

Will growing volatility
see battery investment
charge ahead or
power down?



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Building a better
working world

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Smart investors know it pays to look beneath the surface. On the face of it, the global renewables sector is on a high, buoyed by a record US\$1.8t investment in clean energy in 2023¹ which saw the biggest ever absolute increase in new capacity — 507GW, two-thirds of it solar.²

But dig a little deeper and the picture isn't quite so rosy. Despite last year's surge, investment remains below what is needed to meet the COP28 target of tripling renewables capacity by 2030.³ And now challenges loom on the horizon that may see progress slow, just as acceleration is needed.

Building clean energy assets is one part of the equation – connecting them to the grid is another. But network gridlock has now reached acute proportions in many mature markets. Around the world, about 1,500GW of renewables capacity is languishing in ever-growing queues to connect to the grid, according to a 2023 International Energy Agency (IEA) report. According to the IEA, we need to add or replace 80 million kilometers of power lines by 2040 to meet climate goals – that's equivalent to the globe's entire existing grid.⁴ At

the same time, we need to massively scale the level of investment. The EY-Eurelectric Grids for Speed study says that, in Europe alone, we need to double the annual investment in our distribution grids to €67b (about US\$73b) by 2050.⁵ Connection delays of multiple years mean developers, deprived of a timely route to market, are feeling the strain as project value erodes. Frustratingly, this is a problem that has been brewing for years, left to play out through inadequate planning and worsened by postponed grid enhancements.

The situation is exacerbating an already tight capital crunch. In 2024, investors face much higher costs of capital, as well as shallower pools to draw it from. Projects locked in grid queues are tying up money that would otherwise be cycling through the system to keep driving growth. Instead, the handbrakes are on development pipelines. Freeing up liquidity will take more than a few interest rate reductions – the sector should prepare for two or three years (at least) of more constrained financing and raised expectations from investors. Even when gridlocks ease and capital begins flowing, project costs are likely to remain higher as engineering, procurement and construction providers protect margins, particularly when skilled talent is scarce and expensive. In the meantime, expect to see more consolidation across the developer landscape, as increasing costs of development and longer timelines to commence construction cause stress in the market. This represents a great opportunity for well-capitalized developers to both grow through acquisition and vertically integrate into independent power producers.

In the 63rd edition of RECAI, the top rankings are retained by mature markets where investors are attracted to both clear demand for renewables and established value for projects. Strong policy support and incentives are keeping the US, China Mainland and Germany out in front. Grid constraints in Spain have seen the country drop out of the top 10, with Canada and Japan moving in off the back of clear intent to maximize the potential of offshore wind. A new government in Argentina with ambitions to transform the energy industry – and the economy – has seen the country climb three spots in the index.

Over time, we can expect to see investor interest pivot toward markets where renewables are more directly replacing a heavy dependence on carbon. The reality is that some form of carbon pricing or framework will be needed to incentivize a faster move away from the use of fossil fuels in transport, agriculture, heating and carbon-intensive industries. When the link between the price of carbon and the value of renewables is more

explicit, the attractiveness of investment in carbon-intensive economies such as India and Australia is likely to rise.

As renewables proliferate and electrification grows, we will face growing challenges to system adequacy, grid management and price volatility. Battery energy storage systems (BESS) can form part of the solution, and investment in BESS is increasing. But, as we explore in this report's "Analysis," the relative immaturity and complexity of this market makes it difficult to capture strong returns. The primary role of BESS – to balance electricity supply and demand on the grid – means that the value each battery offers is highly localized. Yet, even in the UK, which is probably the most mature in terms of enabling BESS participation, the market still lacks the requisite level of sophistication to both operate individual assets for optimal performance and then reward them for doing so.

Until we have truly data-led, intelligent grid orchestration, as well as advanced platforms that enable accurate, real-time management of individual batteries, both returns for investors and value delivered to our electricity network will be constrained. These are problems that will be resolved with time. Pricing signals will align with individual batteries' value, and revenue opportunities will grow quickly for those savvy investors that can optimize their assets. Until then, successful investment depends on deep knowledge of each specific target market, as well as an understanding of how technology is evolving – and willingness to accept a level of volatility. Our article suggests four factors to help potential investors frame their BESS business case and highlights top markets for investment now.

We are nearly at the decade's halfway point. The race to decarbonize has now entered a critical stage, and we simply must rapidly pick up the pace to meet our climate goals in time. The sooner we can put enabling policies and mechanisms in place, including those that cut connection barriers, and level the investment playing field across countries, the sooner we can build the clean, sustainable energy system our future depends on. The sooner we can build the clean, sustainable energy system our future depends on.

Key takeaways

- ▶ Despite last year's record-breaking investment in the energy transition, the world is not on track to triple renewables by 2030.
- ▶ Network gridlock and high capital costs could delay progress just when acceleration is needed.
- ▶ The US, China Mainland and Germany retain the top three spots in RECAI 63. Canada and Japan enter the top 10, while Spain and the Netherlands drop out.
- ▶ Big movers in the index include Belgium, which has moved up four spots to 17th, and Argentina, which is now in 26th, pushed up three places due to the new government's commitment to re-energize the economy. Changes to solar feed-in tariffs have seen Vietnam fall six places.
- ▶ BESS will play a vital role in a more volatile grid, balancing supply and demand of increased distributed energy resources, and embedding flexibility. BESS deployment is forecast to quadruple to 572GW/1,848GWh by 2030, much of this adopted at grid scale.⁶
- ▶ The new ranking of the attractiveness of global BESS investment markets by EY reveals that countries or regions with a modern, digitized grid infrastructure and high levels of energy price volatility, which enable operators to "stack" revenues, offer the best opportunities for sustainable returns. The US, China Mainland and the UK are the top three BESS markets.
- ▶ Four factors can help investors navigate this complex, highly regionalized and fast-changing market.



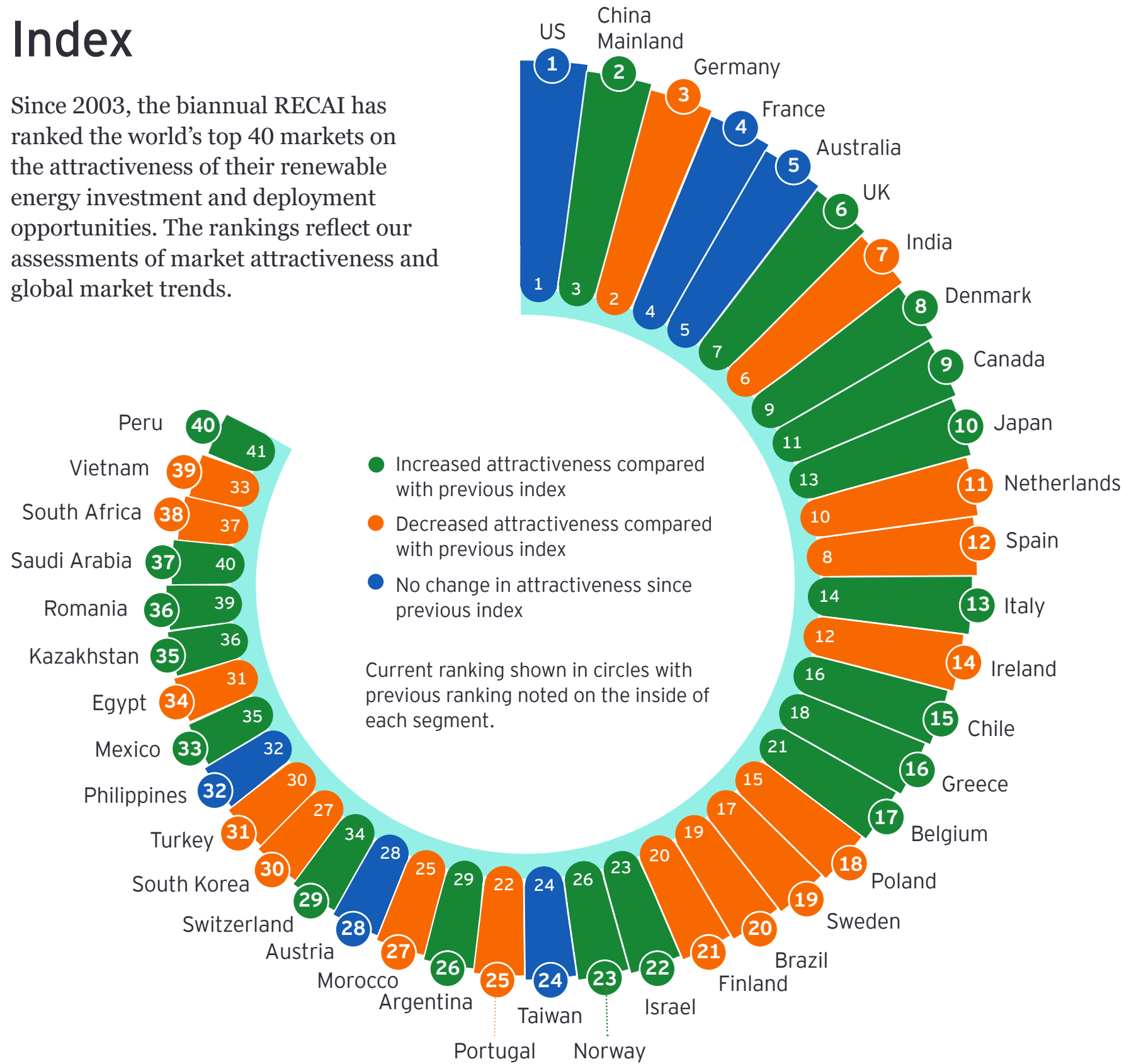
Arnaud de Giovanni
EY Global Renewables Leader



Ben Warren
RECAI Chief Editor
Ernst & Young LLP

Index

Since 2003, the biannual RECAI has ranked the world's top 40 markets on the attractiveness of their renewable energy investment and deployment opportunities. The rankings reflect our assessments of market attractiveness and global market trends.



0 US
 Retaining the top spot, the US added 4.6GW of solar in Q1 2024, with installed capacity now at 100GW.⁷ Federal support for grid upgrades is set to boost renewables transmission.⁸

-2 Ireland
 Only 0.6GW of utility-scale renewables was installed during 2023, short of the 1.6GW required annually to meet 2030 goals. Ireland's Climate Change Advisory Council urges planning reforms to accelerate progress.¹³

+1 China Mainland
 Draft legislation aims to prioritize renewables and displace fossil fuels, encouraging both international and domestic investment while improving infrastructure in rural areas.⁹

-1 Brazil
 Conflicts are growing around "green grabbing," with private institutions appropriating land to build wind farms and other energy assets, and creating investment risk around uncertain ownership.¹⁴

0 France
 The French government has reiterated its commitment to deploy renewable energy at speed, awarding a tender to build 270MW of floating offshore wind capacity off the Brittany coast. However, the exclusion of emissions targets in the new energy sovereignty bill has raised concerns about decarbonization progress.¹⁰

-3 South Korea
 A continued reliance on fossil fuel-generated power and non-competitive market structure is slowing down South Korea's energy transition. Subsidized tariffs have led to record debt levels within the sector and eroded investment in new energy assets.¹⁵

+1 UK
 In a significant hike from the previous round, the sixth round of the Contracts for Difference scheme has received more than £1b (about US\$1.3b) in government funding – £800m (around US\$1m) for offshore wind.¹¹ The battery energy storage pipeline is up 67% on last year, reaching 95GW.¹²

-1 South Africa
 South Africa's Integrated Resource Plan has warned that, while renewables will help decarbonize the power sector, they will be insufficient alone in ensuring energy security in 2050. Coal, nuclear and gas will continue to play a significant role, according to the Plan.¹⁶

See page 26 for RECAI methodology.

Normalized index

The RECAI uses various criteria to compare the attractiveness of renewables markets, such as the magnitude of the development pipeline, that reflect the absolute size of the renewable investment opportunity. Hence, the index naturally benefits large economies. However, by normalizing with the gross domestic product (GDP) — that is, dividing the “raw” RECAI scores by the log of GDP — we can see which markets are performing above the expectations for their economic size.

In this way, the normalized index helps reveal ambitious plans for energy transition in smaller economies, creating some attractive alternatives for potential investors.

Normalized ranking	Market	Previous ranking	Movement vs. previous	RECAI ranking
1	Denmark	1	●	8
2	Greece	3	▲	16
3	Chile	5	▲	15
4	Australia	4	●	5
5	Ireland	6	▲	14
6	Morocco	2	▼	27
7	Finland	9	▲	21
8	Germany	13	▲	3
9	France	10	▲	4
10	Portugal	7	▼	25
11	Netherlands	8	▼	11
12	UK	17	▲	6
13	Belgium	20	▲	17
14	Spain	11	▼	12
15	Sweden	15	●	19
16	Israel	18	▲	22
17	Poland	15	▼	18
18	Norway	23	▲	23
19	India	16	▼	7
20	Jordan	12	▼	48
21	Canada	21	●	9
22	Honduras	22	●	56
23	US	30	▲	1
24	Italy	27	▲	13
25	China Mainland	34	▲	2
26	Kazakhstan	19	▼	35
27	Argentina	33	▲	26
28	Taiwan	25	▼	24
29	Austria	24	▼	28
30	Dominican Republic	32	▲	45
31	Philippines	29	▼	32
32	Japan	43	▲	10
33	Panama	38	▲	52
34	Romania	35	▲	36
35	Egypt	26	▼	34
36	Brazil	41	▲	20
37	Bulgaria	37	●	53
38	Peru	39	▲	40
39	New Zealand	42	▲	42
40	Switzerland	46	▲	29

0 Denmark

Denmark has published its biggest-ever offshore wind tender, with at least 6GW of capacity to be auctioned across six areas.¹⁷ The Viking Link interconnector with the UK has commenced operations, improving energy security.¹⁸

+1 Greece

Renewable energy capacity has doubled in the last four years, with green electricity now accounting for 50% of generation.¹⁹ High energy prices and government support are driving the establishment of localized energy generation communities.²⁰

+2 Chile

Chile's renewables sector continues to grow, with more than 16GW capacity installed to date.²¹ This is forecast to double over the next decade, driven by President Gabriel Boric's proposed measures to reduce red tape for onshore wind investment.²²

+2 Finland

Finland has set ambitious targets of becoming Europe's first carbon negative economy.²³ A key driver will be the growth of its offshore wind sector, with the domestic TSO having announced five new areas to house large projects due to come online prior to 2030.²⁴

See page 27 for normalized RECAI methodology.

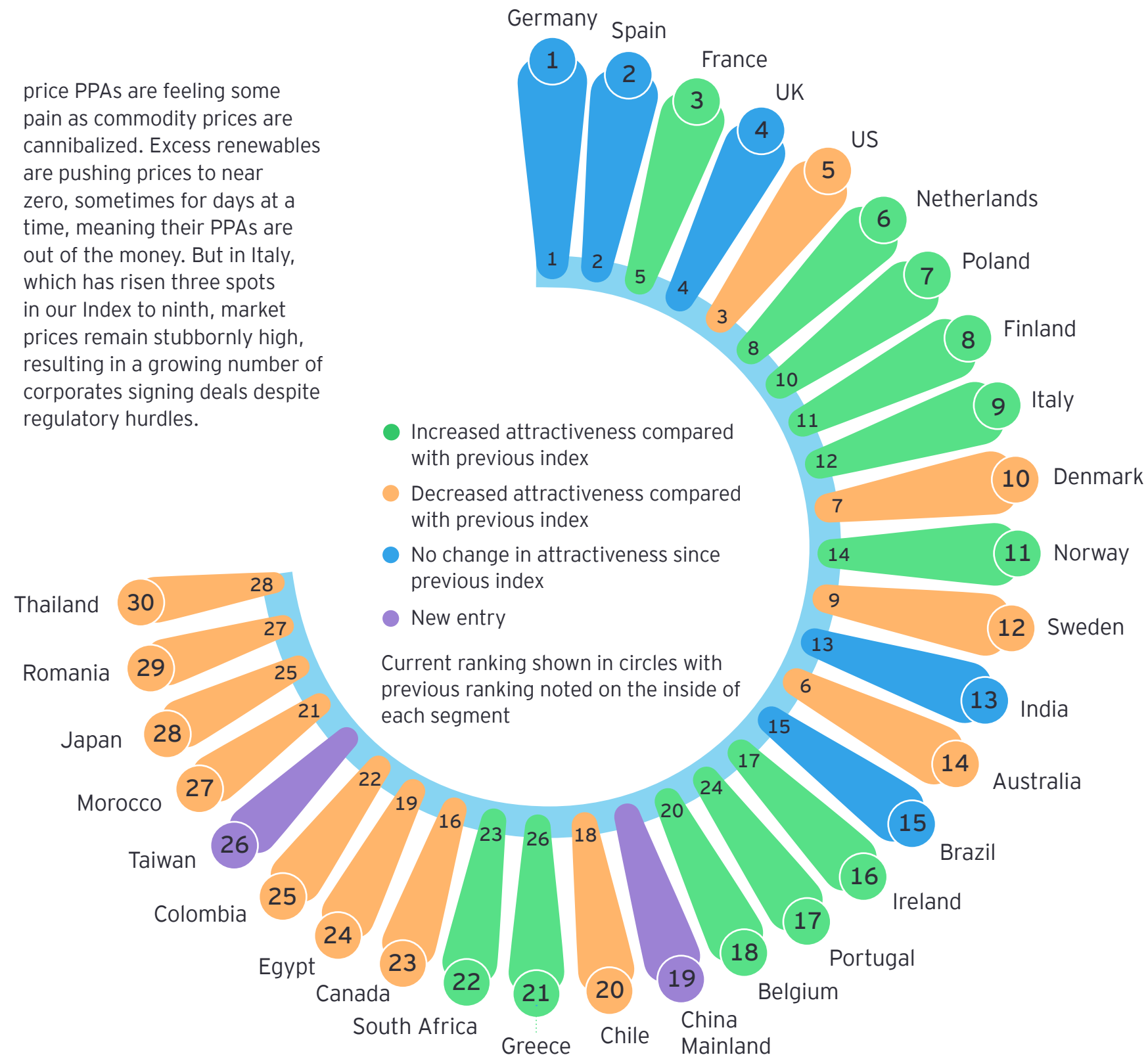
Buyers in the driving seat as corporate PPA market gains pace

2023 saw a record number of corporate power purchase agreements (PPAs) around the world (46GW),²⁵ but 2024 began a little quieter. Lowering power markets had prompted some corporates to replan their next tranche of PPAs but now, as energy markets trend upward, many are more comfortable to lock in low PPA prices.

After more than two years of a sellers' market, with lots of corporates chasing relatively scarce and often-delayed projects with rising prices, we see a distinct shift. Buyers are regaining the upper hand in negotiations. PPA prices had become unsustainably high in a number of lower-priced wholesale markets – leading to unattractive deals – but now we are seeing a correction to lower PPA prices in line with markets. Lower solar equipment costs are supporting this move, but wind costs are typically not reducing to the same degree, so economics are tight.

This edition's PPA Index highlights the regional diversity of the market. In Spain, corporates with fixed

price PPAs are feeling some pain as commodity prices are cannibalized. Excess renewables are pushing prices to near zero, sometimes for days at a time, meaning their PPAs are out of the money. But in Italy, which has risen three spots in our Index to ninth, market prices remain stubbornly high, resulting in a growing number of corporates signing deals despite regulatory hurdles.



France

A late starter in the corporate PPA race, France is now playing catchup, with a large number of deals over the past six months pushing the country up two spots to third position. Market positivity is high due to a new scheme that will see the government support PPAs through bank guarantees issued by Bpifrance. The scheme is designed to encourage extractive and manufacturing sectors to sign PPAs of 10 years or more and for 10GWh or greater from assets not yet commissioned. Most PPAs in France involve relatively small assets (less than 40MW), and about two-thirds are solar, with the remaining onshore wind.

Poland

The largest PPA market in Eastern Europe continues to grow, rising another three places in our Index to seventh. More large deals are being signed, as offtakers with a heavy manufacturing focus drive PPAs with an average capacity of around 60MW. Solar dominates onshore wind, making up about three-quarters of deals. We see a trend toward mixed wind and solar deals, as baseload PPAs are increasingly difficult to obtain from a single technology due to a reduced bank appetite for profile risk.

Greece

The deal count in Greece is still quite small, but this nascent corporate PPA market is showing signs of growth, rising five places to 21st. This is a market dominated by solar projects that make the most of the sunny Mediterranean climate, with only a few onshore wind deals. As in many other markets, large industrial and IT conglomerates dominate the offtaker list but, interestingly, there has also been a public sector PPA by Thessaloniki Water Supply and Sewerage Company (EYATH). This echoes a trend seen in other markets, including the UK, where a few government organizations have signed public sector PPAs.

China Mainland and Taiwan

These corporate PPA markets are appearing in our top 30 PPA Index for the first time, as they begin opening to private offtakers. In Taiwan, the Taiwan Semiconductor Manufacturing Company (TSMC) has agreed a couple of very large offshore wind deals (600MW-920MW) which, while not due to commence operations until 2026, are already having an impact, setting a precedent for government support. A recent government announcement that it would offer credit guarantees for green PPAs is aimed at widening the pool of potential customers. China Mainland also has seen the beginning of a couple of new private PPAs. In early 2024, Linde signed a 320GWh solar PPA (for power from the Guangdong and Jiangsu provinces) while, in 2022, BASF signed a solar and wind PPA for its Zhanjiang site, making use of the new renewable energy trading rules in the Guangdong province. With increased liberalization of power markets in China Mainland and Taiwan over the coming years, we expect to see more corporate PPAs.

See page 29 for PPA methodology.

Renewables highlights from around the world

Ambitious decarbonization targets are driving a clean energy push in some markets, with milestone wind and solar tenders, as well as innovative projects in carbon capture and hydrogen. But challenges remain amid a volatile transition, as seen, for example, in Spain, where grid constraints and low prices threaten solar investments. Here, we take a closer look at 10 global markets — from Germany’s record-breaking solar to energy “shock therapy” in Argentina, the manmade island extending the electricity grid in Belgium and India’s bid to become a green hydrogen leader.

3

Down 1

RECAI ranking



Germany: Solar auctions set records; bids open for more wind

Germany's highly effective approach to state tenders continues, with record participation in the country's latest round of solar photovoltaic (PV) auctions. Bids received totaled 5.5GW capacity, far surpassing the 1.6GW up for auction and resulting in projects receiving support of just 4.44 and 5.47 cents per kilowatt hour, significantly less than previous tenders.²⁶ Solar PV is central to Germany's renewables ambitions, with recent changes to project planning, licensing and registration aiming to help expansion of solar projects.

Wind-generated power is also a priority of Germany's Federal Network Agency (BNetzA), which is opening bids for both offshore and onshore wind projects this year. BNetzA's decision to put almost 15GW of onshore wind out to tender brings welcome certainty for the sector, according to Bärbel Heidebroek, President of the German Wind Energy Association: "This should provide a strong motivation for the industry to continue to seek new approvals at high speed."²⁷

The government has also outlined a US\$17b plan to subsidize gas power plants to transition to hydrogen.²⁸ Tenders are expected to open soon for four gas plants with a total capacity of up to 10GW, although details remain unclear, and some say the capacity goal is too low to effectively speed up the end of coal-fired power. The government has also announced it will subsidize power plants that run exclusively on hydrogen with a capacity of up to 500MW, for energy research.

7

Down 1

RECAI ranking



India: Record renewables added but funding shortfall looms

In the financial year 2023-24, India added approximately 26GW of new power capacity, more than 70% coming from renewables. Overall, renewables now make up 33% (about 144GW) of total installed energy capacity, with the share of coal and lignite dropping below 50% for the first time.

A record level of renewable energy auctions (for about 41GW of capacity) highlighted innovative approaches to new energy projects, including wind-solar hybrids, and firm and dispatchable renewable energy. Combined renewable energy and storage solutions made up about 37% of the total capacity auctioned. Tariffs for battery energy storage systems (BESS) have dropped about 59% from August 2022.

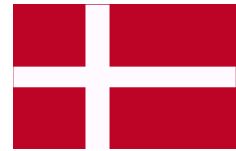
But India could still miss its renewables ambitions unless it can close a forecast US\$100b+ funding shortfall.²⁹ More investment is needed in renewable energy generation, storage and transmission capacity if the country is to meet the International Energy Agency's Net-Zero Emission Pathway by 2030.

India also aims to be a global green hydrogen hub, committing more than US\$2b in incentives.³⁰ These target both domestic electrolyzer manufacturing and hydrogen production, though the short tenure of the scheme and relatively low subsidies offered may limit its potential. So far, winners have focused on the export market due to domestic uncertainty around policy and pricing.

8

Up 1

RECAI ranking



Denmark: Largest ever wind auction and historic carbon capture deal

The launch of Denmark's largest ever offshore wind auction, with a minimum of 6GW capacity awarded across six wind farms, includes sustainability mandates such as the requirement to use recyclable turbine blades. The tenders will give winning bidders the freedom to establish as much offshore wind as possible in their awarded areas, with the hope that enough power will be generated to use at home, export to neighboring countries and support green hydrogen production. Projects will be built without state subsidies, with operators paying an annual concession payment to the Danish government, which will retain 20% ownership of each wind farm. Lars Aagaard, Denmark's Minister for Climate, Energy, and Utilities, said the scheme moves Denmark "... *one large step closer to becoming Europe's green power.*"³¹

Cementing its role as a leader in carbon capture and storage (CCS), Denmark has completed the largest ever government procurement of carbon dioxide removal credits, worth approximately US\$24m. The agreement saw three companies, BioCirc, Bioman ApS and Carbon Capture, win in a bidding process that demonstrated high market interest in capturing and storing biogenic carbon dioxide from biomass.³² Already achieving one of the OECD's lowest emission intensities, Denmark aims to achieve net zero by 2045.

A newly announced alliance with India will focus on green fuels, including hydrogen. The alliance aims to foster innovation, collaboration and partnerships between Danish and Indian organizations, with shipping giant Maersk playing a key role.³³

9

Up 2

RECAI ranking



Canada: New tax credit scheme and more certainty for offshore wind

Both Newfoundland and Nova Scotia have made moves to encourage offshore wind projects off their respective coasts. The provinces have signed memoranda of understanding (MoU) with the federal government to allow the development of jointly managed land, which should deliver more certainty to investors. Nova Scotia is building a regulatory framework for these projects and opens bidding next year for 5GW of capacity to be built by 2030. Newfoundland is also pushing ahead with several green hydrogen projects worth about US\$66m.

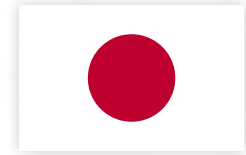
In Alberta, a moratorium on renewable energy projects has been lifted, but an "agriculture-first" approach to approving new projects will see prime farming land and areas with pristine views off limits. The changes are not expected to affect projects already under construction, but the Canadian Renewable Energy Association warns it may have a negative impact on investor confidence.³⁴

Canada is also hoping to replicate the success of the US Inflation Reduction Act, with plans to introduce investment tax credits for clean energy. As with the Inflation Reduction Act, the Canadian scheme will offer 10-year certainty for these credits as part of a US\$45b government pledge but, in a key difference from the American version, production tax credits are not included. The announcement has already seen a rise in interest from investors, according to some sources.³⁵

10

Up 3

RECAI ranking



Japan: Expansion of offshore wind zone to create opportunities

Japan's expansion of its offshore wind power zone will create installation opportunities in economic zones and help the country reach its goal of 10GW of offshore wind capacity by 2030. With floating offshore wind critical to help Japan phase out coal and liquefied natural gas, if passed, this new legislation will allow wind farms to be installed further out to sea. January saw the government issue two tenders for offshore wind off the coasts of the Aomori and Yamagata prefectures, with developers to be selected by December.³⁶

Japan is also set to unify subsidy rules around electric vehicles (EVs) and solar panels, with the EU to build a supply chain based on common principles and reduce reliance on China. The two regions are working to align rules to their respective decarbonization programs, ensuring procurement decisions go beyond price to consider sustainability accountability. The draft agreement opens the doors to collaboration with the US and other like-minded countries.³⁷

The country's latest round of solar PV capacity auctions yielded a low average price of JPY5.11/kWh (about US\$0.034) due to a JPY0.00/kWh bid submitted for a 19MW PV project that had already signed a private power purchase agreement but needed to secure a grid connection. The auction selected 134MW of PV projects ranging in size from 550kW to 29.9MW.³⁸

12

Down 4

RECAI ranking



Spain: Curtailment and constraints put brakes on solar

In 2024, curtailment remains a key issue, with market players potentially facing bankruptcies and scrambling to divest. In April, the average day-ahead hourly wholesale power prices reached a historic low of just over €5 (about US\$5.40) per MWh, with the impact of zero or negative prices also being felt in other solar-dominated countries, such as Bulgaria and Greece.³⁹

Grid constraints are growing, forcing the shutdown of 1.2TWh of renewable capacity in 2023 and costing the economy around US\$2.3b. The impact is likely to make location a much bigger factor for investors, with some suggesting projects in northern Spain (where there are less favorable solar conditions) will be more attractive than those in sunnier central and southern areas. Energy consultancy Aurora Energy Research warns that the Badajoz region, where 800MW of solar capacity is planned by 2030, is particularly at risk of curtailments due to low demand. Congestion also highlights the essential role for battery energy storage.⁴⁰

Across Europe, a general fall in energy prices and tough economic conditions for households are seeing enthusiasm for rooftop solar wane, but the decline is especially dramatic in Spain. In 2023, solar installations were about half of that for 2022, a year where the market was buoyed by subsidies and energy security fears. Considering new forms of installations, including for groups of households or communities, could help re-energize the sector, according to solar industry group UNEF.⁴¹

17

Up 4

RECAI ranking



Belgium: Expanding capacity through floating solar and groundbreaking island

Belgium has ambitious goals to boost offshore energy capacity through wind and floating solar, with targets to triple offshore wind capacity to 8GW by 2040. The idea is to build floating solar farms between wind turbines, to make the most of the country's relatively small coastline and existing infrastructure. Pilot studies around environmental impact and costs are underway, with hopes to build a 5MW demo project by 2026.⁴²

Meanwhile, the government is preparing to issue a tender for a North Sea project designed to increase capacity by 3.5GW by 2026. The project will be located as part of the Princess Elisabeth program, designed around the construction of a man-made island that will act as an extension of the electricity grid, connecting wind farms to the mainland and to neighboring countries.⁴³ An example of the power of collaboration between industry and government, the project will be central to meeting Belgium's clean energy goals.

Residential solar is also a priority. A temporary reduction in value-added tax for solar PV installations on buildings less than 10 years old has helped boost uptake. Belgium added 1.8GW of solar capacity in 2023.⁴⁴

26

Up 3

RECAI ranking



Argentina: Solar hits new high and reforms re-energize renewables

"Shock therapy" interventions from Argentina's newly elected President Javier Milei aim to release the country's clean energy sector from the constraints of difficult macroeconomic conditions, restrictions on foreign players and the lack of financial viability for renewables projects. Changes include regulatory reforms, a review of electricity and gas tariffs (previously heavily subsidized), and incentives to accelerate renewables projects and large investments (US\$300m+).⁴⁵ The journey to implementing these reforms is not assured, but their passing into law could revitalize Argentina's clean energy sector and offer exciting opportunities for investors.

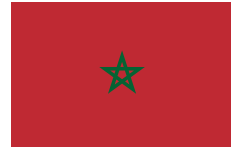
Despite abundant sunshine, Argentina has struggled to reach its solar power potential, with challenges including outdated grid infrastructure and persistent fossil fuel subsidies. But now the solar sector is accelerating under the RenovAr renewable energy auction program. According to a report by the Administrative Company of the Wholesale Electricity Market Sociedad Anónima (CMMESA), energy from solar contributed 3.33% of Argentina's total energy needs in March 2024, reaching a new milestone.⁴⁶

CMMESA is also leading a government process seeking expressions of interest for energy storage projects. The initiative will favor projects linked to the lithium industry, with Argentina one of the world's biggest lithium producers. Already, several winning bids in recent renewables auctions featured battery storage components, including a 10MW wind power plant proposed by Nuevas Energías Sustentables.⁴⁷ Pumped storage remains dominant though, with the Córdoba province calling for tenders for a US\$100m contract to overhaul its 750MW pumped storage hydropower plant.⁴⁸

27

Down 2

RECAI ranking



Morocco: Surge in solar and wind to increase energy independence

Morocco will invest US\$1b a year in solar and wind power to reduce its electricity imports, which currently meet about 90% of the country's energy needs. A recently launched tender for a 400MW wind farm project will help boost Morocco's strategy to source 52% of its electricity mix from renewable sources by 2030. The Nassim Nord project, to be built in northern Morocco, is part of a new program to boost private sector investment in clean energy.⁴⁹ However, the potential of Morocco's renewables ambition may not be realized without significant investment in its grid, admits Energy Minister Leila Benali. The government is planning a new north-south transmission cable to improve connectivity.⁵⁰

Industries seeking energy independence are also driving the rapid expansion of wind energy. More companies, including in the cement and fertilizer sectors, are installing their own wind farms to take control of their energy needs.

Green hydrogen is also on the agenda, with one million hectares of land earmarked for projects. The first 300,000 hectares will soon be made available to both foreign and local investors, with interest already high, according to government sources.⁵¹

39

Down 6

RECAI ranking



Vietnam: Tariff changes set to reduce solar revenue

Changes to Vietnam's feed-in tariff subsidies (FiTs) for new solar and wind projects will reduce revenue and returns certainty for investors. A new pricing framework will set prices for both ground-mounted solar power plants and floating solar power plants based on the average annual solar radiation intensity in their region. This means that FiTs across northern, central and southern Vietnam will vary. Prices will now also be set annually rather than 20 years in advance, making forecasting more difficult.⁵²

A green energy collaboration with Australia aims to boost sustainability in both countries.⁵³ Australia's knowledge sharing around creating clean energy regulation should help Vietnam build a strong policy base for investment. The arrangement is an example of how Vietnam's net-zero ambitions and renewables growth are attracting increasing interest from global collaborators. In March, Dutch company Fugro extended its MoU with the country to develop offshore wind farms.

Vietnam is also seeking foreign investors to help it fulfil its goals of producing up to 500,000 tonnes of clean hydrogen annually by 2030 (rising to up to 20 million tonnes per year by 2050). Over a gradual run-up phase, the government will consider how policy mechanisms such as tax credits and land rights could be used to help develop an industry in blue and green hydrogen production that will be exported or used internally to abate heavy-emitting industries.⁵⁴

Four factors to guide investment in battery storage

Demand for battery energy storage systems (BESS) is increasing amid growing grid volatility. Our ranking of battery investment attractiveness reveals hot spots, but four factors can help investors navigate a complex market.

Why BESS and why now?

Our energy system is transforming faster than expected. According to EY modeling, multiple transitions reshaping the world's energy systems are progressing at speed, with renewable energy set to dominate global generation by 2038. Already, more than 15% of global power comes from wind and solar, with this expected to increase 2.5x by 2030 under existing policies, market conditions and growth trajectories. Rapid electrification of industry, transport and households, as well as the massive build-out of data centers, will see electricity demand soar 1.7x by 2050.⁵⁵ This will create highly localized energy systems, that are potentially more resilient, sustainable, equitable and affordable.

But all of this depends on our electricity network and infrastructure, and our ability to maximize the output of power produced. The proliferation of renewables and electrification presents significant challenges to system adequacy, grid management and price volatility. We'll need to urgently upgrade and expand the grid to connect more distributed energy resources and build out flexibility at scale to withstand intermittent power supply and demand. Without these enhancements, we risk outages, higher bills for consumers and more grid curtailments. For example, in the UK, the US, Germany and Ireland, curtailment rates have risen from around 2% in 2015 to 8% in 2022 as the share of renewables has doubled in the system.⁵⁶ Similarly, load shedding events are becoming more regular. In April

this year, a period not typically associated with deficient power reserves, load shedding was triggered in Canada, Texas and Hawaii to stabilize the supply-demand balance due to decreased wind and solar availability.

In this evolving energy system, storage will be vital. While different energy storage technologies will be adopted in different ways around the world, it's likely that BESS will become the dominant technology deployed at grid level.

Comparing BESS with other energy storage technologies

We believe BESS is the most promising of existing energy storage technologies due to its superior energy density, efficiency, modularity and response times. BESS can be built relatively quickly for less capital than many other energy projects, and its ability to play multiple roles means it can solve multiple challenges within a changing energy system across a range of durations and power requirements.

In brief

- ▶ BESS will play a key role in a dynamic energy system, smoothing supply and demand peaks, and helping defer the cost of grid expansion and upgrades.
- ▶ The scale of the US and China markets means they lead our ranking of the most attractive targets for battery investment, but this is a complex landscape to master.
- ▶ Four factors can help investors build a strong business case, and navigate opportunities and risks.

Authors

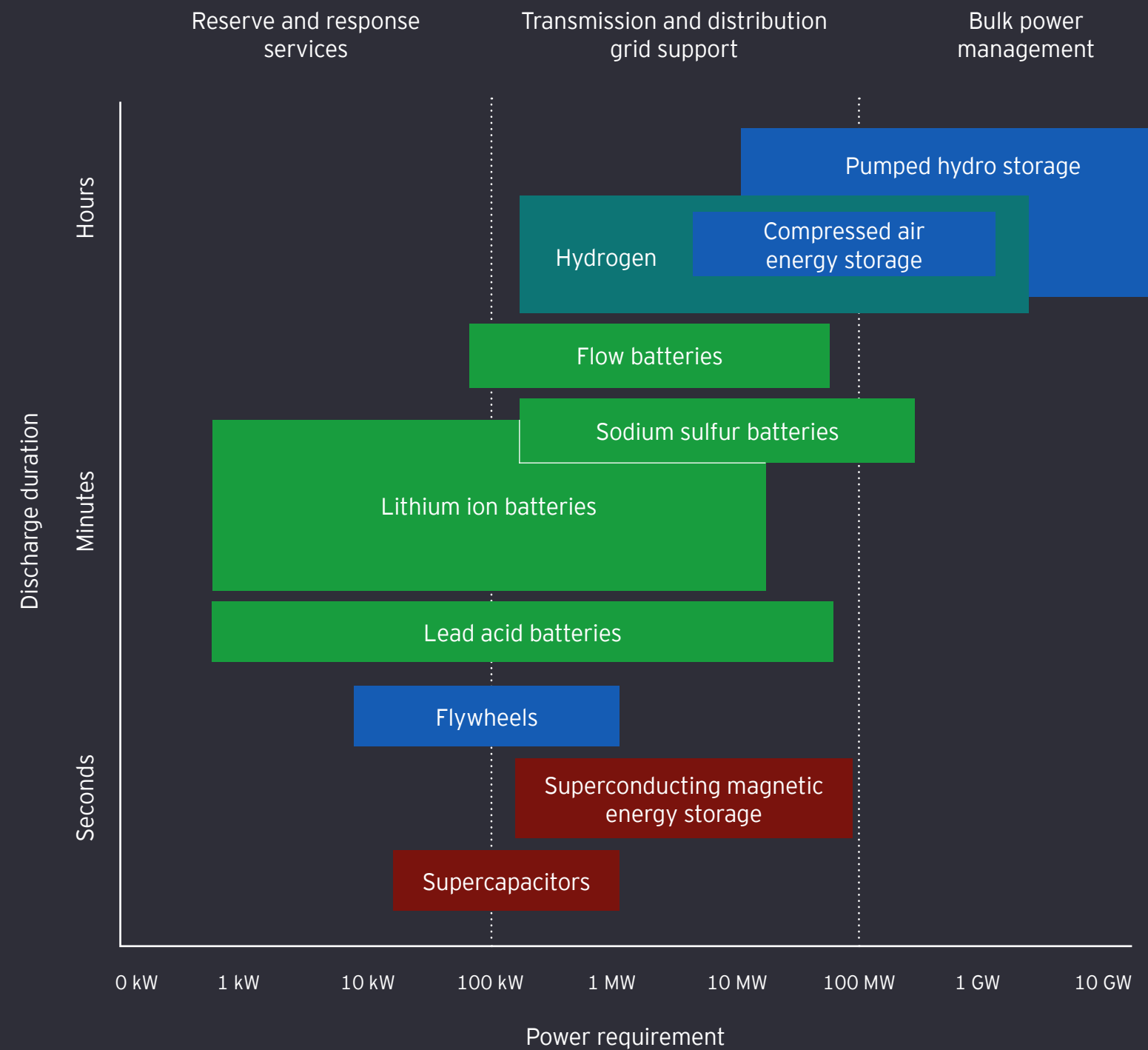
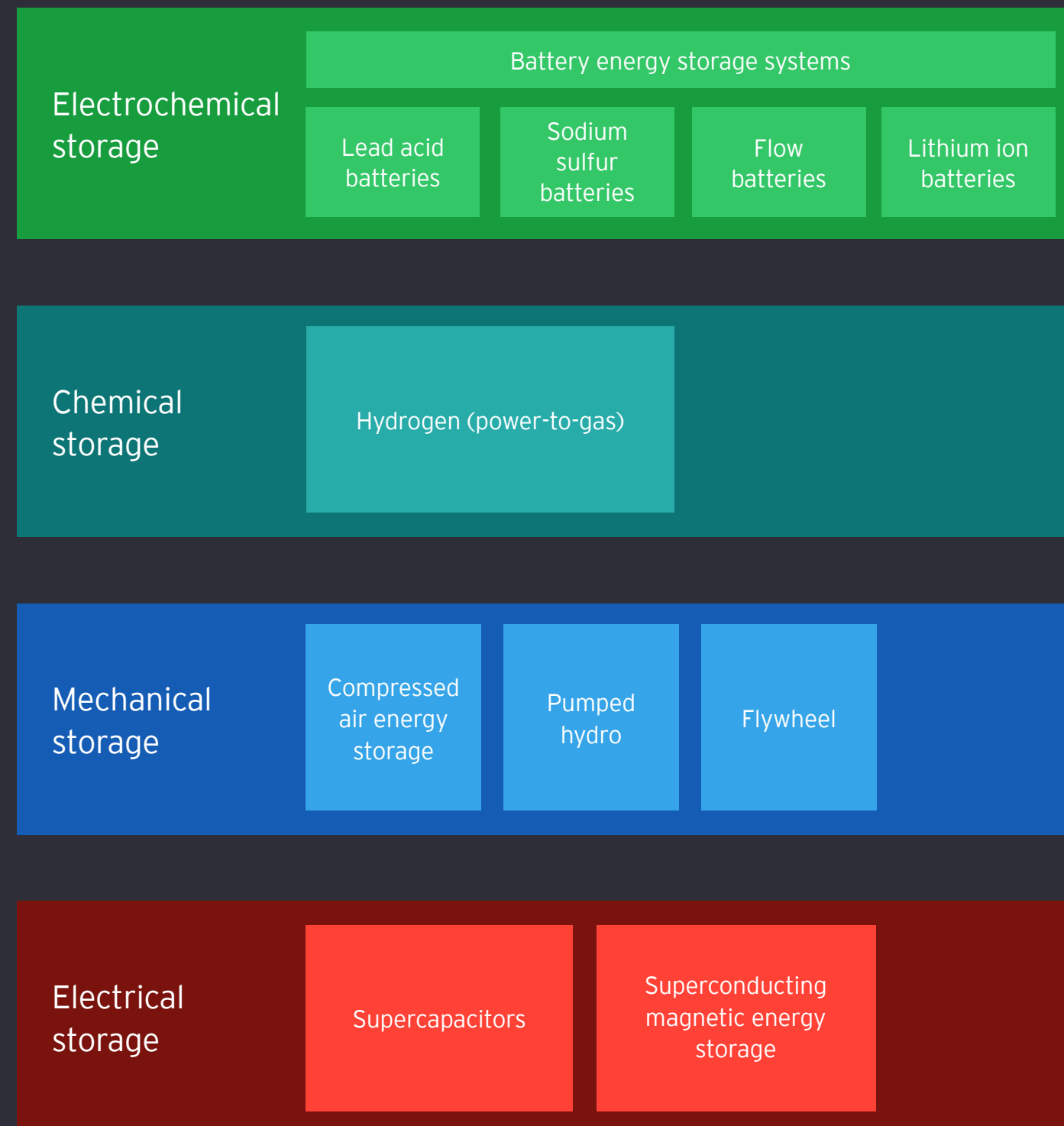


Louise M. Shaw
EY UK&I Energy and Infrastructure Corporate Finance Leader
lshaw@uk.ey.com

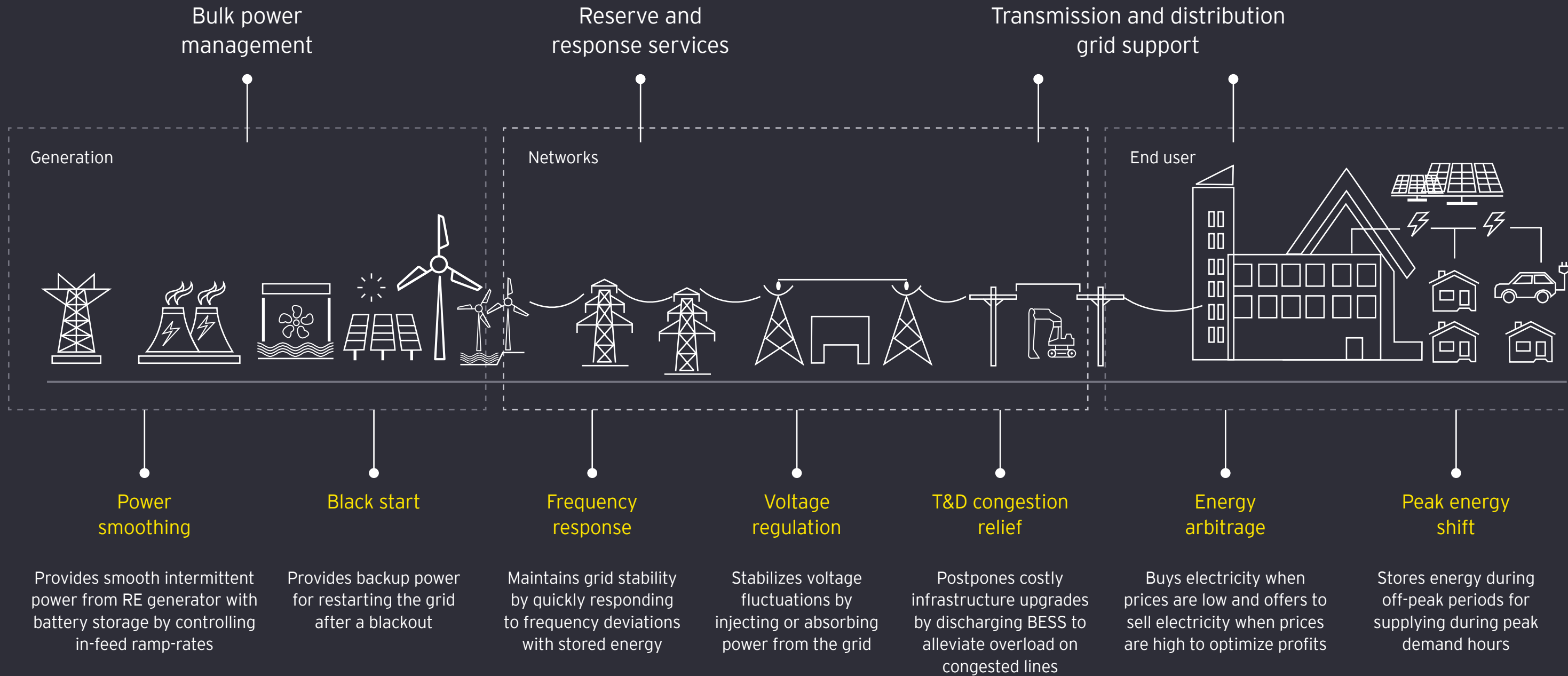


Andrew Horstead
EY Global Power & Utilities Lead Analyst
ahorstead@uk.ey.com

Overview of energy storage technologies based on application



BESS can deliver a range of services across the electricity value chain



In South Africa, EDF Renewables is constructing Umoyilanga, a collocated power plant of wind, solar and battery that will provide TSO Eskom with continuous power for 14 hours of the day.⁵⁷

AusNet conducted a residential battery trial with a ~6.6 kWh battery to flatten residential demand profiles and flatten peaks. Combined customer and network benefits were expected to reach AU\$6800 (about US\$4,500)/year for five years.⁵⁸

In the US, Green Mountain Power installed 30MW of utility-scale and residential battery systems, enabling customers to use its network of stored energy in times of peak demand. Benefits reached US\$3m/year from 2020 to 2022 and are expected to top ~US\$6m by 2030.⁵⁹

Where are the most attractive BESS investment opportunities?

As demand for energy storage increases, so too does investment in BESS. Deployment is forecast to quadruple to 572GW/1,848GWh by 2030, much of this adopted at grid scale.⁶⁰

But the ability to yield healthy returns requires mastering a highly regionalized, fast-changing and complicated market. The new ranking of the attractiveness of the world's battery energy storage markets by EY aims to help guide investors, considering factors including project pipelines and regulatory support, which should be assessed alongside market design and maturity, technical considerations, financing options and even cultural fit. An attractive market is one that offers:

Revenue stacking potential: Unlike other renewables assets, battery operators generally need to “stack” revenues to make investment worthwhile. Regions that allow BESS to participate across multiple markets (i.e., ancillary, energy arbitrage and capacity) offer the best opportunity to do this.

Energy price volatility: Higher volatility – usually in places with high penetration of solar and wind generation and lower degrees of interconnection – increases energy arbitrage opportunities for BESS (i.e., the ability to store power when it's free or cheap and then sell back to the grid when prices are higher).

Intelligent grid infrastructure and operations: Markets with a modern, digitized grid enable batteries to compete with other technologies in the race for dispatch. BESS can respond far more quickly than most competing technologies such as gas, but optimizers need to be able to use sophisticated technology, including artificial intelligence (AI), to interface with system operators.

Three key BESS markets

Ancillary: Ancillary services reward battery operators for supporting grid stability and include frequency response, voltage control, peak shaving and backup support.

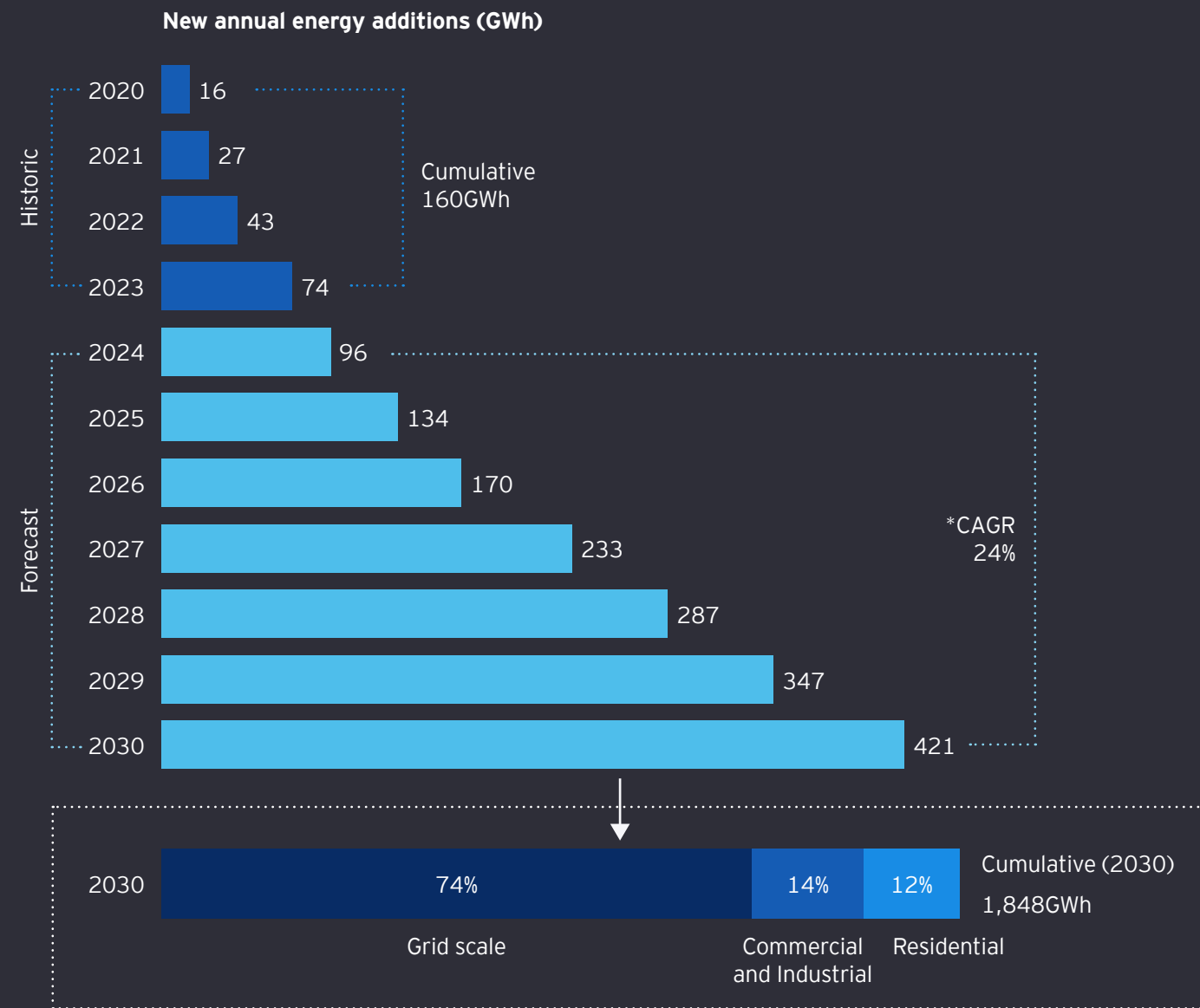
Energy arbitrage: Battery operators can earn revenues by helping to balance the grid, by buying and storing energy at times of low demand, and releasing it at times of high demand, when it is most needed (usually morning and afternoon peaks). Revenues can be earned by participating in wholesale trading through options including day-ahead, intraday and forward.

Capacity: Capacity markets, which allow battery operators to win contracts to provide capacity in the future, offer secure and steady, if relatively modest, returns, but they don't exist in all markets.



Annual global battery storage installations are expected to quadruple between 2023 and 2030, driven by grid scale applications

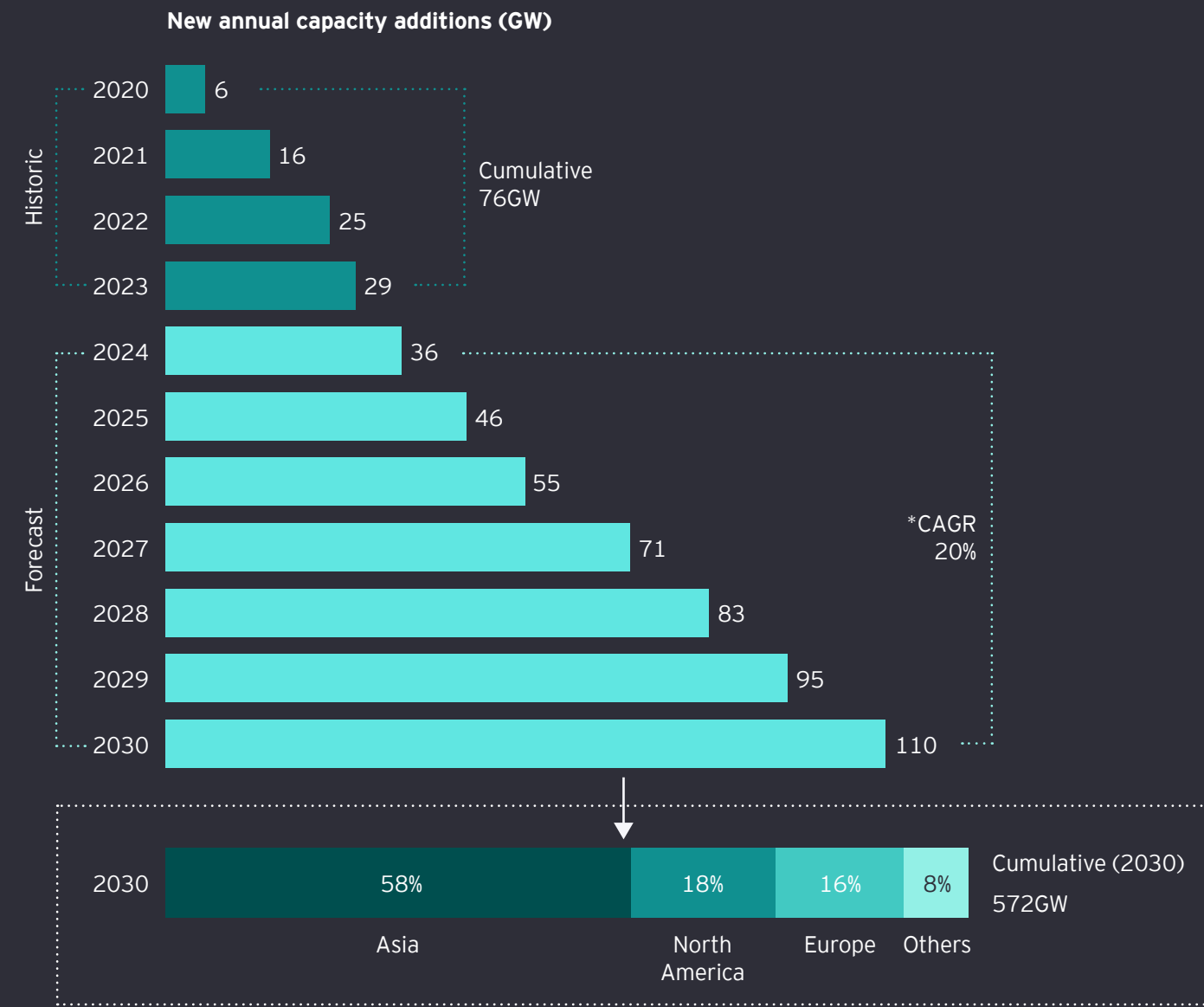
Global battery storage energy capacity (GWh, 2020-30)



*Compound annual growth rate

Source: EY Insights analysis of data from IEA; Rystad Energy.

Global battery storage power capacity (GW, 2020-30)



*Compound annual growth rate

Source: EY Insights analysis of data from IEA; Rystad Energy.

Market	Rank	
US	1	<ul style="list-style-type: none"> ▶ Demand for BESS is expected to increase sixfold by the end of the decade. Capacity is expected to almost double in 2024 to more than 30GW. ▶ The US battery market is growing fast, supported by 30% tax credits offered under the Inflation Reduction Act.⁶¹ ▶ California leads, mandating BESS in all new buildings.⁶² ▶ Independent system operators such as NYISO, CAISO, ISO-NE have enabled participation of battery storage in ancillary markets.
China Mainland	2	<ul style="list-style-type: none"> ▶ Strong government support with subsidies is accelerating rapid energy storage development, with a target to achieve 100GW of BESS by 2030. ▶ New energy storage plans to reduce BESS costs by 30% by 2025.⁶³ ▶ China contributes >50% of global lithium-ion battery storage exports.⁶⁴
UK	3	<ul style="list-style-type: none"> ▶ The UK's battery storage capacity is projected to expand to 24GW by 2030. ▶ Sophisticated energy market design includes a well-established and diverse revenue stack for BESS. Upgrades to the National Grid ESO's Open Balancing Platform supports the bulk dispatch of battery storage in real time. ▶ A new energy bill classes BESS as a generation asset, easing rules around construction and offering specific tariff structures. ▶ The government is committing £20b (around US\$25b) to establishing a world-leading battery industry by 2030.⁶⁵
Australia	4	<ul style="list-style-type: none"> ▶ Daily spot markets for power and system frequency control services offer diverse revenue streams. ▶ Storage capacity from batteries, virtual power plants and pumped hydro are projected to increase to 61GW in 2050. ▶ The federal government has agreed with states to establish a Capacity Investment Scheme, allowing BESS to tender to fill expected reliability gaps.
Germany	5	<ul style="list-style-type: none"> ▶ Favorable market conditions, including some grid fee exemptions and construction subsidies, create more opportunities for BESS. ▶ Energy storage can participate in day-ahead and intraday markets.
Italy	6	<ul style="list-style-type: none"> ▶ Italy targets 71GWh (12 GW to 15GW) of Terna storage tenders by 2030.⁶⁶ ▶ Twelve- to 14-year fixed-price long-term contracts are offered, indexed to inflation, with Terna as the counterparty. ▶ First auctions are planned for December 2024, with first capacity delivery expected from 2027. ▶ The government will soon tender for utility-scale storage capacity and issue a regulated framework for BESS investments.
South Korea	7	<ul style="list-style-type: none"> ▶ South Korea is pushing to become the top BESS market after China and the US.⁶⁷ ▶ Mandates call for energy storage systems in all new public buildings.⁶⁸ ▶ Government incentives will include tax breaks for BESS installation.
India	8	<ul style="list-style-type: none"> ▶ India has joined the Global Energy Alliance for People and Planet's BESS Consortium, a multistakeholder partnership that aims to bring clean, affordable energy to Africa, Asia, Latin America and the Caribbean. ▶ As part of the consortium, India has agreed to secure 5GW of BESS commitment by the close of 2024.⁶⁹ ▶ A new government funding scheme will award funding for BESS projects of 4GWh capacity, with financial support of up to 40% of capital cost.⁷⁰
France	9	<ul style="list-style-type: none"> ▶ France is accelerating battery capacity at speed, fueled by tax credits for BESS investment.⁷¹ ▶ More BESS projects have prompted the energy regulator to reopen a postponed auction for demand response power.
Japan	10	<ul style="list-style-type: none"> ▶ Japan offers multiple revenue streams for BESS, including rolling weekly and day-ahead markets. ▶ BESS can compete for three-hour blocks in capacity auctions. Winners will receive subsidies equivalent to the "fixed costs" of a qualifying project, which would include a stand-alone facility, for a period of 20 years.

Building a robust business case for BESS investment

A decision to invest in BESS is a long-term one – these projects typically run for 20 years or more with battery upgrades. Although there is strong momentum behind BESS investments, most markets still face challenges around how to incorporate the range of features offered by storage. These include merchant revenue variability, financing, market design, grid fees, connection delays and asset monetization. Gaining the requisite level of confidence in a business case requires specific, in-depth knowledge of the target market, as well as an understanding of rapidly evolving technology and an acceptance that this is a market reliant on volatility. Considering four factors can help investors frame their approach to BESS opportunities and navigate risks.

Our ranking of the top markets for battery energy investment assesses factors including installed capacity and pipeline as well as government support, such as tenders, subsidies, policy and deployment targets.

1. How can I build a resilient investment case?

An evolving energy mix and uncertainty over the scaling of storage means conditions are changing quickly

Batteries earn revenues through three main markets (ancillary, energy arbitrage and capacity) which operate with different processes across different timescales. Evolving conditions and policies across geographies will have varied implications on these models, but, over time, as markets become saturated in the short to mid term, the revenue stack for project owners is expected to shift from frequency response and other ancillary services toward energy arbitrage via wholesale trading and balancing systems, and capacity markets.

In markets such as the UK, ancillary services have typically accounted for the majority of revenues for BESS. In 2022, 84% of the BESS revenue stack came from frequency response services. But as BESS came to dominate these markets, saturation set in, deflating prices. By 2023, average revenues were down sevenfold and, so far in 2024, frequency response revenues makes up only 20% of the stack.⁷² Across European markets, ancillary services provided 40% of the revenues in 2023, falling to 33% in 2024.⁷³ In the US, BESS ancillary revenues fell 48% from 2021 to 2023.⁷⁴

The value for BESS is moving firmly toward energy arbitrage through wholesale trading and balancing systems, such as the UK National Grid ESO's Open Balancing Platform, which supports the bulk dispatch of battery storage in real time. In the UK, wholesale trading revenues jumped from around 7% of the revenue stack in 2022 to 30% in 2024 (to date), while balancing revenues have jumped from 7% to 17%. In the US, BESS revenues from arbitrage are expected to increase 47% by 2030.⁷⁵

While arbitrage is an increasingly important part of the revenue stack, markets such as Spain, which rely solely on this, have so far struggled to gather pace. The investment case for battery assets would strengthen with the benefit of additional revenues stacked from other sources such as ancillary services and the capacity market. With the sector expecting the government to approve a capacity market in the next few months, Spain's battery storage market is tipped for growth.

In the future, optimization and the right bidding strategy will become critical to ensure maximum returns for storage assets. Future value opportunities will be localized as renewables proliferate and volatility increases. Negative or zero-price events, already on the rise, will become more frequent, expanding opportunities for storage. Founder of energy technology and insights firm, EnAppSys and director of consultancy Encora Energy Paul Verrill says we should prepare for "very interesting summers in continental Europe because (countries including) the Netherlands and Germany are doubling down on solar, and that's going to create these massive excess generation periods, when storage can effectively time shift." Colocation storage in markets with this level of volatility is also becoming integral to the business case of solar PV projects.

As well as location, the importance of timing cannot be underestimated when BESS capacity is growing so quickly and can be deployed with relatively short development lifecycles. First-mover advantage is significant and can make a huge difference to the profitability and resiliency of investment, with ancillary markets becoming saturated and the evolution of longer duration storage.

Within just three to five years, more than 50% of BESS revenues are expected to come from wholesale markets, with 30% from balancing, depending on the location. Island states will likely experience a higher degree of volatility – price spreads in Australia have increased more than six times over the past five years. But they also doubled on average across Europe over that time, showing that even markets with the inbuilt resilience offered by electricity interconnectors are seeing more fluctuations.⁷⁶

Determining optimal location can increase profit margins by positioning closer to areas with higher grid congestion and renewable energy concentration.

Determining locations with the strongest flexibility needs:

Electricity grid congestion: understanding the levels of grid congestion in an area

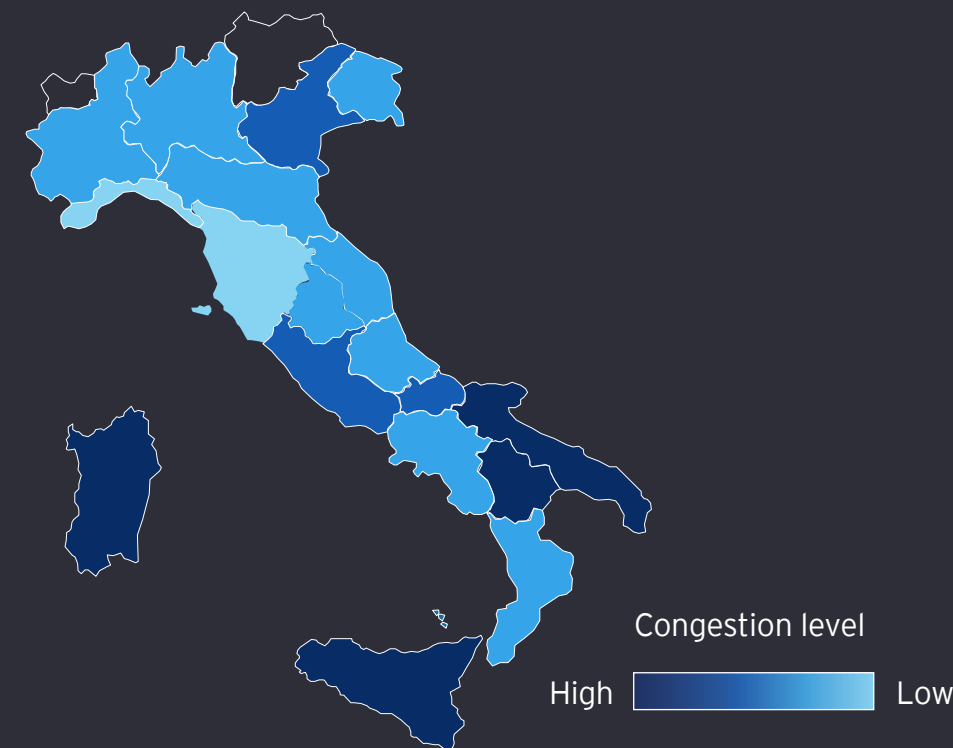
Grid investment: understanding levels of planned grid investments

Market prices: assessing the spread of intraday prices and levels of volatility

Renewables fluctuations: identifying regions with high solar or wind power shares which can cause grid instability

Location analysis: Italy

Southern part of Italy appears very attractive for stand-alone BESS



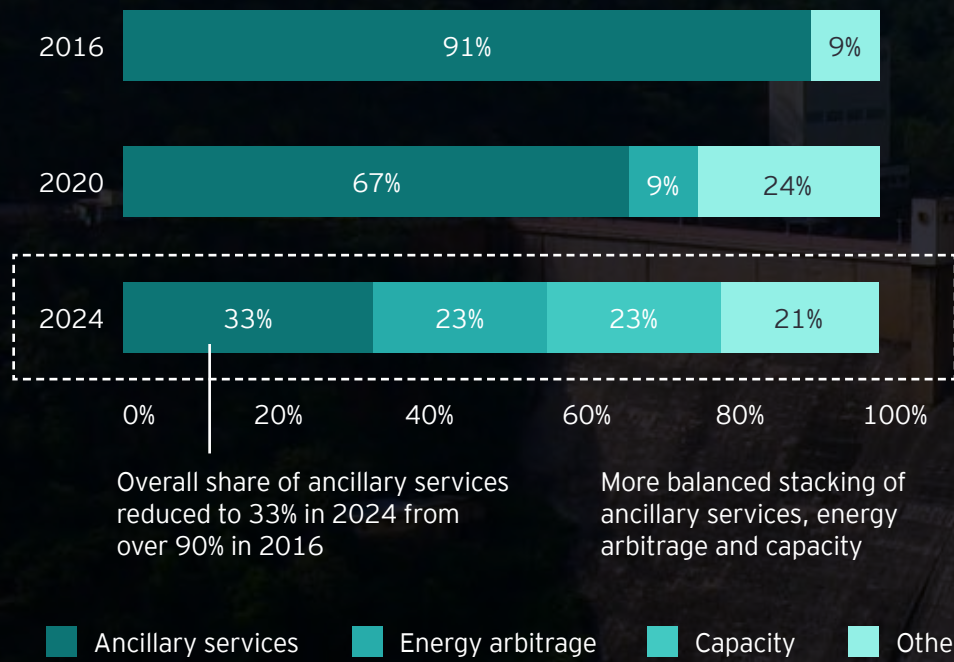
>50%

of BESS revenues are expected to come from wholesale markets by the end of the decade.

As grid operators acknowledge the need to secure future capacity, more regulators are introducing or reforming capacity market mechanisms to allow BESS participation. For example, Italy is transitioning its existing mechanism to a regulated model, with 15-year capacity auctions offering the confidence of long-term certainty. The UK holds auctions for one- or four-year-ahead capacity contracts, with the latest (2024) round of auctions expected to increase BESS capacity by around 80%.⁷⁷

Growing saturation of ancillary services, and rising opportunities in arbitrage and capacity markets, is leading to a shift in the BESS application service portfolio

Stacking of battery storage application in Europe (%) 2016-24



Note: **Ancillary services:** Includes services such as frequency regulation, voltage control, reactive power support and reserve capacity.
Energy arbitrage: Trading electricity for profit from demand price discrepancies.
Capacity market: Offers guaranteed power availability, boosting grid reliability.
Others: Includes energy trading, power backup, firming and ramp control.

Source: EY Insights analysis of data from Wood Mackenzie, LCP Delta, Modo Energy.

Key takeaways

- ▶ Align your project to market need: Consider how the energy mix is evolving in your target market to ensure your BESS project stays in step.
- ▶ Watch for signals: Markets where system operators give clear signals around the role of batteries offer more certainty for future revenue opportunities.
- ▶ Assess the viability of different markets: Are arbitrage, ancillary and capacity markets mature, saturated or yet to be established for BESS? Review where BESS is most competitive against other players to forecast the best opportunities for returns.
- ▶ Consider the impact of timing and location: In countries or regions where demand is strong, the ability to move quickly to establish projects first can boost profitability. Location within a region is also critically important and requires investors to assess factors including grid constraints, planned grid investments, and fluctuating solar and wind conditions.
- ▶ Build agile bidding strategies to hedge against uncertainty: Bidding strategies with revenue stacking at the core, that complement ancillary services and wholesale market access without taking undue risk with imbalance prices, can maximize returns in a volatile market.
- ▶ Stay vigilant to regulatory changes: Regulators and system operators are continually adapting market rules as needs change, which may alter opportunities for BESS. For example, the UK's introduction of new quick reserve products will enable greater participation for batteries to provide more real-time solutions to grid imbalances.

2. How will I maintain the competitiveness of my battery?

Digital capabilities are crucial to optimize performance

Continuing to capture value in a fast-changing market requires an agile mindset. Roger Hollies, Chief Technology Officer at energy technology firm Arenko, describes batteries as the Swiss Army Knife of energy storage. He says a flexible approach stands the best chance of success. “One of the earliest pieces of advice I got was ‘you don’t know what you’re going to be using this battery for in two years’ time’ ... You just have to build in flexibility in terms of the asset for the batteries themselves, but more importantly, your digital footprint has to be adaptable to bring in new concepts, (and) new interfaces with different market players.”

AI and digital tools will be essential to adapt at speed. “Understanding and leveraging AI and digital tools for optimized storage trading strategies can help companies de-risk investments, navigate regulatory changes quickly, and better monetize opportunities presented by new market structures and market volatility,” explains EY Global Energy & Resources AI Lead Ana Domingues.

For example, a move to real-time trading and dynamic pricing in markets such as the UK, the Netherlands, Australia, California and Texas creates more opportunities for BESS participation but will depend on intelligent grid orchestration, as well as real-time monitoring and specialist expertise to competitively price the bid or offer and correctly manage the state of charge through the wholesale power market.

“

Leveraging AI and digital tools for optimized storage trading strategies can help companies de-risk investments, navigate regulatory changes quickly, and better monetize opportunities presented by new market structures and market volatility.

Within wholesale trading, there are a variety of trading products (including day-ahead, intraday and forward) and different trading strategies will need to be tailored based on factors such as the type of battery, warranty, the market conditions – and even the owner’s risk appetite. André Bosschaart, Head of Analytics at EnAppSys, says intraday trading offers more revenue potential, but reaping this value requires “thinking as an asset-backed trader – an owner has a right to dispatch an asset, but not an obligation ... (so) estimate the value of all possible products now and in the future.”

Mastering data generated by BESS will also become more important. Says Roger Hollies, “There are huge amounts of data coming from the asset. The real power is combining that data with market data and understanding past, present and future markets. That’s really important for optimization and also reconciliation.”

This will be even more crucial as battery duration evolves. Declining costs, shrinking revenues from frequency markets and regulatory support mean longer-duration batteries are likely to become inevitable, potentially making shorter-duration products commercially unviable. According to Ben Guest, Managing Director at asset management firm Gresham House, “the commercial opportunity for batteries will grow to eight to 12 hour durations.” Eight-hour batteries are already installed across several markets, including the US and Israel. However, it’s important to note that longer-duration batteries require higher capex, both to build and to maintain, though, as Paul Verrill explains, “it’s not a simple calculation. The battery is less arduously used if it’s bigger, so in a way it extends its life. There are also reliability benefits because a half-hour battery is cycling massively.”

Investors will also need to consider how alternative storage systems may erode the future business case. For example, the declining cost of electrolyzers may see hydrogen storage emerge as a cost-competitive alternative as early as 2027.⁷⁸ In the near term, the scaling of vehicle-to-grid (V2G) technology as EV adoption increases may displace BESS in some use cases, perhaps strengthening the case for larger-scale projects, though, as Ben Guest notes, “battery storage can likely negate the need for longer duration storage when you factor in demand response possible from an increasingly electrified heating and transport system.”

Key takeaways

- ▶ Partner with, or invest in, quality optimizers, digital tools and data analytics: Operating your system to enhance performance, maximize revenues and prolong life is crucial to deliver return on investment over the project lifecycle.
- ▶ Stay on top of battery duration developments: Be aware of how technology is maturing, as well as the impact on regulatory decisions, and operate your battery portfolio accordingly.
- ▶ Be vigilant about the impact of technology changes on competitiveness: Evolving BESS market and technological advances may introduce uncertainties and potentially elevate costs compared with other established energy sector technologies.
- ▶ Factor in the cost of augmentation and replacement: Longer-duration batteries require higher capex, both to build and to maintain, and investors will need to balance these additional costs with potential revenues.

3. What are the optimal business models or financing structures for BESS?

BESS projects are capital-intensive so will require financing. But these are not “set and forget” investments

BESS are active assets that need managing throughout their life. This means the ability to tie up capital with development, construction, operating and optimization capability is key to successful BESS projects.

We see many examples of investments in BESS platforms by private equity or infrastructure funds, such as Statera being bought by EQT, Zenobē financed by KKR, and Global Infrastructure Partners' backing of Eolian. Major energy players such as Shell, NextEra Energy and EDF are also increasing their investment in batteries as part of trading and hedging strategies, acquiring assets as well as platforms.

Investors need to ensure their finance and offtake strategies are linked. For example, they should consider whether the goal is long-term contracted revenues or if they are willing to take merchant risk for a potentially higher return. There is a myriad of different offtake structures emerging in markets such as the UK, with a range of floor structures (which provide fixed income). Regardless, an acceptance of volatility and a willingness to take a longer-term view over various cycles is important. BESS development lifecycles are short, and supply and demand can correct relatively quickly, though market dynamics differ. For example, the UK has seen numerous cycles of boom and bust within just a few years. But if electrification rates slow – André Bosschaart does not believe demand in the Netherlands will grow as quickly as some anticipate – investments may take longer to pay off.

Lenders typically require a level of long-term contracted revenues to project finance battery storage projects, although some are considering taking on an element of merchant revenues based on forecasts of the revenue stack. The quality of the sponsor and operation of a BESS asset is also very important to the debt market, as Peter Allcock, Director at SMBC Bank International, explains: “We want to speak to the developer and quiz them on their choice of optimizer and choice of asset location ... the capabilities of the

sponsor are very important to us.”

Successful projects are executed by investors with differentiated capabilities across the value chain and strong management teams with local market capabilities. Relationships with landowners can smooth the development process, as can understanding local planning regimes and regulation, and offtake markets, and strategies that align.

More broadly, considering colocation or behind-the-meter projects can optimize earnings potential over the longer term. The UK's largest battery and solar facility, Warrington Renewables (York), has signed a hybrid power purchase and optimization agreement with Norway's Statkraft. We've also seen major offtake agreements with colocated projects in California, Texas and Australia.

Deals with corporates wishing to strengthen green credentials could also offer opportunities for BESS. Paul Verrill says these deals are on the rise in the UK: “We are seeing lots of renewable PPAs with above market prices. A company that has a solar project and wants to truly be green can only use power that comes from that solar project – they need time shifting, so they need batteries. [These deals are] almost like a private subsidy because [they're] above the market.”

Key takeaways

- ▶ Focus on high-quality development management teams and optimizers: This is vital for a successful investment that can withstand an ever-changing regulatory backdrop, market dynamics and energy mix.
- ▶ Align interests between parties: protect long-term success through contracting and financing structures.
- ▶ Remain focused on the growing importance of BESS in an increasingly decarbonized and localized energy landscape: Amid a volatile revenue environment, take a long-term view of how investment in battery storage will pay off.

4. How can I navigate supply chain complexity and geopolitical risks?

The ability to reduce capex will be vital to the scaling up of BESS investment.

We expect costs of grid-scale BESS to fall by around 20% to 30% across key markets by 2030 as technology advances and government subsidies increase, and battery cell supply chains feel the impact of a recent slowdown in EV adoption.⁷⁹ These reductions may be offset by volatile commodity prices and supply chain bottlenecks. For example, slow lead times around building electricity transformers can delay the connection of new BESS projects to the grid.

China Mainland's dominance of the battery supply chain, and growing resource nationalism and protectionism in many markets, could impact the viability of future projects. While some markets are moving to reduce dependence on others by establishing domestic battery industries, this will be expensive and complex. Localizing the supply chain across the EU and the US would require about US\$170b of investment by 2030, according to our estimates.⁸⁰ Investors will also need to keep an eye on how the evolution of technology innovation may also change demand for commodities and reshape the supply chain –

for example, vanadium and sodium-ion batteries may challenge the dominance of lithium post-2030.

Battery recycling could help mitigate some supply chain risks. As BESS players expand their services across the value chain, we see more investing in recycling, sometimes as part of broader vertical integration. Iberdrola, Glencore and FCC Ámbito collaborate to develop lithium-ion battery circularity solutions, focusing on recycling and second-life applications in Spain and Portugal.

With 2024 seeing half the people in the world heading for an election, there is potential for the political landscape to shift during the course of this year. Broader geopolitical factors will play a part in the evolution of the business case for BESS, particularly if new governments backtrack on clean energy commitments or if wider factors influence global oil and gas prices. Peter Allcock notes that "battery storage thrives on market volatility"; however, investors should prepare for a range of geopolitical scenarios to build an agile, resilient business model.⁸¹

Our clean energy future depends on grid-level energy storage. Without the ability to hedge against the inherent volatility of more distributed and intermittent energy resources, global efforts to decarbonize our energy system may be undone by an unreliable, insecure and more expensive power supply. The many features of BESS make it a promising option to embed flexibility and stability across our grid, but we'll need a massive scaling of investment in these assets to meet demand. Investors that act now to understand where current opportunities lie, and explore how highly regionalized markets may evolve, can win lucrative rewards while helping build a more sustainable energy system.

Key takeaways

- ▶ Ensure project lead times allow for supply chain complexities: Delays getting materials, waiting for transformers to be built, as well as the risk of higher inflation and development costs, could impact the business case.
- ▶ Conduct robust due diligence: Assessing supply chain resilience and sustainability (including ESG issues) can mitigate against volatility.
- ▶ Stay on top of technology developments: Build operating strategies that consider the impact of new battery technologies, accelerating degradation of current technology and revenue potential.
- ▶ Beware obsolescence: While it's unlikely, current battery technologies could be rendered obsolete by new breakthroughs in an industry advancing at speed.

RECAI 63 scores

Ranking	Market	Previous ranking	Movement vs. previous	Score	Technology-specific scores							
					Onshore wind	Offshore wind	Solar PV	Solar CSP	Biomass	Geothermal	Hydro	BESS
1	US	1	●	73.6	59.7	61.2	56.5	51.2	30.1	49.2	39.1	57.6
2	China Mainland	3	▲	72.0	53.6	57.8	61.5	55.8	52.6	30.6	52.9	57.1
3	Germany	2	▼	70.5	54.2	52.1	55.2	31.7	51.5	39.5	28.9	41.4
4	France	4	●	68.7	56.2	50.4	53.0	32.6	48.1	39.3	40.8	31.3
5	Australia	5	●	68.5	53.0	34.0	56.9	50.1	42.1	15.7	24.7	47.7
6	UK	7	▲	68.4	59.5	60.1	45.8	15.1	56.2	37.6	37.9	49.5
7	India	6	▼	66.5	51.5	25.7	61.8	48.7	44.3	24.7	48.2	31.8
8	Denmark	9	▲	64.3	52.7	52.3	47.1	17.3	44.1	16.4	21.5	18.2
9	Canada	11	▲	64.1	60.3	34.2	46.3	19.8	36.1	34.8	45.8	27.0
10	Japan	13	▲	64.0	49.0	53.5	49.6	19.1	57.6	44.6	30.5	31.1
11	Netherlands	10	▼	63.6	51.0	49.4	47.4	16.1	52.7	24.7	26.5	21.8
12	Spain	8	▼	63.6	51.5	35.8	50.2	48.2	40.4	15.4	23.0	25.9
13	Italy	14	▲	62.8	48.4	42.7	50.3	35.7	42.4	39.3	49.2	32.8
14	Ireland	12	▼	62.8	48.9	46.5	46.7	19.9	37.1	18.1	22.0	29.8
15	Chile	16	▲	61.3	51.6	25.2	47.8	54.2	37.3	49.5	41.8	30.1
16	Greece	18	▲	60.6	50.0	31.5	47.7	35.3	44.8	29.1	36.3	29.5
17	Belgium	21	▲	60.4	54.4	39.6	42.2	18.4	44.9	20.3	27.1	29.6
18	Poland	15	▼	60.3	48.1	41.5	47.9	13.9	47.1	19.9	35.1	26.0
19	Sweden	17	▼	59.7	50.1	41.1	40.7	16.1	44.9	18.6	35.4	26.1
20	Brazil	19	▼	59.6	50.1	33.1	53.0	25.9	49.2	12.9	46.6	19.1

RECAI 63 scores

Ranking	Market	Previous ranking	Movement vs. previous	Score	Technology-specific scores							
					Onshore wind	Offshore wind	Solar PV	Solar CSP	Biomass	Geothermal	Hydro	BESS
21	Finland	20	▼	58.9	57.0	41.9	36.5	15.5	46.2	15.5	26.0	22.0
22	Israel	23	▲	58.8	42.6	15.2	54.2	48.3	31.1	14.7	17.7	20.9
23	Norway	26	▲	58.7	51.8	40.7	41.2	15.3	34.8	17.7	45.7	19.9
24	Taiwan	24	●	58.0	45.8	47.9	43.1	19.0	35.9	30.5	33.3	20.5
25	Portugal	22	▼	57.4	41.2	34.4	47.2	25.2	38.8	23.0	24.2	25.2
26	Argentina	29	▲	56.9	52.4	26.4	49.4	31.8	42.0	21.5	40.7	13.2
27	Morocco	25	▼	56.0	43.7	17.1	50.7	51.9	26.0	13.7	32.9	15.5
28	Austria	28	●	55.8	45.3	22.4	43.6	14.3	44.4	17.6	35.6	22.6
29	Switzerland	34	▲	55.4	47.1	17.8	41.5	18.5	37.3	25.3	39.4	20.7
30	South Korea	27	▼	55.2	37.7	43.2	44.4	18.4	49.4	18.6	29.0	32.5
31	Turkey	30	▼	54.9	50.7	20.5	45.6	28.0	42.6	43.5	43.2	23.4
32	Philippines	32	●	54.4	39.4	29.1	47.1	19.9	40.0	44.1	41.8	18.3
33	Mexico	35	▲	54.2	41.8	21.3	48.6	33.8	34.6	40.2	33.4	12.5
34	Egypt	31	▼	53.6	43.8	14.8	53.5	48.1	29.7	11.4	22.8	16.7
35	Kazakhstan	36	▲	52.8	46.3	16.0	42.9	18.0	36.0	16.1	40.8	19.8
36	Romania	39	▲	52.5	40.2	24.1	43.3	13.5	38.0	18.0	34.2	15.3
37	Saudi Arabia	40	▲	52.0	43.2	24.8	45.7	43.6	25.0	15.4	11.8	15.1
38	South Africa	37	▼	51.9	44.8	20.0	43.6	48.8	33.1	12.6	19.4	18.3
39	Vietnam	33	▼	51.8	44.3	43.8	40.0	17.2	40.2	12.7	45.2	14.4
40	Peru	41	▲	50.9	42.5	16.6	42.7	23.2	33.5	19.2	44.0	16.9

RECAI 63 methodology

The index rankings reflect our assessment of the factors driving market attractiveness in a world where renewable energy has gone beyond decarbonization and reliance on subsidies.

We have defined the questions being asked, based on what we see as global market trends affecting investment and deployment priorities, and the challenges and success factors impacting EY clients:

- ▶ Is there a long-term need for additional or replacement energy supply? If so, is there a strong case for energy from renewable resources in particular?
- ▶ Is the market actively seeking to reduce reliance on fossil fuels?
- ▶ Is policy hindering or helping the ability to exploit renewables opportunities?
- ▶ Are essential components in place to ensure project delivery, such as long-term contracts, grid infrastructure (including storage) and availability of finance?
- ▶ What does the strength of natural resource, track record and project pipeline reveal about the outlook for particular renewable technologies?
- ▶ Even if all other elements are in place, does the macro stability and investment climate enable or impede the ease of doing business?

These index pillars therefore put emphasis on fundamentals such as energy imperative, policy stability, project delivery (including capital availability) and diversity of natural resource – factors that will increasingly become key market differentiators as markets move toward grid parity, and “artificial” motivations, such as government targets or the ring-fencing of technologies, become less critical.

Determining the rankings

Each parameter within the five pillars comprises a series of data sets that are converted into a score, from one to five, and weighted to generate parameter scores. These are weighted again to produce pillar scores, then an overall RECAI score and ranking. Weightings are based on the EY assessment of the relative importance of each data set, parameter and pillar in driving investment and deployment decisions. Each technology is also allocated a weighting based on its share of historical and projected investment levels.

RECAI 63 includes battery storage in place of marine technology. This has led to an adjustment to the weightings, reducing the total proportion allocated to solar, onshore wind and offshore wind.

Separate from the main index, EY technology-specific indices rankings reflect a weighted average score across the technology-specific parameters, and a combined score covering our other macro and energy market parameters. This is because some markets may be highly attractive for specific technologies but face other major barriers to entry.

Data sets are based on publicly available or purchased data, EY analysis or adjustments to third-party data. We are unable to publicly disclose the underlying data sets or weightings used to produce the indices.

If you would like to discuss how EY RECAI analysis could help your business decisions or transactions, please contact the RECAI advisor [Phil Dominy](#).

Normalized RECAI methodology

With the largest global markets tending to top the core RECAI, there are many smaller markets where renewable energy is growing rapidly and becoming highly attractive. By dividing a market's RECAI score by logarithm of the average of the three preceding years' GDP to produce a "normalized score," the index identifies those smaller renewable energy markets that perform best on the core RECAI pillars of energy mix, government support, project delivery and natural resource. Removing a market's economic size showcases those that are efficient in terms of their size and the most attractive for investors. The normalized index also highlights larger markets that score well in the core RECAI but could be doing more to support the green transition.

See the normalized index ranking on page 5.



PPA Index scores

Ranking	Market	Previous ranking	Movement vs. previous	Normalized score (0-100)	PPA Index score	PPA market maturity	PPA future market score	PPA policy score	RECAI score
1	Germany	1	●	100.0	30,040,622	89.0	88.0	54.4	70.5
2	Spain	2	●	84.9	25,498,812	91.4	85.7	51.2	63.6
3	France	5	▲	76.7	23,038,698	76.9	81.3	53.6	68.7
4	UK	4	●	72.0	21,615,991	93.7	66.5	50.7	68.4
5	US	3	▼	69.5	20,864,269	95.1	52.7	56.6	73.6
6	Netherlands	8	▲	62.1	18,644,576	75.5	76.5	50.7	63.6
7	Poland	10	▲	60.1	18,051,671	69.8	77.2	55.6	60.3
8	Finland	11	▲	57.9	17,386,021	67.9	82.2	52.9	58.9
9	Italy	12	▲	55.3	16,615,232	63.4	82.8	50.4	62.8
10	Denmark	7	▼	54.9	16,483,532	61.9	81.1	51.0	64.3
11	Norway	14	▲	49.9	15,004,443	67.4	76.6	49.5	58.7
12	Sweden	9	▼	49.2	14,768,531	66.3	76.5	48.8	59.7
13	India	13	●	48.7	14,617,819	77.9	41.6	67.9	66.5
14	Australia	6	▼	46.5	13,962,498	87.2	40.3	58.0	68.5
15	Brazil	15	●	36.9	11,091,808	82.5	53.1	42.5	59.6
16	Ireland	17	▲	34.7	10,432,306	58.3	49.7	57.3	62.8
17	Portugal	24	▲	34.0	10,213,841	44.2	78.5	51.2	57.4
18	Belgium	20	▲	29.6	8,879,865	63.7	46.5	49.7	60.4
19	China Mainland	-		29.5	8,853,858	39.5	46.8	66.5	72.0
20	Chile	18	▼	28.4	8,546,531	52.3	50.8	52.5	61.3
21	Greece	26	▲	23.2	6,971,142	47.7	48.2	50.0	60.6
22	South Africa	23	▲	21.1	6,343,583	65.6	35.1	53.1	51.9
23	Canada	16	▼	19.3	5,786,146	47.7	37.2	50.8	64.1
24	Egypt	19	▼	19.1	5,749,686	51.8	38.2	54.2	53.6
25	Colombia	22	▼	18.5	5,545,520	58.0	38.2	49.9	50.1
26	Taiwan	-		18.4	5,532,552	63.2	25.4	59.4	58.0
27	Morocco	21	▼	17.6	5,285,972	43.1	37.2	58.8	56.0
28	Japan	25	▼	17.0	5,096,013	43.9	34.5	52.6	64.0
29	Romania	27	▼	12.7	3,805,271	37.6	36.3	53.1	52.5
30	Thailand	28	▼	11.6	3,477,696	48.5	23.0	61.5	50.8

PPA Index methodology

By analyzing the same 100 markets as in the full RECAI database, the goal is to create a new ranking that focuses on the attractiveness of renewable power procurement — via offsite corporate PPAs — rather than the attractiveness of renewable project investment.

The final score for the top 30 markets is calculated from a weighted combination of 12 key parameters, which act as a proxy for corporate PPA potential. The PPA Index focuses on four pillars (three PPA-specific pillars together with a RECAI score pillar):

- ▶ **PPA market maturity** – this focuses on activities carried out within each market in the past decade. It concentrates on market maturity, looking at past PPA deal frequency and volume, as well as a quantitative analysis of more recent PPA deal growth.
- ▶ **PPA future market** – this forward-looking score assesses the forecast activity of each market. Forecast power capacity is a key driver of the magnitude of a market, so this has a significant weighting on the score as well as the wholesale power price relative to the levelized cost of energy (LCOE) or PPA price in each market. Forecast capacity installations and a weighted project pipeline score from RECAI are used. The index has focused on wind and solar PPAs (together weighted at 93%) as these represent the vast majority of offsite corporate PPAs.
- ▶ **PPA policy score** – this focuses on the ease of operation in a given market. If a market is to have potential for corporate PPA growth, supporting government policy must be in place for efficient and large-scale expansion. This is considered in the core RECAI, but is also examined here, with a more nuanced focus on PPA supportive policy.
- ▶ **RECAI score** – the overall score yielded by RECAI is also factored in as one of the fundamental pillars, because it provides a strong overview of the existing and potential strength of a market's renewable energy landscape.

The PPA Index uses a multiplicative formula to prioritize well-rounded markets with strengths in all aspects of corporate PPA development and integration. For example, this will mean that markets with zero PPA deals to date will score zero overall and will not yet be included.

However, with strong weighting on forward-looking parameters, even markets with just a few deals to date could score highly if significant growth is expected in the corporate PPA market within the next five years – the horizon of RECAI.

The RECAI PPA Index score (which can be very large) has been normalized into a score from 0 to 100, to create a more manageable reference value. The leading market will score 100 – but this does not mean that the market is perfect for corporate PPAs. It means that, relatively speaking, it is the most attractive market for corporate PPAs across the coming five years.

Data sets are based on publicly available or purchased data, EY analysis or adjustments to third-party data. We are unable to publicly disclose the exact data sets or weightings used to produce the indices.

For more information on the services that EY teams provide to corporates around renewable energy strategies and PPAs, please refer to our website: www.ey.com/uk/ppa.

PPA market maturity

(Sources: Pexapark, DLA Piper and EY analysis)

1. Number of PPAs signed in the past five years
2. Total PPA volume in the past five years
3. Number of PPAs signed in the past year
4. Total PPA volume in the past year

PPA future market

(Sources: Wood Mackenzie, GlobalData, IRENA, IEA, Pexapark and EY analysis)

1. Pipeline of projects:
 - a. Forecast power capacity
 - b. Forecast installation growth
 - c. Project pipeline
2. Wholesale power pricing:
 - a. Wholesale power price relative to the historic LCOE
 - b. Wholesale power price relative to the PPA price

PPA policy score

(Sources: World Bank, GlobalData, IEA and EY analysis)

1. Ease of doing business index (World Bank)
2. Renewable energy imperative:
 - ▶ Renewable energy percentage of total generation
 - ▶ Percentage of population with access to electricity
 - ▶ Forecast energy consumption growth
 - ▶ CO₂ emissions

RECAI score

(Source: EY analysis)

1. Macro fundamentals
2. Energy imperative
3. Policy
4. Project delivery
5. Technology

Special thanks to Pexapark for providing access to their data.

What EY teams can do for you

A global renewables industry is maturing quickly, shaped by new technologies, new business models and new ecosystems. Opportunities are growing, but so is complexity, which creates uncertainty, risk and delay.

The number of organizations generating renewable energy is growing all the time. And so is the number of investors ready to finance new energy projects and innovation. For organizations intent on playing a leading role in renewables, the ability to move quickly and decisively will become more valuable, but also more difficult.

How do you find the right strategy to lead your organization through the transition to renewables? What's the actionable plan that executes that strategy while making best use of all the tax breaks, incentives and finance structures available? Which new technologies should you back, and to what extent? How do you take what works in one country and scale it globally? What can you learn from what's working elsewhere?

Leaders need decisive answers that point to clear actions, and rapid access to the capabilities that will help them take those actions.

At EY, we're using the combined experience of the EY Global network to help you accelerate your transition to the world of renewable energy. We're supporting you

to find better answers, take decisive action and move forward faster. We do that by sharing our deep experience in renewables across the globe and providing all the capabilities you need in one integrated EY team – from defining the right long-term strategy, to helping deliver and operate power generation assets, to managing tax incentives and financing structures.

We're committed to changing the way we do business, and we're playing a leading role in efforts to help others change. With **EY Global Renewables**, you'll be ready to lead your organization through the transition to renewables – and play your role in building the decarbonized, sustainable economy that creates measurable long-term value for everyone. It's an economy that may be more successful today and creates a legacy for future generations. It's the better working world that we all must build together.



Contacts



Arnaud de Giovanni
EY Global Renewables Leader
arnaud.de.giovanni@fr.ey.com



Ben Warren
RECAI Chief Editor
Ernst & Young LLP
bwarren@uk.ey.com

Authors



Louise M. Shaw
EY UK&I Energy and
Infrastructure Corporate
Finance Leader
lshaw@uk.ey.com



Andrew Horstead
EY Global Power & Utilities
Lead Analyst
ahorstead@uk.ey.com

Advisor, research and modeling team



Phil Dominy
Senior RECAI Advisor
Ernst & Young LLP
pdominy@uk.ey.com



Nathan Docker
Head of Research
EY UK&I Energy and Infrastructure Corporate
Finance Senior Executive, Ernst & Young LLP
nathan.docker@uk.ey.com



Malika Cornwall
Head of Modeling
EY UK&I Energy and Infrastructure Corporate
Finance Executive, Ernst & Young LLP
malika.cornwall@uk.ey.com

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