Republic of Guyana Oil & Gas Master Plan Update Final Report

February, 2021

Japan Cooperation Center Petroleum
Chiyoda Corporation

Contents

Chapter 1
Introduction

1.1 Outline of Oil & Gas Master Plan

(1) Objectives of Master Plan

Guyana's challenging situation of energy supply:

- Significant **dependence on import**
- **Vulnerability** of energy security
- Increasing **environment burden** (such as CO_2, SO_X, NO_X, etc.)

Objectives of Master Plan

❖ To develop **feasible solutions** of oil and gas utilization and to quantify **economic viability** of the solutions,

aiming at:

- ✓ **Well-balance** of indigenous oil and gas utilization, domestic market and exporting
- ✓ Development of **domestic industry**
- ✓ **Harmonization** with Guyana's Policy of "Clean and Green Society"

1.1 Outline of Oil & Gas Master Plan

(2) Historic Back Ground and Update Study (1/2)

Phase 1 - Master Plan Preliminary Study (Completed in Mar. 2018)

- Survey of Guyana energy situation from Public Domain Information
- Analysis of current energy situation in Guyana
- Presumption of study conditions
- Identification of Oil & Gas utilization projects
- Preliminary evaluation of feasibility and economics

Review of Phase 1 Study and Confirmation of Phase 2 Study

(Meeting in Nov, 2018)

Phase 2 - Master Plan Study (Completed in May, 2019 - Nov., 2019)

- Provision of additional information (by Guyana)
- Review and identification of study conditions and scenarios
- Definition and evaluation of oil & gas utilization projects
- Roadmap to Guyana's future vision

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1.1 Outline of Oil & Gas Master Plan

(2) Historic Back Ground and Update Study (2/2)

Guyana's Provision of Comments on MP Study 2019 (Nov. 2019 - Jan. 2020), and
Reflection of current changing energy situation

Update Study of Master Plan (May, 2020 - Feb., 2021)

Review and update of study scenarios and conditions → Review and update of evaluation of oil & gas utilization projects → Update of Roadmap to Guyana's future vision

1.1 Outline of Oil & Gas Master Plan

(3) Study Scenarios

① Gas utilization scenarios

		2024	2030	2035	2040	2045
Associated Gas delivered to domestic use	Phase-1	35mmSCFD				
		① **Gas to Power for domestic use** (Stepwise development)				
	Phase-2		200mmSCFD	400mmSCFD	600mmSCFD	
			② **Gas to LNG for export** (Stepwise development)			

② Oil utilization scenarios

		2024	2030	2035	2040	2045
Crude oil delivered to domestic use			15 / 20kbpd			
		① **Refinery for domestic use**				

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1.1 Outline of Oil & Gas Master Plan

(4) Study Contents

① **Technical Study**

Concept of plan

Market review

Block flow and descriptions

② **Economic study**

Study conditions (Feedstock price, Product price, etc.)

CAPEX, OPEX (*1)

IRR and sensitivity analysis

③ **Reporting**

Final report

(*1): **CAPEX and OPEX**. described in this report are estimated based on the index basis **for Master Plan purpose**, **NOT for EPC purpose.**

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1.2 Update Study Plan

(1) Gas to Power Study

Study case in 2019 study
Update study case in 2020 study

		2019 Study		2020 Update Study	
Gas to Power					
	Gas Supply	**Gas Supply: Specified Case by Guyana** 35MMSCFD in 2024 ~		**Gas Supply: Specified Case by Guyana** 35MMSCFD in 2024 ~	
	Power Demand Forecast	**Power Demand: Base Case** Annual Growth Rate 3%		**Power Demand: High Case** Annual Growth Rate 5%	
	Gas to Power Scenario	**Gas Max Scenario** (Note3) Gas supply is utilized for power at the maximum while renewable power is assumed to keep the power supply shown by GPL's plan in 2020. (Source GPL 2016-2020 D&E Programme).		**Gas Max Scenario** Please refer to Note3.	
		Renew Max Scenario (Note4) Renew power is assumed to supply 65% of power demand in 2035. (Source: Renewable Vision of Guyana)		**Renew Max Scenario** Please refer to Note4.	
	Feedstock Gas Price	**Gas Price: Base Case** $4/mmBtu	**Gas Price: Low Case** $3/MMBtu	**Gas Price: Base Case** $4/mmBtu	**Gas Price: Low Case** $3/MMBtu
	IRR Target	**IRR Target: Base Case** IRR 15%	**IRR Target: Low Case** IRR 5% and 10%	**IRR Target: Base Case** IRR 15%	**IRR Target: Low Case** IRR 5% and 10%

1.2 Update Study Plan

(2) Gas to LNG Study

Study case in 2019 study
Update study case in 2020 study

		2019 Study	2020 Update Study
Gas to LNG			
	Gas Supply	**<u>Gas Supply: Specified Case by Guyana</u>** 200 MMscfd in 2030 ~ 2034, 400 MMscfd in 2035 ~ 2039, 600 MMscfd in 2040 and later	**<u>Gas Supply: Specified Case by Guyana</u>** 200 MMscfd in 2030, 400 MMscfd in 2035, 600 MMscfd in 2040
	Feedstock Gas Price	**<u>Feedstock Gas Price: Base Case</u>** $4/mmBtu	**<u>Feedstock Gas Price: Low Case</u>** $3/MMBtu
	Product Price	**<u>Product Price: Base Case</u>** LNG: $10/MMBtu LPG : $0.878/Gallon ($430/ton)	**<u>Product Price: Low Case</u>** LNG: $8.5, and $6.0/MMBtu LPG: $0.61 /Gallon($300 /ton)

1.2 Update Study Plan

(3) Refinery Study

Study case in 2019 study
Update study case in 2020 study

	2019 Study			2020 Update Study		
Refinery						
Domestic Oil Demand	**Domestic Oil Demand: Reference Case** Annual Growth Rate 4.78% (Note6) Growth rate of domestic oil demand in 2010 to 2016 was 4.78%/y (Source; GEA Annual Report).			**Domestic Oil Demand: High Case** Annual Growth Rate 7%		
Start of Refinery	**Start of refinery is 2027.** (Note7) Oil power is replaced completely by gas power in 2027.			**Start of refinery is 2027. (Note7)**		
Crude oil Market Basis	**WTI Price** $ 60 /bbl	**WTI Price** $ 50 /bbl	**WTI Price** $ 40 /bbl	**WTI Price** $ 60 /bbl	**WTI Price** $ 50 /bbl	**WTI Price** $ 40 /bbl
Feedstock Crude Oil Price	**Base Case** $57/bbl	**Low Case-1** $47/bbl	**Low Case-2** $37/bbl	**Base Case** $57/bbl	**Low Case-1** $47/bbl	**Low Case-2** $37/bbl
Product Sales Price	**Base Case**	**Low Case-1**	**Low Case-2**	**Base Case**	**Low Case-1**	**Low Case-2**
Gasoline	$74 /bbl	$65 /bbl	$56 /bbl	$74 /bbl	$65 /bbl	$56 /bbl
Jet	$73 /bbl	$63 /bbl	$52 /bbl	$73 /bbl	$63 /bbl	$52 /bbl
Diesel	$74 /bbl	$63 /bbl	$53 /bbl	$74 /bbl	$63 /bbl	$53 /bbl
FO (LS/HS)	$64/53 /bbl	$54/-45 /bbl	$43/36 /bbl	$64/53 /bbl	$54/-45 /bbl	$43/36 /bbl
LPG	$600 /ton	$400 /ton	$300 /ton	$600 /ton	$400 /ton	$300 /ton

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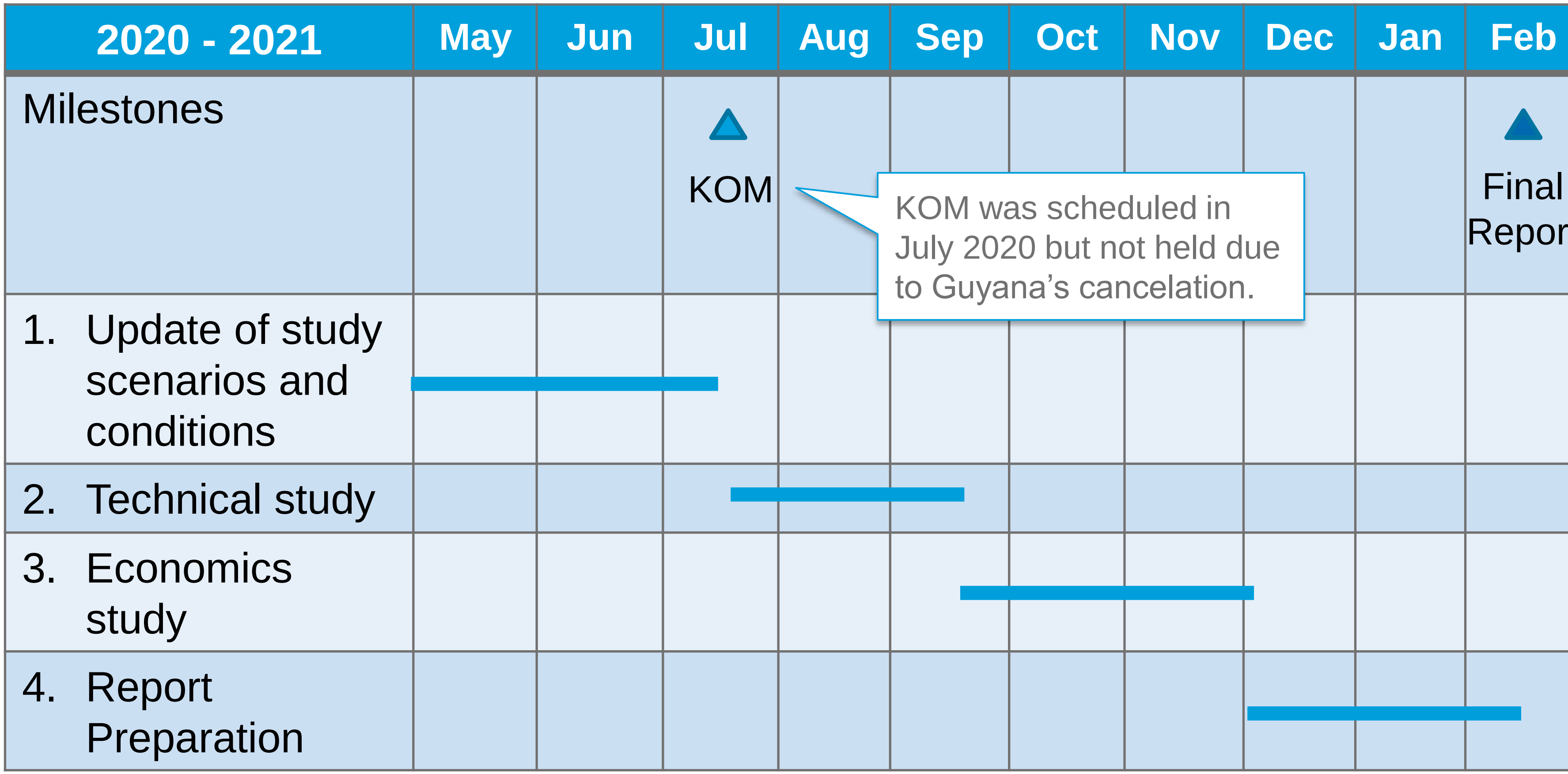
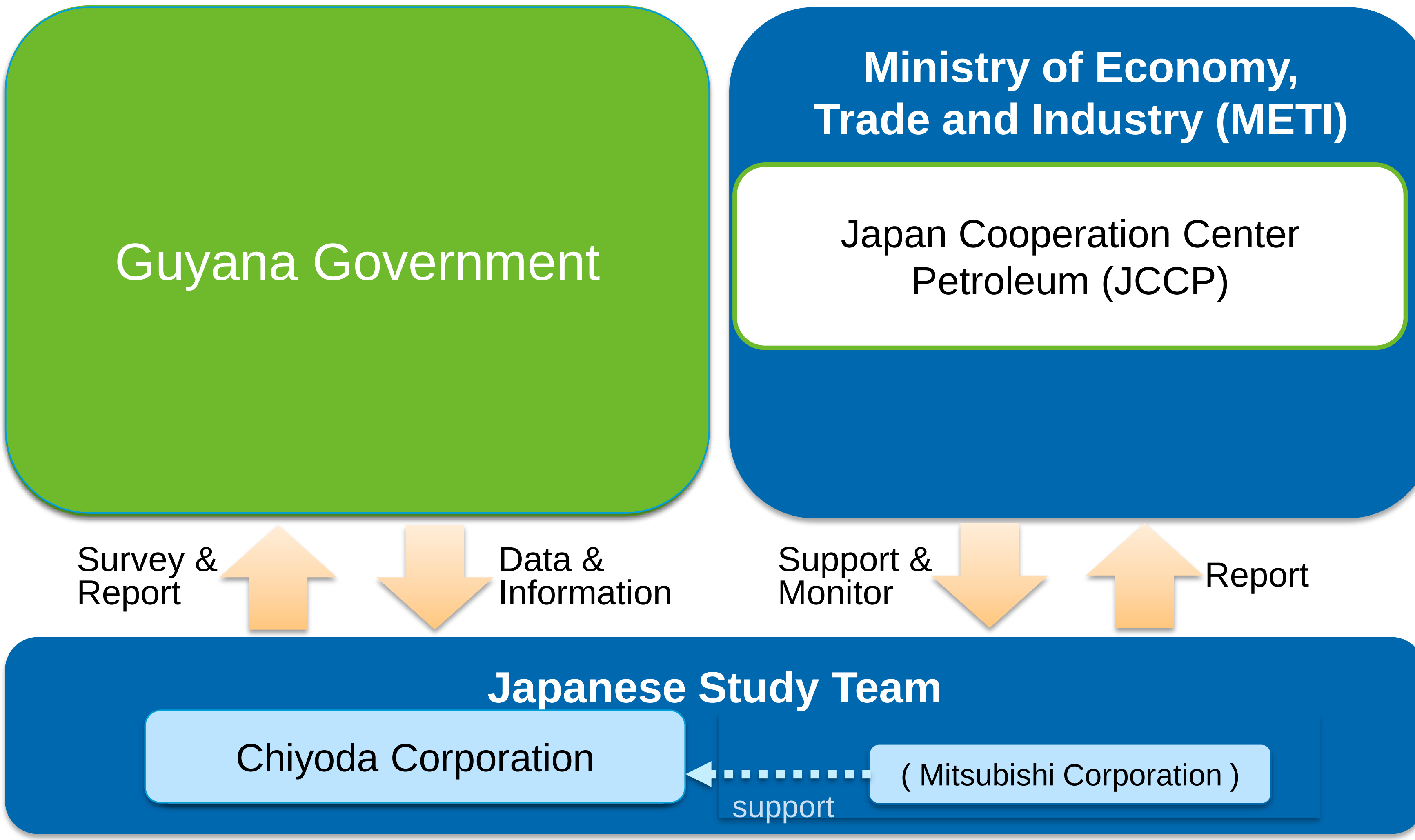
1.3 Study Schedule



1.4 Study Organization



Chapter 2
Gas Utilization Plan

2.1 Gas Resource Availability

2.1 Gas Resource Availability

The profile of associated gas availability is provided by DOE at Kickoff Meeting on May 22, 2019 as shown below.

(mmSCFD)	2024~	2030~	2035~	2040~
Associated Gas- Phase1	35	35	35	35
Associated Gas- Phase2	—	200	400	600

Based on the profile of gas availability, the study is carried out by two plans of utilization:

Gas to Power Plan:

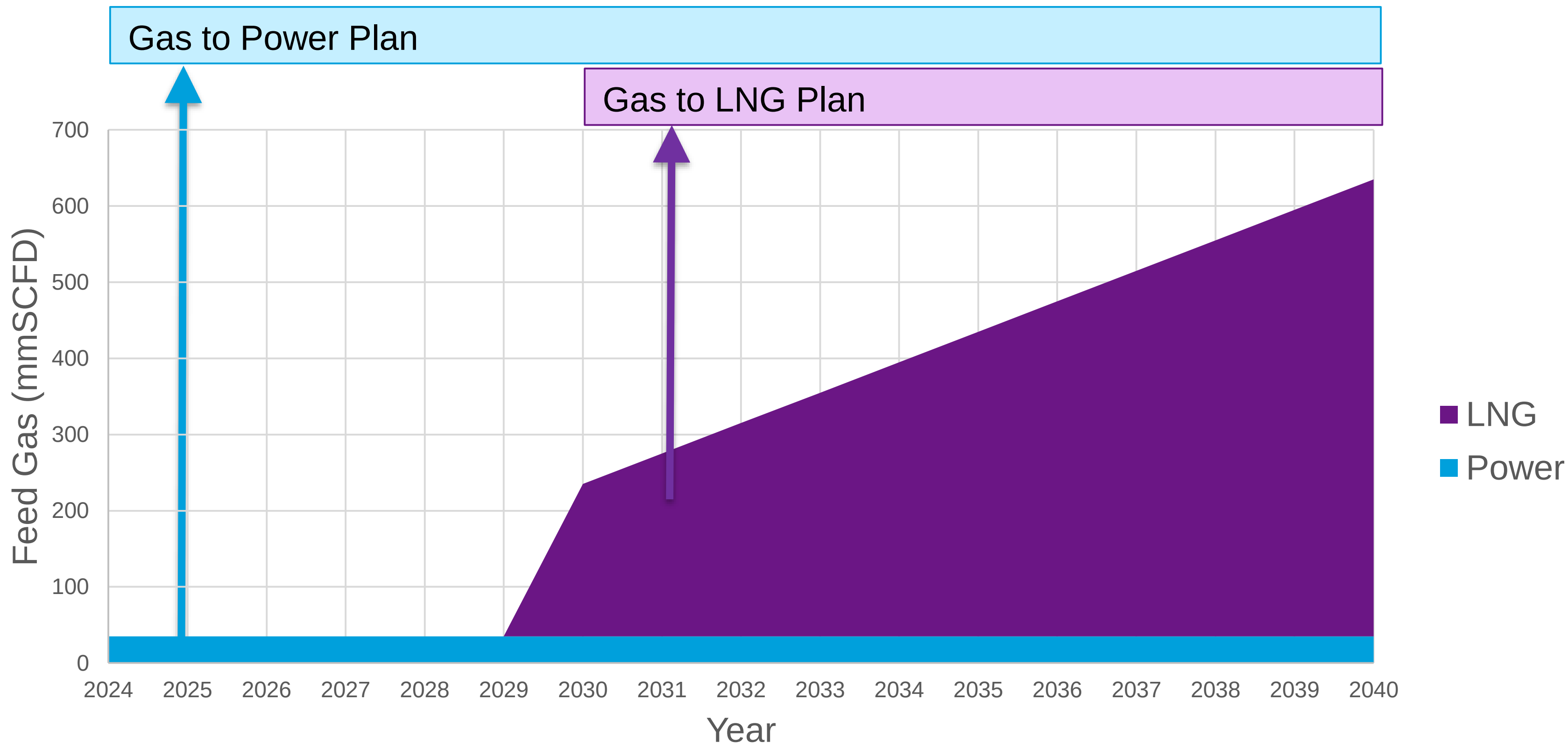
Phase1 associated gas (35 mmSCFD) is planned to be utilized for power generation.

Gas to LNG Plan:

Phase2 associated gas (200 to 600 mmSCFD) is planned to be utilized for LNG production.

2.1 Gas Resource Availability

- The profile of associated gas availability and two plans of utilization are shown below.
- After 2040, the gas availability will be kept at 600 mmSCFD.



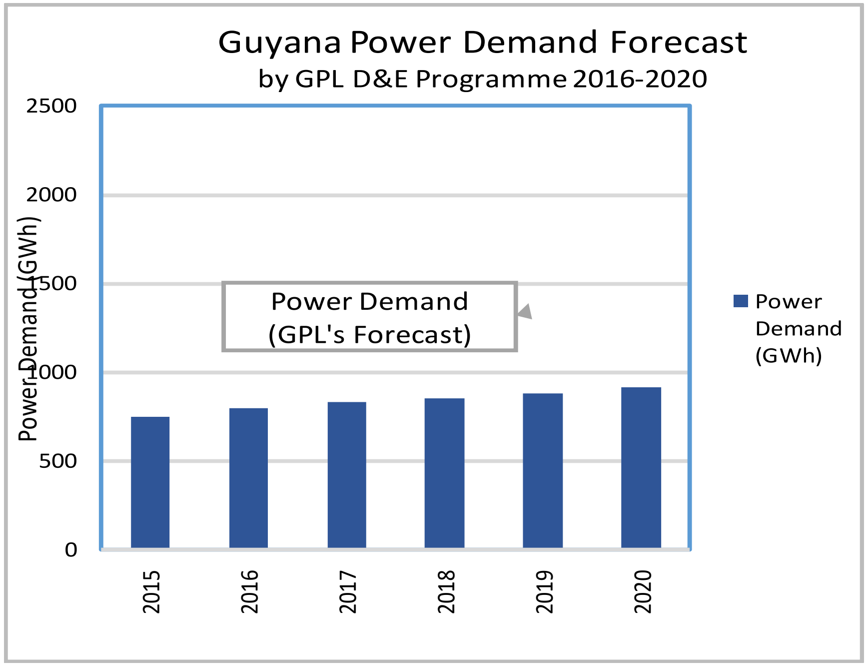
Chapter 2
Gas Utilization Plan

2.2 Gas to Power Plan

2.2 Gas to Power Plan
2.2.1 Guyana Power Demand Forecast

(1) Power Demand Forecast by GPL

- The power demand in Guyana from 2016 to 2020 is projected by GPL considering various future aspects in detail. (Source: GPL D&E Programme 2016 - 2020)
- In GPL's projection, annual growth rates of power demand were shown below.



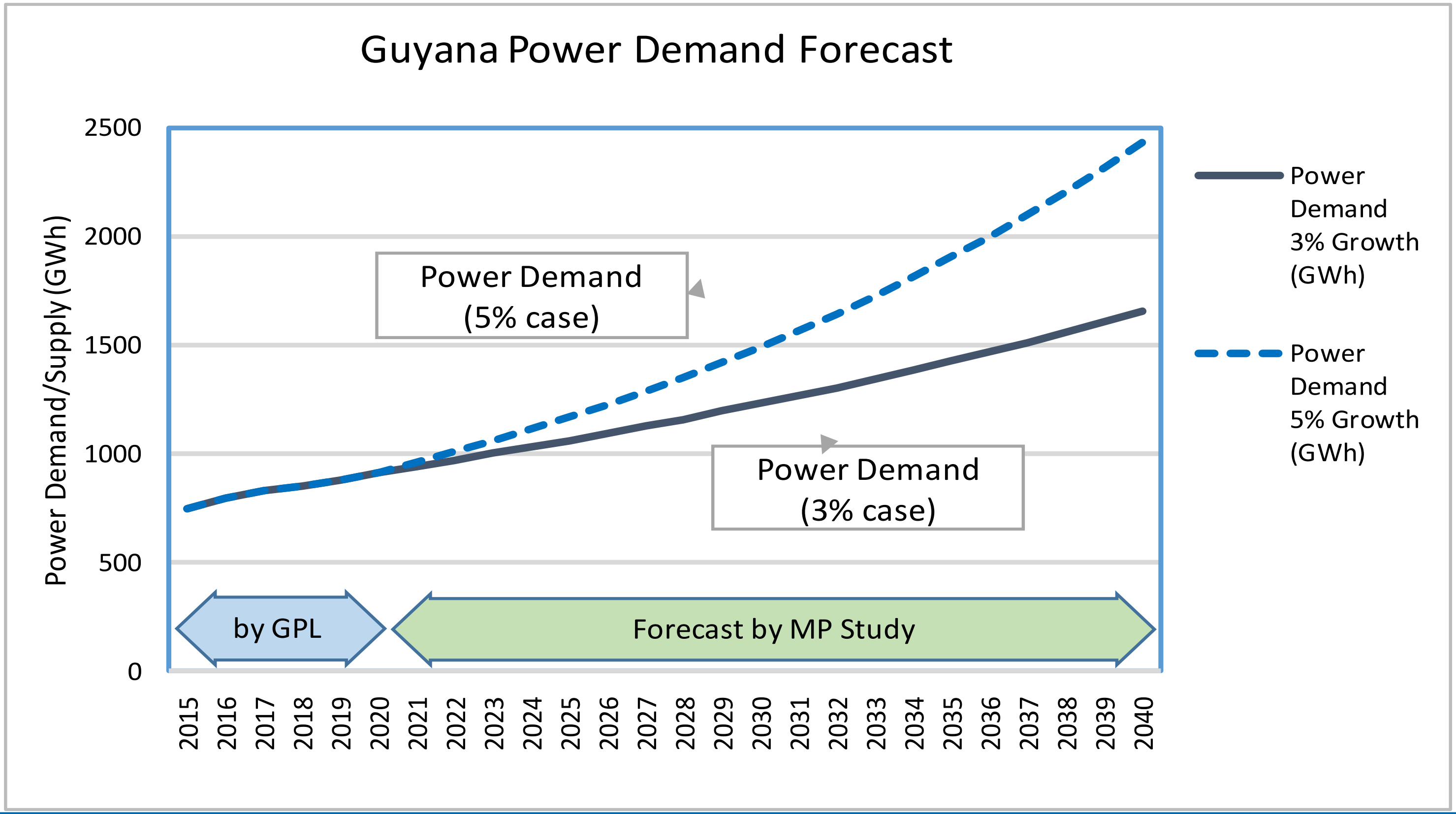
GPL's Forecast		
Year	Power Demand (GWh)	Annual Growth (%/Yr)
2015	751 (history)	-
2016	796	6.0%
2017	830	4.3%
2018	855	3.0%
2019	881	3.0%
2020	916	4.0%

2.2.1 Guyana Power Demand Forecast

(2) Power Demand Forecast by MP Study

Two cases of growth rates are taken up for power demand forecast from 2021 to 2040, following the GPL projection up to 2020.

- **Base Demand Case : growth rates 3%/year**
- **High Demand Case : growth rates 5%/year**



2.2 Gas to Power Plan
2.2.1 Guyana Power Demand Forecast

(2) Power Demand Forecast by MP Study

(Note) Reference data

- In 5% growth case (High demand case), power demand forecast in 2040 is 2,430 GWh and 3,000KWh/capita.
- In 3% growth case (Base demand case), power demand forecast in 2040 is 1,654 GWh, 2,000KWh/capita.
- As a reference, global statistic data shows that world average of power demand is 3,100KWh/capita in 2016

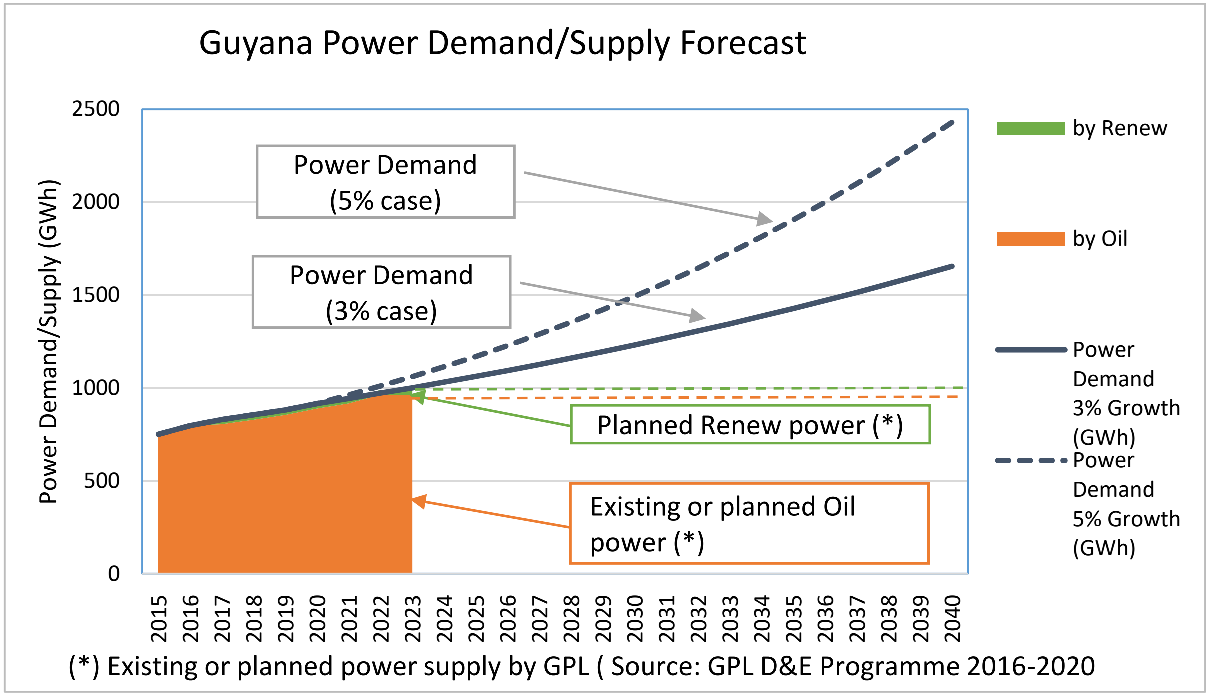
Power Demand in 2040		
	GWh	KWh/capita
5% growth case (High demand case)	2,480	3,000
3% growth case (Base demand case)	1,654	2,000

2.2 Gas to Power Plan
2.2.1 Guyana Power Demand Forecast

(3) Power Demand and Supply
- Base and High Power Demand Cases

① Existing and Planned Power Supply by GPL

GPL shows the existing oil power including the planned expansion, retirement, and addition for 2016 to 2020 and the development plan of 10MW wind power in 2017.
(Source: GPL Development and Expansion Programme 2016-2020)



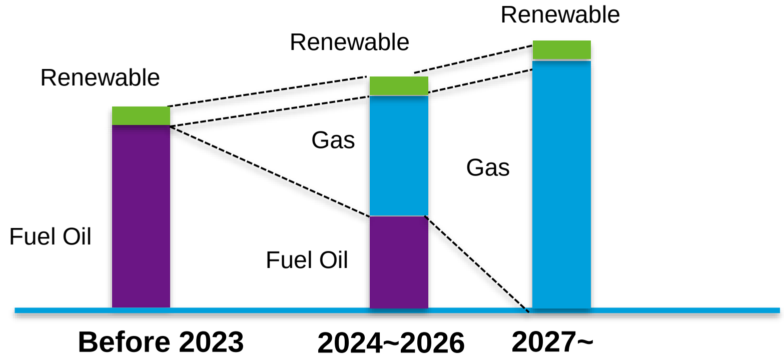
2.2 Gas to Power Plan
2.2.1 Guyana Power Demand Forecast

② Power Supply Scenario in MP study

In the study of gas to power plan, the development of gas power is studied for the following two scenarios.

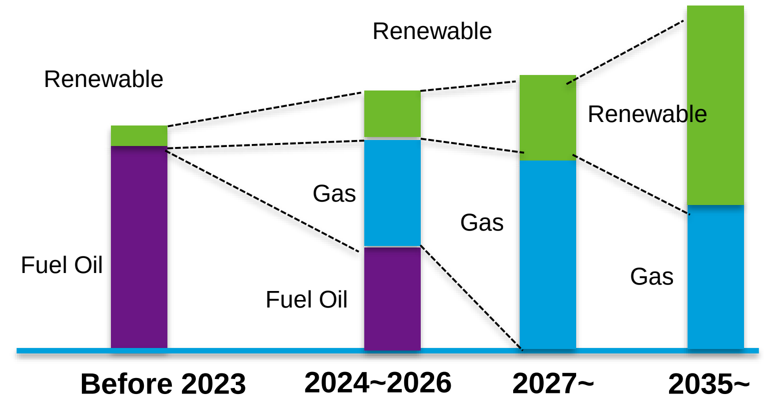
- **<u>Gas Max. Scenario</u>**

The domestic gas will be available from 2024 and utilized for power generation as much as possible.
Power supply by renewable energy is assumed to keep the GPL's plan of 10 MW capacity.



- **<u>Renewable Max. Scenario</u>**

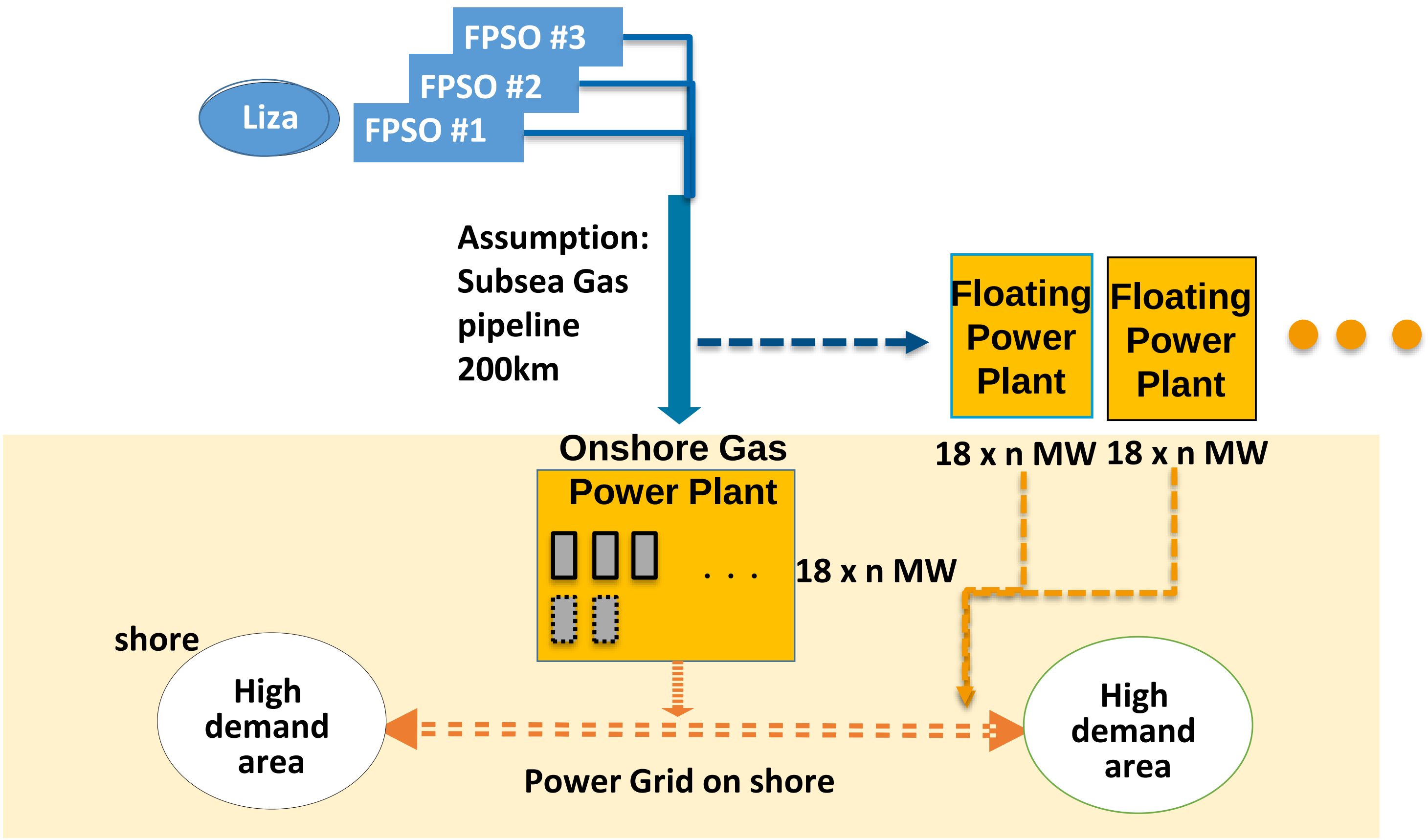
According to the renewable vision of Guyana, renewable power will be increased from 10MW in 2020 to 65% of total supply in 2035 and later. Rest of supply will be covered by fuel oil (before 2024), fuel oil/gas (2024-2026) and gas (after 2027).



2.2.2 Gas to Power Options

(1) Overview of Gas to Power Options

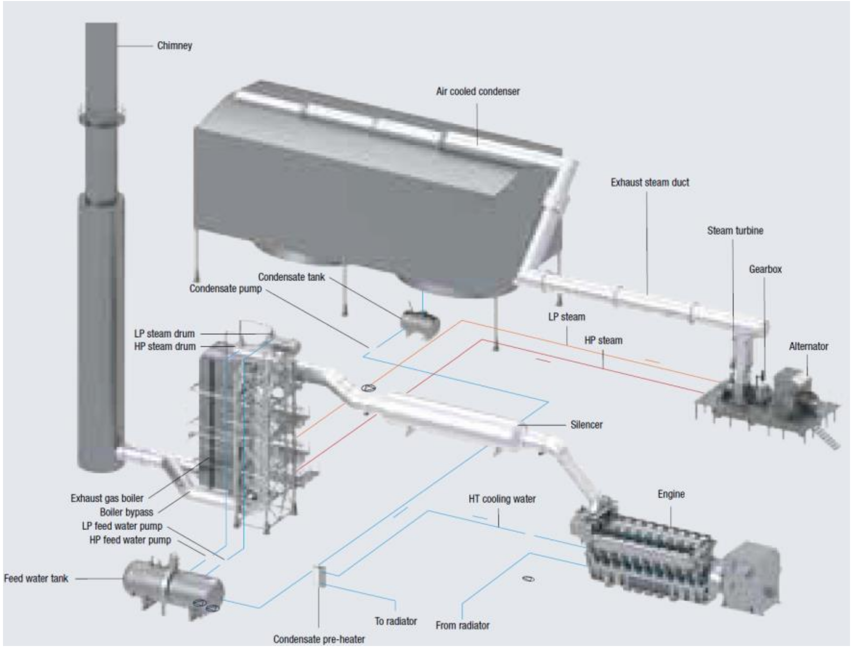
① **Onshore gas power plant** with phased development
② **Floating gas power plant** with phased development



(2) Technical Overview of Gas to Power

① Onshore Gas Engine Power Plant

Source: Wartsila

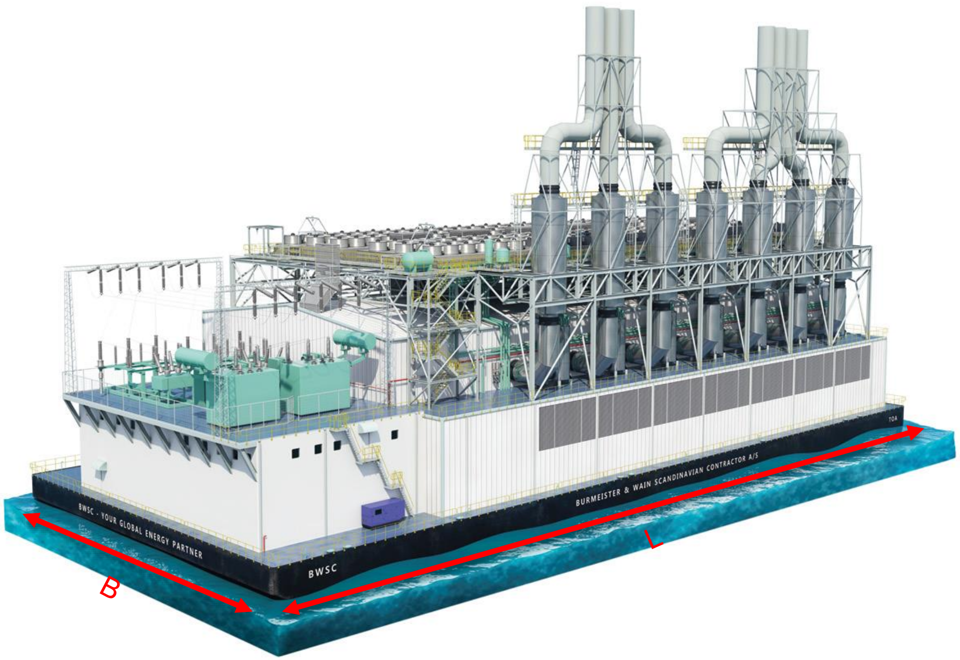


Source: MAN Diesel & Turbo

Note: **<u>Gas engine</u>** is taken up for both onshore and floating plants in this study, considering the magnitude of Guyana's power demand and the development of power supply by step. (Detail is shown in Appendix 2.2-1)

(2) Technical Overview of Gas to Power

② Floating Gas Engine Power Plant

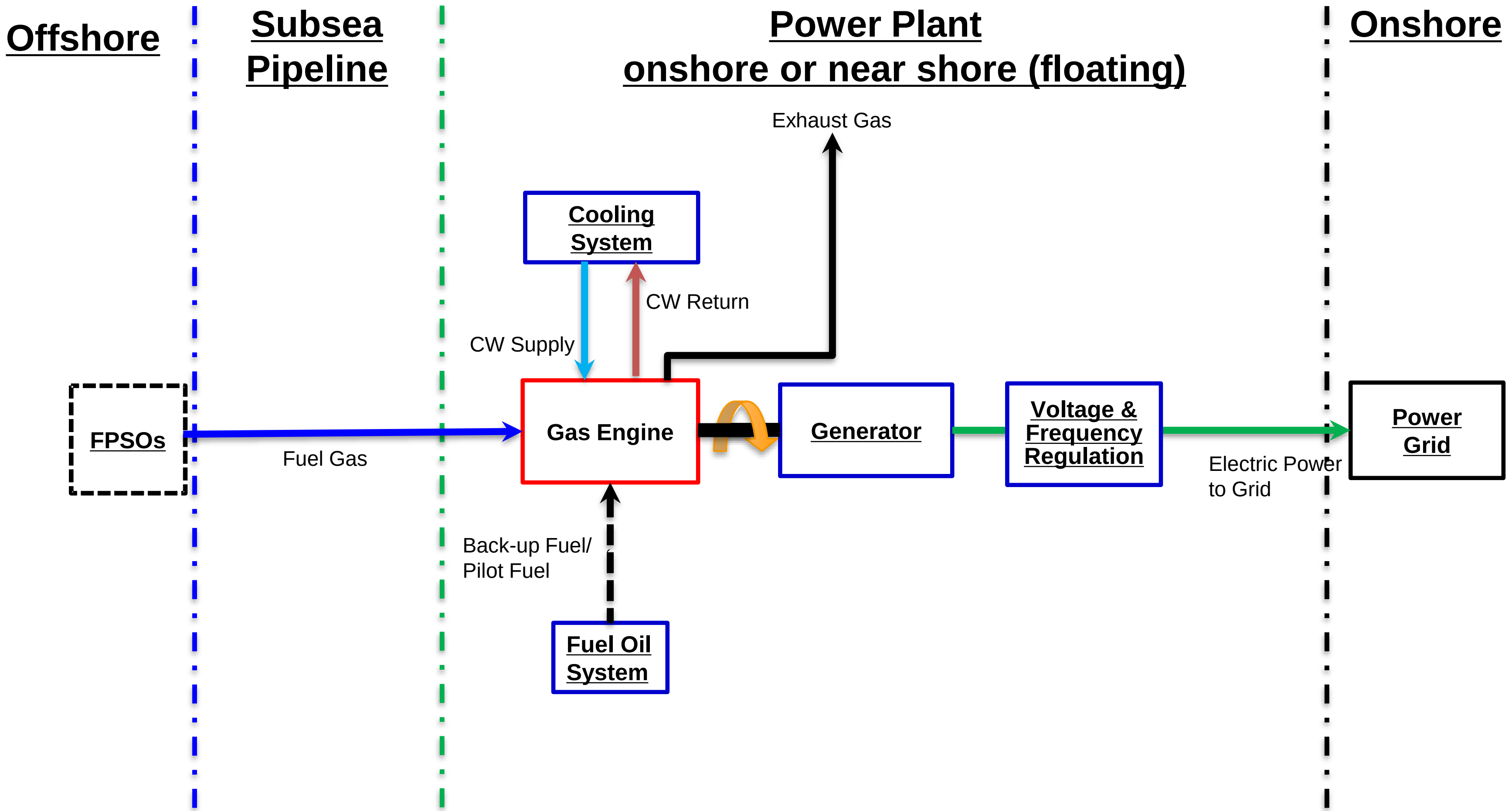


Source: Mitsui E&S

Source: MAN Diesel & Turbo

90MW Floating Power Plant: L=71m x B=32m

(2) Technical Overview of Gas to Power
③ Block Flow: Onshore and Floating Gas Engine Power Plant

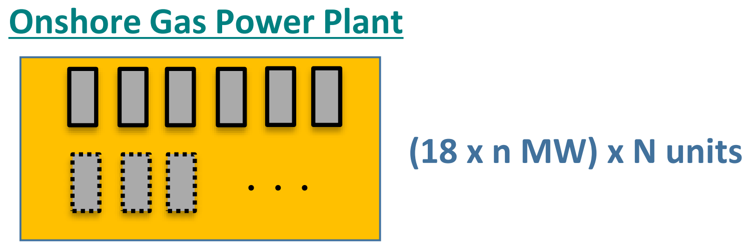


2.2 Gas to Power Plan
2.2.2 Gas to Power Options

(3) Conceptual Features

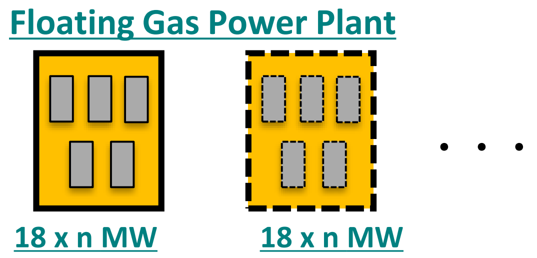
① Onshore gas power plant with phased development:

- Increase by unit (e.g. 90MW) when power is necessary
- Beneficial to local/national contents



② Floating power unit (e.g. 90MW) with phased development

- Increase by unit (e.g. 90MW) when power is necessary
- "Lease and Operation" can be applied with less investment
- Less risk of construction schedule (built in dedicated facilities and transported to Guyana)



2.2.2 Gas to Power Options

(4) Basic Condition for Analysis

① Gas engine capacity

- 18MW/engine

② Plant configuration

- On-shore Power Plant:
  - (18MW/engine x n engines) x N units as per power demand
- Floating power plant:
  - 90MW(5 engines), 72MW(4 engines), and/or 54 MW(3 engines) as per power demand

③ Net Capacity Factor:

- Gas Power: 80% (at maximum)
- Renewable: 30% (for wind power)

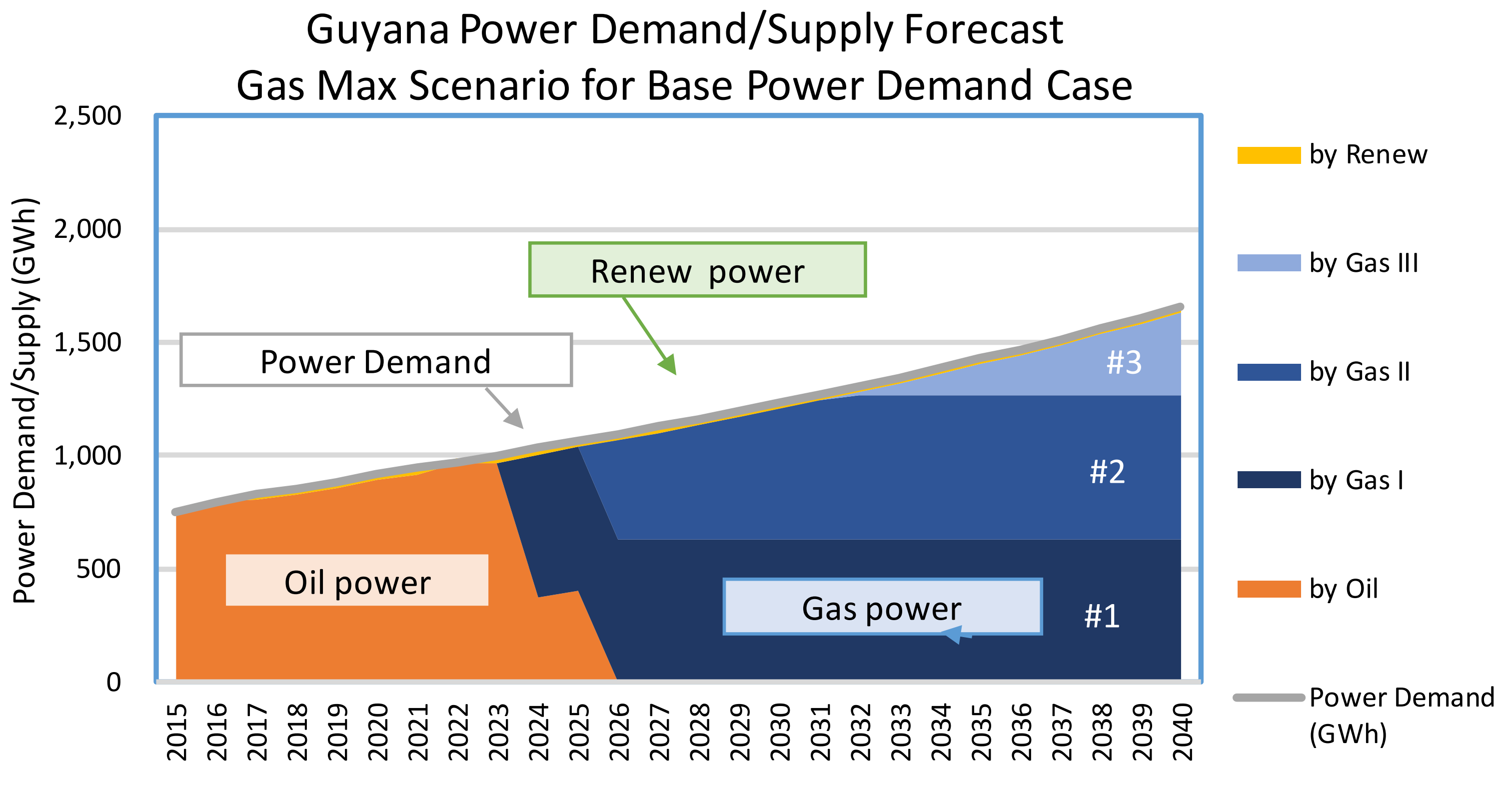
④ Construction duration:

- Onshore Power Plant: 3 years
- Floating Power Plant: 2 years

2.2.3 Gas to Power Scenario for Base Demand Case

(1) Gas Max Scenario

for Base Power Demand Case (3% Growth)



Source: Capacity 2015-2020 and Demand by D&E Programme 2016-2020
Capacity 2020-2030 by CYD's assumption

2.2.3 Gas to Power Scenario for Base Demand Case

(1) Gas Max Scenario

for Base Power Demand Case (3% Growth)

① Development of Gas Power

- Gas delivery to on or near shore is assumed to start in 2024.
- Before 2024, power supply is based on the existing or planned power including oil power and renewable power, as shown by GPL.
- As gas delivery starts in 2024, Gas Power #1 (90MW) starts in 2024 ,and Gas Power #2 (90MW) in 2026 and #3 (90MW) in 2032.

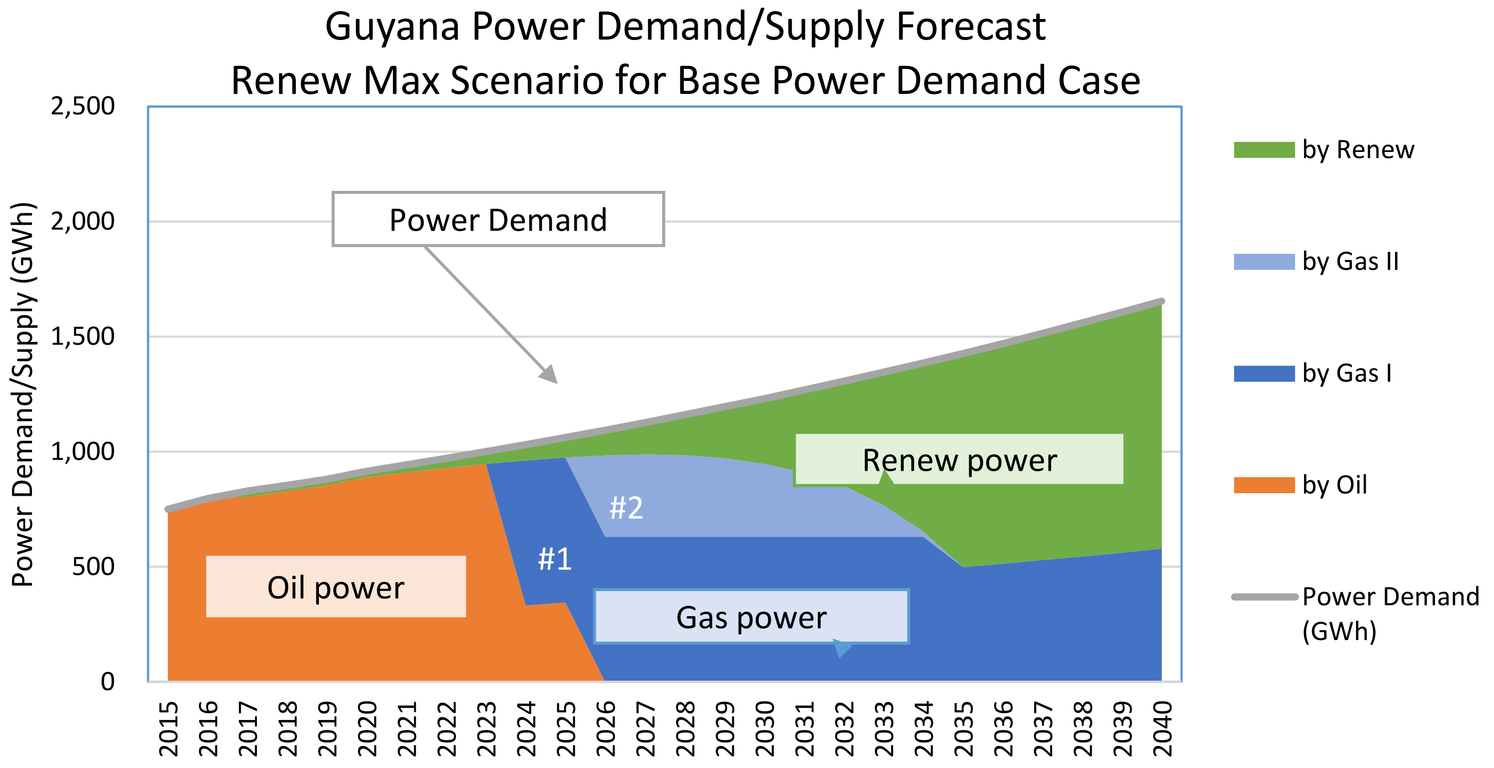
② Operation of Oil and Renewable Power

- Renewable power keeps the operation with the capacity planned in 2017.
- Oil power can be extinguished in 2026 by the start of gas power #2.

2.2.3 Gas to Power Scenario for Base Demand Case

(2) Renewable Max Scenario

for Base Power Demand Case (3% Growth)



Source: Capacity 2015-2020 and Demand by D&E Programme 2016-2020
Capacity 2020-2030 by CYD's assumption

2.2.3 Gas to Power Scenario for Base Demand Case

(2) Renewable Max Scenario

for Base Power Demand Case (3% Growth)

① Development of Renewable power

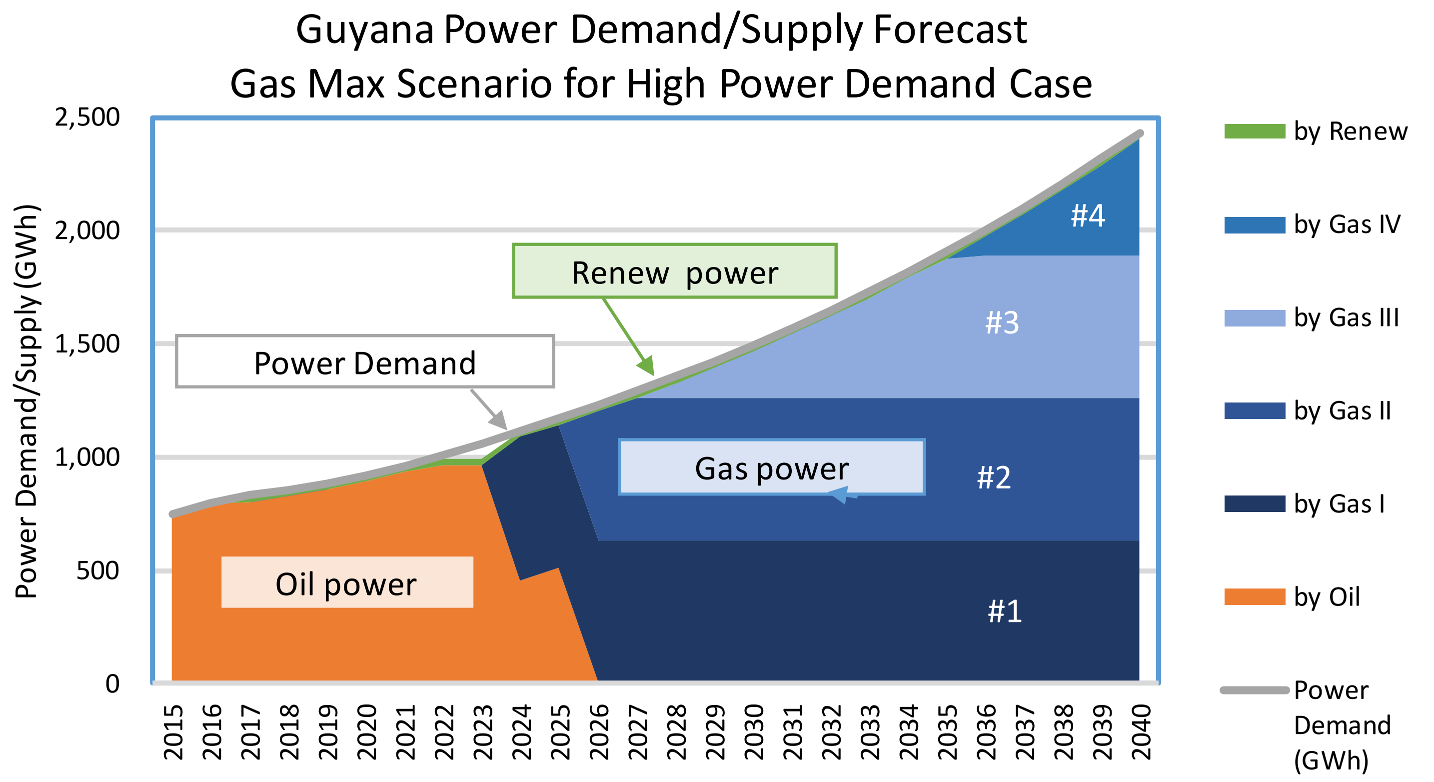
- Power supply by renewable energy is 65% of power demand, 927.6 GWh in 2035. Renew power is 318 MW-wind power equivalent.
- Renew Power is assumed to increase by a constant ratio from 2020 to 2035.
- After 2036 renewable power is assumed to grow at the same growth ratio as power demand.

② Development of Gas Power

- Gas power #1 (90MW starts in 2024 and Gas Power #2 (90MW) follows in 2026.
- After gas power #2 starts in 2026, the oil power can be extinguished.
- Gas power #2 starts in 2026 but stops the operation from 2035 to 2042 due to the development of renew power supply.

2.2.4 Gas to Power Scenario for High Demand Case

(1) Gas Max Scenario
for High Power Demand Case (5% Growth)



Source: Capacity 2015-2020 and Demand by D&E Programme 2016-2020
Capacity 2020-2030 by CYD's assumption

2.2.4 Gas to Power Scenario for High Demand Case

(1) Gas Max Scenario

for High Power Demand Case (5% Growth)

① Development of Gas Power

- Gas delivery is assumed to start in 2024.
- Before 2024, power supply is based on the existing or planned power including oil power and renewable power, as shown by GPL.
- As gas delivery starts in 2024, Gas Power #1 (90MW) starts in 2024, followed by Gas Power #2 (90MW) in 2026, #3 (90MW) in 2028 and #4 (90MW) in 2036.
- Before gas power starts in 2024, power supply shortage is anticipated to be 21GWh in 2022 and 72GWh in 2023, which are 2% and 7% of respective power demand.

② Operation of Oil and Renewable Power

- Renewable power keeps the operation with the capacity planned in 2017.
- Oil power can be extinguished in 2026 by the start of gas power #2.

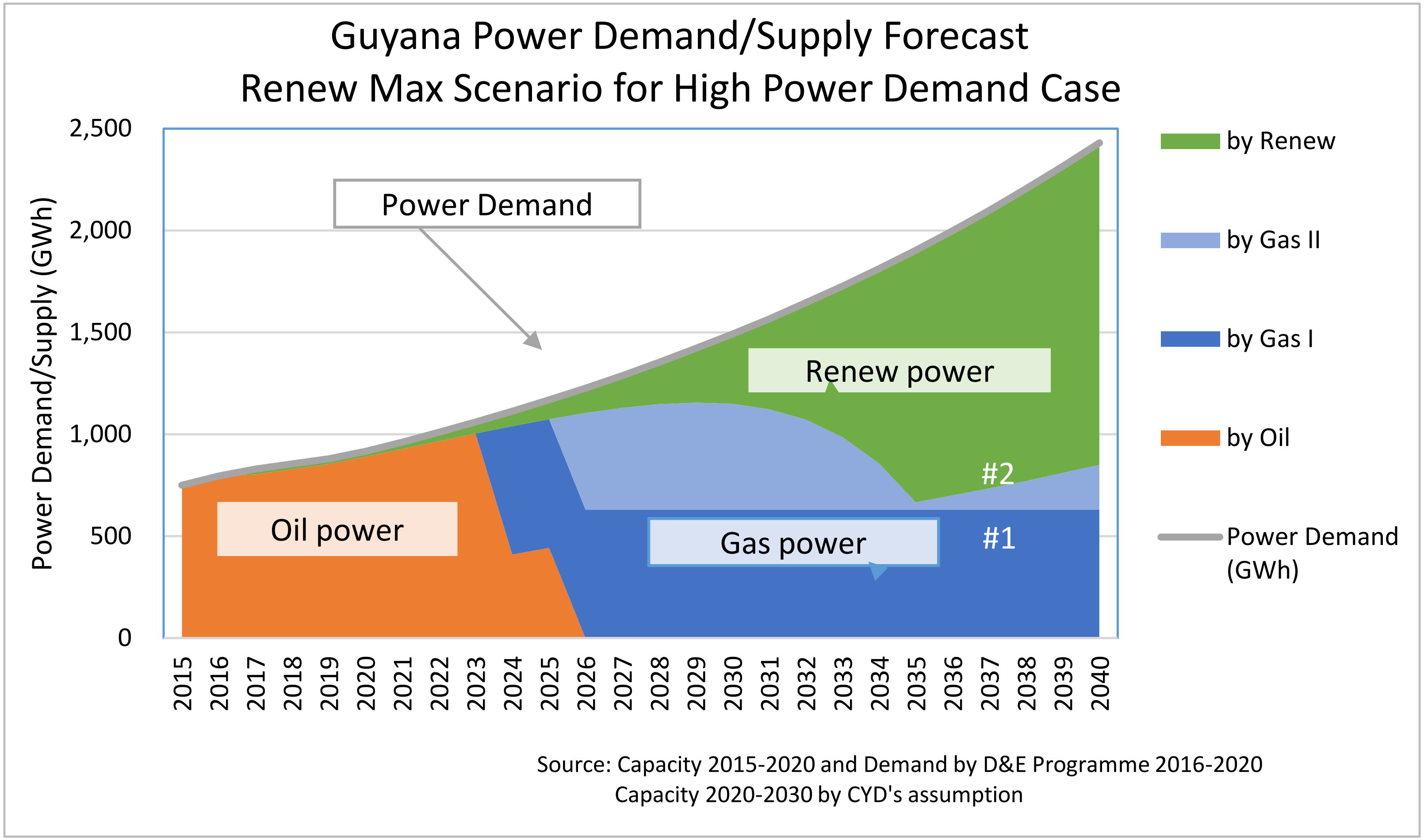
(Note) Consideration on Gas Consumption

For high demand case, gas power #4 starts in 2036 and gas consumption after 2039 will exceed the gas delivery of 35 MMscfd. The shortage will be 1 MMscfd in 2039 and 11 MMscfd in 2044.

2.2.4 Gas to Power Scenario for High Demand Case

(2) Renewable Max Scenario

for High Power Demand Case (5% Growth)



2.2.4 Gas to Power Scenario for High Demand Case

(2) Renewable Max Scenario

for High Power Demand Case (5% Growth)

① Development of Renewable power

- Power supply by renewable energy is 65% of power demand in 2035.
- After 2036 it is assumed to increase at the same growth ratio as power demand.

② Development Plan of Gas Power

- Gas power #1 (90MW) is introduced in 2024 and Gas Power #2 (90MW) is introduced in 2026.
- Oil power can be extinguished after gas power #2 starts in 2026.

2.2.5 Economic Analysis

(1) Basic concept and conditions for economic analysis

- Economic evaluation is performed by **cash flow analysis** and economic viability is evaluated by **IRR(Internal Rate of Return).**
- **Financial data** for the cash flow analysis are assumed as shown below.

Item	Input Data	Remark
Plant Operation Period	20 years	
Depreciation Period	10 years by liner depreciation	
Ratio of Equity and Loan	Equity: 40%, Loan: 60%	
Interest of Loan	3%	
Loan Period	20 years	
Inflation	No inflation is considered	
Income Tax	30%	
Property Tax	2.0%	

2.2 Gas to Power Plan
2.2.5 Economic Analysis

- **CAPEX & OPEX Estimation**

Onshore Power Plant		
CAPEX*1)		
Total Project Cost	**1,342**	**USD/kW**
OPEX*2)		
Fixed O&M	**$6.90**	**/kW-year**
Variable O&M Expense	**$5.85**	**/MWh**

Floating Power Plant		
CAPEX*1)		
Total Project Cost	**1,459**	**USD/kW**
OPEX*2)		
Fixed O&M	**$6.90**	**/kW-year**
Variable O&M Expense	**$5.85**	**/MWh**

Note 1) CAPEX is estimated based on the index basis **for master plan purpose, NOT for EPC purpose**.

2) OPEX is also estimated using the cost index, which is including costs for utility supplies, catalysts, operating labor/materials, maintenance labor/materials, insurance & property tax, and etc. Fuel gas cost is separately accounted, not included in OPEX.

(2) Study Conditions

Study Conditions				
Power Demand Forecast	Base Demand (3% growth per annum)		High Demand (5% growth per annum)	
Fuel Gas Supply	35MMSCFD			
Fuel Gas Price	Base Price (4$/MMBtu)	Low Price (3$/MMBtu)	Base Price (4$/MMBtu)	Low Price (3$/MMBtu)

2.2 Gas to Power Plan
2.2.5 Economic Analysis

(3) Study Result Overview – Base demand case

As the result of cash flow analysis, **power selling price** required to attain the target of IRR 15% is shown below.

Power Selling Price for 15% IRR (cent/kwh)			
Study Conditions	Power Demand Forecast	Base Demand (3% growth)	
	Fuel Gas Price	Base Price (4$/MMBtu)	Low Price (3$/MMBtu)
On-shore	Gas Max	7.02	6.26
	Renewable Max	7.08	6.31
Floating	Gas Max	7.11	6.34
	Renewable Max	7.17	6.40

Note: Current electricity rate in Guyana is reported to be **¢32 /kWh**.

(Source: JICA report on Guyana Renewable Study, May 2018)

(4) Study Result Overview – High demand case

As the result of cash flow analysis, **power selling price** required to attain the target of IRR 15% is shown below.

Power Selling Price for 15% IRR (cent/kwh)			
Study Conditions	Power Demand Forecast	High Demand (5% growth)	
	Fuel Gas Price	Base Price (4$/MMBtu)	Low Price (3$/MMBtu)
On-shore	Gas Max	7.98	7.20
	Renewable Max	7.09	6.32
Floating	Gas Max	8.14	7.33
	Renewable Max	7.18	6.41

(5) Analysis on "Gas Max" and "Renewable Max" Scenarios

① **Base Demand Case**

For base demand case, "Renewable Max" scenario cannot show better economics, which is due to the significantly low availability of #2 Gas Power, though the renewable power lightens the burden of gas power.

Power selling price (cent/kwh)		
Demand	Base Demand	
Fuel Price	Base Price	
Target IRR	IRR 15%	
Scenario	Gas Max	Renew Max
On-shore	7.02	7.08
Floating	7.11	7.17

(5) Analysis on "Gas Max" and "Renewable Max" Scenarios

② **High Demand Case**

For high demand case, "Renewable Max" scenario shows better economics, which is because the renew power can lighten the burden of gas power, keeping the good availability of gas power.

Power selling price (cent/kwh)		
Demand	High Demand	
Fuel Price	Base Price	
Target IRR	IRR 15%	
Scenario	Gas Max	Renew Max
On-shore	7.98	7.09
Floating	8.14	7.18

(6) Analysis on “Base Demand” and “High Demand” cases

① Gas Max Scenario

Because the renew power is limited, the demand increase will directly enlarge the burden of gas power.

Power selling price (cent/kwh)		
Demand	Base Demand	High Demand
Fuel Price	Base Price	
Target IRR	IRR 15%	
Scenario	Gas Max	
On-shore	7.02	7.98
Floating	7.11	8.14

(6) Analysis on "Base Demand" and "High Demand" cases

② **Renew Max Scenario**

The renew power can cover the demand increase and lighten the burden of gas power.

Power selling price (cent/kwh)		
Demand	Base Demand	High Demand
Fuel Price	Base Price	
Target IRR	IRR 15%	
Scenario	Renew Max	
On-shore	7.08	7.09
Floating	7.17	7.18

2.2.5 Economic Analysis

(7) Analysis on “Base Price” and “Low Price” cases

Low price of fuel gas will enable better economics of gas power.

Power selling price (cent/kwh)				
Demand	Base Demand			
Fuel Gas Price	Base	Low	Base	Low
Target IRR	IRR 15%			
Scenario	Gas Max		Renew Max	
On-shore	7.02	6.26	7.08	6.31
Floatong	7.11	6.34	7.17	6.40

(8) Analysis on target IRR

Lower target of IRR could ease the electric selling price of gas power.

Power selling price (cent/kwh)						
Demand	Base Demand					
Fuel Gas Price	Base Price					
Target IRR	15%	10%	5%	15%	10%	5%
Scenario	Gas Max			Renew Max		
On-shore	7.2	6.5	5.9	7.1	6.5	5.9
Floating	7.1	6.5	5.9	7.2	6.6	5.9

Note 1 : Consideration on excess gas

- As the result of gas to power study, excess gas is anticipated for some cases. 25 MMscfd excess gas will be available for renewable max scenario in base demand case, which will be the largest amount.
- Possible option to utilize the excess gas could be fertilizer production, but it is not economically viable because the amount of the excess gas is not enough for internationally competitive plant scale.

An example of internationally competitive plant scale:

1) Fertilizer Plant Capacity

  – **Urea: 3,500 TPD**

2) Feedstock gas amount 74 mmSCFD

Source: Phase 1 Master Plan for Guyana (March, 2018):

Note 2 : Power Price Sensitivity for IRR 15%

- ✓ Demand: base case,
- ✓ Fuel gas price: base case

1. Sensitivity by CAPEX (Fixed OPEX)

	Onshore (¢/kWh)					Floating (¢/kWh)				
	-20%	-10%	Base	+10 %	+20 %	-20%	-10%	Base	+10 %	+20 %
Gas Max	6.39	6.71	**7.02**	7.35	7.66	6.46	6.78	**7.11**	7.44	7.77
Renewable Max	6.44	6.75	**7.08**	7.40	7.73	6.51	6.83	**7.17**	7.50	7.83

2. Sensitivity by OPEX (Fixed CAPEX)

	Onshore (¢/kWh)					Floating (¢/kWh)				
	-20%	-10%	Base	+10 %	+20 %	-20%	-10%	Base	+10 %	+20 %
Gas Max	6,88	6.95	**7.02**	7.09	7.16	6.97	7.04	**7.11**	7.18	7.25
Renewable Max	6.94	7.01	**7.08**	7.16	7.23	7.03	7.10	**7.17**	7.24	7.31

2.2.6 Concluding Remarks

① **<u>Gas to Power solution is economically viable for Guyana.</u>**

- Gas to Power solution is observed to be economically viable.
- Phased development will be preferred in view of economics.

② **<u>Significant difference is not observed between onshore and floating solutions.</u>**

- No significant difference is observed in economics between onshore and floating gas to power plans.
- The selection will depend on the site conditions, complexity of permissions, man-powers in the country, etc.

③ **<u>Economical viability is sensitive to fuel gas price.</u>**

- Economical viability is more sensitive to fuel gas price than the other parameters, CAPEX and OPEX.

2.2.6 Concluding Remarks

④ **<u>Optional plan could be considered in case of renewable energy shift.</u>**

- In case energy shift to renewable is achieved to be renewable 65% of power supply in 2035, the additional power capacity by gas are necessary only for several years after oil power is closed.
- Effective solution may be;
  - ✓ Lease of floating power plant for the duration, instead of construction of new power plant,
  - ✓ Extend of oil power plant shut down, etc.

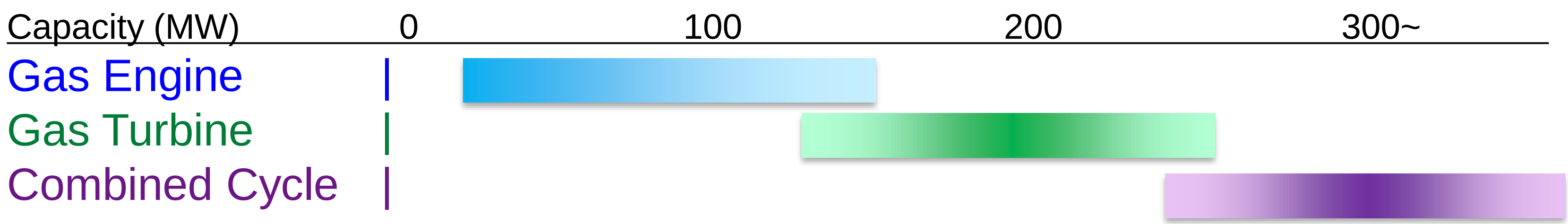
⑤ **<u>Excess gas option</u>**

- In the early phase of gas introduction for gas to power and when renewable plan is achieved, the excess gas for power will be expected 25mmSCFD at maximum.
- Fertilizer production is a possible option to use the excess gas, but the amount of excess gas is not sufficient for internationally competitive production.
- When LNG production is started, the excess gas can be fed to LNG plant.

Appendix 2.2-1 Gas to Power Selection

● Selection of Gas to Power Application

Regarding gas to power generation**, gas engine** is taken up for the study, considering the magnitude of Guyana's power demand (240MW in 2040) and the development of power supply by step.



Concept	Pros	Cons
Gas Engine	• Higher unit CAPEX ($/kW) • Lower O&M expense • Good efficiency (lower fuel cost) • Quick start up	• Not applicable to large scale plant • Not compact layout
Gas Turbine	• Lower unit CAPEX ($/kW) • Smaller footprint (layout) • Applicable to mid~large scale	• Not good efficiency • Higher O&M Expense
Combined Cycle	• Lower unit CAPEX ($/kW) • Excellent efficiency (low fuel cost) • Lower O&M expense • Smaller footprint (layout)	• Applicable to large scale plant (i.e. >250MW)

Chapter 2
Gas Utilization Plan

2.3. Gas to LNG Plan

2.3.1 Gas Availability

(1) Gas Availability for LNG

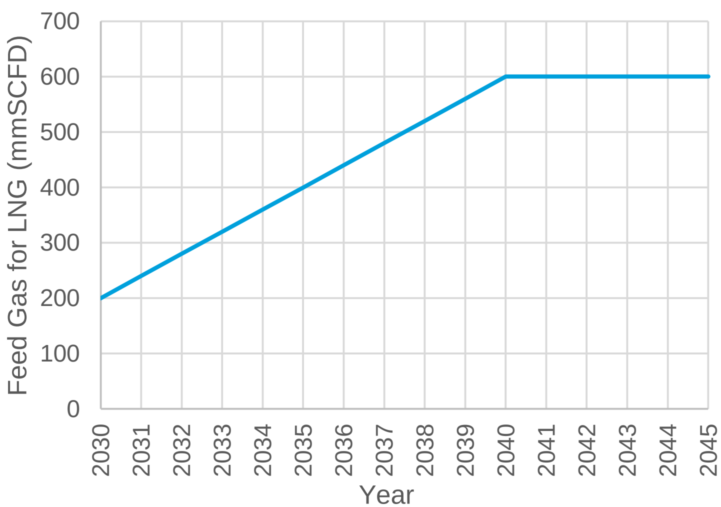
Gas availability for LNG is assumed as follows :

① 2030: 200 mmSCFD (linear increase in 2030-2035)

② 2035: 400 mmSCFD (linear increase in 2035-2040)

③ 2040 and later : 600 mmSCFD

(Source: Information provided by Guyana DOE at KOM, May 22, 2019)



Feed Gas Condition (Assumption)

Feed Gas Source	Unit	Associated Gas (assumed in 2019)
Composition	(dry basis)	
N_2	Mol%	0.5
CO_2	Mol%	1.0
C1	Mol%	80.0
C2	Mol%	7.0
C3		6.0
C4		3.8
C5		1.2
C6+		0.5
Total	Mol%	100.0
Feed Gas Pressure	Bar, a	78
Temperature	^oC	5
Feed Gas GHV	Btu/scf	1278
LNG GHV	Btu/scf	1110 - 1140
Impurity		-
H_2S	ppmv	0

(Note: Chiyoda internal data)

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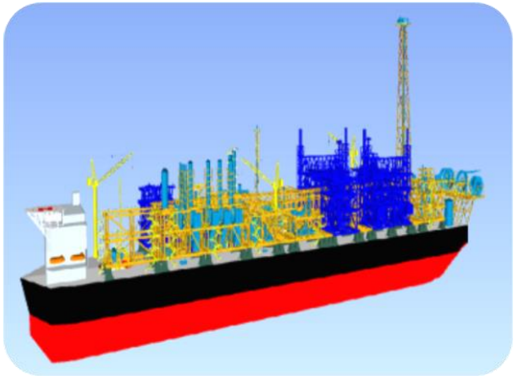
2.3 Gas to LNG Plan
2.3.2 Gas to LNG Options

(1) Technology Overview

Concept	Configuration
Onshore LNG	• Typical LNG plants built in over the world • Both stick built and modular built can be considered
Near shore FLNG	• Floating LNG • Storage provided in floaters • Simple breakwater may be considered for protecting floaters as well as offloading operation
Offshore FLNG	• Floating LNG at offshore field • Storage provided in floaters • LNG offloading at offshore



2.3.2 Gas to LNG Options

(1) Technology Overview

Concept	Pros	Cons
Onshore LNG	• Proven concept • Higher contribution to national/local contents	• Needs pipeline from wells • Needs long jetty structure for LNG offloading
Near Shore FLNG	• Recognized as proven technology • Shorter schedule of construction by reliable fabricators	• Needs pipeline from wells • Less national/local contents
Offshore FLNG	• Recognize as proven technology • Shorter schedule of constructed by reliable fabricators • No pipeline is required to onshore	• LNG Offloading at offshore, potential lower offloading availability • Potentially longer delivery

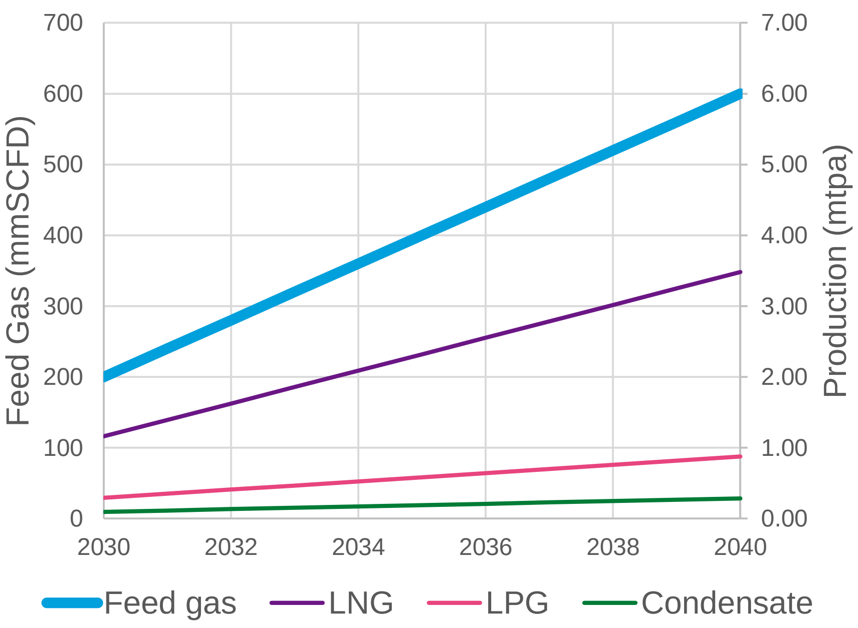
Considering specific features in Guyana's geographic characteristics i.e. wide shallow beach and steep at offshore causing higher cost in laying gas pipeline and making difficult to build the plant onshore or nearshore, **the study case is focused on offshore FLNG solution for gas to LNG.**

2.3.2 Gas to LNG Options

(2) Products of LNG Options

Based on Chiyoda's internal FLNG study utilizing associated gas, the relationship between feed gas and productions (LNG, LPG and Condensate) can be estimated as shown below.

Year	Feed gas (mmSCFD)	LNG (mtpa)	LPG (mtpa)	Condensate (mtpa)
2030	200	1.16	0.29	0.10
2031	240	1.39	0.35	0.11
2032	280	1.62	0.41	0.13
2033	320	1.86	0.47	0.15
2034	360	2.09	0.53	0.17
2035	400	2.32	0.58	0.19
2036	440	2.55	0.64	0.21
2037	480	2.78	0.70	0.23
2038	520	3.02	0.76	0.25
2039	560	3.25	0.82	0.27
2040	600	3.48	0.88	0.29



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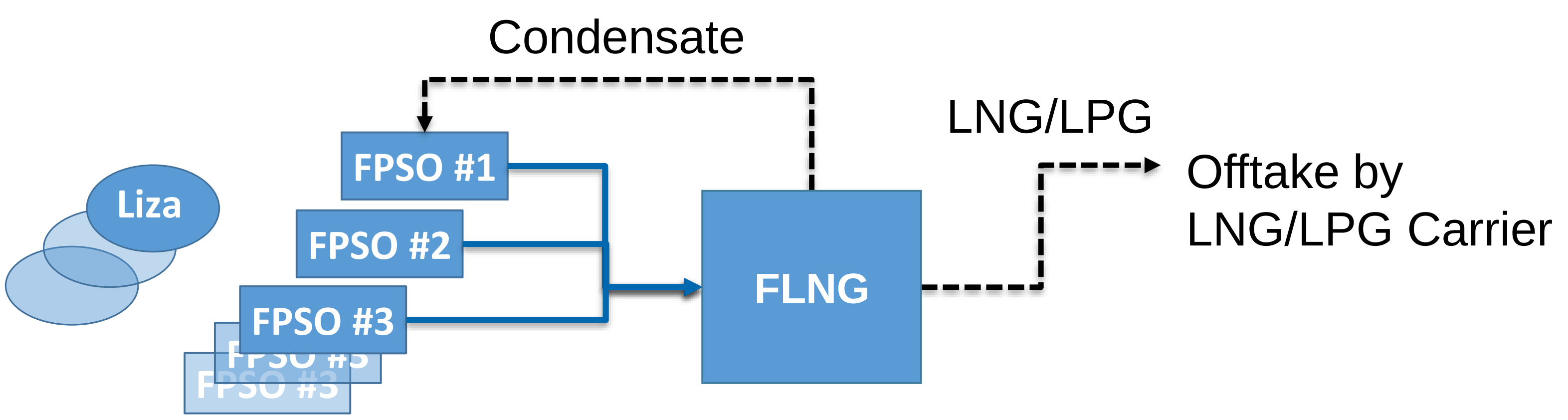
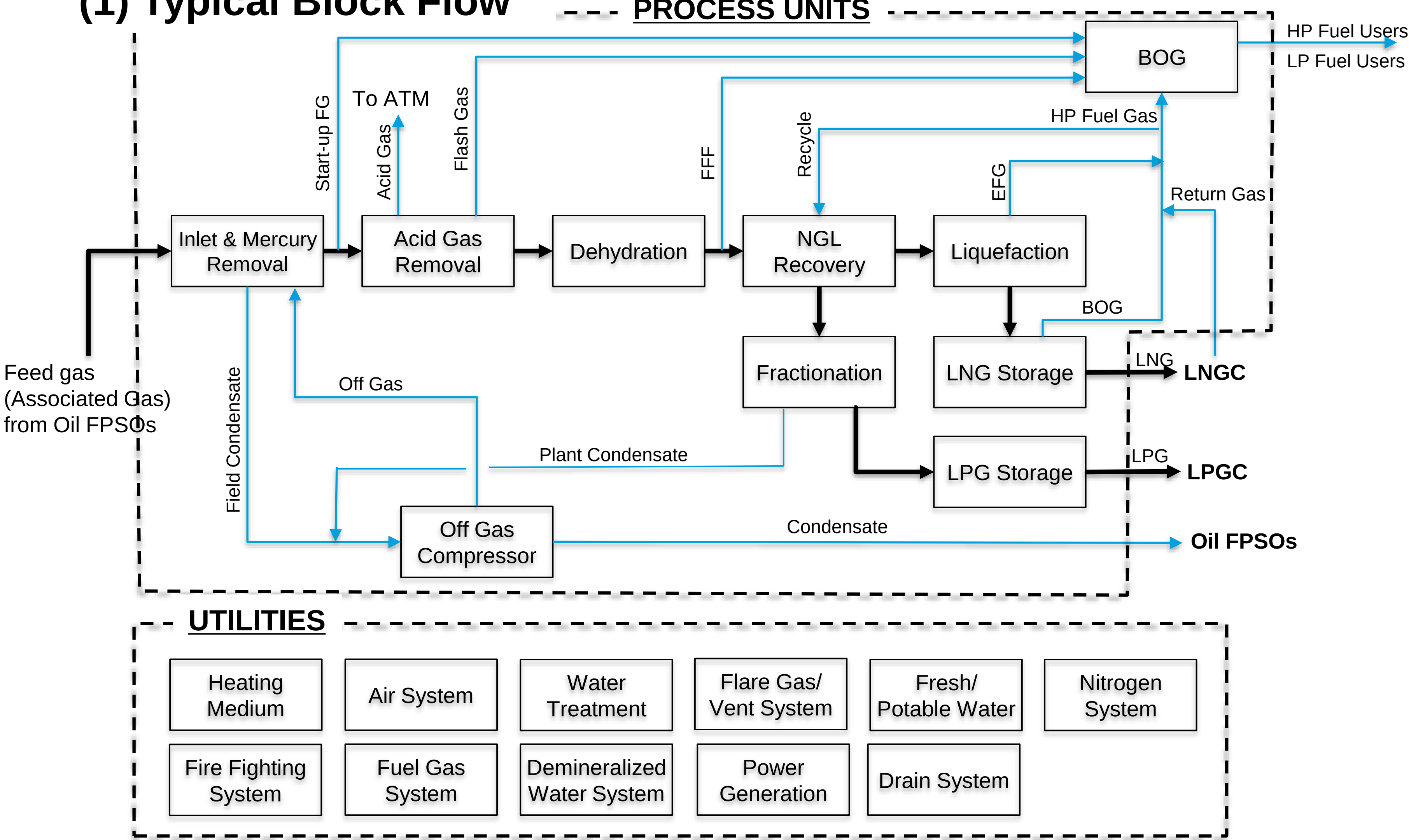
(2) Products of LNG Options

- It has to be noted that **the product will be multiple: LNG, LPG and Condensate**.
- **LNG and LPG** are considered for storage in FLNG and offload from FLNG for the study in this phase.
- **Condensate** produced at FLNG is considered to be sent back to FPSO because of its off-spec property.



2.3 Gas to LNG Plan
2.3.3 FLNG Overview

(1) Typical Block Flow



(2) Key Features

- **Feed Gas Pretreatment**
  Acid gases, mercury and water contained in the feed gas are removed prior to being fed into liquefaction to prevent freezing and plugging in the liquefaction unit.
- **Liquefaction**
  Methane is extracted from the treated gas via scrub column by removing heavier components (LPGs and C5+). Methane is chilled and condensed to -161 ^{o}C as LNG.
  Separated heavier components are sent to Fractionation Unit for further separation.
- **Fractionation**
  Fractionation purifies LPGs and C5+ (Condensate). LPG reinjection system to the liquefaction feed is equipped for adjusting LNG heating value.
- **Product Storages & Offloading (**LNG/LPG)
- **Utilities & Offsite**
  Power Generation, Instrument Air, N2, Water etc.

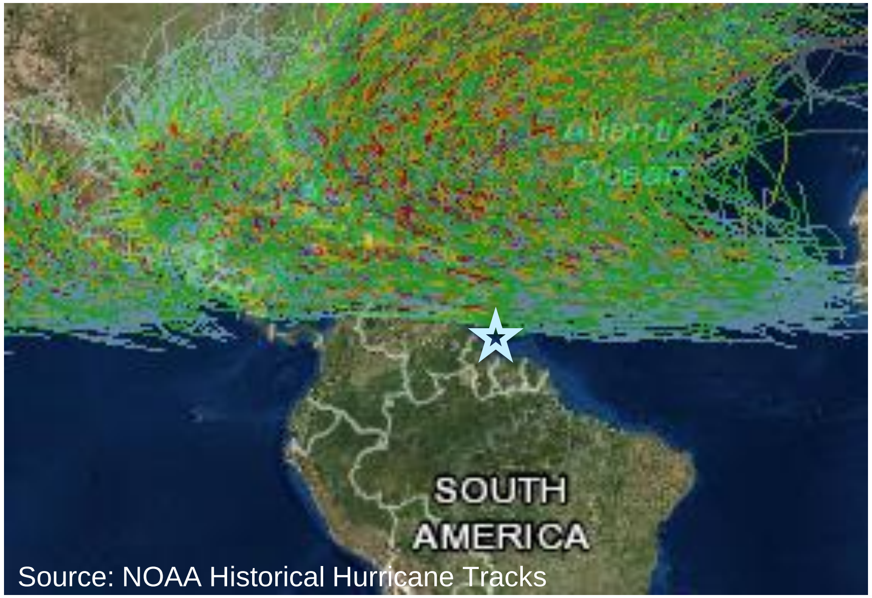
2.3 Gas to LNG Plan
2.3.3 FLNG Overview

(3) Overview of FLNG

Suitability for Offshore Guyana

- low latitude:
- benign ~ moderate condition
- out of hurricane zone

- Side-by-Side LNG offloading
- External turret mooring system



External Turret Mooring System

Side-by-Side LNG offloading

(3) Overview of FLNG


Source: https://www.petronas.com/our-business/upstream/liquefied-natural-gas-lng

New Built FLNG

- Applied at Prelude FLNG, Petronas PFLNG 1 & 2, Coral FLNG
- Flexible in production capacity, multiple product storage and storage capacity. (having said that, ~4mtpa would be maximum from track records)
- Large offtake LNG carrier, lower transportation cost
- Higher CAPEX, Longer delivery as of now

→ To be taken up for the study

Conversion FLNG

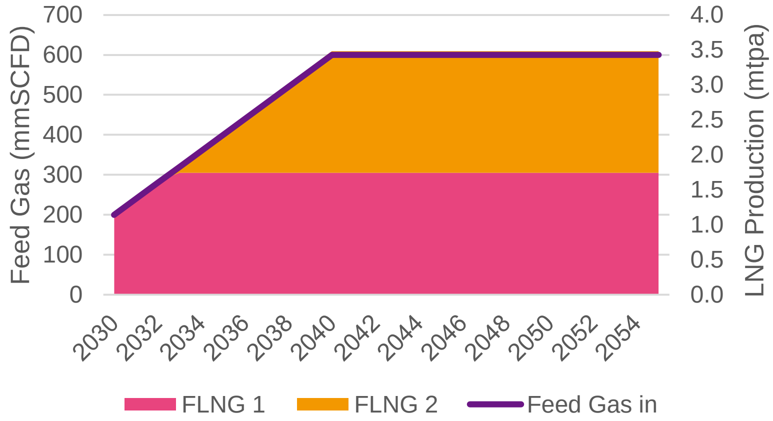
- Applied at Cameroon FLNG, BP Tortue Phase 1
- Limited deck space to cause limited production capacity ~2.5mtpa/unit and storage capacity (depending on donor carrier)
- Difficulty in multiple product storage
- Smaller offtake LNG carrier, higher transportation cost
- Lower CAPEX, Shorter delivery

2.3.4 Economic Analysis

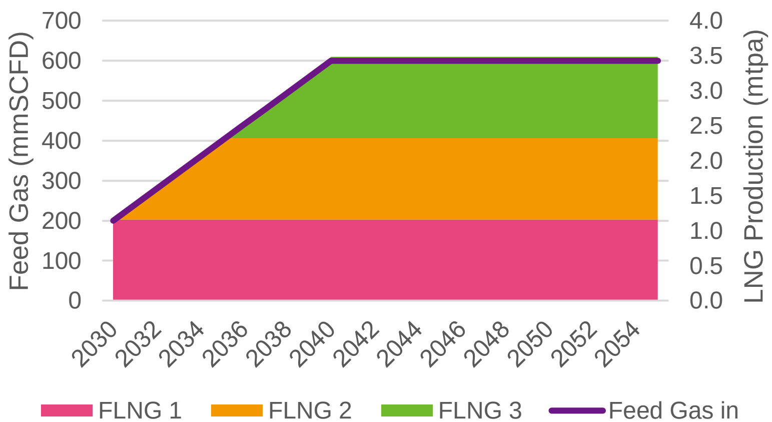
(1) FLNG Development Plan

- Small Scale FLNG Case
  200 mmSCFD (1.2mtpa) x 3
- Medium Scale FLNG Case:
  300 mmSCFD (1.8mtpa) x 2
- Large Scale FLNG Case:
  600 mmSCFD (3.5mtpa) x 1

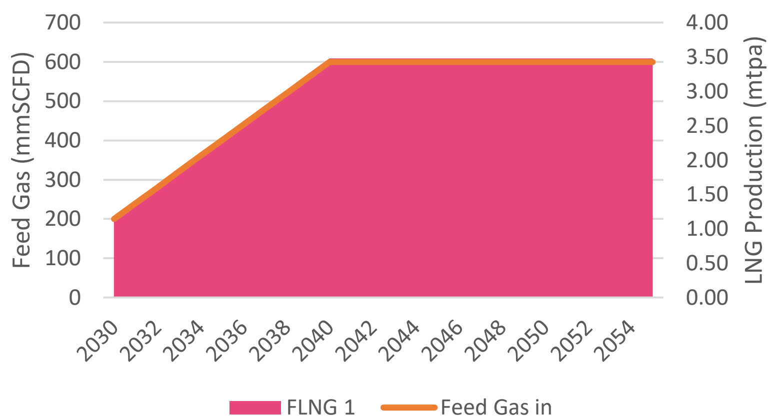
Mid Scale FLNG (2 FLNGs)



Small Scale FLNG (3 FLNGs)



Large Scale FLNG (1 FLNG)



2.3 Gas to LNG Plan
2.3.4 Economic Analysis

(2) LNG Markets

The market of Guyana's LNG is assumed to be South America –East and West, Europe and Japan. The shipping cost is estimated below.

Destination Market	Europe	South America-East	South America-West	Japan
Calculation Basis	Average of UK and Spain	Brazil	Chile	Japan
Shipping Cost ($/mmBtu), by 170,000m^3 LNG carrier	0.59	0.47	0.87	1.59
Distance (n.m)	3,700	2,837	4,117	9,216
Round Trip days	20.0	15.8	24.1	48.9

(3) Basic Conditions for Economic Analysis (1/3)

① Feedstock Gas price

	Base Price Case *1)	Low Price Case *2)
Feed Gas Price	$4/mmBtu	$3/mmBtu

Note *1) Source: EIA Annual Energy Outlook 2019
*2) Source: EIA Annual Energy Outlook 2020 and EIA Short-term Energy Outlook June 2020

② Product Selling Price

	Base Price Case	Low Price Case	
LNG price at destination market *3)	$10 /mmBtu	$8.5 /mmBtu	$6 /mmBtu
LPG price *4)	$0.878/gallon	$0.61/gallon	

Note *3) Source: Chiyoda in-house data
*4) Source: EIA Mont Belvieu LPG price

2.3.4 Economic Analysis

(3) Basic Conditions for Economic Analysis (2/3)

③ CAPEX and OPEX

		Note
CAPEX	$1,400/LNGton for New built FLNG	Based on historical LNG CAPEX in recent 10 years and Chiyoda's in-house estimation.
OPEX	5% of CAPEX	

④ Construction Duration

		Note
Construction Duration	60 months for New built FLNG	The schedule is taken into account for the economic analysis.

.

(3) Basic Conditions for Economic Analysis (3/3)

⑤ Financial parameters for analysis

Item	Input	Remark
Plant Operation Period	20 years	
Depreciation Period	10 years by liner depreciation	
Ratio of Equity and Loan	Equity: 40%, Loan: 60%	
Interest of Loan	3%	
Loan Period	20 years	
Inflation	No inflation is considered	
Income Tax	30%	
Property Tax	2.0%	

(4) Cash Flow Analysis for Base Price Case

① Overview

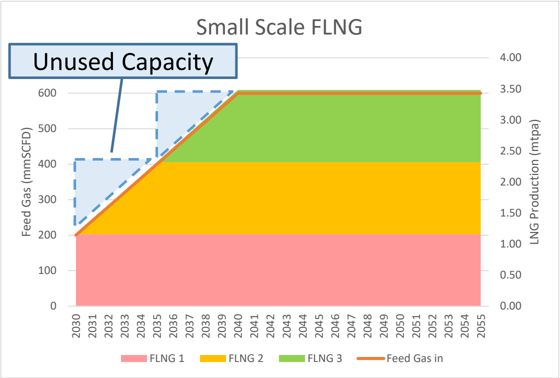
IRR for Base price case			
Study Conditions	Base price case		
Feedstock Gas Price	4$/MMBtu		
Products Selling Price	LNG 10$/MMBtu		
	LPG 0.878$/gallon		
FLNG Development Plan	Small-scale	Medium-scale	Large-scale
Destination Markets	IRR		
South America- East	12.8%	11.1%	8.3%
Europe	12.5%	10.8%	8.1%
South America- West	11.6%	10.1%	7.6%
Japan	9.4%	7.9%	5.9%

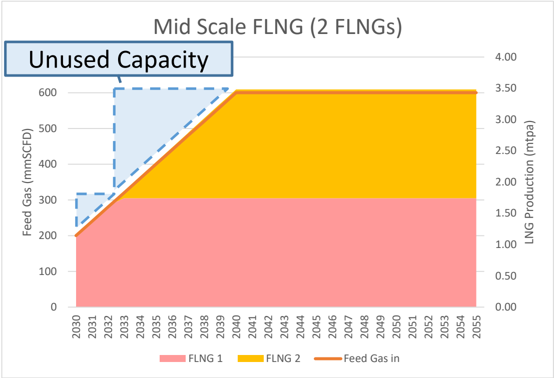
2.3.4 Economic Analysis

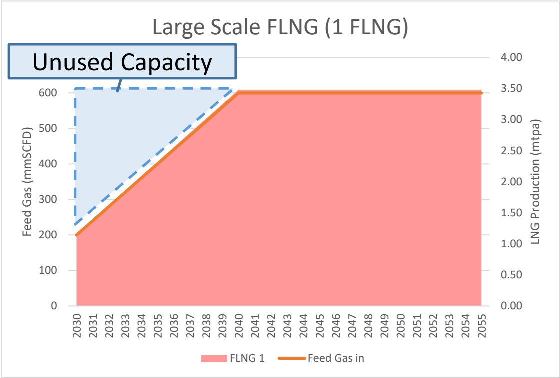
(4) Cash Flow Analysis for Base Price Case

② FLNG Development Plan

- Three plans of FLNG development are studied;
  - Small-scale FLNG (200 mmSCFD (1.2 mtpa)) x 3
  - Medium-scale FLNG (300 mmSCFD (1.8 mtpa)) x 2
  - Large-scale FLNG (600 mmSCFD (3.5 mtpa)) x 1
- As shown in the above slide, **the small-scale plan shows better economics** than the other plans. It is due to the difference of un-used capacities for the early stage of startup. The economic advantage of the small-scale plan can be observed for every destination market.







(4) Cash Flow Analysis for Base Price Case

③ Selling Products

- As selling products, the contribution of LPG selling is studied below.

IRR for selling product options				
Destination Market	Selling Product	Development Plan		
		Small-scale	Medium-scale	Large-scale
South America- East	LNG + LPG	12.8%	11.1%	8.3%
	LNG	5.6%	4.5%	3.2%

- **<u>Sales of LPG will significantly improve the economics</u>** of all plans, though the production of LPG is 25% of LNG in weight and the revenue of LPG is 16% of that of LNG.

2.3.4 Economic Analysis

(4) Cash Flow Analysis for Base Price Case

④ Destination Market

- Four areas are taken up as possible destination markets for Guyana LNG,

IRR for destination markets				
Destination Market	Development Plan			Note
	Small-scale	Medium-scale	Large-scale	Shipping cost from Guyana
South America- East	12.8%	11.1%	8.3%	0.47 $/mmBtu
Europe	12.5%	10.8%	8.1%	0.59
South America- West	11.6%	10.1%	7.6%	0.87
Japan	9.4%	7.9%	5.9%	1.59

- If the LNG selling price is equally assumed to be 10 $/MMBtu, **South America East, West and Europe shows better economics** as the destination markets. This is due to the difference of shipping cost from Guyana to the destination markets.

(5) Cash Flow Analysis for Low Price Case

① Overview

IRR for Base/Low price cases				
Feedstock Gas Price		Base Price (4$/MMBtu)	Low Price (3$/MMBtu)	
Products Selling Price		LNG 10$/MMBtu	LNG 8.5$/MMBtu	LNG 6.0$/MMBtu
		LPG 0.878$/gallon	LPG 0.61$/gallon	
Development Plan		Small-scale	Small-scale	Small-scale
Destination Market	South America- East	12.8%	9.2%	-0.7%
	Europe	12.5%	8.9%	-1.6%
	South America- West	11.6%	8.0%	-3.8%
	Japan	9.4%	5.3%	-13.1%

(5) Cash Flow Analysis for Low Price Case

② LNG Selling Price at 8.5 $/MMBtu

- The low price case of feedstock gas at 3 $/MMBtu and selling LNG at 8.5 $/MMBtu is taken up in comparison with the base price case.
- As shown in the overview**, IRR for the low price case will be lower by 3-4 % than the base price case**, though the feedstock gas price is lowered.
- For the markets of South America-West and Europe, IRR will be around 9%, but the LNG selling price at 8.5 $/MMBtu will be rather optimistic for the markets.
- For the market of Japan, the LNG selling price 8.5 $/MMBtu will be within the range of forecast, but IRR will be further low around 5%.

③ LNG Selling Price at 6 $/MMBtu

- The LNG selling price at 6 $/MMBtu is taken up.
- IRR for the selling price at 6 $/MMBtu will be infeasible even in the preferable markets like South America-West and Europe.

Note: Sensitivity Analysis of Economics (1/3)

The sensitivity analysis of economics is carried out regarding CAPEX, feedstock gas price, and product selling price.

(1) IRR sensitivity to CAPEX

IRR for the change of CAPEX					
CAPEX ($/LNGton)	**800**	**1000**	**1200**	**1400** (Base)	**1600**
Feed Gas Price ($/MMBtu)	**4**				
LNG Selling Price ($/MMBtu)	**10**				
Development plan	Small Size				
	IRR				
S.America East	24.1%	19.8%	16.0%	12.8%	10.0%
Europe	23.8%	19.5%	15.8%	12.5%	9.6%
S.America West	23.0%	18.8%	14.9%	11.6%	8.8%
Japan	21.2%	16.6%	12.8%	9.4%	6.6%

Note: Sensitivity Analysis of Economics (2/3)
(2) IRR sensitivity to feedstock gas price

IRR for the change of feed gas price					
CAPEX ($/LNGton)	1400				
Feed Gas Price ($/MMBtu)	2	3	4 (Base)	5	6
LNG Selling Price ($/MMBtu)	10				
Development plan	Small Size				
	IRR				
S.America East	17.5%	15.3%	12.8%	9.9%	6.5%
Europe	17.2%	15.0%	12.5%	9.5%	6.1%
S.America West	16.6%	14.4%	11.6%	8.6%	5.0%
Japan	15.0%	12.5%	9.4%	6.0%	2.0%

Note: Sensitivity Analysis of Economics (3/3)
(3) IRR sensitivity to LNG selling price

IRR for the change of LNG selling price					
CAPEX ($/LNGton)	1400				
Feed Gas Price ($/MMBtu)	4				
LNG Selling Price ($/MMBtu)	7	8.5	10 (Base)	11.5	13
Development plan	Small Size				
	IRR				
S.America East	2.3%	8.2%	12.8%	16.5%	19.6%
Europe	1.9%	7.9%	12.5%	16.2%	19.3%
S.America West	0.5%	6.8%	11.6%	15.6%	18.7%
Japan	-4.1%	4.0%	9.4%	13.9%	17.3%

2.3 Gas to LNG Plan
2.3.5 Concluding Remarks

① **As Gas to LNG plan, offshore FLNG looks the most preferable solution for Guyana.**

- Considering Guyana's geotechnical characteristics, offshore FLNG looks most preferable solution for Gas to LNG.

② **Phased Development is more attractive.**

- Phased development with smaller scale FLNG will be more appropriate than medium or large scale FLNG.

③ **South America-East, West and Europe are preferable destination markets for Guyana LNG**

- From the viewpoint of shipping, South America-East, West and Europe are more preferable than Japan, assuming the LNG selling price be the same.

④ **Economic viability of Gas to LNG is sensitive to LNG selling price in the market.**

- The economics of Gas to LNG plan is highly sensitive to the LNG selling price in the destination market.
- Even if the feedstock gas price is lowered, lower selling price of LNG would deteriorate the economics.

2.3.5 Concluding Remarks

⑤ Economics is sensitive to CAPEX, however, Conversion FLNG may be attractive but challenging.

- Conversion FLNG may be an attractive option in view of lower CAPEX, but it is challenging to accommodate multiple products production and storage in/on the FLNG, and higher shipping cost.

Chapter 3
Oil Utilization Plan

3.1 Domestic Oil Demand

3.1 Domestic Oil Demand
3.1.1 Demand Forecast in Guyana

Historical data of domestic oil demand from 2010 to 2016 is shown by GEA Annual Report. For decision of refining capacity, oil demands on 2027 are assumed as following two-cases;

・Reference Demand Case* ･･･4.78% of annual growth rate, minimum refinery capacity to be estimated

(Note) 4.78% is the average of annual growth rate from 2010 to 2016.

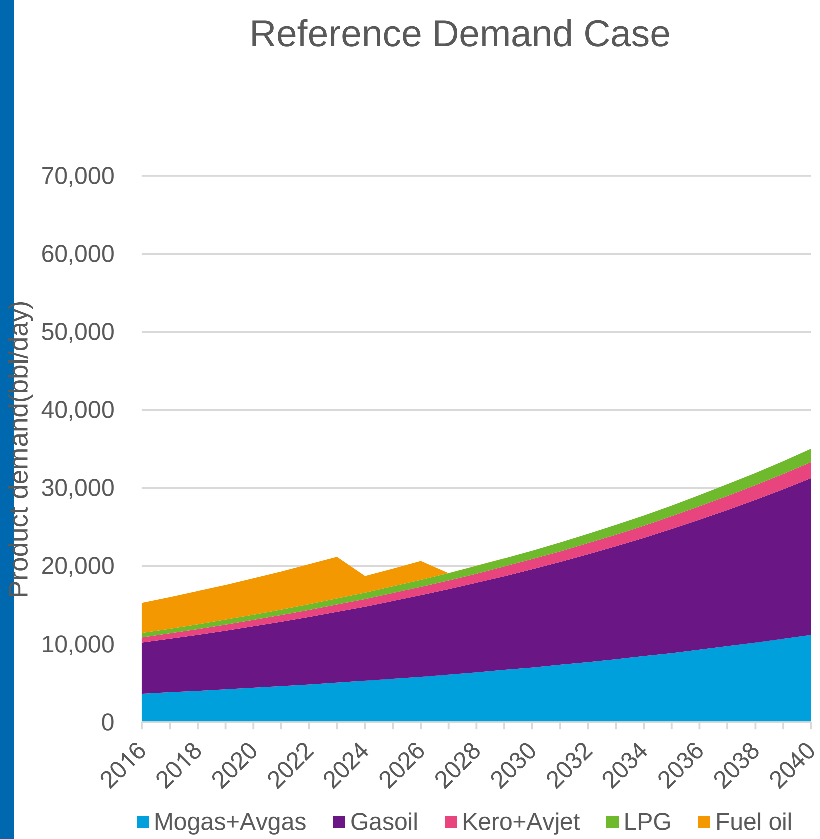
・High Demand Case ･･･7.00% of annual growth rate, maximum refinery capacity to be estimated

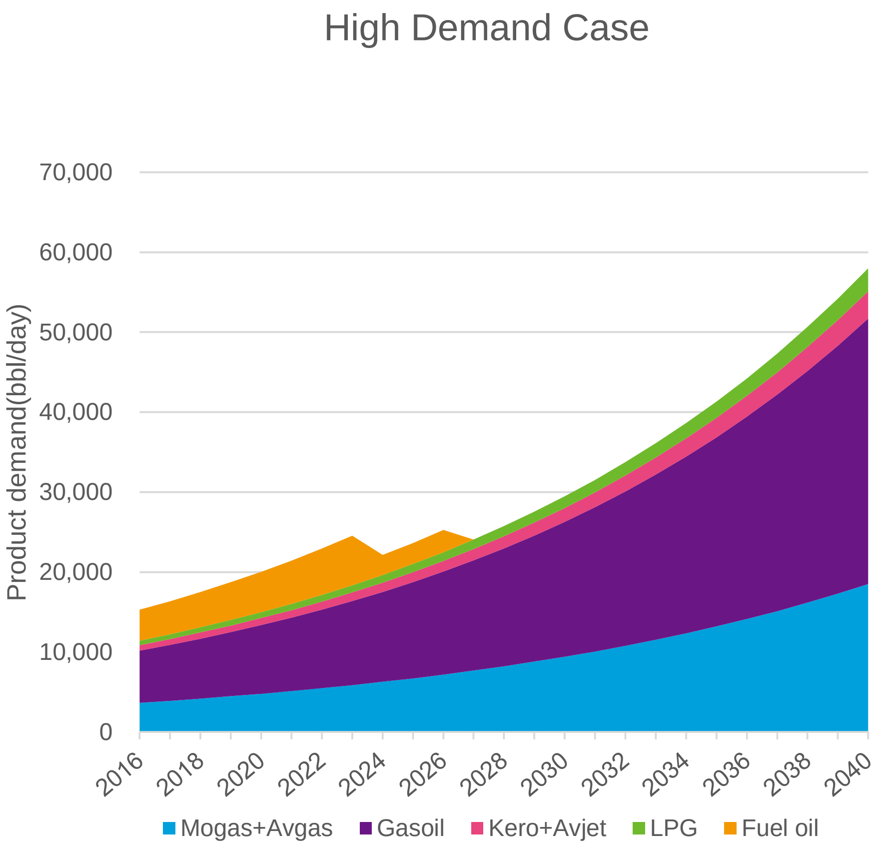
*Equivalent to 2019 Study

Domestic Oil Demand			
		Reference Demand Case	High Demand Case
	Average Growth Rate for forecast from 2016 to 2040	4.78%	7.00%
	Oil Demand Forecast in 2027	bbl/d	bbl/d
	Mogas+Avgas	6,099	7,681
	Gasoil	10,934	13,770
	Kero+Avjet	1,124	1,415
	Fuel oil	0	0
	LPG	946	1,192
	Total (bpd)	19,102	24,058

3.1 Domestic Oil Demand
3.1.2 Trend Outlook

Based on the projection of fuel oil replacement, refinery is planned to be started in 2027. The refinery capacity described here-in-after is based on the demand forecast in 2027.





Chapter 3
Oil Utilization Plan

3.2 Refinery Plan

3.2 Refinery Plan
3.2.1 Crude Assay Assumption

Crude oil specification for refinery feedstock in this study is assumed to be equivalent to Liza crude oil shown as follows;

LIZA216	Whole crude	Butane and Lighter IBP - 60F	Lt. Naphtha C5 - 165F	Hvy Naphtha 165 - 330F	Kerosene 330 - 480F	Diesel 480 - 650F	Vacuum Gas Oil 650 - 1000F	Vacuum Residue 1000F+
Cut volume, %	100.0	1.3	4.8	15.7	14.1	17.0	30.2	16.9
API Gravity,	32.1	120.0	81.9	55.5	42.3	34.0	23.9	9.6
Specific Gravity (60/60F),	0.865	0.563	0.663	0.757	0.814	0.855	0.911	1.003
Carbon, wt %	86.0	82.5	83.9	85.6	86.1	86.4	86.5	85.9
Hydrogen, wt %	13.3	17.5	16.1	14.4	13.8	13.3	12.7	12.2
Pour point, F	37.4			(117.9)	(67.4)	9.8	102.1	126.0
Neutralization number (TAN), MG/GM	0.216	0.000	0.010	0.066	0.147	0.221	0.307	0.263
Sulfur, wt%	0.510	0.000	0.000	0.003	0.060	0.286	0.600	1.337
Viscosity at 20C/68F, cSt	14.1	0.5	0.6	0.9	2.0	7.2	217.0	93,484,288.4
Viscosity at 40C/104F, cSt	7.9	0.4	0.5	0.7	1.4	4.2	61.7	1,945,296.4
Viscosity at 50C/122F, cSt	6.3	0.4	0.5	0.7	1.2	3.3	37.5	414,704.2
Mercaptan sulfur, ppm	6.0	0.0	0.0	0.1	0.3	0.2	0.0	0.0
Nitrogen, ppm	2,162.1	-	-	0.0	2.4	169.4	1,606.9	8,258.9
CCR, wt%	3.8						0.4	18.7
N-Heptane Insolubles (C7 Asphaltenes), wt%	1.0						-	5.2
Nickel, ppm	16.5							84.3
Vanadium, ppm	26.6							135.6
Calcium, ppm	8.2							
Reid Vapor Pressure (RVP) Whole Crude, psi	7.6							
Hydrogen Sulfide (dissolved), ppm	-							
Salt content, ptb	82.8							
Paraffins, vol %	29.8	100.0	80.7	39.9	39.9	34.2	19.7	2.6
Naphthenes, vol %	37.1	-	19.3	51.6	40.5	42.9	42.1	16.9
Aromatics (FIA), vol %	33.1	-	-	8.5	19.6	22.9	38.2	80.5
Distillation type, TBP								

Reference: Exxon Mobil HP

3.2.2 Modular Refinery

(1)Introduction

Even keeping steady growth, conventional size of refinery is too large for Guyana from viewpoint of supply-demand balance.

“**Modular refinery**” explained hereunder, is appropriate for Guyana to support the domestic demand in 2027 and later to 2040.

	Conventional	Modular
Capacity	>100 kbpsd	**20 ～3k bpsd**
CAPEX	>5,000 million USD	**>150 million USD**
Technical Reliability	Good	**Good**
Amount of Product	Excessive	**Good**
Production cost	Low	**Low – medium**

(2)Modular Refinery Technical Benefits

Modular refining concepts provide:

- single-source project management
- quick construction in challenging environments
- superior quality control for reliable and cost-effective constructions

Modular refinery suits the project with:

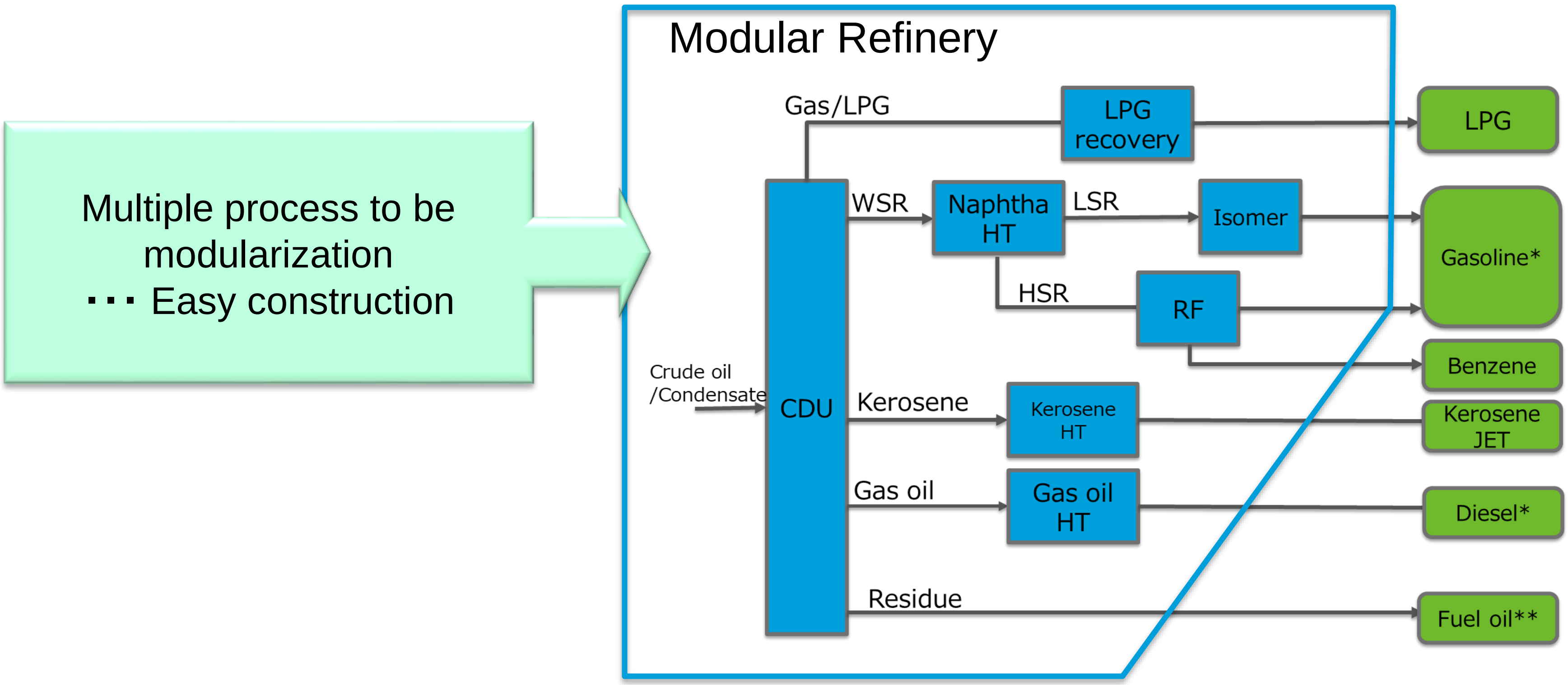
- Strict product specifications
- Short project timelines requiring fast track delivery
- Limited, critical onsite resources
- Remote locations

Source: https://www.uop.com/processing-solutions/refining/modular-refining-units

3.2 Refinery Plan
3.2.2 Modular Refinery

(3)Technical Features

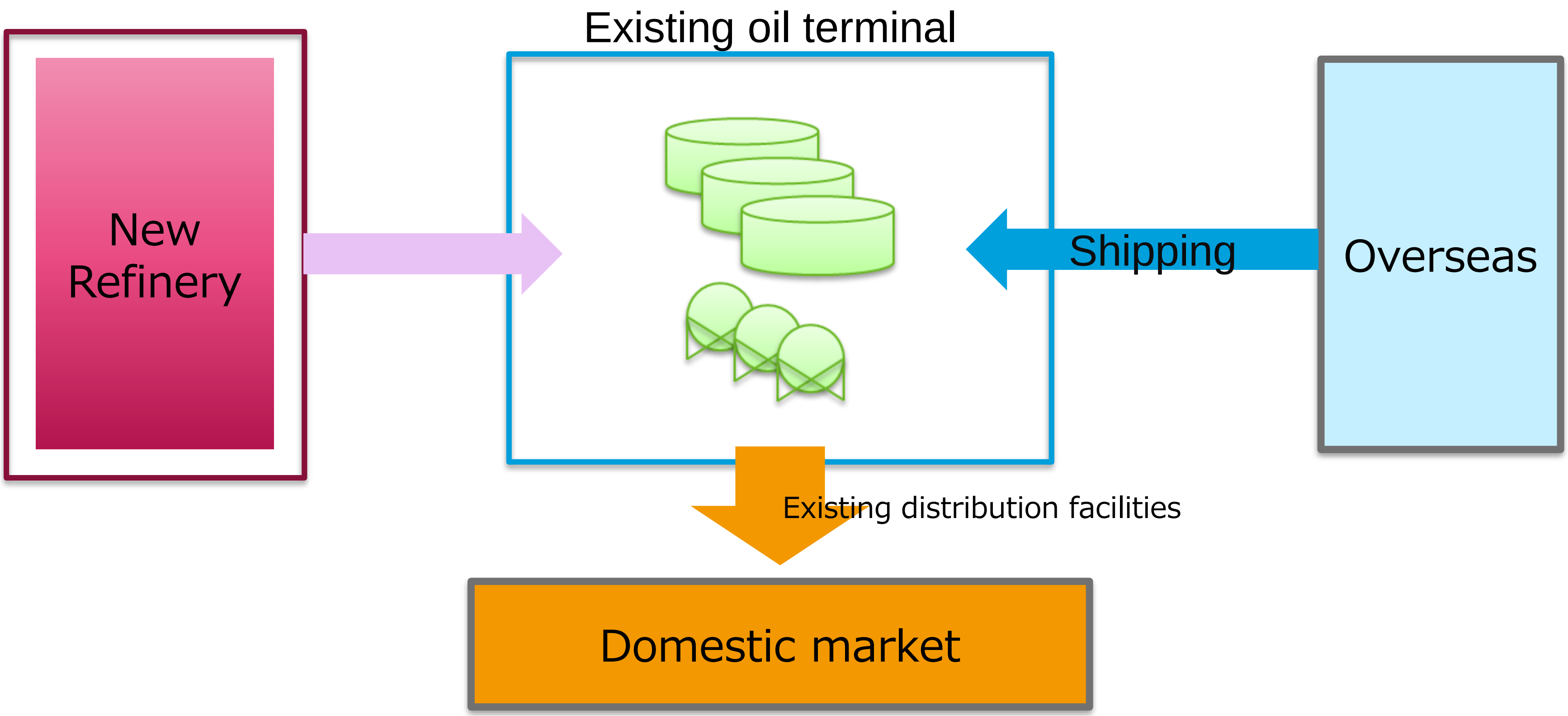
Usually, refinery is constructed as an aggregate of a variety of process units (crude distillation, hydro-treating, reforming etc.). Therefore, it requires long period and huge cost for construction, in general.
Modular refinery is the combination of some simple module units, which enables to reduce cost and schedule.



3.2 Refinery Plan
3.2.3 Refinery Location

Refinery location is decided by various factors, distance to urban area for distribution, distance to big river for utility water, stable flat area for construction and etc.

Modular refinery, which requires limited site area, can be constructed close to existing oil terminal to reduce storage, jetty and loading facilities cost.



3.2 Refinery Plan
3.2.4 Refinery Scheme Evaluation

(1)Strategies of Study

Based on crude assay data and Chiyoda's in-house process information, following three schemes are taken up in this study, because simple modular refinery(Scheme-1) produce large amount of high sulfur FO, undesirable for Guyana.

Scheme-2 and 3 include upgrading technology which can convert high sulfur FO to low sulfur FO or desirable products, gasoline and diesel.

Scheme-1 : Base Scheme

Simple Modular Refinery

Scheme-2 : LSFO Scheme (Low sulfur Fuel Oil)

Scheme-1 + AR-HDS*

Scheme-3 : RFCC Scheme

Scheme-2 + RFCC**

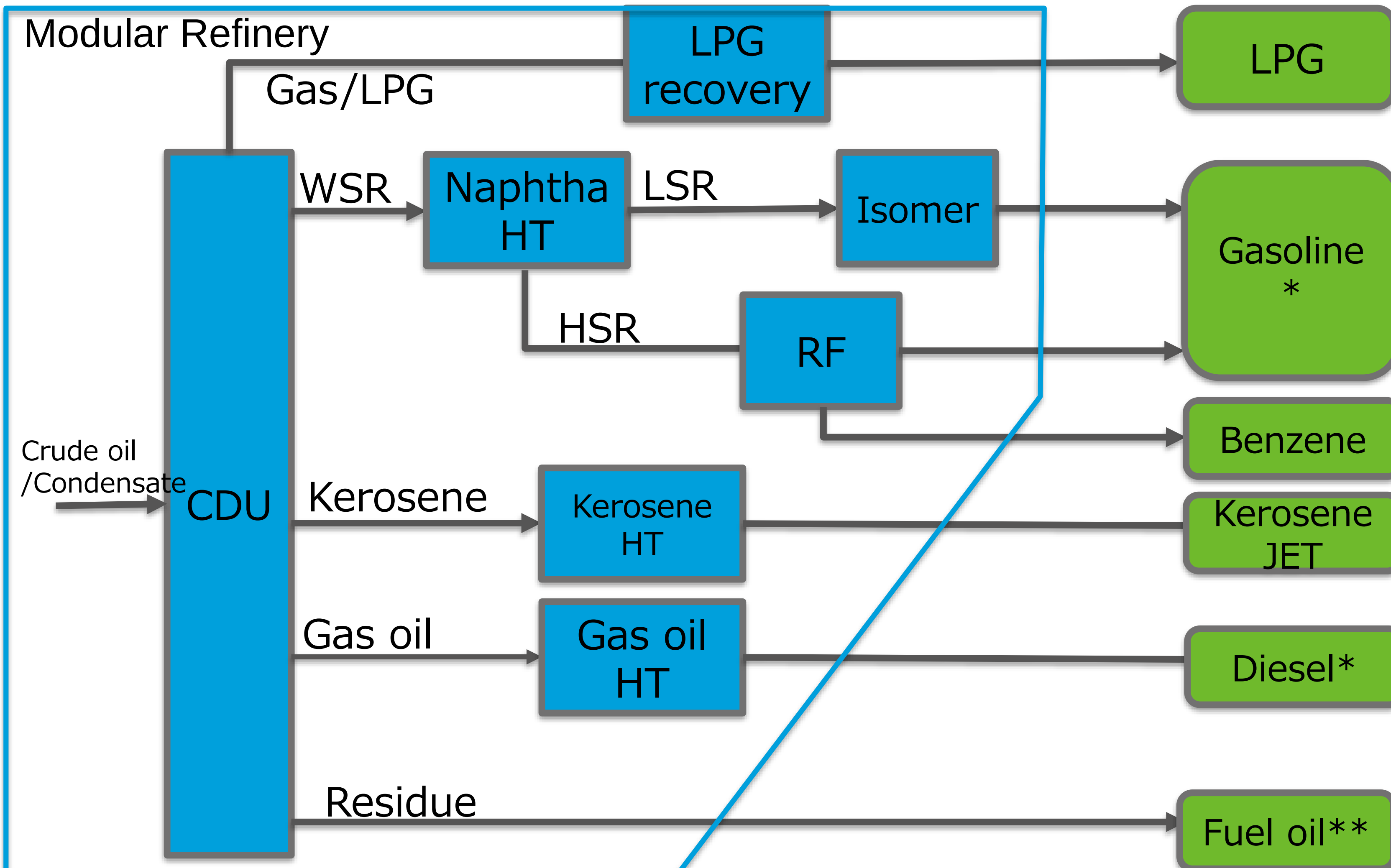
	Scheme-1 Base	Scheme-2 LSFO	Scheme-3 RFCC
Modular Refinery	✔	✔	✔
AR-HDS		✔	✔
RFCC			✔
Utility plant	✔	✔	✔
Off-Site	✔	✔	✔

*AR-HDS : Atmospheric Residue Hydro-Desulfurization process

**RFCC : Residue Fluid Catalytic Cracking

3.2.4 Refinery Scheme Evaluation

(2) Scheme-1 Block Flow



* Sulfur free grade(10 ppm)
**High sulfur grade

3.2.4 Refinery Scheme Evaluation

(3) Scheme-1 Features

1.Modular refinery function

- CDU(Column Distillation Unit + Desalting)
  - separating each product by distillation
- LPG recovery
  - Recovering LPG for product
- Naphtha HT (hydro-treating)+ isomerization/RF(Reforming)
  - High octane and low sulfur gasoline production
- Kerosene and Gas oil HT(hydro-treating)
  - Low sulfur and high quality of diesel and JET fuel production

2.Atmospheric residue handling

- To be utilized for utility or produced as high sulfur fuel oil for export

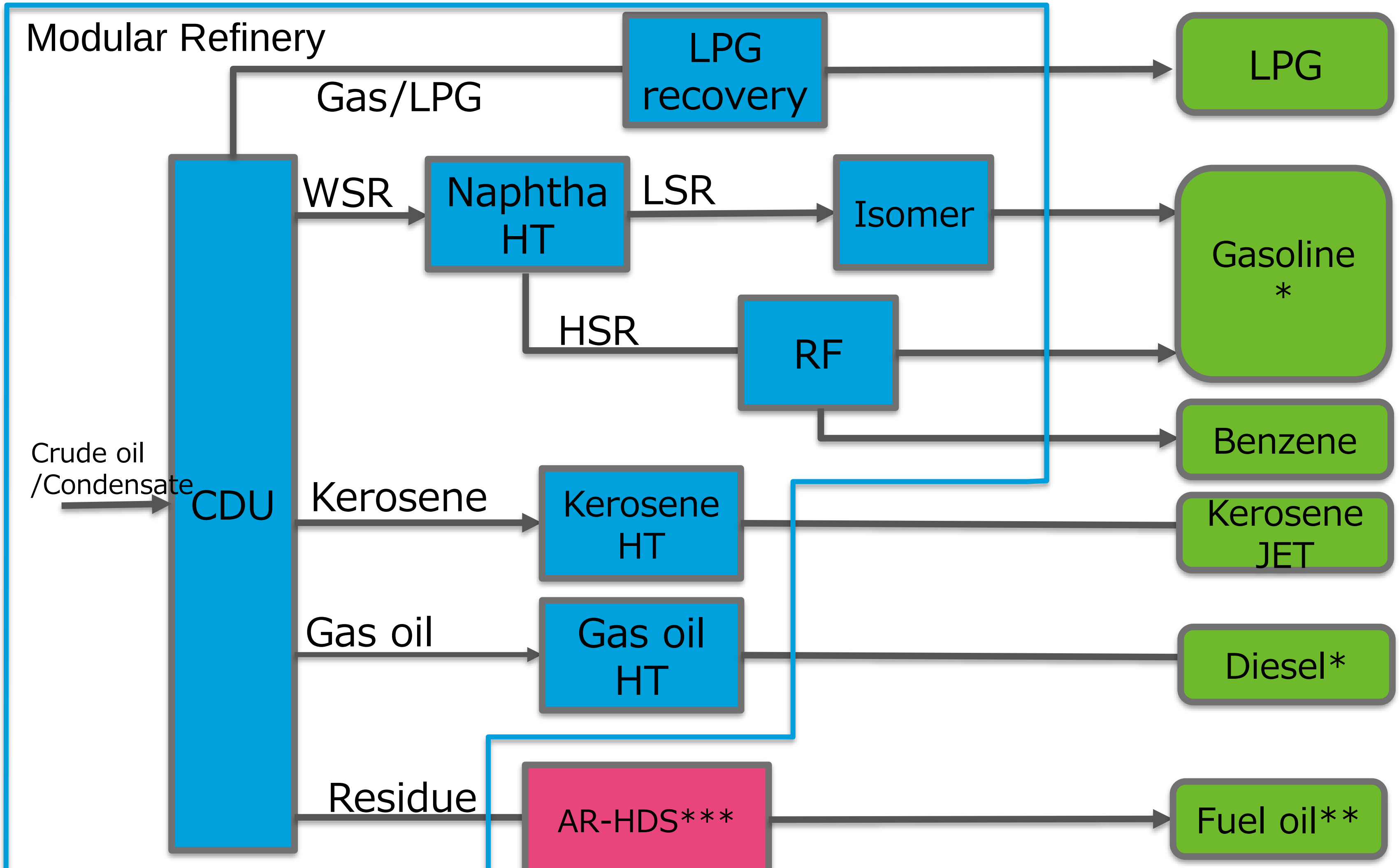
3.Utility

- Boiler and power generation for self-producing in refinery

4.Storage and off-site

- Making the most of existing oil terminal by adjacent location

(4) Scheme-2 Block Flow



* Sulfur free grade
**Low sulfur grade(<0.5%)
***Additional facility to modular

3.2 Refinery Plan
3.2.4 Refinery Scheme Evaluation

(5)Scheme-2 Features

1.Modular refinery function

- CDU(Column Distillation Unit +Desalting)
  - separating each product by distillation
- LPG recovery
  - Recovering LPG for product
- Naphtha HT(hydro-treating)+ isomerization/RF(Reforming)
  - High octane and low sulfur gasoline production
- Kerosene and Gas oil HT(hydro-treating)
  - Low sulfur and high quality of diesel and JET fuel production

2.Atmospheric residue handling

- Processing by AR-HDS to produce low sulfur banker fuel(meet to IMO* regulation)

*IMO : International Maritime Organization

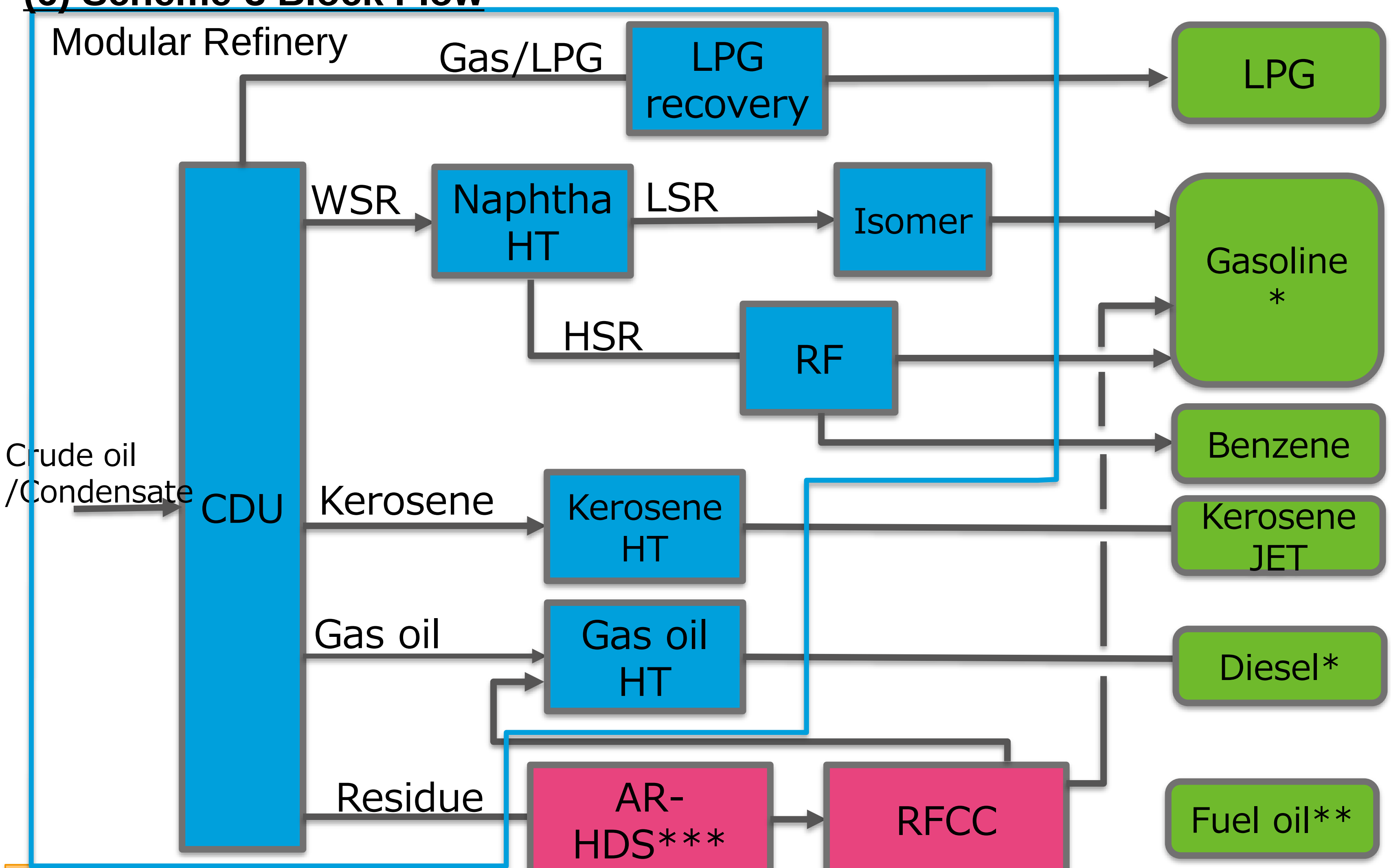
3.Utility

- Boiler and power generation for self-producing

4.Storage and off-site

- Making the most of existing oil terminal by adjacent location

(6) Scheme-3 Block Flow



* Sulfur free grade
**Low sulfur grade(<0.5%)
***Additional facility to modular

3.2.4 Refinery Scheme Evaluation

(7)Scheme-3 Features

1.Modular refinery function

- CDU(Column Distillation Unit + Desalting)
  - separating each product by boiling point difference
- LPG recovery
  - Recovering LPG for product
- Naphtha HT(hydro-treating) + isomerization/ RF(Reforming)
  - High octane and low sulfur gasoline production
- Kerosene and Gas oil HT(hydro-treating)
  - Low sulfur and high quality of diesel and JET fuel production

2.Atmospheric residue handling

- Processing by AR-HDS and RFCC, residue can be converted to high value products (Gasoline and Diesel)

3.Utility

- Boiler and power generation for self-producing

4.Storage and off-site

- Making the most of existing oil terminal by adjacent location

3.2.5 Refinery Product Calculation Result

(1)Country in-out Balance of Reference Demand Case

Based on above refinery scheme, amount of refinery products is calculated by LP Simulator.

Starting refinery in 2027, net import balance is shown as follows;

- All refinery capacities are set as 15,000bpsd in Reference Demand case based on the Kero+Avjet production
- Import of gasoline, diesel and other petroleum product can be reduced by refinery operation.
- In Scheme-1 and 2 Fuel oil will be exported, which does not exist in domestic market.
- In Scheme-3, no Fuel oil is produced.

		Scheme-1		Scheme-2		Scheme-3	
Refinery Capacity		15,000		15,000		15,000	
bbl/day	Demand	Product	net import	Product	net Import	Product	net Import
Mogas+Avgas	6099	2651	3448	2910	3189	6561	-462
Diesel	10934	4020	6914	5220	5713	6502	4432
Kero+Avjet	1124	1124	0	1124	0	1124	0
Fuel oil	0	6329	-6329	5110	-5110	0	0
LPG	946	206	740	206	740	747	199
Total	19103	14330	4773	14571		14933	

All of Fuel oil to be Export

3.2.5 Refinery Product Calculation Result

(2)Country in-out Balance of High Demand Case

Starting refinery in 2027, net import balance is shown as follows;

- All refinery capacities are set as 20,000bpsd in Reference Demand case based on the Kero+Avjet production
- Import of gasoline, diesel and other petroleum product can be reduced by refinery operation.
- In Scheme-1 and 2 Fuel oil will be exported, which does not exist in domestic market.
- In Scheme-3, no Fuel oil is produced.

		Scheme-1		Scheme-2		Scheme-3	
Refinery Capacity		20,000		20,000		20,000	
bbl/day	Demand	Product	net import	Product	net Import	Product	net Import
Mogas+Avgas	7681	3535	4146	3880	3801	8748	-1067
Gasoil	13770	5443	8327	7044	6726	8752	5018
Kero+Avjet	1415	1415	0	1415	0	1415	0
Fuel oil	0	8438	-8438	6814	-6814	0	0
LPG	1192	275	916	275	916	996	195
Total	24057	19107	4951	19428		19911	

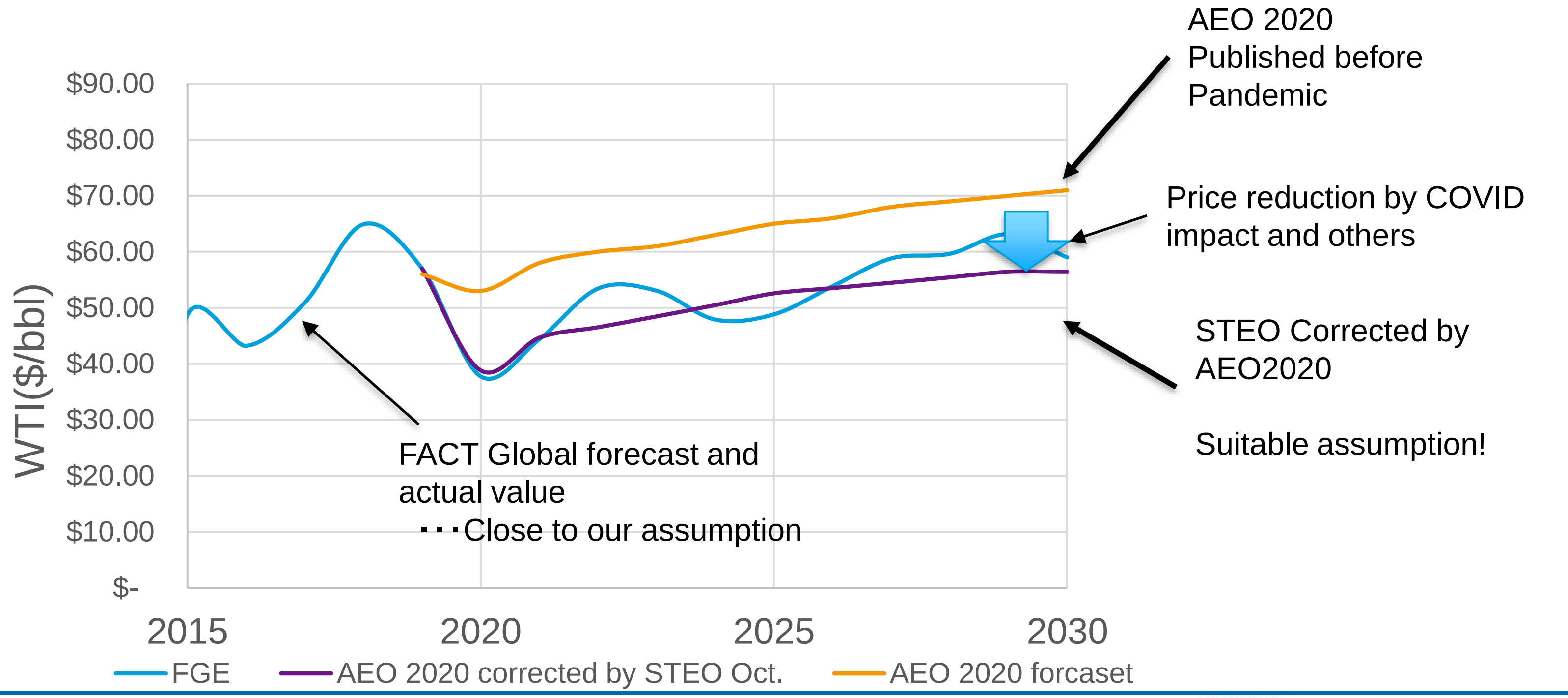
All of Fuel oil to be Export

3.2 Refinery Plan
3.2.6 Crude Oil Price

(1)WTI Market Forecast

Latest annual energy outlook provided by EIA(AEO2020, yellow line) expects WTI price will increase steadily, which does not take COVID impact into consideration.

We combine the annual energy outlook with EIA short term energy outlook(STEO) for pricing assumption of Guyana Master Plan(purple line).



3.2 Refinery Plan
3.2.6 Crude Oil Price

(2)Refinery Feedstock Price

Based on the above Crude oil market forecast, the economic study takes up the following three cases of crude oil prices. Crude of LIZA equivalent is assumed to be processed in new refinery in Guyana.

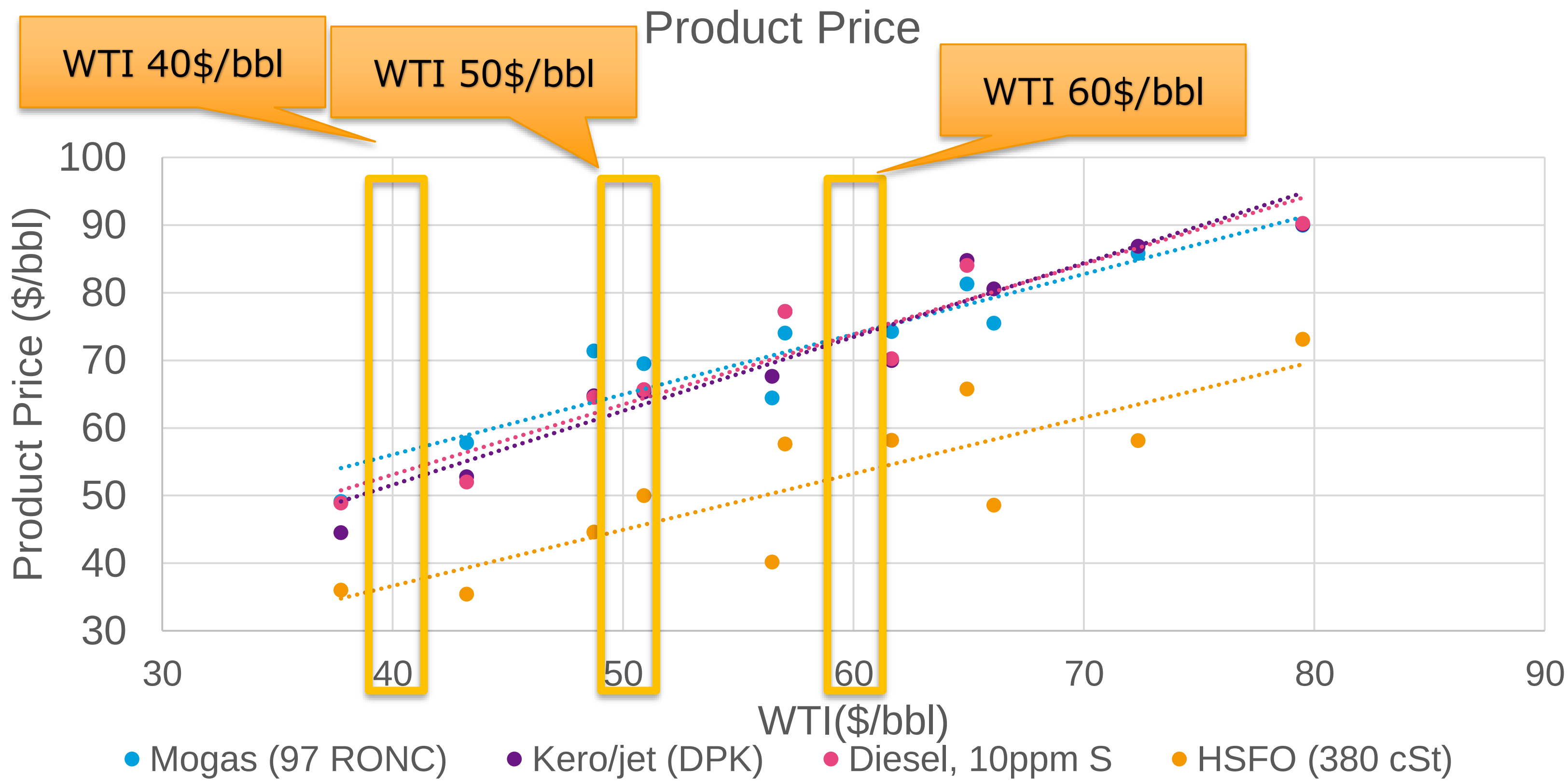
		Base Case*	Low Price Case-1	Low Price Case-2
WTI	$/bbl	60	40	50
LIZA equivalent*	$/bbl	57	37	47

*Corrected by API difference(-3$/bbl)

3.2.7 Product Sales Price

(1)Petroleum Product Price

Products price of each product are estimated by following chart, which is based on actual number in US gulf.



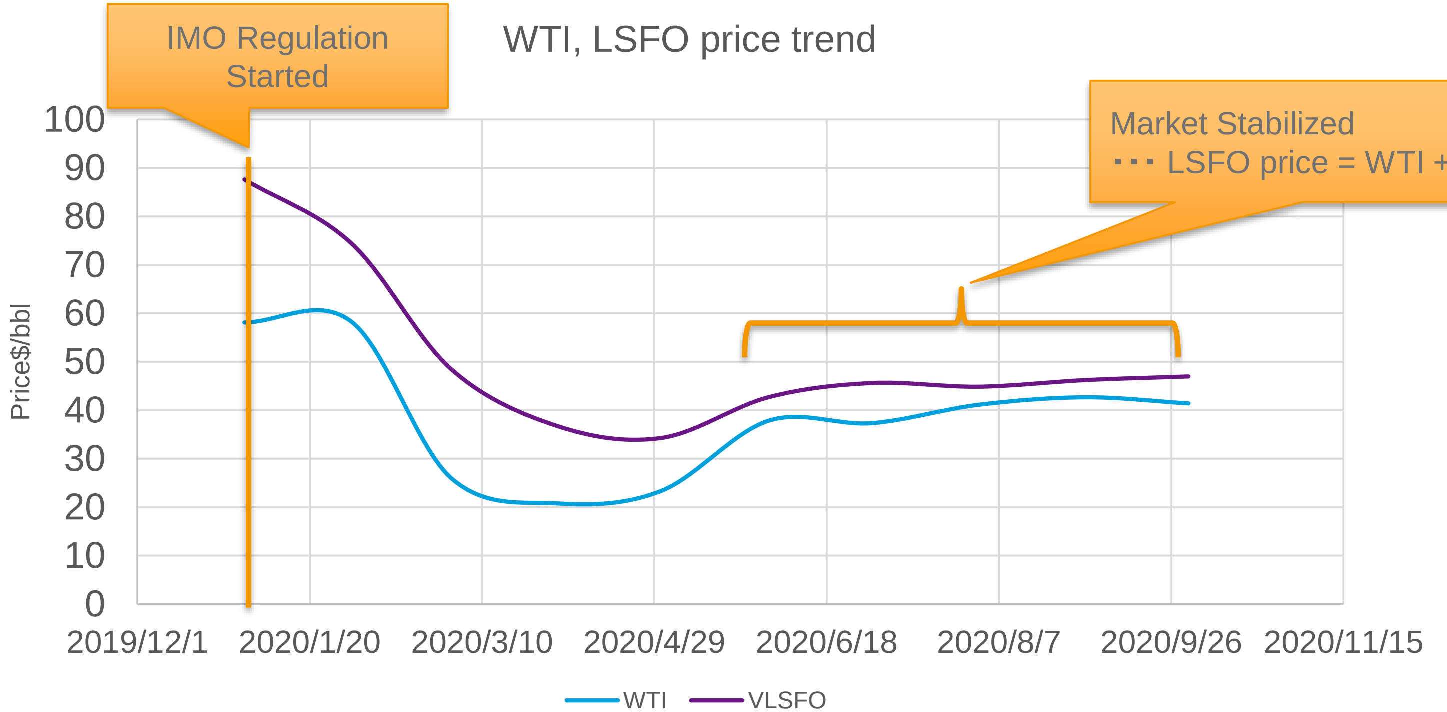
*Reference: Oil Market Intelligence(2015～)

3.2.7 Product Sales Price

(2)Bunker Fuel Price

After Jan. of 2020, Bunker Fuel oil which meet to IMO regulation(0.5% sulfur contents) started to be traded. So bunker fuel oil shall be revised by actual price in 2020.

Chiyoda estimates that latest price is suitable for Master plan study, because early value has high spread because quickly replace.

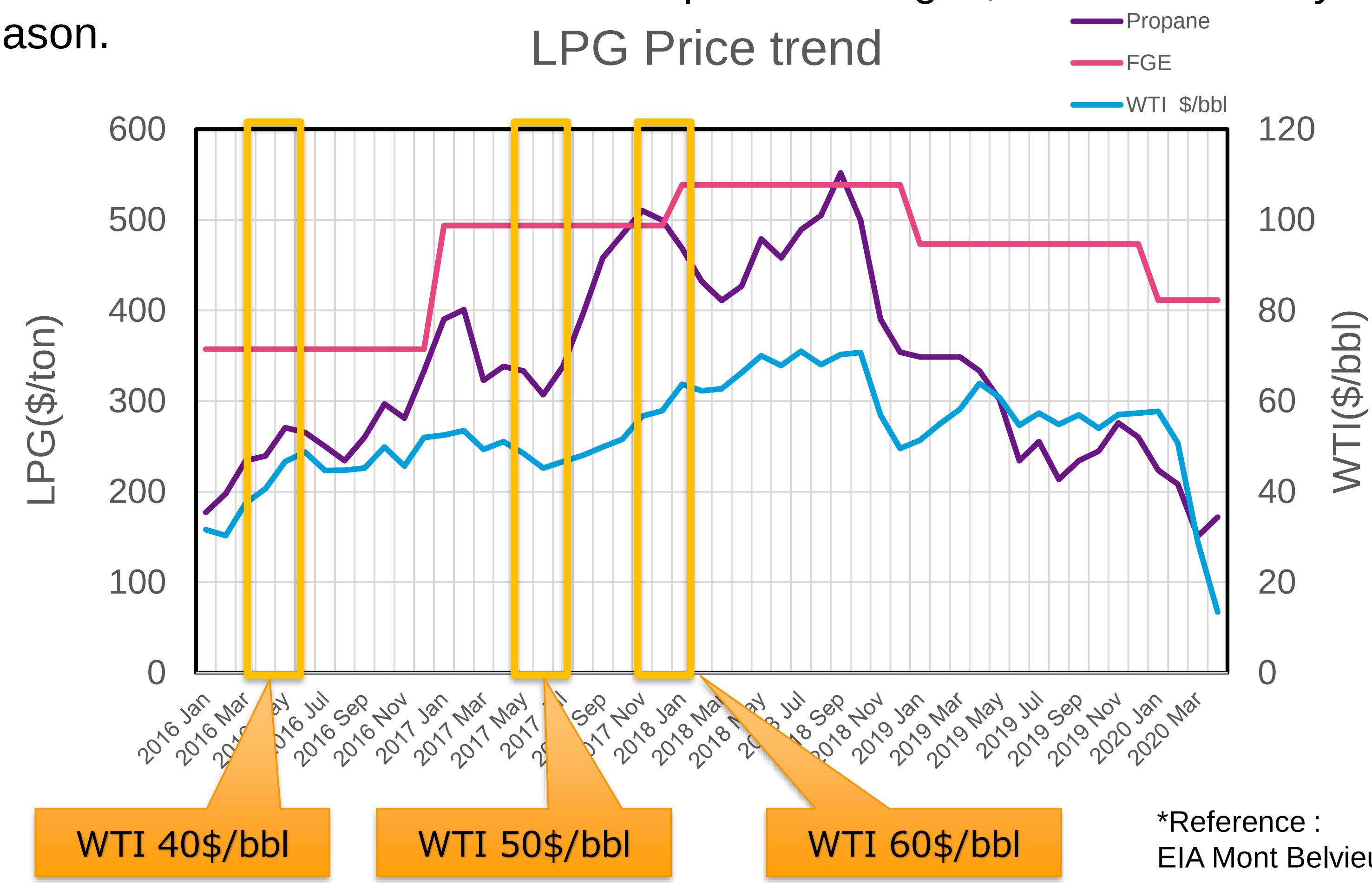


https://shipandbunker.com/prices/am/usgac/us-hou-houston#VLSFO

(3)LPG Price

LPG(Propane, US gulf) and WTI trends are shown as follows.

It has moderate correlation with WTI price in US gulf, even affected by the season.



*Reference :
EIA Mont Belvieu LPG price

3.2.7 Product Sales Price

(4)Price Summary

Product sales price to be proposed as follows based on above price trends.
Chiyoda will execute economics study in following 3 Cases.

	Base Price Case	Low Price Case-1	Low Price Case-2
Crude oil (WTI)	60 $/bbl	50$/bbl	40$/bbl
LIZA equivalent	57$/bbl	47 $/bbl	37$/bbl
Product price @US Gulf			
Gasoline	74$/bbl	65$/bbl	56$/bbl
JET	73$/bbl	63$/bbl	52$/bbl
Diesel	74$/bbl	63$/bbl	53$/bbl
FO(LS/HS)	64$/bbl / 53$/bbl	54$/bbl / 45$/bbl	43$/bbl / 36$/bbl
LPG	600$/bbl	400$/ton	300$/ton

3.2 Refinery Plan
3.2.8 Economics Evaluation

(1)Economics Study Basis

- Economic evaluation is performed by cash flow analysis.
- Economic viability is evaluated by **IRR(Internal Rate of Return).**
- Financial parameters for IRR calculation is as follows:

Item	Input Data	Remark
Refinery Scheme	Scheme-1, Scheme-2, Scheme-3	
Plant Operation Period	20 years	
Depreciation Period	10 years by liner depreciation	
Ratio of Equity and Loan	Equity: 40%, Loan: 60%	
Interest of Loan	3%	
Loan Period	20 years	
Inflation	No inflation is considered	
Income Tax	30%	
Property Tax	2.0%	

(2)Study Result Summary

Base Price Case (WTI 60$/bbl) — **Refinery Scheme**

	IRR%	Scheme-1	Scheme-2	Scheme-3
Demand	Reference Demand Case	5.1	14.2	14.7
	High Demand Case	8.2	17.2	18.0

Low Price Case-1 (WTI 50$/bbl) — **Refinery Scheme**

	IRR%	Scheme-1	Scheme-2	Scheme-3
Demand	Reference Demand Case	5.3	15.8	16.4
	High Case	11.6	18.9	19.8

Low Price Case-2 (WTI 40$/bbl) — **Refinery Scheme**

	IRR%	Scheme-1	Scheme-2	Scheme-3
Demand	Reference Demand Case	11.7	17.4	18.0
	High Case	14.9	20.6	21.6

(3)Reference Demand Case Study Result

		Scheme-1 Base	Scheme-2 LSFO	Scheme-3 RFCC
Refinery Capacity*	bpsd	15,000	15,000	15,000
Total Investment	mmUSD	217	344	543
-On-site	mmUSD	123	253	418
- Util. Off-site	mmUSD	37	33	45
- Owner's cost, working capital	mmUSD	57	59	80
OPEX	mmUSD/year	8.0	14.3	23.1
IRR(equity)	%	5.1	14.2	14.7

3.2.8 Economics Evaluation

(4)High Demand Case Study Result

		Scheme-1 Base	Scheme-2 LSFO	Scheme-3 RFCC
Refinery Capacity*	bpsd	20,000	20,000	20,000
Total Investment	mmUSD	258	411	648
-On-site	mmUSD	148	303	503
- Util. Off-site	mmUSD	44	40	55
- Owner's cost, working capital	mmUSD	66	68	90
OPEX	mmUSD/year	9.6	17.1	27.9
IRR(equity)	%	8.2	17.2	18.0

3.2.9 Conclusion Remarks

① **Modular refinery can be applied into Guyana.**

- Modular refinery is appropriate for balancing supply and demand of petroleum product in Guyana. It will help improvement of foreign currency balance.

② **In order to upgrade atmospheric residue, addition of treatment facilities are economically viable.**

- Atmospheric residue should be treated by upgrading process, AR-HDS.
- AR-HDS process can reduce sulfur contents in residue and produce low sulfur fuel oil, which satisfies for IMO regulation

③ **Installing further residue upgrading facilities, refinery can improve the economical viability.**

- Integrating with additional processes (RFCC), refinery will enjoy more attractive economic viability.
- RFCC process can convert residual fraction to high value products such as gasoline and diesel, which is very robust for refinery profit and makes import/export balance good.

3.2.9 Conclusion Remarks

④ **The refinery should be located next to existing oil terminal.**

- Modular refinery should be located close to existing oil terminal, so that investment of off-site and distribution system can be minimized.

⑤ **Stable and robust economics of refinery project can be expected.**

- With Stable Spread between crude oil and oil product, Modular Refinery must expect robust economics, which will help Guyana Government's FID.

Chapter 4
Concluding Remarks

4.1 Overview of Oil & Gas Master Plan

(1) Overview

The update study of oil and gas master plan for Guyana has been carried out from May, 2020 to February, 2021. This follows Phase 1 master plan study in 2017 to 2018 and Phase 2 study in 2019.

The update study covers higher demand and lower price cases in addition to Phases1 and 2 studies. As the results of the studies, promising solutions to utilize Guyana's indigenous oil and gas have been developed.

As gas utilization solutions,

- **Gas power plant** (onshore or floating, 90MW + stepwise development) and
- **FLNG plant** (1.2mtpa + stepwise development)

As oil utilization solutions,

- **Modular refinery** (15,000 / 20,000 bpd) empowered by additional upgrading processes

4.1 Overview of Oil & Gas Master Plan

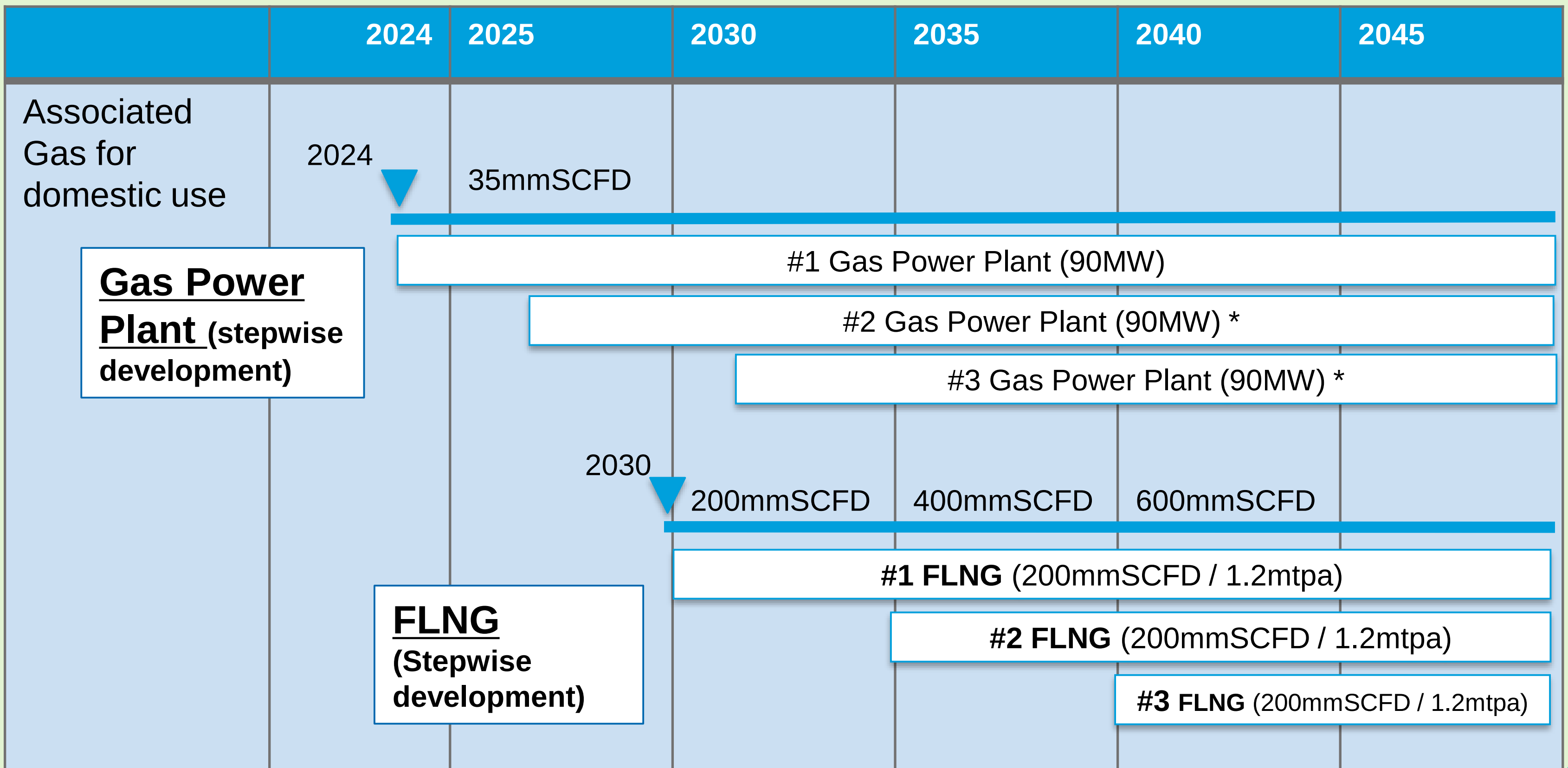
(2) Attainment of objectives

The above-shown solutions can attain the objectives of master plan as shown below.

- ✓ **Well-balance** of domestic use and exporting
  - For domestic use, gas power plant and modular refinery will contribute, and
  - For exporting, FLNG will contribute the development of Guyana.
- ✓ Development of **domestic industry**
  - Gas power plant and Modular refinery will activate the employment and domestic industry during the construction and operation
- ✓ **Harmonization** with “Clean and Green Guyana Vision”
  - Gas power plant will harmonize the gas power and the renewable power in Guyana.

4.2 Roadmap of gas and oil utilization

① Gas utilization solutions



*** Gas power stepwise development depends on the progress of renewable power development.**

4.2 Roadmap of gas and oil utilization

② Oil utilization solution

	2024	2025	2030	2035	2040	2045
Crude oil for domestic use **Refinery** **for domestic use**		2027 ▼	15,000/20,000 bpd			
		Modular Refinery (15,000 / 20,000 bpd)				

*** Refinery capacity depends on the future oil demand in Guyana.**

4.3 Concluding Remarks
4.3.1 Gas to Power Plan

① **Gas to Power solution is economically viable for Guyana.**

- Gas to Power solution is observed to be economically viable.
- Phased development will be preferred in view of economics.

② **Significant difference is not observed between onshore and floating solutions.**

- No significant difference is observed in economics between onshore and floating gas to power plans.
- The selection will depend on the site conditions, complexity of permissions, man-powers in the country, etc.

③ **Economical viability is sensitive to fuel gas price.**

- Economical viability is more sensitive to fuel gas price than the other parameters, CAPEX and OPEX.

4.3 Concluding Remarks
4.3.1 Gas to Power Plan

④ Optional plan could be considered in case of renewable energy shift.

- In case energy shift to renewable is achieved to be renewable 65% of power supply in 2035, the additional power capacity by gas are necessary only for several years after oil power is closed.
- Effective solution may be;
  - ✓ Lease of floating power plant for the duration, instead of construction of new power plant,
  - ✓ Extend of oil power plant shut down, etc.

⑤ Excess gas option

- In the early phase of gas introduction for gas to power and when renewable plan is achieved, the excess gas for power will be expected 25mmSCFD at maximum.
- Fertilizer production is a possible option to use the excess gas, but the amount of excess gas is not sufficient for internationally competitive production.
- When LNG production is started, the excess gas can be fed to LNG plant.

4.3 Concluding Remarks
4.3.2 Gas to LNG Plan

① **As Gas to LNG plan, offshore FLNG looks the most preferable solution for Guyana.**

- Considering Guyana's geotechnical characteristics, offshore FLNG looks most preferable solution for Gas to LNG.

② **Phased Development is more attractive.**

- Phased development with smaller scale FLNG will be more appropriate than medium or large scale FLNG.

③ **South America-East, West and Europe are preferable destination markets for Guyana LNG**

- From the viewpoint of shipping, South America-East, West and Europe are more preferable than Japan, assuming the LNG selling price be the same.

④ **Economic viability of Gas to LNG is sensitive to LNG selling price in the market.**

- The economics of Gas to LNG plan is highly sensitive to the LNG selling price in the destination market.
- Even if the feedstock gas price is lowered, lower selling price of LNG would deteriorate the economics.

4.3.2 Gas to LNG Plan

⑤ **Economics is sensitive to CAPEX, however, Conversion FLNG may be attractive but challenging.**

- Conversion FLNG may be an attractive option in view of lower CAPEX, but it is challenging to accommodate multiple products production and storage in/on the FLNG, and higher shipping cost.

4.3.3 Refinery Plan

① **Modular refinery can be applied into Guyana.**

- Modular refinery is appropriate for balancing supply and demand of petroleum product in Guyana. It will help improvement of foreign currency balance.

② **In order to upgrade atmospheric residue, addition of treatment facilities are economically viable.**

- Atmospheric residue should be treated by upgrading process, AR-HDS.
- AR-HDS process can reduce sulfur contents in residue and produce low sulfur fuel oil, which satisfies for IMO regulation

③ **Installing further residue upgrading facilities, refinery can improve the economical viability.**

- Integrating with additional processes (RFCC), refinery will enjoy more attractive economic viability.
- RFCC process can convert residual fraction to high value products such as gasoline and diesel, which is very robust for refinery profit and makes import/export balance good.

4.3.3 Refinery Plan

④ **The refinery should be located next to existing oil terminal.**

- Modular refinery should be located close to existing oil terminal, so that investment of off-site and distribution system can be minimized.

⑤ **Stable and robust economics of refinery project can be expected.**

- With Stable Spread between crude oil and oil product, Modular Refinery must expect robust economics, which will help Guyana Government's FID.

4.4 Way Forward of Oil & Gas Master Plan

Phase 2 Master Plan Study (May, 2019 – November, 2019)
Update study of Master Plan (May, 2020 – February, 2021)

↓

Selection of Project(s) for Feasibility Study (Decision by Guyana Government)

↓

Feasibility Study

Feasibility Study of selected project(s) → Decision by Guyana Government: **Selection of Project(s) for FEED**

↓

FEED

FEED (Front End Engineering Design) → Decision by Guyana Government: **FID**

Thank you