Kingdom of Saudi Arabia

Strategic Priorities for Environmental Technology Program

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Executive summary

The National Policy for Science and Technology, approved by the Council of Ministers in 1423 H (2002 G), defined 11 programs for localization and development of strategic technologies that are essential for the Kingdom's future development. This report represents the strategic priorities for one of these programs, the Environmental Technology Program (ETP).

The ETP plan was developed in response to key environmental concerns in Saudi Arabia, among which are: establishing an advanced environmental technology industry, enhancing the competitiveness of Saudi Arabia in the world environmental technology market, and joining the international community to protect the environment and promote sustainable environmental development.

Environmental technologies are particularly important in the Kingdom, where waste, pollution, air quality and degradation of natural resources have significant environmental implications. The importance of advanced environmental technologies is to protect the environment and maintain a high quality of life within the Kingdom.

The Environmental Technology Plan is based on input from a variety of stakeholders and representatives from Saudi institutions with a vested interested in developing a platform for environmental technology in the Kingdom.

The planning process included the following steps:

- Identifying the key needs of the Kingdom for environmental technologies.
- Assessing the strengths, weaknesses, opportunities, and threats for the program, including an analysis of KSA environmental technology publications and patents, and an assessment of international research institutes.
- Defining a mission and vision for the Kingdom's Environmental Technologies Program.
- Defining the key technologies and other program areas needed to address. the Kingdom's needs in Environmental Technologies research, development and innovation.

Executive summary

As a result of the process, the key environmental needs of the Kingdom were grouped into the following four main categories:

- Waste:

1. Municipal waste water.
2. Municipal solid waste.
3. Industrial waste water.
4. Hazardous medical waste.
5. Hazardous waste.
6. Industrial solid waste.
7. Agricultural waste.

- Pollution:

1. Food contamination.
2. Oil contamination.
3. Radioactive contamination.
4. Thermal pollution.
5. Noise Pollution.

- Air Quality:

1. Ambient air quality.
2. Greenhouse gases.

- Degradation of Natural Resources:

1. Desertification.
2. Degradation of coastal areas.
3. Biodiversity.
4. Degradation of water resources.

In each of these areas, avoidance technologies, monitoring and assessment technologies, control technologies, and remediation and restoration technologies were considered and prioritized based on multiple criteria. The priorities for Saudi Arabia during the first five-year plan are to transfer, localize, and develop the following environmental technologies:

1. Municipal solid waste remediation and restoration technologies.
2. Food contamination avoidance technologies.
3. Air pollution monitoring & assessment technologies.
4. Greenhouse gases avoidance, monitoring & assessment technologies.
5. Desertification monitoring & assessment technologies.

Within each of these priority areas, KACST will work in concert with universities and industry to develop the necessary network for research, development and innovation in this field. The ETP will be directed by a program manager, who will be responsible for the overall execution of the plan. The ETP Advisory Committee, with stakeholder membership, will oversee the implementation of the plan. They will establish and review performance metrics and provide advice on the project portfolio. The Advisory committee will advise the program manager and will also report to the National S&T Plan Supervisory Committee, which will oversee all of the Strategic Technology Programs.

Introduction

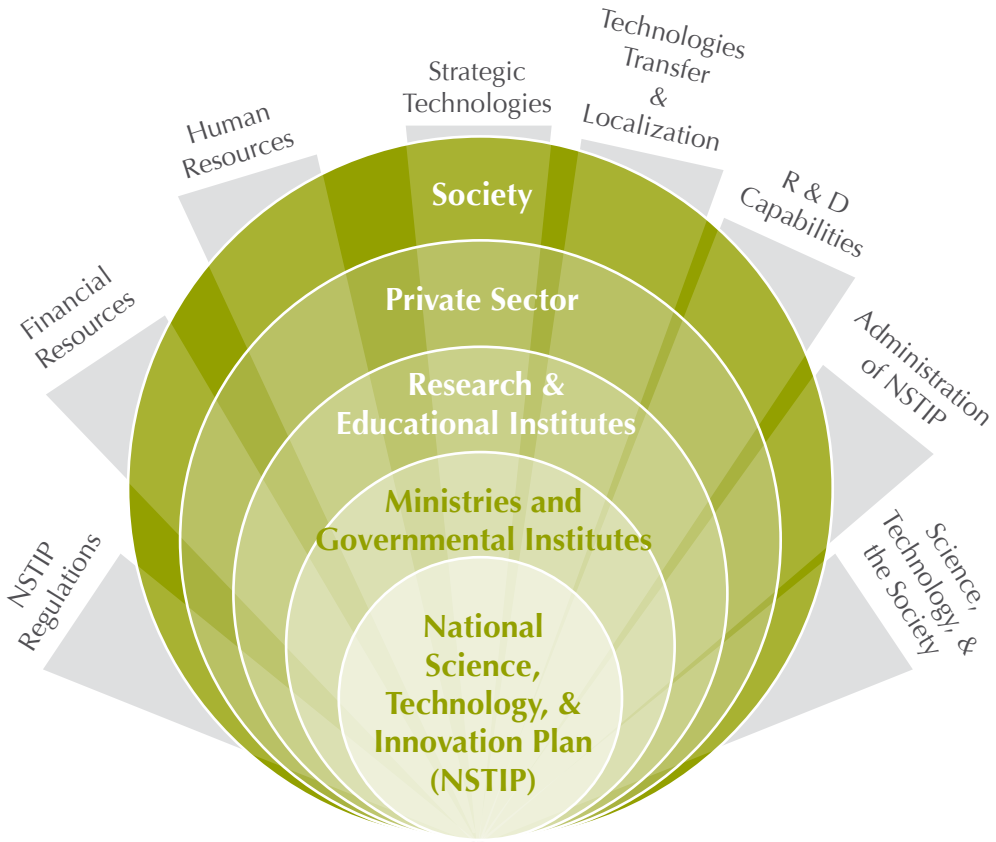
Background

KACST was directed by a 1986 Royal Decree to "propose a national policy for the development of science and technology and to devise the strategy and plans necessary to implement them." In July 2002, the Council of Ministers approved the national policy for science and technology, which drew up the broad lines and future direction of science, technology, and innovation (STI) in the Kingdom, considering the role of KACST as well as that of universities, government, industry, and society at large. The plan, depicted in figure 1, encompasses:

1. Strategic and advanced technologies.
2. Scientific research and technical development capabilities.
3. Transfer, development and localizing technology.
4. Science, technology and society.
5. Scientific and technical human resources.
6. Diversifying financial support resources.
7. Science, technology and innovation system.
8. Institutional structures for science, technology and innovation.

Introduction

Figure 1: Science and Technology Programs



In the «Strategic and Advanced Technologies» area, KACST is responsible for implementing the following technology areas:

1. Water
2. Oil & Gas
3. Petrochemicals
4. Nanotechnology
5. Biotechnology
6. Information Technology
7. Electronics, Communication, & Photonics
8. Space and Aeronautics
9. Energy
10. Environment
11. Advanced Materials

Each plan establishes a mission and vision, identifies stakeholders and users, and determines the highest priority technical areas for the Kingdom.

Introduction

Program Scope

The scope of ETP is national: it is an environmental research and innovation plan for the Kingdom of Saudi Arabia. The plan involves universities, industry, and government stakeholders. KACST has overall responsibility for the development and execution of the plan.

The scope of activities under the Environmental Technologies Plan includes projects and policies designed to meet the Kingdom's needs as articulated in the National Policy for Science and Technology. The program will not undertake freestanding basic or fundamental research in environmental topics, although basic research may be included as part of environmental technology development processes. The scope does not include the development of environmental rules and standards. For implementation, the program will concentrate on areas of application and projects that lead to technology localization, transfer and development through efficient utilization of available skills and resources.

The program's main deliverables are environmental technologies that are localized and developed through building prototypes, pilot plants, designs, and similar products. These localized technologies will be exploited by end users, including technology incubators and Technology Innovation Centers to serve defined needs. The program's main method is research and development (R&D). The program scope includes technical work that supports the transferring, localization and development of technology, spanning research to applications. As a result, scope realization will require collaboration and coordination with all related parties along the localization and development paths.

The program is comprised of major stakeholders in the Kingdom's environmental domain from both the public and private sectors. These stakeholders are both benefactors and beneficiaries of the program. The synergy generated by marshalling the mutual efforts of these stakeholders is a main strategic core competency of the program. The time span of this plan is the first 5-year phase of the 20-year National Policy for Science and Technology.

Introduction

Plan Development Process

The development of this plan began with the identification of relevant stakeholders within the Kingdom and the creation of vision and mission statements. In addition, background research was conducted to identify the current international position of the Kingdom in Environmental Technologies and the capacity of other countries' environmental technologies. The process for developing the Environmental Technologies Plan is outlined in figure 2 and figure 3.

Figure 2: Development Process for the Environmental Technology Program

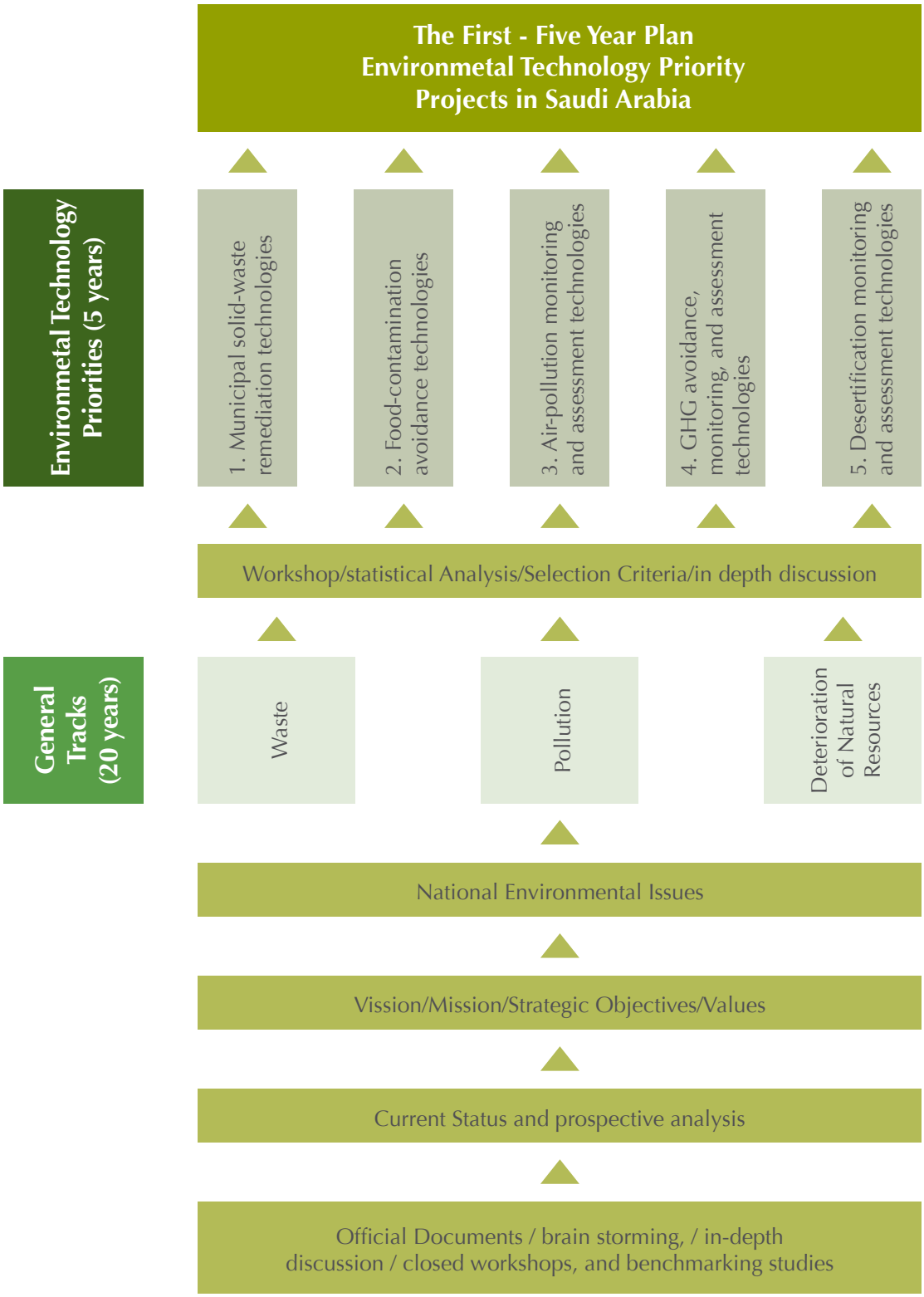
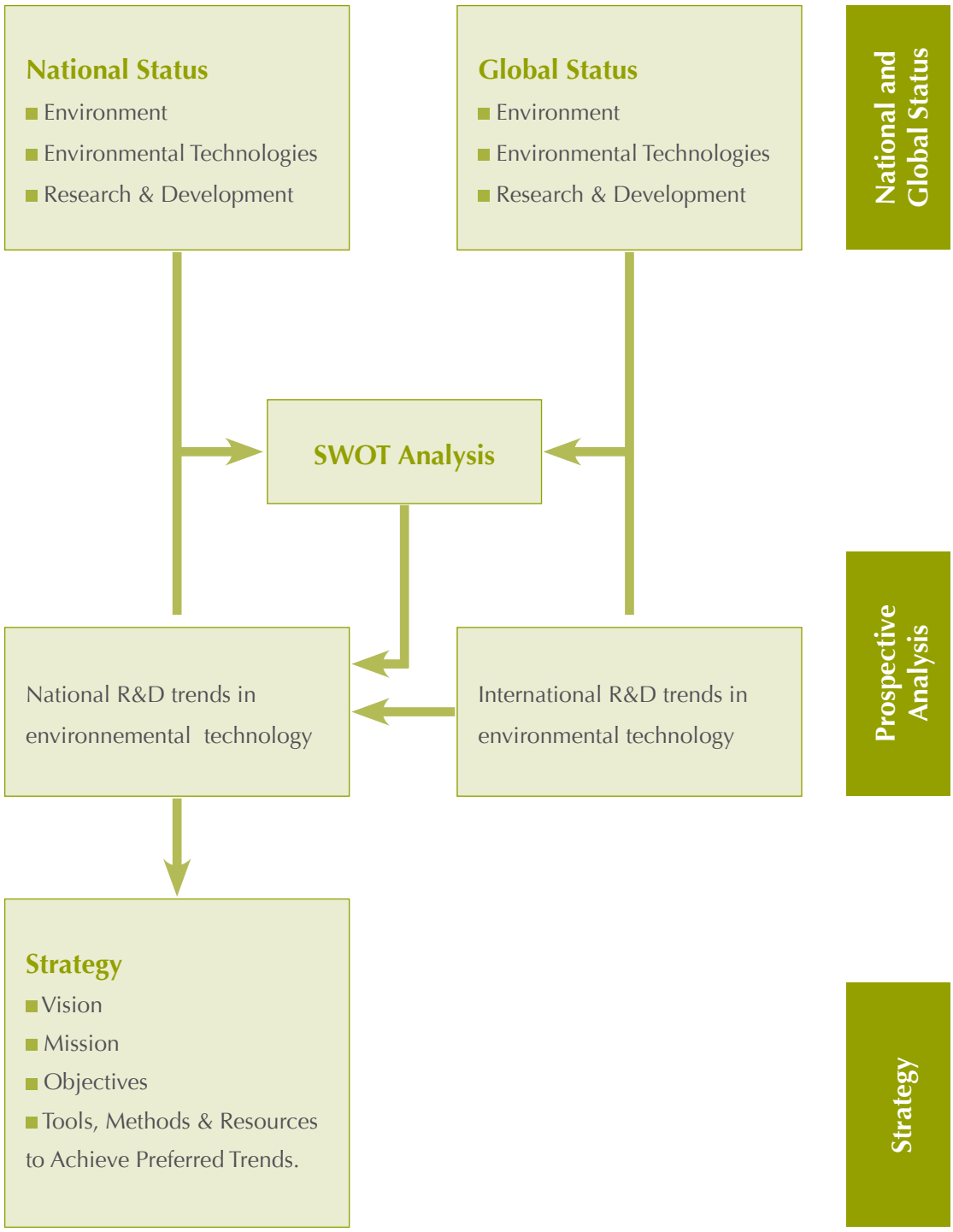


Figure 3: Framework Method for Studying National and Global S&T Status for the Environmental Technology Program.



KSA Environmental Technology Needs

The key needs of the Kingdom as outlined in the 20-year National Policy for Science and Technology are the following:

- To solve national environmental problems and respond to international environmental challenges.
- To support national industry with sound environmental technology solutions to improve production efficiency, and to promote environmental protection and sustainable development.
- To meet the high demand for sound environmental technologies that support the accelerating national development.
- To enhance national capabilities to fulfil regional and international obligations in environmental conventions.
- To achieve domestic capability in critical environmental technologies.
- To improve employment, investment opportunities and economic diversification in the Kingdom.

Stakeholders Roles

The stakeholders for ETP include KACST, PME, KSA universities, various independent or specialized research institutes, other government agencies, and private companies. Table 1 shows the roles of these stakeholders in the program.

Strategic Context

Table 1: Stakeholders and their roles:

Stakeholders	Roles
KACST	■ Plan, coordinate and manage the program.
	■ Conduct applied research, technology transfer and prototype applications development.
	■ Manage and participate in national projects.
	■ Provide support for university and industrial participation in national projects.
	■ Provide and manage national research facilities.
	■ Provide advice and services to government on science and technology.
Universities	■ Create new basic and applied scientific knowledge.
	■ Train students in science and engineering.
	■ Host and participate in Technology Innovation Centers.
	■ Participate in collaborative projects.
Independent or Government Specialized Research Centers	■ Create new applied scientific knowledge.
	■ Participate in collaborative projects.
Ministries and Government Agencies	■ Operation and implementation of environmental projects.
	■ Provide input to program on government R&D needs.
	■ Reduce regulatory and procedural barriers to R&D and innovation.
	■ Support R&D in universities and industry.
Private Sector	■ Develop and commercialize products and processes resulting from the program.
	■ Communicate company needs to program.
	■ Support and participate in collaborative R&D projects.
	■ Support and participate in the Technology Innovation Centers.

Analysis of Comparable Environmental Technology R&D Institutes

As part of the background work for this plan, the planning team reviewed several other environmental technology research laboratories around the world, selected to include a mix of government supported laboratories with functions similar to that of KACST's ETP in diverse countries. They included:

- National Environmental Engineering Research Institute (NEERI), in India.
- National Institute for Environmental Studies (NIES), in Japan.
- Centre for Ecology and Hydrology (CEH), in United Kingdom.
- The U.S. EPA Health and Environmental Effects Research Laboratory (NHEERL), in the United States of America.

These institutes are working in a range of technical areas similar to those considered for this plan, including:

- Global Environment.
- Waste/Recycling.
- Atmospheric Environment.
- Health.
- Municipal solid and hazardous wastes.
- Biodiversity.
- Environmental Informatics.
- Safe land.

A full description of these laboratories' programs can be found in a separate document.[1]

Analysis of Environmental Technology Publications and Patents

Environmental R&D is a multidisciplinary field that spans many research areas, including food science, meteorology, environmental engineering, biotechnology, toxicology, and geosciences. The overall field, "environment," as well as sub-topics, were defined in close consultation with KACST researchers and other KSA stakeholders, who provided detailed lists of keyword terms that were used to develop search queries for publication and patent database.[2] The KSA environment program identifies five sub-topics: municipal solid waste remediation technologies, food contamination avoidance technologies, air pollution monitoring and assessment technologies, greenhouse gases avoidance, monitoring, and assessment technologies, and desertification monitoring and assessment technologies. The scope of this study was restricted to only recent publication (2005-2007) and patent (2002-2006) activity in these fields.

There is general agreement that publications and patents strongly correlate with scientific research capacity, although publication and patent counts alone do not fully represent the quality or scope of research. Nonetheless, publication and patent activity have long been used as indicators for knowledge creation and research output.[3] Several indicators, including forward citations

1 Strategic Review: Environmental Technology. Report prepared by SRI International for KACST.

2 ISI Web of Science and Delphion were queried for scientific publication and U.S. patent application data, respectively. The ISI Web of Science is a database of peer-reviewed articles in major scientific journals from around the world. Delphion is a searchable database of global patent activity, including the U.S. Patent and Trademark Office (USPTO). The USPTO is one of the world's major granters of patents and it has been argued that the U.S. market is so large that most important inventions from around the world are patented there.

3 Seminal research in the use of publications as a measure of scientific productivity includes A.J. Lotka, "The frequency distribution of scientific productivity," Journal of the Washington Academy of Sciences, vol 16 (1926); D. Price, Little Science, Big Science, (New York: Columbia university Press, 1963); J.R. Cole and S Cole, Social Stratification in Science, (Chicago: The University of Chicago Press, 1973); J. Gaston, The reward system in British and American science, (New York: John Wiley (1978); and M.F. Fox, "Publication productivity among scientists: a critical review," Social Studies of Science, vol 13, 1983.

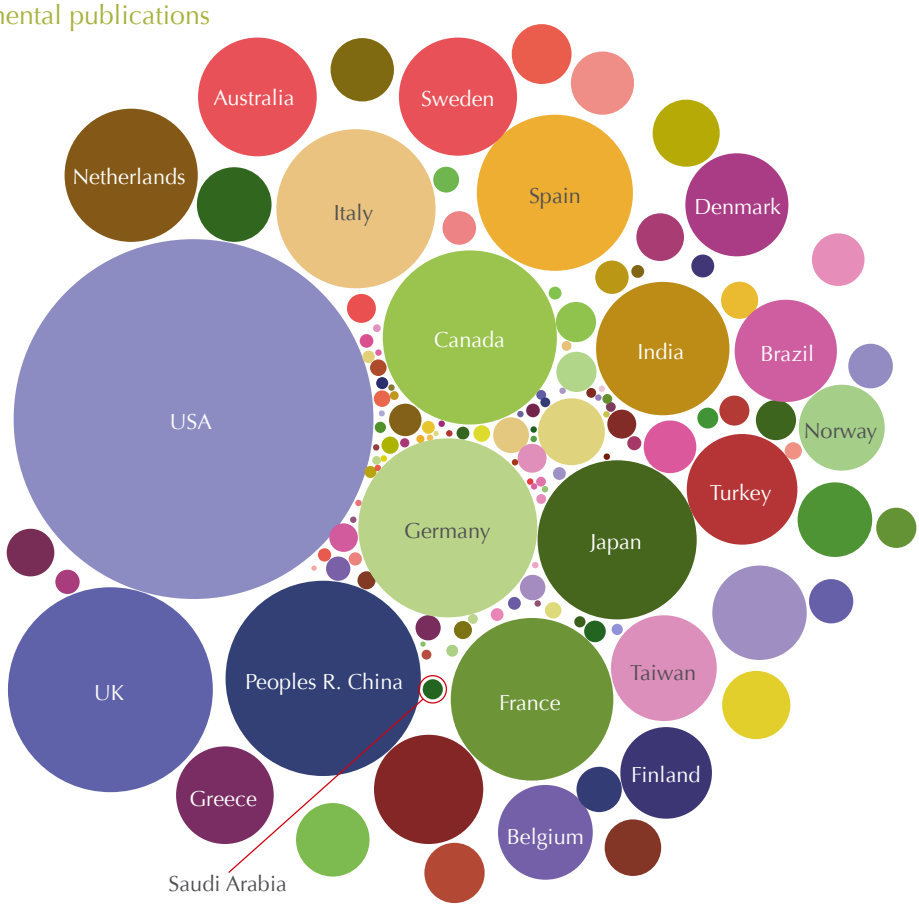
(the frequency at which publications and patents are cited by others), a measure of impact, and co-authoring relationships, an indicator of scientific collaboration, are presented below. Together, these indicators provide measures of collaboration, globalization and impact of science and technology research in fields related to the KSA environment program.

Findings

Global Environment Publication Activity

Between 2005 and 2007, there were 11369 articles published worldwide related to KSA energy research priorities.[4] As shown in figure 4, the United States was the world's largest producer of related articles, generating 2760 articles over this time period. The United Kingdom was a distant second, producing 981 articles followed by the People's Republic of China and Germany with 923 and 729 articles respectively. Saudi Arabia was tied for the 62nd largest producer of publications, producing 12 articles in ISI-indexed journals[5].

Figure 4: Environmental publications



4 Throughout this report, "environment" refers only to the subset of environment-related fields defined by the KSA environment program.

5 A publication is assigned to a country if any of the publication's author's affiliations are located in that country. Because publications often have multiple authors, a single publication may be assigned to multiple countries. Aggregate figures, such as total global publication output, count each publication only once, but adding up sub-totals may yield a result larger than the reported total due to multiple counting.

Strategic Context

As shown in table 2, air pollution monitoring and assessment technologies R&D accounts for the highest proportion of environment related publications followed by food contamination avoidance technologies, greenhouse gas avoidance, monitoring, and assessment technologies, municipal solid waste remediation technologies, and desertification monitoring and assessment technologies.

Table 2: Environment Sub-Topics (2005 - 2007)

Sub-Topic	Publications
Air Pollution Monitoring and Assessment Technologies	3888
Food Contamination Avoidance Technologies	3440
Greenhouse Gases - Avoidance, Monitoring, and Assessment Technologies	2673
Municipal Solid Waste Remediation Technologies	2464
Desertification Monitoring and Assessment Technologies	387

Benchmark Countries

Average publication impact is calculated as the number of citations of articles from a particular country divided by the total number of articles published by authors from that country. For instance, a country that published 50 articles that were cited 100 times would have an average publication impact of two. Between 2005 and 2007, the United States had the highest average publication impact of all countries at 3.17 followed by Germany and the United Kingdom. The average publication impact for Saudi Arabia was 0.67 with 8 citations of 12 articles. Table 3 presents publication and citation counts for benchmark countries.[6]

Table 3: Benchmark Countries Energy Publication (2005 -2007)

Country	Publications	Total Citations	Average Publication Impact
USA	2760	8760	3.17
Germany	729	2262	3.10
UK	981	3039	3.10
South Africa	68	182	2.68
Australia	321	845	2.63
Singapore	48	118	2.46
New Zealand	97	229	2.36

6 Benchmark countries include global leaders in terms of total environment publication output in addition to a list of specific countries provided by KACST.

Country	Publications	Total Citations	Average Publication Impact
France	597	1306	2.19
Canada	707	1511	2.14
Japan	610	1254	2.06
Italy	578	1185	2.05
India	443	880	1.99
Spain	592	1020	1.72
Peoples R. China	923	1455	1.58
Brazil	250	387	1.55
South Korea	217	290	1.34
Saudi Arabia	12	8	0.67

Environment Research Organizations

Environment R&D publications are produced at several thousand research institutions in more than 130 countries. As shown in table 4, the three institutions producing the largest number of publications related to KSA environmental research priorities are the Chinese Academy of Sciences (287), the United States Department of Agriculture (223), and Consejo Superior de Investigaciones Científicas (131). The Chinese Academy of Sciences remains the number one producer of articles related to greenhouse gases avoidance, monitoring, and assessment technologies, air pollution monitoring and assessment technologies, and desertification monitoring and assessment technologies. However, the United States Department of Agriculture is the leading producer of food contamination avoidance technologies while Consejo Superior de Investigaciones Científicas is the leading producer of municipal solid waste remediation technologies related articles.

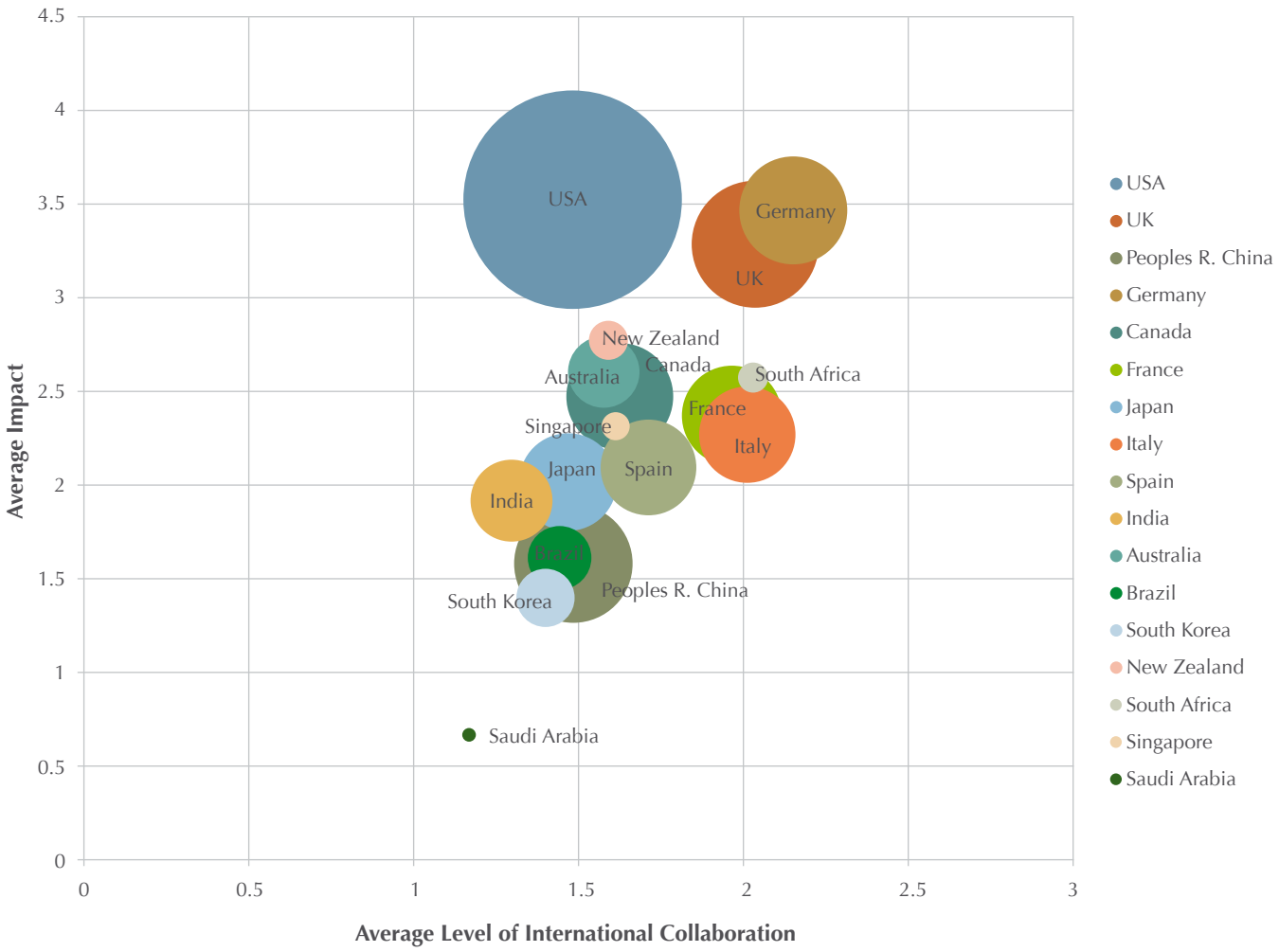
Table 4: Global Environment R&D Organizations (2005 - 2007)

Institution	Total Publications	Average Impact	Food Contamination Avoidance Technologies	Greenhouse Gases - Avoidance, Monitoring, and Assessment Technologies	Air Pollution Monitoring and Assessment Technologies	Municipal Solid Waste Remediation Technologies	Desertification Monitoring and Assessment Technologies
Chinese Acad Sci	287	1.76	26	65	67	42	95
USDA	223	2.56	143	29	20	19	13
CSIC	131	1.86	42	14	13	53	10
Univ Texas	106	3.27	26	19	43	17	2
INRA	91	2.76	50	18	5	16	2
Indian Inst Technol	85	4.11	4	10	28	47	
Univ London Imperial Coll Sci Technol & Med	82	2.62	7	16	37	22	
NASA	82	5.94		33	43		8
Univ Wageningen & Res Ctr	79	2.70	46	22	5	5	3
CNR	76	2.55	14	10	39	12	3
US EPA	76	2.71	4	15	47	10	1
Natl Ctr Atmospher Res	75	7.72		50	26		1
Harvard Univ	74	4.58	15	10	49	1	
Tech Univ Denmark	74	2.47	20	5	13	42	
Univ Utrecht	69	4.59	18	29	16	6	3

International Collaboration and Publication Impact

For countries with a similar level of publication activity, those countries with a high level of international collaboration also tend to produce publications with a high level of impact. In this study, international collaboration is calculated as the average number of countries represented per publication, based on authors' addresses. Figure 5 plots a country's level of international collaboration (horizontal axis) against the average impact of its publications (vertical axis). Countries such as Germany and the United Kingdom that show significant international collaborative activity also tend to produce papers with a higher average impact. Saudi Arabia has both a low level of international collaboration and a low level of impact.

Figure 5: Environment Collaboration and Publication Impact (2005 - 2007)



KSA International Collaboration Activity

The 2005-2007 environmental technologies dataset included only two articles in which authors affiliated with KSA institutions collaborated internationally. These papers had coauthors in the United Arab Emirates and the United States.

Environment Journals

Table 5 presents journals with a significant level of publication activity related to KSA environmental technology sub-fields from 2005-2007.

Table 5: Environment Journals (2005-2007)

	Source	Records
Greenhouse Gases - Avoidance, Monitoring, and Assessment Technologies	ENERGY POLICY	163
	GEOPHYSICAL RESEARCH LETTERS	104
	CLIMATIC CHANGE	76
	JOURNAL OF CLIMATE	69
	ENERGY	58
	ATMOSPHERIC ENVIRONMENT	50
	AGRICULTURE ECOSYSTEMS & ENVIRONMENT	46
	CLIMATE DYNAMICS	45
	JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	45
	ENVIRONMENTAL SCIENCE & TECHNOLOGY	33
Municipal Solid Waste Remediation Technologies	WASTE MANAGEMENT	199
	JOURNAL OF HAZARDOUS MATERIALS	139
	CHEMOSPHERE	98
	WASTE MANAGEMENT & RESEARCH	76
	BIORESOURCE TECHNOLOGY	71
	ENVIRONMENTAL SCIENCE & TECHNOLOGY	70
	RESOURCES CONSERVATION AND RECYCLING	62
	COMPOST SCIENCE & UTILIZATION	31
	WATER SCIENCE AND TECHNOLOGY	29
	SCIENCE OF THE TOTAL ENVIRONMENT	28

	Source	Records
Food Contamination Avoidance Technologies	JOURNAL OF FOOD PROTECTION	167
	INTERNATIONAL JOURNAL OF FOOD MICROBIOLOGY	126
	FOOD CONTROL	111
	JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY	83
	BRITISH FOOD JOURNAL	71
	JOURNAL OF FOOD ENGINEERING	70
	FOOD ADDITIVES AND CONTAMINANTS	60
	FOOD CHEMISTRY	53
	APPLIED AND ENVIRONMENTAL MICROBIOLOGY	43
	JOURNAL OF APPLIED MICROBIOLOGY	40
Air Pollution Monitoring and Assessment Technologies	ATMOSPHERIC ENVIRONMENT	442
	SCIENCE OF THE TOTAL ENVIRONMENT	120
	JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	110
	ENVIRONMENTAL MONITORING AND ASSESSMENT	105
	ENVIRONMENTAL SCIENCE & TECHNOLOGY	105
	JOURNAL OF THE AIR & WASTE MANAGEMENT ASSOCIATION	78
	ATMOSPHERIC CHEMISTRY AND PHYSICS	72
	ENVIRONMENTAL POLLUTION	70
	WATER AIR AND SOIL POLLUTION	61
	CHEMOSPHERE	55
Desertification Monitoring and Assessment Technologies	JOURNAL OF ARID ENVIRONMENTS	47
	ENVIRONMENTAL GEOLOGY	19
	LAND DEGRADATION & DEVELOPMENT	12
	CATENA	11
	GEOMORPHOLOGY	10
	ENVIRONMENTAL MONITORING AND ASSESSMENT	10
	ARID LAND RESEARCH AND MANAGEMENT	8
	GLOBAL CHANGE BIOLOGY	8
	GEOPHYSICAL RESEARCH LETTERS	7
	INTERNATIONAL JOURNAL OF REMOTE SENSING	6

Environment Patent Activity

As shown in table 6, between 2002 and 2006, there were 784 environment-related patent applications filed with the United States Patent Office (USPTO). The majority of these (486) listed at least one inventor from the United States. Other countries with a significant number of inventors include: Japan (85 applications), Canada (30 applications), and Germany (29 applications). There was one environment-related patent application that listed an inventor from Saudi Arabia over this time period. "Plastic recycling system and process," listed Horne, David, from Saudi Arabia, as the sole inventor.

Table 6: Environment Patents (2002-2006)

Country	Municipal Solid Waste Remediation Technologies	Food Contamination Avoidance Technologies	Air Pollution Monitoring and Assessment Technologies	Greenhouse Gasses Avoidance, Monitoring, and Assessment Technologies	Desertification Monitoring and Assessment Technologies	Total
United States	57	391	18	25	0	486
Japan	3	69	11	2	0	85
Canada	8	19	2	1	0	30
Germany	2	25	2	0	0	29
South Korea	1	17	8	0	0	26
United Kingdom	4	16	2	1	0	23
France	0	18	0	1	0	19
Australia	1	8	0	1	0	10
India	0	8	0	1	0	9
Italy	0	9	0	0	0	9
Spain	1	5	0	0	0	6
China	1	3	0	0	0	4
New Zealand	0	3	0	0	0	3
South Africa	0	2	0	0	0	2
Saudi Arabia	1	0	0	0	0	1
Brazil	0	0	0	0	0	0
Singapore	0	0	0	0	0	0

While the majority of environment related patent applications are defined as individually owned patent applications (584 applications) by the United States Patent Office, some institutions are designated as the patent assignee on a number of applications. These institutions that have records as inventors in environmental technology might be targets for collaboration. Kraft Foods Holdings Inc. is listed as the patent assignee on 12 environment related applications followed by Procter & Gamble Company (6 applications), Conair, Inc. (4 applications), and Unilever Bestfoods North America (4 applications). The only patent application with an inventor from Saudi Arabia was designated as an individually owned patent.

Table 7: Leading Environment Assignees (2002-2006)

USTPO Assignee	No. of Patents Apps.
Individually Owned Patents	584
Kraft Foods Holdings Inc.	12
Procter & Gamble Company	6
Conair, Inc.	4
Unilever Bestfoods North America	4

SWOT Analysis for KSA Environmental Technology Program

This section presents a SWOT (strengths, weaknesses, opportunities, and threats) analysis of the Saudi Arabia environmental R&D activities relative to achieving its vision. In a SWOT analysis, terms are defined as follows:

Strengths: internal attributes of the organization that are helpful to achieving the objective.

Weaknesses: internal attributes of the organization that are harmful to achieving the objective.

Opportunities: external conditions that are helpful to achieving the objective.

Threats: external conditions that are harmful to achieving the objective.

Strategic Context

Strengths:

- Issuance of "General Environmental Regulations" (GER): Meeting these requirements should boost demand for environmental technologies at the local level.
- Increasing determination within Saudi Arabia to conserve and protect the environment.
- Promising investment opportunities in environmental technologies at the local level.
- Availability of appropriate technical and scientific infrastructure required for scientific research in different environmental fields.
- Interest by major national institutions; such as King Abdulaziz City for Science and Technology, King Abdullah University for Science and Technology, and other universities; in advanced technologies such as nanotechnology, biotechnology, and advanced materials: Integration of these technologies could contribute to the development of advanced environmental technologies.
- Support by the General Authority for Investments for investing in environmental technologies.
- Financial support within the terms of the National Science and Technology Policy for environmental technology R&D.
- Growing demand for environmental technologies and lack of market competition at the local level.
- Ability of national scientific, technical, and environmental agencies to enhance construction of necessary infrastructure for transfer, localization, and development of environmental technologies.

Weaknesses:

- Lag in implementing General Environmental Regulations, leading to a slower uptake of environmental technologies at the local level.
- Failure to stimulate growth in the scientific and technical infrastructure.
- Low priority of environmental sciences in the National Science and Technology Policy.
- Lack of national private-sector investment in environmental protection and preservation, despite great opportunities available in the field.
- Lack of international cooperation in technology transfer.
- Lack of interest by local corporations to pursue R&D activities in the environment and its applications (with the exception of ARAMCO and SABIC).
- Inadequate scientific infrastructure; particularly technical personnel, equipment, and instrumentation.
- Inadequate strategic planning by relevant environmental agencies.
- Inability of national universities to establish facilities specializing in environmental engineering. The merger between science and engineering is necessary to develop and advance environmental technologies.

Strategic Context

Opportunities:

- Growing international market for environmental technologies; equivalent to about 600 billion US dollars in 2006.
- Higher return on investment (ROI) from environmental technologies: An estimated ROI of 25:1 for each dollar invested compared to a 1:1 ROI for military technologies.
- Commitments by industrial nations to transfer proven environmental technologies to developing countries.
- Growing international demand for environmental technologies, products, and services.
- The idea of global "environmental security", and its relationship to international security, integrity of natural systems, and economic and social welfare.
- Ratification by Saudi Arabia of regional and international environmental conventions.

Threats:

- Global competition to develop innovative environmental technologies.
- Reluctance of international experts and scientists to work in Saudi Arabia.
- Complex technology-transfer procedures.
- International commitments by Saudi Arabia to protect and preserve the environment.
- Global competition to acquire environmental technologies.
- Negative image of Saudi Arabia: In international environmental rankings Saudi Arabia is ranked 136 out of 146 countries.

Higher Strategy

This section provides the vision for the Kingdom in Environmental technology R&D, and the mission, values, and strategic goals for the program.

Vision

The vision for the KSA Environmental Technology Program is:

"Achieving environmentally sustainable development"

Mission

The mission for the KSA Environmental Technology Program is:

To transfer, localize, and develop high quality environmental technologies for environmental preservation and the development of natural resources through strategic alliances.

Higher Strategy

Program Values and Culture

To achieve excellence, the program will develop an internal culture through both the sponsorship of its leadership and commitment of its operational teams, based on the following values:

- The precepts of the Holy Quran and the Prophet Sunnah.
- Excellence of work.
- Professional integrity and ethical behavior.
- Openness and transparency.
- Commitment to achieving objectives.
- Support of creativity and innovation.
- Teamwork and collaboration.

Program Strategic Goals

The ETP strategic goals were determined in line with the goals and objectives of the National Policy for Science and Technology and the key needs of the kingdom. These goals are:

1- Establishing a national infrastructure for environmental technologies.

2- Transferring, localizing, and developing high quality environmental technologies to tackle national environmental issues.

3- Promoting innovative research and development in environmental technologies.

4- Contributing to the conception of advanced environmental technology industries to enhance the national economy.

5- Developing national and international strategic partnerships.

6- Providing scientific consultation in the field of environmental technologies.

Selection Process

An initial list of 18 pressing environmental issues in Saudi Arabia and a list of four general types of environmental technology were developed and discussed with the stakeholders. The initial list of 18 pressing environmental issues was classified into four main themes as follows:

- **Waste:**

1. Municipal waste water*.
2. Municipal solid waste.
3. Industrial waste water*.
4. Hazardous medical waste.
5. Hazardous waste.
6. Industrial solid waste.
7. Agricultural waste.

- **Pollution:**

1. Food contamination.
2. Oil pollution.
3. Radioactive contamination.
4. Thermal pollution.
5. Noise Pollution.

- **Air Quality:**

1. Ambient air quality.
2. Greenhouse gases.

- **Degradation of Natural Resources:**

1. Desertification.

2. Degradation of coastal areas.
3. Biodiversity.
4. Degradation of water resources*.

* Issues handled by Water Technology Program.

The four general types of environmental technology were:

- **Avoidance Technologies:** Technologies (equipments and processes) used to prevent or minimize generation of pollutants.
- **Monitoring and Assessment Technologies:** Technologies used to establish, monitor and asses the Condition of the environment.
- **Control Technologies:** Technologies that render hazardous substance harmless before they enter the environment.
- **Remediation and Restoration Technologies:** Technologies used to render hazardous substances harmless.

The combinations of environmental issues and types of environmental technologies were then analyzed using several sets of criteria. One set of criteria was applied to prioritized the most pressing environmental issues in Saudi Arabia on the following perspectives:

- **Health:** seriousness of health issues and degree of exposure.
- **Economic:** cost-benefit ratio.
- **Strategic:** direct and indirect relationships to national strategic objectives.
- **Social:** effect on quality of life and social welfare
- **Geographical:** geographical extent of the issue.
- **Political:** international obligations.

Other technology-related criteria were also considered in prioritizing environmental technologies for the Kingdom. These included:

Demand for technology:

- Compatibility with existing technology and future industrial development.
- Applicability of technology to end users.
- Ability to solve technical problems related to other technologies.

Technology Areas

Environment conducive to transfer, localization, and development:

- Intellectual property rights.
- Presence of a national scientific infrastructure.
- Scientific and technological cooperation.
- Ability to exploit international conventions.
- Integration with other strategic technologies.

Quality and Efficiency:

- Technology life cycle.
- Environmental impact of technology.
- Social impact of technology.

Technology economics:

- Magnitude of labor market and employability of national workforce.
- Cost-benefit ratio.
- Economic losses from a failure to adopt technologies.

Preliminary Priority Technology Needs

The application of the selection criteria to the list of pressing environmental issues and general types of technology resulted in five preliminary priority technology needs (PPTN):

1. Municipal solid waste remediation and restoration technologies.
2. Food contamination avoidance technologies.
3. Air pollution monitoring & assessment technologies.
4. Greenhouse gases avoidance, monitoring & assessment technologies.
5. Desertification monitoring & assessment technologies.

The next step will be to identify specific technologies within these high priority categories, and to develop a roadmap with targets, milestones, and assigned responsibilities for each specific technology.

Implementation Plan

Within KACST, the ETP manager will be responsible for the overall execution of the plan. Some portions of the plan may be managed by other parts of KACST. For example, the technology innovation centers and technology incubators may be managed by the Technology Development Center, which may specialize in the management of these kinds of programs. In this case, the program manager's role will be to provide technical input to the design and evaluation of these programs rather than to manage.

Many aspects of the plan represent new functions, especially in developing and managing national technology programs that include industry and universities and may involve international collaborations. A major task for the first year of the program will be for KACST to develop the necessary governance infrastructure. That will require hiring a managerial staff that is capable of overseeing large scale technical initiatives that span several different institutions. Although it is critical to start new research programs, it is essential to build the skills necessary to lead and develop these programs, and to plan them carefully. As part of the initial activities under this plan, KACST staff members will visit programs of a similar nature elsewhere in the world to discuss their management practices and lessons learned.

The ETP Advisory Committee will oversee the implementation of the plan. It will meet approximately four times a year and review progress in the program. Key performance indicators will be established for each subprogram. General performance indicators include:

- Growth or establishment of technology-based businesses due to the Environmental Technology Program.
- Amount of revenue and jobs created.
- Successful importation of technology resulting in new businesses or applications.

Implementation Plan

- Movement of projects to incubators.
- Licenses and licensing revenue to universities and research institutes.
- Environmental technology-related patents.
- Private sector funding of university and KACST ETP (indicates the value private sector places on university or KACST environmental technology R&D).
- Number and level of presentations in international conferences.
- Number and impact of publications.
- Extent of domestic and international R&D collaborations.
- Numbers of environmental technology advanced degrees awarded.

The advisory committee will also sponsor and oversee studies of emerging areas of environmental technology, to serve as the basis for developing new program areas. This plan is intended to be a dynamic document that will be updated at least annually and more frequently if required. In addition to the advisory committee input, it is expected that workshops with the research community, users, industry and other stakeholders will also contribute to both a continual evolution of the plan as well as a stronger environmental technology research in the Kingdom.

Diagram (1) illustrates the proposed implementation plan for the ETP in a broad perspective. The adopted approach for the implementation plan captured the concept of the Retrospective Analysis[8], which will insure: a) a dynamic-loop of planning , b) a coherent and smooth transition among various implementation stages, from the higher strategy stage to the marketing and financing stage, and c) attention to communicating visions, attracting resources from business and government, stimulating investigations, and monitoring progress.

8 Retrospective analyses cover time frames from typically decades past to the present, while prospective analyses cover time frames from the present to typically a decade or more into the future. Source: Ronald N. Kostoff, and Robert R. Schaller." Science and technology roadmaps". IEEE transactions on engineering management.

Implementation Plan

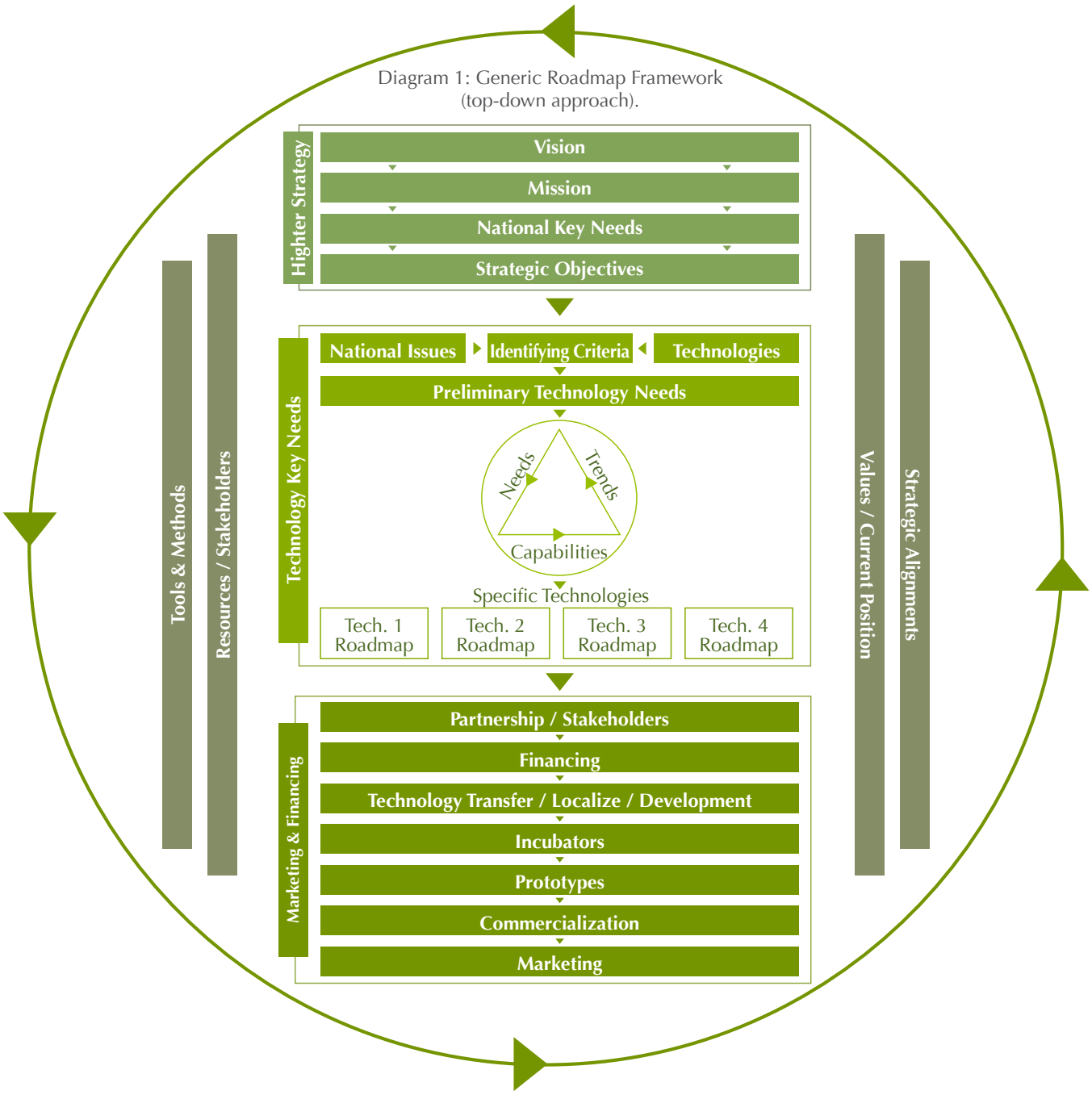


Diagram 1: Generic Roadmap Framework (top-down approach).

Appendix A

Environmental Technology Program Stakeholders:

The process of developing this plan included several workshops that focused on environmental technology needs in the Kingdom and on defining programs to meet those needs. Workshop participants and stakeholders members represented themselves as individuals and did not necessarily represent their organizations.

Appendix A

STAKEHOLDERS	REPRESENTATIVES
King Abdulaziz City for Science and Technology	Dr. Ahmed Mohammed Al-Abdulkader
	Mr. Abdullah Sultan Al-Khalid
	Mr. Abdullah Hassan Al-Naser
	Dr. Yusuf Saleh Al-Hafiz
	Dr. Kamel Mohammed Sheikho
	Prof. Ahmed Hammadi Al-Harbi
	Prof. Mohammed Abdalrauf bin Hussein
	Eng. Mohammed Ahmed Al-Shamsi
Presidency of Meteorology and Environment Protection	Dr. Samir Hamza Oyoni
	Eng. Nabil Asaad Murshid
	Dr. Taha Mohammed Zaatari
	Dr. Abdullah Ahmed Al- Haddad
National Commission for Wildlife Conservation and Development	Mr. AbdulAziz M. Al-Muhanna
	Mr. Omar A. Khoshim
Commission for Development of Makkah and Medina	Eng. Adnan J. Al-Saati
Ministry of Municipal and Rural Affairs	Mr. Abdalaziz F. Aldogather
Ministry of Trade and Industry	Eng. Ziad Ahmed Al-Yahya
King Fahad University of Petroleum and Minerals	Dr. Ala'edeen A. Bukhari
King Abdulaziz University	Dr. Mansour A. Al-Mazroui
Saudi ARAMCO	Dr. Khalid A. Al-Abdulkader
SABIC	Dr. Ahmed M. Alhazmi
The Council of Saudi Chambers of Commerce	Eng. Ahmad AbdulAziz Alsmari

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Doc. No. 21P0001-PLN-0001-ER01