Working Paper 271

Feedstock for the Petrochemical Industry

Saon Ray
Amrita Goldar
Swati Saluja

February 2014

INDIAN COUNCIL FOR RESEARCH ON INTERNATIONAL ECONOMIC RELATIONS

Table of Contents

List of Tables

List of Figures

List of Abbreviations

APM:	Administered Price Mechanism
BBL:	Oil Barrel
Bcm:	billion cubic meters
BG:	British Gas
BPCL:	Bharat Petroleum Corporation Limited
CST:	Central Sales Tax
EPC:	Engineering, Procurement and Construction
GAIL:	Gas Authority of India Limited
HDPE:	High Density Polyethylene
HMEL:	HPCL-Mittal Energy Limited
HPCL:	Hindustan Petroleum Corporation Limited
IOCL:	Indian Oil Corporation Limited
KG:	Krishna Godavari
Kt:	Kilotonnes
KTA:	Kilotonnes per Annum
LLDPE:	Linear Low Density Polyethylene
LNG:	Liquefied Natural Gas
LPG:	Liquified Petroleum Gas
Mmbtu:	million british thermal units
MT:	Metric Tonne
MMT:	Million Metric Tonne
Mmtpa:	million metric tonnes per annum
NELP:	New Exploration Licensing Policy
NGL:	Natural Gas Liquids
NOC:	National Oil Companies
OIL:	Oil India Limited
ONGC:	Oil and Natural Gas Corporation
OPAL:	ONGC Petro Additions Ltd.
PLL:	Petronet LNG Limited
PP:	polypropylene
PPAC:	Petroleum Planning and Analysis Cell
PVC:	Poly vinyl chloride
PX:	Paraxylene
RIL:	Reliance Industries Limited
UP:	Uttar Pradesh

Abstract

Petrochemicals play a vital role in the economy. The products of the industry are the building blocks in many industries including polymers, synthetic rubber, synthetic fibres, fibre intermediates and basic chemicals. The industry uses a variety of hydrocarbon feedstock such as different cuts of naphtha from refinery and natural gas (ethane and propane). Of the total ethylene capacity in the country, nearly 67 per cent is naphtha-based and 33 per cent is gas-based. This paper examines the feedstock scenario for petrochemicals in India in terms of availability, pricing, regulatory and fiscal issues. It also examines the feedstock scenario in the neighbouring region and assesses the competitive position of Indian petrochemical producer vis-à-vis producers in these countries. It provides an illustrative per unit cost of production for ethylene produced from both naphtha and ethane for India. Besides, it identifies the future challenges to the growth of the sector in India and suggests policy measures to strengthen India's competitive position.

____

JEL Classification: *L65, D24, Q48, Q37*

Keywords: *natural gas price, naptha price, cost of production, import duty*

Author Emails: *sray@icrier.res.in*

____

Disclaimer:

Feedstock for the Petrochemical Industry

Saon Ray, Amrita Goldar, Swati Saluja

Section 1: Introduction

1.1 Petrochemical industry

Petrochemicals constitute a very important segment of world chemicals market, with a share of nearly 40 per cent. The industry is important as it has several linkages with other sectors of an economy. Petrochemicals have backward linkages with other industries in petroleum refining, natural gas processing and forward linkages with industries that deal in a variety of downstream products. Also, the industry offer alternatives, which serve as substitutes for natural products and hence, has the capacity to meet the constantly growing demand that would otherwise strain the natural resources. In addition, downstream processing units contribute to employment generation and entrepreneurial development in the SME segment, serving a vital need of the economy.

The industry uses a variety of hydrocarbon feedstock such as different cuts of naphtha from refinery and natural gas (NGL, ethane, propane, butane, LPG). This paper examines the feedstock scenario for petrochemicals specifically for India in terms of availability, pricing, regulatory and fiscal issues. Besides, it highlights some of the major challenges faced by the industry and related policy measures that would strengthen domestic competitive position.

This paper is organised in the following manner: Section 1 introduces the petrochemical industry. Section 2 presents a picture of the status of the Indian petrochemicals, demand for feedstock and the regulatory issues determining the choice and availability of feedstock. Section 3 presents an analysis of the demand and pricing of feedstock for the petrochemicals sector and an illustrative per unit cost for ethylene produced from naphtha and natural gas in India. Section 4 highlights some of the fiscal anomalies in the petrochemicals sector. Section 5 concludes with the challenges faced by the sector as well as some policy recommendations to boost growth of the sector.

Section 2: Availability of different feedstock for Indian Petrochemical Industry

2.1 Status of Indian Petrochemical Industry

The chemical and the petrochemical sectors together constitute around 14 percent of domestic industrial activity. The Indian petrochemical industry constitutes around 40 per cent of chemical sector output. According to an ASSOCHAM study, the Indian petrochemical industry, valued at $40 billion, in 2012 is expected to grow at 12-15 per cent annually over the next five years.

At present there are three naphtha[1] based, three gas based and one mixed feed cracker complexes in the country with a combined annual ethylene capacity of 3.3 MMT. The major players in Indian petrochemicals industry are Reliance Industries Limited, Haldia Petrochemicals and GAIL (India) Limited. With the commissioning of their petrochemical complex last year at Panipat, Indian Oil Corporation has also emerged as another major player. The location of petrochemical units is given in Table 1 along with the feedstock used. As is apparent from Table 1, the major feedstock used in Indian petrochemical units is naphtha and natural gas (propane and butane). The major intermediate products produced in the country are ethylene, propylene, butadiene, benzene, toluene and xylene.

Table 1: Existing Naphtha / Gas Cracker (2011)

Name of Unit	State	Feedstock	Ethylene Capacity* (TPA)	Sourcing of feedstock
Reliance, Vadodara	Gujarat	Naphtha Cracker	130000	Jamnagar Refinery
RIL, Hazira	Gujarat	Naphtha/ NGL Dual Feed	750000	Jamnagar Refinery/Imported
Reliance, Gandhar	Gujarat	Gas	300000	Natural Gas produced by ONGC (Gandhar on-shore and South Bassein)
Reliance, Nagothane	Maharashtra	Gas	400000	Natural Gas produced by ONGC (Bombay High)
GAIL, Auriya	Uttar Pradesh	Gas	400000	Natural Gas produced ONGC (South Bassein)
Haldia Petrochemicals Ltd., Haldia	West Bengal	Naphtha	520000	IOCL Haldia Refinery//Imported
IOC, Panipat	Haryana	Naphtha	857000	IOC Refinery (Panipat/Mathura)

Source: http://chemicals.nic.in/petro1.htm   ** as of 2011*

2.2 Feedstocks in Petrochemicals

Four crucial factors govern the choice of feedstock in petrochemical plants: availability, cost, power consumption and the product portfolio to be produced. With respect to availability, the plant owners need to be assured of continuous availability of feedstock (This has been discussed in depth in section 3, along with cost of feedstock in section 3.1). Even though power accounts for 10 per cent of the cost involved in the cracking of feedstock, an un-

[1] Naphtha is the term denoting the overhead liquid fraction obtained from atmospheric distillation units in refineries. It is a mixture of hydrocarbons boiling in the range of the lowest boiling component to 200°C.

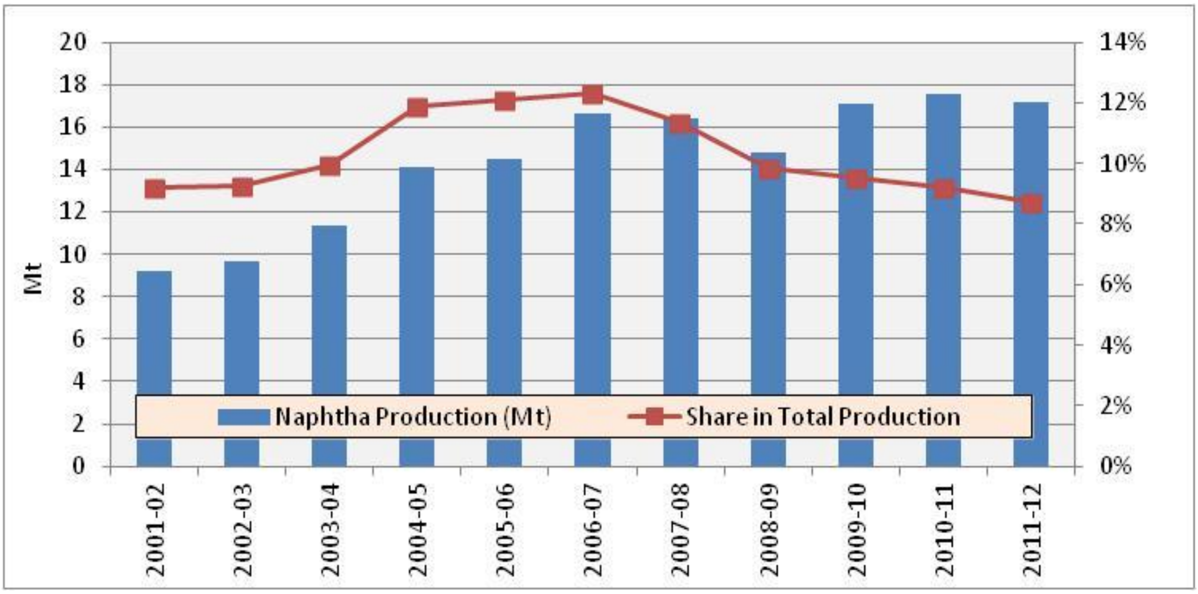
interrupted high quality power is required for the same. Hence, many petrochemical complexes use captive power. As per the portfolio of products, naphtha is used when a wide range of co-products (including propylene and butadiene derivatives) is desired while natural gas and NGL are preferred when the ethylene output of a cracker is to be maximized since they yield a higher proportion of ethylene. The current section examines the relative costs in producing petrochemicals using different feedstock while the portfolio of products desired, another critical factor in the choice of feedstock, is discussed below.

2.3 Naphtha for Petrochemicals

As of April 2011, India had a total refining capacity of 193.398 mmtpa and an annual crude throughput level of 206.2 mmt. Refining throughput has increased steadily. In addition to these, there are currently three refineries under different stages of construction – HMEL refinery at Bhatinda (Punjab),[2] IOCL refinery at Paradip, and Nagarjuna Oil Corporation Limited (NOCL) at Cuddalore.

Domestic naphtha production has been increasing overtime as can be seen from Figure 1 below. As expected, there is a slight dip in the year 2008-09 due to the global recession. However, production picked up in the next year i.e. 2009-10. In following years, this trend has continued. The share of naphtha in total production of petroleum products has, however, been declining in recent times. Currently, naphtha accounts for approximately 8.7 per cent of total production of petroleum products.

Figure 1: Naphtha Production in India



Source: MoPNG, 2013

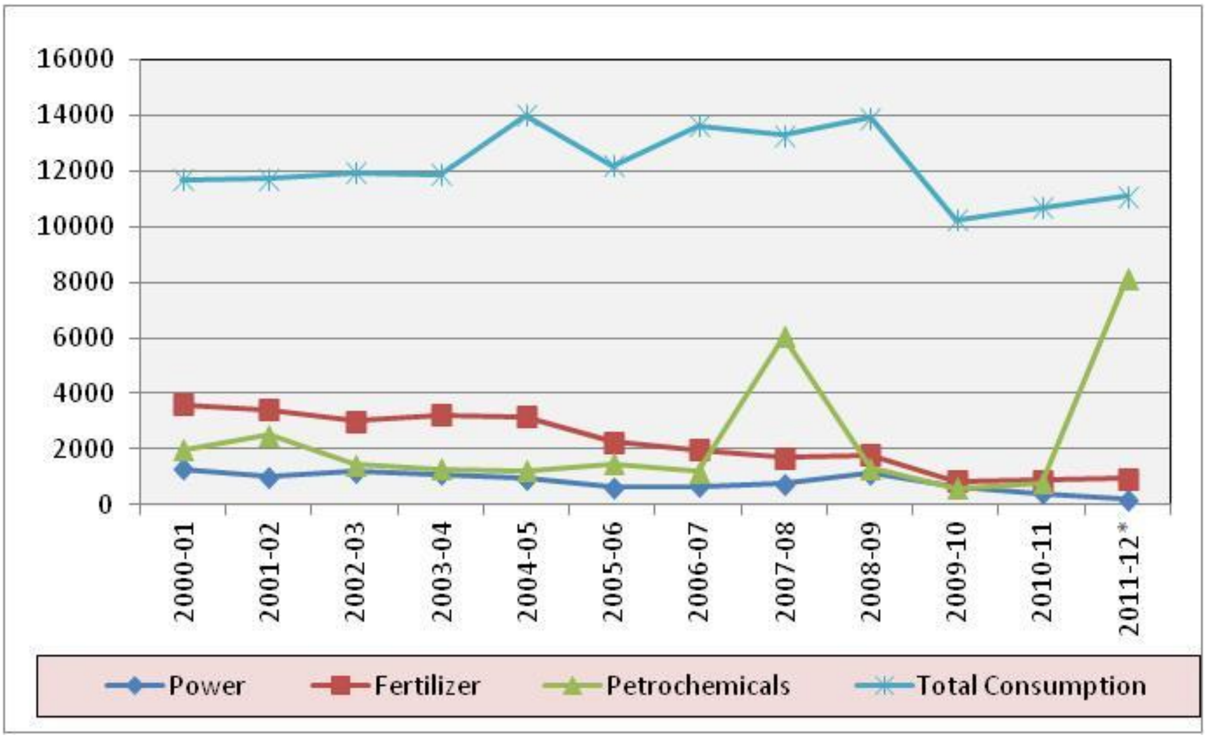
The fertiliser and petrochemicals sector are the largest naphtha consuming sectors in the country. A significant part of naphtha is consumed by the power generation sector as well.

---

2 Dedicated to the nation by the Prime Minister on April (28th April, 2012)

Figure 2 presents data for domestic naphtha consumption. It can be seen that after 2008-09, consumption has shown a declining trend. This could be due to falling consumption by the fertiliser and power sector over time due to availability of Natural Gas. The petrochemical sector, however, shows high volatility in consumption over the years.

Figure 2: Sector-wise Naphtha Consumption – India ('000 tonnes)



*provisional

Source: MoPNG, 2013

As regards trade trends, India shows an interesting trend of rapidly increasing imports as well as exports. Data shows that Indian naphtha exports took off after 2003-04 with only a small dip witnessed in 2008-09. Import trends, on the other hand, peaked in 2007-08 and thereafter, declined. One possible reason for simultaneous export and import of naphtha is that naphtha produced in India is heavy and unsuitable for the petrochemicals sector. Other factors for imports include the level of state taxation (up to 18 percent in Gujarat), high cost of over ground transportation of naphtha and requirement of separate unloading facilities, which make domestic transportation extremely costly and un-competitive.

2.4 Natural Gas for Petrochemicals

According to the BP Statistical Review 2013, India's proven gas reserves currently stand at 1.3 trillion cubic meters, which are 0.7 per cent of the world's total proven gas reserves. In 2011-12, the production of gas in the country was 47.56 billion cubic meters (bcm) while imports constituted 13.67 bcm. In 2010-11, while India's proven gas reserves were estimated to be 1.45 trillion cubic meters, and the production was 52.2 bcm. Around half of the production for domestic natural gas was contributed by the state-owned ONGC and OIL. The balance was from private/JV companies. From a regional perspective, KG Offshore (RIL) and Mumbai Offshore (BG, RIL and ONGC) were the largest contributors to the country's gas production after National Oil Companies (NOCs) during year 2010-11.

A large part of demand is met with domestic production (around 80 per cent) with the balance fed by LNG imports. The massive jump in the production from private/JV in 2009-10 categories is also a notable feature. The discovery of D-6 block of the Krishna Godavari (KG) basin was one of most prolific gas discoveries under NELP and is the major reason for the sharp increase in private sector gas production. Other NELP discoveries in the eastern offshore basin include those by ONGC (KG-DWN-98/2) and the Gujarat State Petroleum Corporation (KG-OSN-2001/3).

It is noteworthy that natural gas from the KG basin contains predominantly methane (lean gas). For economically feasible ethylene cracking, natural gas should ideally contain 10-15 per cent of C2-C3 streams by weight. Thus, natural gas sourced from Middle East, containing higher ethane and propane fractions, cannot technically be done away with even with higher domestic production. Rich gas (containing greater C2+ contents) is preferred by the petrochemical industry. ONGC's Bombay High and South Bassien fields, and to a limited extent, onshore fields in Dahej are the only source of rich gas in India and supplies gas to Nagothane, Gandhar and Pata.

Like production, consumption too has been increasing. Data on natural gas in India shows that gas used for energy purposes dominates consumption. Usage by both fertiliser and petrochemical sectors, which use natural gas as feedstock, is comparatively small. The industry-wise off-take of natural gas in India shows a sharp increase in consumption after 2008-09. Much of this increase in consumption came from the power sector. Consumption by the fertiliser sector has also shown an increase while that by the petrochemical sector remained more or less at its earlier level.

To supplement its domestic gas resources, India started importing natural gas as late as 2004-05 with the construction of LNG terminal at Dahej. The quantum of natural gas imports has been increasing rapidly over time. A major part of Indian LNG imports are sourced from Qatar (75 per cent). Other important sources are Australia and Russia. The near-total dependence on Qatar is due to the fact that Petronet LNG Limited (PLL) signed a contract with RasGas, Qatar in July 1999 for import of 7.5 million metric tonnes per annum (MMTPA) LNG for a period of 25 years.

2.5 Feedstock Demand Projections for the Petrochemical Sector

There are two ways of estimating the future demand for feedstock from the Indian petrochemical industry. In the first approach, conversion ratios from building blocks to feedstock can be used to make estimates using plant-wise existing capacities. In the second approach, forecasts can be made using the conversion ratios from final products to building blocks and then to feedstock based on plant-wise final products' capacities. However, due to paucity of data on the existing capacities of final products for individual petrochemical plants, the first approach has been used for making projections.

In this paper, the building blocks' capacities, (specifically the ethylene capacity of individual petrochemical plants) and conversion ratios based on the choice of feedstock is used for making feedstock demand projections. While making estimates, it is assumed that capacity utilization is 100 percent for all the plants. The conversion rate from ethylene to naphtha has been assumed to be 3.31 while from ethylene to ethane/propane at 1.27.

Table 2: Naphtha and Natural Gas Requirement from Building Blocks Data (in Kt)

Petrochemical Plants	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Naphtha Based							
RIL (Baroda)	496.8	596.16	596.16	596.16	596.16	596.16	596.16
HPL, Haldia	2219.04	2219.04	2219.04	2219.04	2219.04	2219.04	2219.04
IOC Cracker, Panipat	2838.384	2838.384	2838.384	2838.384	2838.384	2838.384	2838.384
Natural Gas Based							
RIL (Nagothane)	508	508	508	508	508	508	508
RIL (Gandhar)	508	508	508	508	508	508	508
GAIL, Auraiya	635	635	635	635	635	635	635
RIL,Jamnagar	-	-	-	-	-	1778	1778
Dual Feed Plants							
RIL (Hazira) (Naphtha)	2278.656	2278.656	2278.656	2278.656	2278.656	2278.656	2278.656
RIL (Hazira) (Natural Gas)	218.44	218.44	218.44	218.44	218.44	218.44	218.44
ONGC Petro additions Ltd. (OPaL) (Naphtha)	-	-	-	-	1821.6	1821.6	1821.6
ONGC Petro additions Ltd. (OPaL) (Natural Gas)	-	-	-	-	698.5	698.5	698.5
BCPL (Naphtha)	-	-	-	364.32	364.32	364.32	364.32
BCPL (Natural Gas)	-	-	-	139.7	139.7	139.7	139.7
Total Naphtha demand (Kt)	**7832.88**	**7932.24**	**7932.24**	**8296.56**	**10118.16**	**10118.16**	**10118.16**

Source: Industry Estimates

As shown in the table 2, naphtha demand is expected to be 7,832 Kt in 2010-11 and increase to 7,932 Kt in 2011-12 and 2012-13 due to expansion plans of RIL plant at Baroda. With the expectation of setting up of BCPL plant in 2013-14 and ONGC Petro additions Ltd. (OPaL) in 2014-15, the naphtha demand is expected to reach 8296 Kt in 2013-14 and 10,118 Kt in 2014-15 and stay the same till 2016-17.

Section 3: Economics of Feedstock for Petrochemicals

In keeping with its feedstock intensity, the growth in petrochemical industry has led to a concomitant increase in feedstock demand as well. The following section analyses the feedstock demand of specific petrochemical plants and the petrochemical industry as a whole. The section also contains estimates of the feedstock prices paid by the petrochemical industry. Using these estimates as well as data from other sources, the economics of ethylene cracking and polymer production has been explored. As expected, it can be seen that global petroleum product prices as well as the relative cost dynamics of two feedstock sources, i.e.

naphtha and natural gas, have an important role to play in determining this industry's profit margins.

3.1 Feedstock Costs to the Petrochemical Industry

The cost of feedstock is the single largest cost in the production of petrochemicals. Estimates show that cost of feedstock accounts for 40-60 per cent of total costs. However, while availability is not much of an issue for naphtha, demand for propane and butane is curtailed due to both pricing as well as domestic unavailability. LNG imports are, therefore, an increasingly sought option.

3.1.1 Naphtha Price for Petrochemicals

After the dismantling of administered price mechanism (APM) on April 1, 2002, the price of naphtha is wholly market driven. Domestic naphtha prices are derived using the concept of refinery transfer price (RTP). RTP is determined by the landed cost of the imported product at the nearest refinery port (plus transportation cost, if any). This adjusted price is referred to as 'ex-refinery price' and is inclusive of refining margin. While details of RTP for naphtha are not openly available, a close approximation to the cost can be done using secondary data sources such as Indian Petroleum and Natural Gas Statistics. An estimate of RTP for naphtha is presented in Table 3. The current refinery transfer price for naphtha is around Rs. 44540 per tonne.

Table 3: Estimate for RTP of Naphtha in 2011

	Price Details	**Unit**	
1	FOB Price at Arab Gulf of Naphtha	$/bbl	102.3
2	Add: Ocean Freight from Arab Gulf to Indian Ports	$/bbl	2.0
3	C&F Price ((1)+(2))	$/bbl	104.3
4	OR	Rs./MT	42768.6
5	Import Charges (Insurance/Ocean Loss/LC Charge/Port Dues)*	Rs./MT	263.2
6	Customs Duty (@5%)	Rs./MT	2151.6
7	Import Parity Price (((3)+(5)+(6))	Rs./MT	45183.4
8	Export Parity Price	Rs./MT	41968.7
9	Trade parity Price (80% of (7) +20% of (8))	Rs./MT	44540.5
10	Refinery Transfer Price (RTP) for Naphtha	Rs./MT	44540.5

Data Source: MoPNG 2012, PPAC website

Note: *calculated using import charges to C&F price ratio for diesel

Assumption: 1. Exchange Rate $1= 45.58 (Source: RBI) 2. 1 tonne = 9 barrels of Naphtha (*Source: Platts Naphtha Specification- conversion factor*)

3.1.2 Natural Gas Price for Petrochemicals

The gas utilisation policy rules imply that gas will be allocated according to sectoral priorities set up by the government. The order of priority has been laid down to give first priority to the existing plants to ensure utilisation of capacities already created and to obtain faster monetisation of natural gas. The second preference is given to substitute liquid fuels in energy-intensive industries and the third preference to plants in easing bottlenecks and expansion. Petrochemical manufacturers that are interested in switching to gas due to cost economies, do not have access to low-priced gas and have to pay higher prices to private companies and LNG importers.

Compared to naphtha, natural gas prices are more regulated. The prices of APM gas and gas produced from certain joint ventures (discovered fields exploration policy) are set by the government or according to a fixed formula (for private companies in the joint venture). In a recent decision, the government raised the APM price to match the price of NELP D-6 gas (US$4.2 per mmbtu). Under the new policy regime covering NELP gas, gas producers can 'discover' the price of gas themselves, but are required to get its 'value' approved by the government. The NELP document, however, did not contain specific guidelines on the determination of prices or the price discovery process. The pricing of D-6 gas was the first example of gas pricing under NELP.[3]

From the petrochemical sector point of view, the relevant domestic gas prices are outlined in Table 4. Panna–Mukta–Tapti gas production is under a joint venture between British Gas, Reliance and ONGC. KG-D6 is owned by RIL a consortium of RIL, BP and Niko.

Table 4: Gas Prices for Indian Petrochemical Industry in 2010

	Petrochemical Plant	**Source**	**Regime**	**Price (US$/mmbtu)**
1	Reliance, Gandhar	APM Gas	APM	5.25 to 5.50
2	Reliance, Nagothane			
3	GAIL, Auriya			
4	-	Panna–Mukta–Tapti fields *	Discovered Fields	5.65 to 5.79
6	-	D-6 *	NELP	4.20

Source: industry sources

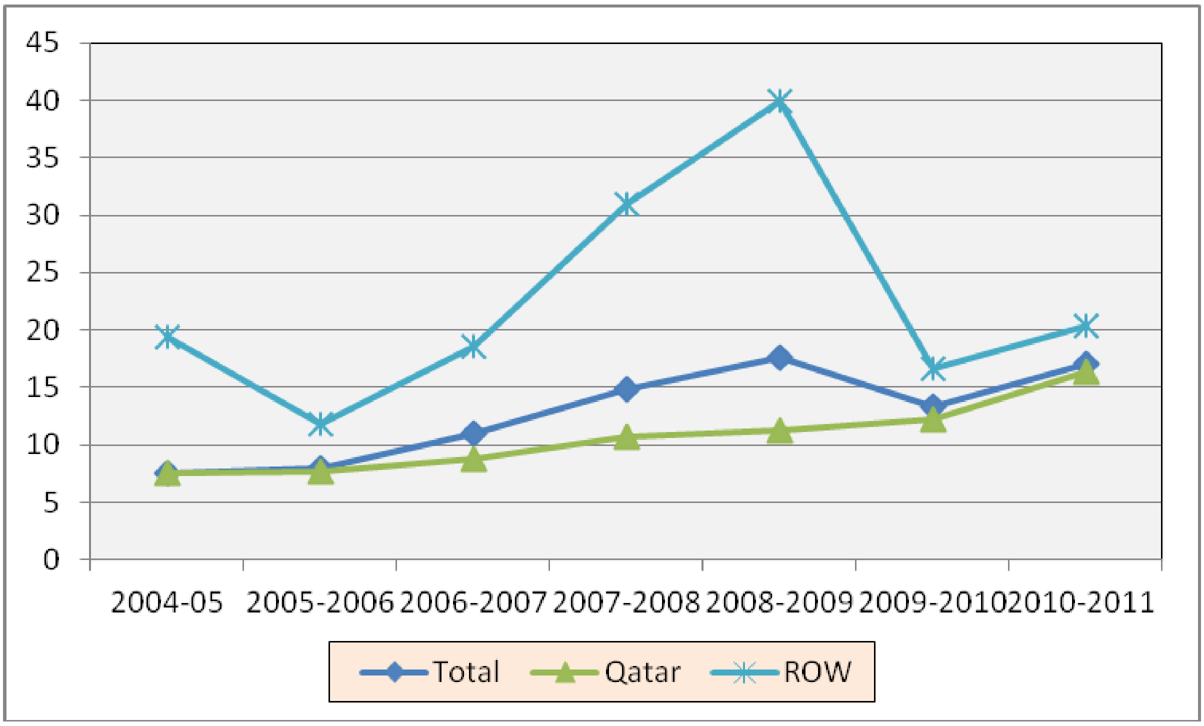
[3] The Rangarajan Committee (2012) appointed to examine the production sharing contract mechanism in the petroleum industry has recommended a netback approach to gas pricing in 2012. It has suggested that since there are several sources of gas imports, the average of the netback (calculated as the imported LNG price minus the liquefaction costs at the port minus the transportation and treatment costs of natural gas from wellhead to liquefaction plant) of import prices at wellheads can be taken as the average global price for Indian imports. Also NELP X has been announced and the auctions for 46 oil and gas blocks are expected to kick off in February 2014.

Note: ∗While currently no recorded information is available as regards the gas usage for petrochemicals, both these fields are operated by Reliance /JVs of Reliance.

Under the regime covering LNG prices are determined on the basis of long-term and short-term contracts, and spot purchases. Using data on imports and exports of LNG compiled by the Ministry of Commerce, the cost of LNG ($/mmbtu) can be calculated easily. The prices that are derived are CIF (Cost Insurance and Freight) and not FOB values generally quoted. Figure 3 presents the data for LNG import prices for All LNG, Qatar and Rest of the World.

From a different perspective, the costs can also be seen as the difference between long-term and spot prices. Here, Qatar prices could be taken as the long-term contract prices, while prices for the rest of the world or ROW (other countries from where India is importing) can be taken as the spot prices prevailing during the time.

Figure 3: LNG Import Price for India ($/mmbtu)



Data Source: MoC, 2012

Calculation Assumptions: 1. ROW includes Oman, Nigeria, Algeria, Australia, Trinidad and Tobago, Egypt, Malaysia, etc. 2. 1 tonne LNG = 52000 BTU. 3. Exchange Rate:

	2004-05	**2005-2006**	**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**
Rs./US$	44.9315	44.2735	45.2849	40.241	45.917	47.4166	45.5768

Source: RBI

It can be clearly seen that spot prices for LNG have been quite volatile over the years. Compared to this, the prices charged by LNG sourced from Qatar is gently upward sloping. On the whole, it can be seen that LNG prices peaked in 2008-09. It fell sharply in 2009-10 but then rose again to near 2008 levels in 2010-11.

3.2 Economics of Ethylene Cracking

The following section provides an illustration of the per unit cost of production for ethylene produced from both naphtha and ethane. Olefins are generally produced the world over either by gas cracking (gas-based petrochemicals) such as ethane, propane and butane, or from naphtha (naphtha-based petrochemicals). Paraffins, i.e., straight chain hydrocarbons, yield olefins when heated at a high temperature. Thus, the lighter fraction is suitable for petrochemical plants in the production of olefins and hydrogen because of the presence of paraffinic hydrocarbons. Hence, in the refinery, C5−90°C cut is separated in the naphtha re-distillation unit and is sold to the petrochemical industry. The heavier fraction, i.e., naphtha in the boiling range of 90°C−200°C is catalytically reformed in a refinery either to produce high-octane gasoline and/or aromatics (benzene (B), toluene (T), and xylenes (X)). Gas based petrochemicals are manufactured using different streams of natural gas liquids as their feedstock. Natural gas liquids (NGL) are heavier than the methane that is recovered from natural gas.

It needs to be highlighted that the yield of olefins decreases with the increasing molecular weight (hence with boiling point) of hydrocarbons. Thus, if ethane is thermally cracked, it will yield 80 percent ethylene. When propane, butane, naphtha, and gas oil are used as feedstock for cracking, the yields will be lower at 45 per cent, 37 per cent, 30 per cent, and 25 per cent respectively (Ray Chaudhuri, 2011).

In India, olefins are produced primarily by thermal cracking of hydrocarbons. Naphtha and/or natural gas, diluted with steam, is fed in parallel to a number of gas or oil fired tubular pyrolysis furnaces. In the cracking process, a heavier hydrocarbon molecule is fractured or broken into two or more lighter fragments. These light hydrocarbons are thereupon further cracked to lighter olefins and propagated till the reaction temperature is brought down. After cracking, the remaining processes involve a series of fractionators in which the various product fractions are successively separated. Table 5 shows the cost of production for ethylene using naphtha and natural gas. It should be noted that the following calculation assumes that naphtha was available at the rate of US$ 940 per tonne and ethane was available at US $8.3 per mmbtu. The capital expenditures for the two crackers are US$ 715 million (naphtha) and US$ 718 million (ethane) respectively.

Table 5: Ethylene Production Costs using Naphtha and Ethane Feedstock

			Naphtha			Natural Gas			
	Units	**Production**	**Units/Kt Prod**	**Price (US$/Unit)**	**Cost (US$/MT)**	**Production**	**Units/Kt Prod**	**Price (US$/Unit)**	**Cost (US$/MT)**
Ethylene Production	Kt/y	356				500			
Fixed Costs									
Annual Capital Recovery (10% disc. Rate)					155.1				110.74
Operating Expenditure									
Feedstock	Kt/y	1141	3.21	922.0	2959.62	687	1.37	373.30	512.91
Fuel	Kt/y	167	0.47	829.8	390.01	340	0.68	880.0	598.40
Inventory Maintenance (interest @14%)					21.78				13.67
Other Operating Expenditures					48.0				143.6
Total		1308			**3419.41**	1027			**1268.59**
By-Products									
Ethylene	Kt/y	**356**				**500**			
Propylene	Kt/y	181.3	0.51	1407.00	-717.57	17	0.03	1407.00	-47.84
BTD/C4 Olefins	Kt/y	103.1	0.29	1298.10	-376.45	17	0.03	1298.10	-44.14
Gasoline	Kt/y	216.9	0.61	880.00	-536.80	11	0.02	880.0	-19.36
Hydrogen	Kt/y	21.3	0.06	2047.50	-122.85	66	0.13	2047.50	-270.27
Methane	Kt/y	170.9	0.48	820.00	-394.15	40	0.08	820.00	-65.60
Propane	Kt/y	14.6	0.04	857.00	-35.10				
Butane	Kt/y	31.4	0.09	900.00	-79.54				
Fuel Oil	Kt/y	46.2	0.13	649.00	-84.37				
Total		1141			-2346.82				
Total Cost of Production	(US$/MT)				**1227.69**				**932.12**
Ethylene (Transfer Price)	(US$/MT)				**1184.5**				**1184.5**
Price-Production Cost	(US$/MT)				**-43.19**				**252.38**

Source: Authors' Calculation

Data Source: CMAI (2012), Seddon (2010), Platts (2012)

Assumptions: 1. Discount rate of 10% used to calculate the capital recovery factor and thus the annual capital recovery 2. Inventories equivalent to 1 month consumption/production of inputs (naphtha and fuel) and outputs (ethylene, propylene) maintained. Return payable on working capital loans assumed @ 14%. 3. 3.21 tonnes of naphtha used per tonne of ethylene production. 4. Residual Naphtha is used as fuel in the plant. 5. In terms of capacity, this is a medium sized plant. Typical world-scale operations produce 1 million tonnes of ethylene.

From the table, it can be seen that at 2011 prices ethylene production using ethane was much more profitable as compared to naphtha-based production. In fact, in this case naphtha based standalone crackers are running into losses. Production at such high feedstock prices thus renders ethylene cracking disadvantageous from an economic angle. Details of the costing methodology used for the present analysis are contained in Annexure 1. Moreover, the above illustration assumes relatively high ethane prices. The business profitability would considerably increase if ethane prices, as prevailing in the Middle East,[4] are taken into account.

The costs shown in the table refer to standalone ethylene crackers. The product profile would change significantly when an integrated system, rather than a standalone system, is considered. In an integrated system, the products as well as by-products produced by a cracker are processed and further value is added. The economics of an integrated system is illustrated in the following section where the cost of polymer production is discussed.

3.3 Economics of Polymer Production

In recent times, a vast majority of crackers operate on an integrated basis producing downstream saleable goods, or intermediates, rather than olefins. This includes not just polymers and resins (polyethylene and polypropylene), but also aromatics – benzene, toluene and xylene (BTX), especially because of the large amount of pyrolysis gasoline produced. In still larger integrated complexes, the latter are further processed to styrene, nylon and polyester.

As has been noted in Table 5, standalone crackers using naphtha are rendered economically unviable at high naphtha prices. The following table looks at the production costs in an integrated complex. Table 6 shows an estimate of polymer and benzene production costs using the earlier derived ethylene production costs from Table 5.

It should, however, be noted that the integrated complexes require additional capital expenditure to be incurred. For the current calculation, capital expenditures of the following magnitude were incurred- polyethylene (US$ 230.2 million), polypropylene (US$ 107.9 million) and Benzene (US$ 23.2 million) manufacturing complexes. Table 6 below shows the comparative picture of polymer and aromatic production using naphtha.

[4] The petrochemical industry in the Middle East was built upon cheap ethane from “stranded” gas, intrinsically low cost due to surplus availability and the high costs of movement (as LNG) to energy markets (Luciani, 2007).

Table 6: Polymer and Aromatic Production Costs using Naphtha as Feedstock

		PE				PP				Benzene			
	Units	Production	Units/Kt Prod	Price (US$/Unit)	Cost (US$/MT)	Production	Units/Kt Prod	Price (US$/Unit)	Cost (US$/MT)	Production	Units/Kt Prod	Price (US$/Unit)	Cost (US$/MT)
Total Production	Kt/y	**386**				**181**				**124**			
Fixed Costs													
Annual Capital Recovery*					45.9				45.9				14.42
Operating Costs													
Feedstock													
-Ethylene	Kt/y	355.5	0.9	**1227.7**	1129.5								
-Octene-1	Kt/y	34.8	0.1	1485.0	133.65								
-Propylene	Kt/y					181.3	1.0	**1407**	1407				
-C6+Reformate	Kt/y									216.9	1.7	**880.0**	1535.31
Fuel					17				14				2.0
Inventory Maintenance**					6				3.2				1.60
Other Operating Expenditures					53				42				85.0
Total					1339.1				1463				1623.91
By-Products													
Polyethylene	Kt/y	**386**											

		PE				PP				Benzene			
	Units	**Production**	**Units/Kt Prod**	**Price (US$/ Unit)**	**Cost (US$/MT)**	**Production**	**Units/Kt Prod**	**Price (US$/Unit)**	**Cost (US$/MT)**	**Production**	**Units/ Kt Prod**	**Price (US$/Unit)**	**Cost (US$/MT)**
Polypropylene						**181**							
Benzene										**124**			
C6+Raffinate										93	0.7	936	-697
Total Cost of Production	(US$/MT)				**1385.1**				**1512.1**				**941.3**
Relevant Market Price	(US$/MT)				**1331**				**1514**				**1103**
Price-Production Cost	(US$/MT)				**-54.06**				**1.89**				**161.7**

Source: Authors' Calculation

Data Source: Industry Consultations

*10% discount rate ** Interest @14%

Assumptions: 1. Discount rate of 10% used to calculate the capital recovery factor and thus the annual capital recovery. 2. Inventories equivalent to 1 month production of outputs (PE, PP and Benzene) maintained. Return payable on working capital loans assumed @ 14%. 3. No distribution costs have been included in the calculation.

The following table (Table 7) shows a comparative picture of the revenue streams from generic standalone and integrated petrochemical production units. Revenues for both have been calculated as the profit/loss per unit production multiplied by the total production per year. Details of the cost calculation have been provided in Annexure 2.

Table 7: Revenue Streams for Standalone and Integrated Naphtha Based Petrochemical Production Units

	Revenue (in Million $ per Year)	
	Standalone	Integrated
Ethylene	-15.4	
PE		-20.9
PP		0.3
Benzene		20.1
Others		
	-15.4	-0.5

Source: Authors' Calculation

As can be seen from Table 7, integrated complexes make much more economic sense in the times of high naphtha prices. While the illustrative standalone cracker makes large losses, these losses are more than recouped by large integrated complexes. This is an important result and shows the economic rationale of vertical integration witnessed in the petrochemical sector in recent times.

Section 4: Fiscal Anomalies in pricing of feedstock for different segments of the industry

Feedstock security is a critical issue for India to compete with low cost global producers since the cost of raw materials account for 40-60 per cent of the total production cost, depending on the procurement source and price. India has one of the highest indirect tax incidences on raw materials for petrochemicals compared to many developing and developed countries. The Indian import duty structure provides for no incremental tariff protection between key petrochemical inputs and their end-products (building blocks) or for products such as polymers of downstream industries. Basically, there is no differentiation in the rate of tariff in India – both inputs as well as downstream products attract the same duty. As shown in Table 8, the import duty for polymers, in India is 5 per cent, while for Malaysia it is 20-30 per cent, Thailand 5 per cent, Philippines 15 per cent, Indonesia 20 per cent and China 6-8 per cent. This adversely affects the competitiveness of domestic industry.

India has the highest import duty on naphtha at 5 per cent, same as on polymers, resulting in a zero duty differential between raw materials (naphtha) and finished products (polymers). Similarly, import tariff on propane and butane, is 5 per cent, same as imposed on ethylene and propylene which are derived by cracking propane and butane. Import duty at 10 percent is applicable on reformates, a primary feedstock for the polyester value chain, whereas downstream products like Paraxylene (PX) has zero duty, making investment in the value chain unattractive.

Like most other countries in the world, which exempt duties on raw materials imported to manufacture petrochemicals, India also needs to build in appropriate tariff incentives between input and output to improve the viability of petrochemical units.

Table 8: Import Duty Structure for South Asian Countries

(in percentages)

Product	India	China	Malaysia	Thailand	Philippines	Indonesia	Saudi Arabia	Japan	US	EU
Naphtha	5	1	0	0	3	0	5	0	0	0
LDPE	5	6.5	30	5	15	15	12	6.5	6.5	6.5
LLDPE	5	6.5	30	5	15	15	12	6.5	6.5	6.5
HDPE	5	6.5	30	5	15	15	12	6.5	6.5	6.5
PP	5	6.5	30	5	15	15	12	6.5	6.5	6.5
PVC	5	6.5	20	5	15	10	5	6.5	6.5	6.5
PS	5	6.5	20	5	15	10	12	6.5	6.5	6.5
Duty Differential	0	5.5	30/20	5	12	15/10	7	6.5	6.5	6.5

Source: Industry Estimates

There also is a need to bring in uniformity in sales tax rates across India on various petrochemical products to support investment. For instance, crude oil, which is included in the list of declared goods under the Central Sales Tax (CST) Act, attract a sales tax of 4 per cent while the sales tax on natural gas and naphtha are higher and varies from state to state. Thus both natural gas and naphtha should be included in the list of 'declared goods' under the CST Act and taxed at a uniform rate or uniform VAT in case CST is abolished. In the case of polymers and all articles of plastics, there is a need to establish a single national level VAT/GST at a uniform rate across states.

According to the Indian Chemical Council (ICC), internal transaction costs are one of the highest in India. In comparison to other Asian countries, VAT rates in India are significant, which together with state levies and entry taxes, further aggravate local transaction cost. There exist large variations in the state level taxation paid by petrochemical complexes. For instance, VAT on naphtha is applied at the rate of 18.5 per cent and 5 per cent in Gujarat and West Bengal respectively. For natural gas, maximum VAT in the range of 21 per cent is applied in Uttar Pradesh.

Table 9: State-wise Sales Tax Rates Applicable on Naphtha and Natural Gas

State	Naphtha	Natural Gas
Gujarat	16 + 2.5%	12.5+2.5%
Haryana	12 + 5%	-
Uttar Pradesh	21	21-24
West Bengal	5	-

Source: MOPNG (as on 1.4.2013)

Besides, under the current state tax laws in India, sale by domestic input manufacturers to producers of exported products are subject to state sales tax laws. This hinders the growth of exports and encourages exporters to source the inputs through imports rather than sourcing them domestically. As a result, domestic manufacturers of such inputs are forced to export their output. However, deemed exporters should not be asked to pay tax on inputs since exports are not taxed. It, therefore, is necessary that existing sales tax regulations be changed in states to make deemed exports tax-free. This would ensure that domestically produced naphtha is used in the petrochemical sector and imports are reduced. For Indian importers, on a comparative level, the cost of feedstock would always be higher since they will have to pay MOPAG import duty of 5 per cent plus certain state level VAT. Thus, for commercial and economic reasons, uniformity in state taxation would imply only one factor, mainly differences in transportation costs would contribute to variability in input prices.

There is need to correct the above discussed dualities in fiscal structure existing in India so that it can emerge as a globally attractive location for investment in petrochemicals.

Section 5: Conclusion and policy recommendations

The petrochemicals sector is a major segment of manufacturing industry and plays a pivotal role in various downstream industries. However, despite the importance of the petrochemicals industry in the manufacturing sector, the sector still lacks a climate that is conducive to new investment that is needed to meet future projected demand. This is partly because of oversupply in the global market, leading to a steep decline in the prices of petrochemicals. In addition, factors like establishment of new capacities in Middle East backed by subsidised feedstock, low import duties on finished products coupled with high internal transaction costs, infrastructural constraints has resulted in reduced interest in this sector. The above mentioned factors emphasize the need to identify and take appropriate steps to maintain competitiveness and cost effectiveness of the Indian petrochemical industry.

According to estimates made by the Indian Chemical Council, India's revenues from the chemicals and petrochemicals sector is expected to reach $200 billion by 2020. Considering the current trend in capacity addition, the domestic petrochemical sector is expected to double its production capacity in the next few years. It is in this direction that petroleum, chemicals and petrochemicals investment regions (PCPIRs) with their integrated and resource efficient approach, could turn out to be vital for the Indian economy. The government has identified several locations like Haldia-Nayachar (West Bengal), Dahej (Gujarat), Visakhapatnam

(Andhra Pradesh), Mangalore (Karnataka), Cuddalore-Nagapattinam (Tamil Nadu) and Paradip (Orissa) to set up PCPIR units. These PCPIRs will be set up in a 2,000 sq km area with an estimated investment of $280 billion. Out of these, Dahej in Gujarat, Haldia in West Bengal, Paradeep in Orissa and Vishakhapatnam in Andhra Pradesh have already been notified by the government. The proposal for a PCPIR at Cuddalore has been approved while the project at Mangalore in Karnataka is in the planning stage. Some companies like Total, Saudi Aramco, Shell, ExxonMobil Chemicals, Borealis and Itochu Singapore have shown keen interest in the development of PCPIRs. Thus, the PCPIR policy, which involves huge investment to increase petrochemical production capacities, is expected to result in improved trading of feedstock, intermediates, and final products both inside and outside the country. It also is projected to provide considerable opportunities to players in the field of equipment designing, manufacturing, engineering, procurement and construction (EPC), industrial automation, project and programme management.

5.1 Policy recommendations

Although the government has made various initiatives such as PCPIR, some areas of concern still remain.

- ❖ Naphtha and ethane, the feeds for ethylene crackers, are the key component of raw material costs (around 50 per cent) the world over. In such a scenario, the issue of feedstock selection has emerged as an even important source of comparative competitiveness for petrochemicals companies across the globe. Given India’s huge dependence on oil imports and the volatility of crude oil prices, there is need for integrated plants across the value chain.
- ❖ However, due to the huge amount of capital involved in setting up the petrochemical plants and the high costs in India due to lack of duty waivers, lower tax exemptions, high interest costs, etc., domestic companies may look for organic and inorganic opportunities globally to set up manufacturing facilities in energy rich countries. Dow, Shell, etc. are working to increase their presence in countries like Saudi Arabia, Kuwait, Qatar, etc.
- ❖ There is an urgent need to realign fiscal structure on naphtha and natural gas so that the progressive duty structure encourages value addition within the country. The state duties on naphtha and ethane in India should be made more uniform and similar to other countries wherein the duty differential is quite high, a 5 percent duty differential should be created between inputs and outputs.

References

APIC (2012), Country Paper from India, Review of 2011 & Outlook for 2012, Indian Petrochemical Industry, Chemicals & Petrochemicals Manufacturers' Association.

Central Pollution Control Board (2008), Development of National Emission Standards for Petrochemical plants, Ministry of Environment & Forests, Govt. of India.

Corbeau A. (2010), Natural Gas in India, Working Paper, International Energy Agency, Paris.

CPMA (2011), Report of the sub-group on Petrochemicals for the 12th Five Year Plan, Chemicals and Petrochemicals Manufacturers Association, New Delhi.

CPMA (various years), Presentations.

Department of Chemicals & Petrochemicals (2012), Report of the Sub-group on Petrochemicals for the 12th Five Year Plan, Sub-group on Chemicals & Petrochemicals for the 12th Five Year Plan, Department of Chemicals & Petrochemicals, Government of India.

Directorate General of Hydrocarbons (2010-11), Hydrocarbon Exploration and Production Activities India, Directorate General of Hydrocarbons, Ministry of Petroleum and Natural Gas, Government of India.

FICCI (2010), Handbook on Indian Chemical Industry, Sustaining the India Advantage.

GoI (2007), Report of the working group on Chemicals and petrochemicals 11th five year plan, (2007) Department of Chemicals & Petrochemicals, Government of India.

Hydrocarbon Processing (2012), Optimize olefin operations, Hydrocarbon Processing Houston.

Hydrocarbon Processing 2012, Alternate feedstock options for petrochemicals: A roadmap, Houston.

IEA (2011), Energy Statistics of Non-OECD Countries 2011 Edition, International Energy Agency, Paris.

ICC (2012), Pre-budget memorandum for the union budget, Indian Chemical Council.

Jain, A. (2011), Natural Gas in India: Liberalisation and Policy, University of Oxford for the Oxford Institute for Energy Studies.

KBC (2011), Global Energy Perspectives Petrochemicals: How far will the global restructuring go?

Lok Sabha Secretariat (2007), Demand and Availability of Petrochemicals, Standing Committee on Chemicals and Fertilisers, Ministry of Chemicals and Fertilisers, GoI.

Luciani G. (2007), The GCC Refining and Petrochemical Sectors in 2006, Paper presented at Eight Mediterranean Social and Political Research Meeting, Florence, 21-25 March 2007.

Matar S. (2000), Chemistry of Petrochemical Processes, Gulf Publishing Company, Texas.

MOCF (2011), Annual Report 2010 - 2011, Ministry of Chemicals and Fertilisers, Government of India.

MoPNG (2010-11), Indian Petroleum & Natural Gas Statistics, Economics Division, Ministry of Petroleum and Natural Gas, Government of India.

MoPNG (2011), Indian Petroleum and Natural Gas Statistics 2009-10, Ministry of Petroleum and Natural Gas Statistics, GoI.

MoPNG (2012), Indian Petroleum and Natural Gas Statistics, 2010-11, Ministry of Petroleum and Natural Gas.

MoPNG (2013), Indian Petroleum and Natural Gas Statistics, 2011-12, Ministry of Petroleum and Natural Gas.

Morgan Stanley (2010), Petrochemicals: Preparing for a Supercycle, Morgan Stanley Blue Paper.

Purvin and Gertz Inc. (2011), East-Of-Suez Petrochemical Feedstock Market Outlook- 5 year Outlook.

Ray Chaudhuri U. (2011), Fundamentals of Petroleum and Petrochemical Engineering, CRC Press, Taylor and Francis Group, Boca Raton.

Seddon D. (2010), Petrochemical Economics: Technology Selection in a Carbon Constrained World, Imperial College Press, London.

Wagialla K.M. (2007), Petrochemical Aromatics from Liquid Hydrocarbons: Techno-economic Assessment, Paper presented at 7th Saudi Engineering Conference, King Saud University, Riyadh.

3rd India-Africa Hydrocarbons conference (2011), FICCI and Ministry of Petroleum and Natural Gas (MOPNG), Government of India.

Websites

International Energy Consulting Corporation (2011). India Energy Handbook. Available: http://www.psimedia.info/handbook/India_Energy_Handbook.pdf

Mercados – Energy Markets India (2010). Study on Common Pool Price Mechanism for Natural Gas in the country. Available: http://petroleum.nic.in/gaspricepooling.pdf

Ministry of Petroleum and Natural Gas (2003). Natural Gas. Available: http://petroleum.nic.in/ng.htm

Harsh Kanani (2011). Pricing of Natural Gas in India. Available:

Oil & Gas Journal (2011). India's gas use could displace 100,000 b/d of Naphtha. Available: http://www.ogj.com/articles/2011/08/india-gas-use-could-displace-some-naphtha.html

CARE Ratings (2011). Indian Natural Gas Industry. Available: http://www.giiresearch.com/report/care215072-indian-natural-gas-industry-september-2011.html

Department of Chemical and Petrochemicals (2007). Report on the working group on chemicals and petrochemicals – 11th five year plan. Available: http://planningcommission.gov.in/aboutus/committee/wrkgrp11/wg11_petrochem.pdf

Finance Ministry (2011). Interim Report of the Task Force on Direct Transfer of Subsidies on Kerosene, LPG and Fertiliser. Available: https://docs.google.com/viewer?a=v&q=cache:RPsmpQmqG8YJ:finmin.nic.in/reports/Interim_report_Task_Force_DTS.pdf+&hl=en&gl=in&pid=bl&srcid=ADGEEShc8fwa8sm4G8ajHcn8OmZd8C3OZNhJgDq0ZOUkrYoYYfAW3Yp-mGjF1WkBssE-eMOb2kyeyU2s9iw0DYgLBOjHbGNQogWVV1ABP8KdP7azwEhI0667OviOnn8Lc4_Lz1juwhp&sig=AHIEtbTbw33MSskxoCpenxZ2uoR3jIbVoQ&pli=1

Purvin & Gertz (2011). East-of-Suez Petrochemical Feedstock Market Outlook. Available: http://www.purvingertz.com/products.cfm?productid=99

MoC (2011). Export Import Data Bank, Ministry of Commerce website. Available: http://commerce.nic.in/eidb/default.asp

Businesswire (2011). Research and Markets: Top Ten Trends in the Petrochemical Industry in 2011. Available: http://www.businesswire.com/news/home/20110110006191/en/Research-Markets-Top-Ten-Trends-Petrochemical-Industry

Department of Chemicals and Petrochemicals (2012). Opportunities in Petrochemicals. Available: http://chemicals.nic.in/petro1.htm

CRISIL (2012). Crisil Budget Analysis. Available:http://www.crisil.com/pdf/research/CRISIL-Research-budget-analysis-2012-13.pdf

ASSOCHAM (2012). Press Release : Petrochemical Capacity set to grow by 12-15 per cent. Available : http://www.assocham.org/prels/shownews.php?id=3324

Deccan Herald (2011). India's anti-dumping move violates WTO laws. Available : http://www.deccanherald.com/content/97088/indias-anti-dumping-move-violates.html

Infraline Energy (2012). Bengal seeks duty sops on HPL's naphtha imports. Available : http://www.infraline.com/Details/Bengal-Seeks-Duty-Sops-On-Hpls-Naphtha-Importscompany-In-Talks-With-Govt-To-Resume-Sales-Tax-Remission-Scheme-103266.htm

Annexure 1: Estimation Details for Ethylene Production Costs

Two simple generic plants with naphtha and natural gas as feedstock have been modelled in the current paper to compare and contrast ethylene production costs.

1.1 Fixed Cost Calculation

The investment cost for setting up a naphtha based plant (355 ktpa) and a gas based plant (500 ktpa) have been assumed to be USD 715 million and USD 718 million. The figures for annual capital recovery (includes depreciation, maintenance, overheads, etc.) have been calculated using a discount rate of 10%. It has been assumed that the plants maintain inventories of inputs (naphtha and fuel) and outputs (ethylene, propylene) equivalent to one month consumption/production. This leads to added interest costs for working capital (interest levied at the rate of 14%) that the plants have to pay.

1.2 Operating Expenditure

Feedstock costs are the largest component determining ethylene production costs. To calculate feedstock costs, we assume that 3.21 tonnes of naphtha is used per tonne of ethylene production. In the case of natural gas, it is assumed that 1.37 tonnes are required for one tonne of ethylene production. The difference in per unit consumption requirement coupled with the price difference between two fuels naphtha and natural, leads to a wide variance in the total feedstock costs of the two types of ethylene crackers.

It has been assumed that residual naphtha being used as fuel for naphtha based ethylene cracker. The price of fuel is thus quite close to the price of feedstock. For gas based plants, the fuel used is pygas and it is costlier than the feedstock per unit cost.

1.3 By-Product Cost Estimation

The product slate that can be produced by naphtha based plants is much larger than the gas based plants due to natural gas's high ethane but low propane and butane content. In addition to ethylene, natural gas by-product slate includes small quantities of propylene, BTD/C4 Olefins, gasoline, hydrogen and methane. The product slate for naphtha based production is much wider with by-products including large quantities of propylene, gasoline, methane, BTD/C4 Olefins and small quantities of fuel oil, butane, propane, and hydrogen. The latest prices for each have been taken from CMAI data sources. Details for calorific values and material balances (input requirements) have been taken from Seddon (2010).

Annexure 2: Estimation Details for PE, PP and Benzene Production Costs

A generic integrated complex has been modelled for showing the economic rationale of vertical integration. The results show that in the times of high naphtha prices, whole or part of the cracking losses can be recouped by large integrated complexes.

2.1 Fixed Cost Calculation

Integrated complexes that produce both building blocks (ethylene, propylene) as well as polymers (PE, PP) require additional capital expenditure to be incurred. For the current calculation, capital expenditures of the following magnitude were assumed to have been incurred- polyethylene (US$ 230.2 million), polypropylene (US$ 107.9 million) and Benzene (US$ 23.2 million) manufacturing complexes. Figures for annual capital recovery (including depreciation, maintenance, overheads, etc.) have been calculated using a discount rate of 10%.

Inventories equivalent to 1 month production of outputs (PE, PP and Benzene) have been assumed to be maintained. The related return payable on working capital loans has been assumed to be 14%.

2.2 Operating Expenditure

It has been assumed that the integrated plant is operating on a closed-loop system i.e. it consumed all of its by-products in its initial stages (ethylene cracker) and thereupon uses them to produce polymers. For the estimation of fuel costs, it has been assumed that residual naphtha is used as fuel for the plant.

2.3 By-Product Cost Estimation

The integrated complex is assumed to produce PE, PP, Benzene and C6+Raffinate as by product.

Details for calorific values and material balances (input requirements) have been taken from CPMA data sources. The latest prices for by-products have been taken both from CPMA and CMAI data sources.

LATEST ICRIER'S WORKING PAPERS

NO.	TITLE	AUTHOR	YEAR
270	USING IPRS TO PROTECT NICHES? EVIDENCE FROM THE INDIAN TEXTILE AND APPAREL INDUSTRY	SUPARNA KARMAKAR MEENU TEWARI	JANUARY 2014
269	MONSOON 2013: ESTIMATING THE IMPACT ON AGRICULTURE	ASHOK GULATI SHWETA SAINI SURBHI JAIN	DECEMBER 2013
268	REMOTENESS AND UNBALANCED GROWTH: UNDERSTANDING DIVERGENCE ACROSS INDIAN DISTRICTS	SAMARJIT DAS CHETAN GHATE PETER E. ROBERTSON	SEPTEMBER 2013
267	NORMALIZING INDIA PAKISTAN TRADE	NISHA TANEJA MISHITA MEHRA PRITHVIJIT MUKHERJEE SAMRIDHI BIMAL ISHA DAYAL	SEPTEMBER 2013
266	RECESSION AND CHILD LABOR: A THEORETICAL ANALYSIS	SAHANA ROY CHOWDHURY	April 2013
265	IMPACT OF MACRO-ECONOMIC ENVIRONMENT ON DIVERSIFICATIONPERFORMANCE RELATIONSHIP: A CROSS COUNTRY STUDY OF INDIA AND JAPAN	SAPTARSHI PURKAYASTHA	MARCH 2013
264	FACTOR INCOME TAXATION, GROWTH, AND INVESTMENT SPECIFIC TECHNOLOGICAL CHANGE	MONISANKAR BISHNU, CHETAN GHATE AND PAWAN GOPALAKRISHNAN	MARCH 2013
263	INDIA'S ROLE IN FACILITATING TRADE UNDER SAFTA	NISHA TANEJA SHRAVANI PRAKASH PALLAVI KALITA	JANUARY 2013

About ICRIER

Established in August 1981, ICRIER is an autonomous, policy-oriented, not-for-profit, economic policy think tank. ICRIER's main focus is to enhance the knowledge content of policy making by undertaking analytical research that is targeted at informing India's policy makers and also at improving the interface with the global economy. ICRIER's office is located in the institutional complex of India Habitat Centre, New Delhi.

ICRIER's Board of Governors includes leading academicians, policymakers, and representatives from the private sector. Dr. Isher Ahluwalia is ICRIER's chairperson. Dr. Rajat Kathuria is Director and Chief Executive.

ICRIER conducts thematic research in the following seven thrust areas:

- Macro-economic Management in an Open Economy
- Trade, Openness, Restructuring and Competitiveness
- Financial Sector Liberalisation and Regulation
- WTO-related Issues
- Regional Economic Co-operation with Focus on South Asia
- Strategic Aspects of India's International Economic Relations
- Environment and Climate Change

To effectively disseminate research findings, ICRIER organises workshops, seminars and conferences to bring together academicians, policymakers, representatives from industry and media to create a more informed understanding on issues of major policy interest. ICRIER routinely invites distinguished scholars and policymakers from around the world to deliver public lectures and give seminars on economic themes of interest to contemporary India.