17th INTERNATIONAL CONFERENCE & EXHIBITION ON LIQUEFIED NATURAL GAS (LNG 17)

MINIMIZING THE CO_2 EMISSION FROM LIQUEFACTION PLANT

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17 April, 2013

International Organizers

Host Association

1.Introduction

- The 1st generation LNG power chain for Japan started with gas supplies from Alaska Kenai LNG, Brunei LNG and ADGAS LNG, and resulted the planned air pollution reduction has been successfully achieved.
- Reduction of CO_2 emission to solve global warming
- After the Fukushima Daiichi Nuclear Power Station accident caused by the March 11, 2011 tsunami, LNG will be a solution for reduction of CO_2 emission

Reduction of CO_2 Emission from Liquefaction Plant

- Acid gas removal and carbon capture and storage (CCS)
- Optimizing the liquefaction system.
- Minimizing the flare load during train start-up and shut down
- Optimizing the prime mover system, including e-drive
- Carbon capture and storage (CCS) from the flue gas of the plant

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2. Study Basis (1/2)

- Plant Location: Oceania
- Feed Gas Composition:

Component	Mol%
CO_2	1.0
N2	0.1
C1	86.5
C2	8.2
C3	3.4
C4	0.8
C5	0.0

- Feed Gas Condition
  – Pressure: 70bar
  – Temperature: 27deg.C
  – An air cooling system was used for the plant

2. Study Basis(2/2)

- Feed Gas Price: 2/4/6 US$/mmbtu
- Plant Capacity: 9-10MTA by 2 trains
- Liquefaction Process: C3-MR Process
- Delivery Pressure of CCS: 150bar
- CO_2 Price for EOR: 40 US$/t$CO_2$
- Carbon Tax for CO_2 Emission: 16-154 US$/t$CO_2$

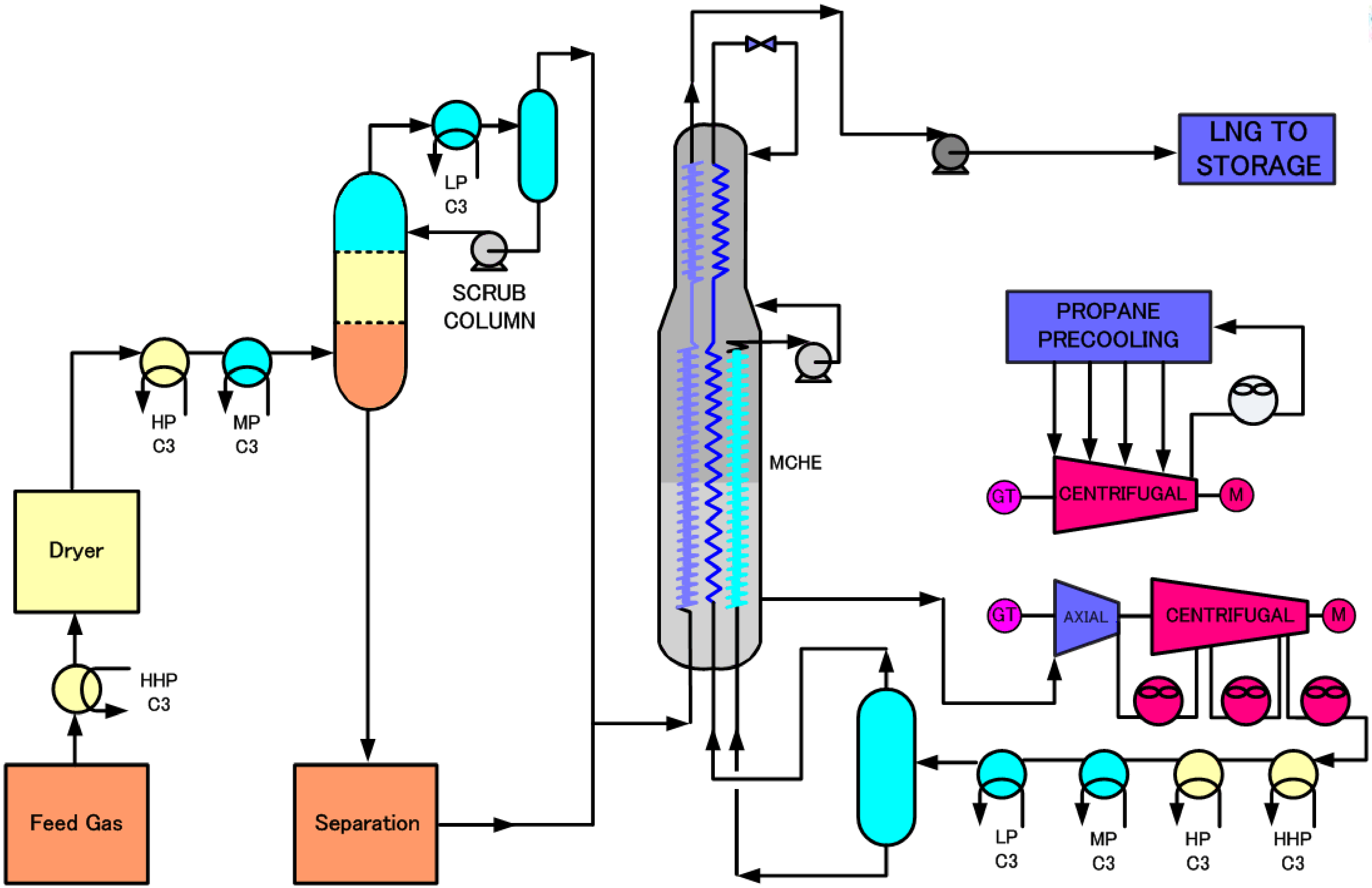

Fig. 2.1 Typical C3-MR Process Flow Diagram

Table 2.1 Carbon Tax Example

Country	Currency	Carbon Tax, Currency/tCO_2	Currency/ US$	Carbon Tax US$/$tCO_2$
Finland	euro	20	1.318	26.4
Sweden	SEK	1,010	0.153	154.2
Norway	NOK	371	0.179	66.3
Denmark	DKK	90	0.177	15.9
Australia	A$	23	1.037	23.8

3. Study Result

3.1 Acid Gas Removal (AGR) and Carbon Capture and Storage (CCS)

3.2 Optimizing the liquefaction system

3.3 Minimizing the Flare Load

3.4 Driver Option

3.5 Comparison of Fuel CO_2 Emission

3.6 CCS Costs Estimation for Fuel CO_2

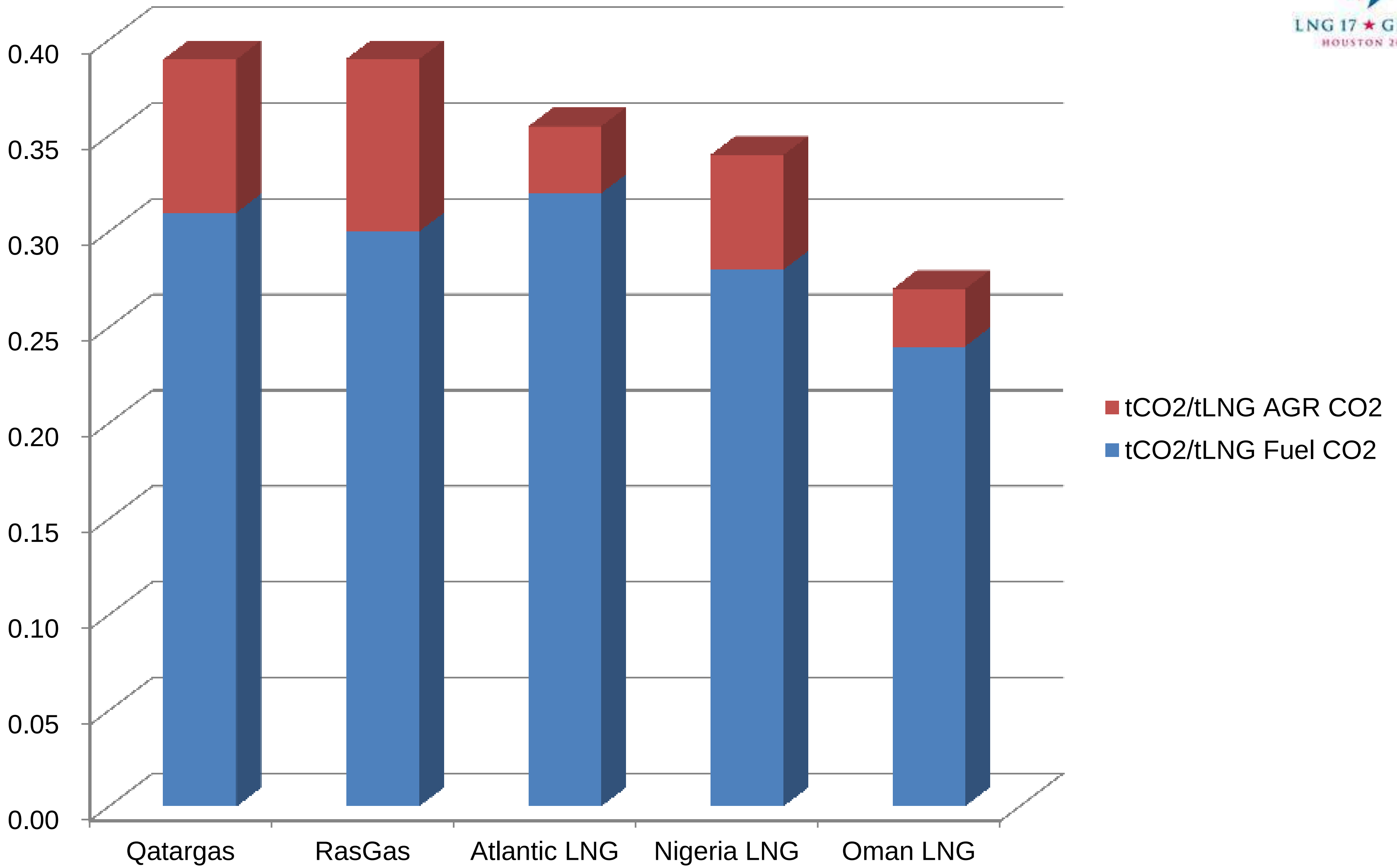

Fig. 3.1 tCO_2 Emission /tLNG from Operating LNG Plant

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3.1 Acid Gas Removal (AGR) and Carbon Capture and Storage (CCS)

- 4 Stage Compression
- Dehydration at the 4th Stage Inlet
- CCS Cost
  - Additional Equipment Costs
  - Additional Fuel Cost

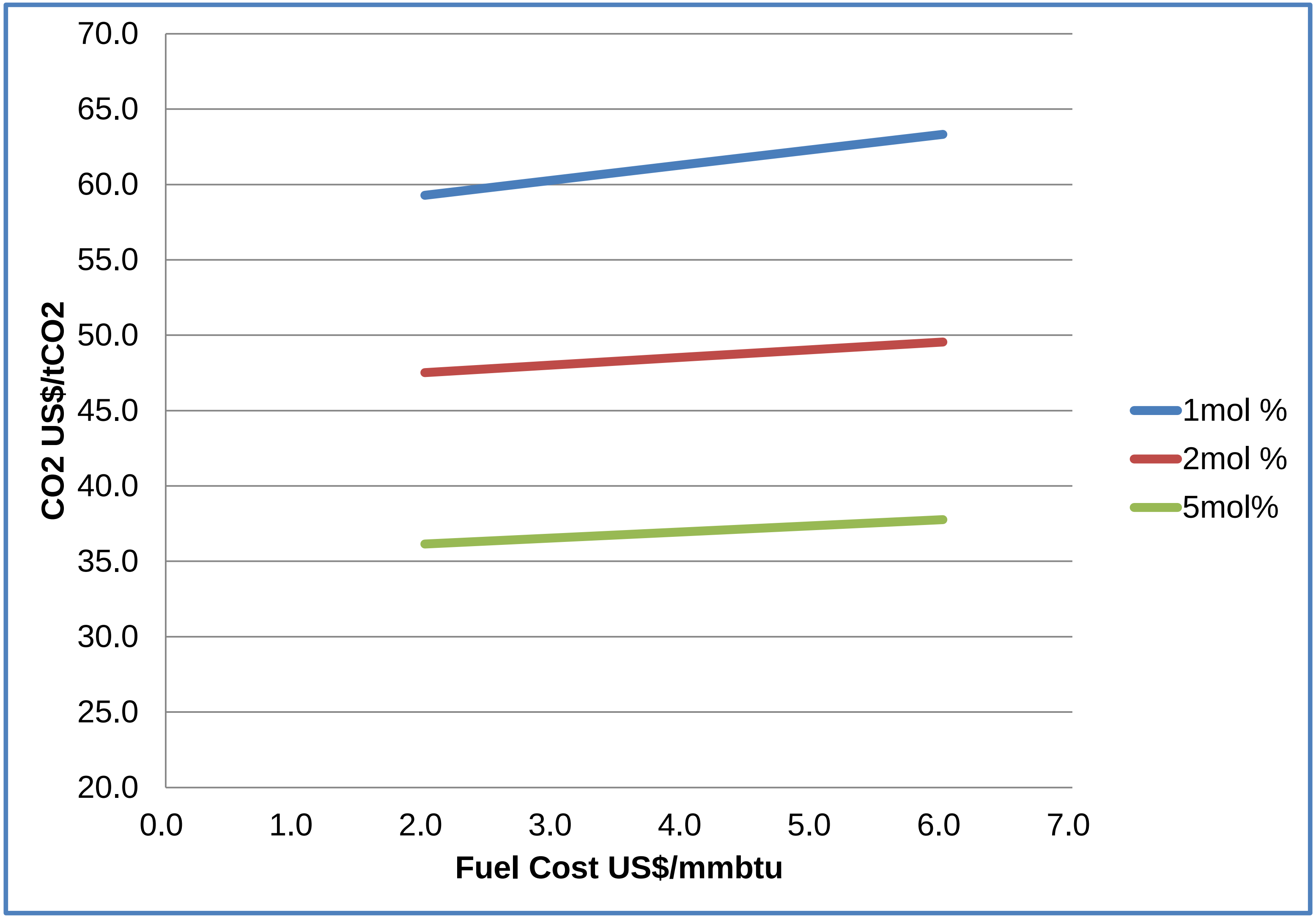

Fig.3.2 AGR CO_2 CCS Cost

3.2 Optimizing the liquefaction system – Turbo-Expander Application

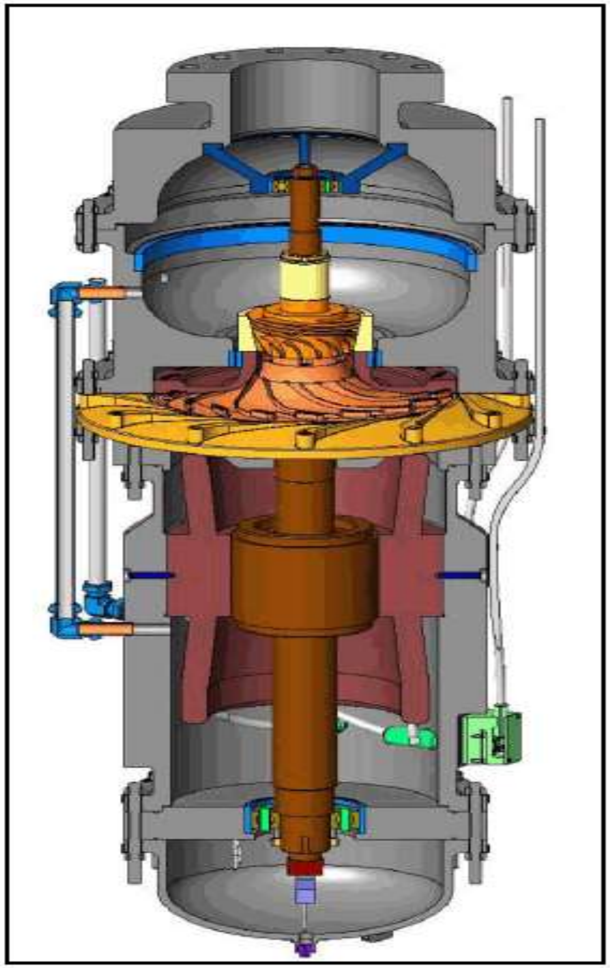

Fig.3.3 Cross section of Two-Phase Expander

Ref: Kikkawa et. al."Completing the Liquefaction Train by Using Two-Phase LNG Expanders" AIChE Spring Meeting, Tampa, Florida, USA, Apr.27-30 2009

Table 3.1 Expected Cycle Efficiency Improvement

Expander Location	Liquid Expander	Two-Phase Expander
LNG	2.5%	3.0%
Light MR	0.5%	0.7%
Heavy MR	2.2%	2.8%

Wet Surface Air Cooler (WSAC) Application

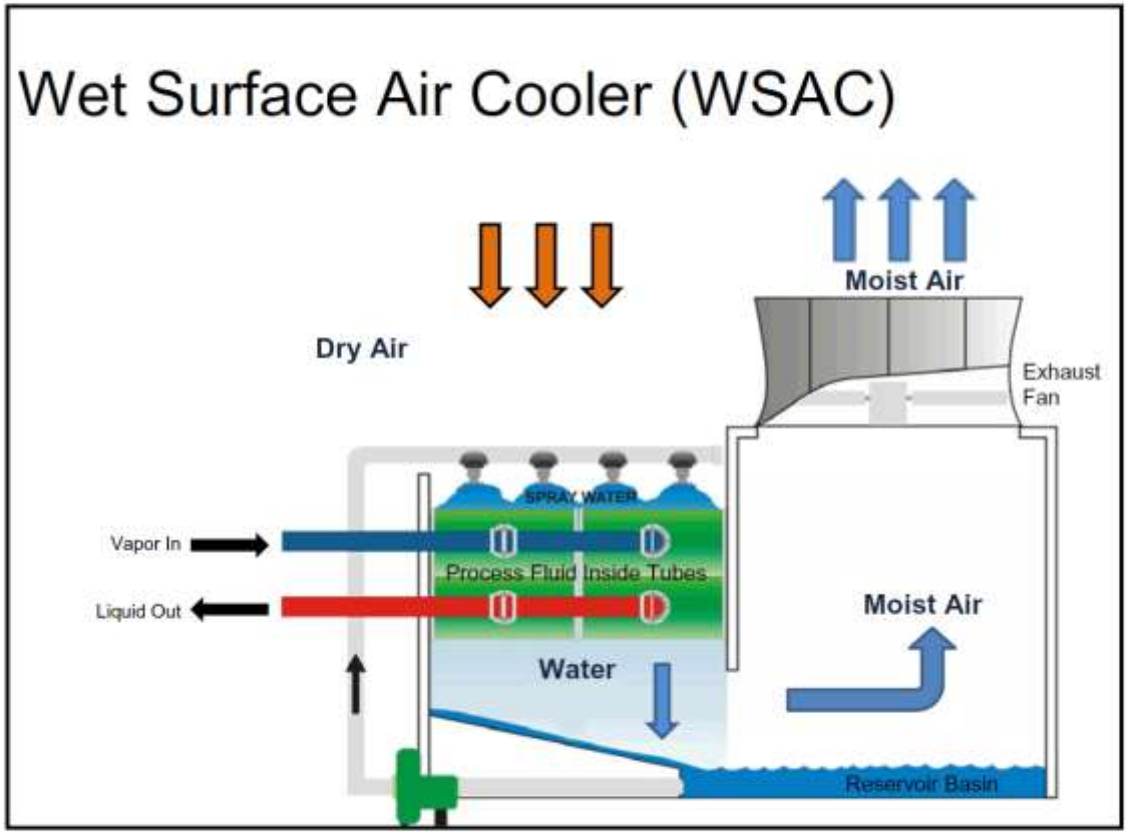

Fig. 3.4 WSAC Flow Diagram

Ref: Kuo, J. C. et. al., "49e. New Cooling Application: Total Heat Removal from Base Load LNG Plant", AIChE Spring Meeting, Chicago, IL, Mar. 13-17, 2011

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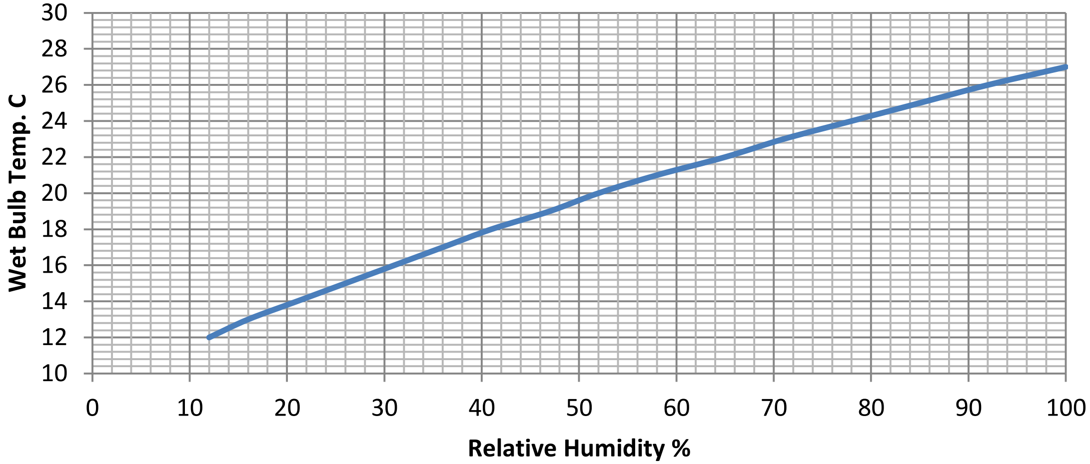

Fig.3.5 Wet Bulb Temperature vs. Relative Humidity @ 27 deg.C

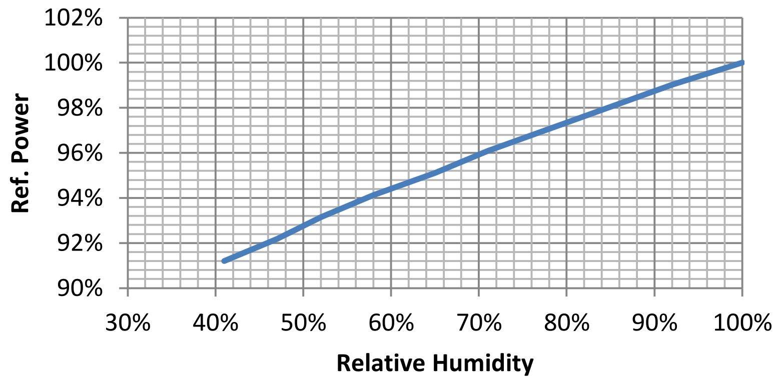

Fig.3.6 Ref. Power vs. Relative Humidity of Air for WSAC Application

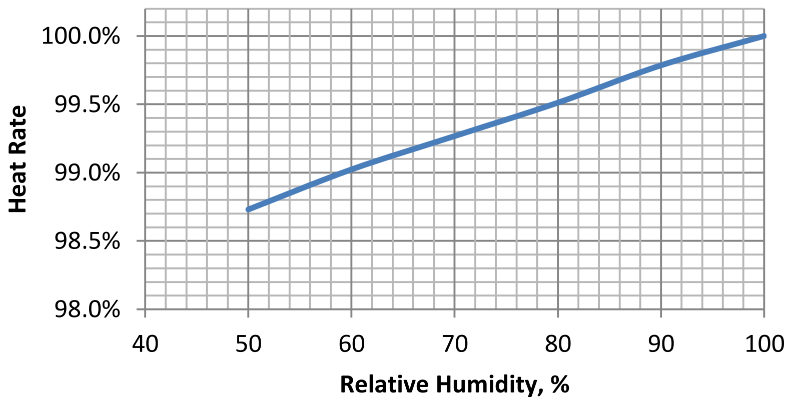

Fig.3.7 Heat Rate vs. Relative Humidity of Air for GE Frame 7

3.3 Minimizing the Flare Load

(a) Start-up and Scheduled Shut Down

(b) Flare Load from Relieving Device

3.4 Driver Option

Table 3.2 Performance of Gas Turbine by GE

Name	GE Model	Type	ISO Power (MW)		Thermal Efficiency
			GT	ST	
LM2500	LM2500+G4	Aero	31	-	40.4%
LMS100	LMS100	Aero	100	-	43.7%
Frame 6	Frame6B	Heavy Duty	42	-	32.1%
Frame7	Frame7EA	Heavy Duty	86	-	32.7%
Frame9	Frame9E	Heavy Duty	130	-	33.1%
S106B	S106B	Combined Cycle	38	22	49.0%
S106FA	S106FA	Combined Cycle	67	42	52.9%
S109E*	S109E	Combined Cycle	123	70	53.0%

*Note: The Option 3 configuration is based on this type.

Table 3.3 Driver Configuration for Driver Options

Case	C3 Compressor Driver	MR Compressor Driver	CCS
Option 1	Frame 7 (C3+HP MR)	Frame 7 (LP +MP MR)	No
Option 2	LMS100 (C3+HP MR)	LMS100 (LP +MP MR)	No
Option 3	Steam Turbine	Frame 9	No
Option 4	Motor	Motor	No
Option 5	Motor	Motor	Yes

OPTION−1
Compressor and Driver Configuration

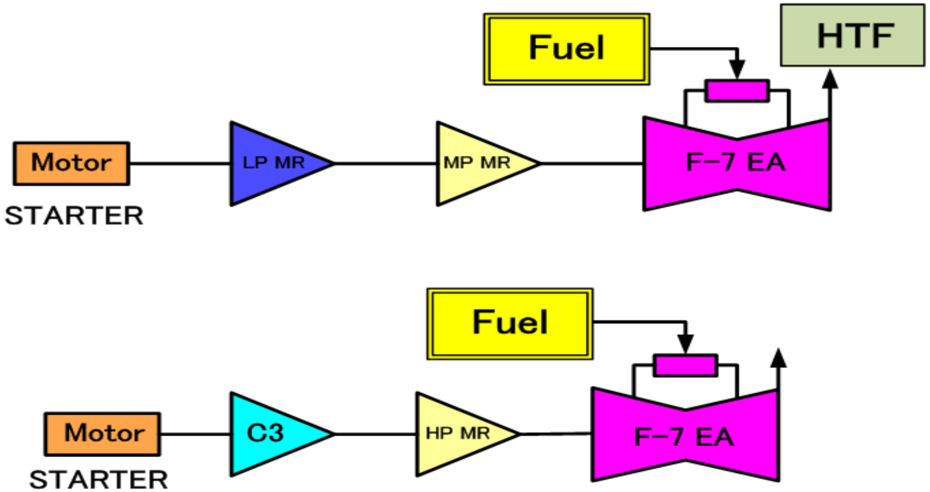

Fig.3.8 Option-1 Configuration

OPTION−2
Compressor and Driver Configuration

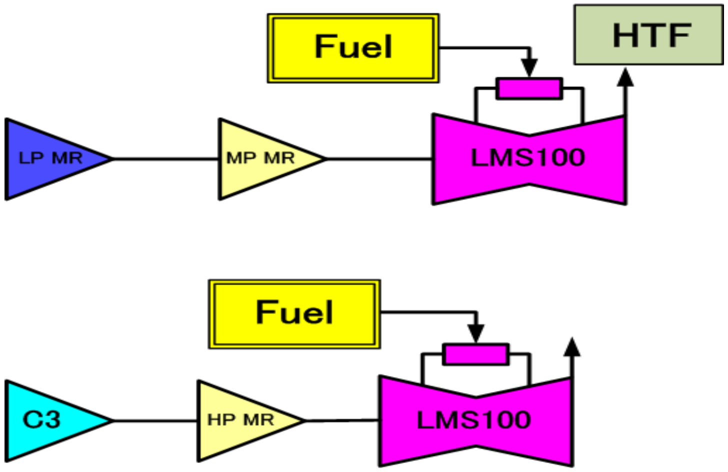

Fig.3.9 Option-2 Configuration

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OPTION-3

Compressor and Driver Configuration

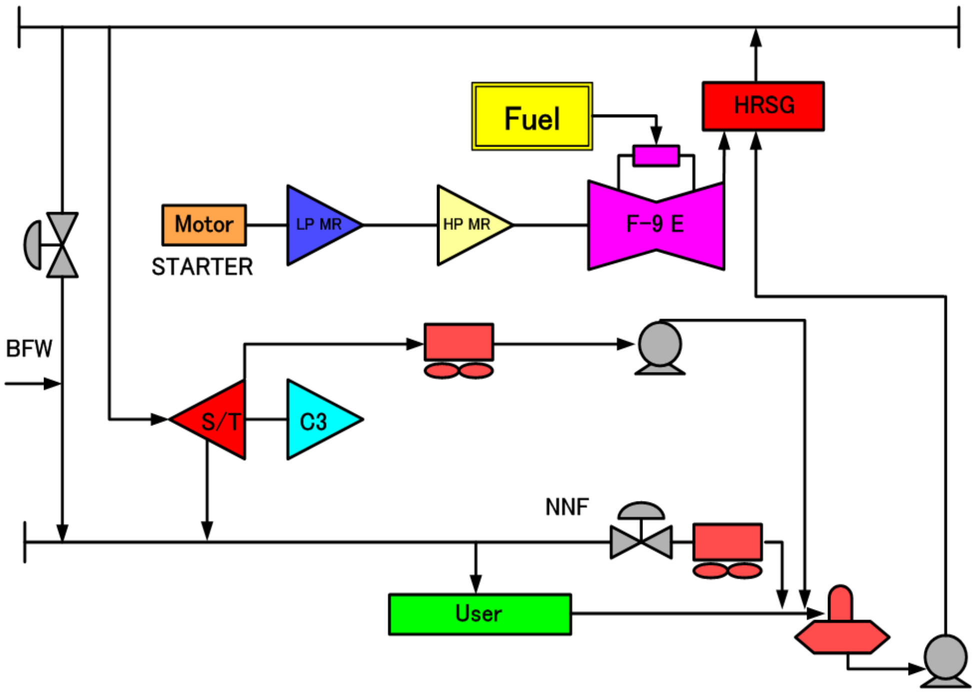

Fig.3.10 Option-3 Configuration

OPTION-4

Compressor and Driver Configuration

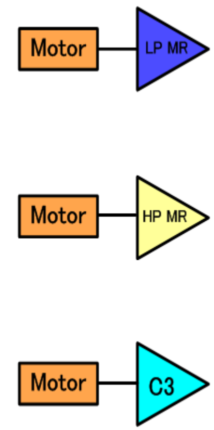

Fig.3.11 Option-4 Configuration

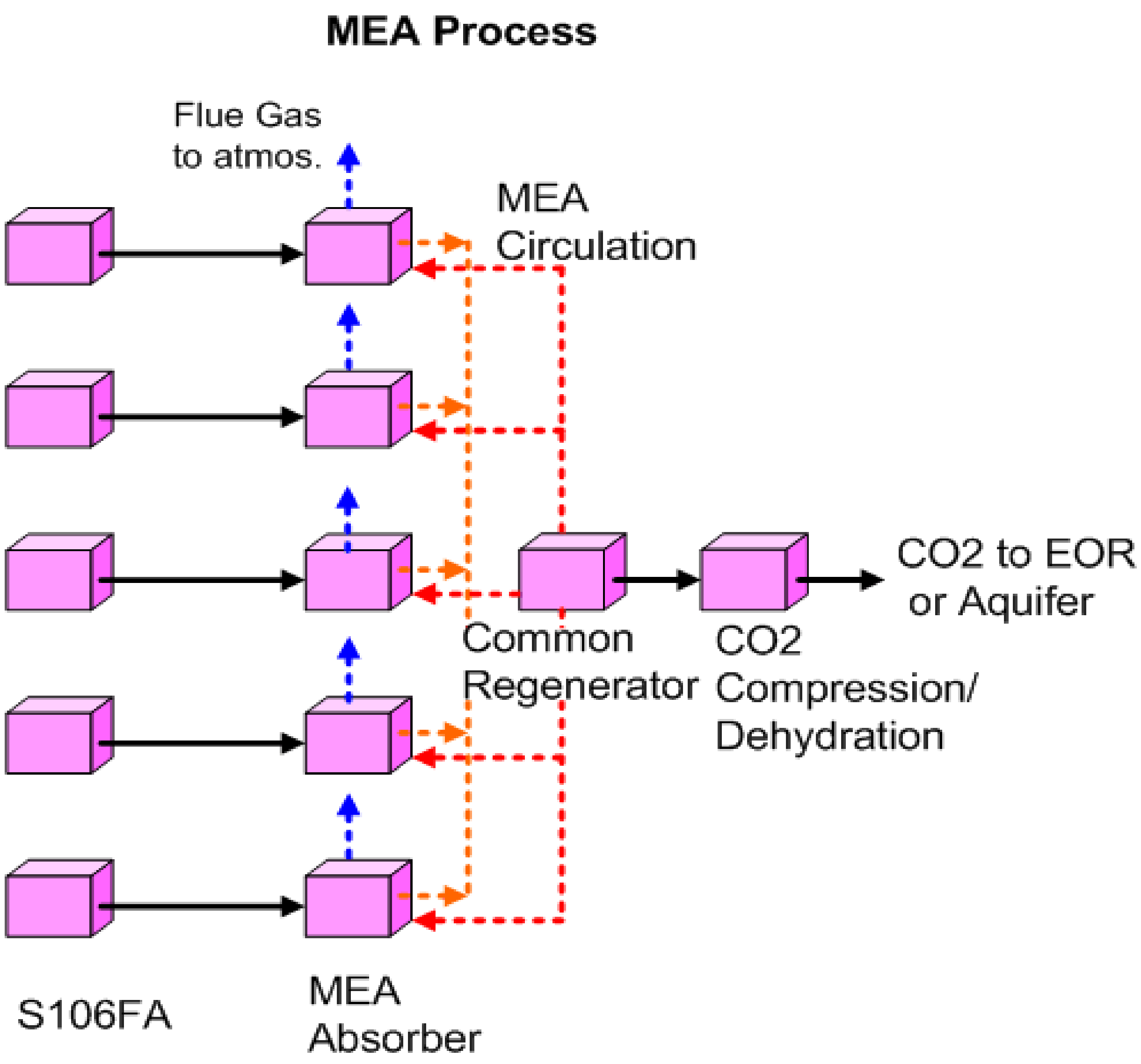

Fig. 3.12 Process Configuration for Fuel CO_2 CCS

Table 3.4 Power Plant Configurations for Driver Options

Case	Operation	Stand-by	Remarks
Option-1	Frame 6 x3	Frame 6 x1	
Option-2	LM2500+ x 4	LM2500+ x1	
Option-3	S106B x2 +Frame 6	Frame 6 x1	
Option-4	S106FA x4	S106FA x1	
Option-5	S106FA x5	S106FA x1	

3.5 Comparison of Fuel CO_2 Emission

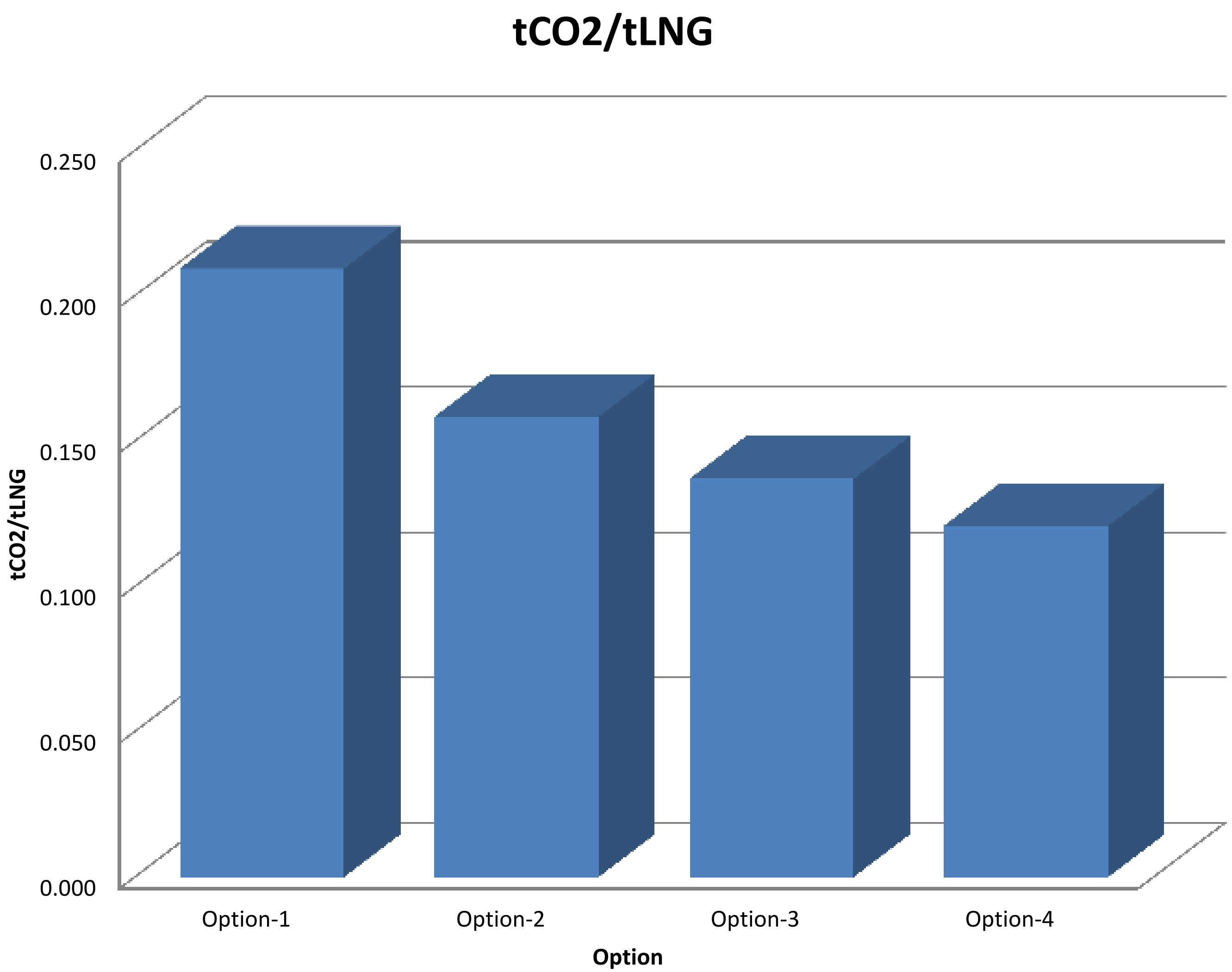

Fig. 3.13 Fuel CO_2 per ton LNG

3.6 CCS Costs Estimation for Fuel CO_2

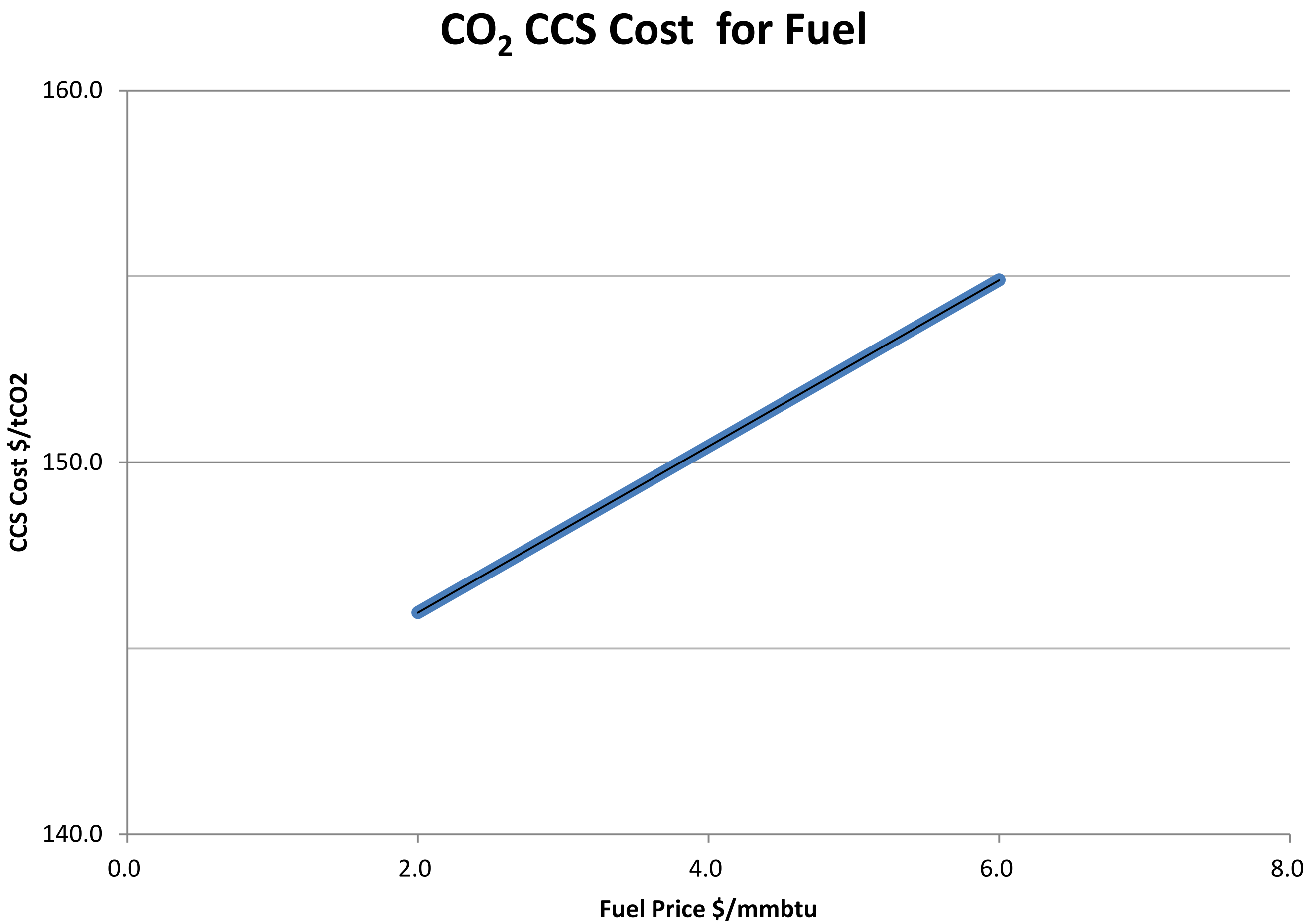

Fig.3.14 CO_2 CCS Cost for Fuel CO_2

4. Conclusion and Future Consideration

- Wide options to address the reduction of CO_2 emissions from the liquefaction plant towards zero.
- The AGR CCS will be reasonably justified when EOR operation is located near the LNG plant. Increasing the thermal efficiency of the driver system will be reasonably justified by reduction of the fuel requirement. However, the CCS of fuel CO_2 will be difficult to justify even where EOR can be used at the location.
- In Future, the CCS of fuel CO_2 will be performed at the LNG plant site if the social/government requests further reduction.