System Value Analysis
BRUNEI DARUSSALAM

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Accenture Strategy & Consulting

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01
EXECUTIVE SUMMARY

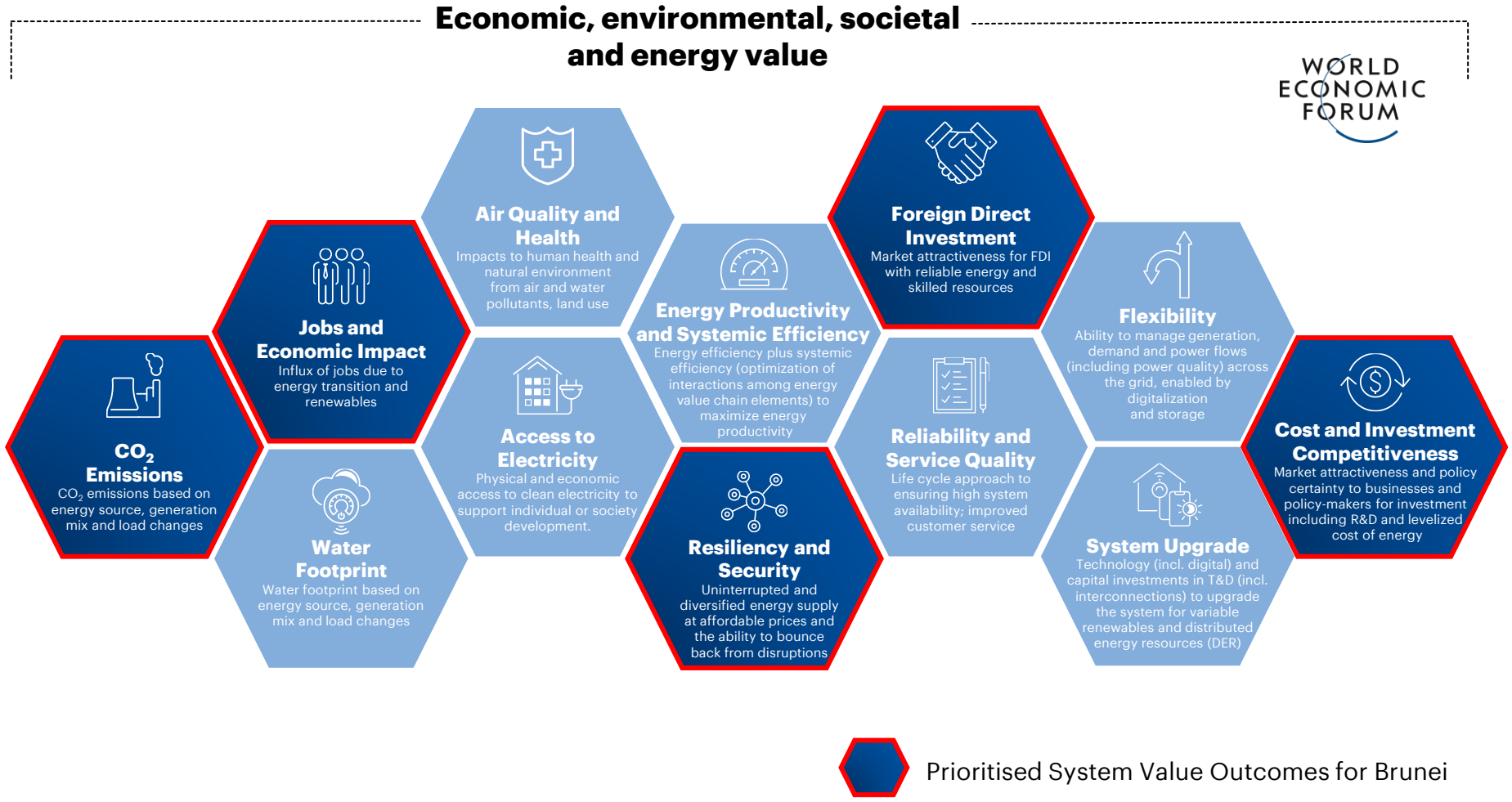
System Value Analysis | Focus Areas for Brunei

The System Value framework more holistically evaluates economic, environmental, social and technical outcomes of potential energy solutions across markets. The framework aims to shift political and commercial focus beyond cost to include value.

Each of these key dimensions represent **an outcome that delivers value to society or the energy system** (e.g. jobs & economic impact, system flexibility).

The framework considers both quantitative and qualitative outcomes.

Key dimensions for Brunei have been prioritised based on current market dynamics and relative maturity of transition towards an integrated energy system delivering net-zero GHG emissions.



Brunei Darussalam Market Analysis | Executive Summary

30% Target Renewables by capacity in the Electricity mix by 2035, to be majorly fulfilled by Solar PV

99% Share of Electricity generation from Natural Gas, followed by ~1% from Oil and less than ~0.5% from Solar as of 2019

50% Target reduction in 2035 BAU emissions estimated at 30.2 MT. Net Zero emissions targeted by 2050

4.8GW Estimated total Solar PV potential in Brunei across Floating, Rooftop and Ground-mounted Solar PV

39% Share of Power Sector emissions in Brunei's total emissions in 2019 followed by other industrial combustion and transport system

33% Share of industrial combustion excluding the Power Sector in Brunei's total CO2 emissions in 2019

0.08Mt Brunei's potential Green H2 production using identified 2.3 GW floating solar PV potential

8.2 Mt Brunei's estimated hard-to-abate emissions in 2035 from Natural Gas Processing, Ammonia Production, Power Generation and Cement manufacturing

60% Electric vehicles (EVs) sales target by 2035

92% Share of privately owned cars in Brunei's transportation ecosystem with very limited uptake of public transport.

Four Solutions for Brunei's Energy Transition

1
Distributed Solar

Given land constraints in Brunei, distributed solar could be an effective way to increase the country's Solar PV capacity. The business case for increase in renewables in the grid would be both environmental and economic.

The potential of Distributed solar has been estimated at ~1,000MW in Residential rooftops, of which 30% is proposed to be delivered in this solution with additional 100MW installed in the Commercial & Industrial sector.

2
Floating Solar for Grid and Green H2

Brunei has floating solar potential of ~2.3 GW which presents an opportunity both for use in the electricity grid as well as for green hydrogen production.

Adding 500MW of this potential to the grid would lead to increase in Solar PV penetration to 30%. The remainder 1.8GW could be leveraged to replace Grey H2 with Green H2 both for domestic use and export to large scale buyers of H2 such as Japan to meet their demand for clean H2

3
Carbon as a Business (CCS)

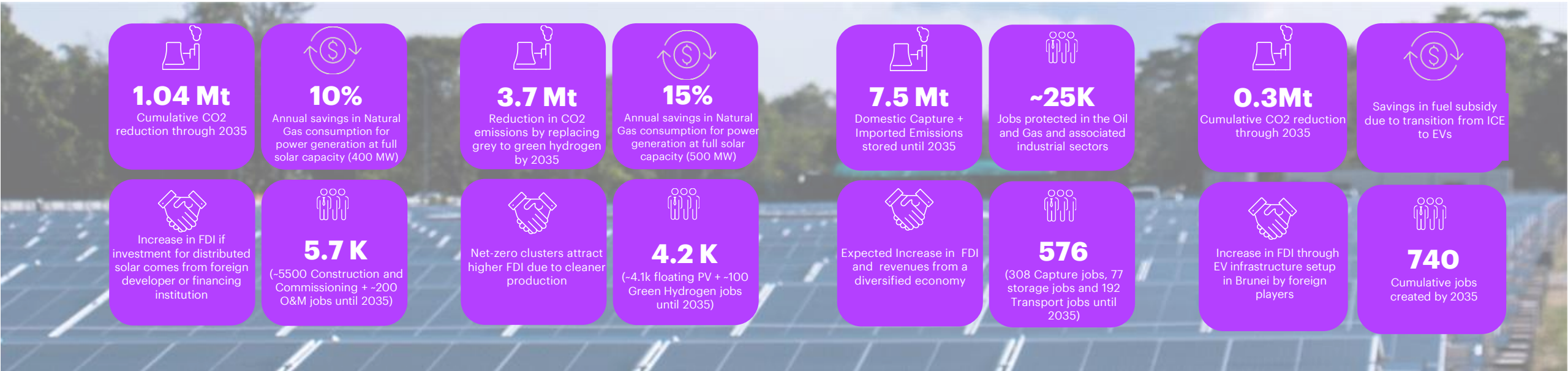
CCS could be the only viable option to decarbonize industries with hard-to-abate emissions. With significant domestic and overseas CO2 capture opportunity from heavy industries, and availability of storage resources, Brunei could aim to be a player in an emerging regional CCS hub ecosystem.

Public funding, adequate policy support and regional partnerships would be necessary for the creation and commercial feasibility of CCS as a business

4
Transport Electric Vehicles

Opportunity in transport is to both switch from ICE to EVs and to reduce car ownership by boosting public transportation. This solution will yield greater benefits if solutions 1 and 2 are adopted successfully to create a low-carbon electricity grid.

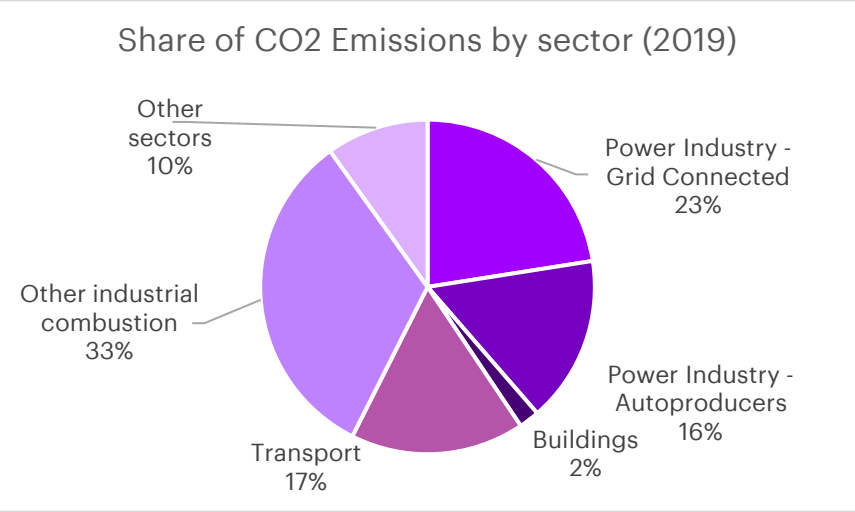
Public transportation modes (public bus, taxis, city fleets) should be strengthened along with creating infrastructure to drive higher uptake of public transport to drive demand efficiency.

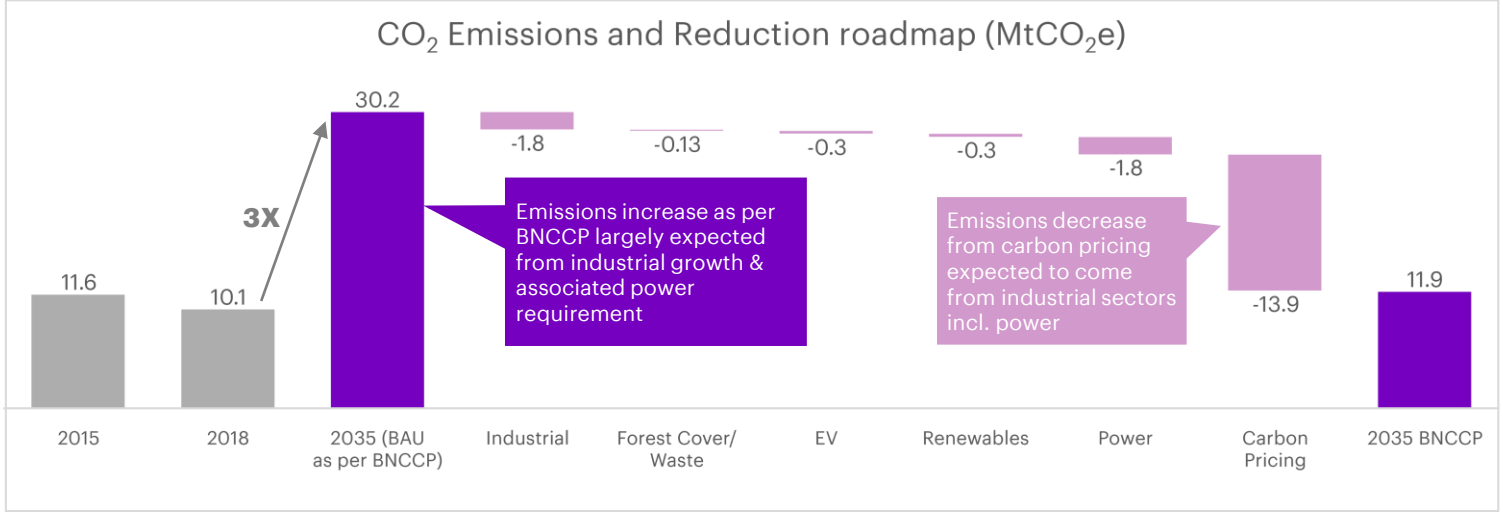


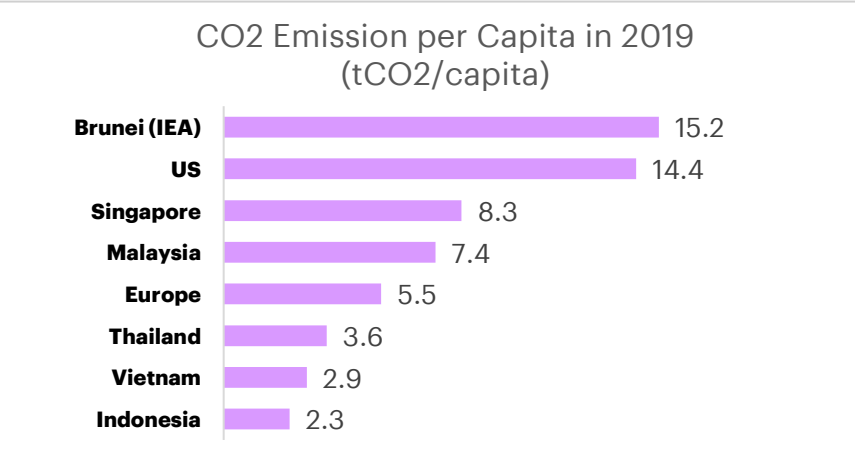
02
MARKET ANALYSIS

Overview of Emissions and Reduction Targets

As part of its National Climate Change Policy, Brunei has committed to a 50% emissions reduction by 2035 and has announced target to reach Net Zero by 2050. The 2035 BNCCP emissions reduction target has been used as the baseline for this study.







>50% by 2035
Compared to BAU 2035 emissions

100% by 2050
To achieve net-zero emissions across the economy

- Brunei has committed to **cut emissions by 50% by 2035** and achieve **Net Zero by 2050**
- The 50% emissions reduction target is with respect to the **2035 BAU scenario** in which emissions are expected to **rise to 30.2 Mt – a 3X increase from 2018** levels - largely from **industrial growth** and associated **power requirement**
- **Carbon Pricing** has been identified as one of the **main strategies** in the BNCCP to achieve the outlined targets, with a Carbon Pricing mechanism **planned to be implemented** in the country by **2025**
- The planned Carbon Pricing is expected to be applied to all **industrial facilities and power utilities emitting beyond** an emission **threshold limit**

*Power Industry - Power and heat generation plants (grid connected & auto-producers), Other industrial combustion - Combustion for industrial manufacturing and fuel production, Non-combustion – Industrial process emissions & agriculture & waste, Buildings – Non-industrial stationary combustion, Transport – Mobile combustion (road & rail & ship & aviation)

Source(s): EDGAR, IEA, BNCCP

Overview of Brunei Darussalam National Climate Change Policy

Brunei Darussalam National Climate Change Policy (BNCCP) has defined 10 key strategies for Energy Transition and Low Carbon Economy to deliver a 50% emissions reduction from BAU scenario by 2035

What is BNCCP?

Brunei Darussalam National Council on Climate Change (BNCCC), and Brunei Climate Change Secretariat (BNCCS) launched the **Nation's first climate change policy, the Brunei Darussalam National Climate Change Policy, BNCCP, on 25th July 2020.**

The policy is guided by the principles of achieving **Wawasan Brunei 2035** and promoting Brunei Darussalam's economic security, sustainability and prosperity through **a low carbon approach** in three key areas:

- Diverse economy by increasing non-oil and gas industry activities
- Increase O&G production and exports
- Protect Brunei's pristine environment

10 Key Strategies for Low Carbon Economy 2035

01 - Industrial Emissions

6% reduction in overall emissions in industries through zero-routine flaring and As Low As Reasonably Practicable (ALARP)

02 - Forest Cover

0.1% emission reduction by increasing forest cover and by planting 500,000 new trees and 80% of emissions can be absorbed by existing forest cover as a natural sink

03 - Electric Vehicles

1% reduction in emissions by increasing EV sales by **60%** annually

04 - Renewable Energy

1% reduction in emissions by increasing **30%** of the total share in power generation from renewables and 100MW Solar PV installation by 2025

05 - Power Management

10% reduction in emissions from electricity by managing power efficiency

06 - Carbon Pricing

46% emission reduction is expected while imposing a price on carbon emission from carbon-intensive industries (all sectors) and power utilities

07 - Waste Management

0.32% emission reduction in municipal waste by limiting waste to 1 kg/person/day

08 - Climate Resilience and Adaptation

Strengthen climate resilience against flood and forest fires.

09 - Carbon Inventory

Mandatory green house gas reporting for transparency monitoring and tracking purposes

10 - Awareness & Education

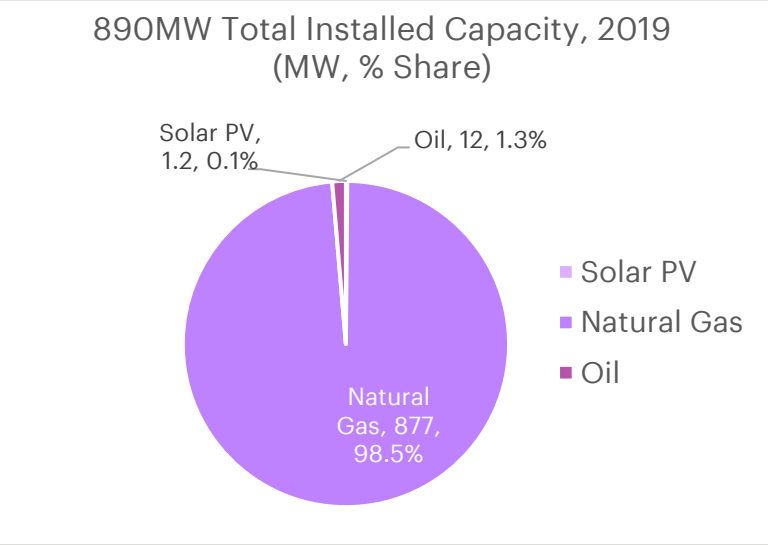
Increased awareness around mitigations and adoption responses

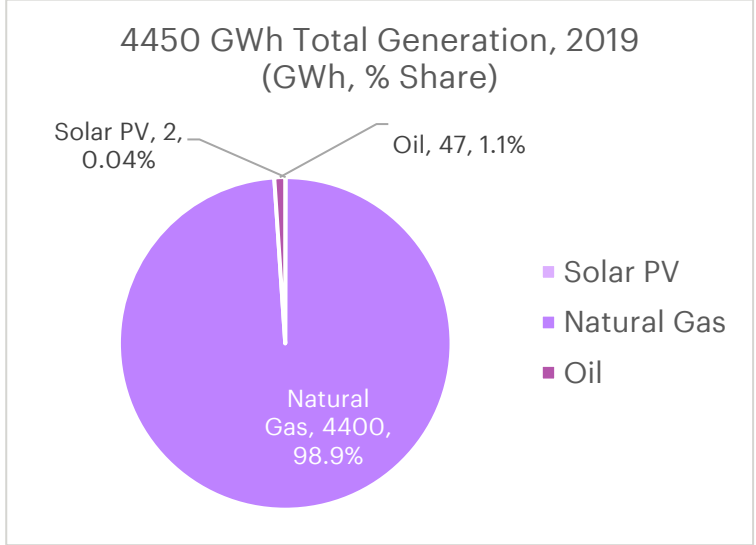
Additionally, **45% of Energy Intensity reduction** from the baseline year (2005) is targeted, in line with its regional commitment under ASEAN working group on climate change (AWGCC)

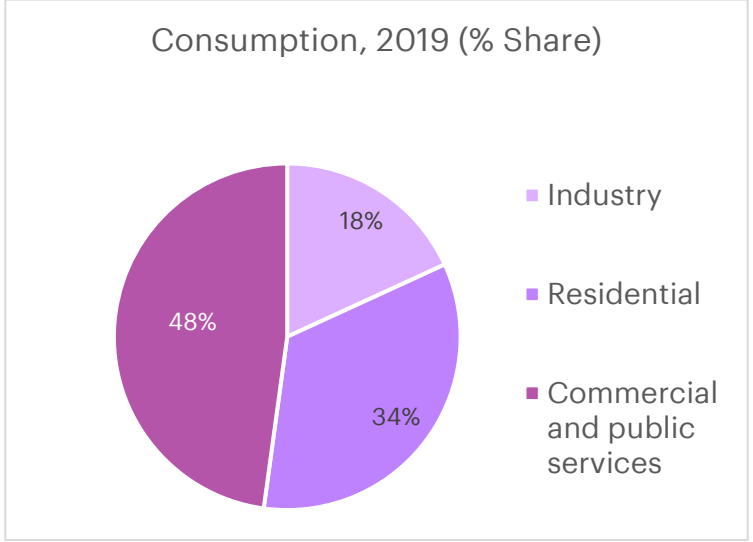
Source(s): BNCCP, AWGCC

Overview of Electricity System (1/2)

Brunei's electricity sector is dominated by Natural Gas as the primary source of generation, with diesel being used to power the electric system in the Temburong district. Solar PV contributed less than 1% of the total share of generation in 2019







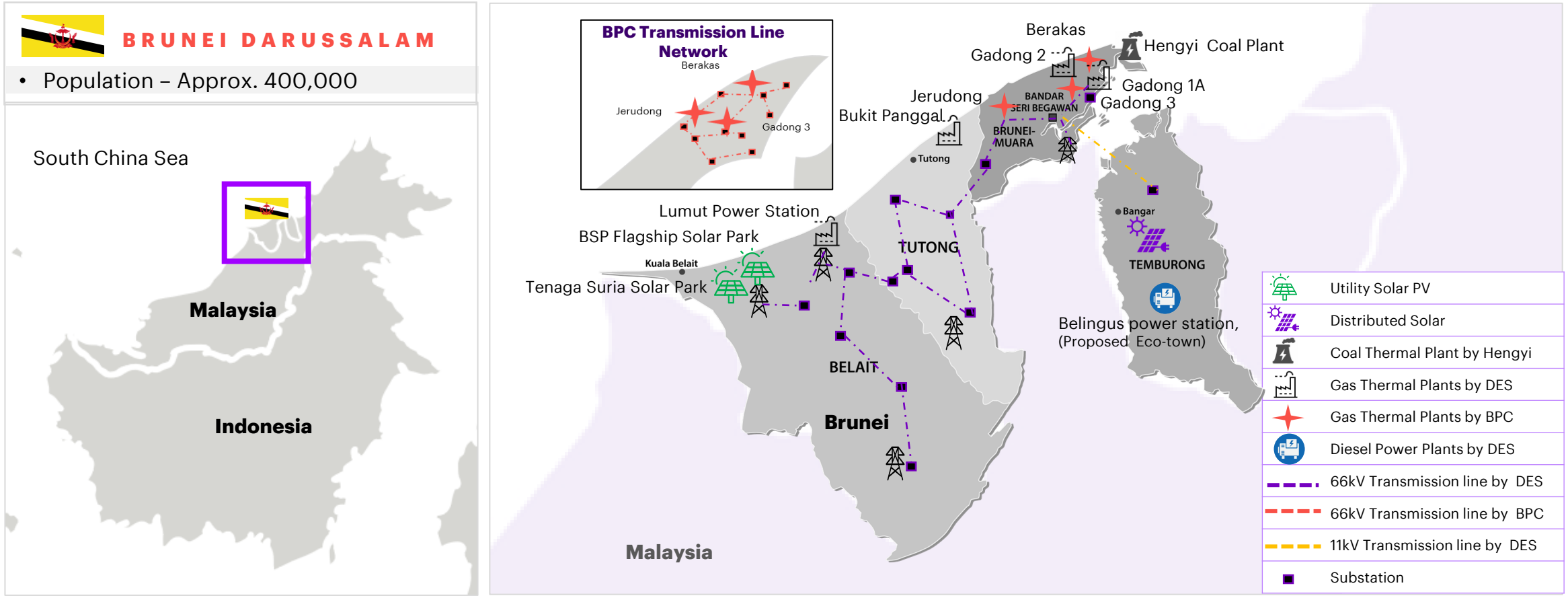
- In addition to grid-connected capacity, there are 2 off-grid electric power systems for Industrial Captive Use
  - **220 MW (4 x 55 MW) Coal Power plant** to supply to a petrochemical and refinery project owned by the Hengyi Industries
  - **100MW -** Gas combustion turbines and co-generation gas combustion turbines for oil and gas operations by BSP & BLNG respectively
- Brunei does not currently import or export electrical power
- Peak demand for electricity system was 632 MW in 2019, 607 MW in 2020 and 629 MW in 2021

*Industry - Mining and quarrying, Chemical, Iron and Steel, Construction & Monitoring; Residential -includes consumption by households, excluding fuels used for transport. Includes households with employed persons; Commercial and public services - As per ISIC Revision 4 (un.org) Transportation, Repair, and installation of machinery, Wholesale and retail trade; repair of motor vehicles and motorcycles, Water supply; sewerage, waste management, and remediation activities

Source: IEA, Accenture Research

Overview of Electricity System (2/2)

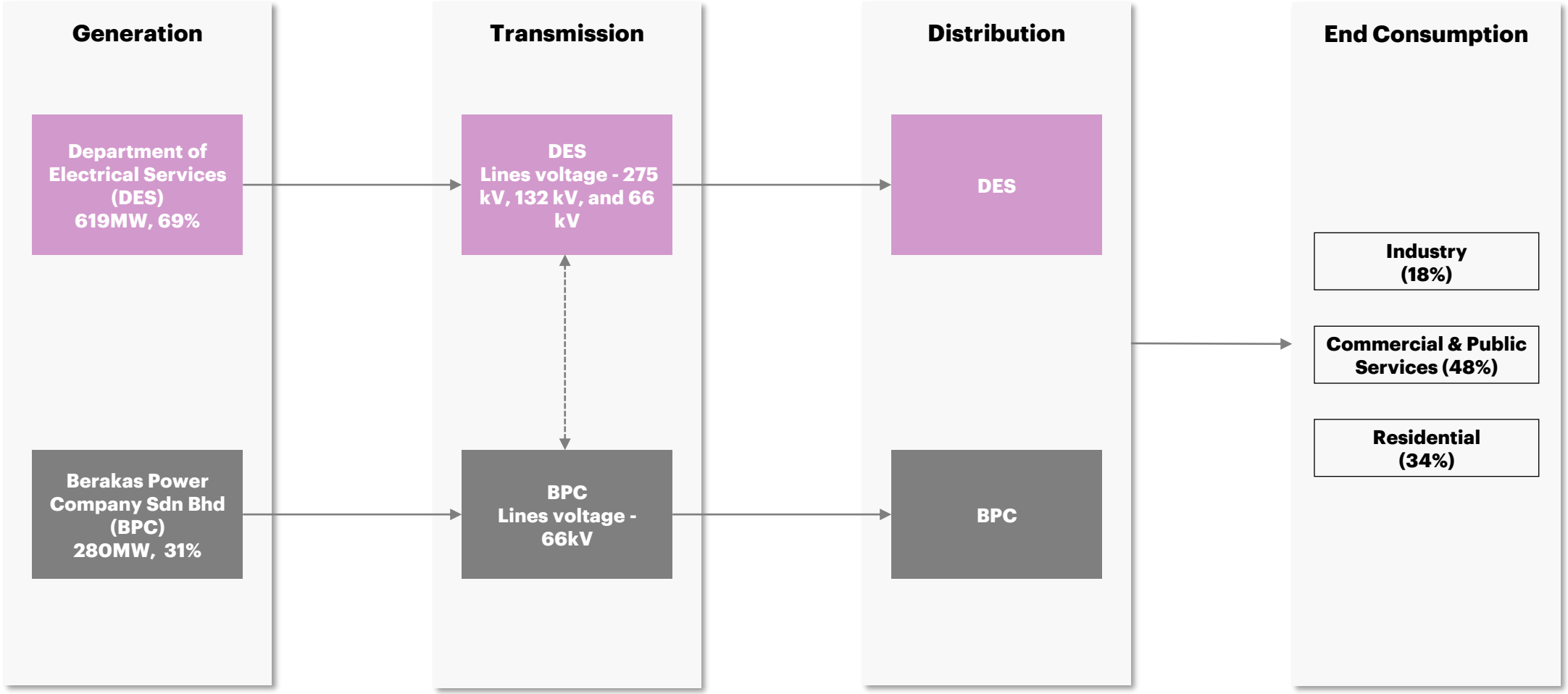
DES and BPC are the two power utilities in Brunei that operate their own generation, transmission & distribution infrastructure across the country. The transmission networks are loosely interconnected with one another for power exchange whenever required



Source(s): ERIA, Accenture Research

Brunei Darussalam Electricity Market Structure

Brunei's electrical power system consist of two players – DES and BPC both of which are vertically integrated across power generation, transmission and distribution, and exchange power at defined power purchase rates whenever required

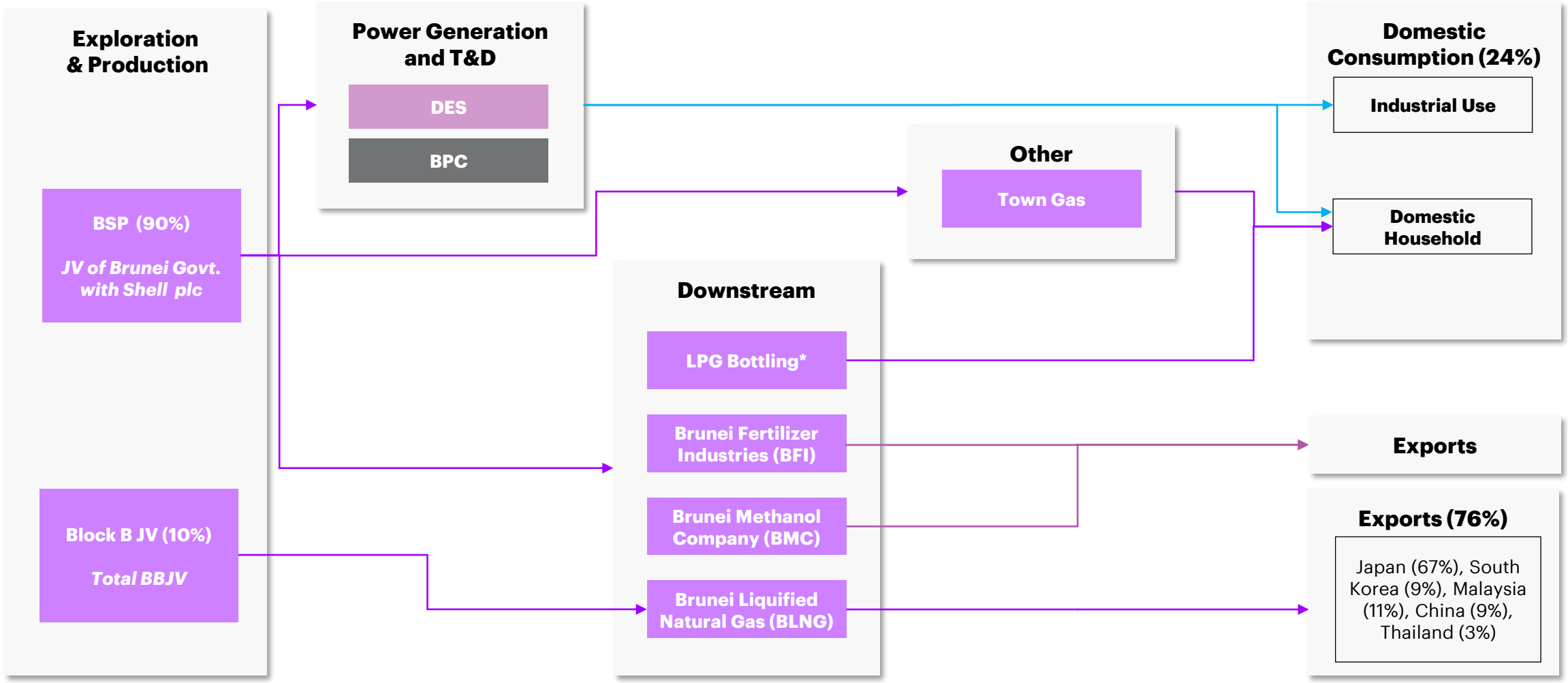


Source(s): ERIA, IEA, Accenture Research

Legend GLC | State owned/ controlled

Brunei Darussalam Natural Gas Market Structure

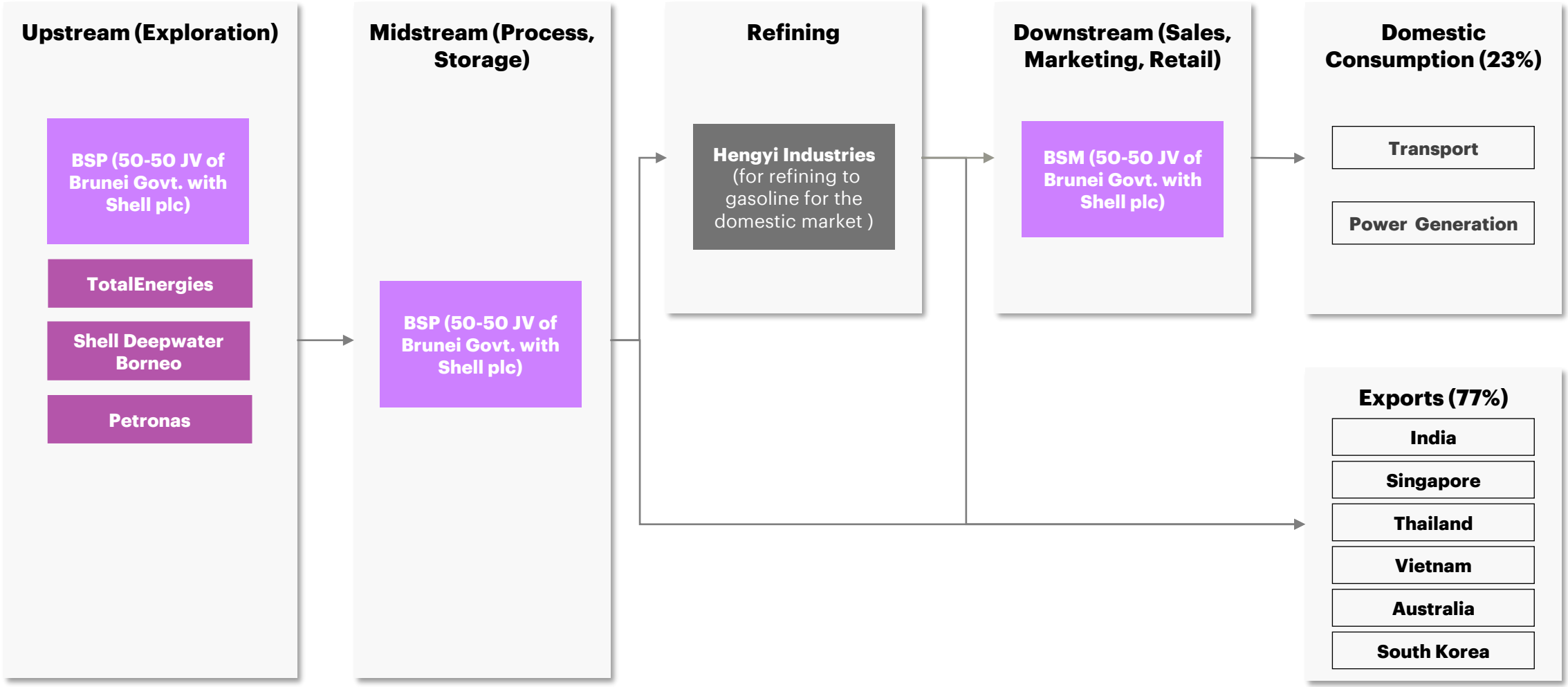
76% of Brunei's natural gas is exported as LNG while 24% of the gas is consumed within the country for power production and household use and in the downstream petrochemical industry such as in Fertilizers and Methanol production



Source(s): bp, Ministry of Energy, Brunei, Accenture Research
*Note - bottled by BLNG, distributed by BSM

Brunei Darussalam Oil Market Structure

77% of Brunei's Oil is exported to countries like India, Singapore, Thailand, etc. whereas 23% of the oil is consumed locally as a fuel in the transportation sector and a small portion is used for power generation



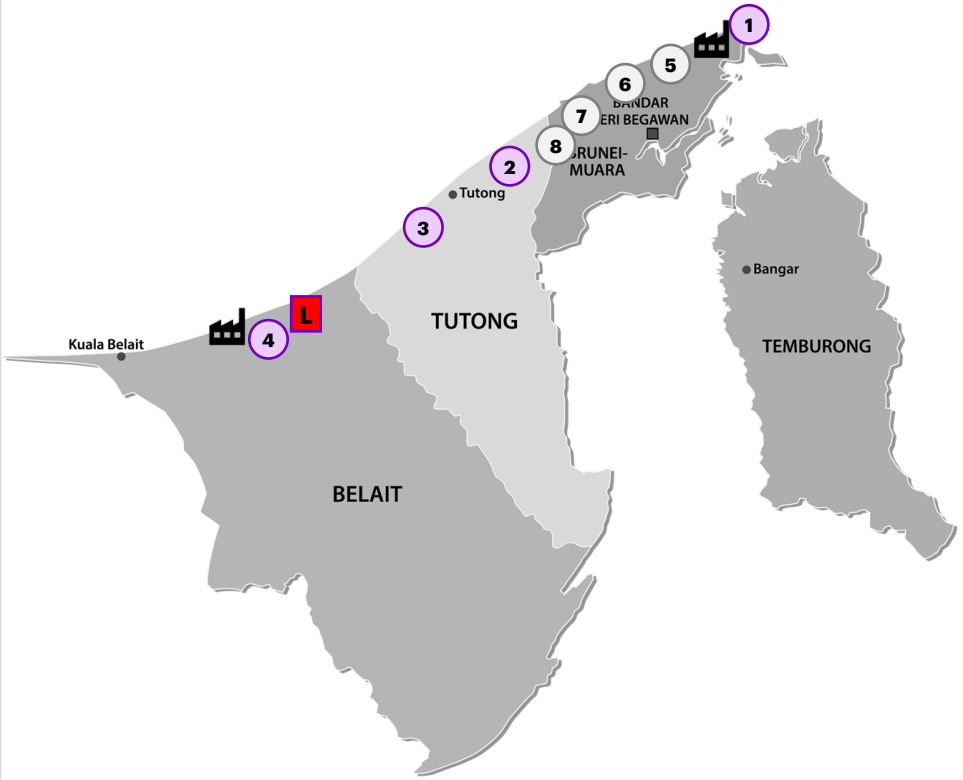
Source(s): OEC, Ministry of Energy, Brunei, Accenture Research

Legend GLC | Partially State owned/controlled | Privately Owned

Energy Transition Opportunities in Industrial Clusters

Brunei has 8 industrial clusters, including 4 that house energy-intensive heavy industries. While light industries could focus on electrification powered by Solar PV for decarbonization, Hydrogen and CCS would hold the key to decarbonize heavier industries

Industrial Clusters in Brunei



O&G infrastructure

- Oil Refineries
- LNG Export Terminal

Industrial Clusters

1	Pulau Muara Besar	O&G downstream
2	Bukit Panggal Industrial Park	Energy intensive Ind.
3	Telisai Industrial Park	Mixed Industries
4	SPARK Sungai Liang	O&G downstream
5	Salambigar Industrial Park	Light Industries
6	Anggerek Desa Tech. Park	ICT & High Tech
7	Digital Junction	ICT & High Tech
8	Bioinnovation Corridor	Halal related Ind.

Heavy Industries – H2 / CCS Opportunity

Light Industries – Electrification / Renewables Opportunity

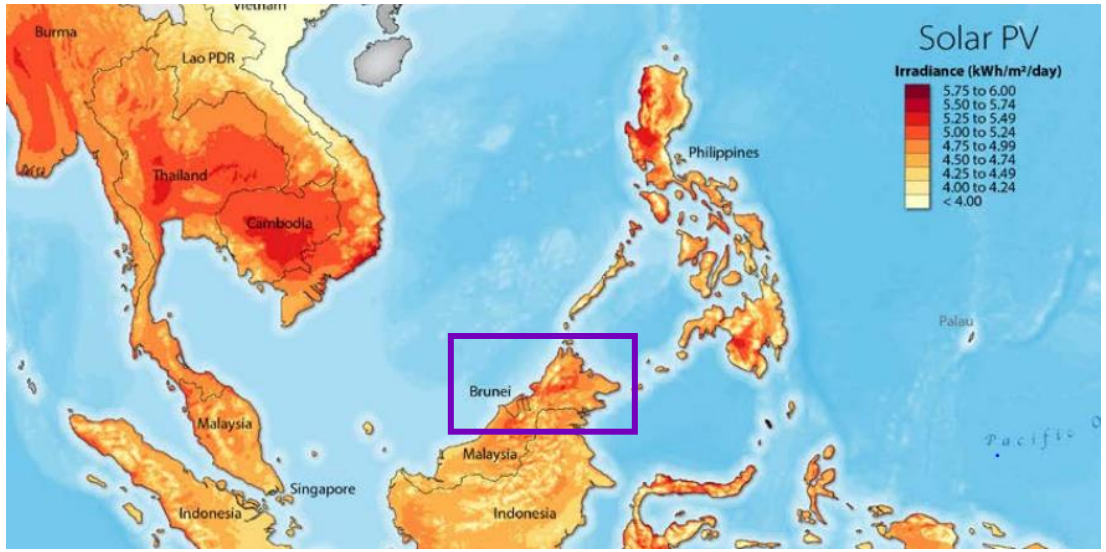
- **Industrial combustion** account for **33% (2.7Mt)** of Brunei's total CO2 emissions
- Of Brunei's **8 industrial clusters, 4** largely contain **energy intensive Oil & Gas and Petrochemical industries.**
- Brunei could find an opportunity in **aggregating domestic demand** from its **heavy industries** for **low-carbon hydrogen** and **CCS** deployment.
- In the **short-medium term**, growth in demand for low-carbon H2 could come from **existing uses, e.g., refining.** In the **longer term**, low-carbon hydrogen could also be used as an **energy source** to **power industrial processes**
- For **Light industries,** the energy transition opportunity would lie in **electrifying industrial processes** and power them with renewables
- **Carbon Pricing** could be an important mechanism to encourage emissions reduction from industrial clusters, thus **boosting domestic demand for low-carbon technologies**
- **Energy efficiency** could be another key lever to reduce industrial emissions by driving process optimization and circular industrial practices

Source: Invest Brunei Darussalam

Brunei Renewable Potential | Resource Quality

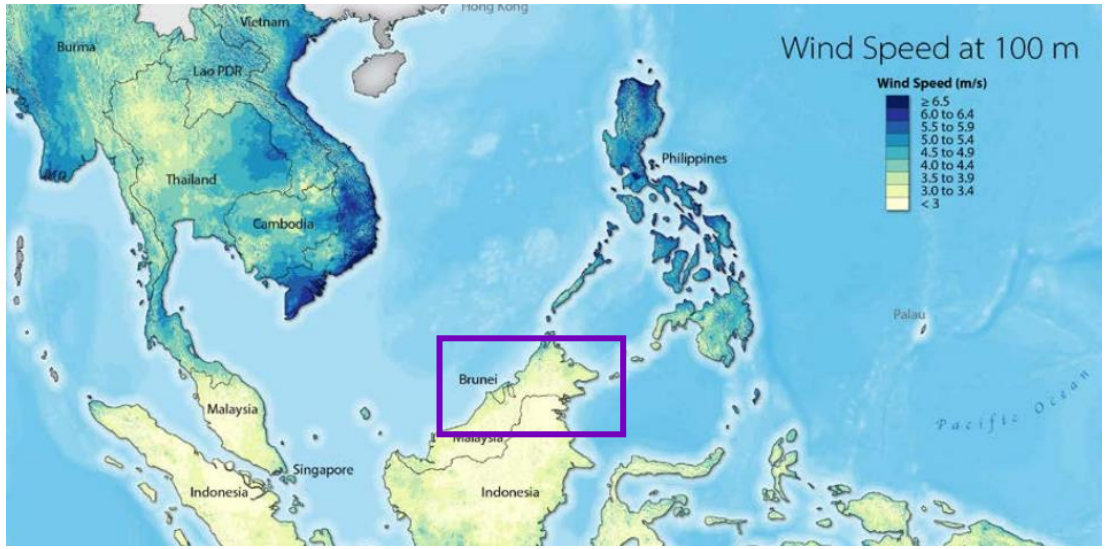
Brunei has high solar irradiance, which permits capacity factors north of 20%. Its wind resource quality is low and less competitive compared to its neighbors - new piloted technologies for low wind speed might make offshore wind viable in the future

Brunei Solar PV Resource Quality



Brunei Darussalam has **solar radiation** comparable to **Malaysia** and other neighboring ASEAN countries ranging from 4.00 to 4.99 kWh/m2/day. PV seasonality index for Brunei is 1.20 indicating good potential of solar PV as per the country range (1.17 – 1.23) with **Capacity Utilization Factor** of around **15 to 22%*.**

Brunei Wind Resource Quality



Onshore wind speeds for Brunei are **low** compared to neighboring countries. However, **offshore wind speeds are higher than onshore** and can potentially be leveraged using **turbine technology suited for low wind speeds in the future**** since existing technologies are still in the pilot phase. Low wind speed turbines can be deployed for Offshore wind once the technology becomes more mature

Note:
- **The Seasonality Index** is the ratio between the highest and the lowest monthly long-term PV generation averages
- ****Wind class (IEC) III/ IV** are the design standards of wind turbine generators (WTGs) suitable for zones with low wind speeds, less than **7.5m/s** on an annual average. They are designed with large rotor blades and higher hub heights (>100m) to capture larger amount of energy at same rated power.

Source(s): NREL-USAID, *Renewables.ninja, Springer

Brunei's Solar PV Hot-Spots and Potential

Brunei's current installed Solar capacity is 4.63MW, with 60MW additional planned by 2024 and a target to reach 300MW by 2035. Studies highlight a total theoretical potential of up to ~4.8GW across utility-scale ground-mounted/floating and rooftop solar PV

Solar PV Installed and Announced Projects

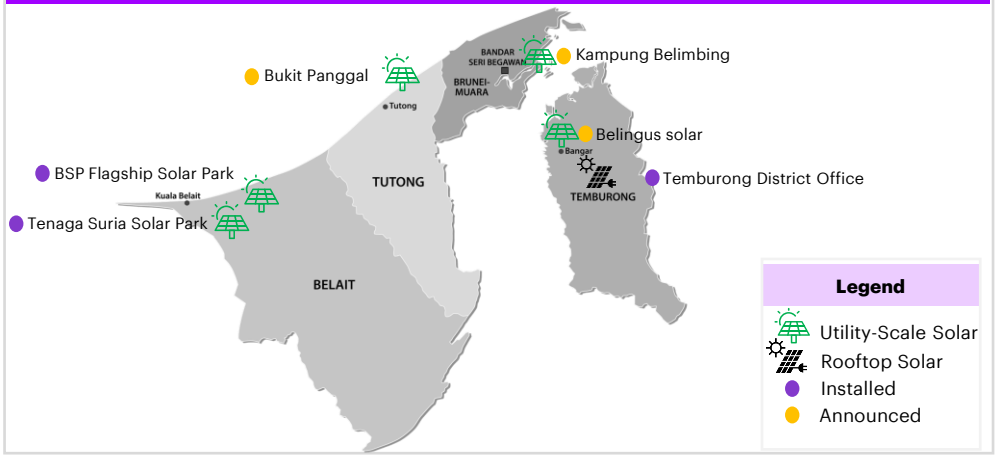
Installed PV Capacity
4.63 MW

- **4.5 MWp of utility solar PV** near Belait and a **cumulative 0.13 MWp** of rooftop solar PV in Temburong district
- **Limited rooftop** installation due to **long payback periods** of 10 to 13 years for residential due to **highly subsidized gas-based electricity tariffs**

Announced Projects
60 MW

- 3 utility-scale solar projects announced by the Ministry of Energy: **Belingus Solar (15MW)**, **Bukit Panggal (15MW),** and **Kampung Belimbing (30MW)**
- 30 MW project expected to start operations in 2023 and the two 15MW projects in 2024

Installed and Announced PV Projects in Brunei



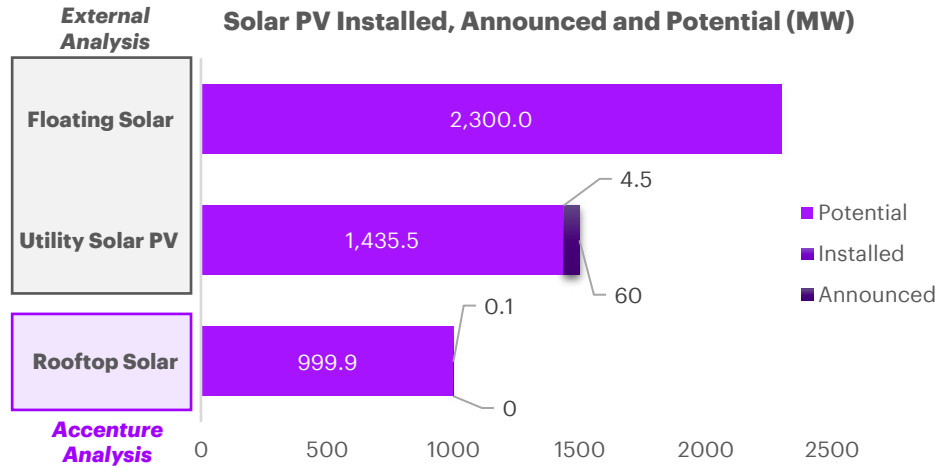
Solar PV Target and Theoretical Potential*

Solar PV Target by 2035
300 MW

- Brunei plans to gradually increase installed capacity of Solar PV to about **200 MW by 2025**, and about **300 MW by 2035,** including 50 MW of distributed solar

Theoretical Solar PV Potential
~4800 MW
(includes floating, utility-scale, and rooftop PV)

- **~2300[1] MW of nine potential sites for floating solar** have been identified by the Ministry for the deployment of medium-to-long-term projects
- **~1500[2] MW of utility scale solar** sites have been identified by NREL-USAID
- **~1000MW[3]** of residential rooftop PV potential has been estimated (based on rooftop area data from ABCi)



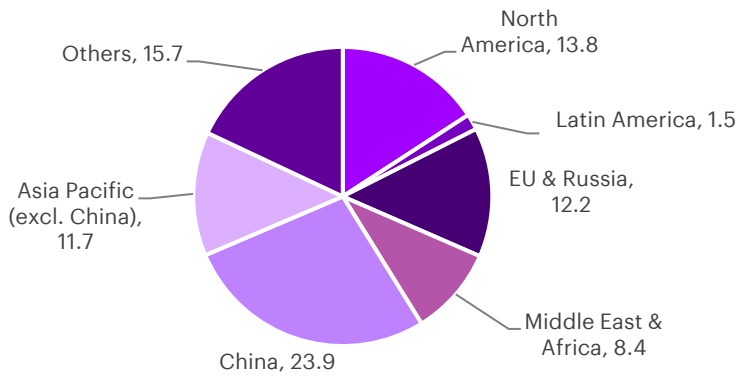
*Theoretical potential is a high-level estimate based on available land and rooftop area and does not include grid feasibility assessment

Source(s): [1]The Brunei Post, [2]NREL-USAID 2020, [3]Accenture Analysis

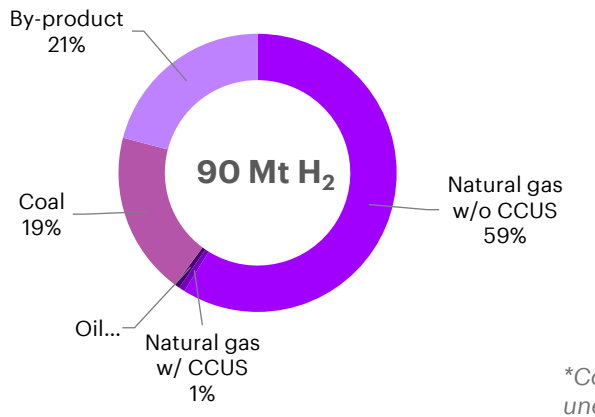
The Hydrogen Opportunity for Brunei

Most of the global H2 consumed today is used for Refining and Ammonia production, and bulk of it is produced from Fossil Fuels. APAC makes up for ~ 50% of H2 demand, and an ERIA study estimates Brunei to have potential of 1.28MTPA, from both gas and RE

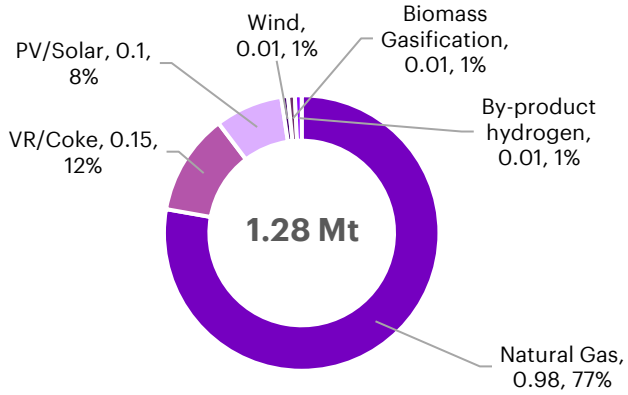
Global H2 Consumption by region, 2020 (Mt)



Global H2 production by source, 2020

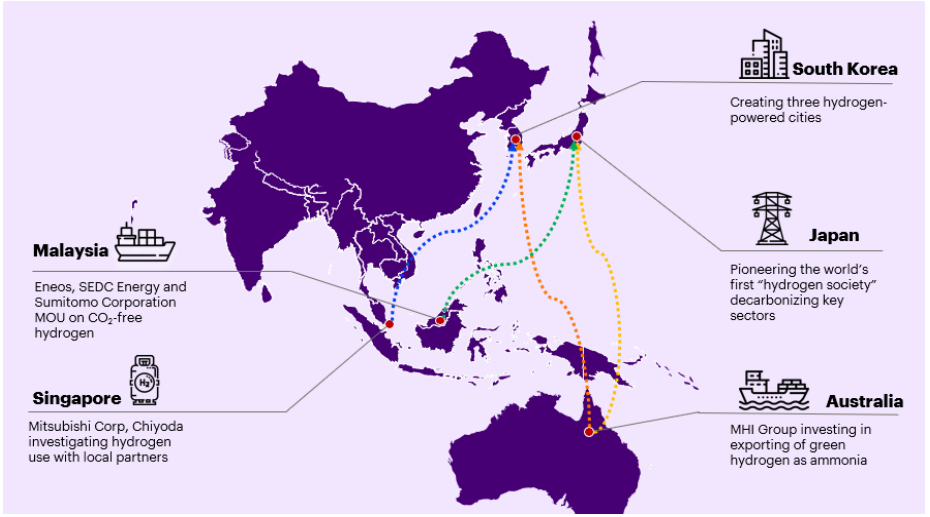


ERIA study – Brunei's Hydrogen Potential*



Considering 4.5 trillion f^3 Natural Gas from small-medium fields considered uneconomical for LNG production; 3GW Solar PV for Green H2

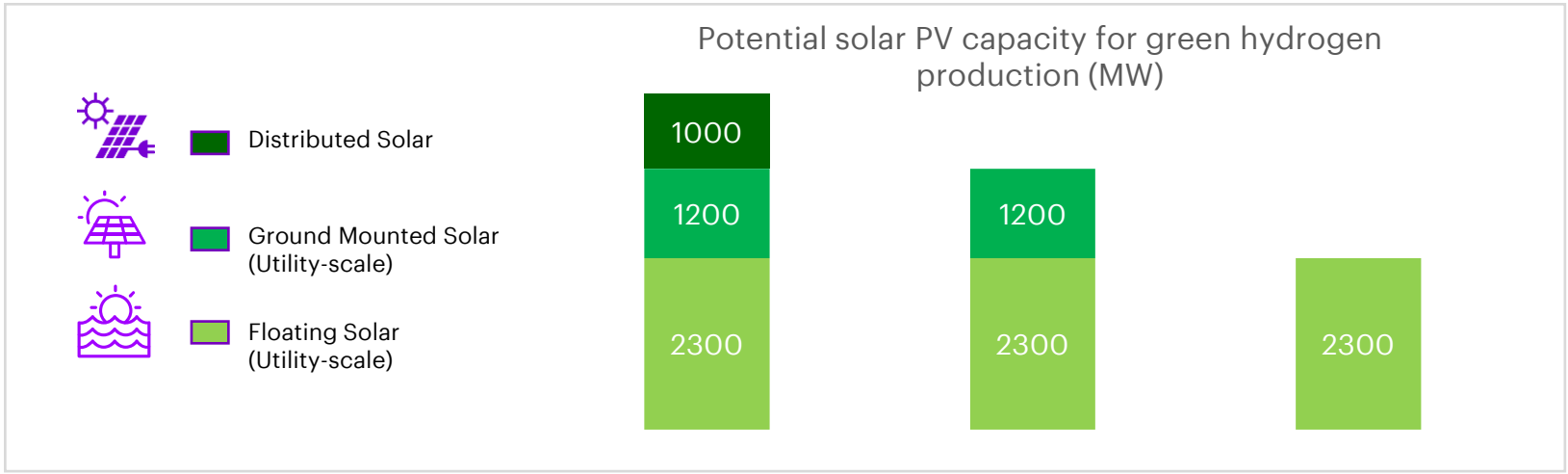
- Global H2 demand was **~90Mt in 2020**, with most demand from Refining and Industrial use. **China** accounts for a **bulk of H2** demand and the rest of **Asia Pacific** had a demand of **~12Mt** in 2020
- H2 production led to **~900 Mt of direct CO2 emissions in 2020**, equivalent to **combined emissions of Indonesia and the UK**
- **Singapore, Japan, Australia** and other **APAC** nations are looking at hydrogen's potential as a fuel source besides replacing fossil fuel-based H2 in existing industrial processes
- An **ERIA study** estimates Brunei's **H2 potential** at **2.75 Mtoe (1.28 Mt)** considering **4.5 trillion Natural Gas** from **small-medium O&G fields** considered **uneconomical** for **LNG** production, and considering **3GW** of **Solar PV** used for **Green H2**
- Green H2 could help the region's **expanding economies** decarbonize **hard-to-electrify sectors like energy intensive industries** and **heavy transport**



Source(s): IEA, Energy Science & Engineering, MHI

Green Hydrogen Potential Production in Brunei

Brunei's potential green hydrogen production could be powered by solar PV. The total potential output of green hydrogen ranges from 0.08 to 0.156 Mt per year based on different sources and levels of Solar PV capacity utilized



Key system parameters	Units	Total Solar Potential excl. 300MW[1]	Total Solar Potential excl. 1,000 MW[2]	Total Floating Solar Potential
Potential Solar PV Capacity in Brunei	MWp	4,500	3,500	2,300
Electricity Generated	MWh/year	8,672,400	6,745,200	4,432,560
Electricity Consumed by Electrolyser	MWh/year	8,672,400	6,745,200	4,432,560
Hydrogen Produced	Mn Ton (Mt) / year	**0.156**	**0.122**	**0.08**

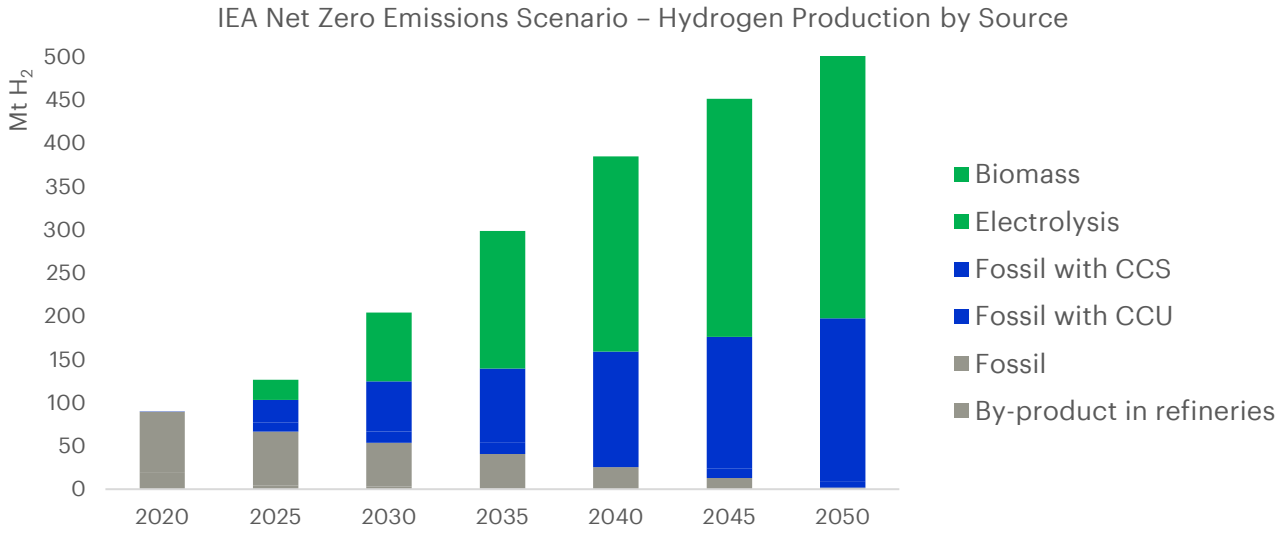
Key Assumptions and Considerations

- Estimation has been done to understand green H2 production potential from different levels and sources of Solar PV – Utility-scale ground mounted and Floating Solar and Distributed Rooftop Solar
- Capacity Utilisation Factor (CUF) of PV has been considered as 22% for Brunei
- Power generation profile would change across the 3 cases of utilization
- Efficiency of the electrolyser (PEM) is considered as 55.5 kWh/kg and Hydrogen production is calculated at 18kg/hr
- Utilisation of electrolyser is considered as 69%.
- If Storage is used with Solar PV for producing Green H2, the required electrolyser size would decrease for the same levels of utilisation.

Source(s): ScienceDirect, [1]Target PV capacity for energy-mix by 2035, [2]Distributed PV Capacity plus Target PV capacity by 2035, Accenture Research

Transition to Low Carbon Hydrogen

While Green H2 is expected to scale with declining RE costs, Blue H2 demand is still expected to play a key role in the global energy transition; large scale buyers of H2 such as Japan are considering both blue and green H2 for their decarbonization



- Market for **low-carbon H2** is expected to **grow significantly**, increasing both in existing use in Refining and Industries, as well as **expanding to use as a fuel** in **Transport** and **Energy sector**
- While **Green H2** is expected to **scale** with **declining RE costs** across the world, **Blue H2** would be required to supplement low-carbon H2 supply with a **significant share even in 2050**
- Currently annual global **H2** production from **fossil fuels with CCS** is **~0.7 Mt**. Additional 50 projects currently under development could bring it to **>9 Mt by 2030**
- Global **H2 electrolyser capacity** was **~300MW in 2021**. Additional 350 projects currently under development and 40 more in early stages of development could bring Green H2 supply to >**8Mt by 2030**, which is still much lower than the **80Mt required in the IEA NZE scenario**

Japan betting big on Hydrogen

2 mn tons/yr
Current H2 demand

3 mn tons/yr
Target demand by 2030

20 mn tons/yr
Target demand by 2050

Japan pursuing bilateral cooperation for low-carbon H2 policy, technology and supply chain

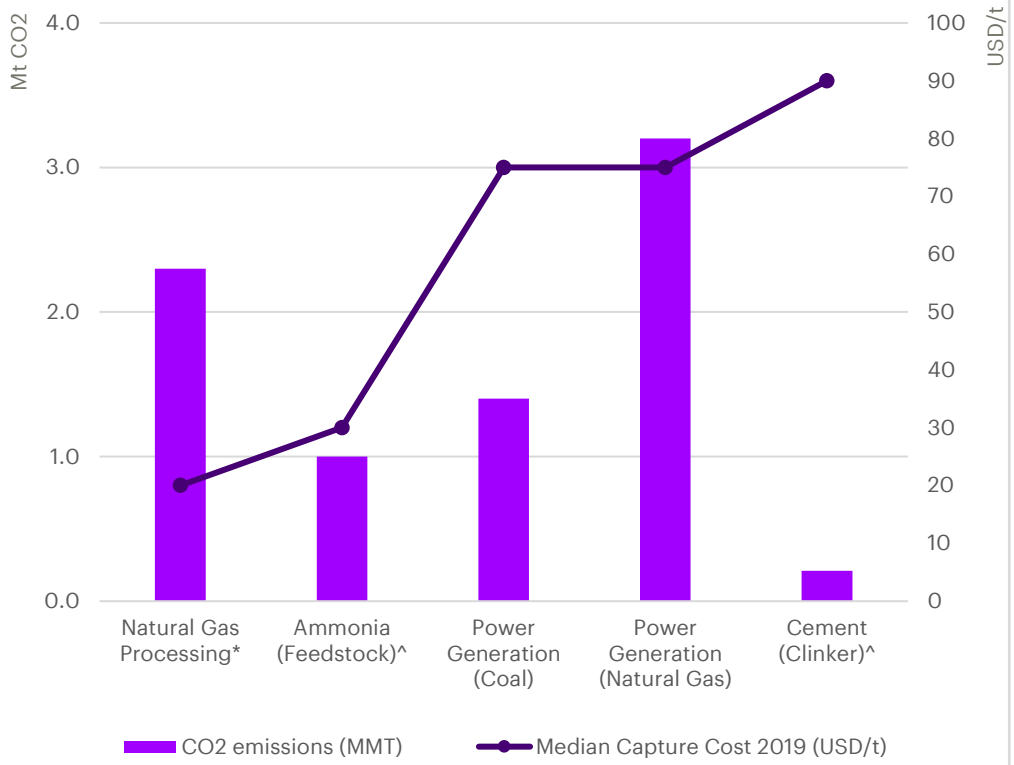
- Japan is leading efforts to use **low-carbon H2** to decarbonize its economy, and issued a **Basic Hydrogen Strategy**, becoming the first country to adopt a national hydrogen framework
- Japan's '**Strategic Roadmap for Hydrogen and Fuel Cells**' identifies **both Fossil Fuel + CCS** and **RE-based H2** as important to meet its future H2 demand
- Japan is **highly focused** on securing access to **low-carbon hydrogen**, pursuing **bilateral ties with Australia, UAE, Malaysia, India, EU** etc**,** apart from Brunei to collaborate on **policy, technology** and **supply-chain** to set up global low-carbon H2 supply chains

Source(s): METI - Japan, IEA

CCS | Brunei's Domestic Opportunity

For Net Zero by 2050, industrial sectors with hard-to-abate emissions could have CCS as the only option to reduce emissions. Sectors such as Natural Gas Processing and Ammonia present the least capture costs owing to highly concentrated CO2 streams

Estimated CO2 Emissions from select Industrial Sectors in 2035 and Current Capture Costs



Notes:
*Cradle-to-gate CO2 emissions from Processing stage based on projected 2035 Natural Gas production as per Rystad report
^Emissions from existing plants assumed to operate at full capacity by 2035

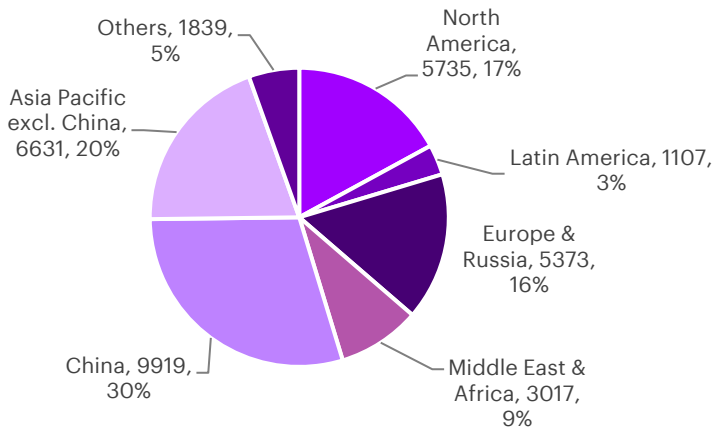
- The **cost of carbon capture** varies **greatly** by sector, from a range of **USD 15-25/t CO_2** for industrial processes producing **highly concentrated CO_2 streams**, such as natural gas processing, to **USD 40-120/t CO_2** for processes with **dilute gas streams**, such as cement production
- **CCS for Natural Gas Processing** is currently the **most mature** and **cost-competitive** amongst the industrial sectors, and accounts for most of the CCS capacity currently operational in the world.
- In the **fertilizer** industry, **CCS** is often the **cheapest option** to reducing emissions.
- CCS is the only **alternative to retiring conventional power plants early** or operating at lower capacity factors or with alternative fuels. **Retrofitting CCS equipment** can enable **continued operation** of existing plants, as well as associated infrastructure and supply chains, but **with significantly reduced emissions.**
- With a **growing global market** for **Carbon-neutral products**, there could be an opportunity for Brunei to invest in **CCS for strategic export industries** such as **Oil & Gas and Fertilizers**
- Enabling **national policies** and fostering **industry collaboration** for CCS adoption will be key for the industrial sector to get to net zero by 2050. **Carbon Pricing** would be an important element to incentivize industries to invest in CCS.
- With **4 industrial clusters** that largely contain **heavy industries** such as Oil & Gas, Cement and Fertilizers, there is an opportunity to **aggregate demand** and build **shared CCS infrastructure** for domestic industries.
- Planning for an **Integrated energy system** with a **CCS grid** to **capture CO2** from heavy industries to either **use** it in **downstream industries** or for **storage**, alongside the existing oil and gas infrastructure and potential future RE and hydrogen supply infrastructure, will help **optimize investments** and **reduce emissions** from the **energy system operations**.

Source(s): IEA, bp, Brunei Cement History, IPCC Emissions Factor, IGU, Journal of cleaner production, Accenture Research

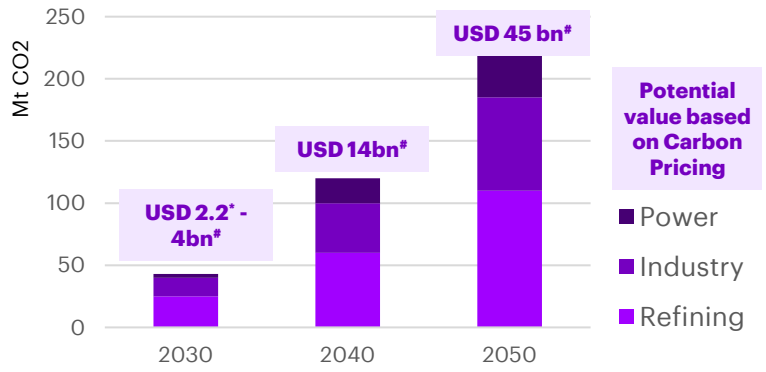
CCS | Opportunity in South-East Asia

With its location at the center of South-East Asia, Brunei is well placed to serve some of the region's CCS needs. There have been several projects and partnerships announced by Brunei's neighboring countries on CCS although projects are yet to be operational

Global CO2 Emissions by region, 2019 (Mt)



Projected CCS requirement in South East Asia (IEA NZE by 2050 scenario)



* As per Singapore planned Carbon Tax in 2030 – median value
\# As per IEA NZE scenario Carbon Price in emerging markets

CCS gaining traction in South-East Asia

Malaysia

- Petronas deploying **Captive CCS** for its **Kasawari sour gas field** in **Malaysia**, with first injection into a **depleted gas field** planned in **2025,** eventually expected to reach **3.7 Mt /yr**

Indonesia

- Repsol plans to develop a **Captive CCS** facility for its **Sakakemang** Block **natural gas field** in **Indonesia** with the captured CO2 stored in **two depleted gas fields — Gelam and Dayung**
- Pertamina, along with J Power & Japan NUS Co., is exploring **depleted oil and gas fields** for a **Captive CCS facility** with capacity up to **0.3 Mt CO_2/yr** for its **Gundih gas field** in **Indonesia**
- **Centre of Excellence** for **CCU/CCS** established in **Indonesia** with support from **ADB**

Singapore

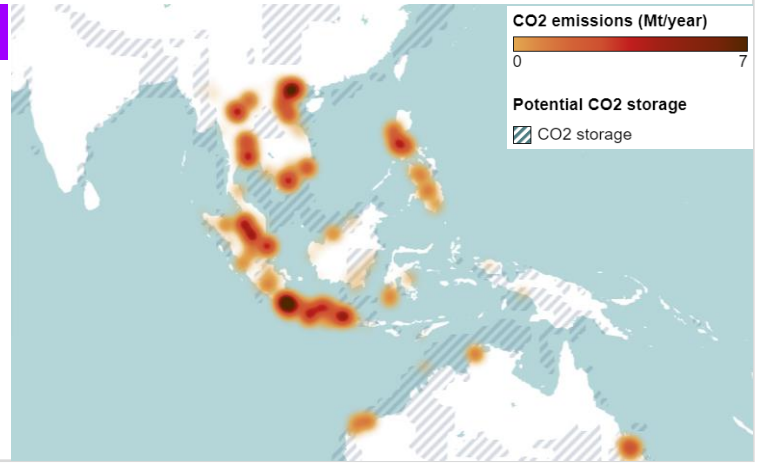
- Four companies, including Chevron, have signed an MoU to develop **Singapore's 1st carbon capture system**
- ExxonMobil announced plans to build a **CCS network** in SEA, with a **collection hub** in **Singapore** for capturing CO2 emissions from manufacturing facilities for storage in the region

Asia CCS Network

- Asia CCS Network established to collaborate on **policy, technology, deployment** of **CCS in Asia** with members such as **Indonesia, Malaysia, Singapore**, **India, Japan, Australia, US** etc.

Brunei's CCS Opportunity

- With its location in the **center of South-East Asia**, Brunei is well suited to serve the region's CCS needs
- A CCS **hub approach** to aggregate CO2 from **multiple sources** from the region will provide economies of scale. Some of the **largest industrial clusters** located in **Indonesia, Malaysia, Thailand** and **Viet Nam** can be potential sources
- Since Brunei is not party to the **London protocol**, there would be **no legal hurdles** to **importing CO2**



Source(s): IEA, MHI, IEA, Accenture Research

CCS Hub Opportunity for Brunei

Brunei's cross border trading of CO2 for CCS can grow depending on enforcement and levels of carbon pricing instruments **(carbon tax and emission trading scheme (ETS))** in importing countries that would incentivize their industries to opt for CCS

Carbon Pricing Instruments in East Asia

- **Carbon Tax** – a cost is added to all emissions, equal to the level of the tax. There is no cap on emissions in a tax-based system
- **Emission trading scheme** - setting a cap on emissions and requiring emitters to hold a certificate for each ton of CO_2 that they emit, and price is floated based on auctions.

Parameters	Indonesia	Malaysia	Singapore	Japan	China
Carbon Tax	$2.13/tCO2 was proposed to commence in Apr 2022 (delayed)	Considering for longer-term	$3.65/tCO2 in 2022, $18/tCO2 in 2024 and up to $50 to $80/tCO2 in 2030	Proposed Maritime Carbon Tax for $56/tCO2 in 2025 and $324/CO2 in 2035	No plans
Emission Trading Scheme (ETS)	Drafting regulation/procedures on ETS in power sector	Plans to launch pilot ETS in 2026	No plans	$ 2.60/tCO2 for excess reduction credits	ETS with $8.5/tCO2e
Domestic CO2 Storage Potential	Yes	Yes	No	No	Yes
Industrial Clusters with CO2 Capture Prospect	Java Island	1700 industrial clusters by 2025	Jurong Island & Bukom Island	Eastern Japan	North/ South China
Industrial Emissions (2019)	215 MT	60.5MT	22 MT	386 MT	8400 MT
Plans for new coal plants	~16GW	~0.0 GW	~0.0GW	~2.6GW	85GW
Plans for Commercial CCS Facilities	Yes	Yes	No	No (Looking for partners in other countries)	Yes

Source(s): IEA, WorldBank, Carbonbrief, NewScientist, The Straits Times, Ministry of Environment - Japan, Climate Transparency, Country Economy, WEF

Case Study | Northern Lights CCS

Planned to start operations in 2024, Northern Lights will be a cross-border, open-source 5Mt CCS project, financed by the Norwegian government, Equinor, Shell and Total. The facility is expected to be utilized by industries across Europe for CO2 storage

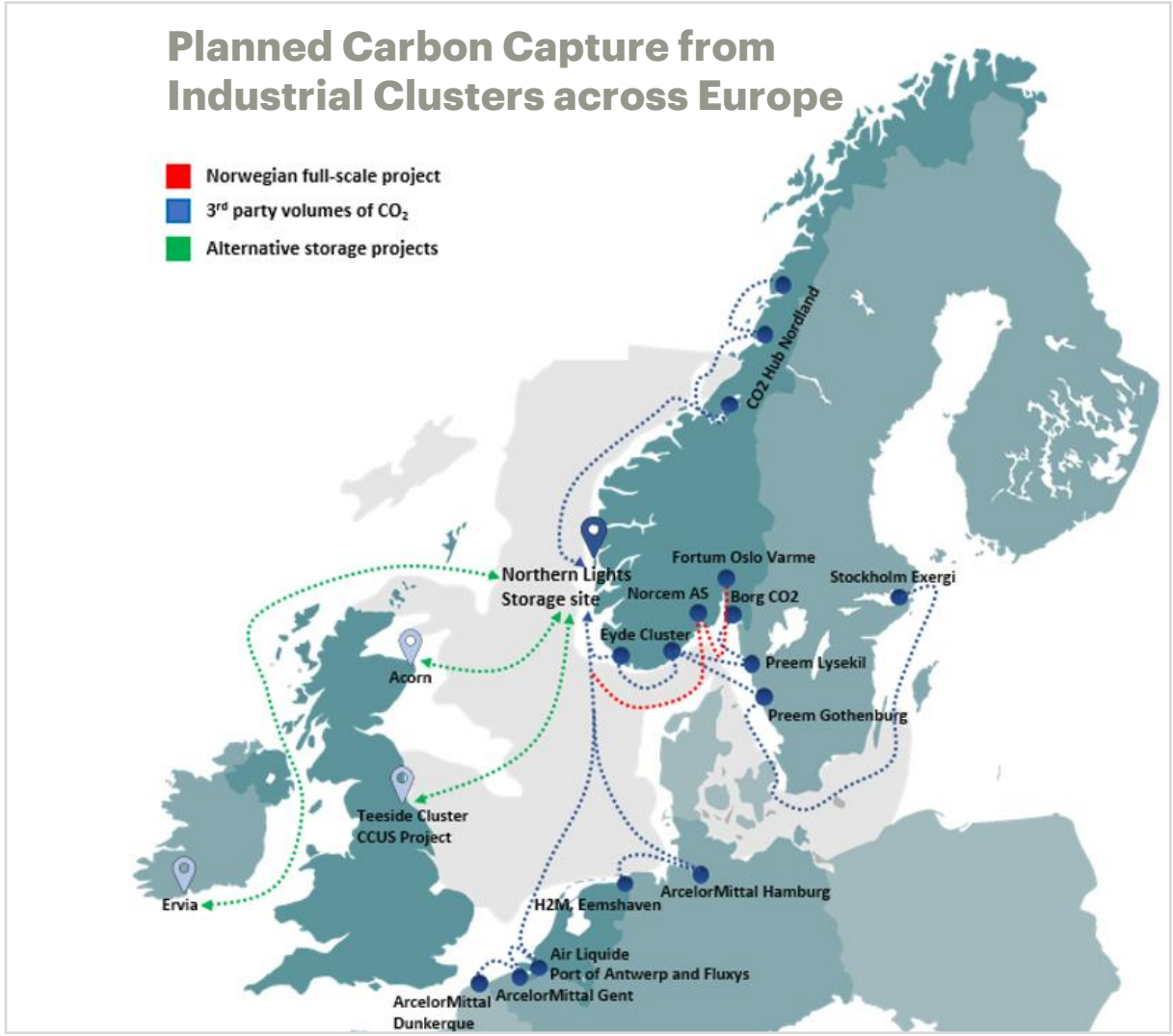
Northern Lights | equinor | Shell | TOTAL

Key Metrics	
Operation date	2024
Storage capacity (Mtpa)	Phase one: 1.5 Phase 1 + Phase two: 5
Planned CO2 sources for Phase 1	0.8 Mt from Fortum Oslo & Norcem 0.7 Mt from 3rd party sources
Storage location	Offshore Saline Aquifer
Pipeline length from receiving terminal to Storage site (km)	110
Transportation type	Pipeline and ship

Financing : Public-Private Partnership with heavy State funding

Of the **$1.63 bn** approved for the **CO2 transport and storage** project, the **Norwegian govt.** will **contribute** a **bulk** of it at **$1.19 billion,** with the **remaining $440 mn** to be covered by **Equinor, Total and Shell.**

For the **Capture Projects** at **Norcem** and **Fortum**, the **Norwegian govt.** will **cover all investment costs up to a threshold**. Above the threshold, the **state** will cover **75%** of the cost while the **companies** will cover the remaining **25%.** A **similar arrangement** is in place for the **operating costs.**



Source(s): IEA, Northern Lights, Reuters

Overview of Brunei Transportation System

Brunei does not have an extensive public transport network and majority of the vehicles are privately owned cars, with a penetration of 649 cars per 1000 people. There are a total of ~272,000 total active registered vehicles in Brunei.

- As per a 2014 government survey, the **share of private cars** in Brunei was **92% in 2014**
- The **public transport** system is mainly concentrated in the **Brunei- Muara District** which has good road infrastructure and accommodates majority of Brunei's population
- **Franchise Bus** (formerly called Purple Bus) is the public bus service in Brunei - as of 2014 it had a **fleet of 105 buses**. There were only around 45 registered taxis in 2014.
- In 2017 a **ride sharing service DART** was launched and it has seen a **high growth rate** in uptake, with the number of **passengers increasing** from **~16000 in 2018** to **~84000 in 2021.** Presently, DART has around 300 registered cars with plans to scale up to 1000 cars in the future. A shuttle service with higher capacity is also being considered as a mode for shared mobility in the future
- **56%** of the population **owned vehicles** with **engine capacity of 1.5L–2.2L** and 19% owned vehicles with engine capacity > 2.2L. **Average fuel economy** of vehicles in Brunei is **low**.
- The **transport sector** contributed **17%** towards total emissions in **2019**

~272,000
Active Registered Vehicles

14,813
New Vehicles registered in 2020

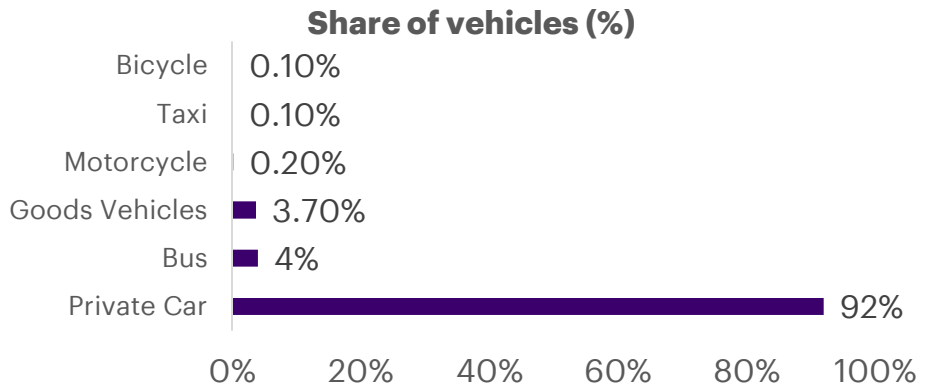
92%
Vehicles privately owned

~100%
Vehicles run on Diesel (22.9%) or Gasoline (77%)

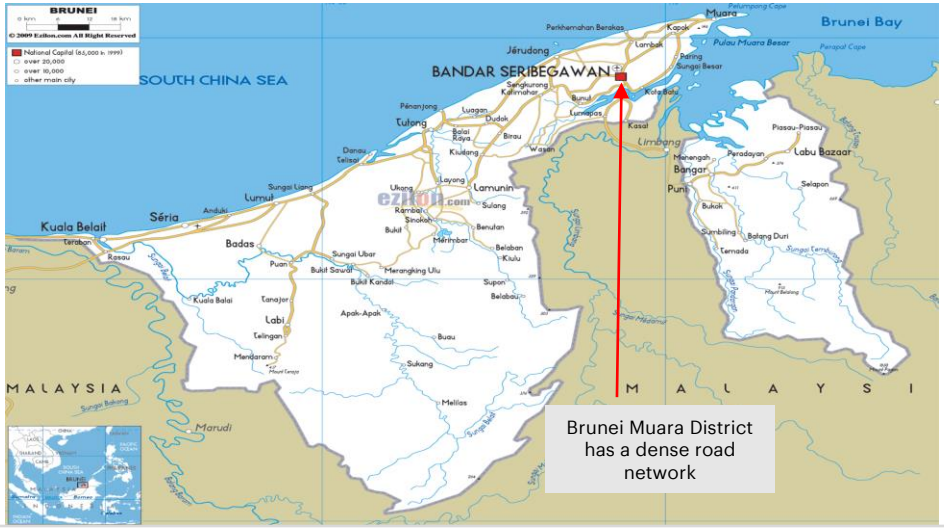
17%
Emissions share of transport sector

- The **Public transport** system is **not very mature** in terms of routes, frequency of services, short operating hours (06:00am to 07:00pm), and limited bus information
- **Private cars** are the **most widely used** mode of transport, leading to traffic congestions
- **Gasoline** for automobiles is **highly subsidized** (except Shell V Power) and accounts for a large portion of the government's **fiscal spend**

Share of Vehicles by type in 2014



Brunei Road Network



Source(s): MTIC, Land Transport Dept. Brunei, ASEAN, MTIC

Electric Vehicle Adoption Outlook in Brunei

Brunei launched a two-year pilot project in 2021 to study the legal and technical requirements, pricing, and infrastructure for the deployment of electric vehicles in order to achieve the target of 60% of total vehicle sales in 2035

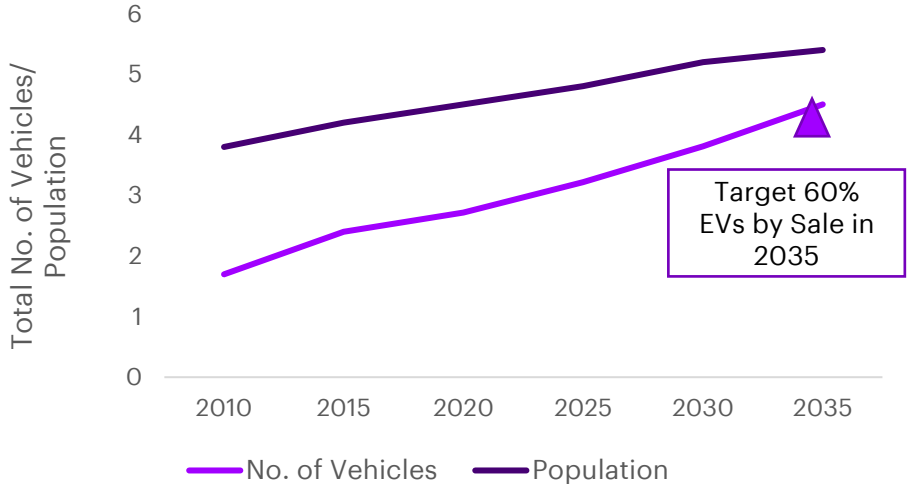
E-Mobility Goals till 2035

- Brunei has an **EV target** of **60% of total vehicle sales by 2035**. Having green vehicles is also part of **Brunei Land Transport Master Plan** (LTMP) as per its Strategic Goal 3
- If achieved, it is expected to **reduce** around **0.3MT** of **CO2 emissions** compared to BAU
- Current **EV penetration** is **<0.1%,** with most of vehicles are **Gasoline (77%)** and **Diesel (22.9%)** with low fuel economy
- Brunei is running a **2-year pilot project** on EVs which started in 2021, to study the technical and legal requirements, pricing, charging locations in line with **BNCCP's strategy** for EVs
- **BSM** (Brunei Shell Marketing) has **plans** to offer a range of **charging options** to support EVs and is also **identifying sites** to set up the **infrastructure**

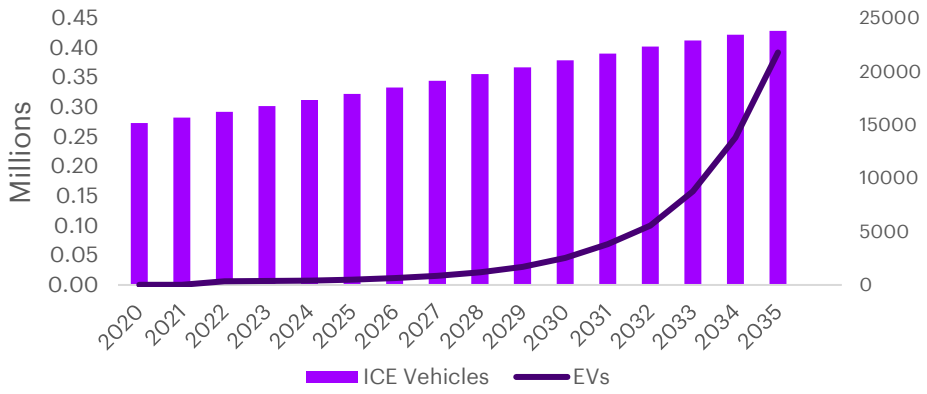
Current Situation of E-Mobility in Brunei

- While the **BNCCP** has **EVs** as one of the **core areas** for **emissions reduction** with **targets to be implemented** in the **next 15 year**, the **current penetration** of **PHEVs** and **BEVs** in transportation is **very low**, **<0.1%** of the total number of vehicles in 2021
- **Electric 2-wheelers** and 3-wheelers are **negligible** in Brunei with most of the existing electric vehicles in the 4-wheeler segment
- Gasoline is **highly subsidized** in Brunei, with total motor fuel subsidies of **116.5 M USD in 2019.** In 2020 **BSM** introduced its high-performance **premium motor fuel V-Power** which is the **only unsubsidized fuel** available in Brunei – however uptake of the product has been low
- Currently there is negligible EV charging infrastructure in Brunei, however **BSM** offers a **high-powered 150kW charger** and **20kW** and **50kW rapid charger** at selected **retail station** and destination site. BSM is also working with car dealerships to **offer home DC chargers** to their customers

Projected No. of Vehicles & Population by 2035 (in 100k)



Projected ICEs & EVs in Brunei (based on BNCCP 2035 Target)

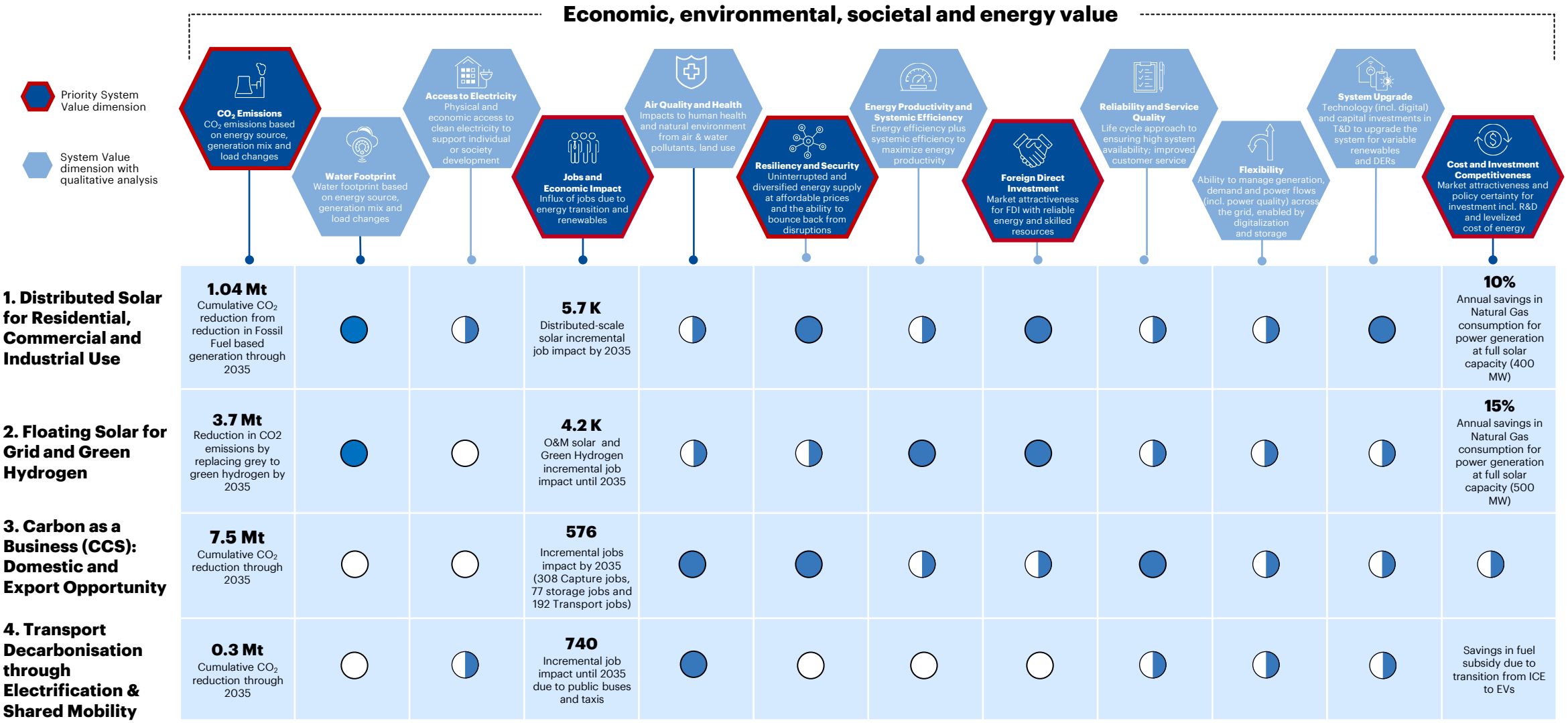


Source(s): MDPI, IEA , UNFCCC, BSM, Accenture Analysis

03
SOLUTIONS

Summary of System Value Impact across all Outcomes

System Value benefits are seen across the recommended solutions for Brunei.



	CO2 Emissions	Water Footprint	Access to Electricity	Jobs and Economic Impact	Air Quality and Health	Resiliency and Security	Energy Productivity and Systemic Efficiency	Foreign Direct Investment	Reliability and Service Quality	Flexibility	System Upgrade	Cost and Investment Competitiveness
1. Distributed Solar for Residential, Commercial and Industrial Use	**1.04 Mt** Cumulative CO_2 reduction from reduction in Fossil Fuel based generation through 2035	●	◑	**5.7 K** Distributed-scale solar incremental job impact by 2035	◑	●	◑	●	◑	◑	●	**10%** Annual savings in Natural Gas consumption for power generation at full solar capacity (400 MW)
2. Floating Solar for Grid and Green Hydrogen	**3.7 Mt** Reduction in CO2 emissions by replacing grey to green hydrogen by 2035	●	○	**4.2 K** O&M solar and Green Hydrogen incremental job impact until 2035	◑	◑	●	●	◑	◑	◑	**15%** Annual savings in Natural Gas consumption for power generation at full solar capacity (500 MW)
3. Carbon as a Business (CCS): Domestic and Export Opportunity	**7.5 Mt** Cumulative CO_2 reduction through 2035	○	○	**576** Incremental jobs impact by 2035 (308 Capture jobs, 77 storage jobs and 192 Transport jobs)	●	●	◑	◑	●	◑	◑	◑
4. Transport Decarbonisation through Electrification & Shared Mobility	**0.3 Mt** Cumulative CO_2 reduction through 2035	○	◑	**740** Incremental job impact until 2035 due to public buses and taxis	●	○	○	○	◑	◑	◑	Savings in fuel subsidy due to transition from ICE to EVs

Analysis performed for given System Value dimension and recovery solution. For more detail, please see specific solution and/or relevant System Value dimension slide(s).

System Value dimension not as relevant to geographic market or not considered with given recovery solution.

Relative System Value dimension benefit for given recovery solution within market

● High benefit ◑ Medium benefit ○ Minimal-to-no benefit

Distributed Solar for Residential, Commercial and Industrial Use

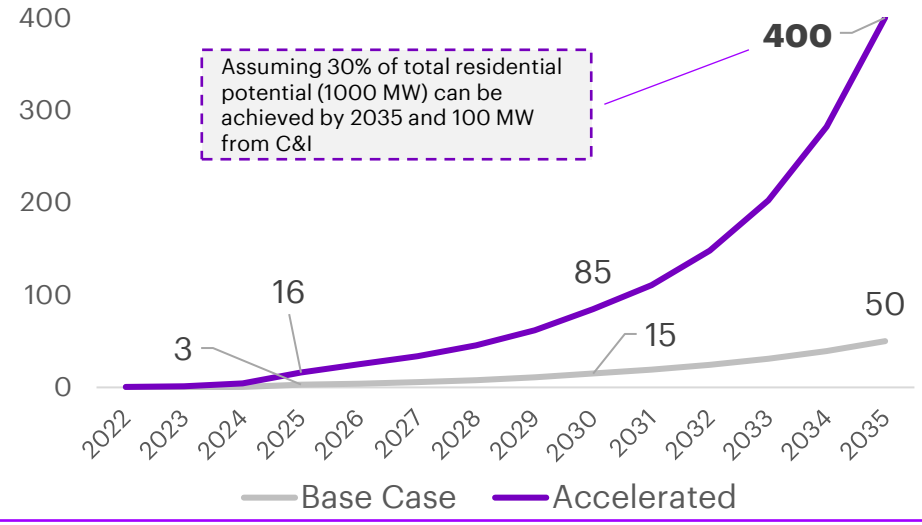
Overview

- As per the Brunei National Climate Change Policy (BNCCP), Brunei aims to achieve a target of **30% of renewables capacity in the electricity mix by 2035, equivalent to 300MW.** The majority share of the target is planned from utility-scale PV solar (250MW) and distributed solar (50MW)
- Brunei's renewable potential is constrained by limited land available to build ground mounted utility scale solar given the government commitment to preserve 70% of its land as forest land to act as natural sink
- In addition, current electricity tariffs are significantly subsidized, leading to **higher payback periods (10-14 years)** and therefore disincentivizing potential customers from investing in distributed solar

Opportunity

- A high-level assessment of Brunei's **potential for rooftop solar PV** was conducted for this study, both across the Residential and Commercial & Industrial Sectors
- From our estimates, the overall residential PV potential for Brunei is ~**1000 MW,** assuming average household area of ~200 sq m, based on data from ABCi. Drawing learnings from countries such as Australia where the distributed solar penetration is around 30-35 percent for the residential sector, Brunei has the potential to achieve **~30% of total residential distributed potential by 2035** – equivalent to **~300 MW** and an additional **100 MW** distributed capacity from Industrial and Commercial sector, assessed conservatively through Google Earth
- One way to accelerate the deployment of residential rooftop solar in Brunei could be to leverage the new **housing developments** which are included in the **National Development Plan every 2 years**; this would include ~1,000 new houses every 2 years, with potential additional capacity of 50+MW by 2035 (~ 10MW every 2 years)
- The existing **Net Energy Metering** scheme could be leveraged to drive adoption of the rooftop solar capacity, in addition to **rebalancing of the existing tariff subsidy** – which mostly incentivizes gas – **towards solar** (see next slide on different scenarios, depending on Levelized Cost of Electricity across the two technologies); finally, deployment might also be supported by new financing models such as **Solar-as-a-Service,** where consumers pay a monthly fee to rent and use the solar panels
- High levels of penetration of distributed solar (20%+), paired with **Net Energy Metering** schemes, may affect the reliability of the grid; however, in the case of Brunei, the penetration of solar as part of the generation mix, including the proposed distributed solar capacity in this solution, as well as the 300MW BNCCP target, would reach **17% by 2035**; however, while the need for battery storage is not immediate, it is key for the government to think about the optimal timing and incentives to deploy **battery storage** in the years to come. Finally recent business models such as Shared-Ownership Model for Behind the Meter Batteries involve CAPEX sharing between the consumer and utility where consumers can attain self-sufficiency and store the excess solar generation and the utility can better manage the demand supply during peak and off-peak hours

Projected Distributed Solar Capacity Addition in Brunei (MW)



System Value Impacts – Benefits

5536 + 200
Construction & Commissioning + O&M distributed scale solar incremental job impact until 2035

1.04 Mt
Additional CO2 emission reduction vs Base Case until 2035

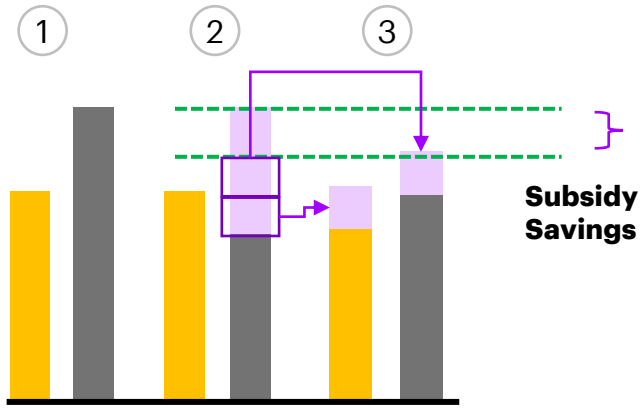
Increase in FDI if investment for distributed solar comes from foreign developer or financing institution

10%
Annual savings in Natural Gas consumption for power generation at full solar capacity (400 MW)

Distributed Solar Business Model Feasibility

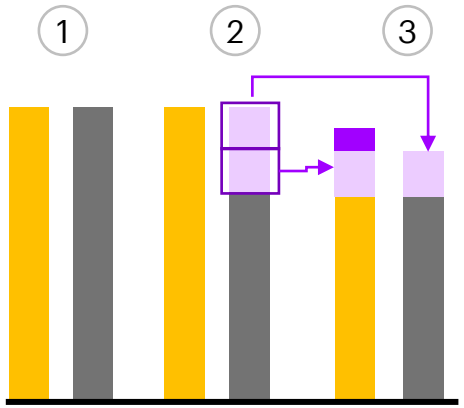
By redirecting a part of the existing subsidies for electricity generated from gas, redistributing the subsidy as an upfront sum to front CAPEX costs, factoring in the future carbon tax, and quantifying the value of the gas capacity freed up for export, distributed solar deployment is highly likely to be financially viable and feasible, even in the instance where the solar LCOE is higher than gas

Solar LCoE < Gas LCoE



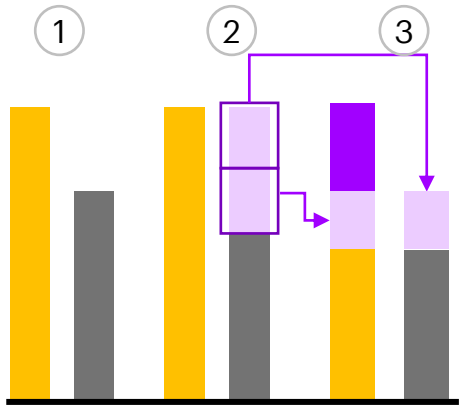
1. Solar LCOE initially cheaper than unsubsidized Gas LCOE
2. Due to subsidies to Gas, subsidized Gas LCOE is lower than (unsubsidized) Solar LCOE
3. Government only needs to divert only a part of the subsidy that was being given towards Gas and divert it to Solar, for Solar to achieve grid parity along with certain savings in Subsidy

Solar LCoE = Gas LCoE



1. Solar LCOE initially equal to unsubsidized Gas LCOE
2. Due to subsidies to Gas, subsidized Gas LCOE is lower than (unsubsidized) Solar LCOE
3. Government needs to divert some part of the subsidy that was being given towards Gas and divert it to Solar for Solar to achieve Grid Parity

Solar LCoE > Gas LCoE



1. Solar LCOE initially higher than unsubsidized Gas LCOE
2. Due to subsidies to Gas, subsidized Gas LCOE is further lower than (unsubsidized) Solar LCOE
3. Government needs to divert a part of the subsidy that was being given towards Gas and divert it to Solar and consider additional value levers such as Green Financing and Carbon Tax for Solar to achieve Grid Parity

Legend

- Solar Levelized Cost of Electricity
- Gas Levelized Cost of Electricity
- Government Subsidy
- Value levers such as 1) Financing for CAPEX upfront, 2) Carbon Tax, 3) Gas freed up for export

Floating Solar for the Grid and Green Hydrogen Production

Overview

- Given **land constraint**, Brunei's identified **Floating Solar potential** of **~2300 MW** presents a good alternative to Utility-scale Ground Mounted Solar in the country's energy transition journey. The identified potential can be used to **decarbonize the electricity grid** as well as to **produce Green H2.**
- Besides reducing emissions from the **electricity sector** which is **largely Natural Gas-based** and **contributes** to **most** of Brunei's **total emissions**, use of floating solar to power the grid would also **free up Natural Gas for exports**, unlocking much more value than using the gas to produce subsidized electricity.
- Green H2 can have **2 types of end uses** : **replacing Grey H2** in **existing applications** such as Oil Refining, and **future use as a fuel** in **industrial processes** and **transport**. **Grey H2** is a **significant source of global CO2 emissions** which can be abated by using Green H2 instead.

Opportunity

- Current cost of utility-scale floating solar in Brunei is comparable to ground-mounted PV systems at **~45$/MWh.** This is expected to **decline further** with **falling Solar PV costs** and **economies of scale.**
- While current **cost of Green H2 from floating PV** is estimated at **~3.5$/kg H2,** it is expected to **reduce** further **to US$ 2-2.5 per kg by 2030,** making a viable business case for Green H2 in Brunei.

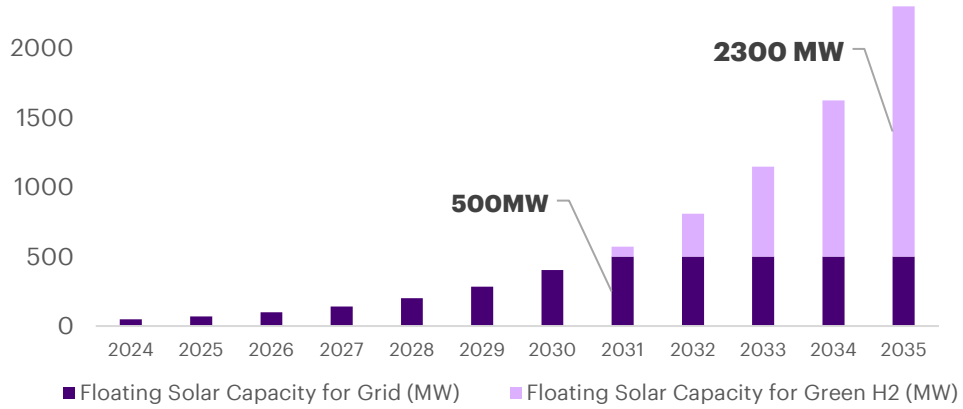
Grid Connected Capacity

- Installing **500MW of utility-scale floating solar** would lead to a 30% Solar penetration in the grid, assuming deployment of distributed solar as per solution 1
- With the proposed **increased penetration of variable renewables**, **a detailed study of the grid** would help evaluate whether digital upgrades, installation of battery storage and / or physical grid upgrades are required to ensure the reliability and flexibility of the grid.

Green Hydrogen

- The remaining **1800MW of Floating Solar** can be used to produce **Green H2 of ~0.06 Mtpa** by **2035.** Green H2 production could present an opportunity both for **domestic use** to meet local demand in industries, and the surplus could be **exported.**
- Green H2 can be exported to potential markets such as **Japan and South Korea** which are expected to have **sizable demand for clean H2** in their journeys to Net Zero. Brunei can leverage its **learning** from the pilot **AHEAD hydrogenation project** to develop this export market.
- Brunei's **Oil Refining industry** offers an opportunity for domestic demand of Green H2. Using projected Oil Production, **demand for H2 in Oil Refining** is estimated at **~0.03 Mtpa in 2035**.

Projected Floating Solar Capacity (MW)



Note: Green H2 will be produced from floating solar capacity above 500MW from 2031 onwards. Total Green H2 produced in Brunei till 2035 will be 0.11MT.

System Value Impacts – Benefits

4.1k Floating PV+
100 Green Hydrogen
O&M solar and Green Hydrogen incremental job impact until 2035

3.3 Mt Grid +
0.4 Mt Green H2
Reduction in CO2 emissions by replacing grey to green hydrogen by 2035

FDI
Net-zero clusters attract higher FDI due to cleaner production

15%
Annual savings in Natural Gas consumption for power generation at full solar capacity (500MW)

Source(s): CE Delft, CEEW, IRENA, S&P, ETC

Ways to Manage Increasing RE Penetration in the Grid

By 2035, Brunei could have **~30%** of solar PV penetration in the grid. Hence, effective planning of the grid would be necessary to ensure that the energy system is resilient and flexible enough to avoid high curtailment and stability issues.

1 Grid Digitalization (Shorter term)

Penetration of more solar in the grid leads to demand supply gap at certain times of the day (ToD). Digitalization can help integrate more solar energy by some of the following ways:

- **Demand Response** provides an opportunity for the consumers to shift the demand of electricity to other times of the day reducing the demand supply gap. Effective scaling of the **Unified Smart Metering System (USMS)** launched in Brunei in 2020 can enable demand response
- **Distributed Energy Resource Management System (DERMS)** helps the utilities to manage the Distributed Energy Resources such as rooftop solar in the grid.
- **Smart Grid** allows for two-way communication between the utility and its customers, and the sensing along the transmission lines makes the grid smart, enabling grid balancing

2 Energy Storage Deployment (Medium term)

Energy Storage technology absorbs power from the grid and then injects it later, thus providing flexibility to the grid. The services offered by battery storage can be in the form of **energy arbitrage, reserves and ancillary services, black start, T&D upgrade deferral.** Battery storage can be installed across the power system:

- **Generation (Behind the Meter):** Energy Storage behind the meter helps in storage of surplus electricity to be used later. Storage with Solar provides grid balancing and cost arbitrage to the prosumers
- **Transmission:** Integrating Battery Storage with transmission system can inject or absorb electricity. It helps in reliability services and provides congestion relief to the network
- **Distribution:** Storage in distribution network helps to integrate more distributed energy resources and defers network upgrade

3 Grid Infrastructure Upgradation (Longer term)

Grid Digitalization and Energy Storage Deployment can defer the upgradation of the grid infrastructure, but at some point, there may be a requirement of network upgrades. Following are some of the upgrades required for effective renewables integration into the grid:

- **Transmission infrastructure** to connect new renewable capacity to the main grid
- **Conductor Capacity:** The transmission and distribution cables have a limited capacity to transmit power. The conductor needs to be upgraded to meet the transmission requirement of additional renewable capacity
- **Other Equipment:** such as transformers, protection devices, circuit breakers needs to be upgraded to cater to the additional supply and demand of electricity

Highly Integrated & Upgraded Systems | **Flexible & Sustainable Grid** | **Resilient & Secured Systems** | **Reliability & Service Quality** | **Cost-Effective Infrastructure**

Source: Accenture Research

Global Case Studies on Sustainable Variable Renewables Growth

Experience from other markets suggest the need to start planning on sustainable solutions to manage increasing renewable penetration, based on capacity additions for short, medium and longer terms

Grid digitalization to maximize RE

Italy's national grid is digitalizing with Advanced Distribution Management System (ADMS) integrated to weather forecasting, this can provide visibility and modeling tools. This can help in predicting solar generation.

Challenge: Variability of grid-connected solar PV creates uncertainty and impacts on voltage profiles, and protection schemes

Solution: Integrated ADMS with weather forecasts can help in accessing information accurately and making better decisions that help in successfully integrating solar power. Benefits include:

- Real time data and network visibility helps to optimize the management of resources
- It will help in predicting the contribution of renewable power for better capacity planning
- It will help in planning demand and supply more accurately

Energy storage assisting RE integration

Energy storage is enhancing **Australia's** T&D networks and providing flexible peaking capacity

Challenge: The Australian grid faces an increasing mix of challenges due to rapid installation of wind and solar energy leading to limited flexibility and transfer capacity between regions. These result in high costs for energy consumers, electricity reliability issues, and potential curtailment of clean energy generation

Solution: Australia is installing some of the huge Energy Storage Systems for instance 'Western Battery' by Neoen with 500MW/1000MWh. These systems can be utilized to provide flexible peaking capacity, ancillary frequency control services, and the potential for other network services.
The layering of these services enables the storage asset to deliver maximum value to the benefit of all customers across different regions

Grid Upgrade to accommodate Solar PV

Utilities in **California, USA** are upgrading older areas of grid to modernize equipment and handle increased rooftop capacity

Challenge: California has one of the highest renewable penetrations of ~41% and has large distributed solar capacity. However, the power grid has lower hosting capacity to accommodate distributed solar and 2-way flow of power is not provisioned in some localities

Solution : SCE and PG&E utilities in California are upgrading the infrastructure such as transformers, conductors, and substation equipment to accommodate more and more solar rooftop.
California has also an approved 10-year transmission plan to upgrade the grid infrastructure to accommodate renewable energy in the grid. This plan would cover 23 projects of around USD 3 billion investment

Source(s): Schneider Electric, Fluence Energy, Wired, Californiacarbon Western Battery, spglobal 2021

Summary of the Solar Solutions (Distributed + Floating Solar)

Brunei can leverage an attractive solar opportunity, both in Distributed and Utility-scale Floating Solar to drive its energy transition goals by enabling significant emissions reductions as well as by unlocking higher value from Natural Gas from exports

400 MW Distributed Solar by 2035

- Brunei can aim to install ~30% of the total residential rooftop solar potential (estimated at 1000 MW) and additional 100 MW from Commercial and Industrial sector
- The National Development Plan can be leveraged to accelerate the deployment of residential rooftop solar in Brunei (this may include ~1,000 new houses every 2 years, with potential additional capacity of 50+MW by 2035 (~ 10MW every 2 years))

500 MW Floating Solar by 2035

- Brunei has a total floating solar potential of ~2300MW that can be used in powering the grid as well as Green Hydrogen production
- Keeping the grid considerations in view, we propose deployment of 500 MW floating solar for powering the gird and 1800 MW for green hydrogen production

Scenario	Solar Capacity Added	% Solar penetration in Grid by 2035	GHG Emissions Reduction (Million Metric Ton) by 2035	% Annual value savings in Natural Consumption in 2035	Cumulative jobs created by 2035
Accelerated Distributed Solar Deployment Case (400 MW by 2035)	**400 MW (+250 MW*)**	**17%**	**1.04 Mt**	**10%**	**5.7k** (~5500 Construction and Commissioning + ~200 O&M jobs until 2035)
Grid Connected Floating Solar Deployment Scenario (500 MW by 2035)	**500 MW (+250 MW*)**	**21%**	**3.3 Mt**	**15%**	**4.2k** (~4.1k floating PV + ~100 Green Hydrogen jobs until 2035)
Accelerated Distributed Solar Deployment Case (400 MW by 2035) + Grid Connected Floating Solar Deployment Scenario (500 MW by 2035)	**900 MW (+250 MW*)**	**31%****	**4.37** Mt**	**25%**	**~10k** (~5.7 k from Distributed Solar + 4.2 k from Floating Solar)

*Note: The 250 MW capacity is as per the existing solar PV targets in Brunei
**Note: The 31% penetration as a result of the Distributed Solar Deployment and Floating Solar Deployment may not be a direct addition of the individual scenario penetration percentages to avoid double counting of the 250 MW base case PV deployment

CCS as a Business: Domestic and Export Opportunity

Brunei could have adequate storage resources to create a Northern Lights CCS equivalent and could aim to be a player in a regional CCS hub ecosystem. Levels of Carbon Pricing and/or state-funding would determine CO2 share from domestic and overseas markets

Assumed Potential size*	Domestic Carbon Pricing Scenarios	Assumed Overseas Carbon Pricing [1]	Share of CCS Utilization of Domestic vs Overseas industries	
5 MTPA	Low carbon tax @5-10 USD/t	47 USD/t		All CCS capacity would be utilized by CO2 imports from countries with higher Carbon Pricing / Tax
	Selected scenario for SVA analysis			
	Carbon tax @30-40 USD/t	47 USD/t		Domestic Carbon Pricing at par with that of Singapore's planned 2030 minimum, could incentivize a few industrial sectors such as Natural Gas Processing that has the least capture cost to opt for CCS
	Carbon tax @50-60 USD/t	47 USD/t		Domestic Carbon Pricing at par with that of Singapore's planned 2030 maximum could incentivize additional industrial sectors such as Ammonia production to opt for CCS

*Comparable to commercial sized projects such as Northern Lights

[1]Median value of Singapore's planned 2030 Carbon Tax

Brunei Domestic Industry

Import from Overseas

Source(s): NCCS Singapore, Northern Lights

CCS as a Business: Domestic and Export Opportunity

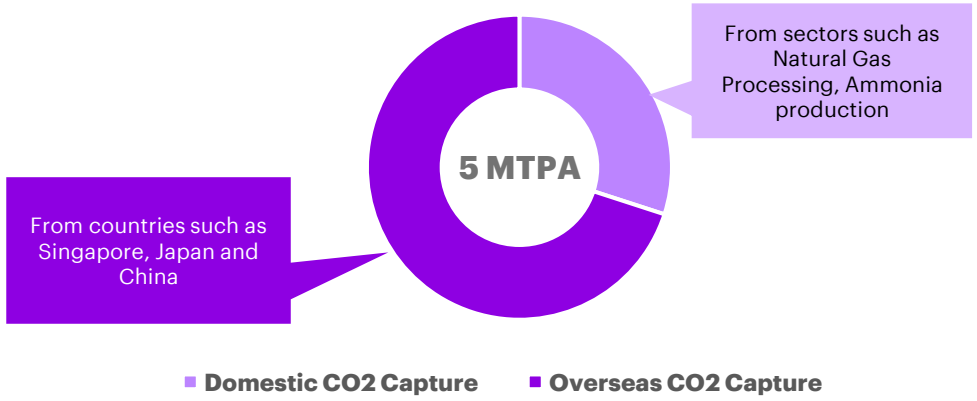
Overview

- With **adequate CO2 storage capacity** expected to be available, Brunei can aim to create **CCS infrastructure comparable to Norway's Northern Lights** project which targets to capture 5Mtpa CO2 by 2030.
- The **share of utilization** of such a CCS project between **domestic industries and export markets** such as Singapore would depend on the **Carbon Pricing levels and/or State funding** for CCS in both Brunei and the importing countries.
- Given the **high capital costs and risks** associated with CCS, **State funding** could be an important lever in to enable market development of CCS in the region.
- Investment in CCS capture, transport and storage infrastructure would greatly benefit from **economies of scale** associated with **aggregated demand** from both domestic and overseas industries – **industrial clusters** could be leveraged to create **shared infrastructure** to drive down CCS costs.

Opportunity

- While **several CCS projects** have been announced by other countries such as Malaysia and Indonesia in the region, most of them have been planned for **captive use** and would use **depleted oil and gas fields** for storage. In such a situation, Brunei could leverage **first mover advantage** in planning to become a player in **regional CCS hub** that would cater to **multiple industrial clusters** across the region and use **Saline Aquifers** which have significantly higher storage capacities than Depleted Oil & Gas fields.
- Brunei could leverage **existing trade relations** with countries such as **Singapore, Japan and China** to serve their CCS needs. While **Singapore** and **Japan do not have** suitable **storage resources** of their own, China has implemented several CCS demonstration projects for captive use. All 3 countries have announced CCS as a key solution area to decarbonize heavy industries and could **partner with Brunei** to **share some of its CCS** capacity to meet their targets.
- Brunei can target to capture **5 Mtpa CO2 by 2035** with the **major share initially coming from imports** from **countries** that have **adequate carbon pricing and/or State funding** for CCS but **limited storage resources,** and **gradually ramping up domestic capture** as **Brunei brings in carbon pricing.**
- For **domestic industries, Carbon Pricing** would be **key to incentivize** uptake of CCS. Tapping into the domestic CCS opportunity will not only create additional jobs (building the infrastructure, operating the facilities, etc) but also **help protect jobs** in the **O&G sector** which has a **significant contribution to Brunei's economy** but is associated with **hard to abate emissions**

Domestic and Overseas share in 5Mtpa project by 2035 in the Moderate Domestic Carbon Pricing Scenario



System Value Impacts – Benefits

576
Incremental jobs impact by 2035 (308 Capture jobs, 77 storage jobs and 192 Transport jobs)

~25K
Jobs protected in the Oil and Gas and associated industrial sectors

7.5 MT + 17 MT
Domestic Capture + Imported Emissions Stored until 2035

Expected Increase in FDI and revenues from a diversified economy

Source(s): IEA , Brunei Labour Force Survey 2020, SINTEF, Accenture Research

Accelerators for Carbon Capture and Storage

Taking cues from countries like UK, Netherlands and the US, various policy instruments can be introduced to help the business case for CCS in Brunei. Brunei can also leverage green financing from international finance entities for CCS investments.

Policy and Funding instruments used for Incentivizing CCS

- **Carbon Pricing Instruments (CPI) -** Carbon taxes impose a financial penalty on emissions such as that in Singapore and Norway. Emission Trading Schemes involve a cap on emissions from large industrial emitters and use ETS certificates for trading carbon credits in the market, such as that in Europe and China
- **UK infrastructure fund for CCUS -** Grant Support of USD 1.4 billion Capital funding provided directly to targeted projects or through competitive programs to overcome high upfront costs
- **US 45Q and 48A tax credits -** Tax credits at USD 12-50/t CO2 captured or stored is awarded to industries who invest in CCS, thereby making such projects more commercially-viable. A proposal is now in Congress to boost it to as high as $175/ t CO2. Tax credits are applicable to both long-term underground storage and enhanced oil recovery.
- **Regulated Asset Base (RAB) Funding Model in UK -** A RAB model in the Transportation & Storage (T&S) context would involve a regulator granting operators licenses to provide T&S services, allowing them to charge a regulated price (a T&S Fee) to CO2 capturers for their use of the T&S network. The regulated price would be set by the regulator periodically, and would be based on a function of the approved costs of developing the T&S infrastructure, which may increase or decrease against estimates as construction progresses

Source: IEA, U.S.Senate, CMS-Law.now

International Financing for CCS		Pilot projects	Capacity building*	Capital Support	Operating or revenue support
Development finance institutions, MDBs	CCS trust funds (ADB, World Bank)	●	●		
	Concessional loans from MDBs	●		●	○
	IFC-leveraged investment	○		●	○
Climate finance/multilateral climate funds	Green Climate Fund	●		●	○
	Global Environment Facility	●		●	○
	Climate Technology Centre and Network	●	●		
Sustainable debt securities	Green/sustainability bonds	○		●	●
	Transition bonds	○	○	●	●
	Bank loans	○		●	●

ADB = Asian Development Bank. MDB = Multilateral Development Bank. IFC = International Finance Corporation
Note *- including legal and regulatory development and technology assistance.

Legend ● Eligible ○ May be eligible

Transport Decarbonization through Electrification & Shared Mobility

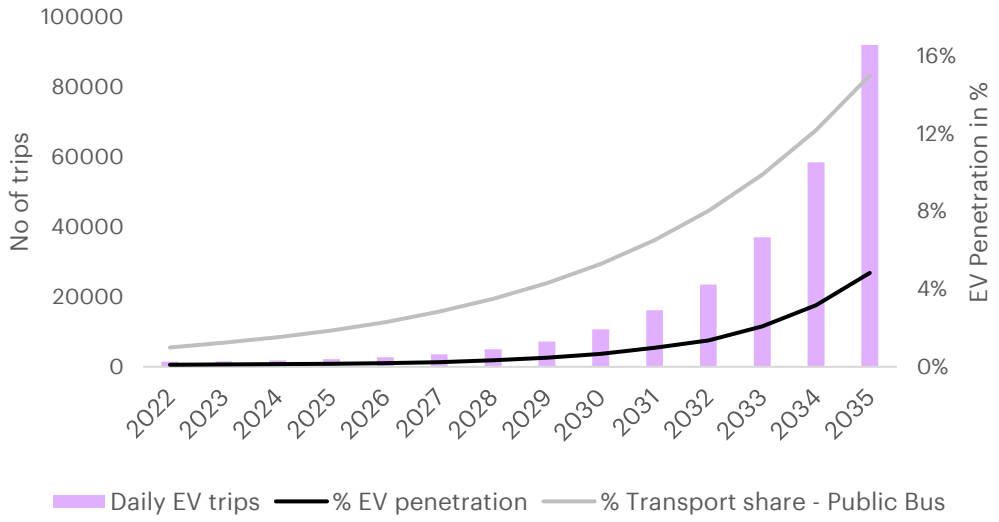
Overview

- Brunei has one of the highest per capita vehicle ownership around the world (649 vehicles per 1000 people). The transport sector accounts for nearly half of Brunei's energy consumption with ~80% consumed by cars
- The low cost of running a car (on account of significant Government subsidies on fuel) and lack of an effective public transportation system continues to ensure that private cars are the preferred option. Presently, the Transport sector accounts for ~17% of the emissions in Brunei
- Brunei plans to achieve a target of **60% of EVs by annual sales volume in 2035**

Opportunity

- Emissions reduction from the Transport sector can be done both by increasing the usage of public transport (and/or reducing ownership of private vehicles) and Electrification of transport vehicles
- With the current electricity mix dominated by Natural Gas, achieving the EV targets will be more meaningful if the Renewable Energy contribution in the electricity generation mix is enhanced
- As the current penetration of public transport is very low, Brunei can leverage this opportunity to use Electric Vehicles to achieve its transport related targets as -
- **Electrification of transport -**
  - **Public Buses** – Leveraging Electric buses to build public bus transport facilities in Brunei. This would require a close collaboration between technology, manufacturing and grid companies to ensure smooth operations of the Electric buses
  - **Taxis** – Propose to increase the number of taxis plying on Brunei roads, improve their service quality and reliability. Enabling measures such as upfront financing support and favorable licensing requirements for EVs, can enhance the EV uptake for Taxis
  - **City Fleets** – The procurement model for the Government and municipal fleets can be modified to enable rapid adoption of EVs
  - **Private EVs** - Reducing Total Cost of Ownership and setting up adequate EV charging infrastructure are the critical factors for enabling the transition from ICE vehicles to Electric Vehicles
- **Enabling public transport through new and upgraded infrastructure -**
  - **Bus Rapid Transit System** – These can be an effective enabler to enhance adoption of Public Buses in Brunei. A BRT typically incorporates provision of segregated right-of-the-way infrastructure, rapid and frequent operations
  - **Monorail Systems** – As the adoption of public transport increases, monorail systems can also be explored as a future mode of transport

Projected EV penetration and Public Bus Share



System Value Impacts – Benefits

0.3 Mt
Cumulative CO_2 emissions reduction from EVs until 2035

Savings in fuel subsidy due to transition from ICE to EVs

Increase in FDI through EV infrastructure setup in Brunei by foreign players

740*
Incremental job impact until 2035 due to public buses and taxis

Source(s): WorldAtlas, Land Transport Whitepaper, Land Transport Masterplan *Note – Assumed 3 incremental jobs per each Public Bus and 1 job per each Taxi

How are global leaders enabling Public Transport Electrification?

Learnings can be drawn from various countries/cities around the word that have led the way in electrifying their public transport.

	Case Studies	Key Learnings
Public Buses	 • Shenzhen (China) was the first city in the world to achieve 100% electric bus fleet • The electrification led to reduction of **1.35 MMT CO2** emissions per year • The bus fleet now consumes ~**73% lesser** energy as compared to 2016 levels • The bus operators were incentivised with an annual subsidy of USD 75,500 for each vehicle, **80% funded by the Shenzhen city authorities and 20% from central government**	• Build **close partnerships in manufacturing, utilities and energy generation** to ensure sufficient charging capacity and grid management processes are in place • Deploy **fiscal incentives, build supporting infrastructure**, and optimise fleet scheduling • **Defining technical specifications** to ensure operational efficiency and interoperability
	 • Santiago (Chile) has the largest deployment of electric buses in South America • The **procurement model** was altered to incentivise operators for adopting EVs by awarding larger contract terms to operators with >50% EV bus fleet • Established an **electric corridor with segregated lanes** with access to bus depots with charging infrastructure at either end of the electric bus corridor.	
Taxis/Shared Mobility	 • Dundee (United Kingdom) has **~20% taxis and private rental vehicles fleet of EVs** • Installation of **rapid charging hubs** has accelerated the EV adoption in taxi owners • To encourage electrification of the taxi fleet, Dundee introduced significant **changes to taxi licensing policy** whereby all new private hire licences are required to be for EVs	• Establish **long-term incentive mechanisms** to encourage drivers and/or taxi owners to transition to an EV fleet • **Licensing requirements** can be modified to further enhance the uptake of EVs • Generate **awareness and educate the drivers/owners** about the holistic benefits of EVs (both economical and environmental)
	 • In Taiyuan (China) ~**8300 taxis were electrified within an 8-month period** on account of a planned taxi fleet renewal • When the taxi licences were due for renewal, the authorities seized this opportunity to establish subsidies which covered ~66% of the cost of a new vehicle • The subsidies were borne by the combination of Municipal government, Provincial government and the Central government	

Source: IEA

How are global leaders enabling Private Transport Electrification?

Learnings can be drawn from various countries/cities around the word that have led the way in electrifying their private transport.

Private EVs

Case Studies

- Norway has set a **national target for 100% of new cars to be zero-emission by 2025**
- With a set of enabling government policies, Norway has achieved **75% of new car sales from EVs in 2020** vis-à-vis ~75% of new car sales from diesel cars in 2010
- The **Norway EV Association** has ~80,000 members and works in conjunction with the government to promote better charging infrastructure, lobby for EV-friendly policies, and encourages adoption of EVs among consumers
- The transition to EVs was driven by **purchase tax exemptions** (purchase/import tax and VAT exemptions)
- Norway introduced a **legislation in 2017 that requires new buildings to have at least 50% of the parking facilities equipped for electric car charging**

- San Francisco (USA) set up an EV Working Group in 2015 with targets to achieve **100% new passenger vehicle registrations to be EVs by 2030**
- An **EV Readiness Ordinance** was passed in 2018 which requires that new residential, commercial, and municipal buildings should have sufficient electrical infrastructure to charge vehicles in 20% of parking spaces
- In 2020, San Francisco also started working together with C40 (global network of cities representing ~20% of global economy) to **establish guidelines and criteria for developing on-street fast charging infrastructure**

- In Liuzhou (China) there was a 10-month EV car test drive campaign run by a local manufacturer that resulted in ~**70% of the total 15000 participants buying EVs**
- The local municipal authority intervened with supporting policies such as **vehicle purchase subsidy, reserved parking spaces for EVs, and charging subsidies**
- Leveraged **Public Private partnership** for building charging infrastructure in the city

Key Learnings

- Roll out **incentives** (e.g purchase tax exemptions, dedicated lanes, etc) to **encourage early adopters** to try EVs
- Establish **co-creation avenues** to define policies **with due considerations to consumers' needs and opinions** to ensure faster uptake (e.g., San Francisco EV working group)
- Leverage **multiple communication channels** (TV, social media, print media, etc.) **to create awareness** among consumers about the benefits of EVs and disseminate information about the Government policies

Source: IEA

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	Organisation	Peer Reviewer/Contributor
1	**Brunei Shell Petroleum (BSP)**	Agnete Johnsgaard-Lewis, Hjh Rosita Hassan, Shirley Sikun, Zukri Rahman, Rachel Ho, Yusri Mat Yussof
2	**Department of Energy (DoE), Prime Minister's Office**	Hj Azhar Hj Yahya, Hjh Dina Yahya, Matiin Kasim, Ahmad Ridza Abdul Rahman, Freddie Tong, Shaikh Dzulamali Shaikh Hj Abdul Mutalib, Jasrin Serudin
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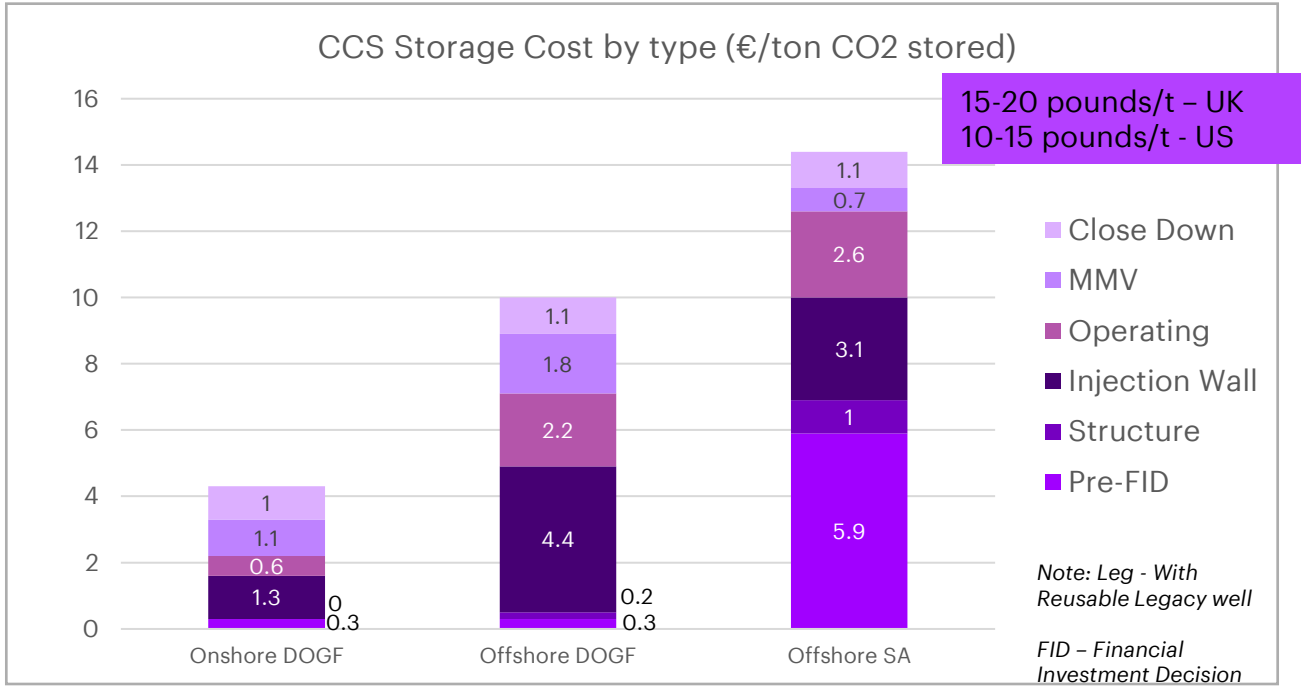
5	**Ministry of Transport and InfoCommunications (MTIC)**	Hjh Lailatul Zuraidah Hj Mohd Hussain
6	**Authority Of Building Construction Industry (ABCi)**	Nurhafizah binti Haji Hamdani

Appendix

CCS: Lessons from the North Sea

With high capital costs, the choice of CCS facilities between Onshore and Offshore, and Depleted Oil & Gas Fields vs Saline Aquifers will be influenced by resource availability, expected demand, future potential and presence of existing infrastructure.



UK's CCS Projects

HyNet North West

Type: DOGF

Capacity: 4.5MT CO2/yr *(Initial)*
10MT CO2/yr *(post 2030)*

COD : 2025

acorn

Type: Saline Aquifer

Capacity: 0.3 MT CO2/yr *(Phase 1)*
5-10 MT CO2/yr*(post 2030)*

COD : 2024 (Phase 1)

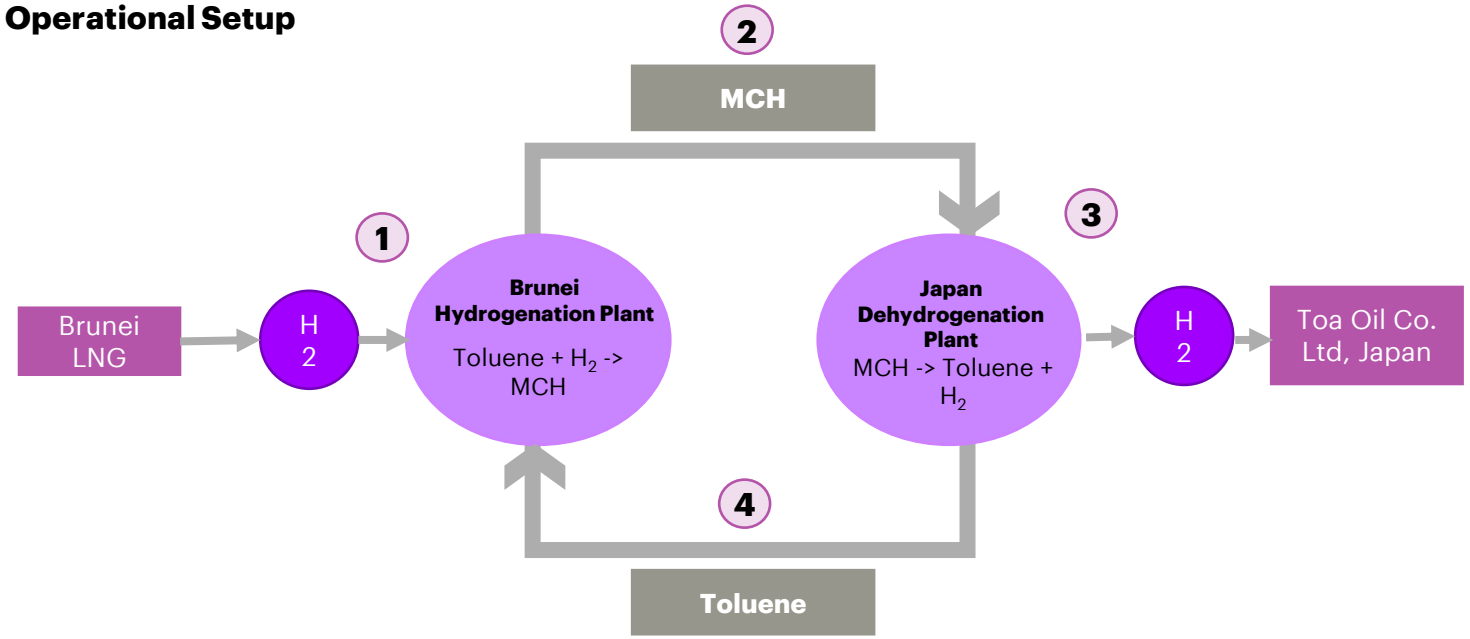
- Carbon capture **capacity Saline Aquifers** is known to generally be **manifold higher** than that in **depleted oil and gas fields.**
- **Both storage technologies** present the **same capture costs** (including compression/liquefaction for transport), which represent the **major share of total CCS costs @55-75€/ton** CO2
- However, **exploration costs for SAs** could be high and could be nearly as high as the entire storage costs for offshore DOGF, including its operations. This is because **DOGF already have been extensively explored** and surveyed for its Oil & Gas production, leading to **lower exploration costs**
- In theory, **EOR and CCS** can be operated **simultaneously** on a field generating additional revenue; however, setting up and **operating** infrastructure for both facilities **together** can be **challenging** due to **leakage risks** and **infrastructure crowding**
- With **long** expected **operational life** of commercial CCS facilities **~40 years**, **exploration activities** should **focus** on **large reservoirs** capable of storing CO2 from both single and multiple sources over its lifetime based on expected **long-term demand**

Source(s): Global CCS Institute, Accenture Research

Brunei - Japan Hydrogen Supply Chain Demonstration Project

The world's first international Hydrogen supply chain was set up between Brunei and Japan as part of a demonstration project that converted H2 from Brunei's Natural Gas supply to Methylcyclohexane (MCH) for shipping to Japan

Operational Setup



Project Timeline

July 2017	AHEAD established
Nov 2019	Construction of hydrogenation plant in Brunei completed
Dec 2019	First MCH arrived in Japan
Apr 2020	Operation to separate H2 from MCH at dehydrogenation plant in Kawasaki started
May 2020	Supply of H2 dehydrogenated from MCH to gas turbine started
Jun 2020	Toluene obtained from dehydrogenation sent back to Brunei for reuse
Dec 2020	Demonstration completed

- The **world's first global hydrogen supply chain project** saw Brunei Darussalam and Japan transporting over **200 Mt of Hydrogen**
- The demonstration operation was started by The **Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD)** and the project was subsidized by the New Energy and Industrial Technology Development Organization (NEDO)
- The H2 shipped from Brunei's first hydrogenation plant at the **Sungai Liang Industrial Park (SPARK)**, was used as **fuel for gas turbine power generator** in Japan's **Toa Oil Company**
- **Capacity** of hydrogen transportation: **210 tons/year** at full operation

1. Supply chain starts with procurement of H2 in Brunei Darussalam
2. H2 is mixed with Toluene to produce MCH (MCH) and shipped to Japan
3. MCH dehydrogenised to produce H2, which is sent to Tao Oil Company to power the gas turbines
4. Toluene left after dehydrogenation is sent back to Brunei Darussalam

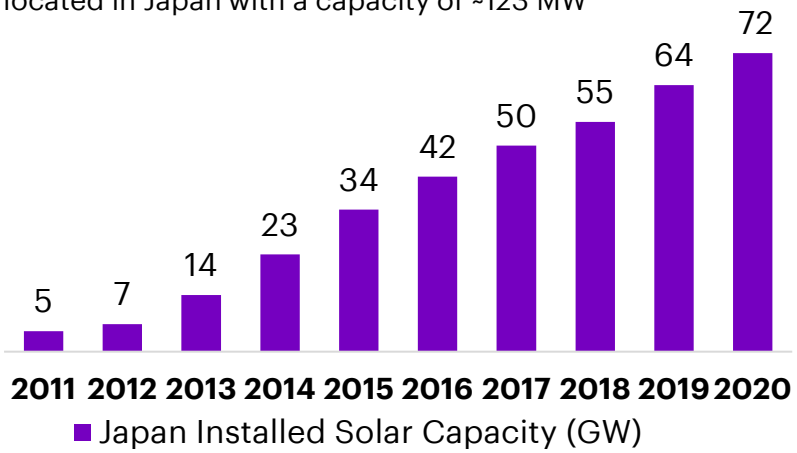
Source: NYK

How to scale distributed solar given the land constraints in Brunei

Brunei can take inspiration from Japan that has achieved exceptional solar growth despite very limited land area. Emerging PV technologies and concepts such as Agrivoltaics can also provide efficient land usage for the solar installation.

Japan's solar growth story

- Japan has a population density of 347 people per sq.km whereas Brunei has a density of 75 people per sq.km (slightly less than Malaysia). Japan has an average annual solar irradiation of 990-1660 kWh/m^2 as compared to 1575-1812 kWh/m^2 for Malaysia
- Despite the land constraints and low solar irradiance levels, Japan has witnessed exponential solar growth, from 5GW in 2011 to 72GW in 2020
- The growth has been enabled by technological advancements including **floating solar technologies and measures such as Feed-in-Tariffs**
- 74 out of the world's 100 largest floating solar plants are located in Japan with a capacity of ~123 MW



New Concepts and Emerging Solar PV technologies

Many new solar panel technologies have been developed to improve the efficiency of the cells, thus reducing the space requirements per unit power generation.

Bifacial Solar Panels - Typical efficiency improvement of 6-9% vs conventional panels. Carports and roof with white surfaces are best use cases

Floating Solar Panels – Cooling effect of water beneath the panels can boost efficiency by ~12%. Solar aquaculture is being adopted for local community (jobs & food).

Agrivoltaics-Efficiency of PV panels is highest on farmland compared to any other landscape

Agrivoltaics – Co-locating solar panels alongside agriculture land

- Agrivoltaics can provide an additional source of income to farmers when they lease their land for solar panels installation and boost the yield of vegetables and decrease water consumption

Case in Point- The InSPIRE project by U.S. Department of Energy

The InSPIRE project is aimed to demonstrate the agrivoltaic opportunities for cost reductions and environmental compatibility of solar energy . The InSPIRE Research Site in Tucson Arizona has reported results as:

- **3x** increase in crop yield (Peppers and Tomatoes)
- **50% less** water consumption
- **2% higher** solar panel production output

Financing Models for Distributed Solar

Brunei can learn from examples of financing models which have succeeded in other markets with high distributed solar deployment

- **Green Loans -** In **Turkey,** the World Bank has been providing **concessional loans** (lower interest rate) from time to time in cooperation with two Turkish development banks – the Development Investment Bank of Turkey (TKYB) and the Industrial Development Bank of Turkey (TSKB) – or state-owned banks under the **"Sustainable Cities"** project. Usually, provided by development finance institutions (DFIs) and non-governmental finance organizations with higher risk rates compared to commercial banks

- **Central Fund Assistance (CFA) -**
  - **Poland** presents a special case from among the EU countries for being the fastest in the last few years in terms of adding solar PV capacity, with **75% of this capacity coming from small-scale prosumer micro-installation systems** (less than 50kW). Ministries launched "My Electricity**"** program for urban area that allows individuals to receive the subsidy of ~1263 USD for a small (2 kW–10 kW) installation of PV on their own roof
  - In most of the states of **India,** the residential sector enjoys benefit of subsidized electricity; thus, CFA has been introduced by Ministry of New Renewable Energy (MNRE) under "**Rooftop Solar Program"** to encourage movements towards installation of rooftop solar in houses. As per the scheme, 40% subsidy for the first 3 kW and 20% subsidy beyond 3kW and upto 10kW of solar panel capacity

- **Feed-In Tariffs –**Japan has witnessed exponential solar growth, from 5GW in 2011 to 72GW in 2020 despite land constraints, this has been possible due to measures such as **Feed-in-Tariffs** for the Solar PV power supply. Similarly, launch of Feed-in tariffs (FiTs) scheme (for rooftop) have been the main driver for the growth of solar in **Vietnam** as it allows owners to sell their electricity at **US$ 83.8 per MWh** to state-owned Vietnam Electricity.

- **Fiscal Incentives -** In Vietnam, **solar developers were exempted from corporate income tax** for the first four years of operation. Income tax also was reduced by 50% in the following nine years and then by 10 years until the 15th year of operation. Imported equipment has also been exempted from import tariffs

- **On-Bill Financing -** 20 states in the **U.S**. have utilities with on-bill financing programs. Financing is made available to a consumer for the purchase of a rooftop solar system and the payback is collected by the utility through a monthly charge on the consumer's bill. Four large utilities in California (San Diego Gas & Electric, SoCalGas, SoCal Edison & Pacific Gas and Electric) operate on-bill loan programs for commercial customer

