TECHNO-ECONOMIC FEASIBILITY PROJECT—
PHENOL MANUFACTURING

Submitted To:

Submitted By:

MARKET INTELLIGENCE. CONSULTING

September 21, 2022

Index

1. Introduction and Background

Phenol (also called carbolic acid) is an aromatic organic compound with the molecular formula C_6H_5OH. It is a white crystalline solid that is volatile. The molecule consists of a phenyl group ($-C_6H_5$) bonded to a hydroxy group ($-OH$). Mildly acidic, it requires careful handling because it can cause chemical burns.

Acetone, propanone or dimethyl ketone is an organic compound with the formula $(CH_3)_2CO$. It is the simplest and smallest ketone. It is a colourless, highly volatile, and flammable liquid with a characteristic pungent odour.

Phenol and acetone are downstream derivatives of Cumene which are prepared by benzene and propylene. Further, the demand for Phenol is driven by its derivatives, such as bisphenol-A (BPA) and phenolic resins. Bisphenol A is primarily used to manufacture polycarbonate and epoxy resins, which have applications in automotive, electronic, and construction products. Additionally, Phenol formaldehyde resin (Phenolic Resin), which contributes to the primary end use of Phenol, is primarily used in wood additives as well as moulding and laminating resins, and varnishes, paints, and enamels. Finally, salicylic acid is another derivative of Phenol that is used in the pharmaceutical sector for skin treatment.

Acetone is mainly used in producing methyl methacrylate (MMA) and bisphenol-A (BPA). With the increasing demand for acrylates in the consumer electronic market to produce DVDs, and smartphones, there has been an increased demand for acetone.

ONGC Petro additions Limited (OPaL) was established in 2006 and co-promoted by GAIL, GSPC, and Oil and Natural Gas Corporation (ONGC). OPaL has established a massive petrochemical plant in the PCPIR/SEZ at Dahej, Gujarat.

The complex's primary Dual Feed Cracker Unit can produce 400 KTPA of Propylene, 1100 KTPA of Ethylene, and the Associated Units. It consists of a Pyrolysis Gasoline Hydrogenation Unit, Butadiene Extraction Unit and Benzene Extraction Unit. In addition, the polymer plants of OPaL have 2X360 KTPA of LLDPE/HDPE swing unit, 1X340 KTPA of Dedicated HDPE and 1X340 KTPA of PP.

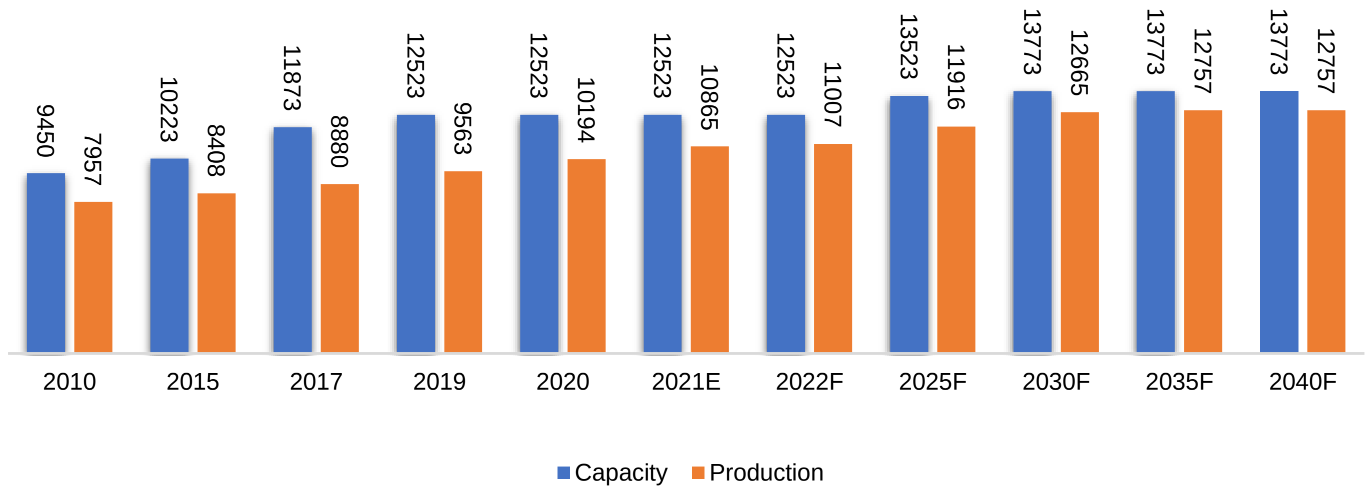
OPaL intended to carry out a detailed Techno-Economic Feasibility Study for Phenol manufacturing. New Age TechSci Research Private Limited was awarded to conduct this study as a consultant. Based on TechSci's recommendations, OPaL would strive to implement the commercial capacity of Phenol.

The study broadly covers areas related to

- Demand Supply Analysis
- CapEx and OpEx Analysis
- Detailed Project Cost Estimation
- Net Realization
- Profitability Projections
- Payback
- SWOT Analysis
- Process and Licensor Evaluation
- Project Schedule & Implementation Strategy
- Regulations
- Risk Factor & Mitigation

2. Demand Supply Gap Analysis (April 2020 to March 2040)

Global Phenol Capacity and Production, By Volume (000' Tonnes), 2010-2040F



Source: TechSci Research

The capacity of Phenol stood at 12.5 million tonnes in 2020, which is expected to reach around 13.8 million tonnes by 2030 and is expected to remain the same till 2040. Due to COVID-19, a surge in demand for Phenol was observed in the market. Acetone is produced as a by-product during the manufacturing of Phenol, which can be further used in the manufacturing of Iso Propyl Alcohol (IPA). Companies are planning to increase the capacity of Phenol to produce IPA as forwarding integration of product portfolios across the globe. The demand for Phenol is anticipated to grow at a CAGR of 3.42% by 2040. Ineos Group, Cepsa Corporation, Kumho Chemicals, and LG Chem are the leading global producers of Phenol.

Ineos group operates phenol and acetone plants at sites in Gladbeck, Germany; Antwerp, Belgium; and Mobile, Alabama, in the United States. All three sites use their proprietary technology, which has significant advantages in energy consumption and other factors over competing technologies. In Europe, the major competitors for the Ineos group are Cepsa, Novapex, Borealis, and Versalis. In North America, Ineos group's significant competitors are Shell and Honeywell. Further, the Ineos group sells to most of the significant phenol and acetone consumers globally, including Covestro (previously Bayer), Olin (previously Dow), Sabic, Fibrant (previously DSM), Evonik, and Lucite.

2.1 Capacity, By Location, 000' Tonnes, 2010-2040F

Company	Location	2010	2015	2021E	2022F	2025F	2030F	2035F	2040F
Ineos Group Ltd	China	0	0	400	400	400	400	400	400
	Belgium	680	680	680	680	680	680	680	680
	Germany	650	650	650	650	650	650	650	650
	USA	540	540	540	540	850	850	850	850
Cepsa Corporation	China	0	250	250	250	250	250	250	250
	Spain	450	450	450	450	600	600	600	600
Kumho P&B Chemicals., Inc.	South Korea	380	380	680	680	680	680	680	680
LG Chem	South Korea	600	600	600	600	600	600	600	600
Advansix	USA	500	500	500	500	500	500	500	500
PTT Phenol	Thailand	250	250	500	500	500	500	500	500
Formosa Chemical and Fibre	Taiwan	300	300	300	300	400	400	400	400
Zhejiang Rongsheng	China	0	0	400	400	400	400	400	400
Mitsui Chemicals	Japan	390	390	390	390	390	390	390	390
Shell Chemicals	USA	240	240	390	390	390	390	390	390
Taiwan Prosperity Chemical Corp.	Taiwan	360	360	360	360	360	360	360	360
SABIC Innovative Plastics	USA	320	320	320	320	320	320	320	320
Altivia Petrochemicals	USA	300	300	300	300	300	300	300	300
Chang Chun Chemical	China	0	300	300	300	300	300	300	300
Chang Chun Plastic	Taiwan	300	300	300	300	300	300	300	300
Mitsui Phenols Singapore Pte. Ltd.	Singapore	300	300	300	300	300	300	300	300
Versalis	Italy	300	300	300	300	300	300	300	300
Olin Corporation	USA	295	295	295	295	295	295	295	295
Rabigh Refining and Petrochemical	Saudi Arabia	0	0	270	270	270	270	270	270
Mitsubishi Chemical Corporation	Japan	250	250	250	250	250	250	250	250
Rhodia Solvay	Brazil	250	250	250	250	250	250	250	250
Shanghai Sinopec Mitsui	China	250	250	250	250	250	250	250	250
Georgia Gulf Corporation	USA	227	227	227	227	227	227	227	227
CNOOC Huizhou	China	0	0	220	220	220	220	220	220
Others	Rest of Global	1318	15541	1851	1851	2291	2541	2541	2541
Total		**9450**	**10223**	**12523**	**12523**	**13523**	**13773**	**13773**	**13773**

Source: TechSci Research

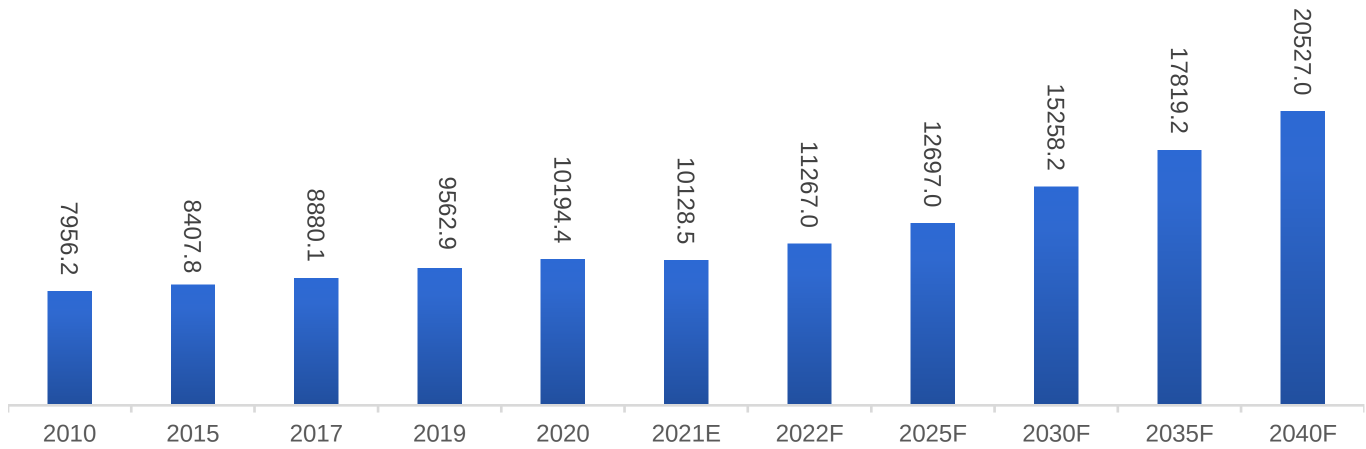
Major Expansions for the Manufacturing of Cumene, Phenol and Acetone, By Location

Company	Licensor	Product	Capacity (000' Tonne)	Location	Likely Year of Commissioning
Formosa Chemicals and Fibre Corp	Lummus Technology	Cumene, Phenol & Acetone	400	Ningbo, China	2025
PKN Orlen	UOP's Q-Max	Cumene, Phenol & Acetone	200	Plock, Poland	2024
PKN Orlen	Badger	Acetone and Isopropanol	140	Plock, Poland	2024
Reliance Industries Ltd	NA	Cumene, Phenol & Acetone	200	Jamnagar, Gujarat	Planning Stage Only

Ineos Group	Ineos	Cumene	750	Marl, Germany	2022 (Q1)
Haiwan Chemical	KBR	Cumene, Phenol & Acetone	320	Shandong, China	2024

Source: Company Investor Presentations

2.2. Global Phenol Demand, By Volume (000' Tonnes), 2010-2040F



Source: TechSci Research

Demand (000' Tonnes)										CAGR		
2010	2015	2017	2020	2021E	2022F	2025F	2030F	2035F	2040F	2010-2020	2021-2030F	2031F-2040F
7956	8408	8880	10194	10828	11267	12697	15258	17819	20527	3.1%	3.9%	3.0%

2.3. Global Phenol Demand Supply Scenario (000' Tonnes), 2010-2040F

Parameters	2010	2015	2021E	2022F	2025F	2030F	2035F	2040F
Capacity	10,223.00	10,223.00	12,523.00	12,523.00	13,523.00	13,773.00	13,773.00	13,773.00
Production	7,956.00	8,408.00	10,865.00	11,007.00	11,916.00	12,665.00	12,757.00	12,757.00
Demand	7,956.24	8,407.84	10,828.50	11,267.00	12,697.00	15,258.20	17,819.20	20,527.31
Demand (Y-O-Y Growth Rate, %)		4.99%	6.22%	4.05%	3.82%	3.39%	3.36%	2.80%
Demand / Supply Gap			36.00	-260.00	-781.00	-2,593.00	-5,062.00	-7,770.00

Source: TechSci Research

2.4. Global Phenol Trade Dynamics, By Value (USD Million) and By Volume (000' Tonnes), 2010-2020

Importer Country	2010		2011		2012		2013		2014	
	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume
China	921.15	624.09	1254.40	762.21	838.16	594.00	546.86	365.95	317.35	217.06
Netherlands	577.75	487.72	775.05	532.16	647.05	503.63	710.36	0.00	602.43	397.93
Germany	366.04	292.13	366.79	248.71	404.01	267.11	523.54	325.77	422.17	263.51
India	185.48	116.74	235.02	139.54	240.93	168.00	269.99	199.81	340.48	216.05
Taiwan	10.00	6.00	41.69	24.33	14.34	10.08	36.33	26.14	95.46	65.68
Others	1419.21	1109.26	1770.24	1109.65	1609.41	1043.76	1782.96	1140.60	1782.03	1061.95
Total	**3479.62**	**2635.93**	**4443.18**	**2816.59**	**3753.90**	**2586.58**	**3870.04**	**2058.27**	**3559.92**	**2222.17**
	2010		2011		2012		2013		2014	

Exporter Country	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume
USA	1056.88	633.26	1277.03	713.59	1211.91	668.23	985.67	522.21	920.21	484.06
South Korea	0.07	0.03	5.34	2.57	18.25	10.69	3.05	1.67	0.56	0.29
Thailand	273.93	169.23	425.97	214.96	360.37	225.67	393.82	248.47	335.68	197.30
Saudi Arabia	1.06	0.95	15.45	8.71	19.83	12.33	13.27	8.84	10.20	6.66
Taiwan	1016.22	578.10	1142.35	600.59	891.96	562.76	770.17	471.67	716.42	426.94
Others	4502.95	2519.64	5106.81	2358.73	4716.10	2163.29	4763.80	2243.94	4967.32	`2399.23
Total	**6851.11**	**3901.22**	**7972.96**	**3899.14**	**7218.11**	**3642.96**	**6929.77**	**3496.80**	**6950.38**	**3514.48**

Importer Country	2015		2016		2017		2018		2019		2020	
	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume
China	160.39	172.97	207.39	248.42	329.85	365.64	530.6	418.75	462.23	467.64	488.26	709.92
Netherlands	379.94	417.13	278.51	358.48	381.13	407.37	487.06	494.25	358.23	326.44	283.79	298.75
Germany	303.9	323.52	332.86	384.79	368.14	404.36	368.85	340.29	275.77	269.08	197.75	266.22
India	236.81	244.89	245.27	271.61	264.6	266.94	352.52	258.89	167.75	156.37	109.69	160.06
Taiwan	76.66	83.56	98.52	120.56	169.51	177.02	264.31	205.74	162.91	165.69	70.24	105.56
Others	1072.68	1104.14	944.69	1106.58	1222.29	1192.89	1145.81	839.93	875.6	671.22	768.29	640.7
Total	2230.37	2346.2	2107.23	2490.43	2735.51	2814.21	3149.15	2557.85	2302.49	2056.44	1918.09	2181.22

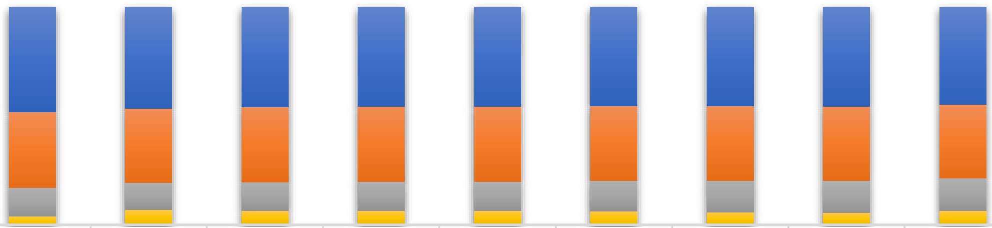
Exporter Country	2015		2016		2017		2018		2019		2020	
	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume
USA	668.58	522.84	584.62	495.75	609.87	448.55	351.58	311.68	214.12	224.77	235.92	342.73
South Korea	0.03	0.02	0.44	0.45	0.54	0.5	552.9	434.66	314.25	322.96	185.53	266.61
Thailand	213.77	197.49	247.77	260.85	333.19	313.55	284.32	226.64	183.13	196.59	143.78	225.12
Saudi Arabia	17.04	12.67	25.09	19.76	44.74	26.16	229.86	204.87	261.05	250.25	152.87	190.36
Taiwan	529.29	460.23	406.83	404.71	371.84	288.27	26.89	19.4	56.64	60.49	123.91	180.53
Others	3322.49	2240.61	3409.88	2352.03	4186.49	2873.47	1703.61	1360.6	1273.3	1001.39	1075.99	975.87
Total	4751.19	3433.86	4674.62	3533.53	5546.67	3950.48	3149.15	2557.85	2302.49	2056.44	1918.01	2181.22

Source: TechSci Research

Phenol HS Code:2907110

2.5. Demand, By End Use

Global Phenol Demand, By End Use, By Volume (000' Tonnes), 2010–2040F



	2010	2015	2020	2021E	2022F	2025F	2030F	2035F	2040F
Bisphenol-A	48.15%	46.60%	45.73%	45.58%	45.54%	45.35%	45.39%	45.50%	44.79%
Phenolic Resin	34.74%	33.93%	34.59%	34.51%	34.49%	34.45%	34.21%	34.25%	33.81%
Pharmaceuticals	13.11%	12.50%	13.22%	13.30%	13.43%	13.91%	14.57%	14.60%	14.84%
Others	4.00%	6.97%	6.46%	6.61%	6.54%	6.29%	5.84%	5.65%	6.56%

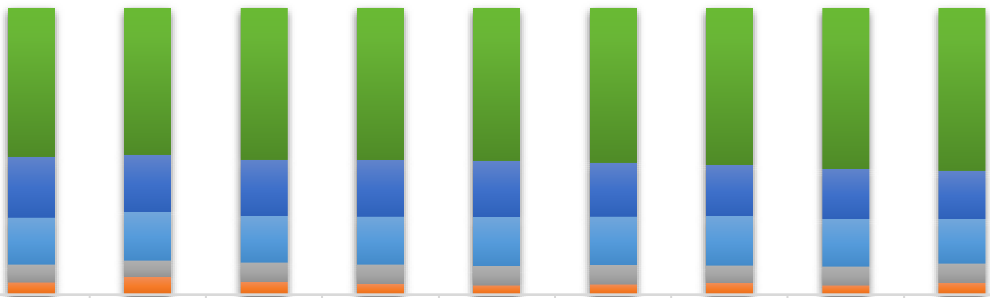
Source: TechSci Research

Demand by End Use	2010	2015	2020	2021E	2022F	2025F	2030F	2035F	2040F
Bisphenol-A	3830.93	3918.04	4661.80	4935.91	5131.06	5757.89	6924.92	8107.75	9194.18
Phenolic Resin	2764.00	2852.63	3525.99	3736.69	3885.46	4373.56	5219.06	6103.09	6940.28
Pharmaceuticals	1043.06	1050.91	1347.69	1440.38	1513.51	1766.67	2223.80	2601.61	3046.25
Others	318.25	586.26	658.88	715.49	736.99	798.85	890.38	1006.79	1346.59
Total	7956.24	8407.84	10194.37	10828.46	11267.01	12696.97	15258.16	17819.23	20527.31

Others include Caprolactam, Aniline, Cyclohexanone, etc

Source: TechSci Research

2.6 Demand, By Region (000' tonnes), 2010-2040F



	2010	2015	2020	2021E	2022F	2025F	2030F	2035F	2040F
Asia-Pacific	51.72%	51.04%	52.84%	53.05%	53.25%	53.80%	54.72%	56.05%	56.72%
Europe	21.24%	20.00%	19.75%	19.70%	19.65%	18.80%	17.86%	17.55%	16.84%
North America	16.50%	17.05%	16.04%	16.62%	17.05%	16.93%	17.23%	16.55%	15.53%
Middle East & Africa	6.15%	5.72%	6.82%	6.91%	6.72%	6.91%	6.12%	6.55%	6.71%
South America	4.39%	6.19%	4.55%	3.72%	3.33%	3.56%	4.07%	3.30%	4.20%

Demand By Region	2010	2015	2020	2021E	2025F	2030F	2035F	2040F	CAGR (2010-2020)	CAGR (2021E-2030F)	CAGR (2031F-2040F)
APAC	4114.97	4291.36	5386.71	5744.50	6830.97	8349.27	9987.68	10411.29	2.7%	4.2%	2.0%
Europe	1689.91	1681.57	2013.39	2133.21	2387.03	2725.11	3091.64	3091.08	1.8%	2.8%	1.1%
North America	1312.78	1433.54	1635.18	1799.69	2149.60	2628.98	2859.99	2850.62	2.2%	4.3%	0.7%
MEA	489.31	480.93	695.26	748.25	877.36	933.80	1167.16	1231.66	3.6%	2.5%	2.6%
South America	349.28	520.45	463.84	402.82	452.01	621.01	712.77	770.93	2.9%	4.9%	2.9%
Total	**7956.24**	**8407.84**	**10194.37**	**10828.46**	**12696.97**	**15258.16**	**17819.23**	**20527.31**	**-**	**-**	**-**

Source: TechSci Research

The total global capacity of Phenol stood at 12.5 million tonnes as of 2021, with the Asia Pacific leading the market at 38% share. As of 2021, the demand for Phenol in the Asia Pacific region stood at around 5.7 million tonnes and is expected to grow at a CAGR of 4% to reach nearly 8.3 million tonnes by 2030.

Several capacity additions have taken place in the region to meet the growing demand for Phenol, supported by growth in the construction, automotive, and infrastructure sectors. In May 2017, CNOOC and Shell Petrochemicals Company Limited (CSPC) started a 220 KTPA plant in Huizhou, Guangdong, China. Similarly, in 2018, Petro Rabigh commissioned its Phase II 250 KTPA unit in Saudi Arabia. Moreover, in 2018, Deepak Phenolics Limited (DPL), a wholly owned subsidiary of Deepak Nitrite Limited, commenced commercial production of Phenol and Acetone at Dahej, in Gujarat, India, with an installed capacity of 200 KTPA of Phenol and 120 KTPA of Acetone. In 2019, Zhejiang Rongsheng started its 400 KTPA unit in Zhoushan, China.

In the Asia Pacific region, the largest derivative market for Phenol is Phenolic Resin, holding approximately 41% of total consumption. Phenolic resins are widely used as a binding and insulating material due to their excellent heat resistance and high mechanical strength properties.

The second-largest derivatives market of Phenol in the Asia Pacific region is Bisphenol -A (BPA), which holds around 30% of total consumption. Moreover, the growth of Phenol in the Asia Pacific region is attributed to the increase in demand for BPA downstream derivatives such as polycarbonates and epoxy resins across various industries, including construction, automotive, consumer electronics, Etc. Additionally, BPA derivative epoxy resin is also used to encapsulate electrical & electronic components, fiber-reinforced plastics material, and adhesives for structural purposes.

Other downstream phenol sectors include capro-lactam (Capro), alkylphenols, aniline, and adipic acid. China is Asia's largest phenol market. Phenolic resin is China's largest phenol downstream sector, holding nearly 60% of the market share, whereas BPA, the second-largest market in China, is at 25%.

Growth in the Asia Pacific region can also be attributed to rising disposable income, growing consumer spending, and rapid urbanization.

Major Infrastructure Investments in Asia Pacific Region

- The Beijing Municipal Commission of Development and Reform announced in 2019 a total of 300 major construction projects of approximately USD35 billion.
- Similarly, the Indian government's Affordable Rental Housing Scheme (AHRC) to provide affordable rental accommodation to migrant workers will drive the growth in the residential construction sector.

- The Malaysian government provides stamp duty exemption to first-time home buyers until 2025. Such a scheme will accelerate the housing projects in the country and boost the construction infrastructure.
- The Australian government is spending approximately USD14 billion on infrastructure projects, including road and rail projects, supporting the infrastructure growth in the country.
- Japan's government is strongly investing in expanding railway networks in the country. The construction of the USD19 billion Chuo Shinkansen Maglev Rail Line is already underway. Moreover, the extension of the Hokkaido Shinkansen rail line from the Shin-Hakodate-Kokuto rail line to the Sapporo rail line is also underway. Both lines are expected to be operational by 2022 and 2030, respectively.

Ineos Phenol holds 2270 KTPA of Phenol Capacity, and the company is the leading producer of Phenol and Acetone in Europe. As per the current market scenario in Europe, Acetone oversupply is projected to get worst by 2022, while Phenol demand is expected to strengthen further due to the growing demand from downstream industries & imposition of anti-dumping duties by selected countries.

In 2019, Ineos Phenol started construction work in Marl, Germany, for a new state-of-the-art 750 KTPA Cumene unit. This project is likely to be operational by H2 2022 and will supply Cumene to the downstream Phenol unit.

The markets for Phenol and Acetone are traditionally viewed as regional because of the physical difficulty of transporting and storing Phenol and the resulting high freight costs.

Phenol availability was reduced in Europe in 2020 because of a six-week outage of the region's giant plant, Ineos in Antwerp, Belgium, which resulted in a constant force majeure. Also, the Spanish producer Cepsa declared force majeure after a technical issue forced a temporary shutdown of one line at its Huelva plant.

At the start of 2018, high consumption levels diminished the availability of Phenol. The pandemic also hampered demand for Phenol used in construction in 2020 and 2021 (H1) due to stagnant demand for BPA-based epoxy resin and polycarbonate.

North America Phenol Market holds around 16% share in global Phenol demand. The decline in production trend was observed in the US market because of a reduction in order from the end-use application of Bisphenol- A (BPA). BPA is mainly used to produce polycarbonate, primarily in the automotive sector, construction industry, and optical media applications. With a decline in demand from the automotive sector in the North, the need for Phenol declined in 2019 and 2020.

Global Acetone Demand, By Volume (000' Tonnes), 2010-2040F

2010	2015	2017	2019	2020	2021E	2022F	2025F	2030F	2035F	2040F
4973.9	5872.7	6323.5	6931.6	7665.8	8134.9	8587.2	10176.5	13094.7	16563.4	20235

Global Acetone Demand Supply Scenario, 2010-2040F, (000' Tonnes)

Parameters	2010	2015	2021E	2022F	2025F	2030F	2035F	2040F
Capacity	5084.4	6265.8	7513.8	7513.8	8113.8	8263.8	8263.8	8263.8
Production	4973.9	5872.7	7790.2	8175.5	9256.8	11248.4	13516.8	16083.9
Demand	4973.9	5872.7	8134.9	8587.2	10176.5	13094.7	16563.4	20235.0
Y-O-Y Growth Rate, %		4.64%	6.12%	5.56%	5.94%	4.94%	4.72%	3.72%
Demand - Supply Gap			-344.7	-411.8	-919.7	-1846.3	-3046.6	-4151.1

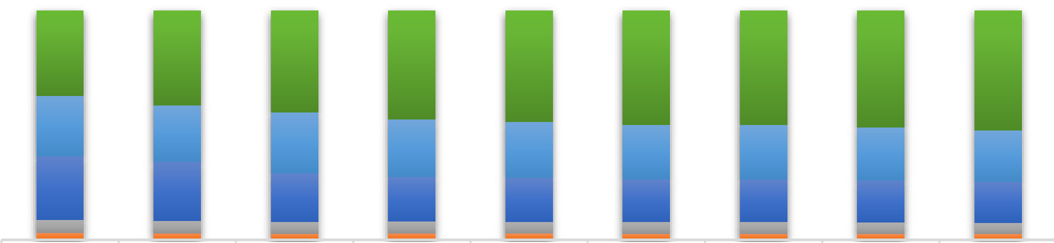
- India contributed to ~2% of the global acetone market demand (FY2020).
- Growth in pharmaceutical, automotive, and solvent-based products like thinners supports phenol demand.
- China contributed to ~18% of the global acetone market demand (FY2020).

Global Acetone Demand, By End Use, By Volume (000' Tonnes), 2021 & 2040F

End Use	2021	2040F
Pharmaceuticals & Solvents	40.61%	42.03%
Bisphenol-A (BPA)	24.85%	22.13%
Methyl Methacrylate (MMA)	14.63%	16.15%
Methyl Isobutyl Ketone (MIBK)	12.71%	11.43%
Others	7.20%	8.26%

- Manufacturing of Bisphenol-A and IPA will drive future demand.
- Pharmaceuticals & Solvents is the most prominent end-use

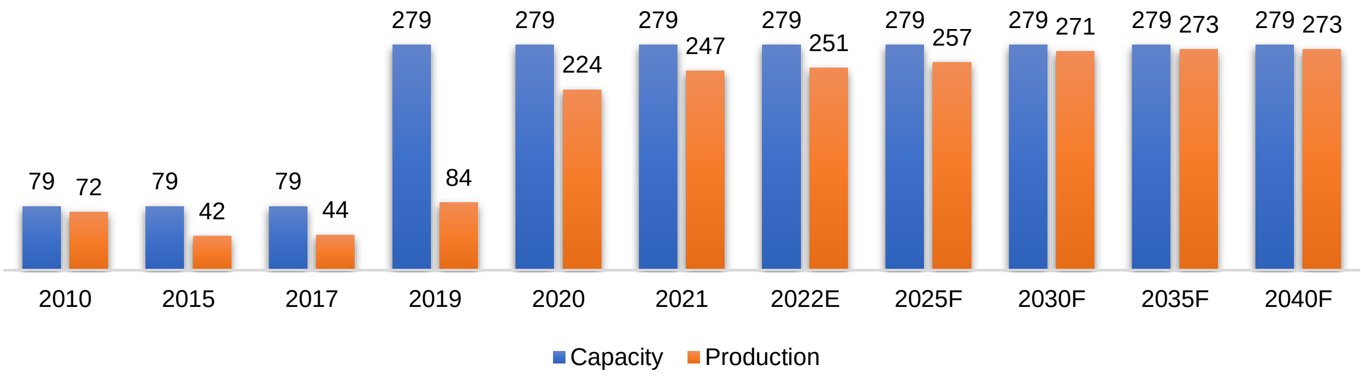
Global Acetone Demand, By Region, By Volume (000' Tonnes), 2010–2040F



	2010	2015	2020	2021E	2022F	2025F	2030F	2035F	2040F
Asia-Pacific	37.08%	41.31%	44.34%	47.31%	48.40%	49.69%	49.69%	50.97%	52.21%
North America	26.38%	24.70%	26.69%	25.10%	24.60%	23.78%	23.78%	23.04%	22.41%
Europe	27.69%	25.62%	21.02%	19.44%	19.01%	18.70%	18.70%	18.35%	17.95%
Middle East & Africa	5.71%	5.42%	5.20%	5.32%	5.22%	5.12%	5.12%	4.99%	4.85%
South America	3.13%	2.95%	2.76%	2.83%	2.77%	2.72%	2.72%	2.65%	2.58%

- Asia-Pacific is the most prominent region.
- India contributed to ~5% of the Asia-Pacific acetone market demand in FY2022.
- In China and India, Acetone is used to manufacture vitamins API and antibiotics (cephalosporins).

2.7. India Phenol Capacity and Production, By Volume (000' Tonnes), FY2010-FY2040F



Source: TechSci Research

The current capacity of phenol in India is approximately 279 KTPA. Three players dominate India's phenol market: Deepak Phenolics Ltd, Hindustan Organic Chemicals Ltd., and SI Group India Ltd. Hindustan Organic Chemicals Ltd. was the most significant player until FY2017, with an installed capacity of 42 KTPA. However, Deepak Phenolics, which started phenol production in FY2019 at the Dahej plant with a total of 200 KTPA, is the most significant Indian player. India's phenol demand is primarily driven by Phenol Formaldehyde resin which accounts for nearly 70% of the total market in India.

Deepak Phenolics Ltd.

Deepak Phenolics Ltd. (DPL) is a wholly owned subsidiary of Deepak Nitrite Limited. The company commenced commercial production of Phenol and Acetone in the year FY2019. The company is also supported by its capacity to manufacture 260 KTPA of Cumene for captive consumption. The technology for manufacturing Phenol and Acetone has been sourced from Kellogg Brown & Root International Inc. (KBR), and technology for manufacturing Cumene has been sourced from Honeywell UOP LLC. ThyssenKrupp Industrial Solutions (India) Pvt Ltd. was selected as the greenfield contractor's Engineering, Procurement, and Construction Management (EPCM) contractor.

Hindustan Organic Chemicals Ltd. (HOCL)

Hindustan Organic Chemicals Ltd., a PSU under the Ministry of Chemicals and Fertilizers, was incorporated in FY1960. Hindustan Organic Chemicals Ltd. was India's second-largest producer of Phenol and Acetone until Deepak Phenolics commissioned the largest phenol capacity of 200 KTPA at the Dahej plant in FY2019. Hindustan Organic Chemicals Ltd. commissioned Phenol and Acetone manufacturing unit at Kochi in the year FY1987 with an installed capacity of 40,000 TPA of Phenol and 24640 TPA of Acetone. Similarly, a hydrogen peroxide plant with an installed capacity of 5225 TPA was commissioned in FY1997. The technology for manufacturing Phenol and Acetone has been sourced from Honeywell UOP LLC. FACT Engineering and Design Organization was selected as the greenfield contractor's Engineering, Procurement, and Construction Management (EPCM) contractor. Hindustan Organic Chemicals Ltd. (HOCL also implemented ISO 9001 and ISO 14001 systems for Quality Control (QC) Laboratories separately for Phenol/Acetone to improve existing customer relationships.

SI Group India Ltd.

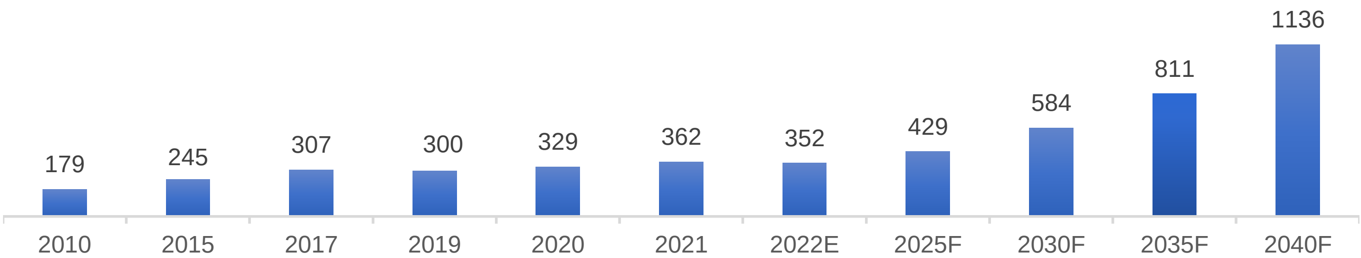
SI Group: India Private Limited (SIGIL) is a subsidiary of SI Group Inc., and the company is engaged in the manufacturing and marketing Phenolic resins and organic chemicals. The company also imports Phenol from South Africa. The company has three manufacturing units located in Navi Mumbai, Raigad, and Ratnagiri. SI Group - India Private Limited (SIGIL) has 37 KTPA of phenol capacity installed at its Navi Mumbai plant. The company is also supported by the ability to manufacture 60 KTPA of Cumene for captive consumption. Similarly, a hydrogen peroxide plant with an installed capacity of 5225 TPA was commissioned in FY1997. The technology for manufacturing Phenol and Acetone has been sourced from Honeywell UOP LLC.

2.8. Capacity, By Company, By Location (000' Tonnes), FY2010-FY2035F

Company Name	Location	2010	2015	2021	2022E	2025F	2030F	2035F
Deepak Phenolics Ltd.	Dahej, Gujarat	0	0	200	200	200	200	200
Hindustan Organic Chemicals Ltd.	Kochi, Kerala	42	42	42	42	42	42	42
SI Group India Ltd.	Navi Mumbai, Maharashtra	37	37	37	37	37	37	37
Total		79	79	279	279	279	279	279

Source: TechSci Research

2.9. India Phenol Demand, By Volume (000' Tonnes), FY2010-FY2040F



Source: TechSci Research

Demand										CAGR		
2010	2015	2017	2020	2021	2022F	2025F	2030F	2035F	2040F	2010-2021	2022E-2030F	2031F-2040F
179	245	307	329	362	352	429	584	811	1136	6.58%	6.54%	6.91%

2.10. India Phenol Trade Dynamics, By Value (USD Million) and By Volume (000' Tonnes), FY2010-FY2021

Importer Country	2010		2019		2020		2021	
	Value	Volume	Value	Volume	Value	Volume	Value	Volume
USA	32.08	33.7	55.61	42.67	30.65	31.79	40.87	65.94
Thailand	29.48	27.86	111.28	81.06	52.64	53.33	17.94	25.04
South Africa	7.98	8.24	18.44	15.75	14.67	16.77	11.75	18.85
China	9.55	6.97	14.64	10.36	0.18	0.18	16.99	18.32
South Korea	0	0	35.08	25.8	12.59	13.37	10.06	13.32
Others	27.5	0.02	70.27	50.77	23.85	23.9	20.51	29.16
Total	**106.59**	**100.56**	**305.32**	**226.41**	**134.58**	**139.34**	**118.12**	**170.62**
Exporter Country	**2010**		**2019**		**2020**		**2021**	
	Value	**Volume**	**Value**	**Volume**	**Value**	**Volume**	**Value**	**Volume**
China	0	0	0	0	6.76	8.51	16.53	29.38
Iran	0.03	0.04	4	2.4	9.43	6.3	4.78	5.15
Brazil	0	0	0	0	0.1	0.1	3.52	4.98
Turkey	0	0	0	0	0.06	0.07	3.4	3.51
United Arab Emirates	0.05	0.05	1.16	0.67	2.88	2.24	2.6	2.72
Others	0.54	0.31	1.21	0.77	4.39	4.34	4.06	5.3
Total	**0.62**	**0.4**	**6.37**	**3.84**	**23.62**	**21.57**	**34.89**	**51.05**

Source: Ministry of Commerce

Note: - The Data mentioned above is for financial year.

India's phenol market is import driven, and 47% of the total demand was fulfilled through sense in FY2021. Deepak Phenolics which started India's largest phenol plant at Dahej, with a production capacity of 200 KTPA, achieved an average utilization rate of 90%-95% in 2021. India will remain a net importer of Phenol as domestic demand is higher than domestic production.

In 2021, India exported around 51 KT of Phenol under HS code 2907110 to China, Iran, Brazil, and Turkey. During the same period, India imported more than 100 KT of Phenol from the US, Thailand, and South Africa. Deepak Phenolics is the sole exporter of Phenol, and the company prefers to export rather than sell to the local market due to better realization.

2.11. India Phenol Demand Supply Scenario, FY2010-FY2040F (000 Tonnes)

Parameters	2010	2015	2021	2022E	2025F	2030F	2035F	2040F
Capacity	79.00	79.00	279.00	279.00	279.00	279.00	279.00	279.00
Production	71.82	42.12	246.90	250.70	257.35	271.05	273.42	273.42
Import	112.40	199.68	170.62	148.73				
Export	0.40	1.50	51.05	44.65				
Inventory	4.50	3.12	4.94	2.56				
Demand	179.00	237.00	362.00	352.00	429.00	584.00	811.00	1136.00
Demand (Y-O-Y Growth Rate, %)		2.99%	9.91%	-2.58%	6.50%	6.80%	6.90%	7.01%
Demand / Supply Gap				-102.00	-171.00	-313.00	-537.00	-863.00

Source: TechSci Research

India's phenol demand is anticipated to increase at a CAGR of 6.73% to reach 1136 KTPA by FY2040 from 362 KT in FY2021. India's phenol market is primarily import-driven. Total import in FY2021 stood at nearly 171 KT. Increasing import demand is attributed to the rising demand for Phenol from downstream segments such as Phenol Formaldehyde resins, pharmaceuticals, the Requirement of By-product Acetone for Isopropyl Alcohol manufacturing, Etc. Moreover, India's demand-supply gap is expected to reach 863 KTPA by FY2040. The increasing demand for Phenol for the manufacturing of Phenol Formaldehyde Resin in the country, coupled with the growing need to produce Bisphenol- A in the country, is anticipated to drive the demand for Phenol in coming years. Phenolic resins, Bisphenol-A, and Pharmaceuticals contribute to around 84% of the total market in India. Further, Phenol is used as a solvent in the pharmaceutical industry, and the demand is expected to grow.

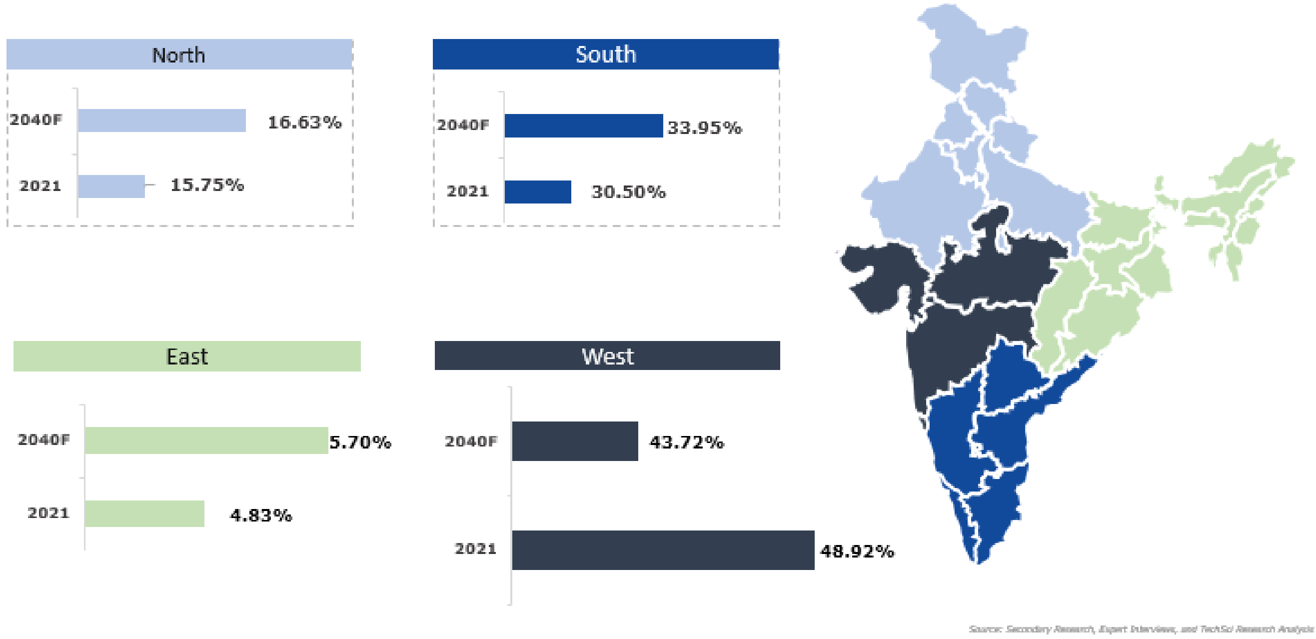
Indian producers are ramping up their production, and still, there is ample scope for setting up a new greenfield unit in West or South India. GAIL and IOCL are in the exploratory phase for setting up the Phenol-Acetone unit in the western region. All these capacities are speculative and have not been considered for demand-supply gap estimation.

India Acetone Demand Supply Scenario, FY2010-FY2040F (000 Tonnes)

Parameters	2010	2015	2021	2022E	2025F	2030F	2035F	2040F
Capacity	45.00	45.00	169.00	169.00	169.00	169.00	169.00	169.00
Production	44.00	26.00	149.00	152.00	155.00	164.00	165.00	165.00
Import	80.00	127.00	82.00	101.00				
Export	0.50	3.18	28.16	34.00	-			
Inventory	0.89	0.52	2.99	3.03				
Demand	123.00	149.00	200.00	216.00	262.00	358.00	474.00	605.00
Demand (Y-O-Y Growth Rate, %)	-	3.49%	3.18%	8.05%	6.22%	6.88%	5.52%	4.71%
Demand / Supply Gap				-65.00	-106.00	-194.00	-309.00	-440.00

Source: TechSci Research

Demand, By Region, By Market Share (%), FY2021 & FY2040F



Geographically, the Indian Acetone Market is categorized into North, South, East, and West Regions. The West region is estimated to account for the largest share in the market and is likely to dominate during the forecast period, followed by the South region. Due to various end-user industries and the marginal extent of the market penetration in the states such as Gujarat, and Maharashtra, the west region dominates the Indian Acetone Market. In the Southern Region, the pharmaceutical industry is one of the fastest growing sectors, which is more likely to boost the demand for acetone in the forecast period. Furthermore, the recent government initiative of the Production Linked Incentive (PLI) scheme to encourage the pharmaceutical industry to expand its production capacities, diversify its product portfolio and emerge as a global competitor is expected to fuel the overall demand for the product.

Demand Market Share, By End Use, By Volume, FY2021 and FY2040F

End Use	2021	2040
Pharmaceuticals & Solvent	61.46%	55.23%
Bisphenol-A (BPA)	12.04%	16.83%
Methyl Methacrylate (MMA)	11.55%	10.48%
Methyl Isobutyl Ketone (MIBK)	10.10%	11.59%
Others	4.85%	5.87%

Source: TechSci Research

Acetone, also known as 2- propanone, is one of the essential aliphatic ketones widely used for numerous applications such as for the manufacturing of solvents, Bisphenol-A (BPA), Methyl methacrylate (MMA), Methyl Isobutyl Ketone (MIBK), and others. As of now, solvent manufacturing constitutes the significant demand for acetone in India, followed by BPA and MMA. Acetone-based treatments clear chemical stains and are becoming more popular in producing various solvents. Due to its miscibility with water and other organic molecules, it is anticipated to see a growing demand in the production of solvents. Over the projected period, personal care is expected to lead to the need for solvents, as polish removers and aids in the consistency of its demand. The rising use of acetone in skincare products for oily skin is projected to increase demand. The market for acetone in the personal care business is expected to be positively influenced by the exponentially expanding skincare concerns and anti-aging efforts. Further, it also finds application in manufacturing fragrances, hair care products, and cleansers.

Bisphenol A (BPA) demand is anticipated to expand rapidly in the upcoming years due to its use in manufacturing polycarbonate and epoxy resin. To cater to the rising demand for BPA, leading Indian players Aditya Birla and Reliance Industries Limited are planning to set up new BPA facilities. Polycarbonates are becoming increasingly popular in various end-use industries, including electronics, automotive, and construction. The product's desirable qualities, including ductility, amorphousness, UV light transparency, glare reduction, and excellent resilience to extreme temperatures, are key factors driving demand for the product.

Methyl Methacrylate (MMA) produced using acetone is applicable in the electronics industry for smartphones, laptop displays, Etc. Further, it is used to create PMMA which is also used in the electronic industry to produce flat-screen computers and liquid crystal displays.

One of the key market drivers for acetone is the rising pharmaceutical industry. Acetone serves a wide range of applications in the pharmaceutical industry. In the pharmaceutical industry, it is utilized as a solvent in fillers and active components to guarantee proper medicine dose. It also serves as an antiseptic. It is commonly used in the medical industry to disinfect and sterilize surgical instruments and devices. According to dermatologists, acne can also be treated with acetone and alcohol. The rising use of acetone for manufacturing Isopropyl alcohol, majorly consumed for synthesizing sanitizers, is anticipated to spur the demand for acetone in the forecast period.

2.12. Current Anti-Dumping Scenario of Phenol in India

There is an anti-dumping duty levied on exports of Phenol to India from Thailand and the USA, vide notification number F.No. 8/4/2020-DGTR. The case was filed by Deepak Phenolics Ltd., Hindustan Organics Chemicals Ltd., and SI Group India Pvt. Ltd. It was concluded that exports from Thailand were below their average value. Imports from Thailand caused injury to domestic manufacturers. The authority recommended imposing anti-dumping duty on all imports. The reference price as per the Preliminary Findings is USD990.83 per tonne.

In 2020, the import price of Phenol from the USA and Thailand ranged between USD650 – USD750 per tonne. These price changes are market-driven and are based on the fluctuation of prices in the feedstock (benzene, propylene, and Cumene). The Director General of Foreign Trade has revoked the anti-dumping duty on phenol imports from 31st October 2021. This is concerning phenol imports from European Union, South Korea, and Singapore. Currently, there is no significant import from these three countries/regions. As per the industry, imports from Thailand, the USA, China, and South Africa will impact the bottom line of domestic manufacturers.

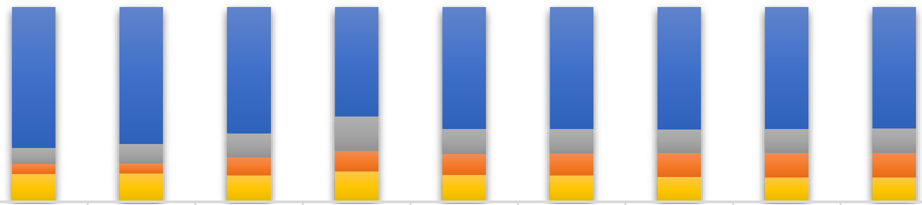
Present Scenario of Anti-Dumping Duty (ADD)

Countries	Quantum of Duty Imposed	Remarks
USA	USD 250 per MT - USD 350 per MT	Nil
Thailand	USD 250 per MT - USD 350 per MT	Nil
South Korea	US$ Nil to 253.06 per MT	Removed effective from 31/10/2021
European Union	US$ Nil to 253.06 per MT	Removed effective from 31/10/2021
Singapore	US$ Nil to 253.06 per MT	Removed effective from 31/10/2021

Source: DGFT

2.13. Demand By End Use

India Phenol Demand, By End Use, By Volume (000' Tonnes), FY 2010– FY 2040F



	FY2010	FY2015	FY2020	FY2021	FY2022E	FY2025F	FY2030F	FY2035F	FY2040F
Phenol Formaldehyde Resin	72.26%	70.27%	64.65%	56.13%	62.37%	62.44%	62.60%	62.35%	62.15%
Pharmaceuticals	8.20%	9.84%	12.45%	17.57%	12.90%	12.61%	12.12%	12.35%	12.53%
Bisphenol-A	4.98%	5.09%	9.35%	10.63%	10.82%	11.41%	12.39%	12.55%	12.74%
Others	14.56%	14.80%	13.55%	15.67%	13.91%	13.54%	12.89%	12.75%	12.58%

Others include Caprolactam, Aniline, Cyclohexanone, etc

Source: TechSci Research

Demand by End Use	2010	2015	2020	2021	2022E	2025F	2030F	2035F	2040F
Phenol Formaldehyde Resin	130	167	213	203	220	268	366	506	706
Bisphenol-A	9	12	31	38	38	49	72	102	145
Pharmaceuticals	15	23	41	64	45	54	71	100	142
Others	26	35	45	57	49	58	75	103	143
Total	**179**	**237**	**329**	**362**	**352**	**429**	**584**	**811**	**1136**

Source: TechSci Research

Historic End-Use Sectorial Growth in India

Demand by End Use	CAGR 2010-2021	CAGR 2022E-2030F	CAGR 2031F-2040F
Phenol Formaldehyde Resin	4.59%	6.58%	6.83%
Bisphenol-A	15.71%	8.36%	7.21%
Pharmaceuticals	15.76%	5.71%	7.28%
Others	8.05%	5.53%	6.63%

Others include Caprolactam, Aniline, Cyclohexanone, etc

Source: TechSci Research

The phenol formaldehyde resin sector dominated the Indian phenol market in FY2021. The demand for phenol formaldehyde resin relies mainly on the construction industry. India will continue to show an uptrend in phenol demand led by growth in the automotive and construction industries. Bisphenol-A is the second most dominant segment, which held approximately 10% of the market share in FY2021. The demand for Bisphenol-A is led by the demand for polycarbonate products, which are used in sectors such as automotive, construction, and automotive industries. Bisphenol-A is used in the downstream epoxy resin manufacturing process as well. The pharmaceutical industry is another end-use phenol segment poised to grow at a CAGR of approximately 12% during the forecast period.

India Phenol Demand

Growth Drivers for India Phenol & Acetone Market

Product	Domestic Market Demand	Export Potential	Import Substitution
Plywood	Yes	Yes	
Electric and Electronic Components	Yes	Yes	Yes
Adhesive	Yes		
Solvent and API Ingredient	Yes	Yes	
Engineering Thermoplastics	Yes		Yes

Driving Factors (Short Term Forecast Amid Pandemic Situation)

Pharmaceuticals: Phenol is an important chemical compound used to produce essential pharmaceutical excipients and disinfectants in India. Indian pharmaceutical sector, one of the fastest-growing industries, is expected to advance at a CAGR of around 11.50% during the 2021-30 period. India is the largest producer of generic drugs globally and is expected to supply more than 48% of the global demand for various vaccines, around 43% of the generic drugs market in the USA, and 25% of all medicines in the UK in 2020. Conducive policies for encouraging FDI, PLI Schemes, Tax benefits, and favourable government policies coupled with promising growth prospects have helped the industry attract private equity, venture capitals, and foreign players.

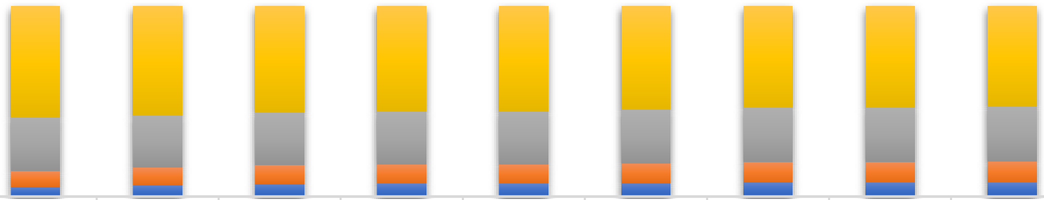
Phenolic Resin: The largest end-use sector for Phenol is the manufacturing of thermosetting resins phenol-formaldehyde. The condensation of formaldehyde produces these resins with Phenol in the presence of a catalyst. These resins find use as adhesives for binding wood products that comprise particle board, fiberboard, and plywood. Phenol-formaldehyde resins are used as molding compounds. Their thermal and electrical properties allow use in electrical, telephones, automotive, and parts of appliances and kitchen utensils. Other services for phenol-formaldehyde resins include:

- Phenolic foam insulation.
- Foundry mold binders.
- Decorative and industrial laminates.
- Binders for insulating materials.

An increasing number of household units, backed by growing disposable income, is aiding the country's furniture market. The per capita household income in Indian cities such as Ahmedabad, Surat, and Hyderabad is increasing at a significant rate. Moreover, major stores like IKEA plan to set up major retail hubs in these cities. The growing influence of western culture and shifting consumer preferences towards luxury living are expected to play a pivotal role in driving the furniture market in India.

Shifting Consumer Preferences: In India, the average age of home buyers has dropped from 40 to 27 years. The youth prefer modern furniture over traditional furniture due to their distinct and independent preferences. Indian consumers are becoming more sophisticated in their lifestyle choices thanks to rising literacy rates and the growing influence of western culture. Phenol is combined with formaldehyde to produce phenolic resins, which are used in a wide range of applications, including furniture, plywood, oriented strand board, laminates, foundry molds, and adhesives, which in turn stimulate the demand for phenol.

2.14. Demand, By Region, By Volume, FY2010-FY2040F



	2010	2015	2020	2021	2022E	2025F	2030F	2035F	2040F
West	58.23%	57.48%	55.61%	55.27%	55.11%	54.21%	53.12%	52.88%	52.50%
South	28.21%	27.20%	27.80%	27.91%	27.98%	28.25%	28.61%	28.80%	28.97%
North	8.30%	9.21%	9.81%	9.92%	9.96%	10.28%	10.64%	10.81%	10.94%
East	5.26%	6.11%	6.78%	6.90%	6.95%	7.26%	7.63%	7.51%	7.59%

Source: TechSci Research

Market Drivers

Government Support for Self-Reliance for Availability of Critical Electronic and Automotive Components

Government support for self-reliance is one of the most influencing factors supporting the demand rise for Phenol. Various government initiatives, including the 'Atmanirbhar Bharat,' are giving policy support for self-reliance in multiple chemicals such as Phenol for the application in critical electronic and automotive components. The electric vehicle policy of the Indian government is providing an enabling environment for electric vehicles during the forecast period. Hence, the factor remains equally influential during the forecast period also.

Booming Pharmaceutical Sector

Phenol is an essential component of various pharmaceutical products. As the pharmaceutical sector is booming in India with the rising population and hospitalizations, the demand for phenol is expected to increase in the pharmaceutical industry. The impact of the booming pharmaceutical sector on the demand rise for phenol is somewhat medium and lesser as compared to the effect of government policies. The result of the booming pharmaceutical industry remains the same during the forecast period as the products using phenol in pharmaceuticals are also rising gradually.

Robust Growth of Construction Sector

One of the essential downstream products of Phenol is Bisphenol A which is used to manufacture epoxy resins in adhesives, fillings, and composite materials. As the major consumer of sealants, fillings, and composite materials is the construction sector, the robust growth in the construction sector is thus an essential factor affecting demand rise in the Indian phenol market. The construction sector is experiencing growth because of the industry's revival after the pandemic-related lockdowns. The effect of the change in the construction sector remains the same during the forecast period as the demand for housing and infrastructure is rising with the growth in population and increasing government initiatives such as 'housing for all'.

Anticipated Recovery in Economy

The country suffered significant economic loss because of the coronavirus pandemic-related lockdowns and the suspension of economic activity. The demand for the construction sector fell, affecting the market for phenol in India. The economic activity is reviving with the recovery in the economy as the pandemic fades away. This anticipated economic recovery is expected to support demand rise for phenol as general economic recovery benefits all markets. The effect of economic recovery is lesser during the forecast period.

Availability of Feedstocks and Technology

The availability of feedstock and technology is also an influencing factor supporting the demand rise in India for phenol. The availability of Cumene as a feedstock is increasing in India with the rise in demand from the construction sector. The technology related to Cumene and Phenol production is also growing in India, with the companies becoming self-reliant in the production of phenol. This is also expected to support demand rise both during the estimated year and during the forecast period.

Fluctuation in Raw Material Prices

The raw material for phenol is Cumene which is prepared from Benzene, which is a petrochemical feedstock. Hence, the demand for phenol is negatively affected by the fluctuation in raw material prices. The effect of change in the raw material prices is lesser during the forecast period than in the estimated year because the recent volatility in the prices of raw materials has been high, and the prices are expected to stabilize during the forecast period.

Supply Chain Disruption

Supply chain disruption also affects the demand for phenol in India as the coronavirus-related supply chain disruptions, including lockdowns, port congestion, Etc., have a downside effect on the overall market for phenol. The demand is shown to be affected negatively by supply chain disruptions during the forecast period because supply chain-related demand fluctuations are a general phenomenon.

Fragmented Downstream Market

The demand for Phenol is negatively affected by a fragmented downstream market. The downstream market for the products such as bisphenol A and epoxy resins, pharmaceuticals, and phenol-formaldehyde resins is highly fragmented in India. There are many small-scale suppliers in place of prominent market players. This has a downside effect on the market during the estimated year and the forecast period.

2.16 Global Trade Phenol and Acetone Historical Trade Value and Future Trade Directions

2.16.1 Global Acetone Trade Dynamics, By Value (USD Million) and By Volume (000' Tonnes), 2010-2020

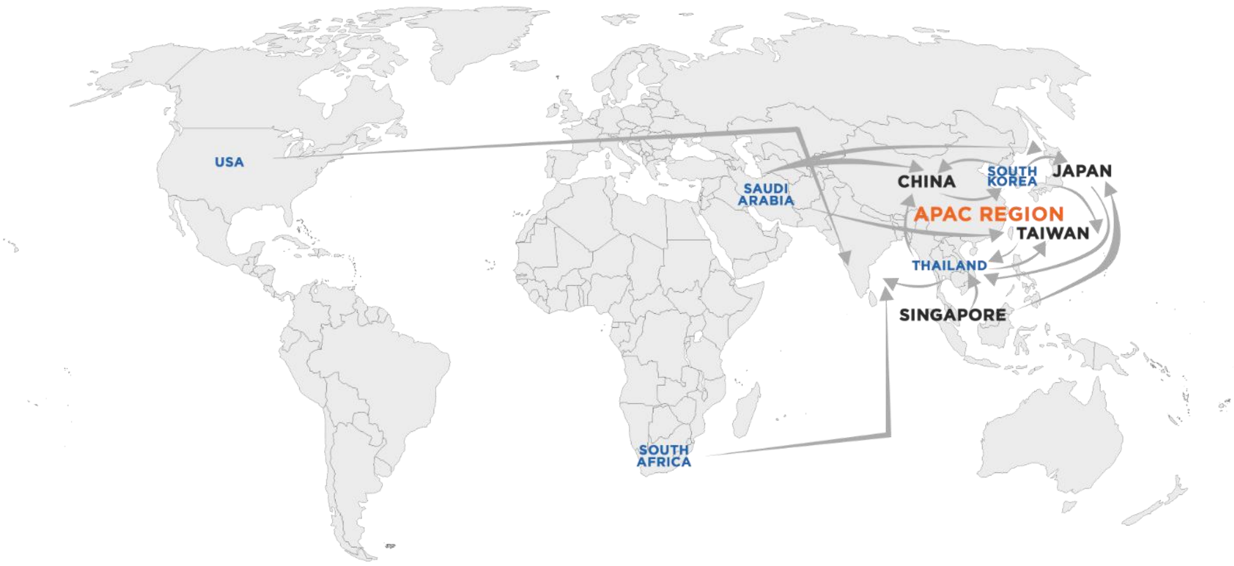
Importer Country	2010		2011		2012		2013		2014	
	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume
China	633.19	752.21	760.60	744.77	673.48	690.21	533.07	488.69	528.84	476.34
Belgium	125.77	134.54	142.33	122.62	179.25	166.15	193.17	178.36	193.28	179.10
Netherlands	194.59	220.89	226.54	191.71	152.13	135.43	149.91	132.47	179.68	0.00
Germany	130.59	142.75	172.86	155.54	179.88	167.73	223.52	206.55	247.03	221.45
India	77.99	84.49	101.49	90.99	103.71	100.67	131.08	114.67	137.27	115.67
Others	561.28	574.39	680.63	579.26	450.99	384.67	478.16	345.89	523.52	408.28
Total	1954.35	2154.46	2375.62	2125.56	1982.31	1869.56	2018.98	1731.39	2188.16	1707.98
Exporter Country	**2010**		**2011**		**2012**		**2013**		**2014**	
	Value	**Volume**	**Value**	**Volume**	**Value**	**Volume**	**Value**	**Volume**	**Value**	**Volume**
Belgium	361.03	445.11	425.47	409.33	439.89	424.92	462.12	408.10	582.40	505.77
Taiwan	206.45	252.06	269.00	267.23	232.42	248.93	285.73	273.98	263.45	251.28
South Korea	68.31	85.29	101.60	100.74	78.54	82.21	170.92	160.88	239.44	227.03
Thailand	90.87	102.14	87.70	82.60	76.97	74.65	83.36	72.88	42.97	38.26
Saudi Arabia	0.00	0.00	36.11	46.47	54.31	68.99	57.51	60.31	68.08	67.84
Others	488.72	362.61	353.29	323.34	380.01	371.77	379.36	352.97	366.91	334.92
Total	**1872.92**	**2002.74**	**2101.26**	**1993.85**	**1957.64**	**1884.64**	**1957.89**	**1742.59**	**2149.57**	**1829.55**

Importer Country	2015		2016		2017		2018		2019		2020	
	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume
China	267.14	436.63	265.41	475.50	360.42	494.59	429.26	677.71	334.13	779.67	533.89	707.17
Belgium	148.07	201.86	135.69	245.67	225.18	308.90	295.76	356.32	254.63	354.36	220.35	347.95
Netherlands	126.72	153.11	94.80	144.61	162.76	226.94	132.36	171.48	88.21	128.35	105.20	135.76
Germany	146.95	204.26	133.52	239.08	186.74	244.85	205.73	240.93	108.57	155.17	92.62	135.66
India	99.58	145.14	80.56	132.67	119.18	149.85	87.45	122.98	38.54	77.25	67.35	81.09
Others	336.80	393.54	339.81	530.76	531.38	590.00	464.35	554.16	321.22	357.67	384.20	348.30
Total	**1346.44**	**1832.27**	**1240.23**	**2075.10**	**1932.65**	**2411.06**	**1980.63**	**2568.84**	**1383.15**	**2215.42**	**1622.72**	**2040.94**

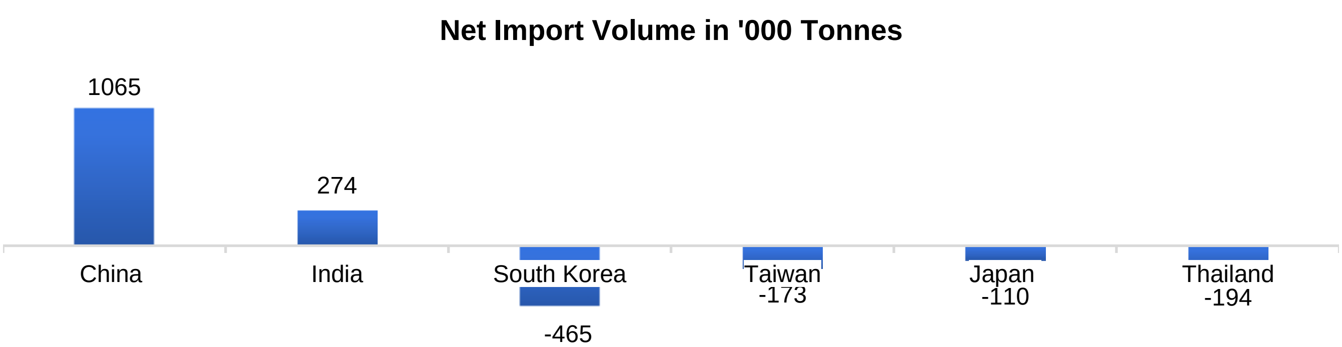
Exporter Country	**2015**		**2016**		**2017**		**2018**		**2019**		**2020**	
	Value	**Volume**	**Value**	**Volume**	**Value**	**Volume**	**Value**	**Volume**	**Value**	**Volume**	**Value**	**Volume**
Belgium	354.04	474.87	306.08	483.74	412.81	549.33	468.16	584.72	314.78	506.08	310.66	476.77
Taiwan	146.42	251.69	135.05	259.47	169.15	240.55	144.11	243.67	96.45	241.71	157.68	226.33
South Korea	106.62	194.85	127.32	236.15	203.72	287.41	199.13	328.38	88.44	219.73	152.52	213.88
Thailand	22.79	38.58	65.63	112.14	112.47	156.78	126.99	203.31	82.20	200.03	154.72	204.81
Saudi Arabia	38.13	64.86	26.11	54.71	64.60	65.30	123.84	160.09	106.66	222.88	121.88	181.31
Others	206.78	296.32	193.72	341.47	190.64	215.44	137.57	174.49	115.57	195.26	135.46	184.03
Total	**1246.30**	**1866.27**	**1138.25**	**1964.50**	**1599.40**	**2042.60**	**1572.22**	**2171.20**	**1091.21**	**2097.12**	**1372.17**	**1938.07**

2.16.2 Global Phenol and Acetone Trade Flow Directions in Asia Pacific, Europe, Middle East and Africa and North America region

APAC Net Import of Phenol, By Country, 2020

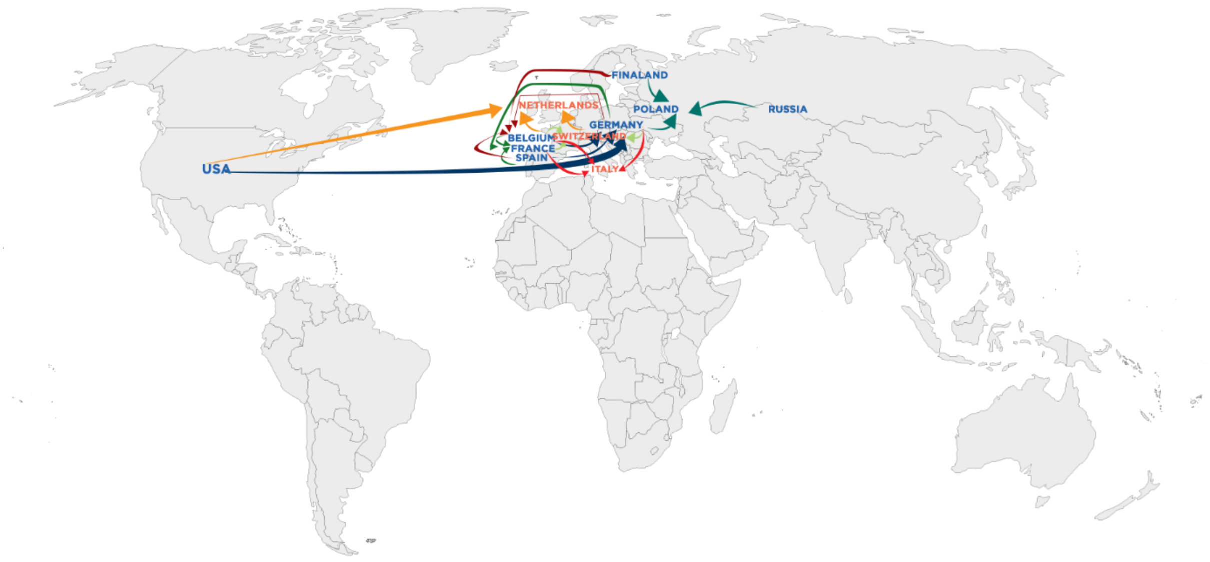


APAC Net Import of Phenol, By Country, 2020

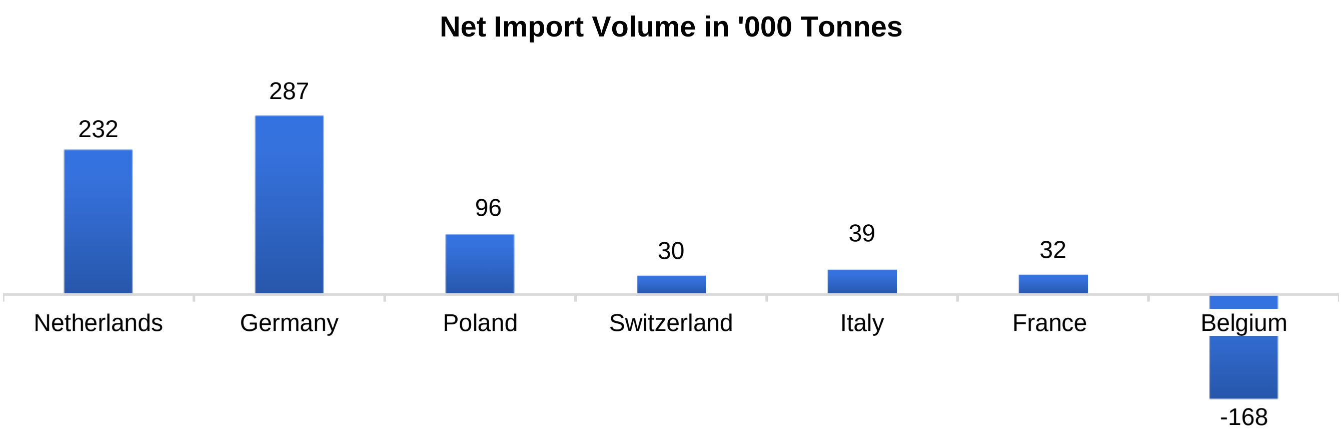


Source: UN Comtrade

EMEA Trade Flow Phenol, By Country, 2020

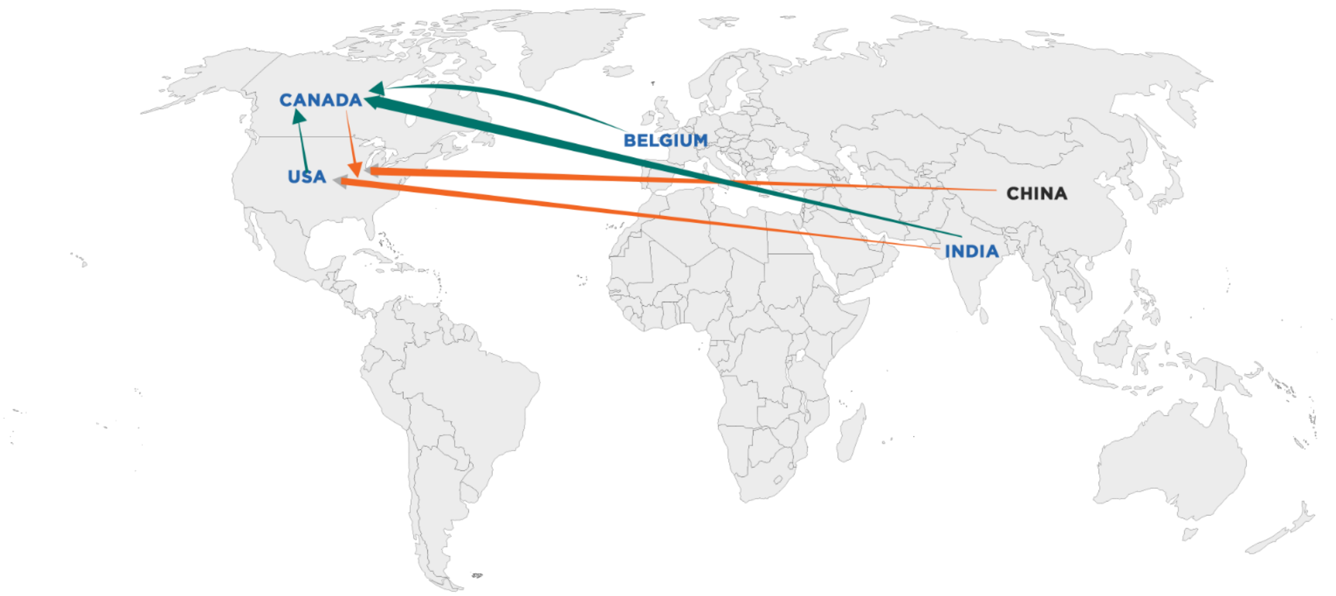


EMEA Trade Flow Phenol, By Country, 2020

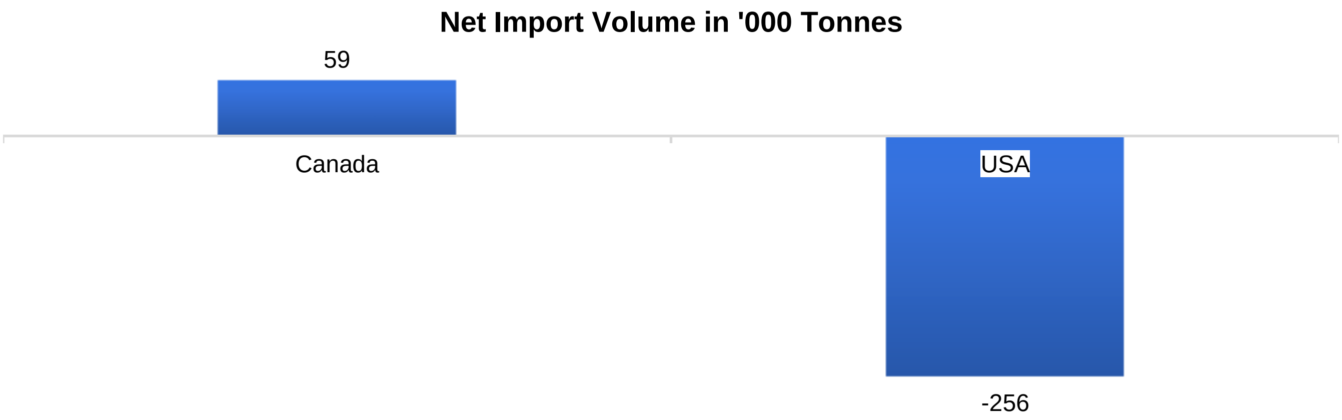


Source: UN Comtrade

North America Trade Flow Phenol, By Country, 2020



North America Trade Flow Phenol, By Country, 2020

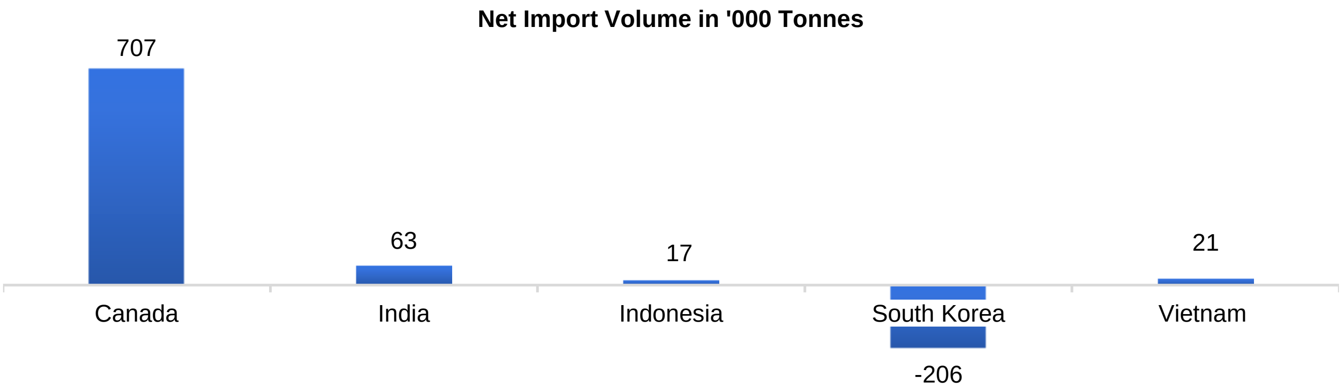


Source: UN Comtrade

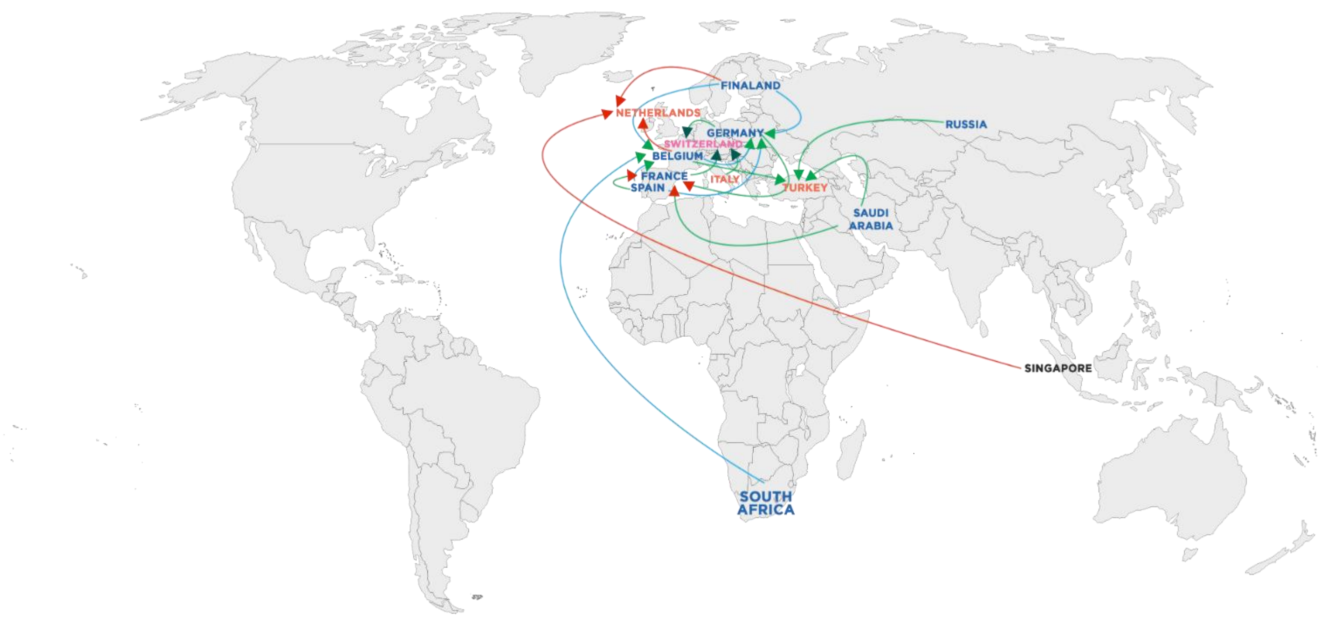
APAC Net Import of Acetone, By Country, 2020

Source: UN Comtrade

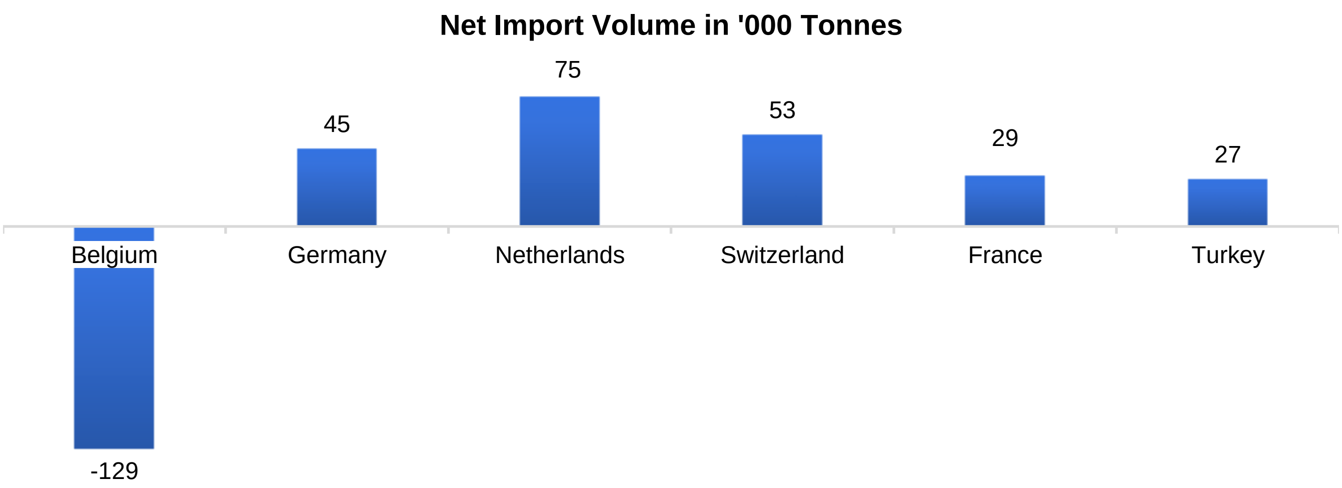
APAC Net Import of Acetone, By Country, 2020



EMEA Trade Flow of Acetone, By Country, 2020



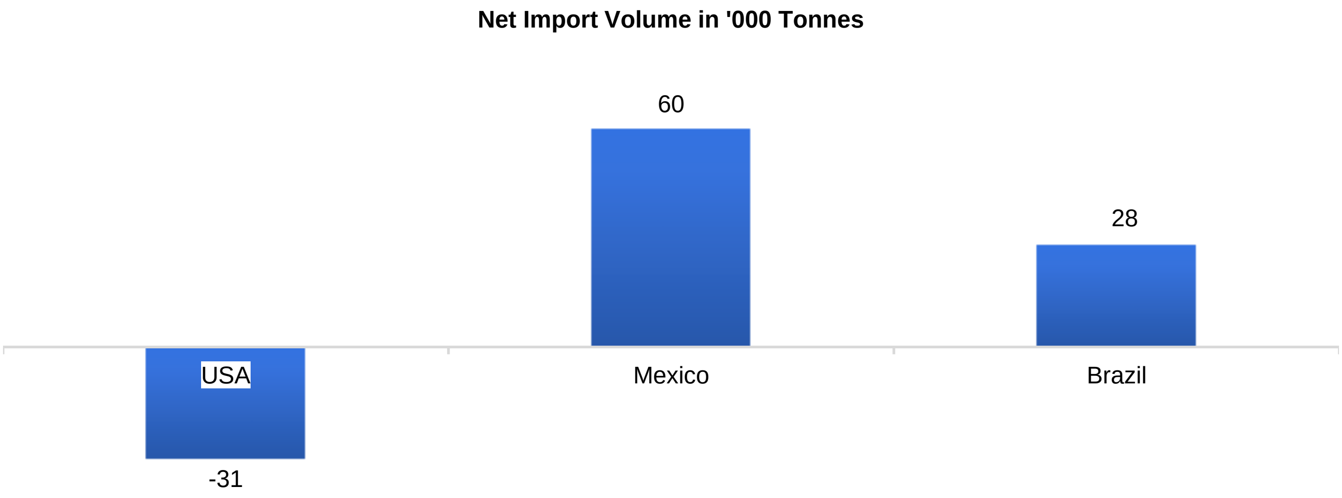
EMEA Trade Flow of Acetone, By Country, 2020



Source: UN Comtrade

North America Net Import of Acetone, By Country, 2020

North America Net Import of Acetone, By Country, 2020



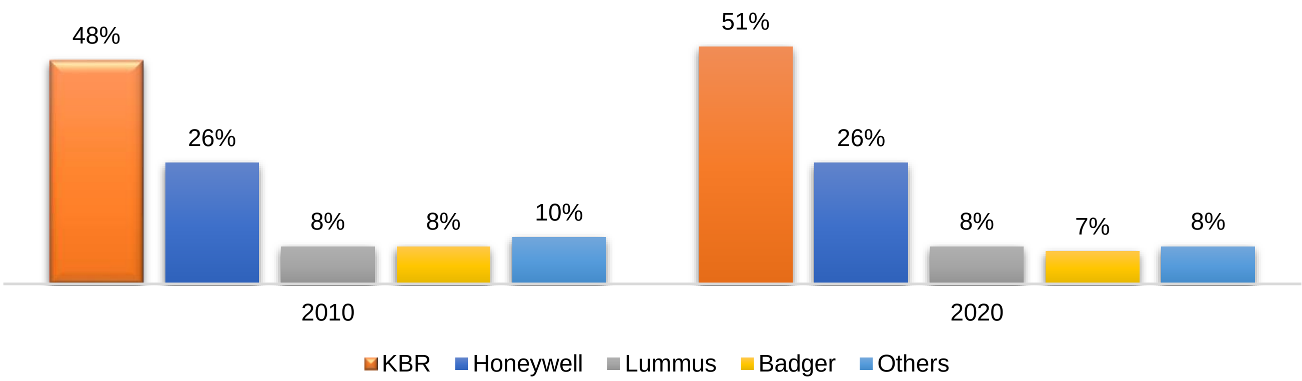
Source: UN Comtrade

2.16.3. Region Wise Trade (000' tonnes), 2010-2020

		2010	2015	2016	2017	2018	2019	2020
APAC	Capacity	4129.00	5299.00	5299.00	5499.00	5899.00	5899.00	5899.00
	Production	3277.93	3539.86	3724.39	4006.14	4494.75	5038.40	5409.15
	Demand	4114.97	4291.36	4406.45	4593.67	4811.19	5014.77	5386.71
	Surplus / Deficit (-)	-837.04	-751.50	-682.06	-587.53	-316.44	23.63	22.44
EUROPE	Capacity	2773.00	2773.00	2783.00	2783.00	2783.00	2783.00	2783.00
	Production	2441.37	2281.51	2206.48	2254.44	2206.92	2147.05	2350.07
	Demand	1689.91	1681.57	1715.29	1767.14	1834.81	1893.45	2013.39
	Surplus / Deficit (-)	751.46	599.94	491.19	487.30	372.11	253.60	336.68
NORTH AMERICA	Capacity	2422.00	2422.00	2572.00	2572.00	2572.00	2572.00	2572.00
	Production	1874.91	2015.28	1942.37	1966.20	1850.80	1981.21	2068.74
	Demand	1312.78	1433.54	1447.04	1459.89	1471.55	1478.42	1635.18
	Surplus / Deficit (-)	562.13	581.74	495.33	506.31	379.25	502.79	433.56
MEA	Capacity	0.00	0.00	270.00	270.00	270.00	270.00	270.00
	Production	0.00	0.00	221.40	229.50	218.70	224.10	224.10
	Demand	489.31	480.93	508.14	537.25	578.64	632.11	695.26
	Surplus / Deficit (-)	-489.31	-480.93	-286.74	-307.75	-359.94	-408.01	-471.16
SOUTH AMERICA	Capacity	250.00	250.00	250.00	250.00	250.00	250.00	250.00
	Production	210.00	207.50	212.50	205.00	200.00	205.00	210.00
	Demand	349.28	520.45	521.04	522.15	547.21	544.13	463.84
	Surplus / Deficit (-)	-139.28	-312.95	-308.54	-317.15	-347.21	-339.13	-253.84

Source: TechSci Research

2.16.4 Global Share of Technology Licensors for Phenol and Acetone Manufacturing, 2010 & 2020



Source: TechSci Research Estimates

The significant technologies available to produce Phenol are KBR Technology, Honeywell UOP, Lummus Technology, Badger Technology, and others. Most of the technologies public use the Cumene process to produce phenol and acetone. The technology of KBR holds the highest share among all the technology licensors, with a percentage share of 51% as of 2020. The KBR technology involves the oxidation of Cumene with air at high efficiency to produce Cumene Hydroperoxide (CHP). CHP then undergoes concentration and cleaving to form phenol and acetone in the presence of an acid catalyst using the KBR's advanced cleavage system. Once the catalyst is removed, the cleavage mixture is fractioned to produce high purity phenol and acetone. The benefits of KBR technology over other technologies are that it increases efficiency and integration, maximizes plant reliability and operability, offers reduced capital and operating costs, and produces the highest yields and lowest emissions possible. KBR was awarded a technology license by Haiwan Chemicals to manufacture Phenol/Acetone in 2019.

Phenol & Acetone Specification – KBR Technology

Phenol Specifications		
Parameters	**UOM**	**Specifications**
Appearance	-	Clear Colorless Liquid
Purity (Dry Basis)	wt%	99.99 Min
Water Content	wt-ppm	200 Max
Color, Pt/Co	APHA	5 Max
Sulfuric Acid Discoloration Test	%	95 Min
Freeze Point	°C	40.85 Min
2-Methylbenzofuran	wt-ppm	3.0 Max
Hydroxyacetone	wt-ppm	2.0 Max
Acetophenone	wt-ppm	2.0 Max
AMS+Cumene	wt-ppm	3.0 Max
Total Organics excluding Cresols	wt-ppm	35 Max
Total Cresols	wt-ppm	30 Max
Total Carbonyls	wt-ppm	10 Max
Acetone Specifications		
Parameters	**UOM**	**Specifications**
Appearance	-	Clear Colorless Liquid
Purity (Dry Basis)	wt%	99.99 Min
Color, Pt/Co	APHA	5 Max
Water Content	wt%	0. Max
Specific Gravity (20°C/20°C)	-	0.791-0.793
Acidity (Based on Acetic Acid)	wt%	0.001 Max
Alkalinity (As Ammonia)	wt-ppm	1.0 Max
Water Solubility	-	Completely Soluble
Distillation Range (including 56.1°C)	°C	0.6 Max
Permanganate Time	Minutes	240 Min
Non- Volatile Matter	g/100 ml	0.001 Max
Benzene	wt-ppm	5 Max
Methanol	wt-ppm	250 Max

Phenol Specification – Honeywell Technology

Parameter	Unit	Value	
		GR. I	GR. II
Crystallization temperature, min.	°C	40.6	40.2
Water solubility determined by turbidity or OPaL essence of the standard solution max.	mg Cl	0.2	0.6
Water content, max.	%(m/m)	0.2	0.3
Color of liquid phenol, max.	Pt/co sale degrees	25	25
Cumene and alpha-methyl styrene content, max.	% (m/m)	0.015	0.015
The content of carbonyl compounds, max.	% (m/m)	0.007	0.007
Mesityl oxide content, max.	% (m/m)	0.005	0.005
Total Sulfur content	ppm(m/m)	2	2
Formic acid content	% (m/m)	0.0015	0.0015

3. Basis and Objectives of Pre-Feasibility Study (PFS)

Considering the growing market scenario, OPaL proposes to enter the phenol business. With the increasing demand (within India and across the globe), there is a need to set up a phenol manufacturing unit in India. The market for this product has gained pace tremendously, and there are more significant opportunities in the indigenous and export markets.

Following are the Key Objectives of the Pre-Feasibility Study:

- Three players, namely Deepak Phenolics Ltd. (DPL), Hindustan Organic Chemicals Ltd (HOCL), and SI Group - India Private Limited (SIGIL) have a presence in the Indian phenol market. However, to cater to the increasing demand for phenol in the domestic market and to capture opportunities in the export market, OPaL plans to manufacture phenol and acetone.
- OPaL has its manufacturing unit of benzene and propylene feedstocks to produce Cumene and phenol, which can significantly reduce the manufacturing cost, giving an added advantage over the rest of the players.
- Acetone is a by-product of the phenol manufacturing process used to produce downstream derivative IPA, which has application in producing hand sanitisers. Due to the COVID-19 pandemic, demand for acetone has increased significantly in India. To capture the increasing demand for acetone, OPaL aims to produce acetone.
- By setting up a manufacturing unit for phenol and acetone in India, OPaL can reduce import dependency and foreign trade risk.

It will also help to reduce the import of phenol and acetone, which can further strengthen the foreign exchange reserve of India.

4. Optimum Option for the Pre-Feasibility Study (PFS)

OPaL is planning to enter the Phenol and Acetone market with a capacity of 200 KTPA and 120 KTPA, respectively. Different grades of Propylene need to be evaluated for better realization during the pre-feasibility study to conclude the Optimum option for the PFS.

Options	Feed	Total Phenol/Acetone Capacity
Option-1	200 KTPA Phenol + 120 KTPA Acetone (Propane Furnace Additional)	200/120 KTPA
Option-2	200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene)	200/120 KTPA
Option-3	200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)	200/120 KTPA

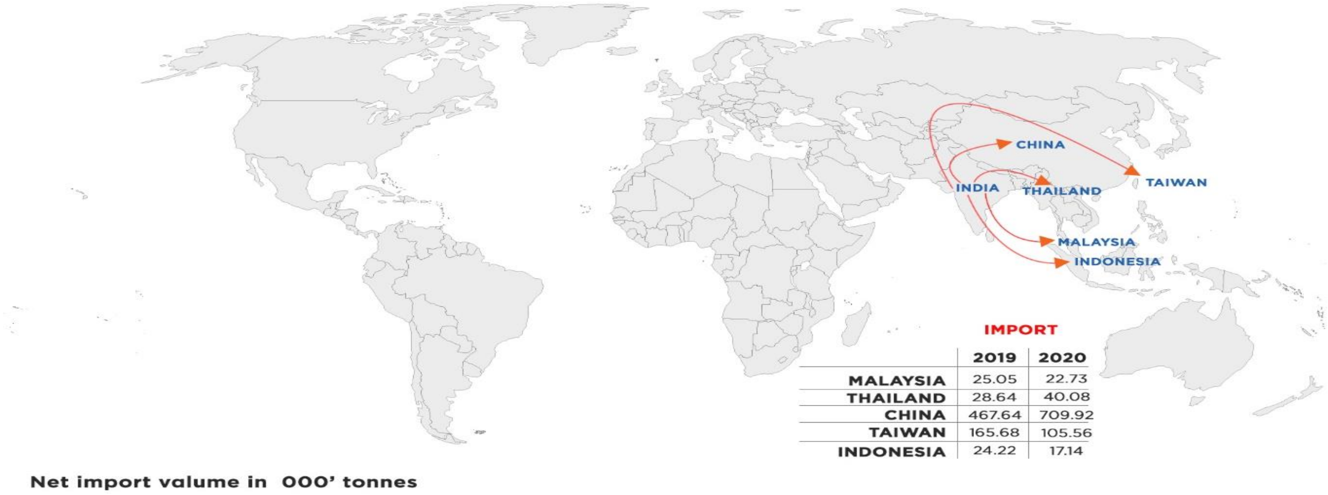
4.1 Export Potential Market of Phenol for OPaL

OPaL can export phenol to countries such as China and Taiwan. In 2020, China imported around 710 thousand tonnes of phenol from various countries across the globe. Similarly, in 2020, Taiwan imported about 105.56 thousand tonnes of phenol from multiple countries. As China and Taiwan in the Asia Pacific are the major importers of phenol, OPaL can export the phenol to these countries for better realization. South Korea, Indonesia, Vietnam, Pakistan, Japan, and Indonesia may be considered by OPaL for export. Thailand and Indonesia, which imported 40.08 and 17.14 thousand tonnes of phenol in 2020, could serve as the potential export market for OPaL. OPaL will be competitive with all Southeast Asian countries, including Thailand and Indonesia.

	2019			2020		
Countries	**Import**	**Export**	**Net Export Potential**	**Import**	**Export**	**Net Export Potential**
China	467.64	7.57	460.07	709.92	17.29	692.63
Taiwan	165.68	604.88	-439.20	105.56	180.52	-74.96
Thailand	28.64	196.58	-167.94	40.08	225.11	-185.03
Malaysia	25.05	0.49	24.56	22.73	0.25	22.48
Indonesia	24.22	0.23	23.99	17.14	0.27	16.87

Note: Import and Export Volumes are in Thousand Tonnes

Source: UN Comtrade



Indian Subcontinent Countries Having Less Potential for Phenol in Asia Pacific Region

Countries such as Nepal, Bangladesh, Myanmar, Pakistan, and Sri Lanka had combined export of fewer than five thousand tonnes as of 2020. Bangladesh and Pakistan constitute around 80% of the demand in these countries, as these countries do not have phenol producers along with negligible imports because of poor demand for downstream phenol derivates such as bisphenol-A phenol-formaldehyde resin, Etc. Further, the presence of pharmaceutical companies is also significantly less in these countries. Therefore, exporting to these countries is not viable as per the current demand scenario.

5. Process Description, Product Slate, Specifications, Applications and Unit Capacities

Phenol is a colourless organic derivative of Benzene, which can be produced via various routes and synthesized as a highly demanded petrochemical. The most common process for manufacturing Phenol is via Cumene Route. In this process, Cumene is obtained using Benzene and Propylene, which is further oxidized to yield Hydroperoxide, which is finally subjected to acid catalysis to form Phenol/Acetone. Phenol can be categorized as monohydric, dihydric, and polyhydric based on the number of hydroxyl groups attached. Phenol is predominately utilized as a chemical feedstock to produce a highly valued derivative, Bisphenol A, which is consumed for producing remarkable plastics like epoxy resins and polycarbonates. The product also finds large-scale applications in making derivatives like Phenolic Resin and Caprolactam, which are used on a large scale in the construction and polyester industry.

Cumene Manufacturing Process by Honeywell Process

Cumene is produced by the reaction of benzene and propylene with the help of an acid catalyst. Cumene is mainly produced as a feedstock for manufacturing Phenol and Acetone. The Honeywell Q-Max process had selected the most promising catalyst based on zeolite for Cumene production. The Honeywell Q-Max process produces nearly equilibrium levels of Cumene between 85 to 95 mole % and Di isopropyl Benzene (DIPB) between 5 and 15 mole %.

Cumene Production Reaction

$$\underset{\text{propylene}}{C_3H_6} + \underset{\text{benzene}}{C_6H_6} \rightarrow \underset{\text{cumene}}{C_6H_5\text{-}C_3H_7}$$

$$\underset{\text{propylene}}{C_3H_6} + \underset{\text{cumene}}{C_6H_5\text{-}C_3H_7} \rightarrow \underset{\text{diisopropyl benzene (DIPB)}}{C_3H_7\text{-}C_6H_4\text{-}C_3H_7}$$

Process description

(1) An alkylation reactor, a distillation section, and a trans-alkylation reactor make up a Q-max unit. Both reactors have a fixed bed configuration. Four catalyst beds are enclosed in a single reactor vessel in the alkylation reactor. The reaction temperature in the alkylation zone is 150-260°C.

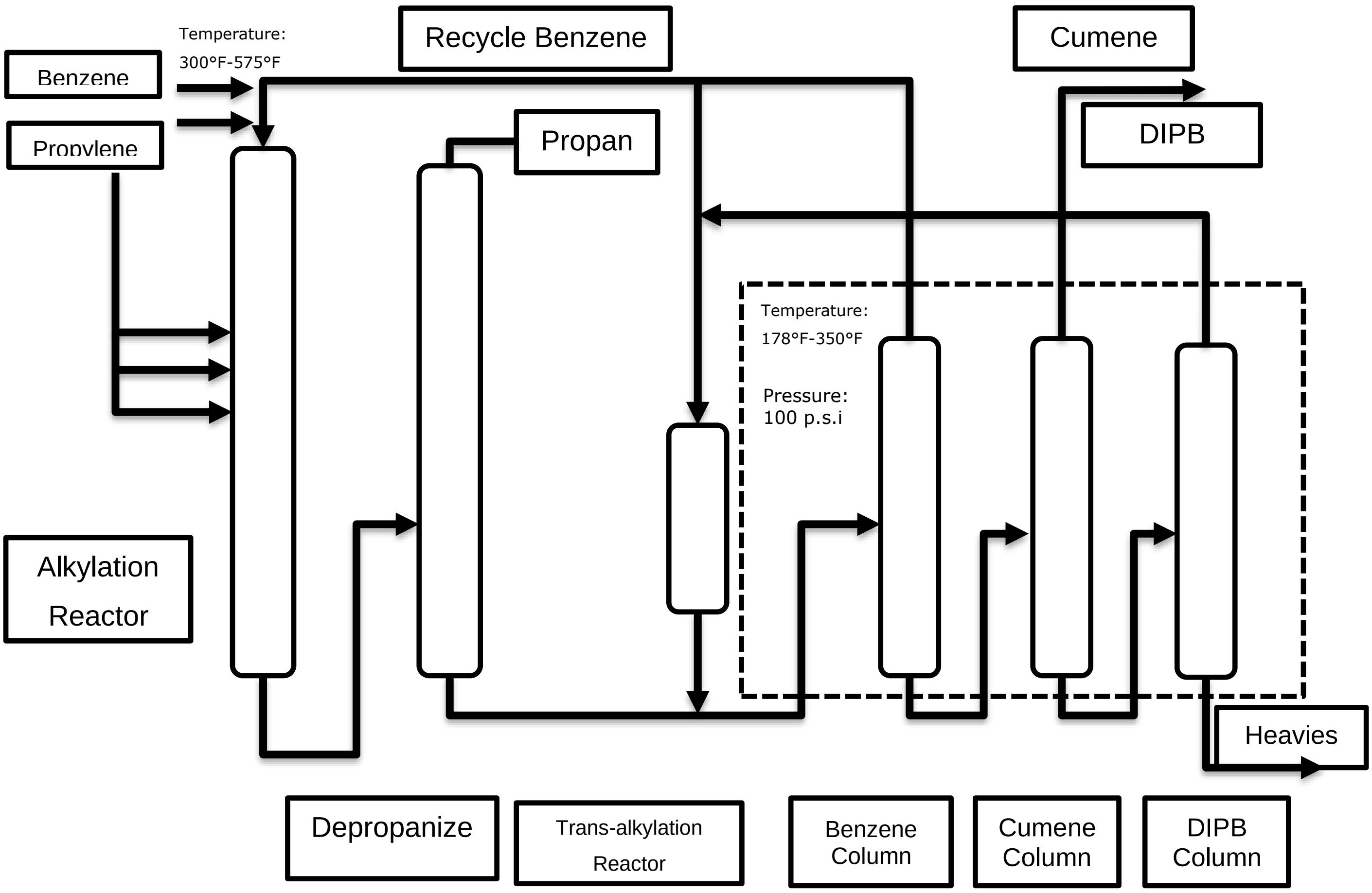
(2) Propylene and a combination of new and recycled benzene are fed into the alkylation reactor, where the propylene reacts completely to produce Cumene. The depropanizer column receives the effluent from the alkylation reactor, which eliminates the propane that entered the unit with the propylene feed and any excess water that may have accompanied the feeds.

(3) The bottoms of the depropanizer column are delivered to the benzene column, where the benzene is collected and recycled overhead. The temperature range of the benzene distillation column lies in the range of 178°F-350°F. The bottom of the benzene column is delivered to the Cumene column, which recovers the Cumene product overhead. The bottom of the Cumene column, which is diisopropyl benzene, is transferred to the DIPB column, where the diisopropyl benzene is collected and recycled back to the trans-alkylation reactor. The bottoms of the DIPB column contain a tiny stream of heavy aromatic by-products, often employed as a blending component in high-octane gasoline.

(4) Both the alkylation and trans-alkylation reactors use regenerable catalysts. The unit can be constructed for slightly longer cycles if needed. However, the standard design cycle duration between regenerations is two years. The catalyst's ultimate life span is at least three cycles.

Gaseous Emissions from Cumene Process

Gaseous Emissions from Cumene unit		
Item	Phase	Disposal Method
Propane Vent	Gas	LPG or Fuel
Fractionator Overhead Receivers	Gas	Closed system type or vent to the relief header
Benzene Drag	Gas	Gas blanketed and vented to the atmosphere intermittently



Source: Dryden's Outlines of Technology

Phenol Manufacturing Process by Honeywell Technology

Traditional Method

Phenol is a major petrochemical consisting of an aromatic ring called carbolic acid. Most of the Phenol producers across the globe preferred to produce Phenol via Cumene (Hock Process/Rearrangement) due to its feasibility in producing Phenol and other derivatives.

1. Hock Rearrangement for Phenol Manufacturing

In hock rearrangement for phenol manufacturing, oxidation of Cumene to Cumene Hydroperoxide and subsequent cleavage is done to produce Phenol and Acetone.

(1) Oxidation

The primary purpose of the oxidation section is to produce Cumene hydroperoxide (CHP) from fresh and recycled Cumene streams. Cumene is heated to a reaction temperature of 60-85°C and pressure of 500-760 mmHg and fed to a series of oxidizers. Fresh air, provided by a centrifugal compressor, enters each oxidizer's bottom. As the air flows upward through the liquid column, it oxidizes Cumene to CHP. The oxidizer spent air contains a significant amount of Cumene. In the spent air treatment section, condensation recovers Cumene, and the remaining volatile organic compounds (VOCs) are incinerated.

(2) Cumene Stripping (Concentration)

The oxidizer effluent typically contains about 22-28 wt—% CHP, with the remainder being unreacted Cumene and a small portion of oxidation by-products. The processing system to remove Cumene from oxidizer effluent utilizes vacuum distillation. Cumene, recovered in the overheads, is recycled to the oxidation area. The concentrated oxidate contains 80-85% CHP.

(3) Cleavage Reactor

The acid-catalyzed decomposition of CHP forms phenol and acetone. This step is carried out in a 2-stage cleavage system, where the operating conditions are set to maximize yields of phenol, acetone, and AMS and minimize the formation of heavy by-products. In this system, the reaction temperature is maintained at 130-140°C.

- The concentrated CHP solution from the Cumene stripping section is fed to the first cleavage reactor. Acetone is recycled from fractionation and is used to control the reaction temperature and minimize the formation of undesirable by-products.
- Net reactor product is pumped to the 2nd stage reactor to complete the reaction of CHP and dicumyl peroxide (DCP). The cleavage product is cooled before entering the neutralization section.

(4) Neutralization and Wash

The cleavage effluent contains the acid used as the catalyst for the cleavage reaction. In this section, the acids are neutralized and extracted. These operations are performed using a two-stage neutralization system.

Fractionation to Recover and Purify Phenol and Acetone

The major sections are:

(1) Acetone Fractionation

After cleavage and neutralization, the mixed organics are fractionated and purified. The acetone fractionation system serves the purpose of (1) crude separation of acetone and hydrocarbons from phenol and heavies and (2) purification of acetone product.

The acetone fractionation train consists of two columns: The Crude Acetone Column and the Acetone Product Column. In the crude Acetone Column, the neutralizer product is fractionated to an overhead stream consisting of acetone, water, Cumene, AMS, and other light materials, and a bottoms stream consisting of phenol and heavier components. The vapor distillate is sent to the Acetone Product Column for acetone purification. The purpose of the Acetone Product Column is to remove light ends, separate water, and hydrocarbons, and produce on-spec acetone products.

(2) Phenol Fractionation and Heavies Removal

The phenol fractionation section is fed with the bottoms of the crude acetone column. This stream consists of phenol, a small number of organics lighter than phenol, and heavy organics such as cumyl phenol, AMS dimer, and tars. The purpose of the phenol fractionation section is to isolate and purify the phenol product and to recover valuable organics for recycling. This is achieved in a three-column fractionation train that includes the Crude Phenol Column, the Hydrocarbon Removal Column, and the Phenol Finishing Column.

Crude acetone column bottoms are pumped directly to the Crude Phenol Column, where the bulk of the phenol is taken overhead along with all of the lighter organics. The net overhead of this column is fed to the Hydrocarbon Removal Column. This column separates hydrocarbons from phenol using water as an azeotroping agent. A resin bed treater is provided between the Hydrocarbon Removal Column and the Phenol Finishing Column when very high purity phenol is desired. The treater improves the phenol purity by removing trace carbonyl impurities. The bottom stream of the Crude Phenol Column is fed to the Heavies Removal Column, where phenol is recovered in the overhead stream and recycled to the Crude Phenol Column. Heavy materials, including acetophenone, cumyl phenol, and AMS dimers, are removed from the bottom of the Heavies Removal Column.

(3) AMS Fractionation and Hydrogenation

One of the major by-products of the phenol/acetone process is alpha-methyl styrene (AMS), which is formed by dehydration of dimethyl benzyl alcohol (DMBA) and oxidation by-product. In this section, trace amounts of phenol are removed from the crude AMS, then fractionated and hydrogenated to Cumene for recycling to oxidation.

Alternatively, AMS can be recovered as a byproduct from the phenol plant, where the distillation is designed to produce high purity AMS.

(4) Dephenolation

The purpose of this section is to prepare effluent water for biological treatment and recover phenol from water streams for process economic reasons. Phenol removal and recovery are affected in the Dephenolation step. Collected process water is treated in a solvent extraction system for the recovery of Phenol.

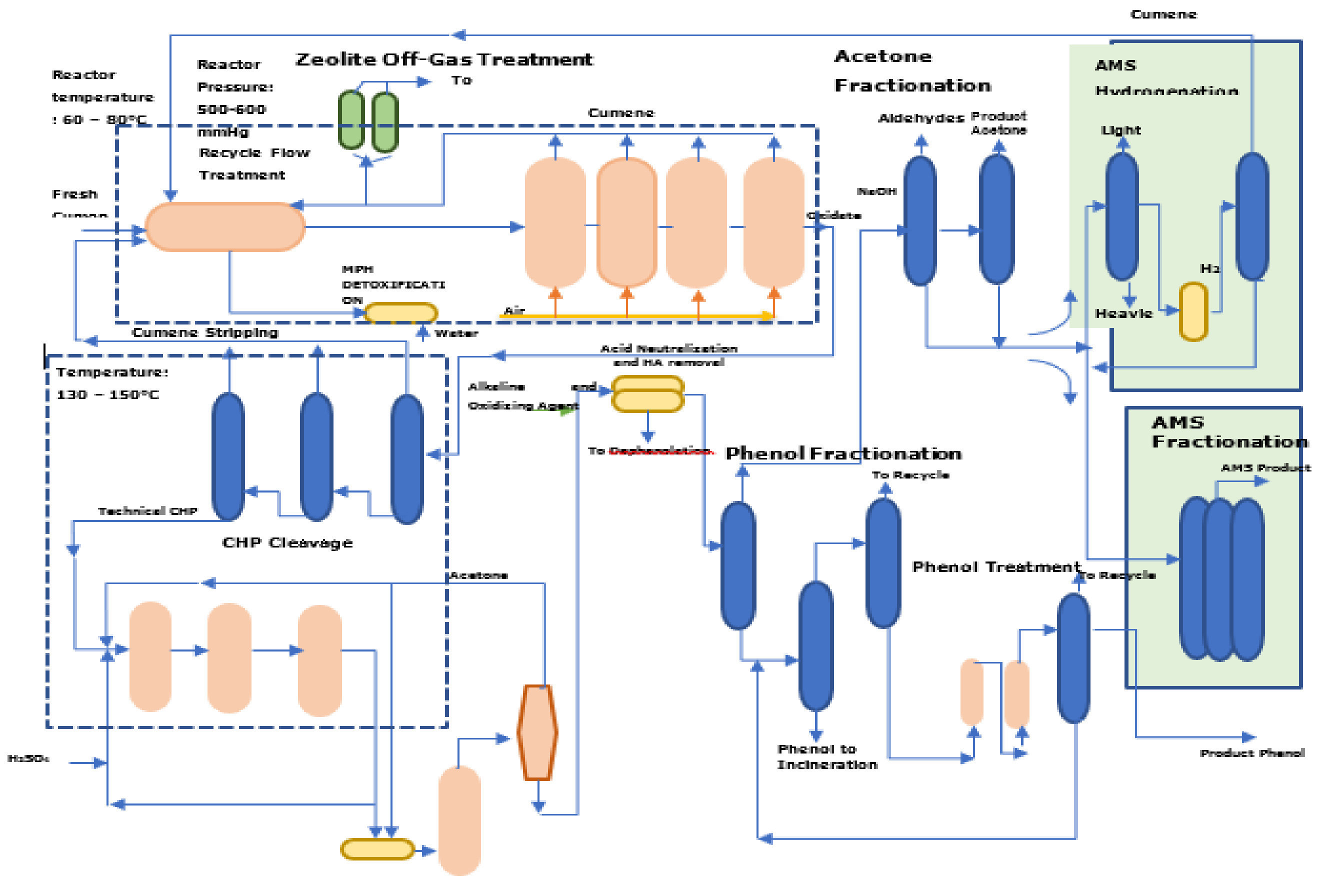
(5) Vent System and Emergency Relief Scrubber

The vent system is designed to collect vapor streams to recover phenol, acetone, and hydrocarbons and condense these materials from the vapor. The residual vents are then directed to the Spent Air Incinerator, thus resulting in a single-point vapor emission source virtually free of VOCs.

Solid Waste

The Phenol process produces no continuous solid residue effluents. Solid waste, however, is produced in the form of spent catalyst from the Phenol Resin Treater, that can either be landfilled or incinerated.

Block Diagram of Phenol Manufacturing



Source: INEOS Phenol

5.1 Product Specification

Tentative product specifications may vary based on licensors guidelines.

Properties		Units	Value
Cumene Content		Wt.%	> 99.9
Appearance	Water white, clear with no turbidity		
Color, APHA		Pt-Co	< 10
Distillation range (including 152.5ºC.)		°C.	< 1.0
Bromine Index			< 50

Impurities	Value (wt. ppm)
Benzene	< 10
Toluene	< 5
Ethyl benzene	< 200
n-Propyl benzene	< 300
Butyl benzenes	< 150
Cymenes	> 50
Di-isopropyl benzenes	< 5
Sulfur	< 1
Phenols	< 50
Peroxides	<100

Source: OPaL

Phenol

Property	Value
Phenol, wt.% min	< 99.99
Water Content, wt. ppm max	< 50
Colour, Pt-Co max	< 5
Solidification Point (dry), ºC min	< 40.85
Iron Content, wt. ppm	0.1
Ash Content, wt. ppm	1.0
Total Carbonyls, wt. ppm as mesityl oxide	< 12
3-Methyl Cyclopentanone, wt. ppmx	< 2
2 Methyl Benzofuran, wt. ppm	< 5
Hydroxyacetone, wt. ppm	< 3
Benzaldehyde, wt ppm	< 5
Cyclohexanone plus Cyclohexanol, wt ppm	< 5
Total organics excluding cresols, ppm	< 12
Residue on Evaporation, wt%	0.01

Source: OPaL

Acetone

Property	Value
Purity (dry basis), wt.%	> 99.75
Color, Pt-Co	< 5
Water Content, wt.%	< 0.2
Permanganate Test Time, hours	>4
Distillation Range, ºC including 56.1ºC (760 mm Hg)	< 0.5
Aldehydes, wt. ppm max	20
Benzene, wt. ppm max	1
Non-volatiles, wt. ppm max	5
Iron Content, wt. ppm	< 0.1
Ash Content, wt. ppm	< 1
Methanol, wt. ppm	< 250
Residue on Evaporation, wt. ppm	< 0.002

Source: OPaL

5. 2 Applications of Phenol

- The demand for Phenol is mainly determined by its derivatives, especially bisphenol-A (BPA) and phenolic resins, which account for the largest share of Phenol's market.
- Bisphenol A is the most common downstream application of Phenol, primarily used to manufacture polycarbonate and epoxy resins. The demand for polycarbonate mainly arises due to the growing demand for automotive, electronic products, business equipment, and construction products.
- Phenol formaldehyde resin (Phenolic Resin), which contributes to the primary end use of Phenol, is primarily used in wood additives as well as molding and laminating resins, varnishes, paints, and enamels.
- Phenolic resins are mainly used as durable binders and adhesives in structural wood panels and as binders in mineral wool insulation. Brake linings, foundry binders, insulating foams, and composites are just a few applications in the automotive and construction industries.
- The third largest consumer contributing to the demand for Phenol is Caprolactam, which is primarily used to manufacture nylon six fibers, engineering resins, and film.
- Other derivatives of Phenol contributing to its demand include alkylphenols, xylenols, aniline, and miscellaneous (p-nonylphenol, p-dodecyl Phenol). Phenol also finds its application in manufacturing certain preservatives, disinfectants, lubricating oils, herbicides, insecticides, pharmaceuticals, Etc.

6. Block Flow Diagram and Plot Plan Estimations

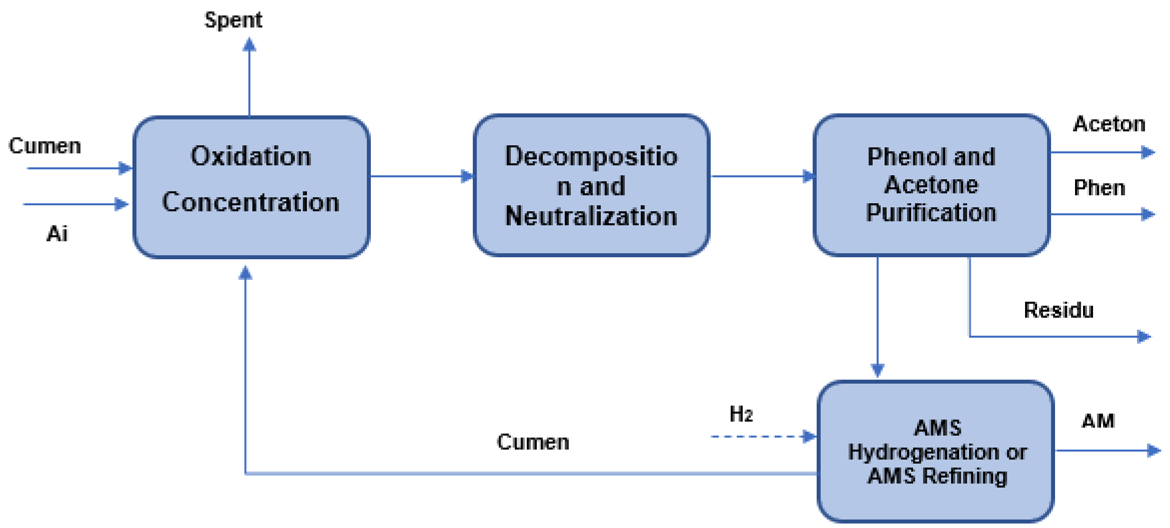
6.1 Honeywell Phenol Technology

In the initial stage, the purified Cumene is fed into the oxidation vessel with diluted Soda Ash (soln.) to maintain the solution pH between 6.0 and 8.0. Later, the mixture is kept in contact with air under a temperature range of 110 – 1150C. In response, the Cumene will convert into Cumene Hydroperoxide (CHP). The conversion of Cumene to Cumene Hydroperoxide has a low yield. Therefore, a sequence of three to five reactors is operated at a temperature range of 110 – 1150C.

In the final stage, after the concentration level of Cumene Hydroperoxide in the oxidizer surpasses the 80% mark, the mixture is further fed to a reactor in which Cumene Hydroperoxide is split into Phenol and Acetone under mild temperature (65 – 750C) and pressure in the presence of sulfuric acid (gradual quantity) and several non-oxidizing inorganic acids. The Phenol, Acetone, and other derivatives mixture are separated by distillation of the mix.

In the Honeywell Phenol Technology, 1.31 tonnes of Cumene is consumed to produce 1 tonne of Phenol.

Block Diagram for Honeywell Phenol Technology



Source: UOP Honeywell

6.2 The Kellogg Brown & Root (KBR) Phenol Technology

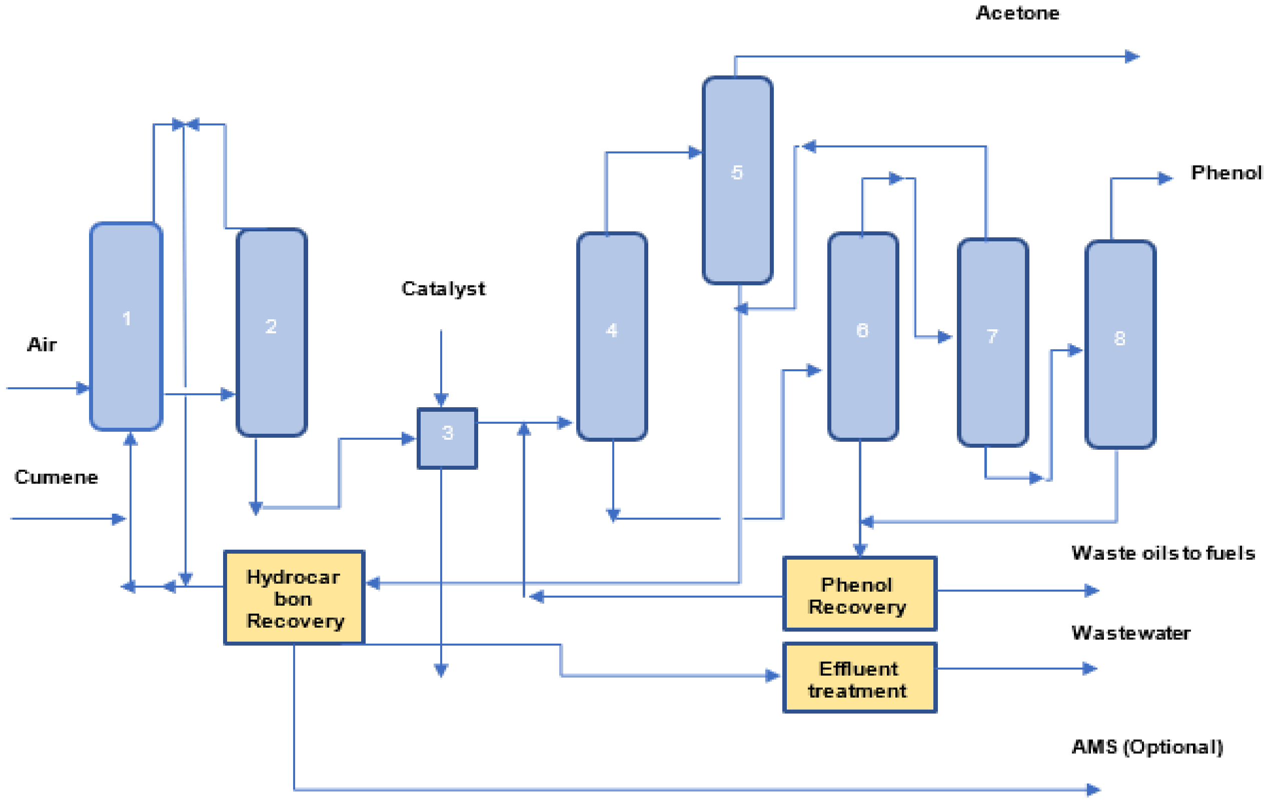
KBR technology involves oxidation of Cumene to Cumene Hydroperoxide (CHP) in the presence of air with high efficiency of approximately 96%. Under suitable reaction conditions using an acid catalyst, the peroxide is subsequently concentrated and cleaved to produce phenol and acetone, giving a high yield of approximately 99%. The cleavage mixture undergoes neutralization and fractionation to produce alpha-methyl styrene (AMS) and acetophenone (AP).

AMS thus produced can either be hydrogenated to Cumene and subsequently recycled to oxidation, or it can be utilized as a pure by-product. The Kellogg Brown & Root (KBR) technology involving hydrogenation of AMS produces a high-quality product with few heavy results by using approximately 1.31 tons of Cumene to produce 1 ton of phenol and 0.616 tons of acetone.

Typical Properties of Phenol

S. No.	Property	Specifications
1.	Appearance	Clear
2.	Purity (dry basis), wt.%	99.99 min.
3.	Total Organic Impurities ppm wt.%	< 30
4.	Water, ppm wt.%	< 200
5.	Color (APHA)	< 5
6.	Solidification point (dry material), °C	40.85 min
7.	Total Carbonyls, ppm Wt	< 10
8.	Sulfuric acid discoloration (SAD) test, %	95 min
9.	Iron, ppm wt.%	< 0.2

Block Diagram for KBR Technology



Source: Kellogg Brown & Root (KBR)

6.3 Lummus Phenol Technology

Lummus technology of producing phenol and acetone involves two steps: oxidation of Cumene-to-Cumene hydroperoxide (CHP) in the presence of air and its subsequent decomposition to phenol and acetone under acid-catalyzed conditions.

Both fresh and recycled Cumene is fed to a series of oxidizers equipped with an exclusive internal design where the Cumene is oxidized to produce Cumene hydroperoxide (CHP). These oxidizers help to enhance safety and improve the selectivity of the process.

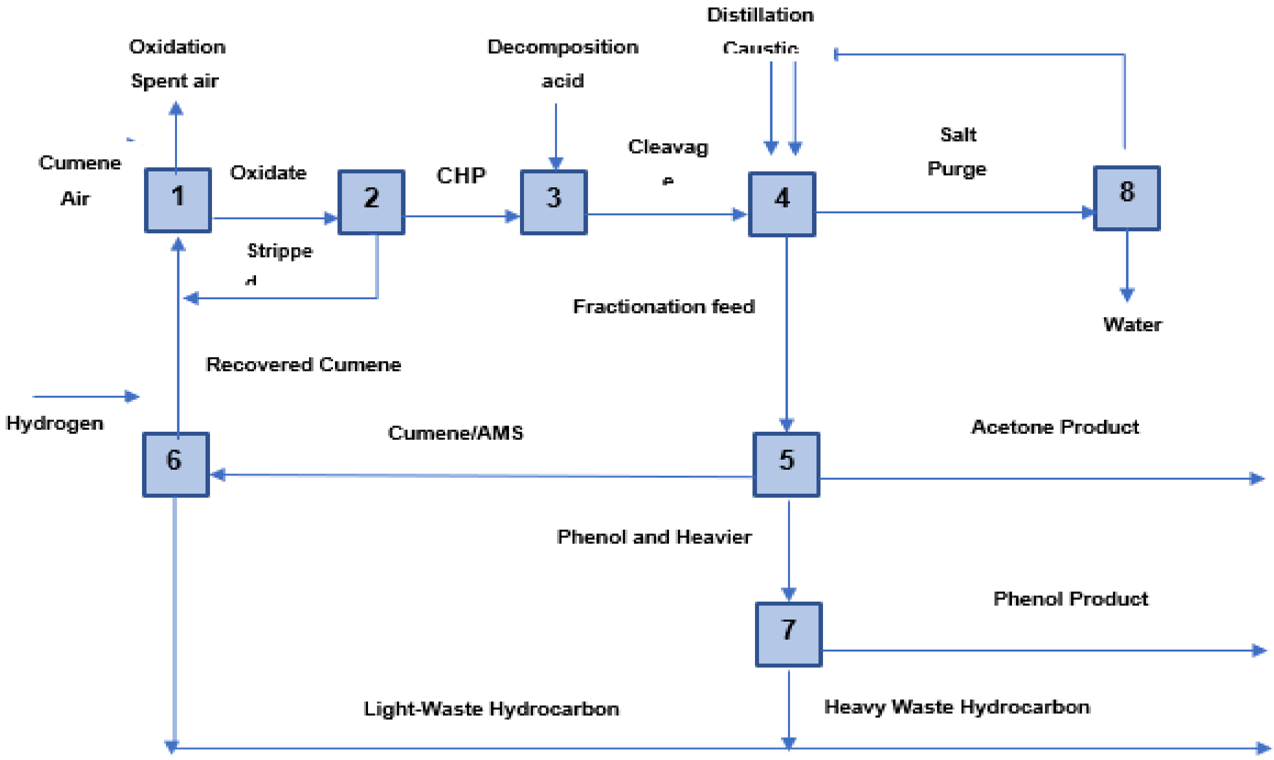
The peroxide is further concentrated in two evaporative stages. Concentrated CHP is fed directly to the two-stage cleavage unit, which undergoes decomposition under optimized conditions to produce phenol and acetone. Alpha methyl styrene (AMS) is also recovered as a by-product.

The effluent of the cleavage section undergoes neutralization and fractionation to separate Cumene, acetone, and by-products in the first distillation column recovering pure acetone. Further, Cumene and Alpha Methyl Styrene (AMS) are sent to the hydrogenation system where AMS is hydrogenated to Cumene, and the resulting hydrogenated hydrocarbons are recycled back to oxidization.

The bottoms from the first fractionation column that consists of phenol, Cumene, AMS, and heavy by-products are further fractionated to eliminate heavy by-products. The carbonyl impurities present are removed using an extractive distillation technique yielding high purity phenol.

This process of producing high-quality phenol features integrated wastewater and vent gas treatment system which conforms to national and international environmental regulations. In Lummus technology, approximately 1.30 tons of Cumene is consumed to produce 1 ton of phenol.

Block Flow Diagram of Lummus Technology



Source: Lummus

6.4 Badger Acetone-to-Cumene (ATC) Technology (without use of propylene feedstock)

Badger ATC technology provides flexibility to use 100% acetone as a feedstock to produce phenol bypassing the use of propylene. However, it can also be used and integrated into propylene-based Cumene plants.

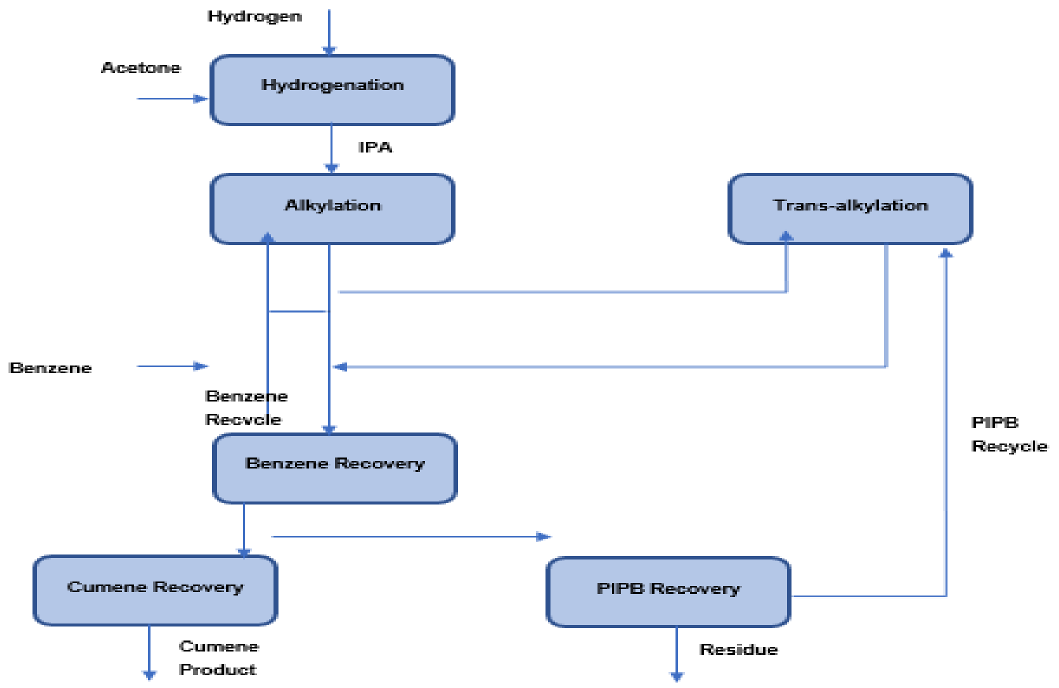
Process Description

1. Hydrogenation

In the first phase, acetone, and hydrogen is hydrogenated in the presence of nickel catalyst to convert into isopropanol (IPA).

2. **Alkylation:** In the alkylation process, benzene and IPA are converted to Cumene in a liquid phase in an alkylation reactor. Further, a fraction of Cumene is alkylated to polyisopropylbenzenes (PIPB). PIPB would then be recovered in the distillation column.
3. **Trans-alkylation:** A small amount of polyisopropylbenzenes (PIPB) formed in the alkylation process is converted to Cumene by the reaction of benzene in the liquid phase.
4. **Purification:** In the purification process, unreacted benzene is sent to alkylation and trans-alkylation reactors to recover Cumene products.

Block Diagram for Badger Acetone-to-Cumene (ATC) Technology



Source: Badger

6.5. Plot Plan Estimations

The total area of the project is estimated to be 147,200 m2. Area Breakup is shown in the table below. Out of the site's total area, 33.33% will be developed as a greenbelt area.

Area Breakup at Site:

S. No	Process Unit	Area (m^2)	% Of Plot Area	Common Facility
1	Boiler	12000	8.15	Common Facility
2	Substation	1200	0.82	Common Facility
3	Security Room	580	0.39	Common Facility
4	Cooling Tower	1400	0.95	Common Facility
5	Green Belt Area	50000	33.97	Common Facility
6	Fire Water Tank	2260	1.54	Common Facility
7	Flare	200	0.14	Common Facility

8	Process water/DM Water	450	0.31	Common Facility
9	N_2 Storage	320	0.22	Common Facility
10	Production	27300	18.55	New Facility
11	Product Storage & Raw Material	12140	8.25	New Facility
13	Drum Storage	80	0.05	New Facility
14	DG Room	75	0.05	New Facility
15	Warehouse	600	0.4	New Facility
16	Chemical Store	1150	0.77	New Facility
17	Other	37,445	25.44	Common & New Facility
	Total	**147,200**	**100**	

Others include Office, Road & Open Area, Mounded Bullets, etc.

For financial calculation, TechSci Research has not considered the common facility except some portion is considered from others.

7. Utility Systems

Utility Requirement to Produce Phenol by Cumene Route (200 KTPA)

7.1Steam Generation

Around 75.25 tons per hour (TPH) of steam is required for producing Phenol through Cumene route.

7.2 Water Requirement

The total water requirement for the cooling tower will be 209 Cubic meters per MT. The water requirement for running the plant will be used in the cooling tower, manufacturing process, and steam generation.

7.3 Energy / Power Requirements

The total power requirement for the plant to run is estimated to be around 5.40 MWh.

Based on preliminary estimate, major utilities consumed in above process are:

	Units	Hourly Consumption	Consumption Per MT of Phenol
HP Steam	T	35.75	1.43
MP Steam	T	24	0.96
LP Steam	T	15.5	0.62
Power	kWh	5445	182
Cooling Water	m3	7550	209-240

7.4 Plot Area and Initial Investments

Plot area is estimated to be around 16-18 hectare(ha) with initial investment of 1650-1800 Crore

7.5 UOP Phenol Process Utility Requirement

Raw Materials and Utilities requirement per metric ton of Phenol	
Cumene, tons	1.31
Steam, tons	3.2
Electricity kWh	152
Water, cooling (m3)	209

7.6 Lummus Process Utility Requirement

Raw Materials and Utilities requirement per metric ton of Phenol	
Cumene, tons	1.30
High and medium pressure steam (metric tons)	2.30
Electricity kWh	190

Source: TechSci Research

8. Catalyst and Chemicals

Cumene

Process Description

In the Cumene phenol process, benzene is alkylated with propylene to produce Cumene in the alkylator reactor. Zeolite is used as a catalyst for the alkylation reaction. By-products such as Di Iso Propyl Benzene (DIPB) and Tri Iso Propyl Benzene (TIPB) are also formed, which is collectively called polyisopropylbenzenes (PIPB). Further, polyisopropylbenzenes (PIPB) included in the alkylation process are converted to Cumene by the reaction of benzene in the liquid phase.

Material Balance to Produce Cumene

S. No	Raw Materials	Quantity (MT)
1.	Propylene	0.367
2.	Benzene	0.657
3.	N_2 Purge for Vacuum system	0.0005
4.	Air Leak into system	0.00016
5.	Adsorbent/Clay	0.0005
6.	Catalyst	0.000007

Source: UOP Honeywell

Supplier and Quantity Details of Catalyst and Chemicals		
Product Name	(Quantity in tonnes)	Companies
Caustic Soda	4880	GACL, DCM Shriram, Meghmani Organics
Sulphuric Acid	1640	GSFC, GACL, Kutch Chemicals, OCCL
MSHP Catalyst	2	BASF SE
Nickel Fixed Bed Catalyst	5	John Matthey Chemicals GmbH, UOP
Activated Carbon	14	Seika Corporation
Adsorbent AZ-300 5X8	54	UOP
AMS Hydrogenation Catalyst	6	John Matthey Chemicals GmbH

Phenol

Purified Cumene is oxidized with air under a temperature range of 110–115°C to produce Cumene hydroperoxide (CHP). CHP is then split into Phenol and Acetone under mild temperature (65 – 75°C) and pressure in the presence of sulfuric acid and several non-oxidizing inorganic acids. The Phenol, Acetone, and other derivatives mixture are separated by distillation of the mixture.

Material Balance to Produce Phenol and Acetone from Cumene Route

S. No	Raw Materials	Quantity (MT)
1.	Cumene	1.32
2.	Oxygen (Air)	2
3.	Hydrogen	0.00116
4.	Caustic soda (30%wt.)	0.029
5.	Sulfuric Acid (as 98% H20)	0.0082
7.	Absorbed Nitrogen	0.001
8.	Process Nitrogen	0.00916
9.	N_2 purge/Diluents	0.003
10.	Column Air Leak	0.003
12.	Activated Carbon	0.00007

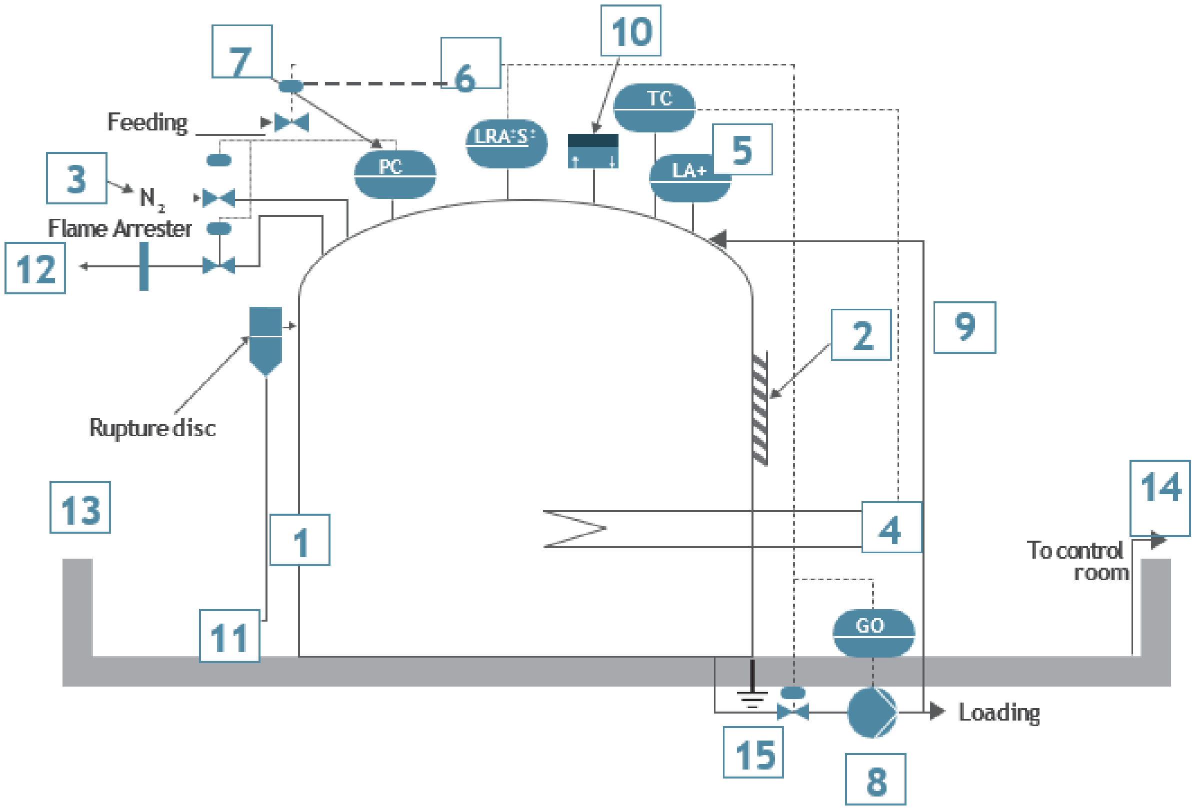
Source: KBR

Liquid Effluents, Air Emission and Product Recovery to produce Phenol and Acetone from Cumene Route

S. No		Liquid Effluents	Air Emission	Recovery/Product	Solid Waste
1.	Phenol			1	
2.	Acetone			0.64	
3.	Recovery column bottoms/heavies			0.1240	
4.	Alpha Methyl Styrene (AMS)			0.0420	
5.	Acetone Purge			0.0016	
6.	Lights Hydrocarbon Purge			0.0033	
7.	Wastewater	0.570			
8.	Spent Air		1.50		
9.	Spent Resin				0.0001
10.	Spent Carbon				0.00007
11.	Spent Catalyst				0.00001
Total		**0.570**	**1.50**	**1.81**	**0.00018**

Source: UOP Honeywell

9. Offsite Storage System, Flare System and Effluent Treatment System



General Design Recommendations:

1. General design: vertical storage tank
2. Material: stainless steel
3. Insulation: rock wool or similar
4. Inert gas blanketing
5. Soft heating avoiding wall temperature above 75 °C.
6. Temperature control between 50 °C and 60 °C
7. Level with alarm
8. High- and low-level alarm interlocked with pumps shut off valves closed
9. Pressure control
10. Centrifugal pump with magnetic drive, immersed rotor or equivalent to avoid leakages
11. Recirculating (with sampling system)
12. Safety valve low- and high-pressure protection
13. Foam connection for firemen to internal sprinkling

14. To vent treatment

15. Retention pit

16. Leakage monitoring

17. Earthing

Options	Tentative Requirement (T/hr)		Product Output (KTPA)		
	Propylene	Benzene	Cumene	Phenol	Acetone
Option 1- Capacity of 200 KTPA Phenol and 123 KTPA Acetone capacity (Propane Furnace Additional)	11	21	264	200	120
Option 2- Capacity for 200 KTPA Phenol + 123 KTPA Acetone, (with available propylene and benzene) - Here for 80 % phenol plant - DFCU operation (base case) considered for 8500 Hrs.	9	15	264	200	120
Option 3- Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)	11	21	264	200	120
Option 4- Capacity for 350 KTPA PVC Resin and 200 KTPA Phenol + 120 KTPA Acetone (Propane Furnace Addition)	11	21	264	200	120
Remarks	Available line from storage to Plant to be considered		Required facility to be developed		
Acetone, Phenol & Cumene storage tanks (7 days storage)			5063 Tons	3836 Tons	2301 Tons
Gantry for Phenol & Acetone	Required Facility to be developed				
Unloading Gantry for Propylene *	Propylene is unloaded from the pressurized tanker into the Propylene sphere with the help of an unloading compressor. The vapours from the storage vessel are compressed and pushed into the road tanker to transfer liquid from the tanker to the sphere. The unloading rate is 40 M3 /Hr. Unloading gantry details: Loading/Unloading arms are of top loading type. Loading/Unloading arm & Vapor arm connecting flanges				

9.1 Flare System

Flare area will be approximately 180 m^2 covering 0.1% of plot area

S. No.	Stack Attached to	Type of Emission	No. of Stack	Stack Height (m)	Air Pollution Control Measures
1.	Flare	VOC	1	65	Smokeless Flare

Source: TechSci Research

A flare system is provided to burn lighter hydrocarbons. The ideal flare height should be 65 m, taking care of the maximum possible emergency release from the plant.

Benzene, Propylene is the base chemicals required for producing Phenol. The reaction of Benzene with Propylene gives an intermediate product, Cumene, which is hydrated to give Phenol. In these reactions, various non-condensable components, unrecycled benzene, a carcinogen & others are released whose uncontrolled discharge into the environment is dangerous. As a result, a flare system is designed. It is an arrangement of 316 stainless steel pipes consisting of a flared hood where flash vapors are collected and sent for environmental abatement procedures. 3000 KW/Hour of Natural Gas is used to fuel an autooxidation reaction to dispose of environmentally hazardous compounds safely.

Along with flare system, following facilities shall be integrated in the plant.

Air Emission - Type of Gas Evaluation and Mitigation

S. No.	Stack Attached to	Stack Height (m)	Pollutants	Mitigation
1	Cogen Plant Boiler	81	PHx, NOx, Sox	ESP & Adequate Stack Height
2	Boiler for Phenol & Cumene	81	PHx, NOx, Sox	ESP with adequate stack height will be provided
3	Incinerator for 304 Nm3/hr. Vent gas	30	PHx, NOx, Sox	Adequate Stack Height will be provided
4	DG Set	25	PHx, NOx, Sox	Adequate Stack Height will be provided

9.2 Effluent Treatment System

Effluent Treatment System is integrated to reduce the BOD, COD, and phenol contents to acceptable levels before discharging. The standard ETP system consists of an equalization tank, aeration basin, and clarifiers. As the effluents have a high COD/BOD ratio, ETP is provided with cooling tower blowdown or DM/CPU regeneration waste to meet the bio-treatment requirements. Further, treated water will undergo ultrafiltration (UF) and reverse osmosis (RO).

Effluent treatment plant will be approximately 2300 m^2 covering around 1.5% of land area

Wastewater Generation Detail

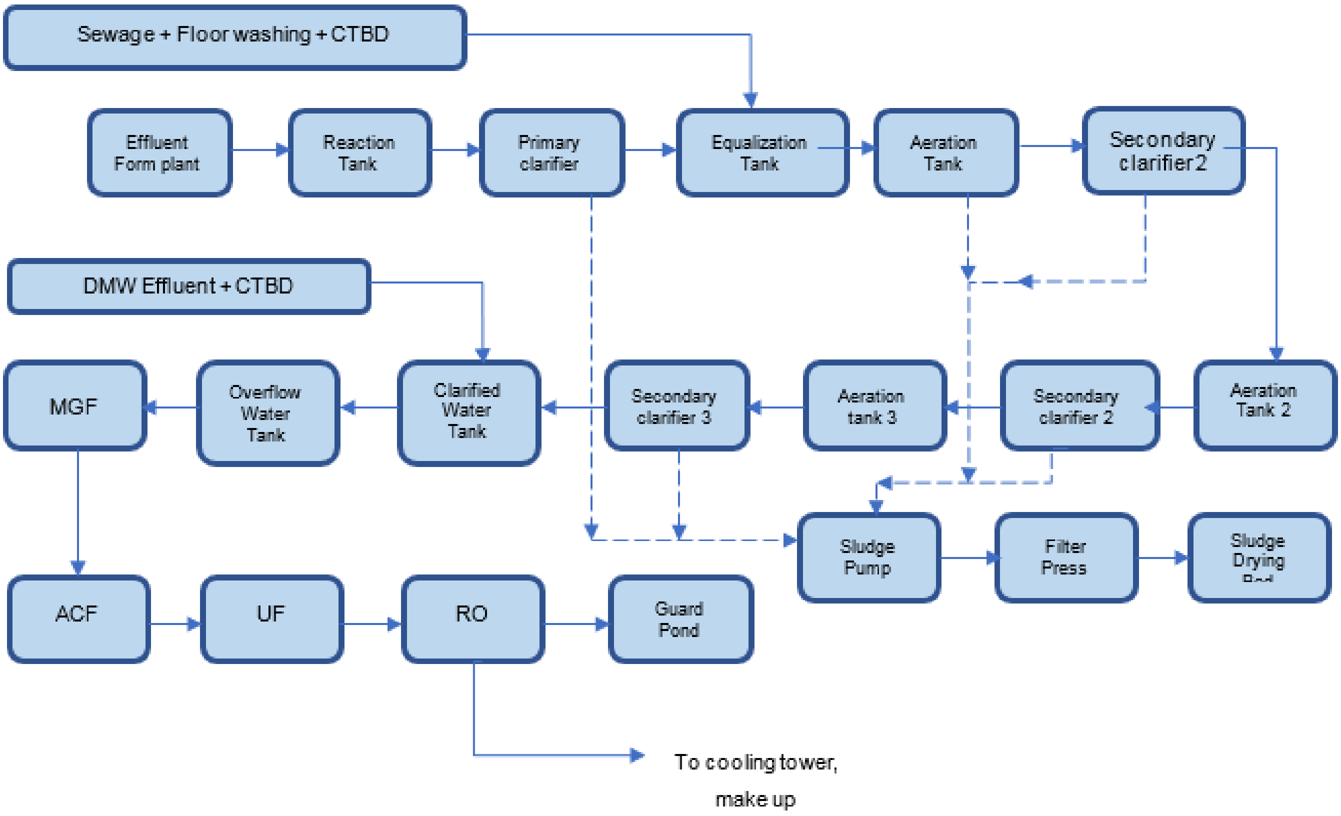
S. No	Description	Wastewater Generation Detail in KLD	Remarks
1	**Industrial**	**2240-2251**	NA
1.1	Process	570	NA
1.2	Boiler	110-111	NA
1.3	DM-CPU Regeneration	230-240	NA
1.4	Backwash from Raw water treatment	330	NA
1.5	Cooling & Chilling	1000	NA
2	Total Water to ETP	2300	NA
3	Recycle water from RO	1330	NA
4	Effluent from inlet UF+ R.O. system	0	Two stage RO with 80% recovery is considered
5	Final discharge to drain	950	NA

Source: TechSci Research

Type of Waste Generated and their Treatment and Disposal

S. No.	Type of Waste	Treatment / Disposal
1	ETP Sludge	Collection, Storage, Transportation and disposal of waste at TSDFs (Treatment, Storage and Disposal Facilities)
2	Used Oil	Collection, Storage, Transportation, and disposal of used oil to registered vendor for re-processing. Can also be reprocessed using filtration machine.
3	Spent Carbon from process & OSBL facilities	Collection, Storage, Transportation, and disposal of waste at TSDFs
4	Discarded Container/ bags	Collection, Storage, and Transportation to registered vendor for recycling / disposal.
5	Spent Resin	Collection, Storage, Transportation and Disposal at TSDF site.
6	Spent Catalyst/ Adsorbent	Collection, Storage, Transportation and Disposal at TSDF site.
7	Heavy and Light Impurities from Process Plant	Send to Authorized Vendor / Common Hazardous Waste Incineration Facility located nearby.

9.3 Block Diagram for Effluent Treatment Plant



Source: KBR

Phenol Storage & Transportation Overview

Phenol is stored in insulated storage tanks, maintained at 113°F more than ambient pressure and temperature to prevent the crystallization of molten phenol into its hydrated form. The tank capacity is 7500 m3. The tank is a conical roof-shaped storage vessel equipped with two thick insulated walls, a low-pressure maintenance system connected with a heat exchanger, and made from 316 stainless steel to prevent any corrosion. The equipment costs around 4-5 crore depending on the quality.

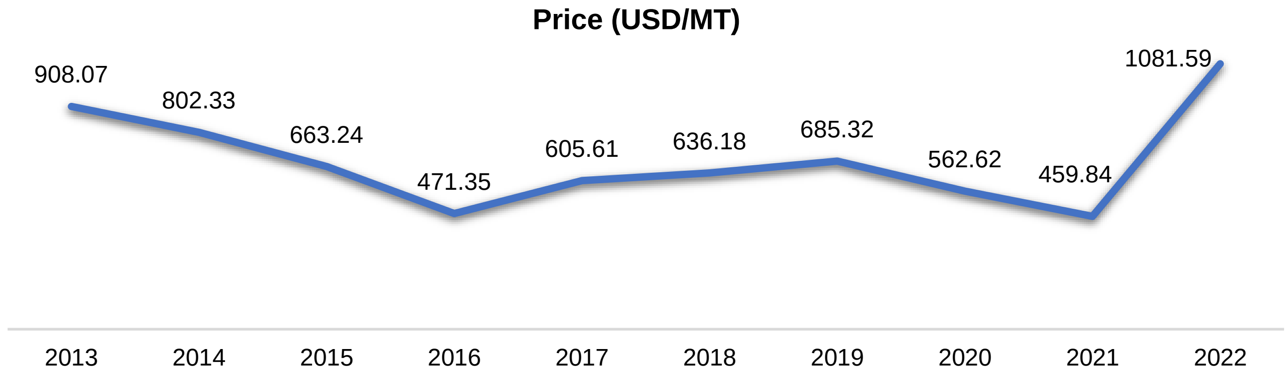
A closed Tanker System is used for the Transportation of Phenol and is loaded/unloaded using a loading arm mechanism. Further, Stainless-steel tanks are used with insulation of 2-inch thickness. The product is classified under Hazard Class 6.1 as per D.O.T and I.M.O regulations.

Gantry:

Additional tank/truck gantry is required to dispatch and receive other products. The new tank/truck gantry comprises 24 bays for propylene (chemical and refinery grade), benzene, phenol, and acetone. All these bays are designed for top-loading through loading arms (with spring-loaded dead-man valve for all products) and for bottom-unloading through unloading hoses. The associated facilities comprise pumps for loading/unloading products.

10. Feed, Product, and Utility Prices

India Benzene Historical prices (FY2013-FY2022)



Source: TechSci Research

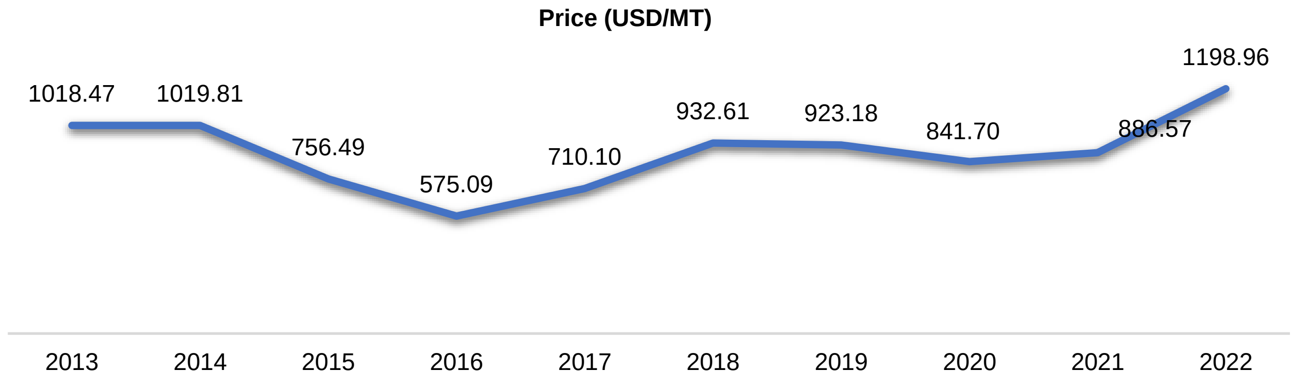
In 2013, crude oil prices were at a peak, which resulted in increased prices of Benzene in the domestic market. Gradually with the decline in crude oil prices in the international market and the strengthening of the Indian rupee compared to the dollar, benzene prices declined from USD 908/MT in 2013 to USD 471/MT in FY2016. Since FY2016, a price trajectory was witnessed till FY2019. The domestic prices of benzene shoot by around 13% and reached 685 USD/MT. Further, the prices of Benzene increased in FY 2019, compared to FY 2018, due to augmenting demand in downstream industries. Political stability in the central government has also strengthened Indian rupees and increased capacity utilization by Cumene, cyclohexane, and nitrobenzene producers.

The rising shortage of Benzene in China and South Korea has resulted in an increase in the price of Benzene across India in FY 2019.

Weak volumes and margins characterized the India benzene market in the 2nd half of 2019 and the 1st half of 2021. Benzene export and domestic prices stumble due to weaker demand for styrene, nylons, and phenol-formaldehyde resins.

From Q2 2021 onwards, Benzene prices climbed higher because of the surging demand for LAB, Caprolactam, Styrene, and Insecticide production in the country. South Korea and the Southeast Asian market witnessed a consistent rise in the pricing trend of Benzene during Q3 of 2021. Chinese market showcased mixed sentiments, and a decline in the prices of Benzene was seen from July to August. In India, Benzene prices encountered a steep climb backed by the high demand from various end-use industries and an upsurge in feedstock crude oil prices. Ex-Mumbai Benzene prices settled at USD1139.50 in September 2021. Skyrocketing freight charges due to the extreme shortage of containers also sent ripples to the prices of Benzene in the region.

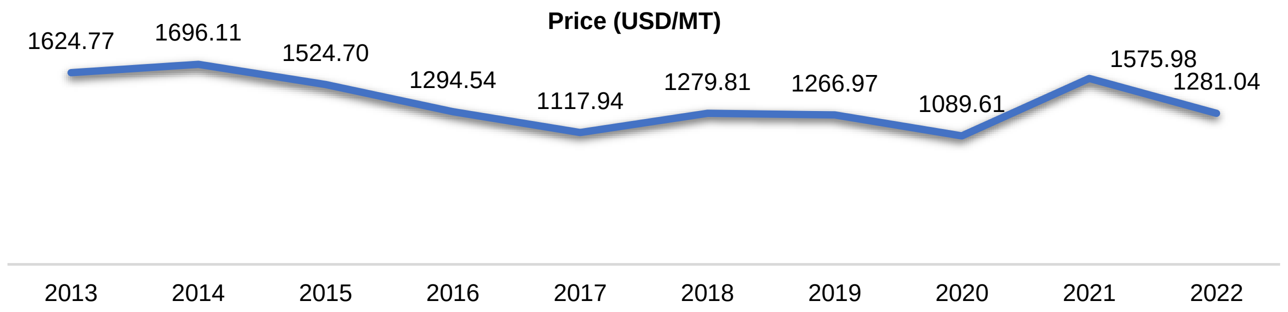
India Propylene Historical Prices (FY 2013-FY 2022)



Source: TechSci Research

Propylene supply across South Korea, Southeast Asia, and India was observed to get tighter by the end of 2021, with price discussions gradually picking up. Various planned and unplanned outages affected the functioning of fluid catalytic cracking (FCC) and steam cracking Naphtha units in Japan. Strong domestic demand in South Korea restricted the cargo availability for exports. The market in China was stable, with buyers indicating the commissioning of two Propane Dehydrogenation (PDH) units in July, possessing a total nameplate capacity of 1050 KTPA. Formosa Petrochemical Corporation (FPCC) announced a maintenance shutdown of its No. 3 cracker located in Taiwan on August 11 for nearly 1.5 months. The cracker has a Propylene production capacity of 600 KTPA. In addition, Yeochun NCC (YNCC) and SK Global Chemical started turnarounds for their crackers from August to October 2021. With producers highlighting tight regional supply, CFR China Propylene prices were assessed at around USD900 per tonne levels Q4 of 2021.

India Cumene Historical Prices (FY 2013-FY 2022)

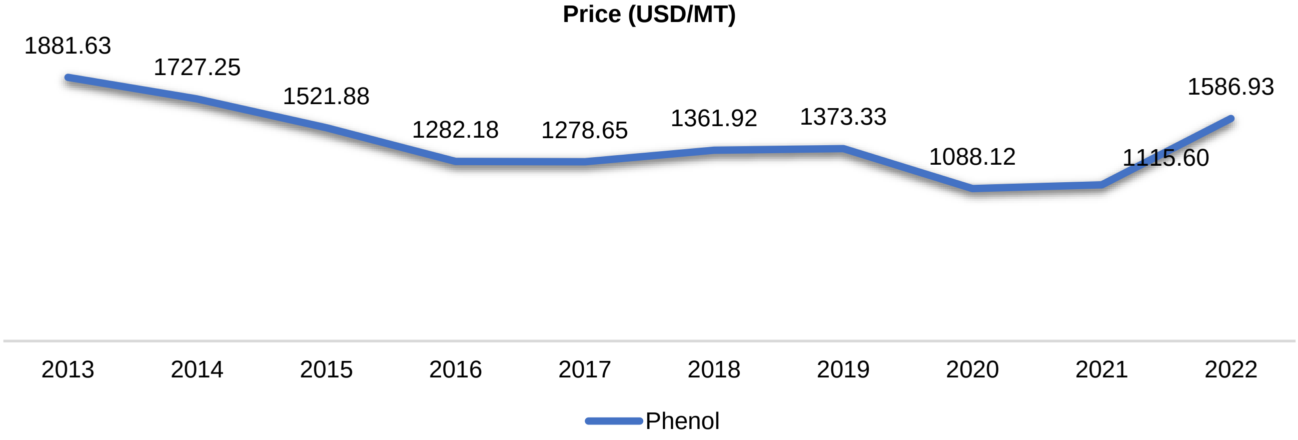


Source: TechSci Research

The Cumene prices remained stable during the 2013-2021 period. In 2021, the supplies in the Asia Pacific during the first quarter remained tight since several major plants went for maintenance and were operating at low efficiencies due to feedstock shortages. ENEOS Corp production plant in the Miyagi prefecture, Japan, shut down its aromatic's unit for several weeks due to the 6.1 magnitude earthquake in February 2021, followed by the low inventory levels after some plants went for turnaround during the Chinese lunar new year holidays. The demand was driven by the restocking practices to fill the inventories, followed by surged consumption from the Phenol-Acetone manufacturers.

Cumene benzene is majorly dependent on the prices of benzene and propylene. India is a surplus in the production of benzene, and the prices are not volatile compared to propylene prices. The prices of Cumene are expected to remain stable in the coming months of FY 2022, as no significant change in the prices of benzene is expected.

India Phenol Historical Prices (FY 2013-FY 2022)



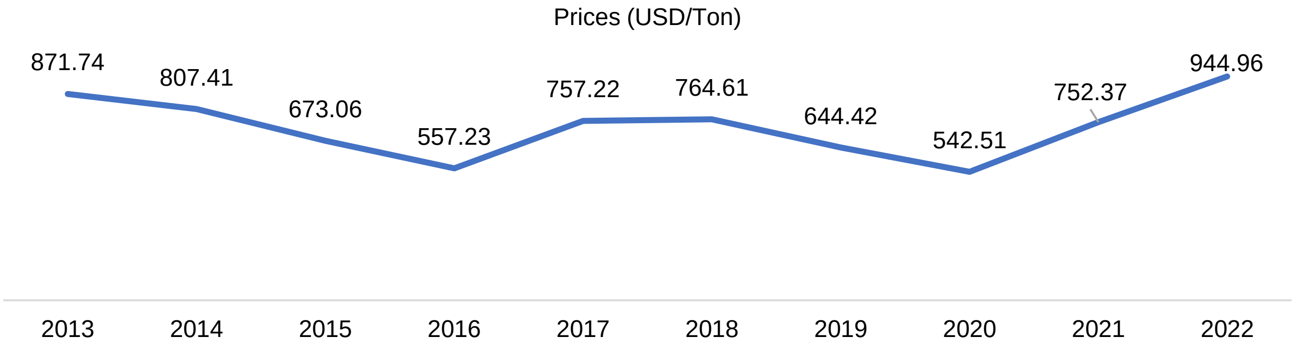
Source: TechSci Research

In FY 2016-2019, phenol prices remained stable because of the stable prices of the raw material and oversupply conditions in Northeast Asia and Southeast Asian countries.

The prices of Phenol have increased from USD1115 per tonne in FY 2021 to USD1586 per MT in FY 2022 on behalf of the change in prices of benzene and propylene in the domestic market. The prices of benzene are expected to go down in the coming weeks, which may result in a decrease in the price of Phenol.

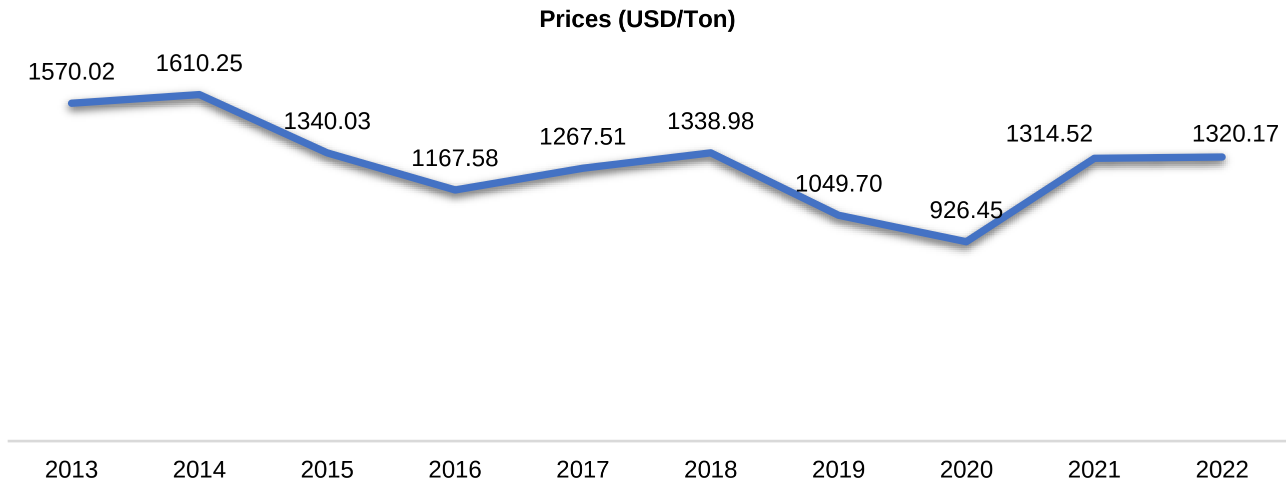
The price increase is reported because of changes in demand dynamics in the domestic market. The demand is volatile and expected to be stable in the coming weeks.

Historical Prices (FY 2013-FY 2022)



Source: TechSci Research

India Iso-propyl Alcohol (IPA) Historical Prices (FY 2013-FY 2022)



Source: TechSci Research

11. Regulations

11.1. Government Duty in Domestic Market

The Government of India applied 18% GST on Phenol traded within the country. The custom duty imposed on imports is 7.5%, and the social welfare surcharge is 10%. Phenol is imported under the 29071110 HS code.

Import Duty on Phenol HS Code (29071110)	Percentage
Basic Custom Duty	7.5%
Integrated Goods & Services Tax (IGST)	25%
Social Welfare Surcharge	10%
Compensation Cess	Nil
Specific Duty	Not Applicable
Preferential Duty	Not Applicable
Total Duty	**42.5%**

Source: - Department of Commerce, Ministry of Commerce and Industry, Government of India

11.2. Duty Barriers in Export Market

Asia-Pacific Trade Agreement, 4270 products including phenol

The Asia Pacific Trade Agreement (APTA) was the Bangkok Agreement. The Bangkok Agreement was signed in 1975 and was the oldest Preferential Tariff Agreement (PTA) among the developing countries. It is facilitated by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), which acts as its Secretariat. Its original members were Bangladesh, India, Lao PDR, Philippines, Sri Lanka, Thailand, and the Republic of Korea (ROK). Thailand and the Philippines did not ratify the Agreement. Lao PDR has not issued any customs notifications on tariff concessions. China joined the Agreement in 2001.

Revision of the Agreement was made in 2005 and was renamed the Asia Pacific Trade Agreement (APTA). APTA targets gradual tariff liberalization. The new agreement has devised a common rule of origin. Following the 1st and 2nd negotiations concluded in 1975 and 1990, respectively, revitalization began in the early 2000s. This brought the conclusion of the 3rd round of negotiations in 2005. This round involved 4,270 products with an average Margin of Preference (MoP) of 27.22% which also includes phenol.

Source: - United Nations ESCAP

India Malaysia Comprehensive Economic Cooperation Agreement (CECA)

Article 2.5

Tariff Reduction and Elimination

1. Except as otherwise provided for in this Chapter, each party shall gradually liberalize, where applicable, applied MFN tariff rates on originating goods of the other party by its Schedule of Tariff Commitments as set out in Annex 2-1.

2. Nothing in this Chapter shall preclude any Party from unilaterally accelerating the reduction and elimination of the applied MFN tariff rates on originating goods of the other party as set out in its Schedule of Tariff Commitments in Annex 2-1. Article 2.6

Customs Valuation

To determine the customs value of goods traded between the countries of the Parties, provisions of Part I of the WTO Agreement on Implementation of Article VII of GATT 1994, as may be amended, shall apply, mutatis mutandis, to this Agreement.

Schedules of Tariff Commitments as per Annex 2-1

The tariff lines subject to tariff reduction and elimination under this Annex are categorized as follows: (a) Normal Track (i) Applied MFN tariff rates for tariff lines placed in the Normal Track will be reduced and subsequently eliminated by the following tariff reduction and elimination schedule: (AA) Normal Track 1: 1 July 2011 to 30 September 2013; (BB) Normal Track 2: 1 July 2011 to 30 June 2016 (ii) Where the applied MFN tariff rates are at 0%, they shall remain at 0%. Where they have been reduced to 0%, they shall remain at 0%. No Party shall be permitted to increase the tariff rates for any tariff line, except as otherwise provided in this Agreement. (b) Sensitive Track Applied MFN tariff rates above 5% for tariff lines in the Sensitive Track will be reduced to 5% by 30 June 2016.

Source: - Department of Commerce, Ministry of Commerce and Industry, Government of India

India Singapore Comprehensive Economic Cooperation Agreement (CECA)

Singapore and India signed the Comprehensive Economic Cooperation Agreement (CECA) on 29 June 2005 in New Delhi, India. Chapter 1 of the CECA lays down the definitions and rules for interpreting the terms mentioned in the agreement. It also specifies that the objective of the agreement is to strengthen the economic, political, and social relations between both the countries and promote trade in goods in services and facilitate investment. The agreement will also foster the relations between India and ASEAN.

ARTICLE 1.2

OBJECTIVES

The objectives of this Agreement are:

(a) To strengthen and enhance the economic, trade, and investment cooperation between the Parties.

(b) To liberalize and promote trade in goods in accordance with Article XXIV of the General Agreement on Trade and Tariffs.

(c) To liberalize and promote trade in services in accordance with Article V of the General Agreement on Trade in Services, including promotion of mutual recognition of professions.

(d) To establish a transparent, predictable, and facilitative investment regime.

(e) To improve the efficiency and competitiveness of their manufacturing and services sectors and to expand trade and investment between the Parties, including joint exploitation of commercial and economic opportunities in non-Parties.

(f) To explore new areas of economic cooperation and develop appropriate measures for closer economic cooperation between the Parties.

(g) To facilitate and enhance regional economic cooperation and integration to form a bridge between India and the Association of Southeast Asian Nations (“ASEAN”) region and serve as a pathfinder for the India-ASEAN free trade agreement.

(h) To build upon their commitments at the World Trade Organization.

There is no special privilege or exemption on duty or taxes for phenol under the HS code 29071110.

12. Financial Analysis

Assumptions:

1. For the calculation of total capital investment, equipment cost is derived through conducting various primary interviews with industry experts.

2. To calculate the plant's direct cost, the standard norms have been considered against the equipment cost. The below listed are the following norms-

- Purchased equipment installation: 15%
- Instrumentation and controls (installed): 10%
- Piping (installed): 2%
- Electrical (installed): 1%
- Buildings (including services): 2%
- Service facilities (installed): 5%

Note- The plant direct cost includes the equipment cost plus the above-listed parameters.

3. Total indirect plant cost includes Engineering and supervision, Construction expenses, Legal expenses, Contractor's fee, Contingency, etc. which have been calculated using standard norms against the equipment cost.

4. ISBL facility includes equipment required in the process to manufacture phenol which constitutes around 70% of the total equipment cost. OSBL facility includes wastewater treatment plants, effluent treatment plants, different types of wet scrubbers to mitigate GHG emissions contributing about 20% to the equipment cost.

5. Total fixed capital investments is the summation of plant direct and indirect cost.

6. For calculating some of the parameters of operating cost, the following standard norms have been considering for phenol-

- Packaging Cost (calculated): 1% of Annual Sales Revenue @ 100 Percent Capacity Utilization
- Maintenance and repairs: 1.5% of Total Capital Investment
- Plant Overhead and Administrative Costs: 7.5% of Maintenance and repairs + Labour
- Distribution and selling costs: 2.5% of Annual Sales Revenue @ 100 Percent Capacity Utilization
- Research and development costs: 1.5% of Total Capital Investment

7. Expenditure of capital investment will be in the following phase-

- 5% of Total Capital Investment: 2023
- 25% of Total Capital Investment: 2024
- 35% of Total Capital Investment: 2025
- 35% of Total Capital Investment: 2026

8. Operating Revenue is bifurcated between-

- 200000 tons phenol, and 120000 tons acetone merchant sale in option 1.
- 200000 tons phenol, and 120000 tons acetone merchant sale in option 2.
- 200000 tons phenol, and 120000 tons acetone merchant sale in option 3.
- 350000 tons PVC, 200000 tons Phenol, 120000 Acetone and coproducts merchant sale in option 4.

9. Operating revenue for each year is calculated by multiplying the capacity utilization for respective year to the annual sales revenue @ 100 percent capacity utilization considering inflation rate.

10. Operations will start in 2027.

11. Cash flow has been calculated till 2046.

12. Total operating cost is calculated based on capacity utilization at that period.

13. Inflation rate has been considered as 4.5%.

Option 1: Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)

CapEx

Option 1: Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)			
			INR Crore
A	Total Fixed-Capital Investment	A1 + A2	1,567.80
A1	**Total Direct Plant Cost**		**1,132.30**
1	Delivered main equipment (includes auxiliary equipment)	100%	838
2	Purchased-equipment installation	15%	126
3	Instrumentation and controls (installed)	10%	84
4	Piping (installed)	2%	17
5	Electrical (installed)	1%	8
6	Buildings (including services)	2%	18
7	Service facilities (installed)	5%	42
A2	**Total Indirect Plant Cost**		**436**
9	Engineering and supervision	10%	84
10	Construction expenses	25%	209
11	Legal expenses	2%	17
12	Contractor's fee	10%	84
13	Contingency	5%	42
B	**Working Capital**		**42**
14	Safety and hazard analyses	5%	42
C	OSBL Facilities		159
	TOTAL CAPITAL INVESTMENT	A + B	1,769

Note- As co-product revenues has not been considered in this option therefore propane furnace cost is not taken in capital investment.

Opex

Option 1: Capacity of 200 KTPA Phenol and 120 KTPA Acetone capacity (Propane Furnace Additional)			
	ITEM		INR Crore
C	Manufacturing Cost		1600.81
C1	Raw materials and Catchem		1344.29
1	Raw materials	-	1250.26
2	Catalyst & Chemicals		94.03
C2	Labor		26.91
3	Salaries & Wages (calculated)	-	26.91
C3	Variable Overheads		199.07
4	Packaging Cost (calculated)		24.52
5	Utilities (calculated)		174.55
C4	Fixed Overheads		30.54
6	Maintenance and repairs (1.5% of fixed-capital investment) (Capex)	1.5%	26.53
7	Plant Overhead and Administrative Costs (7.5% of 3 + 6)	7.5%	4.01
D	Selling Overheads		80.55
9	Distribution and selling costs (2.5% of sales value)	2.5%	56.54

10	Research and development costs (1.5% of manufacturing cost)	1.5%	24.01
	Total Production Cost		1681.36

Cashflow

Capacity of 200 KTPA Phenol and 120KTPA Acetone Capacity (Propane Furnace Additional)									
	Year of operation	**1**	**2**	**3**	**4**		**5**	**6**	**7**
	Capacity Utilization						90.00%	100.00%	100.00%
	Description								
	Operating Period	**2023**	**2024**	**2025**	**2026**	**Total**	**2027**	**2028**	**2029**
	Expenditure Phasing	**5%**	**25%**	**35%**	**35%**				
	All Figures are in INR Crore								
1	**Capex (In INR Crore)**	**-88**	**-442**	**-619**	**-619**	**-1,769**			
	Total Investment (In INR Crore)	**-88**	**-442**	**-619**	**-619**	**-1,769**			
	Expenditure Phasing/Capacity Utilization						90.00%	90.00%	100.00%
2	**Operating Revenue**						**2035.28**	**2393.16**	**2532.56**
	Phenol						1386.69	1631.03	1726.59
	Acetone						648.59	762.12	805.98
5	**Operating Cost**								
	Raw Material & Catchem					80.3%	1209.86	1421.64	1503.44
	Labor					1.6%	26.91	28.12	29.39
	Variable Overheads					11.6%	179.17	208.03	217.39
	Fixed Overheads					1.8%	27.48	31.91	33.35
	Selling Overheads					4.7%	72.49	84.17	87.96
	Total Operating Cost						**1515.91**	**1773.88**	**1871.53**
6	**Gross Margin (EBITDA/PBITDA)**						**519.37**	**619.28**	**661.03**
	Margin %						25.52%	25.88%	26.10%
	Net Cash Flow	**-88**	**-442**	**-619**	**-619**		**-1249.31**	**619.28**	**661.03**
	Cost of Capital (10%)					1	0.91	0.83	0.75
	Discounted Cash Flow						0.91	0.83	0.75
	Undiscounted Cash Flow						-1135.74	511.80	496.65
	Cumulative Cash Flow						-1249.31	619.28	661.03

Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)								
	Year of operation	**8**	**9**	**10**	**11**	**12**	**13**	**14**
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
	All Figures are in INR Crore							
1	**Capex (In INR Crore)**							
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2	**Operating Revenue**	**2680.09**	**2836.22**	**3001.43**	**3176.28**	**3361.30**	**3557.11**	**3764.33**
	Phenol	1827.74	1934.82	2048.17	2168.16	2295.18	2429.65	2571.99
	Acetone	852.35	901.40	953.26	1008.11	1066.12	1127.47	1192.34
5	**Operating Cost**							
	Raw Material & Catchem	1589.95	1681.43	1778.18	1880.50	1988.70	2103.13	2224.15
	Labor	30.71	32.09	33.53	35.04	36.62	38.27	39.99
	Variable Overheads	227.18	237.40	248.08	259.25	270.91	283.10	295.84
	Fixed Overheads	34.85	36.42	38.06	39.77	41.56	43.43	45.38
	Selling Overheads	91.92	96.05	100.38	104.89	109.61	114.55	119.70

	Total Operating Cost	**1974.60**	**2083.40**	**2198.24**	**2319.45**	**2447.41**	**2582.48**	**2725.07**
6	**Gross Margin (EBITDA/PBITDA)**	**705.49**	**752.82**	**803.20**	**856.82**	**913.89**	**974.63**	**1039.26**
	Margin %s	26.32%	26.54%	26.76%	26.98%	27.19%	27.40%	27.61%
	Net Cash Flow	**705.49**	**752.82**	**803.20**	**856.82**	**913.89**	**974.63**	**1039.26**
	Cost of Capital (10%)	0.68	0.62	0.56	0.51	0.47	0.42	0.39
	Discounted Cash Flow	481.86	467.44	453.38	439.68	426.34	413.34	400.68
	Undiscounted Cash Flow	705.49	752.82	803.20	856.82	913.89	974.63	1039.26
	Cumulative Cash Flow	736.49	1489.31	2292.51	3149.33	4063.22	5037.85	6077.11

Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)						
	Year of operation	**15**	**16**	**17**	**18**	**19**
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2037**	**2038**	**2039**	**2040**	**2041**
	All Figures are in INR Crore					
1	**Capex (In INR Crore)**					
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%
2	**Operating Revenue**	**3983.61**	**4215.68**	**4461.26**	**4721.15**	**4996.18**
	Phenol	2722.67	2882.17	3051.03	3229.77	3418.99
	Acetone	1260.95	1333.50	1410.23	1491.38	1577.19
5	**Operating Cost**					
	Raw Material & Catchem	2352.13	2487.47	2630.60	2781.96	2942.04
	Labor	41.79	43.67	45.64	47.69	49.84
	Variable Overheads	309.16	323.07	337.61	352.80	368.68
	Fixed Overheads	47.42	49.56	51.79	54.12	56.55
	Selling Overheads	125.09	130.72	136.60	142.75	149.17
	Total Operating Cost	**2875.59**	**3034.48**	**3202.23**	**3379.32**	**3566.27**
6	**Gross Margin (EBITDA/PBITDA)**	**1108.03**	**1181.19**	**1259.03**	**1341.83**	**1429.91**
	Margin %	27.81%	28.02%	28.22%	28.42%	28.62%
	Net Cash Flow	**1108.03**	**1181.19**	**1259.03**	**1341.83**	**1429.91**
	Cost of Capital (10%)	0.35	0.32	0.29	0.26	0.24
	Discounted Cash Flow	388.36	376.36	364.70	353.35	342.31
	Undiscounted Cash Flow	1108.03	1181.19	1259.03	1341.83	1429.91
	Cumulative Cash Flow	7185.14	8366.33	9625.36	10967.19	12397.10

Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)						
	Year of operation	**20**	**21**	**22**	**23**	**24**
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2042**	**2043**	**2044**	**2045**	**2046**
	All Figures are in INR Crore					
1	**Capex (In INR Crore)**					
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%
2	**Operating Revenue**	**5287.23**	**5595.24**	**5921.19**	**6266.14**	**6631.18**
	Phenol	3619.29	3831.32	4055.78	4293.39	4544.92
	Acetone	1667.94	1763.92	1865.41	1972.75	2086.26
5	**Operating Cost**					
	Raw Material & Catchem	3111.32	3290.35	3479.67	3679.89	3891.63
	Labor	52.08	54.42	56.87	59.43	62.10
	Variable Overheads	385.27	402.60	420.72	439.65	459.44
	Fixed Overheads	59.10	61.76	64.54	67.44	70.48
	Selling Overheads	155.88	162.90	170.23	177.89	185.89
	Total Operating Cost	**3763.65**	**3972.03**	**4192.03**	**4424.31**	**4669.55**
6	**Gross Margin (EBITDA/PBITDA)**	**1523.58**	**1623.21**	**1729.17**	**1841.83**	**1961.63**
	Margin %	28.82%	29.01%	29.20%	29.39%	29.58%
	Net Cash Flow	**1523.58**	**1623.21**	**1729.17**	**1841.83**	**1961.63**

	Cost of Capital (10%)	0.22	0.20	0.18	0.16	0.15
	Discounted Cash Flow	331.58	321.14	311.01	301.15	291.58
	Undiscounted Cash Flow	1523.58	1623.21	1729.17	1841.83	1961.63
	Cumulative Cash Flow	13920.68	15543.90	17273.06	19114.90	21076.53

NPV	**6336.97**
IRR	**21.20%**
Payback Period After Project Completion (Simple)	**2.95**
Payback Period After Project Completion (Discounted)	**3.27**

Option 2: Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene)

CapEx

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene) (80 % phenol plant - DFCU operation (base case) considered for 8500 Hrs. operation)			
			INR Crore
A	**Total Fixed-Capital Investment**	**A1 + A2**	**1,392.11**
A1	**Total Direct Plant Cost**		**1,000.48**
1	Delivered Main Equipment (Includes Propylene Purification And Auxiliary Equipment)	100%	740.00
2	Purchased-Equipment Installation	15%	111.00
3	Instrumentation And Controls (Installed)	10%	74.00
4	Piping (Installed)	2%	14.80
5	Electrical (Installed)	1%	7.40
6	Buildings (Including Services)	2%	16.28
7	Service Facilities (Installed)	5%	37.00
A2	**Total Indirect Plant Cost**		**391.63**
9	Engineering And Supervision	10%	74.00
10	Construction Expenses	25%	185.00
11	Legal Expenses	2%	16.75
12	Contractor’s Fee	10%	74.00
13	Contingency	5%	41.88
B	**Working Capital**	**15 + 16**	**37.00**
14	Safety And Hazard Analyses	5%	37.00
C	Osbl Facilities		120
	Total Capital Investment	**A + B+C+D**	**1,549.11**

OpEx

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene) (80 % phenol plant - DFCU operation (base case) considered for 8500 Hrs. operation)			
	ITEM		**INR Crore**
C	**Manufacturing Cost**		**1284.40**
C1	Raw Materials and Catchem		1068.03
1	Raw Materials	-	992.05
2	Catalyst & Chemicals		75.98
C2	Labour		25.04
3	Salaries & Wages (Calculated)	-	25.04
C3	Variable Overheads		164.47
4	Packaging Cost (Calculated)		24.52
5	Utilities (Calculated)		139.95
C4	Fixed Overheads		26.86
6	Maintenance And Repairs (1.5% Of Fixed-Capital Investment) (Capex)	1.5%	23.24

7	Plant Overhead And Administrative Costs (7.5% Of 3 + 6)	7.5%	3.62
D	Selling Overheads		75.80
9	Distribution And Selling Costs (2.5% Of Sales Value)	2.5%	56.54
10	Research And Development Costs (1.5% Of Manufacturing Cost)	1.5%	19.27
	Total Production Cost		**1360.20**

Cashflow

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene) (80 % phenol plant - DFCU operation (base case) considered for 8500 Hrs. operation)								
Year of operation		**1**	**2**	**3**	**4**		**5**	**6**
Capacity Utilization							90.00%	100.00%
	Description							
	Operating Period	**2023**	**2024**	**2025**	**2026**	**Total**	**2027**	**2028**
	Expenditure Phasing	**5%**	**25%**	**35%**	**35%**			
All Figures are in INR Crore								
1	**Capex (In INR Crore)**	**-77**	**-387**	**-542**	**-542**	**-1,549**		
	Total Investment (In INR Crore)	**-77**	**-387**	**-542**	**-542**	**-1,549**		
	Capacity Utilization							
2	**Operating Revenue**						**1628.23**	**1914.53**
	Phenol						1109.35	1304.83
	Acetone						518.87	609.70
5	**Operating Cost**							
	Raw Material & Catchem					78.9%	961.23	1129.49
	Labor					1.8%	25.04	26.17
	Variable Overheads					11.9%	148.03	171.87
	Fixed Overheads					1.9%	24.17	28.07
	Selling Overheads					5.5%	68.22	79.21
	Total Operating Cost						**1226.69**	**1434.81**
6	**Gross Margin (EBITDA/PBITDA)**						**401.54**	**479.72**
	Margin %						24.66%	25.06%
	Net Cash Flow	**-77**	**-387**	**-542**	**-542**		**-1147.58**	**479.72**
	Cost of Capital (10%)					1	0.91	0.83
	Discounted Cash Flow						-1043.26	396.46
	Undiscounted Cash Flow						-1147.58	479.72
	Cumulative Cash Flow						-1147.58	-667.86

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene) (80 % phenol plant - DFCU operation (base case) considered for 8500 Hrs. operation)									
Year of operation		**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Capacity Utilization		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
All Figures are in INR Crore									
1	**Capex (In INR Crore)**								
2	**Operating Revenue**	**2026.05**	**2144.07**	**2268.97**	**2401.15**	**2541.02**	**2689.04**	**2845.69**	**3011.46**
	Phenol	1381.27	1462.19	1547.85	1638.54	1734.53	1836.15	1943.72	2057.59
	Acetone	644.78	681.88	721.12	762.61	806.49	852.90	901.97	953.87

5	**Operating Cost**								
	Raw Material & Catchem	1194.48	1263.21	1335.89	1412.76	1494.05	1580.02	1670.93	1767.08
	Labor	27.34	28.57	29.86	31.20	32.61	34.08	35.61	37.21
	Variable Overheads	179.61	187.69	196.14	204.96	214.19	223.82	233.90	244.42
	Fixed Overheads	29.33	30.65	32.03	33.47	34.98	36.55	38.19	39.91
	Selling Overheads	82.78	86.50	90.39	94.46	98.71	103.16	107.80	112.65
	Total Operating Cost	**1513.54**	**1596.62**	**1684.31**	**1776.86**	**1874.53**	**1977.62**	**2086.43**	**2201.27**
6	**Gross Margin (EBITDA/PBITDA)**	**512.52**	**547.45**	**584.66**	**624.29**	**666.49**	**711.42**	**759.26**	**810.19**
	Margin %	25.30%	25.53%	25.77%	26.00%	26.23%	26.46%	26.68%	26.90%
	Net Cash Flow	**512.52**	**547.45**	**584.66**	**624.29**	**666.49**	**711.42**	**759.26**	**810.19**
	Cost of Capital (10%)	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39
	Discounted Cash Flow	385.06	373.92	363.03	352.39	342.01	331.88	322.00	312.36
	Undiscounted Cash Flow	512.52	547.45	584.66	624.29	666.49	711.42	759.26	810.19
	Cumulative Cash Flow	-155.34	392.11	976.77	1601.06	2267.54	2978.96	3738.23	4548.42

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene) (80 % phenol plant - DFCU operation (base case) considered for 8500 Hrs. operation)						
	Year of operation	**15**	**16**	**17**	**18**	**19**
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2037**	**2038**	**2039**	**2040**	**2041**
	All Figures are in INR Crore					
1	**Capex (In INR Crore)**					
2	**Operating Revenue**	**3186.89**	**3372.54**	**3569.01**	**3776.92**	**3996.94**
	Phenol	2178.13	2305.74	2440.82	2583.82	2735.19
	Acetone	1008.76	1066.80	1128.19	1193.10	1261.75
5	**Operating Cost**					
	Raw Material & Catchem	1868.75	1976.28	2090.00	2210.26	2337.43
	Labor	38.89	40.64	42.46	44.38	46.37
	Variable Overheads	255.42	266.92	278.93	291.48	304.59
	Fixed Overheads	41.71	43.59	45.55	47.60	49.74
	Selling Overheads	117.72	123.01	128.55	134.34	140.38
	Total Operating Cost	**2322.49**	**2450.43**	**2585.49**	**2728.04**	**2878.52**
6	**Gross Margin (EBITDA/PBITDA)**	**864.40**	**922.11**	**983.52**	**1048.88**	**1118.42**
	Margin %	27.12%	27.34%	27.56%	27.77%	27.98%
	Net Cash Flow	**864.40**	**922.11**	**983.52**	**1048.88**	**1118.42**
	Cost of Capital (10%)	0.35	0.32	0.29	0.26	0.24
	Discounted Cash Flow	302.97	293.81	284.89	276.20	267.74

	Undiscounted Cash Flow	864.40	922.11	983.52	1048.88	1118.42
	Cumulative Cash Flow	5412.82	6334.93	7318.45	8367.33	9485.75

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene) (80 % phenol plant - DFCU operation (base case) considered for 8500 Hrs. operation)						
	Year of operation	**20**	**21**	**22**	**23**	**24**
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2042**	**2043**	**2044**	**2045**	**2046**
	All Figures are in INR Crore					
1	**Capex (In INR Crore)**					
2	**Operating Revenue**	**4229.78**	**4476.19**	**4736.96**	**5012.91**	**5304.94**
	Phenol	2895.43	3065.06	3244.63	3434.71	3635.94
	Acetone	1334.35	1411.13	1492.33	1578.20	1669.01
5	**Operating Cost**					
	Raw Material & Catchem	2471.93	2614.16	2764.58	2923.66	3091.88
	Labor	48.46	50.64	52.92	55.30	57.79
	Variable Overheads	318.30	332.62	347.59	363.23	379.58
	Fixed Overheads	51.98	54.32	56.76	59.31	61.98
	Selling Overheads	146.70	153.30	160.20	167.41	174.94
	Total Operating Cost	**3037.36**	**3205.04**	**3382.05**	**3568.91**	**3766.18**
6	**Gross Margin (EBITDA/PBITDA)**	**1192.42**	**1271.15**	**1354.90**	**1444.00**	**1538.77**
	Margin %	28.19%	28.40%	28.60%	28.81%	29.01%
	Net Cash Flow	**1192.42**	**1271.15**	**1354.90**	**1444.00**	**1538.77**
	Cost of Capital (10%)	0.22	0.20	0.18	0.16	0.15
	Discounted Cash Flow	259.51	251.49	243.69	236.11	228.73
	Undiscounted Cash Flow	1192.42	1271.15	1354.90	1444.00	1538.77
	Cumulative Cash Flow	10678.17	11949.32	13304.22	14748.22	16286.99

NPV	**4781.00**
IRR	**19.22%**
Payback Period After Project Completion (Simple)	**3.28**
Payback Period After Project Completion (Discounted)	**3.42**

Option 3: Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)

CapEx

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)			
			INR Crore
A	**Total Fixed-Capital Investment**	**A1 + A2**	**1,670.76**
A1	**Total Direct Plant Cost**		**1,206.66**
1	Delivered Main Equipment (Includes Auxiliary Equipment)	100%	892.50
2	Purchased-Equipment Installation	15%	133.88
3	Instrumentation And Controls (Installed)	10%	89.25
4	Piping (Installed)	2%	17.85
5	Electrical (Installed)	1%	8.93
6	Buildings (Including Services)	2%	19.64
7	Service Facilities (Installed)	5%	44.63
A2	**Total Indirect Plant Cost**		**464.10**
9	Engineering And Supervision	10%	89.25

10	Construction Expenses	25%	223.13
11	Legal Expenses	2%	17.85
12	Contractor's Fee	10%	89.25
13	Contingency	5%	44.63
B	**Working Capital**		**44.63**
14	Safety And Hazard Analyses	5%	44.63
C	Osbl Facilities		175
D	Gantry System (External Procurement Of Propylene - Refinery Grade And Polymer Grade)		47
	Total Capital Investment	**A + B+C+D**	**1,937.39**

Opex

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)			
	ITEM		**INR Crore**
C	**MANUFACTURING COST**		**1685.01**
C1	Raw materials and Catchem		1421.41
1	Raw materials	-	1327.38
2	Catalyst & Chemicals		94.03
C2	Labour		25.04
3	Salaries & Wages (calculated)	-	25.04
C3	Variable Overheads		208.16
4	Packaging Cost (calculated)		33.61
5	Utilities (calculated)		174.55
C4	Fixed Overheads		30.40
6	Maintenance and repairs (1.5% of fixed-capital investment) (Capex)	1.5%	26.53
7	Plant Overhead and Administrative Costs (7.5% of 3 + 6)	7.5%	3.87
D	Selling Overheads		70.50
9	Distribution and selling costs (2.5% of sales value)	2.5%	45.23
10	Research and development costs (1.5% of manufacturing cost)	1.5%	25.28
	Total Production Cost		**1755.52**

Cashflow

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)								
Year of operation		**1**	**2**	**3**	**4**		**5**	**6**
Capacity Utilization							90.00%	100.00%
	Operating Period	**2023**	**2024**	**2025**	**2026**	**Total**	**2027**	**2028**
	Expenditure Phasing	**5%**	**25%**	**35%**	**35%**			
All Figures are in INR Crore								
1	**Capex (In INR Crore)**	**-97**	**-484**	**-678**	**-678**	**-1,937**		
	Total Investment (In INR Crore)	**-97**	**-484**	**-678**	**-678**	**-1,937**		
2	**Operating Revenue**						**2035.28**	**2393.16**
	Phenol						1386.69	1631.03
	Acetone						648.59	762.12
5	**Operating Cost**							
	Raw Material & Catchem					81.3%	1279.27	1503.20
	Labor					1.4%	25.04	26.17

	Variable Overheads					11.6%	187.35	217.53
	Fixed Overheads					1.7%	27.36	31.77
	Selling Overheads					3.9%	63.45	73.68
	Total Operating Cost						**1582.47**	**1852.34**
6	**Gross Margin (EBITDA/PBITDA)**						**452.81**	**540.82**
	Margin %						22.25%	22.60%
	Net Cash Flow	**-97**	**-484**	**-678**	**-678**		**-1484.57**	**540.82**
	Cost of Capital (10%)					1	0.91	0.83
	Discounted Cash Flow						-1349.61	446.96
	Undiscounted Cash Flow						-1484.57	540.82
	Cumulative Cash Flow						-1484.57	-943.75

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)								
Year of operation		**7**	**8**	**9**	**10**	**11**	**12**	**13**
Capacity Utilization		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
All Figures are in INR Crore								
1	**Capex (In INR Crore)**							
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2	**Operating Revenue**	**2532.56**	**2680.09**	**2836.22**	**3001.43**	**3176.28**	**3361.30**	**3557.11**
	Phenol	1726.59	1827.74	1934.82	2048.17	2168.16	2295.18	2429.65
	Acetone	805.98	852.35	901.40	953.26	1008.11	1066.12	1127.47
5	**Operating Cost**							
	Raw Material & Catchem	1589.69	1681.16	1777.90	1880.20	1988.38	2102.80	2223.79
	Labor	27.34	28.57	29.86	31.20	32.61	34.08	35.61
	Variable Overheads	227.32	237.55	248.24	259.41	271.08	283.28	296.03
	Fixed Overheads	33.20	34.69	36.25	37.88	39.59	41.37	43.23
	Selling Overheads	76.99	80.46	84.08	87.86	91.81	95.95	100.26
	Total Operating Cost	**1954.55**	**2062.43**	**2176.33**	**2296.56**	**2423.48**	**2557.47**	**2698.92**
6	**Gross Margin (EBITDA/PBITDA)**	**578.02**	**617.66**	**659.89**	**704.88**	**752.80**	**803.84**	**858.19**
	Margin %	22.82%	23.05%	23.27%	23.48%	23.70%	23.91%	24.13%
	Net Cash Flow	**578.02**	**617.66**	**659.89**	**704.88**	**752.80**	**803.84**	**858.19**
	Cost of Capital (10%)	0.75	0.68	0.62	0.56	0.51	0.47	0.42
	Discounted Cash Flow	434.27	421.87	409.74	397.89	386.30	375.00	363.96
	Undiscounted Cash Flow	578.02	617.66	659.89	704.88	752.80	803.84	858.19
	Cumulative Cash Flow	-365.73	251.93	911.82	1616.70	2369.50	3173.33	4031.52

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)					
	14	**15**	**16**	**17**	**18**
Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%

	Operating Period	2036	2037	2038	2039	2040
All Figures are in INR Crore						
1	**Capex (In INR Crore)**					
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%
2	**Operating Revenue**	**3764.33**	**3983.61**	**4215.68**	**4461.26**	**4721.15**
	Phenol	2571.99	2722.67	2882.17	3051.03	3229.77
	Acetone	1192.34	1260.95	1333.50	1410.23	1491.38
5	**Operating Cost**					
	Raw Material & Catchem	2351.75	2487.07	2630.17	2781.51	2941.56
	Labor	37.21	38.89	40.64	42.46	44.38
	Variable Overheads	309.35	323.27	337.82	353.02	368.91
	Fixed Overheads	45.17	47.21	49.33	51.55	53.87
	Selling Overheads	104.78	109.49	114.42	119.57	124.95
	Total Operating Cost	**2848.26**	**3005.92**	**3172.38**	**3348.12**	**3533.66**
6	**Gross Margin (EBITDA/PBITDA)**	**916.07**	**977.69**	**1043.30**	**1113.14**	**1187.48**
	Margin %	24.34%	24.54%	24.75%	24.95%	25.15%
	Net Cash Flow	**916.07**	**977.69**	**1043.30**	**1113.14**	**1187.48**
	Cost of Capital (10%)	0.39	0.35	0.32	0.29	0.26
	Discounted Cash Flow	353.18	342.67	440.07	322.44	312.70
	Undiscounted Cash Flow	916.07	977.69	1381.12	1113.14	1187.48
	Cumulative Cash Flow	4947.59	5925.28	6968.57	8081.71	9269.20

Capacity for 200 KTPA Phenol + 120 KTPA Acetone, (Propylene - 80 % in house and 20 % external procurement)							
Year of operation		19	20	21	22	23	24
Capacity Utilization		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**
All Figures are in INR Crore							
1	**Capex (In INR Crore)**						
	Capacity Utilization	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2	**Operating Revenue**	**4996.18**	**5287.23**	**5595.24**	**5921.19**	**6266.14**	**6631.18**
	Phenol	3418.99	3619.29	3831.32	4055.78	4293.39	4544.92
	Acetone	1577.19	1667.94	1763.92	1865.41	1972.75	2086.26
5	**Operating Cost**						
	Raw Material & Catchem	3110.82	3289.82	3479.11	3679.30	3891.01	4114.90
	Labor	46.37	48.46	50.64	52.92	55.30	57.79
	Variable Overheads	385.51	402.86	420.99	439.93	459.73	480.42
	Fixed Overheads	56.30	58.83	61.48	64.24	67.13	70.15
	Selling Overheads	130.57	136.44	142.58	149.00	155.71	162.71
	Total Operating Cost	**3729.57**	**3936.41**	**4154.80**	**4385.39**	**4628.87**	**4885.97**

6	**Gross Margin (EBITDA/PBITDA)**	**1266.61**	**1350.83**	**1440.44**	**1535.80**	**1637.26**	**1745.21**
	Margin %	25.35%	25.55%	25.74%	25.94%	26.13%	26.32%
	Net Cash Flow	**1266.61**	**1350.83**	**1440.44**	**1535.80**	**1637.26**	**1745.21**
	Cost of Capital (10%)	0.24	0.22	0.20	0.18	0.16	0.15
	Discounted Cash Flow	303.22	293.98	284.98	276.23	267.71	259.41
	Undiscounted Cash Flow	1266.61	1350.83	1440.44	1535.80	1637.26	1745.21
	Cumulative Cash Flow	10535.81	11886.64	13327.08	14862.88	16500.14	18245.36

NPV	**5235.33**
IRR	**17.63%**
Payback Period after project completion (Simple)	**3.59**
Payback Period after project completion (Discounted)	**3.87**

Option 4: Combined Capacity for 350 KTPA PVC Resin and 200 KTPA Phenol + 120 KTPA Acetone

Cashflow:

Capacity for 350 KTPA PVC Resin and 200 KTPA Phenol + 120 KTPA Acetone							
Year of Operation		**1**	**2**	**3**	**4**		**5**
Capacity Utilization		**5%**	**25%**	**35%**	**35%**		70.00%
	Operating Period	**2023**	**2024**	**2025**	**2026**	**Total**	**2027**
All Figures are in INR Crore							
1	**Capex (In INR Crore)**	**296**	**1482**	**2075**	**2075**	**5,929**	
	Propane Furnace Addition	**138**	**692**	**968**	**968**	**2,766**	
	Propane Furnace Addition in DFCU					**2,366**	
	Propane Sourcing Infrastructure					**400**	
	Total Investment	**435**	**2174**	**3043**	**3043**	**-8,694**	
2	**Operating Revenue**						**4462.07**
	PVC					1.000	1831.36
	Phenol						1386.69
	Acetone						648.59
	Net Revenue Gain Over Base Case from Existing Products						595.42
3	**Operating Cost**						
	Raw Material					72.8%	1748.61
	Catchem					4.6%	92.91
	Labor					1.8%	53.82
	Variable Overheads					12.0%	336.37
	Fixed Overheads					3.3%	96.57
	Selling Overheads					5.5%	155.23
	Total Operating Cost						**2483.51**
4	**Gross Margin (EBITDA/PBITDA)**						**1978.56**
	Net Cash Flow	**-415**	**-2075**	**-2905**	**-2905**		**-6715.56**
	Margin (%)						44.34%
	Cost of Capital (10%)					1	0.91

Capacity for 350 KTPA PVC Resin and 200 KTPA Phenol + 120 KTPA Acetone									
Year of Operation		6	7	8	9	10	11	12	13
Capacity Utilization		90.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
All Figures are in INR Crore									
1	**Capex (In INR Crore)**								
	Propane Furnace Addition								
	Total Investment (In INR Crore)								
2	**Operating Revenue**	**5683.25**	**6387.42**	**6745.11**	**7122.96**	**7522.11**	**7943.78**	**8389.25**	**8859.84**
	PVC	2490.09	2925.97	3094.33	3272.38	3460.67	3659.80	3870.38	4093.09
	Phenol	1631.03	1726.59	1827.74	1934.82	2048.17	2168.16	2295.18	2429.65
	Acetone	762.12	805.98	852.35	901.40	953.26	1008.11	1066.12	1127.47
	Net Revenue Gain Over Base Case from Existing Products	799.99	928.88	970.68	1014.36	1060.01	1107.71	1157.56	1209.65
3	**Operating Cost**								
	Raw Material	2155.69	2368.88	2507.63	2652.01	2806.03	2968.67	3141.20	3325.55
	Catchem	126.77	149.50	158.46	167.91	177.82	188.31	199.42	211.19
	Labor	56.24	58.77	61.42	64.18	67.07	70.09	73.24	76.54
	Variable Overheads	372.31	389.06	406.57	424.86	443.98	463.96	484.84	506.66
	Fixed Overheads	104.11	108.80	113.69	118.81	124.15	129.74	135.58	141.68
	Selling Overheads	170.64	178.31	186.34	194.72	203.49	212.64	222.21	232.21
	Total Operating Cost	**2985.75**	**3253.33**	**3434.11**	**3622.50**	**3822.54**	**4033.42**	**4256.49**	**4493.83**
4	**Gross Margin (EBITDA/PBITDA)**	**2697.49**	**3134.09**	**3311.00**	**3500.45**	**3699.57**	**3910.37**	**4132.75**	**4366.01**
	Net Cash Flow	**2697.49**	**3134.09**	**3311.00**	**3500.45**	**3699.57**	**3910.37**	**4132.75**	**4366.01**
	Cost of Capital (10%)	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42

Capacity for 350 KTPA PVC Resin and 200 KTPA Phenol + 120 KTPA Acetone						
Year of Operation		14	15	16	17	18
Capacity Utilization		100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2036**	**2037**	**2038**	**2039**	**2040**
All Figures are in INR Crore						
1	**Capex (In INR Crore)**					
	Propane Furnace Addition					
	Total Investment (In INR Crore)					
2	**Operating Revenue**	**9357.01**	**9882.25**	**10437.15**	**11023.41**	**11642.80**
	PVC	4328.60	4577.67	4841.07	5119.62	5414.21
	Phenol	2571.99	2722.67	2882.17	3051.03	3229.77
	Acetone	1192.34	1260.95	1333.50	1410.23	1491.38
	Net Revenue Gain Over Base Case From Existing Products	1264.08	1320.96	1380.41	1442.53	1507.44
3	**Operating Cost**					
	Raw Material	3514.86	3716.03	3929.13	4152.96	4389.21
	Catchem	223.65	236.85	250.82	265.62	281.29

	Labor	79.98	83.58	87.34	91.27	95.38
	Variable Overheads	529.46	553.28	578.18	604.20	631.39
	Fixed Overheads	148.06	154.72	161.68	168.96	176.56
	Selling Overheads	242.66	253.58	264.99	276.92	289.38
	Total Operating Cost	**4738.67**	**4998.04**	**5272.15**	**5559.92**	**5863.21**
4	**Gross Margin (EBITDA/PBITDA)**	**4618.34**	**4884.21**	**5165.00**	**5463.49**	**5779.58**
	Net Cash Flow	**4618.34**	**4884.21**	**5165.00**	**5463.49**	**5779.58**
	Cost of Capital (10%)	0.39	0.35	0.32	0.29	0.26

Capacity for 350 KTPA PVC Resin and 200 KTPA Phenol + 120 KTPA Acetone						
Year of Operation		**19**	**20**	**21**	**22**	**23**
Expenditure phasing / Capacity Utilization		100.00%	100.00%	100.00%	100.00%	100.00%
	Operating Period	**2041**	**2042**	**2043**	**2044**	**2045**
All Figures are in INR Crore						
1	**Capex (In INR Crore)**					
	Propane Furnace Addition					
	Total Investment					
2	**Operating Revenue**	**12297.19**	**12988.59**	**13719.10**	**14490.92**	**15306.43**
	PVC	5725.74	6055.20	6403.62	6772.08	7161.74
	Phenol	3418.99	3619.29	3831.32	4055.78	4293.39
	Acetone	1577.19	1667.94	1763.92	1865.41	1972.75
	Net Revenue Gain Over Base Case from Existing Products	1575.28	1646.16	1720.24	1797.65	1878.54
3	**Operating Cost**					
	Raw Material	4638.75	4904.77	5186.62	5486.05	5800.67
	Catchem	297.89	315.47	334.08	353.79	374.67
	Labor	99.67	104.16	108.84	113.74	118.86
	Variable Overheads	659.80	689.49	720.52	752.94	786.83
	Fixed Overheads	184.50	192.81	201.48	210.55	220.03
	Selling Overheads	302.40	316.01	330.23	345.09	360.62
	Total Operating Cost	**6183.01**	**6522.70**	**6881.77**	**7262.16**	**7661.66**
4	**Gross Margin (EBITDA/PBITDA)**	**6114.18**	**6465.89**	**6837.32**	**7228.76**	**7644.77**
	Net Cash Flow	**6114.18**	**6465.89**	**6837.32**	**7228.76**	**7644.77**
	Cost of Capital (10%)	0.24	0.22	0.20	0.18	0.16

NPV	**25804.87**
IRR	**19.20%**
Payback Period After Project Completion (Simple)	**3.27**
Payback Period After Project Completion (Discounted)	**3.39**

Debt Service Coverage Ratio: Option-4

Debt Service Coverage Ratio (DSCR): Combined Scenario (INR Crore)									
Particulars	**1st Year**	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**6th Year**	**7th Year**	**8th Year**	**9th Year**
(a) Profit After Tax	829.97	1367.95	1694.66	1827.04	1968.81	2117.81	2275.55	2441.96	2616.51
(b) Add Back Interest on Term Loan	652.06	630.32	543.38	456.44	369.50	164.15	120.68	77.21	33.74
Total (a+b)	**1482.03**	**1998.28**	**2238.04**	**2283.48**	**2338.31**	**2281.95**	**2396.22**	**2519.16**	**2650.24**
(c) Interest on Term Loan	652.06	630.32	543.38	456.44	369.50	164.15	120.68	77.21	33.74

(d) Term Loan Instalment	0.00	869.41	869.41	869.41	869.41	869.41	869.41	869.41	869.41
Total (c+d)	**652.06**	**1499.74**	**1412.80**	**1325.85**	**1238.91**	**1033.56**	**990.09**	**946.62**	**903.15**
DSCR	**2.27**	**1.33**	**1.58**	**1.72**	**1.89**	**2.21**	**2.42**	**2.66**	**2.93**
Average DSCR (for Loan Period)	**1.93**								

Breakeven Point: Option-1 (Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)

Break Even Point at Optimum Capacity Utilization (4th Year)	
	(Rs. Crore)
(A) Gross Revenue	**2680.09**
(B) Variable Expenses	
Raw material and Catalyst & Chemicals	1589.95
Variable Overheads	227.18
Labor	30.71
Selling Overheads	91.92
Total Variable Expenses	**1939.75**
(C) Contribution	**740.34**
(D) Fixed Expenses	
Fixed Overheads	34.85
Interest on Term Loan	132.65
Depreciation	176.87
Total Fixed Cost	**344.37**
(E) Break Even Point	**46.51%**

Break Even Point: Sensitivity Analysis- Option 1 (Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)

Project Sensitivity Analysis	
Project Sensitivity	Break-Even Point
Present Break-Even Point	46.51%
Selling Price decreases by 11%, raw material price remains same	77.29%
Increase in raw material price by 16.5 % with no change in selling price	72.04%
Increase in raw material price by 9 % with decrease in selling price by 5%	74.34%
Increase in cost of production by 14.5% with no change in selling price	75.01%

Profitability: Sensitivity Analysis- Option 1 (Capacity of 200 KTPA Phenol and 120 KTPA Acetone Capacity (Propane Furnace Additional)

Project Sensitivity Analysis		
Project Sensitivity	Profit After Tax	Percentage Change
Profit After Tax (at optimum capacity utilization)	395.57	Nil
Selling Price decreases by 11%, Raw Material Price remains same	174.96	56% decrease
Increase in raw material price by 16.5 % with no change in selling price	199.26	50% decrease
Increase in raw material price by 9 % with decrease in selling price by 5%	188.21	52% decrease

Increase in cost of production by 14.5% with no change in selling price	181.32	54% decrease

Profitability: Sensitivity Analysis- Option 1 (Current Prices)

Project Sensitivity Analysis			
	Project Sensitivity	Profit After Tax	Percentage Change
	Profit After Tax (at optimum capacity utilization)	192.31	Nil
1	Selling Price decreases by 11%, Raw Material Price remains same	-75.77	139% decrease
2	Increase in Raw Material price by 16.5 % with no change in selling price	-537.99	380% decrease
3	Increase in raw material price by 9 % with decrease in selling price by 5%	-92.50	148% decrease
4	Increase in Cost of Production by 14.5% with no change in selling price	-545.53	384% decrease

13. Project Schedule and Implementation Strategy

Project Implementation Schedule																								
Activity		**Month**																						
	1	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
1. Kick Off Meeting, Detailed Engineering and Licensing	■	■																						
1. Engineering																								
Basic Engineering/ Documents	■	■	■																					
Detail Engineering/ Documents		■	■	■	■	■																		
1. Civil Work																								
Company Registration			■																					
Land Acquisition			■																					
Finalisation of Building Design				■	■	■																		
Invitation of Tenders and Award					■	■	■																	
Factory Shed								■	■	■	■	■	■	■	■	■	■	■						
Auxiliary Building								■	■	■	■	■	■	■	■	■	■	■						
Administrative Block								■	■	■	■													
Other Construction								■	■	■	■													
Disbursal of Finances								■	■	■	■	■	■	■	■	■	■	■						
3. Plant and Machinery																								
Specification Detailing		■	■																					
Invitation of Quotations				■																				
Placing Orders					■																			
Mechanical Piping & Fittings										■	■	■	■	■	■	■	■	■	■	■	■	■		
Delivery at Plant Site & Inspection															■	■	■							
Installation and Commissioning																	■	■	■					
Check-up of the Plant & Machinery																				■	■			
4. Arrangement of Power/Water								■	■	■	■													
5. Other Items																								
Finalize Management Reporting																		■	■	■	■			
Finalize Official Practices																		■	■	■	■			
Executive Systems																		■	■	■	■			
6. Training and Personnel																					■			
7. Start -up/ Commercial Production																						■	■	■

Environmental Protection & Energy Conservation

Air Pollution

For criteria pollutants and selected pollutants, air emissions are characterized by location, effective emission heights, and emission factors; the hazard potential of each pollutant is quantified, and the affected population is determined; the national and state emission burdens are calculated, and the industry's emissions growth factor is determined. The information in this part was gathered through industry collaboration.

Selected Pollutants

1. Cumene Peroxidation Vent

   In a reaction vessel, the Cumene feed is exposed to air to oxidize it. There is a constant flow of air in and out of the room. Vaporized hydrocarbons and some volatile trace elements are carried in the off-gas stream. Condensation is used to recover Cumene from spent gas for recycling. Before the gas is released into the atmosphere, the emission control equipment is the last piece of equipment to be used.

2. Cleavage Section Vents, Combined

   The composite emission factors are calculated by combining emission factors obtained through sampling and industry communication. The Cumene hydroperoxide concentration vent and the Cumene hydroperoxide wash vent, as well as the Cumene hydroperoxide concentration vent and the combined Cumene hydroperoxide cleavage and product wash vent, are incorporated in these emission factors.

   The Cumene hydroperoxide stream is washed, concentrated to at least 80% Cumene hydroperoxide, recycled, and the Cumene is removed. Then the Cumene hydroperoxide is broken down into products using an acid catalyst. The catalyst is then removed from the product stream.

3. Storage Tank Vents, Combined

   The phenol tanks' emission factor is an average of 0.06 grams of phenol per kilogram of phenol produced and an estimate of 0.012 grams of phenol per kilogram of phenol produced.

4. Product Transport Loading Vent; Combined

   The displacement of hydrocarbon-containing vapors in the filled compartment results in emissions from product transport loading. According to estimations, emissions of 0.061 g of acetone per kilogram of phenol and 0.20 g of phenol per kilogram of phenol from the phenol loading and shipping area.

5. Fugitive Emissions

   Pressure relief valves, pump seals, compressor seals, pipeline valves and flanges, equipment purges, Process drains, wastewater separators, and laboratory analyses are some of the sources of fugitive emissions. Sampling. Reports of 0.022 g/kg phenol produced as the total non-methane hydrocarbons (measured as methane equivalents) from pumps and sewers. Pumps and sewage systems create not all fugitive emissions, nor are they always the most significant.

Control Technology

Air emissions from Cumene's production of acetone and phenol include hydrocarbons. This section describes the industry's current emission control technology. Some control strategies are condensation, absorption, adsorption, floating roof tanks, and cremation. This section also covers potential developments in emissions control technology.

The most popular technique for reducing emissions from the Cumene peroxidation vent is adsorption. Additionally, cremation, absorption, and condensation are employed.

Condensation is most frequently responsible for regulating emissions in the cleavage region. Additionally, absorption and incineration are used. Condensation, adsorption, absorption, and incineration are the mechanisms used to control emissions in the product purification sector. Tank emissions are reduced using floating roofs, especially for acetone and cumene storage tanks. Although less frequently than floating roofs, condensation, sealed dome roofs, and conservation vents are also utilized. Emissions from product transport loading are reduced through vapor recovery or absorption. All plants do not manage this emission source. EPA is researching the range of fugitive emissions and available control options.

Major Emission Control Methods in Use at Cumene Peroxidation Plants

Vapor Condensation

Condensation is a method for removing organic substances from an air stream. When the partial pressure of a compound is equal to or greater than its vapor pressure at a specific temperature, vapor will condense. Similar to this, the material will condense if the temperature of a gaseous mixture is lowered to the saturation temperature, which is the point at which the vapor pressure equals the partial pressure of one of the constituents. Condensation can therefore be caused by either raising the system pressure or decreasing the temperature. Since increased pressure is frequently impractical in air pollution management applications, lower temperatures are typically used to condense organic pollutants. The ability of condensation to control organic emissions is restricted by partial equilibrium pressure. The partial pressure of the material still in the gas rapidly lowers while condensation takes place, preventing total condensation.

Activated Carbon Adsorption

A phenomenon known as adsorption occurs when molecules cling to the surface of a substance. A particular adsorbent, or adsorbing agent, will only adsorb specific molecules since the process is highly selective. "adsorbate" refers to the sense that adheres to the adsorbent. Three steps are involved in adsorption. Adsorption-induced separation occurs when the adsorbent and stream containing the adsorbate come into contact. The stream is then separated from the adsorbent to remove the unabsorbed portion. To replenish the adsorbent, the adsorbate is finally released. The best adsorbent for organic vapors is activated carbon. Given enough carbon, carbon adsorbs 95 to 98 percent of all organic moisture from the air at room temperature, regardless of fluctuations in concentration and humidity. Although a combination of organic vapors in the air is not uniformly absorbed by carbon, the components with higher boiling points are preferred. An activated carbon bed absorbs organic moisture when a contaminated gas stream is passed over, leaving behind a cleansed stream. Adsorption happens wholly and quickly at first, but when the carbon bed gets close to its limit, vapor traces start to show up in the exhaust air. This is where the activated carbon breaks. If the gas flow is maintained, more organic material is adsorbed but at a slower rate.

Solvent Absorption

Absorption is the process of dissolving one or more soluble components in a solvent and removing them from a gas mixture. To enable interphase diffusion between the materials, absorption equipment is designed to provide maximum contact between the gas and the liquid solvent. The degree of a chemical reaction and the solubility of the gas in the particular solvent are two elements that affect absorption rate, but the solvent surface exposed is the most crucial one.

The figure shows a vent gas scrubber-cooler system used on a Cumene peroxidation vent. This system uses an aqueous Na2CO3 solution as the scrubbing liquid to absorb hydrocarbons from off-gases in a tray tower. Some of the cleaning solutions are recycled through the scrubber with makeup solution, while some are delivered to the oxidation section. The scrubbed gas is cooled, the condensate removed, and the gas is released into the environment.

Incineration

Carbon dioxide and water are produced when the hydrocarbons in the emissions from a Cumene peroxidation phenol factory are wholly burned. Depending on the manner of combustion and temperature, NOx may be created. If any, the amount of sulfur in the auxiliary fuel affects how much SOx is produced. The kinds of incinerators used to burn hydrocarbons at facilities producing acetone and phenol from cumene (such as direct flame afterburners, catalytic afterburners, or flares) were not mentioned.

Solid Waste Disposal

There isn't much solid waste in the facility; instead, it will only consist of dried sludge from the effluent treatment plant, canteen wastes, used office supplies, broken office chairs, and rags for cleaning. Thermal incineration or tipping are the two methods used to dispose of solid waste. Due to the extensive range of feed materials that must be disposed of, designing a solid waste incinerator is challenging. Determining the solid waste material's burning properties is crucial. Controlling fly ash in the solid incinerator is a significant issue. Several techniques were used for this goal, including filter baffles, two-stage combustion, and the provision of sizable secondary chambers where settling could occur at moderate speeds. Special separating tools like electrostatic precipitators can be used if the fly ash issue is persistent. The generated flash can be used as a landfill.

Noise Pollution

Pumps, burners, electric motors, valves, steam vents, etc. are the leading causes of noise pollution in our plant. Pipes and hoses striking the floor, panels, Etc., which cause rattling noises, are modest causes of the noise pollution and can be stabilized using adsorbent mounts. To avoid vibration and clatter, all of the bolts should be tightened. Severe noise pollution could be caused by venting process gas out the condensers. This results from the turbulent mixing of the stationary gas with high-velocity gas. Steam leaks are another typical source of noise, and at 25 feet from a leak, the sound level can sometimes reach 100 dB. All steam leaks need to be promptly fixed. The use of ear protection equipment is recommended when the noise level cannot be decreased to a humane level. The industry must take the necessary steps to regulate noise levels coming from its sources inside the building to maintain the ambient air quality requirement for noise at less than 75 dB(A) during the day and 70 dB(A) at night.

14. SWOT Analysis

Strengths

- OPaL is promoted by Oil and Natural Gas Corporation (ONGC) and co-promoted by GAIL and GSPC. The long legacy, financial health and market reputation are vital advantages.
- The company's executives have decades of experience in plastic, chemicals, engineering, and successful start-ups. Market know-how and network are vital advantages.
- OPaL has set up a grass root mega Petrochemical complex at Dahej, Gujarat, in PCPIR/SEZ, giving the company an added advantage in procuring critical materials such as Benzene & Propylene from existing ONGC-operated plant facilities.
- With a surplus supply of upstream products, the company can quickly enter Phenol-based markets such as BPA, phenol-formaldehyde resins, and others & diversify its product portfolio.
- Strategic location & proximity to western ports is an added advantage to capturing India's phenol market and procuring raw material.
- The accessibility of cheap labour in the Indian domestic market makes Phenol production economical, along with better netbacks from the downstream industries.

Weakness

- Constant fluctuations in the International Crude Oil prices primarily influence phenol's market.
- Because of the surplus availability of Benzene, price competitiveness is intense.

Opportunities

- Increasing demand for acetone to produce IPA for sanitization purposes due to the COVID-19 pandemic.
- Export potential in Asia-Pacific Countries such as China, Singapore, Malaysia, Thailand, and Indonesia.
- The introduction of new manufacturing technology and the process by market leaders will result in lower costs of CapEx and OpEx.
- Supply chain disruption for Phenol and acetone in the Asia Pacific and Europe region will further rise in realizations, resulting in better prospects for the Indian companies.
- Consistently rising consumption of Polycarbonate and Bisphenol A had the attention of several market players. The incremental demand will be created from new greenfield projects.
- The consistent offtakes from the automotive, construction, electronics, and several other major industries in India have driven the demand outlook of Phenol along with a substantial forecasted CAGR of more than 10%.

Threats

- Phenol/Acetone has surplus capacity at the global level, which can pose a potential threat for new players as existing players may supply the product at a lower cost.
- Due to the increasing concerns about the shortage of fossil resources and the environmental impact of petroleum-based products, the research on bio-based substitutes of phenol such as lignin, tannin, Etc., is increasing. Lignin is an attractive biomass substitute for phenol production because it is renewable, often available as a waste material, and yields products with a lower carbon footprint.
- Phenol/Acetone has surplus capacity at the global level, which can pose a potential threat for fresh players as existing players may dump the product at a lower cost

15. Risk Factors and Mitigation

1. **Cost Overrun, Mitigation:** Thorough project planning is required to insulate from any higher investment cost.
2. **Sourcing of Feed, Mitigation:** Adding a Propane furnace to supply crucial feedstock, i.e., propylene (chemical or refinery grade), will significantly lower the production cost and help achieve an assured supply of raw material.
3. **Acetone is likely to be surplus soon, Mitigation-** OPaL should opt for downstream integration of Bisphenol A, MIBK, MMA, IPA, Etc.
4. **Delay in Project Commissioning, Mitigation:** Considering the experience and competition, OPaL should take all necessary approvals and vendor finalizations sourcing of key feedstock so that the plant can be operational in 48 months.

16. Technology Licensors

S. No	Licensor	Details
1	Honeywell UOP	Formerly known as UOP LLC or Universal Oil Products, it is an American multinational company developing and delivering technology to the petroleum refining, gas processing, petrochemical production, and major manufacturing industries. The company's roots date back to 1914, when the revolutionary Dubbs thermal cracking process created the technological foundation for today's modern refining industry.
2	The Kellogg Brown & Root (KBR) Technology	Morris Woodruff Kellogg founded M.W. Kellogg in 1901 as a small pipe fabrication company in New York and expanded it to become a renowned engineering company. The engineering prowess of Kellogg and its appetite for invention resulted in the development of new technologies and industry milestones, such as the first catalytic cracking facility in the world and the first liquid ethylene cracking facility based on crude oil in Europe.
3	Lummus Phenol Technology	The Versalis/Lummus Technology phenol process makes use of cutting-edge technology to air oxidize cumene before it is broken down into phenol and acetone with the help of an acid catalyst. Modern technology reduces the development of heavy by-products and increases conversion, increasing overall yield while ensuring a smooth, dependable, and safe operation.
4	Badger Acetone -to- Cumene (ATC) Technology	A joint venture of affiliates of the Shaw Group Inc. and ExxonMobil Chemical Co is principally engaged in marketing, licensing, and developing technologies to produce ethylbenzene, styrene monomer, Cumene, and bisphenol-A.

17. Recommendations

Most Suitable Plant Set-up Option: Phenol

- Option 1 requires no external sourcing of raw materials due to the addition of a propane furnace in which propane is already being sourced from ONGC, LNG Processing unit, Dahej. At the same time, benzene is available from the existing Dual Feed Cracker Unit. Due to the renegotiation of its long-term purchase contract with ONGC for C2/C3/C4, which has already improved its operating profitability coupled with inhouse production of raw materials, the option has been observed with an attractive NPV, IRR, and payback period. Despite having similar CapEx and Opex values in three options, Option 1 seems most feasible as it won't require refinery and chemical grade propylene sourcing from the international and domestic market. With the help of a new long-term purchase agreement for C2/C3/C4 with ONGC, OPaL could increase operating profitability. ONGC would continue to be OPaL's primary feedstock supplier, but a minor amount of the remaining feedstock must be obtained from other sources.
- Option 2 has a maximum operating rate is 80% phenol plant (160 KTPA) considering the base case of DFCU operation for 8500 Hrs. Operation. There is a significant reduction in CapEx and Opex due to a lower operating rate, but the cost of production per tonne basis is slightly higher than Option 1.
- Option 3 has a capacity of 200 KTPA Phenol + 120 KTPA Acetone, while 80 percent is in-house while the rest is externally procured. This will have a slightly higher Capex but have the flexibility of using merchant propylene up to 20 percent. This will also help in using lesser pure chemical and refinery grades. Still, availability in India and the international market at competitive prices is doubtful considering the ambitious plan of current suppliers BPCL and HPCL into propylene derivative petrochemical products.

Features	Option 1	Option 2	Option 3
CapEx (INR Crore)	1769	1549	1937
OpEx (INR Crore)	1681	1360	1756
NPV (INR Crore)	6337	4781	5235
IRR	21.20%	19.22%	17.63%
Payback Period (Years) Simple	2.95	3.28	3.59
Propylene	Available through DFCU and Propane Furnace Addition	Up to 80% (DBN – 8500 Hrs. Operation)	External Procurement (Up to 20 Percent)
Benzene (Raw material & Feed)	Available through DFCU	Available through DFCU	Available through DFCU
Margin %(Starting from First Year of Operation	25.52%	24.66%	22.25%

200 KTPA Phenol+120 KTPA Acetone (Propane Furnace Additional)

200 KTPA Phenol + 120 KTPA Acetone, (Propylene : 80 % In-house+ 20 % external)

200 KTPA Phenol + 120 KTPA Acetone, (with available propylene and benzene)

Preference Rank:	1	2	3

OPaL will have sufficient propylene after the commissioning of the propane furnace. Therefore, Option 1 will have better NPV, IRR, Payback Period, and margin despite having the highest CapEx.

Option 1 is most feasible in terms of execution and realization as it won't require refinery and chemical-grade propylene sourcing from the international and domestic market.

Options 2 & 3 have significantly lower NPV and IRR, while CapEx is marginally higher due to the addition of a gantry storage system for handling propylene.

Option 1, 2, 3, and 4 were presented to OPaL, wherein Option 4 emerged as the configuration with the highest NPV and was therefore recommended by TechSci for further pursue configuration and licensor identification. The report basis, financial analysis, and recommendations are based on the conventional execution mode. The OPaL's existing data was used to calculate ethylene production cost. At the same time, the cost of production is also calculated with the new feed structure, including the new propane furnace. Adding a propane furnace appears to be most practical as this will optimize the Opex and the feed within Opal. The schedule will remain the same as informed above, and the cash flows, IRRs, Capex and taxation etc., can be reassessed at OPaL's end based on their experience and choice of execution methodology.

Most Suitable Plant Set-up Option: PVC+ Phenol

Features	Option 1 (PVC)	Option 1 (Phenol)	Option 4
CapEx (INR Crore)	4159	1769	8694
OpEx (INR Crore)	1203	1681	3253
NPV (INR Crore)	13376	6337	25805
IRR	20.03%	21.20%	19.20%
Payback Period (Years) Simple	3.22	2.95	3.27
Propane (Raw material & Feed)	Propane through Parent Company ONGC	Propane through Parent Company ONGC	Propane through Parent Company ONGC
EDC/ VCM (Raw material & Feed)	Not Required	Not Required	Not Required
Benzene (Raw material & Feed)	Not Required	Available through DFCU	Available through DFCU
Chlorine Sourcing	Chlor-Alkali units (DCM Sriram, Meghmani, GACL) in proximity	Not Required	Chlor-Alkali units (DCM Sriram, Meghmani, GACL) in proximity
Jetty Facility	Not Required	Not Required	Not Required
Co-product Realization	NA	NA	Yes

Option 1 (PVC): 350 KTPA PVC + Captive Ethylene | Option 1 (Phenol): 200 KTPA Phenol +120 KTPA Acetone (Propane Furnace Additional)

Option 4: 200 KTPA Phenol + 120 KTPA Acetone and 350 KTPA PVC Resin Plant (Propane Furnace Additional)

Option 4 appears to be the most feasible & realistic option among the other three options due to the attractive NPV, IRR, and payback period. Moreover, the margin percentage is also the highest. Furthermore, the coproduct will contribute to the PVC + phenol project with propane furnace addition to DFCU and be accounted for in the revenue. The revenue part of the cash flow considered additional LLDPE, PP, HDPE, and production with surplus ethylene and propylene. Surplus ethylene shall be consumed to manufacture 35% LLDPE and 65% HDPE.

OPaL will have sufficient ethylene, propylene, and benzene after commissioning the propane furnace. Therefore, Option 4 will have better NPV, and margin (coproduct revenue realization) despite having the highest CapEx. Incremental ethylene and propylene availability due to propane furnaces increase the incremental margin.

Factors Influencing the Position for the Proposed Project- Phenol

- Few players in the market
- The high entry barrier for the Phenol market
- Higher growth is anticipated in downstream industries
- The higher demand-supply gap in the domestic market
- Margin is likely to be higher
- Export potential to ASEAN countries
- Possibility of downstream integration by putting a capacity for the manufacturing of IPA and Bisphenol-A
- Technological maturity and Cumene/benzene/propylene route is the preferred process for the manufacturing of Phenol
- The strategic location of the plant benefits the export of the product
- Access to all significant feed and feedstocks
- Integrated Phenol projects may be explored owing to increased custom duty on bisphenol A, epichlorohydrin, & polycarbonate.

Action Plan and Strategies

1. The demand-supply gap emerging in India justifies the creation of large Phenol and Acetone capacity immediately through the Cumene route.
2. Considering the availability of benzene and propylene, 200 KTPA Phenol capacity can be created.
3. The avenues for export are also open if OPaL wishes to do so.
4. Evaluating the Technology & Licensor for Phenol production process through Cumene need to streamline post receiving the financial clearance from Board of Directors.
5. India's Phenol imports in FY 2022 are expected to reach around 170 KTPA. Only three players are manufacturing phenol in the country. Deepak Phenolics Ltd is the leading player in the country and controls the domestic market, thus creating an opportunity for OPaL to enter the Phenol and Acetone market.
6. Higher return and increasing import volume of phenol will help the company to capture the domestic market.
7. OPaL can also integrate the phenol production unit to manufacture its derivatives such as Bisphenol A, MMA, and Isopropyl Alcohol.
8. OPaL may look into the sourcing of RGP (Refinery grade propylene) and CGP (Chemical Grade Propylene) and using high PGP (Polymer grade propylene) for polypropylene or propylene derivatives manufacturing.
9. OPaL is recommended to complete the project per the implementation schedule. Otherwise, there will be a possibility of cost over-run and time over-run.
10. Project is viable, primarily on account of captive production of benzene and propylene using existing display coupled with the incorporation of propane furnace in dual feed cracker unit, which is expected to give an upper edge to the company in gaining higher profit margin.

18. Annexure

Specification

Cumene Feedstock			
Property		Units	Value
Cumene Content		wt%	NLT 99.9 *
Appearance	Water white, clear with no turbidity		
Color, APHA		Pt-Co	NMT 10
Distillation range (including 152.5ºC.)		ºC.	NMT 1.0 *
Bromine Index			NMT 50 *
Impurities, wt ppm	Benzene		NMT 10 *
	Toluene		NMT 5 *
	Ethyl benzene		NMT 200 *
	n-Propyl benzene		NMT 300 *
	Butyl benzenes		NMT 150 *
	Cymenes		NMT 50 *
	Di-isopropylbenzenes		NMT 5 *
	Sulfur		NMT 1
	Phenols		NMT 50
	Peroxides		NMT 100

NLT = Not Less Than

NMT = Not More Than

** Value considered for performance guarantees*

PHENOL PRODUCT	
	Value
Phenol, wt% min	NLT 99.99 *
Water Content, wt ppm max	NMT 50 (1)
Colour, Pt-Co max	NMT 5 *
Solidification Point (dry), ºC min	NLT 40.85 *
Iron Content, wt ppm	0.1 *
Ash Content, wt ppm	1.0 *
Total Carbonyls, wt ppm as mesityl oxide	NMT 12 *
3-Methyl Cyclopentanone, wt ppmx	NMT 2 *
2 Methyl Benzofuran, wt ppm	NMT 5 *
Hydroxyacetone, wt ppm	NMT 3 *
Benzaldehyde, wt ppm	NMT 5 *
Cyclohexanone plus Cyclohexanol, wt ppm	NMT 5 *
Total Organics excluding cresols, ppm	NMT 12 (2)
Residue on Evaporation, wt%	0.01

ACETONE PRODUCT	
	Value
Purity (dry basis), wt%	NLT 99.75 *
Color, Pt-Co	NMT 5 *
Water Content, wt%	NMT 0.2 *
Permanganate Test Time, hours	NLT 4 *
Distillation Range, ºC including 56.1ºC (760 mm Hg)	NMT 0.5 *
Aldehydes, wt ppm max	20

Benzene, wt ppm max	1
Non-volatiles, wt ppm max	5
Iron Content, wt ppm	NMT 0.1 *
Ash Content, wt ppm	NMT 1 *
Methanol, wt ppm	NMT 250 *