produce most of the world's electricity.

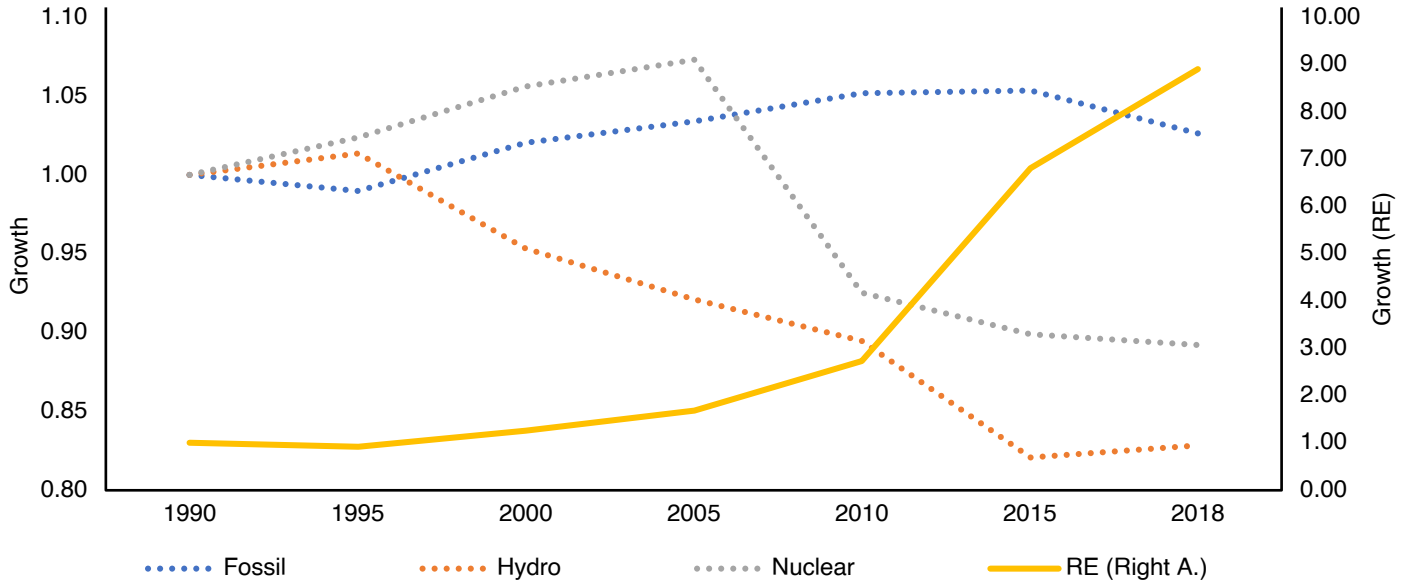
The global RE transition, proxied by the NhRE (i.e., solar, wind and geothermal) share in electricity generation, has significantly accelerated over the last decade

Figure 1. Share of electricity generation by fuel resource.



Source: Author's calculations from ENERDATA. NhRE includes wind, solar and geothermal resources.

Figure 2. Evolution of the share of electricity generation by fuel resource.

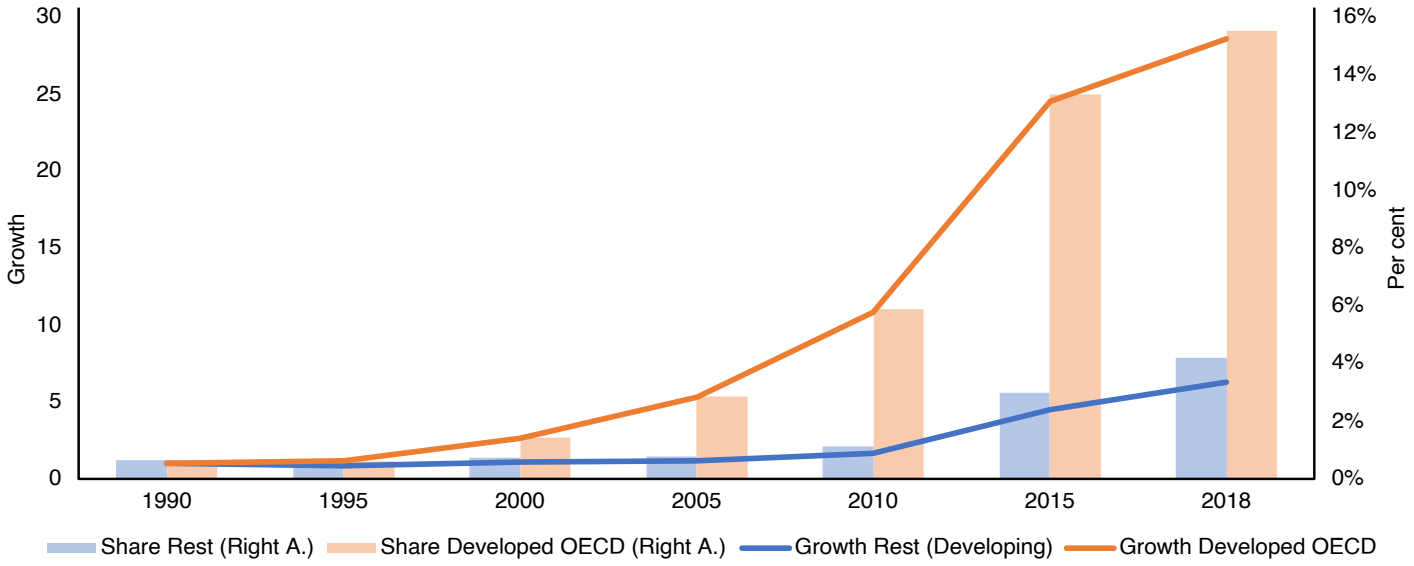


Source: Author's calculations from ENERDATA.

Note: NhRE includes wind, solar and geothermal resources. Fossil fuel resources include oil, gas and coal. Growth is defined as current shares relative to 1990.

The RE transition seems to have progressed particularly quickly in developed OECD economies.[4] Figure 3 shows that the average NhRE share was approximately 0.5% for both groups of countries in 1990. The developed OECD nations increased their average NhRE share to 15% in 2018, 28.6 times their share in 1990, while the developing world only increased their share by about 6.3 times over the same period. Figure 3 also shows that both groups' transition speeds increased after 2010. Several factors may have contributed to this trend. They include cost reductions in RE technologies owing to technological advancements and the introduction of stronger RE subsidies and policy supports in many countries. The increased global capital flows following the 2008 global financial crisis are also a contributing factor (Monnin 2015; United Nations Environment Programme, Frankfurt School of Finance and Management, and BloombergNEF 2019; Yilmaz 2021b).

Figure 3. Evolution of the NhRE share of electricity generation by income group.



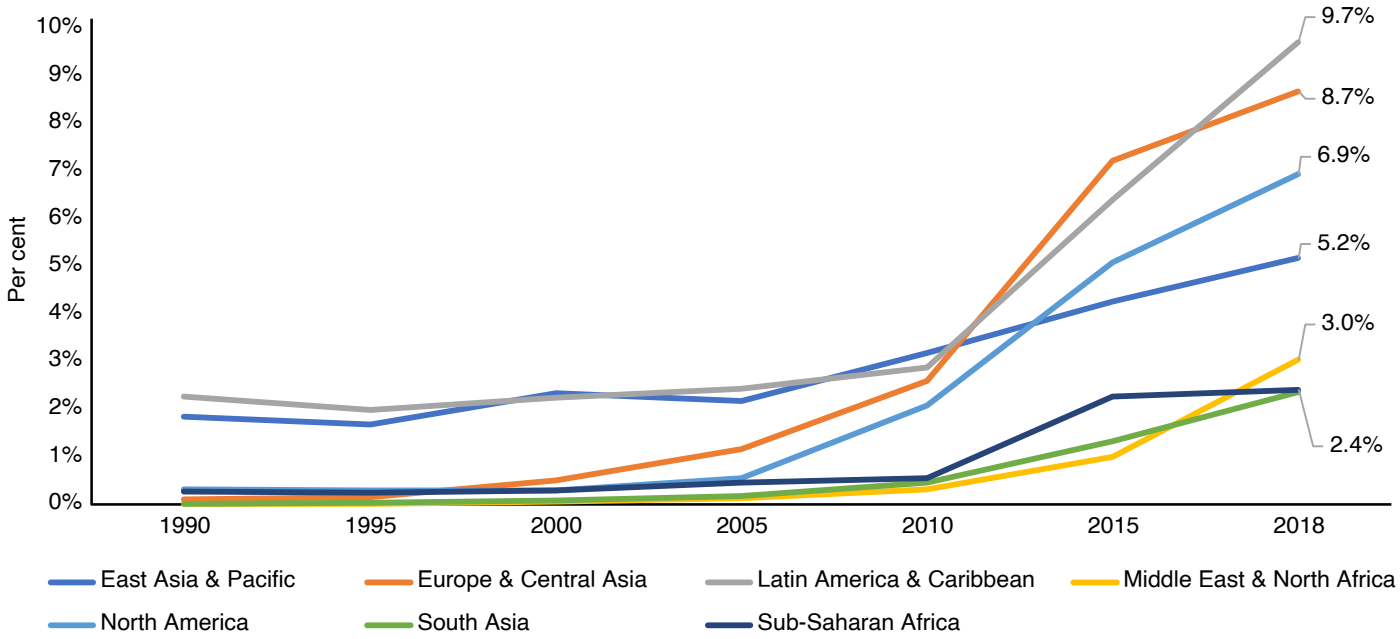
Source: Author's calculations from ENERDATA.

Note: NhRE includes wind, solar and geothermal resources. Growth is defined as current shares relative to 1990.

The RE transition trends also significantly vary across regions. Europe and Central Asia and Latin America and the Caribbean recorded more substantial RE transition performances than the other regions, especially after 2010 (Figure 4).[5] These two regions increased their average NhRE shares in electricity generation by close to 10%, which is substantially higher than the world average (6%). Until 2010, however, Latin America and the Caribbean had the same average NhRE share as East Asia and the Pacific. The two regions diverged in the following years, as Latin America and the Caribbean almost doubled its NhRE share. The Middle East and North Africa, sub-Saharan Africa and South Asia have the lowest historical transition performances. Like Figures 1 and 2, Figure 4 shows that the RE transition speed has increased since 2010 in almost all regions.

The RE transition trends also significantly vary across regions

Figure 4. NhRE share of electricity generation by region.



Source: Author's calculations from ENERDATA.

Note: NhRE includes wind, solar and geothermal resources.

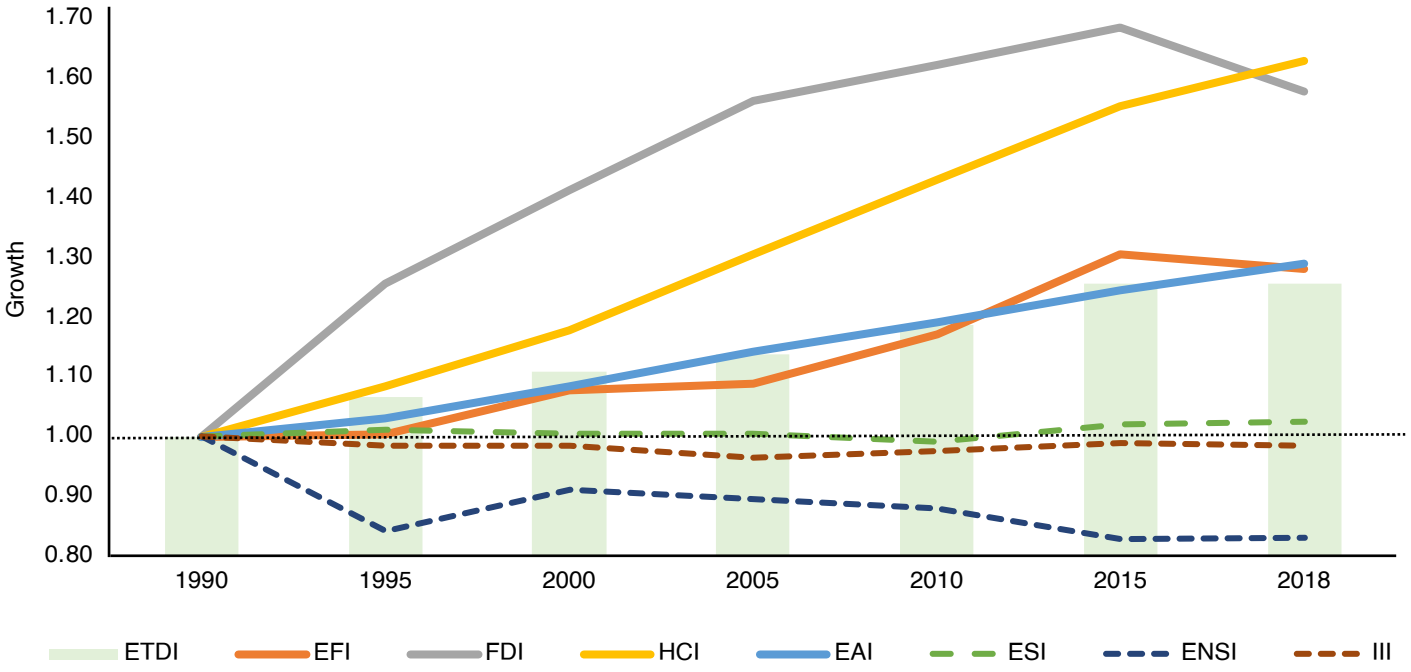
RETPI Trends

The RE transition trends presented above give an overview of countries' historical RE transition performances but provide little information about their potentials. To better understand their potentials, we employ the RETPI, developed by Yilmaz (2021a). Figure 5 shows trends in the RETPI and its subindices over the last three decades. The figure shows that the RETPI steadily increases until 2015 and then flattens. Among the seven subindices of the RETPI, the economic factors, financial development, human capital, and energy access subindices seem to have supported its growth. All four experienced substantial increases over the last three decades. Notably, the economic factors and financial development subindices have declined slightly since 2015, explaining some of the RETPI's flattening in recent years. Of the remaining three subindices, the energy security and institutional infrastructure subindices appear to have remained mostly stable. The environmental sustainability subindex has moderately declined over time.

The RETPI scores show that the transition potential is generally higher among developed OECD countries than among developing countries

The RETPI scores show that the transition potential is generally higher among developed OECD countries than among developing countries (Figure 6). This result is not surprising considering that developed countries have better outlooks for most of the determining factors of the RE transition. Figure 6 also displays a flattening trend after 2015 for both income groups, indicating a potential deceleration in the RE transition in the coming years. The decline seems sharper for developed OECD countries. Figure 7 shows trends in the RETPI by region. Europe and Central Asia have the highest transition potential, whereas sub-Saharan Africa and South Asia have the lowest.

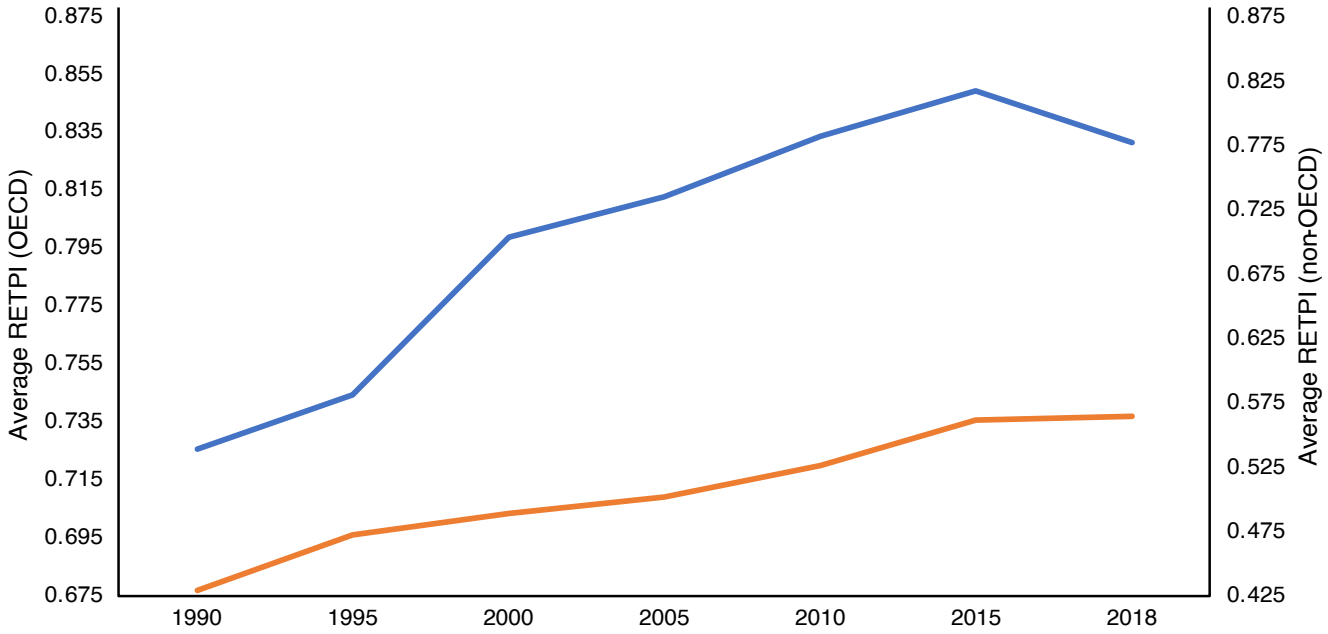
Figure 5. Evolution of the RETPI and its components over time.



Source: Author's calculations using data from Yilmaz (2021a).

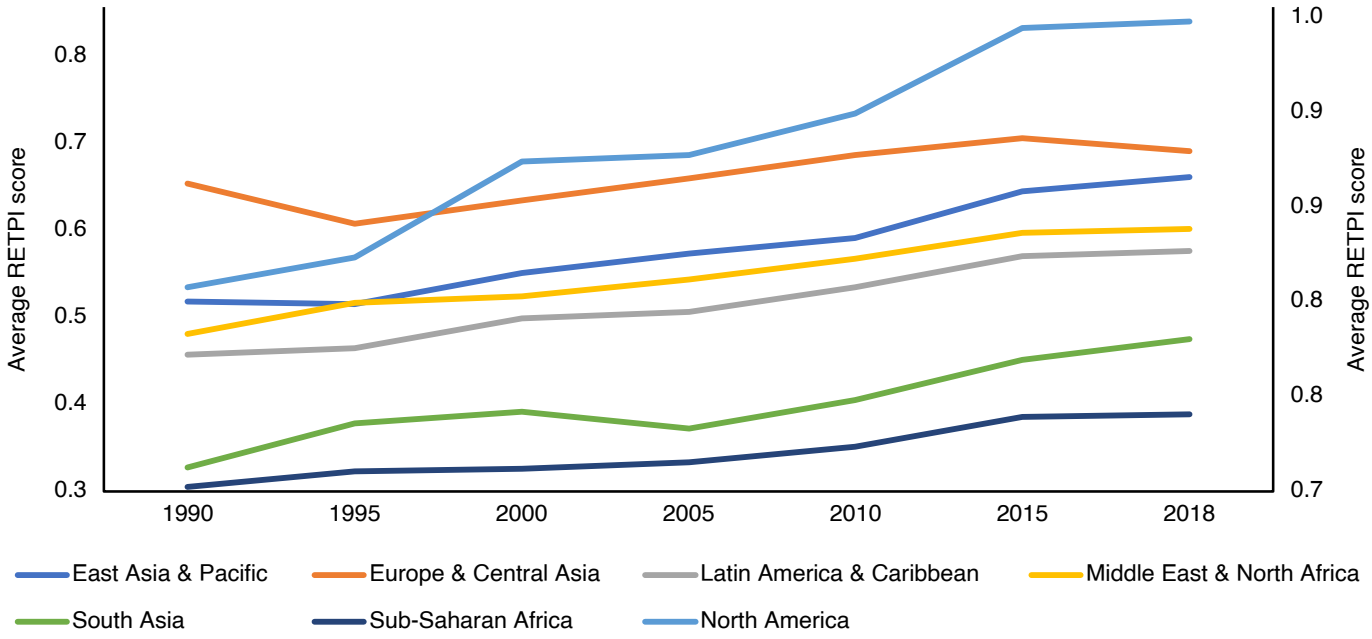
Note: RETPI= RE transition determinant index; EFI= economic factors subindex; FDI= financial development subindex; HCI= human capital subindex; EAI= energy access subindex; ESI= energy security subindex; ENSI= environmental sustainability subindex; III= institutional infrastructure subindex. The numbers are shares relative to the given index's level in 1990.

Figure 6. RETPI by income group.



Source: Author's calculations using RETPI data from Yilmaz (2021a).

Figure 7. RETPI by region.



Source: Author's calculations using RETPI data from Yilmaz (2021a).

2. RE Transition Gaps

A country's transition gap is defined as the difference between its potential and its performance as of 2018

Most European countries are leading the RE transition, ranking in the top deciles for both potential and performance indicators

This section provides a comparative discussion of countries' RE transition gaps. A country's transition gap is defined as the difference between its potential and its performance as of 2018. Potential is measured by RETPI scores, and performance is measured by the NhRE share in electricity generation.[6] To make comparisons, countries are ranked according to their RETPI scores and NhRE shares. Each ranking is then split into 10 deciles containing 15 countries. The top (10th) decile includes the top-ranked countries (i.e., those with the highest potential or performance), and the bottom (first) decile includes the lowest-ranked countries. Thus, countries whose performance (i.e., NhRE share) decile ranks are greater than their potential (i.e., RETPI score) decile ranks are overperformers. The overperformers are leading the regional and global RE transitions. Conversely, countries whose performance decile ranks are lower than their potential decile ranks are underperformers. Underperformers have negative transition gaps that are yet to be closed.

Europe and Central Asia

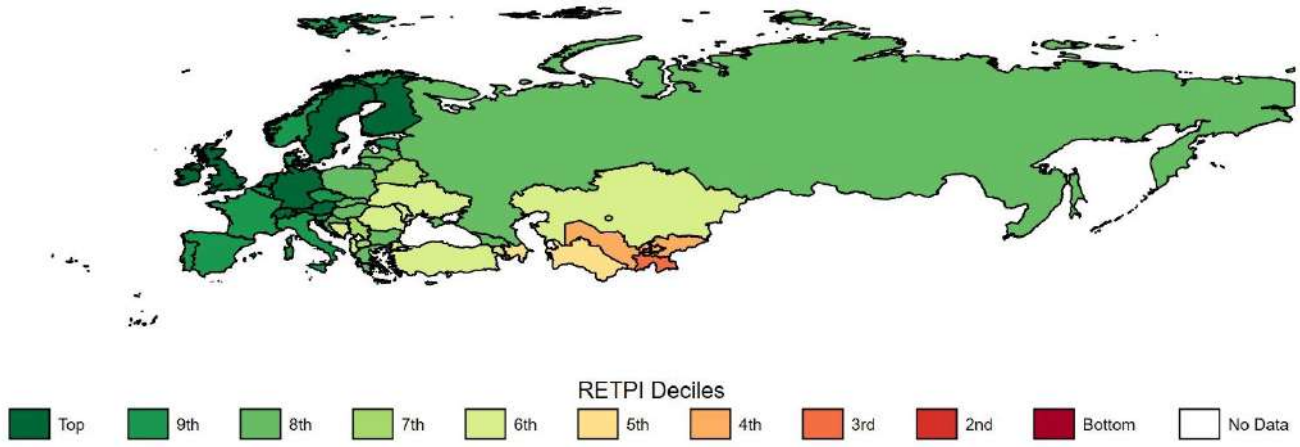
Most European countries are leading the RE transition, ranking in the top deciles for both potential and performance indicators. Considering the European Union's (EU's) efforts, such as the European Green Deal,[7] many European countries aim to make clean energy usage mainstream. However, significant differences still exist at the country level (Figure 8a). Eastern (e.g., Serbia, Romania and North Macedonia) and southern (e.g., Greece and Croatia)

EU members generally have lower RE transition potentials relative to western EU members. Outside of the EU, countries in Eastern Europe and Asia have average RETPI scores. In particular, Central Asian countries, such as Azerbaijan, Turkmenistan, Uzbekistan, the Kyrgyz Republic and Tajikistan, have the lowest RE transition potentials in the region.

Figure 8b shows European and Central Asian countries' RE transition potential and performance decile ranks along with their country-specific NhRE shares in 2018. In the figure, countries are ordered according to their RETPI scores. We observe that Germany, Ireland and the United Kingdom are the overperforming EU countries in the top decile. In contrast, some Nordic countries (e.g., Finland, Sweden and Norway), Austria and Switzerland are underperformers. In other words, their transition performance is below their potential. One potential explanation for this result is their relatively high utilization of hydropower for electricity generation.[8]

In the second highest decile, Belgium, Denmark, Spain, Portugal, Italy and Lithuania also outperform their potential. In this group, Denmark is particularly notable, as it has one of the highest NhRE shares in the world, 48%, as of 2018. Among the Eastern European countries, Greece, Poland, Croatia, Turkey and Romania are notable overperformers. Their NhRE shares are also much higher than the global average, at over 10%. The fossil-fuel-rich countries in this region, such as Russia, Belarus, Kazakhstan, Moldova, Azerbaijan, Turkmenistan and Uzbekistan, significantly underperform their potential. Their NhRE shares are less than 1%. However, two countries in this region, the Kyrgyz Republic and Tajikistan, rely considerably on hydropower resources, which generate more than 90% of electricity in these countries.

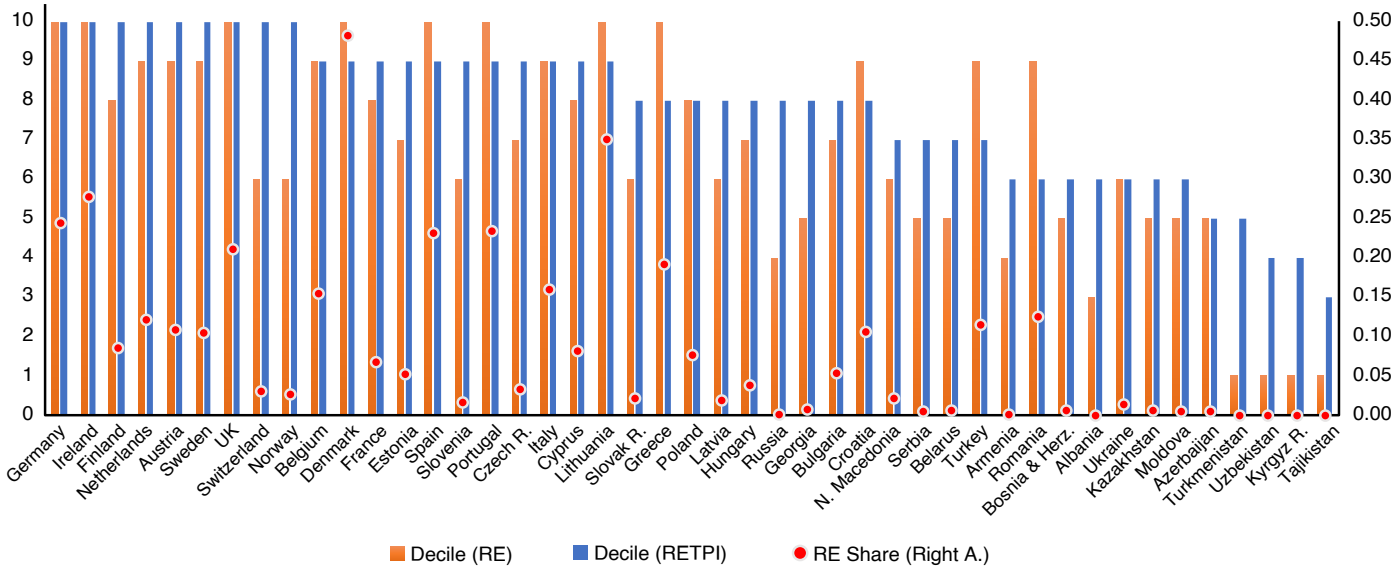
Figure 8a. 2018 RETPI scores, Europe and Central Asia.



Note: Author's calculations using RETPI data from Yilmaz (2021a). RETPI is the RE transition determinant index.

Overall, the nature of the RE transition seems to vary significantly across countries in this region. The resource-dependent (Western Europe) and fossil-fuel-rich nations (Eastern Europe and Central Asia) in this region are transitioning from fossil fuel and nuclear resources to NhRE. On the contrary, the Nordic and Central European countries have mainly transitioned from hydroelectricity sources to NhRE.

Figure 8b. RE transition potential and performance, Europe and Central Asia**.**



Note: Author's calculations using ENERDATA and RETPI data from Yilmaz (2021a). RE is the NhRE share in electricity generation. RETPI is the RE transition determinant index.

East Asia and the Pacific

Among East Asia and Pacific nations, Singapore, Hong Kong, Japan and Australia have strong RE transition potentials

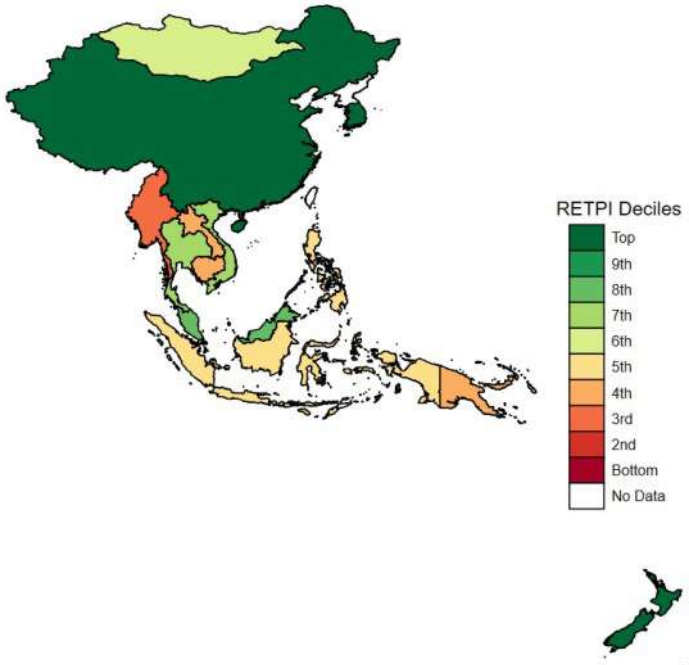
Among East Asia and Pacific nations, Singapore, Hong Kong, Japan and Australia have strong RE transition potentials (Figure 9a). After these high-income countries, South Korea, China and New Zealand have the second-highest RE transition potentials in the region. However, the countries with high RE transition potentials in this region mostly underperform. For instance, despite their high potentials, Hong Kong's and Singapore's transition performances are surprisingly low (Figure 9b). Their NhRE shares remain below 1% as of 2018, and they are almost fully dependent on fossil fuels for electricity generation. Both countries recently launched RE programs to increase their RE usage by 2030.[9] Japan and Australia also underperform, although their performances are somewhat close to their potential.

New Zealand is a pioneering country in this region, leading the RE transition with an outstanding performance among countries with the second-highest potential. It has the highest NhRE usage in the region, with a 23% share, and only 18% of its total electricity

generation relies on fossil fuels. Hydroelectric resources generate the remaining share of its electricity. As a major global energy consumer, China underperforms its potential, with an 8% share of NhRE in electricity generation. Despite the relatively low performances of most of this region's developed and emerging economies, the developing nations in this region perform well. Mongolia, Indonesia, Philippines and Papua New Guinea outperform their potential, with a nearly 9% NhRE share on average.

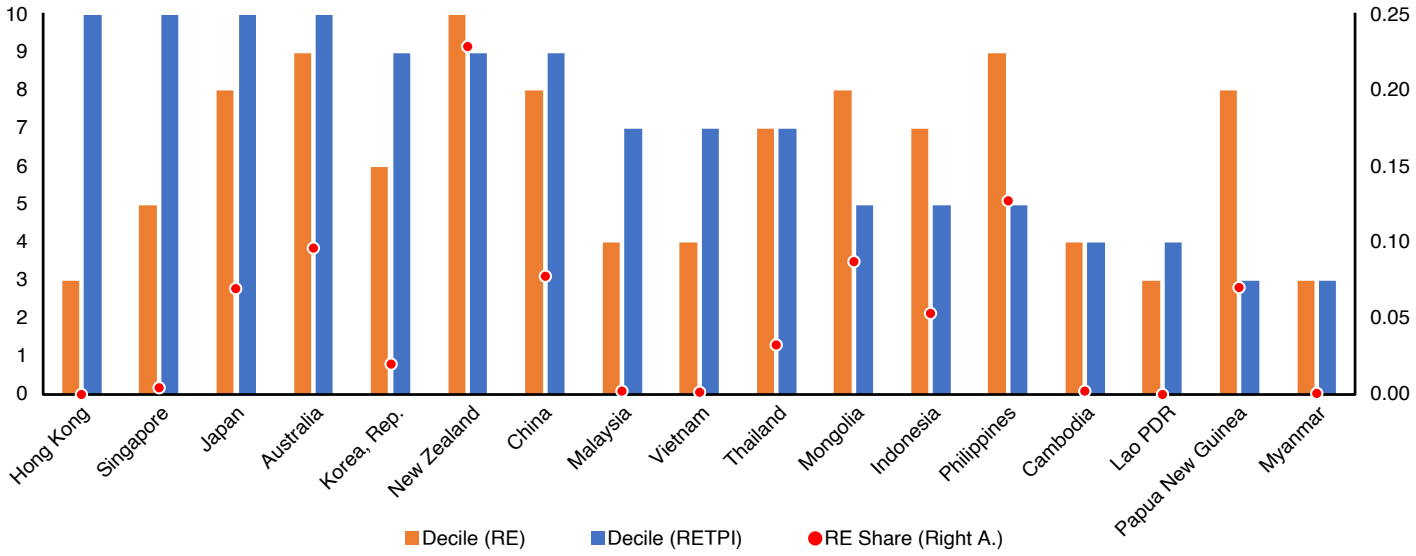
The countries in the East Asia and Pacific region are tending to transition from fossil fuel resources to renewables. Some Pacific nations have rich hydropower resources. As a cleaner alternative to fossil fuels, these resources may reduce the speeds of these countries' RE transitions.

Figure 9a. 2018 RETPI scores, East Asia and the Pacific.



Note: Author's calculations using RETPI data from Yilmaz (2021a). RETPI is the RE transition determinant index.

Figure 9b. RE transition potential and performance, East Asia and the Pacific.



Note: Author's calculations using ENERDATA and RETPI data from Yilmaz (2021a). RE is the NhRE share in electricity generation. RETPI is the RE transition determinant index.

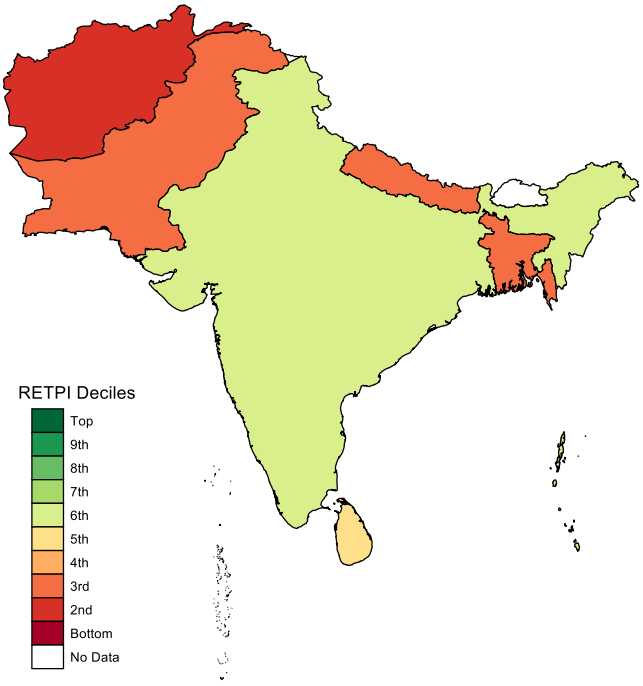
South Asia

South Asian countries have moderate-to-low RETPI rankings as of 2018, implying that this region has limited RE transition potential

South Asian countries have moderate-to-low RETPI rankings as of 2018, implying that this region has limited RE transition potential. India has the highest RETPI score, and Afghanistan has the lowest RETPI score in the region (Figure 10a). However, all of the countries in this region outperform their potentials, except for Afghanistan, as Figure 10b shows. According to the figure, India, Sri Lanka and Pakistan are ranked in the eighth, seventh and sixth transition performance deciles. These rankings are all higher than their transition potential decile ranks.

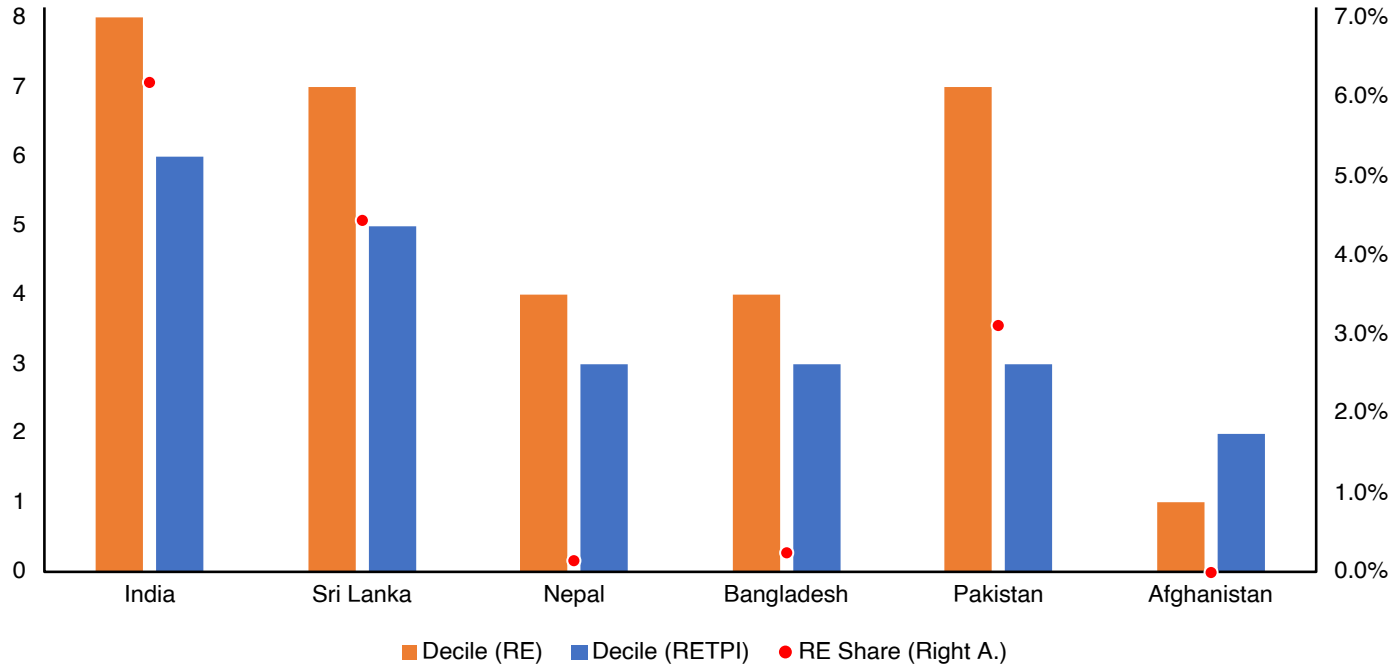
Electricity generation in this region substantially utilizes fossil fuel and hydropower resources. For instance, in Nepal and Afghanistan, the share of hydroelectricity in total electricity generation is over 90%. In contrast, India, Sri Lanka, Bangladesh and Pakistan mostly utilize fossil fuels, which comprise 57% to 100% of total electricity generation. This finding shows that most countries in this region are shifting from fossil fuel resources to NhRE.

Figure 10a. 2018 RETPI scores, South Asia.



Note: Author's calculations using RETPI data from Yilmaz (2021a). RETPI is the RE transition determinant index.

Figure 10b. RE transition potential and performance across countries in South Asia.



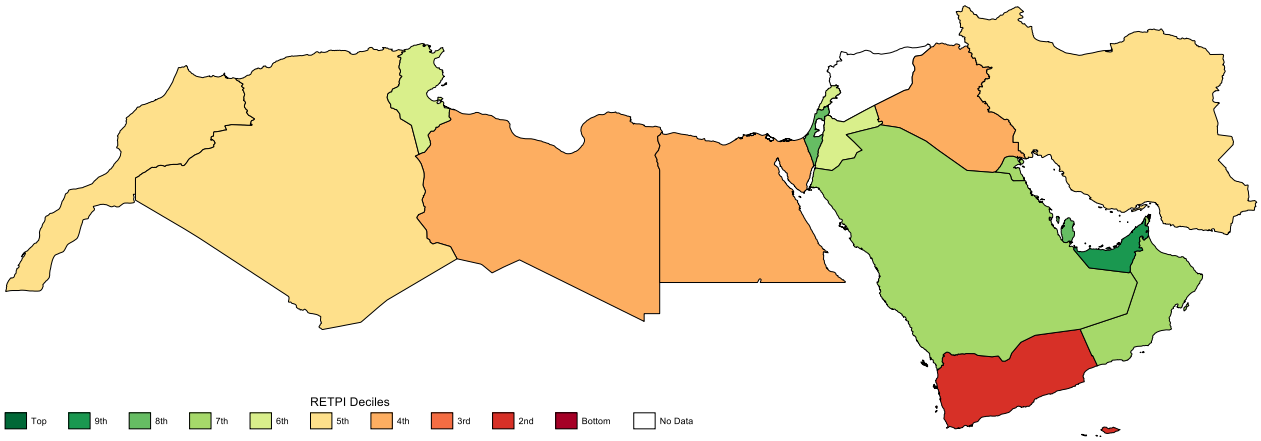
Note: Author's calculations using ENERDATA and RETPI data from Yilmaz (2021a). RE is the NhRE share in electricity generation. RETPI is the RE transition determinant index.

The RETPI scores of countries in this region vary significantly, indicating considerable variation in their RE transition potentials

Middle East and North Africa

The RETPI scores of countries in this region vary significantly, indicating considerable variation in their RE transition potentials (Figure 11a). The UAE is ranked in the highest RETPI decile. Israel, Qatar and Bahrain are ranked in the second-highest RETPI decile, followed by other resource-rich economies, such as Saudi Arabia, Oman and Kuwait. North African countries generally have moderate RE transition potentials, with below-average RETPI scores. Yemen has the lowest RETPI rank among the nations in this region.

Figure 11a. RETPI scores in 2018, Middle East and North Africa.

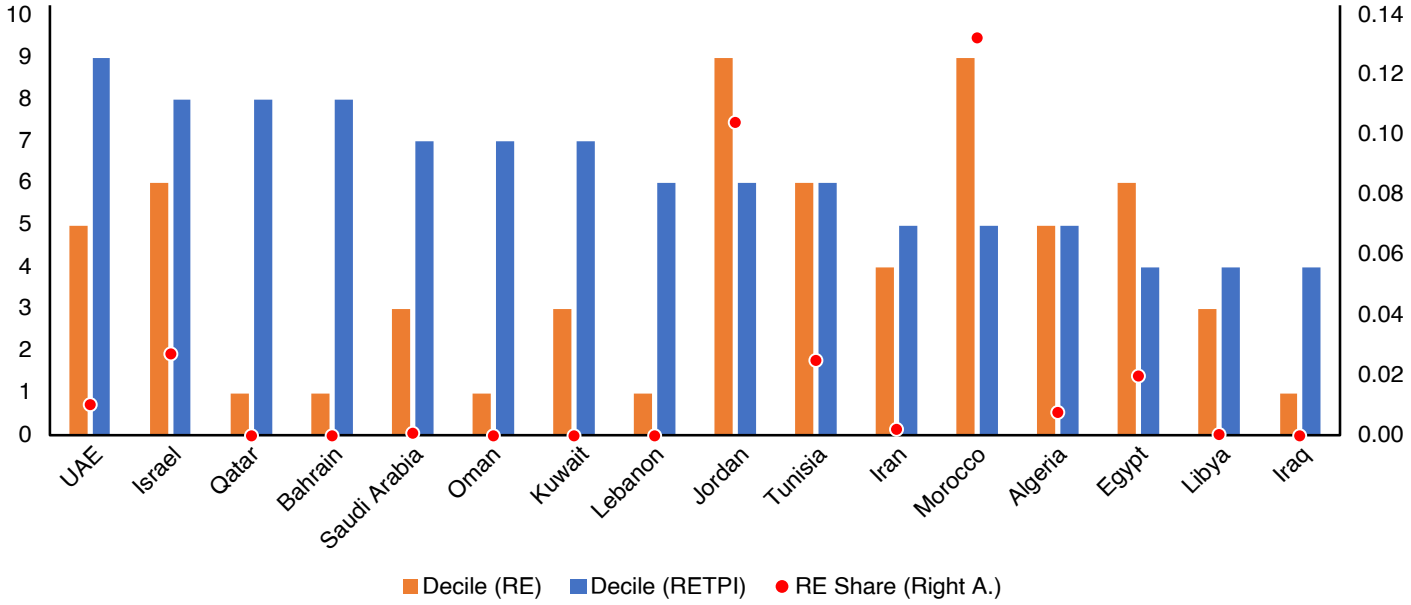


Note: Author's calculations using RETPI data from Yilmaz (2021a). RETPI is the RE transition determinant index.

Given its rich fossil fuel resources, this region is a major oil and gas supplier. This property is naturally reflected in this region's electricity generation strategy, which largely relies on fossil fuels. Specifically, fossil fuels comprise 96% of total electricity generation on average. Ambitious attempts have been made to reduce reliance on fossil fuels for electricity generation in this region.[10] However, current NhRE energy usage remains very low, especially among the region's resource-rich countries (Figure 11b). The UAE and Israel perform relatively well, although they are still below their potentials.

In contrast, the non-resource-rich economies in this region, such as Jordan, and some North African countries, such as Tunisia, Morocco, Algeria and Egypt, are overperformers. In particular, Jordan and Morocco lead the RE transition in this region. Jordan generates more than 10% and Morocco 13% of its total electricity from NhRE. The region's hot climate and long summers offer abundant sunshine, creating good opportunities for solar energy. As expected, water resources are scarce in this region, minimizing the potential for hydropower. Additionally, fast wind speeds, especially in mountain areas, and geothermal resources provide alternative RE possibilities.

Figure 11b. RE transition potential and performance, Middle East and North Africa.



Note: Author's calculations using ENERDATA and RETPI data from Yilmaz (2021a). RE is the NhRE share in electricity generation. RETPI is the RE transition determinant index.

Sub-Saharan Africa

Countries in sub-Saharan Africa generally have the lowest RETPI scores, meaning that they have poor RE transition potentials (Figure 12a). Mauritius and South Africa have moderate transition potentials, with above-average RETPI scores. Countries in this region face various economic, social and institutional challenges that may explain their low RETPI scores.

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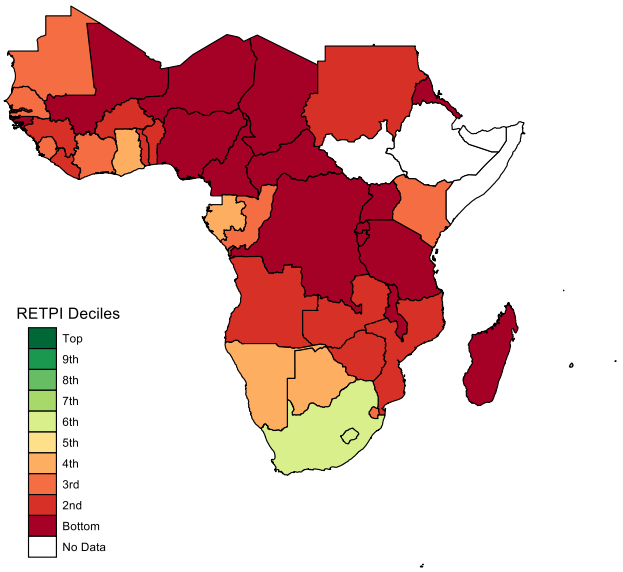
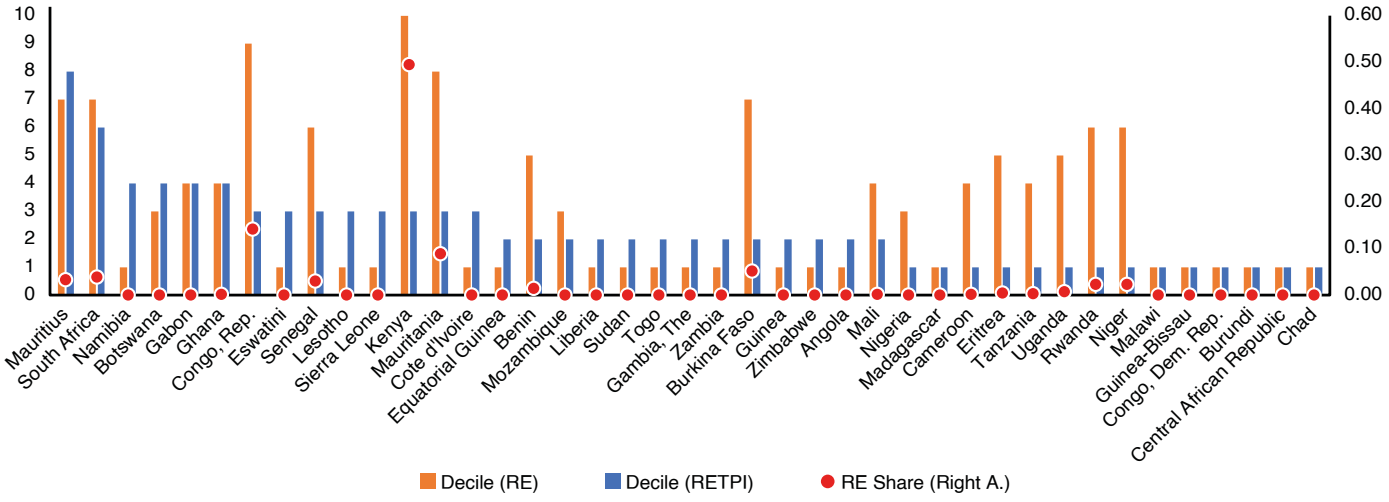
The Republic of Congo, Kenya and Mauritania have exceptional transition performances, with NhRE energy shares above 10% despite their low RETPI decile ranks (Figure 12b). Kenya has recently attracted a significant amount of private investment in RE production, particularly from geothermal resources. It is the only country utilizing geothermal resources in the region. As of 2018, Kenya produces about 50% of its total electricity from NhRE. The Republic of Congo, in contrast, utilizes mostly solar energy, whereas Mauritania's NhRE electricity generation mainly comes from wind.

Figure 12a. RETPI scores in 2018, sub-Saharan Africa.



Note: Author's calculations using RETPI data from Yilmaz (2021a). RETPI is the RE transition determinant index.

Figure 12b. RE transition potential and performance, sub-Saharan Africa.

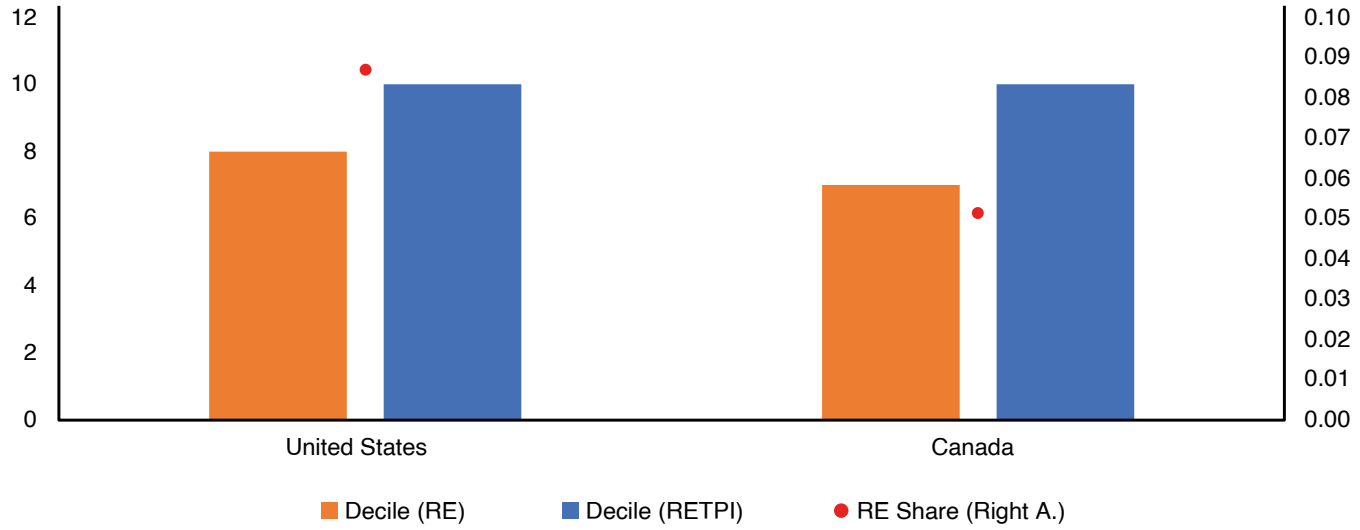


Note: Author's calculations using ENERDATA and RETPI data from Yilmaz (2021a). RE is the NhRE share in electricity generation. RETPI is the RE transition determinant index.

North America

The United States and Canada are the only two countries in this region. Both countries have high RE transition potentials, ranking in the top RETPI decile. However, their transition performances are below their potentials (Figure 13). The United States generates only 9% and Canada only 5% of its electricity from NhRE resources. Both countries have highly diversified electricity generation mixes, as they utilize almost all renewable and non-renewable resources. Canada relies more on hydroelectric resources, which comprise 59% of total electricity generation. The United States relies more on fossil fuels, with 65% of total generation. Thus, although both countries are net oil exporters, their RE transition patterns seem to differ.

Figure 13. RE transition potential and performance, North America.



Note: Author's calculations using ENERDATA and RETPI data from Yilmaz (2021a). RE is the NhRE share in electricity generation. RETPI is the RE transition determinant index.

Latin America and the Caribbean

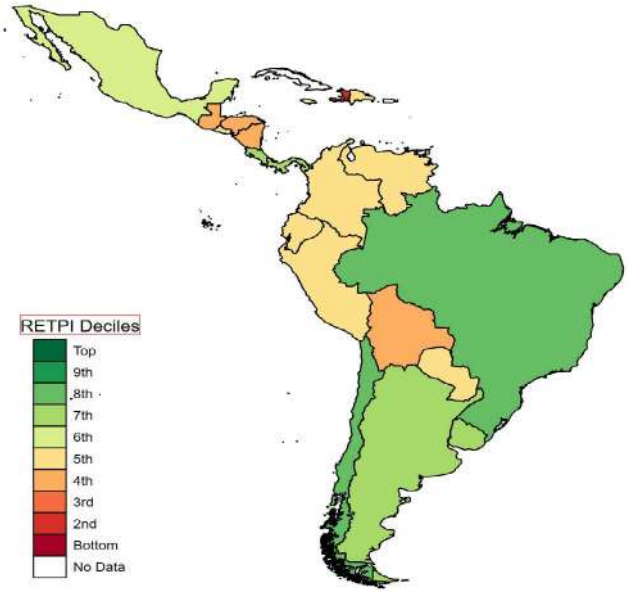
According to the RETPI decile rankings, Chile and Brazil have the highest RE transition potential (eighth decile). Haiti has the lowest RETPI (second decile) in the region (Figure 14a). Argentina and Mexico, the two major emerging economies in this region, have average RETPI scores, indicating moderate transition potentials.

According to the RETPI decile rankings, Chile and Brazil have the highest RE transition potential

In general, most of the countries in the region outperform their RE transition potentials (Figure 14b). Chile, Costa Rica, Uruguay, El Salvador, Honduras and Nicaragua produce relatively large portions of their electricity using NhRE. Specifically, the NhRE shares in these countries range from 11% to 38%. Among the region's fast-growing emerging economies, Brazil's overperformance is worth noting, as it generates 9% of its electricity using NhRE.

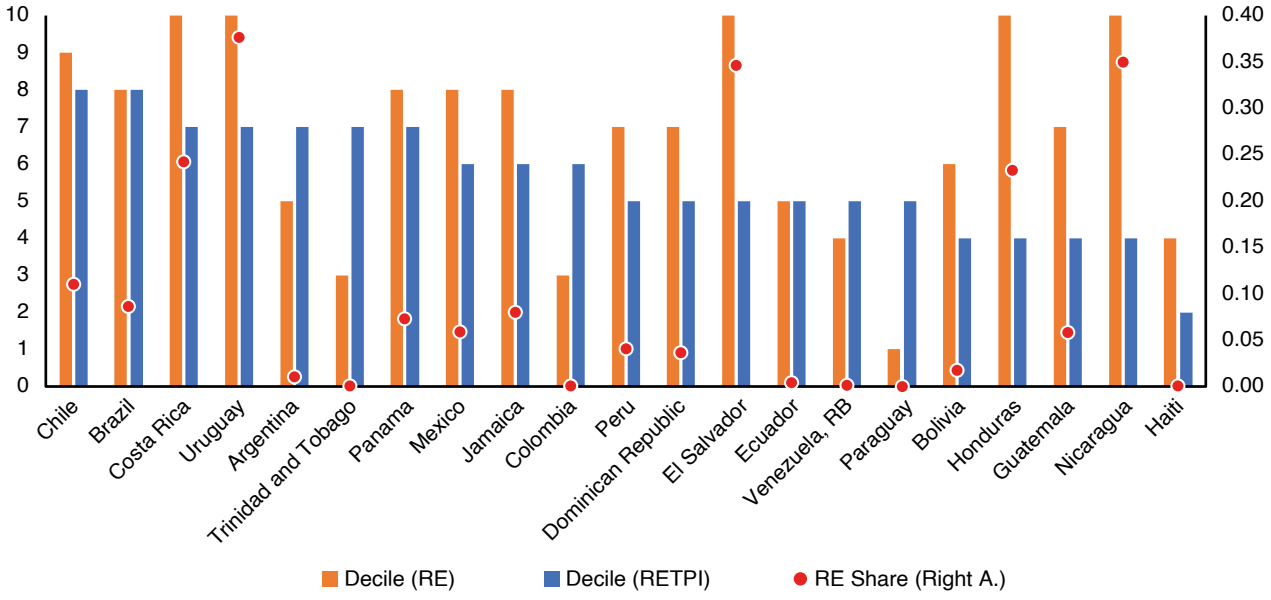
This region has rich renewable and non-renewable resources. Hydropower resources are generally abundant, making hydropower a reliable electricity source for most countries in the region. Electricity generation from these resources varies across countries, from as low as 9% to as high as 100%. On average, 47% of regional electricity generation is from hydropower, and 45% is from fossil fuels as of 2018.

Figure 14a. RETPI scores in 2018, Latin America and Caribbean.



Note: Author's calculations using RETPI data from Yilmaz (2021a). RETPI is the RE transition determinant index.

Figure 14b. RE transition potential and performance, Latin America and Caribbean.



Note: Author's calculations using RETPI data from Yilmaz (2021a). RETPI is the RE transition determinant index.

3. Concluding Remarks

This commentary raised the essential question of whether countries' RE transition potentials (i.e., proxied by the RETPI) and performances (i.e., proxied by the NhRE share) differ. The descriptive analysis first discussed global trends in RE transition performance and potential and trends by region and income groups. We then expanded the analysis to country-specific comparisons.

The results show that the RE transition has accelerated since 2010 in most countries, particularly in developed economies. Countries in Europe and Latin America have exhibited particularly strong transition performances over the last decade. However, countries' RE transition potentials have flattened since 2015, which may suggest a potential deceleration in the RE transition in the coming years.

Our country-specific comparative analysis of RE transition potential and performance identified significant transition gaps across countries. Many developed economies, such as Germany, the United Kingdom, Ireland and Denmark, outperform their high transition potentials. However, several other countries with high RE transition potentials underperform. These underperformers include Finland, Sweden, Norway, Austria and Switzerland in Europe. They also include the United States and Canada in North America and Hong Kong, Singapore, Japan and Australia in East Asia and the Pacific. This result indicates that many developed economies have large transition gaps that have yet to be closed.

Most oil- and gas-rich economies, such as Russia, the UAE and Saudi Arabia, also underperform their potentials. Their comparative advantages in oil and gas resources play an essential role in their high use of fossil fuels in electricity generation. However, recently declared targets in many of these countries, such as Vision 2030 in Saudi Arabia,[11] envision significant improvements to RE penetration levels.

Many resource-dependent emerging economies, such as India, Brazil, Turkey, South Africa and Indonesia, outperform their potentials. Others, such as China, Malaysia and Argentina, underperform. Most sub-Saharan African countries also tend to outperform their RE transition potentials, although their potentials appear to be somewhat limited. Because resource dependency is risky for growth and raises energy security concerns, developing and emerging countries have strong motivations to transition to RE. These countries' generally higher performances relative to their RE transition potentials are a clear signal of these strong motivations.

Endnotes

[1] Water resources have traditionally been highly utilized for electricity production (Lin and Omoju 2017), and they have their own technical characteristics and resource requirements. Hydroelectricity therefore has different determinants besides those considered in the construction of the RETPI (Burke 2010). Additionally, hydroelectricity production raises some social and environmental concerns (Pfeiffer and Mulder 2013).

[2] The NhRE share is in gigawatthours of electricity production.

[3] Desrochers (2019), Montford (2019), Desrochers and Reed (2019) and Roberts (2019) provide further discussions of these issues.

[4] Following Kim and Loayza (2019), we define the developed OECD as the OECD member countries with at least 40 years of membership. This group includes 21 high-income OECD economies, as Table A1 in the appendix shows.

[5] Regional classifications are based on the World Bank's geographic classifications. Table A1 in the appendix provides the full list of countries and their regions.

[6] Yilmaz (2021a) discusses the strong positive relationship between the RETPI and countries' RE transition performances (i.e., their NhRE shares). He shows that countries with more potential have stronger RE transition performances. However, this general tendency varies at the country level, and this variation is the focus of this study.

[7] For more information on the European Green Deal, see: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[8] For instance, as of 2018, Austria, Sweden, Switzerland and Norway generate 60%, 38%, 55% and 95% of their electricity, respectively, from hydroelectric sources. Finland's share of electricity from hydroelectric sources is 19%, and its share from nuclear sources is 33%.

[9] For further information on Hong Kong's climate action program, see Environment Bureau (2017). For information on Singapore's climate action program, see National Climate Change Secretariat (2016).

[10] For instance, Saudi Arabia has set Vision 2030 targets. For more information, see https://vision2030.gov.sa/en

[11] For more information, see https://www.vision2030.gov.sa/

References

Bourcet, Clémence. 2020. "Empirical Determinants of Renewable Energy Deployment: A Systematic Literature Review." *Energy Economics* 85(C):104563. DOI: 10.1016/j.eneco.2019.104563

Burke, Paul J. 2010. "Income, Resources, and Electricity Mix." *Energy Economics* 32(3):616–26. DOI: 10.1016/j.eneco.2010.01.012

Darmani, Anna, Niklas Arvidsson, Antonio Hidalgo, and Jose Albors. 2014. "What Drives the Development of Renewable Energy Technologies? Toward a Typology for the Systemic Drivers." *Renewable and Sustainable Energy Reviews* 38(C):834–47. DOI: 10.1016/j.rser.2014.07.023

Desrochers, Pierre. 2019. "Wind and Solar Power—The Myth of 'Green' Energy." *Fraser Institute*, October 9.

Desrochers, Pierre, and Andrew Reed. 2019. "Generating Electricity in Canada from Wind and Sunlight: Is Getting Less for More Better than Getting More for Less?" *Fraser Institute Report*, July 30.

Environment Bureau. 2017. *Hong Kong's Climate Action Plan 2030+*. Hong Kong: Environment Bureau.

International Energy Association (IEA). 2021. *The Role of Critical Minerals in Clean Energy Transitions*. Paris: IEA. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

Kim, Young Eun, and Norman V Loayza. 2019. "Productivity Growth: Patterns and Determinants across the World." Policy Research Working Paper Series 8852, The World Bank.

Lin, Boqiang, and Oluwasola E. Omoju. 2017. "Focusing on the Right Targets: Economic Factors Driving Non-hydro Renewable Energy Transition." *Renewable Energy* 113(C):52–63. DOI: 10.1016/j.renene.2017.05.067

Monnin, Pierre. 2015. "The Impact of Interest Rates on Electricity Production Costs." CEP Discussion Note 2015/3.

Montford, Andrew. 2019. *Green Killing Machines: The Impact of Renewable Energy on Wildlife and Nature*. London: Global Warming Policy Foundation.

National Climate Change Secretariat. 2016. *Climate Action Plan: Take Action Today, For a Carbon-Efficient Singapore*. Singapore: National Climate Change Secretariat.

Pfeiffer, Birte and Peter Mulder. 2013. "Explaining the Diffusion of Renewable Energy Technology in Developing Countries." *Energy Economics* 40(C):285–96. DOI: 10.1016/J.ENECO.2013.07.005

Roberts, David. 2019. "Getting to 100% Renewables Requires Cheap Energy Storage. But How Cheap?" *Vox Blog*, September 29. https://www.vox.com/energy-and-environment/2019/8/9/20767886/renewable-energy-storage-cost-electricity

Şener, Şerife Elif Can, Julia L. Sharp, and Annick Anctil. 2018. "Factors Impacting Diverging Paths of Renewable Energy: A Review." *Renewable and Sustainable Energy Reviews* 81(P2): 2335–42. DOI: 10.1016/j.rser.2017.06.042

United Nations Environment Programme, Frankfurt School of Finance and Management, and BloombergNEF. 2019. *Global Trends in Renewable Energy Investment*. Frankfurt: Frankfurt School of Finance and Management.

Yilmaz, Fatih. 2021a. "Understanding the Dynamics of RE Transition: A Determinant Index Approach." Unpublished Manuscript, KAPSARC Methodology Paper.

———. 2021b. *Private Participation in the Renewable Energy Transition*. Riyadh: KAPSARC Data Insight.

Appendix

Table A1. Country list, RETPI scores and ranks.

Rank	Country	Income group	Region	RETPI score
1	United States	Dev. OECD		1.00
2	Hong Kong	Rest	East Asia & Pacific	0.94
3	Singapore	Rest	East Asia & Pacific	0.92
4	Canada	Dev. OECD		0.90
5	Germany	Dev. OECD		0.88
6	Ireland	Dev. OECD		0.88
7	Japan	Dev. OECD		0.88
8	Australia	Dev. OECD		0.85
9	Finland	Dev. OECD		0.85
10	Netherlands	Dev. OECD		0.85
11	Austria	Dev. OECD		0.82
12	Sweden	Dev. OECD		0.82
13	United Kingdom	Dev. OECD		0.82
14	Switzerland	Dev. OECD		0.82
15	Norway	Dev. OECD		0.82
16	Korea, Rep.	Rest	East Asia & Pacific	0.81
17	Belgium	Dev. OECD		0.81
18	Denmark	Dev. OECD		0.81
19	New Zealand	Dev. OECD		0.80
20	China	Rest	East Asia & Pacific	0.80
21	United Arab Emirates	Rest	Middle East & North Africa	0.80
22	France	Dev. OECD		0.80
23	Estonia	Rest	Europe & Central Asia	0.80
24	Spain	Dev. OECD		0.79
25	Slovenia	Rest	Europe & Central Asia	0.78
26	Portugal	Dev. OECD		0.78
27	Czech Rep.	Rest	Europe & Central Asia	0.77
28	Italy	Dev. OECD		0.77
29	Cyprus	Rest	Europe & Central Asia	0.76
30	Lithuania	Rest	Europe & Central Asia	0.75

Rank	Country	Income group	Region	RETPI score
31	Israel	Rest	Middle East & North Africa	0.75
32	Slovak Rep.	Rest	Europe & Central Asia	0.75
33	Qatar	Rest	Middle East & North Africa	0.74
34	Greece	Dev. OECD		0.74
35	Poland	Rest	Europe & Central Asia	0.73
36	Latvia	Rest	Europe & Central Asia	0.73
37	Hungary	Rest	Europe & Central Asia	0.72
38	Russia	Rest	Europe & Central Asia	0.71
39	Bahrain	Rest	Middle East & North Africa	0.71
40	Georgia	Rest	Europe & Central Asia	0.71
41	Chile	Rest	Latin America & Caribbean	0.71
42	Bulgaria	Rest	Europe & Central Asia	0.70
43	Brazil	Rest	Latin America & Caribbean	0.70
44	Croatia	Rest	Europe & Central Asia	0.70
45	Mauritius	Rest	Sub-Saharan Africa	0.70
46	Malaysia	Rest	East Asia & Pacific	0.70
47	Saudi Arabia	Rest	Middle East & North Africa	0.69
48	Costa Rica	Rest	Latin America & Caribbean	0.69
49	Uruguay	Rest	Latin America & Caribbean	0.69
50	Argentina	Rest	Latin America & Caribbean	0.68
51	Oman	Rest	Middle East & North Africa	0.68
52	Kuwait	Rest	Middle East & North Africa	0.68
53	North Macedonia	Rest	Europe & Central Asia	0.68
54	Serbia	Rest	Europe & Central Asia	0.68
55	Trinidad & Tob.	Rest	Latin America & Caribbean	0.67
56	Belarus	Rest	Europe & Central Asia	0.67
57	Vietnam	Rest	East Asia & Pacific	0.66
58	Panama	Rest	Latin America & Caribbean	0.65
59	Thailand	Rest	East Asia & Pacific	0.65
60	Turkey	Rest	Europe & Central Asia	0.65

Rank	Country	Income group	Region	RETPI score
61	Armenia	Rest	Europe & Central Asia	0.64
62	Mexico	Rest	Latin America & Caribbean	0.64
63	Romania	Rest	Europe & Central Asia	0.64
64	Lebanon	Rest	Middle East & North Africa	0.64
65	Bosnia	Rest	Europe & Central Asia	0.64
66	Jordan	Rest	Middle East & North Africa	0.63
67	Albania	Rest	Europe & Central Asia	0.63
68	Jamaica	Rest	Latin America & Caribbean	0.63
69	Tunisia	Rest	Middle East & North Africa	0.63
70	India	Rest	South Asia	0.63
71	Ukraine	Rest	Europe & Central Asia	0.62
72	Kazakhstan	Rest	Europe & Central Asia	0.61
73	South Africa	Rest	Sub-Saharan Africa	0.61
74	Moldova	Rest	Europe & Central Asia	0.61
75	Colombia	Rest	Latin America & Caribbean	0.60
76	Iran	Rest	Middle East & North Africa	0.60
77	Peru	Rest	Latin America & Caribbean	0.60
78	Morocco	Rest	Middle East & North Africa	0.60
79	Mongolia	Rest	East Asia & Pacific	0.60
80	Dominican Rep.	Rest	Latin America & Caribbean	0.60
81	Azerbaijan	Rest	Europe & Central Asia	0.59
82	El Salvador	Rest	Latin America & Caribbean	0.59
83	Ecuador	Rest	Latin America & Caribbean	0.59
84	Venezuela, RB	Rest	Latin America & Caribbean	0.58
85	Indonesia	Rest	East Asia & Pacific	0.58
86	Sri Lanka	Rest	South Asia	0.57
87	Algeria	Rest	Middle East & North Africa	0.57
88	Turkmenistan	Rest	Europe & Central Asia	0.57
89	Paraguay	Rest	Latin America & Caribbean	0.57
90	Philippines	Rest	East Asia & Pacific	0.56

Rank	Country	Income group	Region	RETPI score
91	Bolivia	Rest	Latin America & Caribbean	0.56
92	Uzbekistan	Rest	Europe & Central Asia	0.56
93	Namibia	Rest	Sub-Saharan Africa	0.55
94	Kyrgyz Rep.	Rest	Europe & Central Asia	0.55
95	Botswana	Rest	Sub-Saharan Africa	0.55
96	Cambodia	Rest	East Asia & Pacific	0.55
97	Egypt, Arab Rep.	Rest	Middle East & North Africa	0.55
98	Honduras	Rest	Latin America & Caribbean	0.54
99	Guatemala	Rest	Latin America & Caribbean	0.54
100	Gabon	Rest	Sub-Saharan Africa	0.53
101	Libya	Rest	Middle East & North Africa	0.53
102	Nicaragua	Rest	Latin America & Caribbean	0.52
103	Iraq	Rest	Middle East & North Africa	0.51
104	Ghana	Rest	Sub-Saharan Africa	0.51
105	Lao PDR	Rest	East Asia & Pacific	0.51
106	Nepal	Rest	South Asia	0.50
107	Tajikistan	Rest	Europe & Central Asia	0.48
108	Papua New Guinea	Rest	East Asia & Pacific	0.48
109	Myanmar	Rest	East Asia & Pacific	0.48
110	Congo, Rep.	Rest	Sub-Saharan Africa	0.48
111	Eswatini	Rest	Sub-Saharan Africa	0.48
112	Bangladesh	Rest	South Asia	0.47
113	Senegal	Rest	Sub-Saharan Africa	0.47
114	Lesotho	Rest	Sub-Saharan Africa	0.46
115	Sierra Leone	Rest	Sub-Saharan Africa	0.45
116	Kenya	Rest	Sub-Saharan Africa	0.45
117	Pakistan	Rest	South Asia	0.45
118	Mauritania	Rest	Sub-Saharan Africa	0.45
119	Cote d'Ivoire	Rest	Sub-Saharan Africa	0.44
120	Yemen, Rep.	Rest	Middle East & North Africa	0.43

Rank	Country	Income group	Region	RETPI score
121	Equatorial Guinea	Rest	Sub-Saharan Africa	0.43
122	Benin	Rest	Sub-Saharan Africa	0.43
123	Mozambique	Rest	Sub-Saharan Africa	0.43
124	Liberia	Rest	Sub-Saharan Africa	0.42
125	Sudan	Rest	Sub-Saharan Africa	0.42
126	Afghanistan	Rest	South Asia	0.42
127	Togo	Rest	Sub-Saharan Africa	0.42
128	Gambia, The	Rest	Sub-Saharan Africa	0.40
129	Zambia	Rest	Sub-Saharan Africa	0.40
130	Burkina Faso	Rest	Sub-Saharan Africa	0.40
131	Guinea	Rest	Sub-Saharan Africa	0.40
132	Haiti	Rest	Latin America & Caribbean	0.39
133	Zimbabwe	Rest	Sub-Saharan Africa	0.38
134	Angola	Rest	Sub-Saharan Africa	0.38
135	Mali	Rest	Sub-Saharan Africa	0.38
136	Nigeria	Rest	Sub-Saharan Africa	0.38
137	Madagascar	Rest	Sub-Saharan Africa	0.38
138	Cameroon	Rest	Sub-Saharan Africa	0.37
139	Eritrea	Rest	Sub-Saharan Africa	0.37
140	Tanzania	Rest	Sub-Saharan Africa	0.37
141	Uganda	Rest	Sub-Saharan Africa	0.36
142	Rwanda	Rest	Sub-Saharan Africa	0.35
143	Niger	Rest	Sub-Saharan Africa	0.35
144	Malawi	Rest	Sub-Saharan Africa	0.34
145	Guinea-Bissau	Rest	Sub-Saharan Africa	0.33
146	Congo, Dem. Rep.	Rest	Sub-Saharan Africa	0.31
147	Burundi	Rest	Sub-Saharan Africa	0.30
148	Central African Rep.	Rest	Sub-Saharan Africa	0.28
149	Chad	Rest	Sub-Saharan Africa	0.25

Source: Author's construction from Yilmaz (2021).

Note: Countries included in the study. Developed OECD is considered a separate region. Rep. is short for republic.

Index Data Sharing

The RETPI and subindex scores data are available upon request from the author.

About the Project

Energy transitions toward more sustainable systems are top of the policy agenda in many countries. Despite internationally coordinated efforts (e.g., the Paris Agreement), data shows that countries follow different transitions paths, with some developed economies following a relatively fast transition and many developing nations lagging. Finance has emerged as a key driver of the process, among several factors, such as policy action and technological advancements. There is an unprecedented need for investment in infrastructure, energy efficiency, research and development for mitigation technologies. This project aims to study the dynamics of energy transitions with a primary focus on the role of sustainable finance.

The project consists of five parts. The first part studies the key determinants of energy transitions with a focus on renewable energy, as it has been the most universally applied mitigation option. It constructs a composite index, the renewable energy transition potential index (RETPI), to better measure countries' renewable energy potential. The second and third parts highlight the sustainable finance instruments currently available and their effectiveness in enabling energy transitions. The final two parts attempt to understand the concept of stranded assets and associated risks. They also provide estimates on the potential size of stranded assets and a discussion on mitigation strategies.

The output of this project will improve our understanding of energy transition dynamics in terms of both managing the process and mitigating the associated risks. The project's findings will contribute significantly to the academic literature and policy discussions. More importantly, it will provide direct input into shaping Saudi Arabia's great ambitions for a more vibrant and diversified economy, as expressed in Saudi Vision 2030.

About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment, across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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