

Feasibility Study of CO₂ to Chemical Plant in Saudi Arabia

Executive Summary

Aug 2021

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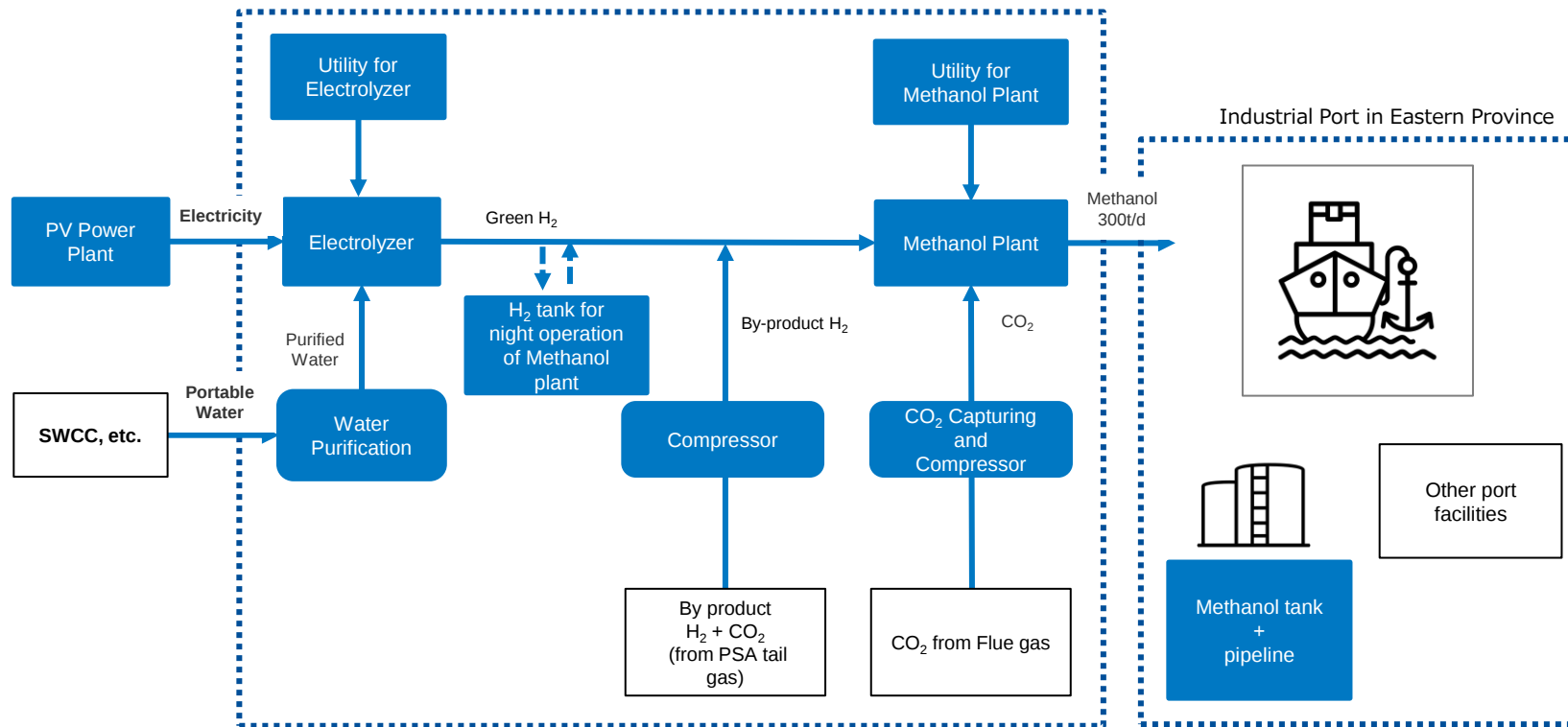
Purpose of Study

The purpose of this study is to clarify the economical & technological feasibility of the CO₂ to Chemical plant project in Saudi Arabia, after conducting a Conceptual Design of the project.

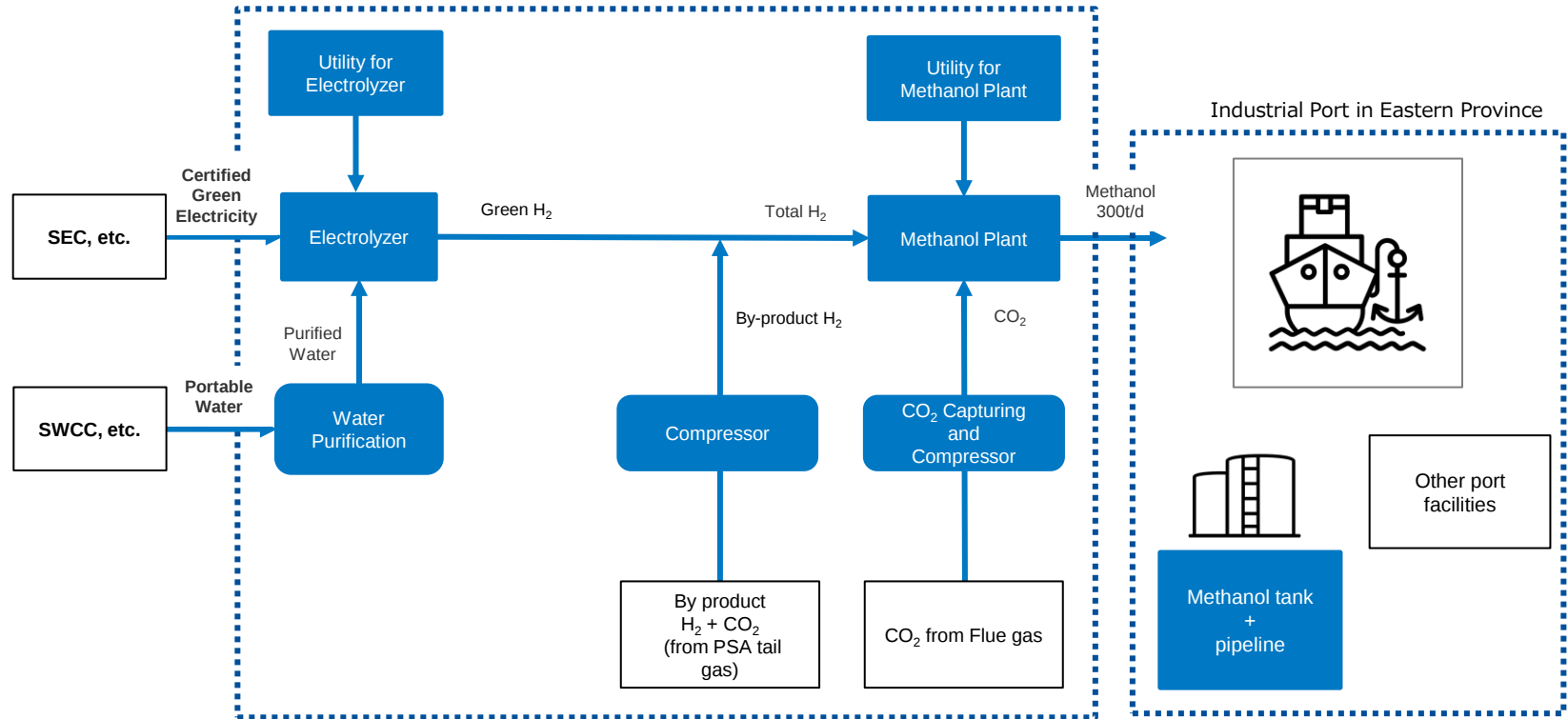
Contents of the Study

- Information collection, investigation, analysis, etc. necessary for the conceptual design of a CO₂ to Chemical (methanol production) plant
 - Conceptual Design of CO₂ to Chemical Plant
 - Feasibility Study of CO₂ to Chemical Plant
- 
- Scope of this executive summary

Entire Picture of the Plant for Case 1



Entire Picture of the Plant for Case 2



Plant Outline

		Case1	Case 2
Location			
	Electrolyzer, Methanol Plant, etc.	Eastern Province	
	PV Power Plant	Northwestern Area	–
Methanol Production			
	Annual Production Capacity	100,000t (300t/d)	
	Furnace	MRF-Z®	
	Catalyst	RITE Catalyst (incl. ZrO ₂)	
	Raw Material	CO ₂ , H ₂ (Green H ₂ : By Product H ₂ = 1 : 1)	
	Green Spec	Methanol with net 0 emission of CO ₂ : “Carbon Neutral Methanol”	
Procurement of Electricity for Electrolyzer			
	Procurement Methodology	Build PV Power Plant	Purchase Green Certified Electricity
	Capacity of Power Generation	243MW	–
	Volume of Green Certified Electricity to be purchased	–	70MWh/h
Procurement of CO ₂			
	Volume of Procurement	435t/d	
Production & Procurement of H ₂			
	Necessary Volume H ₂ in total	28,000Nm ³ /h	
	Necessary Volume of By-Product H ₂	14,000Nm ³ /h	
	Capacity of Electrolyzer	242,750kW	70,000kW
	H ₂ Production Capacity	48,550Nm ³ /h	14,000Nm ³ /h
	Applied Technology	Alkaline	
	Necessary Volume of Purified Water	Appx. 105,000m ³ /y	
	Procurement of Portable Water	Purchase portable water, then purify in a water treatment facility inside the plant	
	Volume of By-Product O ₂	135,000t/y	

Balance of CO₂ utilization & emission

					Source
Final product		Methanol	a	100,000 t/y	Pre-condition
Utilization / CO ₂		Necessary volume of CO ₂ for methanol production	b	1.446 t-CO ₂ /t-Methanol	Study Team analyzed
		Annual treatment volume of CO ₂ , c=a*b		144,589 t/y-CO ₂	
Emission / CO ₂	1	Volume of By-product H ₂	d	9,935 t-y-H ₂	Study Team analyzed
		CO ₂ Emission formula of Gray H ₂ (ton base)	e	9.56 t-CO ₂ /t-H ₂	Study Team analyzed
		CO ₂ emission count of By-product H ₂ utilization	f=d*e	94,993 t/y-CO ₂	
	2	Electricity consuming amount of Methanol plant operation	g	51,148,800 kWh/y	Study Team analyzed
		CO ₂ emission formula of Gas fired PP	h	0.000415 t-CO ₂ /kWh	Ministry of Environment of JPN
		CO ₂ emission count of electricity consuming by Methanol plant operation	i=g*h	21,227 t/y-CO ₂	
	3	Fuel gas consuming for boiler in Methanol plant	j	503,496 mmbtu/y	Study Team analyzed
					Refer to EIA information: https://www.eia.gov/environment/emissions/co2_vol_mass.php 53.07kg-CO ₂ /MMBTU =0.05307t-CO ₂ /MMBTU
		CO ₂ emission formula of Natural gas itself	k	0.05307 t-CO ₂ /MMBTU	
		CO ₂ emission count of NG consuming by Methanol plant operation	l=j*k	26,721 t/y-CO ₂	
		Total emission count	m=f+i+l	142,941 t/y-CO ₂	
Balance		Total emission - Utilization amount	n=m-c	-1,648 t/y-CO ₂	

Summary of CAPEX

Major facility/component	Case 1		Case 2	
	Capacity	CAPEX	Capacity	CAPEX
PV power plant (recalculated and capacity increased)	243 MW		-	
Electrolyzer (\$1,000/kW) (recalculated)	242.7MW		70MW	
Hydrogen tank (recalculated)	206,000Nm3		-	
Utility for Electrolyzer	Water cooling system, N ₂ generation		Water cooling system, N ₂ generation	
Water Purification	315.6m3/day		315.6m3/day	
CO2 capturing (together with compressors for PSA tail gas)	282 t-CO ₂ /day Chemical Absorption		282 t-CO ₂ /day Chemical Absorption	
Methanol plant	100,000 MTPY		100,000 MTPY	
Utility for Methanol plant	Boiler for steam, Water cooling system, N ₂ generation, etc.		Boiler for steam, Water cooling system, N ₂ generation, etc.	
Methanol tank & piping for ship-out/exportation	For Methanol production capacity		For Methanol production capacity	
Total	Total	Approx. 547 M USD	Total	Approx. 314 M USD

Summary of OPEX

OPEX Items	Case 1	Case 2	Unit
	Annual	Annual	
Rent of Industrial Land			USD
Unite Lease Rate for Industrial Land			USD/m ² /y
Size of the Land			m ²
OPEX for Water Desalination			USD
OPEX for Solar Power Generation (capacity increased)			USD
OPEX for CO₂ Capturing & Purification			USD
CO ₂ (Fuel)			USD
Maintenance material cost			USD
OPEX for H₂ Production			USD
H ₂ tank			USD
Water			USD
Electricity cost (USD 0.03/kWh)			USD
Personnel costs (operation management)			USD
Maintenance material cost (including labor cost for regular inspection)			USD

OPEX Items	Case 1	Case 2	Unit
	Annual	Annual	
OPEX for Methanol Production			USD
Catalyst / chemical costs (exchange: every 3 years)			USD
Utility fee (Fuel)			USD
Electricity cost			USD
Water fee			USD
Personnel costs (\$40/h)			USD
Maintenance material cost			USD
OPEX for Methanol Transportation & Loading			USD
Electric fee for pumping			USD
Maintenance material cost			USD
Cost for Seaport Facility	TBD	TBD	USD
Selling, general and administrative expenses	TBD	TBD	USD
Operation consignment costs (personnel costs, etc.)	TBD	TBD	USD
Advertising / promotion expenses (participation in exhibitions, etc.)	TBD	TBD	USD
Total (at the FY when need Catalyst exchange)	Appx. -38 Mil	Appx. -44 Mil	USD

Pre-conditions for financing

DE ratio	Debt 70% / Equity 30%
Ratio of JPN ECA and commercial banks	ECA 60% / Commercial 40%
ECA interest	US Libor + 0.59% (US LIBOR(6M): 0.2%, in total 0.79%)
Commercial banks interest	SAIBOR + 2% (SAIBOR(6M): 1%, in total 3%)
Debt sizing	Case-1: approx. \$383M Case-2: Approx. \$220M Both debt coverages are 70% of whole project Capex basis.

Necessary conditions for realizing the project (100k ton)

Items	Case 1 with PV Power Plant	Case 2 utilizing green certified electricity
Methanol selling price	<u>USD 850/MT</u>	<u>USD 640/MT</u>
CO ₂ treatment service fee	USD 30/t-CO ₂	USD 30/t-CO ₂
Oxygen selling profit	USD 60/t-O ₂	USD 60/t-O ₂
E-IRR (P-IRR)	10.0% (7.43%)	10.2% (7.5%)



Unrealistic due to large
deviation from current
market price (600USD)



Slightly higher
than current
market price

(Sensitivity Analysis)

Necessary conditions for realizing the project (1million ton)

Items	Case 1 with PV Power Plant	Case 2 utilizing green certified electricity
Methanol selling price	<u>USD 460/MT</u>	<u>USD 295/MT</u>
CO2 treatment service fee	USD 30/t-CO ₂	USD 30/t-CO ₂
Oxygen selling profit	USD 60/t-O ₂	USD 60/t-O ₂
E-IRR (P-IRR)	10.2% (7.65%)	10.4% (7.68%)



Below market
price



Significantly below
the market price and
close to the regular
methanol price level

However...

- A large amount of byproduct hydrogen is required (140,000 Nm³/h)
- There is a risk in the amount of green methanol demand
- For Case 1, the capacity of the water electrolysis system for the 1 million ton case will be 2.4GW, and the solar power generation facilities will be huge
- A huge site must be secured near CO₂ supplying facility.
- In Case 2, the issue is whether it is possible to secure the large amount of green certificate electricity needed to produce 1 million tons of methanol.

Possible Positive Factors

	Possible Positive Factors	Estimation
Common	Capex cost down of Electrolyzer / PV plant (maybe Wind also) with technologies improvement & commoditization	Electrolyzer cost is expected to be 1/5 from current price in 2030. ⇒to be mentioned in each case RE plants should also have space of cost down in future.
	Plant operation optimization	Operation may be (partially) automative which can contribute the cost down of personnel cost.
	Spare parts & major OH optimization in Methanol plant and Electrolyzer	There should be some space for refining the cost estimation and if 2% of capex (currently applied as <u>3%</u>) can be applied for this cost, the impact will be significant.
	Optimization of CO ₂ capturing specification	There would be possible alternative system for CO ₂ capturing and also there should be space capacity(cost) down in case of increasing the volume of PSA tail gas application.
	Scale merit of Methanol plant price	If the capacity of Methanol plant could be bigger, the scale merit of plant construction cost also could be competitive rather than 100,000 MTPY case.
Case 1	Electricity/H ₂ selling from owned PV plant during OH period of Methanol plant.	Potentially, during OH period (30days/year), electricity or H ₂ would be sold to the market.
	Free land/space	This could contribute 5.04 M USD / year cost down.
Case 2	Cheaper Green electricity by IPP (for H ₂ production)	If the Green electricity could be supplied with lower rate, significant cost reduction would be realized.

Possible Negative Factors

	Possible Negative Factors	Estimation
Common	Conversion of floating rate to fixed rate	Current estimation of PF, we refer the latest floating interest as fixed rate to our calculation. Thus, this should re-calculate with the fixed rate.
	Coverage of Project finance	Due to several components of the project, Lender may not cover all of scope the project by Project Finance, thus, there may be scope(s) which can not be covered by such financing. (but, may be positively affect to get more competitive condition from lender)
	Methanol price/demand volatility	In our model, the fixed price for methanol selling is applied, thus, this also should be volatile.
	Transportation/exporting facility cost	We didn't apply any additional cost for transporting/exporting of methanol (other than methanol tank/piping), thus, there may be additional cost for arrangement of transport facility at Ras tanura port area.
	Project company's management/operation related cost	These cost should add on in the actual stage of the project, which we don't consider at this FS stage. (like, administration expenses, costs for legal/FA and other expenses)

Challenges for commercialization

- Demand securement of Green(low carbon) methanol with a certain price index/premium
 - Off taking with long term & premium on methanol price (or global price index can be covered instead of this premium paid by off-taker)
 - Fixation of definition, categorization, certification regulation for Green(low carbon) methanol
- (For case-1) Securement of stable and enough transmission line capacity for wheeling electricity generated by PV plant (located around Red seaside) towards methanol plant (located at Arabian seaside) together with necessary wheeling system.
- (For case-2) Fixation/execution of certified electricity regulation in KSA and realization of cheap tariff of such certified electricity.
- Realization of cheaper cost of green H₂ generation
- Securement of a certain CO₂ and by-product H₂ (for methanol price reduction)
- (for the case of Methanol plant capacity 1 Mil MTPY) securement of competitive finance together with the enough coverage of debt. sizing.
- Realization of scale merit on costs of each main facilities/components in the case of Methanol plant capacity 1 Mil MTPY