

هيئة تنمية البحث  
والتطوير والابتكار  
Research Development  
and Innovation Authority

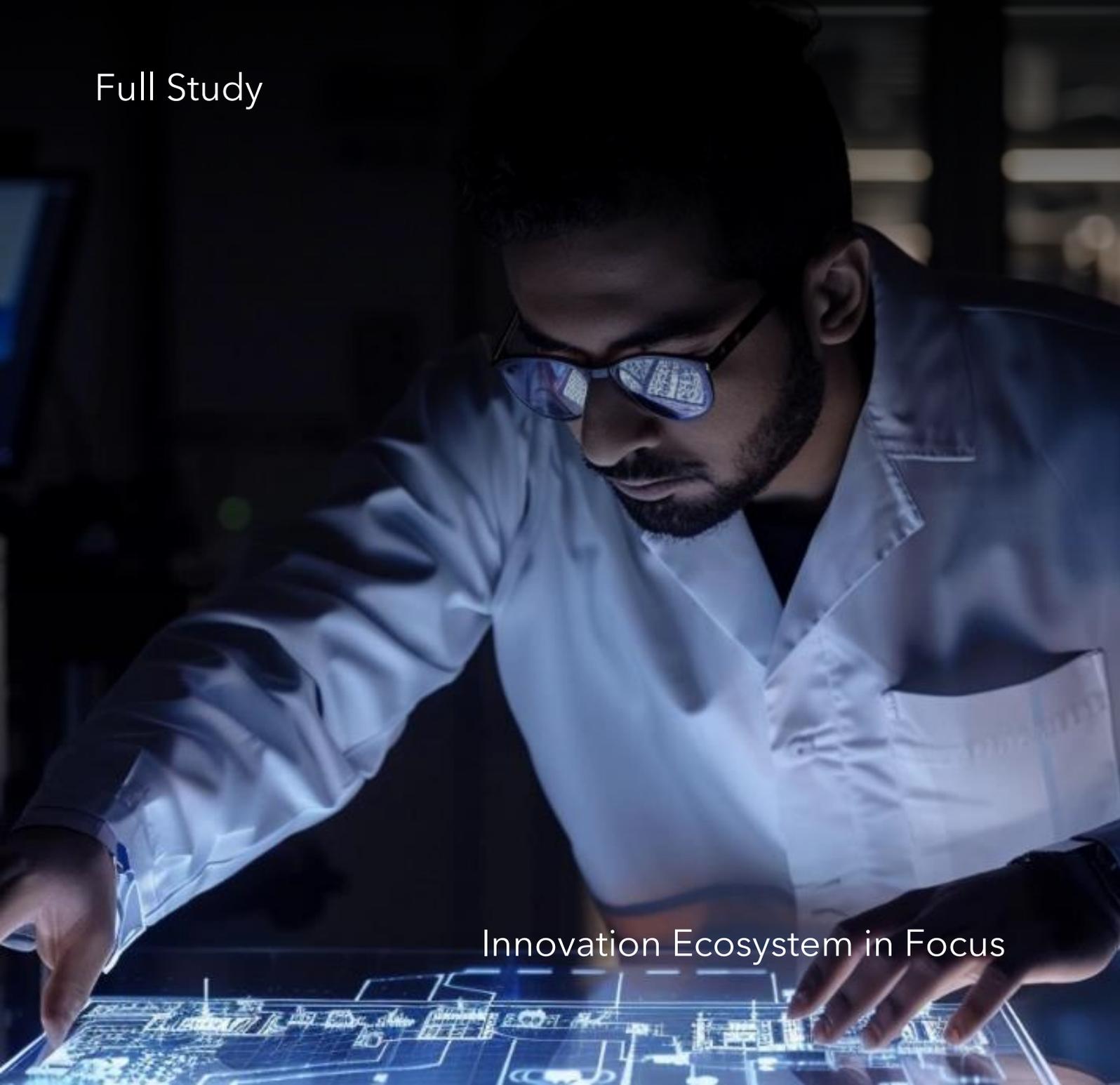


Clarivate™

# Accelerating Technology Transfer from the Lab to the Market in Saudi Arabia

Full Study

Innovation Ecosystem in Focus



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# 1 Background and context

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## 1.1 Introduction

The Kingdom of Saudi Arabia is undergoing a transformative journey emphasizing the importance of a knowledge-based economy as a driving force behind Saudi Vision 2030. This essential transformation is set to elevate the research, development, and innovation (RDI) landscape, positioning Saudi Arabia as a global leader within its national priorities:

- Health and Wellness
- Sustainability and Essential Needs
- Energy and Industrials
- Economies of the future

His Royal Highness Prince Mohammed bin Salman bin Abdulaziz Al Saud has declared Saudi Arabia's goal of becoming a global frontrunner in science, technology, and innovation. The Kingdom targets investing 2.5% of its GDP in RDI by 2040. Establishing the Research, Development, and Innovation Authority (RDIA) in 2021 marked a pivotal step in steering RDI initiatives.

RDIA has engaged Clarivate, a global leader in research and intellectual property data analysis, to collect, collate, and analyze research relationships, outcomes, and documents in Saudi Arabia and worldwide. Examining this data has highlighted areas of strength in research within Energy and Industrial Leadership and areas for improvement. This study aims to inform the reader about how these historical trends can guide the future allocation of resources dedicated to the RDI strategy.

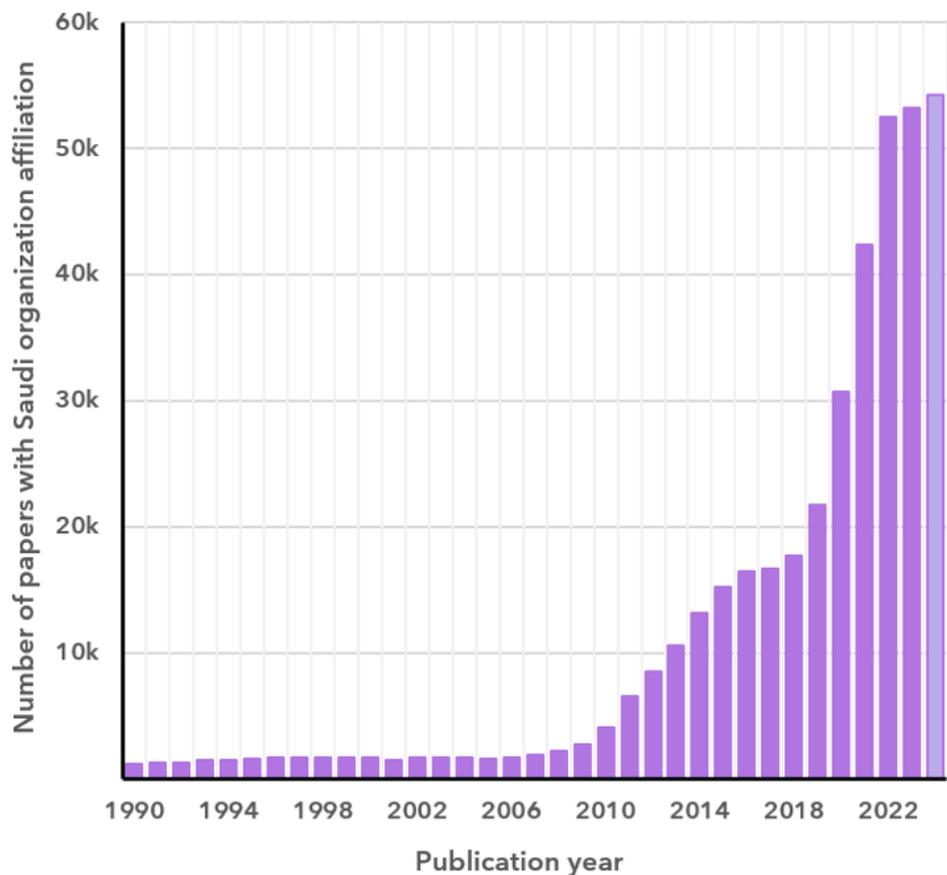


Figure 1 - Growth of Saudi Arabian peer-reviewed scientific research publication, 1990 to 2024 (estimated, pro rata year to date). Includes papers indexed in the Web of Science with a single author organization with an address in Saudi Arabia

## 1.2 Study overview

This study is the third part of a broader analysis program focused on global and local research and innovation. The program aims to comprehensively understand the research ecosystem and its capabilities when viewed within the context of national priorities and specific technologies that align with these priorities. It seeks to examine the Saudi research ecosystem from the perspective of the robust academic research base established over the last 20-30 years (see Figure 1). Additionally, it aims to explore how this research foundation interacts with industry to advance the development of that research into commercial technologies base. The role of academia in the research and development lifecycle is critical and is a foundation for a knowledge-based economy.

The more expansive program, of which this study is a part, therefore focuses on the nature and level of academic-corporate partnership evident within Saudi Arabian research and innovation as a feasibly comparable proxy measure for the level of research dissemination, as compared to other countries and regions, and is further built on a structure that aligns with Saudi Arabia's national priorities. Universities and research institutions perform two essential functions:

- Education
- Research

Technology transfer involves translating research outcomes into products and services and facilitating the deployment of research outcomes into the broader economy through commercial agreements. This process study will evaluate this third function.

In this study, Clarivate used a standard approach for analyzing data and techniques, relying on proven methods that were developed in advance, including:

- Connecting the technical framework within the National Priorities to specific areas of research and technology using an international collection of scientific studies and patents.
- Reviewing the levels of historical commercialization and applied research activities in Saudi Arabia compared to select comparable countries while profiling the capabilities, strengths, and resources available in Saudi Arabia today.
- Modeling the technical readiness level of global R&D for each research topic aligned with national priorities to evaluate the potential commercialization of future research in Saudi Arabia.
- Highlighting gaps in maturity areas to benchmark the current patent activity in Saudi Arabia as a proxy for the commercialization levels of applied research across each research topic in the national framework priorities.
- Review the study metrics for each national priority to identify research topics with the highest potential for significant impact.
- The production of scorecards for each national priority by leveraging:
  - RDIA expert view
  - Global technical maturity
  - Academic research base and Academic-Corporate Partnership activity level.
- Modeling an innovation ecosystem as it would compare globally in technology commercialization to inform future investments in research topics to achieve maximum impact.

This process captured multiple views and activity patterns into a holistic overview of the research opportunities and funding policy choices that can be pursued.

Measuring the technical maturity of a research area was based on a validated data gathering and modeling process that presumes natural progression patterns that

occur within research and innovation. This progression of research from a concept to a product is necessary to evaluate historical performance and model future research potential across national priorities. The model utilized by Clarivate to generate its modeling presumes the following sequence regardless of the specific research area:

Fundamental research	Early shift to applied research	General shift to applied research and development	Strong commercialization signals of developed technologies
Research that seeks to enhance our understanding of nature and provides a foundation for future research through publication.	As potential uses arise, further study to validate them. Patents may be filed.	Validates the commercial potential, reducing the associated risks, enabling focused development and investment towards commercialization.	Patented products are commercialized, competition arises as value becomes clear and litigation may occur.

This study utilizes a technical maturity index (further details of the model are included later) using millions of individual data points across multiple datasets to map these stages of RDI progression. Specifically:

1. Peer-reviewed scientific literature
2. Global patented invention data
3. Global patent case law databases

Using data related to national priorities, Clarivate conducted a top-down analysis of global economic activity and intensity and its connection to commercially directed innovation to model economic value and approximate the future commercialization value of applied research. This model assumes a strong relationship between GDP and robust patents to estimate the value of such inventions. The value estimate was further analyzed to enable historical data to inform future expenditures, plans, and targets for research in Saudi Arabia. Clarivate subsequently utilized the model to prioritize research topics for investment, which were mapped to their maturity recommendations.

In combination, these data sources have been structured in this study on the technical ontology of the broader work program and contextualized to the Saudi National Priorities.

The Kingdom of Saudi Arabia has embarked on an ambitious, long-term program of national transition aimed at creating a knowledge-based economy and a broader society.

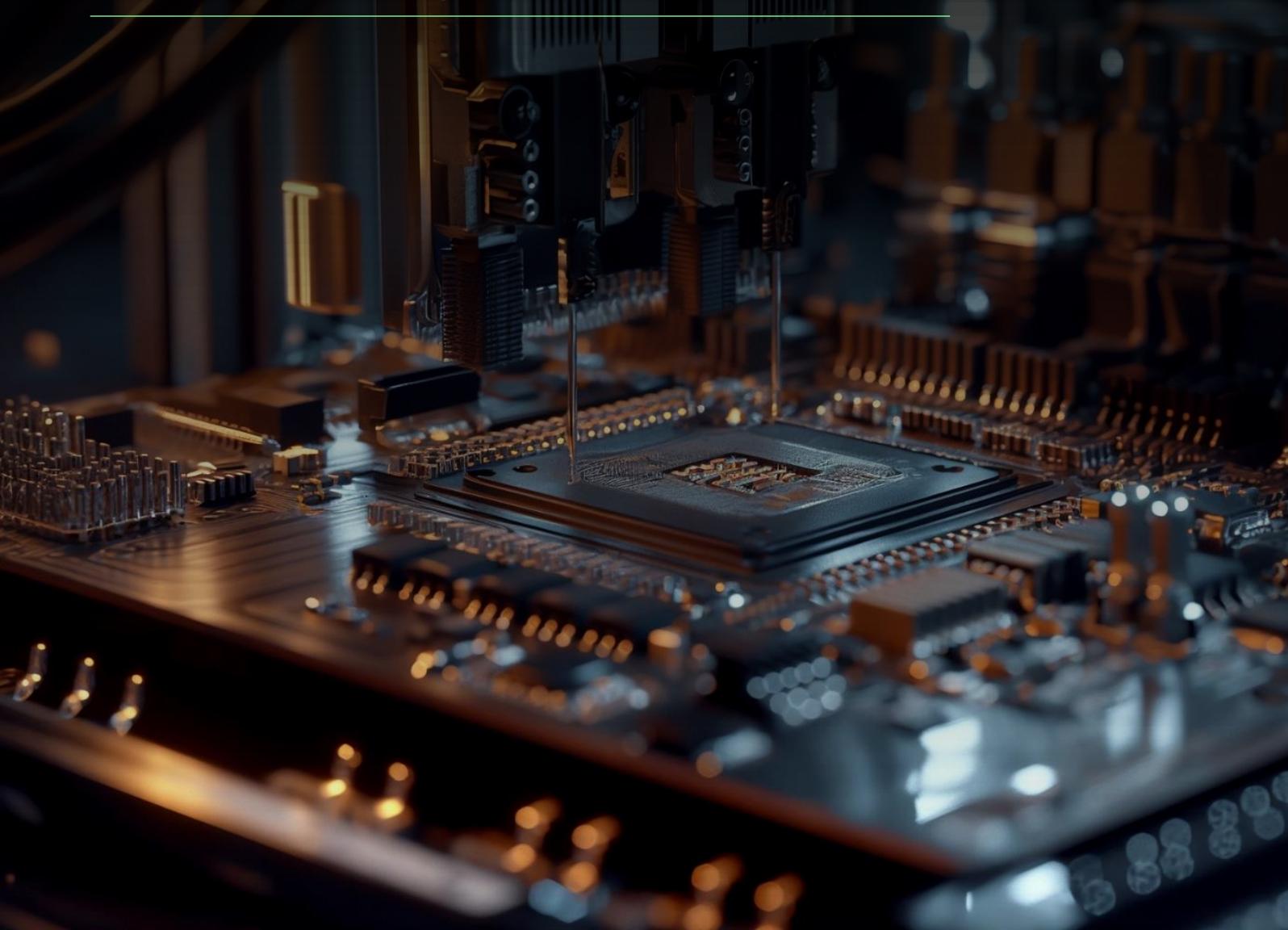
Saudi Arabia has specifically targeted becoming a global leader in science and technology to support this national transition strategy. Significant emphasis has been placed on research, development, and innovation (RDI), fostering a globally competitive ecosystem that encourages RDI activities within the country.

Aligned with the principles and strategies of Saudi Vision 2030, the Research, Development, and Innovation Authority (RDIA) was established in 2021 to oversee the facilitation of RDI initiatives and align the nation's research ecosystem with specific priorities reflecting the RDI strategy.

This study demonstrates the commitment of RDIA, through a data-driven process, to guide and accelerate the aspirations of the Kingdom of Saudi Arabia by commercializing its research results to enhance the lives of its citizens.

# 2 Executive summary

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This study builds on the data analysis and insights from Assessment of Academic-Corporate Partnerships in Saudi Arabia, and Insights into Saudi Arabia's Research and Innovation Ecosystem, within the wider program of research. It seeks to understand the level of collaboration and partnership between academia and industry in Saudi Arabia, and understand the focus of applied research, the current capacity and activities and its technology readiness. It assesses the global maturity of research themes and technologies within the National Priority Areas, evaluating their readiness for commercialization in the private sector.

This study seeks to deliver empirical, measured, and focused insights into the state of global technology readiness and mapping of that status to Saudi Arabia's areas of expertise and capability. It also examines both emerging and established avenues for academic-corporate research collaboration. The data gathered will be utilized to inform the targeted investment program's commercial value and potential impact on the Saudi Arabian economy.

Furthermore, the study evaluates the current landscape of commercial research and development activities in Saudi Arabia, assessing their potential for commercialization. This analysis aims to create a comprehensive understanding of the outcomes generated by the country's research ecosystem. The evaluation criteria—maturity, commercial value, and the depth of Saudi research (including partnerships between academia and industry)—are utilized to offer insights into research within the National Priority Areas.

This study emphasizes a heightened focus on the commercial opportunities arising from global technology trends concerning the National Priority Areas alongside relevant activities in Saudi Arabia. The connection between research and broader commercial potential is most pronounced when analyzing global patent data, which reflects the commercial value generated through scientific and engineering research activities.

The study's primary focus pertains to the strategic allocation of funding towards specific areas within the National Priorities, particularly those that demonstrate a greater need for enhanced academic intervention. A result of this study is that allocation of applied research support may increase commercial outcomes if it occurs at a stage in the development lifecycle where commercial viability is sufficiently defined, avoiding premature engagement. Notably, the recommendation stresses the need to diversify the pool of mid-range Technology Readiness Level (TRL) technologies within these research topics.

The findings of the study advocates establishing invention targets over five years, concentrating on particular research domains. This lays a solid foundation for significantly increasing the value added to the Saudi economy in the coming years while simultaneously facilitating a rebalancing of the Saudi research ecosystem toward the overarching objective of commercializing research outputs.

The potential for the Saudi academic sector to assume a more central role in global technological advancement and commercialization is increasingly apparent. This potential can be significantly amplified through targeted initiatives that provide direct funding for academic research and promote the protection of patentable outcomes stemming from that research.

By establishing a research focus on a broader array of topics earlier in the research lifecycle, guided by the National Priority Areas and the Vision 2030 initiative, there is likely to be a positive impact on Saudi Arabia's Global Innovation Index (GII) ranking. This approach could enhance the knowledge outputs ranking and generate a more pronounced multiplier effect on the broader Saudi economy. A diverse portfolio of technology transfer-ready research assets opens avenues for the licensing of these technologies to international corporate entities and it can serve as core intellectual capital for start-ups seeking investment. These developments contribute to a more

conducive environment for the deployment of research outcomes through innovation within the Saudi economy.

Implementing a structural and strategic shift in Saudi Arabian research towards earlier Technology Readiness Levels (TRL) could potentially establish a foundation for increased economic activity derived from this research transformation. This approach benefits from a structured policy framework within the National Priority Areas and the broader global landscape of innovation needs and demands.

# 3 Key findings



1. Commercial potential is not evenly distributed in the National Priority Areas and varies considerably in technical maturity. This disparity provides significant opportunity for research and innovation policy to target high opportunity areas of research and technology that Saudi Arabia can define as major contributions to global technical knowledge. As RDIA reviews systematic, data-led approaches to funding, there is potential to provide greater diversity of research outcomes for Saudi Arabia. Such increases in diversification provides further opportunities for organic economic growth (greater levels of applied research) as well as improved performance on international comparison metrics (e.g. the annual WIPO GII ranking).
2. In the 2024 WIPO Global Innovation Index, Saudi Arabia ranks 47th overall, 36th in Innovation Inputs and 66th in Innovation outputs. Both elements have shown significant improvement since 2020. The lower ranking in innovation outputs maps to findings within this study; subsequently, the lower level of research ready for commercialization, and following commercialization activity is lower than expected for a comparable sized economy. Action items that target greater economic impact from research and innovation will have a positive effect on Saudi's performance in such international ranking systems.
3. Saudi Arabia is today a source of high-quality applied research inventions, at comparable volumes and quality levels in the National Priorities to compared to median values in OECD and top 25 GII member states. This provides a significant foundation for further advancement of the national strategy surrounding research & innovation, building on the impressive creation of a globally comparable academic research base. However, levels of partnership with the private sector in applied research are low (potentially reflecting wider commercialization barriers) and evidenced by the research outputs of Saudi Arabia heavily focused on academic paper authorship versus protection of ideas in registered intellectual property – a skew which is not evidenced in global comparisons.
4. As a result, the Saudi research ecosystem is globally strong in academic research (see Assessment of Academic-Corporate Partnerships in Saudi Arabia) but appears challenged to find routes to commercialization for that research, either through the local industrial base or via international corporations. Evidence for this includes the lower level (in relative terms) of patent filing from the high quality and high volume of published Saudi academic research. This measurement outcome reinforces the current lower performance within the WIPO Global Innovation Index surrounding knowledge outputs. Creating a more systematic focus not just on applied research but protection of applied research in patent filing will create an opportunity for significant contribution to the Saudi economy.
5. Saudi Arabian research depth and resulting opportunities for technology transfer has grown significantly over the past decade but is concentrated into specific areas of the National Priorities. Today, focus on research that is incorporated in the National Priorities sits at 40% of national applied research outputs measured in invention data. As the national research & innovation strategy continues to focus on the national priority areas, the proportion of academic invention levels within them is expected to continue to rise.
6. Saudi academic research is also focused on research themes and topics that model relatively mature, with 60% of academic inventions falling into research topics that were scored at TRL 8. This contrasts to global academia protecting research as intellectual property rights, which trends towards a more even distribution and includes a higher level of focus in TRLs 4-5. It also contrasts to Saudi corporate activity (primarily Aramco), which has a similar spread. With this current higher maturity focus, commercial adoption of research is likely to

be more fruitful in fields where the outlook of continued growth and private sector interest is likely to remain high even at advanced TRL levels.

7. This focus of academic patent activity in later TRLs is driven by a comparable high concentration of patented research in a small number of research areas: within the National Priority Areas these are crude-oil-to-chemical products and processes, AI in Information and Communications technologies, cancer research and renewable solar farm technology.
8. The concentration of Saudi research in higher TRL levels impinges the number of patent rights produced by academia. Utilizing the funding and wider policy framework of Vision 2030, there is an opportunity to diversify the research topic breadth, particularly in TRL levels 4-7, and thereby increase the absolute number of transferable technologies available for adoption in the Saudi economy. Changing this profile would therefore increase the knowledge outcomes of Saudi Arabia to comparable international norms for an economy of its size. This is a key metric for the WIPO GII score as detailed above, and therefore a driver progress towards Saudi Arabia's Vision 2030 aspirations.
9. The evidence base of protected research globally shows a strong relationship between growth in applied research and earlier TRL levels, highlighting the importance of a greater academic contribution to research themes that sit in at immature TRL levels. An increase in the diversity of transferable technology and knowledge outcomes from academia will also remove existing caps on the creation of new businesses that are directly supported by government-funded research. Providing room for young, newly created enterprises to not simply adopt technologies, but via that transference occurring earlier in the innovation lifecycle, provides young corporations with headroom for their own value-addition via commercialization, making them more attractive for investment.
10. Saudi Aramco is today the key driver of academic partnership, with relatively ad hoc partnership formation occurring elsewhere in Saudi Arabia - there is a concentration within the Saudi R&D ecosystem that would benefit from policy focus on enablement of commercial research drivers: partnership networking, protection of research as transferable/more mobile intellectual property assets.
11. Aramco represents a significant proportion of the overall corporate activity in the National Priority Areas (approximately 60%), and as noted above, has a greater proportion of activity occurring in earlier TRL levels than the Saudi academic sector, specifically driven by research in AI topics.
12. There is a specific set of technologies under the National Priority Areas that are assessed to have both headroom for development by private enterprise (and therefore attractive for adoption from academia) as they sit at mid-range TRL levels. In addition, they exhibit attractive future commercial potential (as evidenced by significant current and predicted pace in invention levels globally) and have an existing research base, interest or evidence of academic-corporate partnership within Saudi Arabia:
  - a. For Economies of the future:
    - i. AI in ICT
    - ii. AGI - Privacy and Security Oriented
    - iii. Smart Agriculture
    - iv. Internet of Things
  - b. For Energy & Industrials
    - i. Hydrogen Production

- ii. Hydrogen Storage and Transportation
  - iii. Sustainable Mining - Waste Management (including for example red mud)
  - iv. Battery Management
  - v. Autonomous Mining - Smart Drilling
- c. For Health and Wellness
- i. Telehealth
  - ii. eHealth
  - iii. Precision Medicine
  - iv. Nanomedicine
- d. For Sustainability and Essential Needs
- i. Air Purification
  - ii. Waste-to-Energy
  - iii. Carbon (CO<sub>2</sub>) Capture
  - iv. Water Desalination
  - v. Carbon (CO<sub>2</sub>) Storage

With linkages to the existing power of the Saudi economy in the energy sector, or the geographic characteristics of the country alongside likely demand international, they represent the key sectors of recommendation from this study for future, targeted technology diffusion from the emerging strength of the Saudi research ecosystem. However, they also include diversification, and via the creation of economic outputs downstream from research funding, an overall broader footprint of the Saudi economy in the years to come.

13. Several research themes (for example: space habitats, deep sea eDNA analytics, analog AI) within the National Priorities were not observed to have activity from the Saudi research community as patented/transferable technologies, and in combination were rated as low in terms of maturity, likely placing their funding priority within a more early-stage research category.
14. In the last year an estimated 4,400 individual inventors were active in the inventions published in 2023. Of these, approximately 1,250 were inventors from academic institutions.
15. The potential for greater research commercialization is particularly evident in that even at relatively low levels of applied research output for an economy of its size, Saudi Arabia already accounts for above baseline levels of economic value in the existing national patent portfolio. This value is concentrated within research topics within the National Priorities (and relatively lacking in other technologies) and reinforces the Vision 2030 strategy. The four national priorities coalesce around Saudi Arabia's strengths in research and innovation and form a powerful basis for future growth and economic return as the country invests further in these fields.
16. Analysis of the economics of global innovation, filtered for areas of national capability and existing research expertise suggests that for every 1 Saudi Riyal invested, successful commercialization of the outputs of that investment can yield 2.25 Riyals of wider economic activity within Saudi Arabia.
17. The importance of academic-corporate partnership is empirically evidenced by the estimated value of an invention produced in such a partnership being increased between \$US 50-170,000 each.
18. Attainment of the RDI aspirations of increasing annual spending in RDI of 2.5% of the country's GDP by 2040 and increase number of highly specialized jobs in RDI sector from a diversified knowledge economy is feasible, building on the significant research & innovation culture within Saudi Arabia today.

# 4 Key opportunities

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Leaning on the metrics and measures of this study, alongside those of the earlier parts of this program, RDIA encourages a broadened approach to the development of new technologies from Saudi Arabia's research ecosystem. Specifically, a recommendation to implement a targeted, incentivized and systematic protection of academic research outcomes in international patent jurisdictions.

This program would contain several steps:

1. Match research funding intensity (number of funded projects, level of funding) and requirements to the placement not just of the likely TRL level of the individual research grant application, but also the wider prospects (commercial potential and market size) of the research topic that are occurring globally.
2. For early to mid TRL research topics, yet potentially highly commercial research areas, research funding requests should contain a focus on the creation of transferable technical assets as seeds for either existing businesses or the creation of new enterprises (e.g. start-ups).
3. Explore the potential for including a requirement for patent registration of technologies that emanate from RDIA funded research projects. This policy may include specific ring-fenced funding of patent registration procedures. Both policies have track records in other countries, specifically, for example, the requirements of the Bayh-Dole Act in the United States, that has nurtured university technology diffusion. However, a requirement to patent without funding for such requirements may mean early jump start of such processes via the funding cycle. The existence of IP assets in research topics that are highly likely to extend into commercial phases in future years lays the groundwork for partnership and potential licensing of technologies by a broad array of potential users of the research produced.
4. Where the overall maturity of a research topic is high (e.g. TRLs 6-9) and the commercial potential of the wider research topic is also high, research funding should prioritize research programs directed towards applied research, and/or highly disruptive technologies in these existing markets. The mode of activity should focus on the sourcing of, or expansion of existing, academic-corporate partnerships. In essence, the mode of research in highly commercial, mature research topics becomes focused on marketability of applied technologies, and less on fundamental basic research unless likely to be disruptive or part of a new development cycle within those markets. Note that patent asset protection of research remains a focus, so that partnership and commercial transfer for research outcomes is facilitated by the potential joint ownership and control of the technologies underpinning the commercial activity.
5. To rebalance the basic versus applied and commercialized technology nature of Saudi research & innovation needs to add approximately 1,500 inventions of the very highest quality (within the global Top 0.5%) over the next 10-15 years to realise the ambition of increasing the annual spending in RDI of 2.5% of the kingdom's GDP by 2040.
6. Leaning on international norms, to achieve these goal targets of economic output, a wider program of invention creation and protection of the order of 100,000 to 300,000 patented inventions over the next 16 years. This equates to between 6,200 and more than 20,000 new inventions filed per annum. Such a program is estimated to be capable of adding \$ 16.61 billion over a 5-10-year period, and kick starting a more mature innovation ecosystem within Saudi Arabia that can build towards national aspirations of \$60 billion by 2040-50.
7. Current levels of inventorship within Saudi Arabia will need expanding to fulfil such levels of national applied research creation, and therefore a review of

potential support measures (education, mentorship, incubation and accelerator programs) is likely required to assist.

8. An envisaged initial target scenario focuses on the creation of almost 50,000 patented inventions across 36 research topics within the National Priorities, yielding ~400 globally leading strong inventions within their fields that can create value for private enterprises within Saudi Arabia when taken to market.
9. Attainment of the increase annual in spending in RDI of 2.5 percent of the country's GDP by 2040 and increase number of highly specialized jobs in RDI sector to the Saudi economy requires a review of wider policy initiatives and regulation that ease potential barriers to successful conversion of potential economic value from research and innovation.

Where Saudi Arabia has low (or unobserved) research commercialization activity and applied research invention levels (see list below), funding approaches could follow a more ad hoc approach to technology transfer activity. As basic and fundamental academic research both locally and globally within these fields generates increased maturity within these technologies this approach can be reviewed, with a priority towards traditional academic knowledge outputs in research publication. Specific research topics include:

- Air quality, traffic, energy and resource management
- Analog AI
- Deep sea environmental DNA analytics
- Deep sea microbes
- OpenRAN
- Space mining and habitat technology
- Automatic 6G network management
- Energy efficient 6G edge infrastructure
- Mobility as a service
- Urban air mobility

In sectors with more niche commercial potential and/or lower levels of existing Saudi research capability or interest, focus should steer towards two potential modes of operation:

- For more mature research topics, it is more likely that corporate and private interests can operate independently, i.e. these are technologies that have specific markets and are sufficiently developed for private R&D programs to target improvement and new solution.
- For less mature research and lower commercial potential and/or Saudi track record in activity, funding can occur in an ad hoc manner. As the research & innovation ecosystem within Saudi Arabia develops, particularly backed by internationally protected research assets that increase investment attraction in new corporate enterprises around specific technical approaches, these less mature sectors will have greater future opportunity to operate in developing markets.

# 5 Program of work

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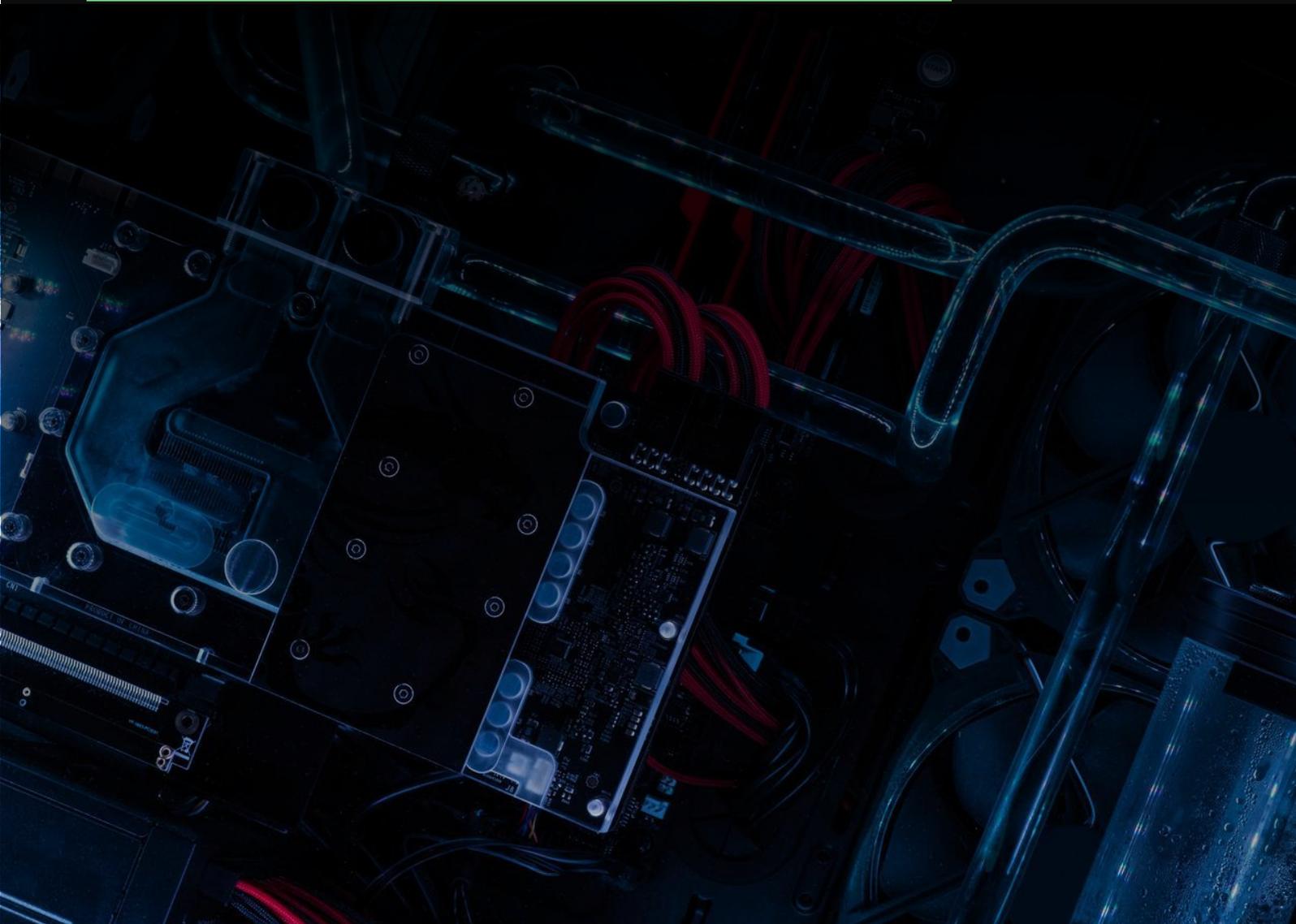
The study follows set procedure of technical and data analysis, using validated and pre-developed methodology, and comprises the following:

1. Transference of the technical ontology produced in Study 1, which maps the National Priorities into discrete areas of research and technology and forming a global corpus of validated technical information across peer-reviewed scientific literature and patented inventions that are relevant to the National Priorities of Saudi Arabia.
2. Review of the commercialization and applied research activity levels of Saudi Arabia versus comparison nations, and profiling of the capability, value, strength and resources active within Saudi Arabia today
3. Modelling the technical maturity status of global scientific and technical research of each category within the ontology, for each National Priority, providing an assessment of the commercialization potential of activity within Saudi Arabia, and/or gaps or areas of maturity focus.
4. Benchmark the current patent activity within Saudi Arabia as a base proxy for commercialization or applied research levels, for each of the categories in the ontology.
5. A review of the study metrics and outcomes as a combined analysis of Saudi Arabia current strength, analyzed alongside the measured commercial growth forecast for research topics in each National Priority Area, to identify research topics that are recommended as high prospects.
6. The production of scorecards for each National Priority, aggregating factors gathered in this study (as well as Assessment of Academic-Corporate Partnerships in Saudi Arabia, and Insights into Saudi Arabia's Research and Innovation Ecosystem of the wider program), including:
  - Global technical maturity
  - Academic research base and quality
  - Academic-Corporate Partnership activity level
7. The creation and analysis of an economic model of global innovation, based on global invention output, that links invention levels to national economic output. This model can then be applied to the current and forecast state of Saudi Arabian technology commercialization, providing guidance on research topics that can be targeted for investment for maximum return on investment to the Saudi economy.

This process provides a way of capturing multiple views and activity patterns into a single holistic overview of the research opportunities and the funding policy choices that can be pursued.

# 6 Methodology

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Measuring a research area's technical maturity is based on an empirical and validated data gathering and modelling process that leans on the natural progression patterns that occur within research and innovation.

As a general model, research, development and innovation (RDI) follow a specific sequence:

### **Fundamental research**

Fundamental research is conducted without a focus on practical applications. Its primary goal is to increase our general knowledge and understanding of nature and its laws. Although this knowledge can help address many important practical problems, it may not provide complete solutions to any specific issue. It establishes a foundation for later technical development. As the utility of the research may not be readily apparent at this stage the inventor may elect to not seek patent protection without further development of the foundational work. The primary mode of dissemination of fundamental research is through publication and education.

### **Early shift to applied research**

Building upon the foundation established through fundamental research, potential applications may become apparent and further research may be undertaken to validate specific application(s). Research institutions may be more inclined to seek patent protection for the results of these efforts as they are more likely to be provide sufficient detail to meet patentability criteria, specifically utility. While early applied research will often result in dissemination through scholarly publication, where patent protection has been sought, these results may also be made available for commercial use through licensing either for commercial or commercially informed research by others.

### **General shift to applied research and development**

As research results in further validation of the potential application the risk profile associated with the realizing upon the commercial potential of the original work is reduced. This allows for more targeted development and investment with a view to achieving commercialization of the discovery as embodied in the patent application and validated through early applied research. This stage of research is less driven by curiosity but rather by the technical challenges associated with creating a commercially viable application of the original work. The dissemination of these results is typically in the form of products being launched onto the market once patent applications have been granted in those jurisdictions.

### **Strong commercialization signals of developed technologies**

Later stage commercialization, once products dependent upon granted patents are brought to market will often see competitive products introduced that may infringe upon the patents. This can result in legal action to either enforce the rights inherent in the patent or to challenge the legitimacy of granted patents. Given the significant costs and complexities of patent litigation, the existence of such actions is a reasonable proxy of the value of the underlying patent and the products based upon its claims.

This evolution of research from curiosity-based exploration to valorization of the exclusivity rights secured from patent protection is captured and mathematically modelled, enhanced via strength, growth, activity and timeline measures.

This study utilizes a technical maturity index (further details of the model is included later) using millions of individual data points across multiple datasets to map to these stages of RDI progression. Specifically:

- Peer-reviewed scientific literature: a fundamental component of the scientific method, the evidential and verification process of testing and reviewing new research in the scientific community can be captured and

assessed as signal mapping to progression of basic research. Typically, fundamental research is only disseminated through publication.

- Global patented invention data: the issuance of intellectual property assets as commercial vehicles for dissemination of technical innovation, alongside the requirement for disclosure of the technology itself in a patent document. Incurring the costs associated with filing a patent expense creates a reasonably strong signal as to research being more applied. Patent data, due to its globally homogenous structure, provides a high-accuracy comparable and analytical framework, and a deep level technical detail – provides the ability to enhance modelling with factors such as inferred invention strength.
- Finally, global patent case law databases can be mapped to patent datasets, so that the frequency of litigation or opposition across different research areas can be directly measured and captured as signal of commercialization itself.

### **An economic model of technology value**

Patent value and commercialization potential are highly subjective and variable at the individual case layer. However, using the data structure around the four National Priority Areas, a top-down analysis of global economic activity, intensity and linkage to commercially-directed innovation, a model of economic value and, as a consequence, potential commercialization value of applied research occurring globally.

This model assumes a strong link between GDP and strong patents (i.e. those that map to the very highest scoring inventions globally, as measured via Clarivate's invention strength model). This is then used to assess the economic impact and value of such inventions. This estimate of value is further analyzed to deduce how the historical generation of such inventions can inform expenditures, plans and targets associated with future research in Saudi Arabia. This model is then further applied to prioritize research topics for investment, mapped to the maturity and recommendations as previously discussed.

In combination, these data sources have been structured in this study on the technical ontology of the wider program of work and contextualized to the Saudi National Priorities.

# 7 Data structure

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As this study, and the wider program of research, intends to analyze the National Priorities under the wider Vision 2020 policy, a dataset has been created that allows a detailed review of both the research activities occurring within Saudi Arabia as well as comparisons to that activity globally.

To facilitate this program of research, a technical analysis was undertaken to identify key research topics under each National Priority. Further, these research topics then go on to define the datasets of the National Priority Areas themselves.

The creation of these content sets is based on three primary sources of information:

- National publication information concerning the missions, aspirations and National Priorities of Saudi Arabia
- The study's technology analyst team, comprising STEM professionals with many years of experience performing innovation and technology research intelligence projects.

In total, 167 topics were identified and collated across both research publications (gathered from the Web of Science) and patented inventions (sourced from the Derwent World Patents Index) from 2014 through to the present day, using traditional keyword and technology classification search techniques.

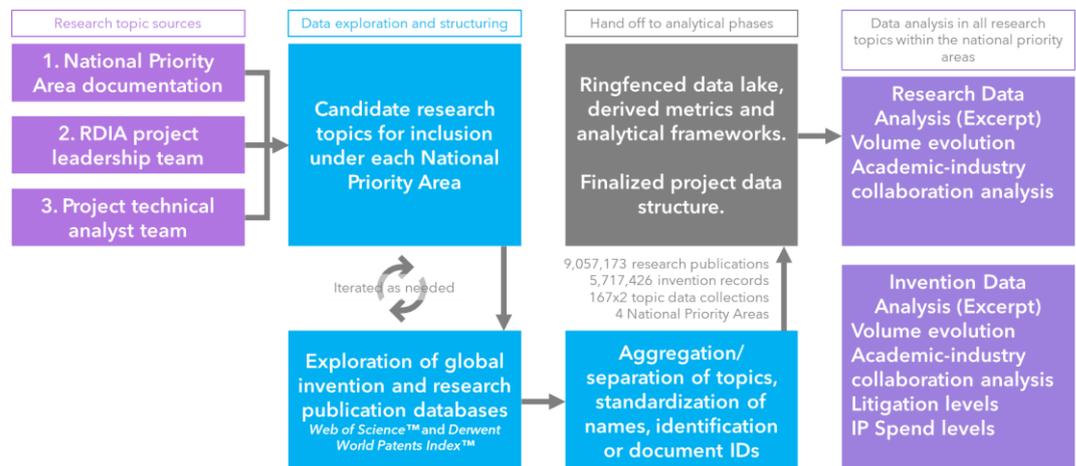


Figure 2 - Summary of project data creation, curation and analysis process

Topics were reviewed by the project technology analyst team for review of completeness, introduction of error or need for further definition and extraction. This is performed via an iterated review and amendment process, using the scientific and engineering expertise of the project's technical analyst team.

Once these data extraction strategies were finalized, the records associated with each research topic category were aggregated, name normalized and ring-fenced into a project specific data lake ready for analytical work up.

The finalized data structure for this study is summarized:

- Over 9 million research publications.
- Over 5.5 million patented inventions.
- This data is then structured into 167 research topic categories, across both research publications and inventions.
- The 167 research topics themselves then define the 4 National Priority Areas.

The number of research topic categories varied slightly across the four National Priority Areas, as shown in Figure 3.

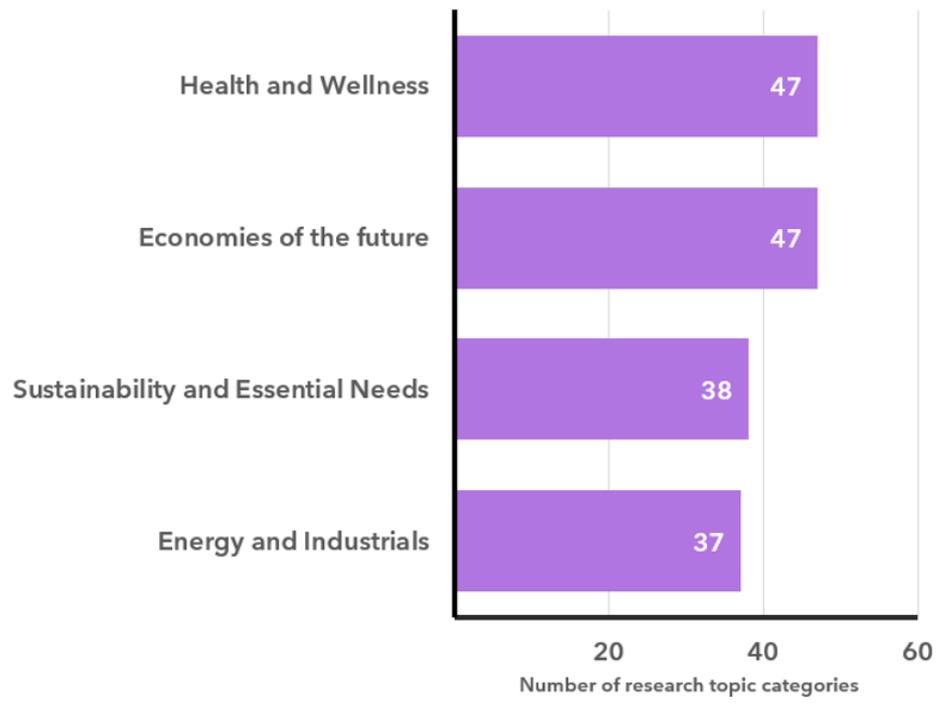
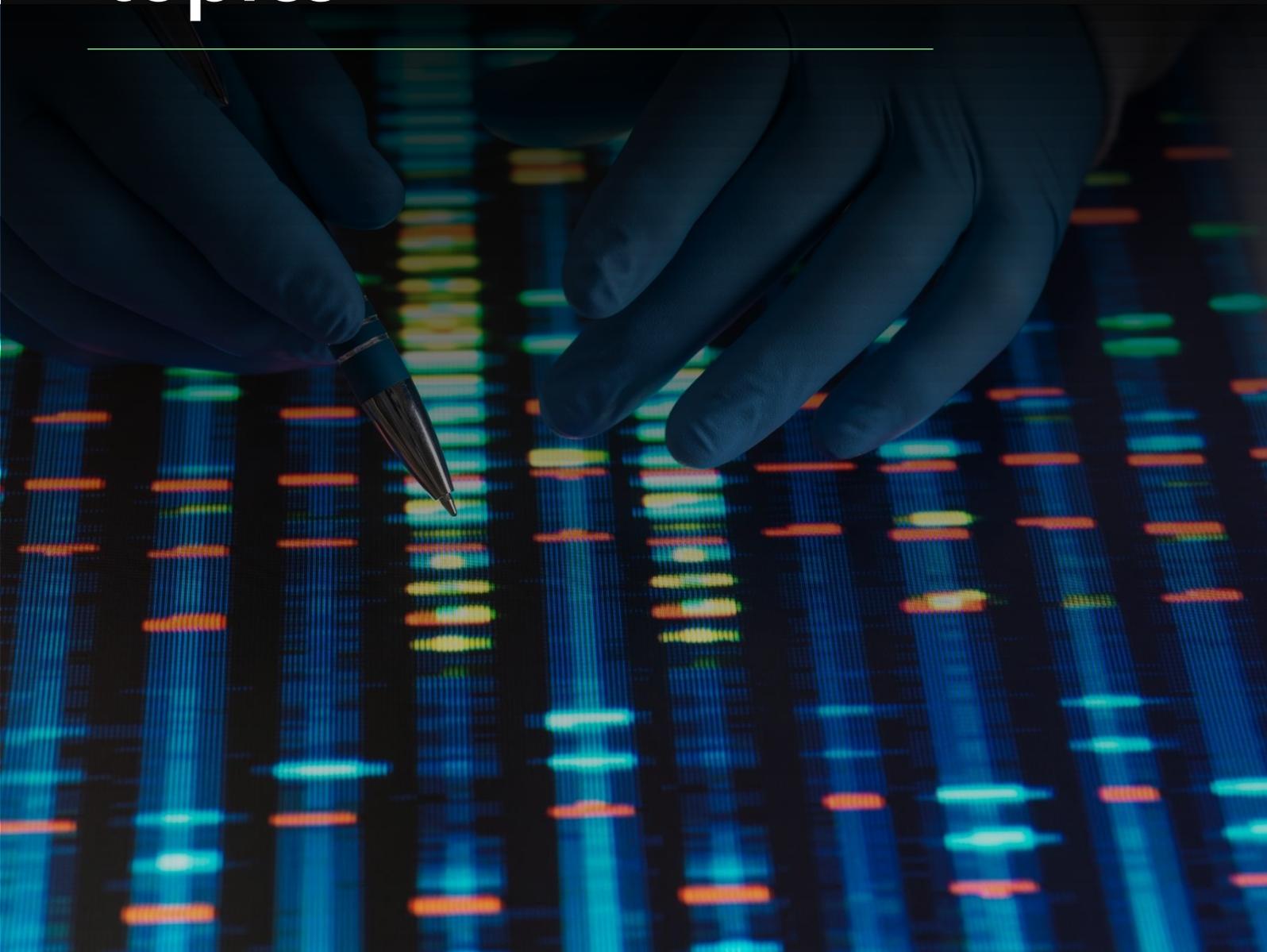


Figure 3 - Number of research topic categories under each of the four National Priority Areas

# 8 Volume of research and invention in the research topics

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It is expected that in a research and innovation intelligence program of this size, there will be significant variation in the volume of published and patented research occurring within the different research topics. The study performs a review of all global research and innovation activity between 2014 to the present day<sup>1</sup>. Here the detail of the research topic category structure is introduced on which analysis of commercial potential and technology maturity will take place.

In addition to variation between the topics, there is further variation between the volume of research publications within a topic, and the corresponding number of inventions in that same topic.

A summary (Table 1) of the National Priority Areas in terms of major areas of concentration in the more basic research detailed in research publications versus more applied research occurring within patented inventions shows:

#### **Economies of the future (Figure 4, see later pages for each visual)**

- Correlation of high levels of research activity since 2014 in Artificial Intelligence (AI) for Information and Communications Technology (ICT) applications and semiconductor technology in general, though noting that there is more than double the number of papers in AI for ICT in that period than patented inventions. This indicates AI, in general, is continuing to need the support of significant academic research.
- Semiconductor invention activity is the highest in any of the 167 research topics, indicating the commercial importance of chip and device design and manufacture as a foundational technology underpinning much of modern economics.
- On minimal levels, research publications are low for nascent telecommunications topics in sustainable 6G and OpenRAN. More generally, telecommunications technology tends to be more applied in nature and therefore a topic supported by large global telecoms corporations (i.e. Samsung Electronics, Huawei, Qualcomm, Ericsson, Nokia, LG Electronics). However, there is agreement in the patented invention volumes on these topics, for example only 138 invention records on energy efficient edge infrastructure for 6G, or 632 inventions surrounding OpenRAN. These are therefore early nascent fields of interest.

#### **Energy and Industrials (Figure 5)**

- Focus for basic versus applied research is very similar, focusing on solar and wind renewable energy sources and technologies, though again noting that the global invention levels in solar farms are more than double the number of research papers in the same period. This disagrees with volumes in photovoltaic modules themselves, where the number of research publications is similar (and slightly higher) than in patented inventions. This view would imply that there is further efficiency and solution to be made in new areas of academic interest in solar energy production while also already being a highly commercial technology using existing technology infrastructure.
- Significant variation occurs in lowest volumes of activity, with research publications at a lower level in more engineering topics around Smart HVAC systems and construction automation technologies. Future derived nuclear power such as Small Modular Reactors (SMRs) is relatively well represented in research, but minimal in patented invention with just 596 inventions published in the last decade.
- Where correlation does occur in low volumes in the Energy and Industrials National Priority is within Sodium-Sulphur battery energy storage

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<sup>1</sup> Note: Where a time axis is incorporated analysis in the study, the cutoff date is visualized as 2023. However, research output data points in the study collections include records published through July 2024. These data points are incorporated in analyses without a time axis.

technologies, with both basic and applied research proxies returning low levels of research output.

Table 1 - Summary view of top/bottom areas of research publications and patented inventions per National Priority Area; includes a view of where significant variation occurs

National Priority Area	Highest Volume of Research Papers	Highest Volume of Inventions	Lowest Volume of Publications	Lowest volume of Inventions	Greatest Mismatch Publications vs Inventions
Economies of the future	AI in ICT	Semiconductors	OpenRAN	Data Ownership & Privacy	Cloud Computing (strongly invention biased)
	Semiconductors	AI in ICT	Sustainable 6G Energy Efficient Edge Infrastructure	Sustainable 6G Energy Efficient Edge Infrastructure	AI in ICT (strongly research biased)
	Quantum Sensing	Cloud Computing	Sustainable 6G Automatic Management	Sustainable 6G Automatic Management	
Energy and Industrials	PV Modules	Solar Farms	Sodium-Sulphur Battery	Small Modular Nuclear Reactor (SMR)	Solar Farms (strongly invention biased)
	Solar Farms	PV Modules	Smart HVAC	Mining Automation Software	Lithium-Sulphur Battery (strongly research biased)
	Wind Turbines	Wind Turbines	Construction Robots	Sodium-Sulphur Battery	
Health and Wellness	Cancer	Cancer	Congenital Gene Therapy	Dengue	Telesurgery (strongly invention biased)
	Cardiovascular diseases	Gastrointestinal	Telesurgery	Congenital Gene Therapy	Cancer (note: mismatched due to significant disparity in volumes)
	Immunotherapy	Biopharmaceuticals	Robotic Prosthetics	Robotic Prosthetics	
Sustainability and Essential Needs	Wastewater Purification/ Treatment	Wastewater Purification/ Treatment	Water Leakage	Carbon (CO2) Transport	Wastewater Purification/ Treatment (note: mismatched due to significant disparity in volumes)
	Aquaculture	Electric Vehicles	Precision Livestock	Waste Landfill	Soil Preservation (strongly research biased)
	Electric Vehicles	Air Purification	Brine mining	Carbon (CO2) Utilization	

### Health and Wellness (Figure 6)

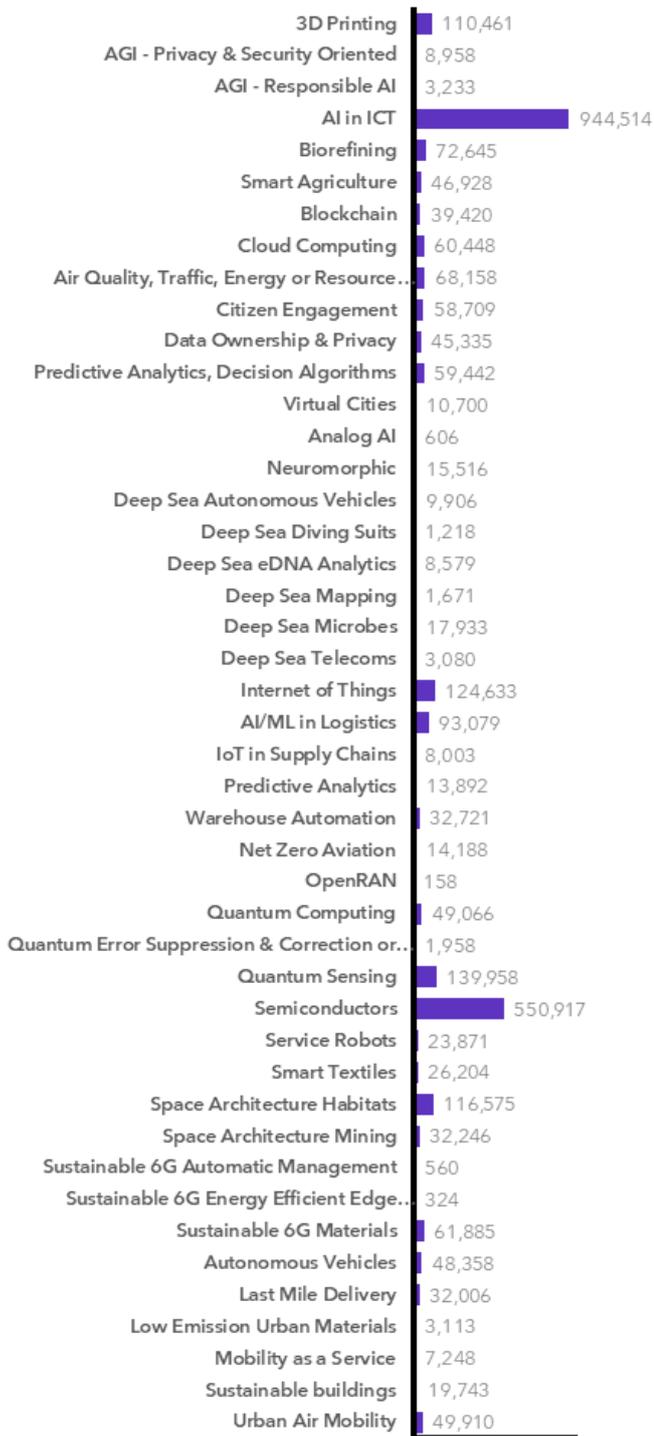
- The highest volume of published research papers in all of the National Priority areas is cancer research, with more than 1.8m papers in the sample period. It is also the top research area within Health and Wellness in terms of patent activity.
- Other than cancer research, basic and applied research focus is seen in cardiovascular and immunotherapy medical research in publications, and gastrointestinal and biopharmaceutical products in patented inventions. The latter includes drug candidates and development, and therefore a significant area of commercialization for pharmaceutical companies globally. This

disagreement is therefore expected, as base research supporting pharmaceutical development is likely to be diluted amongst specific condition targets and therapies.

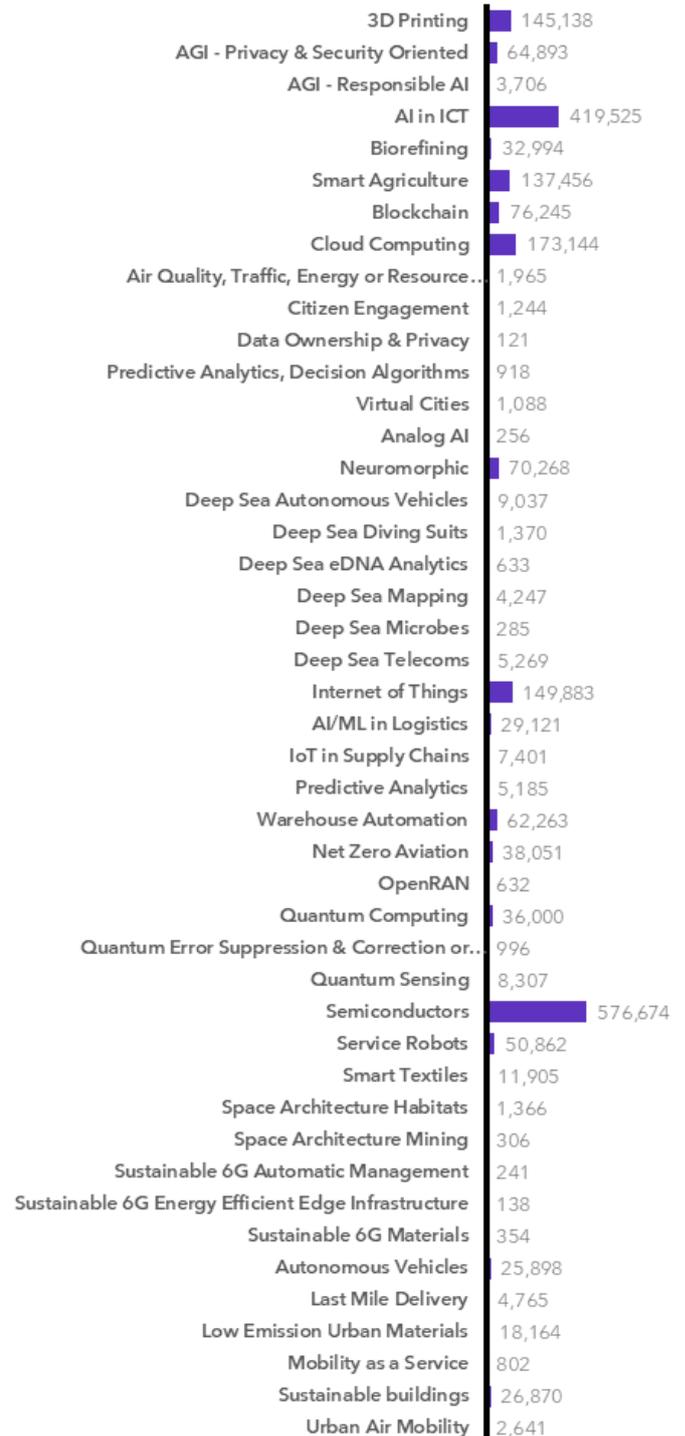
- There is some consistency in low focus areas between published research and invention activity - both reporting the lowest volumes in congenital gene therapy, though this low level should be contextualized as still represented by several thousand research papers and inventions. Similarly, robotic prostheses are also reported to be the lowest among the 47 research topics in the National Priority Area.
- A divergence in focus is observed between the published research and invention occurs in telesurgery technologies, likely due to the convergent and applied nature of the technology enabling remote surgical procedures. Multiple existing technologies in communication, robotics, software and automation are brought together in this type of field, and therefore is expected to be diluted in more basic research, and a topic of some concentration in invention levels. This technology convergence (enablement of a technology platform via several overlapping enabling technologies) is a notable phenomenon in digital health topics more widely.

### **Sustainability and Essential Needs (Figure 7)**

- One of the most significant topics in the study for invention activity is wastewater treatment; this is also the most significant topic in the National Priority Area for research publications - though with a notable variation in overall volume: this is primarily an applied research area represented by invention activity.
- There is agreement between basic and applied research focus on Electric Vehicle technology in terms of proportion of focus, though as for wastewater treatment, a significant volumetric emphasis on invention activity levels with almost 5x the number of patented inventions. Again, this split in level of output indicates the commercial and applied nature of the innovation activity in the segment.
- Aquaculture figures prominently in each of publications and patent filings. In fact, it is the highest volume research publication topic across agriculture as a whole. In invention focus, it ranks 3rd out of 9 in agriculture topics (behind Hydroponics and Eco-Agrochemical), and therefore stands out as a topic of interest in the field.
- Divergence between research publications and inventions were seen in the lower tiers of research in this sector: water leakage research, precision livestock agriculture and brine mining are the bottom three topics of academic interest globally in the National Priority; within global inventions this change to CO2 transport and utilization alongside landfill technologies.
- Also notable as a delta in focus in the Sustainability and Essential Needs priority area is the strong research focus on soil preservation, with almost 80,000 papers but just 12,000 inventions in the last decade. Potentially, this topic produces a naturally lower level of invention output compared to environmental and agricultural science in publication data.



Number of research publications (2014 onwards)



Number of inventions (2014 onwards)

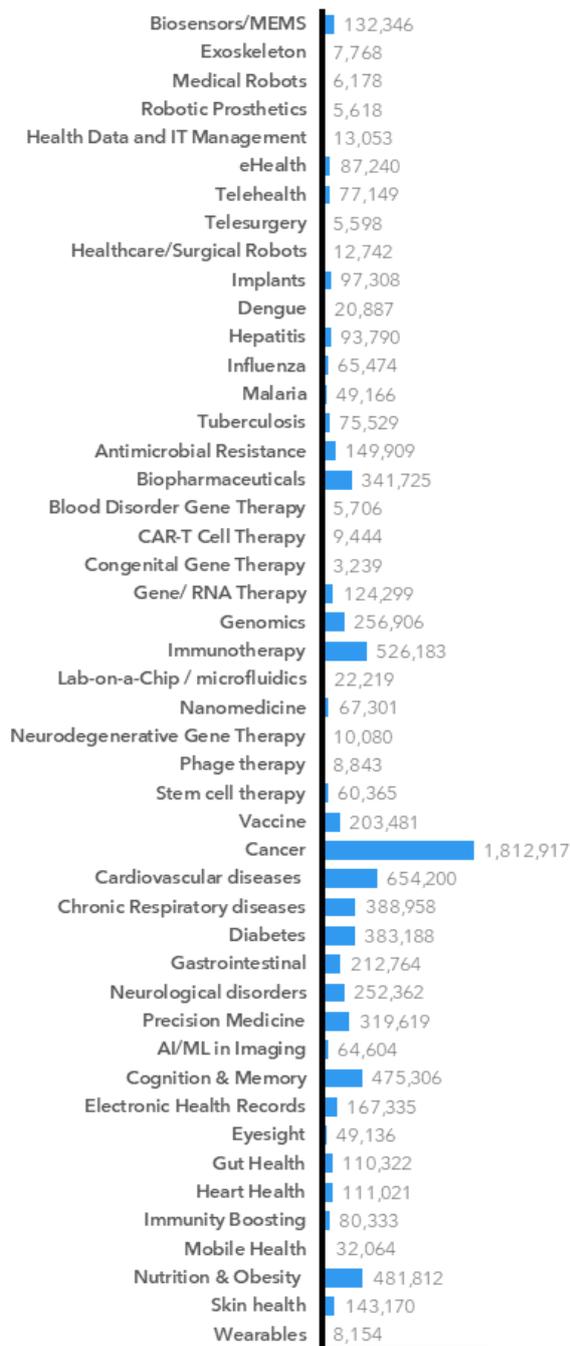
Figure 4 - The number of research publication records (left) and invention records (right) for each of the topics under the Economies of the future National Priority Area, data correct from 2014 through July 2024, annotated as 2014 onwards.



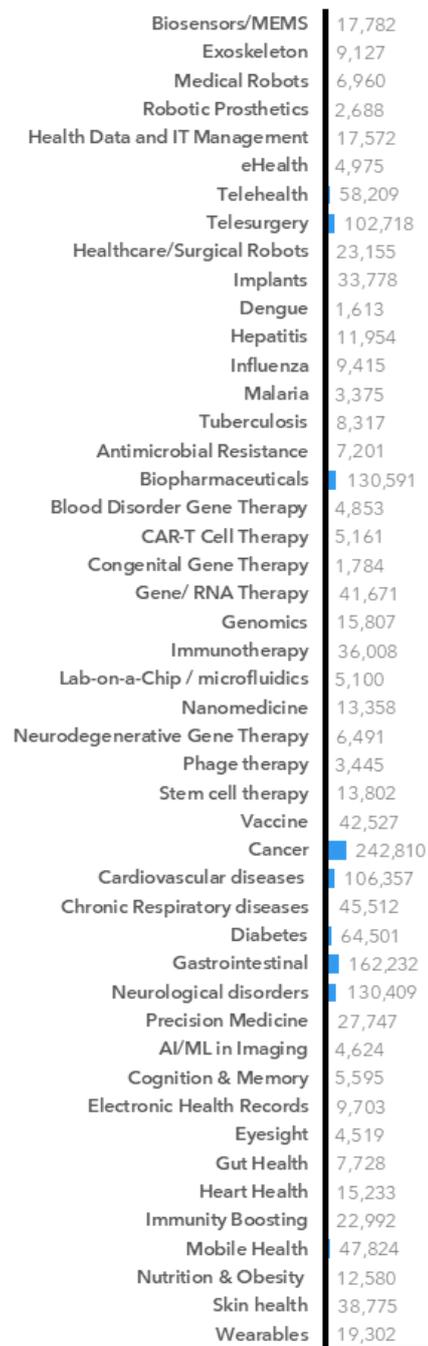
Number of research publications (2014 onwards)

Number of inventions (2014 onwards)

Figure 5 - The number of research publication records (left) and invention records (right) for each of the topics under the Energy and Industrials National Priority Area, data correct from 2014 through July 2024, annotated as 2014 onwards.

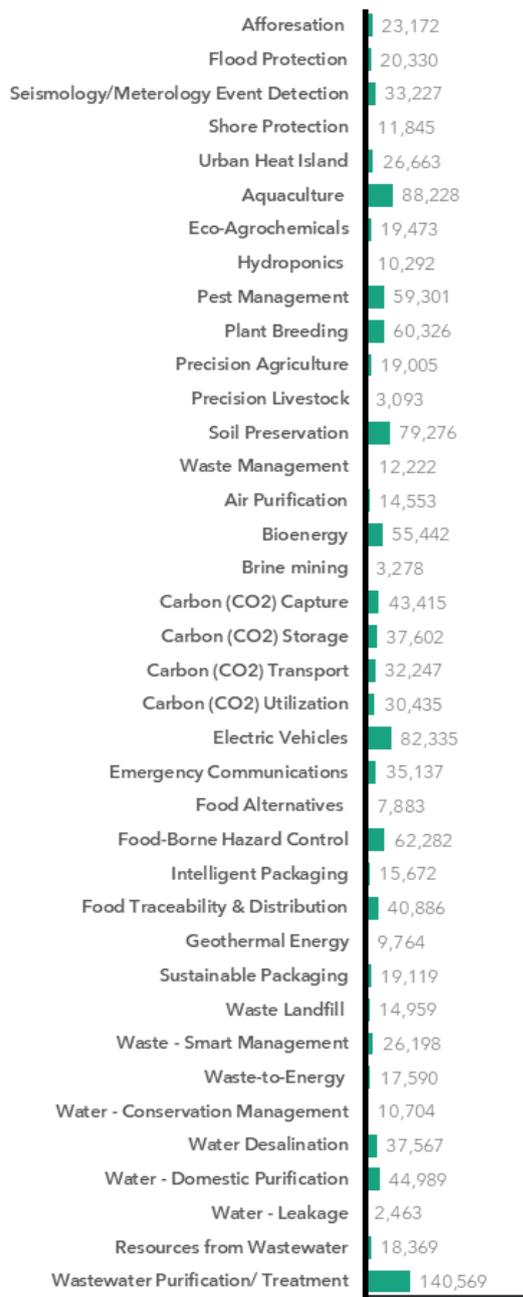


Number of research publications (2014 onwards)

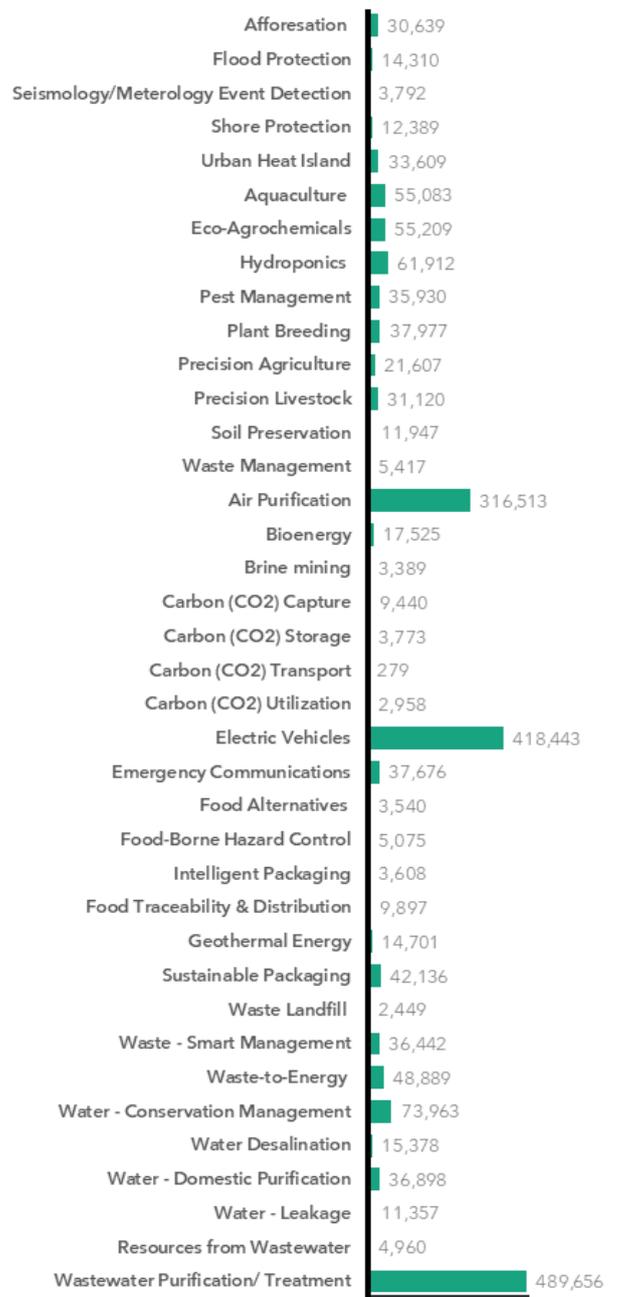


Number of inventions (2014 onwards)

Figure 6 - The number of research publication records (left) and invention records (right) for each of the topics under the Health and Wellness National Priority Area, data correct from 2014 through July 2024, annotated as 2014 onwards.



Number of research publications (2014 onwards)



Number of inventions (2014 onwards)

Figure 7 - The number of research publication records (left) and invention records (right) for each of the topics under the Sustainability and Essential Needs National Priority Area, data correct from 2014 through July 2024, annotated as 2014 onwards.

# 9 Landscape of commercialization activity in the national priority areas

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## 9.1 Overview

This chapter reviews data specific to these research fields from the perspective of patent filing information. This is because patent protection inherently reflects a commercial desire and strategy directly tied to technical content and detail, thereby enhancing the ability to review data at scale regarding capabilities and future commercial potential

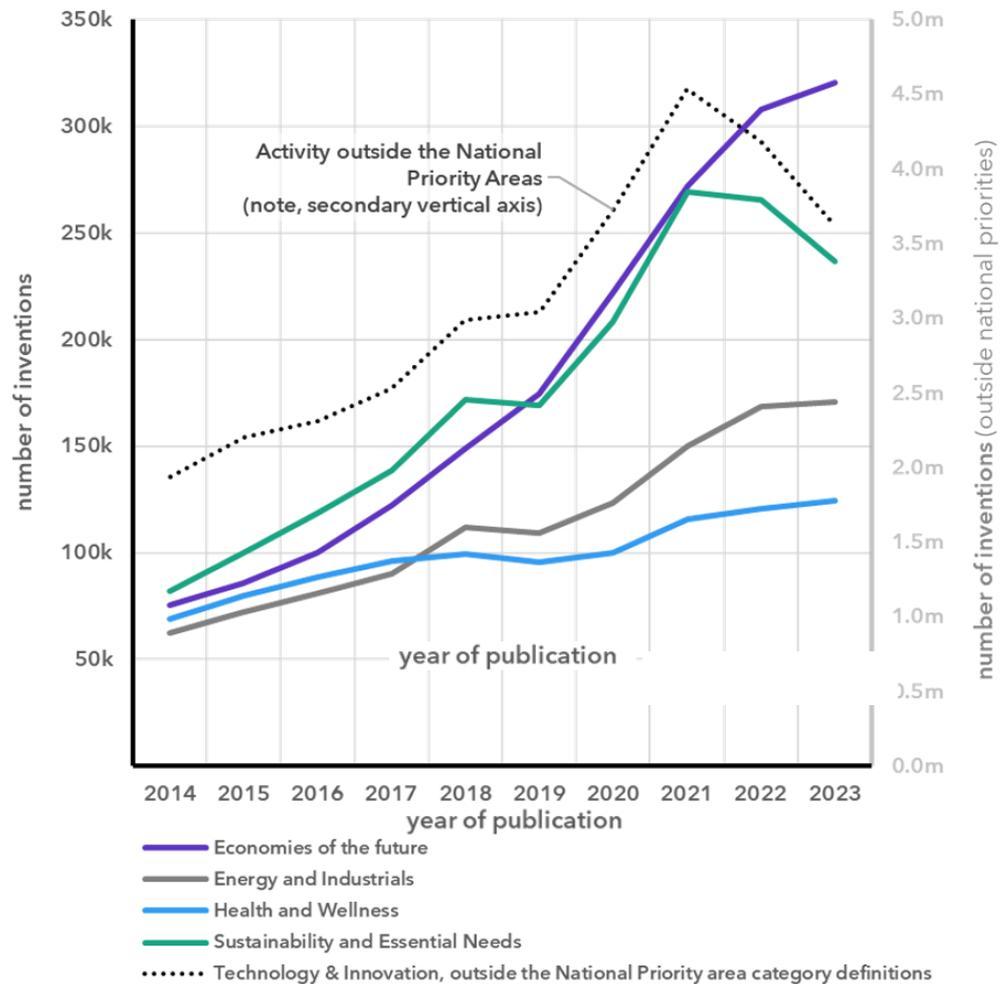


Figure 8 - The number of inventions globally since 2014 that align to research topics within the 4 National Priority Areas; note all other invention activity is also shown, but on a secondary axis, for comparison

A review of global invention levels (Figure 8) reveals that the Economies of the Future is the fastest-growing category of research, while the Health and Wellness sector is lagging behind overall invention growth rates. Research topics related to sustainability are aligned with broader trends in invention growth. In contrast, Energy and Industrials topics, which are national priorities, show a trend more like that of Health and Wellness, diverging from the overall global activity.

Within the Saudi context, data from the same period has seen a shift towards research within the National Priorities even prior to their establishment. This reflects a sensitivity to the capabilities and expertise of the pre-existing research & innovation ecosystem.

Notably, while increasing in focus, it remains at 40% of national activity (Figure 9), with the remainder of invention activity occurring predominantly within the traditional

petrochemical sector. This finding reinforces the need for diversification of the innovation commercialization capability of the national economy.

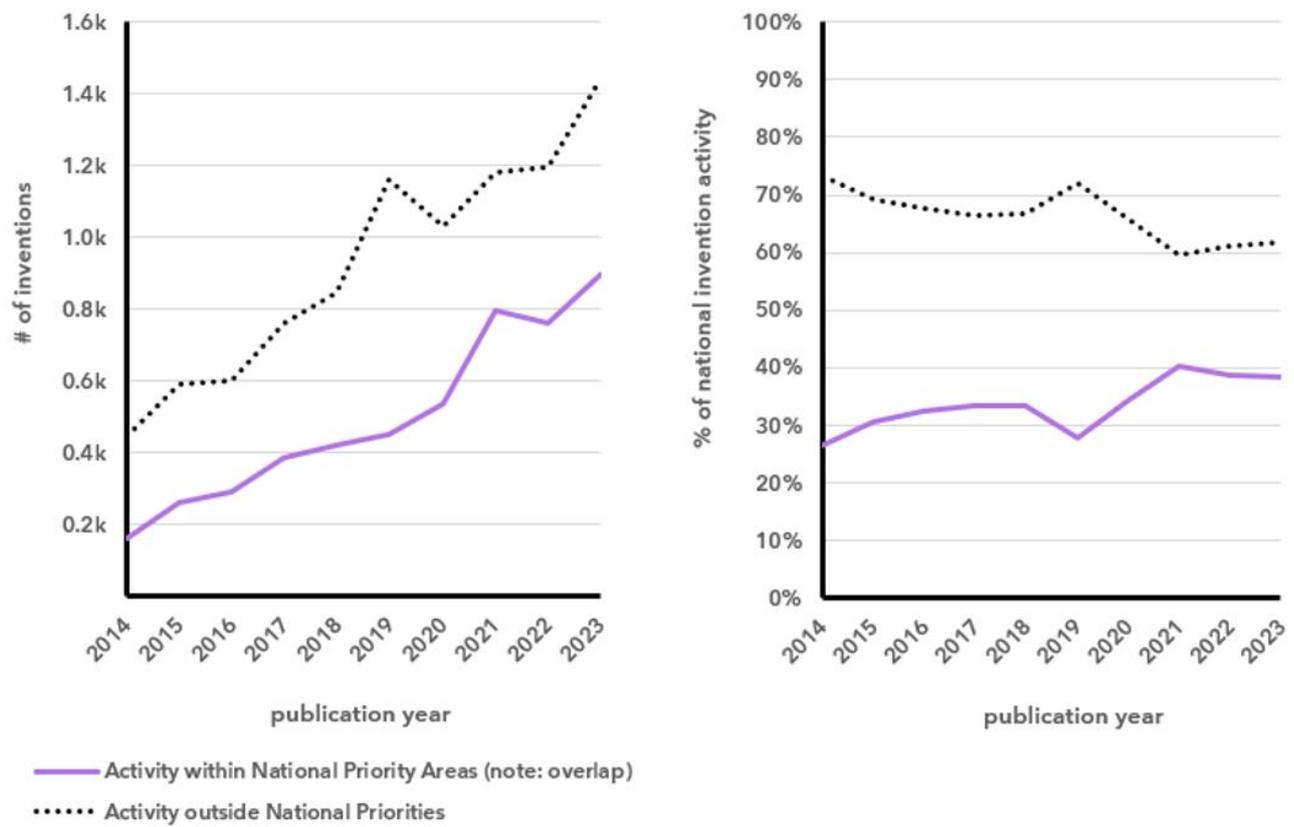


Figure 9 – Number and proportion of Saudi Arabian invention activity within and outside of the definitions of the National Priority Areas, 2014-2023

This increasing focus has created a national portfolio of intellectual property assets that can be studied for their number, strength, directionality and protection profile.

Today, Saudi Arabia has similar levels of IP portfolio size (Figure 10) as the median OECD country in each of the National Priorities and significantly higher than the median GCC country. These levels are also comparable to the top 25 countries listed in the World Intellectual Property Organization’s Global Innovation Index (GII).

Saudi Arabia’s economic strength in the energy sector is reflected in these data, with the volume of inventions generated higher than the medians for OECD and GII Top 25 countries within this National Priority.

Major differentiation to these two country groupings (OECD and GII Top 25) only occurs in research topics outside the national priorities and, to a degree, in the Health and Wellness segment.

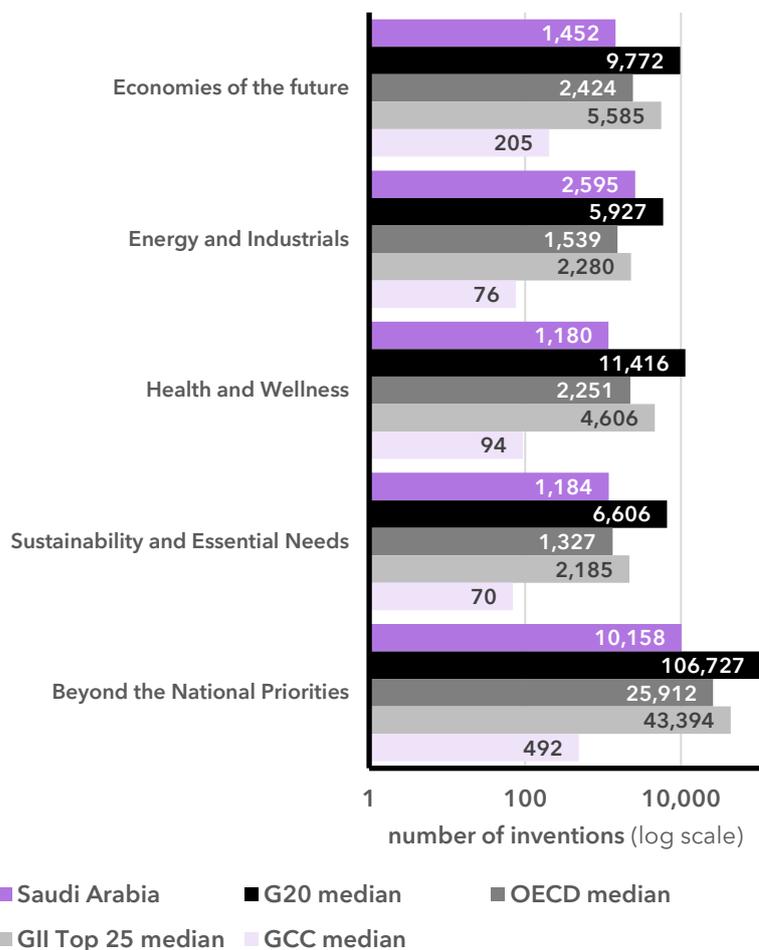


Figure 10 - Number of inventions (2014 onwards) per National Priority Area (and beyond) for Saudi Arabia, G20, OECD, GII Top 25 and GCC. Note median invention volumes for countries in each grouping

**Saudi Arabia is the leading creator of inventions within the GCC member states.**

Overall, Saudi levels of protected applied research are comparable to those of the average OECD member but below those of the average GII Top 25 nation. If, however, the comparison is narrowed to the National Priorities, it is observed that the levels are comparable, reflecting Saudi Arabia's focus on the research within the priorities.

The variance is also evident when reviewing changes in activity levels, either by compound annual growth rates (CAGRs) or simply by average annual change in output. From this viewpoint, Saudi Arabian activity is increasing between 22 and 30% per annum, versus 15% growth for Saudi activity outside the National Priorities.

Saudi Arabia also compares well to the growth rates of the G20, OECD, GCC and GII Top 25 country groupings, which (excluding Saudi Arabia, where the country is a member, i.e. G20 and GCC) show 5-13% growth per year in the research topics of the national priorities. The only comparable grouping is the GCC member states

(excluding Saudi Arabia), which show ~20% per annum increases, though notably from a lower base.

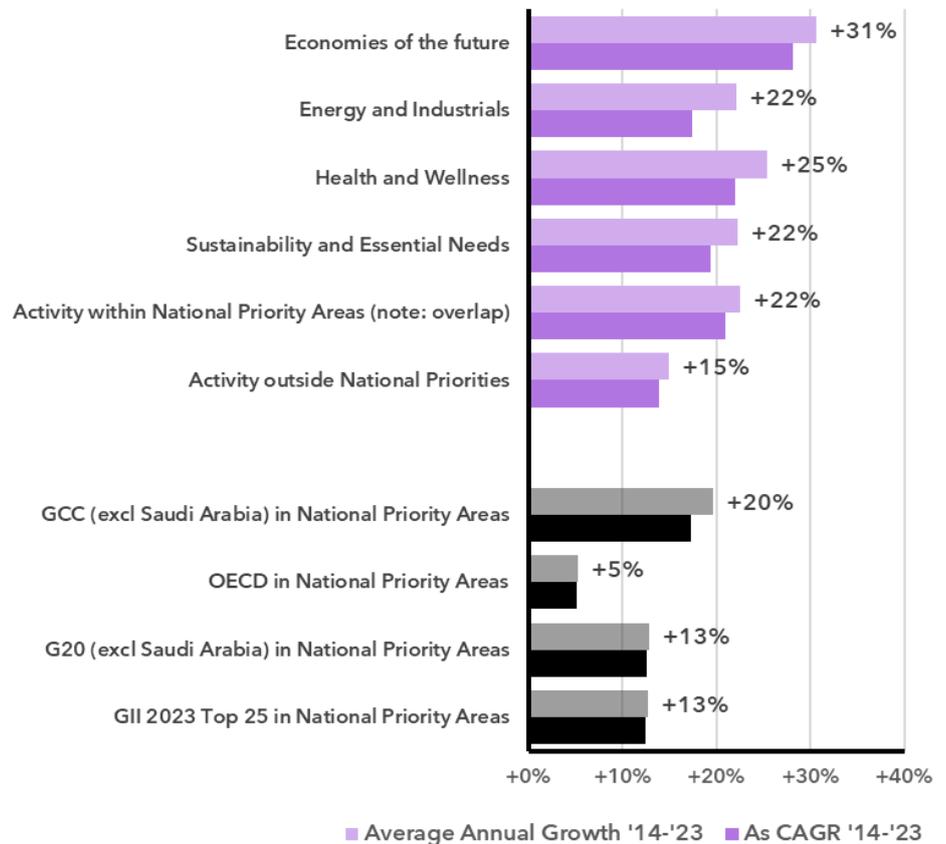


Figure 11 - Average and compound annual growth in annual invention output between 2014 and 2023 by National Priority (and beyond); includes comparison for total growth for Saudi Arabia, G20 (excluding Saudi Arabia), OECD, GII Top 25 and GCC (also excluding Saudi Arabia) in the National Priorities

## 9.2 Comparison of invention metrics

An assessment of the qualitative attributes of inventions can be modelled with a view to profiling the strength of patents within the National Priorities and against the selected country groupings by conducting a review of invention strength metrics.

These metrics are meant to profile the average contribution of invention and, as a result, show the variance in the systematic production of new protectable ideas and innovation. It should, therefore, be noted that, this is affected by scale, in that high average performance at a smaller scale differs in outcome to more modest performance at a high volume.

The invention strength measure used to assess global inventiveness within this study utilises the Derwent Strength Index, produced by Clarivate, and is comprised of four factors listed below. It is noted that there are many models of patent and invention quality and strength available that have been validated and developed.

1. Influence - during the examination of patent applications within patent offices, the application will receive a score based on the number of times an invention is marked as relevant to the downstream patent applications of 3<sup>rd</sup> parties. Such citation statistics are a measure of impact in that they provide a quantification of the proximity of the application to the known art. To the extent that an application has a relatively higher number of citations, that application can be assessed as more similar to the existing patent data than one that has fewer citations. The measure is normalized and de-biased for

- natural variances and pattern changes that occur in technology and geography (typically linked to language bias) and that occur due to time (older inventions are cited more or have been available to be cited more).
2. Success as patent applications: here, the scoring system assesses whether a patent has been successfully examined and thereby granted as an intellectual property asset. This score is varied by the proportion of the world economy in which the same invention has passed this examination test, e.g. an invention granted in Saudi Arabia alone scores lower than an invention that is also granted in the United States, Europe and Japan. As a cautionary note, authoritative studies and statistical reports confirm that it is easier to obtain a patent in some jurisdictions than others due to differences in examination standards, economic incentives, and procedural frameworks. These differences highlight the importance of recognizing the diversity of procedural inconsistencies when comparing grant levels across jurisdictions.
  3. Investment level: the scoring system approximates the level of confidence the patent applicant by counting the number of unique jurisdictions in which an application for the same invention is made. This measure is a sound proxy of confidence as with each jurisdiction in which protection is sought, the costs to the applicant are increased, and it is assumed that an applicant would not incur costs in a jurisdiction without anticipating offsetting those costs through commercial activity. The number of jurisdictions may also correlate with the perceived market size for the invention as the applicant seeks to preserve that market through local patent protection.
  4. Technical Rarity: finally, the invention strength score includes an assessment of whether the mix of technologies covered by the invention were rare in global invention activity when it was filed, or relatively common. This measure, therefore, provides an assessment of where in the development curve the idea sits.

Taken together across the 4 factors for each of the 65 million global inventions and distributed by percentile, each invention is assigned an overall invention score. Those that score well are highly influential on others, covering large economies with formal protection, were confidently invested in by their owner, and occurred early in the development cycle of the technology field. This further maps to high strength, critical and important inventions that create significant value for their owners.

Here, assessing this metric (and in following data views, the sub-metric components) at a mean average level across the previously reviewed groupings of nations: the G20, OECD members, countries ranked in the top 25 of the Global Innovation Index, and the GCC region. Also included in these views is a global baseline for all invention data.

**Saudi Arabia performs above all these comparison baselines for the average strength and quality of invention** (Figure 12). Of the 4 National Priorities, the performance gap to baseline is greatest in the Energy and Industrials and Sustainability and Essential Needs National Priority Areas.

The performance gap is relatively low in the research topics making up the Economies of the Future.

This result is significant – Saudi Arabia is a source of high-quality applied research inventions, at comparable volumes in the National Priorities to average OECD and top 25 GII member states. This provides an excellent foundation for further advancement of the national strategy surrounding research & innovation, building on the impressive creation of a globally comparable academic research base.

Saudi inventiveness does not perform equally across scoring factors within the invention strength system. For example, there is strength in the global footprint of the national invention portfolio, and this is particularly intensified in the energy and sustainability priorities. Also, across the factors, there is a variance of performance in

the Health and Wellness segment, where citation influence (Figure 13) is outlier-low compared to the other priorities. However, the segment scores notably well in technical rarity (Figure 16). In combination, this potentially describes an invention base that is focused on research that is earlier in the wider development cycle, and not yet generating a citation base downstream.

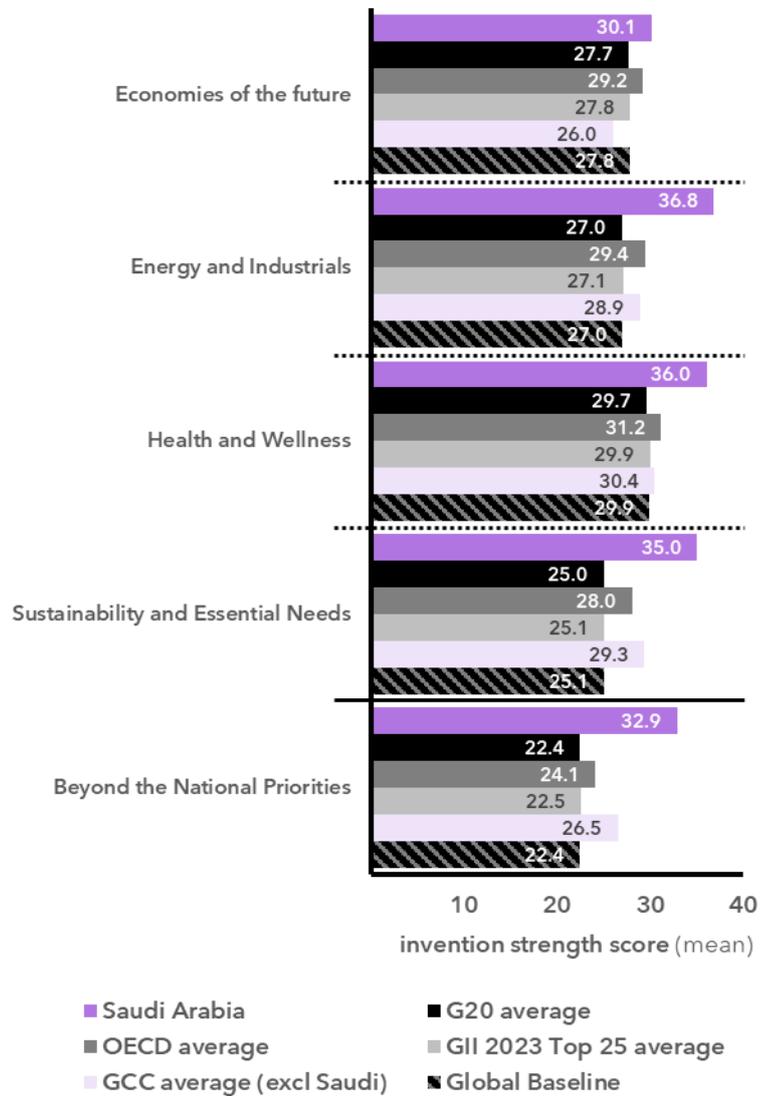


Figure 12 - Average strength score of inventions by country, country grouping (G20, OECD, GII Top 25 and GCC, Saudi Arabia, global baseline) and by National Priority Area

With the commercialization potential of research and innovation policy for Saudi Arabia forming the focus of measurement and analysis in this part of the study and with the earlier finding that Saudi inventions generate much of their comparative strength from the breadth of the national portfolio, a review of the locations and markets into which Saudi inventions have been protected was performed.

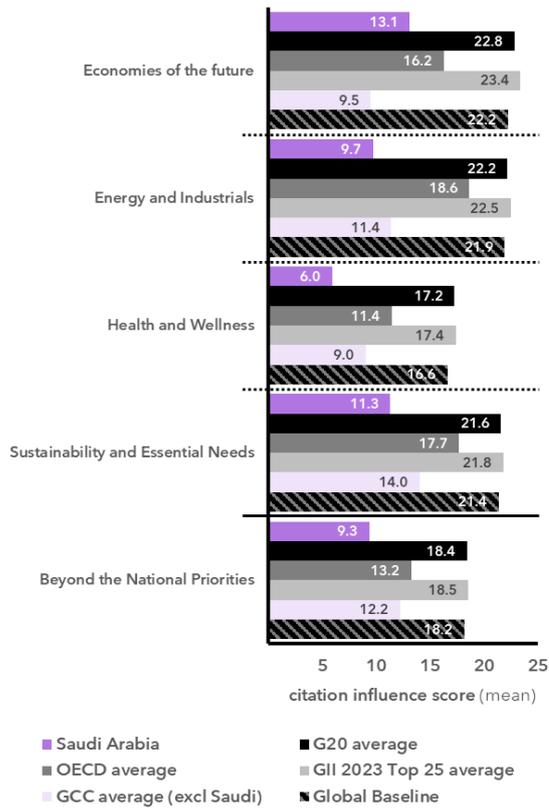


Figure 13 - Average citation influence score of inventions by country, country grouping (G20, OECD, GII Top 25 and GCC, Saudi Arabia, global baseline) and by National Priority Area

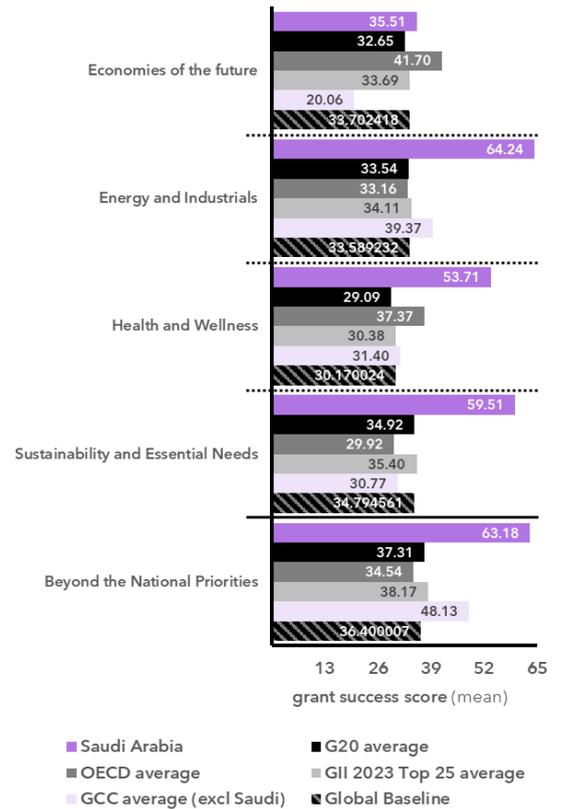


Figure 14 - Average grant success score of inventions by country, country grouping (G20, OECD, GII Top 25 and GCC, Saudi Arabia, global baseline) and by National Priority Area

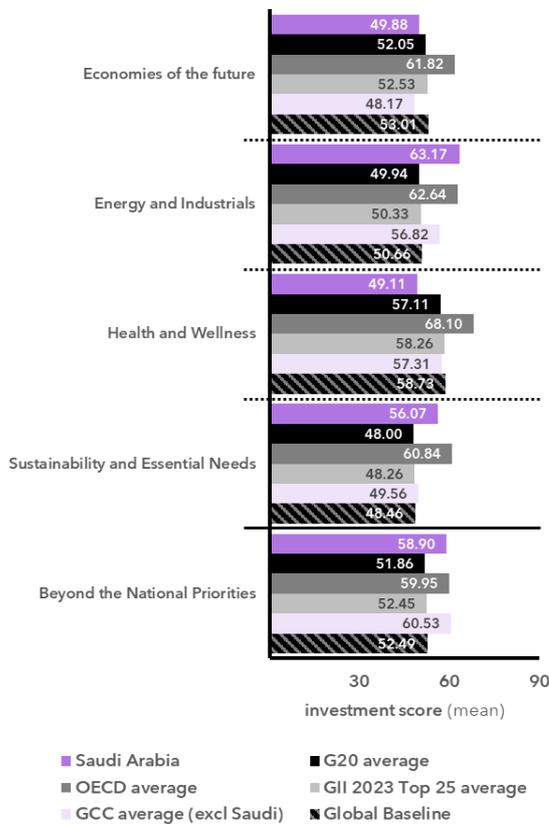


Figure 15 - Average investment score of inventions by country, country grouping (G20, OECD, GII Top 25 and GCC, Saudi Arabia, global baseline) and by National Priority Area

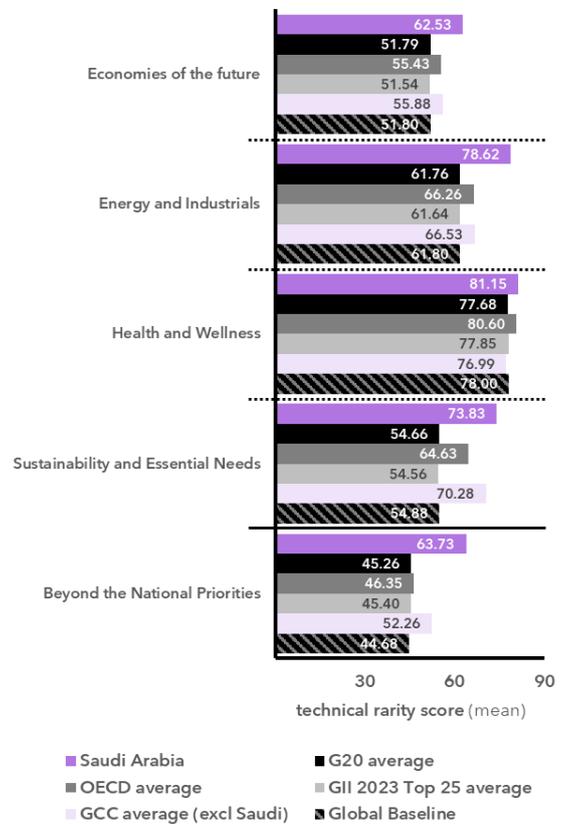


Figure 16 - Average technical rarity score of inventions by country, country grouping (G20, OECD, GII Top 25 and GCC, Saudi Arabia, global baseline) and by National Priority Area

## 9.2 Geographic filing pattern

Patents are geographically localized. This means that for an invention to generate exclusive use within a specific country, that invention needs to be sought and granted in that specific country. This will often result in multiple patent jurisdictions. This pattern of geographic filing provides information on the commercialization intention and markets. A visualization (Figure 17) highlights the locations and markets into which Saudi inventions have been registered as patented inventions, for both all inventions and within each National Priority Area.

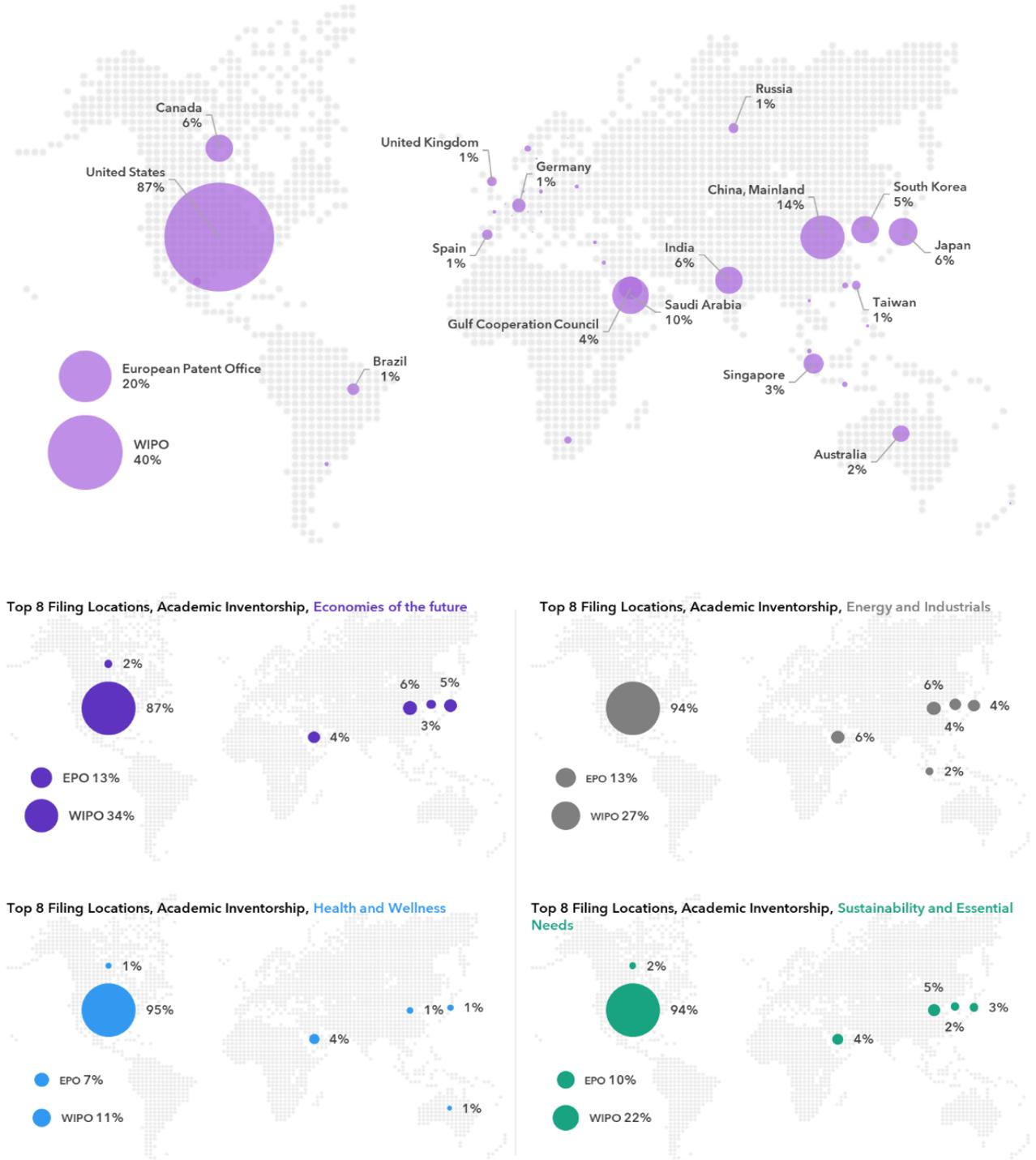


Figure 17 - Geographic locations of where patent filing takes place for Saudi Arabian inventions; four quadrants breakouts for each National Priority Area – top 8 primary locations only.

This section visualizes the proportion of inventions that have been filed for patent protection in the patent offices of the world. Beyond filing applications in discrete patent jurisdictions, two filing routes allow an applicant to seek protection across multiple national jurisdictions: the European Patent Office and the World Intellectual Property Organization. These two important locations are visualized off the map. Notably, EPC filings, covering the countries that are signatories to the European Patent Convention (39 countries), do lead to the granting of a European patent that can either be validated separately in each member state or as a single Unitary patent, while applications via the WIPO do not. An application filed through WIPO instead provides a reduced administration burden route for entry of applications into individual country “national phases” of patent filing. The Saudi Authority for Intellectual Property (SAIP), is a receiving office of applications via the WIPO route, and therefore it is likely this is a relatively common pathway for applicants in the country.

The most common routes for Saudi Arabian patent filing are first via the United States Patent and Trademark Office (USPTO) (~90% of cases) and secondly the WIPO fast track (11-40% of cases). Local filings directly filed with SAIP are notably uncommon, (10% of cases across all activity, and 4-6% within the National Priorities), and usage of the Gulf Cooperation Council joint patent office (which has ended accepting applications since January 2021) was limited to less than 1% of cases.

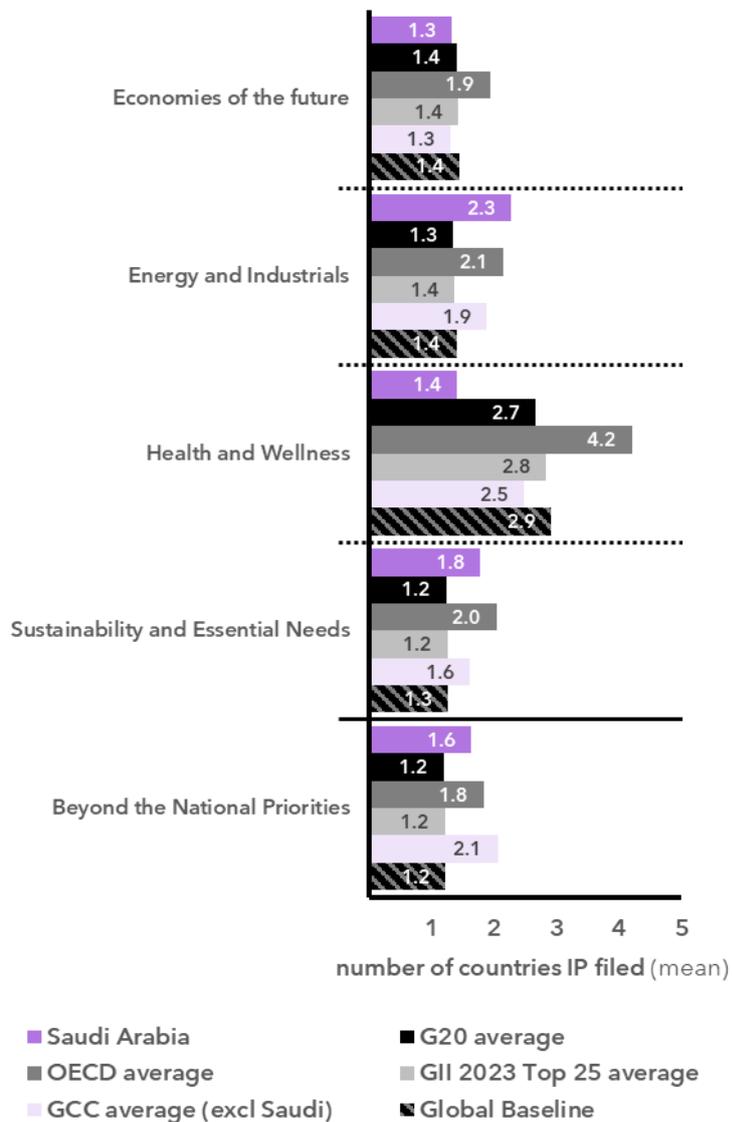


Figure 18 - Average number of countries in which patent IP is filed, by National Priority Area and country grouping (G20, OECD, GII Top 25 nations, GCC and as a global baseline)

This pattern of activity describes a strategy for patent filing that is already focused on the internationalization of applied research contained within patents. Across all variations of the data - total, within each National Priority - a similar pattern emerges: the vast majority protected in the US, via the WIPO fast track second, followed by China, South Korea, Japan and Europe (with some variance in order). With Saudi IP owners filing overwhelmingly in the United States, this is considered a good practice for potential commercialization. The consistent use of well-accepted filing strategies (such as USPTO) likely enhances the success of technology transfer efforts by providing access to global partners, licensees and markets.

The pattern of filing by the Saudi academic sector for international patent protection, a measurement of the average number of countries in which local protection was sought, is above. (Figure 18)

The general strength of the Saudi patent filing strategy is particularly observed - being above or at par with global norms (save and except for Health and Wellness). This may be due to the global reach, pharmaceutical inventions typically seek, being filed in more jurisdictions, (between 2.5 and 4 jurisdictions per invention).

### **9.3 The current focus of applied research in Saudi Arabia**

Moving to the 167 individual research topics selected to be studied within the four National Priorities, a measure of their likely forecast growth through 2026 was performed that provides an analytical view of how Saudi Arabian activity in the most recent period (2020 to the present) aligns to those global growth patterns.

This view (Figure 19), used regularly as an innovation strategy review framework, allows comparison of focus and alignment: where and whether inventorship activity today follows the same patterns exhibited in the global applied research ecosystem.

This visualization is produced by ranking the level of focus in Saudi Arabian invention activity from lowest to highest, and similarly the predicted growth in the same research topics in a ranked manner (from lowest to highest growth). In addition, the predicted 2026 volumes of global activity are added as the size of the research topic in the analysis. Predicted volumes depend on a wider model of innovation s-curve theory that approaches technology and research growth and decay over time as they follow predictable natural patterns of development.

Splitting along the  $x=y$  line, if a country or economy was in perfect alignment with growth patterns, all research topics would appear on this line. However, this is rarely the case and indeed would reflect minimal competitive advantage in global innovation markets for the country.

Areas of misalignment - where Saudi inventorship is focused today but the growth trend is not evident globally are labelled as areas of potential overfocus; conversely, where growth is expected to be greater but Saudi inventorship shows lower activity in recent years are labelled as areas of potential under focus.

The highest areas of growth occur in the Economies of the Future research topics, and Saudi research focus in these areas is broadly in line with these trends. These topics in the top right-hand corner include Artificial Intelligence, Cloud Computing, 3D Printing and Internet of Things.

One outlier is semiconductors, which, while high in volume, show lower overall growth multiplication (significant research having already occurred) but remain a high focus for Saudi Arabia.

A cluster of Health and Wellness topics are also identified as areas of continued high focus for Saudi since 2020, but do not exhibit high predicted growth levels.

Notably, few future high-volume topics with high growth are identified as areas of under-focus for Saudi Arabia, suggesting in broad terms that Saudi applied research occurring within invention data is generally aligned and in agreement with global trends. Research topics with high levels of activity are also topics of high focus for Saudi Arabia.

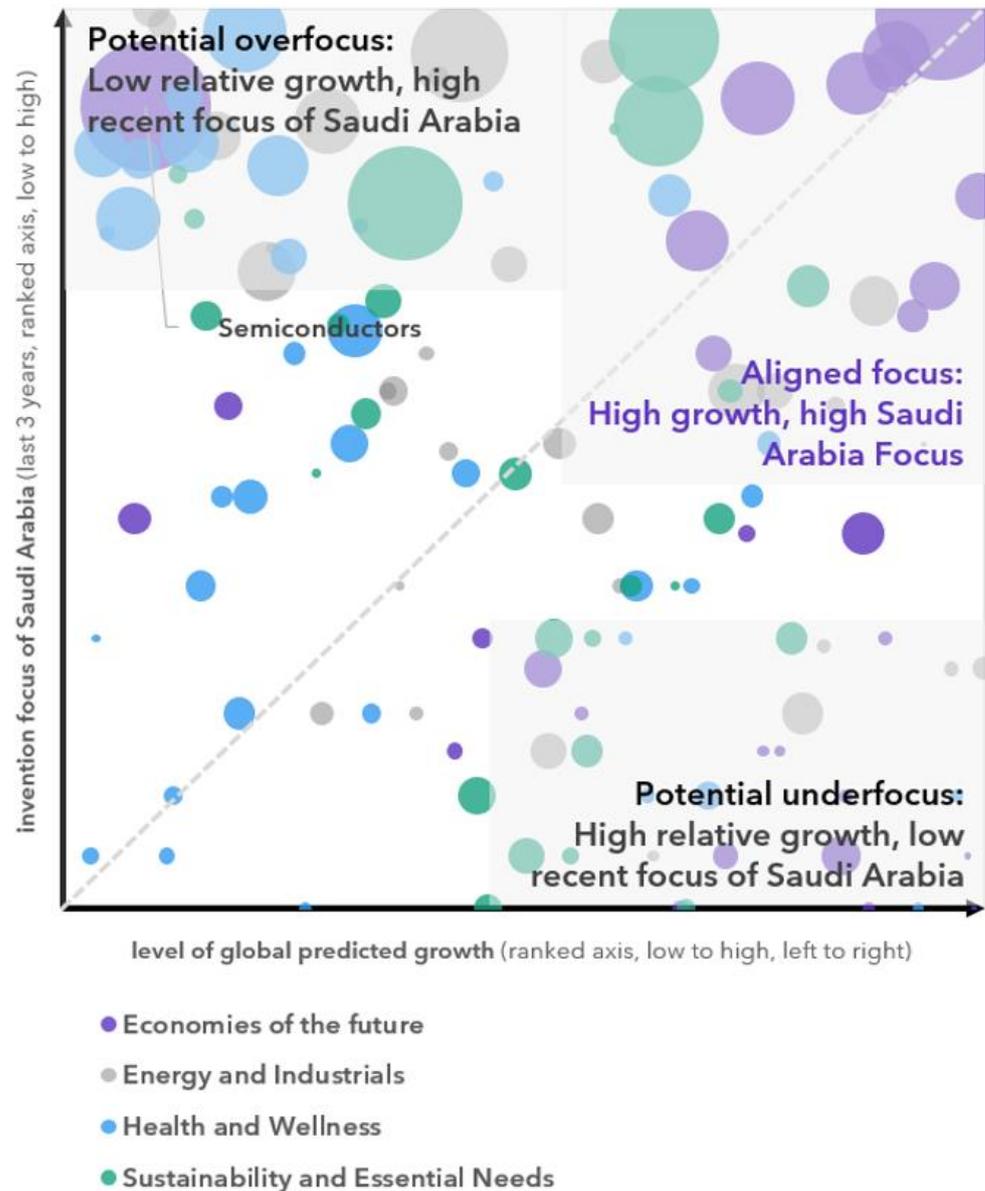


Figure 19 - Scatterplot of the proportion of recent Saudi research occurring within each research topic versus the predicted growth level of global activity; both ranked axes rather than absolute value; bubble size reflects the predicted levels of global invention in 2026.

## 9.4 Inventorship in Saudi Arabia

A major factor in the success of Saudi Arabia's expanding research and innovation program is evaluating the current inventorship base country.

Discrete inventor statistics are complex to measure as there is no standard identifier for inventors in global patent data, unlike, for example, internationally accepted codes for the subject matter of the application. Further factors that complicate measuring an inventor base include:

- Name similarity or commonality in some jurisdictions.
- High variation across national patent filing jurisdictions of name formats.

Accordingly, the global patent source data cannot yield an accurate count of discrete inventors by counting the number of names occurring within the databases.

As such, Clarivate followed a process to minimize variation at the individual record so that only one unique string length existed for surnames/forenames to create an accurate estimate of inventors. This provides for an estimate of the number of inventors per invention and, importantly, how it changes over time.

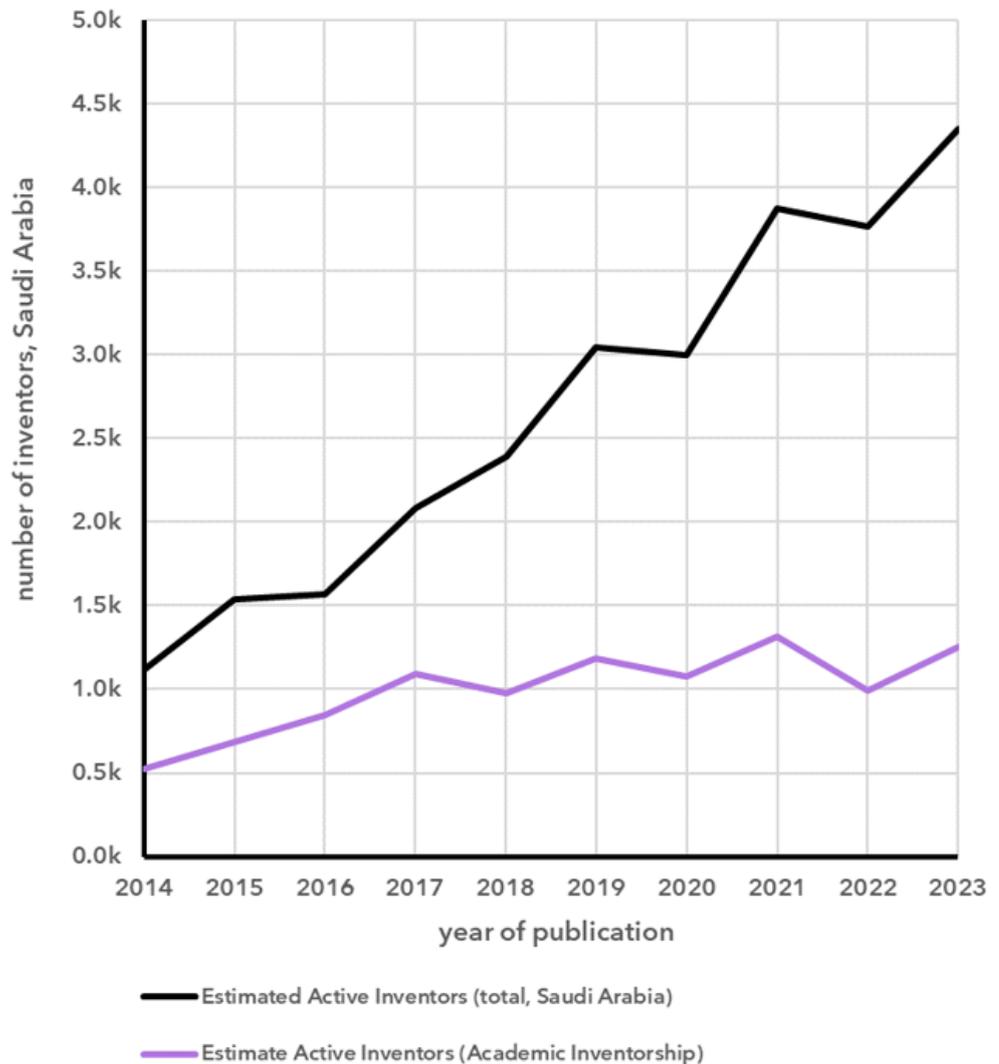


Figure 20 - Estimated number of inventors active in Saudi Arabia between 2014 and 2023

Additionally, this estimate can then be combined with overall invention levels by country and time to estimate the overall number of active inventors in any one year or over the entire ten-year period. This approach also statistically provides for measures (see Table 2) of collaboration (how many inventors contributed to an invention), productivity (the number of inventions expected per inventor over ten years), and the depth of the inventor ecosystem as a function of population.

This process shows that the number of active inventors per year in Saudi Arabia is rapidly rising (Figure 20), which is in line with the overall increase in invention itself. In the last year, an estimated 4,400 individual inventors were active in the inventions published in 2023. Of these, approximately 1,250 were inventors from academic institutions.

Table 2 - Calculation of inventor statistics per invention, inventor productivity in a 10-year period, the depth of the ecosystem and estimated total inventors

Country Comparable	Total Inventions	Collaboration Inventors per Invention	Productivity Inventions per Inventor (10-year)	Ecosystem Depth Inventors per 100k people	Estimated number of Inventors (10-year)
Saudi Arabia	15,802	3.3	1.5	28	10k
median GCC (excl Saudi)	785	3.7	0.6	38	2k
median OECD	35,533	3.3	1.5	124	20k
median G20	142,168	3.1	2.8	69	47k
median GII Top 25 (2023)	55,979	3.2	1.9	293	32k

The growth in academic inventorship has been more muted than the growth overall (~2x versus ~4x increase), also reflecting the overall change in invention output of the academic segment.

Saudi Arabia averages just over 3.3 inventors per invention on collaboration levels, similar to the levels of inventor collaboration evident in median measures for OECD, G20 or GII Top 25 comparator nation groups. Similarly, the productivity of inventors, assessed by how many inventions they produce over the 10-year survey period, is at a comparable level.

The emerging nature of Saudi Arabia’s knowledge economy is evidenced by the observed variation with international median benchmarks of inventorship on a per capita basis. Here, however, Saudi does have the highest number of estimated inventors over the past decade compared to the GCC member states.

## 9.5 Research commercialization performance in Saudi Arabia today

This review examines the research ecosystem regarding the current status of commercialization performance, considering the level of academic-corporate partnerships, the effectiveness of these programs in terms of commercial value, and the balance between academic research publications and applied research in inventions

This analysis provides a view of how the Saudi Arabian research and innovation ecosystem compares globally at an individual research topic level.

Examining the proportion of academic inventions that include a corporate entity (Figure 21) demonstrates performance below comparator nation levels in all National Priorities and in research activity outside the national priorities.

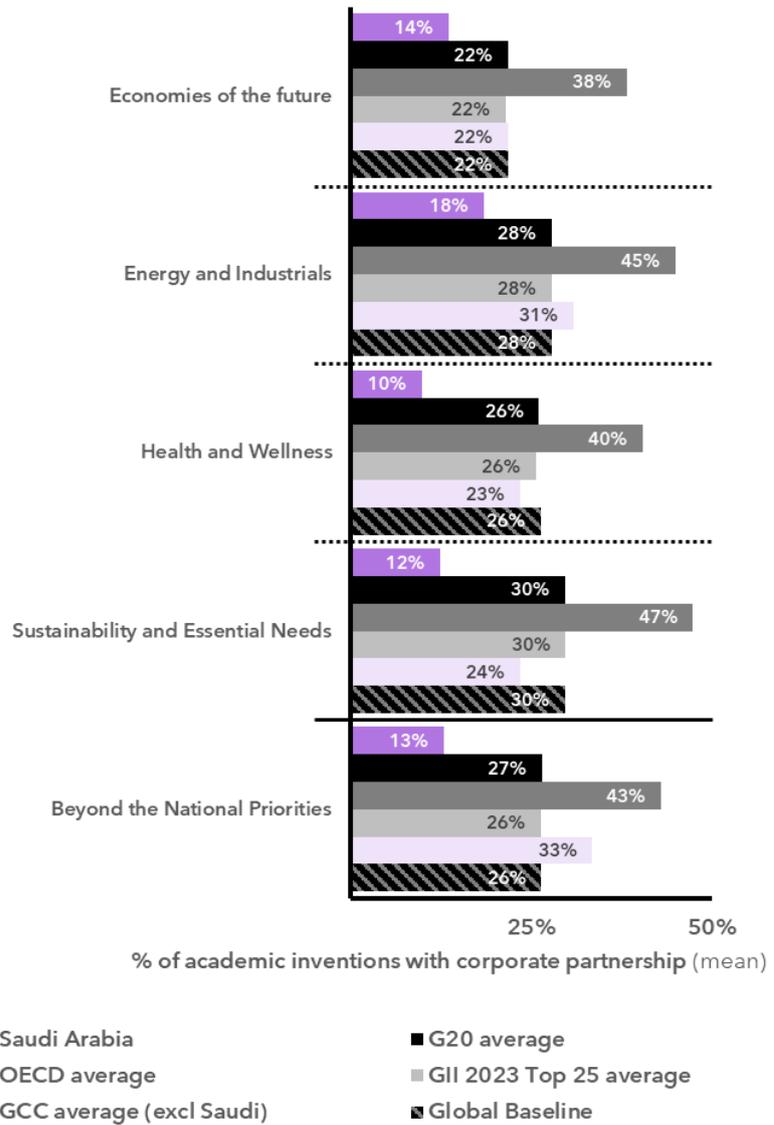


Figure 21 - Proportion of inventions, by national priority area, where the invention is associated with both an academic institution and a corporate entity; includes comparisons with the G20, OECD countries, countries in the GII top 25 and the GCC (excluding Saudi Arabia); also includes a global baseline average

Globally, approximately one-quarter of inventions from academic institutions have a corporate co-owner. This compares to between 10% and 18% in Saudi Arabia, which is significantly concentrated in the energy-related sector and has the lowest percentage in Health and Wellness. Therefore, the R&I ecosystem in Saudi Arabia is relatively reliant on funding from traditional government sources rather than from private enterprises, and corporate support for research at Saudi academic institutions lags other regions.

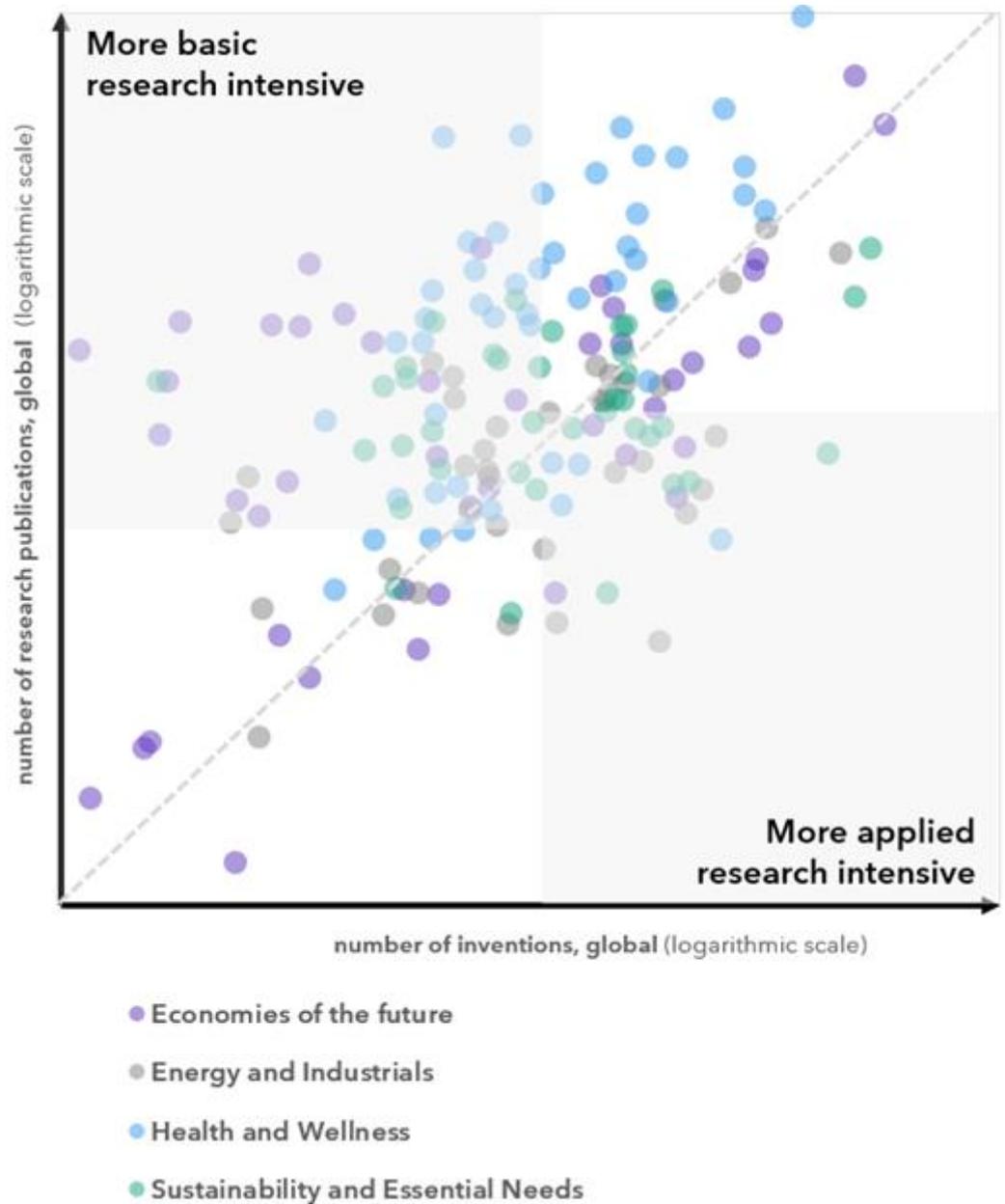


Figure 22 - Scatterplot of research topics across the four national priority areas for the number of research publications in each topic versus the number of inventions; view of all global activity

An additional view of research commercialization profiles is shown, which arrays the research publication and inventorship levels across the research topics that comprise the National Priority Areas.

A view of this array at the global level shows a relatively even spread of topics that trend more basic research-intensive (more commonly occurring in peer-reviewed journal publications) or trend more applied in nature (more commonly occurring in invention data).

There is common variation in location for two of the National Priorities: Health and Wellness and Economies of the Future both trend more basic research-intensive, though potentially for differing reasons.

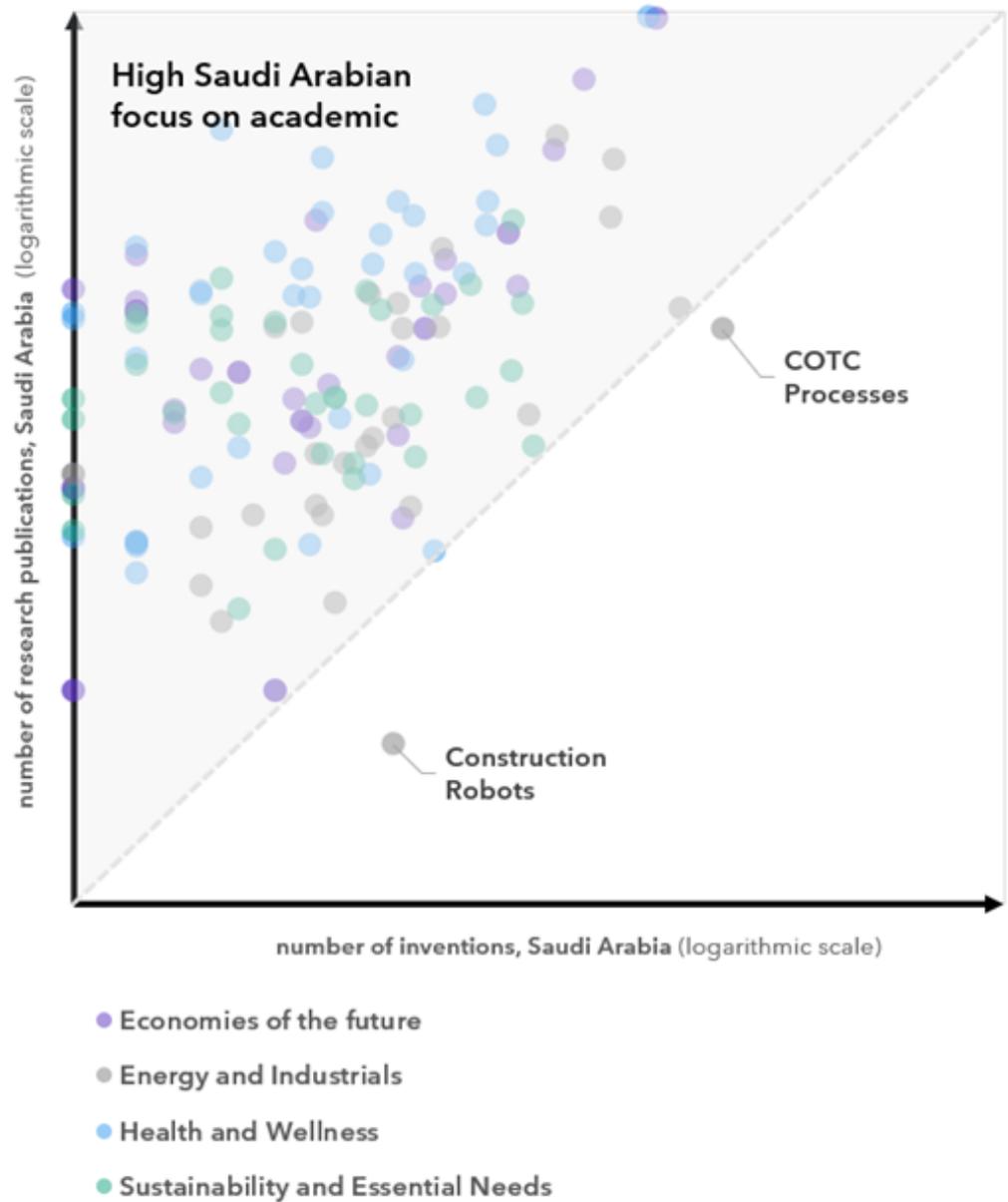


Figure 23 - Scatterplot of research topics across the four national priority areas for the number of research publications in each topic versus the number of inventions; view of activity for Saudi Arabia; areas of higher levels of applied research annotated

Analysis of the research and invention data has consistently shown<sup>2</sup> a high level of base research intensity within life sciences. The need for cross-disciplinarity and specific expertise in biological sciences and chemistry creates a need for partnership with academic institutions to bring research to fruition.

However, this is unlikely to be the same result/effect within the Economies of the Future setting, which is significantly more weighted to digital technologies and topics. Here, the hypothesis would be that these trends occur earlier in the development lifecycle.

Viewing the same analysis, but restricted to Saudi Arabian activity, shows a shift almost entirely to a numerical focus on research publication versus patent filing. Only four research topics out of the 167 measured during this study fall over the  $x=y$  line, three of which are tied to industrial topics in the petrochemical sector.

The nature of this distribution adds to the finding from the partnership levels: the Saudi research ecosystem is globally strong in academic research, but challenged to

<sup>2</sup> See Clarivate Top 100 Global Innovators, 2023, "Reliance on scientific research, by segment"

find routes to commercialization for that research. A lack of corresponding and expected patent filing from such high levels of academic research creates an opportunity to focus on applied research that can significantly contribute to the Saudi economy. This measurement outcome reinforces the current lower performance within the WIPO Global Innovation Index surrounding knowledge outputs. The analysis shows relatively clearly the gap. **The source of this gap is likely to be partially a gap in funding specific to patent protection, in addition to a relatively low level of corporate sponsorship of academic research that is likely to produce commercial, patentable research.**

The importance of this study is further shown below. Using economic modelling detailed later in this study, the level of economic contribution of academia partnering with private corporations provides a significant value addition to the research.

The level of globally strong, critical inventions produced by academia when filing for patents independently, without partnership with corporations, is consistently lower than when such partnership is evident. Using economic modelling, a loss of economic potential can be inferred from a lack of partnership as strong inventions are linked with increased economic potential. For global academic-corporate partnership relationships, between \$50k and \$170k of additional economic value is added, per invention. The desirability of such an association is, therefore, apparent.

Because of the lower levels of partnership in the Saudi research ecosystem and the overall numerically lower levels of "strong" invention when filtered to this layer of detail, this link is not currently meaningful, we conclude because, when measured, it shows a countertrend: adding a corporate partner to an applied research program *reduces* the likelihood of a globally market-critical invention. However, as stated, the low numbers associated with this specific mix of invention requirements reduces the data to single invention figures.

Therefore, this measure today is not an indicator of performance. However, as volumes rise and the goal of strong invention-creation is further realized, this metric will also increase in usefulness.

Using this same economic model, it is also possible to estimate the economic contribution globally of applied research technology at a complete national priority level.

This approach will be used later in this study to identify research topics for potential future investment. Using two different calculation methods - the share of discounted world GDP split by invention levels across the national priorities and as a bottom-up model of the value of critical, globally strong inventions - provides a range of projected economic value for each priority area. These projections are shown for both global innovation asset value and for the asset value of Saudi Arabia today.

Further analyzed as a comparison to Saudi Arabia's economic size as of 2023 as a percentage of the world economy and then further versus the value of Saudi research in patents today.

This view shows the significant technology and research assets Saudi Arabia has within the Energy and Industrials priority - at 5.4% of global technology economic value.

Table 4 - Comparison of the yield of critical, globally strong inventions from academia (comparing those with and without corporate partnership) and the corresponding effect on invention value of partnership; compared to Saudi partnership rates and comparable value add; effect estimated from the variance in yield based on economic assessment of critical, globally strong inventions.

National Priority Area	Strong Invention Yield (Academic-Corporate Partnership)	Strong Invention Yield (Academia alone)	Benchmark <i>Potential</i> Commercial Performance Addition per Invention Filing	Saudi Arabia Strong Invention Yield (Academic-Corporate Partnership)	Saudi Arabia Strong Invention Yield (Academia alone)	Saudi <i>Potential</i> Commercial Performance Addition per Invention Filing
Economies of the future	0.7%	0.4%	+\$ 101k	1.5%	2.4%	-\$ 417k
Energy and Industrials	1.0%	0.7%	+\$ 114k	na	1.9%	na
Health and Wellness	0.9%	0.5%	+\$ 171k	1.2%	0.6%	+\$ 275k
Sustainability and Essential Needs	0.8%	0.6%	+\$ 60k	na	0.7%	na
Beyond the National Priorities	0.4%	0.3%	+\$ 47k	0.6%	0.9%	-\$ 111k

Table 5 - Summary view of the estimated *potential* economic value of current global and Saudi applied research and innovation

National Priority Area	Estimated <i>potential</i> value of global innovation	Estimated <i>potential</i> value of Saudi current innovation	Saudi % of global innovation value (midpoint to midpoint)	Saudi % of global GDP (2023)	Average CAGR
Economies of the future	\$ 1.5 - \$ 2.6 Trillion	\$ 15 - \$ 36 Billion	1.3%	1.1%	+8.7%
Energy and Industrials	\$ 0.8 - \$ 1.9 Trillion	\$ 55 - \$ 88 Billion	5.4%	1.1%	+8.3%
Health and Wellness	\$ 0.9 - \$ 1.3 Trillion	\$ 22 - \$ 29 Billion	2.3%	1.1%	+7.4%
Sustainability and Essential Needs	\$ 1.0 - \$ 1.6 Trillion	\$ 20 - \$ 31 Billion	2.0%	1.1%	+7.4%
Beyond the National Priorities	\$ 12.6 - \$ 15.2 Trillion	\$ 11 - \$ 27 Billion	0.1%	1.1%	+6.4%

The value of Saudi research in all four national priorities is greater than the expected share of the current global GDP (at 1.1%). This compares to research value that sits beyond the national priorities in all other technology areas, where Saudi Arabia's share of innovation value is rated at 0.1%.

This view reinforces the RDI strategy: the four national priorities coalesce around Saudi Arabia's strengths in research and innovation and form a powerful basis for future growth and economic return as the country invests further in these fields.

## 9.6 The opportunity for commercialization of Saudi research

Taking these models of research commercialization ecosystem (and bringing forward models later in the study surrounding economic modeling of innovation contribution) here a summary of the shift in technology commercialization available to Saudi Arabia is shown, building on the strong foundations of high-quality academic research capability.

The output routes of commercial return defined in these models are summarised in two forms: transfer of the research to a corporate entity for them to take the technology to market, or indeed licensing of the academic intellectual property to a commercial entity for them to do the same.

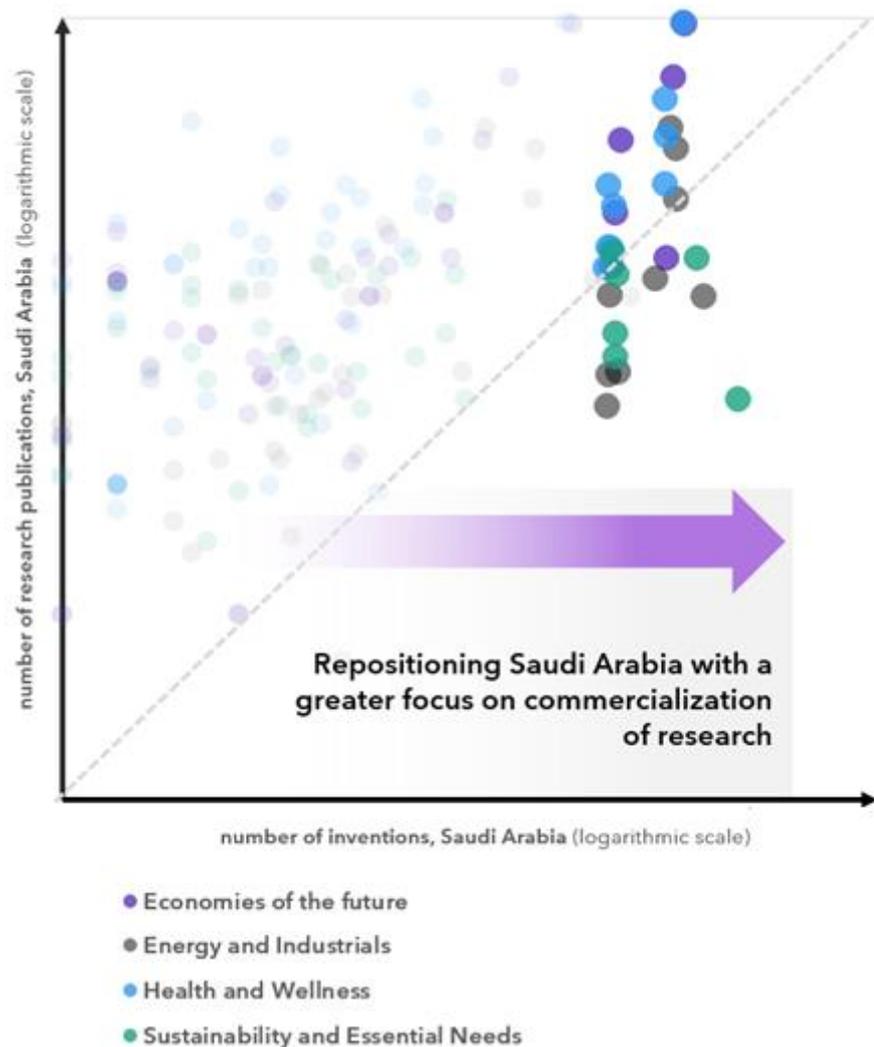
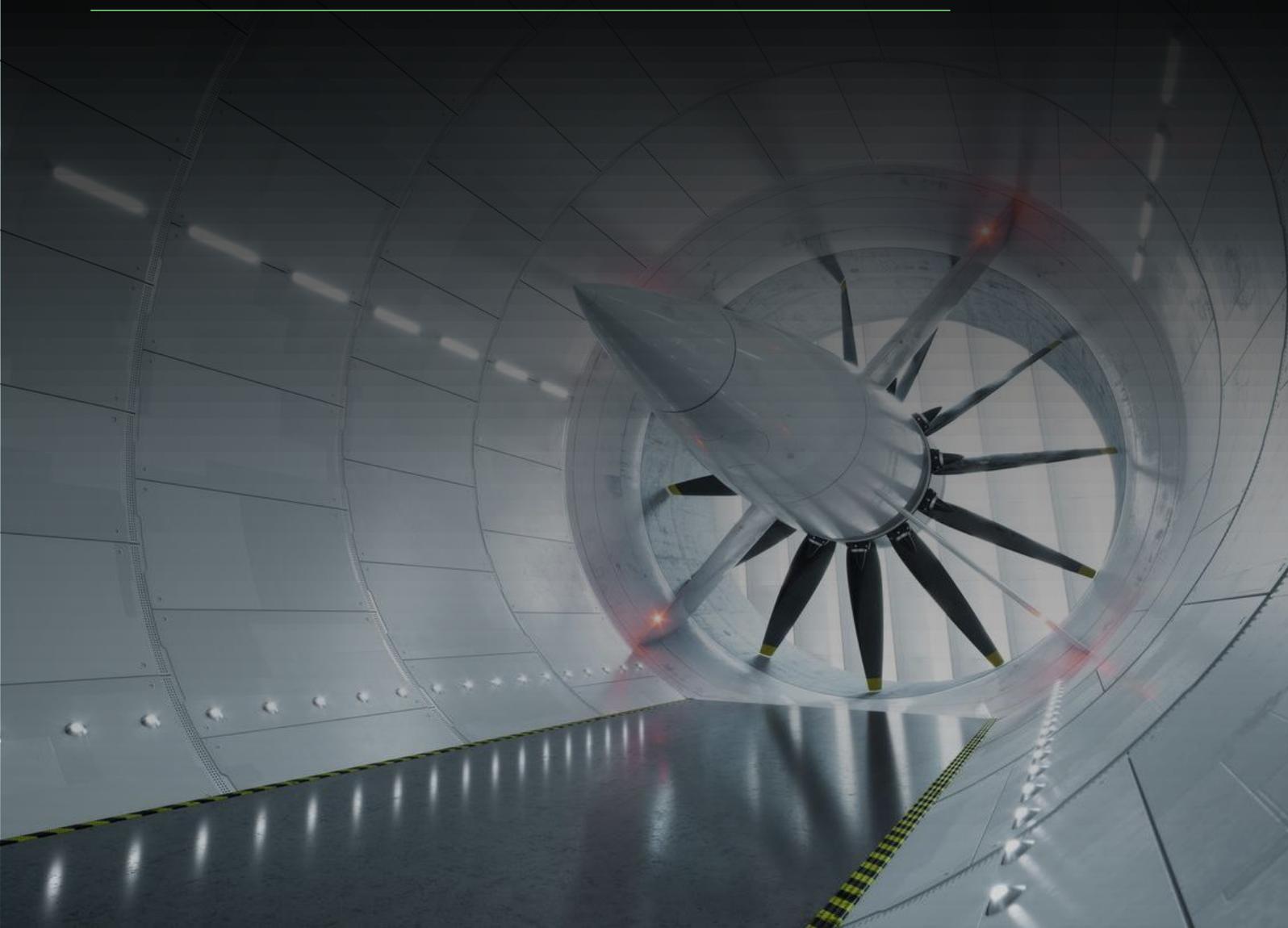


Figure 24 - Scatterplot of research topics across the four national priority areas for the number of research publications in each topic versus the number of inventions; view of activity for Saudi Arabia; areas of higher levels of applied research annotated

An outline strategy for the targeted funding of applied research, with policies that incentivize and fund intellectual property filing programs alongside expanded funding levels for the National Priority Areas would have the effect of re-balancing the output of the Saudi research ecosystem, targeted to specific research topics of existing expertise and capability and aligned to levels of economic growth that can return significant economic value to the country in the next decade and beyond.

# 10 Assessing technical maturity

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## 10.1 Background

Globally the translation of basic research into applied developmental research which can be transferred as a technology to a commercial partner is a complex and dynamic process involving many, and diverse, risks, challenges and interests. Each technology has its own unique implication on the progression from curiosity to commercial outcome and any one technical, market or economic condition could have an adverse impact at any point in the continuum.

As such, in this environment, any individual idea or research proposal has a relatively low (<10%) chance of becoming a commercial product or service.<sup>3</sup> While working to successfully transfer technology from bench to market, owners of IP will seek to reduce the technical and market risks in order to validate further investment in development. When measuring the progression towards achieving economic potential it is common to depict the reduction of technical risk as the increase in commercial readiness of technologies via a common scale known as the Technology Readiness Level (TRL).

Originally developed by NASA in the 1970's and published in 1989, TRL was used to assess the progression of technologies towards mission readiness but has since been adopted by diverse users as a means of articulating the development of technology toward introduction to the market in a consistent manner. Today it is regularly used by RDIA in its funding programs so that the stage of research and development is consistently assessed and communicated.

The TRL scale, which ranges from level 1, an observed, basic scientific principle, through level 9, implementation in an operational environment, is acknowledged to be subjective, but the inclusion of common definitions and criteria in the framework is generally accepted as preferable to arbitrary and inconsistent assessments.

For more general policy planning and understanding how research and innovation is performing at a regional or national level, an approach to technology maturity modelling is beneficial and can operate at a macro scale - at the level of thousands or millions of research projects.

## 10.2 Shifting to modelling

For this study, use has been made of the Clarivate Technology Maturity Index (TMI) - a pre-existing data model that draws upon global research publication, global invention, and global intellectual property litigation data sources to assess the status of technology sectors but not discrete research programs or technologies. The combined use of TRL at the micro level and TMI at the macro level may, however, assist in projecting the likelihood of achieving commercial outcomes from research across the system and National Priorities.

These global data sources were structured around the National Priority areas across 167 research topics, and then further analyzed via the following 9 factors, each providing detailed information and variation on the level of maturity.

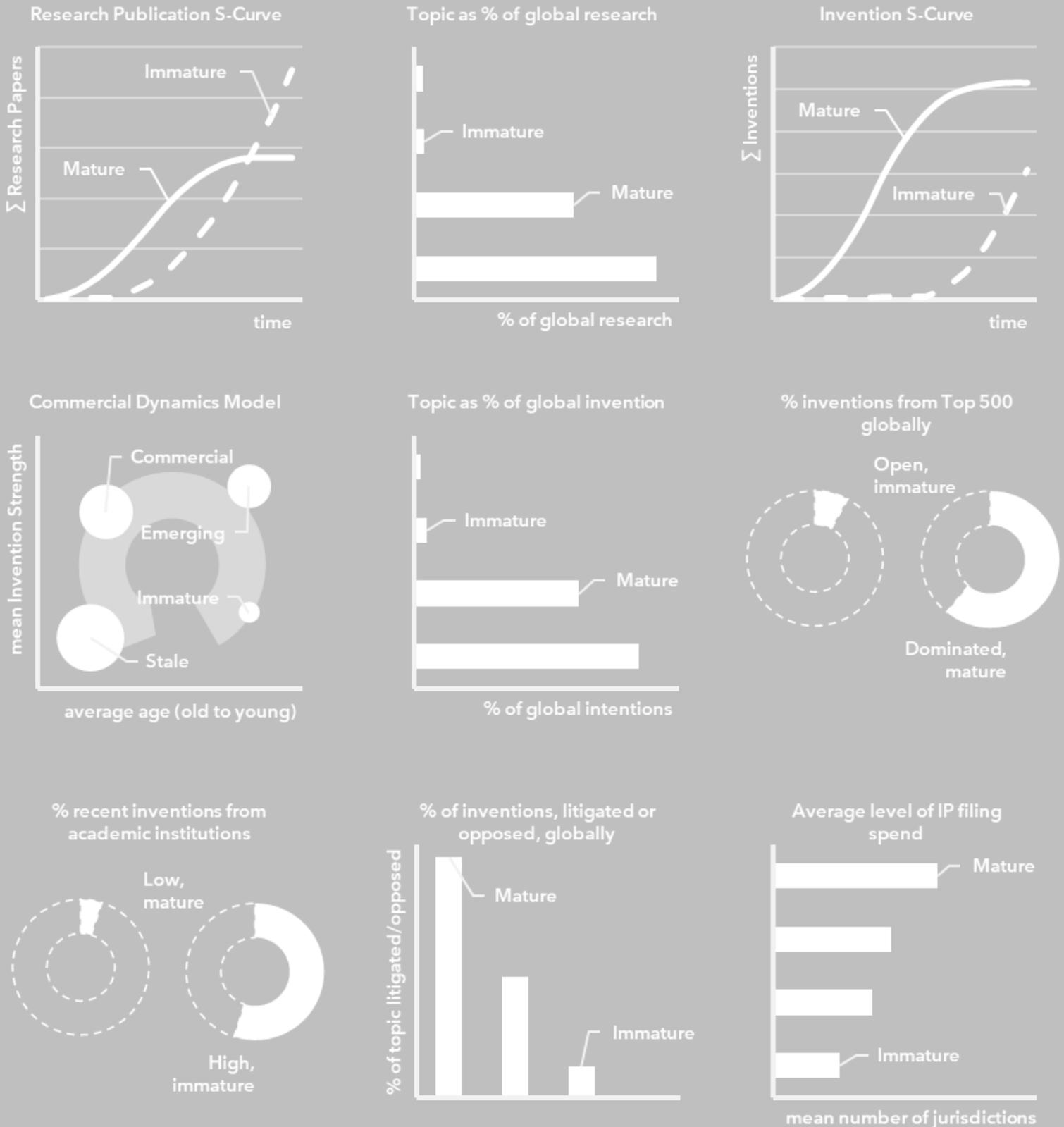
1. Incorporating *innovation s-curve theory*<sup>4</sup> the TMI models the current rate of change of both research publication and global invention levels, assessing the level of approach to *ideality* (or solved/completed research efforts). S-curves track the non-linear natural patterns that occur in development cycles,

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<sup>3</sup> Cartalos, O., Svoronos, A.N., Carayannis, E.G. (2018). The Evaluation Process of Research Commercialization Proposals and its Links to University Technology Transfer (TT) Strategy: A Case Study. In: Kalaitzandonakes, N., Carayannis, E., Grigoroudis, E., Rozakis, S. (eds) From Agriscience to Agribusiness. Innovation, Technology, and Knowledge Management. Springer, Cham. [https://doi.org/10.1007/978-3-319-67958-7\\_14](https://doi.org/10.1007/978-3-319-67958-7_14)

<sup>4</sup> <https://www.open.edu/openlearn/nature-environment/organisations-environmental-management-and-innovation/content-section-1.7>

from near-zero early activity mapping to lower TMI/TRL, through fast-growth in research output and finally again low level/near-zero levels of output as the field reaches completion or saturation. These models are further enhanced by tracking them in both research publication sources in which academic research is significantly more prominent and in global invention data, in which private enterprise is more prolific. Both data sources are used in combination as a proxy for maturity.



2. The size of the research publications and inventions in each research topic, measured as a % of total global research or invention activity during the same time period. A simple metric - more mature fields have more activity within them.
3. Within invention data, a review of the commercial dynamics of the topics. Here a 2x2 model is used to categorize the various topics into different commercial modes based on the average age of activity, and strength of the inventions, as measured via the *Derwent Strength Index*. The 2x2 element includes profiling research topics into those that are recent but weak (mapping to earlier TRL levels), recent and strong (mapping to mid-early TRL levels, as emerging technologies), older and stronger (mapping to later TRL levels, as commercially important technologies) and finally older and weaker technologies extending beyond the TRL system per se, but incorporated into the model as a signature of maturity, see the note on model limitations below).
4. Within invention data, a review of the level of dominance of the technical approach by known large global corporates. Here the Top 500 organizations globally are identified in the patented invention data and assess what proportion of the activity in the last 3 complete years of activity is controlled or developed by those entities. This level of recent, current activity is a proxy for the involvement of large enterprise in the field, and therefore of the overall maturity.
5. Within invention data, the level of academic patent activity within each research topic, in the last 3 complete years of data. A direct measure of technology transfer intention, but also a downgrade of maturity that academia is still prolific and partnering within the space - and therefore mapping to a mid-early TRL level.
6. The level of average intellectual property spend by all applicants in the technology. Leaning on the breadth of protection sought by applicants, this measure brings in spend by proxy: the need for local patent legal counsel in multiple legal jurisdictions, the need for translation of technical documents into local language, and the multiplication of patent office fees - the breadth of geographic filing per case is a good indicator of the level of expenditure. Taken further, IP spend is then a good proxy for commercialization level, as areas with significant commercial potential, as assessed by patent applicants at large, can be discerned from those sectors and segments that are more speculative in nature.
7. The level of intellectual property enforcement: at the end of the commercialization spectrum - the TMI model actively checks for the level of court cases, globally, associated with inventions in each research topic. Patent infringement litigation is an exceptional indicator of commercial realization, as the expense and risk associated with such litigation is very high. In addition, this factor also incorporates "opposition" proceedings that take place within national Patent Offices - where a 3<sup>rd</sup> party challenges the issuance of a patent asset by the office. Taken together, these final factors describe the level of contentious or competitiveness in each research topic, again a proxy for their commercial importance and thus maturity.

To depict the relationship between academic research in the broader field of the National Priorities globally, this study presents the Technology Maturity Index mapped as a TRL 9-point scale. *It must be stressed that this depiction is for ease of use and navigability within the scope of this study, but there are limitations to this mapping and it should not be interpreted as assigning a commercialization potential score to any particular research or technology.* Further, in using this mapping, it is important to understand that:

- The scale from 1 to 9 is defined by the scoring boundaries of the 167 categories. The model assumes that a level 1 and level 9 research front exist

within the dataset, and then distributes all other research fronts across 8 distinct boundaries.

- It is both assumed and observed that research within the national priorities are largely nascent and emerging research topics - therefore the assignment of a research topic at level 9 in the Technology Maturity Index is due to its comparison to the other research topics under analysis.
- Secondly, the TRL system is intended to assess and evaluate an individual research program, rather than the wider research environment in which it sits. As such, while the TMI model may place a topic at a specific TRL level, an individual research project is likely to vary in TRL.
- The TRL model does not extend to the obsolescence of technical approaches as it is primarily used in prospective research program management where it would not be expected to observe the continuation of a research program into a known obsolete technology. However, the Technology Maturity Index, as it mass-analyses all technology and research, extends past the useful life of technology. This, therefore, needs to be considered when assessing levels 8 and 9 of the TMI/TRL mapping. While for the purposes of the National Priorities, few of the technologies are likely to be obsolete per se, this feature does represent a limitation on the correct concordance of the models.
- The TMI model is bi-directional in that it allows for a downgrade in the maturity of technology while the TRL scale only anticipates progression. A technology can become *less mature* if it subsequently affected by a new enabling technology. For example, research into display technology has undergone several overlapping phases over the past century - from cathode ray tubes to plasma displays to today light-emitting diode displays. Within each, there are multiple further development efforts, as well as failed development efforts such as field emission displays that did not become major commercial technologies.

# 11 Technology maturity outcomes

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## 11.1 Overview

With the necessary caveats described above, each of the selected research topics within the National Priorities has been mapped to the individual Technology Maturity Index from 1 - least mature through 9 - most mature.

The maturity levels of the research topics in general align to a normal, gaussian statistical distribution, in that the topics concentrate within 4-6 TRL-levels. Further, the modal average of the TRL level across the topics is central, at TRL 5.

This is, to a degree, due to the relative nature of the TMI model applied to the study's datasets; however, the individual distributions within the four National Priorities vary significantly from this dataset-wide pattern.

## 11.2 Research topic technology maturity by national priority

On the following and subsequent pages, each of the selected 167 research topics that make up the four RDI national priority areas will be allocated a location on the technology maturity index, as scaled on a traditional Technology Readiness Level axis.

**Economies of the future** (Figure 25) is the only priority area with research topics falling into TRLs 1 and 2 (Deep Sea eDNA Analytics, Responsible AI and Cognitive Cities - Predictive Analytics). The distribution in the priority area is also the broadest - only the Health and Wellness priority also has a research theme in TRL 9. In the case of Economies of the future, this is the semiconductors field, reflecting the underlying and mature foundational nature of the technical field to modern society.

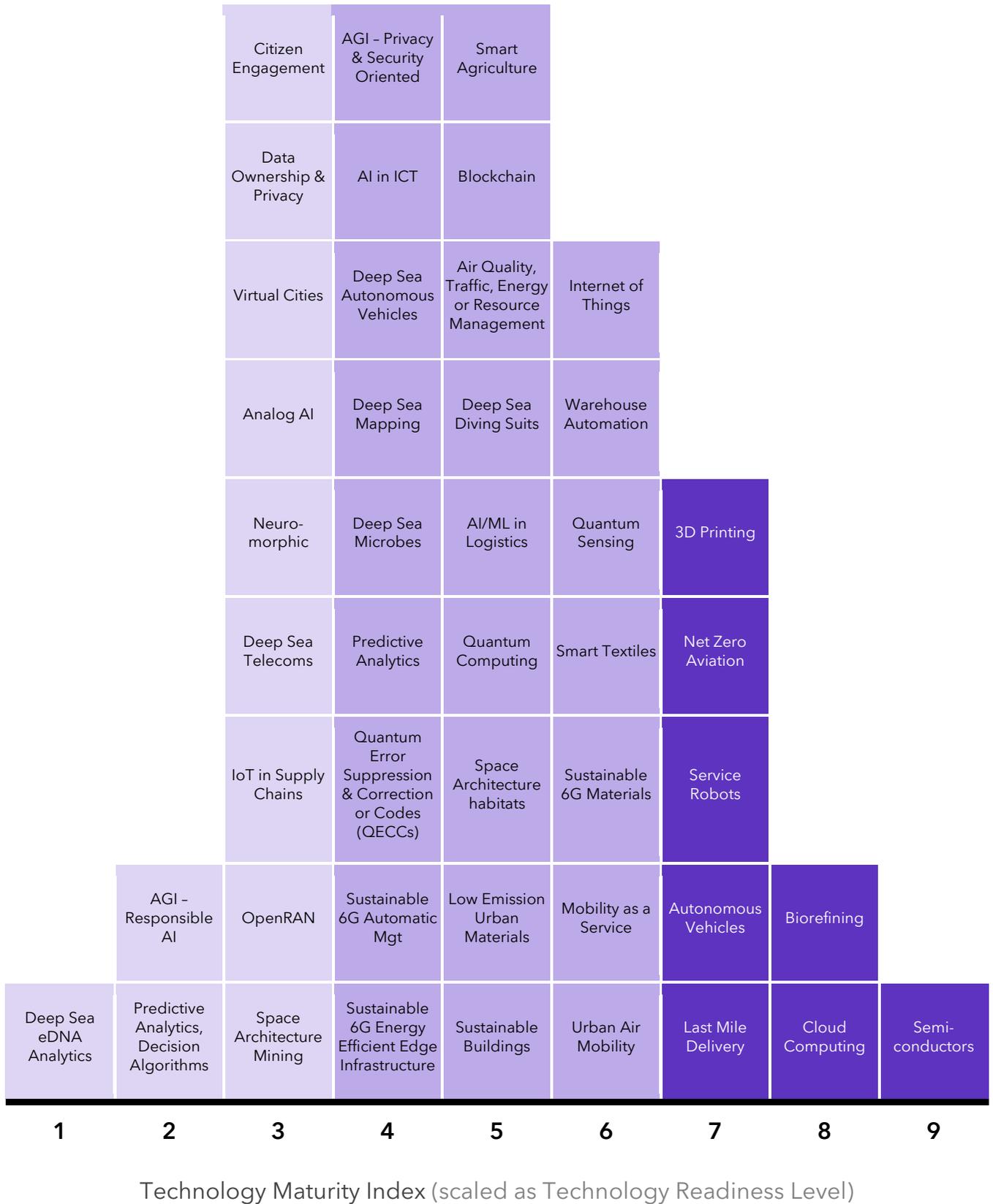


Figure 25 - Technology Maturity Index result for research topics within the Economies of the future National Priority Area; vertical axis represents count of categories in each tier

Therefore, this National Priority Area is the most diverse in potential areas of future potential competitive advantage.

Within Economies of the Future, there is a generally low TRL rating of the Cognitive Cities research themes - all sit within levels of 2-3 except for the Air Quality, Traffic, Energy or Resource Management research category (TRL 5).

Of the most mature categories, an unexpected outcome arose in Net Zero Aviation. However, review of the individual data points reflects a relatively high level of mature-indicating activity, i.e.:

- 14,000 papers and 36,000 inventions,
- 44% of inventions owned by the world's Top 500 patent filers,
- Only 14% of inventions in the last three years emanating from academic institutions globally, meaning the topic is one of focus by commercial entities and private enterprise,
- On average an invention in the technology is filed in 1.9 jurisdictions, and 0.2% of inventions have been actively litigated or opposed, both indicating a level of commercial confidence and an active market for the technology.

AI topics in general trend more immature, despite significant volumes of filing (i.e. AI in ICT gaining 352k new inventions since 2014). Comparing this to Net Zero Aviation, it is shown that:

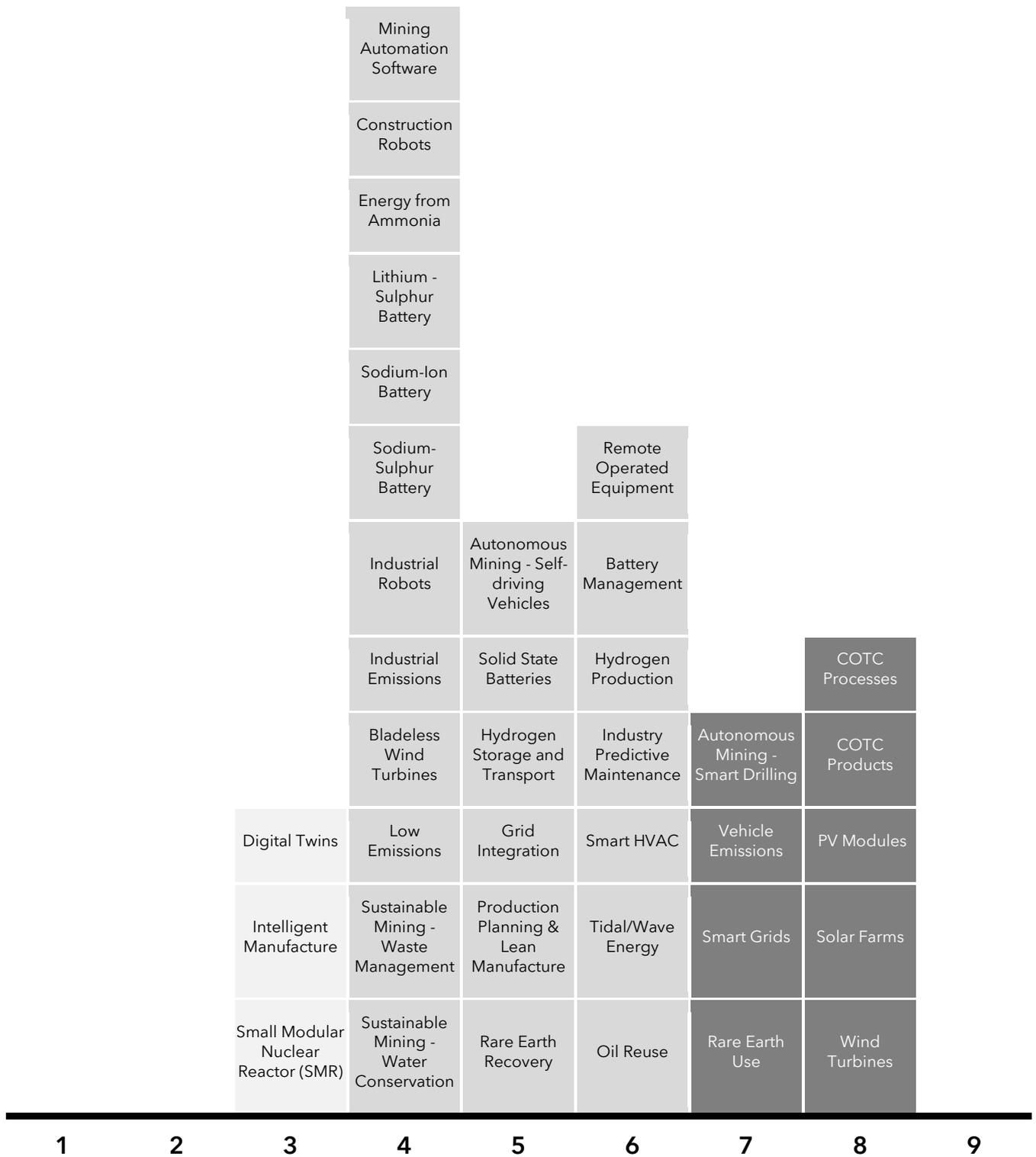
- 35% of inventions from academic institutions in the last 3 years, demonstrating a high degree of current intervention by academia in the continued foundation of the technology,
- On average filed in just 1.3 jurisdictions, indicating confidence by patent applicants is lower and more speculative,
- Just 0.02% of inventions litigated or opposed, indicating the technology is not yet commercial enough for active enforcement of IP rights to be in place.

The low placement of Responsible AGI (though likely containing technology around responsible/ethical AI more generally) reflects a gap in capability as economies adopt automation algorithms to business and consumer information challenges.

Within logistics technologies, the most mature is warehouse automation, likely driven by the widescale adoption and price sensitivity of e-commerce creating a significant need to reduce costs.

However, behind this are technologies like logistics-specific IoT and predictive analytics/automation technologies (TRL 3 and 5, respectively) indicating that there is significant potential for further improvements in supply efficiency chains.

Exploration of outer space is reflected in the TRLs in a logical manner - with habitation more mature (TRL 5) than space mining (TRL 3), with manned spaceflight (at small scale) a current technology, while off-Earth mining still only in conceptual development.



Technology Maturity Index (scaled as Technology Readiness Level)

Figure 26 - Technology Maturity Index result for research topics within the Energy and Industrials National Priority Area; vertical axis represents count of categories in each tier

**Energy and Industrials** (Figure 26), in comparison, tracks as more mature than Economies of the future, with no research themes in TRLs 1 or 2, though notably also none at TRL 9. The focus of the most mature topics are all within the energy space: solar and wind renewable energy as well as crude oil-to-chemical topics (both processes and products). Lower TRL energy topics include tidal/wave energy production and hydrogen production technologies.

Lower TRL topics (but still TRL 3 or above) in the Energy and Industrials priority area focus on Industry 4.0 topics (i.e., digital twins, intelligent manufacture) and the development of Small Modular Reactors for nuclear energy production.

There is variation in the maturity level of battery technology, with battery management being relatively well developed (TRL 6) versus sodium-ion, sodium-sulphur, and lithium-sulphur, all within TRL 4.

The intermix between the development of lower cost/higher energy density battery technologies, and the maturity of solar and wind renewables reflects a challenge for a wider energy transition, in that the need for grid storage at scale to more widely adopt intermittent energy sources.

A notable peak in activity occurs within E&I at TRL 4, which also shows a peak in Sustainability and Essential Needs. This is where the topics of sustainable and autonomous mining generally reside, except smart drilling technology 7).

One interesting disparity between priority areas occurs within the autonomous vehicles space - with the context of autonomous mining, which the model assigns as TRL 5, whereas autonomous vehicle technology more widely (with the Economies of the future National Priority) is assessed at TRL 7. This implies that the automotive sector leads the development of the technology for consumer vehicle applications; though regulatory challenges to autonomous driving by the wider populace is likely to be more significant than those that occur in more controlled environments such as industrial settings. However, it appears the more specific and contextualized development of the technology is still to occur.

The **Health and Wellness** Technology Maturity distribution (Figure 27) is significantly shifted towards more mature TRL levels, in comparison to the other National Priority Areas, with no research themes in TRLs 1-3, and three topics in TRL 9.

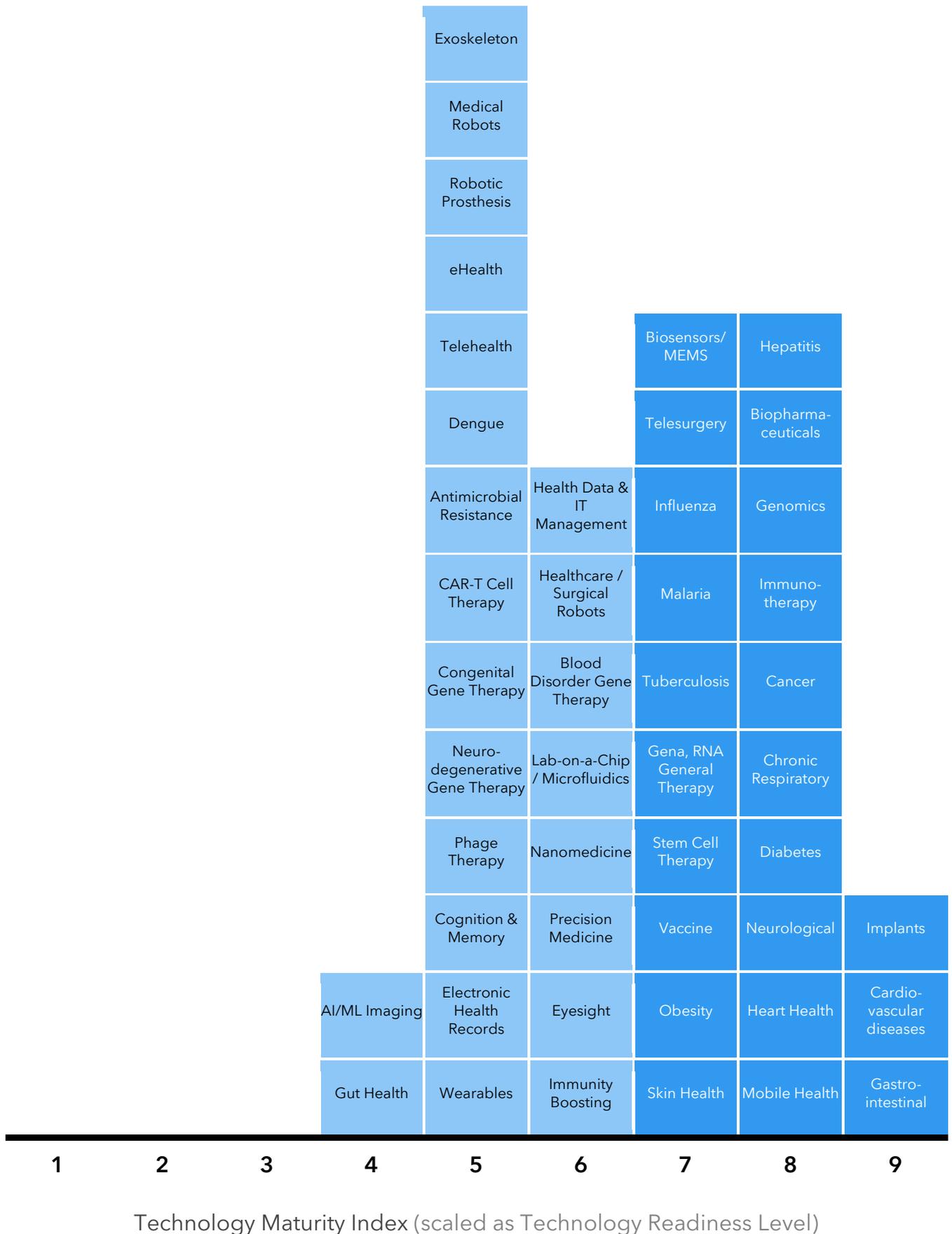


Figure 27 - Technology Maturity Index result for research topics within the Health and Wellness National Priority Area; vertical axis represents count of categories in each tier

This is likely to be due to a) the deeper research base that has occurred in life sciences topics prior to the beginning of the study survey period (2014), and b) the need for greater technology demonstration requirement for active therapies.

For example, the creation of devices intended to be implanted into patients requires a significant regulatory pathway - clinical studies, safety demonstration etc. This requirement is particularly the case for disease therapies; indeed no disease target in the H&W priority sits at a TRL lower than 7, with the exception of Dengue Fever. This indicates a need for further development or opportunity within this specific disease therapeutic area.

More broadly there is a split in maturity between disease targets and preventative or digital health topics. The former sits, on average, at TRL 8 versus TRL 6 for the latter.

This reflects exciting new pathways for the life sciences to develop and deploy significant mortality prevention and life enhancing technologies in the healthcare space, so that intervention with more traditional therapies (pharmaceuticals, clinical care) is reduced in need. This aligns to wider need in national healthcare policy globally that is challenged by aging populations creating healthcare spend inflation that is outpacing wider economic growth. This trend to lower TRLs in non-disease therapies and diagnosis also exists in the assistive space, and indeed the supporting MedTech/biotech sector, both on average rated at TRLs 5-6.

For the **Sustainability and Essential Needs** (Figure 28) National Priority a narrower, much more constrained TRL distribution is shown, with only two research topics in the mature TRL levels of 7-9: Electric Vehicles and Wastewater Purification.

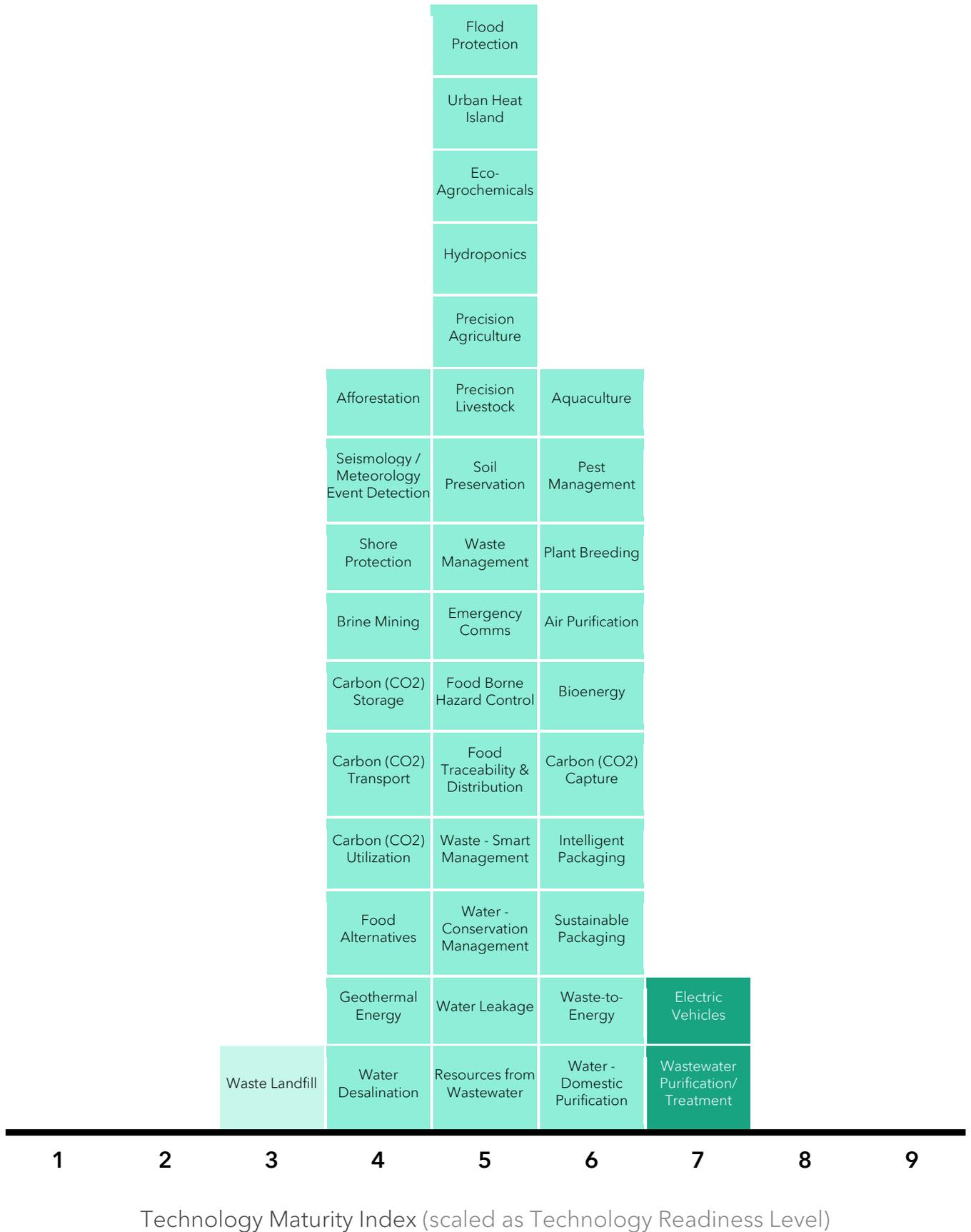


Figure 28 - Technology Maturity Index result for research topics within the Sustainability and Essential Needs National Priority Area; vertical axis represents count of categories in each tier

The narrow variation in the sustainability and base infrastructure categories covered within this National Priority Area benefit from measuring the level of differentiation between different classes of research topic, so that specific detail is more easily visible.

The least mature research themes in the priority area surround climate adaptation technologies, those dealing with the effects of changing climatic conditions such as shore protection, meteorological event detection, flood protection, urban heat island and afforestation. All these research areas are within TRL 4 or 5

The next least mature technology is the treatment and management of CO<sub>2</sub>, with the model primarily assessing it as TRL 4 except Carbon Capture technologies (TRL 6); carbon storage, transportation and utilization of captured carbon remain much earlier in the development pipeline, indicating a flow of technology development from the capability of sequestration approaches to the later management of CO<sub>2</sub>.

Waste management topics have a higher variation in level, with waste to energy technology most mature (TRL 6), followed by smart waste management (TRL 5) and earliest in development - landfill management. The management of landfill sites is of interest to review in more detail to understand its placement, as landfill in itself is an older civil engineering topic:

- 15k research papers - making it the 61<sup>st</sup> smallest topic covered in the National Priority Areas, but only 2,300 inventions globally in the past decade (the 25<sup>th</sup> lowest).
- 83% of inventions emanate from *outside* the world's largest patent filers, making a topic that is ranked more diverse in ownership (and therefore less mature), and 20% of recent activity filed by academic institutions, almost double the rate of the global technology baseline of 11%.
- Just 1 invention has been litigated or opposed, reflecting a very low/almost zero level/value of intellectual property enforcement or contentiousness.
- Taken together - high base research footprint, comparably low applied research footprint, high academic patent activity, low dominance by major corporations and low levels of IP enforcement - mark it as relatively immature field that compares unfavorably to major commercial technology areas.

The Essential Needs topics (food, agriculture and water) are on average more mature than adaptation, carbon or waste management topics.

Within water, the mature technology is wastewater purification, the least mature is water desalination. Alongside Electric Vehicles, wastewater treatment is the equally-most mature research theme in the National Priority Area.

The relatively high expertise of Saudi Arabia in desalination for drinking water places the topic as one for major research consideration by national research and innovation strategy. Comparing the difference in maturity factors between wastewater treatment and water desalination provides a good baseline for understanding the potential direction of the topic:

- Wastewater treatment is a significant research topic: 140k research publications and almost 490k inventions in the past decade. 13% of recent patent activity has come from academia. The field is located in commercial dynamics as a base, stale technology in terms of average invention strength vs average age, and there is a relatively large pool of 227 litigation/opposition events (0.05% of inventions, though the volume itself is notable).
- It can be summarized as a significant topic of interest for applied commercial technology protection, with baseline levels of patent activity from academic institutions and active IP enforcement.
- In contrast, for water desalination: 37k papers, 14k patents (noting the mix between basic vs applied research in papers vs patents is switched), 36%

of activity from academic institutions, it is located as a bleeding edge technology as a low invention strength, youthful segment; and only 4 litigation/opposition events in the last decade (0.03%).

- Taken together, these two sectors (wastewater treatment and water desalination) reflect quite different industries and paradigms. All economies have wastewater that requires treatment, while not all currently rely on desalination for the supply of fresh water.
- Notably, this variation in overall (macro) maturity does not inhibit the potential adoption of new technical approaches into a very mature field such as wastewater treatment that may not itself remain innovative.
- Saudi Arabia has a 5x higher share of invention activity globally in the desalination sector (0.8%) compared to an all-technology baseline (0.04%), placing it as an area of research depth.

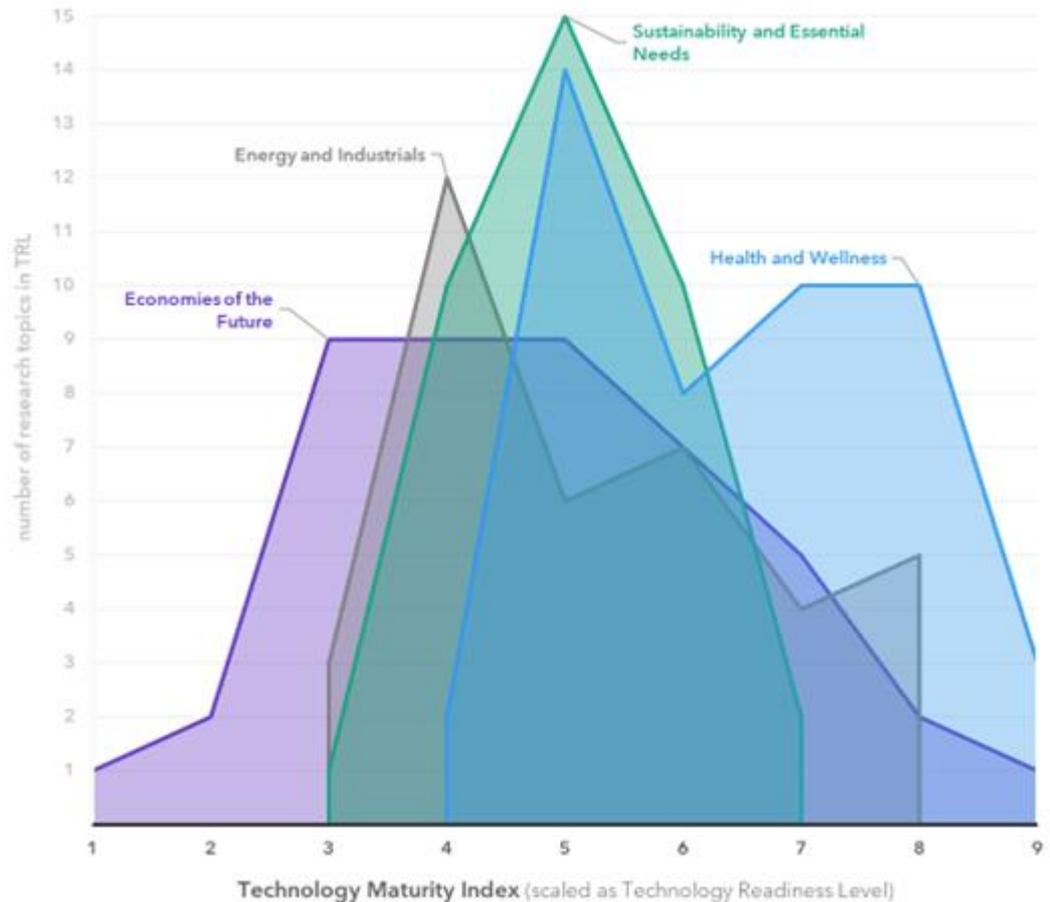


Figure 29 - Plot of distribution of the 4 National Priority Areas across the Technology Readiness Spectrum, for comparison

### Findings

A high-level summary of the predicted growth levels of research topics across the National Priorities (Figure 30) profiles well the outcome of the technology maturity assessment. High levels of growth in individual research themes (in this view, averaged onto an aggregate vertical axis) maps to lower average TRL level (note this is to be expected, as the technical maturity model includes several facets that map to age and directionality, i.e., s-curve shape analysis and commercial dynamics modeling). The variation is however interesting, as it speaks to the degree of reliance on growth potential on the current commercial marketability of research areas, and the comparable dynamics of that reliance.

As an example, **Economies of the future** breaks out as generally earlier in the development lifecycle, but with significant room for growth across further advances in connectivity, digitization and automation topics. The priority area demonstrates less

adherence to growth decline as maturity increases. Topics such as cloud computing, highly developed at TRL 8, have nonetheless grown 30 times in invention volume over the last ten years and predicted in the model to grow further by an additional 50% in inventions and 17% in research publications over the next three years.

As a field which maps to a higher level of research diversity for Saudi Arabia, this National Priority stands apart as a sector in which existing research may be ripe for adoption by commercial entities, and where new academic research can add significant and valuable contribution to global technology in lower TRL levels.

**Health and Wellness**, conversely, maps to significantly more mature research themes, and exhibits a higher drop off in future research growth as maturity increases. This means that for Saudi research the ability to add solutions and improvements at scale, is to a degree, restricted. There are several fields available at lower TRL levels where adoption to commercial and market are available and further academic research will have value, but concentrations of research in highly mature Health and Wellness topics are likely already dominated by global private enterprise.

However, highly mature research areas such as medical and pharmaceutical therapies constantly need breakthrough research that can replace or better existing treatment of significant medical conditions. Therefore, high TRL research topics in the health and wellness priority that are also areas of considerable research capability of Saudi academic institutions would focus on partnerships with corporate entities, so that the strengths of both are combined.

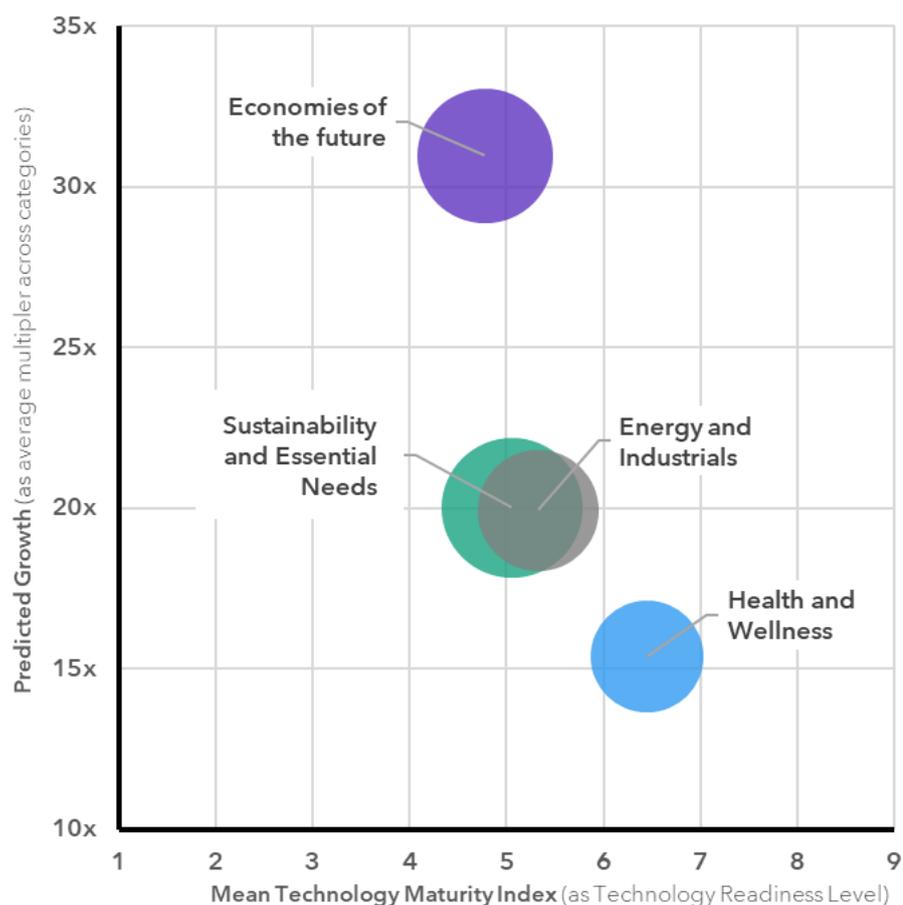


Figure 30 - Average predicted growth in inventive activity globally, versus average technology maturity; by National Priority Area

**Sustainability and Essential Needs** and **Energy and Industrials** sit midway on the TRL spectrum, narrower in maturity variation across the research themes within them, on average, likely to grow at lower rates. Of the two, Sustainability and Essential Needs reflect a lower tendency to growth decay at higher maturity levels (arguably

due to more random distribution and less adherence than Economies of the future topics). Within these topics, the selection of mid-TRL research priorities, partially due to Saudi Arabia's historical and current expertise and market maturity in particularly energy topics, is likely to more readily find openness to partnership and corporate interest or adoption.

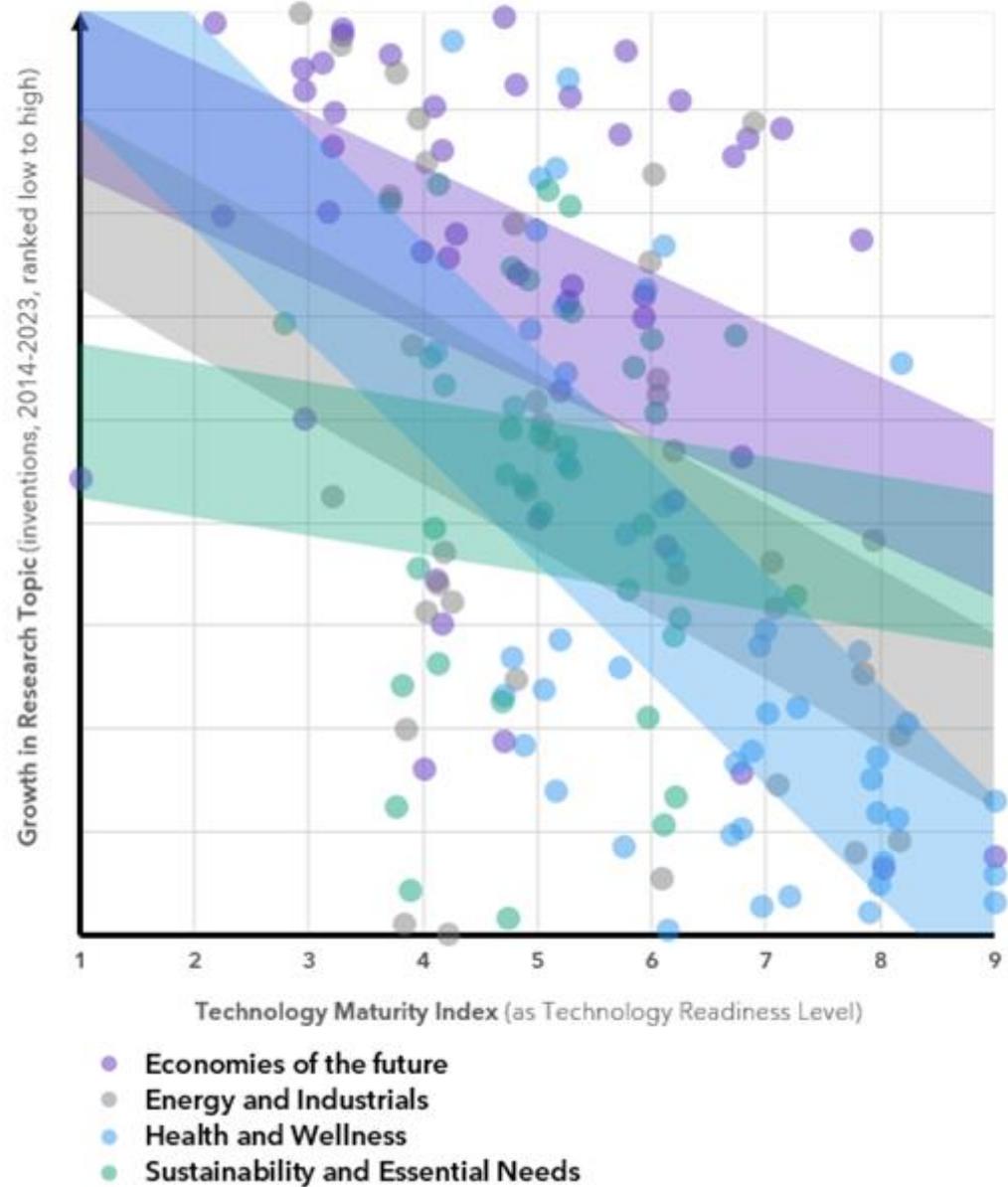


Figure 31 - Detailed scatterplot of global trends in growth versus technology maturity; by National Priority Area, including trend line for each

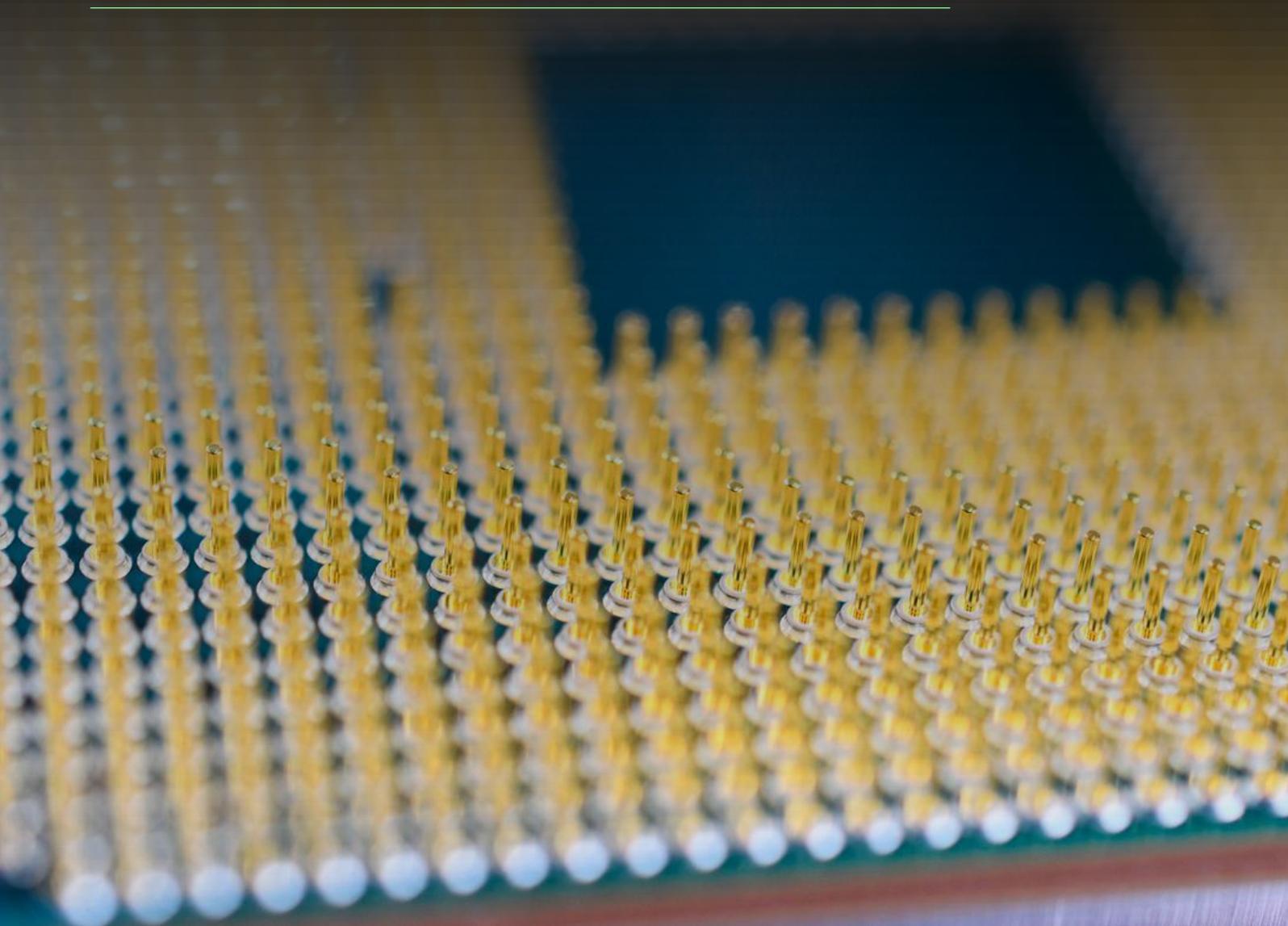
This modeling exercise suggests that, as RDIA funds research in Saudi Arabia, to create the most significant impact, funding should be supportive of less mature fields that have high growth and commercial potential.

This maps to the higher risk profile of lower-TRL research topics that are more difficult for private enterprises and corporations to invest toward and where the intervention of RDIA science and research funding is better suited over a longer investment and return cycle.

The next chapter adds the commercial potential and depth of applied research within Saudi Arabia to assess the dynamics and behaviors of research themes so that the determination of funding policy can be more precisely tuned and directed.

# 12 Benchmarking Saudi Arabian activity via technology maturity

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## 12.1 Overview

Having modeled global activity within the areas of primary interest to Saudi Arabia via the 4 National Priority Areas (Economies of the Future, Energy and Industrials, Health and Wellness, and Sustainability and Essential Needs), the variation and distribution of maturity of individual research themes and topics within them are reviewed. This section of the study shifts to examining the context of research within Saudi Arabia that has occurred over the past decade, and places it alongside the empirical measurement of global technology maturity so that areas of research depth, expertise and existing capability (including nascent or existing academic-corporate research partnership) can be used as a contextualization and as a decision support framework for RDIA.

Specifically, a review of the level of focus of transferable technology is performed (as an asset portfolio of Saudi Arabia) in terms of general maturity/TRL level and individual research topics within the National Priority Areas on the TRL spectrum.

## 12.2 Maturity levels of Saudi invention activity

With a focus on commercial potential, the analysis within this chapter is largely restricted to the invention activities of organizations and institutions in Saudi Arabia, in order to identify the strengths more readily available for uptake by corporate enterprises.

Patents represent an essential enabler of technology transfer, as patents covering specific technical improvements increase the ease with which research, know-how and technical value can be incorporated into contractual language. This enables research partnerships to be fostered more confidently and precisely, where ownership and return are easier to communicate and value.

The analysis of global inventions into the technology maturity/TRL process needs to conceptually separate: 1) the TRL level of an individual patent by an academic institution (or indeed, any patent applicant), which will almost always be relatively early in the maturity, versus 2) the overall maturity of the industry or research topic modeled in this analysis.

In summary, the Technology Maturity Index model may place a research topic at a specific TRL level, while an individual research project that is aggregated in this analysis is likely to vary in its specific TRL.

Therefore, this section will analyze the overall maturity of the research topics of Saudi activity, but not the TRL level of any particular research program.

A review of both Saudi academic (Figure 33) and corporate (Figure 34) patent activity by TRL level highlights the maturity profile of transferable research occurring in Saudi Arabia over the last ten years.

Included in the analysis are global baselines for academic technology transfer activity and global corporate applied research protection. A comparison of these baselines shows a high level of focus on research in the National Priorities by global corporates in TRLs 7 and 8 (and partially 9, most mature), versus lower levels of activity in TRLs 3,4 and 5. This compares to academic tech transfer globally which does have a peak in TRLs 7 and 8, but a more noticeable level and higher focus profile in TRLs 4,5 and 6.

For Saudi academic patenting, 60% of the activity lies within topics rated at TRL 8. This represents almost double the activity of global academic patenting (35%). The introduction of a time element (annotated as a dotted line on both figures 33 and 34) shows how focus changes from the whole decade to just the last three years of complete patent output.

This type of analysis is expected to show a reduction in activity from higher TRL levels, replaced by counter-increase in activity at lower, earlier TRLs. The data reflects the research shift from more complete, more commercial technologies to those requiring greater levels of more basic research input and intervention. This dynamic is demonstrated by global academic patent concentrations, as activity drops in TRLs 7, 8 and 9 to greater focus in, particularly, TRL 4. It also demonstrated by global corporates who perform the same shift, with lower focus on TRL 8 and 9, and greater focus in more recent years on TRL 4.

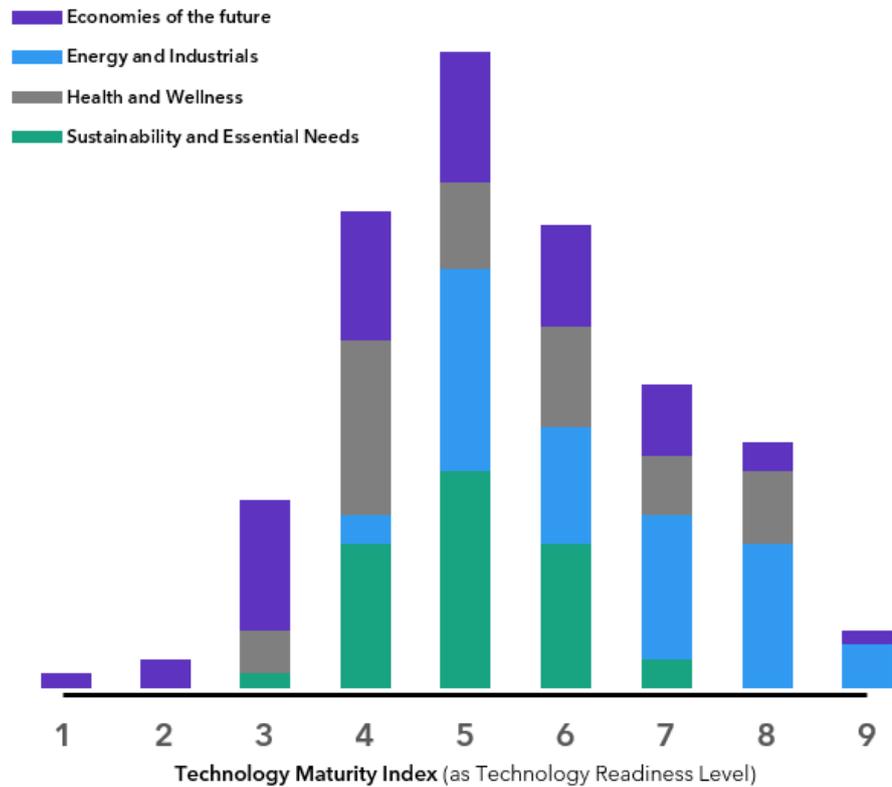


Figure 32 - Summarised distribution of Technical Maturity Index placement of the 167 research topics across all 4 National Priority Areas

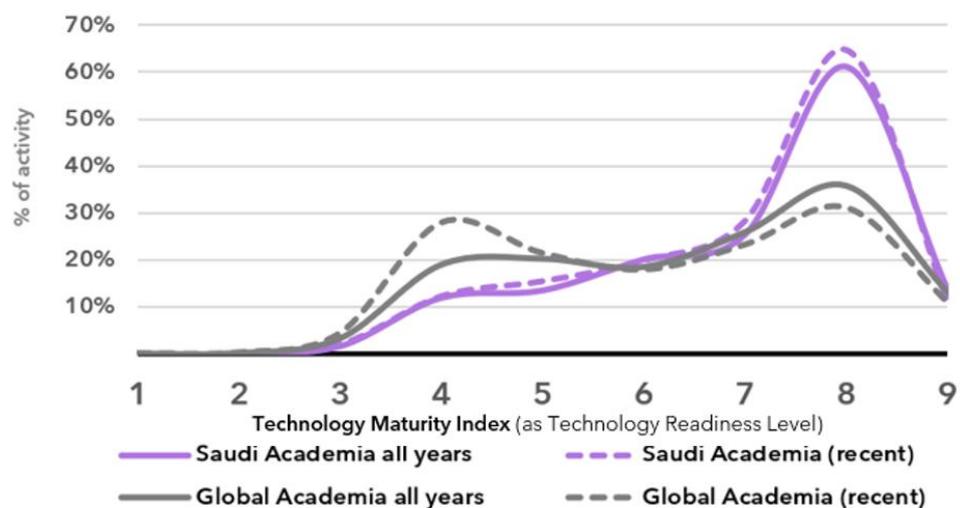


Figure 33 - Proportion of Saudi Arabian academic invention activity by Technology Maturity Index, benchmarked to global academic distribution; dotted line represents recent activity from 2021-2024

This dynamic is not exhibited by Saudi academic patent filing. There has been relatively little shift in focus in recent activity across all TRL levels, indicating a more static research ecosystem that focuses on existing research themes even as they develop and mature globally. In opposition to this expected dynamic, academic focus on research topics ranked in TRL 8 has increased in recent years.

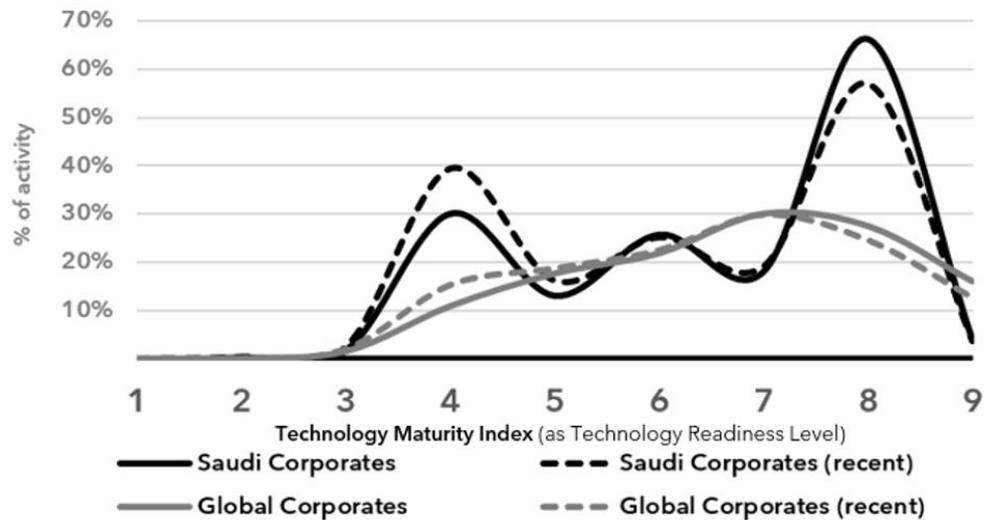


Figure 34 - Proportion of Saudi Arabian corporate invention activity by Technology Maturity Index, benchmarked to global corporate distribution; dotted line represents recent activity from 2021-2024

In comparison, the maturity-of-research focus of Saudi corporate entities (note 60% of which is represented by Saudi Aramco within the National Priority areas) *does* exhibit the expected shift from high TRLs in prior research to lower TRL levels in current research.

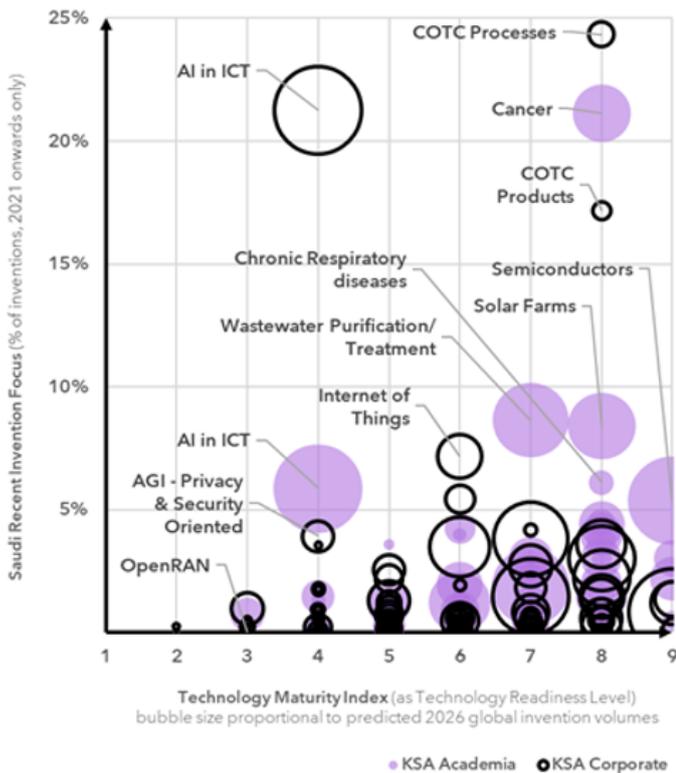
This view demonstrates an interesting structural dynamic of the research & innovation ecosystem within Saudi Arabia that corporates and academia are less synchronized with each other than expected. The global baseline comparison provides evidence that technology transfer involves a pipeline feed of earlier TRL focus topics that is then picked up by private enterprises for development for commercial applications. The lack of an academic patent activity peak from Saudi academic institutes in earlier TRLs (and indeed, the existence of such a peak in Saudi corporations), implies that industrial partners must either develop earlier technologies for later commercialization or source from academic partners outside Saudi Arabia.

Therefore, the technology maturity analysis highlights a need for a shift in approach in the way academic research programs and projects are funded. Targeted outcomes would incentivize an ecosystem that produces research and innovation that supports a mission-driven approach to funding research for ultimate deployment.

### 12.3 Specific areas of focus of Saudi technology transfer

Such a shift in focus will be achieved via prioritization and policy guidance by RDIA: alongside more general technology transfer incentive programs, emulation of existing global tech transfer models in other geographies, the research funding process within Saudi Arabia can be directed at specific areas of the National Priorities and the wider Vision 2030 program.

### Recent Saudi academic & corporate invention focus, versus Technology Maturity



### Academic/Corporate Partnerships, areas of invention activity, versus Technology Maturity

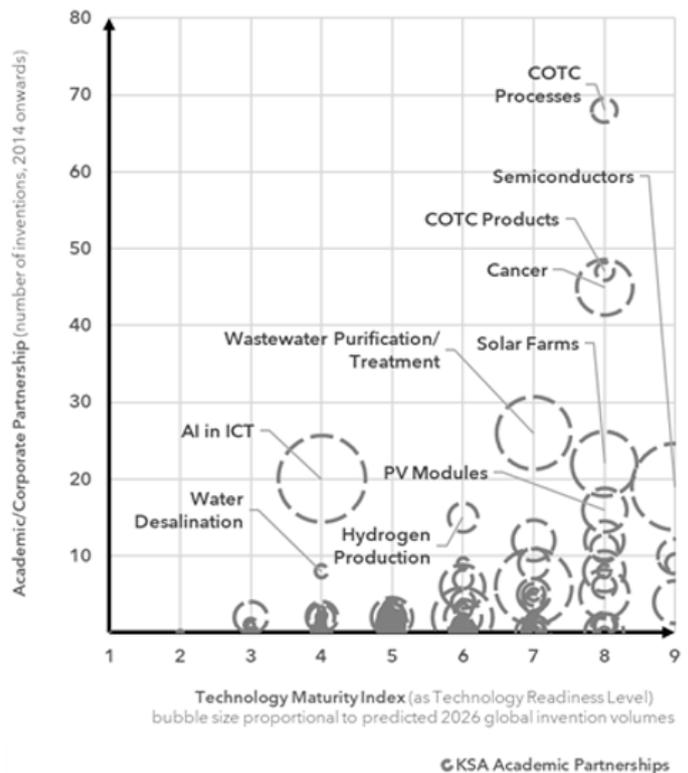


Figure 35 - A review of the recent areas of focus of segments of the Saudi Arabian research ecosystem; specifically the proportion of research within the National Priority Areas in each research topic category from Saudi academic institutions, Saudi corporate entities (left chart) and separately records that imply academic-corporate partnerships (right chart, note vertical axis change from proportion to absolute number of inventions); recent activity is defined as the last 3 complete years of data, plus 2024 year to date; major areas of concentration are labelled

There are many sources of such prioritization – local demand and need, global demand (the focus of this study), and the depth and prowess of existing research areas that can be applied to adjacent sectors and markets.

Starting with the profile of technology transfer and applied research within Saudi Arabia today, an assessment of where within TRL spectrum specific research topics contribute to Saudi patented research. This data view is split between academic and corporate patent activity by TRL and level of recent focus (left chart), and a further view that goes into a higher detail level of existing academic-corporate partnership activity (right chart).

The peaks in TRL 8 from Saudi academic and corporate patent filing are most concentrated in 5 topics – spread amongst the National Priority Areas: crude-oil-to-chemical products and process, cancer research, solar farm renewable energy generation and chronic respiratory conditions. There is a notable split however between corporate and academic focus, with the corporate activity in TRL focused on the petrochemical themes, while academia has focused on healthcare and renewables.

The peak in TRL 4 is predominantly focused on AI research – higher in corporate national output but evident in academic patenting.

Of interest within the analysis is the academic patenting levels within wastewater treatment (TRL 7) and semiconductor research (TRL 9 as a whole, but likely reflecting a spectrum of maturity due to the size of the field and diversity of research directions available).

The further split of analysis onto the location of existing partnerships between Saudi academic and corporate entities largely mirrors the broader national analysis, but some new peaks: water desalination and hydrogen production.

The analysis suggests that funding opportunities should target earlier-stage topics in mid-maturity (such as AI and water desalination) and later-maturity topics, such as healthcare, to increase the likelihood of universities achieving a greater range of technology transfer.

At a more general level, the patent activity of Saudi organizations within the National Priority Areas is relatively concentrated into a few topics, reflected in the digitized nature of the TRL spectrum focus on Saudi patented research activity. 40% of Saudi patent filing during the last decade falls into 5 research topics:

- Energy and Industrials - COTC Processes
- Energy and Industrials - COTC Products
- Economies of the future - AI in ICT
- Health and Wellness - Cancer
- Energy and Industrials - Solar Farms

As a comparison to the wider MENA region (27% of activity in the National Priority Area in the top 5 research themes), or Europe (30% of activity in the top 5), Saudi is relatively more concentrated in its research focus. While not extreme in variation, Saudi Arabia is an international outlier in the diversity of patented research. Also notable is that four of the top 5 for Saudi Arabia sit in TMI/TRL level 8, the exception being AI in ICT. However, it is worth noting that the volume of fields of research is in itself a maturity indicator and therefore some co-occurrence of concentration and maturity is to be expected in patent activity.

The effect of the current profile of Saudi Arabian academic patent activity validates the creation of the National Priorities:

- Targeting funding initiatives towards areas with lower invention output so that a greater diversity of new academic applied research becomes available.
- Once funding policy is complete, technology transfer will be more likely to occur, creating a foundation of value for industry partnerships.
- These two factors will increase performance in several knowledge and technology outputs covered by the World Intellectual Property Organization's (WIPO) Global Innovation Index (GII). Improvement in Saudi performance in the GII is a key performance indicator for the country due to its historic misalignment as a G20 member state but significantly lower GII ranking (2023, 48<sup>th</sup>). Within Saudi Arabia's latest ranking, there is a notable disparity between the level of innovation inputs (i.e. for Saudi Arabia: infrastructure, education attainment, business environment - in total ranking 37<sup>th</sup> globally) and the expected levels of innovation output, such patents, high-tech and ICT exports, trademark filing, website creation etc. (Saudi's output ranking being 67<sup>th</sup>)
- Therefore, creating a research focus on a greater pool of research topics earlier in the research lifecycle in a guided and targeted manner under the National Priority Areas and the Vision 2030 program is likely to create upward pressure on Saudi's GII ranking via increasing of the knowledge outputs ranking, for example:
  - An increase in locally-produced patents, particularly those filed using the Patent Cooperation Treaty (PCT) route administered by WIPO.
  - Increased international licensing of Saudi academic-created technologies via intellectual property assets.
  - The creation of more start-ups, able to gather investment and funding from the private sector as they adopt less mature (i.e. TRL 4, 5 and 6 research topics) technologies from the academic sector and take

them to market, and as a consequence create new products and brands.

- Increase the environment for research and innovation diffusion more generally within the country and economy.

To focus Saudi Arabia's research and boost economic activity, funding targeting key National Priority Areas is required, specifically areas ripe for new research, strong private sector interest, and where Saudi Arabia has the infrastructure and expertise to excel.

Measuring success by the quality of research, especially where intellectual property is registered, focusing on industries where Saudi Arabia can lead or disrupt existing markets will enhance the value of our research in the eyes of international investors and corporations.

The final chapters of this study will, therefore, focus on the intersection of maturity and commercial potential, as well as Saudi Arabia's existing technology transfer profile, to identify topics most likely to create the greatest levels of economic return.

# 13 Assessment of future growth and commercialization opportunity

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## 13.1 Overview

This section brings together insights from earlier chapters of the study. It highlights the commercial potential of research topics within the National Priorities Areas and shows the results of the Technology Maturity Index modeling. It also identifies areas of academic technology transfer in Saudi Arabia, focusing on patent filing activities and examples of academic-corporate partnerships.

As an outcome, research topics are presented within each priority area in the order of their number of characteristics from these different metrics into single scorecards. The scorecards are primarily for used as an ongoing reference of guidance distilling the analytical work in this study into single locations, but they include guidance on targeted modes of engagement with the Saudi research ecosystem, such as areas to be prioritized for technology transfer, early academic development of intellectual assets, or otherwise.

## 13.2 Assessing commercial potential

A primary step in organizing the 167 research themes is assessing the likely commercial potential of the topics.

Global patent data – particularly when assessed at the invention family level – provide a robust signal of commercialization potential due to the cost and disclosure elements a patent application entails.

The filing of a patent application requires the complete disclosure by the applicant of how the invention works, what it is to be used for, how it can be deployed etc. This is part of the validity requirements assessed during patent examination and is the primary purpose of the patent system from a public policy perspective – creating public technical knowledge (even though potentially owned ideas) that can be used by others to create further new solutions to technical problems.

For technologies that are commercially important, the existence of a patented invention is therefore a calculated risk – placing previously private knowledge into the public domain in return for state-granted ownership of the technology. The return of value for the applicant means technology disclosed in the corpus of global patent data represents a direct and unique link between commerce on one side, and technology, research and innovation on the other.

In addition, invention-level data contains significant metadata that corresponds to the importance to the applicant of the technology disclosed within the patent. The filing of a patent in one country is meaningful. The filing of that invention in multiple legal jurisdictions, due to the significant increase in cost, is therefore a strong signal of commercial importance. As an example, the legal fees for drafting a patent application by a professional patent attorney in the United States is typically \$US 8-15,000<sup>5</sup>.

Extending this to further jurisdictions, with further legal fees from locally-certified legal practitioners, translating technical documents, and additional local patent office fees can double or triple this cost.

Costs do change from country to country, with China known as a lower-cost jurisdiction. This means that the volume of patent filing is a good, though not ideal, proxy indicator of the importance of a research field in terms of expected economic return or confidence in future routes to return. Notably, patent data measures directly do not account for the time, infrastructure and resource needed by applicants to perform the research that underpins any single patent application.

For this study, the current volume of patent activity in the sector is used as a starting point to produce a globally common indicator of the size of technology markets.

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<sup>5</sup> <https://ipwatchdog.com/2015/04/04/the-cost-of-obtaining-a-patent-in-the-us/id=56485/>

Added is an analysis of the invention s-curve within that research sector. Those that are trending on an upward path, due to the nature of innovation s-curve theory, will almost certainly continue that upward path. Those in the deceleration phases, similarly, will likely continue to slow. This provides a suitable pathway, particularly for large datasets under analysis in this study, to forecast the volume of commercial activity that will exist in three years from today.

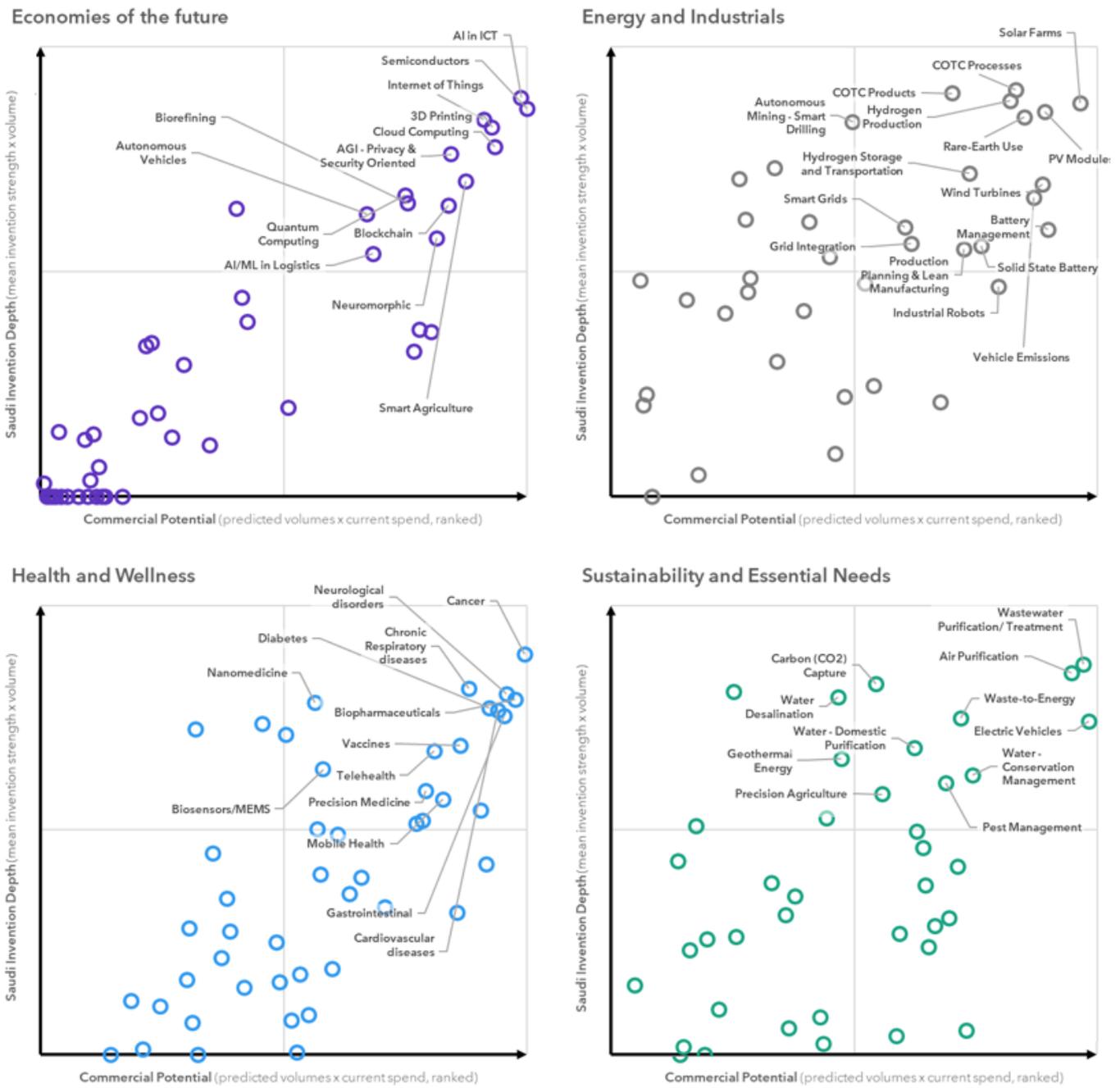


Figure 36 - Views by National Priority Area of research topics arrayed by: the level of Saudi Arabian research strength and depth vs the commercial potential of the research topic; high potential/high invention depth topics labelled

Finally, added is the current level of intellectual property expenditures based on number of jurisdictions protected - one country, two countries etc., in this model, the average number of jurisdictions per invention per research topic category as a commercial multiplier of the market importance of the technical field. Aggregating this calculation for each of the 167 research topic categories as a metric in this study as "commercial potential" - the likely +3 year prediction of the comparable commercial importance of the research topic is shown.

To assess Saudi Arabian research or inventive depth of capability, a similar process is performed, with an amendment from the country filing breadth as a multiplier of activity, to the invention strength score assessed using Clarivate's models.

Invention strength is a broader metric that encompasses a comparative relative importance of the invention within its field of technology, based on four factors:

1. The impact of the invention on the patent applications of 3<sup>rd</sup> party applicants is assessed by patent examiners inside the patent office, as they cite prior patents and patent applications as relevant to the one they are currently examining. Reversing this process, similar in concept to academic citation, though from independent and multinational sources, the strength score is increased if the invention outperforms the expected level of citation of this type compared to other patents of a similar age, technical profile, and from the same geographic source.
2. Whether the invention has been issued as a granted patent or not. Further, the invention strength score is increased and correlated to the size(s) of the economy in which that patent grant (or indeed, multiple grants) takes place - mapping to the size of economic footprint on which the exclusive right to use the technology is now restricted.
3. Incorporating the number of patent applicants who applied for patent protection for the same invention. Similar to the above description of the multiplication of monetary investment for applications in more than one patent jurisdiction, this metric component creates a proxy for the confidence and importance of the invention to the commercial plans and strategies of the applicant.
4. Finally, how rare the general mix of technical approaches detailed in the invention is assessed, compared to all filed inventions by others previously - in essence determining where in its individual innovation s-curve the invention places. For example, early and rarer or later and relatively common.

These component metrics are combined into an overall score and calculated daily in comparison to all other inventions in the Derwent World Patents Index and therefore reflecting a relative importance of each invention record in the database.

To review the relationship of Saudi technology transfer activity and wider market applicability, the average invention strength x volume of Saudi inventions in each of the 167 research topic categories across all 4 National Priority Areas, is plotted against the calculated commercial potential of same topics (Figure 36).

In two priority areas (Economies of the Future, Health, and Wellness), there is some alignment between invention depth and commercial potential - as the market size of the research topics increases, so in general terms, does the depth of invention activity of Saudi Arabia. This link is reduced in both the Energy and Industrials and Sustainability and Essential Needs priority areas.

Several topics of interest emanate from this analysis:

#### **Economies of the future**

- Semiconductors
- AI in ICT
- Internet of things
- 3D printing
- Cloud computing
- Several other related AI topics - privacy & security AI themes, neuromorphic computing architectures, and AI/ML in logistics settings. Also related to this topic is autonomous vehicles.
- Two bioeconomy topics: smart agriculture and biorefining
- Quantum computing

- Also notable is a concentration of unobserved patent activity in this national priority, but it also correlates to very low commercial potential as a whole. They include:
  - Cognitive cities - air quality, traffic, energy and resource management
  - Analog AI computing architectures
  - Deep sea environmental DNA analytics
  - Deep sea microbes
  - OpenRAN
  - Space mining and habitat technology
  - Automatic 6G network management
  - Energy efficient 6G edge infrastructure
  - Mobility as a service
  - Urban air mobility

These unobserved, low-commercialization technologies would be recommended for omission from technology transfer prioritization unless and until fundamental academic research generates significant maturation of the technologies.

### **Energy and Industrials**

- Multiple topics of existing concentrated focus of Saudi Arabia sit as clear high growth topics in the National Priority Area, such as COTC products and process, renewable solar, hydrogen production, reinforcing the position of Saudi as a leader in technologies of known future importance.
- Rare-Earth metal reuse and recycling.
- Battery management

### **Health and Wellness**

- All non-infectious/chronic disease targets in the National Priority Area: cancer, gastrointestinal health, diabetes, chronic respiratory conditions, cardiovascular health, neurological conditions. Clearly representing significant need globally, as societies tend to aging populations, chronic diseases grow in healthcare demand and stretch health spending.
- When the Health and Wellness priority areas was reviewed by the RDIA expert community, these topics were ranked highly as of interest, yet exhibited comparably low growth. However, when view from a commercial potential perspective in this analysis, this lower growth is counterbalanced by the absolute scale of commercialization opportunity and need. That commercialization need is represented well in this model by the average size of intellectual property (on average almost 4 countries per invention, compared to a global baseline of just over 1 jurisdiction).
- This spending level is operating at much higher investment levels per invention than preventative medicine healthcare topics and also higher than infectious disease targets, though interestingly lower than MedTech topics such as biopharmaceuticals itself (4.4 countries per invention).

### **Sustainability and Essential Needs**

- Two topics sit at the extreme correlation of Saudi invention depth and expected commercial potential: wastewater treatment and air purification.
- Electric vehicles are shown as a major growth commercialization opportunity globally, but lower Saudi invention depth (75 inventions over the past decade, 40 from academia) highlights a potential area for exploration of increase of research capability either directly, or via supportive technologies to areas of need within the space, for example battery technology. Its nature as highly commercial in future markets underpins it as an area fruitful for technology diffusion from the university lab to the corporate desktop, and therefore would fall into a mode of representation in national strategy that fosters opportunities for technology transfer.

- Water, as a major essential need topic, and with significant footprint in the Saudi research ecosystem, represents commercialization potential for the national R&I program. The strong global patent footprint of wastewater treatment is a clear focus internationally, but the specialization of Saudi in desalination, particularly when combined with similar expertise in renewable solar power technologies, places it as a key sector for potential technology transfer from Saudi Arabia to international partners.

### 13.3 Combining the view of commercial potential with technical maturity

A critical goal of this study was to understand in detail the relationship between the maturity of the different technical fields and research themes that make up the 4 National Priority Areas alongside their readiness or otherwise for implementation in private enterprise as commercial, marketable innovation.

The analysis in the previous sections of the study combines here to provide this guidance. Research topics at different stages of development change the way research is performed and how research policy should be deployed so the value of that research is best deployed for interaction with the wider economy.

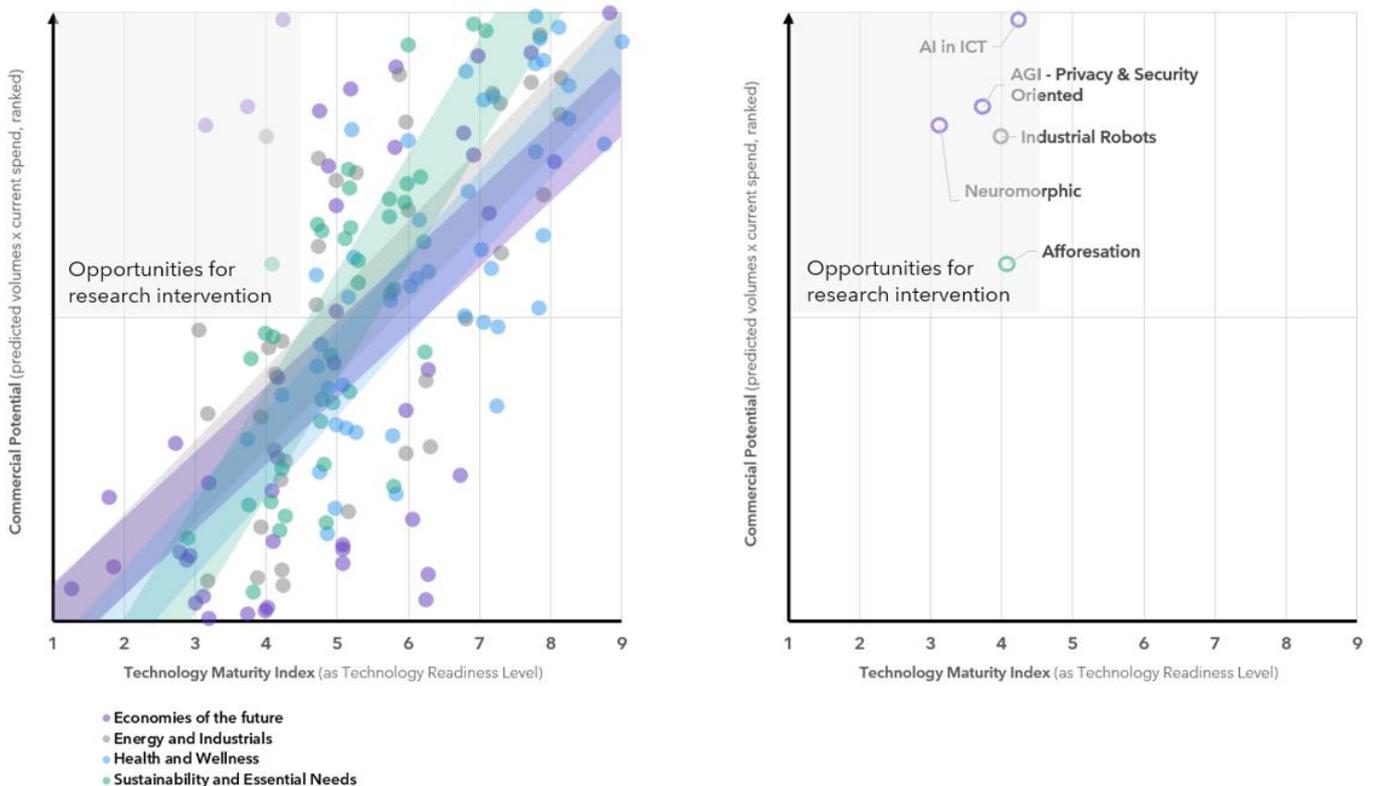


Figure 37 - Scatterplots of commercial potential versus Technology Maturity Index across all research topic categories, annotated by National Priority Area; right chart identifies specific research topics with high commercial potential but lower Technology Maturity

Early technologies, with yet-to-be-developed active markets, necessarily have a focus on governmental intervention in the research space - funding early, likely academic research in these fields that are otherwise considered too risky for corporate R&D to fund.

Similarly, late-stage technologies with significant existing commercial needs and demand – unless undergoing new rounds of technology disruption – likely prove more difficult for academic research to add value to the innovation lifecycle. This is because corporations will fund their own innovation and research programs to take already well-developed technologies to market themselves, ensuring a value-add that they own and control and thus can extract maximum economic return from.

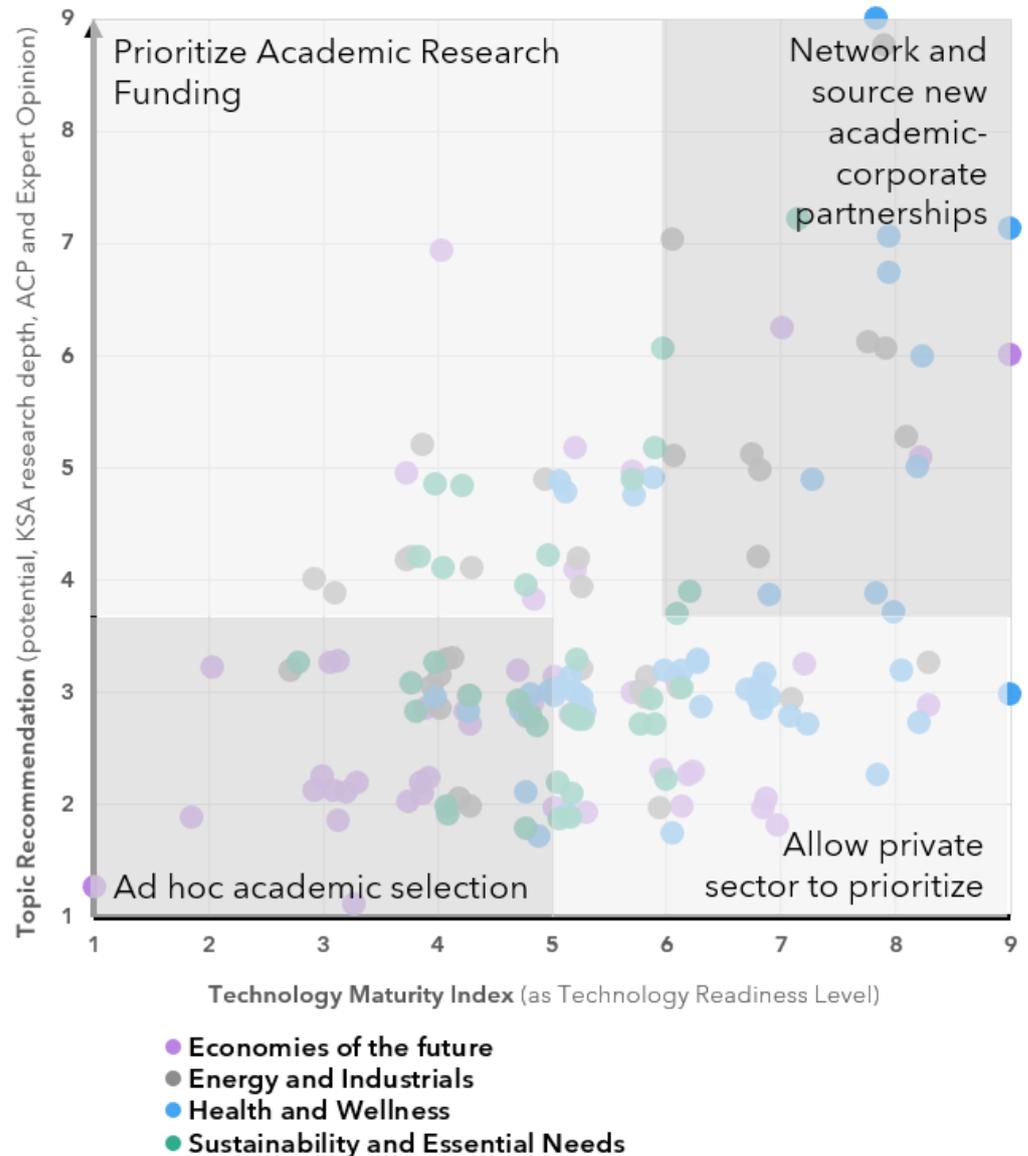


Figure 38 – Summary scatterplot view of the study recommendations of research topics based on the commercial potential measure, the depth of research within Saudi Arabia and the level of academic/corporate potential; all arrayed on the Technical Maturity Index spectrum

An analysis of the Technology Maturity Spectrum, arrayed against commercial potential, has a strong correlation (Figure 37). For Saudi Arabia, operating a prioritized and guided research funding policy approach, it is helpful to target funding approaches sweet spots for intervention in the technology lifecycle. A view highlighting the disparity or misalignment of TRL level versus commercial potential (right-hand chart of Figure 37) provides examples of one such type of sweet spot – research themes with largescale commercial potential yet sit earlier in the TRL spectrum. It is not surprising that the primary concept within this sweet spot is artificial intelligence.

To bring together all the strands of analysis throughout this study, a focus on a combined metric of topic recommendation for research policy and prioritization is created (Figure 38), which includes contributions from:

- Commercial potential: a measure of the future size and current spend levels on technology protection in the research theme
- The depth of Saudi research today – both corporate and academic, is based on the volume of patented inventions that create fertile ground for technology transfer and diffusion. It also includes the strength of individual inventions emanating from Saudi Arabia.
- The level of academic-corporate partnership: measured as the scale of such partnerships observed in the Saudi invention activity within each research topic category and representing evident or nascent networks, links, and capability to partner with local or international private enterprise.

These factors have been combined using ranking logic for each to ensure a balanced contribution of the factors to the overall recommendation.

Arrayed against technology maturity, laying out an overall roadmap of potential policymaking across all 167 research themes and topics that make up the 4 National Priority Areas. Created as an action/recommendation matrix, the framework is further annotated for regions of activity that can be directed to specific modes of research policy support.

Examples of the policy frameworks, for example, via directing research grants and other initiatives of RDIA, based on these modes include:

1. Where maturity is high (e.g. TRLs 6-9) and the recommendation of the research topic is also high, combining the expectation of future commercial potential, existing Saudi capability and interest: these are research themes where further funding should be directed towards applied research, and/or highly disruptive technologies in these existing markets. The mode of activity should focus on the sourcing of, or expansion of existing, academic-corporate partnerships. In essence, the mode of research in highly commercial, mature research topics becomes focused on the marketability of applied technologies and less on fundamental basic research unless likely to be disruptive or part of a new development cycle within those markets.
2. Where maturity is lower (e.g. TRL 3-5, or earlier), and the topic recommendation is also high, research policy should be targeted towards programs that will create enticing, supporting research for corporate entities, moving technologies from fundamental theory to prototype practical demonstrations of specific commercial application. In addition, future technology diffusion and transfer capability should be envisioned as part of the research funding policy by ensuring patentable subject matter produced as part of research programs is protected as, potentially, a requirement. Note that this an existing policy in international jurisdictions, such as the United States<sup>6</sup>. An example of policies that could be applicable to this mode of research is the ring-fencing of patent filing budgets within the research funding policy, removing the monetary barriers for academic institutions to engage in intellectual property protection. The existence of IP assets in research topics that are highly likely to extend into commercial phases in future years lays the groundwork for partnership and potential licensing of technologies by a broad array of potential users of the research produced.
3. In sectors where topic recommendation outcomes are lower – i.e., more niche commercial potential and lower levels of existing Saudi research capability or interest, there exists policy freedom for the national R&I ecosystem to operate more independently or on a case-by-case basis. Within this layer of research

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<sup>6</sup> <https://grants.nih.gov/policy/intell-property.htm>

topics, potential modes of operation split between more mature and less mature technologies:

- a. For more mature research topics, corporate and private interests can likely operate independently, i.e. these are technologies that have specific markets and are sufficiently developed for private R&D programs to target improvement and new solution. Within Saudi Arabia, the concentration of corporate patent activity into a few major entities (i.e. Aramco, SABIC etc.) likely impinges today's ability of this pickup of corporate R&D programs. However, as the research & innovation ecosystem within Saudi Arabia develops, particularly backed by internationally protected research assets that increase investment attraction in new corporate enterprises around specific technical approaches, this sector will have a greater opportunity to operate in niche markets.
- b. For less mature research topics (TRLs1-5) with lower topic recommendations (lower commercial potential and existing patented Saudi research output), a degree of freedom for academia to pinpoint specific research projects that can be funded on an ad hoc basis is desirable. The ongoing dynamics of global research and innovation are likely to affect change in these research topics over time, and therefore, they should be monitored for breakthrough research or the emergence of new markets and applications of technologies within them. More widely, national funding policy directed to specific topics, as advocated in this study, does entail some risk of missing these new breakthroughs and rapid maturation as they occur, and therefore, continuing the liberty of academia within Saudi to seek government funding should be maintained.

Within the basic quadrant breakouts of the recommendation matrix, one area of specific interest for academic technology transfer is the boundary between early TRL research and emerging commercial interest. This boundary is where research is most vulnerable and where policy intervention can play a vital role, ultimately creating a national competitive advantage for Saudi Arabia Arabia).

Highlighted in Figure 39 are 18 specific research themes that sit in this phase of development (TRL 4-7) and score highly in factors specific to Saudi Arabian research capability (e.g. higher commercial potential, higher level of Saudi Arabian academic research, existing academic-corporate partnership).

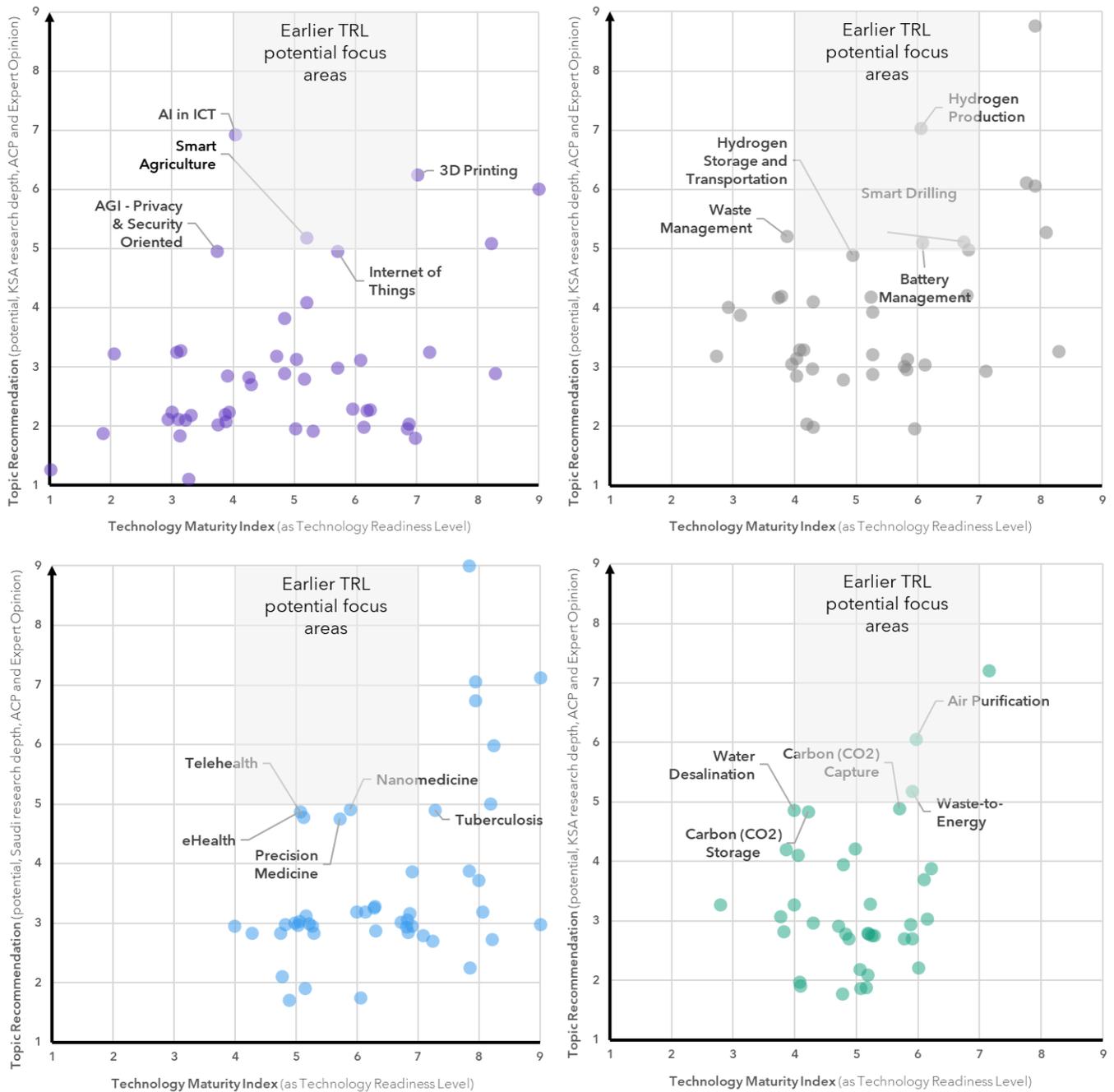


Figure 39 – Breakout scatterplots of Technical Maturity Index versus Topic Recommendation by National Priority Area, annotation for research topics categories of >5 in recommendation and sitting in TRLs 4 - 7.

They include, as identified in Figure 39:

- For Economies of the Future:
  - AI in ICT
  - AGI - Privacy and Security Oriented
  - Bioeconomy - Smart Agriculture
  - Internet of Things
- For Energy and Industrials
  - Hydrogen Production
  - Hydrogen Storage and Transportation

- Sustainable Mining - Waste Management (including for example red mud)
- Energy Storage - Battery Management
- Autonomous Mining - Smart Drilling
- For Health and Wellness
  - Telehealth
  - eHealth
  - Precision Medicine
  - Nanomedicine
- For Sustainability and Essential Needs
  - Air Purification
  - Waste-to-Energy
  - Carbon (CO<sub>2</sub>) Capture
  - Water Desalination
  - Carbon (CO<sub>2</sub>) Storage

These 18 research topics represent fields in existing Saudi research combines with mid-phase TRL to create high levels of specific opportunity and are therefore the key recommended topics for taking into further phases of technology transfer policy.

They represent fields in which the emergence of a globally comparable and successful Saudi Arabian research ecosystem over the past thirty years can be directed to add significant value for both local and international corporate interests who are likely seeking proven technologies that are not yet fully ready for market deployment. Further, the likely demand for solutions and technologies in these fields is high, lowering the risk of research funding occurring on obsolete or unproven future markets.

In addition, these fields are notable for representing the diversification of the Saudi economy from its traditional petrochemical strength, though with notable linkages to that powerful heritage. For example, the hydrogen economy, air purification, and carbon capture and storage topics speak to markets and engineering solutions that clearly build upon energy infrastructure and capability. Similarly, Saudi expertise in water desalination is an active and likely growing need in many geographical regions.

**This study concludes by detailing, in the following pages, ranked tables of outcomes based on the measures developed using global research and invention data, as well as their relevance to the Saudi research ecosystem, including the Technology Maturity Index.**

## 13.4 Scorecards

Reference tables of the outcomes of this study, measuring the factors included across the 167 research topic categories over the 4 National Priority Areas.

Table 6 - Outcome scorecard for Economies of the future research topic categories, ranked by recommendation level; includes Technology Maturity Index/TRL score. Circle fill denotes a metric from highest quartile evidenced (full) to lowest quartile (single quarter).

Category	TMI as TRL	Commer- -cial Potential	Saudi Research Depth	Level of Partner- ship	Expert Opinion	Recommended mode
AI in ICT	4	●	●	●	na	Prioritize academic funding
Semiconductors	9	●	●	●	na	Prioritize tech transfer
3D Printing	7	●	●	●	●	Prioritize tech transfer
AGI - Privacy & Security Oriented	4	●	●	●	●	Prioritize academic funding
Internet of Things	6	●	●	●	●	Prioritize tech transfer
Smart Agriculture	5	●	●	●	●	Prioritize academic funding
Cloud Computing	8	●	●	●	●	Prioritize tech transfer
Blockchain	5	●	●	●	●	Prioritize academic funding
Quantum Computing	5	●	●	●	●	Prioritize academic funding
Neuromorphic	3	●	●	●	●	Ad hoc academic activity
AI/ML in Logistics	5	●	●	●	●	Ad hoc academic activity
Air Quality, Traffic, Energy or Resource Management	5	●	●	●	●	Ad hoc academic activity
Sustainable buildings	5	●	●	●	●	Ad hoc academic activity
Biorefining	8	●	●	●	●	Private sector led
Deep Sea Autonomous Vehicles	4	●	●	●	●	Ad hoc academic activity
Autonomous Vehicles	7	●	●	●	●	Private sector led
Deep Sea Telecoms	3	●	●	●	●	Ad hoc academic activity
Low Emission Urban Materials	5	●	●	●	●	Ad hoc academic activity
AGI - Responsible AI	2	●	●	●	●	Ad hoc academic activity
Quantum Error Suppression & Correction or Codes (QECCs)	4	●	●	●	●	Ad hoc academic activity
Quantum Sensing	6	●	●	●	●	Private sector led
Sustainable 6G Energy Efficient Edge Infrastructure	4	●	●	●	●	Ad hoc academic activity
Sustainable 6G Materials	6	●	●	●	●	Private sector led
Net Zero Aviation	7	●	●	●	●	Private sector led
Citizen Engagement	3	●	●	●	●	Ad hoc academic activity
Predictive Analytics, Decision Algorithms	2	●	●	●	●	Ad hoc academic activity
Analog AI	3	●	●	●	●	Ad hoc academic activity
Sustainable 6G Automatic Management	4	●	●	●	●	Ad hoc academic activity
Mobility as a Service	6	●	●	●	●	Private sector led
Data Ownership & Privacy	3	●	●	●	●	Ad hoc academic activity
Virtual Cities	3	●	●	●	●	Ad hoc academic activity
Deep Sea Diving Suits	5	●	●	●	●	Ad hoc academic activity
Deep Sea Mapping	4	●	●	●	●	Ad hoc academic activity
Deep Sea Microbes	4	●	●	●	●	Ad hoc academic activity
IoT in Supply Chains	3	●	●	●	●	Ad hoc academic activity
Predictive Analytics	4	●	●	●	●	Ad hoc academic activity
Warehouse Automation	6	●	●	●	●	Private sector led
Service Robots	7	●	●	●	●	Private sector led
Smart Textiles	6	●	●	●	●	Private sector led
Space Architecture Habitats	5	●	●	●	●	Ad hoc academic activity
Space Architecture Mining	3	●	●	●	●	Ad hoc academic activity
Last Mile Delivery	7	●	●	●	●	Private sector led
Urban Air Mobility	6	●	●	●	●	Private sector led
Deep Sea eDNA Analytics	1	●	●	●	na	Ad hoc academic activity
OpenRAN	3	●	●	●	na	Ad hoc academic activity

Table 7 - Outcome scorecard for Energy and Industrials research topic categories, ranked by recommendation level; includes Technology Maturity Index/TRL score. Circle fill denotes a metric from highest quartile evidenced (full) to lowest quartile (single quarter).

Category	TMI as TRL	Commer- -cial Potential	Saudi Research Depth	Level of Partner- ship	Expert Opinion	Recommended mode
Solar Farms	8	●	●	●	●	Prioritize tech transfer
Hydrogen Production	6	◐	●	◐	●	Prioritize tech transfer
COTC Processes	8	◐	●	●	◐	Prioritize tech transfer
PV Modules	8	◐	◐	◐	◐	Prioritize tech transfer
COTC Products	8	◐	●	●	◐	Prioritize tech transfer
Autonomous Mining - Smart Drilling	7	◐	◐	◐	●	Prioritize tech transfer
Battery Management	6	◐	◐	◐	●	Prioritize tech transfer
Hydrogen Storage and Transportation	5	◐	◐	◐	●	Prioritize academic funding
Sustainable Mining Waste Management	4	◐	◐	◐	●	Prioritize academic funding
Rare-Earth Use	7	◐	◐	◐	◐	Prioritize tech transfer
Industrial Robots	4	◐	◐	◐	●	Prioritize academic funding
Grid Integration	5	◐	◐	◐	●	Prioritize academic funding
Smart Grids	7	◐	◐	◐	●	Prioritize tech transfer
Sustainable Mining - Low Emissions	4	◐	◐	◐	●	Prioritize academic funding
Solid State Battery	5	◐	◐	◐	●	Prioritize academic funding
Digital Twins	3	◐	◐	◐	●	Prioritize academic funding
Small Modular Nuclear Reactor (SMR)	3	◐	◐	◐	●	Prioritize academic funding
Sustainable Mining - Water Conservation	4	◐	◐	◐	●	Prioritize academic funding
Vehicle Emissions	7	◐	◐	◐	◐	Private sector led
Construction Robots	4	◐	◐	◐	◐	Ad hoc academic activity
Mining Automation Software	4	◐	◐	◐	◐	Ad hoc academic activity
Autonomous Mining - Remotely Operated Equipment	6	◐	◐	◐	◐	Private sector led
Energy from Ammonia	4	◐	◐	◐	◐	Ad hoc academic activity
Production Planning & Lean Manufacturing	5	◐	◐	◐	◐	Ad hoc academic activity
Autonomous Mining - Self-driving Vehicles	5	◐	◐	◐	●	Ad hoc academic activity
Sodium Ion Battery	4	◐	◐	◐	●	Ad hoc academic activity
Sodium-Sulphur Battery	4	◐	◐	◐	●	Ad hoc academic activity
Intelligent Manufacturing	3	◐	◐	◐	●	Ad hoc academic activity
Smart HVAC	6	◐	◐	◐	●	Private sector led
Wind Turbines	8	◐	◐	◐	◐	Private sector led
Industry Predictive maintenance	6	◐	◐	◐	◐	Private sector led
Oil Reuse	6	◐	◐	◐	◐	Private sector led
Rare-Earth Recovery	5	◐	◐	◐	◐	Ad hoc academic activity
Bladeless Wind Turbines	4	◐	◐	◐	◐	Ad hoc academic activity
Lithium-Sulphur Battery	4	◐	◐	◐	◐	Ad hoc academic activity
Net Zero - Industrial Emissions	4	◐	◐	◐	◐	Ad hoc academic activity
Tidal/Wave Energy	6	◐	◐	◐	◐	Private sector led

Table 8 - Outcome scorecard for Health and Wellness research topic categories, ranked by recommendation level; includes Technology Maturity Index/TRL score. Circle fill denotes a metric from highest quartile evidenced (full) to lowest quartile (single quarter).

Category	TMI as TRL	Commer- -cial Potential	Saudi Research Depth	Level of Partner- ship	Expert Opinion	Recommended mode
Cancer	8	●	●	●	●	Prioritize tech transfer
Neurological disorders	8	●	●	●	●	Prioritize tech transfer
Cardiovascular diseases	9	●	●	●	●	Prioritize tech transfer
Biopharmaceuticals	8	●	●	●	●	Prioritize tech transfer
Gastrointestinal	9	●	●	●	●	Prioritize tech transfer
Diabetes	8	●	●	●	●	Prioritize tech transfer
Chronic Respiratory diseases	8	●	●	●	●	Prioritize tech transfer
Precision Medicine	6	●	●	●	●	Prioritize tech transfer
eHealth	5	●	●	●	●	Prioritize academic funding
Telehealth	5	●	●	●	●	Prioritize academic funding
Tuberculosis	7	●	●	●	●	Prioritize tech transfer
Nanomedicine	6	●	●	●	●	Prioritize tech transfer
Gene/ RNA Therapy	7	●	●	●	●	Prioritize tech transfer
Immunotherapy	8	●	●	●	●	Prioritize tech transfer
Mobile Health	8	●	●	●	●	Prioritize tech transfer
Biosensors/MEMS	7	●	●	●	●	Private sector led
Medical Robots	5	●	●	●	●	Ad hoc academic activity
Implants	9	●	●	●	●	Private sector led
Malaria	7	●	●	●	●	Private sector led
Blood Disorder Gene Therapy	6	●	●	●	●	Private sector led
Stem cell therapy	7	●	●	●	●	Private sector led
AI/ML in Imaging	4	●	●	●	●	Ad hoc academic activity
Cognition & Memory	5	●	●	●	●	Ad hoc academic activity
Electronic Health Records	5	●	●	●	●	Ad hoc academic activity
Dengue	5	●	●	●	●	Ad hoc academic activity
CAR-T Cell Therapy	5	●	●	●	●	Ad hoc academic activity
Nutrition & Obesity	7	●	●	●	●	Private sector led
Antimicrobial Resistance	5	●	●	●	na	Ad hoc academic activity
Vaccine	7	●	●	●	na	Private sector led
Health Data and IT Management	6	●	●	●	●	Private sector led
Telesurgery	7	●	●	●	●	Private sector led
Skin health	7	●	●	●	●	Private sector led
Wearables	5	●	●	●	●	Ad hoc academic activity
Hepatitis	8	●	●	●	●	Private sector led
Influenza	7	●	●	●	●	Private sector led
Congenital Gene Therapy	5	●	●	●	●	Ad hoc academic activity
Lab-on-a-Chip / microfluidics	6	●	●	●	●	Private sector led
Neurodegenerative Gene Therapy	5	●	●	●	●	Ad hoc academic activity
Eyesight	6	●	●	●	●	Private sector led
Gut Health	4	●	●	●	●	Ad hoc academic activity
Heart Health	8	●	●	●	●	Private sector led
Immunity Boosting	6	●	●	●	●	Private sector led
Exoskeleton	5	●	●	●	●	Ad hoc academic activity
Robotic Prosthetics	5	●	●	●	●	Ad hoc academic activity
Healthcare/Surgical Robots	6	●	●	●	●	Private sector led
Phage therapy	5	●	●	●	●	Ad hoc academic activity
Genomics	8	●	●	●	na	Private sector led

Table 9 - Outcome scorecard for Sustainability and Essential Needs research topic categories, ranked by recommendation level; includes Technology Maturity Index/TRL score. Circle fill denotes a metric from highest quartile evidenced (full) to lowest quartile (single quarter).

Category	TMI as TRL	Commercial Potential	KSA Research Depth	Level of Partnership	Expert Opinion	Recommended mode
Wastewater Purification/ Treatment	7	●	●	●	●	Prioritize tech transfer
Electric Vehicles	7	●	●	●	●	Prioritize tech transfer
Air Purification	6	●	●	●	●	Prioritize tech transfer
Waste-to-Energy	6	●	●	●	●	Prioritize tech transfer
Water Desalination	4	●	●	●	●	Prioritize academic funding
Carbon (CO2) Capture	6	●	●	●	●	Prioritize tech transfer
Carbon (CO2) Storage	4	●	●	●	●	Prioritize academic funding
Water - Conservation Management	5	●	●	●	●	Prioritize academic funding
Water - Domestic Purification	6	●	●	●	●	Prioritize tech transfer
Geothermal Energy	4	●	●	●	●	Prioritize academic funding
Bioenergy	6	●	●	●	●	Prioritize tech transfer
Brine mining	4	●	●	●	●	Prioritize academic funding
Waste - Smart Management	5	●	●	●	●	Prioritize academic funding
Precision Agriculture	5	●	●	●	●	Ad hoc academic activity
Hydroponics	5	●	●	●	●	Ad hoc academic activity
Emergency Communications	5	●	●	●	●	Ad hoc academic activity
Sustainable Packaging	6	●	●	●	●	Private sector led
Carbon (CO2) Utilization	4	●	●	●	●	Ad hoc academic activity
Waste Landfill	3	●	●	●	●	Ad hoc academic activity
Resources from Wastewater	5	●	●	●	●	Ad hoc academic activity
Pest Management	6	●	●	●	●	Private sector led
Precision Livestock	5	●	●	●	●	Ad hoc academic activity
Food Traceability & Distribution	5	●	●	●	●	Ad hoc academic activity
Afforestation	4	●	●	●	●	Ad hoc academic activity
Aquaculture	6	●	●	●	●	Private sector led
Eco-Agrochemicals	5	●	●	●	●	Ad hoc academic activity
Waste Management	5	●	●	●	●	Ad hoc academic activity
Carbon (CO2) Transport	4	●	●	●	●	Ad hoc academic activity
Food Alternatives	4	●	●	●	●	Ad hoc academic activity
Intelligent Packaging	6	●	●	●	●	Private sector led
Flood Protection	5	●	●	●	●	Ad hoc academic activity
Seismology/Meteorology Event Detection	4	●	●	●	●	Ad hoc academic activity
Shore Protection	4	●	●	●	●	Ad hoc academic activity
Urban Heat Island	5	●	●	●	●	Ad hoc academic activity
Plant Breeding	6	●	●	●	●	Private sector led
Soil Preservation	5	●	●	●	●	Ad hoc academic activity
Food-Borne Hazard Control	5	●	●	●	●	Ad hoc academic activity
Water - Leakage	5	●	●	●	na	Ad hoc academic activity

# 14 Assessment of economic impact of research

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## 14.1 Overview and model

The link between economic growth and research & innovation is complex. However, with data available at scale, it is feasible to assess via the four National Priorities (and to a degree, the individual selected research topics within them) a top-down analysis of global economic activity and the level of intensity and linkage between commercially directed innovation (via global technology invention levels).

This chapter performs such an assessment, reviewing the wider contribution and relationship between global GDP and patented innovation in general. It then distributes this effect across the individual research topics and the National Priority Areas based on the proportion of contribution evidenced in global invention data.

The intent is to supply information on where research intensity focus, particularly via the route of commercialization inherent to patent protection - enabling transfer of research to commercial vehicles and private enterprise - provide the greatest levels of potential economic return.

Specifically, items reviewed include:

1. The link between GDP and patented innovation, to create a scale of potential economic impact attributable to inventions themselves. This step is critical, as it allows direct contextualization of the relative importance and estimated economic value of the different technical approaches described in the technical category structure of this analysis.
2. Distribution of the global GDP amongst the categories on a proportion of activity basis, e.g. if one field represents 5% of all global inventions during the analysis period, this is then scaled as potential additional growth on this proportion.
3. Assessment of the headroom of economic output predicted by the models used in this chapter, i.e. the likely GDP addition implications for Saudi Arabia, assuming current GDP share of global economic activity remains static.
4. Realistic increases in performance available via further funding and concentration of effort in the research & innovation ecosystem in Saudi Arabia alongside the forecast increases in demand and supply of patented innovation.

There is a high degree of correlation between the overall size of economies and the level of important inventions created within them. Analyzing economies based on purely overall levels of patent activity does not produce as significant a relationship, a key finding emulated in previous studies concerning innovation contribution to economic output<sup>7</sup>.

This is a critical dynamic of research and innovation in that contribution to overall economic activity is more strongly associated with key new inventions that impact on and influence the activity of others and have the geographic footprint and a level of technological addition that provides the differentiation space and market to produce a strong level of advantage for their owner. Within the analysis, the level of national GDP contribution is highly determined by the level of national contribution to the strongest 0.5% of global inventions<sup>8</sup>.

This means that as RDIA is seeking to add significant economic output to the national economy via research & innovation, a strategy that is focused on quality rather than simply quantity is more likely to produce significant results. However, also evident in

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<sup>7</sup> How key technology patents stimulate economic growth (globaleurope.eu)

<sup>8</sup> Note, national contribution and the definition of countries in this analysis is based on either the location of a company or institution, or the residence of inventors. This means that an individual invention record can be attributed to multiple countries, if inventors are multinational.

the analysis is that scale of invention overall is an important factor for the generation of important, high strength and critical inventions.

It is here that key aspirations of the Kingdom become an important driver of the analysis, Specifically, increasing annual spending in RDI of 2.5% of the country's GDP by 2040 and increasing the number of highly qualified jobs in the the RDI sector.

Previous studies<sup>9,10</sup> into the synergy between economic value and technology and innovation emanating from patented inventions attributes approximately 16-20% of GDP and 16-18% of employment in the United States and European Union in 2019. Therefore, this figure is used to discount the potential economic importance of patent activity globally and within the National Priority Areas down to 18%.

A top-down analysis of global research, based on the relationship between high-strength and important inventions, suggests an approximate \$US43m economic output yield per high-strength invention, including the reduction in the attribution of GDP output based on the previous studies noted above.

In reverse, this means that every \$US1 billion of GDP - based on high-tech/patent-attributable economic output - requires approximately 23 of these highest-strength inventions.

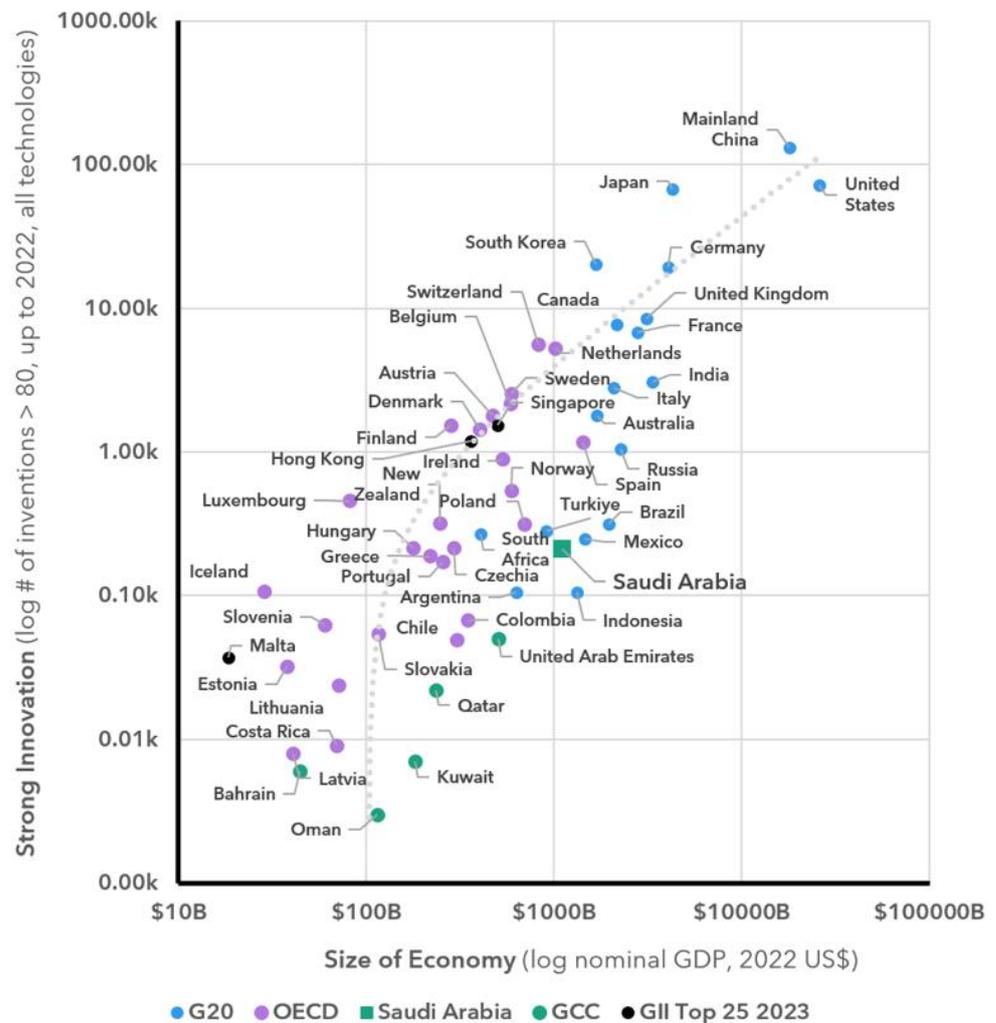


Figure 40 - Correlation of nominal GDP and the creation of strong patented inventions; assessed using the Derwent Strength Index for inventions in the analysis period scoring 80 or greater; data normalised for latest available GDP figures (2023) and across all G20 and OECD countries. Both axes are logarithmic due to high variation in absolute value. Sources: Clarivate Geo-Innovation Trends and World Bank

<sup>9</sup> USPTO IP and the US Economy: Third Edition

<sup>10</sup> WEB\_IPR\_intensive\_Report\_2019.pdf (europa.eu)

Saudi Arabia's economy produces an outlier-high GDP and economic value compared to the broader global pattern of research and innovation performance. Saudi Arabia's economy is larger than would be expected from its current knowledge economy outputs. This is due to the high level of economic value derived from primary industries in Saudi Arabia, i.e., producing similar levels of wealth as the Netherlands but significantly fewer knowledge outputs (i.e., 20 times fewer patents since 2014).

That finding underscores the importance of Vision 2030's research and innovation strategy, as the opportunity and potential for Saudi Arabia to grow are considerable. Leaning on the work and expertise of the researcher community and academic research capability within Saudi Arabia, the contribution of the academic sector to future economic is key to this opportunity.

Extrapolating from these analyses, based on the likely contribution of patents to deep-tech industry using historical models, suggests Saudi Arabia, via RDIA funding and initiatives, needs to add approximately 1,500 inventions of the very highest quality (within the global Top 0.5%) over the next 10-15 years to realize the ambition of increasing annual spending in RDI of 2.5% of the country's GDP by 2040.

Using wider global baselines provides an indicator of the average yield of wider invention levels required to generate high impact, high relevance and key technology-contributing inventions—approximately 0.5%.

Saudi Arabia today yields around 1.0% of inventions falling into the top 0.5% - a 2x greater productivity than the global baseline. However, taken together, it suggests that Saudi Arabia needs to produce, to achieve the goal targets of economic output, of the order of 100,000 to 300,000 patented inventions (current productivity versus broader global baseline activity) over the next 16 years. **This equates to between 6,200 and more than 20,000 new inventions filed per annum.**

Comparing this required activity level to current levels, today, the Saudi academic sector produces approximately 700 new inventions each year. Therefore, an increase of between 9x and 30x is potentially required to produce the level of overall economic contribution envisioned.

To scale this level of effort, it is helpful to compare it to an existing corporation that produces a similar level of revenue to the aspired GDP addition under the Vision 2030 strategy and the scale of inventiveness those corporations invest to support their business. For example, Siemens, a European industrial conglomerate, has produced approximately 173,000 inventions over the past two decades and today reports \$83 billion in annual revenue. Honeywell, a major US aerospace and building automation last reported \$37 billion in revenues and has a corresponding stock of approximately 50,000 inventions.

It is envisioned that the fruits of research and innovation in Saudi Arabia will occur across a diverse range of topics, technologies and industries, but in aggregate will need to produce corresponding levels of applied research output.

This analysis notes several caveats. It is based on a top-down view and draws upon multiple sources of primary information - the current size of the G20 and OECD economies, the level of invention, the strength assessment of that invention activity, and the high correlation between economic output and strong innovation footprint.

The high level of variation in GDP levels between, for example, the United States and China, versus, for example, the Baltic states or Latin America, creates a wide confidence interval in the extrapolated figures. This variation is also evident in the invention levels assessed. While the link between research input, innovation output and downstream economic activity is evident, it will vary significantly within practical deployment.

Also critical is that some technical fields and technical innovations are more important than others, and the average GDP contribution of patented research varies on this basis. In essence, they are more iterative or more fundamental in nature and will differ in terms of the level of dominance by existing market share of companies in the space and the difficulty of adding new ideas. This is where the information pertaining to TRL level, that incorporates this type of information directly within it, is useful barometer of opportunity.

Target ranges of knowledge output will be and should be broad as they are founded on global estimates, and should be used as general guidance of the step change in output required to add the economic return that is being aimed for.

## 14.2 Potential market sizes and growth

Reviewing the footprint of Saudi Arabian applied and potentially commercialized technology alongside estimates of current and future commercial potential provides an important framework for understanding fields of research and innovation that could provide a significant contribution to the Saudi economy in the next decades.

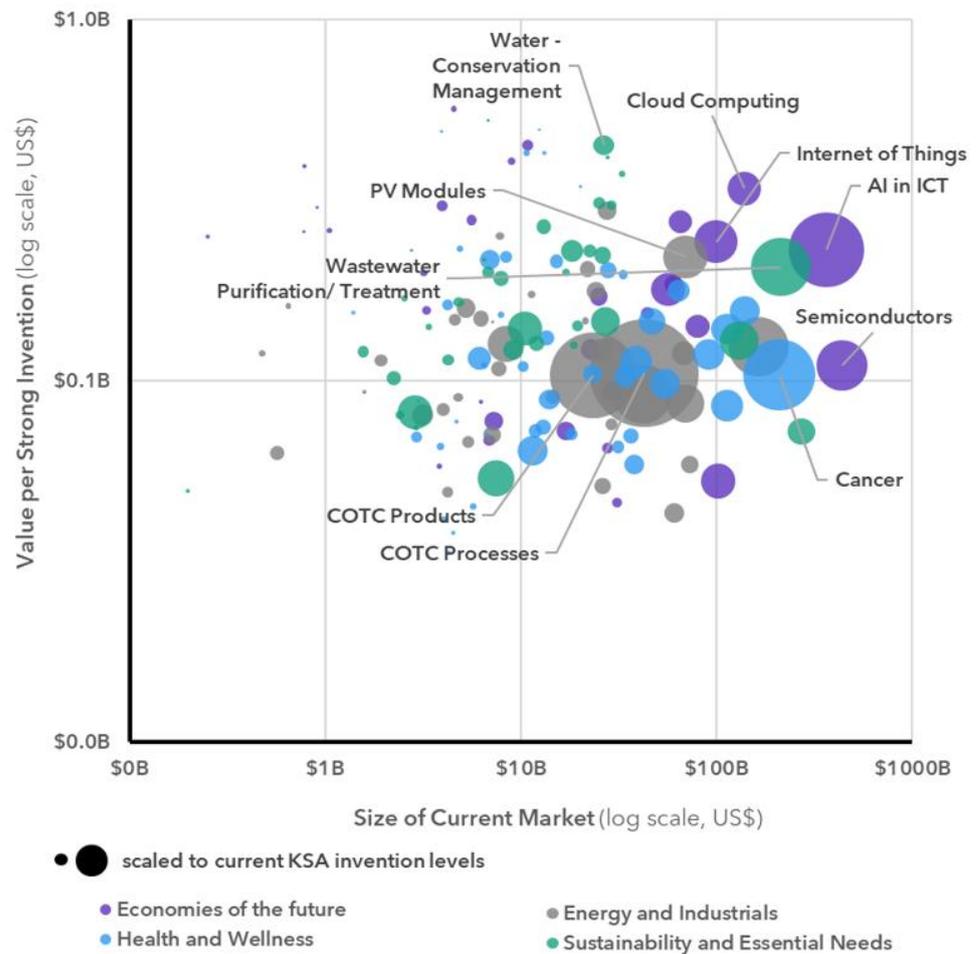


Figure 41 - Scatterplot of the estimated value of a strong invention vs the overall estimated size of commercial market for each research topic within the four National Priorities; both axes are logarithmic; Saudi Arabia's invention footprint is reflected via size of bubble, and annotated for specific research topics of interest.

Metrics included in this analysis include:

- An estimate of the economic value of a strong invention (Figure 41) : based upon the top down review of the link between contribution of key inventions in technologies and industries and wider economy sizes, discounted for the level of economic contribution overall for industries dependent on patented research. This metric varies by sector and research topic based upon the variance of activity in the global invention/global economy - a small topic contributes less economic value than a large one. It is further normalised by the yield of strong invention produced in the research topic. This produces a view of where the addition of a technology or industry critical advancement produces significant economic return, or conversely more diluted and contributory in nature.
- An estimated overall size of the current economic value or market of the research topic - again based on the link between key invention value globally, the share of the global invention/economy mix represented today from activity occurring in applied research/inventiveness. For example, this approach values the technology-value within the semiconductor sector at \$440 billion per year, versus wider market estimates including all factors beyond the patented technology itself, e.g. capital assets etc. at \$611 billion<sup>11</sup>. There are similar matches (with differing estimate variation, likely due to different levels of technology-value contribution) in other sectors in the analysis, such as AI in ICT (\$365 billion in this analysis, versus wider market estimates of \$538 billion), Cloud Computing (\$139 billion vs \$587 billion) or Wastewater Treatment (\$213 billion vs \$327 billion). Therefore, this measure is a useful estimate of the inherent economic value of the invention/technology contribution to markets and economic return.
- Based on these two factors, and based on the rate of expansion or otherwise in research output measured using global invention data, the historical yield of critical invention-creation and the predicted future size of economic value produced as a result, a market growth figure can be estimated (here an estimated 5-Year compound annual growth rate).

Combining these measures and models together, individual research topics have greater GDP addition prospects than others (Figure 42). Examples include AI in ICT settings, which is predicted in this model to grow 11% over the next 5 years and return a further \$250 billion in technology-linked economic value, with each critical invention produced valued at \$250 million. As a drag factor, however, the yield of critical invention means that every thousand patented inventions in the space only produces 4 such strong assets.

By incorporating these measures into the earlier modeling of commercialization maturity, a review of these growth dynamics can be arrayed onto the TRL structure.

In this view, the selection and focus of the research program funding, with a specific target of applied research commercialization and economic return (Figure 43) , produces the following key attributes:

1. The level of relative predicted growth return increases the earlier in the technology maturity spectrum the research topic lies today. From ~9.5% in TRLs 1-3, to 8% in TRLs 4-6 to 7% in TRLs 7-9.
2. In absolute terms, however, a reverse finding is evident. The economic value increase in TRLs 7-9 equates to an addition of \$1.2 trillion globally, versus \$985 billion in TRLs 4-6 and just \$56 billion in TRLs 1-3.

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<sup>11</sup> Semiconductor Market Size, Share, Growth & Forecast [2032] (fortunebusinessinsights.com)

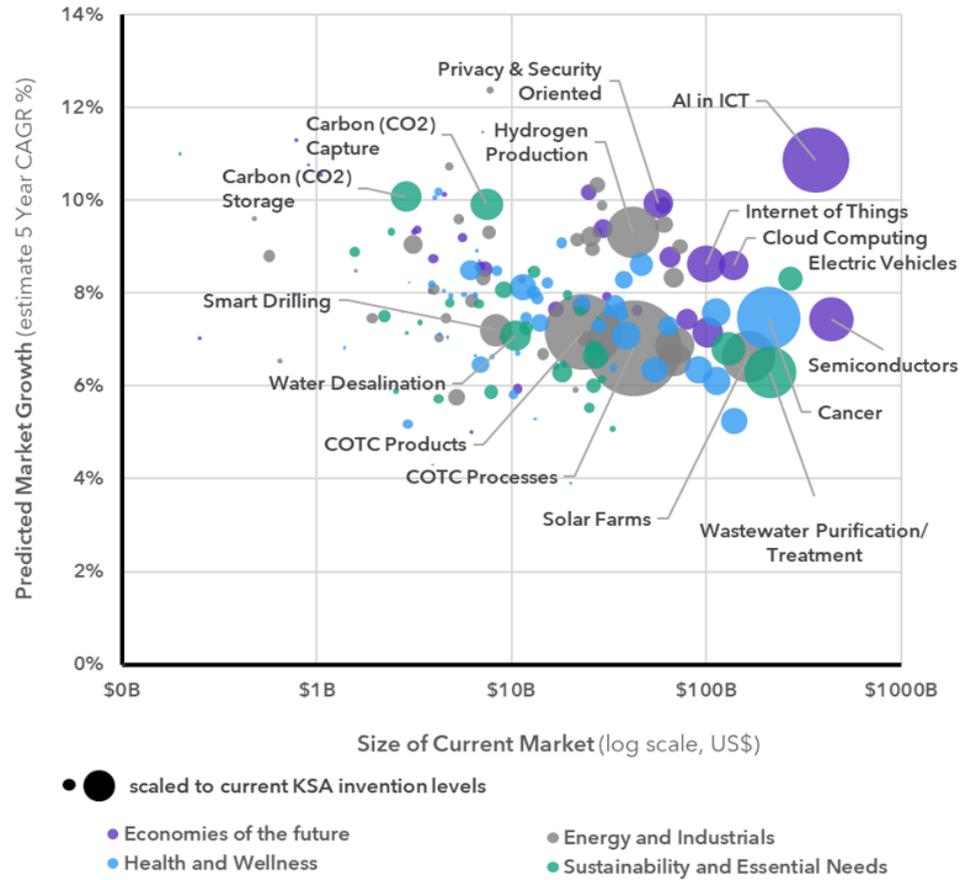


Figure 42 - Scatterplot of the estimated growth in market size predicted over a 5-year period, versus the current estimated size of the commercial market for each research topic within the four National Priorities; x-axis is logarithmic; Saudi Arabia's invention footprint is reflected via the size of bubble and annotated for specific research topics of interest.

This means a research and innovation policy targeting the significant addition of economic activity for Saudi Arabia, reflecting the goals of the Vision 2030, is likely to be most successful by targeting a diverse range of research topics from TRL 4 and up. While the relative growth of economic value of research in the very lowest TRLs is desirable, it is unlikely to produce significant returns within timeframes that align with the national policy.



Figure 43 - Assessment of the link between market growth (globally) and technical maturity; chart plots the current and predicted market sizes for all research topics within each of the TRL levels as a combined view; annotated for the overall growth rate exhibited (as 5-year compound annual growth rate)

### 14.3 Outlining an initial research commercialization business model

The outline business case (Table 10) specifically targets a selection of research topics recommended in the previous chapters and scales the level of target invention levels and funding based on the level of recommendation. Those at recommendation level 5 are targeted for the fewest inventions, and those at level 9 for the highest number of inventions. This process is performed so that the creation of entirely new research capabilities is not required, and existing strengths and knowledge in the Saudi Arabian research ecosystem are leveraged.

Overall, the business case targets the creation of almost 50,000 patented inventions across 36 research topics within the National Priorities, yielding ~400 globally leading strong inventions within their fields that can create value for private enterprises within Saudi Arabia when taken to market.

The business model as a whole, using the analysis performed through this program of work, suggests that for every Saudi Riyal invested, successful commercialization of the outputs of that funding produces 2.25 Riyals of potential GDP addition to the Saudi economy (see Figure 44 for estimated potential return by TRL).

At the current (though likely changing) average GDP per capita of approximately \$26,000, this additional activity would potentially support 2.3 million jobs within Saudi Arabia. This is broader than the direct R&D ambition and aspiration of the Vision 2030

programs but includes the wider supply chain and footprint of support and activity that occurs within a more knowledge-intensive economy.

Table 10 – An outline business model for applied research commercialization activity, assessed by TRL level, envisioning significant addition of patent filing from researchers in Saudi Arabia.

TRL	5-year invention generation target	Target Strong Inventions	Research & Innovation Funding	IP Protection Funding	Successful Commercialization GDP Addition	Total Investment (R&I + IP)	Est. Rate of Return by TRL
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	5,000	30	\$0.47B	\$50.0m	\$1.29B	\$0.52B	148%
5	3,333	21	\$0.31B	\$33.3m	\$0.91B	\$0.35B	162%
6	10,833	97	\$1.02B	\$108.3m	\$4.23B	\$1.13B	276%
7	10,833	93	\$1.02B	\$108.3m	\$4.08B	\$1.13B	263%
8	14,167	105	\$1.33B	\$141.7m	\$4.57B	\$1.47B	211%
9	5,000	35	\$0.47B	\$50.0m	\$1.53B	\$0.52B	195%
	49,167	380	\$4.62B	\$491.7m	\$16.61B	\$5.11B	225%

*note: excluded from investment rate of return calculation is funding for fundamental/basic research that produces only published research in peer-reviewed journals*

As before, the level of GDP addition varies by the current state of global innovation in each of the research topics, as well as by the maturity of those topics. The highest levels of return occur within research topics sitting in TRLs 6-8. Previously, the analysis showed that Saudi patent activity occurred predominantly within TRL 8 and focused on major topics of interest to the current strengths of the Saudi economy, such as the oil and gas sector.

Within the revised approach, significant technology commercialization success is targeted in research topics such as Electric Vehicle technology, Air Purification, 3D Printing, and Wastewater Treatment. Therefore, this approach provides an outline approach of areas of technology and later industrial diversification of the Saudi economy, using its extensive basic research capability created over the past two decades.

A full view of the outcomes of this metric-led policy approach is detailed below (Table 11), specifying the invention-level output targets and research funding levels that can be tracked as milestone delivery.

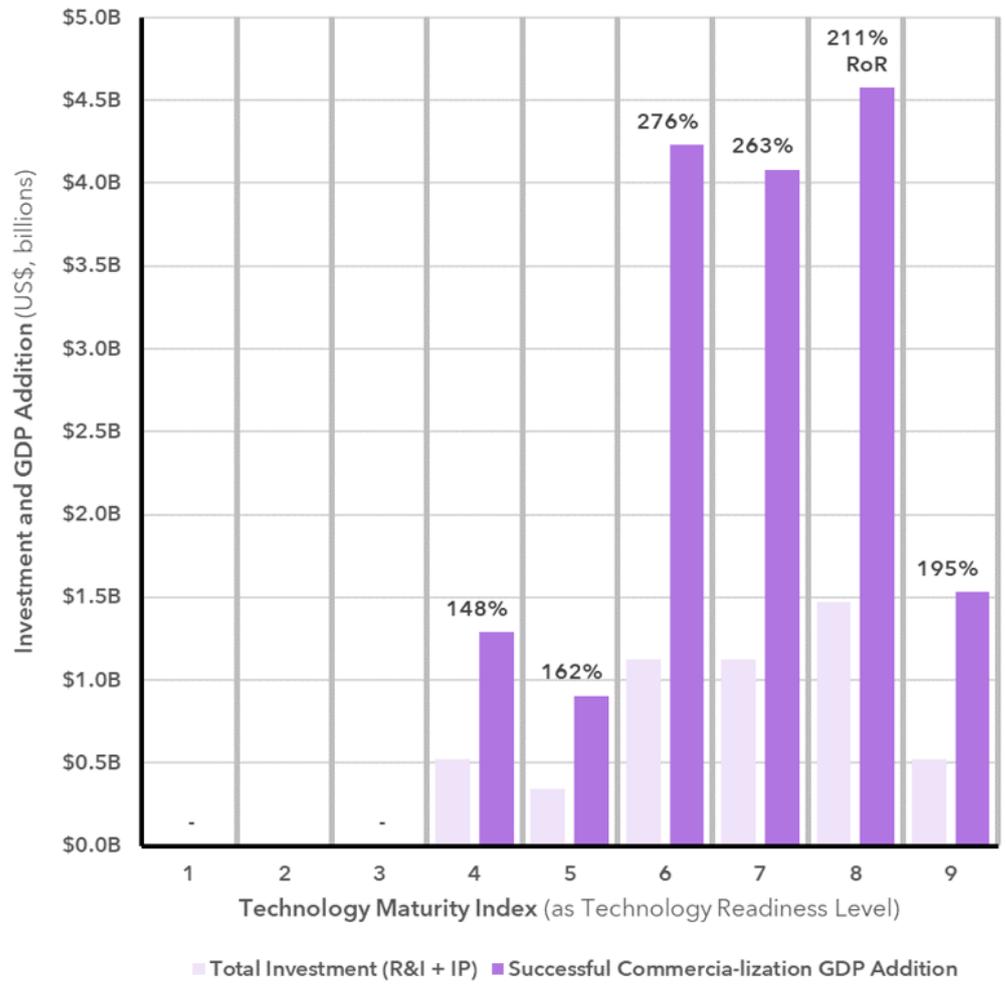


Figure 44 - Assessment of the level of Saudi economy GDP addition from targeted funding of specific research topics for technology commercialization; arrayed by TRL level; includes the business case target investment, and rates of return (RoR) by TRL are annotated.

Table 11 - Outcomes of the metric-led commercialization policy target assessments, based on economic analysis of investment and expected return, research topics recommendation the Saudi research ecosystem; includes TRL, the value of successful commercialization, target number of inventions over the next 5 years, the research and IP protection investment intended and the estimated rate of economic return.

National Priority Area	Category	TMI/TRL	Potential Successful Commercialization GDP Addition	Recommendation Level (Filter > level 5)	5 Year invention generation target	Investment (R&I + IP)	Estimated Rate of Return
Economies of the future	3D Printing	7	\$ 1.21 Billion	6	1667	\$ 0.17 Billion	600%
	Privacy & Security Oriented	4	\$ 0.18 Billion	5	833	\$ 0.09 Billion	106%
	AI in ICT	4	\$ 0.28 Billion	7	1667	\$ 0.17 Billion	60%
	Smart Agriculture	5	\$ 0.23 Billion	5	833	\$ 0.09 Billion	161%
	Cloud Computing	8	\$ 0.09 Billion	5	833	\$ 0.09 Billion	8%
	Internet of Things	6	\$ 0.13 Billion	5	833	\$ 0.09 Billion	52%
	Semiconductors	9	\$ 0.58 Billion	6	1667	\$ 0.17 Billion	235%
Energy and Industrials	Smart Drilling	7	\$ 0.25 Billion	5	833	\$ 0.09 Billion	192%
	COTC Processes	8	\$ 0.61 Billion	6	1667	\$ 0.17 Billion	251%
	COTC Products	8	\$ 0.31 Billion	5	833	\$ 0.09 Billion	258%
	Battery Management	6	\$ 0.55 Billion	5	833	\$ 0.09 Billion	530%
	Hydrogen Production	6	\$ 0.70 Billion	7	1667	\$ 0.17 Billion	302%
	Hydrogen Storage and Transportation	5	\$ 0.26 Billion	5	833	\$ 0.09 Billion	204%
	PV Modules	8	\$ 0.29 Billion	6	1667	\$ 0.17 Billion	68%
	Solar Farms	8	\$ 0.51 Billion	9	1667	\$ 0.17 Billion	197%
	Rare-Earth Use	7	\$ 0.37 Billion	5	833	\$ 0.09 Billion	326%
	Waste Management	4	\$ 0.22 Billion	5	833	\$ 0.09 Billion	148%
Health and Wellness	eHealth	5	\$ 0.20 Billion	5	833	\$ 0.09 Billion	128%
	Telehealth	5	\$ 0.22 Billion	5	833	\$ 0.09 Billion	153%
	Tuberculosis	7	\$ 0.15 Billion	5	833	\$ 0.09 Billion	70%
	Biopharmaceuticals	8	\$ 0.75 Billion	7	1667	\$ 0.17 Billion	332%
	Nanomedicine	6	\$ 0.50 Billion	5	833	\$ 0.09 Billion	478%
	Cancer	8	\$ 0.62 Billion	9	1667	\$ 0.17 Billion	257%
	Cardiovascular diseases	9	\$ 0.54 Billion	7	1667	\$ 0.17 Billion	212%
	Chronic Respiratory diseases	8	\$ 0.28 Billion	5	833	\$ 0.09 Billion	228%
	Diabetes	8	\$ 0.65 Billion	6	1667	\$ 0.17 Billion	275%
	Gastrointestinal	9	\$ 0.41 Billion	7	1667	\$ 0.17 Billion	137%
Sustainability and Essential Needs	Neurological disorders	8	\$ 0.46 Billion	7	1667	\$ 0.17 Billion	166%
	Precision Medicine	6	\$ 0.30 Billion	5	833	\$ 0.09 Billion	252%
	Air Purification	6	\$ 1.24 Billion	6	4167	\$ 0.43 Billion	185%
	Carbon (CO2) Capture	6	\$ 0.60 Billion	5	833	\$ 0.09 Billion	589%
	Carbon (CO2) Storage	4	\$ 0.39 Billion	5	833	\$ 0.09 Billion	350%
	Electric Vehicles	7	\$ 1.33 Billion	7	2500	\$ 0.26 Billion	411%
	Waste-to-Energy	6	\$ 0.22 Billion	5	833	\$ 0.09 Billion	153%
Water Desalination	4	\$ 0.23 Billion	5	833	\$ 0.09 Billion	165%	
Wastewater Purification/ Treatment	7	\$ 0.77 Billion	9	4167	\$ 0.43 Billion	79%	

## **14.4 Barriers to commercialization**

Achieving the levels of GDP growth set out in this chapter is dependent upon overcoming a number of factors that may act as potential barriers to successful technology commercialization. These potential challenges are listed here, alongside possible policies and mitigation approaches.

### **14.4.1 Talent creation and development**

Current estimates of Saudi Arabian inventor base lie below those of median OECD levels; this suggests that the number of researchers that are to be future inventors on the growth of invention levels recommended will need to increase, likely both in terms of transition from authors of papers to inventors who file patents, and in terms of transition from academia to private enterprise.

This will be a target of RDIA's ongoing incentives and policy targets to create the desirability of such a transition, as well as targeted earlier educational expansion to increase the pipeline of STEM researchers available within Saudi Arabia. This will include increasing the gender diversity of the researcher ecosystem. Other areas of mitigation include the integration of critical thinking, creativity and problem-solving skills into the educational curriculum at earlier ages, as well as at university level.

Programs such as the Saudi Basic Science (SBS) and the Saudi Applied Research and Technology (SART) Initiatives play a key role in the support of researcher in their scientific careers and fostering their contribution to the advancement of knowledge. The mandate of RDIA to activate technology transfer within the Kingdom, and effort that is well underway as of this writing, will greatly assist this new creator class.

### **14.4.2 Talent retention**

The creation of a globally aligned volume of technologists and inventors is likely to create opportunities abroad for top research talent. Retaining this research talent within the Saudi economy is, therefore, a key facet of future success and will involve establishing and increasing the desirability of Saudi Arabia as a place to work and live. This would include globally competitive salaries, a clear career development path, and the establishment of research-to-market centres beyond the academic setting alongside the expansion of RDIA research funding available.

### **14.4.3 Legal infrastructure**

Fostering a strong technology transfer ecosystem, where private enterprise is incentivized and can thrive alongside a strong academic research sector requires a legal paradigm within Saudi Arabia that is conducive to supporting business and commercial activity.

Factors that are important to fostering business creation and wider commercial activity include the predictability of legal systems, their speed and transparency, and potential specializations of law and court settings that cater to technology, IP, and contract law.

Other factors include the recognition of foreign judgments and arbitrations where agreements transition into Saudi law. In particular, the ability of private enterprises to trust in contract or intellectual property enforcement procedures creates greater confidence in investors and enterprises for the commercialization of Saudi-created innovation to take place.

### **14.4.4 Regulatory infrastructure**

Maintaining a regulatory environment sensitive to innovation commercialization needs while ensuring compliance with safety, ethics, and wider legal requirements is relatively complex. Factors involved include employment law and employment security, immigration procedures and ease, regulations around new technologies and prototyping.

Mitigations here include the involvement of the private sector as stakeholders in the setting of regulatory processes and procedures, and review of Saudi Arabian regulation with international standards to assist with integration into markets in those international locales.

#### **14.4.5 Entrepreneurship culture**

A shift to a more knowledge-intensive economic foundation will require the creation of new businesses that attract and provide commercial vehicles for technologies developed in the rapidly maturing Saudi academic sector. Doing so requires a culture of entrepreneurship and innovative business models/experimentation in business foundation. In highly advanced start-up clusters, cultural aspects are important, where experimentation in business foundation and tolerance for business failure is high: fail fast and try again.

Commercialization of technologies created in an academic setting, for example, requires academics to potentially transition to commercial professionals, which is often a barrier to success. In addition, many young business fail early not because of the inherent value of their ideas and IP, but because of cash flow challenges. Policies and procedures that are adopted elsewhere include:

- creation of incubator hubs to cater to early needs for premises, power and communications, ensuring early businesses do not fail due to lack of facilities.
- Implementation of business and innovation accelerators: providing access to mentorship, guidance and education programs that facilitate the transition of academic researchers to a business-centric environment.
- Establishment of platform programs for research institutions and the private sector to identify market demands matched to existing research outcomes, providing networking and matchmaking services.

An example of these types of mitigation includes the RDIA announced Design in Saudi Arabia (DISA) incubator program. In addition, RDIA forms a key part of linking academia with the private sector, to support collaboration and the transition of talent and knowledge.

#### **14.4.6 Intellectual property and patents**

For the very youngest companies, much if not most of their value and future potential is tied to research outcomes. This value is a registered intellectual property even if not patented ultimately. Therefore, a potential barrier is the lack of ownership or control over the primary value of these start-ups - e.g., patents and trademarks.

Putting in place a robust process that ensures that transfer wholesale or partial transfer of IP assets is critical for these young companies to source additional funding from potential future investors. In addition, these firms, as they grow, will need to continue applied development and innovation on the original technologies from which they were founded. Therefore, education about the importance of IP and access to frameworks that aid with the protection of new ideas is essential.

#### **14.4.7 Funding and investment**

Beyond the initial funding of new research and innovation via RDIA's portfolio of research grants and project funding, corporate ventures leveraging the technologies that are produced will need access to further capital to fund their growth. A continuous and sustainable source of funding will require attracting sources of private investment and venture capital. Fluctuations or uncertainty in access to additional capital investment can disrupt flourishing businesses or deter their creation or plans for further growth. Having a diverse range of sources of funding - government alongside sources of private finance - provides for a range of possible options of businesses to plan their growth.

RDIA's focus on academic-corporate partnership is vital, as ensuring collaboration with existing businesses allows financial burden and the risk inherent in new technology to be shared and creates stable funding sources.

However, traditional innovation funding sources, particularly in commercialization phases, have relied heavily on venture capital (VC) – private finance vehicles that source and assess investment opportunities but do so with business models that cater to the risk profile inherent to start-up commercialization. Attracting and maintaining a strong VC presence and ecosystem operating within Saudi Arabia is therefore a desirable mitigation to the ongoing funding challenge, and providing an additional investment stream that can be self-sustaining.

Potential policy advances in this area include tax and regulatory benefits provided to VCs operating within Saudi Arabia to incentivise their activities, or the creation of government-backed VCs to invest in high potential start-ups – particularly if sourced from earlier rounds of academic research funding within Saudi Arabia.

Access to capital also concerns education and facilities for start-ups to create and maintain their investment-seeking activities, such as demonstrating performance, developing product development roadmaps, conducting market research and obtaining other resources that allow them to seek funding independently.

#### **14.4.8 Time and global market change**

Inherent to innovation risk, and RDIA's planning for innovation commercialization, is the dynamic nature of markets and consumers for products and services. The business and consumer paradigm of 2024 is significantly different to that of 2004: the needs, solutions, products and desires of consumers and business shifts over time. A potential barrier to commercialization that is planned many years in advance is that fruition is dependent on those technologies and research outcomes retaining relevance for the market demand 5, 10 or 20 years in the future.

Mitigation of market changes focuses on two key facets – diversity and monitoring. Having technology development and research pathways that focus on multiple market access points, and have a more diverse mix of current maturation and readiness provides for routes to success (and failure modes) that reinforce each other. Research capability created within technologies and topics that move to saturation or obsolescence is not lost but can be reprovisioned or amended, while other technical approaches succeed in finding markets for commercialization.

In addition, RDIA will re-assess the commercial potential and tracking for changes in the global innovation ecosystem so correction mechanisms that may be needed are incorporated. Targets and funding policies that are set can be amended and tailored for both the changing global market conditions, and the changing research and innovation ecosystem within Saudi Arabia.

As the time frames for basic, to applied to commercial realisation innovation lifecycles are typically measured in decades, it is highly likely that course correction will be required and mechanisms should be planned for in advance.

#### **14.4.9 Access to markets**

Finally, the transition and diversification of the Saudi Arabian economy is dependent on new or existing corporate entities in the country successfully competing against established global players. This creates a challenge for the research and innovation ecosystem in Saudi Arabia to create avenues of innovation commercialization that compete on capability, price, quality etc. as ring-fenced competitive advantages. Intellectual property plays a key role here, particularly as registered in international locales, as critical inventions that create these advantages can be enforced to limit the ability of others to deliver.

Also important in market access is the desirability and attractiveness of Saudi-created technology and innovation as a source of capability and value for businesses and

consumers in global locations. The circumstances and heritage of Saudi's historical success, expertise and capability provide a clear pathway to new value for customer in international settings. Here, RDIA's focus on the National Priorities on enhancing and strengthening existing capability is critical as it diversifies not to anywhere, but specifically tied to elements such as Saudi Arabia's energy and industrial strength, expertise in arid environments and the benefits of Saudi's physical geography in provoking innovative solutions and local expertise. For example, the transition to renewables from existing petrochemical industries, the capability of Saudi Arabia in water technologies, the needs for sustainable/smart agriculture and the advance nature of Saudi's healthcare system create important solutions with global implications and therefore demand.

# 15 Definitions, metrics and data sources

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## 15.1 General definitions

### Academic institution

An establishment dedicated to education and research, generally conferring academic degrees across various levels of learning. While academia can more widely be used as a term as primary through tertiary education, we limit and define for the purposes of this study the tertiary sector only. However, note, we further expand the definition of academia in this study to government research institutions more generally.

### Academic-Corporate Partnership

Refers to a collaborative arrangement between educational institutions and business entities, aiming to leverage their respective strengths for mutual benefit, often in the realms of research, technology development, and knowledge exchange. The relationship typically involves shared resources, strategic alignment, and a commitment to achieving common objectives that advance both academic and corporate interests. Defined and identified in this study as a scientific publication or a patent family that contains bibliographic information as authors or inventors from organizations that are both an academic institution and a corporate entity.

### Applied Research

Refers to the process of systematic investigation that aims to solve practical problems by applying scientific knowledge. It typically involves collaboration with industry to develop tangible solutions, such as new products, technologies, or processes, that directly address specific challenges in various fields.

### Basic Research

Often also called pure or fundamental research, this refers to the process of systematic investigation aimed at gaining a deeper understanding and knowledge of the underlying principles of phenomena and observable facts, without immediate practical application in mind.

### Commercialization

Commercialization refers to the process of managing, typically via a business or corporate entity, activities in return for

economic or monetary gain. It involves introducing a new product or service to the market and is often associated with the production, distribution, marketing, and sales necessary to achieve commercial success. Frequently used in the context of scaling up business operations to reach a broader market. In this study, it is specific to understanding the level of commercialization activity and directionality of research areas.

### Corporation

A corporate entity is a legally recognized organization designed to conduct business. Typically, a corporation is a body formed and authorized in law to act as legal person, as distinct from the natural persons owning or operating within the entity. Corporate entities can enter into contracts, own assets, and are subject to taxation, while providing limited liability protection to their owners.

### G20

The Group of Twenty is an international forum that brings together the world's major economies. Its members include 19 countries and the European Union, collectively representing most of the global economy. The G20 aims to address issues of global economic importance, ranging from international financial stability to climate change mitigation and sustainable development. Established in 1999, the G20 has evolved to be a central platform for international economic cooperation. The members of the G20 collectively represent most of the world's largest economies, including Saudi Arabia, and accounting for around 80% of gross world product, 75% of global trade, and two-thirds of the world population. The G20 is therefore used a basket of comparable nations for the evaluation of research and innovation benchmarked performance.

### Innovation

Refers the process of progressing new ideas or inventions into products, services or other economic activity that is valued and in demand by businesses or consumers. As a general principle, innovation can encompass the direction of creativity, technical knowledge and information and targets the conversion of into new and useful products and

services. In this study, we focus the definition to technical innovation and the process of developing and applying new technologies or improving existing ones to create advancements in various fields. It involves the use of technical knowledge and expertise to address challenges, enhance efficiency, and create value through novel solutions.

### **Invention**

A novel or unique method, device, or process developed from research and experimentation, typically patented and designed to solve a specific problem or improve existing solutions. Within this study, due to the database structure of the Derwent World Patents Index, we use "invention" as synonymous with "patent family" (see definition) - an individual idea, meeting the criteria of an invention, as patented at various patent offices around the world. This definition includes patent applications that have not yet granted. This definition removes the need to deduplicate multiple patent documents surrounding the single invention/idea, and in turn transforms the collection of multiple patent documents into meta data of invention strength.

### **Nominal Gross Domestic Product (GDP)**

Nominal Gross Domestic Product (GDP) is a macroeconomic metric that measures the total market value of all finished goods and services produced within a country's borders in a specific time period, using current prices without adjusting for inflation. Presented here in US dollars.

## **15.2 Patent related definitions**

### **Case law**

Typically refers to the body of law that is established through judicial decisions in court cases, rather than through legislative statutes or executive action. In this study, the term is specifically targeted at the existence of legal and patent office administrative cases related to patents within the study, that act as a proxy for commercialization activity if the technical field.

### **Opposition**

Patent opposition is a legal process in which a third party challenges the validity of a patent within a specified time after its grant. This procedure can occur before a patent administrative body, such as the European Patent Office in the EU or the Patent Trial and Appeal Board in the U.S. The opposition aims to prevent the patent from being enforced due to reasons such as lack of novelty or non-obviousness.

### **Patent**

A patent is a legal instrument that grants an inventor exclusive rights to use, sell, or manufacture their invention for a limited period, typically 20 years, in exchange for public disclosure of the invention.

### **Patent Grant, Patent Issuance**

The conferral of a formal property right by a patent office to an inventor or their assignee for a limited period, typically 20 years. This grant of a patent application provides the patent holder with the exclusive right to exclude others from making, using, selling, or importing the patented invention without permission. The process involves a thorough examination of the patent application for patentability criteria and, upon successful examination, results in the legal protection of the invention within the jurisdiction of the patent office.

### **Patent Infringement**

Patent infringement occurs when an unauthorized party engages in the making, using, offering for sale, selling, or importing of a patented product or process without the patent holder's consent. This act is considered unlawful as it violates the exclusive rights granted to the patent holder by the patent office within a particular jurisdiction. The scope of what constitutes infringement is detailed in the claims of the granted patent, which inform the public of what is not allowed without the patent holder's permission. Patents are territorial, and thus, infringement can only occur within the

countries where the patent is legally recognized and enforced.

### **Patent Jurisdiction, Patent-Issuing Authority**

Refers to the legal authority granted to a country or region over the creation, use, and enforcement of patents within its territory. This includes the power to grant patents, determine their validity, and adjudicate disputes related to patent infringement. The jurisdiction is defined by the territorial scope within which the patent rights are applicable and enforceable, and it is typically the responsibility of national or regional patent offices to oversee these legal rights. Notably, patents are local rights that are only valid and have exclusivity within the jurisdiction of the patent office. There are multiple "regional" patent jurisdictions, for example, the European Patent Convention or the Gulf Cooperation Council Patent Office.

### **Patent Litigation**

Refers to the legal process initiated by a patent holder against another party who is accused of infringing upon the patent's rights. This process involves a civil lawsuit, where the plaintiff seeks to enforce their patent rights and often includes claims for monetary damages and an injunction to stop the infringement. The litigation is grounded in the patent itself, a legal document granted by the jurisdiction's patent issuing authority, which provides the patent holder with the exclusive right to use, sell, or license the invention for a set period, typically 20 years from the filing date. Note that specific infringement and enforcement procedure will differ in various legal jurisdictions.

### **Patentability**

In order to be valid, a patent application needs to fully disclose an invention so that it can be understood by the average person with training in the technical field, and it must be novel (never seen in the public domain before), useful (typically, it must have a real world use, and must actually work) and not be an obvious extension of previous technology (typically, simply

combining multiple previous ideas together).

### **Technical maturity index (TMI)**

A mathematical model that aggregates global scientific, engineering and technological structured disclosures (i.e. peer-reviewed scientific papers and patented inventions), alongside assertion of technology, to empirically measure the maturity of a technology field, approach or use case. It can be used to assess differing fields and sectors alongside each other, due to the normalization of measures incorporated into the model.

### **Technical readiness level (TRL)**

A scale used to estimate the maturity of a technology during the acquisition phase of a program. It provides a consistent and uniform discussion of technical maturity across different types of technologies. The scale ranges from 1 to 9, with 9 being the most mature technology. TRL assessments are critical in managing the progression of technology from conception to deployment. Originally created in the 1970s by NASA as a way of managing technical development readiness and safety for human spaceflight, the TRL system has been widely adopted by the International Standards Organization in 2013 as a qualitative measure of basic, through applied and then commercialized technology progression. In this study, TRL and TMI become synonymous - as the advanced measurement of global public science, research and technology assertion is captured and mathematically modelled so that it maps empirical measures of maturity onto (in relative terms) to the structure of a TRL.

## **15.3 Research related definitions**

### **Citation**

An academic citation is a formal reference to a published or unpublished source that is used to support the author's arguments or findings in a scholarly work. It acknowledges the original creator of an

idea or piece of information and provides readers with the details necessary to locate the source material themselves. Citations are essential in academic writing to avoid plagiarism, uphold intellectual honesty, and facilitate the verification of facts or ideas presented.

Patent citation is a similar process and refers to any significant document or research paper that a patent applicant, examiner, or third party cites as relevant to the content of a patent application. It serves as a formal acknowledgment of prior art and related work in the field, providing a trail of the intellectual property landscape pertinent to the invention.

In both cases citation is a significant source of impact meta data, as the aggregation and analysis of papers, patents, topics, organizations and economies via citation measures provides a method of assessing the preponderance of downstream reference research and innovation the work has on others, thereby reflecting the importance and impact of the cited work itself.

#### **Papers/publications/documents**

A written document that presents the results of original research or an innovative study in a systematic and standardized format. A core activity of the scientific method, the publication of research via a formal paper is intended to communicate new research and knowledge discovery to the scientific community and to contribute to global and collective knowledge. Such papers are peer-reviewed and published in academic journals, ensuring the integrity and validity of the research presented. Clarivate abstracts publications including research journal articles, editorials, meeting abstracts and book reviews. The terms “paper”, “document”, “Web of Science Document” and “publication” are often used interchangeably to refer to printed and electronic outputs of many types. In the analyses presented here, the terms used exclusively to refer to substantive journal articles, reviews and proceedings papers.

## **15.4 Saudi Arabia Specific Definitions**

### **Research, development and innovation (RDI)**

The Research, Development and Innovation (RDI) sector in Saudi Arabia refers to the collective activities and initiatives aimed at fostering scientific research, technological development, and innovation across various fields. This sector is pivotal to Saudi Arabia’s Vision 2030, driving economic diversification and sustainable development. The RDI sector encompasses a network of institutions, policies, and programs that support and finance scientific research, coordinate activities of research centers, and propose legislation to nurture an environment conducive to innovation and technological advancement.

### **National Priority Areas**

Refers to the strategic objectives set by Saudi Arabia to guide its development and innovation efforts. These priorities include Health and Wellness, Sustainable Environment and Supply of Essential Needs, Energy and Industrials, and Economies of the Future. They are designed to enhance the nation's global competitiveness and align with the goals of Saudi Vision 2030.

### **Vision 2030**

Saudi Vision 2030 is a strategic framework aimed at diversifying Saudi Arabia's economy, transforming the nation into a global investment powerhouse. Launched in 2016, Vision 2030 seeks to foster economic, social, and cultural development by capitalizing on the country's strategic location and enhancing the quality of life for its citizens. It emphasizes three core pillars: a vibrant society, a thriving economy, and an ambitious nation, with a focus on public sector efficiency, private sector growth, research and innovation, and international collaboration.

## 15.5 Description of Data Sources

### Web of Science™

The data used in this study came from the Clarivate Web of Science databases, which give access not only to journals but also to conference proceedings, books, patents, websites, and chemical structures, compounds and reactions.

Web of Science has a unified structure that integrates all data and search terms together and therefore provides a level of comparability not found in other databases. It is widely acknowledged to be the world's leading source of citation and bibliometric data. The Web of Science Core Collection is the premier resource on that platform and includes over 22k peer-reviewed, high quality scholarly journals published worldwide (including Open Access journals), over 308k conferences, over 151k editorially selected books and 92M records going back to 1900.

Coverage is both current and retrospective in the sciences, social sciences, arts and humanities. Clarivate has extensive experience with databases on research inputs, activity and outputs and has developed innovative analytical approaches for benchmarking and interpreting international, national and institutional research impact.

### Darts-ip™

Darts-ip is a comprehensive database and analytics platform that provides detailed information and insights on intellectual property (IP) litigation cases globally.

### Derwent World Patents Index™

The Derwent World Patents Index (DWPI) is a comprehensive database that compiles patent applications and grants from 59 patent issuing authorities worldwide. It provides abstracts in English, detailing the nature and use of inventions, and indexes them into technology categories for easy retrieval. DWPI also defines patent families, linking related patents globally around a Basic Patent (the first

disclosure of the invention appearing in the database), facilitating the tracking of an invention's protection status internationally as further applications or granted patents publish in multiple patent jurisdictions.

## 15.6 Metrics

### Web of Science Documents

This is an indicator to refer to substantive journal articles, reviews and proceedings papers and excludes editorials, meeting abstracts or other types of publication. It is based on the Web of Science Core Collection™ dating till Sunday, December 31, 2023.

### Invention Strength

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).

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