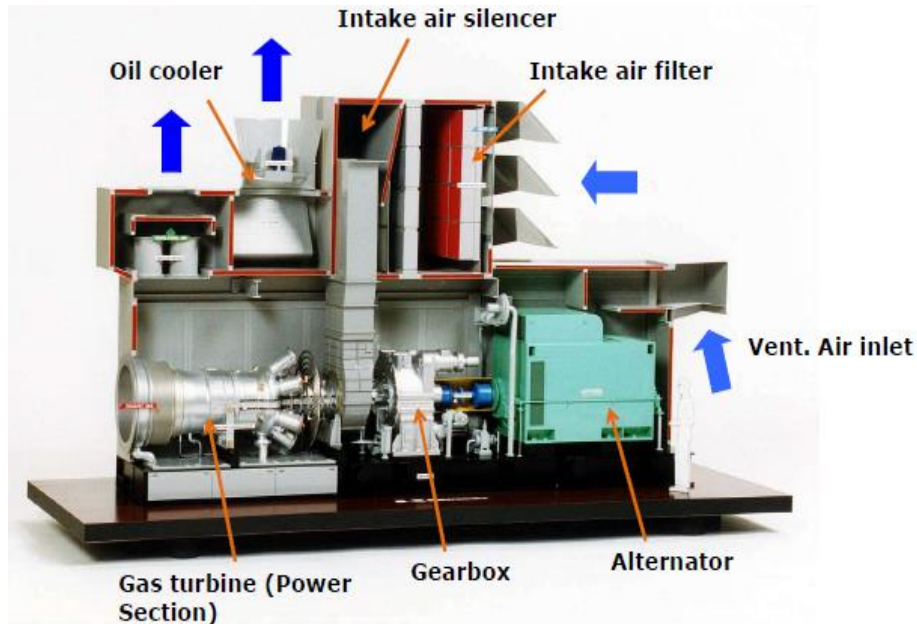


Appendix 2

Malaysia's Cogeneration Systems: Case Studies

A2.1. Case Study No. 1: Paper Mill No. 1 – Paperboard & Packaging



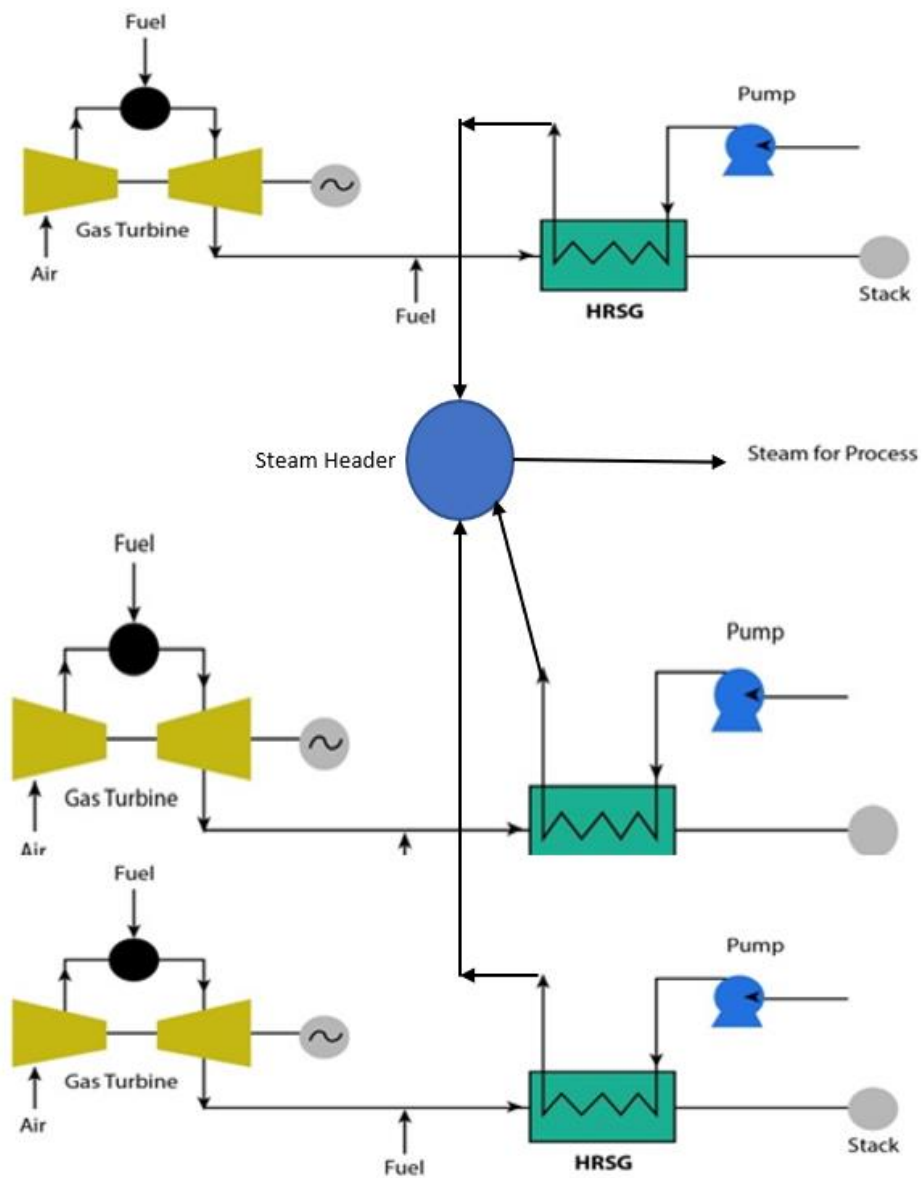
Source: Authors.

Item	Contents
Type of power engine (e.g. gas turbine, gas engine, diesel engine, steam turbine)	Gas turbine
Rated power output (kW)	1 x 32 Mwe
No. HRSG/HRSG pressure (barg) Steam temperature (°C) HRSG capacity from exhaust heat (ton/hr)	1 unit @ 60 barg HRSG Saturated (277°C) 140 t/hr
Fuel	Natural gas
Heat: power ratio	3.01
Estimated electricity demand/year	383,400 MWh/y
Estimated electricity by cogeneration/year	255,600 MWh/y
GT gas consumption/ year	2,840,000.00 MMBtu/y
Estimated operating hours/year	8520 h/y
Approximate cost of investment (RM)	GT: RM55 million HRSG & EPCC: RM20 million

Item	Contents
	Total: RM75 million
Approximate savings (RM/y)	RM11.4 million/y
Simple payback period	years

Source: Authors in consultation with plant operator.

A2.2. Case Study No. 2: Chemical No. 1

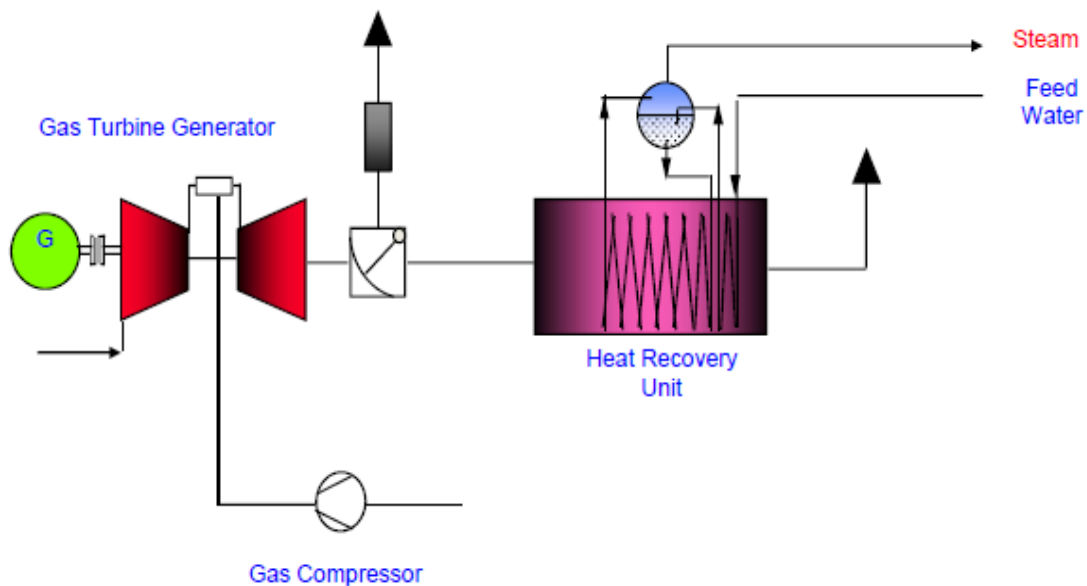


Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output (kW)	3 x 25 MW
HRSG pressure (barg) Steam temperature (°C) HRSG capacity from exhaust heat (ton/hr)	65 barg Saturated (282°C) 3 X 80 t/hr
Fuel	Natural gas
Heat: power ratio	2.2
Estimated electricity demand/year (MWh/y)	783,840
Estimated electricity by cogeneration/year (MWh/y)	613,440
GT gas consumption/year	2,307,500 MMBtu
Estimated operating hours/year (h/y)	8,520 hours/year
Approximate cost of investment (RM)	GT: RM174 million HRSG: RM36 million. Total: RM210 million
Approximate savings (RM/y)	RM33 million/yr
Simple payback period	6.36 years

Source: Authors in consultation with plant operator.

A2.3. Case Study No. 3: Paper Mill No. 2

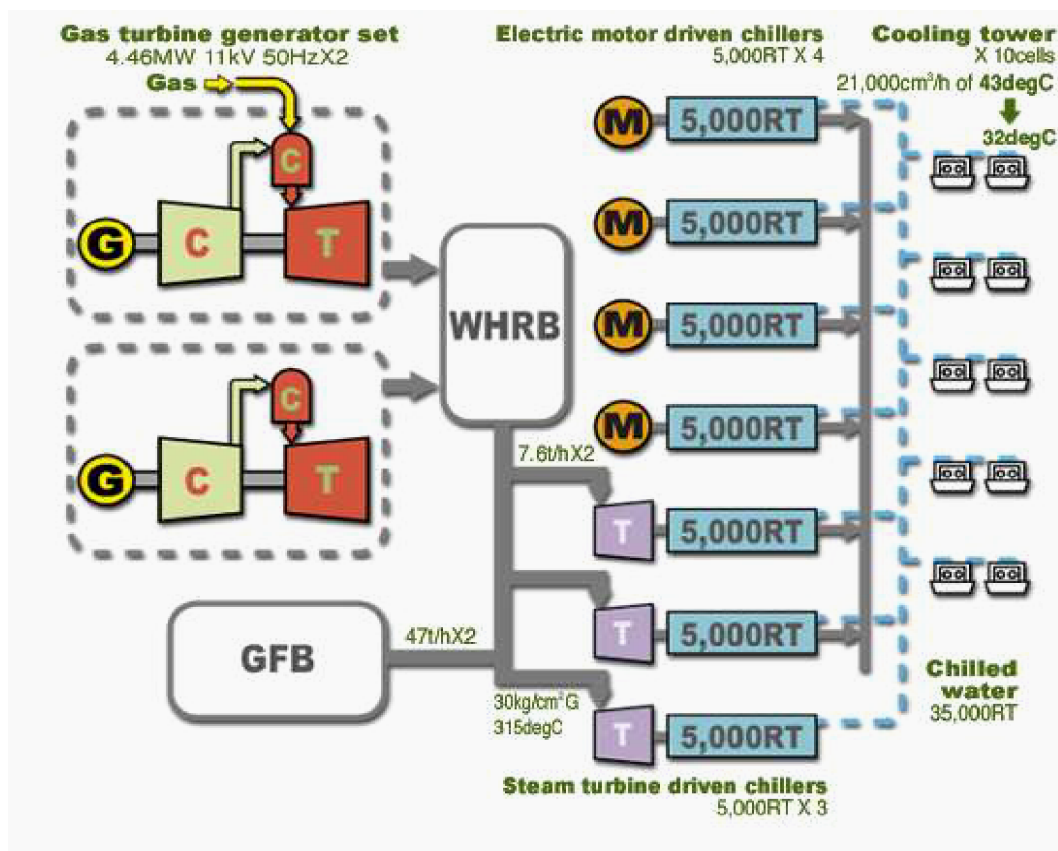


Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output (kW)	1 x 33MW
HRSB pressure (barg) Steam temperature (°C) HRSB capacity from exhaust heat (ton/hr)	65 barg Saturated (282°C) 1 x 100 t/hr
Fuel	Natural Gas
Heat: power ratio	2.08
Estimated electricity demand/year	391,920 MWh/y
Estimated electricity by cogeneration/year	264,120 MWh/y
GT gas consumption/year	3,017,500 MMBtu
Estimated operating hours/year	8,520 h/y
Approximate cost of investment (RM)	GT: RM48 million HRSB & EPCC: RM20 million Total: RM68 million
Approximate savings (RM/y)	RM12.4 million/y
Simple payback period	5.48 years

Source: Authors in consultation with plant operator.

A2.4. Case Study No. 4: Gas District Cooling



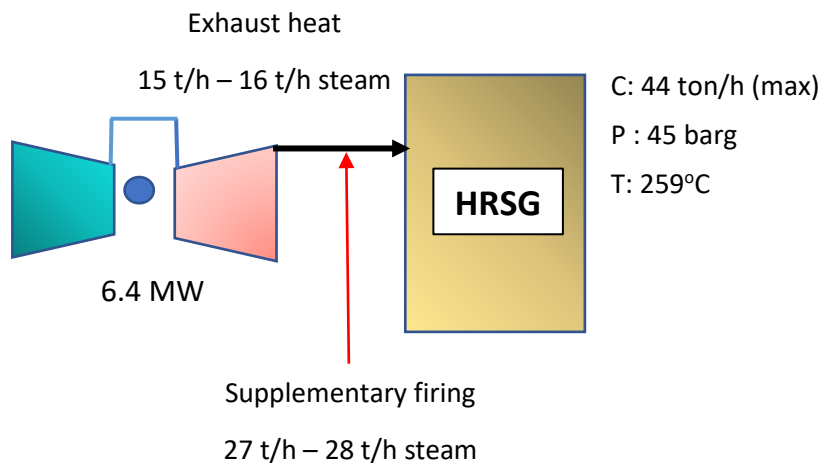
Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output (kW)	2 x 5.4 MW
HRSG pressure (barg)	18 barg
Steam temperature (°C)	Saturated (210°C)
HRSG capacity from exhaust heat (ton/hr)	1 x 15 t/hr
Fuel	Natural gas
Heat: power ratio	0.96
Estimated electricity demand/year	53,700 MWh/y
Est. electricity by Cogen/year	42,960 MWh/y
GT gas consumption/year	1,008,000 MMBtu/yr
Estimated operating hours/year	8640 h/y

Item	Contents
Approximate cost of investment (RM)	GT: RM45 million WHRB & EPCC: RM30 million
Approximate savings (RM/y)	RM17 million/y
Simple payback period	4.4 years

Source: Authors in consultation with plant operator.

A2.5. Case Study No. 5: Edible Oil



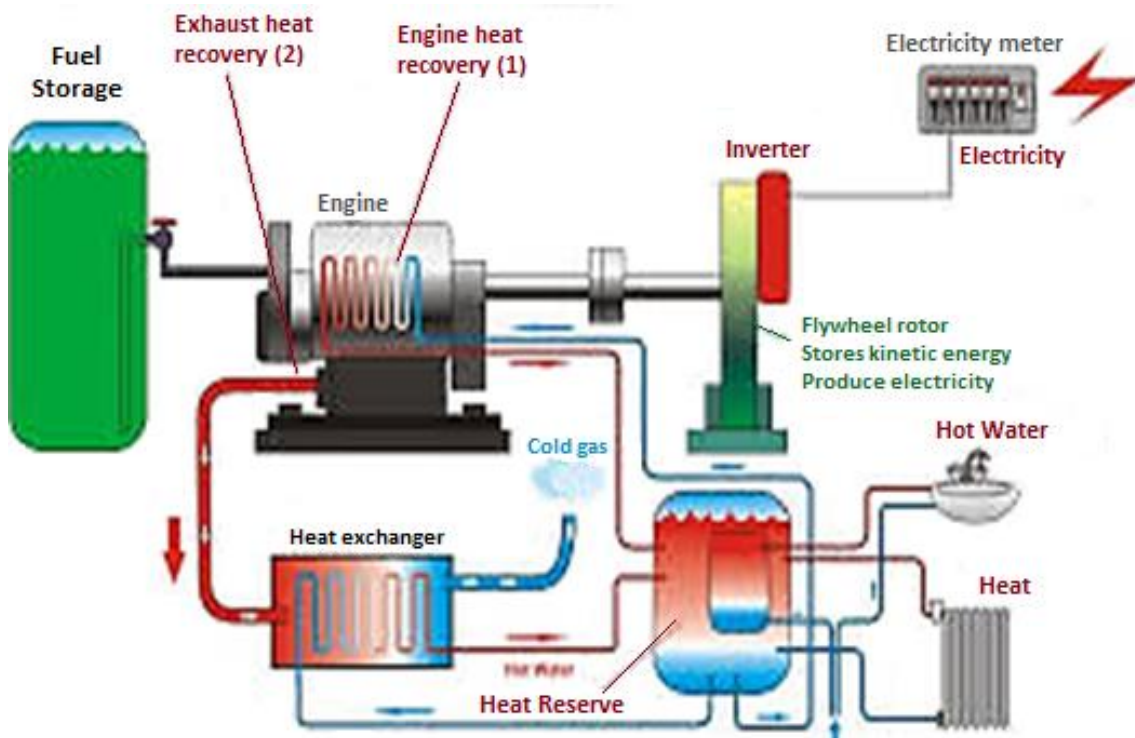
Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output (kW)	1 x 6.4 MW
HRSG pressure (barg)	1 no @ 45 barg
Steam temperature (°C)	Saturated (259°C)
HRSG capacity from exhaust heat (ton/hr)	15 t/hr–16 t/hr
HRSG capacity from duct burner (ton/hr)	27 t/hr–28 t/hr
Fuel	Natural gas
Heat : Power ratio	1.72
Estimated electricity demand/year	68,700 MWh/y
Estimated electricity by cogeneration/year	54,000 MWh/y
GT gas consumption/year	648,000 MMBtu/y
Estimated operating hours/year	8,640 h/y

Item	Contents
Approximate cost of investment (RM)	GT: RM28 million HRSG & EPCC: RM21 million Total: RM49 million
Approximate savings (RM/y)	RM8.1 million/yr
Simple payback period	6 years

Source: Authors in consultation with plant operator.

A2.6. Case No. 6: Glove Manufacturing



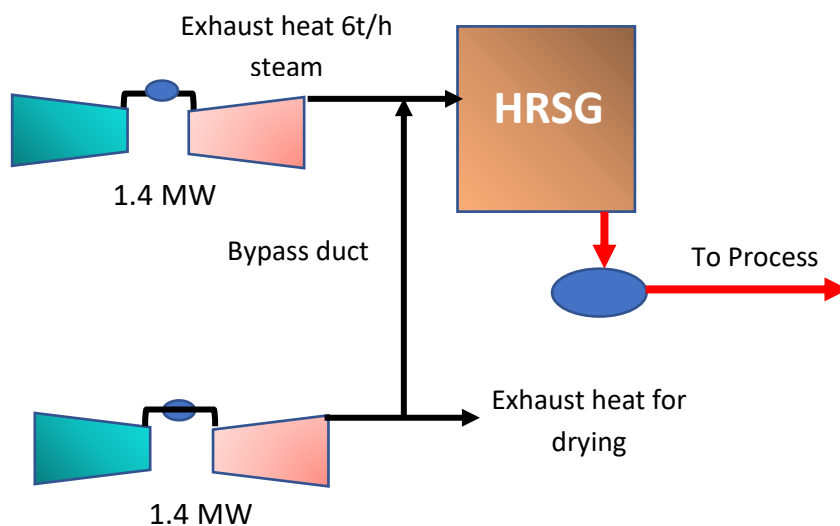
Source: Authors.

Item	Contents
Type of power engine	Gas engine
Rated power output (kW)	1 x 1.2 MW 1 x 2.0 MW
Total HRSG hot water flow (m ³ /h) Steam temperature (°C) No. hot water HRSG utilising exhaust heat	60–100 m ³ /h 60–80°C 2 nos.
Fuel	Natural gas
Heat: power ratio	1.82
Estimated electricity demand/year	30,240 MWh/y

Item	Contents
Estimated electricity by cogeneration/year	25,920 MWh/y
GT gas consumption/year	555,000 MMBtu/yr.
Estimated operating hours/year	8,640 h y
Approximate cost of investment (RM)	Gas engine: RM6 million
Approximate savings (RM/y)	RM2.1 million/yr
Simple payback period	2.85 years

Source: Authors in consultation with plant operator.

A2.7. Case Study No. 7: Chemical Plant No. 2



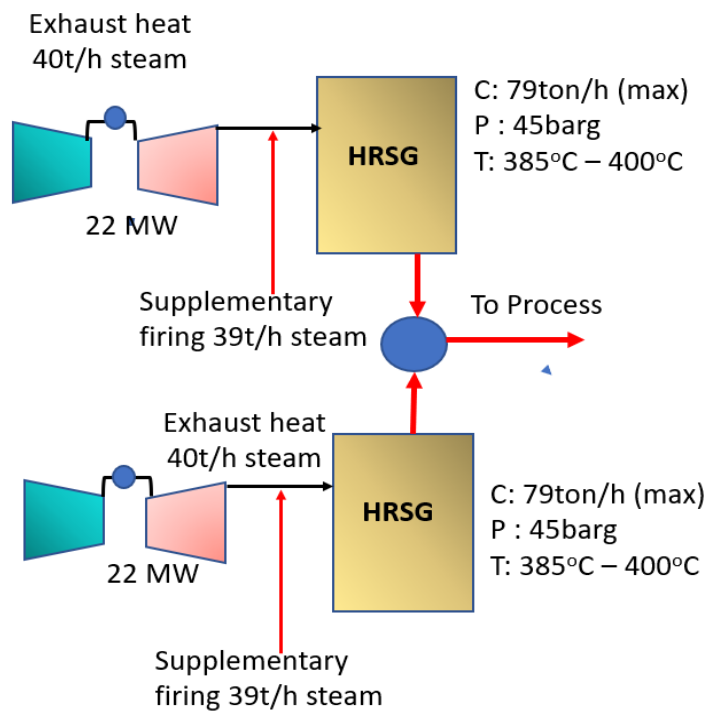
Source: Authors.

Item	Contents
Type of power engine	Gas turbine (GT)
Rated power output	2 x 1,400 kW
HRSG pressure (barg) Steam temperature (°C) Steam capacity from cogeneration (t/h)	13 barg Saturated (195°C) 6 t/h (run at 4 t/h)
Fuel	Natural gas
Heat: power ratio (actual total heat used: steam + drying)	1.48
Estimated electricity demand/year	1,049 MWh/y
Estimated electricity from cogeneration/year	877 MWh/y

Item	Contents
GT gas consumption/year	330,389 GJ/y
Estimated operating hours/year	8,424 h/y
Approximate cost of investment	RM 25 million
Estimated approximate savings (RM/y)	RM4.76 million/y
Simple payback period: longer payback due heat generated not being fully utilised.	5.25 years

Source: Authors in consultation with plant operator.

A2.8. Case Study No. 8: Chemical Plant No. 3



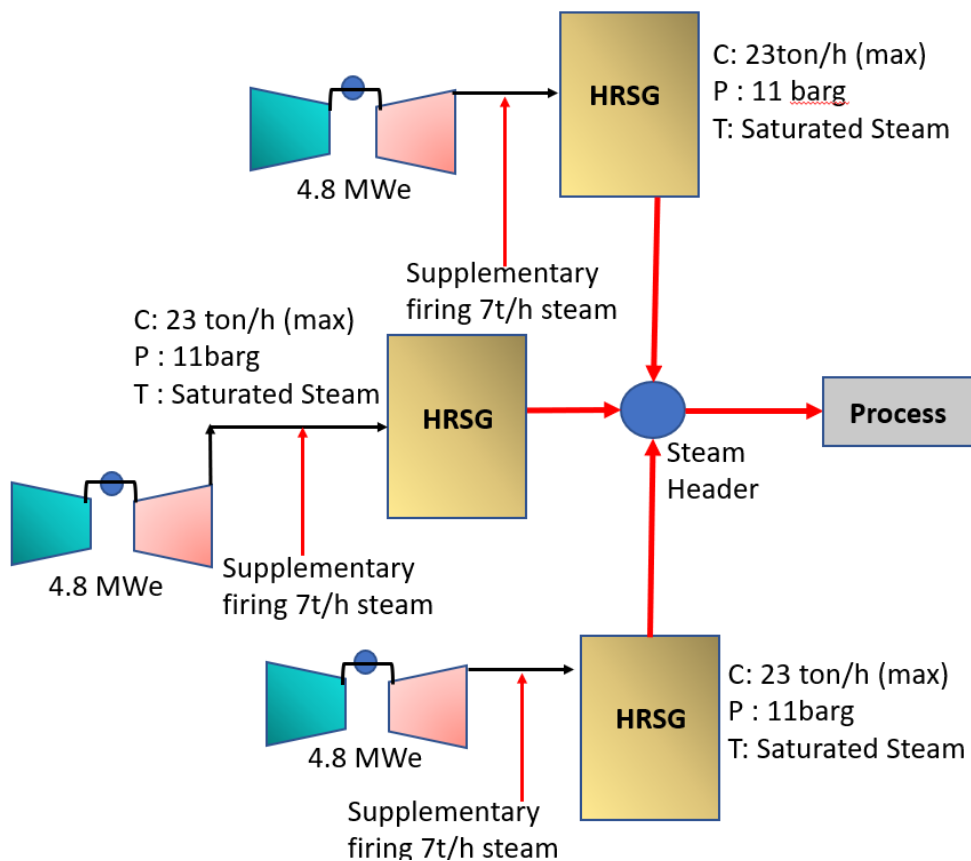
Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output	2 x 22 Mwe
HRSG pressure Steam temperature HRSG capacity (cogeneration/supplementary firing)	45 barg 385°C–400°C 2 X (40 t/h/39 t/h) Total output: 79 t/h (max)
Fuel	Natural gas
Heat: power ratio	1.46

Item	Contents
Estimated electricity demand/year	Not available
Estimated electricity from cogeneration/year	378,400 MWh/y
GT Gas consumption/year	Not available
Estimated operating hours/year (h/y)	8,600 h/y
Approximate cost of investment	RM203.4 million
Approximate savings (RM/y)	RM32.17 million/y
Simple payback period	6.32 years

Source: IEPR (2020).

A2.9. Case Study No. 9: Paper Mill No. 3



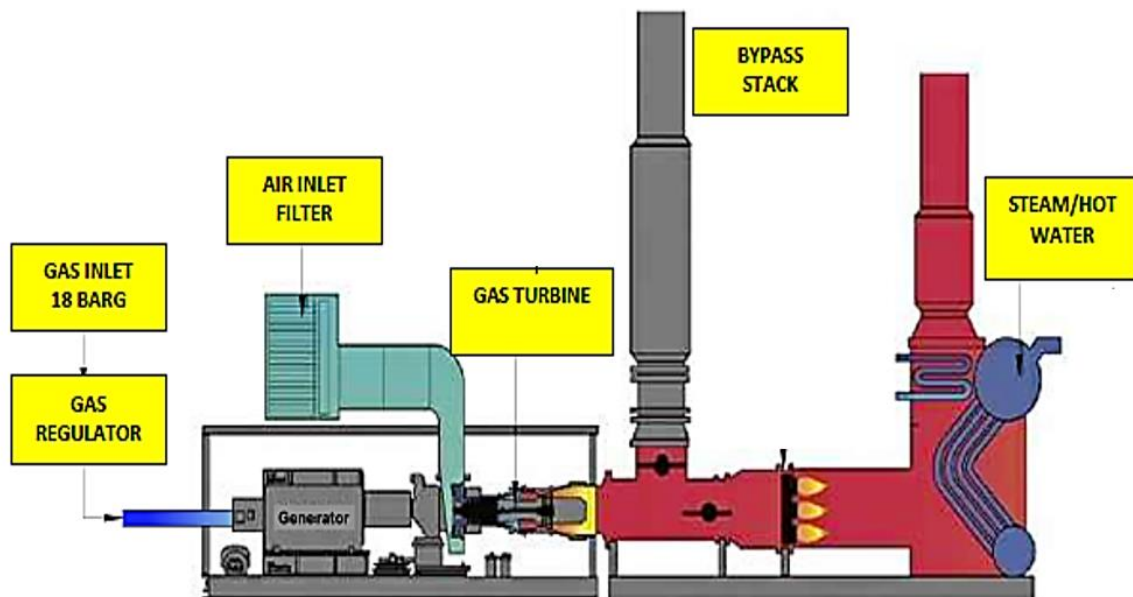
Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output (generating 14.5 MW and 7 MW import from TNB)	3 X 4.8 MW

Item	Contents
HRSG pressure Steam temperature Steam capacity (cogeneration/supplementary firing)	11 barg Saturated (188°C) 3 units HRSG: 16/h (Cogen)/7 t/h (S/F)
Fuel	Natural gas
Heat: power ratio	2.29
Estimated electricity demand/year	184,900 MWh/y
Estimated electricity from cogeneration/year	124,700 MWh/y
GT gas consumption/year	Not available
Estimated operating hours/year	8,600 h/y
Approximate cost of investment	RM47 million
Approximate savings (RM/y)	RM16.83 million / y
Simple payback period	2.92 years

Source: IEPR (2020).

A2.10. Case Study No. 10: Oleochemical Plant No. 1



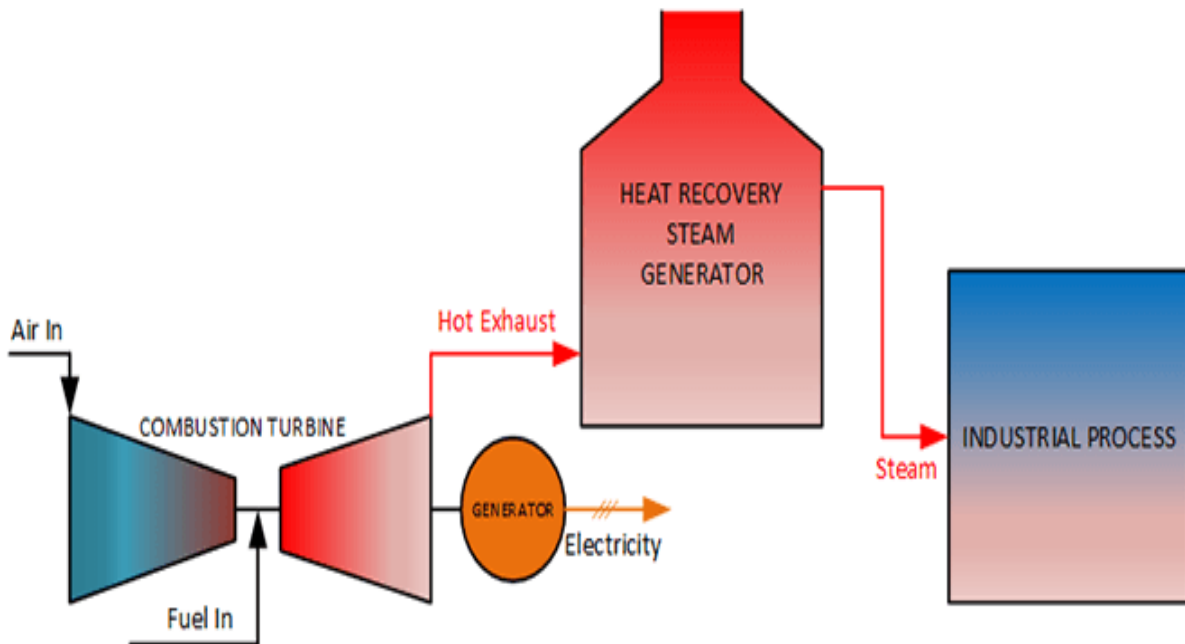
Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output (generation is 5.23 MW)	1 x 6500 kW

Item	Contents
HRSG pressure Steam temperature Steam capacity (cogeneration/supplementary firing)	22 barg Saturated 15 t/h /7.6 t/h
Fuel	Natural gas
Heat: power ratio	1.6
Estimated electricity demand/year (MWh/y)	48,400 MWh/y
Estimated electricity from cogeneration/year (MWh/y)	45,000 MWh/y
GT gas consumption/year	538,076 GJ/y
Estimated operating hours/year (h/y)	8,600 h
Approximate cost of investment (inclusive of all electrical & water treatment auxiliaries, etc.)	RM50 million
Approximate savings (RM/y)	RM995,291/y
Simple payback period (higher payback period due to higher investment on additional equipment as above)	11.51 years

Source: IEPR (2020).

A2.11. Case Study No. 11: Oleochemical Plant No. 2

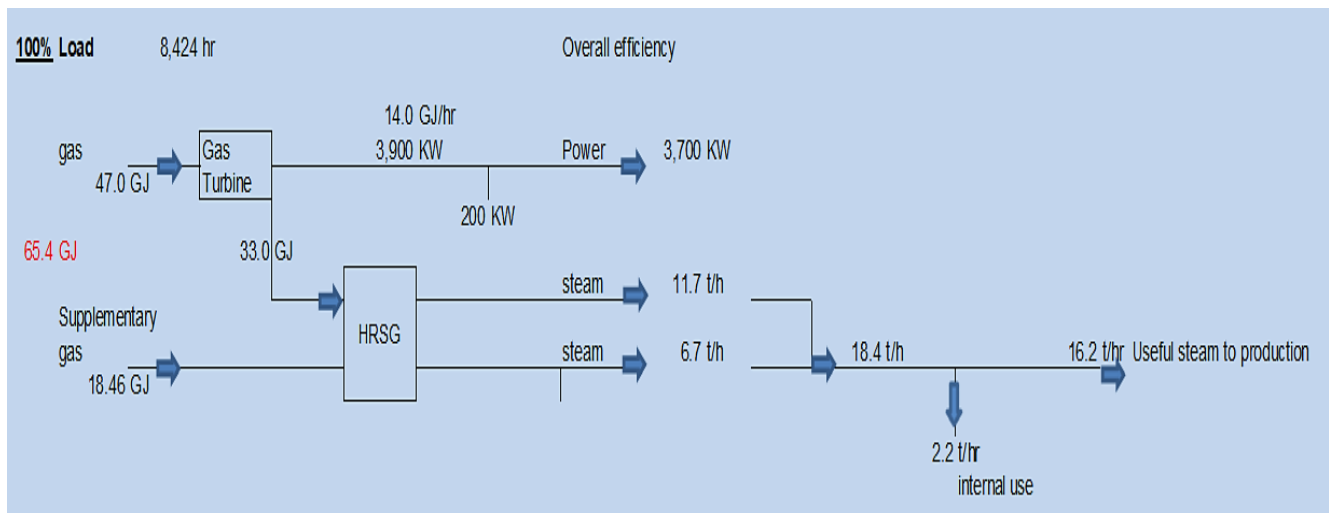


Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output	1 x 6500 kW
HRSG pressure (barg) Steam temperature (°C) Boiler capacity (ton/hr)	16 barg Saturated (204°C) 16.7 t/h
Fuel	Natural gas
Heat: power ratio	1.78
Estimated electricity demand/year	57,850 MWh/y
Estimated electricity cogeneration/year	56,693 MWh/y
GT gas consumption/year	657,000 MMBtu/y
Estimated operating hours/year (h/y)	8,600 h/y
Approximate cost of investment (huge discount - company bought few cogeneration)	RM19.1 million
Approximate savings (RM/y)	RM6 million/year
Simple payback period	3.54 years

Source: Authors in consultation with plant operator.

A2.12. Case Study No. 12: Oleochemical Plant No. 3

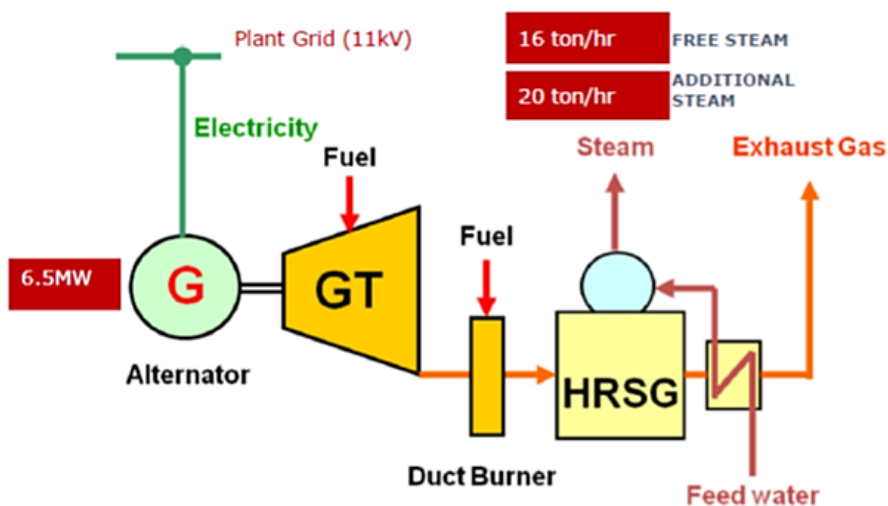


Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output	1 x 4.0 MW
HRSG pressure (barg)	1 @ 10.5 barg
Steam Temperature (°C)	Saturated (186°C)
HRSG capacity from exhaust heat (ton/hr)	11.7 t/h
HRSG capacity from duct burner (ton/hr)	18.3 t/h
Fuel	Natural gas
Heat: power ratio	2.02
Estimated electricity demand/year	34,500 MWh/y
Estimated electricity cogeneration/year	31,200 MWh/y
GT gas consumption/year	605,877 GJ/y
Estimated operating hours/year (h/y)	8,424 h/y
Approximate cost of investment	RM30.5 million
Approximate savings (RM/y)	RM5.59 million/y
Simple payback period	5.5 years

Source: Authors in consultation with plant operator.

A2.13. Case Study No. 13: Oleochemical Plant No. 4



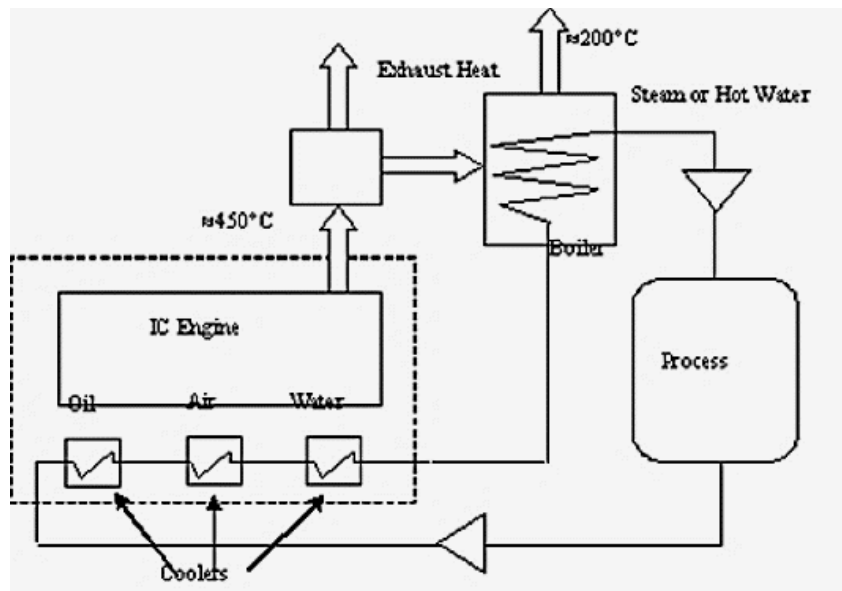
1 x GTG Output @ ISO Rating	7800	kW
1 x GTG Output @ 32° C (Gross)	6540	kW
1 x HRSG Unfired Steam Output (Gross) 16.9	tph	

Source: Authors.

Item	Contents
Type of power engine	Gas turbine
Rated power output	1 x 6.5 MW
HRSG pressure (barg)	16 barg
Steam temperature (°C)	Saturated (204°C)
HRSG capacity from exhaust heat (ton/hr)	16 t/h
HRSG capacity from duct burner (ton/hr)	20 t/h
Fuel	Natural gas
Heat: power ratio	1.7
Estimated electricity demand/year	59,000 MWh/y
Estimated electricity cogeneration/year	52,500 MWh/y
GT gas consumption/year	655,000 MMBtu/y
Estimated operating hours/year (h/y)	8,520 hr
Approximate cost of investment	RM33 million
Approximate savings (RM/y)	RM4.5 million/y
Simple payback period	7.3 y

Source: Authors in consultation with plant operator.

A2.14. Case Study No. 14: Textile Factory No. 1

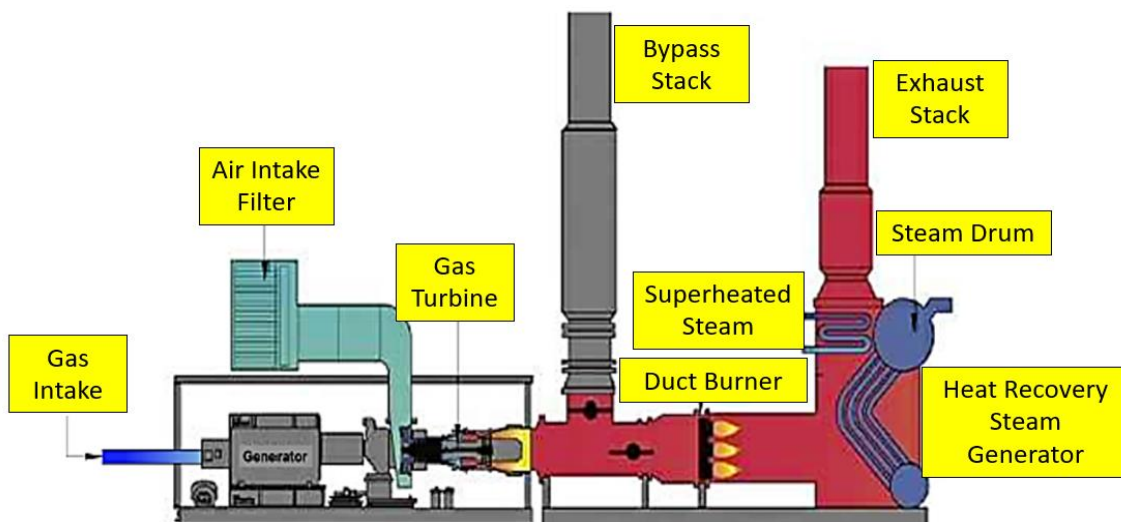


Source: Authors.

Item	Contents
Type of power engine	Gas engine
Rated power output	1 x 5.2 MW
HRSG pressure (barg)	8 barg
Steam temperature (°C)	Saturated (175°C)
HRSG capacity from exhaust heat (ton/hr)	2.2 t/h
Fuel	Natural gas
Heat: power ratio	0.29
Estimated electricity demand/year	44,370 MWh/y
Estimated electricity cogeneration/year	41,600 MWh/y
Gas consumption/hour	1,083 Nm ³ /h
Estimated operating hours/year	8,322 h/y
Approximate cost of investment	RM27.2 million
Approximate savings (RM/y)	RM5.64 million /y
Simple payback period	5.86 years

Source: Authors in consultation with plant operator.

A2.15. Case Study No. 15: Third-Party Utility (ESCO)

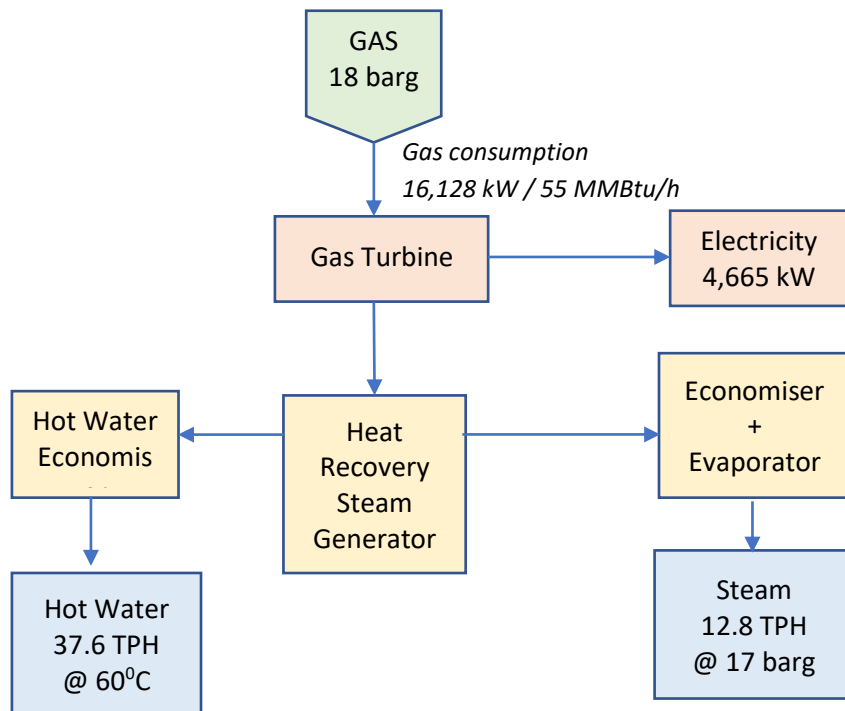


Source: Authors.

Item	Contents
Type of power engine	Gas turbine (GT)
Rated power output	1 x 16.28 MWe
HRSG pressure	60.8 barg
Steam temperature	292°C)
HRSG capacity from exhaust heat (ton/hr)	28 t/h
HRSG capacity from supplementary firing (ton/hr)	60 t/h
Fuel	Natural gas
Heat: power ratio	1.22
Estimated electricity demand/year	133,900 MWh/y
Estimated electricity from cogeneration/year	115,288 MWh/y
GT gas consumption/year	40,508,781 S m ³ /y
Estimated operating hours/year	8,400 h/y
Approximate cost of investment	RM110 million
Approximate savings (RM/y)	RM11 million/y
Simple payback period	10 years

Source: Authors in consultation with plant operator.

A2.16. Case Study No. 16: Textile Factory No. 2

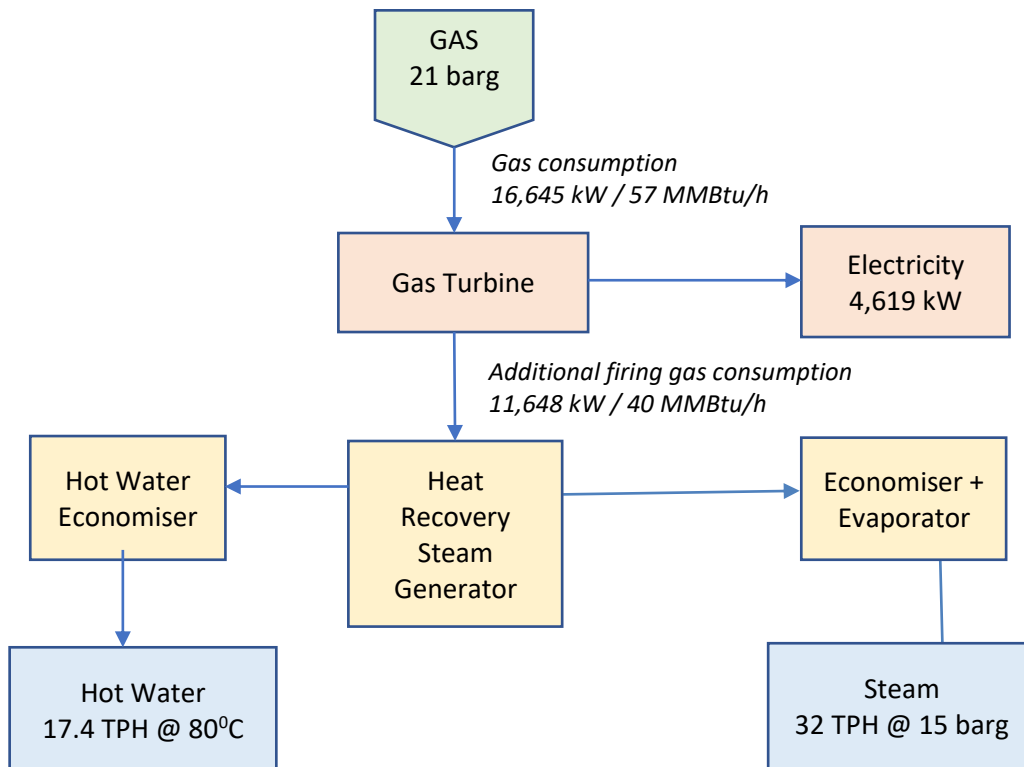


Source: Authors.

Specification	Description
System configuration	<ul style="list-style-type: none"> • 4,665 kW Gas turbine • HRSG • Steam/hot water generator
Operating hours	8,000
GT gas consumption	16,128 kW / 55 MMBtu/h
HRSG capacity	12.8 TPH steam @17 barg
Thermal energy for steam/y	66,560 MWh/y
HRSG capacity for hot water	37.6 TPH 60°C hot water (from 27°C)
Thermal energy for hot water/y	11,584 MWh/y
Heat: power ratio	2.094
Investment cost	RM35 million (US\$8.33 million)
Savings	RM5.68 million/y
Simple payback period	6.16 years

Source: Authors.

A2.17. Case Study No. 17: Oil Refinery

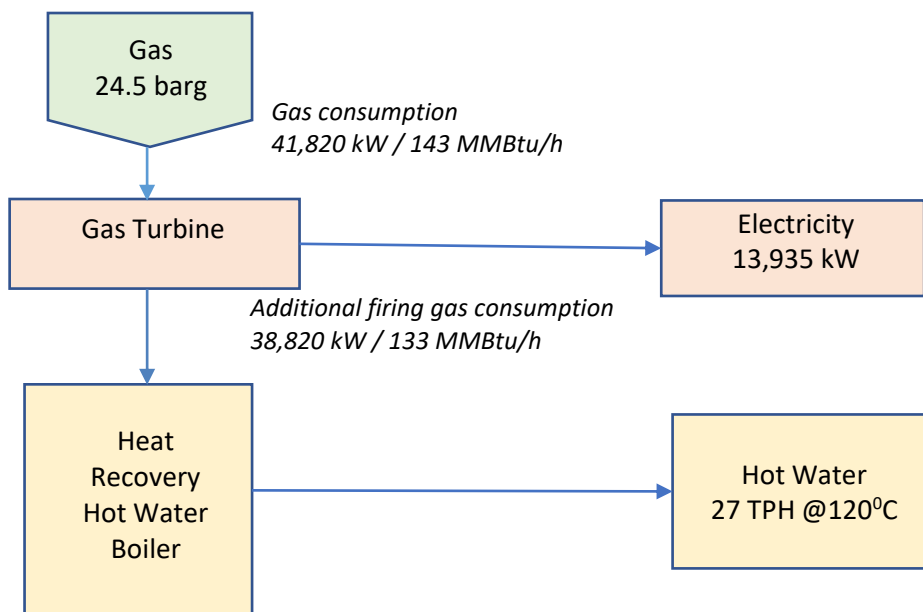


Source: Authors in consultation with Kawan Engineering Sdn Bhd. (2022).

Specification	Description
System configuration	<ul style="list-style-type: none"> • 4,619 kW gas turbine • HRSG • Steam/hot water generator
Operating hours	8,000
GT gas Consumption	16,645 kW 57 MMBtu/h
Gas consumption for additional firing	11,648 kW/40 MMBtu/h
HRSG capacity	32 TPH steam @15 barg
Thermal energy for steam/y	171,800 MWh/y
HRSG capacity for hot water	17.4 TPH 80°C hot water (from 27°C)
Thermal energy for hot water/year	8,640 MWh/y
Heat: power ratio	4.882
Investment cost	RM33 million
Savings	RM7.886 million/y
Simple payback period	4.18 years

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

A2.18. Case Study 18: Rubber Glove Factory

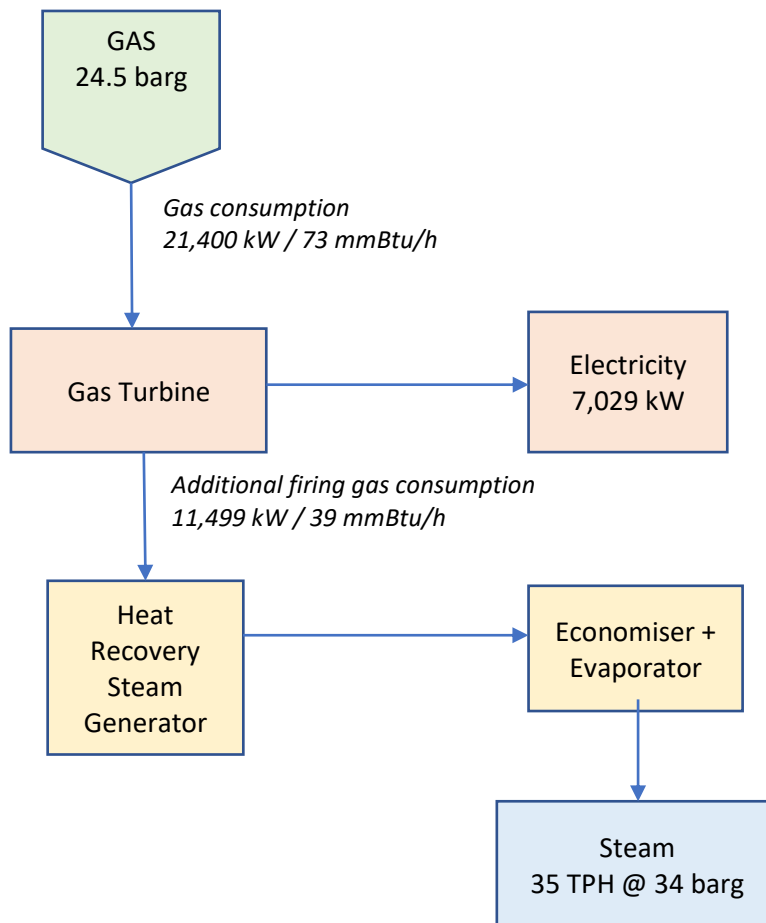


Source: Authors in consultation with Kawan Engineering Sdn Bhd (2022).

Specification	Description
System configuration	<ul style="list-style-type: none"> • 13,935 kW gas turbine • HRSG • Hot water generator
Operating hours	8,000
GT Gas Consumption	41,820 kW/143 MMBtu/h
Gas consumption for additional firing	38,820 kW/133 MMBtu/h
HRSG capacity for hot water	27 TPH @120°C from 90°C
Thermal energy for hot water/year	432,000 MWh/y
Heat: power ratio	3.87
Investment cost	RM46 million
Savings	RM11.03 million/y
Simple payback period	4.17 years

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

A2.19. Case Study No. 19: Oleochemical Plant No. 5

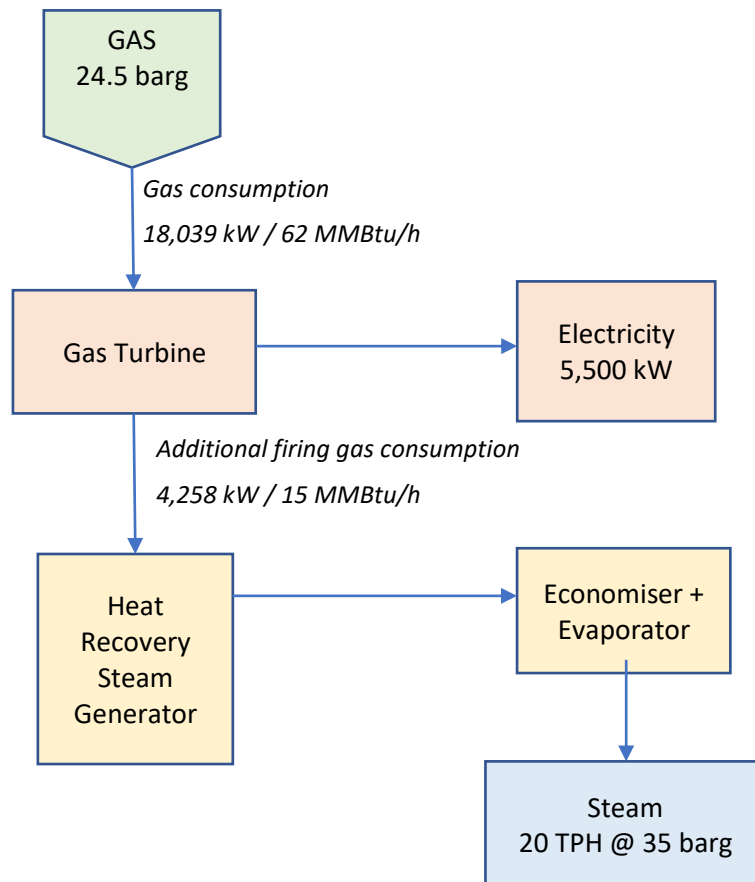


Source: Authors.

Specification	Description
System configuration	<ul style="list-style-type: none"> 7,029 kW gas turbine HRSG
Operating hours	8,000
GT gas consumption	21,400 kW/73 MMBtu/h
Gas consumption for additional firing	11,499 kW/39 MMBtu/h
HRSG capacity	35 TPH steam @34 barg
Thermal energy for steam/y	181,086 MWh/y
Heat: power ratio	3.22
Investment cost	RM37 million
Savings	RM5.974 million/y
Simple payback period	6.2 years

Source: Authors.

A2.20. Case Study No. 20: Biomass Processing Plant

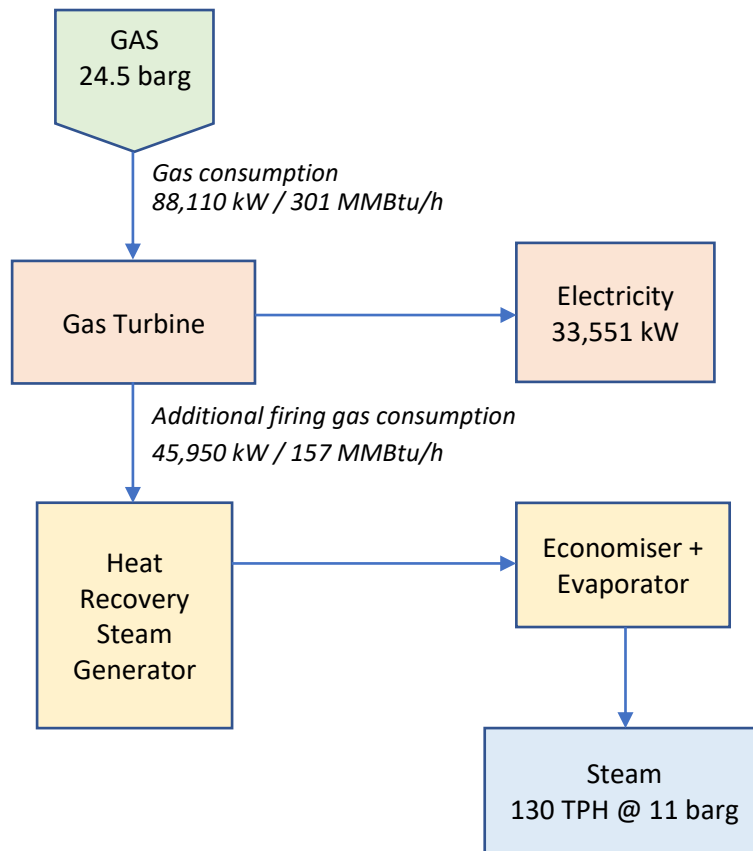


Source: Authors in consultation with Kawan Engineering Sdn Bhd (2022).

Specification	Description
System configuration	<ul style="list-style-type: none"> 5,500 kW gas turbine HRSG
Operating hours	8,000
GT gas Consumption	18,039 kW/62 MMBtu/h
Gas consumption for additional firing	4,258 kW/15 MMBtu/h
HRSG capacity	20 TPH steam @35 barg
Thermal energy for steam/y	103,784 MWh/y
Heat: power ratio	2.35
Investment cost	RM35 million
Savings	RM5.336 million/y
Simple payback period	6.56 years

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

A2.21. Case Study No. 21: Animal Feed Ingredient Plant

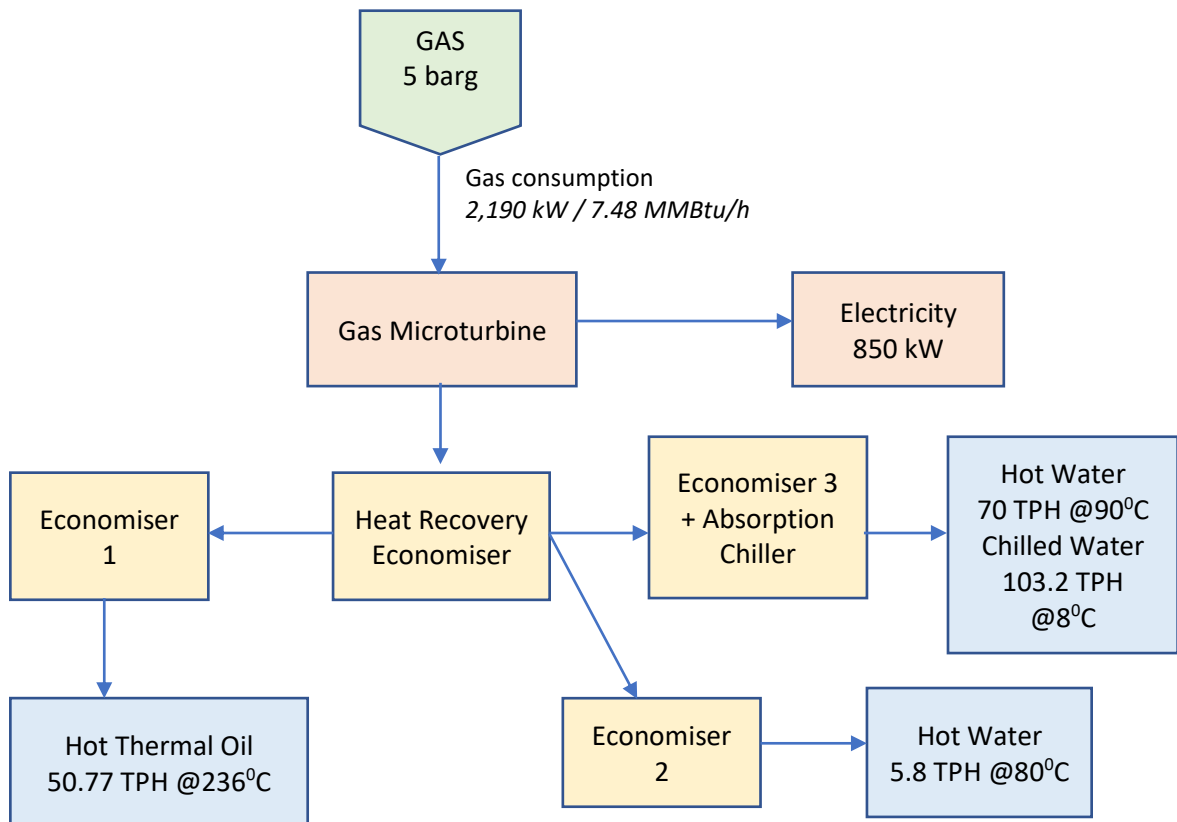


Source: Authors in consultation with Kwan Engineering Sdn Bhd (2022).

Specification	Description
System configuration	<ul style="list-style-type: none"> 33,551 kW gas turbine HRSG
Operating hours	8,000
GT gas consumption	88,110 kW/301 MMBtu/h
Gas consumption for additional firing	45,950 kW/157 MMBtu/h
HRSG capacity	130 TPH steam @11 barg
Thermal energy for steam/y	674,195 MWh/y
Heat: power ratio	2.51
Investment cost	RM144 million
Savings	RM37.83 million/y
Simple payback period	3.8 years

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

A2.22. Case Study No. 22: Chemical Plant No. 3



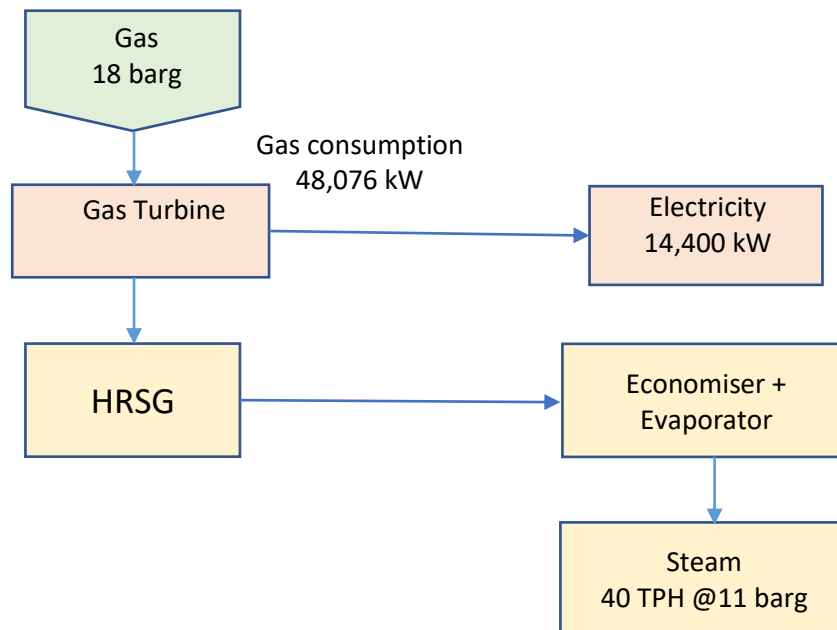
Source: Authors in consultation with Kawan Engineering Sdn Bhd (2022).

Specification	Description
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System configuration	<ul style="list-style-type: none"> • 850 kW microturbine • Economiser • Absorption chiller
Operating hours	8,000
Gas consumption	2,190 kW/7.48 MMBtu/h
Economiser capacity	<ul style="list-style-type: none"> • 50.77 TPH @236°C thermal oil from 227°C • 5.8 TPH 80°C HW from 30°C • 70 TPH 90°C HW from 77°C • 103.2 TPH chilled water @8°C
Thermal energy for thermal oil & hot water	13,535 MWh/y
Electricity: heat ratio	1.99
Investment cost	RM18 million
Savings	RM2.087 million
Simple payback period	8.62 years

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

A2.23. Case Study No. 23: Paper Mill No. 4



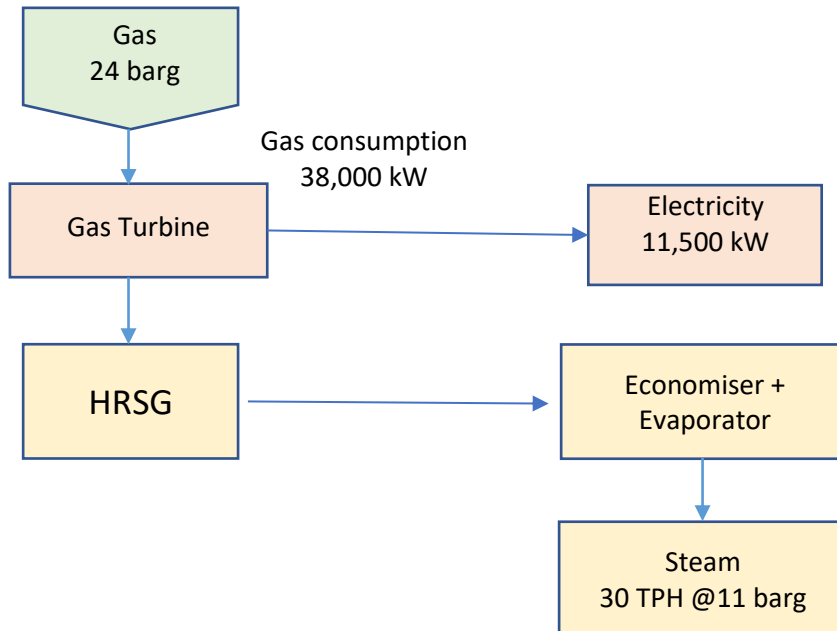
Source: Authors.

Specification	Description
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System configuration	<ul style="list-style-type: none"> • 14.4 MW gas turbine (GT) • HRSG • Steam/hot water generator
Operating hours	8,000
GT gas consumption	48,076 kW/164 MMBtu/h
HRSG capacity	40 TPH @11 barg steam
Thermal energy for steam/y	246,889 MWh/y
Heat: power ratio	2.14
Investment cost	RM86.4 million
Savings	RM25.94 million/y
Simple payback period	3.3 years

Source: Authors.

A2.24. Case Study No. 24: Sugar Mill



Source: Authors.

Specification	Description
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System configuration	<ul style="list-style-type: none"> • 11.5 MW gas turbine • HRSG
Operating hours	8,000
GT gas consumption	38,000 kW/130 MMBtu/h
Gas consumption for additional firing	Nil
HRSG capacity	30 TPH @11 barg steam
Thermal energy for steam/y	185,300 MWh/y
Heat: power ratio	2.01
Investment cost	RM68.9 million
Savings	RM25.2 million/y
Simple payback period	2.7 years

Source: Authors