

The Atlas of Islamic-World Science & Innovation

Guide to Research Methodology

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The aim of *The Atlas of Islamic-World Science and Innovation* is to provide an insightful overview of science and science-based innovation across the Islamic-world, an independent, objective and authoritative assessment of how these capabilities are changing, and analysis of the opportunities and barriers to further progress, and sets out a vision to facilitate transition to an innovation-driven knowledge economy. It does not aspire to be a comprehensive analysis of every sector, but will map key trends from which policymakers, universities, business leaders and other stakeholders will be able to drill down into more detail. As part of our analysis, a priority of the country reports will also be to consider the changes that need to be made in the light of international best practices so that the country's current policies to promote science, technology and innovation can be modified and enhanced, where relevant.

Detailed country studies are a key output of the project, but an equally important feature is its focus on building capacity, as well as catalysing new partnerships and collaborations. Opportunities for capacity building and inspiring new partnerships will be considered at pan-OIC and national levels, being sensitive to the different dynamics of national policy systems. The project is also deliberately designed in phases to ensure that we have the most robust and comprehensive methodology in place to measure and benchmark science and science-based innovation performance across the OIC. Phase 1 will be used to test the methodology and allow for refinements before the rest of the case studies take place.

The paper serves as a guide to the methodology to be applied and the types of areas which could be considered as part of the country reports. It is not an exclusive listing and research will be tailored as appropriate in each country to cover either additions or alternative elements of the national STI system. Country reports will also be written with substantial input from internationally reputed and eminent authorities in the various fields under consideration. Also included within this paper is an outline of the various roles provides an outline of the various players that make up the research team in each country case study, as well as some more detail on project governance.

Project Aims and Objectives:

This methodology paper is guided by the project aims and objectives which were officially endorsed by the Joint Management Team – a high level committee of all project partners and chaired by Professor Ekmeleddin Ihsanoglu, Secretary General of the OIC. The project aims include:

- To map key trends and trajectories in science and technology-based innovation across the fifty-seven OIC Member Countries, and combine quantitative data with qualitative analysis gathered through interviews, workshops and other in-country fieldwork;
- To look in greater detail at a geographically and economically diverse sample of fifteen OIC countries, and offer an independent, objective and authoritative assessment of how their innovation capabilities are changing, and the opportunities and barriers to further progress and recommend steps that countries need to take to transition to an innovation-driven knowledge economy;

- To identify new opportunities for collaboration between scientists, policymakers, the private sector and non-government sector in the Islamic world and Europe, particularly directed towards shared global challenges of climate change, poverty reduction and sustainability;
- To make developments in science, technology and innovation more visible across the OIC and to the wider world, and to produce a series of agenda-setting articles, publications and events which spark scientific, policy and media discussion and debate in the Islamic world, Europe and beyond;
- To build the skills and capacity of science and innovation analysts and decision-makers across the Islamic world, and create new networks for the exchange of ideas, policies and good practice both within the Islamic world, and between the Islamic world and Europe;
- To make the status of S&T commercialization opportunities more visible within OIC countries and the rest of the world, with the aim to attract S&T-focused investments to OIC member states, and to identify opportunities for matching the supply and demand sides of S&T, and joint S&T research and development programs, with the aim to promote integration among OIC countries.

Conceptual and theoretical framework

The methodologies and approaches used in this project will draw upon a large body of academic and practitioner work carried out in, and at the boundaries between, development studies, economics, innovation studies and science policy. We will apply a highly interdisciplinary approach to understanding science and innovation systems and using a more holistic perspective, explore the roles and interactions between different actors in a national innovation system, and how these are affected by wider social, cultural or political factors, nuancing the report accordingly. It should identify the challenges in the current STI systems and set out a vision for the transition to a knowledge-based economy..

Within this holistic understanding of innovation, the research will then look in more detail at the science and technology-based aspects of the system. The key actors that we will examine in all case studies include relevant government departments and funding agencies; a range of universities with scientific expertise (focusing on all aspects of the higher education system from undergraduates to PhDs, research to teaching); non-university research institutions; enterprise and venture capital funds; private R&D-focused businesses; multi-national companies; relevant think tanks / NGOs; science or innovation-based networks or associations; individual scientists and entrepreneurs; national and regional science academies, including the Academy of Sciences for the Developing World (TWAS) and Islamic World Academy of Sciences; and diaspora scientific communities. The role and future of universities will be particularly integral to the research, and in many countries, it is likely that a university department or research centre will be nominated as the National Research Partner.

Central to our analysis across all countries will be an appreciation of the different policies, regulations and legal / governance frameworks that are in place at both state and federal level, as they influence and often connect these actors in the innovation system and stimulate public and private sector investment and expertise. At the same time, given the increasingly complex international nature of innovation networks, our research will emphasise the international dimensions of science and innovation within the Islamic world, by tracing flows of people, ideas and investments across OIC countries, and between OIC countries and the wider world. And we will look closely at how international collaboration – between individual scientists/innovators, universities, firms and policymakers – can contribute to the strengthening of STI capacity, as well as building wider economic, political and cultural linkages.

A central strand of the project's international analysis will be the role of diaspora research communities. Both directly and indirectly, diaspora communities are key conduits for the transfer of knowledge, technology, capital and remittances to their country of origin. This is particularly important for developing countries where diaspora communities can encourage high tech-industries and act as bridges between foreign technology, markets, local innovators and entrepreneurs, whilst also understanding how such opportunities might best complement cultural factors and strengthen local institutions. The project will aim to help OIC-member countries develop policy tools which help diaspora connect and contribute to development in their home countries, particularly where they have chosen to settle in other Islamic-world countries. Similarly, many Islamic-world countries have significant immigrant and emigrant populations, particularly in the manufacturing and services sectors. The influence of such communities on indigenous STI capacity building and the absorptive capacity of a country to leverage such opportunities will be one component of our research. Any analysis of diaspora networks will build on recent reports of the IDB, ISESCO and the Islamic World Academy of Sciences, as well as the latest analysis from policy institutes in the US, Europe and beyond.

User participation and project governance:

This project has been designed with the advice and guidance of a wide range of collaborators across the Islamic World and internationally. The project's governance includes a Joint Management Team of all project partners, which is chaired by Professor Ekmeleddin Ihsanoglu, the Secretary General of the OIC, also reflects the joint-ownership of the project by all participating partners. The JMT has overall responsibility for overseeing the project at every stage and will meet frequently throughout the project. The JMT will ensure that all of the country reports are independently and objectively peer reviewed prior to publication, at which time JMT members will also be invited to make comments and suggest revisions. The JMT will then sign-off reports prior to publication. Project management responsibility then rests jointly with SESRIC and the Royal Society, and OIC Members States are represented by National Focal Points, appointed by the relevant government ministry. Within each country study, a National Focal Point and National Research Partner are appointed to assist in the development of the research. All country case studies are subject to a rigorous Peer Review Process, coordinated by Professor Atta ur-Rahman, Chair of COMSTECH and Fellow of the Royal Society.

Throughout the project, particular emphasis will be placed on ensuring that the findings can be taken forward and used by the OIC member states to strengthen their science and innovation systems. By working closely with our national research partners, (NFPs, universities and other stakeholders throughout the process, our aim will be to build up a cadre of trained research analysts in each country studied who can then become the kernel of a wider pan-OIC/European/North American network and take forward the learning and recommendations of the project.

The project is managed by the joint project managers of SESRIC and the Royal Society,

The research team and process

There are a number of key roles which will guide and shape the research in each country case study. They include National Focal Point (NFP), the two Project Managers, Lead Researcher (LR) and National Research Partner (NRP),

Their roles and responsibilities are described in detail in a separate document dealing with the Terms of Reference of the Project.

Peer Review Process:

All country reports are required to be independently and objectively peer reviewed. Details are given in a separate document dealing with Terms of Reference of Peer Review Process.

Data collection and analysis: Quantitative Data

Science and technology indicators are crucial for monitoring scientific and technological development, and useful for formulating, adjusting and implementing S&T policies. Indicators are normally used to monitor global technological trends, conduct foresight exercises, and determine specific areas of investment.

The main objectives of this exercise will be to:

- Reflect the level and structure of the national efforts undertaken by 15 fifteen countries and assess the trends and developments in S&T;
- identify the challenges faced by different agencies in the economy in conducting S&T activities;
- compare where countries stand internationally;
- propose recommendations for the continued developments of S&T in the respective countries;

For this purpose the project will use the most commonly used indicators on science and technology on an internationally comparable basis. The data may include final and provisional results as well as forecasts established by government authorities. The indicators will cover the resources devoted to research and development, peer-reviewed publications, patent families, technology balance of payments and international trade in highly R&D intensive industries, as well as the underlying economic series used to calculate these indicators.

The relevant data may be collected from the relevant government agency through the National Focal Point and the National Research Partner. In order to ensure the consistency and comparability the methodology used in collecting all the data should be based on the internationally recognised guidelines as put forth by the Organisation for Economic Co-operation and Development (OECD), otherwise known as the Frascati Manual.

Quantitative data collection will be led by SESRIC in Turkey, which has extensive databases on STI-related and other indicators across the 57 OIC member states. Its main statistical database is known as BASEIND (BASic Social and Economic INDicators). It currently contains data on 255 socio-economic variables under 17 categories for the 57 OIC member states, dating back to 1970. These data are being continually updated in three ways:

- National Statistical Offices (NSOs): the content of BASEIND is regularly updated and enriched essentially on the basis of information collected from the National Statistical Organizations (NSOs).
- International Organisations: SESRIC also works closely with international organizations such as International Monetary Fund, United Nations, World Bank, International Labour Organization and World Health Organization to ensure that its data sets are as complete as possible.
- Open sources: SESRIC also uses relevant open sources especially for data related to articles published, citations and patent applications.

In terms of data analysis, SESRIC will compare the performance of the OIC in aggregate, and member states in particular, to wider international trends. Regional and income level comparisons are also provided to support a more detailed analysis based on the fact that OIC member states are different in many regards and any analysis must reflect these differences in the structural basis of their economies.

The reports will also draw on Elsevier's *Scopus* database of publications data. The Scopus publications database allows us to explore a wide range of interesting questions: for example, who is publishing heavily, where there is rapid growth in publications, who is collaborating with whom and the effect this is having on publications, the disciplinary spread of papers, and identify the most active and collaborative institutes.

A useful list of proposed indicators is included as Attachment 1. It includes indicators focused on gross domestic expenditure on R&D, as well as data on human relations capacity and statistics based on sectors, business expenditure, government investment, educational resources, patents, and international trade. This list provides a robust indication of the types of data the research will draw on. Additional indicators may also be considered as appropriate, including broader economic and educational measures, statistics on talent flows, international collaborations, literacy, as well as data on mobile phone usage and broadband infrastructure.

Qualitative Fieldwork:

These quantitative data will be complemented by an extensive amount of qualitative fieldwork in our case study countries, which will be led by the Lead Researcher and the National Research Partner. This will primarily involve interviews and workshops with key actors in the science and innovation systems of each country (as well as international collaborators, diaspora communities and other agencies).

The research will be tailored to the individual country context, whilst also ensuring enough complementarities across all countries to enable rigorous and accurate comparison. We have deliberately chosen a diverse cross-section of country case studies from different geographical and economic backgrounds and through our analysis, we will promote cross-OIC learning and successful models of science and innovation-led development. Phase I – the pilot case studies – will help shape Phase II, the remainder of the case study work. The pilot studies will test the methodology and allow us to further refine it for the remaining countries.

The types of people / institutions we will wish to interview during the fieldwork includes but is not limited to:

- Government departments / agencies
- Universities (private and public)
- Research institutes
- Think tanks
- The private sector – including indigenous companies and foreign / MNCs
- The National Academy of Science
- Regional academies of science e.g, TWAS and IWAS
- Scientists / researchers
- Academics
- Venture capitalists
- Entrepreneurs / Innovators
- Business leaders
- Politicians & leading public servants
- Leading experts and thinkers of or on the country / specific sectors
- Diaspora communities
- Ambassadors and other dignitaries
- Key figures in the national scientific ambition
- 'Home grown' heroes of science

This fieldwork analysis is fundamental to the country case studies, and the project overall. There are numerous players such as the World Bank, the OECD, UNESCO and others who also produce country case studies but these

reports are often weighted towards data and statistics, and targeted at an informed and science-literate audience. Our work will draw on these reports but the niche for this project is to produce widely-accessible outputs that appeal to a range of policymakers, scientists, economists, social scientists, politicians, historians and innovators. Whilst grounded in empirical data and relevant literature, the project reports will adopt a more journalistic style that uses stories and case studies of people and organisations to illustrate wider dynamics in each country's science and innovation system.

The Royal Society project team has significant experience in the development of this style of report. Members of the team previously led a successful two-year project called 'The Atlas of Ideas' which resulted in a series of high-profile reports on the prospects for science and science-based innovation in China, India, Brazil and South Korea. This project was originally modelled on 'The Atlas of Ideas' and earlier reports for this study are downloadable from <http://www.demos.co.uk/projects/atlasofideas>.

Our research in developing countries

At the OIC Conference on Science and Technology in Malaysia in 2003, OIC member states committed to a vision 'to become a community that values knowledge and is competent in utilising and advancing S&T to enhance the socio-economic well-being of the 'Ummah' (the broader Islamic world). This project is seen as making an important contribution to developing that capacity – particularly within less developed OIC member states; and to identifying new opportunities for collaboration between OIC countries and beyond.

Our research in the less developed OIC member states will be grounded in the latest development, economics and innovation theory and practice, which looks specifically at the role of R&D and capacity building in reducing poverty. A major focus of our research will be the extent to which individuals, countries and regions have fostered an absorptive environment, which not only produces new knowledge, but is able to diffuse and adapt existing knowledge and technologies to meet local needs.

We will seek to understand the STI capacity building processes that are underway in each of these countries, specifically looking at initiatives related to healthcare, access to affordable energy and clean water. National partners will be a critical asset in helping to understand the local context but also in helping to develop mechanisms and collaborations which they can then take forward to address these critical issues. More broadly, we will consider the likely success of STI policies in the context of the country's 'framework conditions' – the policies, legal and financial systems, cultural parameters, and basic systems infrastructure – which are so fundamental to economic progress.

In addition to its economic benefits, this project will explore and promote scientific progress as an essential requirement needed to address today's most pressing global challenges, such as climate change, food security and public health. Every country is affected by these pressures, yet only a small number of countries account for the vast majority of the world's research efforts in response to them. There is significant opportunity for scientific engagement across the developing countries of the Islamic-world to galvanise indigenous expertise to provide tailored solutions to problems at local and regional level, and at the same time to build capacity in these countries. By supporting the ambitions of developing countries in this regard, and identifying areas for partnership between Islamic countries and the rest of the world, the project will promote a more prominent role for developing countries in setting global research agendas.

Overarching research themes:

This section gives some more detail of broader research themes within the AIWSI. It is not an exclusive listing and themes will evolve throughout the project. Themes include:

1) *Mapping Islamic-world innovation*

Science and innovation are coming from more people in more places as the 'core' and 'periphery' of global innovation networks become less distinctive. By drawing on and extending the mapping work carried out in recent years by the OIC, *Nature*, the Arab Development Report and others, this project will provide an authoritative and up-to-date account of how patterns and concentrations of advanced science and technology-based innovation, and innovation based on appropriate and indigenous technologies are changing across the Islamic world.

We will gather and interpret the latest data, trends and case studies to determine the rising hotspots for innovation, as well as looking to how STI can contribute to sustainable development and poverty reduction in some of the less-developed countries of the Islamic world. We will assess the distinctive features of national innovation systems within the OIC, and also review the progress of the OIC's own science institutions to strengthen innovation capabilities across the Islamic world.

2) *New insights in history and heritage*

The names of Nasir al-Din al-Tusi, Ibn al-Nafis and Ibn al-Shatir may be less familiar to speakers of European languages than those of Newton, Darwin, Copernicus and Einstein. But these and other Islamic-world scholars belong in the pantheon of thinkers whose work has shaped the direction of modern science.¹ Like that of China, the history of Islamic-era science and innovation is one of a period of great investment and flourishing followed by a slow, steep and seemingly irreversible decline.

The precise reasons are undoubtedly complex and remain the subject of much debate as well as new insights. One view is that there was a gradual move away from a more holistic approach to seeking knowledge across the domains of medicine, chemistry, mathematics, astronomy and religious studies, towards a focus solely on religious studies due to various historical setbacks and social calamities in the Islamic empire. More recent research, however, has extended the period of Islamic-era scientific advance, bringing the beginning of the decline closer to the time when Europe began to reassert itself as a world power, and the nations of the developing world began to be colonized. During the scoping phase of this project, we will review some of the latest historical research (including the work of OIC Secretary General Ekmeleddin Ihsanoglu), and provide a contemporary assessment into the causes of scientific decline in the Islamic world.

3) *Talent flows: from brain drain to brain circulation?*

The story of emerging innovation economies is ultimately a story about people. This project will look in detail at the current and future potential of the scientific and research labour force across the Islamic world. And it will explore the challenges that still persist within national education systems.

Whilst *stocks* of human capital remain important, recent research has suggested that *flows* and *networks* of scientists, engineers and entrepreneurs have an even greater impact on innovation systems in home and host country.² How can we characterise talent flows in and out of the Islamic world? Are diaspora scientists and entrepreneurs now returning to certain countries in order to participate in their growing dynamism as knowledge economies? Where and to what extent is 'brain drain' now becoming 'brain circulation'? To what extent are visa restrictions and other forms of discrimination impeding the free flow of Islamic-world scientists and researchers around the world?

¹ Saliba, G. (2007) *Islamic Science and the Making of the European Renaissance*, Boston: MIT Press

² Saxenian, A. (2006) *The New Argonauts: Regional Advantage in a global economy*, Cambridge, MA: Harvard University Press; Wagner, C.S. (2008) *The New Invisible College*, Washington: Brookings Institution Press

4) *Belief and reason in the modern world*

In Europe and the US, there is a renewed tendency to portray science and religion as conflicting - or irreconcilable - systems of knowledge.³ Debates can appear (at least to the wider public) as polarized and dominated by dogmatic voices. Outside of the West, however, the relationship is often different.

In many Muslim countries, faith is regarded by many as a person's primary identity. Often, religion is enshrined in national constitutions. But even where this is not the case, there is much greater public and political acceptance of the place of belief in policy-shaping, alongside other variables such as evidence from research, political influences, the opinions of business leaders, land-owners and, increasingly, multinational NGOs.

Paradoxically, however, an acknowledgement that religion is an active contributor to societies has been firmly kept out of higher education and research since the end of colonial times in the Muslim world. This has had at least two effects: first, that science and technology fail to connect with an aspect of life that is important to most citizens. And second, that critical questions about religion and its role in society have become absent from research, inquiry and from public debate. These questions include the permissibility of organ transplants, cloning, genetic-modification, weapons of mass destruction and nanotechnology. In each of these examples, public discussion tends to be limited to a minority of people with access to European-language media. Pertinent to this analysis will include an analysis of the broader influences of governance and politics, and its relationship to science and religion.

Despite a recent resurgence of the trend to merge religious studies with science and technology in several Muslim countries, thinkers such as Ziauddin Sardar argue that such separation is among the reasons why innovation and creativity is thin and inconsistent in the OIC world today, and also why indices for higher education and research in the OIC states are among the lowest in the world.

5) *The post-oil economy: innovation for sustainability*

The prospect of a post-petroleum world presents significant challenges for the oil exporters of the OIC countries. Their largest markets (Europe and the United States) have set targets to reduce reliance on fossil fuels and increase the share of renewable forms of energy. For resource-rich OIC member states, a business as usual approach could lead to diminishing returns. On the other hand, smart thinking means that OIC member states could see this shift as an opportunity, rather than a threat.

The AIWSI will identify examples of smart thinking on sustainability from within the OIC. Examples include engaging proactively in international negotiations to reduce greenhouse gas emissions; using the Clean Development Mechanism of the Kyoto Protocol; looking at the opportunities and uncertainties of biofuels; and finding ways to improve development and poverty eradication in sub-Saharan Africa – where most of the OIC Least Developed Countries (LDC) are located. And as the politics of access and availability to fresh water become more intense across large parts of the Islamic world, we will look in particular detail at the prospects for water-related sustainable innovation.

Related to this is the rapidly expanding field of Islamic finance, now estimated to be worth at least \$300 billion dollars annually. From relatively modest beginnings, Islamic based financial products are today being used to lease aircraft, and pay for house-purchases. Islamic finance is a genuine example of Islamic innovation, and is a

³ Dawkins, R. (2006) *The God Delusion*, London: Bantam Press; Dennett, D. (2006) *Breaking the Spell: Religion as a Natural Phenomenon*, London: Allen Lane

partnership between theologians, international banks, and often second-generation Muslims living in Western countries who are capable of bridging tradition and modernity. This project will explore how such financial innovation can support other forms of science and technology-based innovation – for example, through creative models of financing R&D and early-stage companies.

6) International collaboration

Just as the rise of innovation from China and India can at times fuel a climate of anxiety in Europe and the US, so a more innovative Islamic world may prompt fear or suspicion – particularly when set in the context of political Islam, or relations between Western countries and some countries in the OIC. Advances in Iranian nuclear technology are not viewed in the West with the same equanimity as developments in Malaysia's software industry.

But it is short sighted to view these developments purely or primarily as a threat. As the Islamic world's innovation capabilities grow, a central question is whether defensive, national strategies gather momentum, or whether the countervailing impulse towards global collaboration and exchange of new will prove stronger.⁴ What are the current levels of collaboration and exchange both amongst Islamic country and beyond, and what historical, political or economic influences have shaped these relationships? How have events such as September 11 impacted on collaborative endeavours and relationships more broadly?

A sample of the broad research questions

Whilst fieldwork will be tailored to each individual country, there are some broad themes / research questions which will help shape this research across all countries. Below is a sample of the types of questions and themes to be explored in this study. These sample questions also reflect the research priorities identified by the JMT as are listed in the Project's Terms of Reference.

Overarching Framework / Mapping:

- *What are the most eye-catching and distinctive features of this country's STI system?*
- *What are the main structures for science and innovation (institutions, policies, funding etc.)?*
- *What is the history and how rapidly are things developing?*
- *What are the key indicators and metrics that reflect the health of this system?*
- *What is the place of STI in the overall economic priorities of this country?*
- *Who are the 'home-grown heroes' of this country's science?*
- *What are the key transformational moments or snapshots of this country's science and innovation system?*
- *In which fields are the key STI strengths? What are the key areas of potential strength?*
- *How might recognised international best practices be applied or tailored to this country to promote and improve STI?*
- *What legal frameworks / regulations are in place to govern STI? What learnings from other systems might be applied /tailored to this country?*
- *What is the balance between basic and applied research in this country?*
- *How is government policy informed?*
- *How is STI promoted in this country? Does more need to be done in this regard? If so, how?*
- *Where appropriate, what is the place of STI in national development plans?*
- *How absorptive in this country to new and /or alternative technologies?*
- *How is technology diffused across the country?*

⁴ Leadbeater, C. and Wilsdon, J (2007) *The Atlas of Ideas: how Asian innovation can benefit us all*, London: Demos

- *Where appropriate, what are the emerging centres of scientific excellence within this country? Are they internationally recognised?*

People & Human Capital:

- *Can we measure flows of scientific and research talent in and out of this system?*
- *What are the key trends in human capital production?*
- *How best can scientists, inventors and innovators be rewarded / acknowledged internationally?*
- *What are the strengths and weaknesses of the secondary and higher education system?*
- *How do the public and private institutions compare?*
- *How have university enrolment trends changed?*
- *What are the numbers of university graduates at PhD and Masters level?*
- *How well does the HE system prepare for careers in science? How employable are graduates from a business / government perspective?*
- *How do universities encourage a spirit of innovation and entrepreneurship?*
- *Is entrepreneurship / innovation embedded in the university curriculum?*
- *What place does engineering education hold within the broader STI system?*
- *Where are this country's diaspora of scientists/ entrepreneurs around the world? What impact do they have on the country's STI potential? To what extent do they contribute to international collaboration for the country?*

Places:

- *What is the current geographical distribution of STI and how are current patterns likely to change?*
- *Where are this country's science 'hotspots' and which are the places / institutions / companies to watch and why?*
- *What are the differences between the established centres and the 'rising star' cities?*
- *How strong is the divide between rich and poor within the country, and the related absorption and access to science and technology?*
- *What is the impact of different regional systems of innovation?*
- *Is STI policy governed by central and/or regional innovation policy and if so, what is the variable impact of these policy approaches?*

Business:

- *What are the innovation sectors and domains of particular strength?*
- *What is the balance between public and private sector R&D?*
- *What is the contribution of development assistance and philanthropy to R&D?*
- *How much (if any) multinational R&D takes place in this country? Is this sort of investment encouraged?*
- *How innovative is domestic enterprise? Is this changing?*
- *What is the potential for indigenous private sector R&D?*
- *Who are the major indigenous companies and are they doing cutting edge research?*
- *What mechanisms are in place to attract FDI? What other tools might be relevant?*
- *Where there is FDI, how effective has it been in transferring knowledge / skills / competitiveness into domestic industry?*
- *What is the climate for entrepreneurship / venture capital?*
- *How is entrepreneurship viewed in a cultural sense?*
- *What venture capital schemes exist? How effective are they? How might they be improved?*
- *How suited is the regulatory environment to supporting multinational R&D?*
- *Are science / tech parks and business incubators present in this country? How successful are they?*

Culture:

- *How does this country approach the governance and ethics of science?*
- *What role do women play in this country's STI system? How accessible are research careers to women in this country?*
- *What national and institutional policies are in place to overcome obstacles faced by women in their scientific careers?*
- *How do we understand the relationship between Islam, science and politics in this country? How is this changing?*
- *What are the distinctive features of this country's STI trajectory? What do they mean for other world regions?*
- *What social / political trends have an impact on STI – such as the impact of governance / ethics systems, open source movements,*
- *What levels of public engagement are used in decision making on pertinent scientific issues*
- *What is the relationship between science and development?*
- *Is there a culture of cross-over and exchange between academia and business in this country? How successful are initiatives aimed at driving the commercialisation of research?*

Sustainability

- *What are the particular environmental challenges that this country faces?*
- *To what extent is this country rich in natural resources, and how does it manage them?*
- *How secure are this country's supplies of food, energy and water? Are there any conflicts or potential conflicts over resources with its neighbours?*
- *How biodiverse is this country, and how well is this biodiversity being safeguarded?*
- *What adaptive, preventive or mitigative measures are being taken to address climate change?*
- *What are the general patterns of resource consumption and CO₂ emissions?*
- *What is the general picture of public attitudes towards these and other sustainability issues, and how much of an obstacle is this to addressing them?*
- *Where are the most interesting research initiatives taking place in the area of sustainability?*
- *Are there measures in place to incentivise a shift to a more sustainable society, or are there policies which encourage overconsumption / resource depletion?*

Collaboration:

- *How well connected is this country to research and innovation hubs in Europe, the US, Canada, Japan, China, India and elsewhere?*
- *Which other Islamic-world countries does this country collaborate with on science, and how have these relationships changed / evolved? Are they based on historical ties or more current drivers? To what extent does their country's OIC membership drive collaboration?*
- *How successful is the currently collaboration between this country and others?*
- *How can international collaboration be strengthened? What are the barriers to this?*
- *What are the boosts and barriers to collaborating in and with this country?*
- *What is the relationship between the country's foreign policy and its scientific collaborations?*
- *How have the flows of this country's students overseas or foreign students coming there influenced international collaboration trends?*

Prognosis

- *What have been the central themes/stories that have emerged from the research and report writing?*
- *What are the key strengths and weaknesses, challenges and opportunities, of this country's science system?*

- *What recommendations should this country's government adopt to capitalise on these strengths, address these weaknesses and fully realise its scientific potential?*
- *What are the key lessons from this country's scientific development?*
- *How should other countries engage with, or collaborate with, this country to best effect, and what particular opportunities does it have to offer potential collaborators?*
- *What can the other OIC countries learn from this country's experience, and how can they most effectively work together?*

The Overview / Final Report

Based on the country working papers and additional survey/desk-based research across the rest of the OIC member states, the Project Managers (RS/ SESRIC) will produce an agenda-setting overview report, which highlights commonalities and differences between the countries, and draws wider conclusions about the prospects for science and innovation across the Islamic world, and closer collaboration with the rest of the world.

The report will include recommendations for governments, industry and higher education, and short commentaries from leading thinkers in the Islamic world. The final report will be translated into Arabic and French. All outputs, including country working papers and the overview report, will be peer reviewed, to ensure they are high quality, rigorous and independent.

Questions, suggestions and where next?

Should you have any questions or suggestions about this methodology paper, or the respective research roles or the project more generally, please contact either Luke Clarke luke.clarke@royalsociety.org or Mehmet Fatih Serenli on mfserenli@sesric.org. Luke and Mehmet are the Joint Project Managers of the Atlas of Islamic-World Science and Innovation.

ATTACHMENT ONE: Science and technology indicators:

Science and technology indicators are crucial for monitoring scientific and technological development, and useful for formulating, adjusting and implementing S&T policies. Indicators are normally used to monitor global technological trends, conduct foresight exercises, and determine specific areas of investment.

The main objectives of this exercise will be to:

- Reflect the level and structure of the national efforts undertaken by 15 fifteen countries and assess the trends and developments in S&T;
- identify the challenges faced by different agencies in the economy in conducting S&T activities;
- compare where countries stand internationally;
- propose recommendations for the continued developments of S&T in the respective countries;

For this purpose the project will use the most commonly used indicators on science and technology on an internationally comparable basis. The data may include final and provisional results as well as forecasts established by government authorities. The indicators will cover the resources devoted to research and development, patent families, technology balance of payments and international trade in highly R&D intensive industries, as well as the underlying economic series used to calculate these indicators.

The relevant data may be collected from the relevant government agency through the National Focal Point and the National Research Partner. In order to ensure the consistency and comparability the methodology used in collecting all the data should be based on the internationally recognised guidelines as put forth by the Organisation for Economic Co-operation and Development (OECD), otherwise known as the Frascati Manual.

2. LIST OF INDICATORS

Indicators by subject:

Gross domestic expenditure on R&D (GERD):

1. Gross Domestic Expenditure on R&D -- GERD (million current PPP \$)
 - 1.a. GERD (million national currency - for euro area, pre-EMU euro or EUR)
2. GERD as a percentage of GDP
3. GERD -- (million 2000 dollars -- constant prices and PPP)
 - 3.a. GERD -- Compound annual growth rate (constant prices)
4. GERD per capita population (current PPP \$)
5. Estimated Civil GERD as a percentage of GDP
6. Basic research expenditure as a percentage of GDP

R&D Personnel (FTE):

7. Total researchers (FTE)
 - 7.a. Total researchers -- Compound annual growth rate
8. Total researchers per thousand total employment
 - 8.a. Total researchers per thousand labour force
9. Total R&D personnel (FTE)
 - 9.a. Total R&D personnel -- Compound annual growth rate

10. Total R&D personnel per thousand total employment
- 10.a Total R&D personnel per thousand labour force

GERD by source of funds:

11. Industry-financed GERD as a percentage of GDP
12. Government-financed GERD as a percentage of GDP
13. Percentage of GERD financed by industry
14. Percentage of GERD financed by government
15. Percentage of GERD financed by other national sources
16. Percentage of GERD financed by abroad

GERD by performance sectors:

17. Percentage of GERD performed by the Business Enterprise sector
18. Percentage of GERD performed by the Higher Education sector
19. Percentage of GERD performed by the Government sector
20. Percentage of GERD performed by the Private Non-Profit sector

Researchers (headcount):

21. Total researchers (headcount)
- 21.a. Women researchers (headcount)
22. Women researchers as a percentage of total researchers (based on headcount)
- 22.a. Business Enterprise Sector: Total researchers (headcount)
- 22.b. Business Enterprise Sector: Women researchers (headcount)
- 22.c. Business Enterprise Sector: Women researchers as a percentage of total researchers (based on headcount)
- 22.d. Government Sector: Total researchers (headcount)
- 22.e. Government Sector: Women researchers (headcount)
- 22.f. Government Sector: Women researchers as a percentage of total researchers (based on headcount)
- 22.g. Higher Education sector: Total researchers (headcount)
- 22.h. Higher Education sector: Women researchers (headcount)
- 22.i. Higher Education sector: Women researchers as a percentage of total researchers (based on headcount)

Business Enterprise Expenditure on R&D (BERD):

23. Business Enterprise Expenditure on R&D -- BERD (million current PPP \$)
- 23.a. BERD (million national currency - for euro area, pre-EMU euro or EUR)
24. BERD as a percentage of GDP
25. BERD -- (million 2000 dollars -- constant prices and PPP)
- 25.a. BERD -- Compound annual growth rate (constant prices)
26. BERD as a percentage of value added in industry

Business Enterprise R&D Personnel (FTE):

27. Business Enterprise researchers (FTE)
- 27.a. Business Enterprise researchers -- Compound annual growth rate
28. Business Enterprise researchers as a percentage of national total

- 29. Business Enterprise researchers per thousand employment in industry
- 30. Total Business Enterprise R&D personnel (FTE)
- 30.a. Total Business Enterprise R&D personnel -- Compound annual growth rate
- 31. Total Business Enterprise R&D personnel as a percentage of national total
- 32. Total Business Enterprise R&D personnel per thousand employment in industry

BERD by source of funds:

- 33. Industry-financed BERD -- (million 2000 dollars -- constant prices and PPP)
- 33a. Industry-financed BERD -- Compound annual growth rate (constant prices)
- 34. Industry-financed BERD as a percentage of value added in industry
- 35. Percentage of BERD financed by industry
- 36. Percentage of BERD financed by government
- 37. Percentage of BERD financed by other national sources
- 38. Percentage of BERD financed by abroad

BERD performed in selected industries:

- 39. BERD performed in the aerospace industry (million current PPP \$)
- 39.a. Percentage of BERD performed in the aerospace industry
- 40. BERD performed in the electronic industry (million current PPP \$)
- 40.a. Percentage of BERD performed in the electronic industry
- 41. BERD performed in the office machinery and computer industry (million current PPP \$)
- 41.a. Percentage of BERD performed in the office machinery and computer industry
- 42. BERD performed in the pharmaceutical industry (million current PPP \$)
- 42.a. Percentage of BERD performed in the pharmaceutical industry
- 43. BERD performed in the instruments industry (million current PPP \$)
- 43.a. Percentage of BERD performed in the instruments industry
- 44. BERD performed in service industries (million current PPP \$)
- 44.a. Percentage of BERD performed in service industries

Higher Education Expenditure on R&D (HERD):

- 45. Higher Education Expenditure on R&D -- HERD (million current PPP \$)
- 45.a. HERD (million national currency - for euro area, pre-EMU euro or EUR)
- 46. HERD as a percentage of GDP
- 47. HERD (million 2000 dollars -- constant prices and PPP)
- 47.a. HERD -- Compound annual growth rate (constant prices)
- 48. Percentage of HERD financed by industry

Higher Education R&D Personnel (FTE):

- 49. Higher Education researchers (FTE)
 - 49.a. Higher Education researchers -- Compound annual growth rate
 - 50. Higher Education researchers as a percentage of national total
 - 51. Higher Education Total R&D personnel (FTE)
 - 51.a. Higher Education Total R&D personnel -- Compound annual growth rate
- Government Expenditure on R&D:

- 52. Government Intramural Expenditure on R&D -- GOVERD (million current PPP \$)
- 52.a. GOVERD (million national currency - for euro area, pre-EMU euro or EUR)
- 53. GOVERD as a percentage of GDP 54. GOVERD (million 2000 dollars -- constant prices and PPP)
- 54.a. GOVERD -- Compound annual growth rate (constant prices)
- 55. Percentage of GOVERD financed by industry

Government R&D Personnel (FTE):

- 56. Government researchers (FTE)
- 56.a. Government researchers -- Compound annual growth rate
- 57. Government researchers as a percentage of national total
- 58. Government Total R&D personnel (FTE)
- 58.a. Government Total R&D personnel -- Compound annual growth rate
- Government Budget Appropriations or Outlays for R&D by socio-economic objectives (GBAORD):
- 59. Total Government Budget Appropriations or Outlays for R&D -- GBAORD (million current PPP \$)
- 59.a. Total GBAORD (million national currency - for euro area: pre-EMU euro or EUR)
- 60. Defence Budget R&D as a percentage of Total GBAORD
- 61. Civil Budget R&D as a percentage of Total GBAORD
- 62.a.1. Civil GBAORD for Economic Development programmes (million current PPP \$)
- 62.a.2. Economic Development programmes as a percentage of Civil GBAORD
- 62.b.1. Civil GBAORD for Health and Environment programmes (million current PPP \$)
- 62.b.2. Health and Environment programmes as a percentage of Civil GBAORD
- 62.c.1. Civil GBAORD for Education and society (million current PPP \$)
- 62.c.2. Education and Society as a percentage of Civil GBAORD
- 62.d.1. Civil GBAORD for Space programmes (million current PPP \$)
- 62.d.2. Space programmes as a percentage of Civil GBAORD
- 62.e.1. Civil GBAORD for Non-oriented Research programmes (million current PPP \$)
- 62.e.2. Non-oriented Research programmes as a percentage of Civil GBAORD
- 62.f.1. Civil GBAORD for General University Funds (GUF) (million current PPP \$)
- 62.f.2. General University Funds (GUF) as a percentage of Civil GBAORD

R&D Expenditure of Foreign Affiliates:

- 63. R&D expenditure of foreign affiliates (million current PPP \$)
- 63.a. R&D expenditure of foreign affiliates (million national currency - for euro area, pre-EMU euro or EUR)
- 64. R&D expenditure of foreign affiliates as a percentage of R&D expenditure of enterprises

Patents:

- 65. Number of triadic patent families (priority year) 65.a. Number of patent applications to the EPO (priority year) 65.b. Number of patent applications to the USPTO (filing year)
- 66. Share of countries in triadic patent families (priority year)
- 67. Number of patent applications to the EPO in the ICT sector - (priority year)
- 67.a. Number of patents granted at the USPTO in the ICT sector - (priority year)
- 68. Number of patent applications to the EPO in the biotechnology sector - (priority year)
- 68.a. Number of patents granted at the USPTO in the biotechnology sector - (priority year)

Technology Balance of Payments (TBP):

- 69. Technology balance of payments: Receipts (million current dollars)
- 69.a. Technology balance of payments: Receipts (million national currency - for euro area, pre-EMU euro or EUR)
- 70. Technology balance of payments: Payments (million current dollars)
- 70.a. Technology balance of payments: Payments (million national currency - for euro area, pre-EMU euro or EUR)
- 71. Technology balance of payments: Payments as a percentage of GERD

International trade in highly R&D-intensive industries:

- 72. Export market share: Aerospace industry
- 72.a. Total imports: Aerospace industry (million current dollars)
- 72.b. Total exports: Aerospace industry (million current dollars)
- 73. Export market share: Electronic industry
- 73.a. Total imports: Electronic industry (million current dollars)
- 73.b. Total exports: Electronic industry (million current dollars)
- 74. Export market share: Office machinery and computer industry
- 74.a. Total imports: Office machinery and computer industry (million current dollars)
- 74.b. Total exports: Office machinery and computer industry (million current dollars)
- 75. Export market share: Pharmaceutical industry
- 75.a. Total imports: Pharmaceutical industry (million current dollars)
- 75.b. Total exports: Pharmaceutical industry (million current dollars)
- 76. Export market share: Instruments industry
- 76.a. Total imports: Instruments industry (million current dollars)
- 76.b. Total exports: Instruments industry (million current dollars)