GENRAY REFLECTION

Our views on Renewables & Power News

The Singapore Story

THE PRACTICAL EXTENT OF SOLAR RENEWABLE ENERGY

And The Role Of Natural Gas In The Energy Transition

7 June 2021

Artist impression of the upcoming 60MWp floating solar system on Tengah Reservoir. (Photo: PUB/Sembcorp)

On the occasion of the commissioning of Sembcorp's new Tengah Floating Solar Farm in Singapore, Genesis Ray's CEO, Irfan Choudhry takes a holistic look at Singapore's power market, the reality of the enduring and significant role of natural gas and the practical and technical use of solar as a resource.

On 17th May 2021, Sembcorp, together with The Public Utilities Board (PUB), announced with significant fanfare the recently commissioned 60MWp (MW Peak) floating solar power project, the "**Tengah Floating Solar Farm**". Covering approximately 45 hectares of the Tengah Reservoir in western part of Singapore, the project may not be large but is a significant vector for future development and as a showcase project for Singapore's energy sector.

Floating solar makes strategic sense for Singapore. Singapore has been historically dependent on Malaysia for its supply of freshwater. Since its independence in 1965, the Government has made significant attempts to increase self-reliance with the creation of multiple inland reservoirs to store rainwater. Today, these freshwater reservoirs cover approximately 30 square kilometers or about 4% of the land area of the country.

Though many of the reservoirs are used extensively for recreational purposes, some of the largest ones have restrictions of use or limitations on access to public.

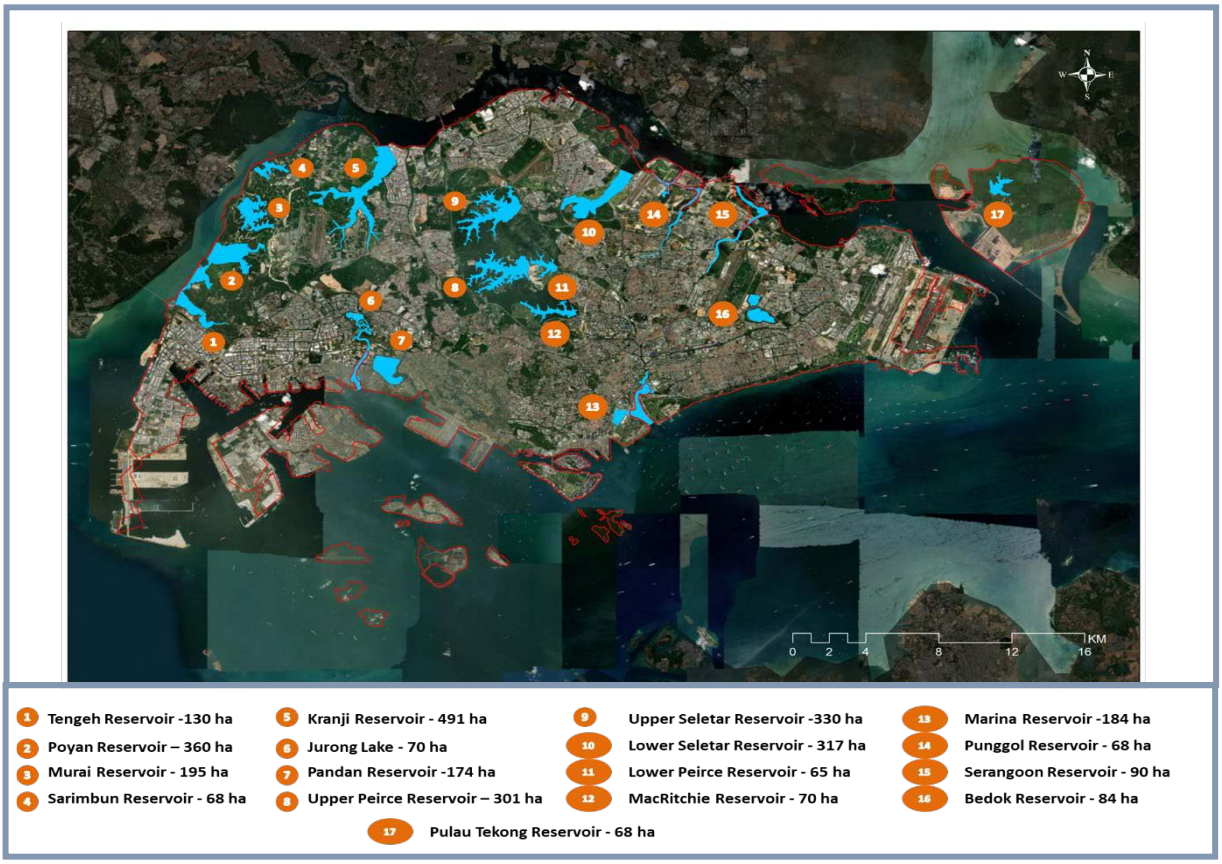

Fig 1: Reservoirs in Singapore
Source: Genesis Ray

The seven largest reservoirs with limited public access (Poyan, Murai, Sarimbun, Kranji, Upper Pierce, Upper Seletar and Pandan) alone cover approximately 20 square kilometers. Covering just a third of the area of these reservoirs with floating solar farms can easily yield another 500 to 600MWp of new capacity.

Apart from the inland reservoirs, shallow coastal areas around Singapore can provide additional areas for the development of floating solar farms. These areas, primarily in the north and eastern parts of the country have limited use for navigation purposes and thus easily available for development of floating energy projects.

A 5 MWp floating solar farm by the local developer Sunseap already exists in the Straits of Johor overlooking downtown Johor Bahru, a major city in southern Malaysia. These coastal waters can easily accommodate another 300 to 500MWp of new floating solar capacity.

Source: Sunseap.com

HOW ACHIEVABLE ARE THE TARGETS UNDER THE SINGAPORE GREEN PLAN 2030?

In February 2021, Singapore unveiled the Singapore Green Plan 2030, a roadmap to the adoption of a more sustainable growth for the next 10 years. The Green Plan has targets for different sectors of the economy, including Energy generation. There is a solar energy target of 1,500 MWp by 2025 and 2,000 MWp by 2030. At close to 500 MWp solar energy capacity today, spread across rooftop and floating solar, there is a need to add about 1.5GWp of new solar capacity by 2030. Floating solar facilities such as Tengah can fill this gap easily. The Tengah project was commissioned within six months, despite the constraints of the ongoing Covid-19 pandemic. Rooftop solar installations take even less time.

With sufficient reservoir and coastal areas available, building another 0.8 to 1.1GWp of floating solar capacity would not be difficult. A similar capacity can be added from rooftop solar on public buildings or temporary vacant lands. Whether it is the public housing rooftops or floating farms on the reservoirs, government has exclusive purview over their use, thus limiting any land acquisition related issues. Therefore, despite being a land constrained nation, Singapore can not only easily achieve the 2030 solar energy target but can exceed that much earlier with ease.

WHAT DOES THE SINGAPORE POWER GRID LOOK LIKE?

Below is the half hourly power demand and supply for the Singapore power grid on 12 May 2021. With no major seasonal variations, this is how a typical day looks for any time of the year in Singapore. Currently, the country has a total capacity of 9.9 GW for base-load gas fired power plants connected to the grid, comprising 7.3 GW Combined Cycle Gas Turbine (CCGT) and another 2.6 GW of CCGTs run in co-generation mode. This is apart from about 260 MW capacity of waste-to-energy Steam Turbines (ST) running almost continuously and another 750 MW of gas fired Gas Turbines (GT) that are rarely dispatched. The System Peak Demand rarely exceeds 7 GW on any given day and has remained so for the past few years due to limited growth in power demand.

On a typical day, solar generation currently makes an almost negligible contribution to the overall energy mix, with natural gas fired CCGTs or Cogen plants contributing to almost 98 per cent of the system power supply.

Gas-fired power generation capacity is highly flexible and ideal for Singapore, a small nation with no other alternative sources of energy and having a power grid that is almost completely independent of its neighbours.

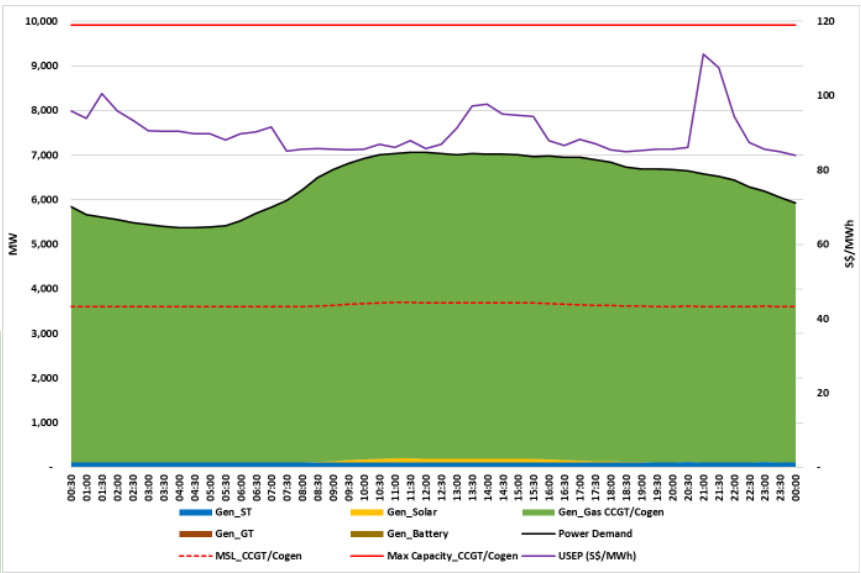

Fig 2: Singapore Power Demand and Supply mix, Wholesale Electricity Prices (May 12, 2021)
Source: Energy Market Company, Singapore

Minimum Stable Load (MSL) defines the level to which a plant can be turned down while it is still running. This allows continuous operations of base-load power plants, while still providing flexibility to meet sudden variations in power demand.

The low MSL levels for natural gas fired power plants ensures that high levels of system reliability can be achieved without the need to constantly switch on and off power plants, which would have an impact on their overall efficiency.

Further, the options available around the supply of natural gas – whether through pipelines from Indonesia and Malaysia or as LNG from across the world, add significantly to fuel flexibility and energy security.

This grid flexibility is also very useful when absorbing intermittent sources of energy such as solar without compromising on high system reliability.

As can be seen from the above chart, battery storage is not a viable option today as average wholesale power prices (represented by USEP) hover around the S$90-100 per MWh range, far below the current battery storage costs.

Thus, it is far cheaper to generate electricity from gas-fired power plants and provide grid balancing to the solar energy intermittency than building large grid scale battery storage facilities.

WILL ACHIEVING THE GREEN PLAN 2030 SOLAR ENERGY TARGETS MOVE THE NEEDLE IN FAVOUR OF RENEWABLE ENERGY FOR SINGAPORE?

Singapore is a relatively mature power market, growing at about 1.7% p.a. over the past 10 years, which is much lower than many of its peers in the Asia Pacific region that are yet to achieve high level of electrification. Being a gas dominant power sector today, will the 2GWp solar energy capacity in 2030 significantly change the energy mix scenario for Singapore?

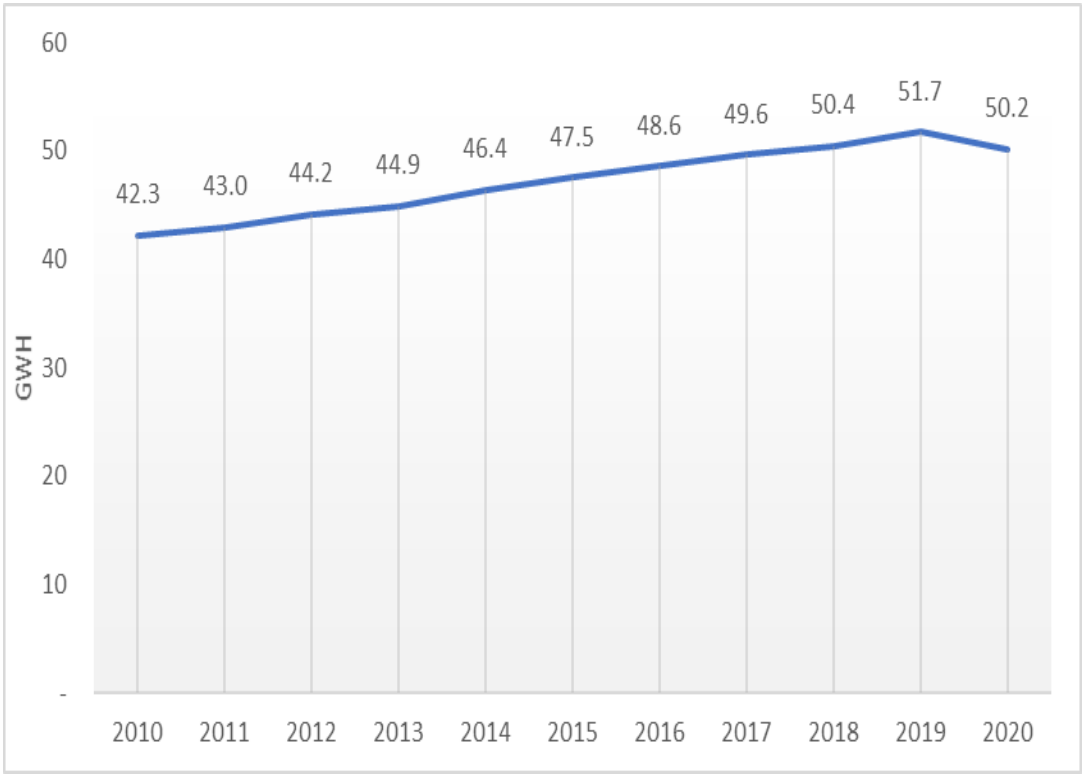

Fig 3: Historical Annual Power Consumption in Singapore (GWh)
Source: Energy Market Authority, Singapore

To answer these questions, let us understand a little more about solar energy and how it affects the overall grid stability, thus highlighting the requirement of a portfolio of fuel and technology solutions.

The chart below shows a typical daily profile for **Global Horizontal Irradiation (GHI)**, created for Singapore based on the last 20 years data from European Space Agency (ESA). Global Horizontal Irradiation (GHI), as defined by World Bank ESMAP program, is the sum of direct and diffuse solar radiation received on a horizontal plane.

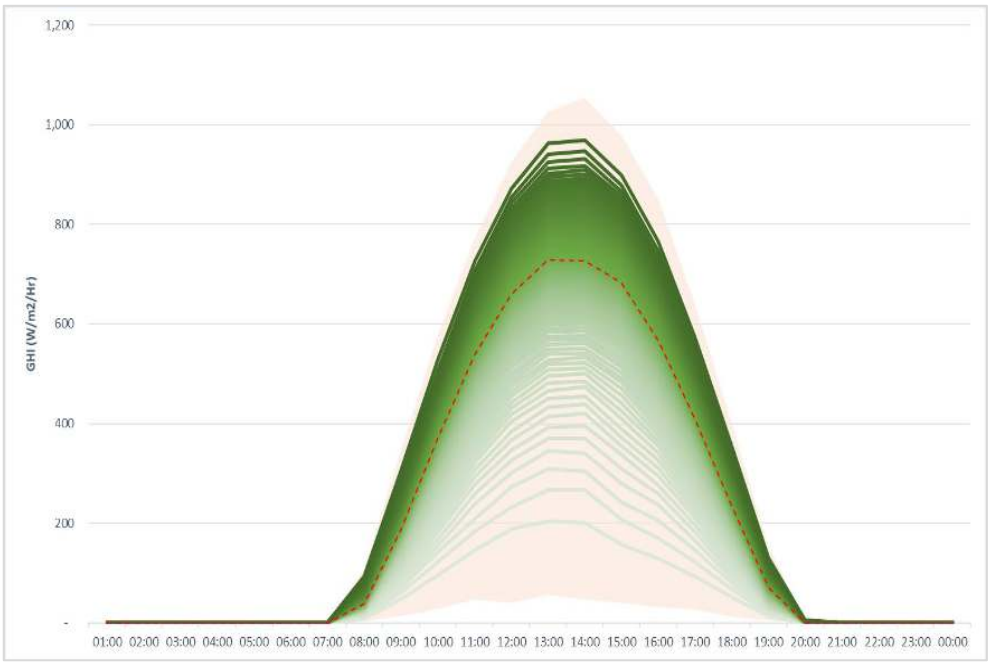

Fig 4: Global Horizontal Irradiation (GHI) for Singapore, Typical Day Profiles from 20-year data, Source: Genesis Ray Analysis, European Space Agency

GHI helps interpret solar radiation across regions. Formally, GHI is a reference radiation for the comparison of climatic zones and is an essential parameter for calculation of radiation on a flat plate collector. In our analysis, half-hourly profiles at different Probability of Exceedance (PoE) ranging from 1% to 99% i.e., P1 to P99 were created and represented by green lines. The maximum and minimum GHI values for any given hour over the past 20 years were reflected in the light orange shaded area.

The P50 profile, reflecting a GHI profile with at least 50 percent likelihood of occurrence is shown in the dotted red line. It is quite evident that solar irradiation, even for a country like Singapore that is located right on the Equator, is far from being predictable. Singapore has high level of cloud cover for most of the year with very high levels of humidity along with temperatures that rarely exceed 33 to 34 degrees centigrade.

Though a P50 GHI profile is a good representation of the average solar irradiation profile for a location, it is obvious that there would be many days when the irradiation levels will be much higher or lower. This intermittency or unpredictability requires an almost instantaneous availability of alternate generation sources that can balance the grid on a real time basis.

To convert these solar irradiation profiles to power generation, we considered a 10MWp power plant using PV module technology from a leading module manufacturer.

The chart below shows the generation of the plant for Singapore's typical ambient conditions, considering a P50 and P90 (a more conservative) profile. For comparison, we also considered the same GHI profiles but at ambient conditions for the Bhadala Solar Park in Rajasthan, India. Bhadala Solar farm, at over 2.2 GW capacity, is one of the largest single location solar farms. The hot and dry desert conditions result in temperatures in May that exceed 45 degrees centigrade, with almost negligible humidity and cloud cover.

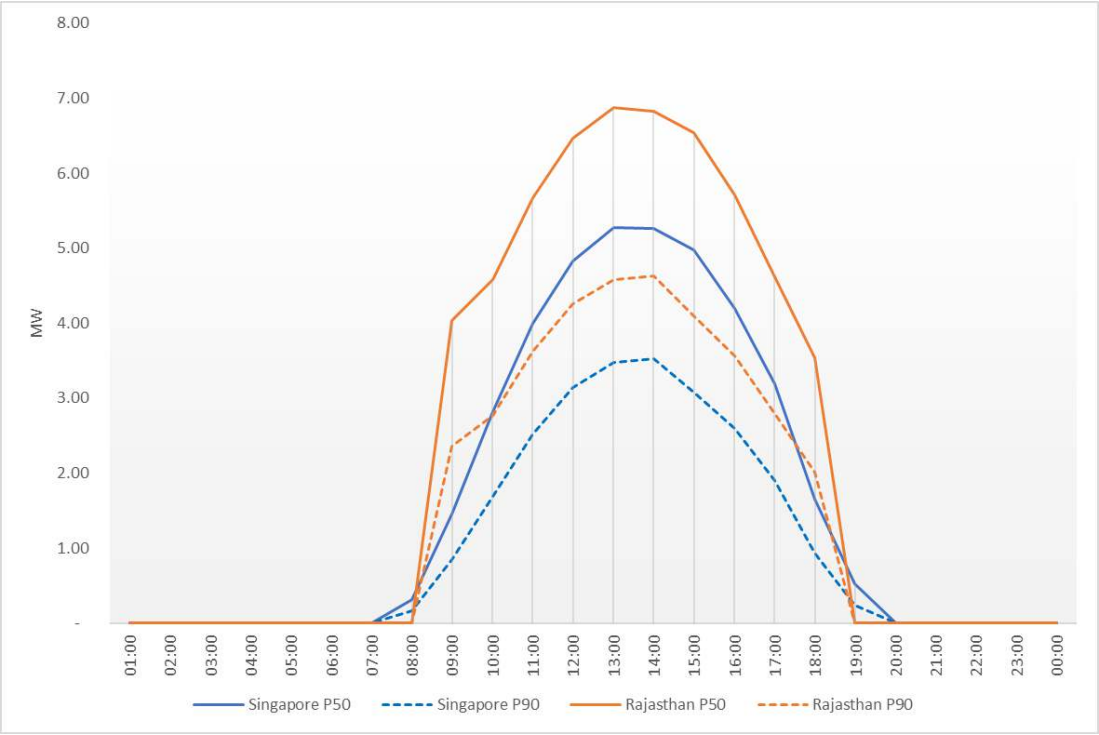

Fig 5: Power Generation from a 10MWp PV Solar Farm in Singapore and Bhadla, Rajasthan at P50 and P90 GHI Profiles , Source: Genesis Ray Analysis

As can be seen from above, higher temperature, low humidity and no cloud cover would result in higher generation output from the same modules and at the same GHI profile. Another observation is that at a P50 profile, a solar energy plant in Singapore would typically not achieve more than 55-60% of the peak generation capacity of the modules. Thus, a 2GWp capacity would at best be able to contribute to no more than 1.1 to 1.2 GW to the grid during peak hours.

Coming back to the Singapore Green Plan 2030; we can imagine a likely scenario for the power sector in 2030, where power demand continues to grow at 1.7% p.a. while a conservative supply scenario considers no power capacity increase.

Even with a 2GWp solar capacity by 2030, solar may not contribute more than 4% to 5% to the total energy mix.

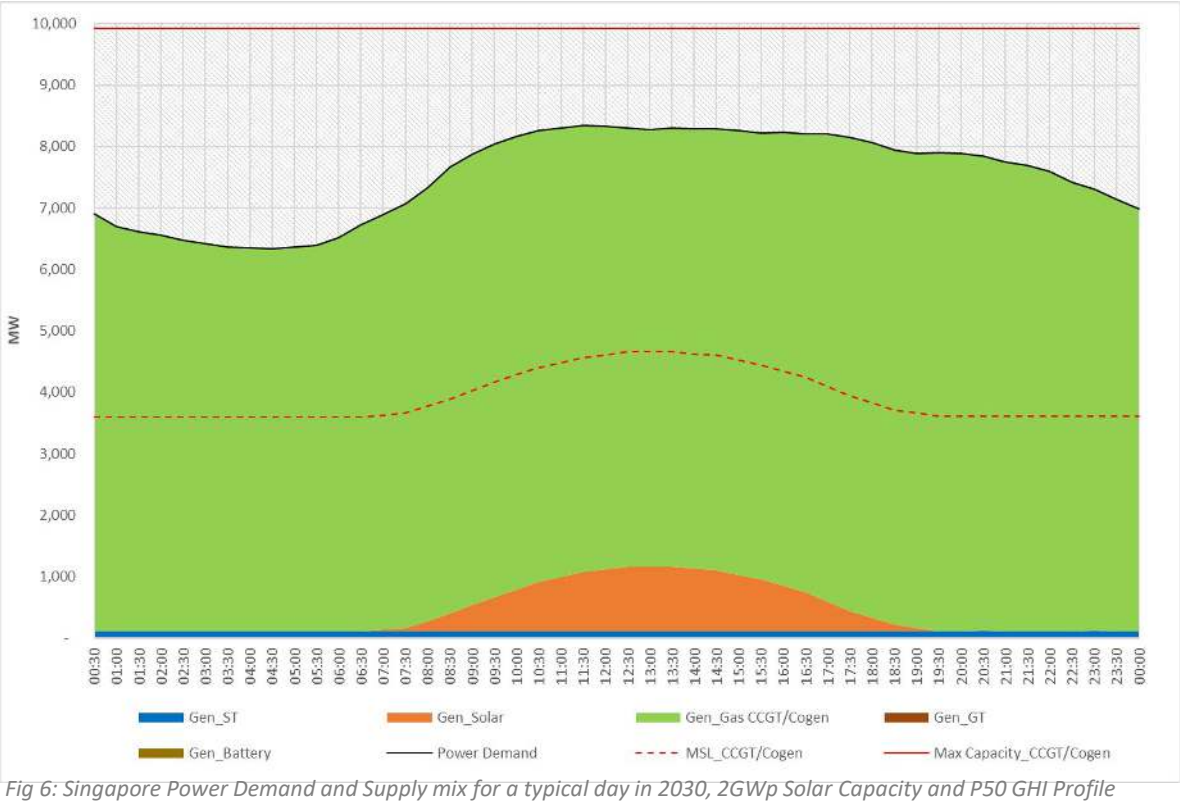

Fig 6: Singapore Power Demand and Supply mix for a typical day in 2030, 2GWp Solar Capacity and P50 GHI Profile
Source: Genesis Ray Analysis

The intermittency of the solar generation can easily be absorbed by the flexibility of the gas fired generation capacity in the country.

IS A 100 PERCENT RENEWABLE ENERGY SCENARIO FEASIBLE FOR SINGAPORE?

With a clear understanding that the achievement of the Singapore Green Plan 2030 is unlikely to significantly move the needle in favour of renewable energy, the next plausible question is whether a 100 percent renewable energy world is indeed feasible, or even desirable, for Singapore. To test this hypothesis, Genesis Ray's team created two hypothetical scenarios for 2030. These scenarios considered the power demand forecast from the previous section and an assumption of solar energy as an exclusive generation source, apart from Waste-to-Energy projects. One scenario considered the need for solar generation and battery storage capacity considering a P50 GHI profile while the other scenario considered the same for a P90 GHI profile.

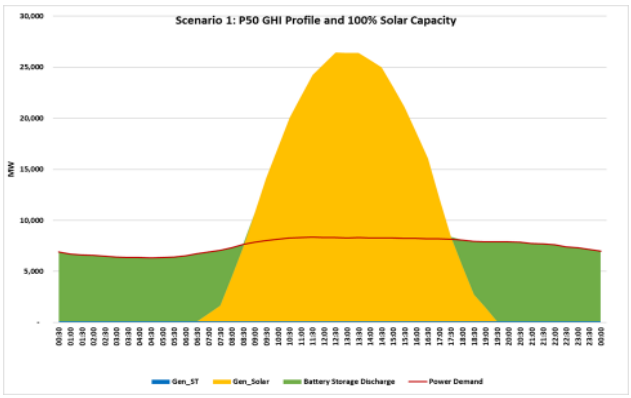

Fig 7: Singapore Power Demand and Supply mix for a typical day in 2030, 100% Solar Capacity and P50 GHI Profile
Source: Genesis Ray Analysis

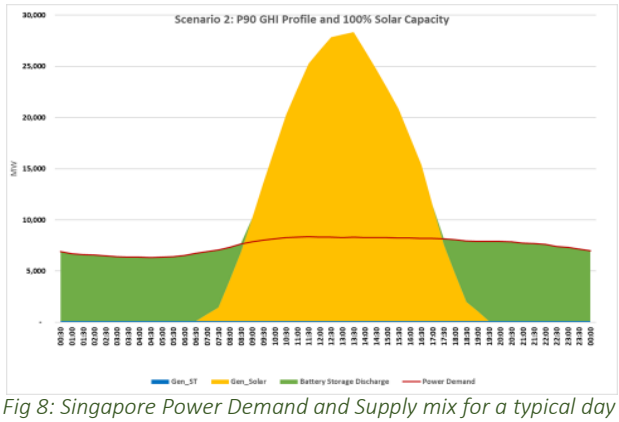

Fig 8: Singapore Power Demand and Supply mix for a typical day in 2030, 100% Solar Capacity and P90 GHI Profile
Source: Genesis Ray Analysis

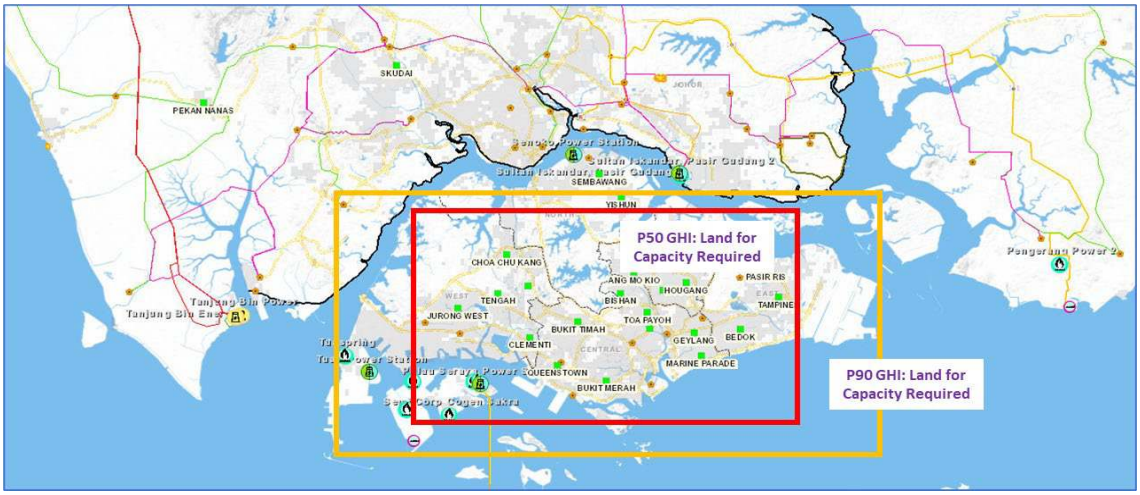

Fig 9: Land Requirement for 100% Solar Capacity Scenarios at P50 and P90 GHI Profiles
Source: GenRay EXPLORER™

To achieve a 100 percent renewable energy scenario, Singapore would need approximately 50GWp solar capacity for a P50 profile and an 80GWp solar capacity for a P90 profile, covering almost every square inch of the land and maritime area of the company. This is clearly not a feasible scenario. This is not even a desirable scenario, as this would require a Battery Storage capacity of almost 190,000 MWh to balance the grid; a size that is 150 times the size of Moss Landing Energy Storage Facility in California (1,200 MWh), currently the largest such facility in the world. Even then, some amount of flexible generation capacity such as gas-fired turbines may be required for those unusually cloudy days.

WHAT ARE THE KEY TAKEAWAYS?

There is an urgent need to increase the share of renewables in the energy mix, not only for Singapore but also for countries across the world, to decrease their reliance on fossil fuels and reduce their overall carbon emissions from the power sector.

Singapore Green Plan 2030 is a realistic attempt in this direction. Though more aggressive targets for renewable energy may be set, a 100 percent renewable energy world is simply not feasible or even desirable considering the current portfolio of commercially feasible renewable energy options. Natural gas must play a dominant role in this energy transition story, providing the much-needed grid stability, reliability, and economic sustainability. As technologies such as Green Hydrogen become more commercially feasible, not only locally but also in other locations considering it can be transported over long distance to where Green Hydrogen cannot be produced, the true transition to a complete renewable energy world would slowly start to take shape. Until then, natural gas and LNG are the best bets to balance the grids and keep the lights on in a predictable manner.

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