



Issues and Challenges in Sourcing and Supply Chains of Crude Oil in India: A Review

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ABSTRACT

Purpose-The domestic production of crude oil in India has witnessed a gradual slowdown since 2011-12 and it stood at 30.49 metric tonnes in 2020-21, measuring a fall of 5.21% in comparison to the previous financial year (Oil and Gas Industry in India, 2022). The Russia-Ukraine conflict has further impeded the global supply chains with catastrophic effects on the supply of crude oil. The war has exacted India to deal with this issue since it imports 85% of its oil (Gadd, 2013). The crude oil demand in India is likely to expand by 50% in 2030 as against a 7% growth the world over, (oil and gas industry report, 2022) working earnestly to maintain the continuity of oil supply chains is the need of the hour. As India's economic growth is directly linked to its energy needs it needs to strategise and ensure uninterrupted crude supply in the future (Fattouh, 2022). The purpose of this review paper is to study the sourcing of crude oil in India, analyse the challenges in the oil supply chain and recommend mitigation strategies and supply chain shifts as necessitated in the long run.

Design/Methodology/Approach- Descriptive research methods have been employed in this study. The sourcing drivers of crude oil in India have been explained and an attempt was made to identify the various issues in supply chains. The study has undertaken supply chain implication thorough review of basic and contemporary literature with a view to providing a detailed insight into various challenges affecting the oil supply chains that have pressurised the governments to rethink and realign their logistics and supply chain infrastructure for permanent solutions. This review paper has been split as per themes to highlight issues necessitating analysis and an attempt has been made to investigate reasons impacting the supply chains for crude oil.

Findings-The study found out that India's decreasing domestic production of crude oil since 2011-12, inadequate pipelines and storage facilities, limited strategic reserves, rising import bills due to oil price hikes, automation in oil operations, Russia Ukraine crisis, transportation hassles, price volatility, environmental challenges and rapidly changing geopolitical environment are some of the factors that pose serious challenges to crude oil supply chains that need to be addressed.

Research limitations/implications-The author has only focused on crude oil sourcing and its supply chains in India. For a comprehensive review, the researchers are recommended to study the gas sector and alternate traditional resources of energy.

Practical implications-It is felt that correct understanding and timely remedy of these issues shall benefit India in strengthening its oil sourcing and resolving the supply chain challenges. It shall assist the government in decision-making and initiating measures to become self-reliant for all its energy requirements without requiring to look above its shoulders for energy from energy-rich nations. The study shall also help private players and consumers alike to understand the larger dynamics of the oil industry. The paper shall also dwell on renewable energy resources as an alternative to fossil fuels that are fast depleting.

Originality/value-A number of literature is available on India's crude oil sourcing, its energy requirements, connected supply chain challenges as well as the adverse effects on the global economy due to supply chain disruptions however, a holistic review of sourcing of crude oil in India and issues in the supply chains is essentially required for a better understanding of what lies ahead and recommend initiatives and measures at all levels and mitigation strategies with an aim to develop lasting solutions.

Keywords: Sourcing of crude oil, supply chain management, oil industry, challenges, disruptions, renewable sources of energy, Russia-Ukraine War.

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I. INTRODUCTION

Owing to rapid ongoing economic growth, India ranks 3rd in energy consumption in the world and its oil requirements are predicted to register two times growth by 2045(Oil and Gas Industry Report, 2022).The year 2021 saw 4.9 million barrels per day (BPD)of oil consumption registering a hike from the previous year which was measured at 4.65 million BPD. The primary energy demand is likely to increase up to 1,123 million tonnes (11% of the global energy demand) as India’s economy takes a mighty leap to touch the US\$ 8.6 trillion mark by 2040(India Energy Outlook, 2021).The share of petroleum, oil, and lubricants (POL)in major imports across India stood at more than 21.4% from the financial year 2015-21 as depicted in **Figure 1**(Chemicals and Resources: Petroleum , 2022).

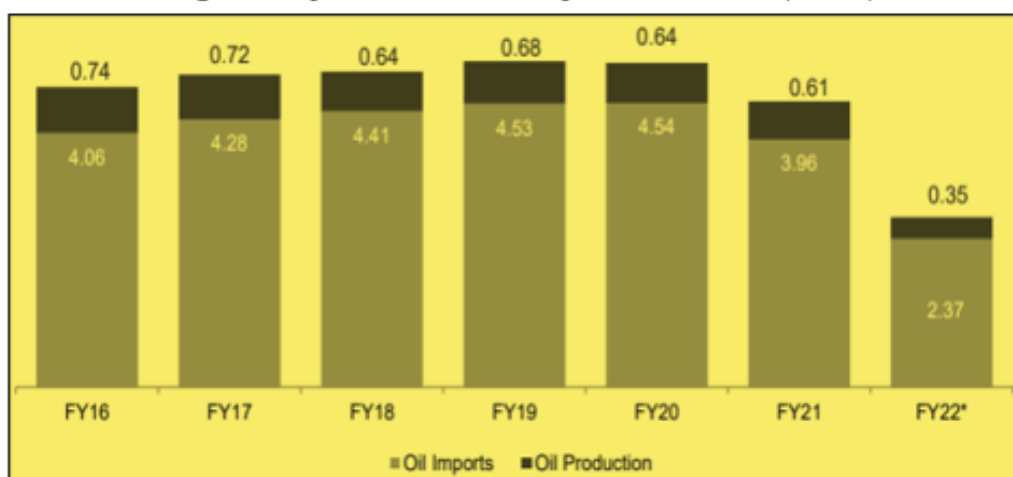
Figure 1. Percentage share of oil imports from the financial year 2015-21



Source: Statista database,2022.

While India’s oil demand is rising exponentially, domestic production is dismally low.In India diesel contributed to approximately 39% of the overall oil consumption in 2019 being one of the primary fuels, the crude oil demand in India is expected to grow from 4.8 million barrels per day (MBPD) in 2019 to 7.2 MBPD in 2030 to 9.2 MBPD in 2050(Oil and Gas, 2022).Imports and domestic oil production in India (MBPD) are shown in **Figure 2**.

Figure 2. Imports and domestic oil production in India (MBPD)



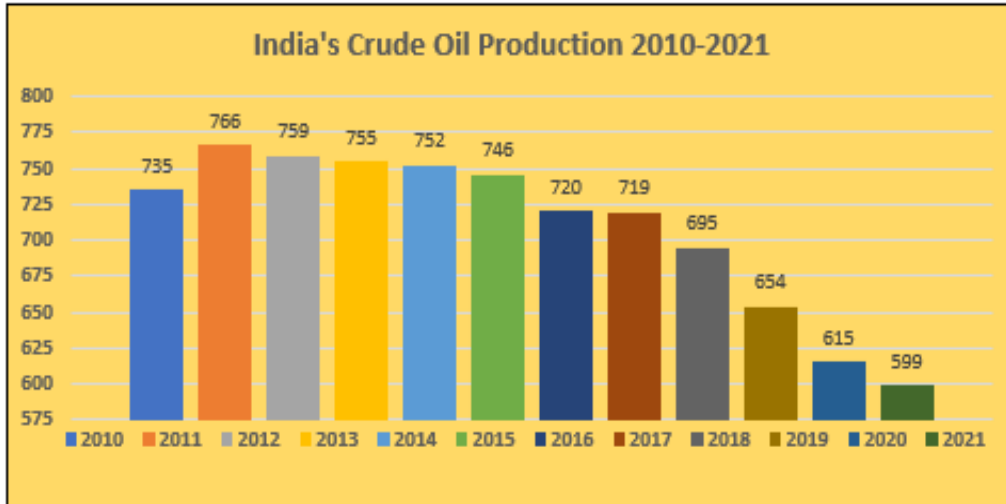
Source: Ministry of Petroleum and Natural Gas, BP Statistical Review, 2020

1.1 Trends in Production and Sourcing of Crude Oil in India

The earliest oil deposits in India were unearthed near Digboi, Assam in 1889. In 2018, approximately 594.49 million metric tonnes of crude oil reserves existed in India while in 2019, India was pitched as the 2ndlargest

crude oil importer with a projected demand of 205.3 metric tonnes. As the domestic production output is constantly falling year on year (Production, India's Crude Oil, 2022), 85% of the oil needs are imported. Domestic production of crude oil over the last 10 years is shown in **Figure 3**. Import of crude oil from 2010-2022 and 2021-22 is as shown in **Figures 4 & 4(a)**.

Figure 3. India's Crude Oil Production: 2010-2021 (Thousand Barrels per day)



Source: Census and Economic Information centre, 2022.

Figure 4. Import of Crude Oil in India (in metric tonnes) from 2010-22

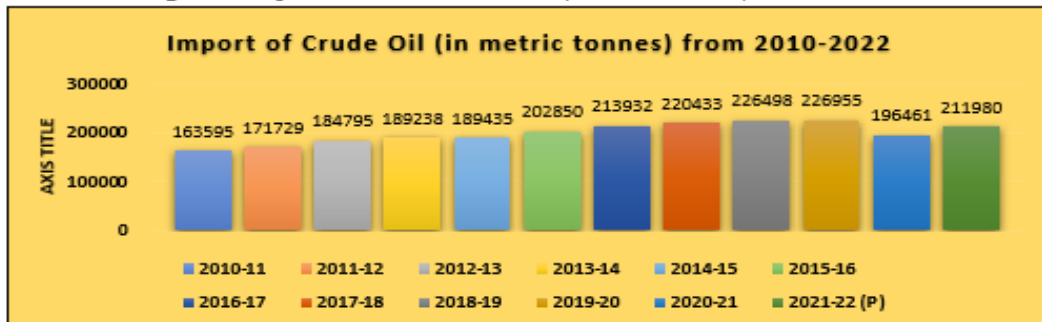
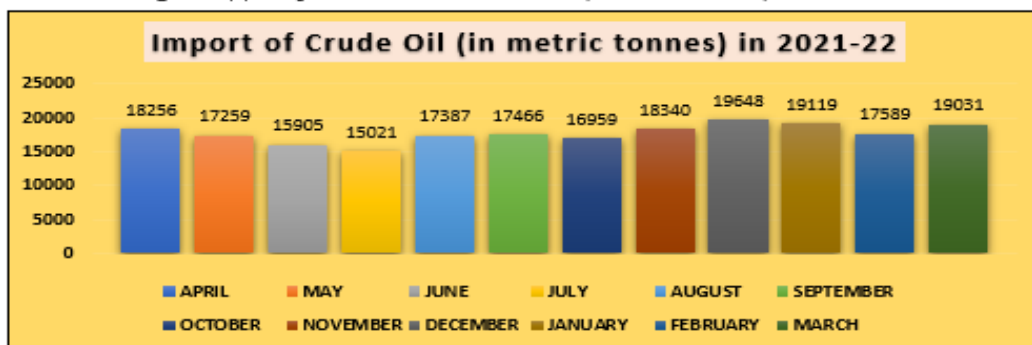


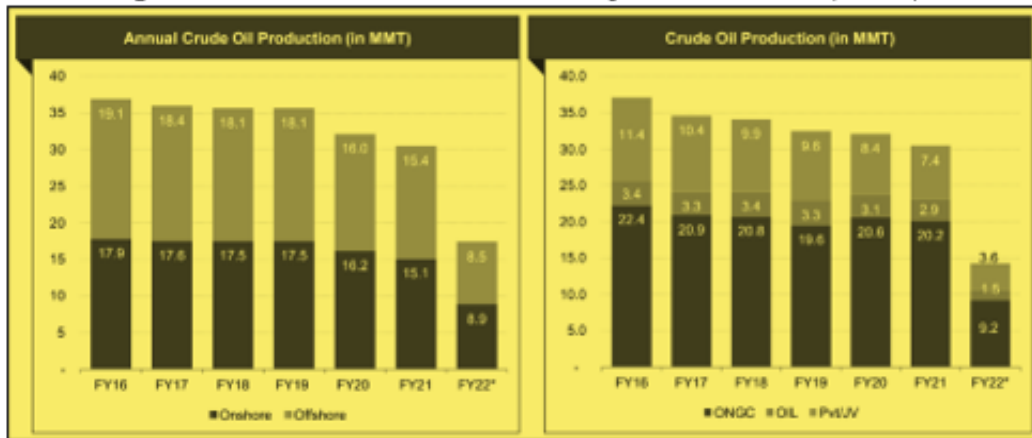
Figure 4(a). Import of Crude Oil in India (in metric tonnes) in 2021-22



Source (Figure 4 & 4(a): Petroleum Planning & Analysis Cell (PPAC) Report, 2022.

Offshore production accounts for half of the domestic production however the share is dwindling due to lower output from Mumbai High Field. 49.51% of crude oil production in India is extracted as a result of onshore production while the remaining half is accounted for from offshore channels. Of the total crude oil production in India in Financial Year 2021, 66.19% (**Figure 5**) was carried out by ONGC (Oil and Gas Industry in India, 2022).

Figure 5. Onshore and Offshore domestic oil production in India (MBPD)



Source: Ministry of Petroleum and Natural Gas, 2022.

1.2 Supply Chain of Oil Industry in India

Some of the significant activities in the crude oil supply chain include production/procurement of oil, shipment of oil to refineries, process of refining, purchase, shipment and distribution to end user. A few factors that underline the mechanics of the industry are as follows (Saswati Tripathi, 2018):

- High volatility in crude oil prices.
- Long lead time in the acquisition of crude oil due to poor/inadequate forecasts.
- Crude oil is the single raw material used for many end products.
- Short-term capacity variations and impromptu halting of production are not feasible.
- Inelastic demand for petroleum products is highly regulated and standardised in nature.
- Cooperation and fine blending across the supply chain poses a major challenge.
- Rigorous quality check at each stage of the supply chain is an inescapable requirement.
- Long and multiple supply chains resulting in increased inventory holding costs.

The oil business in India registers a huge expenditure of more than 20% towards the refining of oil and its further distribution (Saswati Tripathi, 2018). India spends 13% of its GDP on oil supply chain management as compared to 10% in flourishing nations (Annual Report, Ministry of Petroleum and Natural Gas, 2016-17). A typical supply chain in the Indian oil industry has been depicted in **Figure 6**. The oil supply chain in India is largely unaccommodating in terms of product customisation and magnitude of output handled and oil companies constantly endeavour to blend the value chain to bring out the utmost benefits. Customised supply chain management solutions assist in forecasting demands including other aspects such as distribution and refinery planning.



Figure 6. Ideal Supply Chain and Related decisions in Indian Oil Industry

Source: Journal of Supply Chain Management System, April 2018

II. OBJECTIVE OF THE STUDY

The imperative for the oil companies working in concert with the government is to prevent disruption of supply chains caused by various challenges, however, for lasting solutions nations need to work on a policy framework that affords the requisite immunity to supply chains in event of eventualities such as generated by the Ukraine crisis. The governments also need to give impetus to energy alternatives and lower their dependency on fossil fuels by enhancing their capacities to generate renewable energy sources. Hence the present study carries the following objectives: -

- To examine the supply chain issues/challenges of the crude oil industry in India.
- To recommend measures and mitigation strategies to prevent disruption in crude oil supply chains and suggest initiatives required to be adopted by India to redesign supply chains by switching over to renewable energy sources.

III. METHODOLOGY

A descriptive research methodology has been employed while preparing this review paper. The sourcing of crude oil has been identified and an endeavour carried out to explain the various challenges influencing the supply chains of crude oil in India. This study takes forward a detailed appraisal of basic and contemporary literature on the subject and identifies the challenges that are adversely affecting the oil supply chains in India.

The author has compiled available literature, including industry research papers, website documents, internet journals, industry reports, and white papers. Reference material was collected by applying an organised search by using expressions such as “Crude Oil”, “Imports”, “sourcing”, “Ukraine Russia crisis”, “Supply chain disruptions”, “energy mix”, and “renewable sources of energy”. Research databases from India Brand Equity Foundation (IEBF), Petroleum Planning and Analysis (PPAC) Cell, Ministry of Petroleum and Natural Gas, International Energy Agency (IEA), Indian Energy Outlook, and International Journal of Oil, Gas, and Coal Technology were also referred.

The literature has evolved various concerns according to issues and challenges in the crude oil supply chains such as speedily rising energy needs in India, volatile oil prices, and the Ukraine-Russia conflict resulting in disturbance of supply chains. These challenges have been investigated to arrive at recommended lasting solutions.

IV. DISCUSSION AND RESULTS

In this section, the author has discussed the sourcing of crude oil in India and the issues and challenges affecting the supply chains.

4.1 Sourcing of Crude Oil (Production) in India

Having overtaken Great Britain to become the 5th largest economy, India’s economic growth is one of the fastest in the world. Due to its robust economic growth, India is positioned to steer progressive growth in the global energy arena. Almost 80% or more of India’s oil demand is met from imports against domestic production which stands at a mere 15-16%. The State-wise crude oil production trends (Ministry of Petroleum and Natural Gas, 2022) are given in **Table 1**.

Table 1. State-wise Crude Oil Production Trends (thousand metric tonnes)

State/Source	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Onshore						
Andhra Pradesh	254	295	276	322	296	182
Arunachal Pradesh	69	57	55	50	43	41
Assam	4,473	4,185	4,203	4,345	4,309	3,090
Gujarat	4,653	4,461	4,605	4,591	4,626	3,527
Rajasthan	8,848	8,602	8,165	7,887	7,657	5,205
Tamil Nadu	241	261	284	345	395	310
Total Onshore	18,538	17,861	17,588	17,540	17,336	12,355
Offshore						
Total Offshore	18,923	19,089	18,421	18,145	16,868	12,021
Grand Total	37,461	36,950	36,009	35,684	34,203	24,376

Source: Ministry of Petroleum and Natural Gas Data, 2020 (Ministry of Petroleum and Natural Gas, 2022)

4.2 Diversification Trends in Crude Oil Imports during Pandemic and Russia Ukraine War

Supply insecurity has necessitated the diversification of crude oil import sources. Disruptions from the Persian Gulf due to political and social instability have impelled India to diversify its crude import basket. Besides, precariousness in oil-producing regions, depleted supply due to policy shifts, and international sanctions may also raise diversification concerns. As per Ministry of Commerce data, in 2021-22, India imported crude oil worth US\$ 122.45 billion while this figure stood at US\$ 59.48 billion in 2020-21. In 2006-07, India sourced crude oil from 27 countries which increased to 42 in 2020-21 (Powell, 2022). The share of the Persian Gulf remained at around 60%, while it decreased for Africa from 17% to 13% and increased for South American nations from 6% to 12%. Iraq's share increased from 9% in 2009-10 to over 22% in 2020-21. The United States jumped the ladder from 18th position in 2017-18 to 4th largest in 2020-21. Iran being the second largest exporter of crude oil to India in 2009-10 lost out completely in 2020-21. Post Russia's invasion of Ukraine in Feb 2022 followed by sanctions, Russia's Ural crude oil prices fell prompting India to ramp up imports from Russia making it the second-largest oil supplier to India after Iraq (India's Russian Oil Imports jump, 2022).

4.3 Oil Pipeline Network in India

The crude oil pipeline network in India spanned over 10,419 km as of November 2021 with a total capacity of 147.9 million metric tonnes per annum (MMTPA). Of the entire length, IOCL has 5301 km to its credit while ONGC leads with 40.97% in terms of actual volumes. The length and magnitude of major crude oil pipelines in India are shown in Table 2 (Oil and Gas Industry Report, 2022). India has the following six major oil & gas pipelines (6 major pipelines of India, 2020): -

- **Naharkatia-Nunmati-Barauni pipeline.** This pipeline has a large number of subsidiary pipelines and pumping stations along its entire span.
- **Mumbai High-Mumbai—Ankleshwar-Koyali Pipeline.** This is a 210 km double pipeline that links Mumbai High and Gujarat oilfields with the Koyali oil refinery.
- **Salaya-Koyali-Mathura Pipeline.** This is a 1256 km long pipeline that supplies crude oil from Gujarat to oil refineries at Mathura and is further extended till Panipat in Haryana.
- **Hajira-Bijapur-Jagdishpur (HBJ) Pipeline.** Considered the world's largest underground pipeline network, the credit for constructing this 1750 km long pipeline goes to the Gas Authority of India (GAIL).
- **Jamnagar-Loni LPG pipeline.** 1269 km long pipeline is the longest LPG pipeline in the world. Constructed at a cost of Rs 1250 crore, this dual-purpose pipeline transports more than 3.5 lakh LPG cylinders every day.
- **Kandla-Bathinda Pipeline.** 1331 km pipeline is proposed to be assembled by IOC at an expenditure of Rs 690 crore. The pipeline will transport crude oil to the proposed refinery at Bathinda.

Table 2. Length and Capacity of Oil Pipelines in India as of November 2021

	IOCL	BPCL	HPCL	OIL	ONGC	Cairn	HMEL	Others	Total
Length (in kms)									
Crude oil pipeline	9,400	2,596	3,775	654	-	-	-	2,395	18,820
Product Pipeline	5,301	937	-	1,193	1,283	688	1,017	-	10,419
Total	14,701	3,533	3,775	1,847	1,283	688	1,017	2,395	29,239
Capacity of Crude Oil Pipelines (mmtpa)									
Crude oil pipeline	47.5	23.0	34.1	1.7	-	-	-	9.4	115.7
Product Pipeline	48.6	7.8	-	9	60.6	10.7	11.3	-	147.9
Total	96.1	50.3	34.1	10.7	60.6	10.7	11.3	9.4	263.6

Source: Ministry of Petroleum and Natural Gas, 2022.








4.4 Refinery Capacity and Refinery Crude Throughput in India

The first refinery was set up at Digboi in 1901 with a volume of 0.50 million metric tonnes per annum (MMTPA). India has noticed a commendable development in the refining sector over the years and is presently the fourth largest in the world with a capacity of 248.9 MMTPA. India has a total of 23 refineries of which 18 are in the Public Sector, three in the Private Sector, and two functioning as a joint venture. These refineries are geographically well-connected and the overall volume has propelled from a modest 62 MMTPA to 248.9 MMTPA (Ministry of Petroleum and Natural Gas, 2022) over the years.

4.5 Key Domestic Oil Companies in India

Oil and gas being of strategic importance are included in India's eight crucial industries. Various Indian oil companies have made remarkable subscription to the nation's expeditious economic development. Besides oil production, these companies also offer employment to many (Top 10 oil and gas companies, 2022). The major oil companies and the income generated from their operations are shown in Table 3.

Table 3. Major Oil Companies of India and their Income in FY 2021

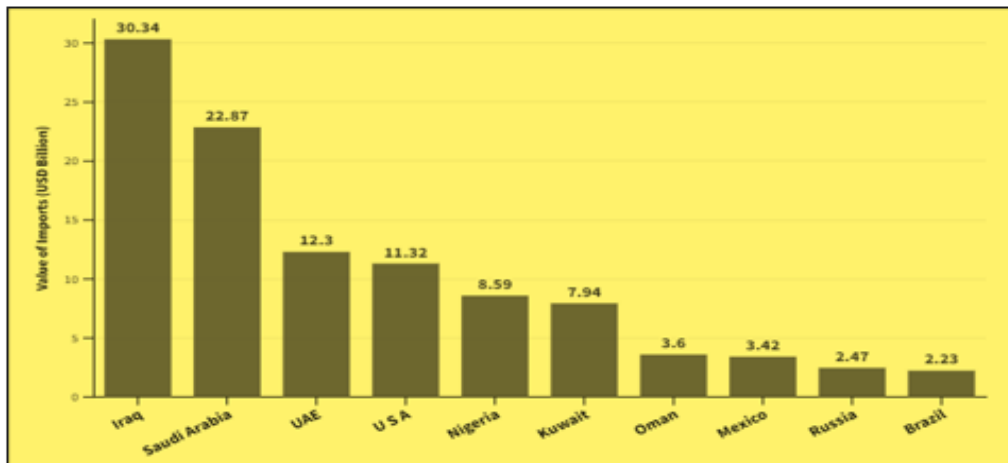
Company Logo	Name of the Company	Ownership	Income in FY 2021 (US\$ Billion)
	Indian Oil Corporation Limited	56.98% State-owned	68.25
	Reliance Industries	Public listed	70.82
	Bharat Petroleum Corporation Limited	54.31% State-owned	40.23
	Hindustan Petroleum Corporation Limited	51.11% State-owned	35.87
	ONGC	68.07% State-owned	8.95
	GAIL India Limited	53.59%	7.71
	Oil India Limited	66.13% State-owned	1.38

Source: IBEF Company's Annual Report, 2022

4.6 Global Crude Oil Imports in India

Approximately 80% of the country's crude oil demand is met with imports. With a marked increase in oil prices and a decline in domestic oil output, India's crude oil import bills are a matter of concern. As per data from Petroleum Planning & Data Cell, India's oil import dependence for was estimated at 85.5% in 2020-21 (Kancharla, 2022). India is set to cross the \$100 billion mark in oil imports in the current fiscal. Around 50 countries export crude oil to India however, the major share is only from a select few. As per data, India imports most of its oil from the Middle East (52.7%), Africa (15%), and the United States (14%) (Where does India get its Oil Supply, 2022). The percentage of global imports of crude oil in 2021-22 is shown in **Figure 7**.

Figure 7. India's Import of Crude Oil in 2021-22: Top 10 Countries

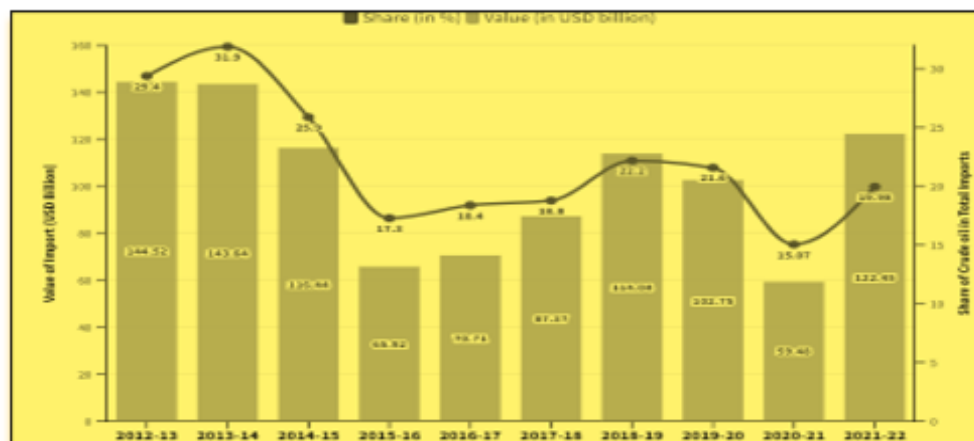


Source: Export and Import databank, Ministry of Commerce.

4.7 Share of Crude Oil in Total Value of Imports carried out by India

During the pandemic, the value of oil imports declined to US\$ 59.48 billion however, the same rose to 122.45 US\$ billion in 2021-22 which is the highest since 2014 (Kancharla, 2022). A decline in the value of imports has been observed over the last 10 years (2012-13 to 2021-22) suggesting a drop in the imports during 2015-16 and the pursuing year before picking up again. The portion of crude oil in the overall imports rose to nearly 20% in 2021-22 in comparison to 15.1% in 2020-21 while the same was 21.6% in 2019-20. India imports large quantities of crude oil from nations such as Iraq, Saudi Arabia, and UAE. Among the African nations, Nigeria tops the chart. The year 2021-22 has seen the unfolding of Russia & Brazil among the top ten nations exporting crude oil to India. The value and Share of Crude Oil imports are shown in **Figure 8**.

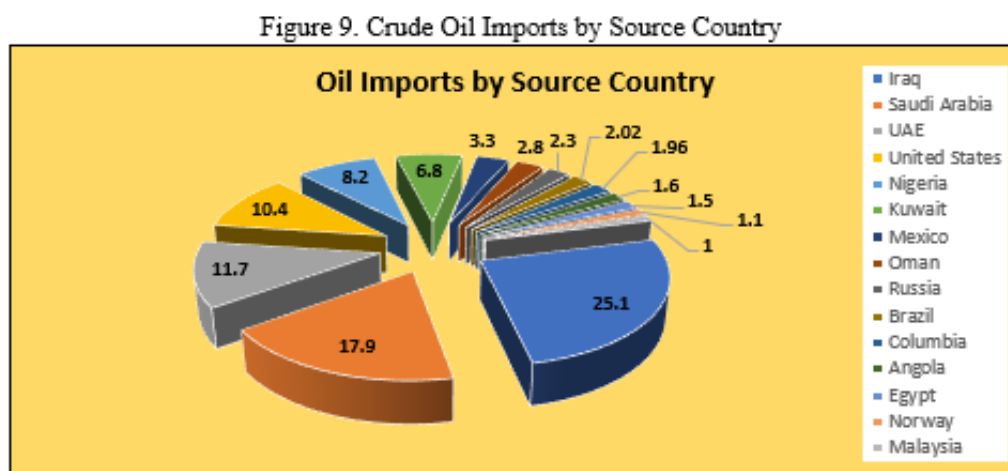
Figure 8. India's Import of Crude Oil (2012-13 to 2021-22, Value & Share)



Source: Department of Commerce's Export Import Data bank.

4.8 Oil Imports by Source Country

During 2011-12, the imports of crude oil increased from 171.73 metric tonnes to 226.95 metric tonnes during 2020-21. **Figure 9** shows the details of 15 countries that are the largest sources of crude oil imports to India in 2021 (Oil and gas Industry in India, 2022).



Source: <https://www.worldstopexports.com/crude-oil-imports-by-country/>, 2022

4.9 Trends in Indian Petroleum industry

The oil in both forms (petrol and diesel) is sold through petrol pumps mostly owned by State owned oil marketing companies. As on date India has more than 69,924 petrol pumps (Petrol Pumps in India, 2022) while in 2011 the country had 41,947 outlets. Indian Oil Corporation (IOC) owns and manages 29,358 petrol stations of which 7,500 are in the rural area. Hindustan Petroleum Corporation Limited (HPCL) is the 2nd largest fuel distributor with 16,707 openings. Trends in the Indian Petroleum industry from 2011-2018 are depicted in **Table 4**.

Table 4. Indian Petroleum Industry at a Glance

Item	Unit	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Production								
Crude Oil	MMT	38.09	37.86	37.79	37.46	36.94	36.01	35.68
Petro Products	MMT	203.20	217.74	220.76	221.14	231.92	243.55	254.40
Consumption								
Crude Oil	MMT	204.12	219.21	222.50	223.24	232.86	245.36	251.93
Petroleum Products	MMT	148.13	157.06	158.41	162.52	184.67	194.60	204.92
Crude Reserves	MMT	652.16	651.55	647.34	635.59	621.28	604.10	594.49
Crude Imports	MMT	171.73	184.80	189.24	189.43	202.85	213.93	220.43
% of Imports	%	32.92	33.55	36.60	29.94	21.16	22.60	23.42

Source: Indian Petroleum and Natural Gas Statistics, 2017-18

4.10 Upstream, Midstream and Downstream Activities in the Oil Industry

Upstream in the oil industry involves exploration and production while midstream activities include transporting resources via pipelines, railways, or tankers to refineries. Distribution/retail is the downstream point of the industry responsible for processing the raw material into end petroleum products. Upstream companies identify deposits, drill wells, and recover raw material through exploration and extraction (Hayes, 2022). In India, the first oil well was dug in Assam in 1866 (Directorate General of Hydrocarbons, 2022). The exploration process is divided into onshore and offshore drilling facilities. Exploration is often high risk and a high-cost venture (Oil & Gas Industry: A Research Guide, 2022). The sequence of these activities (Oil Supply Chains, Best Practices, 2021) has been depicted in **Figure 8**.

Figure 8. Upstream, Midstream, and Downstream activities in Oil Industry



Source: Oil Supply Chain, Best Practices, 2021.

4.11 Strategic Oil Reserves in India

Setup in 2004, Indian Strategic Petroleum Reserve Limited (ISPRL) holds 5.33 million metric tonnes (MMT) as a strategic oil reserve at Vishakhapatnam, Mangaluru, and Padur (Mishra, 2022) (constructed at an estimated cost of INR 23.97 billion) which equals to 9.5 days of oil demand. In addition, the oil companies have 64.5 days of storage facility. Two additional SPR facilities at Chandikhol in Odisha and Padur in Karnataka with a storage capacity of 6.5 MMT have been planned in phase II of the SPR Programme (strategic crude oil reserves, Ministry of Petroleum and Natural Gas, 2021). Taking a clue from China, India decided to commercialise SPR in 2021 in order to generate revenue (Akhilesh Sati, 2021). ISPRL has leased UAE to hold 750,000 MT of SPR. In event of a political or natural disaster, a portion of the reserves may be released to moderate the price rise (In Depth: Strategic Petroleum Reserves, 2018). In response to the global oil price rise in the aftermath of the Russia-Ukraine war, India released 5 million barrels of oil from its strategic reserves to leverage it as a geopolitical tool (Singh, 2021).

4.12 Government Regulations in Sourcing and Oil Supply Chains in India

Before 1999, the Indian government had ownership over the oil sector. Under New Exploration Licensing Policy (NELP), the government awarded exploration rights to domestic and foreign companies through international competitive bidding. Indian government allows 100% foreign direct investment (FDI) in this sector. Only 28 of .5% of production is accomplished by private/joint venture companies (Bhandari, 2020) while the major share is held by ONGC and public sector enterprises. Enhancing crude oil production, acquiring technological expertise, and achieving as near as zero impact on the climate are some of the prime objectives of the government's exploration/production policy. As part of Hydrocarbons Vision 2025, the government aims to build capacity in the hydrocarbon sector, upgrade customer service, and secure oil security to meet strategic and defence requirements. In addition, the government is also working towards encouraging the use of natural gas, ensuring adequate imports, and tapping unconventional sources. Ministry of Petroleum and Natural Gas regulates the oil and gas industry in India including E&P, refining, marketing, distribution, import, export, and conservation (Sakariya, 2011). Exploration and production rights are awarded by the government to eligible private contractors on a revenue-sharing basis.

V. ISSUES AND CHALLENGES IN THE OIL SUPPLY CHAINS

Crude Oil supply chains include domestic and international transportation, materials handling, import/export facilitation, and information technology. In a typical supply chain activities such as disposition, cooperation, and uninterrupted augmentation of an organised set of operations whose goal is to provide maximum consumer service at minimum cost (Chima, 2007). The Supply chain link in the oil industry involves exploration, production, refining, marketing, and consumer. The author feels that there are numerous factors that are obstructing the supply chains in the oil industry. In the process of finding out the dimensions of different factors, the author has categorised these issues/challenges as follows: -

5.1 Automation/Adoption of Technology in Crude Oil Industry in India

“Data is the new oil. It's valuable, but if unrefined it cannot really be used.”

Energy companies are wrestling with past legacies, multiple data sources, and tiresome monotonous operations that adversely affect driving speed and impact (Dia, 2021). Oil suppliers and their partner services generate voluminous data however, due to propriety data formats not allowing open API access, this closed system renders the data redundant. In the oil sector, almost 83% of the data related to drilling, seismic activity, and hydraulics remains untagged and unsearchable. Oil companies can employ deep semantic technology to make sense of this disparate data (Data challenges in ML for Indian Oil and Gas Industry, 2020). The automation issues in the Oil industry and their mitigation strategies are compiled in **Table 5**.

Table 5. Automation / Technology Issues in Oil Industry in India and Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Adoption to technology / automation issues and challenges in the crude oil industry	<ul style="list-style-type: none"> Oil companies still stick to traditional norms of functioning. Closed systems with propriety issues not allowing usage of large data. High operating costs due to lack of adaptation to digital technologies. Unskilled staff forcing oil outlets to depend on IT companies such as Apple, Microsoft, and Google for solutions. Supply chain visibility issues. Data trade-off, harmonisation, and cooperation among supply chain partners. 	itechindia.co, 2021; (Ortega, 2021); (Dia, 2021); (Chima, 2007) (Data challenges in ML for Indian Oil and Gas Industry, 2020); (News and Trends impacting Oil and Gas Supply Chain, 2022)	<ul style="list-style-type: none"> Use of mechanisation in the drilling process to enhance staff safety and expedite the speed of drilling operations. Use of drones and remotely controlled equipment for scrutiny and diagnostics. Installation of smart sensors to automate the rate and flow of oil extraction. Oil companies to train human capital in AI, ML, and software development. Use of Blockchain technology can impact up/downstream operations. Use of advanced analytics for prognostic maintenance, marketing, and distribution efficiency. Effective use of digital technologies to minimise capital expenditures.

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5.2 Impact of Russia Ukraine War on Crude Oil Supply Chains in India

India's energy procurements are facing a crisis due to import difficulties against Russia. Sanctions and multiple curtailments on the global oil value chains are disrupting growth which has pushed the country's economy in the reverse gear. Oil prices and supply are the main concerns for importers. The accessibility of containers and shipping routes is prone to numerous handicaps. Rising prices of crude oil have forced Indian oil marketing companies to slowly escalate fuel costs to lessen their losses. In event of crude oil bills sticking over \$100, India's oil import bill is likely to bloat in the range of \$150-175 billion in 2022-23 (Kar, Russia Ukraine War: Impact on India's Petroleum sector, 2022) which would further hamper government's expenditure plans. Rising oil prices will have severe consequences on inflation, economic progress, and market development. The impact of Ukraine Russian crisis on the oil supply chain and the mitigation strategies are compiled in **Table 6**.

Table 6. Ukraine Russian war impacting crude supply chains and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Effect of Russia Ukraine war on crude oil supply chains in India	<ul style="list-style-type: none"> Jump in domestic oil prices. Hike in inflation. High import bills. Import limitations. India needs to reduce its oil dependency. US Sanctions against Russia's oil exports. Global economy moving towards slow recession. ONGC investments in Russian Oil fields at stake. Rapidly changing geopolitical scenario. 	(Kar, Russia Ukraine War: Impact on India's Petroleum sector, 2022); (Ashraf, 2022); (Krammer, 2022); (how Russia Ukraine war will affect India, 2022); (India Russia Oil trade amid Ukraine crisis, 2022); (Kar, Russia Ukraine War: Impact on India's petroleum sector, 2022)	<ul style="list-style-type: none"> Use of Strategic Petroleum Reserves by government. Need to acquire inexpensive energy supply. Building supply chain resilience. Build brownfield capacity and operational ascendancy. Reinforce commercial and trading capacities. Accelerate clean energy, demand side efficiency and decarbonisation. Strengthen cyber defences. Maintain delicate diplomatic balance between Russia and the West. Increase oil imports from Russia. Boost domestic production

			and broaden import substitution strategies.
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5.3 Transportation / Shipment challenges in the Crude Oil Supply Chains

Distinct modes of shipment such as pipelines, vessels or tankers and railroads are essentially needed to transport oil and petrochemicals. The tank trucks used for the shipment of crude oil and petroleum products are dedicated to the actual class of merchandise and cannot be used for alternative commodities (Ruthramathi, 2019). Several weeks' lead time is essentially required for the oil to reach end users from the shipping point. Long distances and relaxed modes of shipment result in high prices besides large in-transit inventory (Raed Hussain, 2006). Apprehension regarding cooperation and sharing of relevant information between supply chain associates is a major challenge in the oil industry. The impact of transportation challenges on the oil supply chains and their mitigation strategies are compiled in **Table 7**.

Table 7. Transportation Challenges in Crude Oil Supply Chains and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Transportation / Shipment challenges in the crude oil supply chains	<ul style="list-style-type: none"> • Long lead times due to large distances. • Inadequate Rail/road network. • Requirement of vessels / tankers for shipment of crude and processed oil. • Lack of collaboration and synergy among partners. • Lack of information sharing at various levels of up / down and mid-stream activities. 	(Raed Hussain, 2006); (Simchi-Levi, 2012)	<ul style="list-style-type: none"> • Sophisticated information technology to ensure Consolidated process governance, reference systems, and information divide. • Shipment swapping. • Forming supply chain alliances to reduce inventory and inventory costs. • Shipping large quantities to achieve economies of scale. • Switch from Just-in-Time to Just-in-Case • Establishment of large storage facilities. • Shift from quicker delivery means to cheaper and slower transportation modes. • From committed resources to shared resources. • Control over bullwhip effect. • Offshoring vis-à-vis nearshoring.

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5.4 Price Volatility Affecting Sourcing and Supply of Crude Oil in India

Variations in production and utilisation of oil affect prices. Besides other variables, the basic theory of supply and demand also affects oil prices. Supply and demand scenarios based on economic conditions globally and geopolitical worries can make a crucial difference to oil prices. OPEC countries have the capacity to force oil prices to jump by restricting production. Geopolitical tensions in oil-producing countries particularly Saudi Arabia, the Middle East, Iraq, and Iran as well as terrorist attacks, sanctions, and other regional matters also influence oil prices. If refinement doesn't keep up with production, this may lead to a hike in prices (Farlane, 2022). The impact of price volatility and its mitigation strategies are compiled in **Table 8**.

Table 8. Price Volatility Issues in Crude Oil Supply Chains and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Price Volatility affecting crude oil supply chains	<ul style="list-style-type: none"> • Variation in production and consumption as well as supply and demand patterns affect prices. • OPEC countries can force global oil prices to rise/fall. • Refinement capability vis-à-vis production affects prices. • Geopolitical environment/sanctions. • Rising transportation costs. • Russia Ukraine Conflict. • Unplanned supply disruptions can push prices upwards. 	(Farlane, 2022); (Simchi-Levi, 2012); (Independent statistics and analysis, 2022)	<ul style="list-style-type: none"> • Centralised control over production. • Minimising dependency on traditional fuels. • Initiative to reduce impact of OPEC over price control. • Switching over to renewable energy sources. • Maintenance of world order/peace to prevent effect on price rise. • Reducing manufacturing costs through outsourcing. • Reducing transportation costs by depending on regional distribution centers.

	<ul style="list-style-type: none"> • Changes in predictions of economic growth affect oil prices. 		<ul style="list-style-type: none"> • Supply chain flexibility. • Sourcing and production to be closer to demand centers. • Trimming of excise duty and value-added tax.
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5.5 India’s rising Oil import bills Affecting Crude Oil Sourcing

Owing to growing uncertainty in the global economy as a result of Russia-Ukraine war and sanctions imposed on Russia, the oil prices shot up beyond \$130 per barrel leading to an increase in India’s import bill (Mishra H. S., 2022) besides setting off tight supply fears. The hike in crude prices has inflicted a financial burden on the Indian government and oil companies. India witnessed a 108% jump in its oil import bill through December 2021 (Chowdhary, 2022). The prevailing oil price situation is characterised by VUCA (volatile, uncertain, complex, and ambiguous) which is adversely affecting the Indian economy (Partha Ray, 2022). As per Edelweiss, every \$10 hike in the cost of crude oil shall raise the country’s current account deficit by 0.4-0.6% of the GDP (How the crude oil price spike will upend India’s fiscal balancing act, 2022). **Table 9** depicts the impact of rising crude oil import bills on oil supply chains in India and its mitigation strategies.

Table 9. Issues of Rising Crude Prices on Import Bills and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Rising crude oil import bills affecting crude oil sourcing	<ul style="list-style-type: none"> • Uncertainty in the global economy. • Sanctions against Russian oil imports. • Price volatility of oil. • India’s growing energy demands. • Currency depreciation. • Rising oil prices resulting in a \$6.6 billion increase in CAD. • Decline in India’s projected GDP growth. • Import of additional oil at a premium price. • Rise in inflation by 52-65 basis points. • Fuel inflation leading to inflation in other commodities. 	(Mishra H. S., 2022); (Independent statistics and analysis, 2022); (Chowdhary, 2022); (Oil Alarm: India’s oil import bill at 67% of FY 21, 2021); (How the crude oil price spike will upend India’s fiscal balancing act, 2022)	<ul style="list-style-type: none"> • Release of additional crude oil from reserve stock. • Procurement of crude oil from Russia at subsidised rates. • Reduction of taxes on petroleum products to check retail inflation. • Transition to renewable energy sources.

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5.6 Impact of Rapidly Changing Geopolitics on India’s Crude Oil Sourcing

The politics of oil in the past has led to civil wars, inter-state conflicts, producer cartels, and international oil governance (Roy, 2020). As per a study, 90% of its shipment energy and almost 40% of the overall world’s energy is provided by oil. Due to geographical accessibility, transportation economies, shipping time, and ease of obtainability, India largely depends on the Middle East, a region that has been host to resource wars unleashed by the West to secure its energy interests. Regional and religious friction is common and political instability in Iran and Iraq has been a cause of concern for the continuous supply of energy from the Middle East (Rastogi, 2013). Volatility in international crude oil prices as a result of Russia-Ukraine conflict, and supply side disturbances exert noteworthy pressure on the foreign exchange reserves of the country. In the short run, production, supply, sourcing, and price of crude get affected by geopolitical factors. Owing to technological advancements the point of balance in oil production is switching from the Middle East to the Western Hemisphere (Kalita, 2020). As the transition to modern renewable energy progresses the geopolitics of energy will effectively melt away (Stevens, 2019). **Table 10** shows the geopolitical environment having a bearing on oil supply chains in India.

Table 10. Effect of Geopolitics on Crude Sourcing in India and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Impact of Geopolitics on Crude Oil Sourcing and Supply Chains	<ul style="list-style-type: none"> • The Middle East being a major oil supplier to India. • Region susceptible to religious, political, and diplomatic turbulence. 	(Rastogi, 2013); (Sanjay Kumar Kar, 2020); (Roy, 2020); (Kalita, 2020); (Bhandari A., 2022); (De, 2022); (Stevens,	<ul style="list-style-type: none"> • Strengthening bilateral partnership with Saudi Arabia and sustainable friendship with Russia. • Stronger diplomatic ties with the US to promote shared interests.

	<ul style="list-style-type: none"> • US Sanctions against Iran affecting India's oil imports. • Russia Ukraine conflict created transportation hurdles besides sanctions against Russia. • Indian refineries are heavily dependent on the Middle East Crude oil. • Attempt by China to encourage the use of Yuan in oil trade. • Supply disruptions due to current geopolitics. • Hegemony of oil-producing countries. 	2019)	<ul style="list-style-type: none"> • Higher focus on alternate sources of energy. • Ramp up domestic production by adopting innovative technologies. • Diversify import sources of crude oil. • Boost energy effectiveness and circular economy programs. • Fund research and development (R&D) to develop automation. • Integrate energy, environmental and financial markets.
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5.7 Logistics challenges in Crude oil supply chain in India

Oil supply chains involve transportation and storage of heavy equipment and hazardous material which requires specialised vehicles, multiple modes, high capacity, and diligent strategy. Outsourcing activities in oil companies include transportation operations, warehousing management, and yard & dock management (How oil and Gas companies can benefit from 3PL, May 2022). In order to minimise operational costs, overcome restraints of expertise and permit some of the supply chain threats to another party, the oil companies outsource part of their non-core functions to a 3PL (Masha Menhat, 2019). The various logistics issues and challenges in the oil supply chains are compiled in **Table 11**.

Table 11. Logistics Challenges Impacting Oil Sourcing in India and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Logistics challenges in the Crude Oil Industry	<ul style="list-style-type: none"> • Exploration/production requires a substantial logistics framework. • Disruptions can incur huge economical losses. • Inefficient inventory management and unreliable delivery from suppliers. • Increased freight costs due to changing geopolitical scenarios. • Logistics management doesn't afford sufficient time to develop business. • Only a few companies invest in costly as well as complex oil logistics operations. • Safety in operations is of paramount importance. 	(How oil and Gas companies can benefit from 3PL, May 2022); (Masha Menhat, 2019)	<ul style="list-style-type: none"> • Outsourcing freight management helps develop and enhance efficiency. • Make effective use of transportation management systems for data storage, analysis, and shipment management. • Inculcate flexibility in view of changing government regulations and import/export laws/policies. • Maintain and develop effective communication with suppliers and consumers. • Employing 3PL ensures the safety of operations.

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5.8 Challenges in Sourcing and Procurement of Crude Oil in India

India relies heavily on crude imports since its domestic output does not suffice to the ever-increasing energy requirements. Exploration, production, refining as well as importing are complex and expensive processes. Prevailing global geopolitical scenario has necessitated India to focus on its energy security requirements for which the government has given priority to enhance exploration and domestic production as well as procure crude from Russia on a subsidised/discounted price in light of West seizing oil imports from Russia post its aggression of Ukraine. **Table 12** shows the sourcing and procurement challenges of crude oil in India.

Table 12. Sourcing and Procurement Challenges in India and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Sourcing and Procurement Challenges of Crude Oil Industry in India	<ul style="list-style-type: none"> • High Capital costs. • Physically demanding environment. • Deficit of requisite Talent. • Ensuring accessibility, availability and remaining cost 	(Asati, 2021); (India Russia Oil Trade, 2022); (The new challenges of the Oil and gas Industry, 2016); (Mishra R., 2021)	<ul style="list-style-type: none"> • Optimising exploration and production volumes. • Ensure transparency in environment management. • Engaging well trained and spirited human resource. • Ensure digitalisation and

	<p>effective while adopting de-carbonisation.</p> <ul style="list-style-type: none"> • Hike in oil prices due to Russia Ukraine conflict. • Rising global oil demand. 		<p>technological advancements in operations.</p> <ul style="list-style-type: none"> • Competitive energy sourcing. • Sourcing oil from Brazil under a mutually benefiting trade agreement. • Prevent any unplanned shutdown, increase throughput and secure industrial assets. • Maintain dependable diplomatic relations with OPEC countries and keep a distant sight on Iran and Venezuela. • Proposal to form a joint venture of all interested oil PSUs to afford flexibility of importing and refining.
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Compiled by: Surinder Kumar and Neeraj Anand

5.9 Environmental/Climate Change Challenges in Crude Oil sourcing

Oil slicks, damaged land, disasters, and fire occurrences of air and water pollution are adverse environmental impacts of crude oil exploration and production. Most oil companies avoid the high expense of managing waste and contaminants produced by crude oil. Releasing contaminants into water bodies or scattered on open grounds is a threat to the survival of plants and animals. Oil exploration, production, and development come under category ‘A’ in the schedule of Environment Impact Assessment (EIA) notification 2006, requiring advance environmental clearance from the government (Das, 2014). Pollution control strategies in the petroleum industry are both preventive and reactive. The preventive approach includes prevention and reduction, recycling and reuse, treatment, and disposal. Environmental Challenges and their mitigation strategies are shown in **Table 13**. Preventive environmental management tools are shown in **Table 14**.

Table 13. Environmental Issues in Crude Oil Supply Chains and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Environmental concerns in oil sourcing and supply chains	<ul style="list-style-type: none"> • Climate change. • Noise pollution during production and vehicular movement. • Emission of volatile organic compounds. • Fear of accidental leaks. • Contamination of soil and surface water. • Labour safety concerns. • Release of toxic organic and inorganic pollutants. • Gas flares giving off harmful gases. • Acid rains damaging vegetation. 	(Noor, 2021); (Das, 2014); (Sojnu, 2018); (Technical EIA Guidance Manual, 2010); (A renewable energy future for India, 2016)	<ul style="list-style-type: none"> • Use of best practices in E&P activities. • Monitoring of well drilling and workover operations. • Effective preventive maintenance of equipment. • Adhering to regulations on crude oil production. • Environment units to mitigate environment risks. • Focus of renewable sources of energy. • Disposal of hazardous waste. • Imposing penalties for non-adherence of norms. • Increase use of electricity.

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Table 14. Preventive Environmental Management Tools

Management Based Tools	Process Based Tools	Product Based Tools
<ul style="list-style-type: none"> • Environmental Management System • Environmental Performance Evaluation • Environmental Audit • Environmental Reporting and Communication • Total Cost Accounting • Law and Policy • Trade and Environment • Environmental Economics 	<ul style="list-style-type: none"> • Environmental Technology Assessment • Toxic Use Reduction • Environmentally Best Practices • Best Available technology • Waste Minimisation • Pollution Prevention • Cleaner Production • 4-R Concept • Cleaner Technology 	<ul style="list-style-type: none"> • Industrial Ecology • Extended Producers Responsibility • Eco-labelling • Design for Environment • Life Cycle Assessment (LCA)

Source: Technical EIA Guidance Manual, Ministry of Environment and Forests, 2010

5.10 Impact of Restricted Oil Refining Capacity on Oil Supply Chains

Rising demand for petroleum products vis-à-vis concentration of oil reserves in a few geographical areas poses challenge for refining industry. India’s consumption of oil is likely to jump from 5 MBPD in 2017 to 9 MBPD or 472 million tonnes (MT) in 2040. Its existing refining capacity of 249.9 MT per annum shall not be suffice and it needs to boost its refining capacity to 450-500 MT per annum by 2030. This shall include expansion of existing refineries and construction of new ones. A mega refinery complex costing US\$ 44 billion in collaboration with Saudi Arabia and UAE is also planned to be built (Paraskova, 2020). Most refineries face high impact challenges in relation to variability, quality and reliability.

Table 15. Oil Refining Capacity Impacting Crude Supply Chain and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Impact of Shortage of Oil refining Capacity in India	<ul style="list-style-type: none"> • Delay in acquiring land for construction of a refinery. • Increasing crude and feedstock variability. • Monitoring environmental and product quality regulations. • Maintaining equipment reliability. • Lack of pipeline infrastructure. • Transportation challenge. • Corrosion and fouling of equipment. • Cost of operating refinery. • End to end visibility. • Unpredictability in supply chain due to multiple stakeholders. 	(Paraskova, 2020); (Zurlo, 2016); (Valand, 2014)	<ul style="list-style-type: none"> • Quick identification and interpretation of crude oil property. • Adapting to changing operating conditions. • Compliance to air and water quality regulations. • Controlling emissions. • Eliminate smoking flares. • Setting rigorous vehicle emission standards. • Minimise equipment fouling to reduce operating costs. • Improve downstream operations. • Improved system monitoring and predictive analytics to enhance equipment reliability. • Need to invest in capacity expansion. • Implement best practices to optimise supply chains.

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5.11 Import Challenges Impacting Sourcing and Supply Chains of Crude Oil

The growing volume of crude oil imports has been necessitated due to the rapid economic growth that India has been witnessing. Any political or social volatility in the Persian Gulf region (volume risk) may impede imports (India's Oil Imports: Trends in Diversification, 2022). Another risk includes price rises as a result of a reduction in supply or international sanctions against oil procurement from specific countries such as Iran and Venezuela. Table 11 depicts the import challenges faced by India in crude Oil sourcing.

Table 15. Import Challenges Impacting Sourcing of Crude Oil and its Mitigation Strategies

Issues / challenges	Variables	Source	Mitigation Strategies
Import challenges faced by India in sourcing and supply chains of crude oil.	<ul style="list-style-type: none"> • Volume risk as bulk of imports take place from Middle East countries. • Price risk on account of global oil price volatility. • Sanctions against specific countries. • Rise in commodity prices leading to inflation due to unstable oil supply from oil producing nations. 	(India's Oil Imports: Trends in Diversification, 2022);(Shift towards Gas Based Economy, 2020); (Jayaswal, 2022)	<ul style="list-style-type: none"> • Diversification of oil import basket. • Acquisition of oil assets around the world. • Policy reforms to revive E&P Ecosystem. • Reducing crude oil imports. • Investing in evolving renewable energy projects. • Switching towards a gas-based economy. • Strengthening of public transport systems and an early transfer to EV. • Lifting of sanctions on Iran allowing it to export oil. • Intensified accumulation of oil and increasing the SPR. • Major oil importing nations to check price volatility.

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VI. REDESIGNING ENERGY SOURCING AND SUPPLY CHAINS TO IMPLEMENT FUTURE ENERGY SECURITY

6.1 As per India Energy Outlook 2021, industrialising economies are going to witness the largest escalation in energy demand in the coming twenty years. India shall have to deal with several challenges with respect to energy security. Insufficient domestic production, dependency on imports rising above 90% by 2040, and possible supply disruptions are some of them (India has the opportunity to build a new energy future, 2021). Government initiatives and energy changeover policies can fast-track its energy security objective. India's economic growth is sharply tied to fluctuating international price of oil. Some of the significant challenges to India's energy security (Energy Security, 2019) are as follows: -

- Failure to attract foreign investment in domestic exploration.
- Cumbersome Regulatory and Environmental clearances.
- No foreign built reactors in spite of Indo-US nuclear agreements.
- Approximately 304 million Indians lack access to electricity and another 500 million depend on solid biomass for cooking.
- Poorly developed infrastructure for developing conventional and unconventional energy.
- Limited transportation infrastructure to make energy accessible.
- Increasing import bill on account of inadequate domestic supply of hydrocarbons.
- Need to deal with rapidly altering geopolitical environment.
- China's one belt one road project can disturb India's access to energy.
- Failure of IPI (Iran-Pakistan-India) and TAPI (Turkmenistan-Afghanistan-Pakistan-India) gas pipelines.

6.2 As part of *Atmanirbhar Bharat Vision* the roadmap for energy security involves hastening attempts to transition towards a gas-based economy, cleaner use of fossil fuels, higher dependency on bio fuels, aiming to achieve renewables objective of 450 GW by 2030, inching towards alternate fuels such as hydrogen, hydro power, biomass energy, solar power, wind power, nuclear energy and adaptation to digital technology across all energy systems (Shift towards Gas Based Economy, 2020).

6.3 Some initiatives to ensure continuity in energy supply chains are proposed as follows: -

- Initiating energy effectiveness standards at all levels.
- Addressing regulatory issues to increase domestic production of coal.
- Elevate refining and exploration infrastructure to match the demand.
- Set up additional strategic petroleum reserves.
- Boost energy cooperation in the neighbourhood and capitalise on India US nuclear deal.
- Encourage renewable energy.

6.4 Valued at US\$ 220.1 million in 2020, the Electric Vehicle Market in India is anticipated to grow at a compound annual growth rate (CAGR) of 94.4% from 2021 to 2030. To be a global leader India requires to invest funds in fields such as research and development, production of affordable lithium-ion batteries and governance of raw material supply chain (India could lead in EV Market growth, 2022). Dependence on other countries for the raw material shall have to be reduced by securing local supply chains.

VII. CONCLUSION

7.1 High volatility in the global markets, hiking of interest rates by the United States Federal Reserve, fluctuating crude oil prices, early trends of a possible recession in the global economy, turmoil in the geopolitical arena clubbed with ever-rising conflict of interests among major nations and lower GDP growth rates have dumfounded the crude oil sourcing and supply chains the world over. In the long run, the oil industry needs to strengthen its resilience and flexibility in a rapidly changing energy scenario. The supply of crude oil has met with sizeable hurdles due to several routes becoming inoperative on account of the Ukraine conflict. Given the uncertainty and unrest, institutions operating the supply chains must initiate realistic steps to reduce risks and diminish the rush of rising prices and energy deficiency.

7.2 A calculable hiatus in global oil demand on account of a stretched-out pandemic followed immediately by the Ukraine crisis has redefined the government's outlook to fasten up transitions towards more sustainable energy alternatives. Therefore, an effective and orderly transition will be paramount not only to achieving international climate targets but also to arrest serious supply disruptions and price volatility along the way. India needs to expand and reinforce its local resource base, trading imported fuels with home-bred fuels and de-controlling the cost of petroleum products to minimise its import dependence (Ghosh, 2009).

VIII. DIRECTIONS FOR FUTURE RESEARCH

The present study has identified the sourcing of crude oil in India and numerous issues and challenges impacting its supply chains. India's rapidly growing energy demands are not in commensurate with its domestic production. In addition, the price volatility has only resulted in bloated import bills and a current account deficit. With China's growing dominance and influence to secure its energy requirements the pressure on India is real. The government's policies with regards to enhancing domestic production, enhancing the refining capacity, and addressing environmental interests are initiatives in the positive direction. The rapid deterioration of vintage supply chain models is also a critical issue. While the pandemic witnessed congested ports, overpriced cargo capacities, and emergency shipments, the Ukraine conflict contributed to the closure of product lines, transport disruptions, and skyrocketing input costs (Alicke, 2022). Measures to streamline supply chain operations with an aim to achieve structural resilience is an important field for further research. Supply chains will continue to face impediments in the future warranting even more innovations and evolutions in supply chain management. Extensive research in building intelligent and sustainable sourcing has gained importance in recent times (Axsom, 2022). Redesigning new supply chains as a result of adaptation and greater reliance on renewable sources of energy, transition to EV, enhanced awareness and radical policy shifts that shall help India reduce its dependency on crude oil and bring down carbon emissions (Malik, 2019) is also an exciting area warranting more research. An exhaustive understanding of these issues shall pave the way toward India's future energy security as all roads to successful global clean energy transitions go via India.

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