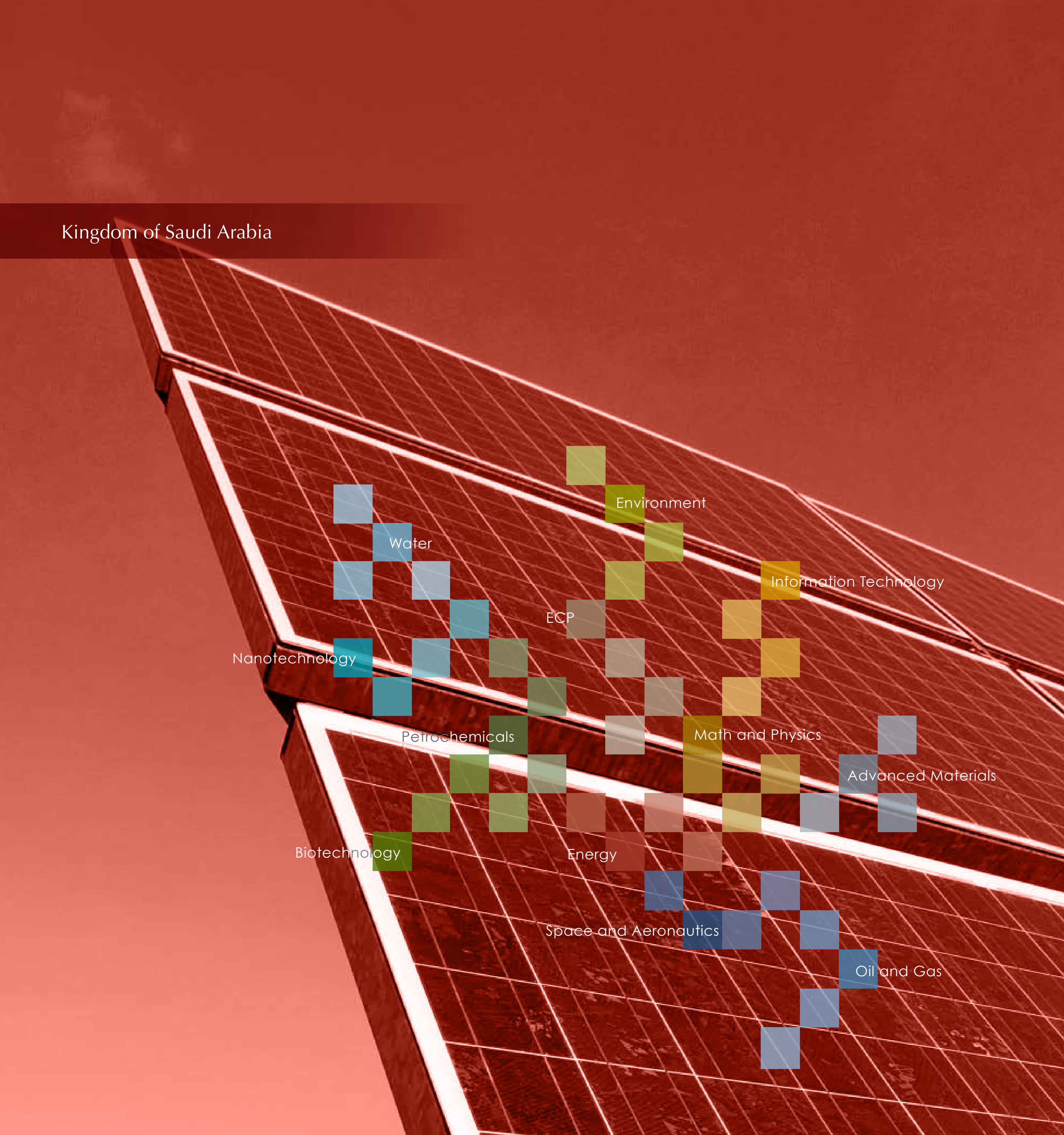

Strategic Priorities for Energy Technology Program

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King Abdulaziz City for Science and Technology

Ministry of Economy and Planning

Strategic Priorities for Energy 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. The King Abdulaziz City for Science and Technology (KACST) was given responsibility for developing 5-year strategic and implementation plans for each of these 11 technology programs. This roadmap is the plan for one of these programs, the Energy Technology Program.

Energy technologies are of particular importance to the Kingdom of Saudi Arabia (KSA). Energy is a key driver of the country's development and economic growth. Furthermore, the electricity sector in the Kingdom faces great challenges in fulfilling the rising demand for electricity consumption that is the foundation for economic and social development. The annual growth of electricity consumption in the KSA is estimated at 6.4 percent. In order to meet this demand, additional generation plants and reinforcement of distribution and transmission systems are needed. The estimated power generation for the year 2023 is estimated at 59,000 megawatts compared with 25,000 megawatts in 2001. Attempts to find scientific solutions to keep pace with this growing demand necessitate technology transfer and the development of technologies to improve electrical energy generation, transmission, distribution, and utilization.

New and renewable energies also show potential to gain a larger share of energy production in the future. High cost and production difficulties related to these technologies still have to be worked out in order to facilitate their more widespread use. Adaptation of these technologies in the KSA will contribute to a balanced and sustainable pace of development in the Kingdom, especially in remote areas. Sustaining the utilization of petroleum oil and gas in the transportation sector is a strategic goal for the Kingdom.

Hence, technologies leading to improved efficiency, fuel economy and reduced impact on the environment need to be developed.
This plan is based on input from the users and stakeholders of energy technologies in the Kingdom, including government agencies, universities and industry. The plan received extensive input, review, and comment from stakeholders through 16 small workshops as well as through a comprehensive workshop attended by more than forty participants.

The planning processes:

- Identified the key needs of the Kingdom for energy research and innovation.
- Assessed the strengths, weaknesses, opportunities, and threats for the program, including an analysis of KSA energy publications and patents and an assessment of international research institutes.
- Defined a mission and vision for the Kingdom's energy program.
- Defined the key technologies and other program areas needed to address the Kingdom's needs in energy research and innovation.

In addition to the technical needs, workshop participants identified a large number of areas where policies need to be changed or barriers removed to facilitate energy technology innovation. These needs include:

- Policies to facilitate research and development (R&D) collaboration between KACST, universities, and industry.
- Policy and organizational changes in universities to improve the ability of faculty members to conduct research.
- Expanded human resources for energy R&D.
- Improved knowledge exchange with respect to international technology developments.
- Expanded international collaboration, including cooperation between Saudi universities and international universities.
- Saudi participation in international standardization bodies.
- Small business contracting preferences to support innovative small companies.

The priority technology areas that emerged from this process are as follows:

- Renewable Energy Generation:
  - Solar Energy (Resource Assessment, Solar thermal, Solar collectors , Solar Cooling, Solar Desalination, Solar photovoltaic (PV) systems, PV Cell fabrication, PV applications).
  - Wind Energy (Resources Assessment, Grid-connected and stand-alone systems, Wind energy applications).
- Conventional Energy Generation:
  - Steam and Gas Turbines (turbine efficiency and blade treatment).
  - Micro-Turbines.
  - Waste Heat Extraction Processes.
  - Multi-Generation.
  - Combined Cycle.
- Electricity Distribution and Transmission:
  - Electrical Transformers (auto/smart transformer, new construction material ,sensors for measurement and protection).
  - Electrical Cables (new insulation material and design for high voltage).
  - Electrical Networks (automation, smart networks, development of software, hardware and sensors for communication in local and wide area networks).
  - Electrical Circuit Breakers; CB (CB for high voltage and extra high voltage; EHV, advanced design and operating mechanism, protection, insulation material.

Executive summary

- Energy Conservation and Management:
- Air Conditioning and Refrigeration(heat pump, central AC, AC cycles, refrigerants, compressor, condenser, energy auditing, control, absorption chillers).
- Lighting System(efficient lighting, ballast, auditing, compact fluorescent lamp, Control).
- Building Envelope (thermal insulation, window glazing, building shading, building energy management, building automation System).
- Boiler / Furnace Efficiency.
- Electric motors.
- Heat Exchangers(compact heat exchangers).

- Energy Storage:
- Super Capacitors.
- High-Speed Flywheels.
- Superconducting Magnetic.
- Advanced Batteries.
- Thermal Energy Storage.
- Pumped Storage.

- Fuel Cell and Hydrogen:
- Hydrogen Production from Hydrocarbon Fuels.
- Hydrogen Storage.
- Proton Exchange Fuel Cell.
- Solid Oxide Fuel Cell.
- Direct Methanol Fuel Cell.
- Stack Fabrication and Testing.
- Fuel Cell Electrodes.
- Fuel Cell Membrane.
- Fuel Cell Catalyst.

- Combustion:
- Automotive combustion.
- Direct Injection.
- Auto-Ignition/ Homogenous Charge Compression Ignition.
- Industrial combustion.
- Efficiency Enhancement.
- Emission Reduction.
- Combustion Modeling.
- Laser Application.
- Fuel Technologies.

The Energy Technology Program consists of a program leadership function, responsible for overall planning, management, and cross-cutting issues, and seven priority technical areas corresponding to the fields above.

The Energy Program will be directed by a Program Manager, who will be responsible for the overall execution of the plan. The Energy Technology Research and Innovation Advisory Committee, with stakeholder membership, will oversee the implementation of the plan. It will establish and review performance metrics and provide advice on the portfolio of projects. The 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

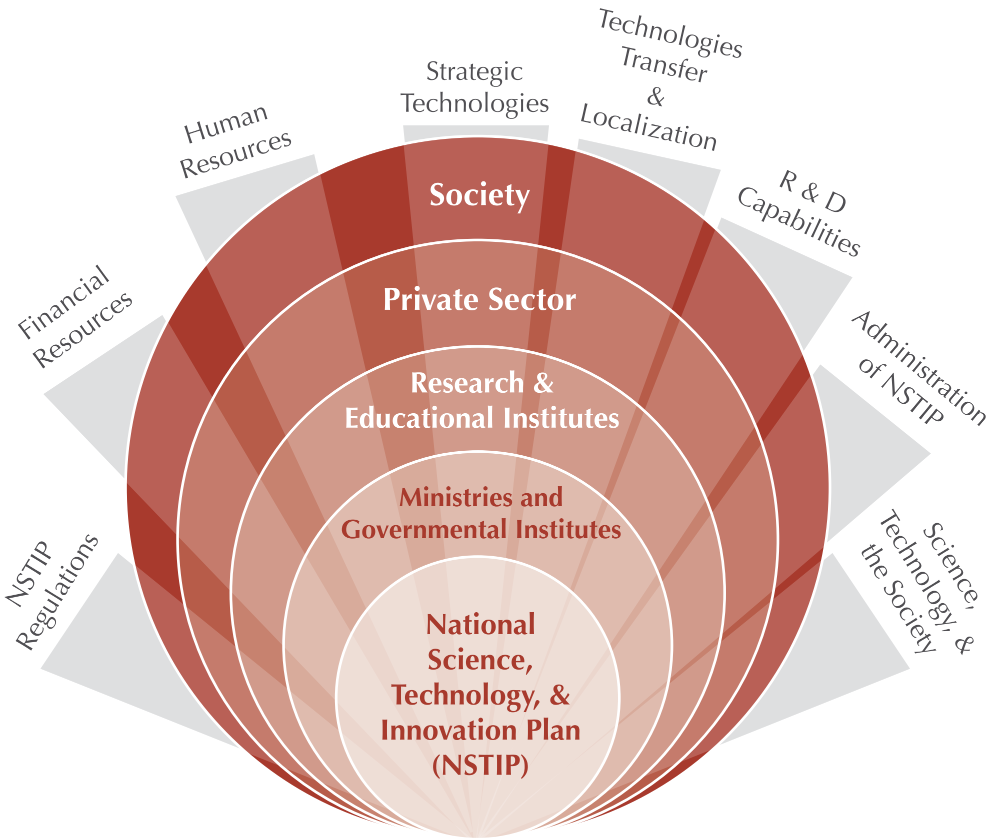
The King Abdulaziz City for Science and Technology (KACST) was directed by its charter of 1986 to "propose a national policy for the development of science and technology and to devise the strategy and plans necessary to implement them." In accordance with this charter, KACST launched a comprehensive effort in collaboration with the Ministry of Economy and Planning (MoEP), to develop a long-term national policy on science and technology. In July 2002, the Council of Ministers approved the national policy for science and technology, entitled "The Comprehensive, Long-Term, National Science and Technology Policy."

KACST and MoEP embarked on a national effort in collaboration with stakeholders to develop the national plan for science, technology and innovation (STI), which drew up the future direction of science, technology and innovation in the Kingdom, considering the role of KACST as well as that of universities, government, industry, and society at large. The plan encompasses eight major programs, depicted in figure 1, as follows:

1. Strategic and advanced technologies
2. Scientific research and technical development capabilities
3. Transfer, development, and localization of 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 Plan



In the «Strategic Technologies» area, KACST is responsible for 5-year strategic and implementation plans for 11 technologies:

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.

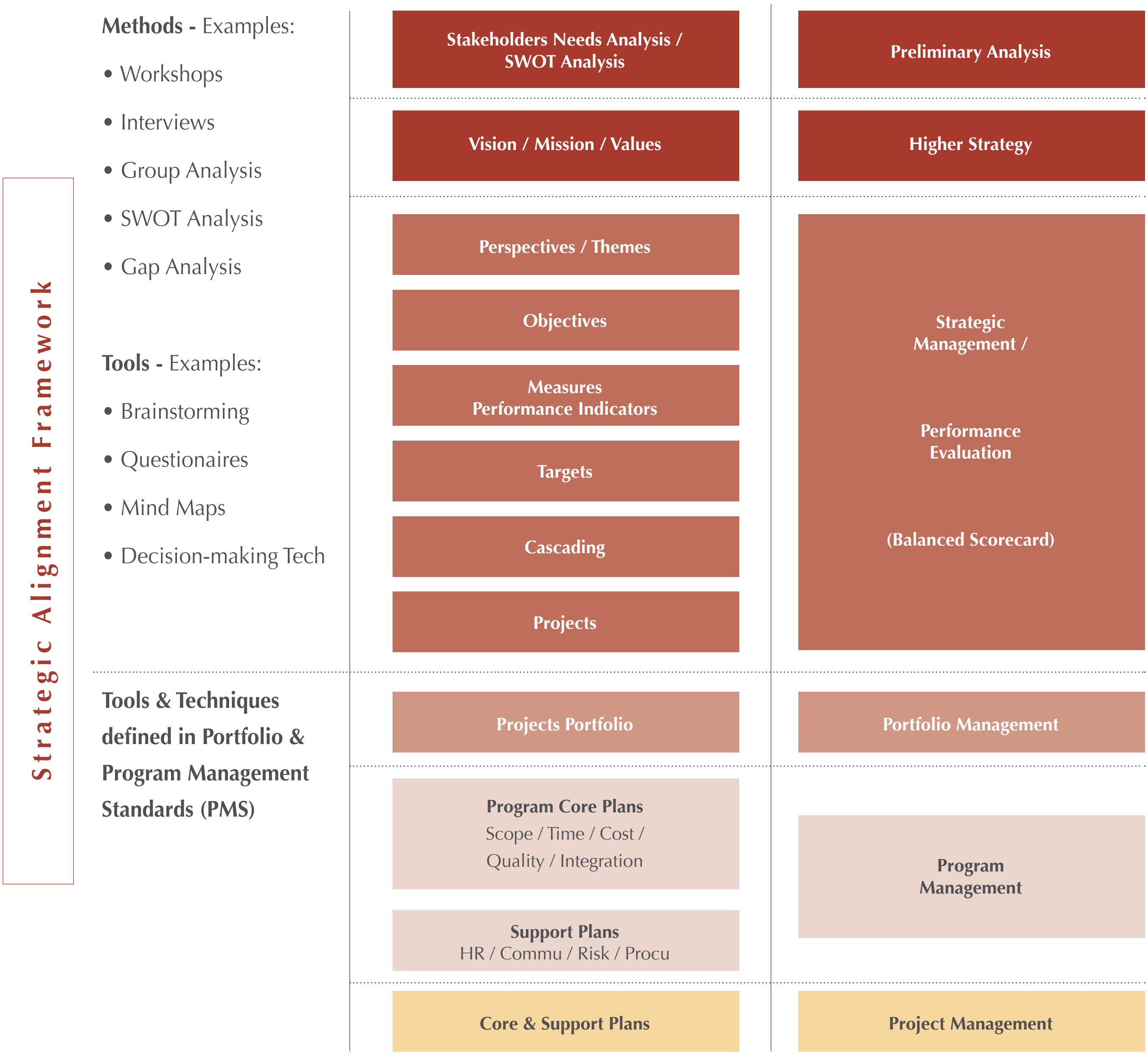
Scope

The scope of this plan is national: it is an energy 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.

Plan Development Process

The development of this plan began with identifying the stakeholders and users of energy research and innovation in the Kingdom, creating vision and mission statements, and conducting background research on the current position of the Kingdom in energy research and development (R&D) and on the role of other energy research institutes around the world. The plan development methodology is summarized in the following figure.

Figure 2: Plan Development Methodology



The plan received extensive input, review, and comment from the stakeholders through conducting 16 small workshops in addition to a comprehensive workshop attended by more than forty participants. This workshop focused on reviewing the elements of the strategic planning activities resulting from the preceding workshops. These elements include the SWOT analysis, vision and mission statements, and technology areas of importance to the Kingdom & other countries. The workshop was also used to brainstorm R&D projects in the selected energy fields. The workshop participant names are listed in Appendix A.

KSA Energy R&D Needs

The following key needs of the Kingdom were identified through workshops with the stakeholders:

- The demand for energy in Saudi Arabia will continue to be extremely high. The current population of Saudi Arabia is about 27 million. The annual population growth rate is approximately 2.9% that represents one of the highest in the world.
- The Kingdom's energy sector faces great challenges due to the growing demand in electricity consumption. The annual demand growth of electricity, which is a major foundation for any economic or social development, is estimated at 6.4 percent. In order to meet this demand, electricity companies are required to make substantial investments in order to increase the generation capacity as well as to upgrade and reinforce the distribution and transmission system. The power generation capacity required in the year 2023 is estimated at 59000 megawatts, compared with 25000 megawatts in 2001.
- There is a critical need to provide energy to the Kingdom's remote areas where renewable energy can be highly competitive in power generation. Connecting these areas to the conventional grid is prohibitively expensive. Furthermore, the KSA is embarking on a new age of industrialization. This new direction manifests itself in gigantic government-sponsored national construction projects such as Economic Cities and Industrial Clusters. In addition, industrial activity is expected to rise significantly due to the Kingdom's joining of the World Trade Organization. New industrial and development installations are therefore expected to add to the demand for energy and require new solutions for generation, distribution, conservation, and management.

Strategic Context

- It is also of interest to the Kingdom to support and improve the use of petroleum in the transportation sector. This sector utilizes nearly 60 percent of the world's oil production. Hence, programs to enhance the energy efficiency, improve the generation, and reduce the environmental impact of fuels need to be emphasized. Moreover, the Kingdom needs to keep pace with world advances in energy related technologies to be a technology producer, rather than just a user, in this field.

In addition to the technical needs, workshop participants identified a large number of areas where policies need to be changed or barriers removed. These needs include:

- Policies to facilitate R&D collaboration between KACST, universities, and industry.
- Policy and organizational changes in universities to improve the ability of faculty members to conduct research.
- Expanded human resources for energy R&D.
- Improved knowledge of international technology developments.
- Expanded international collaboration, including cooperation between Saudi universities and world universities.
- Saudi participation in international standardization bodies.
- Small business contracting preferences to support innovative small companies.

This plan is focused on the technical needs but also includes steps to address the non-technical needs, although some of these are primarily the responsibilities of other organizations.

Stakeholders Roles

The stakeholders for the Energy Research and Innovation Program include KACST, KSA universities, various independent or specialized research institutes, other government agencies, and private companies. The following table shows the roles of each of the stakeholders in the program.

Table 1: Stakeholders and their roles

Stakeholder	Role
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 Energy R&D Institutes

As part of the background work for this plan, the planning team reviewed several other energy technology research laboratories/centers around the world, selected to include a mix of government supported laboratories with functions similar to that of the energy program. These centers include:

- Research Institute for Sustainable Energy (RISE), Australia.
- Centre for Energy Technology (CET), Finland.
- Energy Research Centre of the Netherlands (ECN), Netherlands.
- Korea Institute of Energy Research (KIER), South Korea.
- Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy,United States.

The research foci and scope of the five institutions reflect interesting and useful approaches regarding strategies and options for development of energy research and related technology. From a national planning perspective, the consideration of national government research institutes (United States, the Netherlands, and South Korea) and university-based national institutes (Australia and Finland) provides a continuum of policy and institutional understanding in regard to the strategic role and activities of research institutes.

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

- Renewable energy.
- Methods to produce cleaner fossil fuels.
- Technologies and processes to improve energy efficiency.
- Development of hydrogen and fuel cell technologies.

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

Analysis of Energy Publications and Patents

Energy is a broad field encompassing many different research areas and enabling technologies, such as: mechanical engineering, thermodynamics, chemical engineering, applied physics, and environmental sciences. The overall field, "energy", 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 query publication and patent databases.[2] The KSA energy program identified seven sub-topics: renewable energy generation, conventional energy generation, electricity energy distribution and transferring, energy conservation and management, energy storage, fuel cell and hydrogen, and combustion. The scope of this analysis was restricted to only recent publication (2006 - 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 are presented below. These include forward citations, which are the frequency at which publications and patents are cited by others and are an indicator of impact, and co-authoring relationships, which are an indicator of scientific collaboration. Together, these indicators provide measures of collaboration, globalization and impact of science and technology research in fields related to the KSA energy program.

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

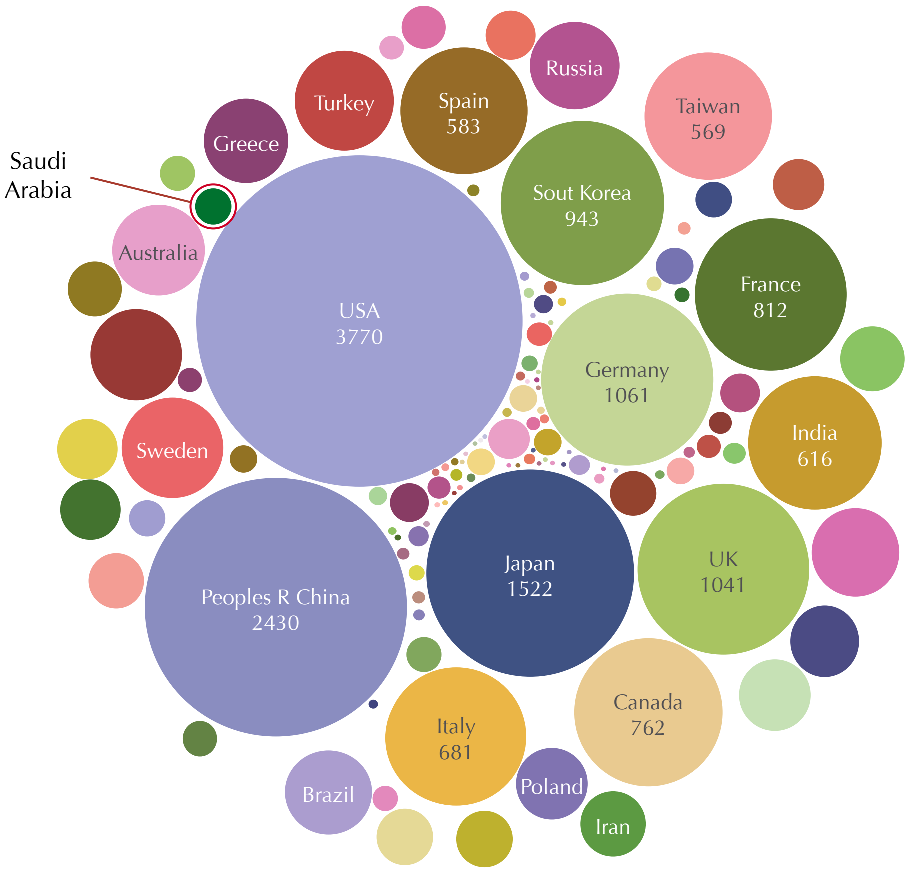
2 ISI Web of Science and Delphion were queried for scientific publication and U.S. patent application data, respectively. The ISI Web of Science is a database of peer-reviewed articles in major scientific journals from around the world. Delphion is a searchable database of global patent activity, including 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.

Global Energy Publication Activity

Between 2006 and 2007, there were 17117 articles published worldwide in energy fields related to KSA energy priorities.[4] The United States was the world's largest producer of related articles, generating 3770 articles over this time period. The People's Republic of China was second, producing 2430 articles, followed by Japan and Germany, with 1522 and 1061 articles respectively. Saudi Arabia was the 43rd largest producer of publications, producing 48 articles in ISI-indexed journals. Figure 3 shows the number of publications produced by selected countries over this time period.[5]

Figure 3: Energy publications (2006 - 2007)



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.

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

Sub-Topic	Publications
Fuel Cell and Hydrogen	4621
Energy Conservation and Management	3727
Renewable Energy Generation	3167
Combustion	2242
Electricity Energy Distribution and Transferring	1964
Conventional Energy Generation	1509
Energy Storage	1045

As shown in table 2, Fuel cell and hydrogen R&D accounts for the highest number of energy related publications (4621) followed by: energy conservation and management (3727), renewable energy generation (3167), combustion (2242), electricity distribution and transferring (1964), conventional energy generation (1509), and energy storage (1045).

Benchmark Country Publication Impact

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 2006 and 2007, the Netherlands had the highest average publication impact of all countries at 1.63 followed by the United States (1.57), Germany (1.34), and South Korea (1.22). The average publication impact for Saudi Arabia was 0.29 with 14 citations of 48 articles. Table 3 below presents publication and citation counts for benchmark countries.[6]

Table 3: Publication Impact (2006 -2007)

Country	Publications	Total Citations	Average Publication Impact
Netherlands	300	490	1.63
USA	3770	5906	1.57
Germany	1061	1423	1.34
South Korea	943	1155	1.22
UK	1041	1223	1.17

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

Country	Publications	Total Citations	Average Publication Impact
Japan	1522	1770	1.16
Peoples R. China	2430	2530	1.04
Australia	288	293	1.02
Finland	125	106	0.85
UAE	13	9	0.69
Egypt	93	32	0.34
Saudi Arabia	48	14	0.29
Algeria	45	12	0.27
Jordan	26	6	0.23
Tunisia	54	12	0.22
Bahrain	10	1	0.10
Kuwait	26	2	0.08
Oman	8	0	0.00
Syria	4	0	0.00

Energy Research Organizations

The energy publication dataset included nearly 40,000 different authors from thousands of research organizations in 119 countries. As shown in table 4, the three institutions producing the largest number of publications related to energy R&D are the Chinese Academy of Sciences (502), Tsing Hua University (249), and the Indian Institute of Technology (211). Shanghai Jiao Tong University is the leading publisher of energy conservation and management related articles while Xian Jiaotong University is the leading producer of electricity energy distribution and transmission articles and the Indian Institute of Technology is the leading producer of conventional energy generation related articles.

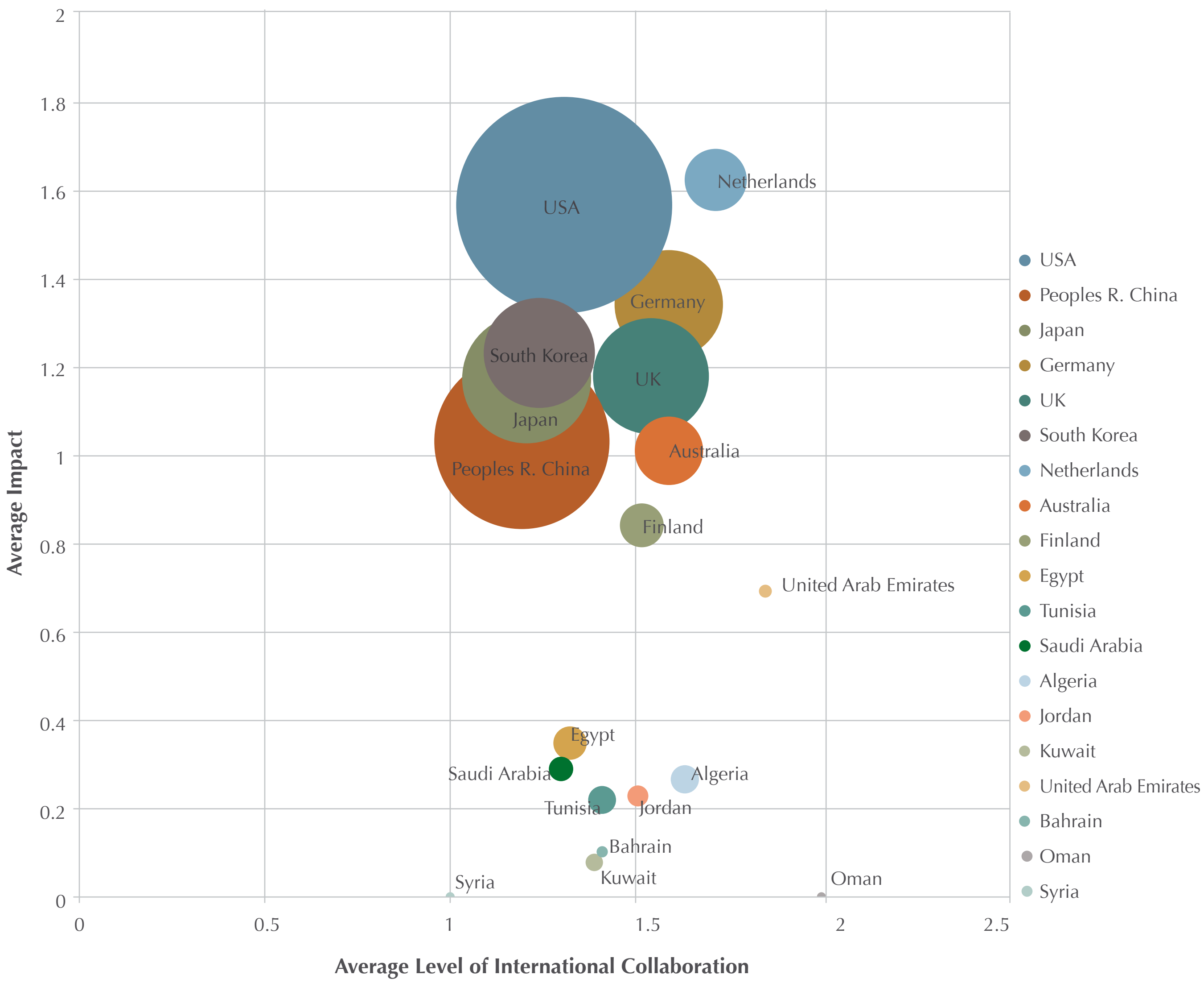
Table 4: Global Energy Research Organizations (2006 - 2007)

Institution	Total Publication	Average Impact	Fuel Cell and Hydrogen	Energy Conservation and Management	Renewable Energy Generation	Combustion	Electricity Distribution and Transmission	Conventional Energy Generation	Energy Storage
Chinese Acad Sci	502	1.56	225	59	124	45	23	23	31
Tsing Hua University	249	0.88	106	46	23	30	20	18	20
Indian Inst Technol	211	0.38	36	60	36	25	30	25	13
Shanghai Jiao Tong Univ	200	0.58	54	90	23	31	10	22	5
Univ Sci & Technol China	145	0.64	32	21	30	45	15	2	10
Xian Jiaotong Univ	137	0.55	18	51	7	27	33	8	1
Penn State University	134	3.37	71	11	9	24	7	13	4
Russian Acad Sci	132	0.28	37	11	17	36	19	6	7
Univ Texas	131	1.25	23	25	16	17	27	21	6
Univ Illinois	115	0.99	29	42	9	18	13	6	3
CNRS	114	1.25	17	16	30	37	5	6	4
Natl Inst Adv Ind Sci & Technol Seto	113	2.18	56	12	24	2	7	10	7
Univ Calif Berkeley	110	1.90	31	21	18	22	10	8	2
Tokyo Institute Technol	109	1.00	42	27	21	9	10	9	9
Seoul Natl Univ	104	1.09	53	17	6	7	16	6	8

International Collaboration and Publication Impact

In this study, international collaboration is calculated as the average number of countries represented per publication, based on authors' addresses. Figure 4 plots a country's level of international collaboration (horizontal axis) against the average impact of its publications (vertical axis).

Figure 4: Energy Collaboration and Publication Impact (2006 - 2007)



KSA Collaboration Activity

As shown in table 5, authors affiliated with KSA institutions collaborated on a significant number of articles with authors from: Canada (4 publications), Egypt (2), and the United States (2). KSA-affiliated authors collaborated on one article with authors from: Ireland, Italy, Jordan, Singapore, Tunisia, and the United Kingdom.

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Table 5: KSA Collaborators (2002 - 2006)

Country	Number of Publications
Canada	4
Egypt	2
United States	2
Ireland	1
Italy	1
Jordan	1
Singapore	1
Tunisia	1
United Kingdom	1

Energy Journals

Table 6 presents journals with a significant level of publication activity related to KSA energy sub-fields from 2006-2007.

Table 6: Energy Journals (2006 - 2007)

	Journal	Publications
Energy Conservation	APPLIED THERMAL ENGINEERING	215
	INTERNATIONAL JOURNAL OF REFRIGERATION-REVUE INTERNATIONALE DU FROID	161
	ENERGY AND BUILDINGS	132
	ENERGY CONVERSION AND MANAGEMENT	123
	BUILDING AND ENVIRONMENT	94
	INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER	88
	ENERGY	60
	INTERNATIONAL JOURNAL OF ENERGY RESEARCH	53
	ENERGY POLICY	49
	APPLIED ENERGY	46

	Journal	Publications
Electricity Distribution and Transmission	IEEE TRANSACTIONS ON POWER DELIVERY	158
	IEEE TRANSACTIONS ON DIELECTRICS AND ELECTRICAL INSULATION	95
	IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY	93
	IEEE TRANSACTIONS ON POWER SYSTEMS	87
	ELECTRIC POWER SYSTEMS RESEARCH	55
	ENERGY POLICY	28
	IEEE TRANSACTIONS ON POWER ELECTRONICS	26
	INTERNATIONAL JOURNAL OF ELECTRICAL POWER & ENERGY SYSTEMS	25
	IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS	25
	IEEE TRANSACTIONS ON MAGNETICS	25
Conventional Energy Generation	JOURNAL OF ENGINEERING FOR GAS TURBINES AND POWER-TRANSACTIONS OF THE ASME	94
	APPLIED THERMAL ENGINEERING	68
	ENERGY	65
	JOURNAL OF TURBOMACHINERY-TRANSACTIONS OF THE ASME	54
	ENERGY POLICY	43
	JOURNAL OF POWER SOURCES	41
	ENERGY CONVERSION AND MANAGEMENT	34
	INTERNATIONAL JOURNAL OF ENERGY RESEARCH	31
	PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART A-JOURNAL OF POWER AND ENERGY	29
	JOURNAL OF PROPULSION AND POWER	26

	Journal	Publications
Combustion	PROCEEDINGS OF THE COMBUSTION INSTITUTE	143
	COMBUSTION AND FLAME	130
	ENERGY & FUELS	86
	FUEL	84
	COMBUSTION SCIENCE AND TECHNOLOGY	61
	PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART D-JOURNAL OF AUTOMOBILE ENGINEERING	50
	ATMOSPHERIC ENVIRONMENT	48
	INTERNATIONAL JOURNAL OF HYDROGEN ENERGY	43
	JOURNAL OF ENGINEERING FOR GAS TURBINES AND POWER-TRANSACTIONS OF THE ASME	38
	APPLIED THERMAL ENGINEERING	37

Energy Patent Activity

Between 2002 and 2006, there were 6029 energy related patent applications filed with the United States Patent Office (USPTO). As shown in table 7, the majority of these (3208) listed at least one inventor from the United States. Other countries with a significant number of inventors include: Japan (1069 applications), Germany (671 applications), and the United Kingdom (310 applications).

Table 7 Energy Patents (2002-2006)

Country	Renewable Energy Generation	Conventional Energy Generation	Electricity Energy Dist. and Transferring	Energy Cons. and Mgmt.	Energy Storage	Fuel Cell and Hydrogen	Combustion	Total
United States	556	1562	388	92	44	283	316	3208
Japan	182	402	58	8	3	158	265	1069
Germany	112	317	29	4	3	39	167	671
United Kingdom	41	232	10	3	3	8	15	310
Canada	30	126	33	10	3	29	31	255
South Korea	2	5	16	0	2	20	4	49
Netherlands	16	6	0	0	0	3	0	25

Country	Renewable Energy Generation	Conventional Energy Generation	Electricity Energy Dist. and Transferring	Energy Cons. and Mgmt.	Energy Storage	Fuel Cell and Hydrogen	Combustion	Total
Australia	11	6	2	0	0	3	0	25
Finland	0	9	9	1	0	0	1	20
China	2	3	6	0	2	2	0	15
Saudi Arabia	0	1	0	0	0	0	0	1
Algeria	0	0	0	0	0	0	0	0
Bahrain	0	0	0	0	0	0	0	0
Egypt	0	0	0	0	0	0	0	0
Jordan	0	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0
Oman	0	0	0	0	0	0	0	0
Syria	0	0	0	0	0	0	0	0
Tunisia	0	0	0	0	0	0	0	0
UAE	0	0	0	0	0	0	0	0

While the majority of energy related patent applications are defined as individually owned patent applications (4174 applications) by the United States Patent Office, institutions are designated as the patent assignee on a significant number of applications. These institutions have established track-records as innovators in energy technology fields related to KSA strategic priorities and could be targets for future collaborative outreach efforts. As shown in table 8, General Electric Company is listed as the patent assignee on 173 energy-related patent applications followed by Mitsubishi Heavy Industries, Ltd. (90 applications), Siemens Westinghouse Power Corporation (86 applications), and Rolls-Royce PLC (64 applications).

Table 8: Leading Energy Patent Assignees (2002 - 2006)

USTPO Assignee	No. of Patents Apps.
Individually Owned Patents	4174
General Electric Company	173
Mitsubishi Heavy Industries, Ltd	90
Siemens Westinghouse Power Corporation	86
Rolls-Royce PLC	64

SWOT Analysis for KSA Energy Research and Innovation Program

This section presents a SWOT (strengths, weaknesses, opportunities, and threats) analysis of the Saudi Arabia Energy Technology Program relative to achieving its vision. In a SWOT analysis, terms are defined as follows:

- **Strengths:** attributes of the organization that are helpful to achieving the objectives.
- **Weaknesses:** attributes of the organization that are harmful to achieving the objectives.
- **Opportunities:** external conditions that are helpful to achieving the objectives.
- **Threats:** external conditions that are harmful to achieving the objectives.

Strengths and weaknesses are internal to the organization while opportunities and threats are defined as external to the organization. For the purpose of this analysis, the "organization" is the Saudi Energy Technology Program, including KACST, universities, other government agencies, and companies. The following table shows the main identified SWOT attributes.

Table 9: SWOT Analysis

	Helpful	Harmful
Internal	**Strengths** ■ Financial and moral support from leadership. ■ Qualified researchers and experts with high motivation to form an active research core. ■ Ability to own some energy technologies.	**Weakness** ■ Lack of team spirit and teamwork among some stakeholders. ■ Lack of proper incentives. ■ Current governmental bureaucratic regulations and rules. ■ Insufficient information and information technology infrastructure.
External	**Opportunities** ■ Attracting qualified researchers, experts. ■ Encouraging local and foreign investments. ■ Ability to produce energy technologies at minimum cost through governmental support. ■ Enormous increase in electricity demand in the Kingdom.	**Threats** ■ Difficulties of transferring some energy technologies. ■ Deficiency of environmental protection regulations. ■ Lack of protection for local technology products from global competition, especially after joining WTO.

Higher Strategy

This section provides the vision for the Kingdom's Energy Technology Program, and defines the mission, values, and strategic goals for the program.

Vision

The vision for the Energy Technology Program is to be an international pioneering and referential program in adaptation and development of energy technologies through advanced working systems.

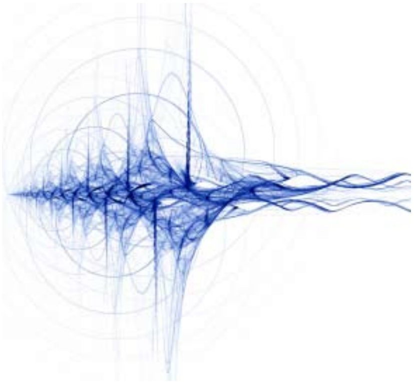
Mission

To build an advanced collaborative system for adapting and developing energy technologies through promoting an effective research and development culture, formulating comprehensive and competitive solutions, and developing expert human resources. This will ensure the optimal utilization of available resources, preserve the environment, and create new investment opportunities. Our higher purpose is to support the national economy and sustained national development.

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:

- 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 strategic goals of the Energy Technology Program are aligned with goals and objectives of the National Policy for Science and Technology and the key needs of the Kingdom that are compatible with and can be acted upon at this program level. Accordingly, the following strategically-aligned goals are selected for the program to work on for the next 5 years:

1- Efficiently exploiting national energy resources.

2- Supporting national self dependence in critical energy technologies.

3- Supporting the local energy industry to attain development and growth with technology solutions that facilitate new product development, improve production efficiency, price/value efficiency, environmental protection , especially in view of the rapidly rising demands for electrical and other forms of energy due to population growth, industrialization and globalization.

4- Developing innovative technologies for special needs that cannot be satisfied efficiently or economically through existing systems. For example, utilization of renewable energy technologies for remote areas.

5- Transferring, adapting and developing technologies for local users and markets through business models that promote creation and maximization of employment and investment opportunities, as well as economic diversification and competitiveness.

6- Supporting societal and cultural development towards optimal exploitation of technology and transformation from consuming to producing culture.

7- Promoting the national image and stature in science and technology.

These goals are the direct program goals which indirectly serve higher national goals such as supporting the national economy, sustained development, self-reliance and security. Furthermore, these strategic goals provide a basis for defining technology area selection criteria and program implementation objectives.

Technology Areas

Selection process

Initial List

An initial list of technology areas in the energy related fields was developed by stakeholders, taking into account the program's strategic goals and the higher strategy. The initial list was entered into a selection matrix that included selection criteria, weights, and scores. This led to a shorter list of priority technologies.

Selection Criteria

The program technology areas are selected based on selection criteria developed through stakeholders' workshops in alignment with the program's strategic goals, while also considering the program's mission. The selection criteria are as follows:

- Need for self dependence in technology/area.
- Ability to generate employment opportunities.
- Ease of transferring technology.
- Ability to generate investment opportunities.
- Possibility for further development of technology.
- Possibility to reduce electricity generation costs.
- Low technology adaptation & development cost.
- Possibility to reduce energy waste.
- Availability of local qualified human resources.
- Contribution to environmental protection.

Selected Technology Areas

The above selection criteria in addition to a weighing mechanism were used to narrow the initial list of the energy technology areas to those listed below:

- Renewable Energy Generation:

- Solar Energy (resource assessment, solar thermal, solar collectors , solar cooling, solar desalination, solar photovoltaic (PV) systems, PV cell fabrication, PV applications).

- Wind Energy (resources assessment, grid-connected and stand-alone systems, wind energy applications).

■ Conventional Energy Generation:

- Steam and Gas Turbines (turbine efficiency and blades treatment).
- Micro-Turbines.
- Waste Heat Extraction Processes.
- Multi-Generation.
- Combined Cycle.

■ Electricity Distribution and Transmission:

- Electrical Transformers (auto/smart transformer, new construction material ,sensors for measurement and protection).
- Electrical Cables (new insulation material and design for high voltage).
- Electrical Networks (automation, smart network, development of software, hardware and sensors for communication in local and wide area network).
- Electrical Circuit Breakers; CB (CB for high voltage and extra high voltage; EHV, advanced design and operating mechanism, protection, insulation material.

■ Energy Conservation and Management:

- Air conditioning and Refrigeration(heat pump, central AC, AC cycles, refrigerants, compressor, condenser, energy auditing, control, absorption chillers).
- Lighting System (efficient lighting, ballast, auditing, compact fluorescent lamp, Control).
- Building Envelope (thermal insulation, window glazing, building shading, building energy management, building automation System).
- Boiler / Furnace Efficiency.
- Electric motors.
- Heat Exchangers(compact heat exchangers).

■ Energy Storage:

- Super Capacitors.
- High-Speed Flywheels.
- Superconducting Magnetic.
- Advanced Batteries.
- Thermal Energy Storage.
- Pumped Storage.

■ Fuel Cell and Hydrogen:

- Hydrogen Production from Hydrocarbon Fuels.
- Hydrogen Storage.
- Proton Exchange Fuel Cell.
- Solid Oxide Fuel Cell.
- Direct Methanol Fuel Cell.
- Stack Fabrication and Testing.
- Fuel Cell Electrodes.
- Fuel Cell Membrane.
- Fuel Cell Catalyst.

■ Combustion:

- Automotive combustion.
- Direct Injection.
- Auto-Ignition / Homogenous Charge Compression Ignition.
- Industrial Combustion.
- Efficiency Enhancement .
- Emission Reduction.
- Combustion Modeling.
- Laser Application.
- Fuel Technologies.

Program Structure

Work in each of the technology areas is achieved through a program structure that starts with identifying specific implementation objectives within three major program domains/perspectives: infrastructure, core operations and value delivery. Performance indicators (and target levels) are defined for each objective and then projects are identified to satisfy the indicators. Stakeholders participated throughout the objectives, indicators and projects definition process (balanced scorecard development process).

Program Objectives

To achieve the program's strategy and strategic goals, the following implementation-oriented objectives were defined by stakeholders:

Infrastructure Objectives

- Develop Human Resources.
- Develop Organizational Culture.
- Develop Effective Financial Management.
- Develop Work Processes and Systems.
- Provide Laboratories and Equipments.
- Develop Knowledge Management System.

Core Operations Objectives

- Select Technologies.
- Establish Strategic Partnerships.
- Develop Technologies:
  - Conduct Fundamental Research.
  - Conduct Applied Research.
  - Build Pilot Plants.
- Localize Technology:
  - Conduct Localization Research & Studies.
  - Build Localization Pilot Plants.

- Transfer Technology:
- Assess Ready Technologies.

Value Delivery Objectives

- Work with the Incubators.
- Work with the Technology Innovation Centers.
- Work with the Program Beneficiaries:
- Provide Cost/Value Efficiency.
- Provide Job Opportunities.
- Provide Investment Opportunities.
- Support Environmental Protection.
- Use National Resources Effectively.
- Support National Goals:
- National Self-Reliance and Security.
- Continuous Development.
- Economic Growth.

Performance Indicators for Objectives

Performance indicators (measures) were defined by stakeholders for each of the program objectives mentioned above. Major performance indicators include:

- Percentage of HR Requirements Fulfilled.
- Program Return on Investment.
- Level of Strategic Objectives Fulfillment by Projects and Work Processes.
- Size of Used Knowledge Assets (Documented and Acquired).
- Level of Strategic Objectives Fulfillment by Selected Technologies.
- Percentage of Activated Strategic Partnerships to Total Required.
- Number of Innovations Leading to New Applications through Fundamental Research.
- Percentage of Applied Research Resulting in Prototypes, Pilot Plants or Applied Solutions.
- Percentage of Pilot Plants Leading to Production Line or Solution.
- Percentage of Applied Research Resulting in adapted Technologies.
- Percentage of By-Product Technologies Resulting from adapted Technologies.
- Percentage of Adaptation Pilot Plants Leading to Production Line or Solution.
- Percentage of ready technologies leading to production lines or solutions.
- Number of ready technologies passed on to Adaptation and development.
- Percentage of Technologies, Prototypes and Pilot Plants Adopted by Incubators from Total Offered.
- Percentage of Pre-Incubation and Production Prototypes Developed with Technology Innovation Centers (TIC's)to Total Offered.

Program Projects Categories

To fulfill the program objectives and achieve satisfactory levels in the performance indicators for each objective, initial program projects were identified by stakeholders, which can be divided into the three main categories outlined below. These projects will be subject to evaluation during implementation and possible cancellation or replacement, if not satisfactory (portfolio management):

- Infrastructure Projects: these are projects to plan, establish and manage the infrastructure required for the success and efficiency of the program including its human capital, knowledge capital, organizational capital, financial capital and other systems / resources.
- Research & Development Projects: these are projects to develop new knowledge and technology in each of the selected technology areas.
- Value Delivery Projects: these are projects to assist the program in delivering value to beneficiaries or in working with incubators and Technology Innovation Centers (TIC's).

Operational Plans

As highlighted in other sections, the energy program comprises a large number of projects including energy-related research and development projects, infrastructure projects and value delivery projects. Success of the program will be largely and critically dependent on success in accomplishing these projects. At the program level, higher level functions are addressed, but of the most importance is the support of individual projects. This section discusses the measures and functions that will be undertaken at these two levels: project and program.

Project Level

To maintain a high success rate in achieving the program's objectives, the following actions will be taken:

1. Achieving the required maturity level in the Program in managing and delivering projects as assessed by international standards.

2. Establishing a Project Management Office (PMO) structure with multiple tiers including program level, organization level (stakeholders / implementers) and project level PMO's.

3. Developing an effective unified process/methodology for project management to be used by the projects. This process could be customized as necessary by individual projects, but will generally adhere to this accepted standard. The unified process will cover all core project functions including scope, time, cost and quality management as well as project facilitating functions such as human resources, risk, communication, and vendor management.

4. Capacity building of project managers and supporting them with implementing PM functions.

5. Ensuring that the knowledge management function identified among the program's infrastructure objectives takes into account learning and building knowledge assets across projects, both sequentially and in parallel, and in both technical and project management domains.

6. Providing resource utilization efficiencies, such as pooling among projects

including human resources, facilities, equipment, labs and automated tools.

Program Level

At the program level, a fundamental question that will guide decisions and actions is «why is program level management needed?» Areas in which management at the program level is needed include:

- Portfolio management provides benefits that cannot be obtained by managing the multiple projects individually. Examples of benefits include:
  - Actions with effects across several projects; positive effects to be sought and negative effects to be avoided.
  - Decisions that can be exposed and handled only with a program perspective.
  - Risks that can be best addressed at a shared program level.
  - A Benefits Statement will be compiled for the Program and a Benefits Monitoring and Management scheme will be applied.
- Governance that will be provided by the Program to the higher national level(s) to ensure program performance and progress monitoring.
- Management of Stakeholders, to include:
  - Higher level stakeholders that cannot be managed/coordinated at the individual project level.
  - Assisting project managers, especially startups, in managing their project stakeholders.
  - Covering stakeholder interdependencies across projects.

One of the most important aspects of program stakeholder management will be to facilitate, realize, and manage the successful and effective change that the program should produce.

The following sections provide specific examples of concerns that will be addressed at program level through the: portfolio management plan, technology transfer plan, quality management plan, human resources plan, communications plan, and risk management plan.

Technology transfer plan

The energy research program will follow internationally recognized best practices in technology transfer. Key elements of the program that are designed to facilitate technology transfer are:

- Involvement of users in the program design: this occurs through user participation in the planning workshop and user involvement in the energy advisory committee. It is well recognized that user involvement in the research design leads to research and outcomes that are more likely to meet the needs of users, and thus are more likely to lead to successful innovation.

- National programs focused on the development of advanced pilot application projects: these projects involve KACST, government agencies, universities, and industry. Knowledge is transferred to companies in the course of the project. This is a proven method for developing technologies that serve a need and can be transferred easily to government or commercial users.

- **Use of university/industry centers as a major research mechanism throughout the plan**: industry involvement in these centers through the provision of advice and funding will encourage university research to be focused on user needs, thereby increasing the likelihood of technology transfer. These centers will also transfer knowledge to industry though the training and graduation of students (who have been trained on problems of interest to industry), who then take jobs in companies or form their own companies.
- **Linkage between the energy program and technology business incubators and other programs will aid the start-up of new energy technology companies.**

Quality Management Plan

The Energy Technology Program will follow international best practices in quality management for science and technology programs. Elements of this plan include:

- Advisory committee review of the overall program design and budget.
- Competitive, peer-reviewed selection processes for university-based research centers and projects.
- Annual reviews of technology development projects to ensure that milestones are being met.
- Periodic (every 5 years) subprogram evaluations conducted by a review committee supported by an experienced evaluator.

Procedures will be developed for disclosing and managing potential conflicts of interest among reviewers. In many cases, some international experts will be used on review panels to reduce possible conflicts of interest and to provide an independent external assessment.

Human Resources Plan

As noted in the SWOT analysis, human resources are a critical barrier for the success of the energy research and innovation program. The availability of skilled people, including both researchers and technical managers and leaders, is likely to limit the growth and success of KSA Energy Technology Program. The plan will require substantial numbers of energy professionals, including additional researchers, technical managers, and technical leaders at KACST, at universities and at companies. A central task of the program management function will be to address this issue.

To achieve the goals of the program, KACST will need to hire or develop additional program managers with the skills to lead national programs. To do this KACST will need additional flexibility with respect to compensation packages, speed of hiring, and ability to hire international staff.

Stakeholders will need additional researchers and engineers with the skills to develop innovative technologies. As part of the activities in this plan, the energy technology program will:

- Work with the other agencies to improve the quality

of undergraduate energy technology education, especially at regional universities.

- Work with new universities to develop research and education programs that especially match the Kingdom's energy technology research needs.
- Work to expand the contribution of women to energy research technology.
- Work to change policies to allow more international hiring, to bring specialized expertise to the Kingdom.
- Support training for researchers to become R&D managers and leaders.

At the undergraduate and especially graduate level, this plan is designed to help increase the numbers of energy researchers through its emphasis on university-industry centers. These centers are designed to train new students with research and innovation skills that are needed by research organizations and industry.

Communications Management Plan

The purpose of the communications management plan is to provide appropriate information to the program participants and stakeholders. One element of the communications plan is to improve communication throughout the KSA energy research community and to expand collaboration among members of the community. Aspects of this include:

- There will be a public website with information on program goals, accomplishments, funding opportunities, and other news.
- Periodic workshops will be held with users and stakeholders to define future program needs.
- Requests for proposals (for university centers, grants, and pilot application development programs) will be announced to the public.
- The program advisory board will review and comment on the program, and advisory board reports will be made public on the website.
- The program will sponsor workshops, conferences, and professional society activities to expand communication and networking throughout the community.
- Presentations on the program will be made at national and international conferences.

Another element of the plan is to define appropriate communications within the management structure of the plan. It is especially important that information about risks or difficulties in the program, such as delays, lack of resources, or non-attainment of goals be rapidly communicated to higher levels of management. A general principle is that management should never be surprised by bad news.

Risk Management Plan

The program presented here is an ambitious program that will challenge the capabilities of the Kingdom. There are several types of risks that could prevent attainment of program goals, including technical risks, market risks, and financial risks.

One source of technical risk to attainment of technical goals is, as described above, the lack of adequate human resources to implement the program. Approaches to managing this risk are:

- Adopting policies to attract people with the needed skills. This may involve raising salaries and recruiting internationally.
- Delaying or phasing in some program elements if people cannot be hired.
- Expanding the pool of people with needed skills through education and training programs, such as university water research centers (see human resources plan).

Another cause of technical risk is overly ambitious goals. To address this risk the program should have an independent review of technical goals to ensure they are feasible, and to adjust technical goals if milestones are not being met.

Market risk is that projects, while technically successful, do not lead to successful products because of poorly understood or changing market conditions, such as the development of other technical approaches. A way to address this risk is through:

- Designing programs based on carefully considered market needs.
- Monitoring international technology and market developments.
- Continual readjustment of plans in responses to changes in the environment.

Financial risk is the risk of funding shortfalls or of cost overruns. The way to address risks in this area is through careful program planning and monitoring, and early identification of possible cost overruns. Another financial risk is due to changes in the plan or funding due to political or policy changes. It will be important for the plan management to maintain communication with policy leaders to ensure they are aware of the accomplishments of the program and to get early warning of any policy changes that may affect the program.

Implementation of the Plan

Within KACST, the energy program manager will be responsible for the overall execution of the plan. Some portions of the plan may be managed by other parts of KACST.

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, in addition to detailed program planning, for KACST to acquire or develop the necessary skills through hiring or training. Although it is critical to rapidly start new research programs, it is essential to build the skills necessary to lead and develop these programs, and to plan them carefully.

The Energy Technology 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 for each objective were described previously. The advisory committee will also sponsor and oversee studies of emerging areas of energy, 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 energy research and innovation network in the Kingdom.

Appendix A: Plan Development Process

The plan received extensive input, review, and comment from the stakeholder participants through conducting 17 one-day workshops. The workshop participant's names are listed in the following table. The level of participation in the workshops varied from one workshop to another. Nearly all the participants attended the comprehensive one-day stakeholder workshop on October 29, 2007.

Table A-1: Stakeholder Participants

Name	Affiliation
Dr. Hani A. Al-Ansari	King Saud University
Dr. Bader A. HabebAllah	King Abdulaziz University
Dr. Omer Al-Rabghi	
Dr. Ibrahim O. HabebAllah	King Fahd University for Petroleum and Minerals
Dr. Khalid A. Al-Shaibani	King Faisal University
Dr. Ali M. Somali	Saudi Aramco
Eng. Tarek A. Al-Naem	
Eng. Salih A. Al-Amri	
Eng. Abdullah A. Al-Katheri	Saudi Electricity Company
Eng. Ahmed A. Al-Hassoun	Turbines Technology Company
Eng. Abdulhamid Al-Mansour	District Cooling Co.
Dr. Abdulrahman Al-Hariri	King Faisal University
Dr.Ibrahim Al-Mofeez	
Dr. Sami Al-Sani	King Saud University
Dr. Khalid Al-Amar	

Appendix A: Plan Development Process

Name	Affiliation
Dr.Khalid Al-Salem	King Saud University
Zeyad Al-Shaibani	
Dr.Yusef Al-Saqeer	
Dr. Mansour Al-Hazza	
Eng. Ahmad Al-Amri	Aleasa Air Conditioning Co
Eng. Abdulrhman Al-Areefi	Saline Water Conversion Corporation
Eng. Mohammed Alghanam	
Eng. Abdullah Alajaln	
Eng. Ibrahim Altasan	
Eng. Mansour Alinzi	Electricity and Co-generation Regulatory Authority
Eng. Fayz Al-Jabri	
Eng. Habeeb Al-Mobarak	Ministry of Water and Electricity
Eng. Homoud Al-Madeen	
Dr. Majed Alhazmi	King Abdulaziz University
Dr. Ahmed AlGhamdi	
Dr. Abdullah Aseri	
Dr. Mohammed Al-Beroni	
Dr. Abulghani Mansour	Umm Alqura University
Dr. Naif M. Al-Abbadi	King Abdulaziz City for Science and Technology
Dr. Yousef M. Al-Yousef	
Dr. Hassan A. AbaOud	
Eng. Saud A. Bin Juwair	
Eng. Gazi N. Al-Motairi	
Dr. Mohammed S. Samai	
Dr. Fozi A. Al-Azhari	
Dr. AbdullAh A. Al-Musa	
Dr. Mazen A. Ba Abad	
Dr. Hussam I. Khonkar	

Portfolio Management

Initial Portfolio Formation

The R&D projects suggested for the program were entered into a project portfolio formation process to form an initial portfolio (subset) based on best utilization of available resources to achieve the program's strategic objectives. This included the following main phases:

Phase 1: Evaluate vs. Strategy

In this phase, only projects aligning with the Program's strategic goals were selected. These projects were distributed into strategic groups (buckets), and the total available resources were distributed/allocated initially to the strategic groups based on strategic significance. The program adopted a Project Distribution Matrix technique for defining the strategic groups. Nine groups resulted from the intersection of two dimensions having three elements each. These are:

- Strategic Technology Paths:
  - Development.
  - Adaptation.
  - Transfer.
- Research & Development Types:
  - Basic Research.
  - Applied Research / Pilot Plants.
  - Product Development / Added Value.

Phase 2: Prioritization for Resources

In this phase, projects competing for the same resources within a group were prioritized from a resource-related viewpoint. The Program adopted a paired comparison technique for this purpose. Accordingly, nine paired comparison tables were developed.

Projects were selected to the portfolio one-by-one starting from the top of the prioritized list in each group down until the initially allocated resource for that group was exhausted. This resulted in formation of a portfolio, but it may be unbalanced.

Phase 3: Select vs. Balancing Factors

In this phase, some projects were eliminated and some new ones were added to those selected in Phase 2. The goal of this process is to balance the portfolio in terms of:

- Research vs. Development.
- Long-Term vs. Short-Term.
- High Risk vs. Low Risk.
- Growth vs. Sustainability.
- Outsourced vs. In-sourced.
- Local / National vs. International.

Portfolio Management Process

Phase 4: Execute and Review vs. Strategy

As indicated, the portfolio formed so far is the initial or start-up portfolio. Projects are then funded and the portfolio is managed over the life of the program through continuous reformation as active projects are evaluated, completed, postponed or cancelled based on their performance in:

- Achieving the strategic objectives they were selected for.
- Achieving satisfactory implementation progress (in terms of scope, schedule, budget and quality).

At the same time, strategic objectives may be adjusted and resources may change, which will require portfolio reformation. This portfolio management process ensures that the program is using its resources most efficiently. Without an objective and methodical process, project initiation and resources utilization is usually subject to personal preferences, organizational political pressures and subjective factors.

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