

Localization of Industrial Lubricants and Petroleum Product Supply Chains in Saudi Arabia's Oil and Gas Sector under Vision 2030.

Abstract

The Saudi initiative to localise its industry is now moving the procurement of oil and gas away from simple import substitution and towards the development of domestic capabilities. Industrial lubricants and other petroleum products serve as a good example since they involve regular demand alongside complex formulations, depend on imported additives, have to meet equipment approval requirements, and also have potential in the area of the circular economy. This study draws on peer-reviewed evidence published between 2020 and 2025 to look at where localisation can generate defensible value throughout the supply chain for lubricants and petroleum products and to identify the capabilities needed to ensure reliability, quality, and cost control. A structured integrative review of thirty studies verified by the DOI was carried out and the studies were coded according to feasibility of localisation, supplier capability, resilience, digitalisation, sustainability, and governance. The findings show that localisation should advance at an uneven rate along the value chain. Activities such as blending, packaging, laboratory testing, warehousing, providing field technical services, collecting used oil, and certain re-refining operations present relatively short-term opportunities, while advanced additive chemistry and special formulations need a much longer period for building up capabilities. The paper puts forward a four-stage maturity pathway for localisation which links anchor demand, qualification systems, technology transfer, workforce development, digital traceability, dual-sourcing, and circular recovery. Success in localisation should be judged by the presence of qualified domestic capability and lifecycle value, not just by the amount of procurement carried out locally. This approach brings together industrial policy, operational reliability, resilience, and environmental performance with Vision 2030.

1. Introduction

The economic transformation in Saudi Arabia focuses on industrial diversification, the creation of value within the country, the development of its workforce, and increasing the depth of its supply chains. In the context of its oil and gas economy, localization is important since the procurement networks involved are extensive, technically complex, and linked to key operating assets. Research into localized manufacturing in Saudi Arabia indicates that localization can contribute to industrialization if it is combined with the adoption of technology, the development of suppliers, and the establishment of production capabilities rather than simply replacing imported finished goods [3–5]. Moreover, the evidence from Saudi Arabia regarding supply-chain integration, resilience, digital transformation, and logistics also stresses that local capacity must be responsive, information-rich, and operationally strong [6–12]. Because of these requirements, industrial lubricants and other petroleum products provide a useful perspective for assessing how localization can progress from a policy goal to a real industrial capability.

Although lubricants make up a small volume compared to the amount of crude oil produced, they are disproportionately crucial for ensuring that equipment is available. Compressors, turbines, pumps, drilling systems, gearboxes, hydraulic circuits, transport fleets, and process equipment all depend on fluids that have the proper viscosity, oxidation stability, wear protection, tolerance to contamination, and compatibility. As a result, a disruption in the supply of lubricants can lead to consequences that go well beyond the cost of the lubricants themselves. The lubricant supply chain also includes separate stages such as the sourcing of base oils, the acquisition of additives, formulation, blending, quality control, packaging, storage, distribution, application engineering, condition monitoring, the collection of used oil, and re-refining. The fact that these stages are modular means that there are various points at which the chain can be localised, but the technical difficulty at these different points is not the same.

The current body of literature on petroleum supply chains points out sustainability, risk exposure, information fragmentation, and technology adoption as ongoing issues [14–18]. Studies in the oil

and gas sector also indicate that resilience and sustainability are influenced by supplier relationships, traceability, organizational coordination, and the ability to redesign material flows [19–25]. Research into lubricants is now more focused on longer fluid life, re-refining, renewable feedstocks, and environmental performance [26–30]. Although these areas provide useful insights, the literature as a whole remains fragmented. The studies carried out in Saudi Arabia usually deal with manufacturing or with the transformation of the supply chain in a general way, petroleum research seldom treats industrial lubricants as a specific category for localization, and lubricant research tends to stress tribology and environmental performance rather than the industrial-policy framework.

The review brings together three areas of evidence: the process of localizing and transforming manufacturing in Saudi Arabia; the resilience and sustainability of the petroleum supply chain; and current developments in the circularity of lubricants and products. It examines which activities lead to the development of strategically valuable capabilities in Saudi Arabia, identifies those which are limited by factors such as chemistry, scale, qualification, or intellectual property, and explores how a step-by-step approach can ensure that asset reliability is maintained while at the same time increasing domestic involvement. Localization is thus viewed as a portfolio of capability decisions spanning various time horizons rather than as a single procurement requirement.

2. Review Context and Conceptual Foundations

Localization is often simplified down to a purchasing ratio, even though such a measure can mask significant differences in industrial depth. A product might be bought from a local distributor even if its formulation, feedstocks, intellectual property, testing, and manufacturing are still carried out abroad. On the other hand, a product that is locally blended can still create real technical employment and develop process capabilities even if the additive packages it uses are imported. Studies of manufacturing in Saudi Arabia back up an approach that is focused on capability, in which local production, digital integration, supplier learning, and technology

absorption all support and strengthen each other [3–5]. The economically important question is not merely where the invoice is issued, but rather which knowledge, assets, quality systems, and decision-making powers are based within the country.

The chain of industrial lubricants is one that consists of petroleum products and has clearly defined technical limits. The base oils form the fluid base, and the additive systems carry out functions such as antiwear, detergent, dispersant, antioxidant, viscosity modification, corrosion protection, and others. The final performance is determined by the interaction of the various components, by the standards of manufacturing, by the need for contamination control, and by the requirements of the application. Since this is the case, the possibility of localisation differs at various stages: warehousing and packaging call for existing industrial capabilities; blending and quality-control laboratories require special process management; and the manufacture of proprietary additives together with the development of high-performance formulations call for chemistry, large-scale production, protected know-how, qualification records, and continuous research investment.

Resilience is the second factor. According to Saudi studies, resilience involves agility, robustness, flexibility, integration, and digital visibility [7–10]. Petroleum research identifies feedstock volatility, quality risk, market change, infrastructure interdependence, and coordination failures [14–19]. Although localization can reduce certain external dependencies, it may also increase risk if one domestic source replaces several qualified international sources. Localization and resilience are therefore complementary only when domestic capacity is coupled with qualification discipline, alternate sourcing, inventory policy, data visibility, and continuity planning.

The third pillar is lifecycle sustainability. Research into the decarbonisation of the oil and gas industry shows that environmental performance is becoming more closely linked with investment decisions, procurement practices, and operating strategy [1]. Studies on the circular economy indicate that petroleum waste streams can be turned into recoverable resources if the

technical and economic conditions allow [2,20]. Research concerning lubricants also points to the extension of drain life, the collection of used oil and its re-refining, as well as the use of less impactful feedstocks [26–30]. Circularity is thus not merely an additional environmental measure; it can lead to the creation of local feedstock loops, service businesses, technical jobs, and a reduced need for virgin materials.

3. Aim, Objectives and Review Questions

This review aims at establishing an evidence-based framework for localising the capabilities of the production and supply of industrial lubricants and petroleum products within Saudi Arabia's oil and gas sector in accordance with Vision 2030, while at the same time ensuring that technical performance, resilience, and lifecycle value are protected.

The analysis is guided by four objectives: identifying localization possibilities throughout the lubricant value chain; assessing the technical, organizational, digital, and sustainability capabilities that affect these opportunities; differentiating between localization pathways in the short, medium, and long term; and converting the findings into governance measures for operators, suppliers, investors, and policymakers.

The review looks at four questions. The first of these, RQ1, is concerned with identifying which lubricant and petroleum-product activities provide the best opportunities for localization at various stages of capability development. RQ2 investigates which technical and institutional capabilities determine whether a localized supply system can meet the requirements regarding reliability and qualification. RQ3 seeks to find out how localization can enhance resilience and sustainability without giving rise to new risks of concentration or of quality. RQ4 examines what governance structure is able to coordinate anchor demand, supplier development, technology transfer, human capital, digital traceability, and circular recovery.

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145 **4. Review Methodology**

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147 An integrative review based on a structured approach was chosen since the research problem
148 involves a range of literatures that use different units of analysis—namely, national industrial
149 localization, manufacturing transformation, petroleum supply-chain management, organizational
150 resilience, digital operations, the circular economy, and lubricant technology. A meta-analysis
151 could not have been used since the evidence consists of conceptual reviews, empirical surveys,
152 case studies, decision models, technology assessments, and sectoral analyses which have non-
153 comparable outcomes. The method in question focuses on transparent selection of the sources,
154 thematic coding, comparison across studies, and the synthesis of these into a framework that is
155 specific to the context.

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157 The time frame for the search was set to 2020–2025 so that it would include evidence relating to
158 the present stage of Saudi Arabia's industrial transformation and the redesign of its supply chains
159 after the pandemic. The search terms used were "Saudi Arabia", "Vision 2030", "localization",
160 "local content", "localized manufacturing", "oil and gas", "petroleum supply chain", "industrial
161 lubricants", "base oil", "supply-chain resilience", "digital transformation", "circular economy",
162 "used oil", and "re-refining". Where possible, scholarly records from Scopus and Web of Science
163 were given priority, while those from Google Scholar as well as from the publishers or via DOI
164 were used to verify the bibliographic information. Only records with a DOI were included in the
165 final set of references.

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167 The criteria for inclusion were articles or reviews written in English and published during the
168 specified time frame that made a direct contribution to at least one of the six areas: Saudi
169 localization, Saudi supply-chain capability, petroleum supply-chain management, oil and gas
170 sustainability, lubricant technology, or lubricant circularity. Whenever possible, publications
171 providing direct evidence about Saudi Arabia were given priority, but studies relating to the

petroleum and lubricant sectors were kept in those cases where there was not enough specialized research focusing on Saudi Arabia. Publications before 2020, non-peer-reviewed comments, studies that did not have a verifiable DOI, and sources that lacked substantial relevance were all excluded. The final set of studies consisted of 30.

The six themes used for coding each source were: value-chain position; localization feasibility; technical and qualification capability; resilience and digital integration; sustainability and circularity; and governance or performance measurement. The evidence was examined in terms of convergence, tension, and transferability with respect to the Saudi oil and gas situation. Cross-sector studies from Saudi Arabia were employed merely to shed light on mechanisms such as localized manufacturing, Industry 4.0 adoption, supplier integration, and capability development. Thus, the synthesis results in an analytical framework rather than in a forecast of market shares or investment returns.

Table 1. Localization opportunity matrix for industrial lubricants and associated petroleum products

Supply-chain stage	Horizon	Localization value	Key technical condition	Principal risk
Packaging and filling	Near	Local jobs, shorter lead times, flexible pack sizes	Clean filling, labeling control, product segregation	Shallow value creation if upstream capability remains external
Warehousing and distribution	Near	Stock visibility, faster replenishment, regional service	Inventory discipline, storage compatibility, traceability	Overstocking or domestic concentration

Supply-chain stage	Horizon	Localization value	Key technical condition	Principal risk
Blending	Near-medium	Manufacturing depth, demand-responsive batches	Dosing accuracy, contamination control, controlled formulations	Batch inconsistency or unauthorized formulation changes
QA laboratories and field services	Near-medium	Local technical authority, condition monitoring, troubleshooting	Validated methods, trained analysts, reference standards	Weak data quality or insufficient competence
Base-oil integration	Medium/selective	Feedstock value capture and supply security	Grade fit, refinery configuration, scale and consistency	Uneconomic capacity or specification mismatch
Additives and specialty chemistry	Longer-term	High-value knowledge, formulation control, innovation	IP access, chemistry expertise, feedstock network, scale	High capital intensity, restricted technology access
Used-oil collection and re-refining	Medium	Circular feedstocks, waste reduction, recovery businesses	Segregation, environmental control, regenerated-oil quality	Contamination, poor collection economics, acceptance barriers

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5. Thematic Synthesis

5.1 Localization Opportunity Across the Lubricant Value Chain

The evidence shows that a selective approach is better than a uniform one when it comes to localization. Since the activities nearest to the final product and the customer usually need less proprietary upstream chemistry, they can be carried out using the current industrial infrastructure and thus are suitable for prioritization. It therefore makes sense to aim at localizing packaging, filling, labelling, warehousing, inventory management and last-mile distribution. Doing so will reduce replenishment times, enhance the ability to respond to customer requests and give better visibility of key stocks. Moreover, Saudi logistics research has also shown that the way the infrastructure is set up and the design of regional distribution hubs affect supply-chain performance, meaning that localization should involve the distribution networks rather than concentrating only on factories [11].

Blending is a more advanced capability since product consistency relies on accurate dosing, the prevention of contamination, batch traceability, tank management, and laboratory release. It is still more feasible than the manufacture of complex additive chemistries. Value can be generated locally through skilled operations, faster batch sizes, shorter order cycles, and closer technical contact with industrial customers. The requirement is that local production must adhere to the same formulation control and quality assurance standards that are expected from global supply; if the location of mixing is changed without also transferring the process knowledge, the analytical capabilities, or the ability to troubleshoot, then only a superficial domestic value is created.

Laboratory testing and field technical services are important since they transform local manufacturing into problem-solving abilities. The information obtained through physicochemical testing, contamination analysis, used-oil analysis, condition monitoring, failure investigation, and

application engineering can be used to extend drain intervals, detect equipment problems, and improve inventory planning. Research into the digital petroleum supply chain shows that information quality and the exchange of information are the key bottlenecks for transformation [19]. By linking laboratory results with asset histories and procurement data, lubricant supply can be turned into a performance service and thus achieve a greater level of localisation than that provided merely by packaging.

The need to differentiate between base-oil localization should be based on specification and economic considerations. Although Saudi Arabia's petroleum-processing capacity may give it access to feedstock and existing infrastructure, the availability of hydrocarbons does not imply that every viscosity grade or performance class should be manufactured locally. The amount of investment required will depend on the refinery's configuration, its product range, the scale of operation, the consistency of quality, and the requirements for the intended lubricants. Therefore, strategy should be directed at matching the domestic base-oil capabilities to actual demand areas rather than assuming that full substitution is possible.

The most challenging aspect is the additive systems sector, since it relies on specialized manufacturing knowledge, intellectual property, established networks for raw materials, environmental controls, the compatibility of formulations, and large-scale production. Imposing early on a requirement for complete local manufacturing might lead to higher costs or a reduction in the range of available products. A more effective approach starts with building up local stocks and providing technical assistance, moves on to the production of certain components, and then proceeds to joint development or licensed manufacturing only when demand and economic factors make it worthwhile. This step-by-step reasoning is in agreement with the evidence that localized manufacturing works best when technology integration and the development of capabilities take place together [4,5].

5.2 Qualification, Reliability and Technology Transfer

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248 In the oil and gas industry, the need to localise products is limited by the risks associated with
249 failure. Just because two lubricants have similar basic viscosity figures does not mean that they
250 are interchangeable. Turbine oils, compressor lubricants, hydraulic fluids, gear oils, greases and
251 engine oils can be subject to approvals from the original equipment manufacturer, industry
252 standards, specifications set by the operator, requirements regarding material compatibility, and
253 experience gained in the field. The business advantages of localisation can be lost if cutting
254 corners leads to increased wear, the formation of deposits, more downtime, greater warranty
255 exposure, or the need for more maintenance. Quality management therefore has to act as an
256 enabling infrastructure for localisation rather than merely serving as a final compliance check.

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258 The requirement alters the meaning of technology transfer since effective transfer involves
259 establishing governance, combining instructions, using laboratory methods, following
260 contamination-control procedures, applying statistical process control, managing changes,
261 carrying out field-trial protocols, troubleshooting, and developing competency. If a licensing or
262 joint-venture agreement transfers a brand or recipe without also including the operating system
263 that ensures consistent performance, it results in dependence rather than in capability. Just as
264 Saudi manufacturing research does, it associates localization with digital and organizational
265 capabilities rather than with physical production alone [3–5].

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267 Qualification should be based on a step-by-step evidence model. Initially, the local facilities have
268 to show that their manufacturing system conforms and that analytical repeatability is achieved.
269 Then, the local batches are compared with approved reference products. Next, controlled field
270 trials are carried out in such a way that operational risk can be managed. Finally, evidence is
271 gathered under a range of operating conditions before the approach is widely introduced. In this
272 way, localization can increase as more evidence becomes available and suppliers are given a path
273 from less risky products to more demanding specialties.

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Research into the petroleum supply chain shows that product quality is a major risk, together with price volatility and market uncertainty [17]. As a result, localization policy may lead to conflicting incentives since it could prompt buyers to boost their spending at home while at the same time holding maintenance teams responsible for reliability. Governance should address these objectives by defining 'qualified local content' to mean domestic value that satisfies the technical requirements. Laboratories, accreditation bodies, trained chemists, and application engineers then become assets for localization in their own right.

5.3 Supplier Ecosystems, Anchor Demand and Industrial Depth

Localization is more likely to achieve self-sufficiency where demand is predictable enough to warrant the investment. Although the big oil and gas companies can offer steady demand, long-term value will depend on whether that demand leads to the development of an ecosystem rather than just a small number of protected suppliers. Studies on green supply chains and Saudi manufacturing show that integration, innovation, resilience, and business performance are interconnected [6,12]. Procurement should therefore recognize and reward gains in capability, good delivery performance, technical improvements, and sustainability results rather than viewing local status as a fixed characteristic.

Since framework agreements that last for several years can reduce demand uncertainty, it becomes more feasible to make investments in blending tanks, filling lines, laboratories, digital systems, and in the training of the workforce. The contracts should include capability milestones, so that a supplier which at the beginning carries out local packaging can then move on to blending, local quality release, field support, and selected product development. This kind of progression results in tangible industrial depth and prevents permanent localization at low-value stages.

Small and medium enterprises have the opportunity to take part in calibration, laboratory services, packaging, transport, maintenance support, used-oil collection, digital traceability, and specialized logistics. Evidence from Saudi Arabia indicates that the resilience of SMEs is affected by their agility, robustness, and flexibility [9]. The firms do, however, encounter barriers relating to financing, certification, demand visibility, and access to technology. Supplier-development programmes therefore require access to shared testing infrastructure, qualification assistance, predictable procurement pipelines, and technical partnerships. Localization is strengthened when smaller firms can connect into a standardised ecosystem rather than having to set up each capability again.

It is still important to have foreign technology partners since the aim is not to get rid of international involvement but to alter the way it takes place. Ways such as setting up joint ventures, granting licences, arranging contract manufacturing, co-developing products, and establishing local technical centres can ensure that knowledge is incorporated while at the same time maintaining access to worldwide research and additive networks. Research carried out in Saudi Arabia across different sectors indicates that the introduction of advanced manufacturing and digital technologies can speed up this process when they are incorporated into the production model [4,5]. The most valuable result is a network in which global chemistry, Saudi manufacturing, local knowledge of application, and the ability to export regionally support each other.

Industrial clustering can also increase the level of localization. By being located close to refineries, petrochemical complexes, logistics corridors, and large consumers, companies can simplify transport and gain better access to utilities, feedstocks, laboratories, packaging suppliers, and recovery streams. It also promotes circularity since used lubricants can be collected on a large scale and then reprocessed in a controlled manner. Policies should therefore take into account the spatial relationships between production, demand, logistics, and recovery rather than looking at suppliers individually.

5.4 Resilience, Digitalization and Supply Assurance

The pandemic revealed the vulnerable nature of globally extended supply chains, including those of companies in Saudi Arabia. Research carried out in the country showed that resilience had an impact on the speed of recovery and that agility, robustness and flexibility are important for performance [7–9]. In the case of industrial lubricants, vulnerabilities could result from the use of imported additive packages, specialty base stocks, packaging materials, shipping disruptions, sudden increases in demand during turnarounds, and the long lead times required for qualification. While localization can shorten certain stages of the supply chain, the resilience gains it provides will vary depending on the design of the network.

A strategy that is resilient ought to divide materials according to their operational criticality and substitutability. For products which are used in large quantities and for which there are multiple acceptable formulations, local capacity together with competitive dual sourcing can be used. In the case of low-volume special lubricants which have proprietary additives, strategic inventory should be used rather than carrying out domestic production at an uneconomic cost. Safety stocks, supplier diversification, and regional warehousing can all help to cope with critical imported additives. The aim is to reduce the expected level of operational disruption, not to maximize the local share of each stock-keeping unit.

The process of digitalization makes it possible to have more dynamic segmentation. Research into the petroleum supply chain emphasizes the benefits of disruptive technologies and improved data sharing when it comes to achieving greater visibility and sustainability [15,19]. Likewise, research on manufacturing in Saudi Arabia links digital transformation to resilience and sustainability [10]. Within a local lubricant ecosystem, digital batch genealogy can connect the raw material batches, the blend records, the laboratory certificates, the packaging, the shipment, the application to the assets, and the analysis of used oil. Because of this traceability, it is possible to quickly contain any deviations in quality and thus increase confidence in domestic suppliers.

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361 Demand sensing is just as important. By combining maintenance schedules, shutdown plans,
362 equipment populations, consumption histories, and laboratory trends it is possible to predict
363 requirements. When demand signals are shared, local producers are given the opportunity to plan
364 their batches and arrange for the replenishment of imported additives, thus reducing the need for
365 emergency freight and excess inventory. Furthermore, data from condition monitoring can show
366 where longer drain intervals are justified, thereby changing the focus of forecasting from volume
367 to asset performance.

368

369 Because oil and gas networks contain sensitive information, cybersecurity and data governance
370 should be included in the integration process. Digital localization therefore calls for standardized
371 data definitions, interoperable certificates, supplier access protocols, traceability rules, and
372 accountable master-data ownership, not just the use of enterprise software; it is precisely these
373 capabilities that enhance manufacturing and provide the necessary evidence for qualification.

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375 5.5 Sustainability and Circularity as Localization Pathways

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377 Sustainability introduces a form of localization that goes beyond simply replacing imports. In the
378 field of oil and gas, circular economy, lifecycle assessment, resource efficiency, and low-carbon
379 operations are increasingly regarded as issues relating to the supply chain [1,2,13,20–25].
380 Lubricants are appropriate for circular strategies since value is still present in used oil after its
381 initial use. It is possible to set up domestic activities through collection, segregation, testing,
382 pretreatment, and re-refining, thereby reducing uncontrolled disposal and the need for virgin base
383 stocks.

384

385 The first and most direct solution is to carry out disciplined collection of used oil. Since mixed
386 waste streams lower the value that can be recovered, it is essential to separate the waste at the
387 source according to the type of lubricant and the level of contamination. Digital manifest records

and chain-of-custody documents can enhance the ability to track the waste from industrial sites to approved processors. When a sufficient amount of clean feedstock has been collected, re-refining can be used to recover base-oil fractions for suitable applications. As noted in current lubricant literature, re-refining and longer drain intervals are considered important routes to sustainability [26,30]. Policies can help promote these activities by setting quality standards for regenerated products, accepting them under procurement criteria, and implementing transparent environmental controls.

The idea of circularity does not mean that there should be automatic closed-loop reuse when it comes to critical equipment. Base oils that have been re-refined must satisfy the applicable specifications, and the final formulations have to go through the same qualification process as products made from virgin materials. In some cases, recovered streams may be more appropriate for use in less demanding applications. It is for this reason that a cascading method is able to maintain technical integrity while at the same time maximizing the value of the material. This difference is important in the oil and gas industry, since sustainability claims cannot take the place of equipment protection.

Bio-based lubricants provide another option, but care must be taken depending on the specific application. Reviews published in 2023 and 2024 indicate that vegetable and plant-derived oils can provide biodegradability and good lubricity, although they do pose problems concerning oxidation, temperature stability, consistency of the feedstock, compatibility with additives, and cost [27–29]. Their most important initial application will probably be in environmentally sensitive or technically appropriate areas rather than in all heavy industrial uses. Research should therefore be directed towards the operating temperatures, dust exposure, duty cycles, and equipment requirements in Saudi Arabia.

Circular supply chains can likewise have an effect on a business's model. Instead of selling litres, suppliers may offer lubrication performance by means of oil analysis, filtration, contamination control, optimisation of the interval between oil changes, recovery, and documented

reprocessing. These types of models link incentives to reduced waste and increased reliability, and they also establish skilled domestic positions in the fields of tribology, laboratory science, logistics, data analysis, and environmental management, thus connecting localisation more directly with human-capital goals.

Saudi industrial lubricant localization value chain

Localization depth increases as technical capability, qualification evidence and circular infrastructure mature.

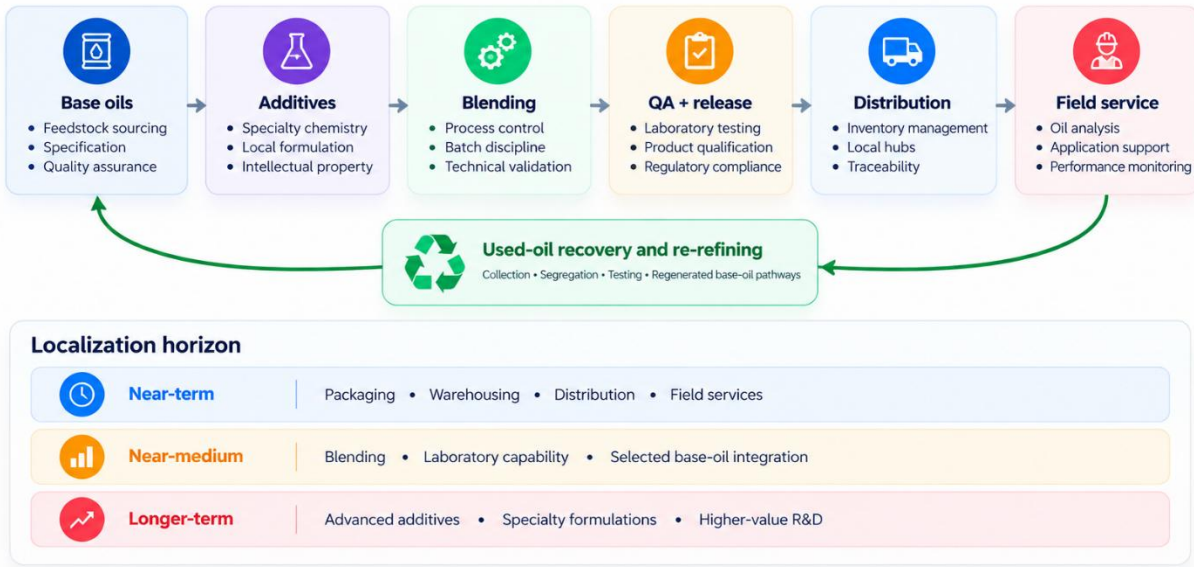


Figure 1. Localization value-chain architecture and differentiated capability horizons.

6. Integrated Localization Framework

The synthesis outlines a four-stage pathway relating to maturity. In the first stage there is supply assurance, which includes domestic warehousing, packaging, inventory visibility and technical distribution. The second stage involves qualified local blending, routine laboratory release, field service and structured supplier development. In the third stage specialty formulation capability, advanced analytical testing, joint development, local engineering support and the selective manufacture of higher-value inputs are introduced. Stage four involves an integrated circular and

export-ready ecosystem that combines technology partnerships, digital traceability, used-oil recovery, re-refining, product innovation and access to regional markets.

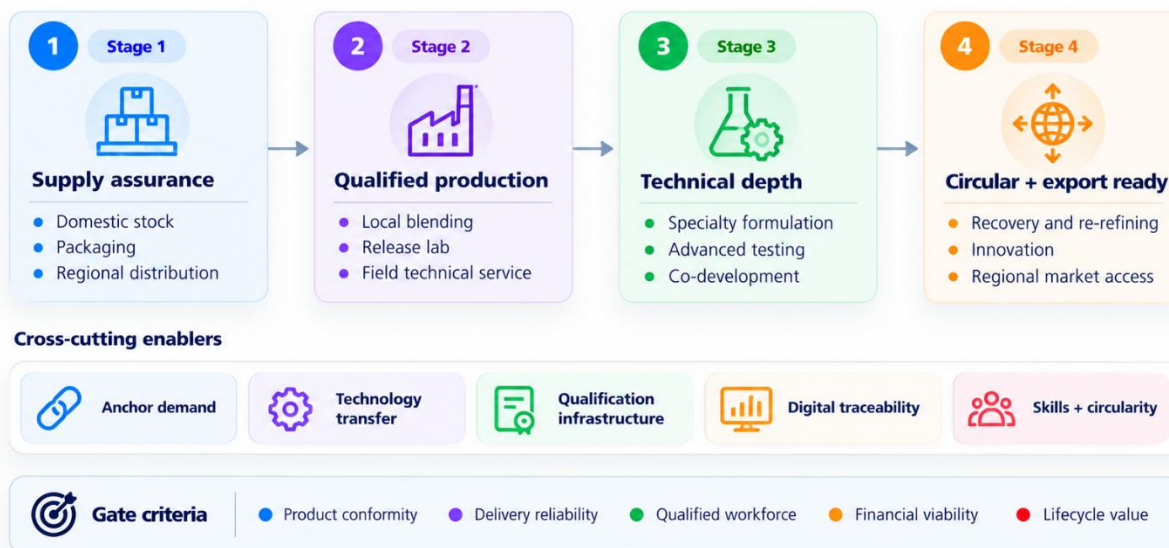
Advancement ought to be based on conditions not on a fixed schedule. A supplier is promoted only when there is evidence of process capability, product conformity, reliable delivery, financial sustainability, and the competence of the workforce. This prevents the establishment of physical capacity before demand exists or before qualification or technical capability has developed. It also allows different product lines to be at various stages at the same time. For example, production of commodity hydraulic fluids can be highly localized while that of a turbine or compressor specialty continues to rely on imported additive technology.

There are five enablers that cut across the various stages: those that link demand with clear opportunity pipelines, technology transfer which includes the transfer of know-how, qualification infrastructure comprising laboratories, standards, field trials, and change control; digital integration for the purposes of forecasting, traceability, and monitoring of supplier risk; and circular infrastructure covering collection, segregation, re-refining, and verified reuse. Figure 1 illustrates how these enablers are distributed along the value chain, and Figure 2 depicts the progression of capabilities without involving technically premature substitution.

Measurement plays a central role; although domestic procurement spending is useful it is not enough. A more effective dashboard should include domestic transformation value, qualified local capacity, critical products that have two qualified sources, supplier on-time performance, batch-right-first-time rates, Saudi technical specialists, local testing coverage, innovation projects, used-oil collection, recovered base-oil utilization, and lifecycle cost. It is precisely because of these indicators that localization can be held accountable for both operational and industrial outcomes.

Capability maturity pathway for localization

Progress is conditional on qualified capability—not on elapsed time or procurement quotas alone.



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461 Figure 2. Four-stage capability maturity pathway with cross-cutting enablers and gate criteria.

462 Table 2. Proposed performance and governance indicators for localization

Dimension	Illustrative indicators	Why it matters	Evidence linkage
Industrial depth	Domestic transformation value; qualified local production capacity; local share by process stage	Separates genuine capability from domestic resale	[3–6]
Technical quality	First-pass batch release; deviation rate; field approvals; laboratory turnaround	Protects equipment reliability and qualification discipline	[14,17,19,26]

Dimension	Illustrative indicators	Why it matters	Evidence linkage
Resilience	Dual-qualified source coverage; critical-stock days; forecast accuracy; supplier recovery time	Tests whether localization actually reduces disruption risk	[7–10,18]
Human capital and innovation	Saudi technical specialists; training completion; co-development projects; local test methods	Measures learning and transfer beyond physical assets	[4–6,10]
Digital integration	End-to-end batch genealogy; electronic certificates; demand-data coverage; traceability completeness	Improves visibility, containment and planning	[10,15,19]
Circularity	Used-oil collection rate; segregated feedstock quality; re-refined utilization; drain-life improvement	Connects localization with lifecycle resource efficiency	[2,20,26–30]

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464 7. Discussion

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466 The key point is that industrial lubricants should be viewed in terms of their capability portfolio
467 rather than as simply a matter of making them domestically or importing them. This approach
468 brings together the different objectives since industrial policy aims at generating domestic value;
469 operations focus on reliability; procurement is concerned with cost and continuity; the
470 sustainability teams want to reduce the overall lifecycle impact; and the technology partners wish
471 to protect their know-how. The staged model incorporates all these considerations since greater

levels of localization can be achieved as more technical evidence and larger market scale become available.

The literature also makes it clear that resilience should not be taken as a general excuse for producing domestically. Although local production can reduce transport distances and improve responsiveness, resilience is based on redundancy and adaptability; substituting several imported sources with a single local supplier may result in a single point of failure at home. On the other hand, a local blender backed by a number of suitable feedstocks, sufficient inventories, digital visibility, and strong controls can enhance continuity. The appropriate unit of analysis is the network configuration, not the nationality of the supplier.

Another consequence relates to value capture. While early stages of localization tend to focus on the visible manufacturing processes, the high-value capabilities are actually found in formulation knowledge, testing, application engineering, data, and the solving of customer problems. If these activities stay outside the company, domestic blending will result in only limited technological spillover. For this reason, the framework considers laboratories, technical services, digital systems, and workforce expertise to be on a strategic level equal to that of production assets.

In the end, circularity can lead to a greater degree of localization after a product has been sold. The recovery of used oil sets up a naturally local reverse supply chain involving collection, segregation, testing, treatment, and controlled re-entry into the markets for materials. This extends the boundary of localization from the stage of production to that of lifecycle stewardship and links the goals of industrialization with resource efficiency and environmental performance.

Another contribution is the difference between the breadth and the depth of localization. Breadth refers to the number of product families or procurement categories that have a local supply option; depth refers to the extent of local capability. A market might have broad local availability yet still rely on imported formulations, additives, testing decisions, and technical expertise. On

the other hand, a more limited range of products, backed by local laboratories, engineering teams, process control, and product-development capability, could indicate a greater level of industrial transformation. This distinction is useful for governance since it stops the overall percentage of spending locally from hiding weak capabilities. It also promotes the setting of staged targets: it is advisable to increase access where the risks are low, to go deeper into local knowledge where there is high strategic value, and to avoid requiring expensive upstream localization until there is adequate demand and technological readiness.

8. Managerial and Policy Implications

Oil and gas companies should start by drawing up a product-criticality map and a capability map; their products must be categorized according to the operational consequences, the complexity of the qualification process, the scale of demand, their level of exposure to imports, and their circular potential. Instead of applying procurement targets uniformly, they should be assigned according to category. Long-term contracts should include requirements regarding local content together with milestones for laboratory capability, technical staffing, digital traceability, continuity planning, and environmental performance.

For both suppliers and investors, differentiation will ever more rely on services and knowledge. Investment proposals must include alongside blending or packaging equipment laboratories, application engineering, data integration, and recovery systems. Partnerships should specify training, process documentation, analytical methods, access to technology, and the right to co-develop so that localisation leads to cumulative learning.

Policymakers ought to base their incentives on qualified capability and additionality. The most effective support is that which establishes a function that was previously missing, enhances competitive depth, fills a vital supply-chain gap, fosters the development of Saudi technical talent, or sets up a circular material loop. Facilities that are shared, industrial clusters, assistance

with certification, research partnerships, and transparent demand pipelines can reduce the barriers to entry without compromising the quality standards. Reports should differentiate between domestic distribution and domestic transformation so that progress properly reflects real industrial depth.

9. Research Agenda and Limitations

The main limitation lies in the fact that there are few peer-reviewed studies which focus specifically on the localisation of industrial lubricants in Saudi Arabia. To address this, the review combines evidence from Saudi sources with research on petroleum supply chains and lubricants that is applicable elsewhere. While this approach improves the breadth of the conceptual coverage, it does so at the cost of being able to make any claims regarding market size, plant economics, or the feasibility of specific products. The period under consideration, 2020 to 2025, highlights current conditions and deliberately omits earlier foundational studies.

Research in the future should quantify Saudi demand according to lubricant family, plot the domestic blending and laboratory capacity, identify the dependencies for imported additives and base stocks, and compare the lifecycle economics of different arrangements for localisation. Studies at the product level should look into the minimum efficient scale, the qualification lead time, feedstock security, energy and water requirements, and export demand. Research should also be carried out in the field with operators and suppliers to find out if the proposed maturity indicators can predict reliability and local value creation.

The second priority relates to circularity. Researchers must assess the amount of used oil generated, the quality of its collection, contamination patterns, the yields from re-refining, and the performance of the regenerated base oil under conditions in Saudi Arabia. Digital research should examine traceability systems that link batch records, certificates, condition-monitoring data, and reverse logistics. Such studies could turn the framework into a decision-support model

which prioritises investments according to technical risk, economic value, resilience, and environmental benefit.

10. Conclusion

If the supply chains for industrial lubricants and petroleum products are designed with the aim of building up capabilities rather than simply relabeling imports, they can make a significant contribution to the objectives of Saudi Arabia's Vision 2030. The potential for localisation varies greatly along the value chain; activities such as packaging, distribution, blending, laboratory services, application engineering, used-oil collection, and some forms of re-refining can lead to relatively early domestic value creation, whereas advanced additive chemistry and specialty formulations demand longer technology development, scaling, and qualification processes.

The four-stage maturity model that has been proposed connects supply assurance, qualified manufacturing, higher-value technical capability and circular export readiness. The main principle underlying it is evidence-based progression, which means that domestic production should be expanded as suppliers show that they have quality, reliability, technical competence, resilience and lifecycle value. Digital traceability, anchor demand, technology partnerships, workforce development and circular infrastructure function as cross-cutting enablers.

This method does not view localization and global integration as being in opposition. It allows Saudi companies to keep their access to international chemistry, research, and technology while at the same time bringing more of the manufacturing, testing, engineering, data, and recovery activities into the Kingdom. The most desirable result is not full self-sufficiency, but rather a diverse, well-qualified, learning-oriented ecosystem which cuts down on unnecessary reliance on foreign sources, promotes high-value jobs in Saudi Arabia, safeguards key assets, and transforms the supply of lubricants from a mere consumables function into a platform for resilience and for the sustainable creation of value.

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