Regional grids key to Singapore's energy future

Singapore's clean energy transition hinges on regional collaboration in power grids and diversified renewable energy imports

Published date: 1 May 2024

Lead author: Dr Dinita Setyawati

Other authors: Aditya Lolla

Contents

About

This report provides an overview of Singapore's power sector and examines the opportunities and challenges for the country's energy transition. Additionally, the report analyses the case for Singapore to be on track with targets based on the International Energy Agency's (IEA) net-zero emissions (NZE) milestone for a net zero electricity sector by 2045, and the ASEAN Climate and Energy Project (ACCEPT).

Highlights

32 TWh

Singapore's renewable electricity supply by 2035 if its current targets are achieved

8.1 GW

Renewable electricity import capacity needed by 2035 for Singapore to be on track to achieve IEA's net-zero power sector target

52-58%

Potential decrease in per capita power sector emissions between 2022-2035, if Singapore aligns with the IEA's NZE milestones

Executive summary

Accelerating cross-border interconnections is critical for Singapore's net-zero target

Renewables are poised to replace gas to power Singapore in the next couple of decades, as the country increases renewable power exchanges with neighbouring countries

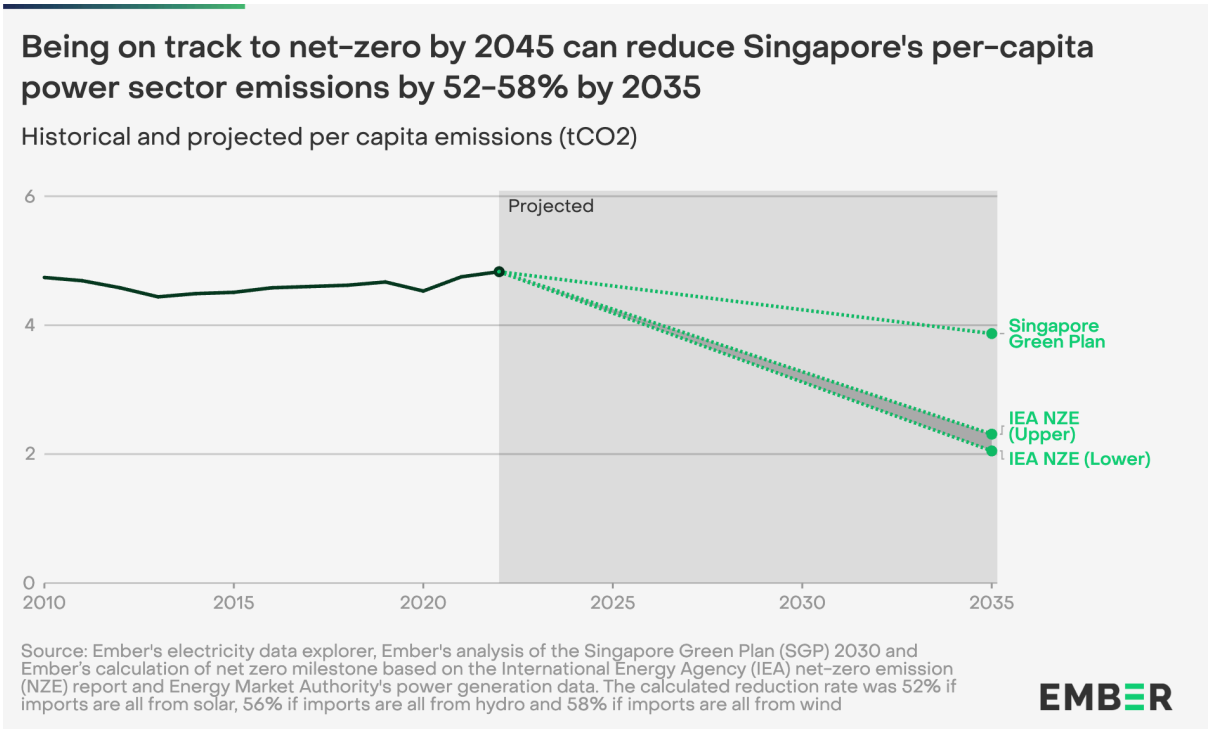
As a small city-state constrained by limited renewable energy potential and land availability, Singapore is actively securing an energy-resilient future by reducing reliance on gas and aiming for more renewable energy imports. Due to its geographical reality, Singapore cannot rely on its domestic energy capabilities alone and must leverage the renewable energy potential of its larger and less resource-constrained neighbours.

Singapore aims to boost solar capacity to 2 GW and build up to 4 GW of interconnections to import clean electricity from neighbouring countries like Indonesia, Viet Nam and Cambodia, based on its 2030 Green Plan. As a result, the share of renewable generation will increase from around 4% in 2022 to 40% by 2035, highlighting the need for enhanced electricity system connectivity to integrate fast-growing renewable energy projects.

In 2022, Singapore announced it will achieve a net-zero economy by 2050. What is unclear, however, is what needs to happen in the near term to meet this target. A net-zero emissions (NZE) path presented in the ASEAN Climate and Energy Project (ACCEPT) indicates that for Singapore's power sector to reach net-zero emissions by 2050, its current gas generation (53 TWh) would need to halve as early as 2040 (26 TWh).

Another path by the International Energy Agency (IEA) in its recent NZE scenario sets out a key milestone of achieving a net-zero power sector by 2045 to achieve economy-wide net zero by 2050.

Based on Ember's calculation, this would mean the share of electricity from gas would drop from 92% in 2022 to 61% by 2035 as renewables are increasingly imported to meet demand. Being on track to net-zero power by 2045 and doubling the target for renewable import capacity from around 4.2 GW to 8.1 GW by 2035 can also reduce 52-58% of Singapore's per-capita power sector emissions by 2035, while also reducing its reliance on imported gas and exposure to energy price shocks.



With its substantial financial resources and positioning, Singapore has the financial muscle to fuel Asia's energy transition, making it well-suited to lead and fund renewable projects in the region. Accelerating renewables and electricity interconnection in the coming decade will not only secure Singapore's clean energy future and improve its energy security but such decisions will also carry implications across the broader Asia-Pacific region.

01 Singapore targets will push share of renewable electricity to 40% (32 TWh) by 2035

Under the Singapore Green Plan 2030, solar generation is set to grow from less than 1 TWh in 2023 to 5.1 TWh in 2035, while renewable imports will reach 26 TWh. However, Singapore needs to double the scale of the planned expansion by 2035 (57 TWh) if Singapore is to align with the IEA's NZE milestone while also meeting growing demand.

02 Up to 16 GW of renewable imports required by 2045 to meet the IEA NZE milestone

The world must reach net-zero power sector emissions by 2045, based on the IEA NZE milestone scenario. To align with this, Singapore must ramp up renewable capacity imports to 8.1 GW by 2035 and further to 16 GW by 2045, as well as maximising its own solar potential of 8.6 GW by 2050.

03 Staying on course to achieve the IEA's net-zero power milestone will help Singapore halve its per capita power sector emissions by 2035

By getting on track to meet the IEA's NZE milestone, Singapore could reduce 52-58% of its per capita power sector emissions by 2035, further decoupling economic growth from emissions. Per capita power sector emissions could drop to 2 tonnes of carbon dioxide (tCO2) in 2035 from around 5 tCO2 in 2022.

"Singapore's energy transition hinges on how fast its Southeast Asian neighbours adopt clean power. By leveraging the country's financial and research strengths, Singapore can secure its clean energy future through regional cooperation in renewable power projects and grid infrastructure."

Dr Yao Lixia
Energy Studies Institute
National University of Singapore

"Singapore could pick up the baton for Southeast Asia's energy transition. By investing in power system connectivity and procuring clean electricity from its neighbours, the country will promote clean energy and facilitate multilateral power trade, allowing renewables resource sharing for a more energy-secure ASEAN."

Dr Dinita Setyawati
Senior Electricity Policy Analyst
Southeast Asia, Ember

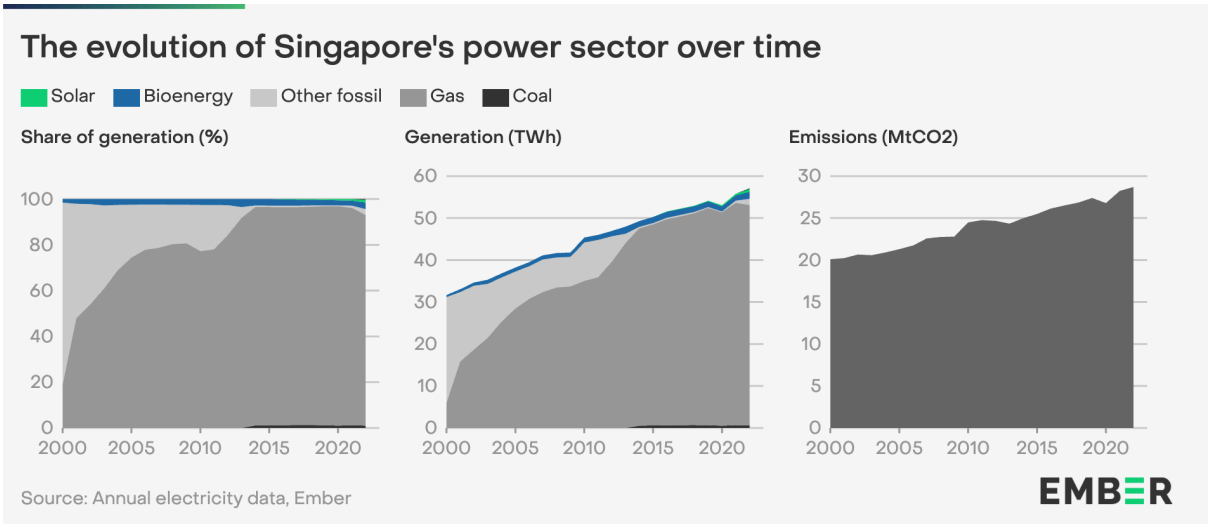
Shifting energy landscape

Singapore's reliance on gas-fueled growth is set to change

The share of renewables will reach 40% of Singapore's electricity generation by 2035, increasing from just 4% in 2022.

Singapore is an advanced city-state with a population of less than 6 million people. With a GDP per capita that is eight times the ASEAN average, Singapore has an increasingly high power demand per capita that is five times the regional average.

Gas generation – which accounts for 90% of Singapore's electricity mix – primarily meets this demand, resulting in growing power sector emissions. Renewables, on the other hand, have not kept up with the rising demand due to Singapore's limited renewable energy sources, land availability and high population density.



Electricity demand is only going to grow

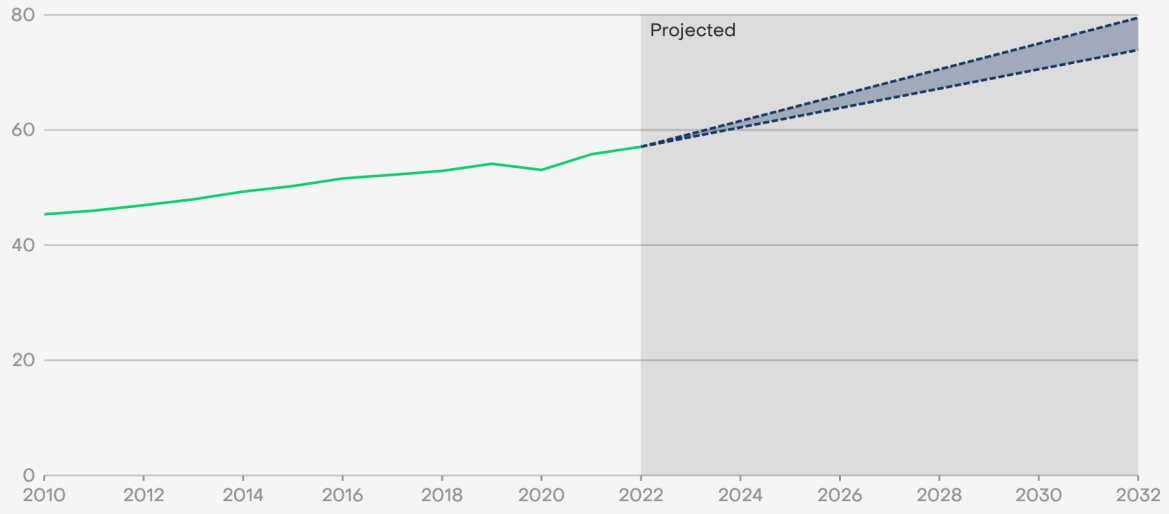
The Electricity Market Authority (EMA) projects that Singapore's electricity demand will grow by an average of between 2.8% and 3.2% every year over the next ten years. Singapore's year-on-year electricity demand grew 5.1% (+2.7 TWh) in 2021 after previously declining in 2020 mainly due to the pandemic. In 2022, the electricity demand increased by 2.4% (+1.3 TWh), as industrial and commercial activities resumed. Overall, electricity demand has grown by 2% on average over the last decade.

Assuming a median 3% average growth rate to 2035 will mean that the country's electricity demand will touch 82 TWh in 2035, up from 55 TWh in 2021 (+49%). The increasing electricity consumption will be driven by economic and population growth as well as demand from new sectors such as the data centre market, which is projected to exceed 1 GW operational capacity in 2024. As of 2022, the industrial and commercial sectors consumed the largest share of electricity at 41% (23 TWh) and 39% (21 TWh), respectively.

With Singapore's expanding energy landscape, additional electricity supply will be needed to secure power for domestic consumption.

Singapore's electricity demand is projected to rise by 30-39% in the next decade

Historical and projected electricity demand (TWh)



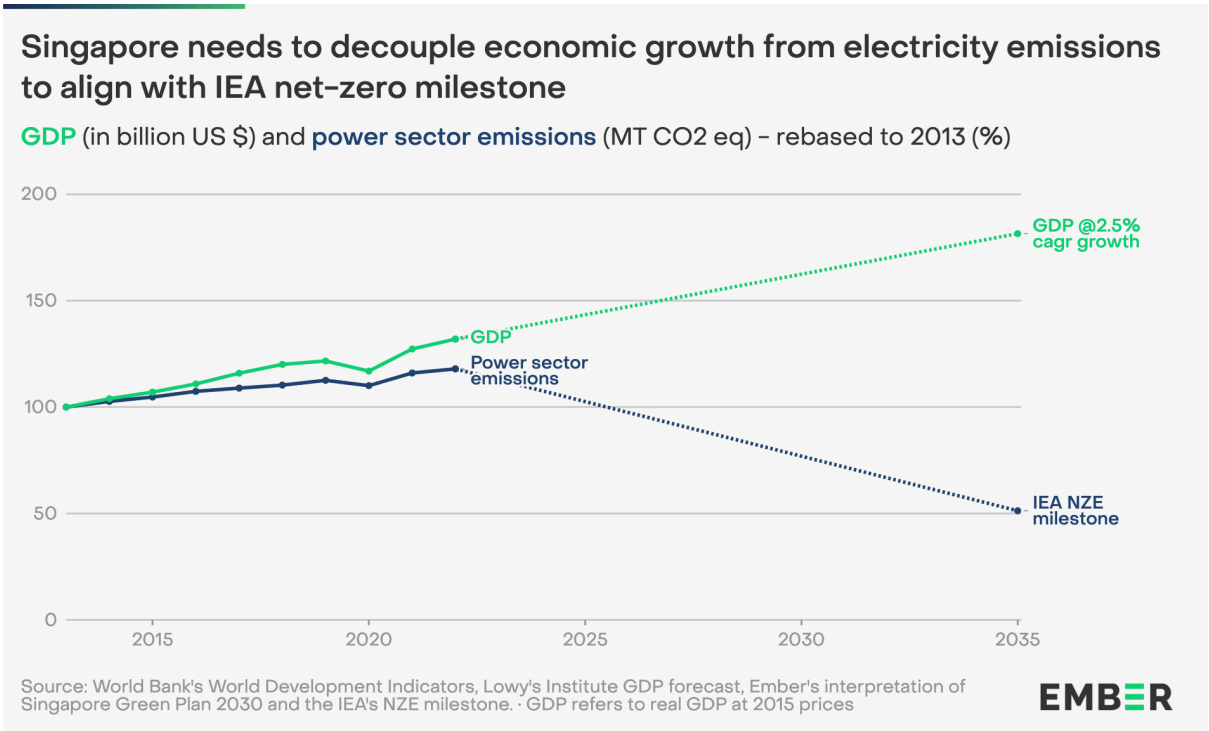
Source: Energy Market Authority (EMA) Statistics, Singapore Electricity Market Outlook (2021)

Decoupling economic growth and power sector emissions could be achieved by ramping up renewables

We found that the year-on-year change in Singapore's GDP is strongly correlated with electricity consumption, and therefore rising emissions, given the country's historic reliance on fossil fuels. Previous studies have also shown the relationship between economic growth and electricity consumption where Singapore's expanding economy has been linked to increasing industrial production in the manufacturing sector and electricity consumption.

Singapore has the opportunity to loosen this linkage by ramping up renewables and energy efficiency to meet rising electricity demand, thereby reducing emissions without compromising economic growth. However, Singapore's only promising domestic renewable

energy option is solar, with a potential of 8.6 GWp by 2050. Due to the country's geography, renewable sources such as offshore and onshore wind are constrained by busy maritime traffic, while hydropower is not viable with the absence of a fast-stream river system.



Solar capacity in Singapore has expanded from just 0.01 GW in 2012 to around 0.6 GW in 2022. However, the country has also continued the trend of switching to fossil gas from other fossil-based power (such as steam plants), with plans to add a Combined Cycle Gas Turbine (CCGT) plant which will ramp up gas capacity to 11 GW by 2028.

Historically, Singapore's power system has relied on gas imports from Malaysia and Indonesia. In 2023, gas made up 92% (53 TWh) of electricity generation, while renewables such as solar met around 2% (0.9 TWh) and bioenergy met almost 3% (1.7 TWh). Meanwhile, only 0.2% (0.1 TWh) of power was imported from the Laos-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP) in 2023.

By relying on gas to meet industrial and commercial needs, Singapore risks a fossil lock-in. This could undermine its emissions reduction efforts as well as locking in dependence on gas imports with their volatile prices. Following a blackout in 2004 and disruptions in fossil

gas supply from Indonesia resulting in spiking electricity prices in 2021, Singapore is continuously seeking alternative energy supplies.

This is reflected in the latest government agenda, which aims to increase the share of renewables to meet Singapore's growing electricity demand, envisioning its future as a renewable energy hub.

In an effort to reduce emissions – Singapore's power sector accounts for about 40% of its total emissions – the government adopted the 'four switches' energy transition policy. The four switches include: increasing efficiency and use of fossil gas as the main source of electricity, deploying 2 GW of solar capacity by 2030, importing up to 4 GW of renewables by 2035 and exploring other clean energy sources like geothermal.

However, with a limited supply of domestic renewable resources, Singapore will need to make use of the renewable potential in neighbouring countries and ramp up energy imports beyond current plans to be on track to meet its net zero by 2050 target.

Singapore Green Plan 2030

Securing Singapore's clean energy future

Regional grids and a diversified renewable imports portfolio are crucial for the country not only to decarbonise its power sector and achieve its net-zero ambitions, but also to improve its energy security

Singapore endorsed the global coal-to-clean power transition statement at the 2021 United Nations Climate Change Conference of Parties (COP26) and the Global Renewables and Energy Efficiency pledge at COP28, together with Brunei Darussalam, Malaysia and Thailand. At the national level, Singapore has plans to improve its energy security and reduce emissions through its 'four switches' policy plan with the end goal of achieving net zero by 2050.

But even if we assume that Singapore completely builds its theoretical solar power potential of 8.6 GW by 2050, this would only be sufficient to generate 15 TWh of electricity (assuming 20% capacity factor) – enough to meet just 12% of the total power demand in 2050. Therefore, the country's net-zero ambitions depend on the success of regional projects to import renewable energy.

While Singapore aims to reach net-zero emissions by 2050, what is unclear is the path the country would need to take, especially in the next one to two decades, to achieve this target. The IEA's global net-zero roadmap provides one path that may provide some indicative answers. In its NZE scenario, the advanced economies in aggregate would need to achieve net-zero electricity by 2035 and emerging markets and developing countries by 2045 to stay on course for net-zero economies by 2050. Under the IEA's classification, Singapore falls under the emerging markets and developing countries category. Further, the IEA's NZE scenario calls for unabated fossil generation to fall by 95% globally by 2040.

Another net-zero emissions path is presented in the ASEAN Climate and Energy Project (ACCEPT), which also requires Singapore to reduce its gas generation (53 TWh in 2023) by half (26 TWh) by as early as 2040.

In both these paths, it is clear that to achieve net-zero emissions by 2050, Singapore would need to import renewable energy from its neighbours to meet electricity demand beyond what its domestic solar capabilities can provide, as demand is set to reach 128 TWh by 2050.

Renewables imports are set to diversify Singapore's power mix and limit over-exposure to gas imports

Under the Singapore Green Plan 2030, the country is set to more than triple solar capacity from 0.6 GW to 2 GW by the end of this decade, reflecting the shifting policy focus to clean energy. With this addition, the share of electricity generated from solar will increase from around 2% (0.9 TWh) in 2023 to 6% (5.1 TWh) by 2035, assuming a 20% capacity factor for solar.

Currently, Singapore is importing up to 100 MW of hydropower from Lao PDR until 2024. The planned two-to-five year extension of this import agreement will raise the total renewables volume to 300 MW. As part of its 'four switches' policy, the government has further approved projects to import 2 GW of renewable energy from Indonesia, 1 GW from Cambodia, and 1.2 GW from Viet Nam by 2035.

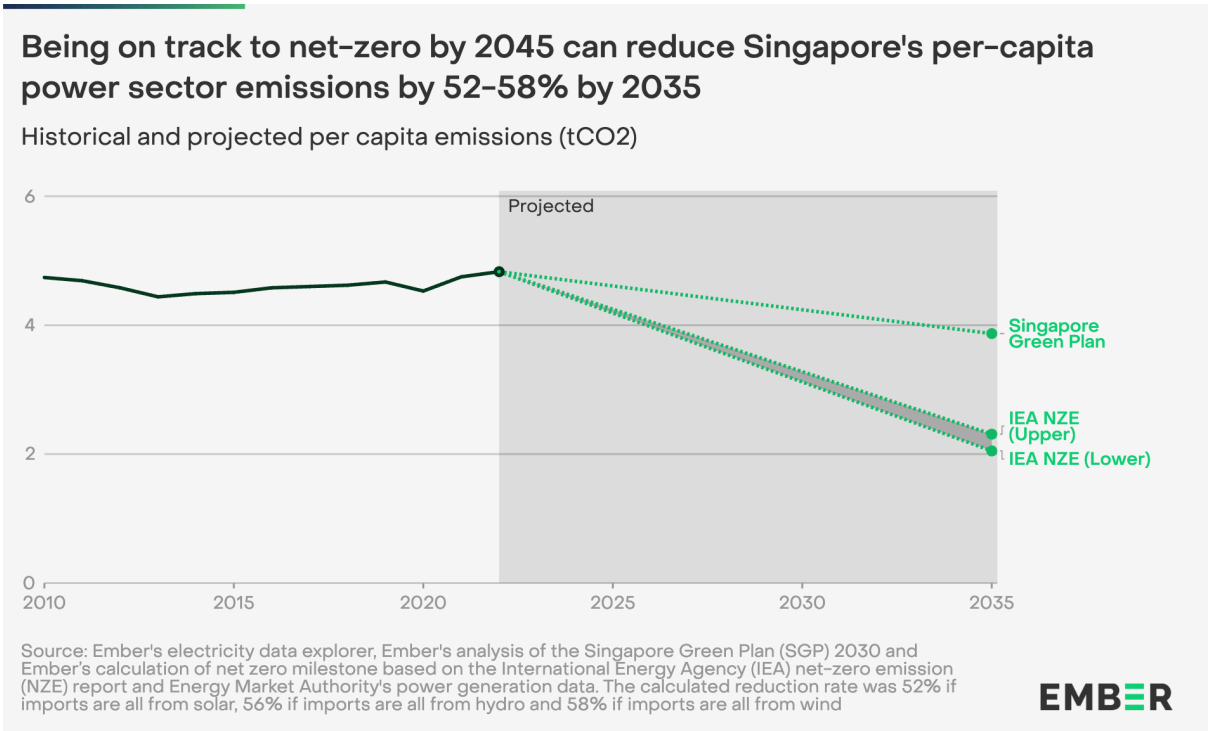
Together, these plans would ensure that domestic solar generates 6% of Singapore's electricity in 2035, growing from less than 1 TWh in 2023 to 5 TWh in 2035, while the combined renewable imports would supply 30% (26 TWh). The overall renewable energy share in the country's power mix is expected to be about 40%. The Economic Development Board of Singapore (EDB) expects the share of gas to fall to about 50% by 2035. This is expected to reduce the country's exposure to gas, and the accompanying price volatility, and provide diversification of energy sources to improve the security of future electricity supply.

Singapore is well-positioned to raise renewable ambitions and build a net-zero power system

To align with the IEA NZE milestones for emerging markets and developing countries and achieve a net-zero power sector by 2045, Ember's estimates show that the share of unabated fossil gas in Singapore's power mix should decline by 60%, from 53 TWh in 2023 to less than a third of electricity generation (25 TWh) in 2035. As coal and oil-fired power plants are completely phased out, renewable imports will generate up to 61% (50 TWh) of power.

Alternatively, under the ASEAN Climate and Energy Project (ACCEPT)'s NZE scenario, electricity demand is forecast to reach 59 TWh in 2035. Aligning with this scenario will require solar's share of power generation to reach 30% by 2035 (18 TWh). Gas will still power more than a third of electricity in 2035 (41 TWh).

A collapse in emissions would be expected under both projections, as renewables increasingly replace gas for electricity generation. For instance, aligning with the IEA's NZE milestone could reduce Singapore's per capita power sector emissions by 52-58% in 2035 – depending on the renewable energy source – which is more than double the 20% estimated drop under existing government plans.



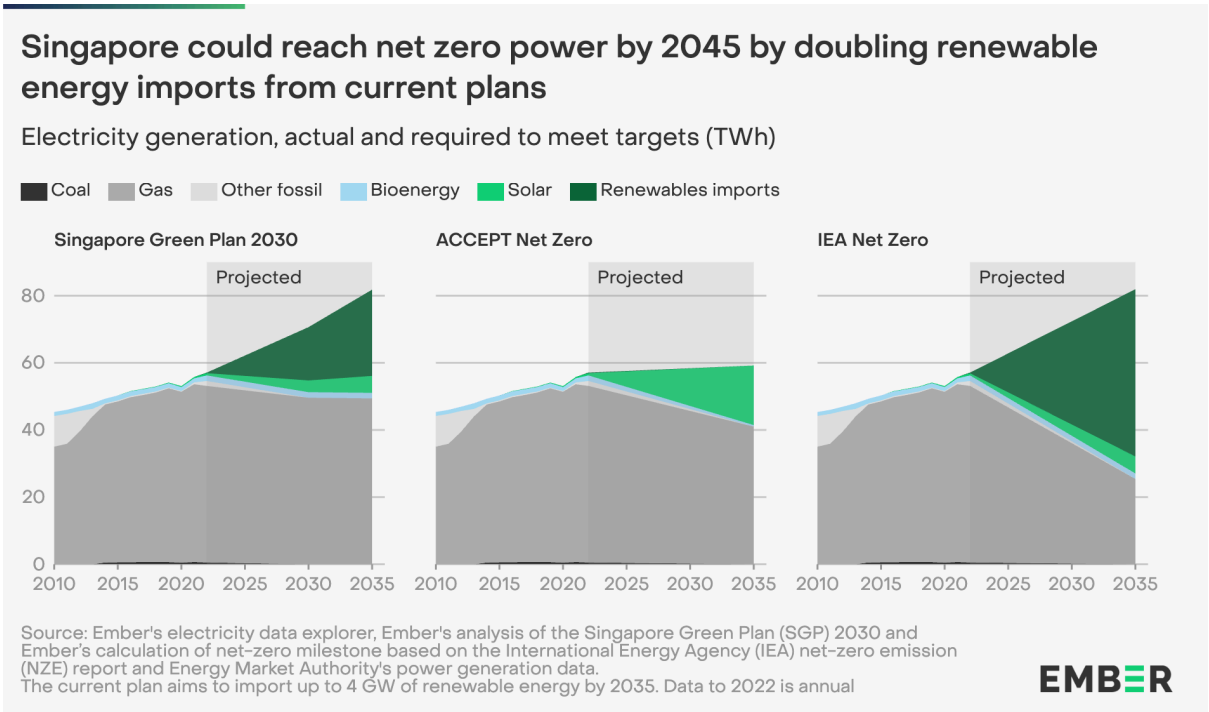
Doubling renewable imports required to accelerate net-zero ambitions

The volatile market conditions for gas have brought challenges for electricity retailers in Singapore, pressuring regulators to hedge the risk against future price volatility. The cost to meet total household electricity demand between 2022 and 2035 could reach $1.7 billion USD based on hedged electricity prices, according to our conservative estimates.

Singapore can therefore turn to cleaner alternative sources of energy, such as imported solar, which could be as low as 13.5 USD cents/kWh. This is significantly lower than its electricity tariff of around 22.4 USD cents/kWh and the cost of domestic electricity production of around 19.4 USD cents/kWh. As both ACCEPT and the IEA's scenarios include tapping Singapore's maximum solar potential of 8.6 GW by 2050, renewable energy imports will need to ramp up to meet the net-zero scenarios.

By setting more ambitious renewable import policies, Singapore has an opportunity to secure its energy future by reducing reliance on gas, and reach its climate targets sooner.

Given the lower cost of renewable energy, Singapore could benefit from fixed tariffs and energy price certainty by doubling energy imports, from 4.5 GW to 8.1 GW by 2035, and further expanding to 15.9 GW by 2045.



A way forward

Accelerating Singapore's energy transition can bring benefits to the entire region

The city-state can not only secure its clean energy future but also accelerate Southeast Asia's energy transition through renewable energy investments, grid interconnections and pioneering market instruments.

For Singapore, cementing renewable imports is key to securing climate commitment and building on multilateral power trade, which encourages investment in clean energy. This is on top of initiatives that Singapore has already taken in the carbon markets and to support the Glasgow Financial Alliance for Net Zero (GFANZ) Asia Pacific Network, which engages with financial institutions to establish net-zero transition plans.

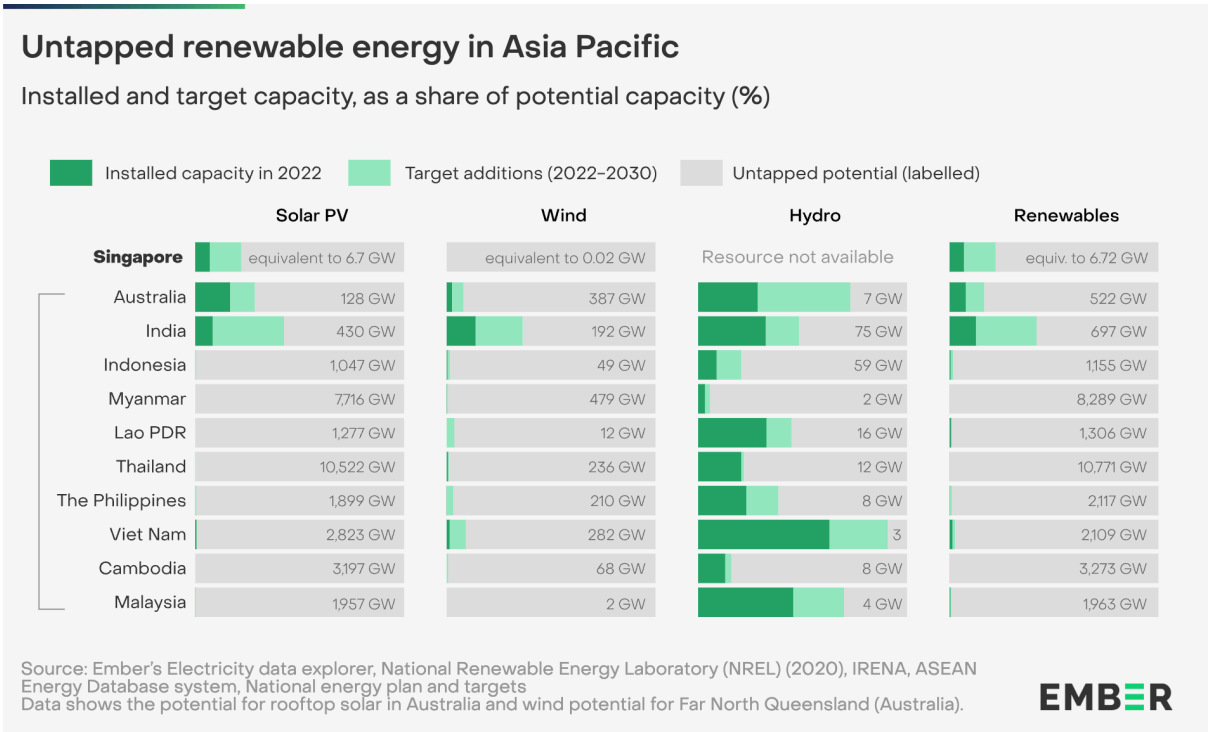
On the research and development front, Singapore has been investing in solar energy research in Southeast Asia. Notable investments include $4.6 million USD in research grants for solar power forecasting in 2017 and $57.4 million USD for solar cell research in 2023, reflecting its commitment to accelerating the region's clean power transition.

Given Singapore's limited renewable energy potential, investing in renewable energy power development projects in other countries with abundant renewable potential would also enable the country to secure the renewable electricity needed to accelerate its own transition.

There is massive untapped renewable energy potential across Southeast Asia and Singapore can potentially accelerate the region's transition to clean electricity through its regional power grid projects. If the grid interconnection plan allowing power trade between Singapore, India and UAE materialises, Singapore would gain access to India's renewable energy

resources and its growing renewable energy sector. Therefore, in facilitating these projects, Singapore can play a wider role in the respective transitions to clean power of countries in Southeast Asia and beyond.

While investing in other markets presents unique challenges, Singapore has the financial leverage to explore its neighbours' robust renewables potential. Through clean energy finance, Singapore can unlock a range of benefits, including competitive renewable energy costs, energy security and mitigation of climate change risks.



Diversifying renewable investments can accelerate the energy transition of Singapore and its neighbours

Singapore stands to benefit from acquiring energy pricing variation and security by shifting its investment portfolio from fossil fuels to renewables, as well as diversifying its target geographies.

With the diverse market structures across Asia Pacific, Singapore can consider multiple routes to becoming a renewable energy project sponsor. One of the recent examples taken by developers from Singapore is investing in countries that allow 100% foreign ownership. Another example is the $5 billion USD investment to build a 3.5 GW solar power plant in Indonesia that will export all of its generated electricity to Singapore.

To achieve the theoretical milestone where 14 GW of wind and 17 GW of solar are imported, an estimated investment of $51-66 billion USD would be required. This budget would cover the construction and operation of wind and solar power facilities, which would be broken down into smaller, manageable projects. If Singapore decides to solely import wind, an investment of $64-100 billion USD would be needed to acquire 36 GW from onshore and offshore farms. On the other hand, an exclusive solar energy strategy would cost $40 billion USD to set up and run solar power plants of 28 GW capacity, based on a calculation in Indonesia. It is important to note that the investment costs may vary depending on the location of the projects.

This kind of investment suggests multiple benefits, including the much-needed cuts in emissions and lower total energy system costs from renewables that are becoming more cost competitive compared with fossils.

Regional grid interconnection is crucial to Singapore's energy security

A key enabler to support Singapore's renewable energy offtake is grid interconnection. Currently, the energy integration in Southeast Asia remains at a nascent stage, and needs to be developed at a faster pace.

The first multilateral power integration project in Southeast Asia, the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP) only commenced in 2022, after years of negotiations. Under this plan, Singapore is importing 100 MW of hydropower from Lao PDR until 2024, by which time a longer contract will be negotiated. Other plans are underway (or in a negotiation phase), including the Brunei Darussalam-Indonesia-Malaysia-Philippines Power Integration Project (BIMP-PIP) and a cross-border solar project involving Australia, Indonesia and Singapore.

As a signatory to the International Solar Alliance (ISA), Singapore is bringing more opportunities for solar cooperation and expansion of grid interconnection under the One World, One Sun, One Grid (OWOSOG) initiative with India and other ISA members.

Being mindful of the high costs associated with developing energy infrastructure, with an estimated $200 billion USD needed to upgrade Southeast Asia's grid infrastructure by 2030, Singapore is well-placed to spearhead the necessary regional collective effort.

The LTMS-PIP demonstrated the importance of securing intergovernmental agreements, the political will and the wheeling charge consensus for future projects involving on-land and undersea transmissions. All in all, grid interconnections allow renewable energy resources to be distributed evenly, spreading the economic and security benefits of energy access at the regional level. But most importantly, it will also secure Singapore's access to energy against future uncertainties.

Progressing towards net zero

Singapore's energy landscape hinges on historical energy dependencies, ultimately leading to energy security concerns. By boosting renewable energy imports and their integration, Singapore can benefit from improving its energy resilience and securing a clean energy future.

To achieve Singapore's ambitious sustainability goals, channelling funds from both the private and public sectors is crucial for financing renewable energy initiatives and grid upgrades. Investment challenges range from a shortage of feasible projects to regulatory barriers and fluctuating market conditions, like increasing interest rates. However, easing of policies and processes may attract new investments in clean energy and make renewable energy projects competitive for private capital. Simultaneously, international partnerships (such as GFANZ), net-zero emissions targets and laws open new pathways and are the building blocks for pouring public and private investment into renewable energy.

The decisions made by Singapore in the coming decade carry implications not only for its own future but also for the broader region's journey towards a cleaner transition. With its substantial resources and positioning, Singapore has the opportunity and the financial muscle to fuel Asia's clean transition and lead renewable expansion projects across the region.

Supporting Materials

Implications

In the IEA's NZE scenario, the global electricity sector reaches net-zero emissions in aggregate by 2045. The scenario also proposes that advanced economies take the lead and reach net-zero emissions by around 2045 in aggregate.

In our calculation, we evaluate different decarbonisation paths available publicly for Singapore aimed at achieving net-zero power sector emissions by 2045. It is to be noted that these are only indicative paths as there are numerous uncertainties to consider, particularly regarding the timeframe required to advance electricity interconnection in the region.

This analysis aims to provide information to policymakers in the region and beyond on potential approaches to fulfil country-level ambitions to achieve net-zero emissions in the long term.

Methodology

Per capita power sector emissions

We calculated per capita power sector emissions using annual population data from the United Nations and the projected population growth for Singapore in 2030 (6.9 million). The emissions generated from different fuel types were calculated by multiplying generation numbers by emissions factors taken from the IPCC 5th Assessment Report Annex 3 (2014). Then, total emission numbers were divided by the population data for a given year.

Electricity mix projection

Projected emissions for 2030 and 2035 were calculated using electricity demand growth of 3% and the energy sources generation breakdown based on Singapore's Green Plan 2030: solar capacity up to 2 GWp, switch other fossil fuels to gas and imports of low-carbon electricity. This report applies the solar photovoltaic capacity factor of 20% based on this study. Capacity for Combined Cycle Gas Turbine (CCGT) plants is calculated to be 85%,

according to a paper published by ETH Zurich and an IEA report. Emissions factor for CCGT plans is calculated to be 508.21(gCO2eq/kWh) according to Ember's electricity data explorer.

Investment costs

The investment cost for gas contracts is calculated based on the capital cost component assumption of CCGT plants, variable non fuel costs, carbon price and fuel cost from the strike price for gas of $10.025 USD mmBTU in Q1 2024 in the Japan Korea Marker Spot Market. Carbon price is calculated based on the average carbon tax rates introduced by the National Environmental Agency Singapore, at $50 SGD per tonne, between 2024 and 2030. The exchange rate used was from 17 Jan 2024, where $1 USD = $1.34 SGD.

The investment cost for solar projects is estimated at the cost of the project in Riau island, Indonesia. The investment for offshore and onshore wind projects is calculated based on preliminary financing, development financing and operational costs, in accordance with the guidelines published by the Wind Energy Investment Guidelines for Viet Nam.

IEA's net-zero emissions milestone

The power mix breakdown for the International Energy Agency's (IEA) net-zero emissions milestone is calculated using the annual electricity demand growth forecast of 3%. We also project gas and other fossil fuels reaching zero generation by 2045 with average annual generation reduction of 2.3 TWh between 2022 and 2045 and solar capacity reaching 8.6 GW in 2050. The capacity factor for solar generation is calculated to be 20%.

We calculate the capacity needed to generate 50 TWh of electricity in 2035 to be 8.1 GW by using 70.08% capacity factor. This capacity factor is assumed from the EMA plans to import up to 4 GW of renewables by 2035, which translates to 30% renewables electricity share, or 25 TWh.

ACCEPT's 2050 net-zero emissions scenario

The power mix breakdown for ACCEPT's 2050 net-zero emissions scenario is obtained from a study written by Handayani et. al (2022) financed by the ASEAN Climate and Energy Project (ACCEPT).

Acknowledgements

With thanks to Dr Yao Lixia from Energy Studies Institute, National University of Singapore, for her review. The contributions of Richard Black, Dody Setiawan and Neshwin Rodrigues in peer reviewing, along with the key roles played by Uni Lee in data validation, and the invaluable efforts of Chelsea Bruce-Lockhart in data visualisation have significantly shaped the outcome of this work. Rosamond Hutt and Ardhi Arsala Rahmani's editing and structural enhancements were also crucial in the development of this report.

Cover image

Solar panels with cityscape of Singapore
Credit: Zoonar GmbH / Alamy Stock Photo