HITACHI
Inspire the Next

Hitachi Proprietary Information

LPG Burning Gas Turbine for Power Generation

Hitachi, Ltd.

Jan. 2014

Shunichi Kuba, Ph.D
Shunichi.kuba.ej@hitachi.com

Contents

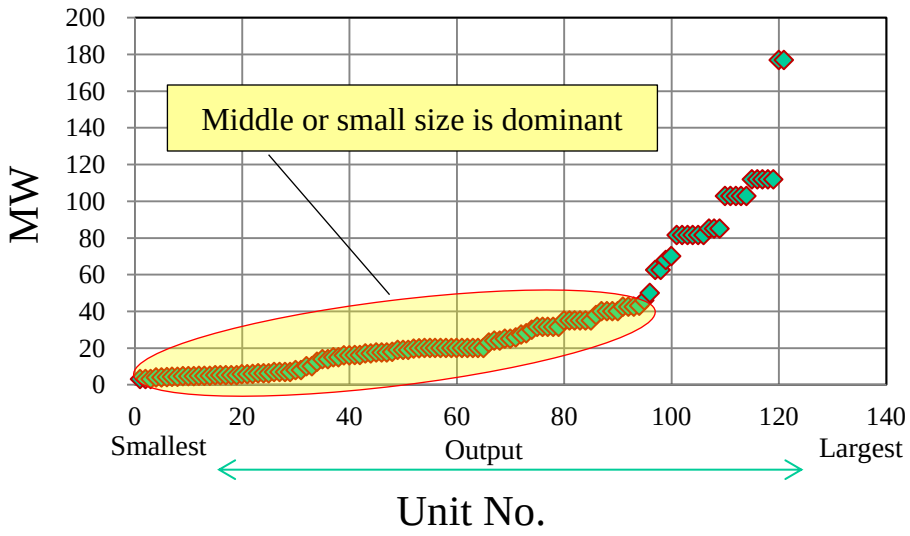
1. LPG burning GT power plants in the world

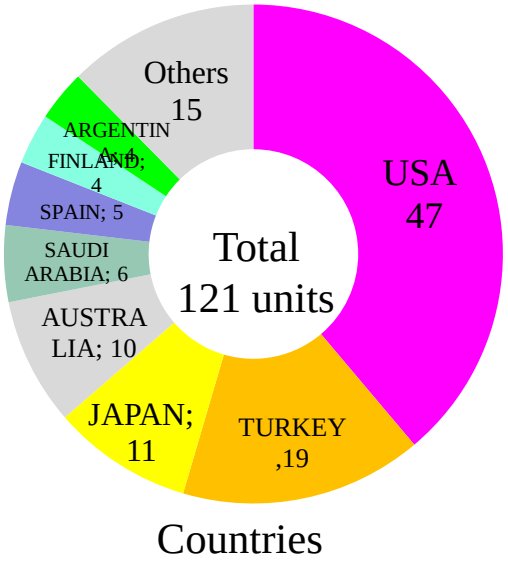
REF:UDI World Electric Power Plants Data Base

- Total 121 units of LPG burning gas turbines were installed in the world since 1964.

Proven technology

- Middle or small size GTs are dominant (Less than 50 MW)
- All units are duel or triple fuel system



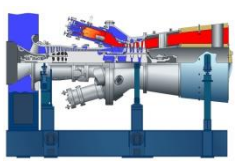


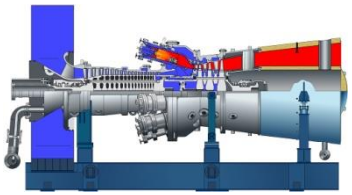
Contents

HITACHI
Inspire the Next

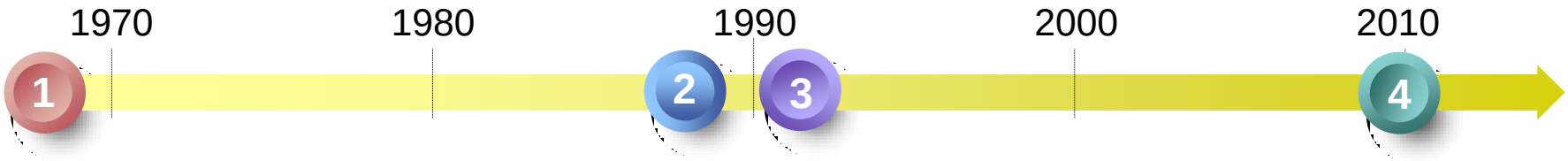
Hitachi Gas Turbine Lineups

	H-15	H-25	H-80
Output	17 MW	28–42 MW	100-110 MW
Sales Units	6	158	13





History

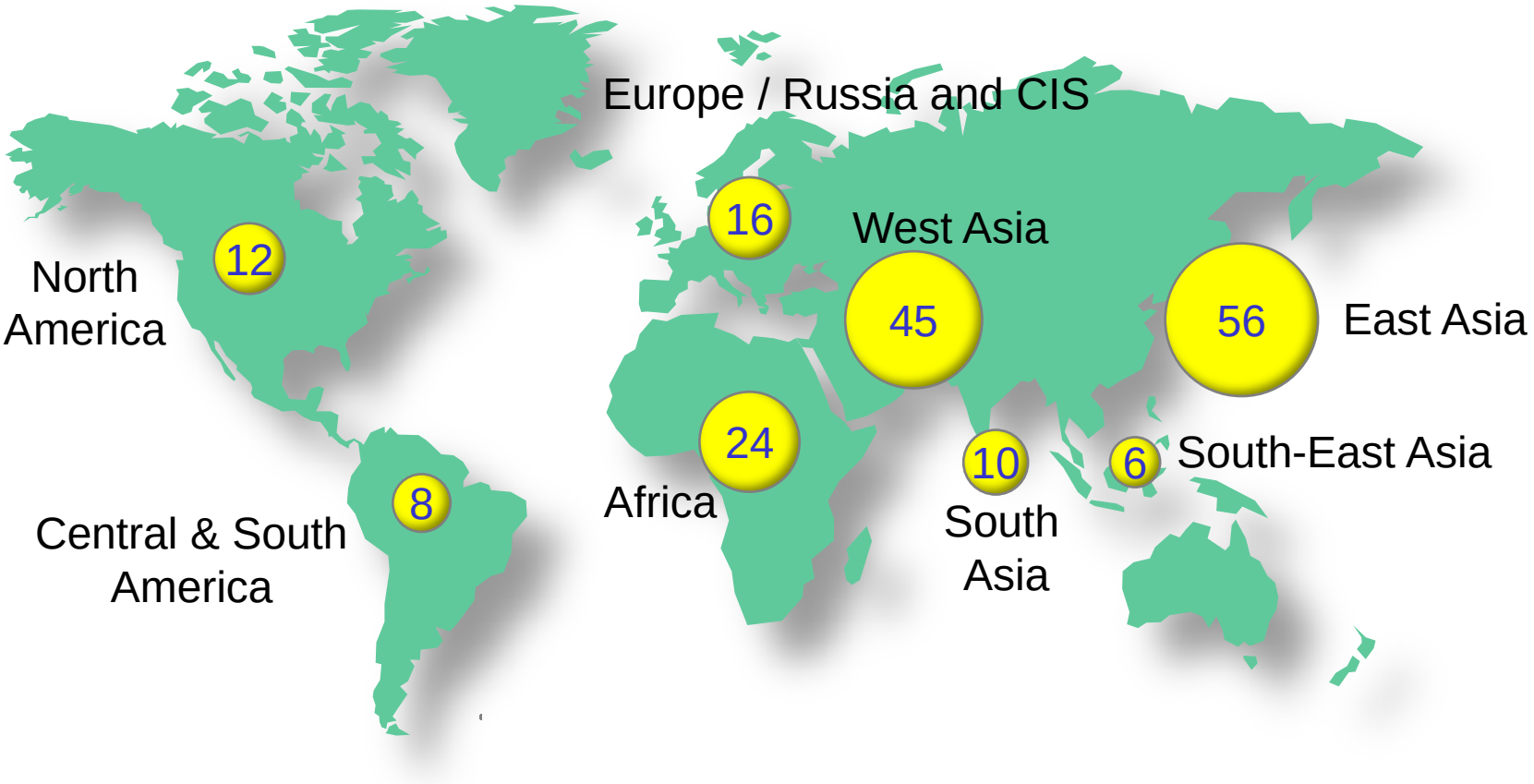


1. 1966 : Hitachi 1st Gas Turbine Released
2. 1988 Nov. : H-25 1st Unit in Commercial Operation
3. 1991 Jan. : H-15 1st Unit in Commercial Operation
4. 2010 Jan. : H-80 1st Unit in Commercial Operation

2-2 Supply experiences – Hitachi Gas Turbines (1/2)

HITACHI
Inspire the Next

Hitachi Gas Turbine in the World

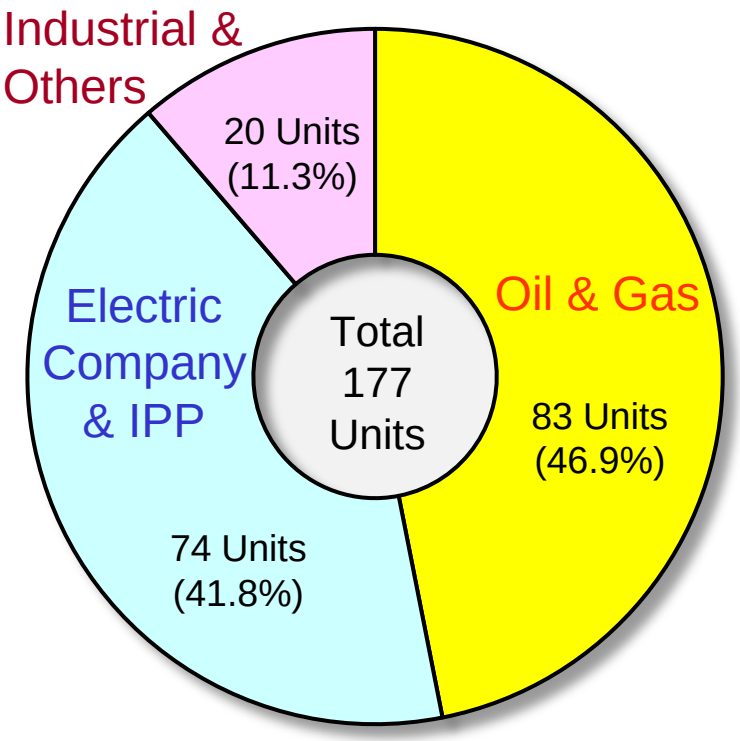


Total **177** units (*) As of Oct. 2013

2-2 Supply experiences – Hitachi Gas Turbines (2/2)

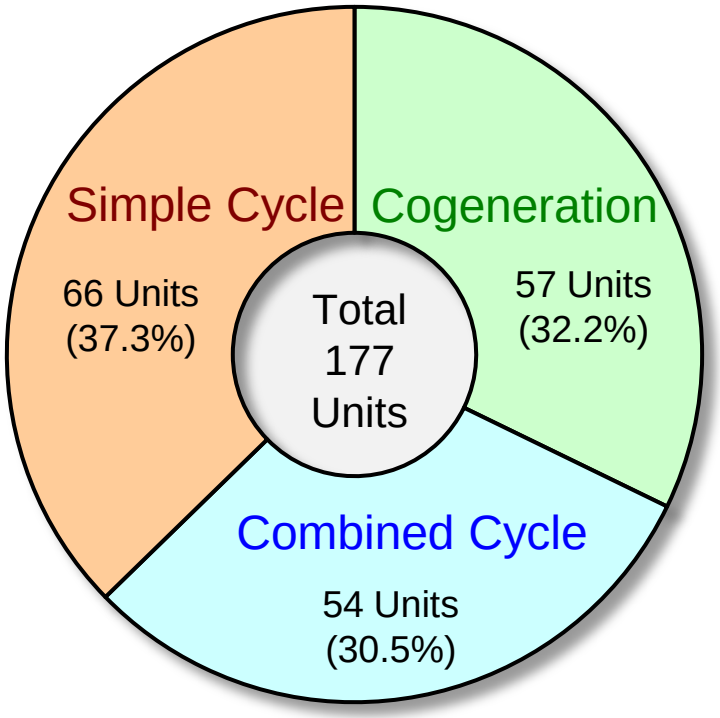
HITACHI
Inspire the Next

Market



Various Plant Applications
Refinery, Chemical plant,
Power plant, IPP,
Fertilizer plant, etc.

Applications



Cogeneration + Combined : > 60%

HITACHI
Inspire the Next

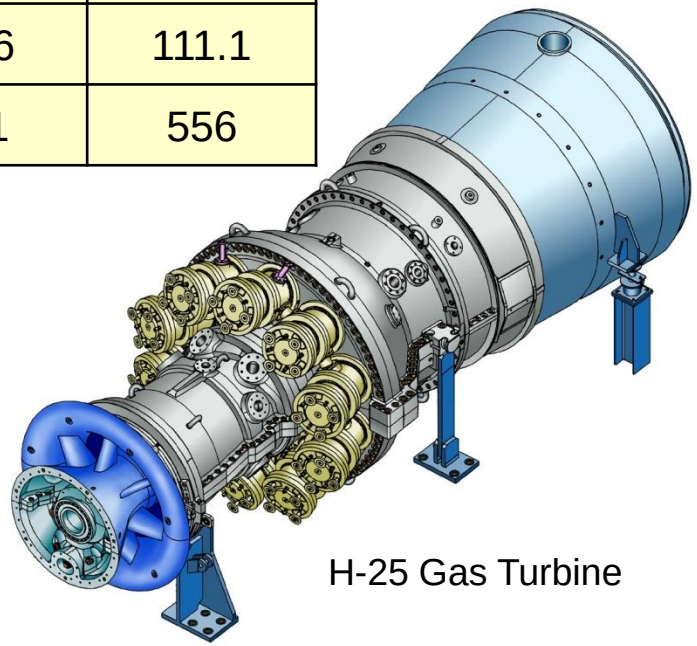
Natural Gas Burning H-15/H-25 ISO Performance

ITEM	UNIT	H-15	H-25		
			H-25(28)	H-25(32)	H-25(42)
Output	MW	16.9	27.5	32.0	41.9
Efficiency	%(LHV)	34.3	33.8	34.8	37.2
Heat Rate (LHV)	kJ/kWh	10,500	10,650	10,350	9,670
	Btu/kWh	9,950	10,097	9,806	9,166
Exhaust Flow	kg/s	52.9	89.5	96.6	111.1
Exhaust Temp	deg. C	564	555	561	556

Natural Gas Case
ISO Condition (Temperature=15deg.C)

In case of LPG burning, following collections shall be considered

Output	: approx. -1.5%
Heat Rate	: approx. +0.2%



H-25 Gas Turbine

HITACHI
Inspire the Next

LPG Burning H-15/H-25 Performance on Typical Site Condition

ITEM	UNIT	H-15	H-25		
			H-25(28)	H-25(32)	H-25(42)
Output	MW	16.0	26.1	30.0	38.7
Efficiency	%(LHV)	33.1	32.9	33.6	35.4
Heat Rate (LHV)	kJ/kWh	10,884	10,935	10,703	10,178
	Btu/kWh	10,318	10,366	10,147	9,647
Fuel Flow	ton/h	3.8	6.2	6.9	8.5

LPG Consumption for 1 year (=8,000 hours operation)

LPG Flow	10^3 ton/year	30	49	56	68
	10^3 m^3/year	59	97	109	134
	Bl/day(appx)	1,000	1,700	1,900	2,300

Fuel : LPG (C_3H_8, 507.6kg/m^3 , Liquid, 288K))
ISO Condition (Temperature=15deg.C)
Inlet / Exhaust Pressure Drop : 4.0 / 13.5 inch H_2O
NOx Level : Approx. 250 ~ 370 ppm@15%O_2

H-25 Gas Turbine

HITACHI
Inspire the Next

LPG Burning H-15/H-25 Performance on Typical Site Condition

ITEM	UNIT	H-15	H-25		
			H-25(28)	H-25(32)	H-25(42)
Output	MW	17.5	28.2	33.2	43.6
Efficiency	%(LHV)	34.1	33.5	34.4	36.3
Heat Rate (LHV)	kJ/kWh	10,565	10,734	10,455	9,918
	Btu/kWh	10,017	10,176	9,911	9,400
Fuel Flow	ton/h	4.0	6.5	7.5	9.3
Steam Flow	ton/h	7.5	11.4	14.2	18.5

LPG Consumption for 1 year (=8,000 hours operation)

LPG Flow	10^3 ton/year	32	52	60	75
	10^3 m^3/year	63	103	118	147
	Bl/day(appx)	1,100	1,800	2,000	2,500

Fuel : LPG (C_3H_8, 507.6kg/m^3 , Liquid, 288K))
ISO Condition (Temperature=15deg.C)
Inlet / Exhaust Pressure Drop : 4.0 / 13.5 inch H_2O
NOx Level : 60ppm@15%O_2

Steam Injection for NOx Abatement

HITACHI
Inspire the Next

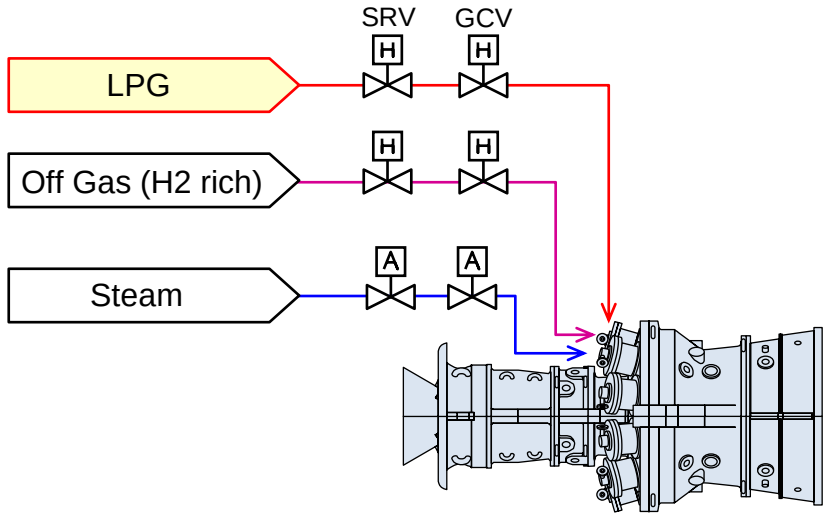
H-25 Gas Turbine for Refinery Plant

No.	Customer	Place	Output	GT Type	Units	NOx Reduction	Fuel	Commercial Operation
1	I-Refinery	Japan	26.25 MW	H-25 (28)	1	Steam Injection	LPG / Heavy Oil	1988
2	S-Refinery	Japan	25.8 MW 24.8 MW	H-25 (28) H-25 (28)	2	Steam Injection	Off Gas / A Heavy Oil	1989 1997
3	T-Plant	Japan	25.35 MW 27.35 MW	H-25 (28) H-25 (28)	2	Steam Injection	Off Gas / A Heavy Oil	1990 1997
4	Y-Refinery	Japan	25.0 MW	H-25 (28)	2	Steam Injection	Off Gas / LPG	1996
5	M-Refinery	Japan	34.15 MW	H-25 (32C)	1	Steam Injection	Off Gas	2005
6	O-Refinery	Japan	32.92 MW	H-25 (32C)	1	Steam Injection	Off Gas / LPG	2005
7	A-Refinery	Japan	33.99 MW	H-25 (32C)	2	Steam Injection	Off Gas / LPG	2007
8	T-Refinery	Japan	33.13 MW	H-25 (32C)	1	Steam Injection	Off Gas / Kerosene	2010
9	L-Refinery	Korea	23.56 MW 29.14 MW 30.38 MW	H-25 (28) H-25 (32C) H-25 (32C)	3	— LNC LNC	Methane Off Gas	2000 2009 2014
10	P-Plant	Brazil	27.12 MW	H-25 (28)	1	Steam Injection	Off Gas / Natural Gas	2006
11	O-Plant	Korea	31.38 MW	H-25 (32C)	1	Water Injection	Off Gas (C1/C3 Gas)	2008

HITACHI
Inspire the Next

Off Gas/LPG Dual Gases Fired H-25 Cogeneration Plant

Customer	Y-Refinery
System	Cogeneration
GT Type	H-25(28) x 2 units
GT Output	25,000 kW
Fuel	Off Gas / LPG
NOx Abatement	Steam Injection
Commercial Operation	June, August. 1996
Location	Mie, Japan



- Shell & API Standard applied
- Operation Track Record
  - Unit A 130,478 hours (at July, 2012)
  - Unit B 139,480 hours (at July, 2013)

Contents

3-1 Merits of LPG Burning Gas Turbine

HITACHI
Inspire the Next

	Items	Merits comparing with diesel burning gas turbine
1	Fuel cost	Fuel cost can be saved greatly Typical value : LPG : 0.86 USD/Gallon 10.2 USD/ MMBTU Diesel : 4.5 USD/ Gallon 35.0 USD/MMBTU
2	Maintenance interval	Maintenance interval can be longer 20- 30 % which depends on operational mode.
3	Performance	Output : Approx. + 0.7 % Efficiency : Approx. + 1.3 % (relative) (depends on operational conditions)
4	Reliability	Rotating equipment (fuel pump) and precision equipment (flow divider) are not required. Reliability of the auxiliary system increases.

Dual fuel burning system with back up fuel is available. Availability of the unit will be higher than single fuel unit such as gas engine or diesel engine.

3-2 Key points in designing of LPG burning GT

HITACHI
Inspire the Next

	LPG characteristics	Reflection required to LPG burning GT
1	High dew point	Easily liquefied by compression under 24-30 barg ・Heating (above 100 deg.C) is required ・Steam tracing is required for LPG line.
2	Heavier specific gravity than air	Suitable ventilation is required to avoid explosion.
3	Combustion characteristics ・High combustion speed ・Rich “C” content	Countermeasure may be required depending on environmental regulation.
4	Impurity	In order to keep high reliability, fuel must strictly satisfy GT supplier’s fuel specifications, not only physical conditions (pressure, temperature) but also chemical compositions such as alkali metals and butadiene, etc.

Note:
In addition to uncertainty of the supply capability, LPG can’t be continuously supplied through pipe line. From these reasons, LPG has been used as back up fuel of middle or small size GTs.

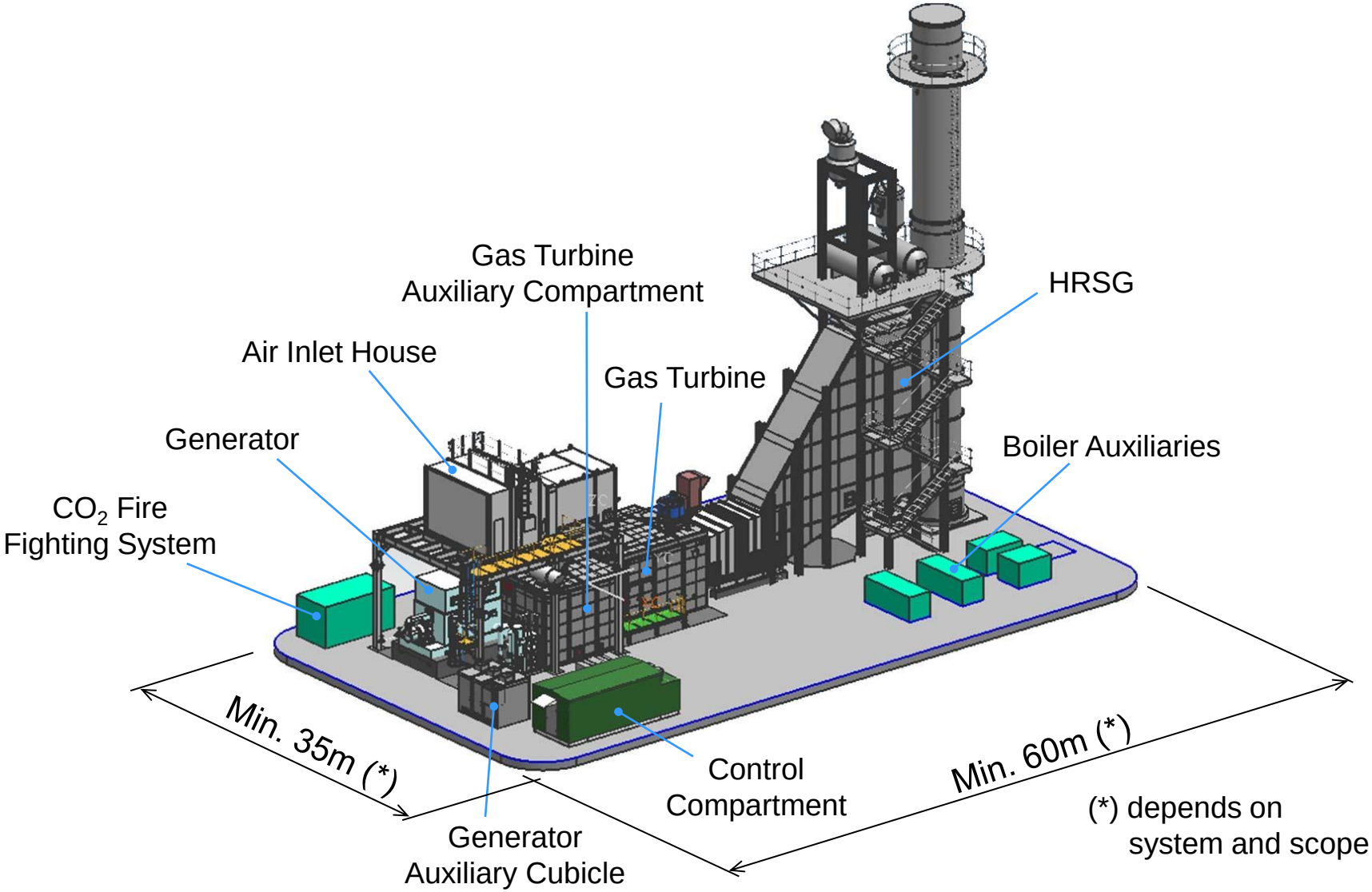
Contents

HITACHI
Inspire the Next

H-25 Simple Cycle Power Plant in Venezuela

HITACHI
Inspire the Next

Typical General Arrangement of H-25 Cogeneration Plant



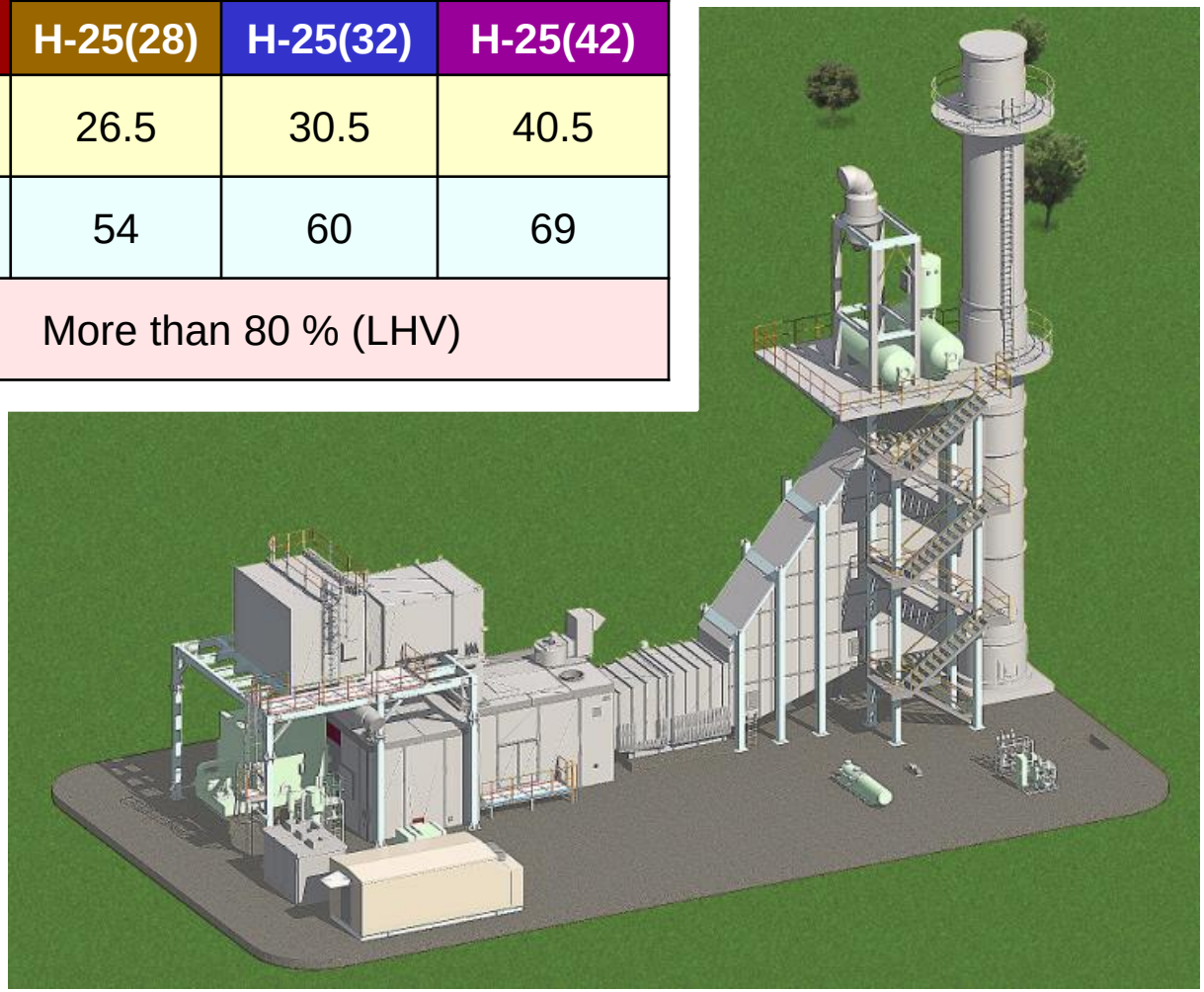
4-2 Cogeneration Plant for Refinery (2/3)

HITACHI
Inspire the Next

Typical Performance for Cogeneration Plant

	H-15	H-25		
		H-25(28)	H-25(32)	H-25(42)
Power Output (MW)	16.2	26.5	30.5	40.5
Steam Flow (t/h) (6 MPa / 300 deg C)	33	54	60	69
Overall Efficiency	More than 80 % (LHV)			

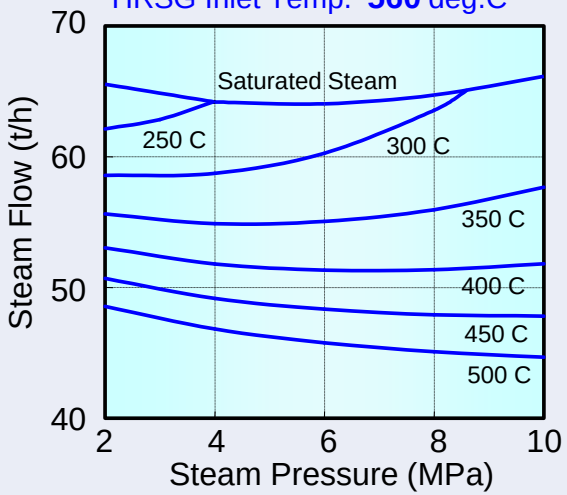
Natural Gas, ISO Base Load Operation

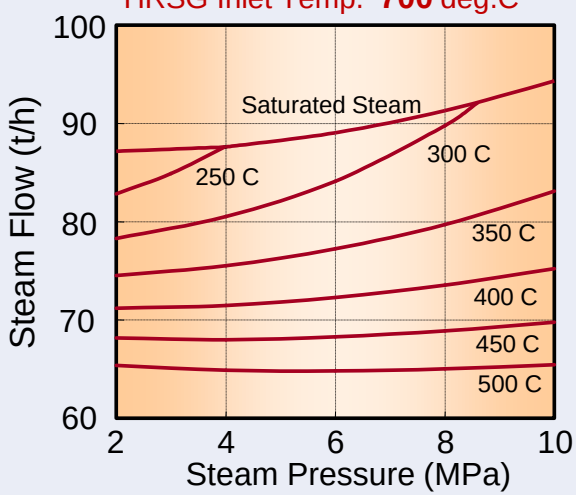


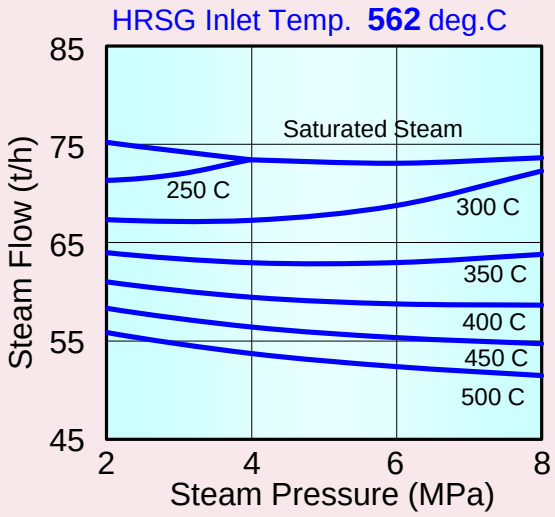
HITACHI
Inspire the Next

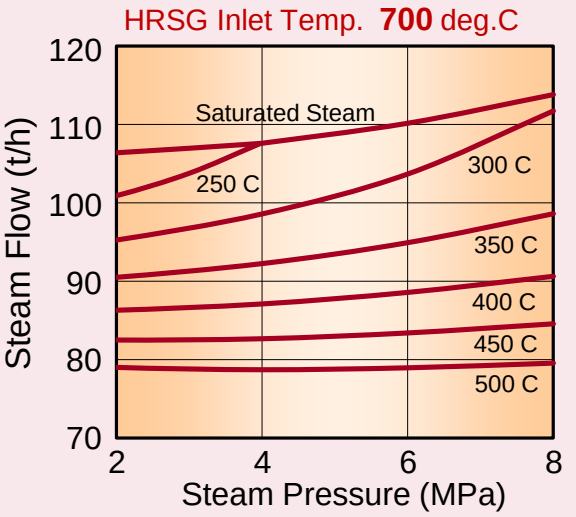
Typical Steam Production Quantity for H-25 Cogeneration System

	UNFIRED Steam Production	FIRED Steam Production
H-25(32)	HRSG Inlet Temp. **560** deg.C	HRSG Inlet Temp. **700** deg.C
H-25(42)	HRSG Inlet Temp. **562** deg.C	HRSG Inlet Temp. **700** deg.C



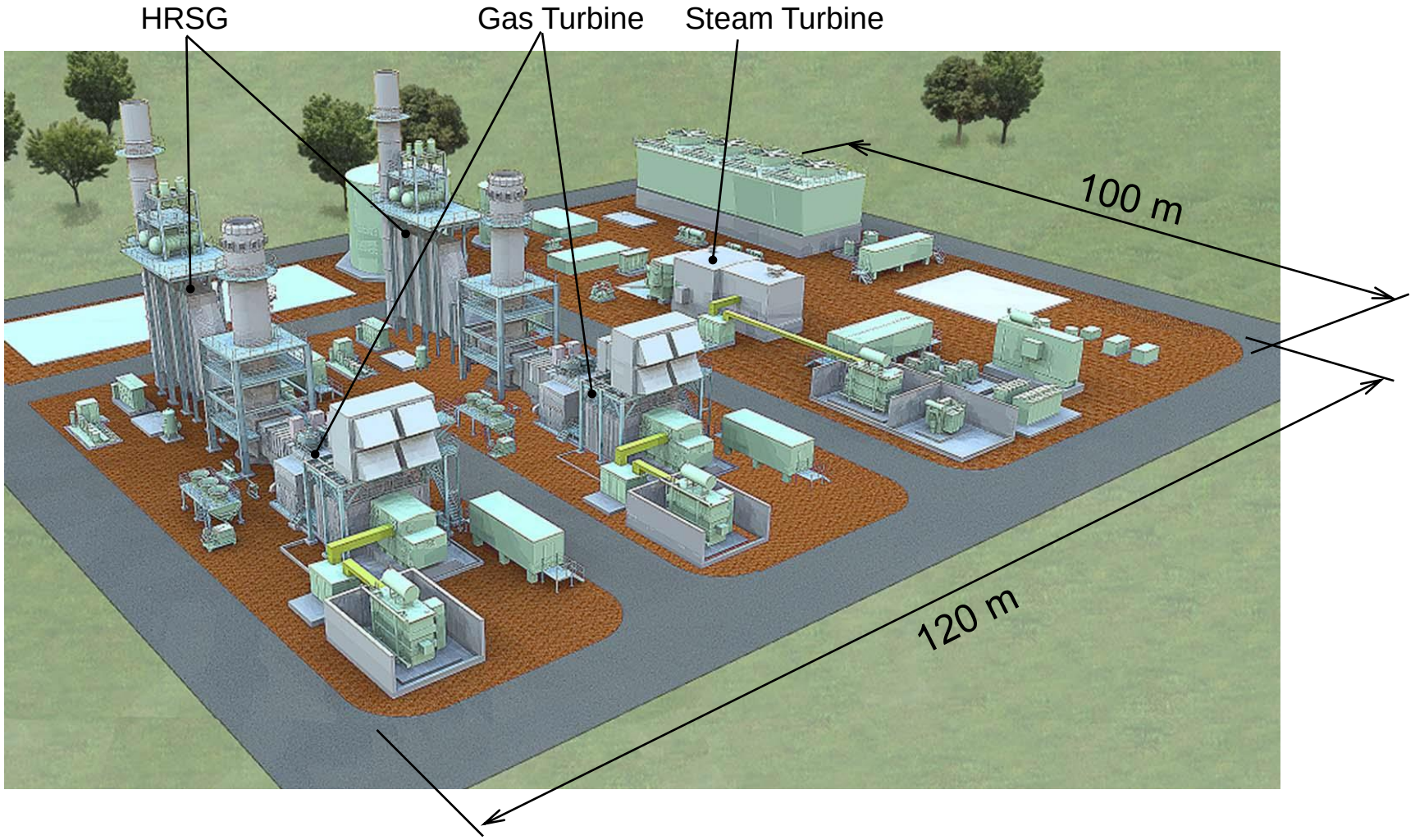






HITACHI
Inspire the Next

Typical General Arrangement of H-25 Combined Cycle Plant (2-2-1)



HITACHI
Inspire the Next

Typical Performance for H-25 Combined Cycle Plant

ITEM	UNIT	H-25 (28)		H-25(32)		H-25(42)	
		1-1-1	2-2-1	1-1-1	2-2-1	1-1-1	2-2-1
Configuration		1 x GT 1 x HRSG 1 x ST	2 x GT 2 x HRSG 1 x ST	1 x GT 1 x HRSG 1 x ST	2 x GT 2 x HRSG 1 x ST	1 x GT 1 x HRSG 1 x ST	2 x GT 2 x HRSG 1 x ST
Total Plant Output	MW	39.9	80.3	45.5	91.4	57.7	115.9
Gas Turbine Output	MW	26.5	26.5 x2	30.5	30.5 x2	40.5	40.5 x2
Steam Turbine Output	MW	13.4	27.3	15.0	30.4	17.2	34.9
Gross Efficiency	%(LHV)	49.7	50.0	50.3	50.5	51.7	51.9

Natural Gas, ISO Base Load Operation

4-4 Tri-generation Plant for EOR (1/3)

HITACHI
Inspire the Next

Tri-generation	
Inputs	Outputs
● GT fuel ● Sea water	● Electricity ● Steam ● Drinking water

Electric Power

HP(High Pressure) Steam

LP(Low Pressure) Steam

Vacuum Ejector

Main Ejector

Sea Water

Cooling Water

Steam Transformer

Fuel

HRSG

Gas Turbine

Generator

No1 No2 No3 No4

Drinkable Water

Brine

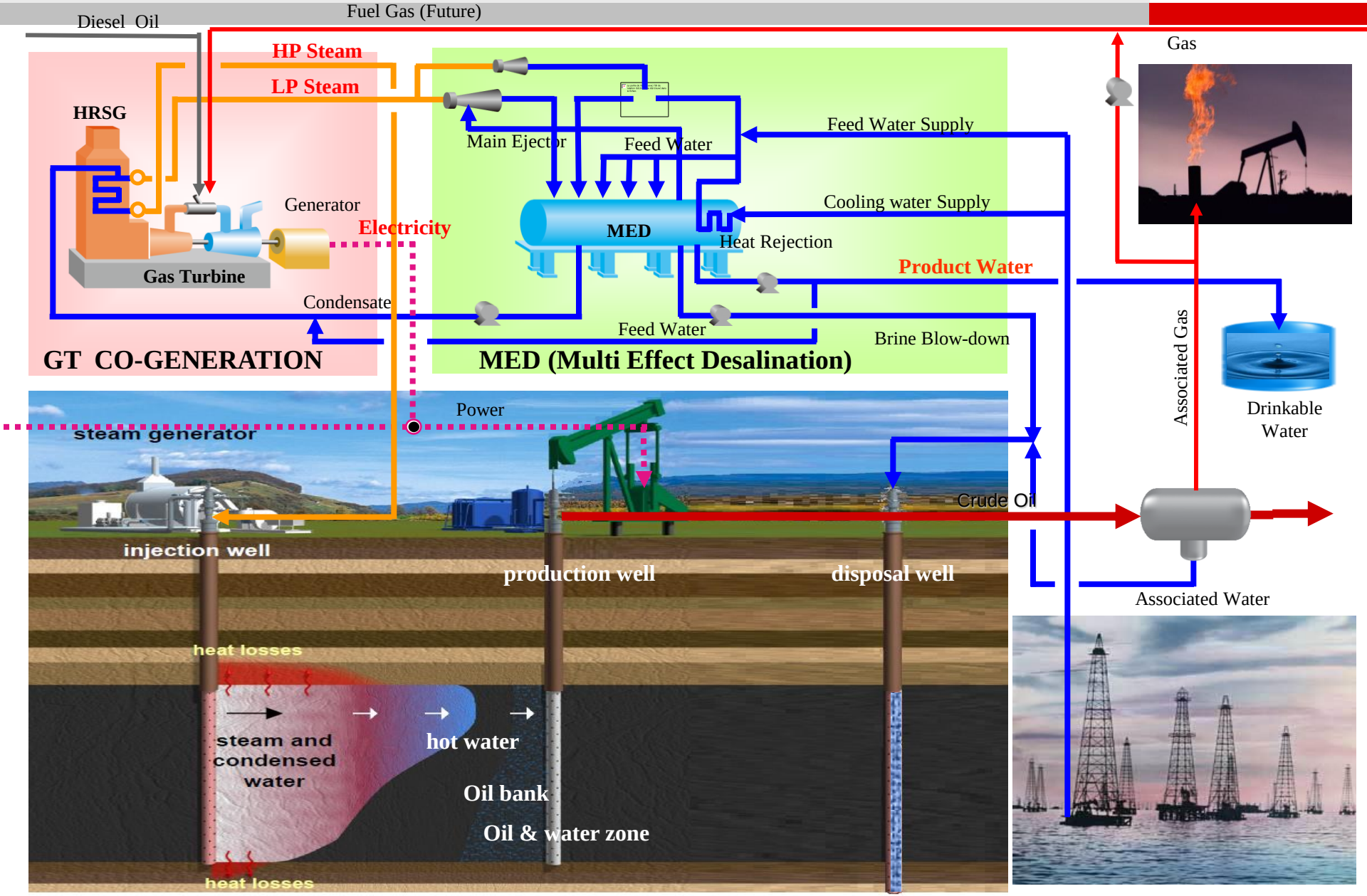
Make-up Water

GT Co-generation

MED-TVC

4-4 Tri-generation Plant for EOR (2/3)

HITACHI
Inspire the Next



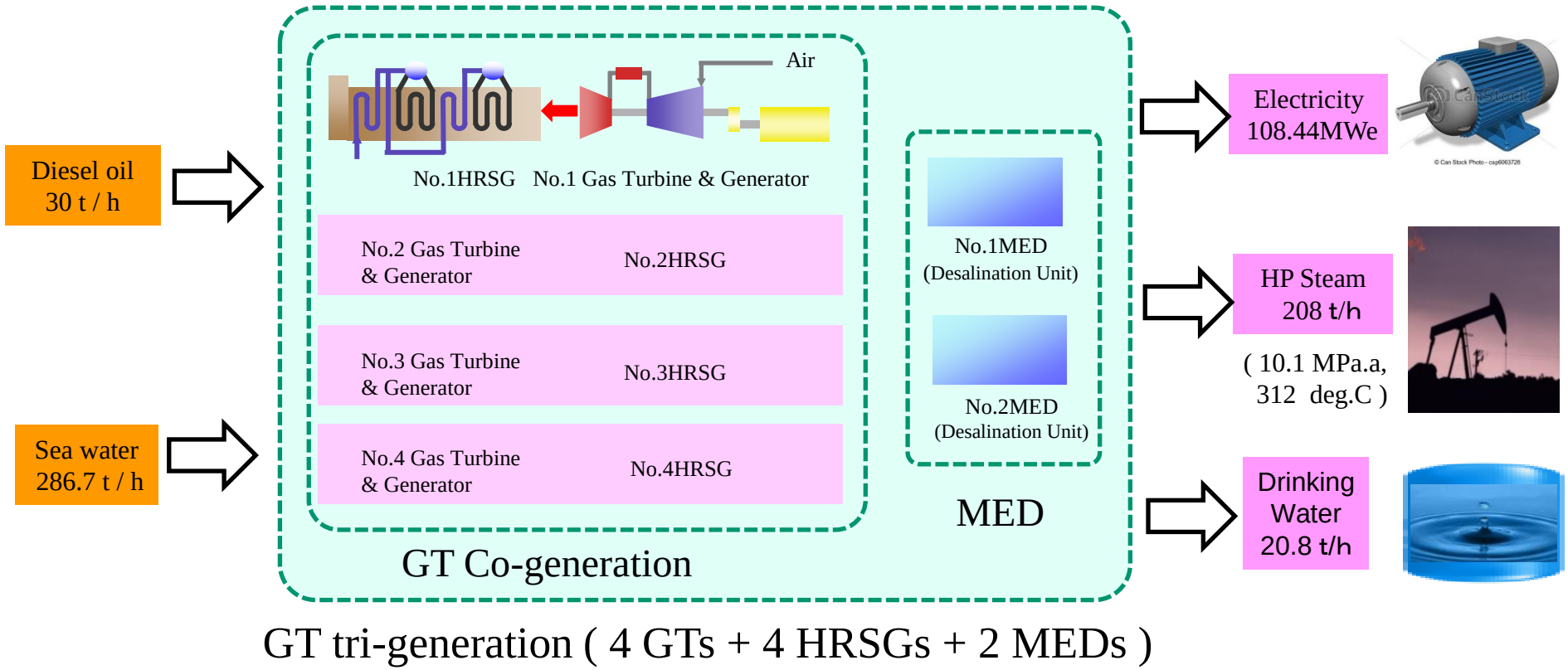
HITACHI
Inspire the Next

Example of Tri-generation Plant Performance

Co-generation Efficiency 80.45%

Higher efficiency is expected in LPG burning than diesel oil

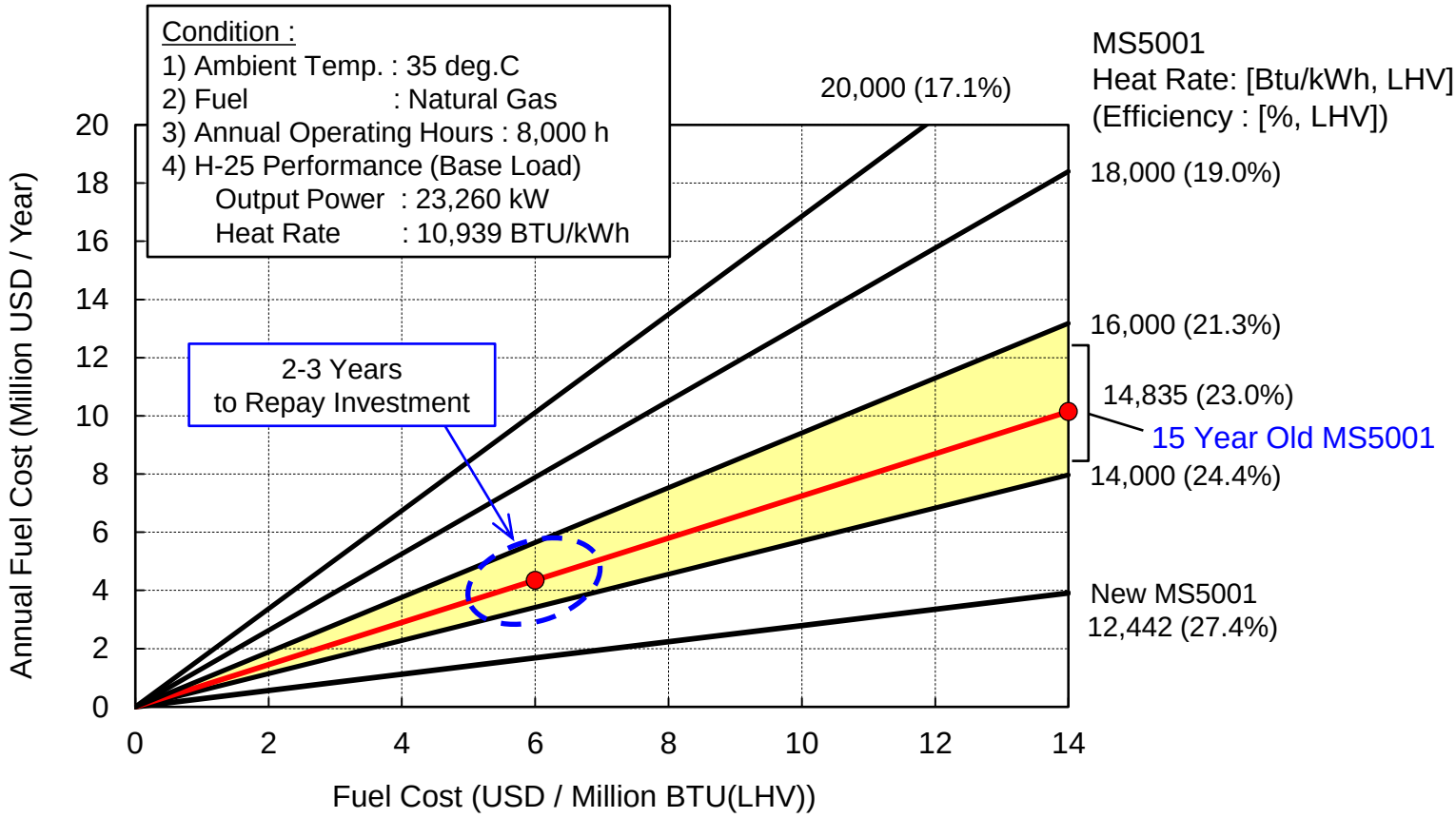
Conditions
Ambient temperature : 30 deg.C
Fuel : Diesel oil



GT tri-generation (4 GTs + 4 HRSGs + 2 MEDs)

4-5 Replacement of Existing Old Unit (1/3)

Benefit of Replacement (Old unit →New H-25) : Both Natural Gas Burning

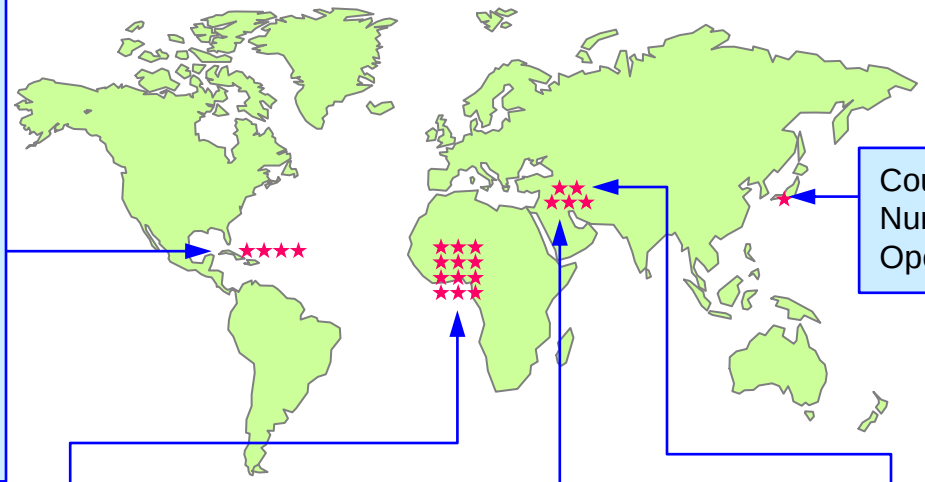


1. If fuel gas is 6 US$/MBTU(LHV), H-25 new plant investment will be recovered in 2-3 years.
2. If gas price is higher, the recovery time becomes shorter.

HITACHI
Inspire the Next

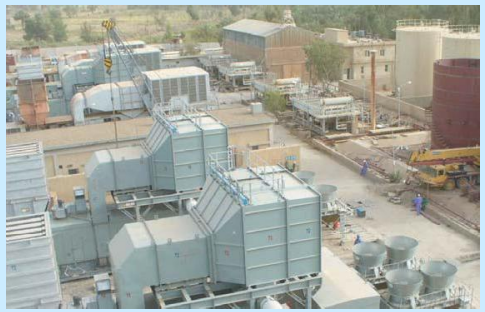
Replacement Records

Country : Bahamas
Number of unit : Four(4)
Operation date : 2002, 2003, 2005,2007



Country : Japan
Number of unit : One(1)
Operation date : Nov, 1988

Country : Nigeria
Number of unit : Six(6), Six(6)
Operation date : 2002, 2005



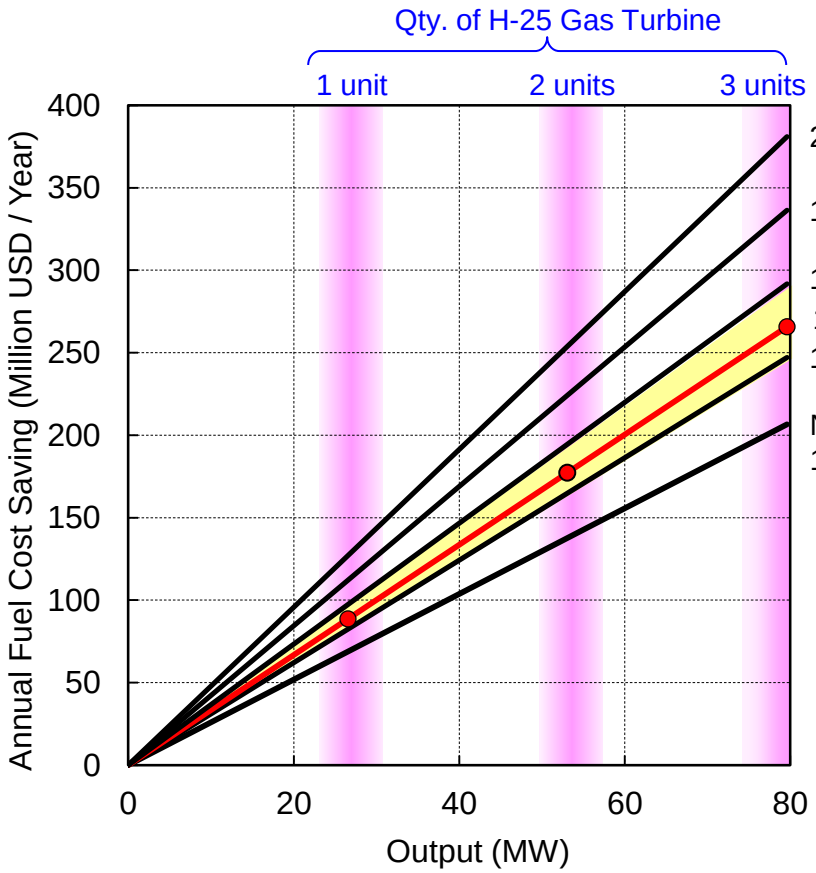
Country : Iraq
Number of unit : Three(3)
Operation date : 2007

Country : Iraq
Number of unit : Two(2)
Operation date : 2007

Total 22 units of MS5001 were already replaced.

4-5 Replacement of Existing Old Unit (3/3)

Benefit of Replacement (Old Diesel burning unit →New LPG burning H-25



MS5001 (Diesel Oil Burning)
Heat Rate: [Btu/kWh, LHV]
(Efficiency : [%, LHV])

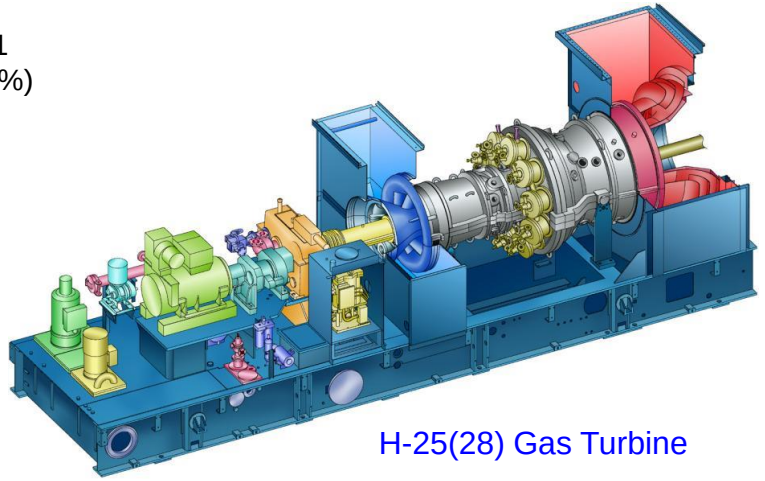
20,000 (17.1%)

18,000 (19.0%)

16,000 (21.3%)
14,835 (23.0%)
14,000 (24.4%)
15 Year Old MS5001

New MS5001
12,180 (28.0%)

Conditions :
1) Ambient Temp. : 15 deg.C
2) Annual Operating Hours : 8,000 hr
3) H-25(28) Performance (LPG Burning)
Output Power : 26,540 kW
Heat Rate : 10,189 Btu/kWh
4) Fuel Cost
LPG : 10 US$/MMBtu
Diesel Oil : 35 US$/MMBtu



H-25(28) Gas Turbine

1. Fuel cost can be saved greatly since the cost of LPG is smaller than Diesel Oil.
2. Benefit of introducing LPG fuel will become larger with new high efficiency Gas Turbine.

Contents

5. Conclusion

HITACHI
Inspire the Next

- LPG burning in GT is proven technology
- LPG burning GT is more efficient and reliable than diesel burning unit.
- LPG is cheaper than diesel oil, therefore LPG is very attractive fuel for GT power generation.
- Various applications using GT are available, simple cycle power plant, co-generation, tri-generation etc.
- Middle size GT may be suitable for LPG burning plant, considering LPG transportation, refinery applications and decentralized power supply.
- To make economical and reliable power plant, skilled engineering know-how is required for plant system design and GT design. Hitachi can supply LGP burning GT certified by enough experiences.

HITACHI
Inspire the Next

Mitsubishi Corporation

Contact in Colombia

Mitsubishi Colombia Ltda.
Mr. Julian Lemos / Ms. Lina Rosada
julian.lemos@mitsubishicorp.com
+57 1 313 7522
lina.rosada@mitsubishicorp.com
+57 1 313 7406