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Advancing Bahrain's Energy Sector: Insights into the BAPCO Modernisation Programme (BMP)

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ABSTRACT

The Bahrain Petroleum Company (BAPCO) has played a key role in the Kingdom of Bahrain's industrial and economic growth since its establishment. The BAPCO Modernization Programme (BMP) represents a major step toward ensuring the long-term sustainability and competitiveness of the country's energy sector. This report outlines BMP's objectives, implementation, financing structure, and projected impact. With an investment of USD 7.3 billion, BMP increases refining capacity to 405,000 barrels per day, enhances energy efficiency, and incorporates improved environmental compliance measures. The program is expected to drive economic growth by increasing exports and strengthening Bahrain's position in global energy markets. Strategic post-modernization efforts such as digital transformation, workforce upskilling, and petrochemical integration are fundamental in ensuring the refinery's long-term competitiveness. This report concludes by recommending the enhancement of petrochemical integration and value-added industries, accelerating digitalization and AI implementation in refining operations, expanding renewable energy integration, and investing in the development of a skilled, future-ready workforce.

Table of Contents

Abstract.....	1
Executive Summary	4
Introduction	5
1. Overview of the BMP	6
1.1. BMP Initiative and Implementation	6
1.2. Rationale Behind the Project.....	8
1.3. Financing Structure and Approach.....	10
2. Future Outlook.....	12
2.1. Projected Outcomes and Impact	12
2.2. The Next Step Forward: Refinery-to-Petrochemical Integration.....	15
2.2.1. Bahrain’s Strategic Move	15
2.2.2. Refinery-Petrochemical Integration in the GCC	19
2.2.3. GCC’s Economic and Strategic Gains from the Integration.....	21
2.3. Critical Sustainability and Post-Modernization Considerations	23
Conclusion	26

EXECUTIVE SUMMARY

The energy sector has played a fundamental role in Bahrain's economic and social transformation, marked by the establishment of the Bahrain Petroleum Company (BAPCO) in 1929, where it was initially formed by the Standard Oil Company of California (SOCAL). The BAPCO Modernization Programme (BMP), one of the largest industrial investments in Bahrain's history, aims to increase refining capacity, improve product quality, and enhance energy efficiency while aligning with Bahrain's Vision 2030 and climate commitments. This report explores BMP's objectives, implementation, and projected impact .

BMP has initially targeted increasing refining capacity from 267,000 to 380,000 barrels per day (bpd), in addition to integrating advanced processing technologies to enhance energy efficiency and environmental compliance. After a year from the inauguration of the project, the capacity was further increased to 405,000 barrels per day. The project's financing was structured through a mix of conventional and Islamic financial instruments, with USD 4.1 billion secured in project debt financing. BMP is expected to generate several economic benefits, including increased export revenues and enhanced competitiveness of Bahraini petroleum products in international markets.

Beyond modernization, the report highlights the necessity of post-BMP strategies, including digital transformation, AI-driven refinery optimization, and workforce upskilling. Sustainability remains a critical focus, with BMP incorporating emission reductions, renewable energy integration, and circular economy principles. Future growth opportunities include petrochemical integration, which can maximize economic returns by shifting toward value-added chemical production.

The long-term success of BMP depends on continued evaluation, industry partnerships, and policy alignment to ensure Bahrain's refinery sector remains competitive in a rapidly evolving global energy landscape. Future studies assessing BMP's impact on employment, trade, and environmental performance will provide valuable insights for policymakers and industry stakeholders.

INTRODUCTION

The energy sector has been at the heart of Bahrain's development progress, propelling the country's rapid social and economic transformation. The discovery of oil in 1932¹ marked the beginning of the country's evolution into a modern industrialized nation, enabled by the establishment of the Bahrain Petroleum Company (BAPCO), initially formed by the Standard Oil Company of California (SOCAL) in 1929². As Bahrain's flagship energy company, BAPCO played a pivotal role in driving industrial growth and shaping the national economy. Figure (1) below shows the refinery in its early days during the 1970s.

Over the decades, BAPCO undertook several initiatives to enhance operational efficiency and economic resilience. Key projects included modernizing refining technologies, adopting cleaner production processes, and upgrading existing infrastructure³. These initiatives established the basis for the BAPCO Modernization Programme (BMP), a project aimed at ensuring the company's long-term sustainability, while reinforcing the country's resources through diverse policies and comprehensive strategies⁴. BMP entails increasing refining capacity, enhancing product slate, and improving energy efficiency, in alignment with Bahrain's Vision 2030⁵. This report aims to outline the BMP initiative, its implementation, and the future outlook for this project. By highlighting modernization in Bahrain's energy sector, this report aims to explore investments and value-adds for continuous growth and sustainability.

¹ Bapco Refining, "About Us," Bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/history/#h1930>.

² Bapco Refining, "About Us," Bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/history/#h1920>.

³ Bapco Refining, "مشروع تحديث مصفاة شركة بابكو للتكرير" (lecture, Bahrain Economists Society, Bahrain, February 10, 2025).

⁴ Ibid.

⁵ Bapco Refining, "Bapco Modernization Programme (BMP)- Introduction," Bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/introduction/>.



Figure 1: Aerial image of the refinery in the 1970s (Source: Bapco.net)

1. OVERVIEW OF THE BMP

1.1. BMP Initiative and Implementation

The BAPCO Modernization Programme (BMP), depicted in Figure (2), is one of the largest strategic industrial expansions in Bahrain, and an important milestone in BAPCO's history. Located in the vicinity of the existing refinery, BMP entails increasing refining capacity from 267,000 to about 405,000 barrels per day (bpd), while considering modern market demands and conditions^{6,7}. By revising refinery configuration to allow for higher production rates, BMP targets reinforcing the product portfolio with higher value products. This approach aims to enhance the company's resilience to market fluctuations and uncertainties, while concurrently increasing gross margins. BMP also aims to improve the refinery's energy efficiency and environmental compliance by installing modern processing units, providing the company with a competitive edge⁸.

⁶Bapco Refining, "Bapco - Bapco Modernization Programme (BMP)," www.bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/introduction/>.

⁷Bapco Refining, "Bapco Modernization Programme (BMP) – FAQ's," www.bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/faqs/>.

⁸ Ibid.



Figure 2: BMP project during the construction phase (Source: Bapco.net)

The project involves replacing some of the oldest units in the refinery with more efficient ones, operating in conjunction with other remaining viable units. This requires several changes and development at the Sitra Tank Farm, Sitra Wharf and the transfer pipelines between the refinery and the Sitra facilities⁹. Figure (3) highlights the location of the BMP in reference to existing infrastructure.

In compliance with local regulations, these upgrades aim to address a variety of environmental concerns, with targets including 50% reduction in SO_x emissions, 50% reduction in seawater consumed per barrel, and 9% reduction in treated wastewater discharge^{10,11}. To achieve these objectives, BMP utilizes an Emission Monitoring System (EMS) on all air point-source emissions, including a Predictive Emission Monitoring System (PEMS) and a Continuous Emission Monitoring System (CEMS)¹². PEMS focuses on providing predicted emissions using measurements from different sources on a one-minute frequency based on mathematical models, while CEMS measures emissions on a continuous basis.

⁹ Ibid.

¹⁰ Ibid.

¹¹ Bapco Refining, "Bapco Modernization Programme (BMP) - Environment," www.bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/bmp-environment/#bmp-environment>.

¹² Ibid.

During the process of developing the BMP, more than 50 environmental and social studies have been conducted, detailing mitigation measures and management plan¹³.

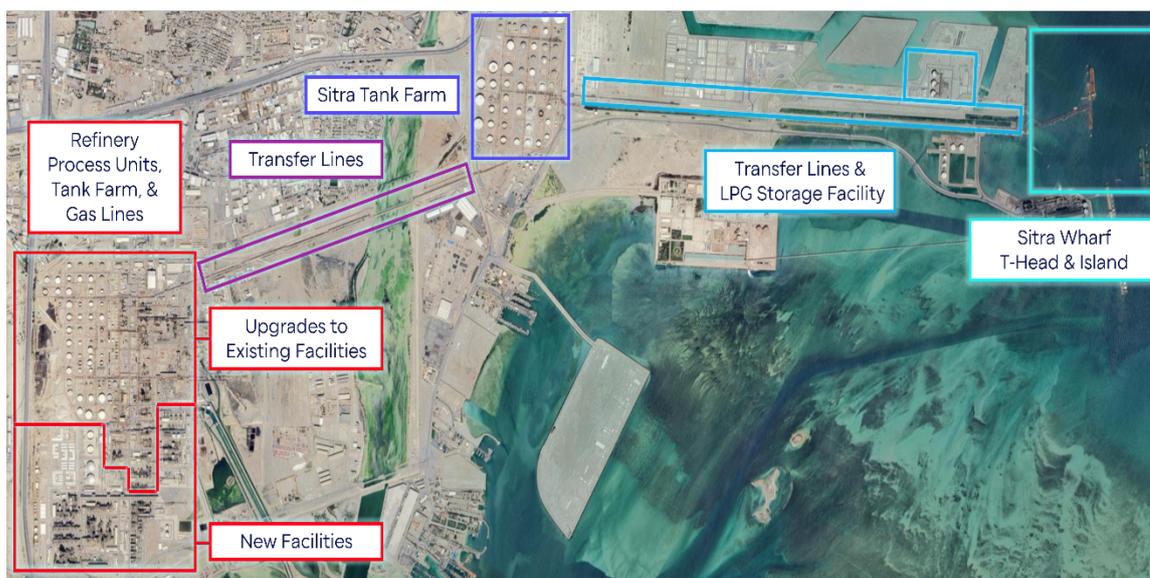


Figure 3: Map of BMP project (Source: Bapco Refining, 2025)

1.2. Rationale Behind the Project

The BMP is set to enhance Bahrain's economy by contributing to gross domestic product (GDP) growth, energy sector competitiveness, job creation, and foreign investment attraction. By expanding output capacity and improving efficiency, the project directly strengthens the energy sector's contribution to GDP. The energy sector is an essential input in Bahrain's national economy, with the extraction of crude petroleum and natural gas, and manufacturing activities accounting for around 29.9% of the GDP in 2023¹⁴. Higher refinery production leads to higher performance in the manufacturing sector nationally. For example, some analyses indicate that increased refinery output contributed to a 4.2% growth in Bahrain's manufacturing GDP in the third quarter of 2024¹⁵.

¹³ Bapco Refining, "Bapco Modernization Programme (BMP) – FAQ's," www.bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/faqs/>.

¹⁴ This value is calculated based on the following source: Tamkeen, "Energy Sector - Skills Report 2024," 2024, <https://www.tamkeen.bh/wp-content/uploads/2024/10/Energy-Sector-Report-English.pdf>.

¹⁵ International Finance Business Desk, "Bahrain's GDP Grows by 2.1% in Q3 2024," International Finance, January 10, 2025, <https://internationalfinance.com/economy/bahrains-gdp-grows-driven-non-oil-sectors-and-digital-advancements/>.

While volatility in global petroleum product pricing presents risks, it also underscores the urgency of proceeding with refinery upgrade. In an era of heightened capital discipline¹⁶, timing becomes critical and delaying modernization could expose Bahrain to prolonged reliance on lower-value outputs that are increasingly uncompetitive. This proactive approach positions Bahrain to withstand price fluctuations while capturing long-term gains from value-added petrochemicals. Section 3.1 below further details the expected economic impact, showing how product pricing dynamics reinforce the case for the timely investment in BMP.

Aligning with the country's Vision 2030, BMP targets diversifying the energy portfolio, thereby enhancing Bahrain's economic competitiveness in the sector¹⁷. By converting more bottom-of-the-barrel heavy residues into higher-value fuels and petrochemical feedstocks, BMP aims to improve BAPCO's product slate and profit margins¹⁸. This ensures strategic market positioning of the company, maintaining the refinery's resilience under various market scenarios and uncertainties. Investing in petrochemicals and higher-value products serves as a buffer against the inherent volatility of energy markets. The refinery's upgraded technologies further enhance market competitiveness by enabling the fulfilment of stricter environmental standards and the refining of a wider array of crude oils efficiently.

BMP is also expected to have a significant socioeconomic impact, mainly through employment opportunities and training initiatives. The project created around 750 job opportunities, and several national entities were engaged in BMP's implementation throughout all phases of execution¹⁹. Upon commissioning, the modernized refinery is prioritizing the employment of Bahraini nationals in technical and leadership roles, with over 500 Bahraini engineers set to oversee and manage the new processing units²⁰. Beyond the refinery gate, the BMP stimulates indirect employment across the economy. Local service

¹⁶ International Energy Agency, *Oil 2025: Analysis and Forecast to 2030* (Paris: International Energy Agency, 2025), accessed August 20, 2025, <https://iea.blob.core.windows.net/assets/c0087308-f434-4284-b5bb-bfaf745c81c3/Oil2025.pdf>.

¹⁷ Bapco Refining, "His Majesty Inaugurates the Bapco Modernization Project," Bapco.net, December 19, 2024, <https://www.bapco.net/en/news-article/his-majesty-inaugurates-the-bapco-modernization-project>.

¹⁸ Bapco Refining, "Bapco Modernization Programme (BMP) – FAQ's," www.bapco.net, accessed February 25, 2025, <https://www.bapco.net/en/page/faqs/>.

¹⁹ Bapco Refining, "مشروع تحديث مصفاة شركة بابكو للتكرير," "المزايا الاقتصادية" (lecture, Bahrain Economists Society, Bahrain, February 10, 2025).

²⁰ Bapco Energies, "His Majesty the King Inaugurates the Bapco Modernization Project," December 18, 2024, <https://bapco-phase2.objects.frb.io/Press-Release-BMP-Launch-Dec-19-English-Clean.pdf>.

providers, suppliers, and manufacturers have benefited from the surge in demand for goods and services tied to the project, from civil works and transportation to catering and equipment supply²¹. The project was executed by a global consortium of engineering firms in partnership with local companies²². This brought an influx of foreign capital, technology, and expertise into Bahrain, as these international contractors established operations on the ground, hired local subcontractors, and transferred know-how. The success of this collaboration is highlighted as a model public-private partnership. Figure (4) below shows the BMP as an expansion to the existing refinery, indicating the scale of the project.



Figure 4: Aerial image of BAPCO Refining and BMP (Source: Bapco.net)

1.3. Financing Structure and Approach

BMP is the largest capital investment in Bahrain's history, with an estimated cost of USD 7.3 billion^{23,24}. A multifaceted financing strategy was employed to support the project. BAPCO secured project debt financing facilities amounting to an aggregate of USD 4.1 billion²⁵. These

²¹ Bapco Refining, "مشروع تحديث مصفاة شركة بابكو للتكرير"،

المزايا الاقتصادية" (lecture, Bahrain Economists Society, Bahrain, February 10, 2025).

²² Robert Brelsford, "Bapco Lets Contract for Sitra Refinery Expansion, Revamp," Ogi.com (Oil & Gas Journal, December 4, 2017), <https://www.ogi.com/refining-processing/refining/optimization/article/17289325/bapco-lets-contract-for-sitra-refinery-expansion-revamp>.

²³ Bapco Energies, "Annual Report 2023," September 12, 2024.

²⁴ Bapco Energies, "BLP Sukuk 2023," December 8, 2024.

²⁵ Ibid.

facilities were formalized through agreements signed in December 2018 and achieved financial close in May 2019. The financing was structured as a limited recourse project financing, relying solely on BAPCO's cash flow generation for debt repayment and earmarked exclusively for BMP-related expenditures.

The BMP financing structure comprises a combination of conventional and Islamic facilities. This includes five export credit agency (ECA)-covered conventional loan facilities provided by regional and international commercial lenders, one uncovered conventional commercial loan facility, and a Shari'a-compliant financing facility structured as an Istisna-Ijara, offered by regional Islamic financial institutions. These facilities are secured by BAPCO's assets and agreements, which have been assigned to both offshore and onshore security agents. Additionally, the company has provided guarantees to mitigate risks associated with adverse domestic pricing changes under specific conditions²⁶.

The financing terms impose specific conditions on BAPCO's operations. The company's revenues are ring-fenced into accounts secured in favour of lenders, restricting dividend distribution until financial completion of the project. Once the project reaches completion, BAPCO will be permitted to distribute dividends, subject to meeting certain liquidity thresholds. The financing facilities are repayable in 25 semi-annual instalments, with the first instalment paid on April 27, 2023. The repayment period extends until mid-2035. Additionally, the terms of the BMP financing allow BAPCO to enter into unsecured working capital facilities, provided that the aggregate amount of such facilities, including finance and capital leases, does not exceed USD 450 million²⁷. The BMP funding structure, through a combination of senior long-term secure debt and equity, underpins BAPCO's efforts to modernize while ensuring long-term financial sustainability and operational resilience.

²⁶ Ibid.

²⁷ Ibid.

2. FUTURE OUTLOOK

2.1. Projected Outcomes and Impact

As one of the largest strategic projects undertaken by BAPCO, BMP is expected to have a significant impact on the company's operations and standings. The project is expected to increase refinery production capacity by 42%, while enhancing energy efficiency by 28%²⁸. The production of value-added products with lower environmental impact will allow the exposure of Bahraini petroleum products to wider international markets, enhancing their competitiveness.

BMP's anticipated economic impact is mainly positive, with expectations of driving sustainability and growth as a main source of exports and foreign exchange. The modernisation is expected to result in a significant rise in kerosene revenues, estimated at a scale of millions of dollars per day²⁹. This is mainly targeted through the allocation of 85% of the refined output allocated for export markets³⁰.

As indicated in Table (1) below, the refinery upgrade focuses on increasing high-value products such as kerosene and diesel. The production of naphtha is expected to increase by 110%, indicating the possibility toward increased petrochemical feedstock production. Similarly, the production of kerosene is set to rise by 90%, likely reflecting increased demand for jet fuel or heating fuel. Gasoline output will remain unchanged, which may indicate that the existing production is sufficient for market needs. On the other hand, fuel oil and asphalt production will be reduced, signalling a shift away from heavier, lower-value products due to environmental regulations and efficiency improvements.

²⁸ Bapco Refining, "مشروع تحديث مصفاة شركة بابكو للتكرير"، "المزايا الاقتصادية" (lecture, Bahrain Economists Society, Bahrain, February 10, 2025).

²⁹ Ibid.

³⁰ Bahrain News Agency, "Bapco Refinery Modernisation: Bahrain's Largest Strategic Milestone," www.bna.bh, December 19, 2024,

<https://www.bna.bh/en/ConstitutionalCourttoconsiderConstitutionalCase1/BapcoRefineryModernisationBahrainslargeststrategicmilestone.aspx?cms=q8FmFJgisl2fwIzON1%2BDqAaw19UkvVSfjpJaUnfhg0%3D>.

Table 1: Feedstock and production levels pre- and post- BMP (Source: *Bapco Refining, 2025*)

Feedstock and products	Existing Refinery (barrels/day)	Post-BMP Refinery (barrels/day)	Percentage change
Crude oil feed	267,000	380,000	+42%
Naphtha	36,978	77,821	+110%
Gasoline	20,000	20,000	0%
Kerosene	53,647	101,665	+90%
Diesel	93,310	160,893	+72%
Fuel oil	46,835	26,543	-43%
Asphalt	7,652	3,000	-61%

Inspecting the crack spreads³¹ of different refinery products for the year 2024 in Figure (5), high-value products, such as diesel (gasoil 10 ppm) and kerosene, are observed to maintain positive crack spreads. As profitable refining outputs, this provides sufficient justification for increasing their production in the BMP. Fuel oil (F.O. 380 cSt), on the other hand, is a weak performer, with crack spreads being mostly in the negative range. This aligns with BMP targets that aim to reduce the production of fuel oil by 43% .

Notably, naphtha has fluctuated significantly, with its spread remaining largely negative throughout the year. However, BMP aims to increase naphtha production by more than double. This decision supports the integration of refinery and petrochemical operations

³¹ Crack spreads are defined as differences between petroleum product prices and crude oil prices, which are often used to estimate refining margins. (U.S. Energy Information Administration, 2011)

where naphtha is a critical feedstock. Expanding petrochemical production has a significant impact on Bahrain’s various national targets, as detailed in the next section.

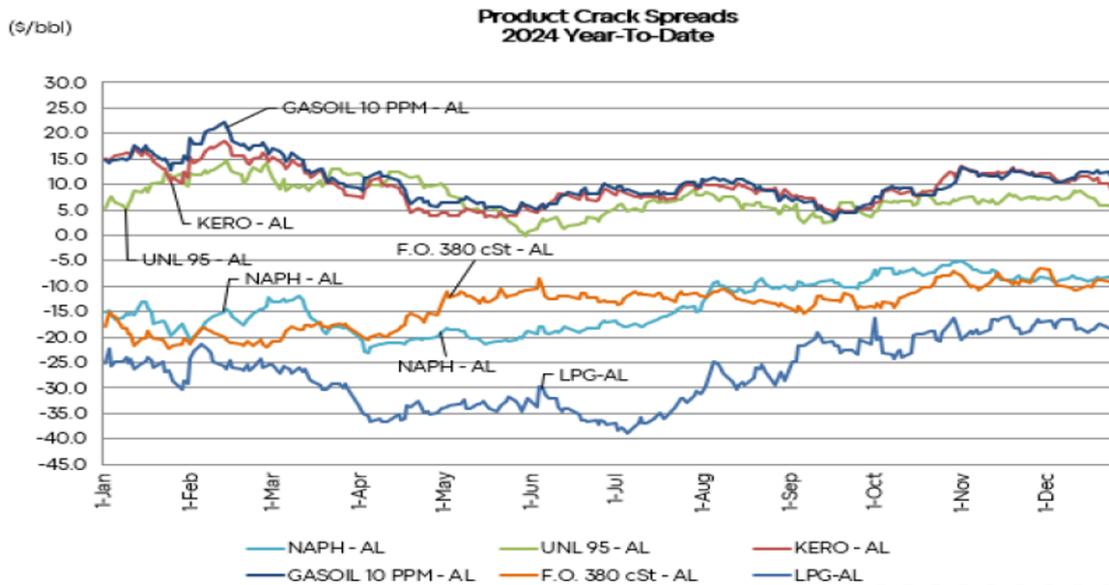


Figure 5: Crack spreads of different refinery products in dollars per barrel for the year 2024 (Source: Bapco Refining, 2025)

Further, the modernized facilities allow for importing crude oil by sea, which opens a new pathway for oil trade to maximize economic benefits in this domain. Literature findings suggest that studies have been conducted to analyse the role of crude oil selection in enhancing cost-effectiveness. A study by the University of Bahrain published in 2022, examined a nonlinear optimization model for a complex oil refinery, focusing on optimal crude selection and feedstock routing to maximize profitability³². By incorporating viscosity index modelling, the study demonstrates that strategic crude selection, by balancing paraffinic content, conversion rates, and product pricing, can improve margins by up to USD 1 million per day³³.

The latter also includes optimized pipeline utilization by maximizing the use of the existing crude oil pipeline capacity provided by Saudi Aramco³⁴. This aligns with international best

³² Lujayn Alsayooof and Mohamed Bin Shams, “The Role of Crude Oil Selection in Enhancing the Profitability of a Local Refinery with Lube Hydro-Processing Capacity,” *Chemical Engineering Research and Design* 185 (July 11, 2022): 146–62, <https://doi.org/10.1016/j.cherd.2022.07.002>.

³³ Ibid.

³⁴ Bahrain News Agency, “Bapco Refinery Modernisation: Bahrain’s Largest Strategic Milestone,” www.bna.bh, December 19, 2024, <https://www.bna.bh/en/ConstitutionalCourttoconsiderConstitutionalCase1/BapcoRefineryModernisationBahrainslargestsstrategicmilestone.aspx?cms=q8FmFJgiscL2fwIzON1%2BDqAaw19UkvVSfjpJaUnfhg0%3D>.

practices, demonstrated through continuous upgrades to logistic facilities. For example, the Port of Rotterdam in the Netherlands has witnessed several investments in the expansion of modern refineries, tank storage, and bioenergy facilities³⁵, whereas Jurong Port in Singapore has shown increased focus on utilizing monitoring technologies and digital twins³⁶.



Figure 6: Sitra Wharf (Source: Bapco.net)

2.2. The Next Step Forward: Refinery-to-Petrochemical Integration

2.2.1. Bahrain's Strategic Move

The integration of refinery and petrochemical industries represents the next strategic phase following the successful completion of the BMP project. This integration was intentionally embedded within the project framework to maximize value creation and optimize resource utilization. A notable example is the substantial 110% increase in naphtha production (Table (1)), a critical feedstock that supports petrochemical expansion. Despite its current negative economic valuation (Figure (5)), naphtha's integration within refinery operations enhances its overall economic potential, positioning it as a valuable input for downstream applications. As depicted in Figure (7), naphtha is the most commonly utilized liquid feedstock for petrochemical production.

³⁵ Port of Rotterdam, "The Port That Will Take You Ahead," Port of Rotterdam, accessed March 18, 2025, <https://www.portofrotterdam.com/en/why-rotterdam/port-will-take-you-ahead>.

³⁶ Terry Bills and Chris Fowler, "Singapore Port Implements a Digital Twin to 'Know Exactly What's Going On,'" Esri, October 22, 2024, <https://www.esri.com/about/newsroom/blog/singapore-jurong-port-jpglass-digital-twin>.

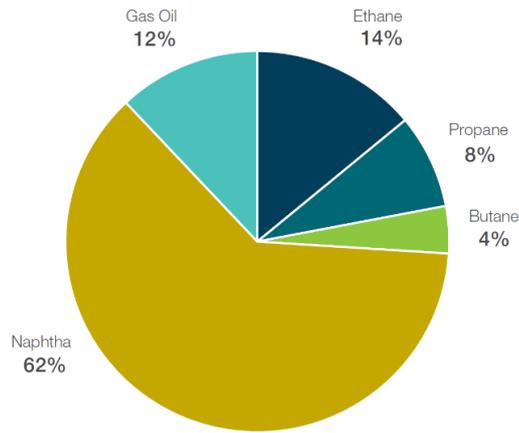


Figure 7: Global ethylene production by feedstock type (*Source: Nexant, GPCA, 2018³⁷*)

This integration is also essential for Bahrain’s economic and environmental positioning, particularly as the petrochemical sector is projected to account for a significant share of future oil demand growth globally, potentially reaching one-third by 2030 and nearly half by 2050³⁸. It shows the evolving role of the oil and gas industry, not as a declining sector but as one adapting to produce high-value-added products. By embedding environmental considerations into both production and consumption processes, these strategic investments align with national energy transition objectives while simultaneously reinforcing economic growth and long-term stability, since the price of petrochemicals is not directly affected by oil price fluctuations. As shown in Figure (8), aromatics margins (segment of the petrochemical industry) remain consistently positive, indicating a generally more profitable sector compared to refining. This is further reinforced by the International Energy Agency’s (IEA) forecast, which indicates that the growth in oil demand for petrochemical feedstocks remains consistently positive from 2022 to 2030, as seen in Figure (9).

Moreover, integrating an aromatics plant into a complex refinery enhances overall margins compared to standalone refining operations, regardless of market fluctuations, while also mitigating risks associated with both the refining and aromatics sectors³⁹. This underscores the economic advantages of an integrated petrochemical-refining system, which will be

³⁷ Nexant, GPCA, 2018. Advancing refining petrochemicals integration in the Arabian Gulf. Gulf Petrochemicals & Chemicals Association (GPCA).

³⁸ International Energy Agency. The Future of Petrochemicals: Towards More Sustainable Plastics and Fertilisers. Paris: IEA, 2018.

³⁹ Quintino, Antonio, Margarida Catalao-Lopes, and Joao Carlos Lourenco. "Can switching from gasoline to aromatics mitigate the price risk of refineries?" *Energy policy* 134 (2019): 110963.

positioning Bahrain for sustained industrial competitiveness and long-term economic resilience.

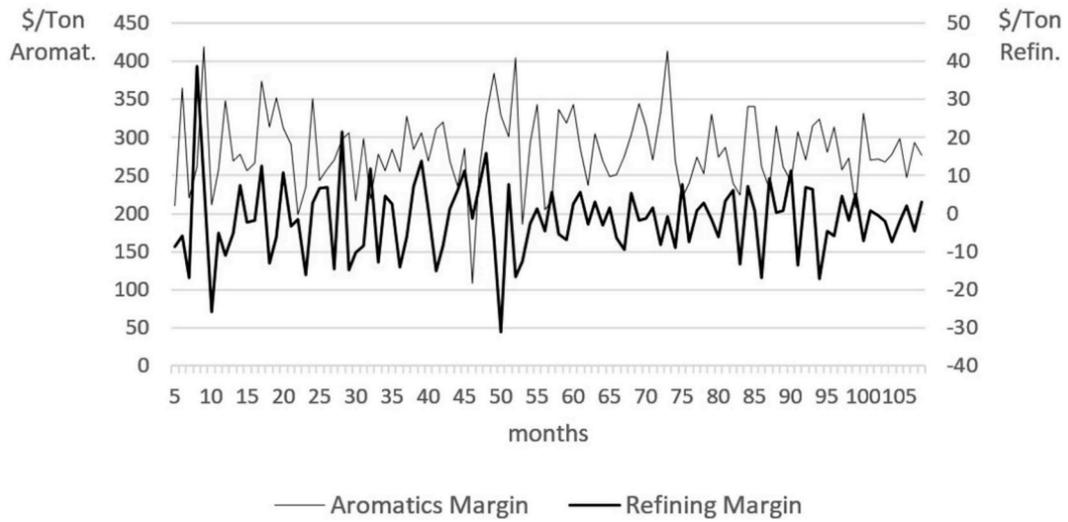


Figure 8 : Margins Volatility for Refining and Aromatics plant (Source: Quintino et al.,2019)

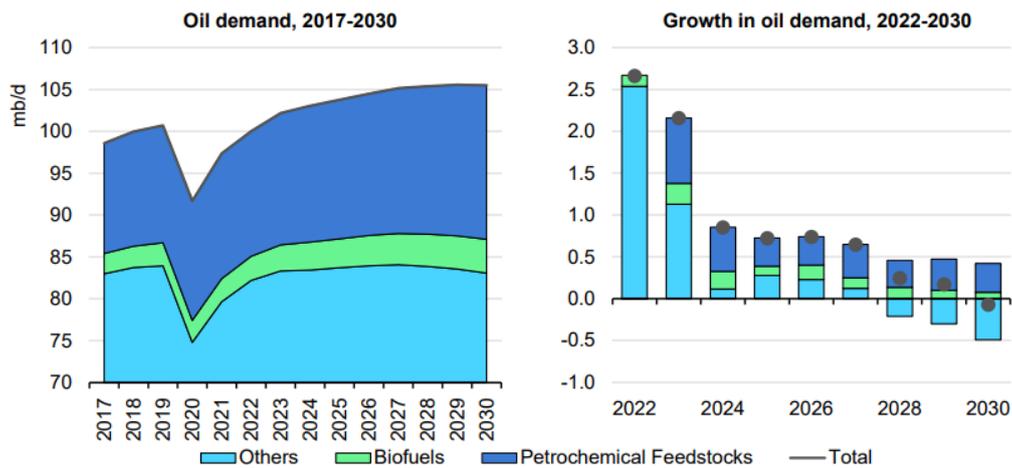


Figure 9: World oil demand forecast, expected to plateau this decade (Source: Oil 2025, IEA, 2025)

While aromatics integration represents a strategic pathway for BMP’s incremental naphtha output, alternative upgrade options can provide additional flexibility depending on market

conditions. This includes gasoline blending, isomerization to higher-value light products, or deeper fractionation into specific naphtha cuts^{40, 41}.

However, recent industry analyses emphasize the increasing importance of refinery- petrochemical integration as a strategy for enhancing profitability, resilience, and long-term viability. According to Wood Mackenzie⁴², over 30% of global refineries are now integrated with petrochemical operations, benefiting from diversified product portfolios and large-scale production capabilities. This trend is particularly evident in China, where second-generation integrated sites such as Hengli and Rongsheng achieve chemical yields exceeding 40%.

Further reinforcing this perspective, a joint report by the International Energy Forum (IEF) and S&P Global, published in 2023, concluded that large-scale integrated refining- petrochemical complexes have exhibited the highest resilience in recent years. The report highlights that as global fuel demand declines, refineries with petrochemical integration capabilities will emerge as the most viable, benefiting from increased operational flexibility and economies of scale⁴³. The financial benefits of such integration are well-documented, with empirical evidence illustrating its substantial impact on refinery profitability. For instance, Wood Mackenzie's analysis of Total's Gonfreville refinery demonstrates that incorporating olefins⁴⁴ and aromatics production led to a net cash margin increase of nearly USD 6 per barrel, translating into an estimated annual uplift of USD 560 million⁴⁵.

⁴⁰ Salman Raza Naqvi et al., "New Trends in Improving Gasoline Quality and Octane through Naphtha Isomerization: A Short Review," *Applied Petrochemical Research* 8, no. 3 (June 27, 2018): 131–39, <https://doi.org/10.1007/s13203-018-0204-y>.

⁴¹ George J. Antos and Abdullah M. Aitani, *Catalytic Naphtha Reforming, Revised and Expanded*, 2nd ed. (Boca Raton, FL: CRC Press/Taylor & Francis, 2004), e-book ed., Taylor & Francis e-Library, 2005, <https://doi.org/10.1201/9780203913505>.

⁴² Wood Mackenzie. "Energy Transition to Drive Refinery and Petrochemicals Integration." Press release, October 22, 2020. <https://www.woodmac.com/press-releases/energy-transition-to-drive-refinery-and-petrochemicals-integration/>.

⁴³ International Energy Forum and S&P Global Commodity Insights. *Oil Refining Industry Insights*. September 2022.

⁴⁴ Olefins are a type of chemical compound made from carbon and hydrogen, commonly used in making plastics, synthetic rubber, and other everyday materials

⁴⁵ Gelder, Alan. "How Much Value Does Refinery-Chemicals Integration Add for Total and Shell?" *Wood Mackenzie*, October 13, 2020. <https://www.woodmac.com/news/opinion/how-much-value-does-refinery-chemicals-integration-add-for-total-and-shell/>.

2.2.2. Refinery-Petrochemical Integration in the GCC

Refinery and petrochemical integrations are expanding across the Gulf Cooperation Council (GCC) countries, maximizing the value of crude oil by shifting its use beyond fuel production to petrochemical manufacturing. This shift enhances profitability and strengthens the region's position in the global chemicals market. Alongside economic benefits, these developments contribute to industrial diversification, reduce dependence on crude exports, and create employment opportunities in downstream industries, supporting sustainable economic growth.

Saudi Arabia has been steadily advancing this integration, developing large-scale projects to increase the value of its crude oil resources. Petro Rabigh, a USD 9.8 billion joint venture between Saudi Aramco and Sumitomo Chemical, was one of the first major initiatives, combining a 400,000 barrels per day (bpd) refinery with petrochemical production to supply key feedstocks for olefins and polymers⁴⁶. Similarly, SATORP, a USD 9–10 billion partnership between Saudi Aramco and TotalEnergies, operates a 460,000-bpd refinery that produces paraxylene, benzene, and propylene, highlighting the economic benefits of integration^{47,48}. Other projects, such as Sadara, a collaboration with Dow, focus on diversified chemicals, while expansions at Jazan and Ras Tanura support efforts to increase petrochemical output. Saudi Aramco's Crude-to-Chemicals (COTC) initiative further builds on this approach, aiming to convert 70–80% of each barrel into petrochemicals, with potential for even higher conversion rates in advanced configurations⁴⁹.

The United Arab Emirates (UAE) has also invested heavily in refinery-petrochemical integration, particularly through Ruwais Refinery and the Borouge Complex. ADNOC's refining capacity at Ruwais exceeds 817,000 bpd, and the company has committed USD 45 billion to expand its downstream operations⁵⁰. A significant aspect of this expansion is Borouge 4, a USD 6.2 billion project set to increase polyethylene production capacity from

⁴⁶ Cobley, Ben. "Rabigh Refining and Petrochemical Project." *IJGlobal*, March 29, 2006.

⁴⁷ TotalEnergies, "Saudi Arabia: Saudi Aramco and Total Sign a Memorandum of Understanding to Build a Giant Petrochemical Complex," TotalEnergies.com, April 10, 2018, <https://totalenergies.com/media/news/press-releases/saudi-arabia-saudi-aramco-and-total-sign-memorandum-understanding-build-giant-petrochemical-complex>.

⁴⁸ TotalEnergies. "SATORP: An Exceptional Partnership." Accessed March 10, 2025

⁴⁹ Saudi Aramco, "Crude Oil to Chemicals," Aramco.com, accessed May 13, 2025, <https://www.aramco.com/en/what-we-do/energy-innovation/advancing-energy-solutions/crude-oil-to-chemicals>.

⁵⁰ "Adnoc Downstream Expansion to Add Petchem Volumes." *Argus Media*, May 24, 2018.

4.5 million to 6.4 million tons per year by 2025. Additionally, ADNOC is developing a mixed-feed steam cracker, utilizing refinery naphtha and liquefied petroleum gas (LPG) to produce petrochemical feedstocks⁵¹. This integrated model allows the UAE to add value to its crude oil by producing polyethylene, polypropylene, and other petrochemicals for global export, reinforcing its position as a leader in the industry.

In Kuwait, the Al-Zour Refinery and PRIZe Petrochemical Complex represents one of the most ambitious integration projects in the region. With a total investment of USD 16.2 billion for the refinery, Al-Zour is now the largest grassroots refinery⁵² in the world, processing 615,000 bpd⁵³. The PRIZe complex, expected to be completed by 2026–2027, will produce 2.76 million tons per year of aromatics and polypropylene, significantly expanding Kuwait's petrochemical sector. The integration of petrochemicals with refining operations ensures greater economic returns, as the refinery's residue fluid catalytic cracker (RFCC) supplies propylene feedstock to an on-site polypropylene plant⁵⁴. This model optimizes feedstock utilization and also strengthens Kuwait's export capacity by supplying paraxylene for global polyester production and benzene for regional styrene plants.

Oman has also advanced its petrochemical industry by integrating the Sohar Refinery with the Liwa Plastics Industries Complex (LPIC), a project valued at approximately USD 7 billion. This integration has transformed Sohar into a significant petrochemical hub. The Sohar Refinery, originally designed to process 116,000 barrels per day (bpd), underwent the Sohar Refinery Improvement Project, which increased its capacity to 198,000 bpd^{55,56}. As part of this integration, LPIC includes a steam cracker capable of producing 800,000 tons per year of ethylene, which serves as a raw material for polyethylene and polypropylene production^{57,58}. Additionally, the Aromatics Oman complex, established in 2010, produces

⁵¹ Brelsford, Robert. "ADNOC, Borealis Advance Borouge 4 Petrochemicals Expansion." *Oil & Gas Journal*, November 17, 2021.

⁵² The "largest grassroots refinery" refers to the biggest newly built oil refinery, constructed from the ground up rather than expanded from an existing facility.

⁵³ Brelsford, Robert. "Kuwait's New Al-Zour Refinery Enters Commercial Operation." *Oil & Gas Journal*, January 9, 2023.

⁵⁴ "Project Highlight: KIPIC's PRIZe Refinery Integration." *The Energy Year*, October 7, 2024.

⁵⁵ OQ. "Expanding Polymer Horizons." Accessed March 13, 2025. <https://oq.com/en/expanding-polymer-horizons>

⁵⁶ Gulf Petrochemicals and Chemicals Association (GPCA). Oman Leverages Asset Integration and Green Hydrogen for Growth. Accessed March 13, 2025.

⁵⁷ ORPIC advances Omani ethylene plant." *Oil & Gas Journal*, July 16, 2014.

⁵⁸ CTCI Corporation. "CTCI Corporation Proud to Be Part of LPIC Project, Hydrocarbon Processing's Top Project Awards Winner." *CTCI E-Newsletter*, no. 466 (January–March 2021).

814,000 tons per year of paraxylene and 210,000 tons per year of benzene, utilizing refinery naphtha as feedstock⁵⁹. This integration enhances Oman's ability to maximize crude value by converting fuel products into high-demand plastics, boosting both export revenues and local manufacturing.

2.2.3. GCC's Economic and Strategic Gains from the Integration

The integration of refining and petrochemical operations in the GCC has emerged as a strategic approach to enhancing economic value, increasing market resilience, and improving global competitiveness. As expanding crude oil processing beyond fuel production to include petrochemicals allows these integrated facilities to yield higher revenue per barrel, thereby fostering economic diversification.

The GCC chemical industry, valued at USD 107.8 billion in 2022, marked a 12.4% increase from the previous year⁶⁰. This shift enables Gulf economies to capture more value from their natural resources, reducing reliance on crude exports while meeting the growing global demand for petrochemicals used in plastics, specialty chemicals, and advanced materials.

Beyond revenue growth, integration improves refinery profitability by allowing petrochemical units to absorb lower-value refinery byproducts. Using a process systems approach, a recent study at the University of Bahrain proposed a framework to help shareholders of oil companies and petrochemical firms identify the benefits and trade-offs of integrating oil refineries with petrochemical plant (ethylene production)⁶¹. The findings indicated that integrated plants were more profitable than non-integrated ones, primarily due to the efficient use of intermediates from both the oil refinery and the ethylene production plant. While both facilities benefited from reduced external feed purchases, the oil refinery experienced greater advantages in terms of production output and profitability. Oil companies are more likely to enhance their performance by integrating their oil refineries with ethylene production plants, rather than operating them independently. This flexibility

⁵⁹ "Omani paraxylene, benzene joint venture to start production by 2009 end." *Plastemart*, May 4, 2009.

⁶⁰ Gulf Petrochemicals and Chemicals Association. "GCC's Chemical Horizon: Unpacking 2022 and Navigating 2023." GPCA, December 26, 2023. <https://www.gpca.org.ae/2023/12/26/gccs-chemical-horizon-unpacking-2022-and-navigating-2023/>.

⁶¹ Khalid Qaied Al Anazi, *An Optimization Study for the Integration of an Oil Refinery and a Petrochemical Plant in the Middle East* (PhD diss., University of Bahrain, 2023).

enables refineries to pivot between fuel and chemical production depending on market conditions, as well as reducing financial risk. For example, SATORP refinery in Saudi Arabia, reported USD 2.4 billion in earnings in 2022, demonstrating the financial resilience that integration provides even during fuel market volatility⁶². Another advantage of refinery-petrochemical integration is enhanced feedstock security and efficiency, as it ensures a stable supply of raw materials while reducing imports and optimizing production. Oman's Liwa Plastics Industries Complex exemplifies this approach by utilizing refinery-produced naphtha and natural gas liquids (NGLs) to maximize polymer production while ensuring operational efficiency. The facility has increased polyethylene and polypropylene output to 1.4 million tons per year, including 838,000 tons of polyethylene and 215,000 tons of polypropylene, strengthening Oman's petrochemical capacity⁶³. The project ensures supply chain security through an NGL extraction plant in Fahud and a 300-kilometer pipeline to Sohar, securing a steady feedstock supply and reducing import dependence⁶⁴.

Furthermore, investments in refinery-petrochemical integration position GCC national oil companies (NOCs) as major players in the global petrochemicals industry, allowing them to compete with leading international firms such as ExxonMobil and Shell. This shift is evident in ADNOC's efforts to expand its petrochemical portfolio. In a major step, ADNOC and Austria's OMV announced a USD 60 billion deal to merge their petrochemical assets, creating Borouge Group International, which will become the world's fourth-largest polyolefins producer⁶⁵. Additionally, ADNOC's acquisition of Germany's Covestro for over USD 13 billion underscores its ambition to transform into a fully integrated energy company, following the model of global industry leaders⁶⁶. Such strategies enable GCC countries to enhance their market share and ensure long-term sustainability in an increasingly competitive energy sector.

⁶² Arab News. "Aramco-Total JV SATORP Ends 2022 with a \$2.4bn Profit." Arab News, March 23, 2023.

⁶³ Raffoul, Sarah. "Oman to Inaugurate \$7bn Liwa Plastics Project Next Week." *Argus Media*, December 12, 2021.

⁶⁴ UK Export Finance. "Liwa Plastics, Oman." *GOV.UK*, April 26, 2016. Accessed March 13, 2025.

<https://www.gov.uk/government/publications/category-a-project-supported-liwa-plastics-oman/liwa-plastics-oman>.

⁶⁵ Malcolm Moore and Ivan Levingston, "Adnoc and OMV Announce Deal to Combine Petrochemical Assets: Two Companies Say They Are Creating World's Fourth-Largest Group in Plastics Called Polyolefins," *Financial Times*, March 4, 2025, <https://www.ft.com/content/0a12bac2-e7f1-4512-a913-428e34f0b598>.

⁶⁶ Ben Dummett, "UAE's Adnoc Buys Germany's Covestro for \$13 Billion," *Wall Street Journal*, October 1, 2024, <https://www.wsj.com/business/energy-oil/adnoc-to-buy-germanys-covestro-for-13-billion-93dc344a>.

2.3. Critical Sustainability and Post-Modernization Considerations

While the modernization of BAPCO's refinery represents a milestone in Bahrain's energy sector, post-modernization success depends on implementing strategic initiatives that align with global best practices and industry innovations. This includes continuous enhancement of operational efficiency and performance optimization by testing and deploying emerging technological systems in control, predictive maintenance, and automation. Digital transformation is an imperative in the future of refining, depending mainly on real-time data monitoring and AI-driven analytics⁶⁷. For example, the utilization of Internet of Things (IoT) sensors, AI-based predictive analytics, and automated monitoring can improve efficiency, reduce operational risks, and optimize production cycles.

AI and analytics applications in refining will continue to evolve, enabling further optimization of refining processes through advanced data analytics, machine learning algorithms, and digital twins. AI-powered models can predict equipment failures before they occur, allowing for proactive maintenance and reducing unplanned downtime^{68,69}. A recent study by the University of Bahrain for a local refinery showed that utilizing machine learning algorithms allows for the detection of leaks in refinery heat exchangers up to 50 days in advance⁷⁰. This highlights the potential of leveraging data-driven techniques in refineries to enhance their capability for automatic leak detection and prompt resolution, thereby improving overall safety, operational efficiency, and compliance with regulatory standards.

Additionally, real-time AI monitoring of refining operations can help optimize crude oil blending, enhance yield prediction accuracy, and streamline regulatory compliance across

⁶⁷ Håvard Holmås et al., "Harnessing the Power of Data in Oil and Gas," BCG, March 22, 2023, <https://www.bcg.com/publications/2023/harnessing-the-power-of-data-in-oil-and-gas>.

⁶⁸ Abdulnaser M. Al-Sabaei et al., "Prediction of Oil and Gas Pipeline Failures through Machine Learning Approaches: A Systematic Review," *Energy Reports* 10 (November 1, 2023): 1313–38, <https://doi.org/10.1016/j.egy.2023.08.009>.

⁶⁹ Ganesh Shankar Gowekar, "Artificial Intelligence for Predictive Maintenance in Oil and Gas Operations," *World Journal of Advanced Research and Reviews* 23, no. 3 (September 2024): 1228–33, <https://doi.org/10.30574/wjarr.2024.23.3.2721>.

⁷⁰ Abdulrahim Mohammed and Mohamed Bin Shams, "Real-Time Framework to Detect Leaks in Industrial Heat Exchanger Networks," *Process Safety Progress*, May 3, 2025, <https://doi.org/10.1002/prs.12690>.

various processing units^{71,72}. For example, ExxonMobil, in partnership with Microsoft, utilized IoT and machine learning tools in the Permian Basin, USA, to reduce costs and increase production, with a goal of advancing toward closed-loop automation⁷³. The application of these technologies is estimated to support production growth by around 50,000 oil-equivalent barrels per day⁷⁴. Similarly, the Abu Dhabi National Oil Company (ADNOC) launched a joint venture company, AIQ, with Group 42 (G42), an Abu Dhabi-based AI and cloud computing company in 2020⁷⁵. The collaboration resulted in accelerating the deployment of artificial reality (AR) and automation solutions across ADNOC's oil fields⁷⁶. Deriving lessons from such international examples highlights how Bahrain can leverage digital transformation to further enhance refinery competitiveness in a data-driven global market.

Additionally, the modernization provides an opportunity to strengthen environmental sustainability and compliance, aligning with Bahrain's broader vision for energy transition. Despite BMP's advancements in energy efficiency and emissions reduction, refining operations remain carbon intensive⁷⁷. Ensuring alignment with Bahrain's 2060 net-zero target necessitates expanding emission control strategies, enhancing renewable energy integration, and optimizing water and waste management optimization.

A critical step in this transition is the adoption of renewable energy sources to power refinery operations. Electricity is essential in various refining processes, including units such as

⁷¹ Abdul Gani Abdul Jameel, "A Case Study on Integrating an AI System into the Fuel Blending Process in a Chemical Refinery," *ChemEngineering* 9, no. 1 (January 3, 2025): 4, <https://doi.org/10.3390/chemengineering9010004>.

⁷² Hamid Reza Hanif, "The Role of Artificial Intelligence in Optimizing Oil Exploration and Production," *EJCMR* 3, no. 5 (2024): 176–90, https://www.ejcmr.com/article_210864_5e5c481a5590952690c1c1ebbb4bf66.pdf.

⁷³ ExxonMobil, "Digital Technologies," ExxonMobil, 2024, <https://corporate.exxonmobil.com/who-we-are/technology-and-collaborations/digital-technologies>.

⁷⁴ ExxonMobil, "ExxonMobil to Increase Permian Profitability through Digital Partnership with Microsoft," ExxonMobil, February 22, 2019, https://corporate.exxonmobil.com/news/news-releases/2019/0222_exxonmobil-to-increase-permian-profitability-through-digital-partnership-with-microsoft.

⁷⁵ ADNOC, "ADNOC and Abu Dhabi-Based Group 42 Launch AIQ – an Artificial Intelligence Joint Venture Company," Adnoc.ae, October 7, 2020, <https://adnoc.ae/en/news-and-media/press-releases/2020/adnoc-and-abu-dhabi-based-group-42-launch-aiq-an-artificial-intelligence-joint-venture-company>.

⁷⁶ ADNOC, "ADNOC and AIQ Accelerate Deployment of Industry-First AR360 AI Solution," Adnoc.ae, October 17, 2024, <https://www.adnoc.ae/en/news-and-media/press-releases/2024/adnoc-and-aiq-accelerate-deployment-of-industry-first-ar360-ai-solution>.

⁷⁷ Liang Jing et al., "Carbon Intensity of Global Crude Oil Refining and Mitigation Potential," *Nature Climate Change* 10, no. 6 (June 2, 2020): 526–32, <https://doi.org/10.1038/s41558-020-0775-3>.

hydrocrackers, hydrotreaters, reformers, and fluid catalytic cracking (FCC)⁷⁸. By integrating solar and wind energy into the refinery's power supply, reliance on fossil-fuel-generated electricity can be reduced significantly. This leads to cutting emissions and improving sustainability metrics, in addition to heightening energy security. Chevron's Lost Hills oil field at the San Joaquin Valley Business Unit in the USA is a notable example on the integration of renewables in refineries. Around 80% of the field's annual energy demand is supplied by a 29MW solar plan, enabling Chevron to reduce consumption of grid power, lower its carbon intensity, and enhance compliance with local standards^{79,80}.

Beyond operational sustainability, petrochemical production is increasingly shaped by global environmental and regulatory pressures. Policies targeting plastic usage, commitments to circular economy models, and rising scrutiny of petrochemical carbon intensity are beginning to influence long-term demand trajectories. For Bahrain, aligning BMP with these shifts requires capturing the integration benefits of higher naphtha output, while also considering investments in recycling partnerships, bio-feedstock blending, and advanced materials research. Such forward-looking measures can help ensure the resilience of the refinery's future product slate in line with global sustainability mandates.

Intensifying emission reduction efforts, sustainable solutions, and social engagement further supports BAPCO's ESG goals, while providing the company with a competitive edge. This highlights an opportunity to cultivate a skilled and future-ready workforce. Long-term growth requires employee upskilling, AI training, and leadership development for the changing energy landscape⁸¹. Upskilling Bahrain's local workforce is essential to ensure that employees can fully leverage the potential of AI-driven refinery operations and digital transformation. Specialized training programs in industrial AI, data analytics, and process automation can empower workers to transition into more technology-oriented roles.

⁷⁸ Ernst Worrell and Christina Galitsky, "Energy Efficiency Improvement in the Petroleum Refining Industry," *ACEEE ACEEE Summer Study on Energy Efficiency in Industry* (2005): 158–69.

⁷⁹ Chevron, "Powering an Oil Field: Leave It to the Sun," chevron.com, May 5, 2022, <https://www.chevron.com/newsroom/2022/q2/powering-an-oil-field-leave-it-to-the-sun>.

⁸⁰ Chevron, "Powering the World Forward with California Sunshine," chevron.com, 2020, <https://www.chevron.com/newsroom/2020/q3/powering-the-world-forward-with-california-sunshine>.

⁸¹ Stephanie Del Carpio et al., "In Oil and Gas, the Energy Transition Requires a People Transition," BCG, October 14, 2022, <https://www.bcg.com/publications/2022/how-companies-can-succeed-in-their-low-carbon-future-efforts>.

Strengthening collaborations with academic institutions and research centres can further support this effort by aligning educational programs with industry needs.

BMP provides a basis to adopt a multi-faceted energy strategy post-modernization, focusing on efficiency, sustainability, digital transformation, and market expansion. Continued investment in workforce upskilling, research collaborations, and targeted policy frameworks can further strengthen BMP's national impact. This is essential in ensuring the agility and competitiveness of Bahrain's energy sector in an evolving global market. In addition, leveraging BMP as a catalyst for broader industrial innovation can create new economic opportunities beyond oil refining. To fully understand its impact, future studies evaluating the long-term impact of BMP on Bahrain's economy, employment, and trade balance will be valuable for policymakers and industry stakeholders.



Figure 10: A depiction of a sustainable energy landscape integrating solar, wind, and innovation in Bahrain (Source: ChatGPT)

CONCLUSION

The BMP represents a landmark investment in Bahrain's energy sector, reinforcing the nation's economic diversification and long-term sustainability. This report has provided an overview of BMP's objectives, financing, implementation, projected impact, and future considerations, demonstrating its role as a transformative project in Bahrain's industrial strategy. The program, with a USD 7.3 billion investment, is the largest industrial initiative in

Bahrain's history, set to strengthen Bahrain's exports, attract foreign investment, and create employment opportunities.

BMP incorporates several sustainability measures, including improved emission reduction and water management. The program's adoption of advanced monitoring technologies ensures regulatory compliance and environmental performance. AI-driven predictive maintenance, real-time data monitoring, and automation are critical in maximizing efficiency and optimizing production cycles. This also presents a key opportunity to invest in workforce upskilling in alignment with technological advancements in refinery operations.

In addition, BMP paves the way for refinery-to-petrochemical integration, leveraging the increase in naphtha production as a key feedstock for advanced petrochemical manufacturing. This aligns with regional trends seen in Saudi Arabia, UAE, Kuwait, and Oman.

In conclusion, to maximize BMP's long-term impact, this report recommends the following strategic actions:

1. Enhance petrochemical integration and value-added industries:
 - a. Establish refinery-to-petrochemical integration facilities to convert naphtha and other byproducts into high-value chemicals.
 - b. Expand investments in aromatics and olefins production.
2. Accelerate digitalization and AI implementation in refining operations:
 - a. Deploy AI-powered predictive analytics, machine learning models, and digital twin technologies to improve operational efficiency.
 - b. Leverage IoT sensors and real-time data monitoring to optimize refinery production, reduce energy consumption, and minimize emissions.
3. Expand renewable energy integration into refinery operations:
 - a. Utilize solar and wind energy to power refinery operations and meet net-zero targets.
 - b. Explore green hydrogen production as a long-term decarbonization strategy.
4. Develop a skilled, future-ready workforce:
 - a. Strengthen partnerships with universities and research institutions to provide specialized training in AI, data analytics, and automation.
 - b. Introduce national workforce upskilling programs to prepare engineers and technicians for next-generation refinery operations.

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