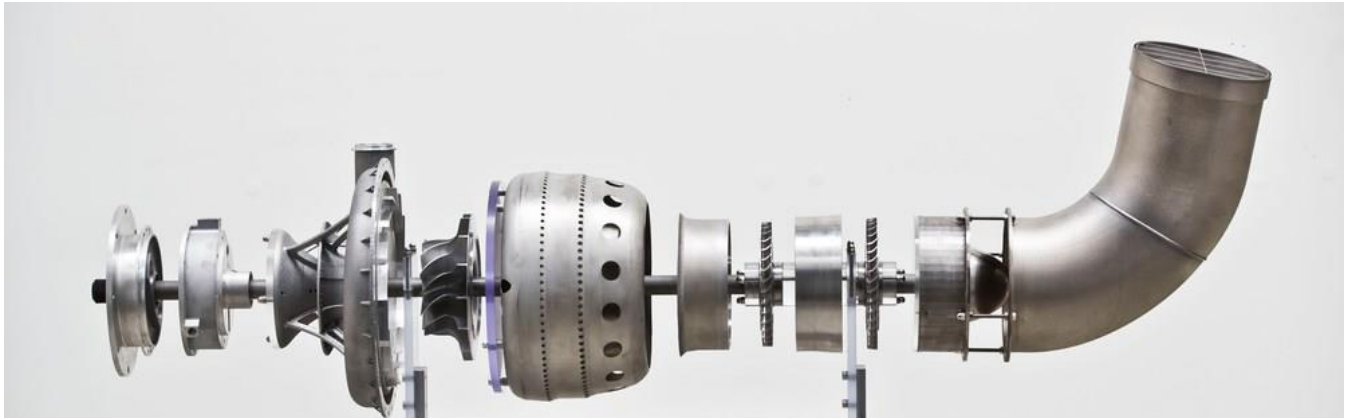


Revolutionizing the Spare Part Industry In the Kingdom of Saudi Arabia



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Abstract

The Kingdom of Saudi Arabia will spend more than SR1 Trillion purchasing industrial equipment and spare parts by 2030, where approximately 75% of large contract value are spent overseas with limited value to the local economy. This begs the question; how does one go about capturing this opportunity when attempting to localize the manufacturing of spare parts and equipment in ways that ensures the creation of high-value jobs for Saudis, facilitate localization, and identify strategic industrial investment opportunities? The localization opportunity could be achieved using reverse engineering, which enables the development of the required engineering know-how (3D CAD models, 2D engineering drawings, and metallurgy analysis) to facilitate conventional subtractive manufacturing or advanced additive manufacturing processes. Noteworthy; Saudi Aramco, SABIC, SEC, SWCC, and Ma'aden represent more than 60% of the whole local market demand for spare parts. Preliminary findings suggest that there are notable cost and time savings when reverse engineering spare parts; based on the list of nominated spare parts for localization, which have been announced during the Armed Forces exhibition in 2018 (AFED). Confirmed findings suggests that using reverse engineering to develop the required engineering know-how could facilitate localizing the manufacturing of spare parts, utilize existing manufacturing facilities, and create high-value jobs for Saudis, which will pave the road towards transitioning into becoming a knowledge-based economy.

Introduction

The Kingdom of Saudi Arabia's 2030 Vision aims at reinforcing and diversifying the capabilities of the economy, turning key strengths into enabling tools that will help transition the Kingdom from a consumer-based economy to a knowledge-based one. The following metrics illustrate the Kingdom's ambitions to capitalize on localization, where spare parts play a major role in localization initiatives as an avenue to catalyze the development of a Thriving Economy:

- The Ministry of Defense will increase its localization from 2% in 2016 to 50% by 2030.
- Saudi Aramco will increase its localization initiatives from 40% in 2016 to 75% by 2030.
- Desalination local content increase (CAPX & OPEX) from 30% in 2016 to 40% by 2020.
- Ma'aden will increase GDP contribution from SR64 Bn in 2016 to SR97 Bn by 2020.
- Increase Privet Investors contribution from 40% in 2016 to 65% by 2030.
- Increase Foreign Investment from 3.8% in 2016 to 5.7% of GDP by 2030.
- Increase shares from non-oil exports from 16% in 2016 to 50% of annual GDP by 2030.
- Increase SEM funding from 5% in 2016 to 20% of required capital by 2030.

The Kingdom of Saudi Arabia will spend more than SR1 Trillion purchasing industrial equipment and spare parts by 2030 (excluding military), where 75% of large contract value are spent overseas with limited value-add to the local economy [1]. Most oil & gas, petrochemical, utility, desalination, mining, and cement plants in the Kingdom were built in the 1970s and 1980s, where approximately 30% of all spare parts have become out-of-warranty, obsolete, discontinued, or no longer offered by OEMs. Nowadays, if spare parts are not available from OEMs, in some cases; companies in the Kingdom are forced to replace expensive systems instead of replacing faulty parts, which would ensure the longevity of their assets.

Market finding suggest that Pumps, Valves, and Compressors has the potential of contributing up to 30% of the local content in the short term for the next 5-years, which comprises 25% of the total industrial equipment sector and represents less than 4% of the local demand served by local suppliers [1]. Additionally, there is an additional 15% - 25% of parts that could be localized coming from assembly and equipment. Over the next 5-years, the following list of parts could be localized:

1. Turbines
2. Gas turbine accessories
3. Bearings
4. Housings
5. Heat exchangers
6. Shafts
7. Boilers
8. Seals/Gaskets
9. Baseplates

Increasing localization by 25 - 30% for the three nominated categories (Pumps, Valves, and Compressors) could add SR1.9 Billion to the GDP and create ~5,700 - 7,250 direct Saudi jobs in the next 6-years. Similarly, extending localization to equipment categories (accounting for exports) could enhance local footprint up to ~SR45 Billion to the GDP by 2030. Noteworthy is that Saudi Aramco, SABIC, SEC, SWCC, and Ma'aden represent more than 60% of the whole local market demand. One of the crippling factors that has prevented potential large or SME companies from establishing presence in the Kingdom is the lack of visibility on demand across all stakeholders; especially segmented by component type, size, and specifications [1]. Some specialized spare parts require long lead-time to procure from overseas (6 – 12 months), where during forced outages; it becomes challenging to reproduce out-of-warranty parts without engineering drawings that are necessary for manufacturing. Moreover, some spare parts are complicated in their geometry but not too difficult to manufacture if engineering drawings were available. Consequently, most strategic industries in the Kingdom are under the mercy of OEMs because they have limited control over their own assets due to the limited know-how about the engineering of the spare parts themselves. Examples of missing manufacturing capabilities that are currently unavailable in the Kingdom, which would help address latent needs in the Kingdom include but not limited to the following:

1. Metal Injection Molding (MIM)
2. Investment lost-wax casting
3. High and low-pressure diecasting
4. Gravity diecasting
5. 7-Axis CNC machining
6. Metal 3D printing
7. Forging

The Kingdom of Saudi Arabia cannot transition into becoming a knowledge-based economy that can implement localization initiatives that would create Saudi jobs if the country does not develop its own engineering know-how about spare parts and their optimization. Moreover, this knowledge-based development ensures a solid bedrock that would serve as a stomping ground to launch decisive initiatives and technology-based startup companies that would ensure reaping the desired goals.

The problems facing SMEs today in contributing towards the Kingdom's 2030 vision could be summarized as follows:

1. Limited support for technology-based SMEs in ways that enables them to receive down payments for awarded projects to help in financing and mobilization.
2. Archaic regulations and policies that have hindered SMEs from entering the market, especially for SMEs with innovative market solutions.

3. Reluctance of government, large companies, and OEMs to work with local technology-based SMEs due in part to limited track record and not having a special process to expedite their contribution towards large projects.

Despite all of the challenges, some local companies and government agencies have made strides in localization in ways that enables them to be more self-sufficient. Below are just three examples that illustrates local efforts in spare part localization:

Current Localization Initiatives



Saudi Arabia is making significant progress in the manufacturing of spare parts and military industries in the Kingdom, which is projected to result in significant savings through domestically manufactured products versus imported ones.

The Saudi Armed forces launches a biannual event; Armed Forces Exhibition for Diversity (AFED), where major companies in the field of manufacturing equipment and spare parts participate in this event. In 2018, the AFED exhibition took place between February 25th until March 3rd, where a plethora of nominated spare parts have been displayed to showcase localization interest by multiple government entities [2]. For example, "the expected savings to be achieved by localizing 50% of the military spending could amount to SR33 billion, which would be reinvested into the Saudi economy," said the director of the local manufacturing support department at the Saudi Defense Ministry, Major General Attiyah Al-Maliki [3]. Incentives for investment and the development provide the opportunities for local manufacturers to contribute towards localizing the manufacturing of nominated spare parts. This exhibition is a valuable opportunity for the private manufacturing sector to meet the armed forces current and future demands. In 2018, the Ministry of Defense displayed more than 80,000 opportunities for the supply of military equipment, spare parts, and tools. The importance of the AFED exhibition is to converge both beneficiaries and suppliers to present their requirements, as well as for local and international companies to display their manufacturing capabilities in the Kingdom of Saudi Arabia.

The objective of the AFED exhibition is as follows:

1. Present manufacturing opportunities of materials and spare parts offered by exhibitors to open channels between the exhibitors and local factories to achieve the goal of self-reliance in this sector.

2. Enable Saudi factories, laboratories, and specialized research centers in the field of manufacturing the opportunity to contribute to the local manufacturing process.
3. Support and develop national industry, in line with the required global standards and quality specifications.
4. Contribute to the localization, transfer, and development of the supplementary materials by networking with international companies to achieve the goals of Vision 2030.
5. Create promising investment opportunities for the private sector and to benefit from the national capabilities and possibilities of attracting foreign investments.

Noteworthy that the AFED exhibition is not restricted to the Armed Forces nominated spare parts for localization; rather, it includes the demand for Saudi Aramco, SABIC, Ma'aden, SEC, SWCC, Saudi Airlines, and Saudi Arabian Railway [3]. The following list of categories represents the various types of spare parts that the AFED exhibitors have identified as lucrative for localization and investment opportunities [2]:

- | | |
|------------------------------------|---------------------------------|
| 1. Batteries | 10. Tiers |
| 2. Electrical materials | 11. Radiators |
| 3. Filters | 12. Plastic parts and materials |
| 4. Gears | 13. Bearings |
| 5. Mechanical and electrical cords | 14. Belts |
| 6. Washers and nuts | 15. Gauges |
| 7. Hoses | 16. Oils and lubricants |
| 8. Metal pipes | 17. Electronic chips |
| 9. Safety materials | 18. Medical supplies |

It's worth mentioning that approximately 800 Saudi companies have applied for localizing the manufacturing of nominated spare parts [3], where only 120 companies out of the total 800 are registered with the Saudi Armed Forces. Additionally, the total number of line items that have been registered for localization by exhibitors is approximately 8,500 line-items, which represents 10.63% of the total amount that the Armed Forces and key local stakeholders are targeting to localize.



Saudi Aramco hosts an annual event dedicated for SMEs to promote localization, where Aramco's top tier suppliers gather with each other to interact with local SMEs to explore potential localization opportunities. The iktva program is considered the stomping ground for Saudi Aramco's localization initiative to create value in every aspect of the company's business while maximizing long-term economic growth and diversification. Saudi Aramco aspires to capture value with their suppliers that produces long-term tangible benefits; such as, quality jobs for a growing Saudi population, innovation, diversification of industry, and increased global competitiveness.

In 2017 Aramco's In-Kingdom-Total-Value-Add (iktva) event took place between December 12th and 13th, where through iktva, Saudi Aramco is developing a world-class supply chain that's locally accessible, reliable, and innovative to meet its needs as the world's leading integrated energy and chemicals company. Aramco's iktva program is the company's response for the Kingdom's 2030 Vision localization initiative.

The forum that was attended by investors from 35 countries highlighted Saudi Aramco vision for the future and outline business opportunities by focusing on developing an accessible, reliable, and efficient supply-chain. The objective is to bridge gaps in the energy sector supply-chain that fosters the development of competitive industrial clusters. The forum provided a platform for all companies interested in establishing operations in the Kingdom to engage with the Kingdom's energy sector stakeholders and their key suppliers. The forum covered topics such as integration of supply-chains, knowledge-economy, human capital development, access to finance, market access, the legal and regulatory environment, SMEs, and infrastructure benefits.

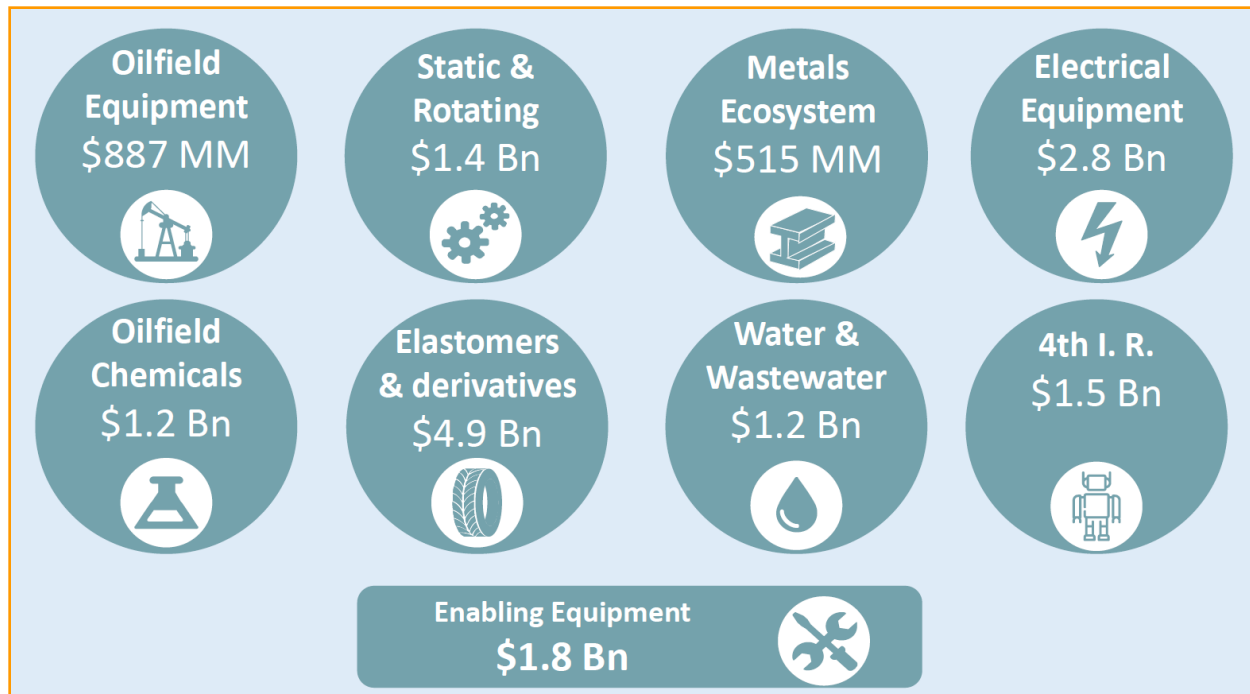


Figure 2: Saudi Aramco's current market gap of \$16 Billion [4]

The overarching objective is to achieve 70% of oil and gas supply-chain localization by 2021. During the 2017 iktva event; Saudi Aramco has identified 140 SME development opportunities, across 10 industrial segments, worth around SR60 Billion [5]. These opportunities include growth within the chemical's conversion parks at SADARA on the Arabian Gulf and Petro Rabigh on the Red Sea coast, where they are expected to help create over 40,000 new jobs, and potentially add around SR30 Billion to the Kingdom's annual GDP. Saudi Aramco is expected to spend more than SR1 Trillion over the next decade, where 70% of these funds would be spent locally [5]. Furthermore, Aramco prefers a large portion of these opportunities to be secured by locally-based SMEs in the following areas:

1. Coiled tubing
2. Drill pipes
3. Drilling collars
4. DV tools
5. Liner hangers
6. Nipple manufacturing for downhole
7. Packers
8. Precision machining downhole tools
9. Upstream perforation explosive charges
10. Whipstock
11. Accumulators
12. Cement plugs
13. Cement retainers
14. Flow couplings
15. Hoisting and rigging components
16. Downhole cables
17. Multi-stage frac
18. Sheaves
19. Slips
20. Swivels
21. Cementing pumps
22. Cross coupling protectors
23. Upstream perforation system
24. Well service tools maintenance
25. Wellhead bonnets

Saudi Aramco has identified the above list of 25 oilfield equipment opportunities that are worth \$887 Million [4]. For example, if one were to consider just the drilling equipment spending and opportunities; there are a lot of opportunities for localization as the below figures will illustrate.

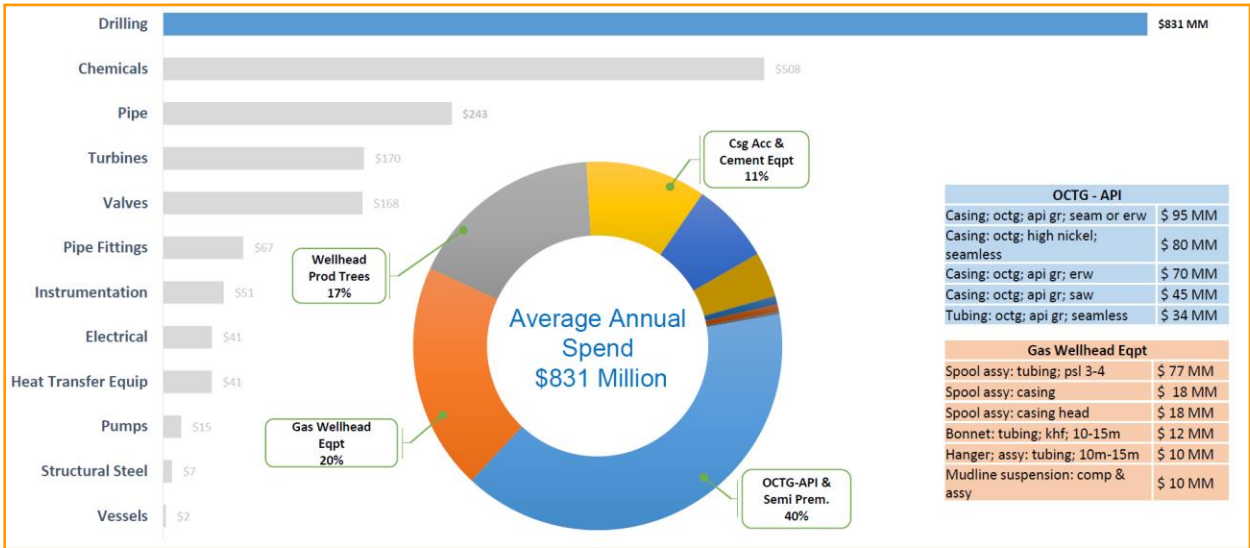


Figure 3: Aramco’s Combined In-Kingdom & Out-of-Kingdom Drilling Equipment Spending [6]

Saudi Aramco estimates an average annual spending of \$831 Million of drilling equipment, which are sourced from outside the Kingdom and very few in-Kingdom manufacturers [6].

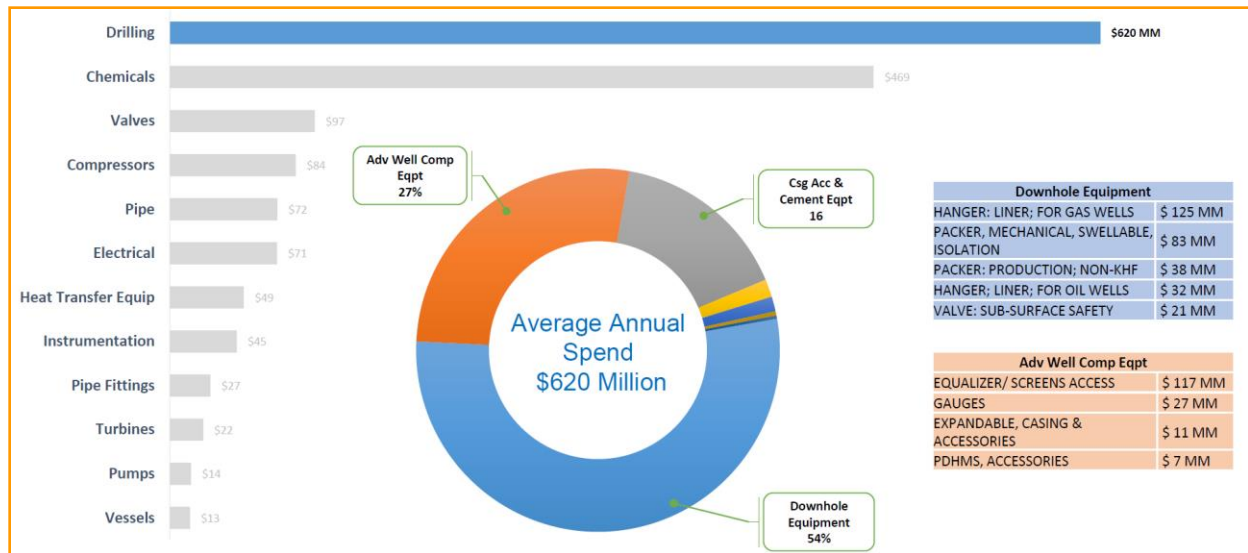


Figure 4: Aramco Drilling equipment currently sourced from outside the Kingdom [6]

Based on the figure above, Aramco spends \$620 Million annually sourcing drilling equipment and spare parts from outside the Kingdom, where approximately 20% of these spare parts could be sourced locally [6]. Part of the reason why these parts have not been localized yet is because they are highly engineered equipment that require field-matter experts who could execute without any compromise to quality.

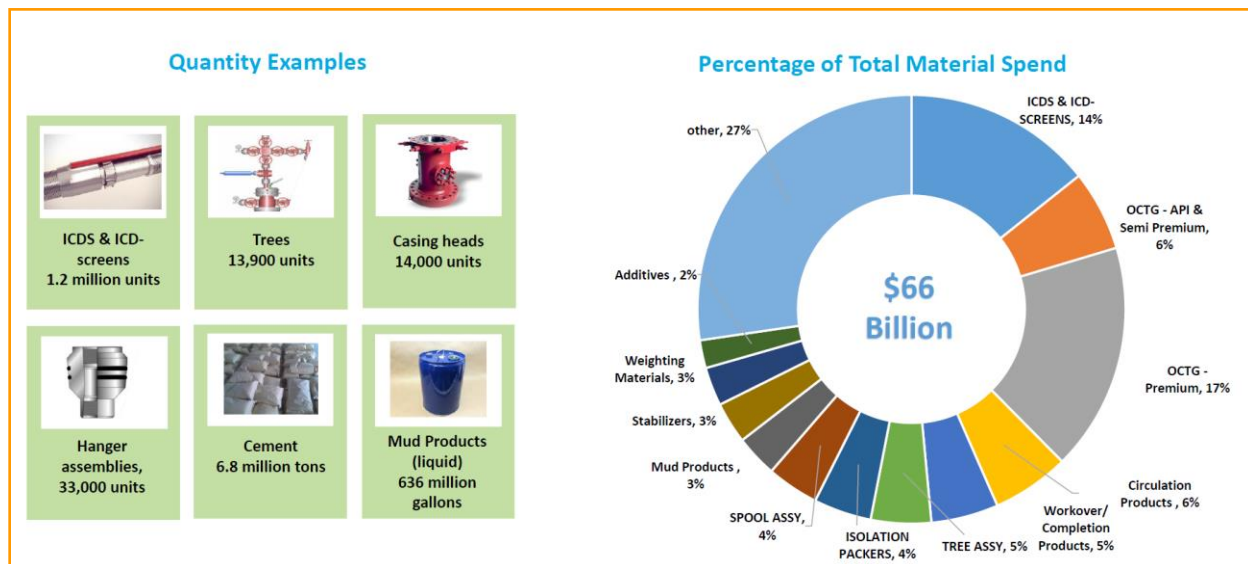


Figure 5: Frilling Material Forecast over the next 10-years [6]

Saudi Aramco predicts that it would spend approximately \$66 Billion over the next ten-years (10), where a gradual localization plan would prove fruitful [6].



A SABIC INITIATIVE FOR 2030 VISION

In order for SABIC to achieve its localization agenda and local industrial development, SABIC launched the “Nusaned” initiative, which is their 2030 Vision response to localization [7]. The objective of the program is to support investors in the following areas:

1. SABIC opportunities available to drive investment and create local demand through:
 - a. Procurement spending
 - b. Product conversion to develop downstream industry using SABIC raw material
 - c. Commercialization of SABIC patents, technologies, or applications
2. SABIC support packages to help in commercializing opportunities, including providing raw materials, technical support, etc...
3. Advise and support on financing startup or existing companies
4. Local workforce development and training support through sponsorship programs
5. Strong alignment between Nusaned program and different local authorities to ease project development

Nusaned aims at addressing some of the issues facing startups and investors alike; starting from idea generation all the way to execution. The program addresses the following key challenges by offering the corresponding solutions:

Key Challenges		Solutions
Lack of clarity on the path forward for the many ideas generated	➤	Robust pre-feasibility assessment to convert ideas to opportunities
Difficulty converting opportunities to feasible business cases without support	➤	Support package to improve financial attractiveness of opportunities
Limited access to funding, especially for SMEs	➤	Support with access to funding companies to provide capital for feasible business cases
Shortage of capabilities to execute and operate productively	➤	Develop workforce and provide functional capabilities
Insufficient coordination across multiple government agencies and private companies	➤	MOUs/agreements signed with external stakeholders to leverage each others strengths
Limited focus on competitiveness and socio-economic impact of the industries to be developed	➤	Opportunities prioritized based on competitive advantage, i.e. high socio-economic impact, strong domestic market and fit with SABIC's capabilities

Figure 6: Nusaned's proposed solutions to key challenges facing startups & investors [8]

The Nusaned program addresses the issues and challenges through its four main pillar programs; which are as follows:

1. Entema: An opportunity gate to originate, receive, and analyze investment opportunities. Further, SABIC aims to provide investors a portal to explore investment opportunities and test their viability and attractiveness to receive SABIC support through Daem. For example, spare parts opportunities fall under the Entema program, where they are classified under procurement opportunities, where these investment opportunities have been showcased during the AFED 2018 exhibition.
2. Daem: SABIC's support package to enable investor opportunities, where SABIC executes the proposed support packages to investors that have been identified through the Entema program. SABIC's support is manifested in one or many of the following challenges:
 - a) Supplying materials and services to SABIC through the procurement registration and technical qualification process at SABIC.
 - b) Product offtake from SABIC at competitive pricing.
 - c) Technical Support and Products Application/Technology commercialization.

- d) Capability Development through customized management and technical sponsorship and training programs to potential local workforce for opportunities qualified.
 - e) Provide access to SABIC's world-class practices in finance, supply chain, manufacturing etc... to understand best practices in execution.
 - f) Offer advice and support on Shared services and global supply chain; such as HR, procurement, supply chain leveraging SABIC cost advantaged position, etc...
3. Investment Fund: Access to funding for companies with feasible business cases.
 4. Muahal: Develop workforce capabilities to enable investor opportunities into the Kingdom by aiming to develop the technical and leadership capabilities of the local workforce for the Nusaned supported opportunities. This is to ensure that investors have the right workforce to execute the opportunity in a competitive and sustainable way.

As part of the Kingdom's Vision 2030, the government has set ambitious targets to diversify the Saudi economy to keep it thriving into the future. Below is a list of some of the Vision 2030 parameters that SABIC aims to contribute towards:






Vision 2030 Objective	2015	2030 Targets
 Increase Private sector contribution to GDP	40%	65%
 Increase SME Contribution to GDP	20%	35%
 Decrease Unemployment Rate	11.6%	7%
 Increase export contribution to non-oil GDP	16%	50%
 Increase localization in O&G sector	40%	75%

Figure 7: Kingdom 2030 Vision parameters relevant to SABIC [9]

SABIC has identified localization as one of the most significant levers to achieve the Vision 2030, where it would like to synchronize its efforts to localize the manufacturing of spare parts; especially those that use SABIC produced raw materials. Below is a list of SABIC enablers that facilitate localization efforts:

1. Product range and capabilities to support local manufacturing industries.
2. Large procurement to support local manufacturing.
3. World-class learning and development facilities to support workforce development.
4. Established technology platform to enable commercialization of products locally.
5. Global footprint to connect investors to Saudi Arabia.
6. World-class practices which can be shared to improve local companies.
7. Robust Shared-Services set-up which can be extended to other companies.
8. Integrated and Global supply-chain which can be leveraged for investors.



The Kingdom of Saudi Arabia is experiencing a tremendous expansion of industrial accompanied by a massive increase in the need for electric power energy due to the essential role that electric power has in the development and growth. Thusly, this huge demand of electric power requires large investments in the field of spare part manufacturing to enable localization.

Saudi Electricity Company – SEC has worked with manufacturers and investors to build a strategic relationship based on mutual interests and the principle of a Win - Win situation, which resulted in the construction of several factories and an increase in production lines reaching 65% of the purchases of power transmission materials from local factories. Further, SEC has been working to increase their local content value and support local manufacturers to enable healthy competition with foreign factories and suppliers alike. At the beginning of 2013, SEC formed a specialized team to study the localization potential at SEC to create strategic plane to improve local content development and attract more manufacturers and investors to build their factories in the Kingdom [10].

SEC has been playing a vital role in supporting the manufacturing of power related parts and equipment, where this role has been implemented by applying the following objectives [11]:

- Promote establishing local manufacturing with SEC's strategic partners.
- Improve the volume (value and number) of locally manufactured power spare parts.
- Attract more foreign investment to the power sector in the Kingdom.
- Transfer Knowledge/technology to the Kingdom.

SEC has put forth great efforts to support and encourage local manufacturing, where it has demonstrated their efforts as follows [12]:

- Provide local manufacturers with the necessary data for localization feasibility studies.
- Publish SEC's five-year plan for their spare part needs.
- Share the specifications of materials and equipment with local manufacturers.
- Hold regular meetings with local manufacturers to open channels of communication and reach to optimum solutions for the obstacles and problems.

- Signed a Memorandum of Understanding (MOU) with the Royal Commission in Yanbu and BAHRI Company to support the localization of spare parts.
- Signed MOU with MODEN to support the localization of manufacturing industries.
- Cooperate and coordinate with Saudi Aramco in their project of localization of electrical industries within the Energy City which they plan on building in the Eastern Province.
- Include local manufacturers with to implement mechanisms and procedures related to the development of new methods of work to enhance localization and increase local content development.

SEC has prepared a booklet for investment opportunities [13] to localize spare parts/equipment in the utility industry. This booklet contains 85 investment opportunities with a total estimated value about SR52 Billion [14].

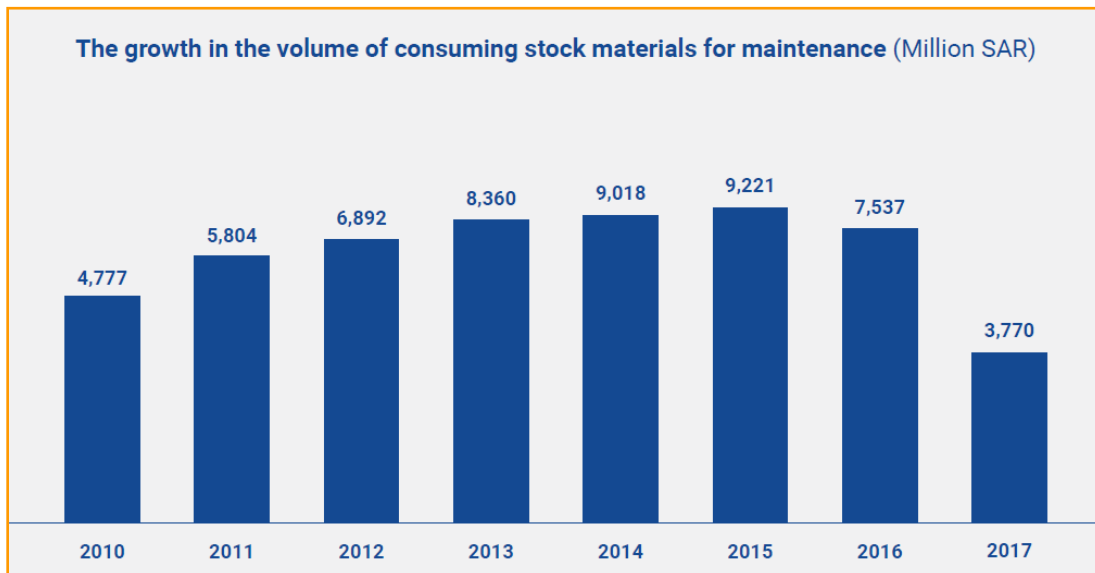


Figure 8: SEC's spare part consumption growth trend [13]

SEC's Strategy to maximize local content consist of three major initiatives to support and motivate local industries [13]:

- Initiative 1: Develop policies and procedures to motivate contractors.
- Initiative 2: Develop policies and procedures to motivate local manufacturers.
- Initiative 3: Identify investment opportunities for localization.

SEC aspires to achieve the following noble objective as a result of their localization efforts by 2021 [13]:

- Deliver electricity to 2.3 million new customers.
- Enhance distribution network lengths by adding 162,000Km.
- Enhance transmission network length and increase reliability by adding 21,500Km.
- Increase the generation capacity to 91,000MW.



المؤسسة العامة لتحلية المياه المالحة Saline Water Conversion Corporation

The spare part market size in the desalination industry is SR166M/year with exportability potential to GCC countries projected to be approximately SR348M/year [15]. Currently, only 1% of spare parts are being locally sourced. The Saline Water Conversion Corporation (SWCC) procurement department does not have enough information on spare part specifications to open competition to alternative suppliers. Furthermore, OEMs provide limited information to local stakeholders in order for them to capture market share. Generic spare parts can be provided by OEMs or alternative local manufacturers, where SWCC procurement department has enough information to define the specifications and open the competition through a bidding process [15].

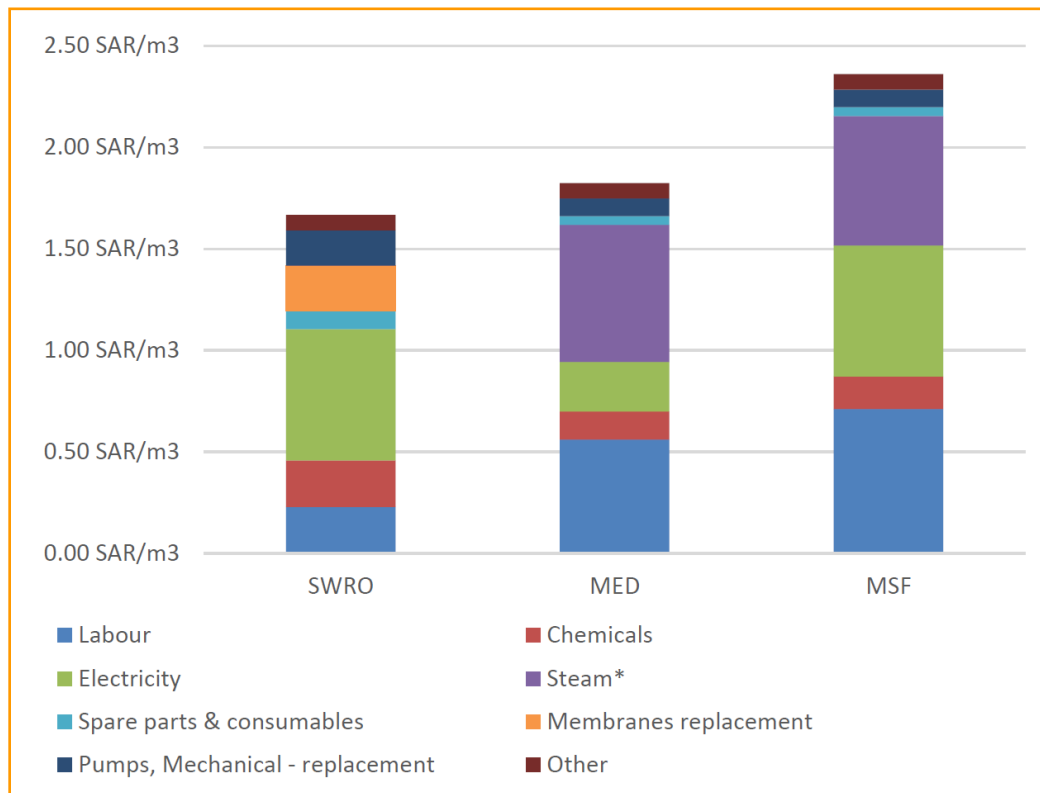


Figure 9: OPEX unit cost/m3 produced (for low-pressure steam) [15]

Figure 9 above illustrates how spare parts and consumables become more lucrative for thermal desalination operation (MSF and MED) when compared to electrical desalination processes (RO).

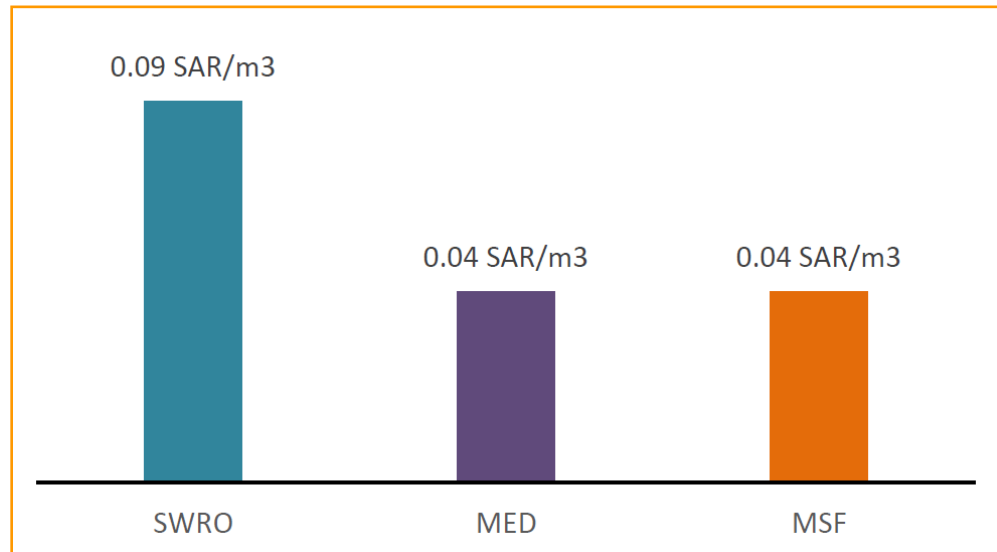


Figure 10: Spare parts & consumables unit cost per technology [15]

Spare parts unit cost is directly related to the equipment cost, where it represents 1/3 of 5% of the equipment cost excluding the membrane as illustrated in Figure 10.

The Industrial Cluster (IC) conducted a study by analyzing four SWCC desalination plants (Ras Al-Khair, Jubail plants, Jeddah plants, and Shoaiba plants) based on the stock inventory and movement for 3-years, and below were the findings [15]:

- Present stock inventory value was estimated at SR1.5Bn.
- All stock movements from 2012 – 2016 represent 150,000 items, 3,000 categories, and over 3,000 OEMs.
- Stock value build over the past 4-years has a value of SR494M and 95% of moving stock is sourced internationally.
- Local spare part manufacturers represent a value of SR7M and 1%.
- The remaining unidentified 4% are most likely manufactured by international companies at a value of SR20M.

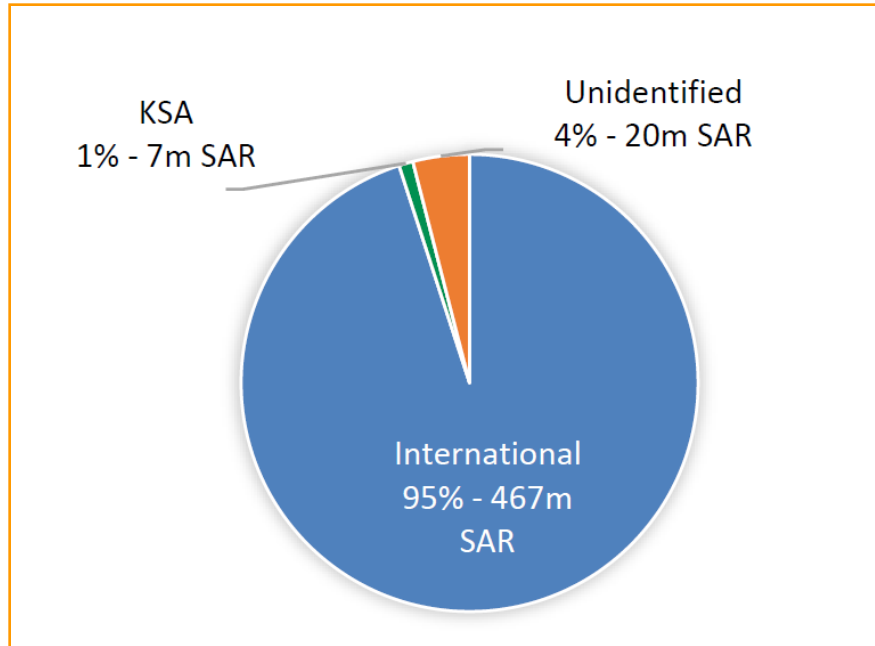


Figure 11: SWCC spare part sourcing distribution [15]

Figure 11 clearly illustrates the overwhelmingly high stock value of spare part items that are currently sourced internationally in both categories (Spare parts & Generic items). Furthermore, the study identified 165 local OEMs that covers 490 categories across spare parts and generics items, where the below figures illustrates the differences between both categories:

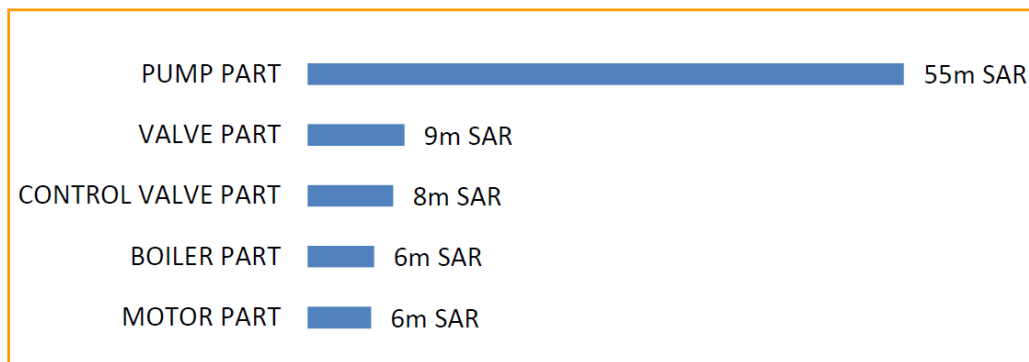


Figure 12: High value desal plant items related to Spare Parts [15]

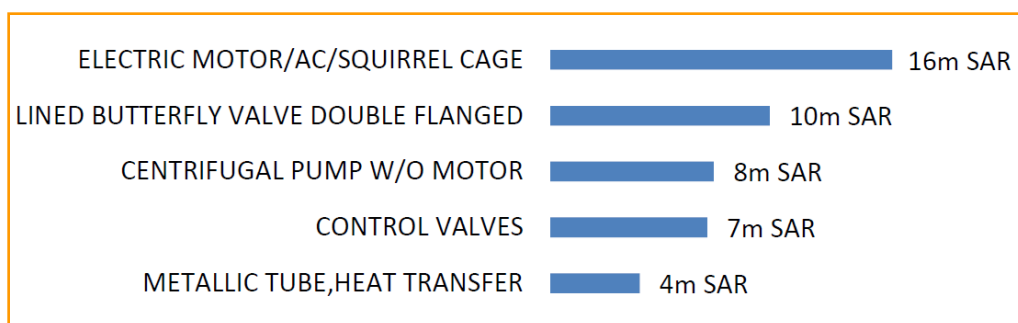


Figure 13: High-value desal plant items related to Generic Items [15]

#	Category	Type	Stock Value (Moving)	Number of items in Category	Number of OEM - International	Number of OEM - KSA
1	Pump Parts	Spare Parts	55m SAR	3,087	130	7
2	Valve Part	Spare Parts	9m SAR	714	103	1
3	Control Valve Part	Spare Parts	8m SAR	571	36	1
4	Boiler Part	Spare Parts	6m SAR	119	12	-
5	Motor Part	Spare Parts	6m SAR	329	41	-
6	Electric Motor/Squirrel Cage/AC	Generic	16m SAR	183	74	-
7	Butterfly Valve/D Flanged	Generic	10m SAR	62	17	-
8	Centrifugal Pump W/O Motor	Generic	8m SAR	35	18	1
9	Control Valves	Generic	7m SAR	81	37	1

Table 1: Stock inventory for the 4 surveyed plants [15]

Table 1 above demonstrates the categories with lucrative spare part localization potentiation in the desalination industry.

Local OEMs represent only 1% of total inventory value from four (4) SWCC plants combined (Ras AlKhair - RAK, Jeddah, Jubail, and Shoaiba), where spare part manufacturing is a captive market dominated by main international OEMs, which did not allow the development of new local spare parts manufacturers.

Korea Case Study

Korea was considered a typical developing country when it launched its industrialization drive in the early 1960s with poor resource and production bases with a large population dependent on foreign powers for national security. The economic situation was more than bleak, where Korea's gross domestic product (GDP) in 1961 was only \$2.3 billion [16]. Manufacturing in Korea at the time accounted for just 15% of GD, where in 1961, Korea's exports totaled \$55 million, and imports \$390 million [16].

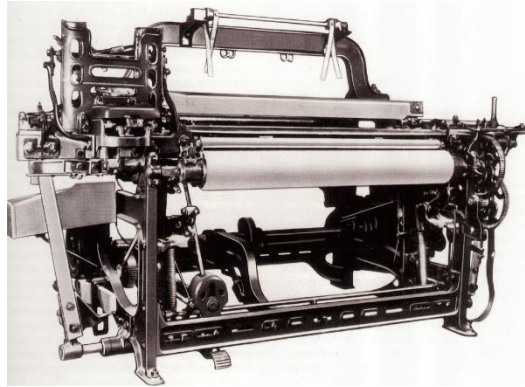
In 1962, Korea launched its five-year economic development plan aimed at developing an industrial base that could support both import substitution and export promotion. Since Korea lacked technological capability, the country relied almost completely on imported foreign technologies. Therefore, Korea pursued two objectives: promoting inward transfer of foreign technologies and developing domestic knowledge to transfer technologies. Unlike other developing countries, Korea, chose to largely omit Foreign Direct Investment (FDI) and instead focus on reverse engineering methods to develop their country. Furthermore, reverse engineering enabled the acquisition of necessary technologies that served as a catalyst to develop the country. Consequently, during the 1970s, Korea made massive investments in machinery and chemicals to enable reverse engineering to enrich their local economy [16]. Korean industries relied more on informal rather than formal channels for technology acquisition. Furthermore, Korea was able to succeed largely because the informal modes of technology transfer that it emphasized contributed in a major way to building a well-educated workforce.

Today, Korea owes its technological development and industrialization to the development of a strong human resource based on an outward-looking development strategy. The two major lessons from the Korean experiences:

1. Human resources are the key to the country's development, which led to economic growth.
2. Nothing can better motivate private businesses to invest in technology development than market competition.

Toyota Case Study

Prior to 1936, the Toyota Company was not known for their cars; rather, they were known for their automatic looming machines that were used to weave fabric [17].



Toyota Automatic Looming Machine

Kiichiro Toyoda was the eldest son of Sakichi Toyoda, the founder of Toyota Weaving Machine. Kiichiro graduated from Tokyo Imperial University, where he followed in his father's footsteps but was more interested in automobile production. In 1929 and 1930, Kiichiro visited the UK and US on a business trip, and was greatly impressed by the modern and huge production line of Ford Motors in Detroit, MI. Kiichiro began to prepare an automobile production line, but he lacked the experience to construct a vehicle from scratch. Furthermore, Kiichiro wanted to create a Japanese car maker independent from Ford & GM that is worthy to compete with them. The President of Toyota at the time, Kiichiro's brother-in-law, was against Kiichiro's plan since automobile manufacturing was not part of their product portfolio, so Kiichiro pursued his passion without the company's approval or support. Kiichiro was persistent, so he visited many factories, universities, and government ministries and later on purchased needed equipment from Germany and the US to test prototype small engines. In 1933 he reversed engineered the latest GM Chevrolet, analyzing all components and identifying Japanese companies that could produce them locally. In 1934, Kiichiro designed a passenger car model which combined GM Chevrolet, Chrysler De Soto, and Ford Model 68 [17].



Process of Reverse Engineering Toyota's First Automobile

President of Toyota could no longer stop Kiichiro, so in December 1933, the Toyota Board approved establishment of an Automotive Department and in January 1934, Kiichiro declared that the first Toyota car must be completed within one year. This was an ambitious deadline for a company that has no experience in producing automobiles, but he received substantial support from people around him at the company. US cars were further analyzed, a large factory was built, and additional equipment was imported using the conventional trial-and-error approach. The engine was modeled after GM's Chevrolet, the chassis after the Ford Model 68, and the cabin design was copied from the Chrysler De Soto.



1936 GM Chevrolet – Engine was copied



1936 Chrysler De Soto – Cabin Design was copied



1936 Ford Model 68 – Chassee Design was copied

After many failures, the team succeeded in casting their engine's cylinder block using trial-and-error. The first Toyota car; the Model A1, was ready in May 1935 and in 1937 Toyota Motor Company was established. In summary, Toyota's first automobile production relied heavily on reverse engineering on GM, Ford, and Chrysler [17].



1936 Toyota Model A1

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