Chapter 3

Case of Cogeneration Systems Installed in Malaysia

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Chapter 3

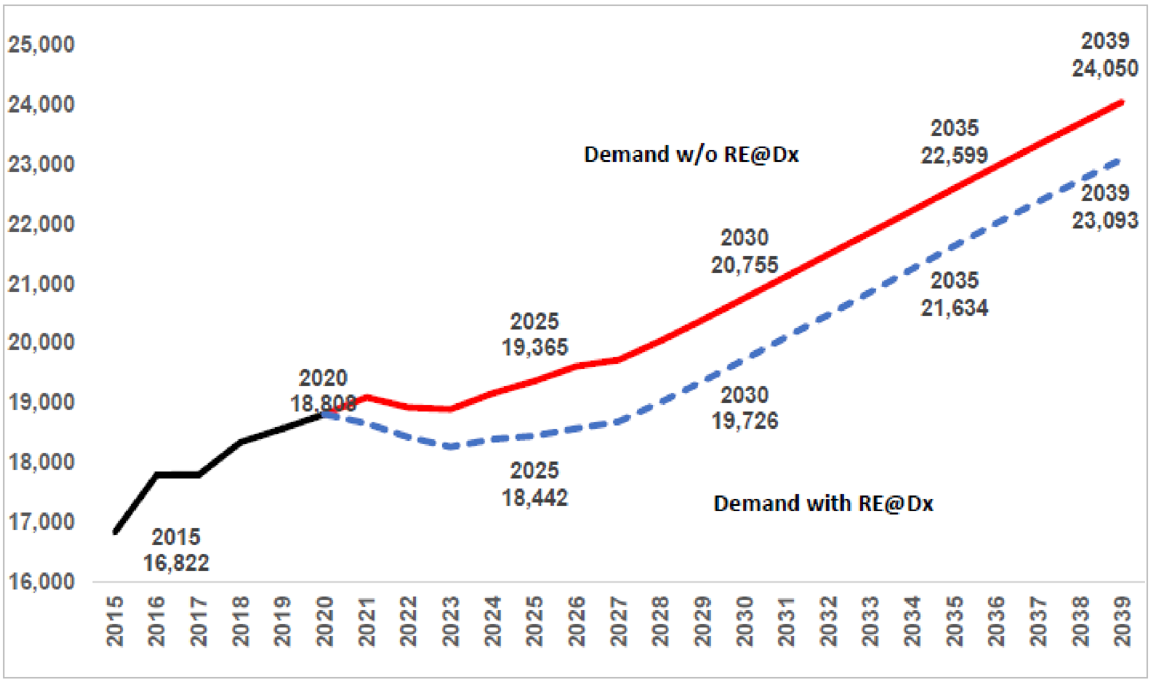
Cogeneration Systems Installed in Malaysia

3.1. Overview of Energy Demand in Malaysia

The total final energy consumption in Malaysia as of 2018 was 64,658 ktoe, out of which electricity consumption was 13,153 ktoe or 152,866 GWh as reported in the National Energy Balance Malaysia 2019. Based on the Energy Commission's report (2018), the installed CGS capacity is low at 3.3% of the total electricity generation of 133,447 GWh for Peninsular Malaysia, and 3.1% of the total electricity generation of 6,539 GWh for Sabah. There are CGS plants in the public and private sectors. The energy sources are natural gas, diesel, biomass, and waste heat from industrial processes.

Historically, the growth of demand from 2015 to 2020 was 16,822 MW to 18,808 MW, or an annual growth rate of 2.3%. The COVID-19 pandemic significantly reduced the overall demand in 2020. However, new peak demand was recorded on 10 March 2020, a week before the imposition of Movement Control Order due to COVID-19 on 18 March 2020. For 2021–2030 and 2030–2039, demand is projected to grow by 0.9% and 1.7% per annum, respectively (Figure 3.1). COVID-19 is expected to cause a temporary decline in demand. But from 2023 onwards, the growth is projected to normalise in line with economic recovery.

Figure 3.1. Peak Demand, Actual 2015–2020 and Projection 2021–2039



Source: Energy Commission Malaysia (2021a).

Cogeneration is recognised as an energy-efficient technology in Malaysia. It enables the simultaneous production of two different forms of useful energy – typically electricity and thermal energy – from a single primary energy source, also known as combined heat and power (CHP), merging the generation of usable heat and electricity into a single process, substantially reducing carbon emissions and energy costs. The electricity generated is normally for on-site use, and any excess may be exported to the local utility network. Thermal energy produced may be used for industry purposes or to produce steam, hot water, or hot air for drying or heating, or chilled water for cooling purposes. As a general observation, electricity generation alone from a simple CGS in Malaysia is not competitive compared to the electricity supply from the national grid. This is because the electricity tariff in Malaysia is relatively low due to government subsidies for electricity generation by power utilities and higher cycle efficiency from combined cycle generation plants. However, the viability of CGS installation improves with increasing heat energy demand in a process plant, for example.

3.2. Introduction: Installed CGS in Malaysia

This part of the study is research conducted on existing CGS installations in Malaysia's industry sector. It reviews the state and viability of CGSs through literature research, published information from Malaysian authorities and institutions, interviews with plant operators, and assistance from equipment manufacturers and system suppliers on a non-disclosure agreement basis. Despite the reported benefits of CGS installations with an improved energy efficiency of as much as 90%, the pace of cogeneration installation in Malaysia has remained sluggish. Moreover, before introducing the New Enhanced Dispatch Arrangement ((Energy Commission Malaysia, 2019a), the private sector experienced some barriers to implementing cogeneration projects, as listed below.

(1) A cogenerator could not export and sell the excess energy generated in the facility through the electricity supply grids unless a power purchase agreement exists with the electricity supply or utility company, which is the only electricity distributor. This was one reason affecting the wider use of cogeneration, as the sale of excess energy may be a factor in the investment consideration. The generation of electricity for sale requires a licence from the Energy Commission, which regulates the generation and supply of electricity in Malaysia. Furthermore, the cost of electricity generation from CGS installation is not as competitive as that of the utility company for the reasons stated above.

(2) The utility company imposes high standby charges on cogenerators that sell excess electricity.

Other challenges to cogeneration in Malaysia are as follows:

(1) Constraints in natural gas supply

(2) Subsidised electricity tariffs make cogeneration projects not as attractive

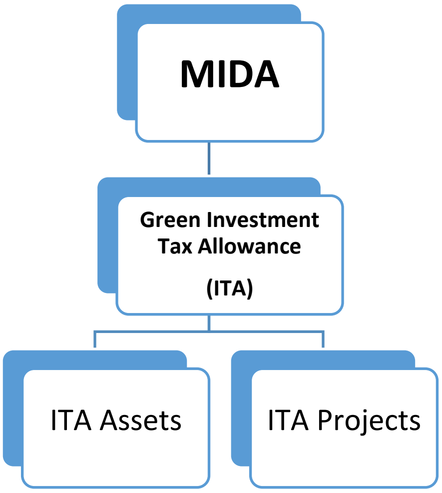
(3) High reserved margin in the grid system

(4) Lack of specific fiscal incentives and financing mechanisms to increase the viability of cogeneration projects

In 2015, the Ministry of Energy Malaysia implemented the National Energy Efficiency Action Plan. Under Key initiative 4, cogeneration for industries and buildings was promoted by addressing barriers such as standby and top-up charges, gas tariff pricing agreement, incentives, technical hurdles such as licensing requirements, and lack of awareness on benefits of cogeneration.

As a result, the Malaysian government offers some attractive incentives for investors in cogeneration plants. These include incentives for companies entering into energy performance contracting (EPC) schemes with ESCOs or investors in cogeneration plants serving their energy needs. Other incentives include import duty and sales tax exemptions, investment tax allowance (ITA), and pioneer status. The Energy Commission evaluates applications for import duty and sales tax exemptions for cogeneration equipment while the Malaysian Investment Development Authority (MIDA) processes ITA and pioneer status applications for energy-efficient investments.

Figure 3.2. ITA Application Flowchart



MIDA = Malaysian Industrial Development Authority.
Source: Authors.

The eligibility of companies applying for ITA is based on the following criteria:

(1) The company must be incorporated under the Companies Act, 2016.

(2) The company must achieve the following green results:

- Conserve the use of energy and/or other forms of natural resources, promote renewable energy, or recycle waste material resources.
- Minimise the degradation of the environment or reduce GHG emissions.
- Promote health and improve the environment.

Table 3.1. Example of ITA Benefits by Comparing Tax Computation based on 'With' and 'Without' Tax Incentives based on an Assumed Green Project Investment of RM10 Million

	Without Tax Incentive (RM)	With Tax Incentive (RM)
Profit before tax	15,000,000	15,000,000
Add/less tax adjustment	2,000,000	2,000,000
Adjusted income	17,000,000	17,000,000
Less capital allowance	(5,000,000)	(5,000,000)
Statutory income	12,000,000	12,000,000
ITA amount		10,000,000
Taxable income		2,000,000
Tax liability/saving @24%	2,880,000	480,000
Overall Tax Savings (Comparing with without tax incentive)		**2,400,000**

Source: Authors in consultation with Kawan Engineering Sdn Bhd in 2022.

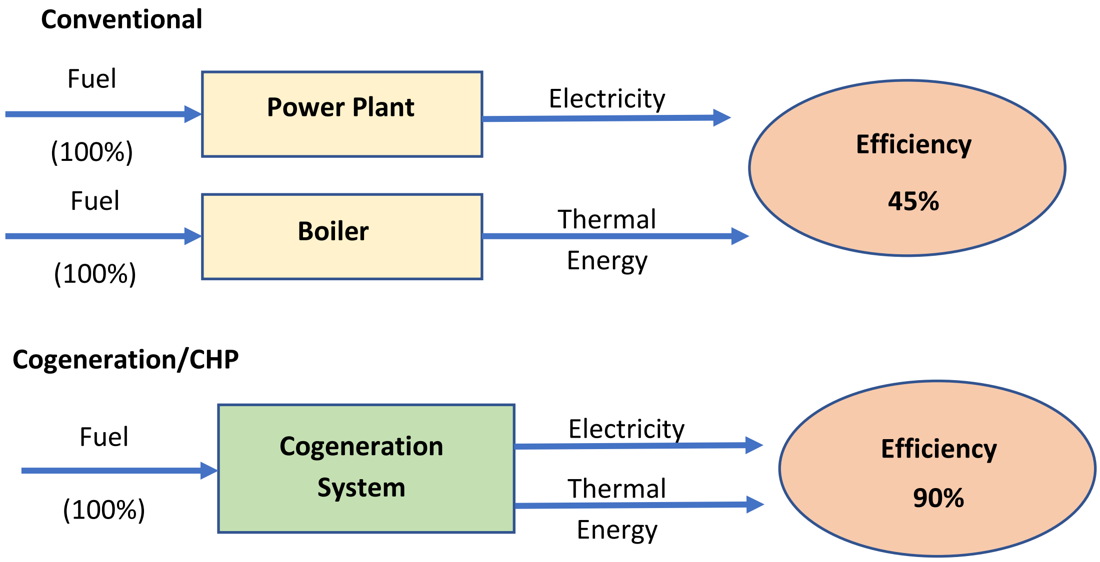
Table 3.1 shows an example of tax benefits under the ITA scheme. This example is based on an assumed green project investment of RM10 million that can be used to offset the statutory income under the ITA scheme. The overall tax saving works out to be RM2.4 million. Green projects include CGS installations.

3.3. Benefits of the Cogeneration System

Cogeneration is an energy-efficient technology (Figures 3.3 and 3.4). CGS benefits are briefly summarised as follows:

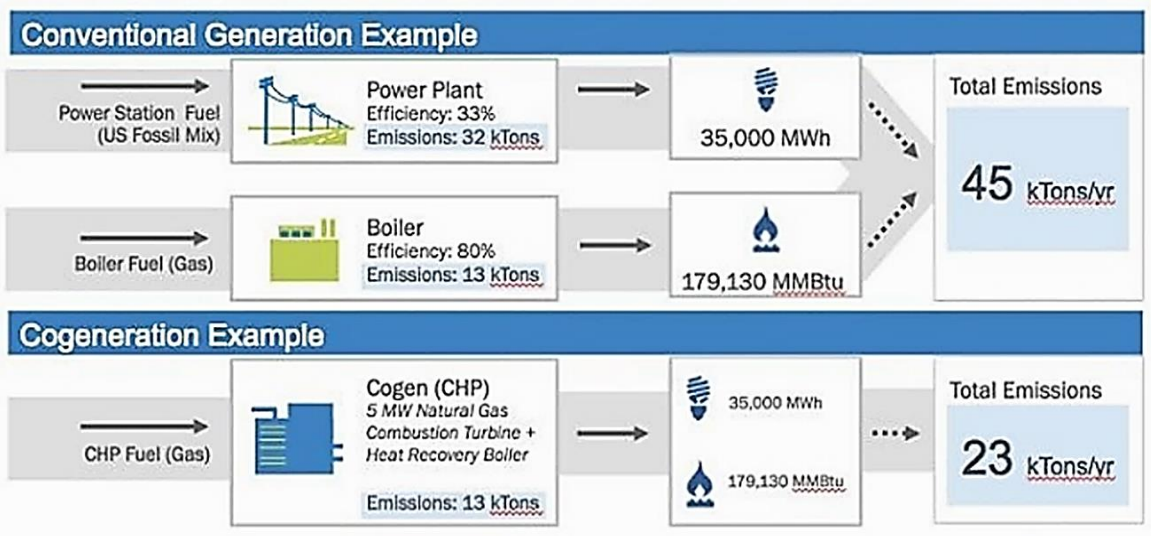
- Improve overall system efficiency in the use of energy resources
- Savings in energy consumption result in saving in running costs
- Improve profitability and competitiveness of the business operation
- Help manage limiting maximum demand and improve the operation of less efficient peaking plants
- Local generation will help reduce demand and energy losses in the transmission and distribution of electricity

Figure 3.3. Cogeneration/Combined Heat Power with Improved Plant Efficiency at 90% vis-à-vis Conventional Plant at 45% Plant Efficiency



Source: REEEP (2020).

Figure 3.4. Example Showing Significant Reduction of Carbon Emissions and Energy Costs



Source: https://blogs.constellation.com/sustainability/what-are-the-benefits-of-cogeneration.

Due to waste heat recovery, CGS can improve the overall plant efficiency (Figure 3.3) and significantly reduce CO_2 emissions (Figure 3.4). Figure 3.4 shows a conventional power plant with an efficiency of 33% and a boiler plant generating 35,000 MWh of electricity and 179,130 MMBtu steam with emission of 45 ktons/y. This example is compared with a CHP system generating the same output of 35,000 MWh electricity and 179,130 MMBtu steam but with a reduced emission of 23 ktons/y.

3.4. State of Cogeneration Installations in Malaysian Industries

Based on electricity generation capacity, three industrial sectors – oil refinery and gas processing, chemical and petrochemical, and iron and steel – take up the largest shares of CGS installation. However, regarding the number of installations, the three largest sectors are utilities, chemical and petrochemical, and palm oil and oleochemical industries. Other industrial sectors taking up significant shares of CGS installation are paper mills and sugar processing plants. CGS installations are also found in cement and rubber glove production plants but to a smaller extent. The Energy Commission Malaysia reports no CGS installation in the commercial sector.

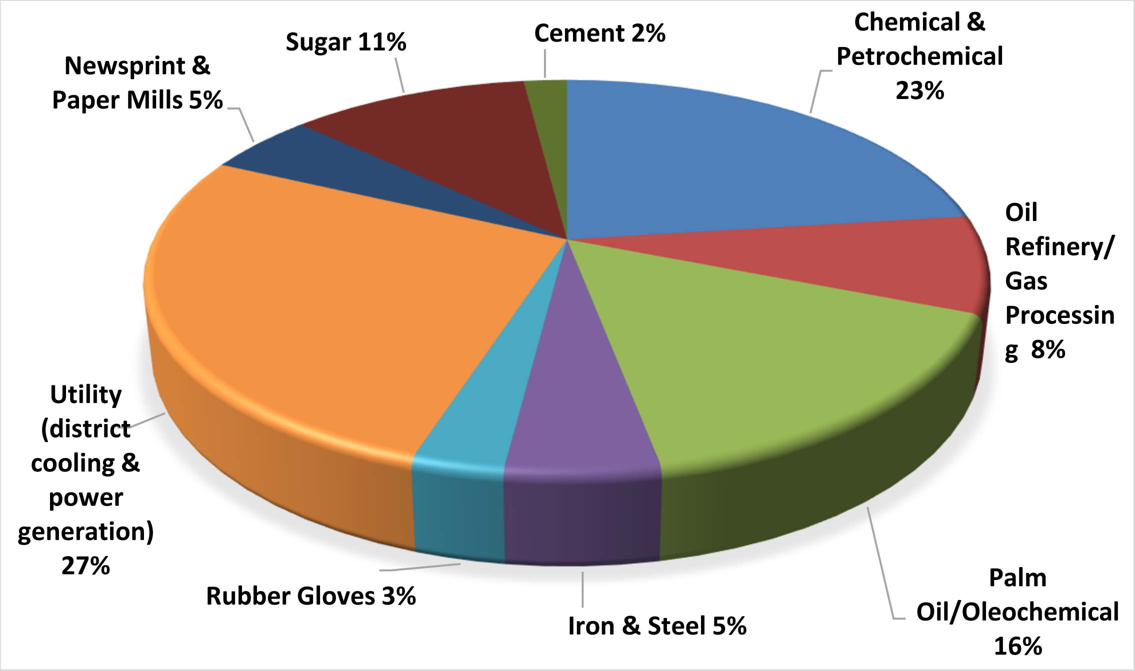
Table 3.2 shows the cogeneration-installed capacities and the number of installations based on the Energy Commission's 2021 publication. The percentage shares by the number of installations and installed capacities are shown in Figures 3.5 and 3.6, respectively.

Table 3.2. Overview of CGS Application and Installation in Malaysian Industries

Category of Industries	No. of CGS Installations	Cogen Installed Capacity (MW)	Share of CGS installed by Number of Installations (%)	Share of CGS Installed by Capacity (%)
Oil refinery/Gas processing	5	574.50	8	28
Iron & steel	3	282.50	5	14
Chemical & petrochemical	14	611.07	23	30
Newsprint & paper mills	3	126.60	5	6
Utility (district cooling & power generation)	17	270.69	27	13
Palm oil/Oleochemicals	10	69.43	16	3
Sugar processing	7	79.51	11	4
Rubber gloves	2	12.00	3	1
Cement	1	12.00	2	1
TOTAL	**62**	**2,050.30**	**100%**	**100%**

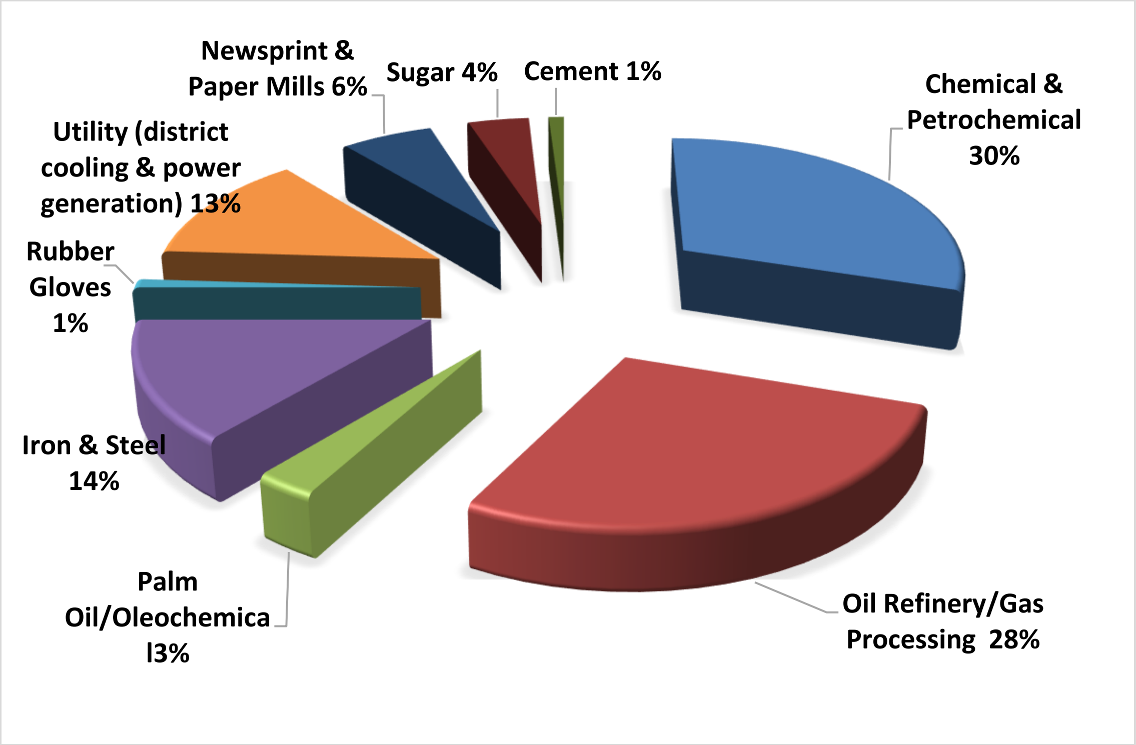
Source: Summarised from Energy Commission Malaysia (2021a).

Figure 3.5. Percentage Shares of CGS Installations in Various Industries, by Number of Installations



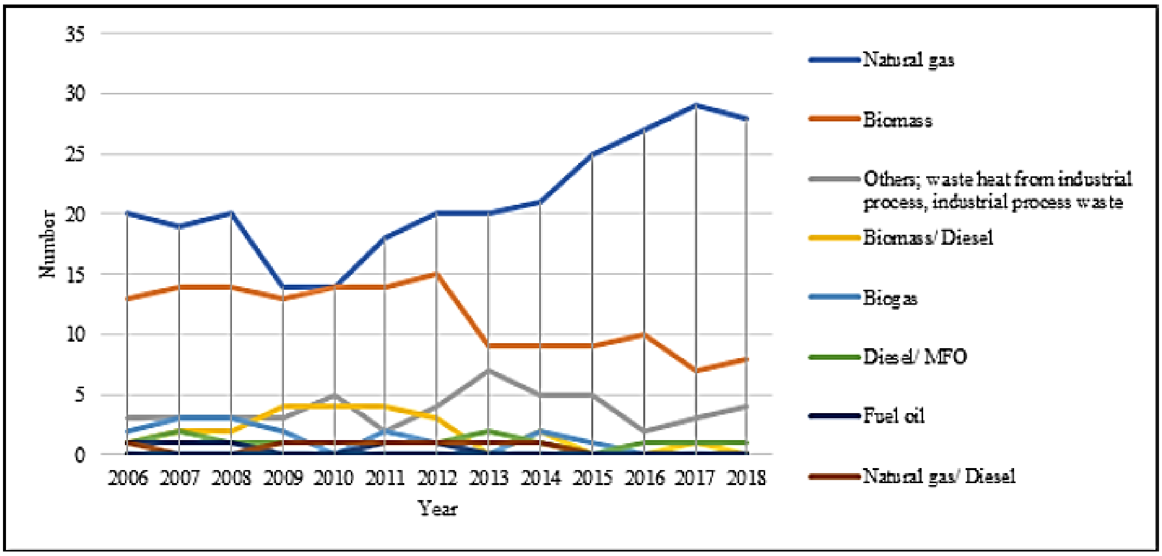
Source: Authors.

Figure 3.6. Percentage Shares of CGS Installations in Various Industries, by Installed Capacities



Source: Authors.

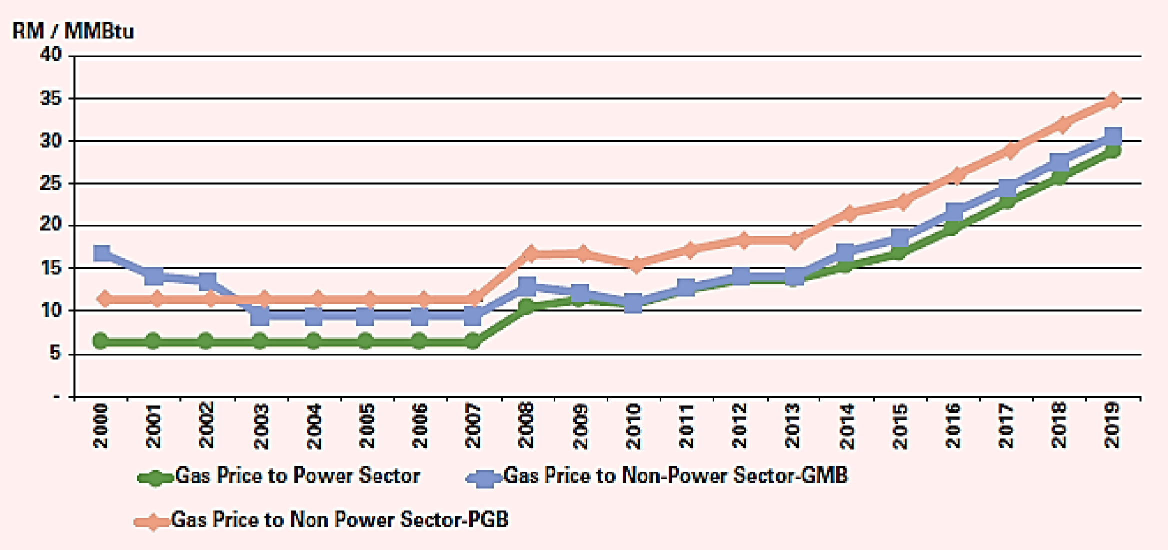
Figure 3.7. Energy Source of Cogeneration in Malaysia, 2006–2018



Source: IEPRe (2020).

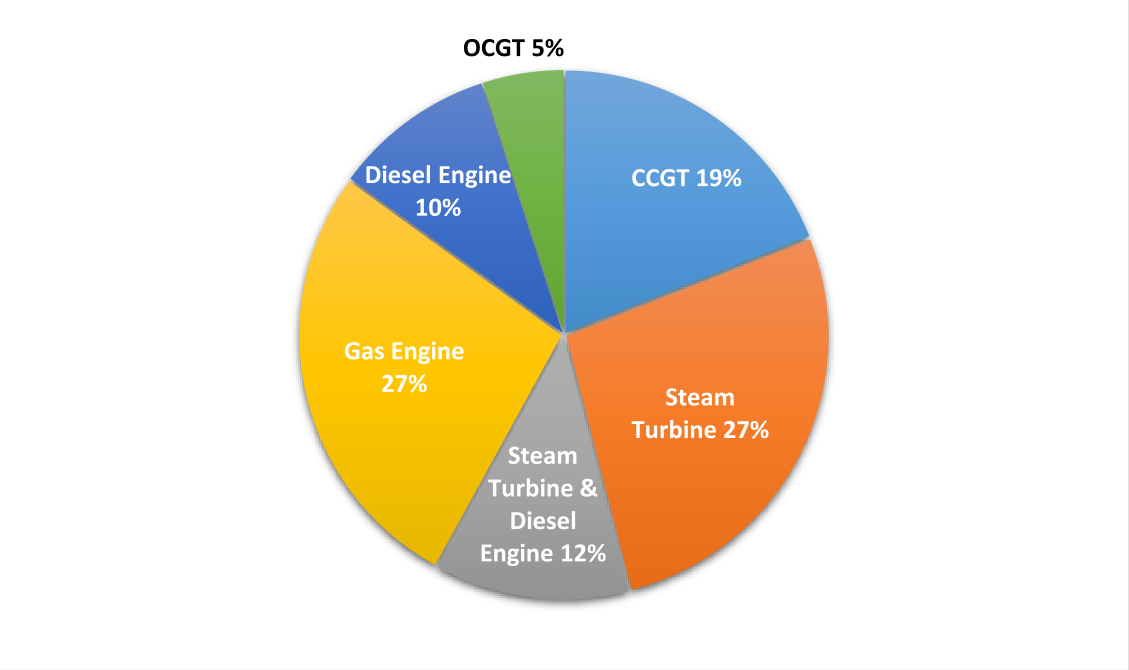
Figure 3.7 shows that most of Malaysia's CGS installations use natural gas, followed by biomass and others, such as waste heat from industrial processes. The availability and reliability of energy sources are essential in cogeneration development. Another vital element in CGSs is the type of prime mover that drives the system. Figure 3.8 shows the extent of rising natural gas prices in Malaysia. Figure 3.9 shows the type of cogeneration technologies deployed in Malaysia in 2018. Steam turbine and gas engines are the most used, representing 27% of all the installations, followed by combined cycle gas turbines (CCGTs) at 19% and diesel engines at 10%.

Figure 3.8. Natural Gas Prices in Malaysia



Source: Energy Commission Malaysia (2020).

Figure 3.9. Percentage of Technology Shares Used by CGS Installations, as of 2018



CCGT = combined cycle gas turbine, OCGT = open cycle gas turbine.
Source: The Institute of Energy Policy & Research (IEPRe) (2020).

3.5. Selected Cogeneration Installations in Malaysian Industries

Technical and operational data on CGS installations in Malaysia are not available in the public domain. The search for technical information on CGS installations had been confined to publications of the Energy Commission Malaysia, *Techno-economic Study on the High-efficiency Cogeneration in Malaysia in the Compendium of Energy Economic Research 2020* (IEPRe, 2020), and industrial sources from CGS plant operators and equipment manufacturers and system suppliers on non-disclosure agreement basis.

The appendices present 24 case studies. Table 3.3 summarises the 24 case studies, listing key information such as energy sources, heat-to-power ratio, estimated payback period, and system configuration. Based on information gathered in this study exercise, a general trend of improved payback periods can be observed for industrial plants with higher heat demand than electricity demand, i.e. higher heat-to-power ratios will improve the viability of CGS installations, as illustrated in Figure 3.10.

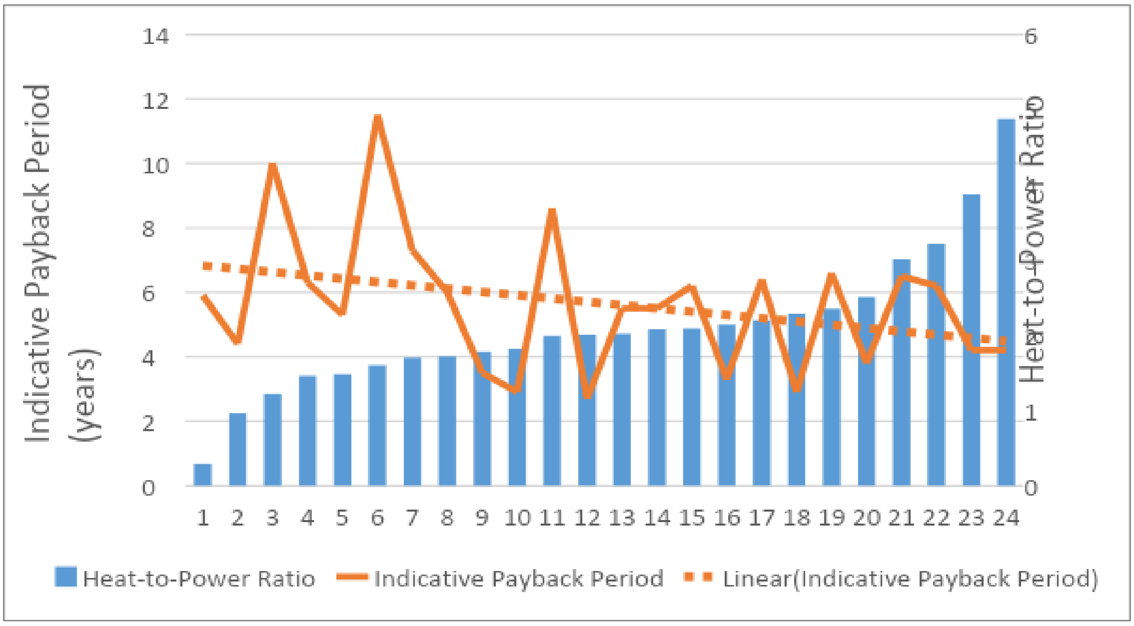
Table 3.3. List of Cogeneration Plants in Malaysia's Industrial and Commercial Sectors

Sector	Energy Source	Heat-to-Power Ratio	Estimated Payback Period (years)	Plant Capacity Generator System Configuration with HRSG/WHRB
Paperboard & packaging	Natural gas	3.01	6.5	• 1 x 32 MWe gas turbine • 1 X 140 t/h @ 60 barg saturated steam
Chemical plant #1	Natural gas	2.20	6.4	• 3 x 25 MWe gas turbine • 3 x 80 t/h @ 65 barg saturated steam each
Paper mill #2	Natural gas	2.08	5.5	• 1 x 33 MWe gas turbine • 1 x 100 t/h @ 65 barg saturated steam
Gas district cooling	Natural gas	0.96	4.4	• 2 x 5.4 MWe gas turbine • 1 x 15 t/h @18 barg saturated steam
Edible oil	Natural gas	1.72	6	• 1 x 6.4 MWe gas turbine • 1 x 15 t/h from waste heat + 17 t/h through supplementary firing @ 45 barg saturated steam
Glove manufacturing	Natural gas	1.82	2.9	• 1 x 1.2 MWe + 1 x 2.0 Mwe gas engine • 2 x heat exchanger with total capacity 80–100 m3/h @ 60°C–80°C
Chemical plant #2	Natural gas	1.48	5.3	• 2 x 1.4 MWe gas turbine • 1 x 6 t/h @ 13 barg saturated steam • Exhaust gas for process drying
Chemical plant #3	Natural gas	1.46	6.3	• 2 x 22 MWe gas turbine • 2 x 40 t/h from waste heat + 39 t/h from supplementary firing at 385°C–400°C superheated steam each
Papermill #3	Natural gas	2.29	2.9	• 3 x 4.8 MWe gas turbine • 3 x 16 t/h from waste heat + 7 t/h from supplementary firing @ 11 barg saturated steam each
Oleochemical #1	Natural gas	1.60	11.5	• 1 x 6.5 MWe gas turbine • 1 x 15 t/h from waste heat + 7.6 t/h from supplementary firing @ 22 barg saturated steam
Oleochemical #2	Natural gas	1.78	3.5	• 1 x 6.5 MWe gas turbine • 1 x 16.7 t/h @ 16 barg saturated steam
Oleochemical #3	Natural gas	2.02	5.5	• 1 x 4 MWe gas turbine • 1 x 11.7 t/h from waste heat + 18.3 t/h from supplementary firing @ 10.5 barg saturated steam
Oleochemical #4	Natural gas	1.70	7.3	• 1 x 6.5 MWe gas turbine • 1 x 16 t/h from waste heat + 20 t/h @ 16 barg saturated steam
Fabric	Natural gas	0.29	5.9	• 1 x 5.2 MWe gas engine • 1 x 2.2 t/h @ 8 barg saturated steam

Sector	**Energy Source**	**Heat-to-Power Ratio**	**Estimated Payback Period (years)**	**Plant Capacity Generator System Configuration with HRSG/WHRB**
Third- party utility supply	Natural gas	1.22	10	• 1 x 16.28 MWe Gas Turbine • 1 x 28 t/h from waste heat + 60 t/h from supplementary firing @ 60.8 barg, 292°C superheated steam
Textile factory	Natural gas	2.09	6.2	• 1 x 4.66 MWe gas turbine • 1 x 37.6 t/h @ 60°C hot water
Oil refinery	Natural gas	4.88	4.2	• 1 x 4.62 MWe gas turbine • 1 x 17.6 t/h @ 80°C hot water
Rubber gloves	Natural gas	3.87	4.2	• 1 x 13.94 MWe gas turbine • 1 x 27 t/h @ 120°C hot water
Oleochemical #5	Natural gas	3.22	6.2	• 1 x 7.03 MWe gas turbine • 1 x 35 t/h @ 34 barg saturated steam
Biomass processing plant	Natural gas	2.35	6.6	• 1 x 5.5 MWe gas turbine • 1 x 20 t/h @ 35 barg saturated steam
Animal feed ingredient plant	Natural gas	2.51	3.8	• 1 x 33.55 MWe gas turbine • 1 x 130 t/h @ 11 barg saturated steam
Chemical plant #4	Natural gas	1.99	8.6	• 1 x 0.85 MWe micro turbine • 1 x 50.77 t/h @ 236°C thermal oil heater from 227°C • 1 x 5.8 t/h @ 80^{oi}C hot water from 30°C • 1 x 70 t/h @ 90°C hot water from 77°C • 1 x 103.2 t/h chilled water at 8°C
Papermill	Natural gas	2.14	3.3	• 1 x 14.4 MWe gas turbine • 1 x 40 t/h @ 11 barg saturated steam
Sugar mill	Natural gas	2.01	2.7	• 1 x 11.5 MWe gas turbine • 1 x 30 t/h @ 11 barg saturated steam

HRSG = heat recovery steam generator, WHTB = waste heat recovery boiler.
Source: Compilation from industries and original equipment manufacturers.

Figure 3.10. Trend of Improved Viability of CGS Installations with a Higher Heat-to-power Ratio



Source: Authors.

3.6. Introduction of Typical CGS Case Studies

This section describes and provides details of three CGS installations from these industrial sectors:

(1) Oleochemical plant #1

(2) Third-party utility (ESCO) operator and distributor of electricity and steam

(3) Paper mill

3.6.1. CGS case study no. 1: Oleochemical-produced fatty acids, methyl esters, and refined glycerine

1) Description of industry motivational factors leading to CGS installation and benefits

A large oleochemical company owns the gas turbine CGS and uses it for the internal electricity and steam supply. The oleochemical company produces fatty acids, methyl esters, and refined glycerine, which are exported.

Established in 1989, this oleochemical company, is committed to supporting its parent company to achieve sustainable goals. Among the targets were a 50% reduction in GHG emissions and a 35% increase in water efficiency compared to the 2010 baseline.

Electricity is supplied from two sources to meet the demand of the factory, 90.4% (31,200 MWh/year) from its CGS. In contrast, the balance of 9.6% (3,300 MWh/year) is imported from the grid, totalling 34,500 MWh/year of electricity demand for production and utility use. However, electricity supply can be obtained from the grid in case of tripping or partial loading of the cogeneration unit. However, some standby and topping-up charges apply.

The plant initially produced its own steam through two water tube boilers 15.8 t/h each at 10 barg saturated steam. With the cogeneration plant, the factory can produce the same amount of saturated steam with free energy recovered from the waste heat from the gas turbine exhaust.

The company set up the CGS to reduce the cost of energy (combined electricity and steam) required by the plant and reduce the GHG emissions from the higher thermal efficiency of the cogeneration plant by adopting heat recovery from the gas turbine generator exhaust. In addition, it can also take advantage of the Malaysian government's incentives through the Green Investment Tax Allowance.

2) System features and operational information

Atmospheric air enters the compressor and is then compressed to a higher pressure and mass ratio as combustion air and cooling air for turbine buckets. Next, fuel is injected into the combustion chamber and burned with the combustion air. The combustion product then flows to the gas turbine at about 1000°C where work is done in turning the gas turbine generator (GTG) shaft to produce electricity. Finally, the waste gas is exhausted at about 500°C to the heat recovery steam generator (HRSG). Table 3.4 describes the specification of the CGS, and Figure 3.11 shows the process flow diagram.

At the HRSG, steam is produced while the available mechanical energy drives the generator to produce electricity. The recovered heat from the gas turbine exhaust can raise 11.7 tons/hour of steam, and a further supplementary firing at the duct can raise another 18.3 tons/hour at the same 10.5 barg saturated steam. The exhaust temperature from the gas turbine exhaust is 500°C. The supplementary firing raises the flue gas temperature to 733°C and exhaust after the economiser is about 90°C. Hence, considerable heat is recovered in the HRSG.

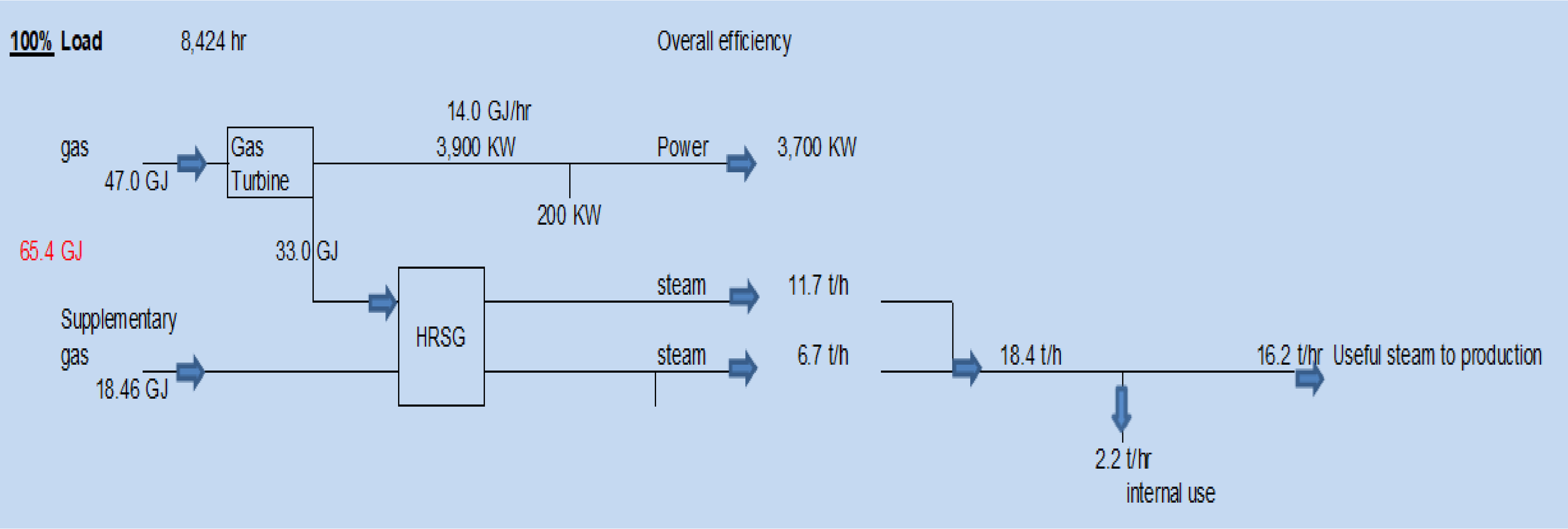
Power output and efficiency decrease quickly at partial load operation and load. Hence, understanding electricity and steam demand is important when selecting the capacity of the equipment during the design stage.

Table 3.4. System Specification of CGS Case Study No. 1

Description	Parameters
Type and rated power output of the prime mover	1 unit x 4 MWe gas turbine
Fuel	Natural gas
Capacity of heat recovery steam generator	1 unit X 30 t/h total saturated steam capacity with: • 11.7 t/h from waste heat recovery • 18.3 t/h from supplementary firing
Energy produced	Electricity and steam
Heat: Power ratio	2.02
Estimated fuel consumption/year	605,877 GJ/year
Estimated electricity demand/year	34,500 MWh/year (100%)
Estimated electricity from cogeneration/year	31,200 MWh/year (90.4%)
Estimated operating hours/year	8,424 hours

Source: Authors.

Figure 3.11. Process Flow Diagram of CGS Case Study No. 1



Source: Authors.

3) Investment and cost benefits: investment through self-financed or EPC through ESCO

The owner and loans funded the investment. Table 3.5 shows the investment and estimated savings. Investment cost includes engineering, procurement, construction, and commissioning (EPCC) costs (excluding land cost) of one unit gas turbine generator, one unit HRSG, and other supporting auxiliaries, pumps, and tanks. A simple payback period of 5.5 years can be achieved (Table 3.5).

Table 3.5. Investment and Return of CGS Case Study No. 1

Description	Cost
Cost of investment	RM30,500,000
Estimated savings	RM5.59 million/year
Simple Payback Period	5.5 years

Source: Authors in consultation with plant operator.

3.6.2. CGS case study no. 2: Third-party utility (ESCO) operator and distributor of electricity and steam

1) Description of industry motivational factors leading to CGS installation and benefits

A third party owned the gas turbine CGS that produces and sells electricity and steam mainly to a nearby large textile factory producing polyester fibre, polyester chips, and polyester film and fabric through a supply contract.

Established in 1973, the textile factory has grown from a simple factory into a sustainable and green company committed to ecological product safety and sustainable production conditions. It was awarded the Global Recycle Standard Certificate for its product.

The factory purchases electricity from two sources: 15 MWe (86%) from the ESCO cogeneration plant and 2.5 MWe (14%) from the national utility of Malaysia, making the total demand 17.5 MWe (100%) for production and utility use. The plant initially produced its own steam but now purchases the entire steam from the cogeneration plant. The existing boilers are on standby mode to support the production lines in case of any failure or abnormality with the cogeneration plant. Standby electricity is also available from the grid at standby and top-up charges.

The cycle efficiency of the cogeneration is typically between 80% to 90%, much higher than the combined cycle gas turbine cycle power plant between 50% to 60%. This is because a large portion of the waste heat is recovered in the HRSG compared to a combined cycle power plant, where some 30% of heat is lost through the heat sink in the condenser. Hence, cogeneration is much more efficient and emits fewer GHGs. Besides having steam at minimum cost, generating electricity at the source of use also eliminates other energy losses, such as transmission and distribution losses, thus lowering electricity and steam costs and making the business more attractive.

In summary, the identified objectives of the cogeneration plant are to:

- Reduce operating costs by generating power in-house and steam by HRSG, utilising the waste heat energy of GTG exhaust gas
- Improve power quality and provide reliable power generation to the existing manufacturing plant
- Meet the normal plant demand with minimum import power from the national grid under normal operating conditions
- Provide reliable steam to the existing manufacturing plants
- Be capable of operating in 'Island Mode' during national grid failure.

2) System features and operational information

Atmospheric air enters the compressor and is then compressed to a higher pressure and mass ratio as combustion air and cooling air for turbine buckets. Fuel is burned with the combustion air in the combustion chamber and enters the turbine at about 1000°C; exhaust gas is about 500°C. Table 3.6 describes the specification of the CGS, and Figure 3.12 shows the process flow diagram.

Exhaust from the gas turbine exit is then channelled to a heat recovery steam generator (HRSG) for steam production, while the available mechanical energy drives the generator to produce electricity. The recovered heat from the gas turbine exhaust can raise 28 tons/hour of steam at a superheated temperature of 292°C. A further supplementary firing at the duct burner can raise another 60 tons/hour of superheated steam. The exhaust after the economiser is about 200°C; hence, a heat recovery of 300°C is achieved in the HRSG.

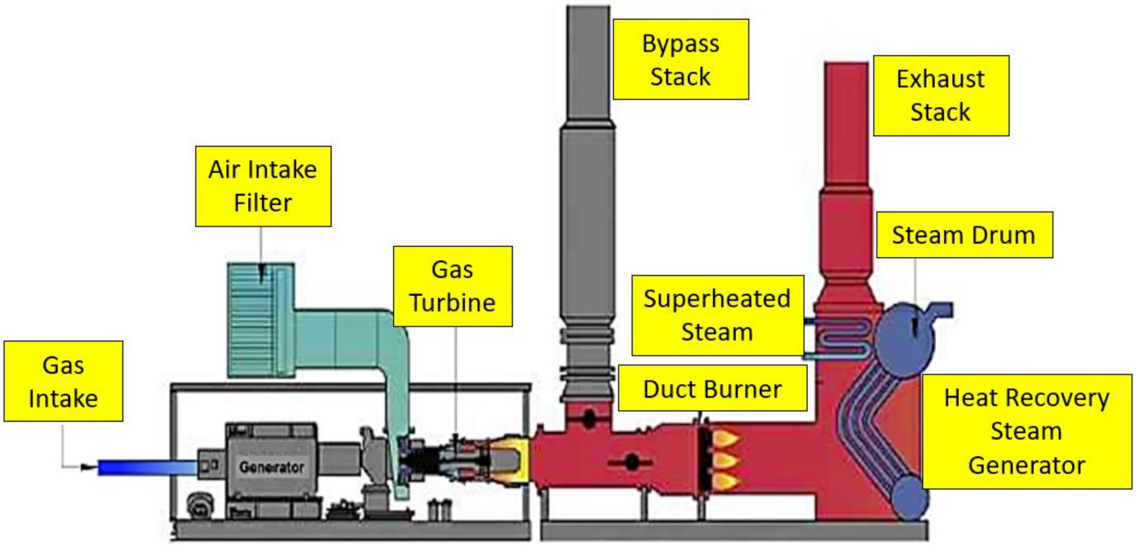
Power output at the partial load will cause the thermal efficiency to decrease quickly. Thus, the design and selection of the capacity of the GTG-HRSG are critical.

Table 3.6. System Specification of the CGS Case Study No. 2

Description	Parameters
Type and rated power output of the prime mover	1 x 16.28 MWe gas turbine
Fuel	Natural gas
Capacity of heat recovery steam generator	1 X 88 t/h total superheated steam capacity @ 292°C supplied through: ● 28 t/h from waste heat recovery and ● 60 t/h from supplementary firing
Energy produced	Electricity and steam
Heat: Power ratio	1.22
Estimated fuel consumption/year	40,508,781 S m3/year
Estimated electricity demand/year	133,900 MWh/year (100%)
Estimated cogeneration generation/year	115,288 MWh/year (86%)
Estimated operating hours/year	8,400 hours

Source: Authors in consultation with plant operator.

Figure 3.12. Process Flow Diagram of CGS Case Study No. 2



Source: Authors.

3) Investment and cost benefits; investment under EPC through ESCO

The investment was funded through an ESCO with a supply contract signed with the buyer. Table 3.7 shows the investment and estimated savings. Investment cost includes the EPCC cost (excluding land cost) of one unit gas turbine generator, one unit HP HRSG complete with duct burners, and other supporting auxiliaries, including auxiliary gas boiler, cooling towers, gas compressor unit, deaerator, screw compressor, water treatment unit, and various pumps and tanks. A simple payback period of 10 years is achievable (Table 3.7).

Table 3.7. Investment and Returns of CGS Case Study No. 2

Description	Cost
Cost of investment	RM110,000,000
Estimated savings	RM11 million/year
Simple payback period	10 years

Source: Authors in consultation with plant operator.

3.6.3. CGS case study no. 3: paper mill

1) Description of industry motivational factors leading to CGS installation and benefits

The case study focuses on a significant and leading industrial-grade paper producer in Malaysia, which started its paper mill business in the 1960s. The mill recycles wastepaper and converts it into a wide range of paper products – from test liners, corrugated medium, various categories of chipboard, wrapping paper, inserting paper, and multiple types of paper.

As a paper mill is an energy-intensive industry, the company has initiated installation of three units of 4.8 MWe CHP plant, thus, generating a total of 14.5 MWe (67%) for its power consumption while topping up with another 7 Mwe (33%) from the grid. At the same time, the waste heat generated is recovered through the HRSG to produce sufficient process steam for the paper mill's use. This has contributed substantially towards reducing carbon emissions while mitigating the escalating cost of energy expenditure.

2) System features and operational information

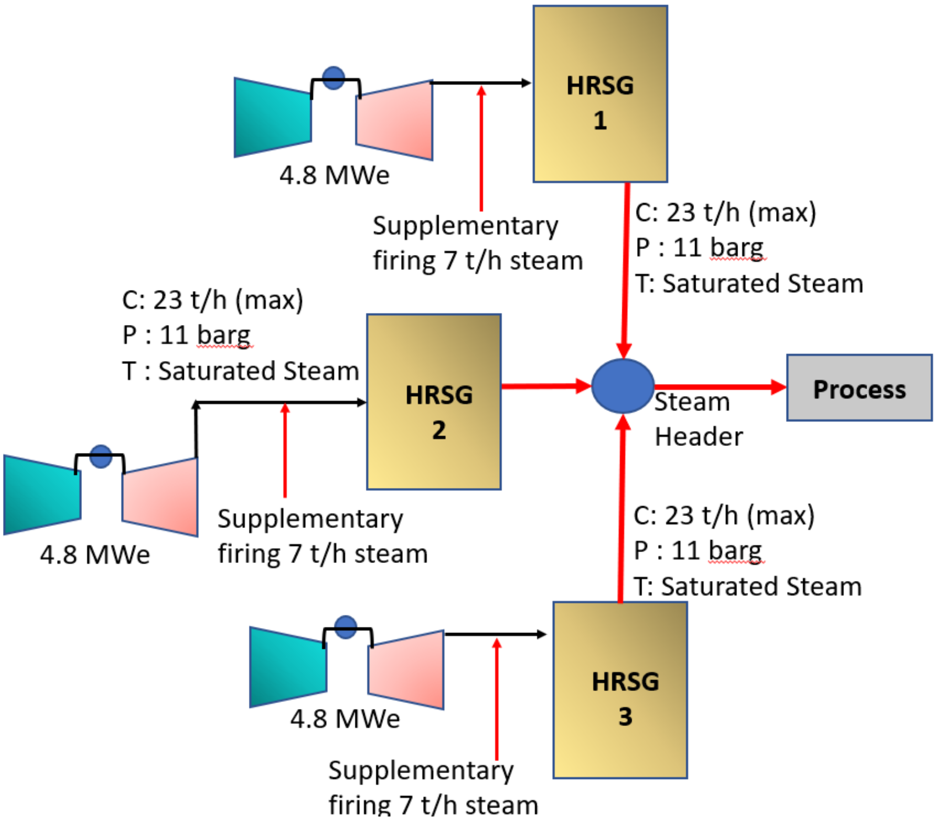
Three 4.8 MWe gas turbine generators operate in the same manner as cases 1 and 2. Exhaust gas from each gas turbine goes into their respective HRSG to produce 16 t/h of saturated steam, and an additional 7 t/h saturated steam from supplementary firing, making a total of 23 t/h saturated steam from each HRSG. The steam from each HRSG is channelled to a common steam header before distributing for process usage. The combined total steaming capacity from the three HRSGs is 69 t/h for the entire paper mill process usage. Table 3.8 describes the specification of the CGS, and Figure 3.13 shows the process flow diagram.

Table 3.8. System Specification of CGS Case Study No. 3

Description	Parameters
Type and rated power output of the prime mover	3 units x 4.8 MWe gas turbine
Fuel	Natural gas
Capacity of heat recovery Steam Generator	3 units X 23 t/h saturated steam supplied through • 16 t/h from waste heat recovery and • 7 t/h from supplementary firing
Energy produced	Electricity and steam
Heat: Power ratio	2.29
Estimated fuel consumption/year	Not available
Estimated electricity demand/year	184,900 MWh/year (100%)
Estimated electricity from cogeneration /year	124,700 MWh/year (67%)
Estimated operating hours/year	8,600 hours

Source: IEPRe (2020).

Figure 3.13. Process Flow Diagram for CGS Case Study No. 3



Source: Authors.

(3) Investment and cost benefits: investment through self-financed or EPC through ESCO

The owner and loans fund the investment. Table 3.9 shows the investment and estimated savings. Investment cost includes EPCC cost (excluding land cost) of three units of gas turbine generator, three units of HRSGs, and other supporting auxiliaries, pumps, and tanks. A simple payback period of 2.9 years can be achieved, as shown in Table 3.9.

Table 3.9. Investment and Returns of CGS Case Study No. 3

Description	Cost
Cost of investment	RM47 million
Estimated savings	RM16.83 million/year
Simple payback period	2.9 years

Source: IEPRe (2020).

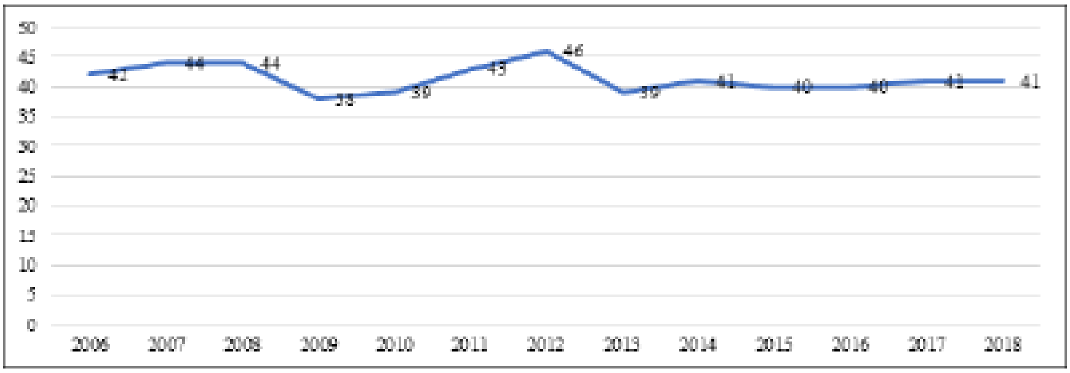
3.7. General Discussion

3.7.1 Overview of CGSs in Malaysia

The uptake of CGS installations in Malaysia has been slow despite the proven and successful cogeneration operation in the industrial sector. It is uncommon to find CGS installations in Malaysia's commercial sector, likely because of the subsidised electricity tariffs and the relatively low or lack of heat demand in the sector. Figure 3.14 shows the sluggish trend of CGS installations in Malaysia from 2006 until 2018, with almost stagnant growth. However, the Energy Commission reported that this number has increased to 62 (Table 3.2).

The increase in the number of CGS installations reported by the Energy Commission Malaysia may be due to the government's promotion following the implementation of the National Energy Efficiency Plan 2015, which includes Key Initiative 4, namely, the promotion of CGSs generating electricity and thermal energy. This action plan initiative focused on promoting cogeneration in industries and buildings by reducing barriers, including standby, top-up charges, and gas tariff pricing.

Figure 3.14. Trend of CGS Installations in Malaysia, 2006–2018



Source: IEPRe (2020).

3.7.2. Cogeneration experiences in Malaysia

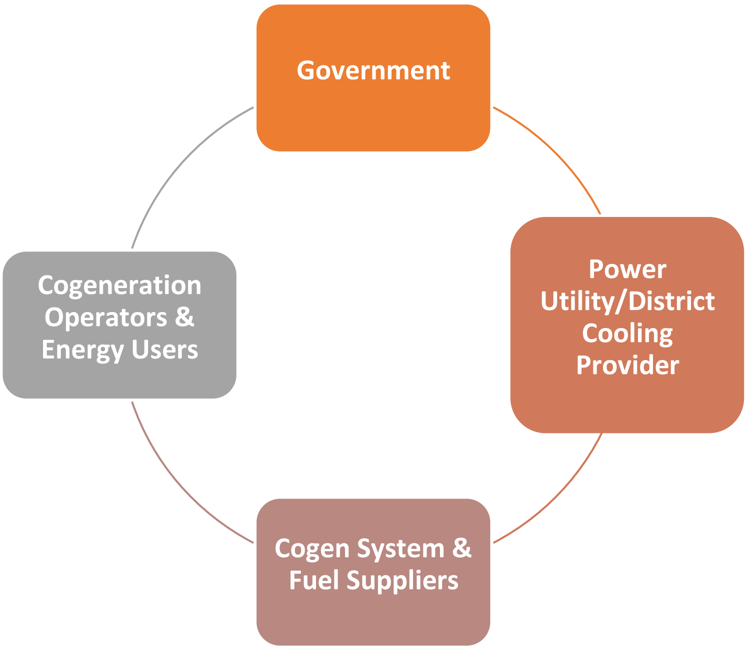
1) Malaysia's cogeneration ecosystem

In the Malaysian context, each of the four key stakeholders plays an essential role in making cogeneration viable (Figure 3.15). The government, the CGS owners cum energy users, CGS and fuel suppliers, and power utilities are the four major stakeholders in cogeneration development. Each has its goals and perspectives on the CGS with interrelated impacts to one another, as summarised below.

- The government intends to improve energy efficiency and reduce CO_2 emissions.
- Cogeneration owners' objectives are to reduce their facility operational costs and improve the reliability and continuity of energy supply.
- The power utility intends to reduce network losses, improve reliability, and improve network efficiency and performance.

- Cogeneration development will enhance the business activities of equipment manufacturers and fuel suppliers.

Figure 3.15. Key Stakeholders in Malaysia's Cogeneration



Source: IEPRe (2020).

2) Government policy and action plan

The National Energy Efficiency Plan 2015, which includes Key Initiative 4 on promoting cogeneration, seemed to have improved cogeneration development in Malaysia. The facilitation in addressing stakeholders' concerns about the barriers previously mentioned in Section 3.2 and the government's incentive scheme seemed to have yielded a positive outlook for CGS installations.

Despite the government's attractive incentives for cogeneration installations, the uptake of cogeneration in the industry remained far off the expectation. The sluggish cogeneration development may be improved by the following:

- Approval and implementation of the long-awaited Energy Efficiency and Conservation Act
- Continuous awareness campaigns on technical and financial benefits
- Reduced subsidies in electricity tariffs
- Capacity building to improve the skill levels for the operation of CGSs.

3) Lessons learned from Malaysia's cogeneration installations

The key findings on Malaysian cogeneration experiences are summarised as follows:

- There is a general lack of knowledge in the industry on detailed cogeneration and financial analysis for CGS planning and design.

- Most cogeneration installations are in medium to large industries. The risk of cogeneration failure may be too high for small-to-medium business operators. An EPC arrangement with ESCOs may address such risk.
- The decision-making process for cogeneration installation is complex. Business operators must consider technical challenges, such as reliability and quality of supply, system protection, metering, operating protocol for connection and disconnection, islanding, and reactive power management. In addition, business operators should consider system operation and performance; licensing requirements; coordination with utility, environmental, and safety characteristics; and reliability and infrastructure costs of fuel supply, such as natural gas. Other challenges include top-up and standby charges, connection/exit fees, planning/siting and/or ownership, and metering arrangement.
- There is a need to establish a business model that involves a utility provider as a strategic partner for large-scale cogeneration as a mini and distributed utility. Such a business model can address technical and financial issues and regulatory and administrative requirements for cogeneration implementation in Malaysia.
- The Malaysian CGS case studies show that most cogeneration installations' payback period is less than 10 years. Figure 3.10 shows that the payback period for CGS installations with a higher heat-to-power ratio seems to improve. This is attributed to the utility's subsidised electricity tariffs, higher power generation, and increased costs in steam generation due to rising fuel costs, especially of natural gas (Figure 3.8).

4) Favourable conditions for considering CGS installation

Generally, the ideal conditions for a CGS installation can be summarised as follows:

- Consistent consumption of a large amount of heat energy
- Wish to benefit from government incentives
- Accessibility to reliable and competitive fuel supply
- Long plant operation with consistent base loads
- Plan to expand, construct, retrofit, or upgrade central plant equipment and facilities.

5) Success factors for successful implementation and operation of CGS facilities

The success of operating a cogeneration facility depends on many factors (Energy Commission Malaysia, 2019b) such as:

a. Technology
b. Type of fuel used
c. Size of the plant
d. Optimised use of heat produced and electricity generated
e. Daily and annual load profiles
f. Annual full-load operating hours
g. Opportunity for sales of excess energy produced

h. Electricity and fuel prices
i. Electricity top-up and standby charges
j. Tax incentives
k. Energy policy and regulatory requirements