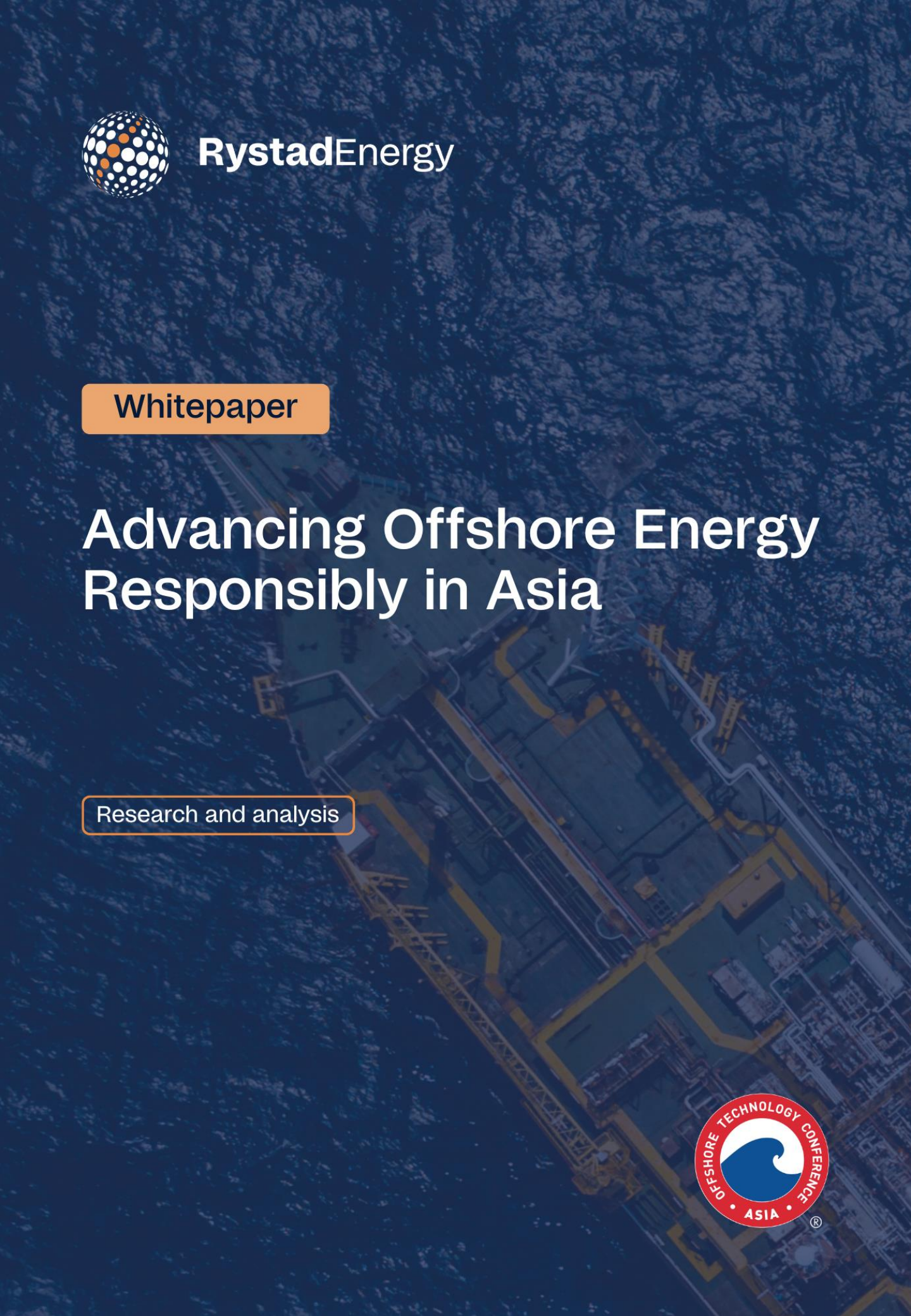
RystadEnergy

Whitepaper

Advancing Offshore Energy Responsibly in Asia

Research and analysis



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Driving a balanced and responsible energy transition in Asia

Asia is entering a pivotal moment in its energy story. As the global system undergoes profound transformation, the region sits at the center of demand growth, industrial capability, and the strategic, yet gradual shift from molecules to electrons. Balancing this transition while meeting an expanding energy appetite represents one of the defining challenges of the coming decades.

This whitepaper, *Advancing Offshore Energy Responsibly in Asia*, outlines the opportunities and realities shaping that shift. It provides a timely assessment of the investments, technologies, and regional capabilities required to deliver energy security today while accelerating decarbonization tomorrow.

Over the next 15 years, global energy demand is projected to rise by roughly 15%, with Asia serving as the primary engine of this growth. Meeting this demand, which is broadly compatible with our long-term 1.9-degree scenario, requires a step-change in capital allocation: total global energy spending must rise by roughly 40% between 2025 and 2045, exceeding $5 trillion annually. Within this context, offshore energy in Asia-Pacific is emerging as a strategic domain for both traditional supply and new low-carbon technologies. Annual regional offshore spending is expected to average around $150 billion through 2035.

Oil and gas will remain a critical pillar of the regional energy system throughout this period. Structural reliance in industry, chemicals, aviation, and shipping ensures these molecules remain essential even as global oil demand nears a plateau in the early 2030s. Consequently, deepwater investment is entering a new phase of relevance. Southeast and South Asia are set to drive close to $40 billion in deepwater investment by 2030. These developments are not merely about production; they are fundamental to energy security and resilient regional supply.

In parallel, Asia is establishing itself as the global growth engine for offshore clean energy. Offshore wind investments in the region are forecast to exceed $750 billion by 2040, and by 2030, Asia is projected to account for nearly 60% of global installed offshore wind capacity. Technologies such as floating solar and offshore carbon capture and storage (CCS) are also progressing rapidly, supported by major regional players including Santos, Petronas, and CNOOC.

Underpinning this transition is Asia's formidable industrial capability. The region has cemented its status as the global factory for low-carbon supply chains, holding a commanding lead in manufacturing capacity for solar cells, wind turbines, and battery technologies, as well as marine construction. This industrial depth is central to global progress and strengthens Asia's strategic position within the transition.

Finally, regional integration remains essential. The ASEAN Power Grid offers a practical mechanism to enhance energy security, unlock renewables and storage investment, and support a more resilient regional power system. Singapore's import commitments alone could catalyze more than $40 billion in renewable and storage investment.

This report provides a clear assessment of the path ahead. Asia's choices in the offshore space will shape global supply chains, investment flows, and decarbonization pathways for decades to come. I believe this whitepaper contributes valuable context to support informed decision-making as our industry navigates this decisive period.

Jarand Rystad
CEO

Chapter 1

Climate and energy in context

01

Accelerating transition amid oil and gas resilience

Global energy demand is expected to grow by 15% over the next 15 years, with renewables and electrification playing a key role amid oil and gas peaking in the energy mix towards 2030.

02

Global energy investments should surpass $5 trillion

To achieve the 1.9-degree scenario, global energy investments are required to rise by 40% from 2025 to 2045, adding over $2 trillion, from $3.3 trillion in 2025 to $5.6 trillion in 2045.

03

Offshore energy investments in Asia-Pacific

Between 2026 and 2035, the annual offshore energy expenditures in Asia-Pacific are expected to be around $150 billion, with strong oil and gas resilience amid transition.

Rystad 2025 House View: Accelerating transition amid oil and gas resilience

Global energy demand will rise by 15% between 2024 and 2040 while the system meeting it is undergoing its most significant transformation in four decades. Over the next 15 years, we expect electrification and renewables to play a steadily larger role in the energy mix. Driven by transport electrification, industrial demand, data center growth, and residential infrastructure, power demand is projected to increase by more than 50% by 2050. However, even as power demand explodes and renewables solar PV and wind, alongside energy storage capacity, are expected to supply nearly half of global power generation by 2040, oil and gas remain essential.

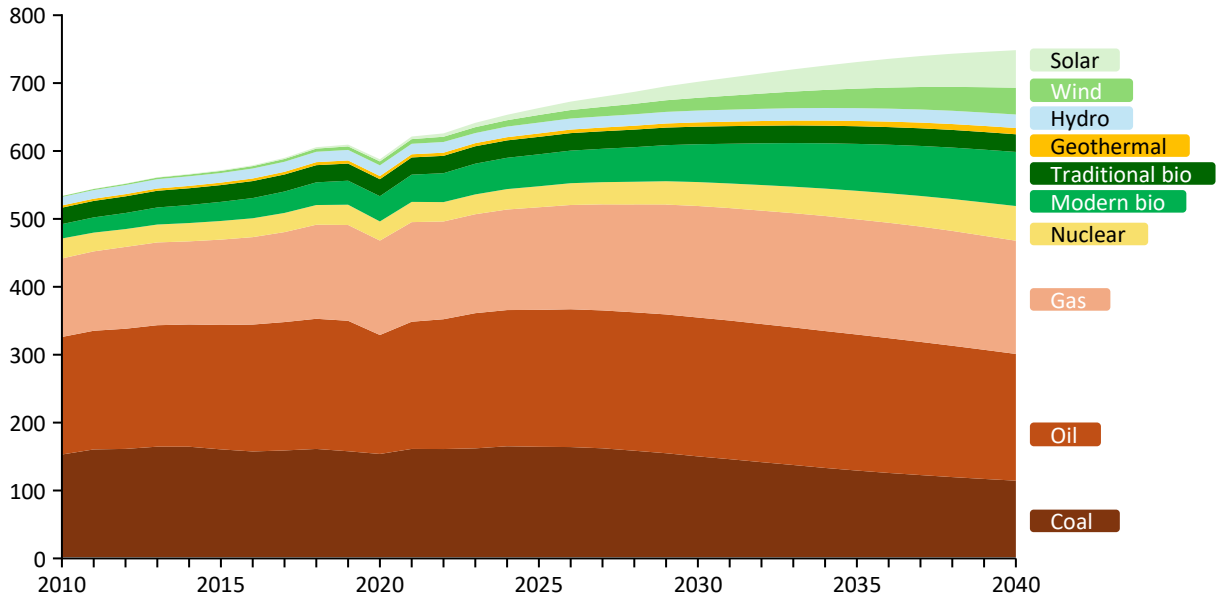
We expect oil demand to peak in the early 2030s, but its importance to heavy industry means the decline will be gradual, with strong reliance on liquid fuels remaining well into the 2040s. Aviation, shipping, petrochemical, and other heavy industries will continue to drive liquid fuels demand. Gas demand is comparably resilient; despite a projected steady decline in gas for residential use, its crucial role in balancing renewables-heavy grids and as a critical input in industry means that neither sees a rapid collapse. Coal, by contrast, enters a structural decline as renewables and gas plants replace coal.

Emissions are expected to peak in 2026 but decarbonization will be uneven by sector and region. China and OECD economies decarbonize faster, driven by policy frameworks and falling technology costs, while emerging markets face the challenge of balancing economic growth with emissions reduction.

Tariffs, local-content mandates, and carbon border measures could raise costs and delay projects, since much of the renewables supply chain is concentrated in China. While this is a meaningful downside risk, our base case assumes cost trends and market forces will sustain the momentum of low-carbon investment, and any disruption will be transient.

Macroeconomic fundamentals will reshape both demand and the transition. Global gross domestic product (GDP) is projected to grow around 45% between 2025 and 2040 – a significant slowdown compared to prior decades. For the past 25 years, China has been a major engine of growth and industrialization, but its contribution will diminish as its population ages and shrinks, and its productivity slows. India and Africa are expected to take on a larger role, although they will not match China's scale or speed.

Global energy demand – House View
Exajoules



Sources: Rystad Energy research and analysis; Rystad Energy House View dashboard

Emissions are nearing peak with current NDC pledges tracking a RE 1.7 degree path to 2035

Global energy demand will continue rising, while the system meeting it is undergoing its most significant transformation in four decades. Renewables, electrification, and efficiency will drive most of the reduction, yet oil and gas remain essential, providing industrial feedstock, supporting energy security, and balancing renewables-heavy grids with flexible, dispatchable capacity. Under the current trajectory, according to Rystad Energy's (RE) House View, emissions are expected to peak in 2026 and then gradually decline, putting the short-term trajectory in the range of 1.9-2.0 degrees.

Over the past year, the global energy conversation has shifted more from climate ambition toward cost, security, and control. Energy affordability, supply resilience, and industrial competitiveness now dominate the debate. While climate targets remain a priority, the conversation is shifting toward a middle ground that balances fossil fuel resilience with an accelerated energy transition.

Against this backdrop, more than 120 countries have submitted their latest emissions-reduction commitments under the Paris Agreement, formalized as Nationally Determined Contributions (NDC). Rystad Energy has analyzed over 400 published NDCs to assess whether the global energy system is on track to align with the agreement.

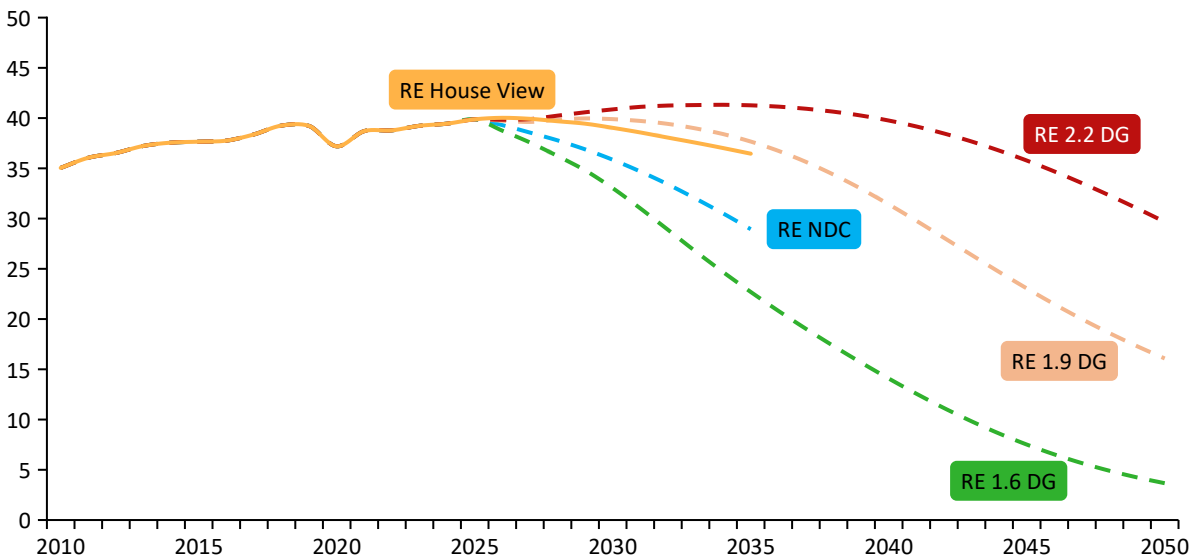
Collectively, the latest round of submissions charts a trajectory distinct from baseline pathways, aligning with a 1.7 degree scenario by 2035. If fully implemented, these targets would lower global emissions by roughly 3% per year, bringing 2035 levels about 10 gigatonnes (25%) below current emissions.

Progress toward these goals is uneven. The UK has already peaked and remains broadly on track, while China appears to be plateauing and would need a sharp emissions downturn this decade to stay aligned with its NDC commitments. India and Indonesia, in contrast, remain off their stated trajectories as emissions continue to rise in key sectors.

Most near-term mitigation under the NDC scenario is concentrated in Asia and Europe, driven by power sector decarbonization and efficiency improvements in transport and buildings. South America delivers smaller absolute reductions but strong relative progress, while Africa's trajectory remains on a higher pathway without stronger measures.

The NDC scenario sits between a Pragmatism pathway (RE 1.9 DG) and a Climate First scenario (RE 1.6 DG). If achieved, NDCs would bend the global emissions curve more quickly than baseline scenarios but would still fall short of the 1.5 degree target.

Global fossil CO_2 emissions, by scenario
Gigatonnes



Source: Rystad Energy EnergyDemandCube

Chinese per capita power demand on track to exceed North American levels

Power demand in Asia grew almost sevenfold between 1990 and 2024, reaching 15,333 terawatt-hours (TWh) last year. The industrial sector consumed more than half of the electricity in the region. While China is the largest consumer in the region, demand growth from other countries accelerated after 2000 as the region has been experiencing rapid economic growth.

Europe and North America saw much more moderate growth during the past two decades as the economic expansion in the two regions was slower than in Asia. The two regions have also increased their efficiency, resulting in lower electric intensity. Looking ahead, electricity demand is expected to continue a strong growth trajectory across all regions.

Asia will remain the main driver of growth during the coming decades, driven primarily by China and increasingly by India, as more of its population enters the middle class. Demand in the region is expected to hit 25,770 TWh by 2040, representing 56% of the world's total. Historically, North America has been the largest power consuming region per capita in the world, but fast growth in China has been closing the gap at a rapid pace.

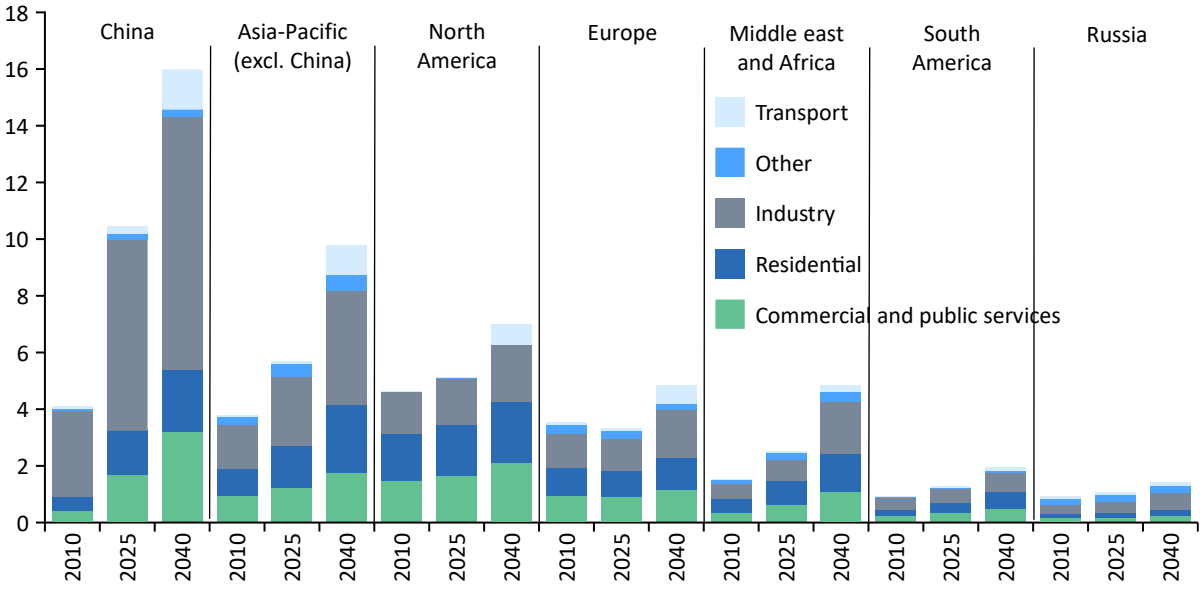
North American per capita electricity consumption has been hovering around 10 megawatt-hours (MWh) per year over the last three decades. Chinese per capita demand, on the other hand, has gone from less than 1 MWh in 1990 to 6.9 MWh in 2024. Due to China's fast economic growth, which is leading to more electricity demand, and flat population growth, annual per capita power consumption is expected to reach almost 12 MWh by 2040.

In North America, future demand growth is expected to be driven mostly by emerging sectors such as data centers and electric vehicles, and an industrial sector resurgence driven by lower energy prices.

Despite flat growth over the last decade, European demand is forecast to enter a new growth phase owing to ambitious decarbonization goals. Industrial transformations such as electric furnaces, heat pumps, and green hydrogen production will drive industrial demand. The technology and transport sectors are also expected increase total consumption.

The Middle East and Africa are together likely to emerge as the third-largest consuming region. Electrification of the economy in the Middle East and higher consumption per capita in Africa will result in demand reaching more than 4,800 TWh by 2040.

Global net power demand by sector and region
Petawatt-hours per year



Source: Rystad Energy Global Power mix analysis dashboard

Global energy investments to climb 40% by 2050 in RE 1.9 degree scenario

Global energy investment has been dominated by fossil fuels for decades. Oil, gas, and coal, along with the supporting infrastructure, maintained a steady 70-90% share of global energy investment. Recently, the trend has changed, with the share of renewables in total energy-related system investments reaching 50% in 2025. Several factors are behind the investment trend shift. As new technologies emerge, costs are reduced and their market competitiveness improves. Regulations, consumer behavior, and prices have also altered the investment landscape.

As we move towards 2050 in the 1.9 degree scenario, new investment patterns form in the energy system. Fossil investments are now at the bottom of the scale, while solar and wind-related investments dominate. To achieve the 1.9 degree scenario, global energy investments are required to rise by 40% from 2025 to 2045, from $3.3 trillion in 2025 to $5.6 trillion in 2045.

Beyond 2045, total investment requirements will stabilize and begin a modest decline, despite continued growth in useful energy demand, as mature renewable and efficiency technologies deliver improved capital productivity and lower unit costs.

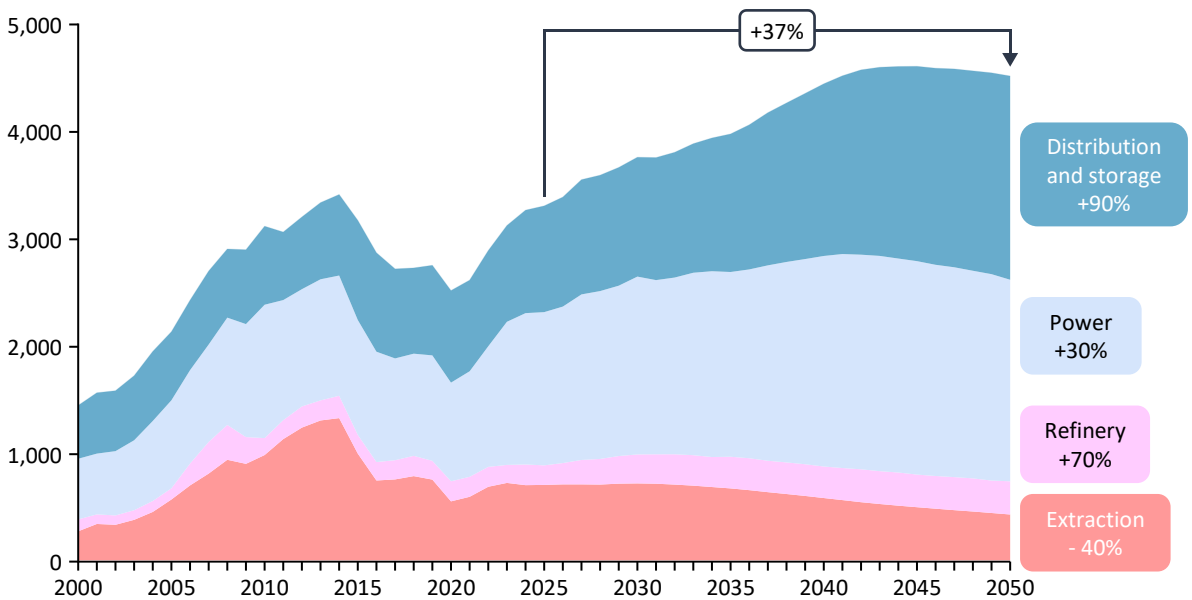
The largest portion of energy-related investments today is linked to power generation, with electricity consumption rising steadily from 14,300 TWh in 2000 to 30,000 TWh in 2025. In 2000, 75% of power plant investments went to fossil generation; by 2025, this had fallen to around 20%. In the 1.9 degree scenario, this share is expected to shrink to just over 4%, while investments in solar and wind are estimated to reach 51% and 34%, respectively, as total power plant investments climb by 30%.

Investments in primary extraction peaked in 2014 after the shale oil boom and are set to fall by 40% by 2050, driven by reduced investments in coal mines as well as oil and gas.

Storage and distribution investments will need to jump by 90% as infrastructure ages and demand for grid capacity continues to rise with electricity demand.

The refining sector, historically driven mostly by crude oil refining, forms the smallest investment share. However, investments are forecast to increase by 70% due to stronger demand for hydrogen ‘refining’ and the conversion of biomass and waste into modern biofuels.

Investments by value chain, RE 1.9 DG
Real USD billion (2025)



Source: Rystad Energy research and analysis; Rystad Energy EnergyScenarioCube

Asia-Pacific emissions can be reduced by nearly 60% in RE 1.9 degree scenario

The Asia-Pacific region emitted approximately 22 gigatonnes of fossil CO2 in 2024, accounting for about 60% of global emissions. In the short term, regional emissions are expected to plateau as China reaches its peak and begins a gradual decline, while other major emerging economies to see slow increases, effectively offsetting each other. In the long run, under Rystad Energy's 1.9 degree scenario, Asia's emissions decline by almost 60% from current levels, to 9 gigatonnes by 2050.

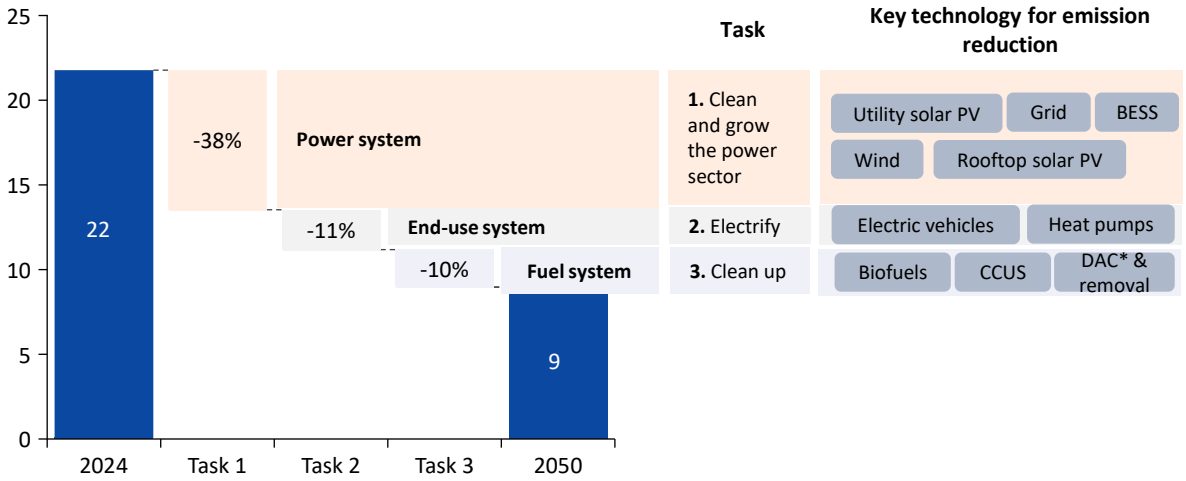
To align with this trajectory, Rystad Energy applies its Three Tasks of Energy transition framework – a structured approached designed to distil the essential actions required for decarbonization.

Task 1: Clean up and grow the power sector
Transitioning to renewable energy sources like solar and wind is essential to reducing emissions from electricity generation. For Asia-Pacific, this task offers the largest emissions-reduction opportunity: close to 40% of the reduction needed to stay aligned with the 1.9 degree scenario. Solar PV capacity is projected to surge from about 1.5 terawatts (TW) in 2025 to nearly 10 TW by 2050, while wind capacity is to grow from 730 GW to over 4 TW. Offshore resources, including wind, wave, and tidal energy, will also play an increasing role, with countries like Vietnam, China, and South Korea well-positioned to harness their offshore energy potential.

Task 2: Electrify everything possible
The next task is electrification across various sectors. Adoption of electric vehicles (EV), industrial electrification and increasing energy efficiency by implementing proper standards and frameworks can significantly reduce emissions. Progress on electrification in Asia is gaining momentum. Currently the region accounts for 75% of global EV ownership. Heavy industries are beginning to deploy electric furnaces and heat pumps, while electrification of heating and cooling systems in buildings is expanding. Overall, this task could deliver around 10% of the total reductions needed to stay aligned with the 1.9 degree scenario.

Task 3: Clean up the residual
Some emissions will persist, necessitating alternative solutions. Carbon capture, utilization, and storage (CCUS) can mitigate emissions from hard-to-abate sectors like cement production. Green hydrogen offers a zero-emission fuel for transportation and industry, while advanced biofuels can serve as low-carbon alternatives in aviation. Collectively, these technologies could contribute around 10% of the total reductions needed.

Fossil emissions reduction by decarbonization task in Asia-Pacific in the 1.9 degree scenario
Gigatonnes CO_2



*DAC: direct air capture
Sources: Rystad Energy EnergyDemandCube

Offshore energy expenditures to increase by 30% in Asia-Pacific over the next 10 years

Harnessing offshore energy has traditionally involved oil and gas, but with low-carbon sources such as offshore wind gaining pace, oil and gas expenditures, both upstream and midstream, are expected to gradually stabilize in the early 2030s.

However, energy consumption is driving higher regional oil and gas spending in the near term. Offshore oil and gas expenditures are expected to reach nearly $125 billion in 2028, replicating the 2014 offshore oil and gas boom. China is expected to spend around $25 billion on average between 2026 and 2030, led by CNOOC's deepwater activities in the Bohai Sea and South China Sea. Australia, Malaysia and Indonesia combined are expected to spend more than $40 billion annually in the offshore oil and gas sector up to 2030.

In the longer term, the region's offshore energy transition will be shaped by wind and near-shore fixed solar. Limited green hydrogen pilot projects are also expected to become operational in China, with offshore CCS also becoming a prominent technology in key markets such as Malaysia and Japan.

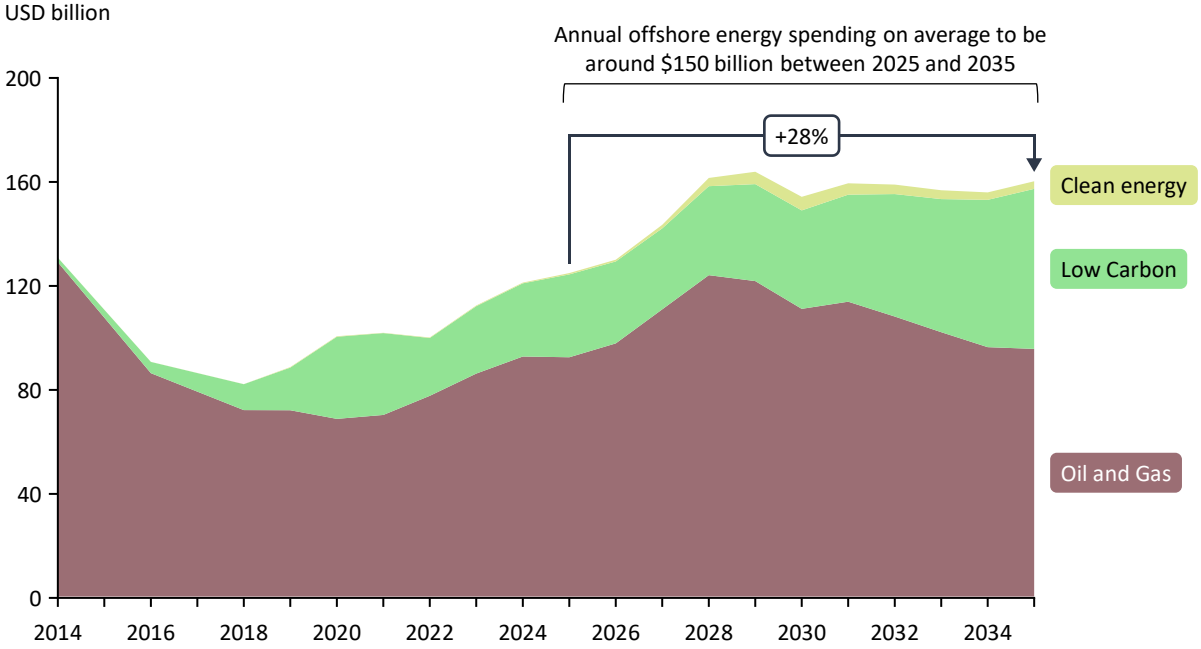
Annual offshore energy expenditures between 2026 and 2035 are expected to remain around $150 billion, with low-carbon spending gaining strong pace towards 2035. Offshore energy expenditures will increase by nearly 30%, from around $125 billion in 2025 to more than $160 billion in 2035.

Offshore oil and gas spending is expected to decline and stabilize over the long term at around $90 billion annually, from a peak of $125 billion in 2028. On the other hand, offshore low-carbon expenditures are expected to increase by nearly twofold, from more than $30 billion in 2025 to around $61 billion in 2035.

With power demand increasing in East Asian markets, offshore wind capacity additions will figure prominently in the long term. China will drive offshore low-carbon spending in the region, followed by South Korea and Japan.

In 2025, Thailand's first offshore CCS project, led by PTTEP, reached final investment decision, with operations expected to commence in 2028. Asia-Pacific CCS expenditures are to increase in the long term as multiple projects start up in the region.

Annual offshore expenditure in Asia-Pacific by energy type, 2014-2035
USD billion



Source: Rystad Energy ServiceDemandCube

Solar PV and wind building a new energy cost hierarchy in Asia

Asia has been doing its part to further the energy transition by embracing an investment strategy shift from a 'green at a premium' model to an 'economics first' approach. Renewable energy costs are foreground in the region's power mix and its long-term planning horizon.

The levelized cost of electricity (LCOE) for solar PV has fallen significantly, from more than $500 per MWh in 2010 to around $70 per MWh in 2025 in real terms, based on a simple average across Asian markets. Solar PV has become the cheapest source of new electricity generation in Asia, thanks to extensive supply chain capabilities as well as clear policy frameworks and the energy transition push.

Another emerging trend involves the combination of solar PV with 4-hour battery energy storage systems (BESS) to create hybrid energy systems. Rystad Energy expects the capital costs for hybrids to decline overtime and compete with onshore wind towards 2035.

Onshore wind remains a key energy source for Asian markets, with good wind speeds prevailing in Vietnam, India, and China.

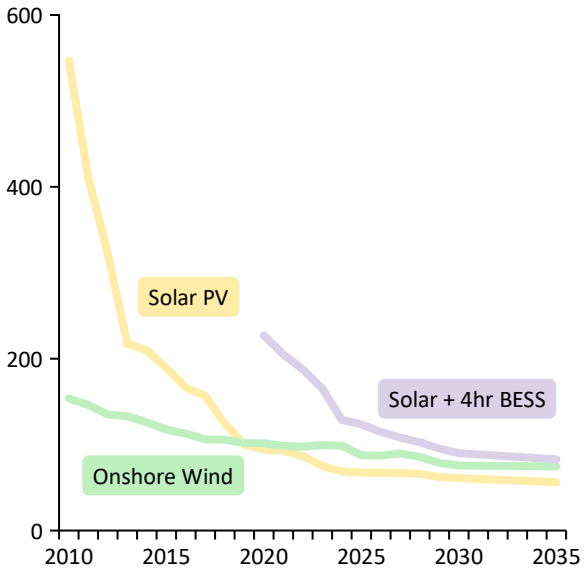
The 2026 LCOE rankings confirm the dominance of solar PV and onshore wind in affordability terms, undercutting traditional baseloads.

However, the 'coal is king' legacy persists in Asia. While coal now sits higher on the average LCOE curve than variable renewables, it remains the low-cost option in specific markets with domestic reserves, subsidized supply, and/or poor renewable resources. Yet the economic case for coal is eroding.

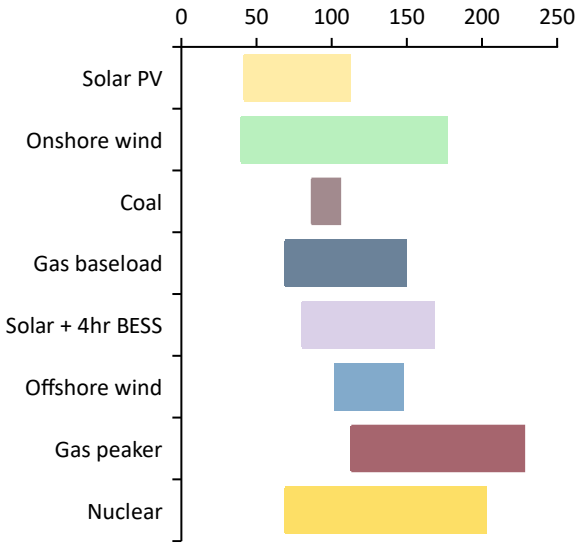
Nuclear and offshore wind currently sit at the high end of the 2026 LCOE rankings, but their value proposition lies elsewhere. For land-constrained economies like Japan and South Korea, or those with poor solar irradiance, these technologies are indispensable. Nuclear offers unmatched density and baseload certainty, while offshore wind is expected to see cost reductions from increasing turbine sizes and a maturing regional industry, offering a viable alternative where land access and transmission is problematic.

Ultimately, the cheapest option is solar, but the most valuable grid will be a diverse one, matching each country's unique requirements.

Asian LCOE trends for key sources*
USD per megawatt-hour (real terms, 2025)



LCOE ranges in Asia in 2026
USD per megawatt-hour (real terms, 2025)



*A simple average was used to avoid skewing the results due to China's high-capacity additions
Source: Rystad Energy research and analysis

Chapter 2

Oil and gas resilience and relevance

01

Asian oil and gas sanctioning to reach $200 billion

Global project sanctioning after 2026 will be heavily shaped by Asia, with over $200 billion in planned investments by 2030 to strengthen energy security and underpin long-term supply.

02

Frontier activity takes center stage in Southeast Asia

Southeast Asia is rapidly advancing its frontier exploration, as Indonesia, Malaysia, and Vietnam roll out joint studies and technical agreements, attracting NOCs, majors, and regional LNG leaders.

03

Gas and LNG fundamentals shift to Asia-Pacific

New supply of LNG is expected to drive prices lower, creating an inflexion point for new demand in Asia-Pacific. Floating LNG will help unlock critical fields, while FSRUs help importers navigate uncertain demand scenarios.

More than $200 billion in sanctioning activity anticipated in Asia by 2030

After the slowdown in global sanctioning activity in 2025, FIDs are expected to rebound after 2026. This will be supported by a substantial rise in offshore activity worldwide, as operators progress on pipeline of projects that have been maturing over the past few years.

Asia will be key in this increase, as the region is projected to attract over $200 billion in investments by 2030. Five countries – China, Indonesia, Malaysia, Kazakhstan, and India – will account for more than 75% of this investment.

In China, growth will be centered around the East China Sea, Bohai Sea, and the Northeast region, where CNOOC and PetroChina-operated fields will help maintain a steady supply of hydrocarbons.

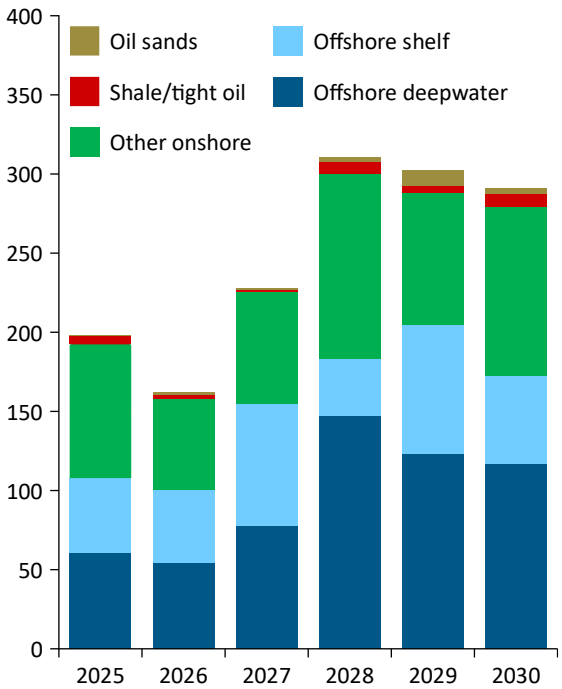
Indonesian growth is driven by Eni's Indonesia Deepwater Development, Inpex's long-awaited Abadi LNG project, and Andaman gas cluster, operated by Harbour Energy and Mubadala Energy, increasing country's production by 35% from current levels.

In Malaysia, the uplift comes from a series of planned PTTEP developments, including Lang Lebah, Chenda, and Sirung. The additional production will be critical for offsetting output decline and supporting Malaysia's strategic role as a stable energy supplier in Southeast Asia.

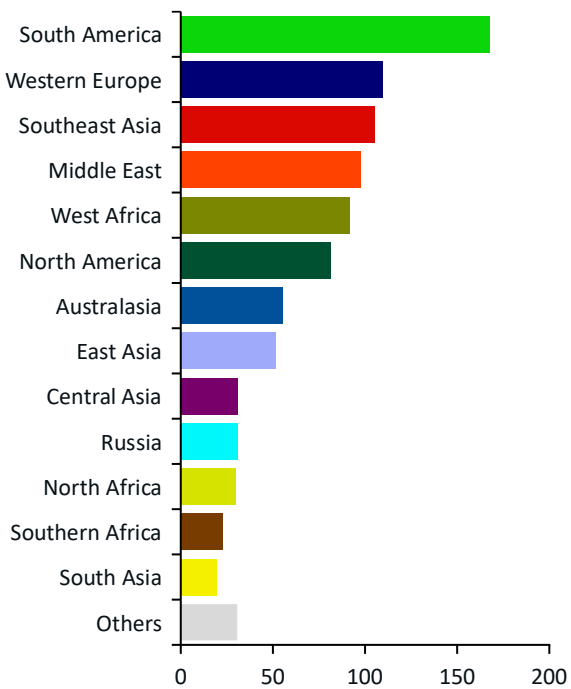
In Kazakhstan, investment continues to be led by the Kashagan and Karachaganak projects, maintaining their positions as cornerstone developments in the country, while in India, the momentum is driven by developments in the Krishna-Godavari Basin.

More than just boosting production, Asia's upcoming wave of project sanctioning will be key to reinforcing Asia's energy security and maintaining the long-term supply outlook.

Global sanctioning activity by supply type
USD billion



Sanctioned offshore investment by region
USD billion, FID in 2025-2030



Source: Rystad Energy Upstream Solution

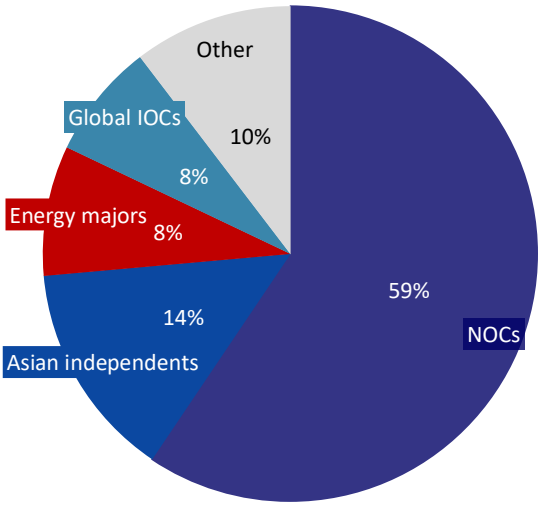
India leads region with the most deepwater blocks awarded from 2020 to 2025

Deepwater exploration activity in Asia has increased significantly over the past five years, reflecting a growing interest in deepwater plays across the region. The number of deepwater blocks awarded rose from just six in 2020 to approximately 22 in 2025. This sharp increase is mainly driven by India's strategic focus on accelerating deepwater exploration efforts. Other countries, including China, Malaysia, and Indonesia, also contributed to the increase.

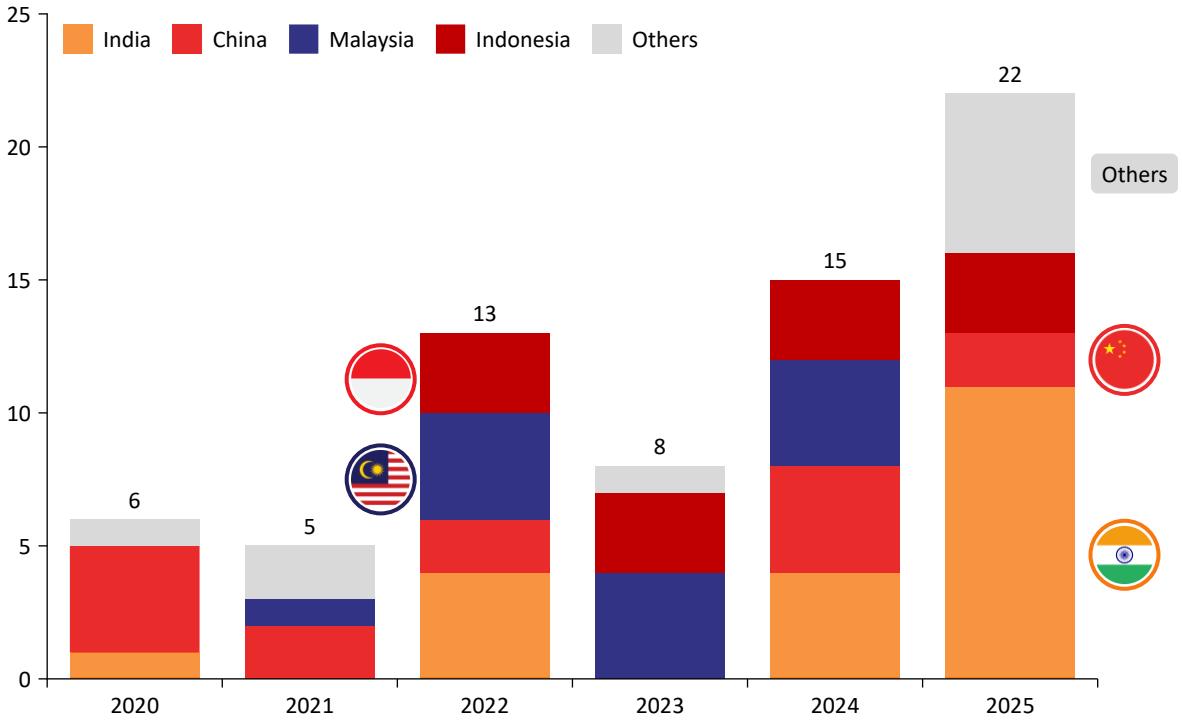
NOCs continue to play a dominant role in deepwater development, accounting for around 60% of blocks awarded from 2020 to 2025 to unlock potential from the deepwater areas in the country.

Asian independent operators and energy majors account for 14% and 8% respective shares, reflecting growing interest from international players in Asia.

Asia's deepwater exploration awards by company type
Share of block awards (2020-2025)



Asia's deepwater exploration awards by country
Blocks awarded count



Source: Rystad Energy upstream solution

Southeast Asia prepares for the next chapter as frontier exploration activity gains pace

Southeast Asia is stepping up frontier exploration to unlock new hydrocarbon volumes, attracting interest from majors, global E&P companies, and national oil companies.

Indonesia has launched a series of exploration joint studies in Andaman and Eastern Indonesia. The race is intensifying as Asia-Pacific liquefied natural gas players Woodside, Petronas, and TotalEnergies are aiming for floating LNG development in Seram Basin and Aru Basin. Japan's Japex and Korea's Posco International have also increased their activity, driven by exploration and production portfolio growth ambitions and the opportunity to anchor cross-border CCS potential, as in North Sumatra and Aru.

Malaysia launched a technical evaluation agreement (TEA) to catalyze exploration in the frontier basins Langkasuka and Layang-Layang. TEA partners will need to submit technical reports outlining their findings, with an option to submit an exploration proposal in an area of interest. The approach has attracted interest from NOCs Pertamina and PTTEP as well as majors BP, Eni, and TotalEnergies.

In Vietnam, Petronas and PetroVietnam have initiated a joint study to explore three frontier blocks in North Vietnam. The blocks are mainly located in Song Hong Basin, adjacent to key deepwater discoveries like ExxonMobil's Blue Whale field.

This frontier push is set to redefine Southeast Asia's upstream, unlocking strategic resources, attracting global capital, and shaping the region's E&P trajectory for the decades ahead.

Ongoing frontier exploration in Southeast Asia

Source: Rystad Energy upstream solution

Asia-Pacific to become balancing market for an oversupplied LNG market in 2029

The Asia-Pacific region is bracing for new supply from the FID wave that followed price spikes in 2022. With an average of about 40 million tonnes (Mt) of LNG capacity coming online every year between 2026 and 2029, the influx of new supply will put downward pressure on LNG prices.

By 2029, we expect the gap between LNG supply and demand to noticeably widen to about 27 Mt. This has not considered pre-FID projects which may further widen the oversupply gap.

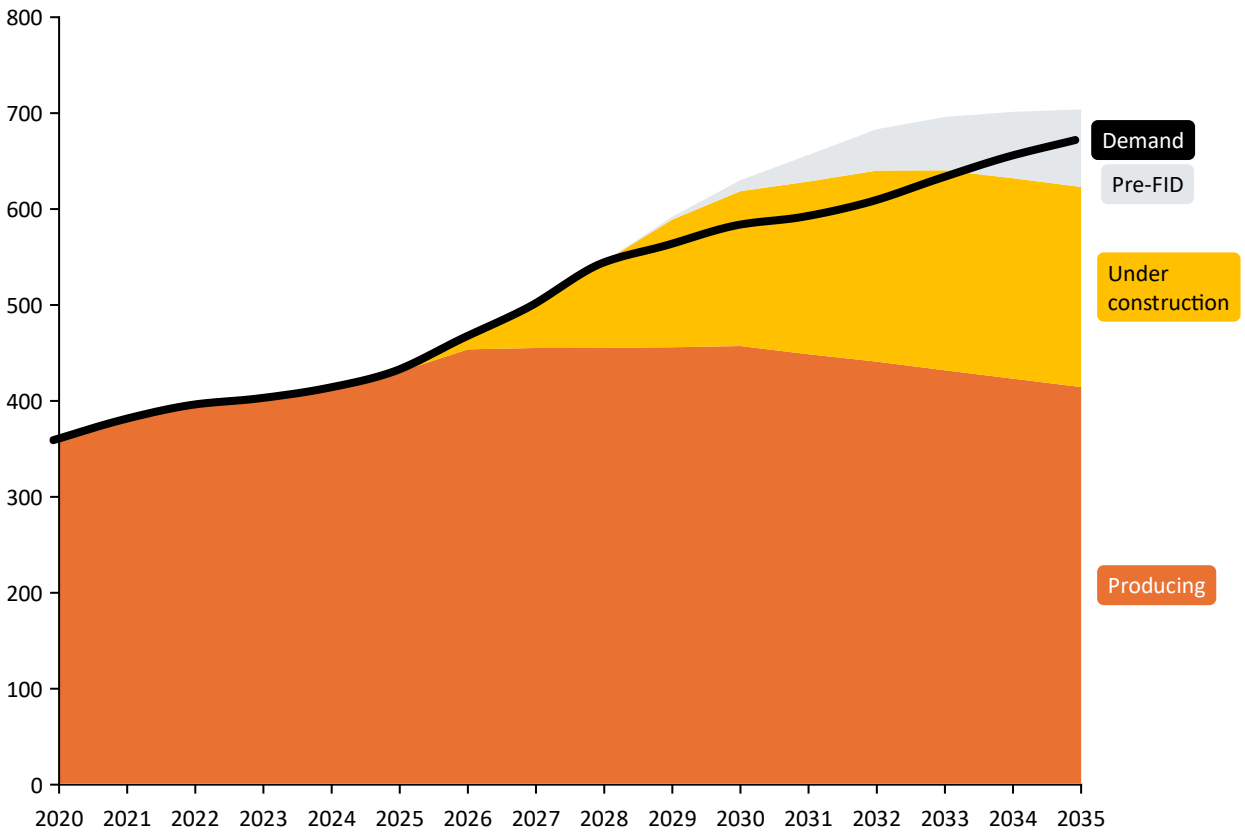
As prices come down from previous highs to match the balancing import markets in Asia-Pacific, we expect LNG demand in the region to grow by 5.7 % annually until 2035.

Growing LNG demand will be created by a rising need for gas-fired generation to meet higher electricity requirements, during a period in which domestic gas production is also expected to decline throughout most of South Asia and Southeast Asia.

As Asia-Pacific will need to consider scenarios where a fast-paced transition towards renewable energy may alter gas requirements, floating storage and regasification units (FSRU) will assist in bridging the LNG regasification capacity required until alternative energy sources take precedence.

The growing supply of LNG presents an opportunity for the Asia-Pacific region to capitalize on more favorable prices as compared to the earlier half of this decade.

Yearly global LNG supply by life cycle and LNG demand, 2020-2035
Million tonnes of LNG



Source: Rystad Energy GasMarketCube

FSRUs and FLNG provide flexibility in various approaches to renewable energy adoption

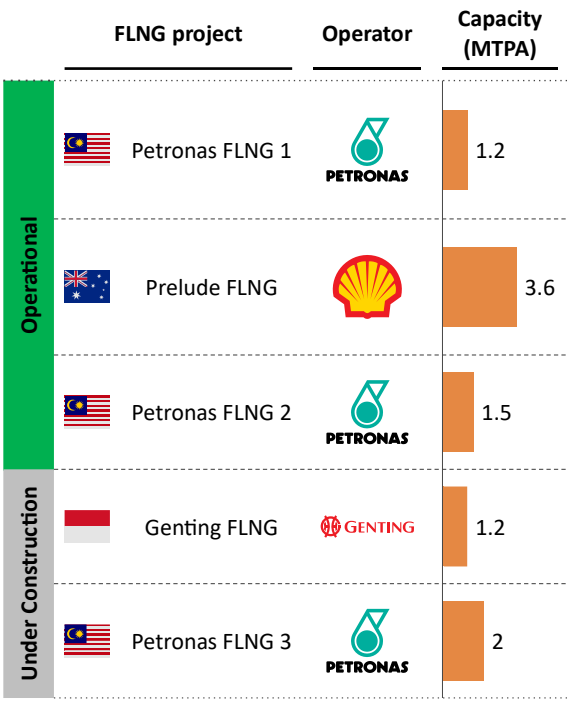
Economic and population growth in Asia-Pacific will increase requirements for all forms of energy. Across all degree scenarios, gas demand increases as gas-fired power generation will be required as a balance for intermittent renewable energy. The domestic gas production and domestic gas demand scenario varies in different markets. A common theme is growing demand for gas, but with gas production unable to keep up, resulting in increased LNG import requirements.

As the transition to renewable energy may ebb and flow depending on the time horizon and economic conditions in each country, provisional regasification capacity will have to be considered for each unique scenario.

Floating storage and regasification units (FSRU) can supply provisional regasification capacity, with the ability to be relocated to other areas in need of regasification instead of being risked as a stranded asset. There is already 37 million tonnes per annum (Mtpa) of operational FSRU regasification capacity in Asia-Pacific, with more projects under construction or planned.

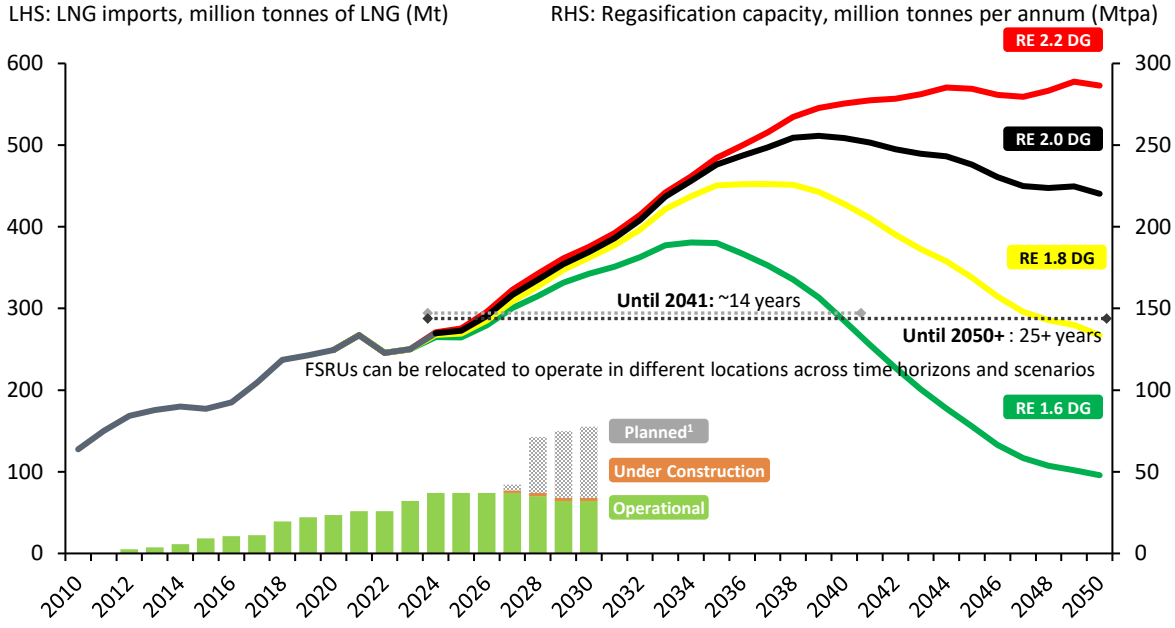
Floating LNG developments enable the monetization of marginal or smaller gas fields that would have otherwise been uneconomic.

Asia-Pacific FLNG liquefaction plants



Yearly Asia-Pacific LNG demand by scenario (2010 to 2050) and FSRU regasification capacity (2010 to 2030)

LHS: LNG imports, million tonnes of LNG (Mt) RHS: Regasification capacity, million tonnes per annum (Mtpa)



Source: Rystad Energy GasMarketCube

Chapter 3

Harnessing offshore clean energy

01

Offshore wind potential and investments

Offshore wind holds strong promise in key markets of Europe and Asia, with more than $750 billion to be spent in Asia-Pacific outside of mainland China in the next 15 years.

02

Offshore carbon capture gaining momentum

The Asia-Pacific region displays strong offshore CCS momentum, with major oil and gas players penetrating the market. Santos, Petronas, CNOOC and PTTEP represent around 60% share in capacity outlook towards 2040.

03

Offshore and floating solar capacity to reach 40 GW

Offshore and floating solar are drawing attention in Southeast Asian markets, while offshore geothermal is limited. However, with mature technology and cost reductions, these can be pivotal in the long term.

Offshore wind emerges as a strong renewable energy option in Asia-Pacific region

As the offshore energy sector evolves to meet decarbonization goals, innovative technologies and strategies have emerged to enhance efficiency and support clean energy integration. Offshore wind, offshore carbon capture, floating solar PV, and geothermal are some of the key technologies for harnessing offshore energy potential. Wave and tidal energy are also being tested as a means to diversify offshore energy sources.

Despite recent cost challenges and project cancellations, offshore wind is still considered promising in some key markets in Europe and Asia, where stronger frameworks and policies have been established. As of 2024, global operational offshore wind capacity was around 79 GW, with mainland China accounting for half the share, followed by the UK, Germany and other key European markets. In Asia outside of mainland China, the Taiwanese market has emerged strong, followed by Japan and South Korea.

Global offshore wind capacity is expected to witness a more than two-fold increase from the current installed base to around 185 GW by 2030.

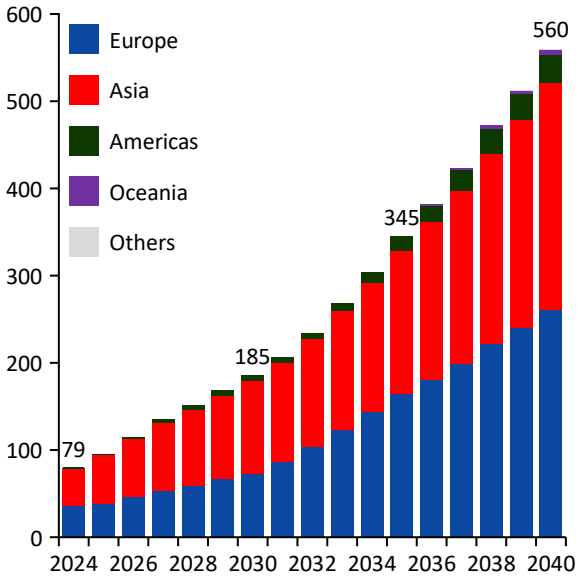
Asia is expected to account for a nearly 60% share, with mainland China accounting for more than 90 GW of installed capacity. The Taiwanese market is also expected to account for significant capacity towards 2030, followed by South Korea and Japan.

The Asian offshore wind market has received strong interest from international developers and local players alike. China Three Gorges and CGN Wind Energy currently lead in Asian offshore wind installations, but Orsted and Copenhagen Infrastructure Partners are also expanding their footprints with projects across the region.

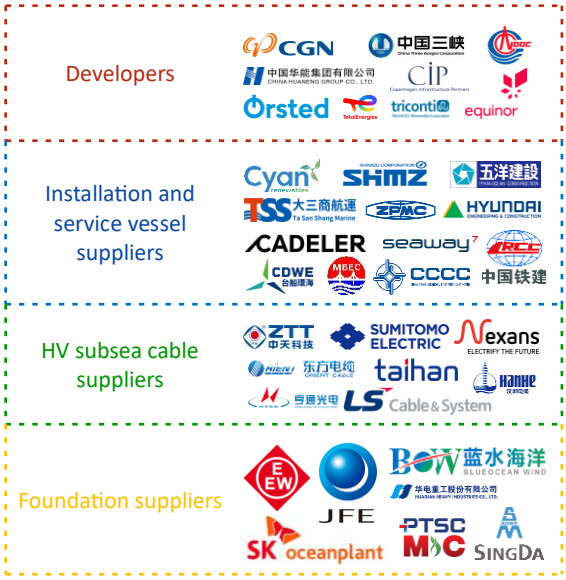
Chinese, Japanese, Korean and Singaporean vessel players have also been active in catering to growing demand in the region. International vessel players such as Cadeler and Seaway7 have also been active in turbine and cable installation activities in the region.

High-voltage subsea cable suppliers and wind turbine foundation manufacturers have also been pivotal in expanding Asian capabilities in offshore wind.

Offshore wind installed base by region
Gigawatts (GW)



Key offshore wind players in Asia-Pacific



Source: Rystad Energy OffshoreWindCube

Offshore wind can unlock $750 billion in investments in Asia-Pacific by 2040

Offshore wind has a been identified as vital for energy decarbonization, but its benefits extend beyond the environmental. The industry generates jobs, contributing to the national gross domestic product (GDP) rates, and has created a demand segment for vessels, shipbuilding, and marine services. Offshore wind projects are complex, often involving multiple components and synergies among deliverables. Offshore wind capital expenditure involves engineering, procurement and construction (EPC) of the foundations, turbines, subsea cables, and substations, and installation and commissioning (I&C) of key components, followed by operational expenditure for both preventive and corrective maintenance. Other spending includes project development and management, including permitting and administrative fees.

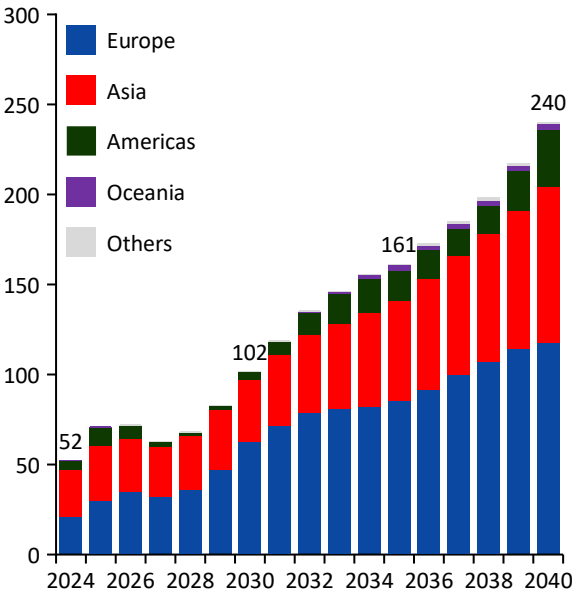
The offshore wind market outside of mainland China has faced challenges since 2021 related to inflation and supply chain scalability. As a result, annual expenditure is expected to remain relatively low at around $70 billion between 2026 and 2029, before scaling up as cost pressures ease.

Europe is expected to account for nearly 52% of annual offshore wind spending between 2026 and 2029, rising to nearly 57% of expenditures in 2030-2035 as technology matures and commercial-scale floating wind is deployed. Between 2026 and 2035, Asia is expected to account for nearly 37% of annual spending. or around $40 billion. A spending surge is expected after 2035 as markets scale, with average annual expenditure reaching close to $200 billion between 2036 and 2040.

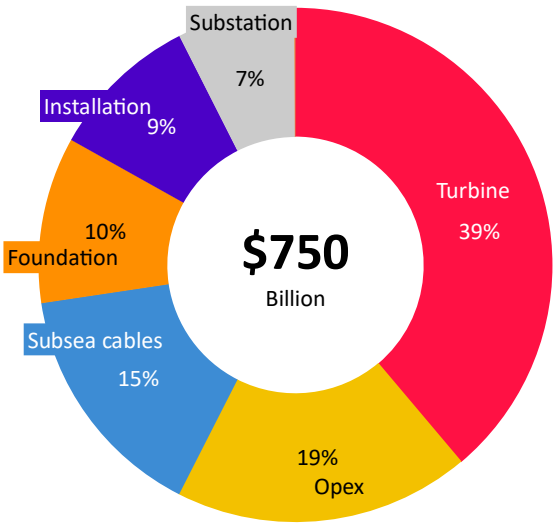
Asia-Pacific is expecting more than $750 billion in total spending from 2026 to 2040, primarily driven by the Chinese and South Korean markets. The Taiwanese market, one of the most mature market in East Asia, follows. Japanese offshore wind projects will also drive longer-term investments as developers look to floating wind projects in the exclusive economic zone (EEZ).

Turbines will account for nearly 40% of total expenditure between 2026 and 2040, followed by operational spending and subsea cables, which combined will approach $255 billion by 2040.

Offshore wind annual expenditure by region
USD billion



Total expenditure in Asia-Pacific, 2026-2040
Percent share by category



Source: Rystad Energy OffshoreWindCube

Other offshore clean energy technologies range from solar to small-reactor nuclear

The offshore clean energy portfolio is not limited to wind. It can include a mix of hybrid projects with innovative deployments of relatively mature technologies such as co-locating offshore solar PV with offshore wind, as well as emerging technologies such as floating small modular reactor (SMR) nuclear.

Rystad Energy's database indicates that most of the 14.3 GWp of operating solar assets installed on a body of water today are located on inland reservoirs. However, despite technical challenges of open sea installation and higher cost, there were a handful of large ocean-based solar projects with total capacity of 6.4 GWp as of the end of 2025, mostly in China.

Several archipelagic and maritime countries in the Western Pacific and Indian Ocean – Indonesia, Philippines, Maldives, among others – could potentially benefit from the adoption of offshore solar. This is especially true for island and remote communities that rely on diesel fuel import for power generation but cannot deploy ground-mounted or onshore floating solar due to a lack of land and inland reservoir availability.

Floating SMR nuclear is another niche technology emerging in recent years. The general enthusiasm around a nuclear 'renaissance' has pushed SMR to top of the agenda for many public and private sector players. Rystad Energy currently tracks 84 SMR projects across 24 countries in various development stages.

While SMR offers inherent mobility and safety advantages over conventional nuclear, with passive design, smaller reactor size, and exclusion zone requirements, public acceptance remains challenging, especially in countries that do not have a history of nuclear power generation. This has led some to pursue floating SMR to either bypass regulatory hurdles or to put more distance between SMR facilities and populated area.

The world's first SMR is a power barge with pressurized water reactor, Akademik Lomonosov, developed by Rosatom and operational since 2020. In 2024, Thailand's Global Power Synergy and Saltfoss Energy agreed to study the feasibility of a power barge concept based on compact molten salt reactor.

Notable offshore and floating clean energy developments in Asia (excluding offshore wind)

China	CHN Energy developed 1 GW offshore solar project (fixed bottom) in Shandong province
	China General Nuclear (CGN) exploring floating SMR design ACPR50S for power, heat and freshwater supply for islands
Philippines	Over 2.2 GW of floating solar capacity awarded in the recent GEA-5 auction.
Indonesia	Masdar and PLN installed the largest floating solar in Southeast Asia with 145 MW capacity
	Rosatom proposed to develop floating SMR in West Kalimantan with capacity of 2x110 MW.
Thailand	Feasibility study for floating SMR with molten salt reactor

Source: Rystad Energy Renewables and Power solution

Floating and offshore solar technology gaining interest from regional developers in Asia

The significant expansion in solar cell and module manufacturing capacity in recent years has substantially reduced costs, leading to widespread adoption of solar PV technologies. While conventional ground-mounted PV remains the primary and most dominant form of solar deployment, parallel technologies such as floating PV (FPV) and offshore solar are also experiencing growth in many Asian markets, with China at the forefront of these developments.

FPV delivers 5% to 10% higher energy yields, largely due to the cooling effect from the water. It eliminates land acquisition costs and can be integrated with hydropower plant reservoirs or thermal plant water bodies, further reducing infrastructure costs. China, Taiwan, India, South Korea and a few Southeast Asian countries will drive growth in FPV capacity to 2040.

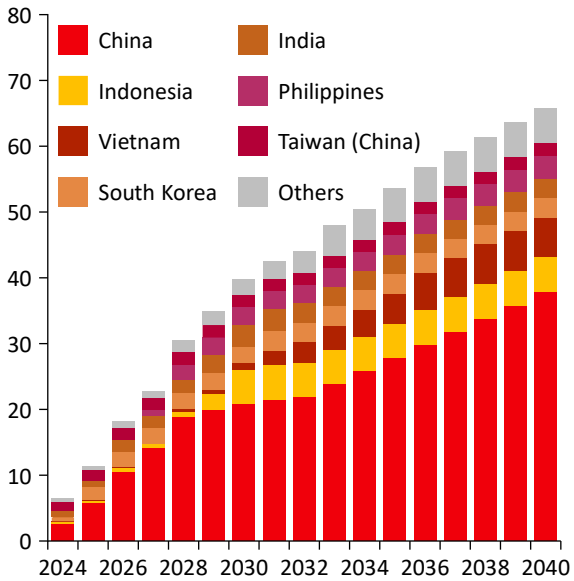
Offshore (sea-based) and near-shore solar PV projects currently have a smaller overall deployment compared to FPV; however, their larger average project size enables them to contribute a higher share of total installed capacity by 2040. These projects could either be floating or fixed-bottom mounted. China has started commissioning many fixed-bottom offshore solar projects, while Taiwan (China) has deployed several near-shore floating solar projects.

China had around 5 GW of installed FPV and offshore PV capacity as of 2025, with installations expected to grow rapidly to about 40 GW by 2040. Coastal provinces are actively supporting offshore PV, with Shandong announcing around 16 GW of fixed-bottom projects and Fujian recently awarding 1.6 GW. Jiangsu and Zhejiang are also anticipating offshore PV deployments in the coming years. Taiwan is also pursing many near-shore floating projects and has commissioned over 500 MW capacity to date.

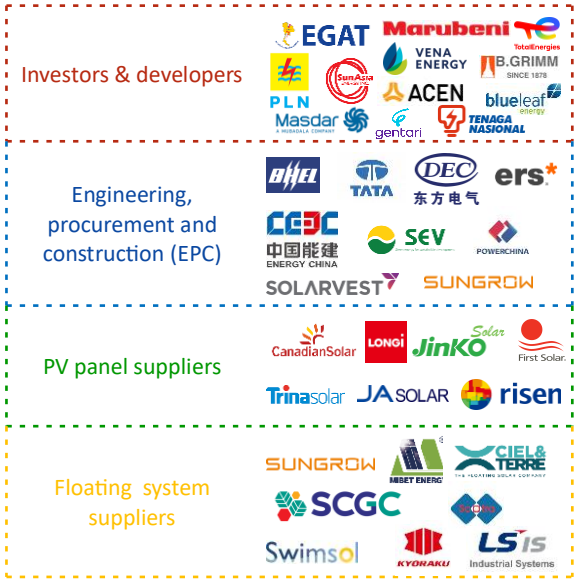
Southeast Asian countries are advancing inland FPV projects with a pipeline exceeding 15 GW by 2040. Indonesia has a pipeline of around 5 GW, which includes the large-scale Cilamaya, Duriangkang, and Cirata projects, with combined capacity of 4.3 GW. The Philippines is also entering the FPV sector, recently awarding over 2.2 GW of FPV capacity slated for commissioning between 2027 and 2030. In Thailand, Electricity Generating Authority of Thailand (EGAT) has plans for more than 2 GW of FPV to be built on its reservoirs.

India has also experienced notable growth in FPV projects, with over 800 MW installed as of 2025. Many of these installations have been done by state-owned power companies utilizing the water bodies of existing thermal and hydro power plant facilities.

Floating and offshore solar installed base by country
Gigawatts (GW_{AC})



Key floating and offshore solar players in Asia-Pacific



Source: Rystad Energy Renewables and Power solution

Santos, CNOOC, Petronas, and PTTEP lead offshore CCS activities in Asia-Pacific

Carbon capture and storage (CCS) has received strong interest from oil and gas players and is experiencing a surge in activity across the energy supply sector.

Europe is expected to lead in CCS, supported by strong policies, commitments, and private equity. North America will follow closely as it embarks on large-scale storage permitting. Asia-Pacific is positioning itself for future growth through regulatory frameworks.

In Europe, BP, Equinor, and TotalEnergies reached a final investment decision (FiD) for Net Zero Teesside Power and the Northern Endurance Partnership in December 2024. Eni has also been active in CCS and has secured consent for HyNet's CO_2 pipeline. ExxonMobil secured the largest US offshore storage lease in 2024, which will complement its Gulf Coast network through the Denbury pipeline acquisition.

ExxonMobil and Shell launched the S-Hub in 2025 and are targeting around 2.5 million tonnes of annual CO_2 storage via cross-border CCS from Singapore by 2030. Offshore CCS is likely to pick up pace toward the 2030s and will be pivotal for European and Asian markets.

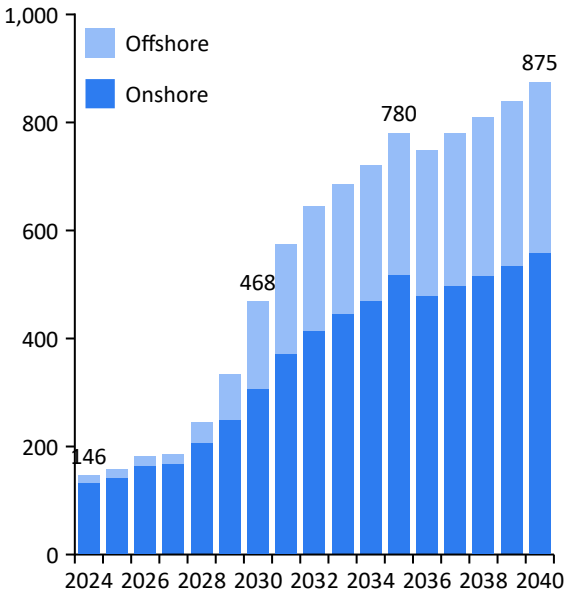
The Asia-Pacific region is showing renewed momentum in CCS project development, with Thailand's PTTEP taking FID on the country's first offshore CCS project at the Arthit gas field in the Gulf of Thailand. The $320-million project is expected to store up to 1 million tonnes of CO_2 annually.

Santos has been actively involved in Asian offshore CCS projects. The Moomba CCS project in Australia has been operating since 2024 and the company plans to take a final investment decision at the Bayu-Undan CCS project in 2027.

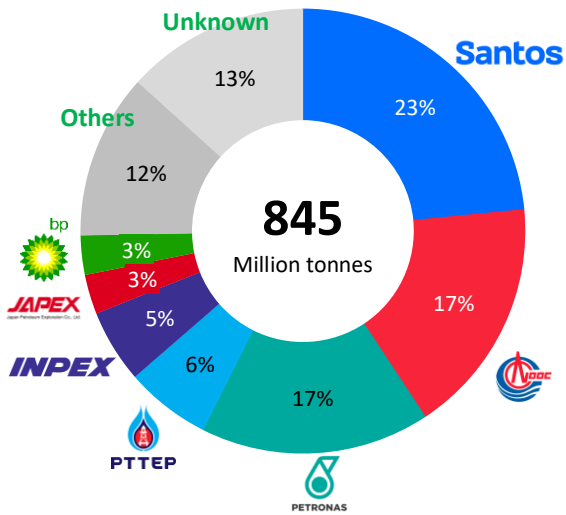
Japex is also working with Petronas to develop a large-scale CCS project that will target depleted fields off the Malaysian coast. A subsidiary of Petronas has recently been awarded Malaysia's first official offshore carbon storage permit for the Duoyong field, marking a significant step to unlocking 5 million tonnes of CO_2 storage capacity by 2030 in the area.

CNOOC has been also present in offshore CCS and is expected to store nearly 150 million tonnes of CO_2 by 2040 in the region. Other entities such as Pilot Energy, Eneos Xplora and Pertamina are also monitoring the offshore CCS sector closely, with strong long-term ambitions.

Global CO_2 storage capacity by storage type
Cumulative million tonnes per year



Total offshore storage capacity in Asia-Pacific*
Percent capacity share



*Indicates offshore storage capacity in Asia-Pacific between 2024 and 2040 by storage operator
Source: Rystad Energy CCUS solution

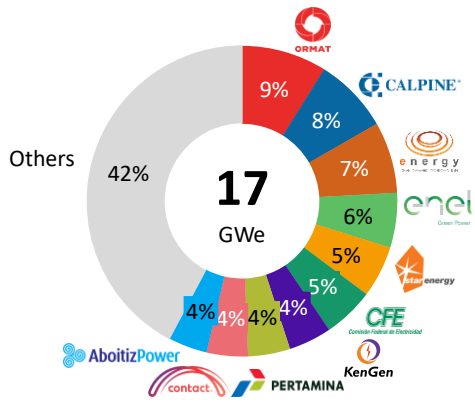
Offshore geothermal remains in early stage, focus on enhanced and advanced systems

Geothermal delivers reliable 24/7 clean energy for power and heating. Rising demand from data centers is strengthening market confidence, reflected in new power purchase agreements in the US and Google's geothermal deal in the Taiwanese market. Asia is expected to lead the market in the medium term, driven by Indonesia, the Philippines, and Japan. Regional capacity could reach 13 GW by 2035, while China will dominate geothermal heating. Global expansion will be supported by major players such as Ormat, Star Energy and Pertamina in Indonesia (60% market share), EDC and Aboitiz Power in the Philippines (2 GW total capacity) and Contact Energy with 50% of New Zealand's capacity.

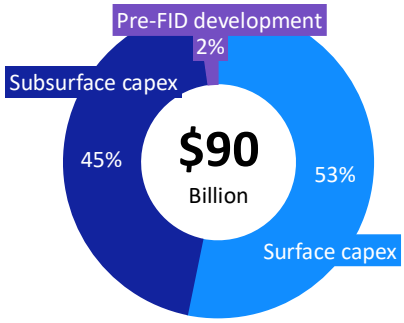
Asia-Pacific is projected to invest over $90 billion in geothermal between 2026 and 2040, led by Indonesia's ambitious expansion and China's growing heating market. High upfront drilling costs and subsurface uncertainty remain major barriers, prompting countries to implement de-risking tools like drilling insurance, exploration support, and risk-sharing schemes.

Geothermal has long relied on hydrothermal resources in volcanic areas, but technologies such as enhanced geothermal systems (EGS) and advanced geothermal systems (AGS) allow access to heat in regions without natural fluids, enabling broader deployment. Offshore geothermal, explored in mid-ocean ridges, remains experimental due to high technical and cost challenges, so industry focus will remain on developing EGS and AGS.

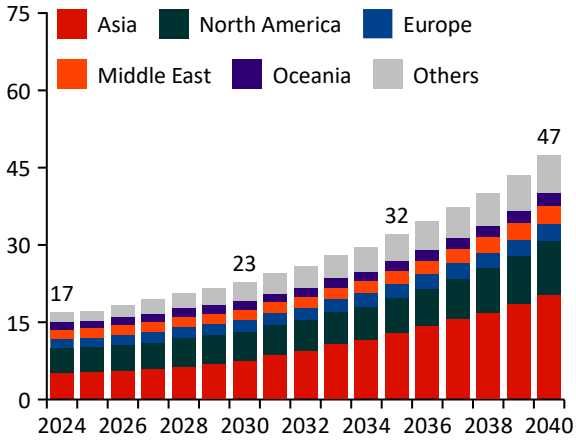
Total geothermal power generation, 2025
Gigawatts electric (GWe)



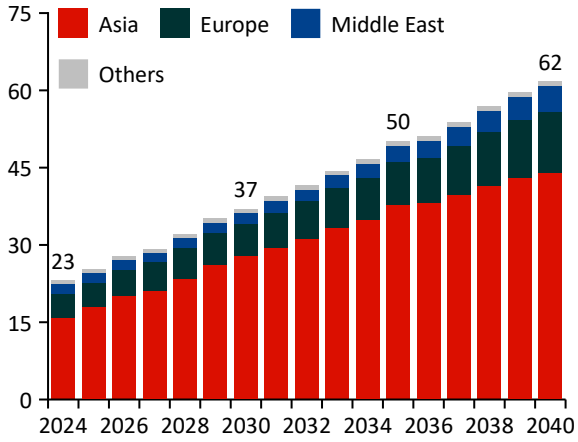
Total expenditure in Asia-Pacific, 2026-2040
USD billion



Geothermal power generation installed capacity
Gigawatts electric (GWe)



Geothermal heating installed capacity
Gigawatts thermal (GWt)



Source: Rystad Energy Geothermal Solution

Chapter 4

Asia’s offshore supply chain capabilities

01

$40 billion deepwater resurgence in Southeast Asia

Asian deepwater oil and gas activities are gaining strong momentum, as South and Southeast Asian markets transit from shelf to deepwater. $38 billion of spending is expected in the deepwater segment over 2026–2030.

02

Korean and Chinese shipyards stay heavily utilized

East Asian shipyards in China and South Korea remain heavily utilized, driven by strong order backlogs for vessels and FPSOs. Delivery lead times for FPSOs have declined to around three years.

03

Asian capabilities exceed in low-carbon supply chain

Asian suppliers account for more than half of the global manufacturing capacities on offshore wind steel foundations, towers, and turbines. Solar cells and batteries are also strongholds for Asian suppliers.

South and Southeast Asia are driving a deepwater resurgence

Asia's offshore development historically has focused on shelf fields, but with these assets maturing, the region is now preparing for a resurgence in deepwater development later in the decade. The trend is driven by increasing energy demand and the pursuit of regional energy security. South Asia and Southeast Asia will be the primary drivers behind most deepwater expansion. Deepwater investment in Southeast Asia is expected to grow at a 31% compounded annual growth rate (CAGR) between 2026 and 2030, and in South Asia at a CAGR of 78%, making deepwater an important part of the regional offshore portfolio.

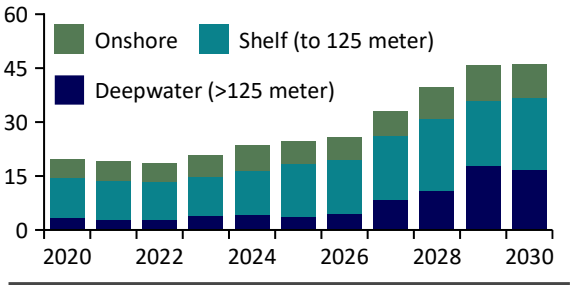
Many operators in South Asia and Southeast Asia are now actively revisiting deepwater opportunities that were previously deferred as viable strategic assets. As a result, a gradual increase in project sanctioning, particularly for deepwater gas developments and phased field expansion, has been noted. Operators are increasingly turning to FPSO solutions and subsea tiebacks to phase deepwater developments more cost-effectively. These technologies enable modular project execution, allowing operators to commercialize priority reservoirs first while deferring future expansion phases until conditions improve.

Several major FPSO projects have progressed into advanced stages, with Northern Hub FPSO's hull already awarded for EPC and the Kelidang FPSO secured on a lease basis. Abadi LNG remains in the FEED stage, and Andaman's FPSO contract award is expected to be announced later, indicating some projects are still early-stage.

As these projects near execution, deepwater-focused supply chain readiness becomes increasingly critical. Unlike shelf developments, deepwater campaigns demand specialized marine and drilling assets, longer lead times, and tighter integration across engineering, fabrication, and logistics cycles. Deepwater projects demand high upfront capital and carry significant risks, which are even greater in Asia because operators have less deepwater experience.

To mitigate risks, we have seen partnerships in recent years, particularly in India. Notable partnerships include Cairn Oil & Gas and TechnipFMC to fast-track deepwater exploration and subsea development in the Krishna Godavari Basin, Reliance and BP's joint development to invest and operate the KG-D6 deepwater gas hub, and ONGC's cooperation with Petrobras to tap Brazil's deepwater experience.

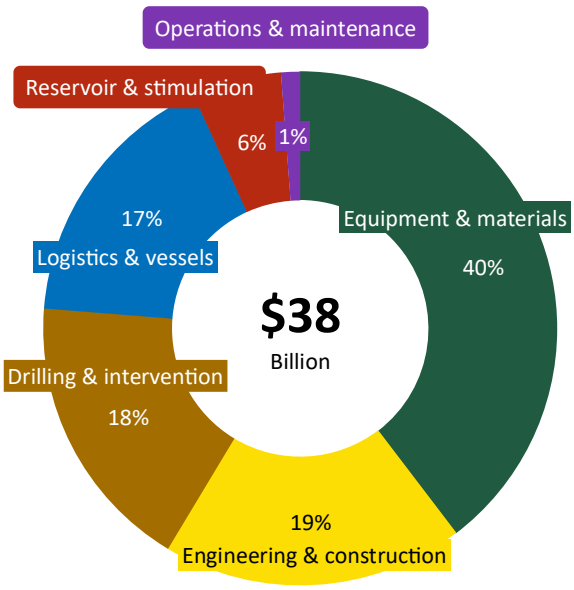
Upstream oil and gas investments* by water depth
USD billion



Top 10 upcoming deepwater projects*

Southern Hub	Siakap North-Petai	Merpati	KG-DWN-98/2
Northern Hub	Block H	Kelidang	Block D6
Abadi LNG			
Andaman Gas project			

Deepwater investments in South & Southeast Asia**
USD billion



*Includes South and Southeast Asia regions.
**Between 2026 and 2030, excludes internal and other segment.
Source: Rystad Energy Service Demand Cube – Oil and Gas

High utilization continues at East Asian shipyards as global demand accelerates

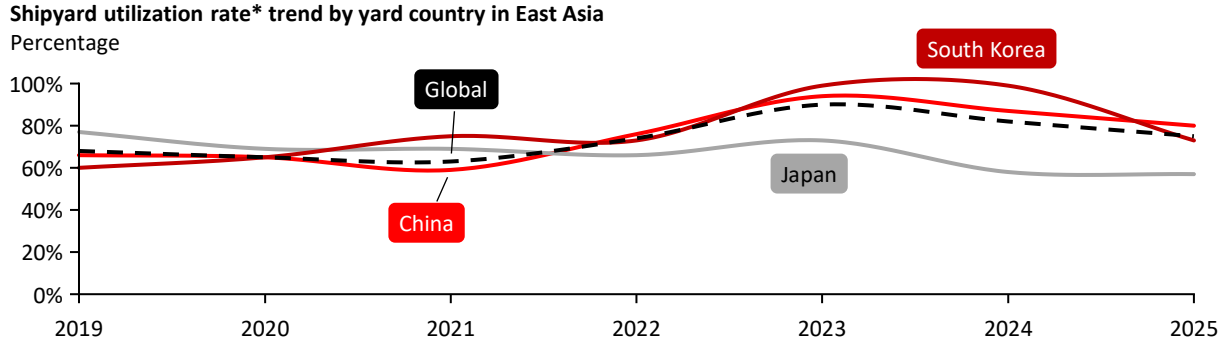
With deepwater sanctioning expected to gain momentum and global offshore development shifting into deeper waters, East Asian fabrication yards are increasingly positioned at the epicenter of delivery – particularly for floating solutions, topsides, and large offshore structures. Across Asia, yard utilization levels have been rising since the pandemic, especially in China and South Korea, led by strong demand recovery for offshore assets, resumed investment activity, and additional capacity requirements driven by the growth of LNG carriers and offshore wind. Most East Asian yards are now operating at or near high capacity, driven by multiple FPSO hull orders, LNG carrier newbuilds, and marine infrastructure projects.

Southeast Asian shipyards are smaller players in global newbuilding compared to China and Korea, but they are gaining momentum in LNG carrier repair, life extension, and conversion work. Companies such as Seatrium and Malaysia Marine & Heavy Engineering are securing a growing pipeline of LNG carrier retrofits, hull and machinery upgrades, air-lubrication system installations, and FSRU conversions. Singapore is also a key regional hub for offshore energy fabrication, especially FPSO topside modules, final integration and commissioning, and other deepwater production units.

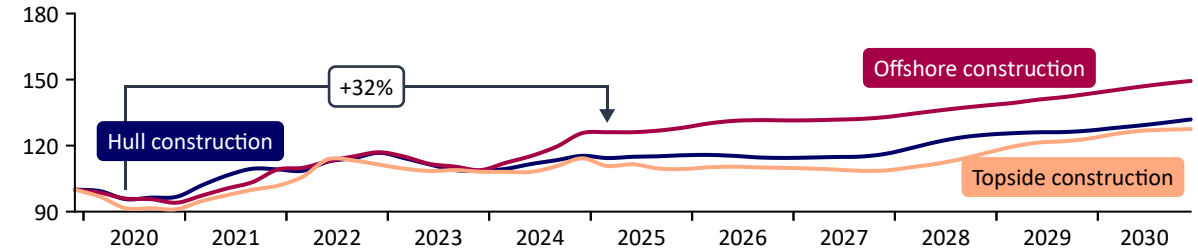
The Abadi LNG development, which carries significant local content requirements, is also seen as a proving ground for Southeast Asia's yard capabilities. With engineering and pre-sanction work awarded to contractors Saipem and McDermott International, both of which operate major fabrication facilities in Batam, the project signals growing confidence that regional yards can support more complex construction scopes typically associated with deepwater developments. This move also marks a strategic localization commitment and the maturing capabilities of Batam-based yards.

Cost pressures are increasingly shaping yard competitiveness across Asia, with post-pandemic inflation driving up fabrication and construction costs by approximately 15-25%. Things moderated slightly in 2023 amid stabilizing commodities and persistent geopolitical tensions. However, from 2024 onwards, pricing trends have resumed an upward trajectory as operators begin early-stage procurement and yard engagement. This forward demand, combined with lingering inflationary effects, continues to exert cost pressure across fabrication yards in Asia.

Shipyard utilization rate* trend by yard country in East Asia
Percentage



Service price inflation trend for Asian shipyard**
Indexed to December, 2019=100



*Includes offshore and shipping
**Covers oil and gas-related works
Source: Rystad Energy Shipping Solution; Rystad Energy Cost & Prices Solution

East Asian shipyards to remain leaders in meeting global FPSO and vessels demand

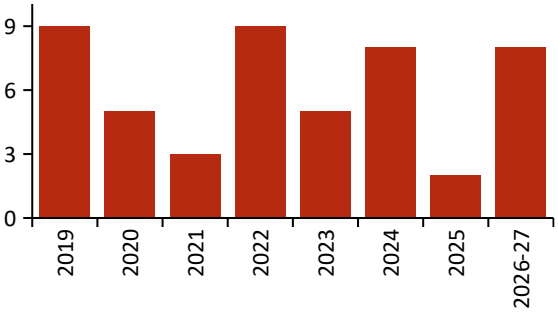
We anticipate a robust pipeline of FPSO newbuilds over the next two years, driven by the development of deepwater projects. However, the outlook for offshore vessel newbuilds is softer, with deliveries trending downward as owners face funding issues. This divergence suggests that while newbuild activity may moderate, specialized offshore production assets will remain a key area of growth.

With global FPSO and vessel construction expected to remain relatively high over the next five years, we anticipate that Asian yards will continue to absorb the majority of this work, given their proven track record of success. China, South Korea, and Japan collectively form the top three countries in terms of yard capacity, enabling the region to handle both FPSO and broader offshore vessel demand.

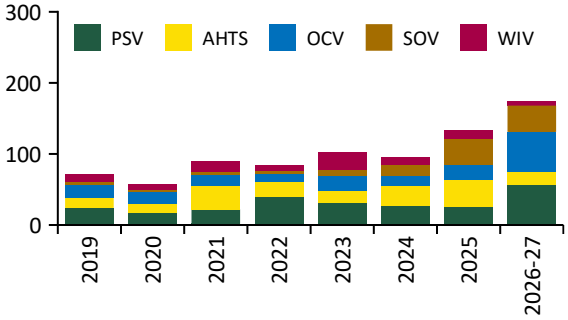
Historically, nearly 95% of FPSO jobs have been executed in Asian yards, with China and Singapore leading the construction, while yards in South Korea are becoming increasingly competitive. Chinese yards such as Cosco Shipping Heavy Industry and China Merchants Heavy Industry currently command a significant share of large-scale offshore fabrication and FPSO hull construction globally. Their deepwater capabilities are supported by robust infrastructure, extensive quayside capacity, and competitive delivery economics, making them preferred partners for high-tonnage FPSO integration and hull fabrication. We have seen Chinese yards improve their FPSO delivery performance, with average lead times falling to 3 years in 2023-2024 from 4.5 years in 2018-2022.

We observe a similar trend for offshore vessels, with over 50% of newbuilds being constructed in Asian yards, and China again emerging as the top country. Recent years have seen strong orders for offshore construction vessels (OCV) and service operation vessels (SOV) and commissioning SOVs (CSOV), driven by integrated offshore project execution (including subsea and multi-purpose construction) and by offshore wind build-out alongside oil and gas maintenance.

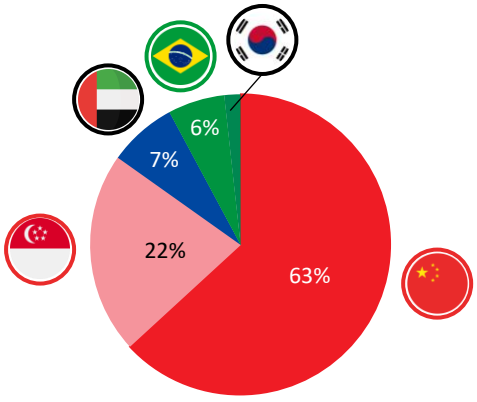
Global FPSO newbuild by delivery year
Number of FPSOs



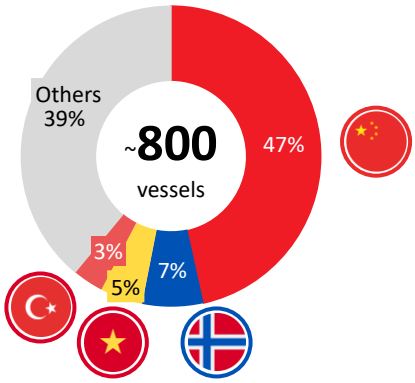
Global offshore vessels newbuild by vessel type**
Number of vessels



FPSO work activity*
Number of FPSO jobs



Number of offshore vessel deliveries by yard location**
Number of vessel newbuilds



*Includes hull and module fabrication, topside integration, and unit modification
**Includes PSV, AHTS, OCV, SOV, and WIV with delivery between 2019 to 2027
Source: Rystad Energy Shipping Solution; Rystad Energy FPSO Solution

Asian low-carbon supply chain capabilities remain prominent across segments

As it has with the oil and gas supply chain, Asia can claim to be the low-carbon supply chain leader. At the end of 2025, Asia accounted for significant low-carbon supply chain capacity including solar cells, wind turbines and steel foundations and towers. With larger fabrication yards in eastern Chinese provinces, Korea, Singapore and Vietnam, Asia has positioned itself as a fabrication hub for offshore substation topsides, towers, and monopile and jacket foundations. With the floating wind industry's long-term scale-up, South Korean suppliers will have the capability to manufacture substantial semi-submersible floating wind foundations.

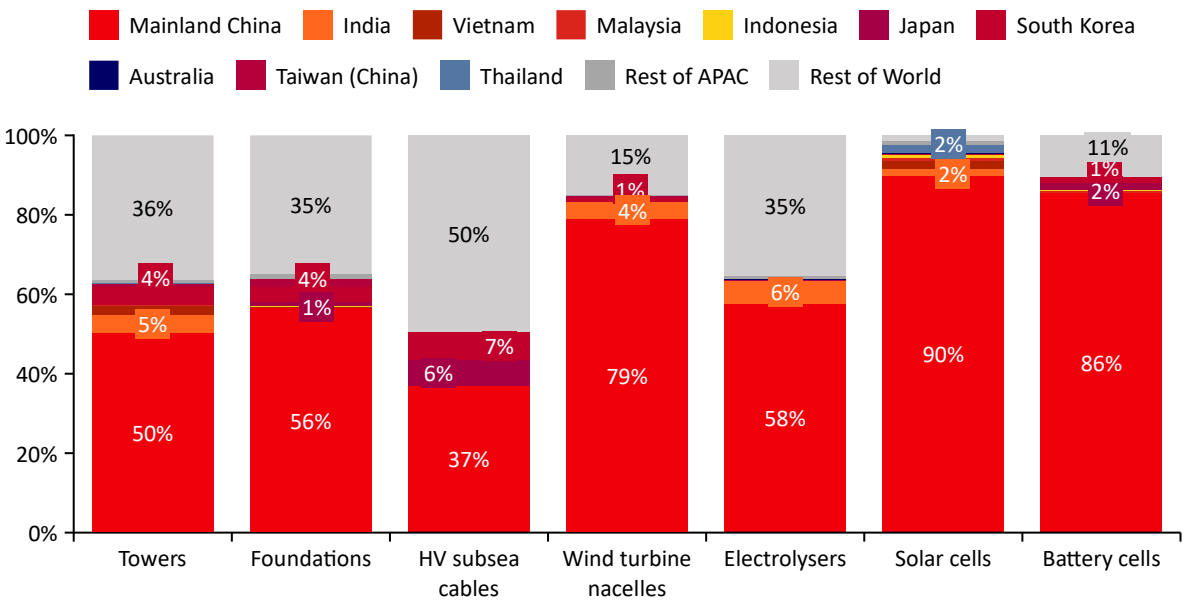
Mainland China has been a global manufacturing hub for solar cells, battery cells and wind turbine nacelles, accounting for nearly 80% of global supply capacity. Nameplate solar cell manufacturing capabilities surpassed 2 terawatts (TW_{DC}) by the end of 2025, with companies LONGi, Jinko Solar and Tongwei having well established bases. Global manufacturing capacity of wind turbine nacelles has surpassed 350 GW, with Chinese suppliers Goldwind, Envision and Shanghai Electric establishing themselves as market leaders.

Outside of mainland China, low-carbon manufacturing bases have been established in India, South Korea, Japan, and Thailand. New localized policies in Indonesia and Malaysia are encouraging the establishment of manufacturing units to cater to the booming solar PV market.

Asia far exceeds other markets in manufacturing capabilities for most components except high-voltage (HV) subsea cables, where supply capabilities are on par with Europe and other markets. With demand for HV subsea cables rising, South Korean suppliers LS Cable & System and Taihan Cable are ramping their Asian manufacturing capabilities to cater to the subsea interconnector market. Suppliers Zhongtian Technology Group (ZTT) and Ningbo Orient Cable are also increasing their manufacturing capacities for the Chinese market.

In the foundation manufacturing segment, including both jackets and monopiles, Asia has significant capacities compared to the rest of the world. Dajin Heavy Industries, EEW and SK Oceanplant have been key foundation manufacturers in the region. Additionally, more than 38 GW of the total 65 GW of global hydrogen electrolyser manufacturing capacity is in mainland China, followed by India.

Low-carbon supply chain by components* and supply markets, 2025
Percentage (%)



*Supply capacity of towers and foundations in tonnes; HV Subsea cables in kilometers; Nacelles, solar cells and electrolysers in GW; Battery cell supply in GWh.
Source: Rystad Energy Solar Solution; Rystad Energy Wind Solution; Rystad Energy Energy Storage Solution

Chapter 5

ASEAN Power Grid

01

ASEAN Power Grid to enhance energy security and system resilience

ASEAN's reliance on fossil fuels and fuel imports leaves countries vulnerable to price volatility. Cross-border renewable imports can help ease this dependence and strengthen long-term power sector stability.

02

Singapore import target to drive $40 billion investment via ASEAN Power Grid

Singapore's 6 GW import targets could translate into up to 25 GW of renewable and energy storage developments – over $40 billion in investments across hydropower, solar, and offshore wind.

03

Cross-border interconnection to advance regional renewable supply chain

Singapore's import target alone may translate into around 20 GW of solar PV equipment demand. Indonesia has introduced a 60% local content requirement for cross-border electricity projects

ASEAN power grid to enhance regional energy security and system resilience

The ASEAN Power Grid (APG) initiative promotes a robust interconnected regional power system, enabling countries to share and optimize diverse energy resources through cross-border transmission. Strengthening cross-border interconnections helps the region to manage rapidly increasing demand.

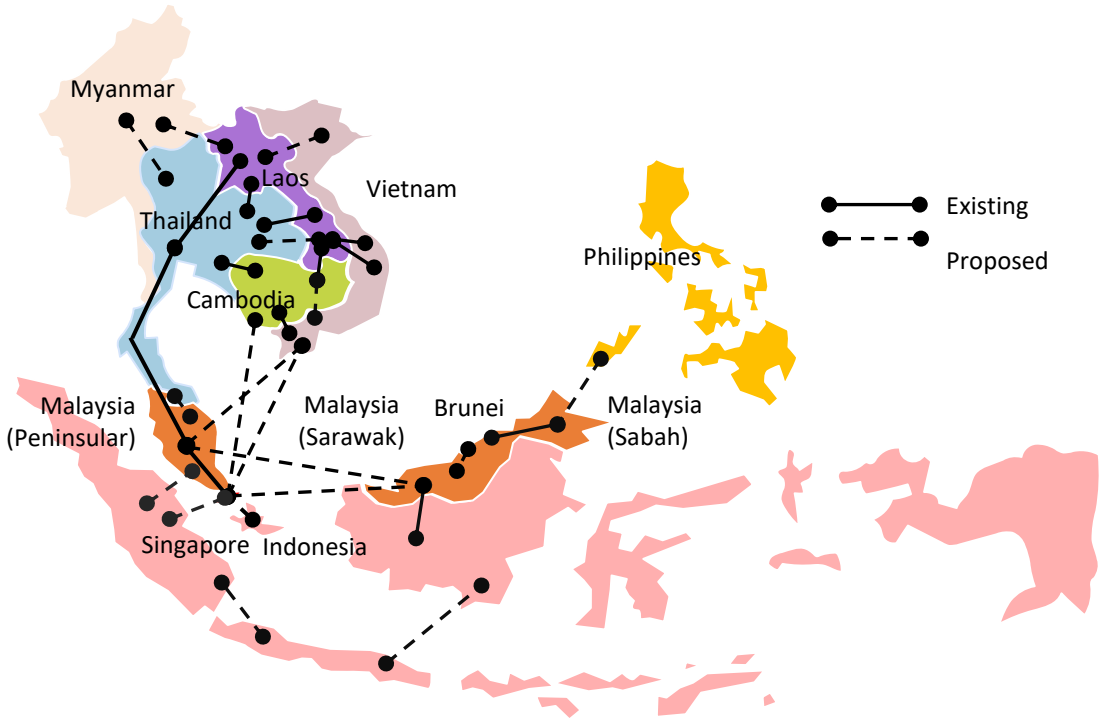
Such collaboration also reinforces ASEAN's collective pathway toward meeting its long-term sustainability commitments. The region's heavy reliance on fossil fuels – around 65% of the capacity mix – combined with significant fuel imports, leaves many countries exposed to price volatility. Accessing renewable resources from neighboring markets can help lessen this dependence and improve long-term stability in the power sector.

Linking power systems across the region can also strengthen overall grid resilience. A common feature of major power outages in recent years has been weak interconnection. From the recent Spain-Portugal incident, to repeated blackouts in Pakistan, and the 2021 Texas event, these systems operated with limited links to neighboring grids. Another factor is the lack of grid-connected energy storage. Both vulnerabilities can be mitigated by expanding cross-border connectivity under the APG.

The establishment of the APG began with bilateral cross-border arrangements, expanded to sub-regional cooperation, and is progressing toward an integrated regional system. Most existing cross-border projects are still structured as bilateral arrangements, with Laos at the center. Laos commissioned the 600 MW Monsoon Wind project in 2025, the region's largest wind farm, dedicated to exports to Vietnam, showing how regional collaboration can enable larger and more ambitious cross-border projects.

The first sub-regional interconnection, Laos-Thailand-Malaysia-Singapore (LTMS), became fully operational in 2022 and was upgraded to 200 MW this year. The scheme is planned to extend to the eastern sub-region via a Brunei-Indonesia-Malaysia-Philippines (BIMP) interconnection. The eastern Malaysia states of Sarawak and Sabah, link-connected in December 2025, could provide a potential foundation.

Given the benefits of the APG, aligning political priorities and regulatory frameworks across countries is essential to turn this vision into reality. Ensuring that all participating countries see clear and mutually beneficial outcomes is also critical for sustained regional cooperation.



Source: Rystad Energy Renewables & Power Solution

Singapore low-carbon power import drive could unlock $40 billion in investment

Singapore has renewed momentum for the ASEAN Power Grid (APG) as the country aims to import 6 GW of electricity from neighboring countries by 2035. This strategy supports the nation's efforts to diversify its energy mix, which is currently about 95% reliant on imported natural gas, and strengthen energy security by reducing its exposure to fuel price volatility.

Singapore has so far approved 8.35 GW of low-carbon import projects from Indonesia, Malaysia, Cambodia, Vietnam, and Australia—exceeding its stated target. This gives Singapore greater flexibility in securing power supply.

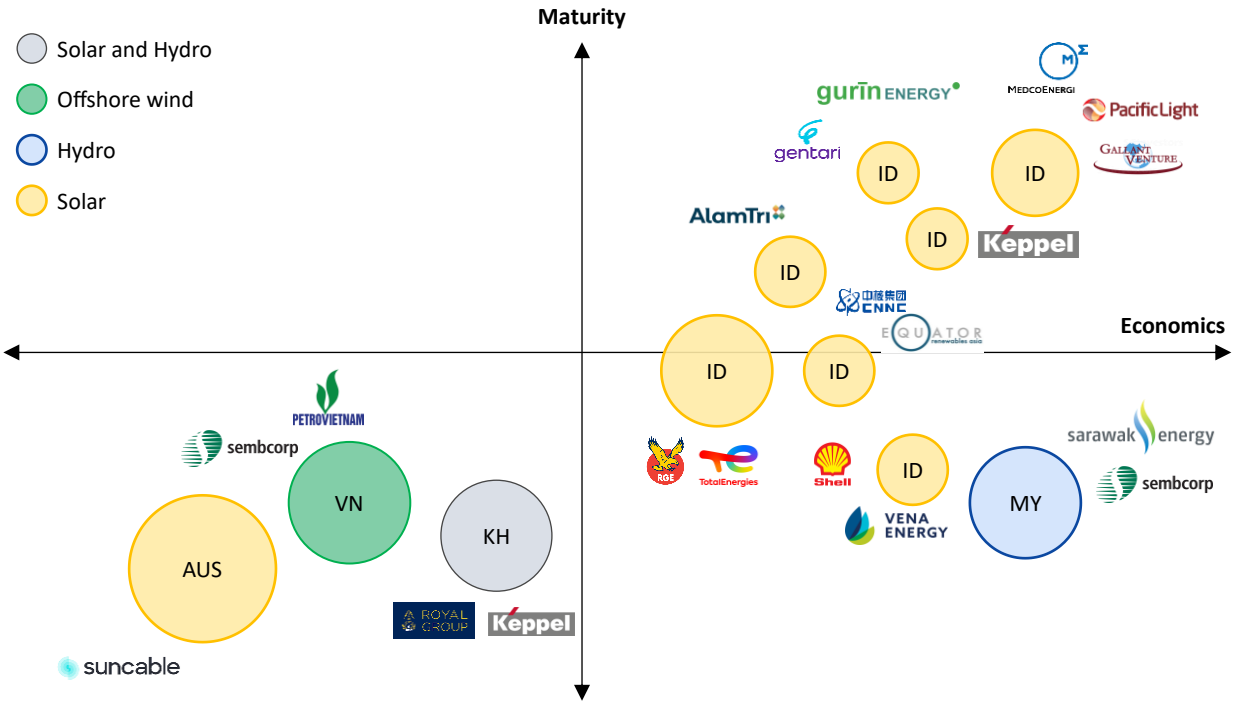
This is expected to open new renewable energy opportunities across the region through cross-border interconnections. Rystad Energy estimates that the full realization of Singapore's import targets will enable more than $40 billion in renewables and energy storage deployment across hydropower, solar, offshore wind and BESS. Further investment is expected for the associated supply chain and related transmission infrastructure.

Most of the leading projects are in Indonesia, where six have already received conditional licenses, supported by their proximity to Singapore. The next milestone is securing a Singapore import license before proceeding to construction. This phase involves regulatory approvals – such as the host country's export license – and reaching financial close. The project that first receives Indonesia's export license will likely move ahead more quickly.

Some developments, such as Medco Power, AlamTri, and Vena Energy, could benefit from their mature project experience in Indonesia. Some also gain an edge by meeting local content requirements for export projects. Gurin Energy and Vena Energy are particularly advanced, having secured supplier framework agreements with manufacturers committed to fulfilling these requirements.

Malaysia, Vietnam, Cambodia, and Australia remain at an early stage due to conditional approvals. Malaysia stands out as more economically mature, benefit from hydropower's high-capacity factor, dispatchability, and long asset life.

Key ASEAN power grid projects by feasibility and maturity*



*Project maturity is based on development progress and stakeholder profile. Each bubble corresponds to a project with one or more developers. Bubbles represent import capacity in megawatts
Source: Rystad Energy Renewables & Power Solution; Rystad Energy research and analysis

Cross-border interconnection to advance regional renewable energy supply chain

The ASEAN Power Grid is set to boost investment in the regional renewable energy supply chain. These large cross-border projects could create billions of dollars in demand for equipment and materials, accelerating the maturity of the regional ecosystem despite still-growing domestic markets. Singapore's 6 GW import target alone may translate into around 20 GW of solar PV equipment demand.

Amid geopolitical uncertainties and rising trade barriers, regional demand from the APG could offer a viable alternative to the US – currently the main export destination – particularly for Southeast Asia's solar supply chain. In addition, the growing need for subsea cables to support cross-border connections may encourage the development of cable manufacturing facilities within the region.

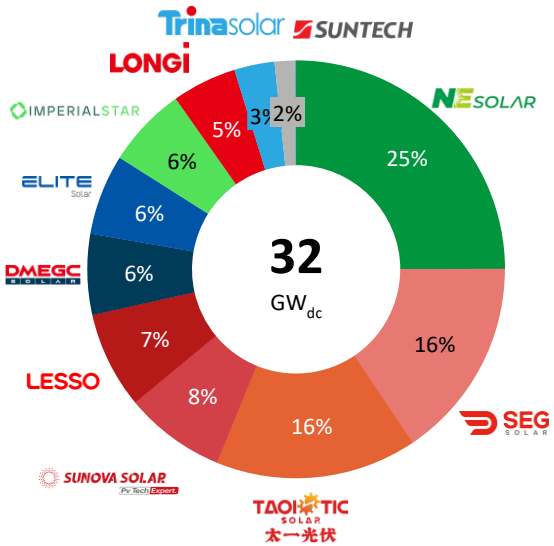
Indonesia has introduced a 60% local content requirement for cross-border electricity projects, consistent with its broader strategy to develop a domestic renewable energy supply chain through similar rules applied to local projects. This requirement is expected to play a significant role in determining which projects can obtain an export license.

Several project developers and equipment suppliers in Indonesia have announced agreements, signaling their commitment to establishing local manufacturing facilities. For instance, Vanda RE – a consortium of Singapore-based Gurin Energy and Malaysian-headquartered Gentari – has signed supplier framework agreement with Chinese solar PV company LONGi to supply up to 1 GW of solar modules. This follows an earlier deal of similar capacity with Trina Solar last year. Vena Energy has also entered a supply framework with Suntech for 2.5 GW per year.

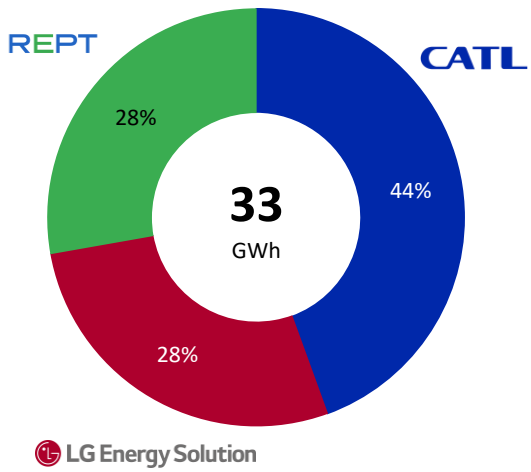
Beyond solar, these initiatives could accelerate the development of Indonesia's battery industry. Gurin Energy and Vena Energy have each signed supply framework agreements with Chinese battery manufacturer CATL to provide battery energy storage systems of 2.2 GWh and 4 GWh, respectively.

CATL broke ground on its first battery factory in Indonesia in June 2025, with operations targeted for 2026. The plant will produce 6.9 GWh annually in its first phase, expandable to 15 GWh, initially serving domestic and overseas batteries for electric vehicle markets before gradually expanding into BESS.

Indonesia solar module production capacity
Annual capacity gigawatts (GW_{dc}) by 2030



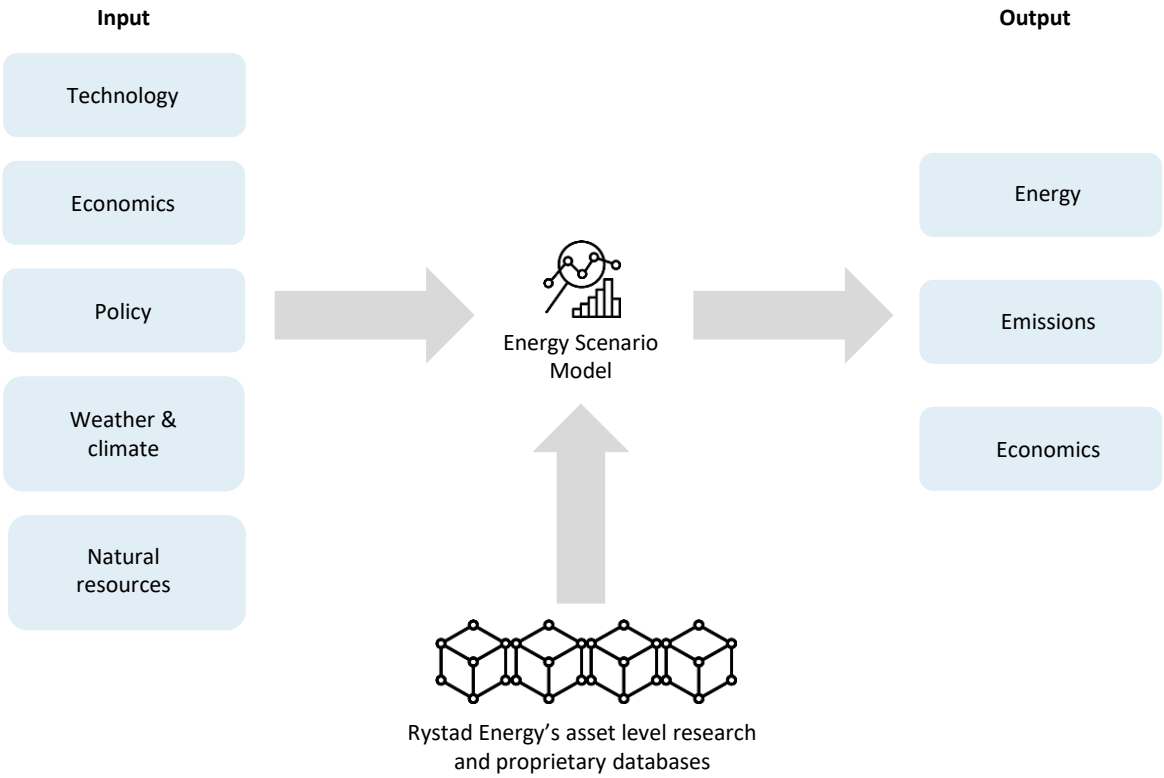
Indonesia battery cell production capacity
Annual capacity gigawatt-hour (GWh) by 2030



Source: Rystad Energy Solar Supply Chain solution; Rystad Energy Energy Storage solution

Appendices

Appendix – Scenario modeling framework



All scenarios are built from the bottom up, drawing on Rystad Energy's proprietary databases that map the global energy system at asset, company, and country levels. The degree-scenario framework spans 11 scenarios covering the period from 1965 to 2100, covering 217 countries and special territories, nearly 70 sub-sectors, and 70 energy carriers, including oil, gas, coal, electricity, bioenergy, and hydrogen.

Each element of the system – from supply and demand to trade and emissions – is modeled with high temporal and spatial resolution to ensure consistency between physical volumes, costs, and efficiencies across sectors. Power generation, manufacturing capacity and end-use consumption are linked through our multiple vertical-specific products.

This level of granularity provides a transparent and data-rich understanding of how changes in policy, cost and behavior influence the global energy system over time.

>60
sectors

217
countries and special territories

+70
energy carriers

Source: Rystad Energy research and analysis

Appendix – LCOE calculations

Methodology for Levelized Cost of Energy (LCOE) Calculation

The levelized cost of energy (LCOE) represents the constant price per megawatt-hour (MWh) that would need to be received over the lifetime of a power generation asset to recover all investment and operating costs, including a return on invested capital. The LCOE is calculated on a consistent, comparable basis across technologies (utility scale solar PV, onshore wind, offshore wind, coal, nuclear, and gas) and countries.

Key Assumptions and Inputs

- *Representative assets*: For each country and technology, the analysis models a representative new-build utility-scale asset entering construction in the specified year. For solar PV and wind (onshore and offshore), location-specific capacity factors are applied, reflecting expected performance of a typical greenfield project using current technology.
- *Fuel prices*: Country and year specific coal and gas price forecasts are applied, sourced from proprietary market outlooks.
- *Construction timelines and asset lifetime*: Project development and construction periods reflect current typical durations by technology and jurisdiction. Economic lifetime is technology specific. Assets are assumed to cease generation at the end of their technical lifetime, with decommissioning costs included in the final year of operation.
- *Capital expenditure (Capex) and fixed/variable operating expenditure (Opex)*: All cost inputs are country, technology, and construction year specific. Costs are sourced from Rystad Energy's global databases.

Discounting and Present Value Calculation

Costs and electricity generation are expressed in nominal terms and discounted to the year of commercial operation using a uniform nominal weighted average cost of capital (WACC) of 7.5%. An underlying inflation rate of 2.5% per annum is applied where required.

The present value of total lifetime costs includes:

- All capital expenditures phased according to the construction schedule
- Fixed and variable operating costs over the full operating life
- Fuel costs (where applicable)
- Decommissioning and site restoration costs

The present value of lifetime electricity generation is calculated by discounting annual net electricity output at the same nominal discount rate.

LCOE Formula

The levelized cost of energy is calculated as:

LCOE = Total lifetime costs (present value) / Total lifetime electricity generation (present value)

This approach yields a nominal LCOE in United States dollars that fully recovers all incurred costs and the required return on capital over the project lifetime.

Source: Rystad Energy research and analysis

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