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Energy and Industrial Leadership RDI National Priority in Saudi Arabia: Analytical Study

Executive Summary

Innovation Ecosystem in Focus

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INTRODUCTION

The Kingdom of Saudi Arabia has bountiful natural resources, which have created a globally leading energy and petrochemical sector. This priority seeks to build on this economic and technological foundation and develop alternative energy sources, including green hydrogen, renewables, battery storage technologies, industrial automation, nuclear power, re-use of industrial material and more cost-effective petrochemical production.

This study prioritizes the following RDI Missions:

- Mission 3.2: Develop cost-effective technologies to achieve 80-85% conversion of crude oil to chemicals by 2030.
- Mission 3.4: Reduce the cost of clean hydrogen to <\$1 USD/kg by 2030.

Energy and Industrials is a complex space that is constantly evolving due to more recent impacts of digital technologies, including artificial intelligence (AI) and the electrification of industries such as automotive, energy production, and alternative energy sources for sectors such as mining.

Within the Saudi Arabian ecosystem of Energy and Industrials, which encompasses corporations, academic

research institutions and start-ups, there may be many paths forward.

Examples include but are not limited to the enhancement of existing leadership positions such as petrochemicals, the establishment of new corporations with international collaboration from synergistic organizations in fields such as energy storage, and the creation of new start-ups specializing in broadly applicable technologies such as Digital twins, Industrial robotics and Predictive maintenance.

Saudi Arabia is home to Saudi Aramco, which is only one of two non-United States corporations within the world's top 10 most valuable companies, with an estimated market cap of \$1.8tn USD. It is the only energy-related organization at the top, while seven of the other ten work in software, technology or semiconductors: Apple, Microsoft, Nvidia, Alphabet, Amazon, Meta, Berkshire Hathaway, TSMC and Eli Lilly.

The Public Investment Fund's investment of \$1bn USD into Lucid Group in 2024 also shows Saudi Arabia's commitment to driving forward the future of battery technology within the automotive sector. This strategic investment has led to the opening of Saudi Arabia's first car manufacturing facility, furthering progress toward the Research, Development and Innovation Authority's (RDIA) mission to become the fourth-largest producer of electric

vehicles (EVs) and EV batteries by 2035.

Within Energy and Industrials related technologies, there are specific intellectual property (IP) factors to consider:

- Software and AI-driven innovations may be applicable across fields such as autonomous vehicles, Digital twins, Intelligent manufacturing and Predictive maintenance. However, across global jurisdictions, there are differing requirements for software

and patentability, regularly requiring technical effect.

- Business methods are also patentable; innovators may need help protecting business-related improvements elsewhere.

The complete list of research topics that define the national priority area of Energy and Industrials within this study, with global volumes across research publications and inventions, is shown in Figure 1.

Figure 1: Number of research publications and inventions within Energy and industrials 2014-2013.



OVERVIEW

The Energy and Industrials RDI national priority area exemplifies Saudi Arabia's growing influence in other key priority areas and technological domains worldwide. This includes the development of capabilities in research topics such as Autonomous mining, Energy storage, Hydrogen, Industry 4.0, Renewables and Sustainable mining.

RDIA is dedicated to steering and executing the Kingdom's RDI strategies across the four national priorities. It has led the organization of capacity-building activities, equipping Saudi leaders and practitioners with the vital skills needed for digital innovation within existing Energy and Industrials research and innovation areas.

Energy and Industrials have a wide variety of research topics. Only three technologies fall into Technology Readiness Level (TRL) 1-3: Digital twins, Intelligent Manufacturing, and Small Modular Nuclear Reactors (SMR). Technologies in TRL 7-9 include COTC products and processes, along with Renewables – PV modules, Solar farms, and Wind turbines. Saudi Arabian invention alignment to commercial potential is well aligned, especially for high-TRL technologies. This alignment displays a preference for near-term return on investment innovation.

- Saudi Arabia has very high invention output and volume in COTC processes, products and Hydrogen

production. Saudi Aramco's significant research, development and innovation power leads all three of these fields.

- Saudi Arabia's scorecard in this study shows relatively low research and invention strength performance in fields such as Industrial emissions and Digital twins. International organizations operating in this space also have lower invention volumes; however, they also appear to specialize traditionally in different research topics compared to Saudi Arabia's academic institutions and local corporations.

Saudi Arabia is set up for success by leveraging corporations such as Saudi Aramco, which has deep research expertise, particularly across Hydrogen, Net zero, Renewables and Industry research topics.

Key opportunities within Energy and Industrials:

- **Leverage Saudi Aramco's academic-corporate partnership (ACP) excellence:** Saudi Aramco has a significant number of local ACPs, also spanning Economies of the Future and Sustainability and Essential Needs. Saudi Aramco's research, innovation, collaboration and economic success require continued diversification and expansion into new areas, such as applying AI into existing business units.



- Expand into non-traditional research topics via the creation of further start-ups. Qudra Energy's work in PV modules and NOMADD Energy and Industrials ACP start-up creation showcases Saudi Arabia's entrepreneurial foundations. A greater number of private organizations are required to achieve industrial leadership, focus on all research topics within Energy and industrials and achieve national missions.
- Prioritize higher-performing and higher-commercial-potential research topics: COTC processes, COTC products, Hydrogen production, Hydrogen storage and transportation, and Sustainable

mining – waste management. Combined, these research topics have the potential to generate \$2.09bn USD for the Saudi Arabian economy if 5,833 inventions are protected, generating the expected yield of very high-strength inventions, and are subsequently successfully commercialized.

- Continue to fund local academia in key research topics with lower TRL:

Research topics with lower TRL require both more academic research funding and ACPs, including Digital twins and Hydrogen storage and transportation. Research topics requiring sustained funding include Industrial emissions, Smart grid and Sustainable mining – waste management.

Saudi Arabia mainly shows innovation strength in more mature technologies. Therefore, the Kingdom should continue to foster ACPs between Saudi Aramco and local academic institutions such as but not limited to King Abdulaziz University, King Fahd University of Petroleum and Minerals (KFUPM), King Abdullah University of Science and Technology (KAUST) and King Saud University.

The opportunities for interdisciplinary collaboration between Energy and Industrials research topics and Sustainability and Essential Needs research topics should be prioritized when considering the potential impact on the Saudi Arabia economy.

Many research topics could be combined or transitioned from one to another across national missions, such as '2.4: Achieve net-zero emissions by 2060', '2.6: Reduce summer surface temperatures by 4C by 2040', '3.1: Increase the share of renewable energy sources to approximately 50% by 2030', and '3.6: Become the 4th largest producer of EV's and EV batteries by 2035.'

The next wave of Saudi Arabian technologies may underpin the complex transformation related to the world's energy production and consumption. Energy transformation could be achieved by setting up cross-functional centers of excellence, including incubators to build specialist

private organizations to supply cutting-edge innovation.

This study's insight provides a multidimensional evaluation of research topics within the Energy and Industrials priority area to provide key actions and options to consider and benchmarks against global leadership. Subsequently, the tailored insight, metrics and findings can enhance both foundational research within academia and commercially applied innovation to achieve Saudi Arabia's national missions and aspirations.

KEY FINDINGS

Drawing upon the insights from research and invention performance, ACPs and the technology maturity evaluation for Saudi Arabia and global organizations, this section provides key findings tailored to the relative position of Saudi Arabia for each technology by using industry-leading metrics to provide next steps.

These findings outline the potential of the research topics specifically for Saudi Arabia, where to invest, and whether more academic funding is required. They also discuss further ACPs, the transfer of technology from academic to private entities, and the potential to continue the existing strategies.

Table 1: Energy and industrials research topic scorecard.

				High	Medium	Low
	Saudi Arabia's research strength	Saudi Arabia's invention strength	Saudi Arabia's partnership strength	Saudi Arabia's research productivity	Technology maturity	Future predicted growth
COTC processes	694	42836	5.1%	1.79	8	6.8%
COTC products	1102	27811	3.9%	2.69	8	7.2%
Hydrogen production	4657	12534	3.8%	2.47	6	9.3%
Hydrogen storage and transportation	1189	1989	0.8%	1.76	5	9.2%
Digital twins	192	149	3.4%	0.61	3	12.4%
NetZero - industrial emissions	187	518	3.8%	0.98	4	7.5%
Smart grids	1508	1092	1.3%	2.12	7	7.0%
Sustainable mining - waste management	223	2051	1.6%	1.68	4	7.8%

Table 1 contains factors analyzing Saudi Arabia's position per research topic, these factors are defined as:

- **Research strength:** Total number of Saudi Arabian research papers multiplied by Category Normalized Citation Impact (CNCI). A document's CNCI is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area.
- **Invention strength:** Total number of Saudi Arabian inventions multiplied by the Derwent Strength Index (DSI). This is a Clarivate™ metric of the strength and quality of a patented idea. Based on the impact of the invention on others (based on the frequency of downstream citation by the patent applications of third parties), the global footprint of patents granted (based on the % of world GDP covered by the patent asset), the investment level in the invention by the applicant (based on the number of patent jurisdictions in which the applicant sought protection) and the inventions rarity (based on the number of inventions in the global database that share the same technology mix).
- **Partnership strength:** The mean partnership % for research papers and inventions in Saudi Arabia.
- **Research productivity:** Productivity relative to global productivity is measured by the number of Saudi Arabian papers on a specific research topic divided by the number of global documents on the same research topic and period.
- **Technology maturity:** Each research topic within the national priority areas has been mapped to an individual Technology Maturity Index from 1 (least mature) to 9 (most mature).
- **Future predicted growth:** CAGR predicted growth extrapolated from historic inventions level.

The Hydrogen storage and transport research topic has medium research and invention strength by volume and CNCI/ DSI, low ACP levels of 0.8%, medium research productivity of 1.76 and medium technology maturity of 5. As there are only 53 inventions from Saudi Arabia in the last 10 years, and 340 research papers seen in Figure 2, it would be **suitable to prioritize early-stage academic research** into

organizations with existing invention strength, such as Saudi Aramco, King Fahd University of Petroleum & Minerals and slightly older inventions from KAUST and KACST.

Numerous Chinese academic institutions with significant strength in this area may enhance invention production through partnerships, such as Beijing Research Institute for Non-Ferrous Metals, Shanghai Hyfun Energy Technology, Zhejiang University, Zhangjiagang Qingyun New Energy Research Institute and South China University of Technology. Hydrogen storage and transport could add \$0.26bn USD to Saudi Arabia's economy; if 1,667 inventions are protected in this field, the likely yield would be around six very strong inventions.

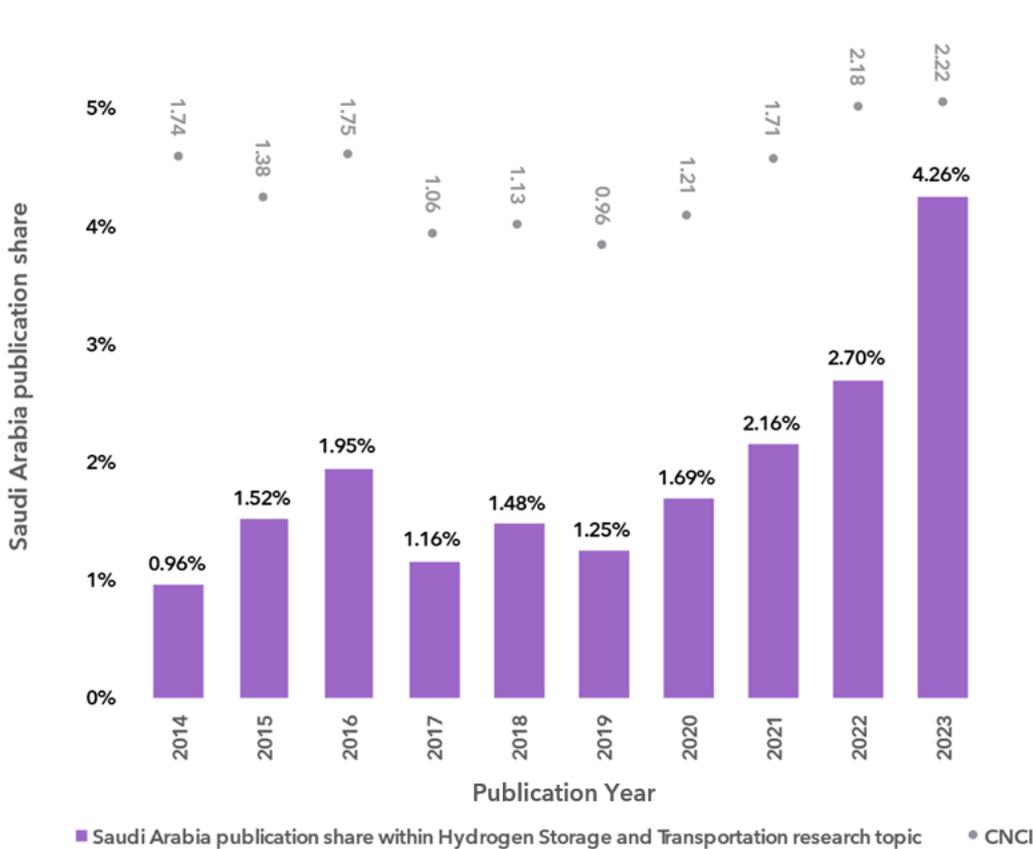


Figure 2: The share of Saudi Arabia from global publications in 'Hydrogen storage and transport' and the CNCI of Saudi Arabia publications in Hydrogen storage and transport.

The Digital twin research topic has relatively low research and invention strength and volumes of 81 research papers and seven inventions from Saudi Arabia. The ACP level for Digital twin technology of 3.4% is quite high within Energy and Industrials, whereas

research productivity is low at 0.61 and 3 technology maturity. The predicted invention growth level is 12.4%. Given **the strength of Saudi Arabia's Energy and industrials sector, investing in early-stage research could benefit established industries.** Saudi Aramco, KFUPM and King Khalid University have seven inventions from Saudi Arabia. International ACPs with potential include GE Aerospace, Siemens, Bosch, Johnson Controls. Additional international organizations are seen in Figure 3.

Similarly, Figure 4 shows that **collaborative research partnerships should be considered** with academia. For example, Guangdong University of Technology, China University of Mining & Technology, Tsinghua University, Beijing Institute of Technology, Beihang University, Tongji University, Chinese Academy of Sciences have a consistent track record holding 20+ inventions each, along with newer entrants such as Zhengzhou University of Light Industry, University of Electronic Science and Technology of China, and Dalian University of Technology.

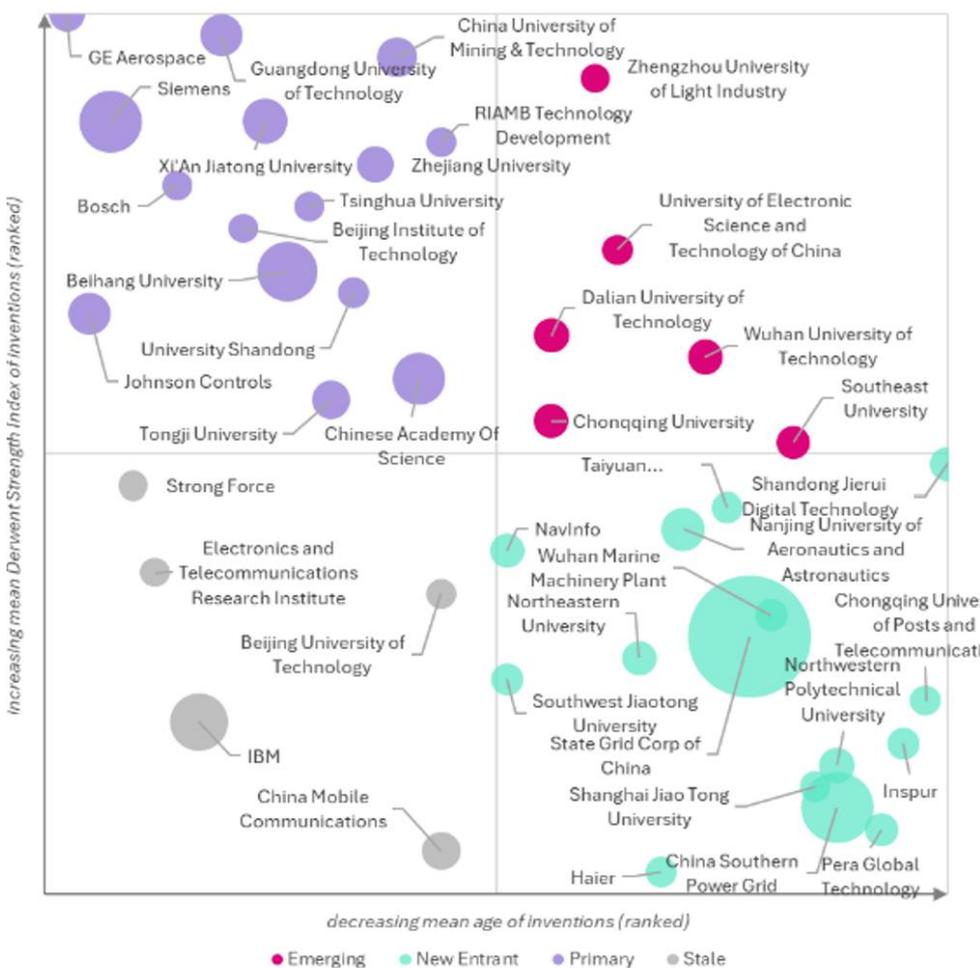


Figure 3: Commercial dynamics model for the top global patent assignees in the research topic 'Digital Twins'.

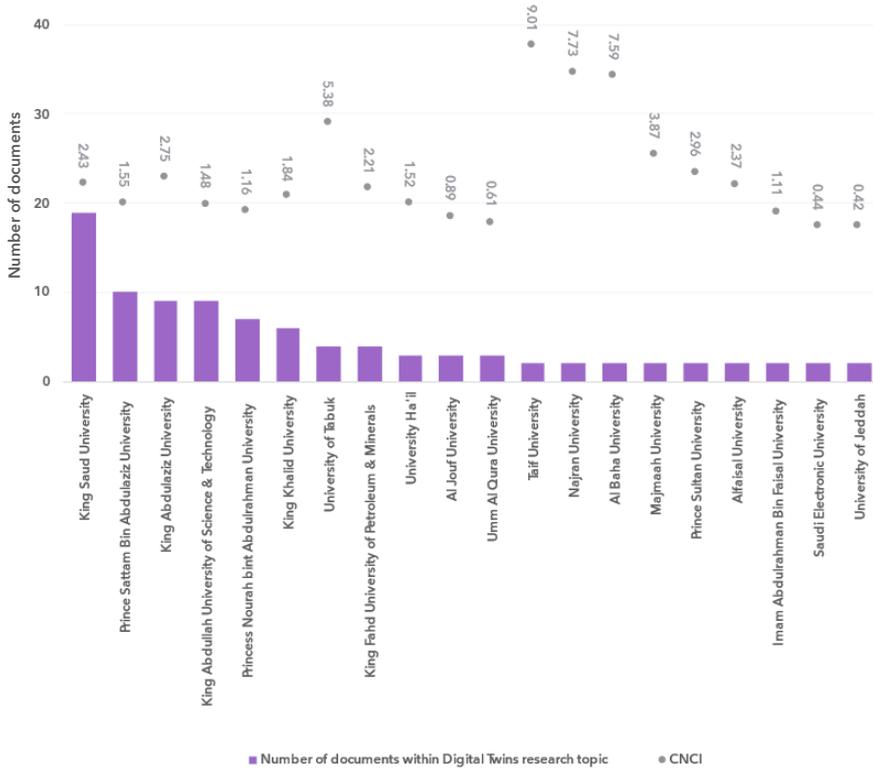


Figure 4: Top 20 Saudi Arabian organizations in terms of the number of publications in the research topic Digital twins in the period 2014-2023 and their corresponding CNCI.

“Industrial emissions and Sustainable Mining - waste management has low research strength but a medium invention strength. It is predicted that this research topic could add \$0.70bn USD to Saudi Arabia’s economy if 833 inventions are protected in this field. The likely yield would be around 23 very strong inventions.”

Industrial Emissions and Sustainable Mining - Waste Management has low research strength regarding volume combined with CNCI. However Sustainable Mining - Waste Management has a medium invention strength.

Notably, Industrial emissions have a higher average research and invention ACP level, at 3.8%, whereas only 1.6% ACPs in Sustainable Mining - Waste Management. Both research topics have a technology maturity level of 4.

Subsequently, it may be prudent to consider **additional funding for early-stage research** to enhance Saudi Arabia’s innovation in these research topics. Leading micro-topics globally within Industrial Emissions are Supply Chain & Logistics Supply Chain as shown in Figure 5.

Saudi Aramco leads with eight inventions, followed by King Fahd University of Petroleum and Minerals and King Abdullah University of Science and Technology within Industrial Emissions. Similarly Saudi Aramco leads with 21 inventions for Sustainable Mining Waste Management, followed by KAUST, University of Alfaisal and the University Prince of Sattam Bin Abdulaziz.

It is predicted that Sustainable Mining - Waste Management could add **\$0.70bn USD to Saudi Arabia’s economy** if **833 inventions** are protected in this field; the likely yield would be around 23 very strong inventions.

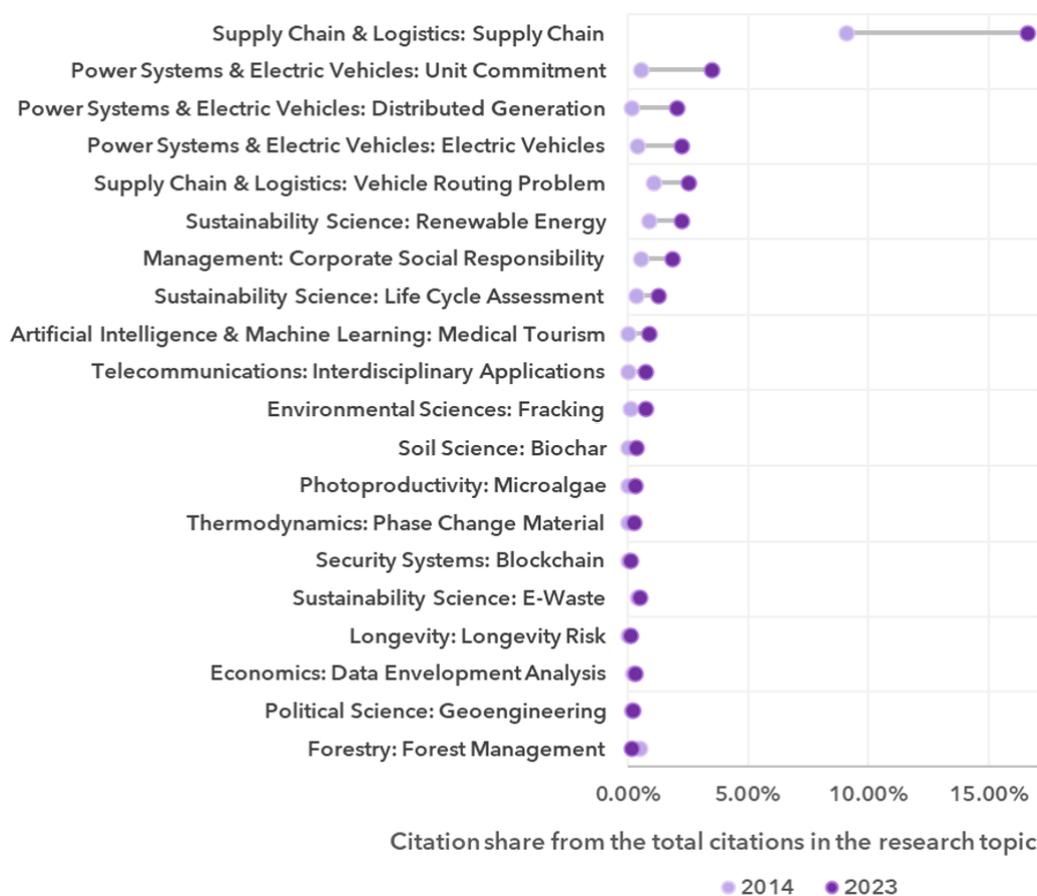


Figure 5: Top 20 emerging micro-topics globally in the research topic Industrial Emissions in the period 2014-2023.

COTC products and Hydrogen production research topics both have medium research publication volume and strength and very high invention volume and strength.

These research topics are fueled by high research and invention partnership rates of 3.9% and 3.8% and similarly high 2.69 and 2.47 research productivity. The technology maturity is 6 and 8, respectively, which equates to medium and high maturity with 9+% growth predicted.

The very low ratio of research papers to inventions of 1 and 7 shows that **these research topics are highly embedded within the Saudi Arabian innovation ecosystem**. King Fahd University of Petroleum & Minerals holds 45 inventions in COTC products and 56 in Hydrogen production.

“The low ratio of research topics to inventions in the research topics COTC products and Hydrogen production research topics, shows that they are highly embedded within the Saudi Arabian innovation ecosystem”

At the same time, Saudi Aramco holds 202 inventions in Hydrogen production, as seen in the top left of Figure 6. As Saudi Arabia has a strong innovation pipeline in this area with many other innovators in hydrogen such as Saudi Iron and Steel, Imam Abdulrahman Bin Faisal University, KAUST and King Abdulaziz City for Science and Technology continuing to transfer technology into the market will maintain growth in this area.

It is predicted that **Hydrogen production could add \$0.70bn USD to Saudi Arabia’s economy if 1,667 inventions** are protected in this field. The likely yield would be around 16 very strong inventions.

ACPs have enhanced this strength, with 47/721 COTC product inventions and 15/340 inventions generated via ACPs, 16 and 5 from Saudi Aramco partnership with King Fahd University of Petroleum & Minerals, respectively, similarly 21 and 6 between

KAUST and Saudi Aramco. Saudi Aramco's COTC products portfolio is notable in the top right quadrant of Figure 7.

It is predicted that COTC products could add **\$0.31bn USD** to Saudi Arabia's economy if **833 inventions** are protected in this field. The likely yield would be around 23 very strong inventions.

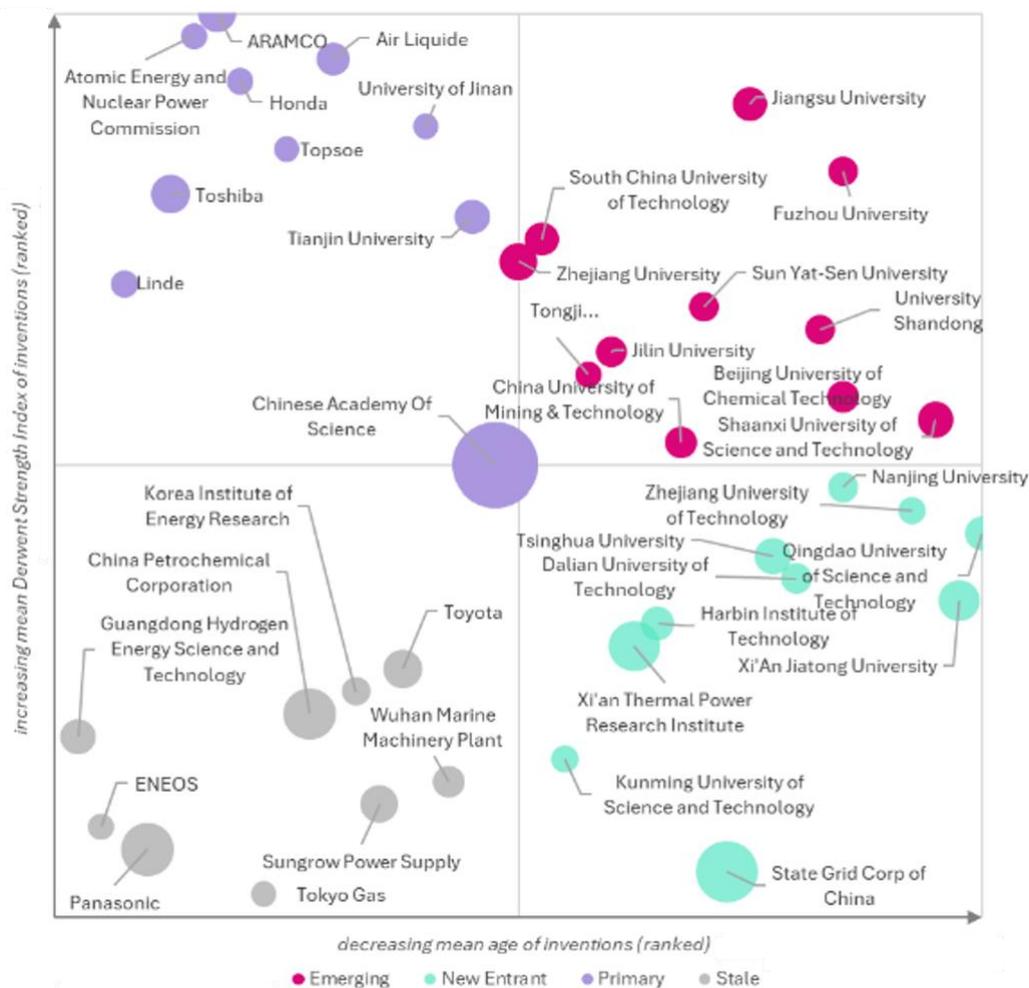


Figure 6: Commercial dynamics model for the top global patent assignees in the research topic 'Hydrogen production.'

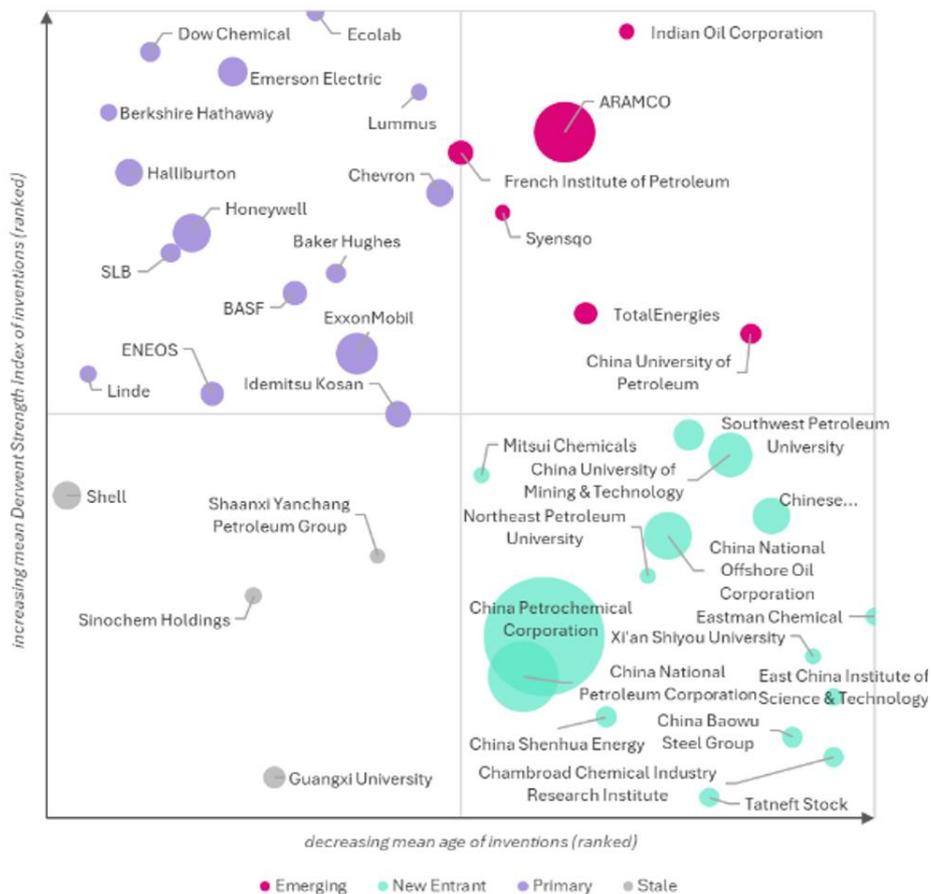


Figure 7: Commercial dynamics model for the top global patent assignees in the research topic 'COTC products.'

COTC processes technology has low research strength by volume and CNCI. However, it has the highest invention strength across Energy and industrials, a high research and invention ACP score of 5.1%, medium research productivity of 1.79 and a high technology maturity of 8.

The research paper-to-corporate ratio of 1 relates to a **more substantial innovation than research pipeline**, which is regularly seen in mature, established technology ecosystems. Stand-out Saudi Arabian innovators seen in Figure 8, include King Fahd University of Petroleum and Minerals with 62 inventions, Saudi Iron and Steel with five inventions, scoring on average 75+ DSI.

Notably, most of Saudi Aramco's inventions in this field originate from outside of Saudi Arabia in countries such as the United States. It is predicted that COTC processes could add **\$0.31bn USD** to Saudi Arabia's economy if **1,667 inventions** are protected in this field. The likely yield would be around 14 very strong inventions.

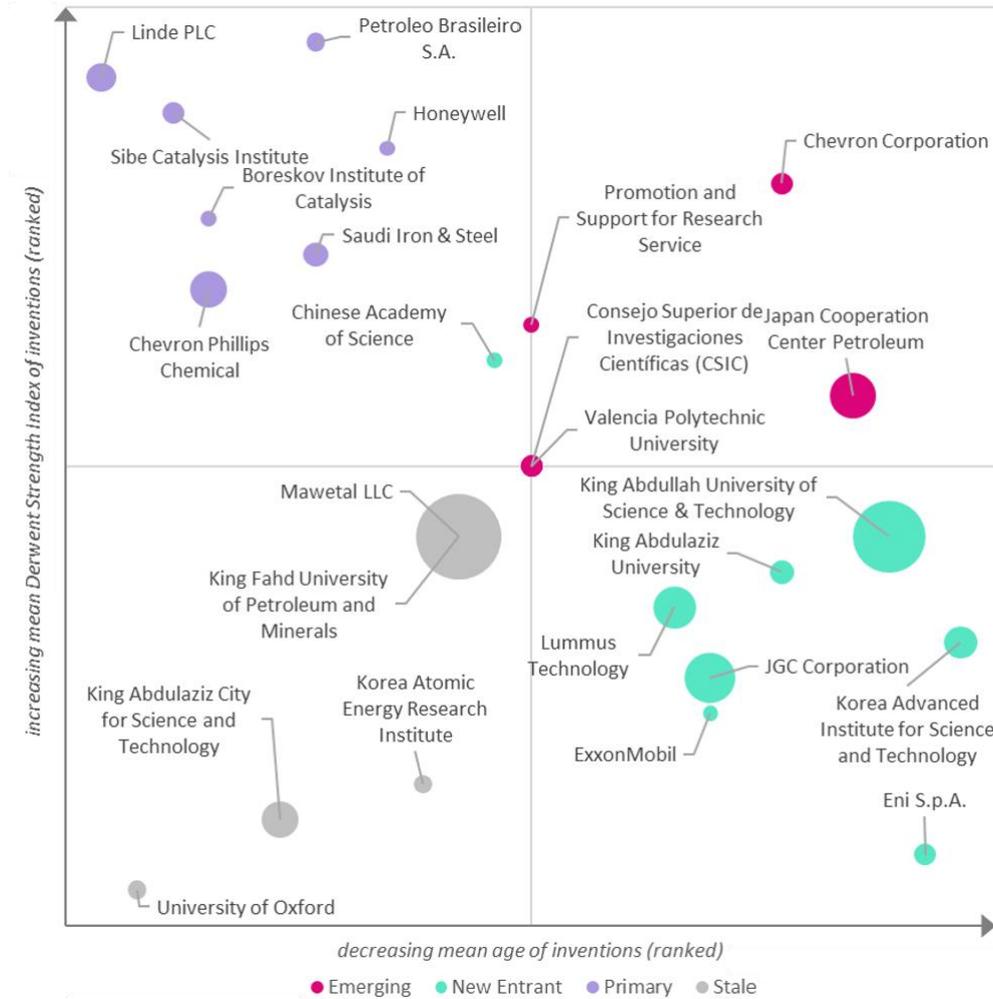


Figure 8: Commercial dynamics model for the top patent assignees active in Saudi Arabia in the research topic 'COTC processes.'

The Smart grid research topic within Table 1 achieves a medium research and invention volumes and strength, medium ACP levels and research productivity, predicted growth and high technology maturity of 7.

The research paper-to-invention ratio is 26, which is expected for a mature technology area. Invention levels are relatively low at 34, and no invention yielding ACPs. Therefore, an option could be to **further focus on the conversion of academic research into academic inventions** in King Abdulaziz, King Fahd University of Petroleum and Minerals and Imam Abdulrahman Bin Faisal University, along with potential ACPs with Saudi Aramco would be the most suitable local ACPs.

International innovators with strong invention portfolios who could assist in translating academic research into commercially applied research include ABB, GE Aerospace, Siemens, Mitsubishi, Hitachi, Samsung, NEC, LG and Panasonic.

In conclusion, for the eight focused research topics within Energy and industrials, Saudi Arabia has very high invention output and volume in **COTC processes and products, and Hydrogen Production. All three of these fields are led by the significant research, development and innovation power of Saudi Aramco.**

Local ACPs such as between King Saud University and Qudra Energy Co have even led to Saudi Aramco's intention to purchase a 50% share of Qudra Energy Co. joint venture Air Products Qudra's subsidiary Blue Hydrogen Industrial Gases Co.



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