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ROLE OF TECHNOLOGY IN SUSTAINABLE DEVELOPMENT IN THE ARAB REGION

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Abbreviations

AOA	Arab Organization for Agricultural Development
EE	Energy Efficiency
EGS	Environmental Goods and Service
ESCAP	Economic and Social Commission for Asia and the Pacific
ESCWA	Economic and Social Commission for Western Asia
ESCWA-TC	ESCWA Technology Center
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GG	Green Growth
GHG	Greenhouse Gases
ICT	Information and communications technology
ILO	International Labour Organisation
IT	Information technologies
KSA	Kingdom of Saudi Arabia
MDG	Millennium Development Goals
MENA	Middle East and North Africa
MOE	Ministry of Environment
MW	Megawatt
NGO	Non Governmental Organisation
OECD	Organisation for Economic Cooperation and Development
R&D	Research and Development
SD	Sustainable Development
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprises
UAE	United Arab Emirates
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

I. INTRODUCTION

Technology plays a critical role in transforming societies and economies through enhancing efficiency, connectivity and access to resources and services. The challenge remains of how the Arab region can harness technologies to achieve sustainable development without harming the human and natural capitals. The basic notion of sustainable development in the 1980s was developed to strike a balance between economic growth and environmental conservation. However, to address poverty along with multiple insecurities of water, energy and food in the Arab region, there is a dire need to harness technology to contribute to sustainability, prosperity and dignity.

Historically, the notion of technology shifted from *tools* to *knowledge* to *culture*. The emergence of the human civilization has been closely connected to the development of infrastructure in water, energy, and agriculture. The impact of technology on society evolved after the realization of the impact of nuclear technology and other environmental externalities including climate change and pollution. Besides, the new knowledge in biochemical knowledge, genetic engineering and bio-engineering created new ethical questions on the limits of technology.

The countries of the ESCWA Region face key challenges in water, energy and food security. This is exacerbated by climate change and energy dependence in spite of the region's potential for solar and wind power and, in some cases, hydropower. Besides, high unemployment, poverty and political instability pose systemic threats and challenges to nurture and build a science and technology base in the region.

One can argue that the environmental crisis, poverty, climate change, and overconsumption are clear indicators for market failure. It is increasingly clear that current business-as-usual trajectories of development are unsustainable, both in their inadequacy of fulfilling the social and economic development needs of billions of inhabitants of the planet, and in the dangers they pose to environmental resources and life-support systems (Dasgupta, 2003; MA, 2003).

In essence, Science and Technology (S&T) are underpinned by social choices, hence a transition to a sustainable green economy is defined by individuals' and institutions' choices on how to use and apply S&T. In doing so, it is important to examine closely the ways in which social institutions and processes shape the priorities of technologies and the conditions under which its potential benefits can be reaped.

In the last two decades, technology has made remarkable advances, using everything from miniature transmitters for tracking butterflies by satellite, using tools like Google Earth to assess policies on forest management, and preparing hand-held field guides to using nano-technology for water treatment, energy efficiency, and medicine. Moreover, the technology contributed to support human development by enabling us to gain access to important information, such as weather forecasts, prices of agricultural products, efficient use of water and energy, and e-learning, e-business, e-governance opportunities. Besides, ICT has led a productivity revolution, as well as supporting new platforms of virtual learning and e-education, e-health, e-business and helped communities to leapfrog technology development and use appropriate technology to manage water, food and energy and conserve nature. Hence, harnessing ICT for green technologies is likely to offer immense opportunities for green growth, green jobs, SME development, and entrepreneurship.

On the other hand, technology may contribute to accelerate resource depletion, consumption, climate change, and pollution. The major challenge in the coming years is to ensure that technology is used to enhance sustainable resource management, and prevent over-exploitation of nature. The notion of decoupling economic growth from fossil energy use is critical to make a transition to a sustainable future.

It is evident that technological advances will continue to accelerate, providing quick and easy access to an increasingly broad range of knowledge and products, ranging from developing renewable energy, water treatment and desalination, food technology to DNA analysis, satellite imaging, bio-technology, and remote sensing. All of these advances in technology provide an opportunity to harness appropriate technologies to support sustainable development and supporting the achievement of Sustainable Development Goals (SDGs) in the Arab region.

The three waves of environmentalism, i.e., from *protection* to *conservation*, to *mainstreaming* environment and sustainability in all sectors including transport, construction, water, agriculture, trade and energy represent a new worldview that reconciles the needs of society, economy and ecology. A critical element in improving or enhancing the productivity of ecosystem services (*natural capital*) is "biodiversity". The natural capital underpins both the social and financial capitals. However, technology (*manufactured capital*) can be designed to enhance and support the natural and social capitals through sound application of technologies in education, governance, rural development, water, environment, agriculture, energy, and health. For example, in the field of agriculture, biodiversity provides the genetic variability from wild relatives of domestic plants and animals that enables farmers to continually improve the food supplies upon which we depend and from which scientists to develop biotechnology to enhance productivity.

Technology transforms natural resources to serve human development. Renewable energy including hydro-power, solar, wind, bio-fuels, and bio-energy and energy form waste are becoming increasingly important in providing energy security and contributing to alleviate climate change risks. Desalination technology in the Arab region is critical for GCC countries to ensure water security. Wastewater reuse technologies are adopted in many Arab countries to augment and enhance water supply. Traditional and local knowledge like decentralised water and wastewater treatment plants are used to serve small communities and refugees.

Technological innovations are paving the way to make optimum use of informatics and telecommunications systems to address environmental sustainability, water and air monitoring, and climate risks and natural disasters. The concept of right to access to information and open source addresses today's needs and promotes active participation in decision making.

Technology contributes to the attainment of SDGs in all sectors including education, water, energy, health, environment, governance, and agriculture. For example, ICT is often used to improve networking, monitoring and response systems to address pollution and disaster response management. ICT plays a key role to communicate local knowledge and to facilitate citizen action at both local and global levels. ICT is used for supporting green technologies and for supporting clusters for innovation in water-energy-food nexus. Technology and ICT can also contribute in reduction of consumption of energy, water and other natural resources through efficient resource use.

ICT is an enabler to green technologies and for the effective and integrated management of water-food-energy nexus. In sum, the Arab region needs to co-develop a new social contract for technology and society. It is imperative to root a culture of science and technology and enhance the enabling environment for ICT-enabled green technologies[1] to make a transition to green economy and contribute purposefully to Sustainable Development Goals (SDGs)[2].

II. SCOPE OF THE STUDY

This study aims to provide an analysis of the role of technology in sustainable development and SDGs in the Arab region. It will review the basic concepts and theories of sustainable development and SDGs. Besides, it will appraise how technology is used in various sectors (mainly water, food, energy, environment, rural development, and education) to achieve SDGs. It will also document policies and experiences in technology for development[3] (T4D) and determine possibilities and challenges for technology transfer. Finally, this study will determine regional priority areas and partnerships in the domain of T4D.

III. TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

The concept of sustainability was addressed in many studies like the *World Conservation Strategy* published by IUCN, WWF and UNEP in 1980, and its successor *Caring for the Earth* in 1991, and in the report of the World Commission on Environment and Development (WCED) in 1987. It was discussed at United Nations Conferences in Stockholm in 1972, Rio in 1992 and Johannesburg in 2002 (Adams, 2009).

The term "sustainable development" was used in 1987 by the Brundtland Commission and has become a widely-used notion in many disciplines like, construction, energy, transport, water, housing and tourism. The term meant the ability to "*meet the needs of the present without comprising the ability of future generations to meet their own needs*". In the 1970s, the term sustainability was used to describe an economy in equilibrium with basic ecological support systems. The three key components of sustainable development include: environmental, economic and social dimensions.

The following is a review of the basic concepts and theories of sustainable development. Sustainability means different things to different people yet it appears to unite them under a shared target. The Brundtland Commission defines sustainable development as 'a development that fulfills

[1] Technologies that apply the concept of zero or minimum waste and apply the concept of Life Cycle Analysis.
[2] Sustainable Development Goals were initiated in Rio+20 as part of global agenda to mainstream environment in economic and social dimensions.
[3] Technologies that contribute to economic growth and prosperity as measured in terms of GDP. While technologies for sustainable development address the value of ecosystem services and sustainability indicators.

the needs of the present generation, without compromising the ability of the future generations to fulfill their needs (WCED, 1987, p. 43). An important element in this definition is the fulfillment of needs of the present generation on the one hand and of the needs of future generations on the other.

The International Union for Conservation of Nature (IUCN) defines the term as: 'Sustainable development means improving the quality of life while living within the carrying capacity of supporting ecosystems.' (World Conservation Union et al., 1991). This definition is broader than the one of the Brundtland-commission. It is evident that this definition includes important elements like the improvement of the quality of life and the carrying capacity of supporting ecosystems. The 'improvement of the quality of life' in this definition seems more ambitious than the 'fulfillment of needs' in the Brundtland-definition. Improving of the quality of life' can be interpreted as equal to fulfilling needs to a higher degree: the quality of life can be thought of as the amount in which people's needs are fulfilled.

The imagined clash between development and conservation of nature was reconciled by the term "sustainable development" but this concept meant many things and the concept lacks quantified indicators and metrics. However, the key notion of taking attention of both intra-generational equity (between rich and poor now) and intergenerational equity (between present and future generations) is the cornerstone for a sustainable future.

As argued by Adams (2009), faith in 'business as usual' to deliver the changes needed owes more to the hopes of those with wealth and power than to a coherent analysis of the state of the environment or the needs of the global poor. We face the risks of tipping points and irreversible changes in the environment and in its capacity to support and sustain human life in all its dimensions. Mainstream sustainable development, according to Adams (2008), encompasses a series of ideas such as *ecological modernization* and *market environmentalism* that promise to steer the world towards sustainability in ways that do not demand too many dramatic changes.

In sum, sustainable development is defined by the volume of economic output generated by "inputs" derived from the services provided from natural assets. The efficiency of utilization of those resources is determined by the sustainability of the patterns of consumption and production, and the efficiency of utilisation of any resources extracted from the environmental commons. The "Green Economy" concept is a developmental model rooted in sustainable development. It is "a system of economic activities related to the production, distribution and consumption of goods and services that result in improved human well-being over the long term, while not exposing future generations to significant environmental risks or ecological scarcities", and "significantly reducing environmental risks and ecological scarcities" by being "low carbon, resource efficient, and socially inclusive[1]".

In this perspective, continued sustainable development, can therefore best be achieved through "Green Growth". To ensure Green Growth, an economy would be work on "fostering economic growth and development, while ensuring that natural assets continue to provide the resources and

[1] UNEP, 2007

environmental services on which our well-being relies[1]", by emphasizing "environmentally sustainable economic progress to foster low-carbon, socially inclusive development[2]".

Both concepts of "Green Economy" and "Green Growth" have been at the centre of policy debates in recent years, and as one of the two themes for Rio+20. The "green economy in the context of sustainable development and poverty eradication" carries the promise of a new economic growth paradigm that is friendly to the earth's ecosystems while also contributing to poverty alleviation as illustrated in Figure 1. This has resulted in a rapidly expanding literature and emerging international practice focusing on "Green Economy" and "Green Growth" [3].

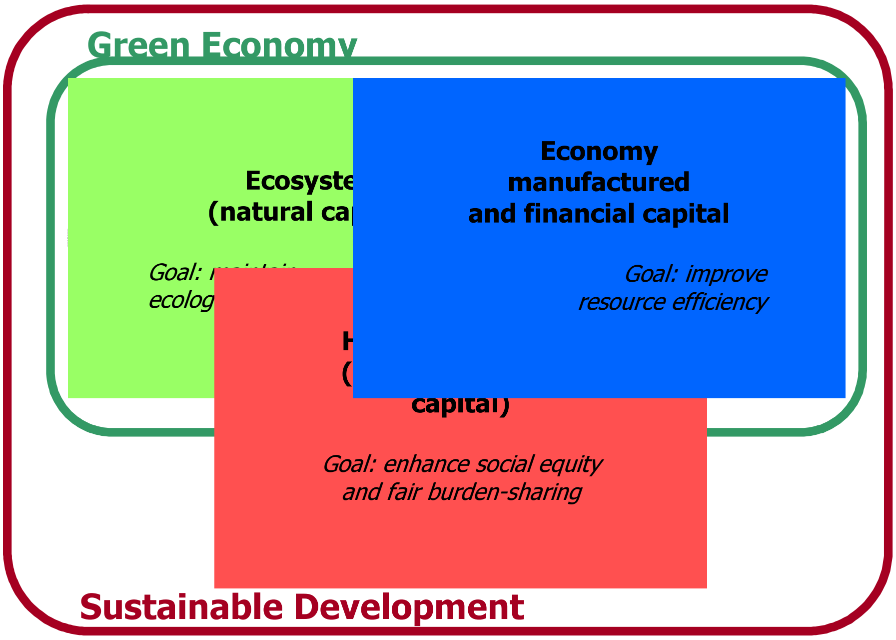

Figure 1. Sustainable Development and the Green Economy

Both "Green Economy" and "Green Growth" offer a novel approach for development, in line with the needs for sustainable development. They both "should be understood as identifying and supporting opportunities to improve natural resource management and provide infrastructure services while meeting the core objectives of human development and well-being[4]". The Green Economy therefore balances the needs of "People", "Planet", and "Profits", by reconciling the "environment" (Planet), where humans live, with the "economy" (Profits), the system of activities that they undertake to improve their "standard of living" (People).

Technology is viewed as the manufactured capital that can contribute to three domains of sustainability; i.e., improves efficiency as in the case of water saving devices, technology for irrigation management and monitoring and technologies of energy efficiency and renewable energy. Also, technology can contribute to enhance ecological resilience as in the case of technologies used

[1] OECD
[2] ESCAP
[3] UNDESA. 2012.
[4] ESCWA, Sustainable Livelihoods and the Green Economy

to monitor the quality of water, air, and soil and water treatment and wastewater reuse technologies. Besides, technology plays a critical role in enhancing social equity through harnessing ICT for education, e-learning, e-government and ICT for rural development and ICT for green technologies for SMEs.

However, it is argued that the notion of sustainable development needs measurable metrics and it should address both climate change and poverty. It is imperative to think beyond GDP as an indicator for progress of societies. These issues were reconciled by articulating the concept of ecosystem services (see insert inbox 1).

Box 1: Ecosystem Services

Nature provides largely unrecognized or "invisible" services to the larger economy that humans would otherwise have to exert effort to provide. For example, forests in a river basin help clean surface water, improve groundwater recharge, and prevent of soil erosion. Such services are difficult to account for, since those who provide the services (i.e. by not clearing the forest) do not directly benefit from the service it provides to others (i.e. a water utility).

Source: UNEP, 2012

IV. Role and Impact of Technology on Sustainable Development

Historically, after the Enlightenment in Europe, science and technology were perceived as a panacea for resolving all human sufferings from poverty to health and livelihood. This view of the notion of "technological fix" was challenged in the last five decades by Kuhn (1961) in his work, "The structure of scientific revolution", in which he argues that theories have meaning within a dominant paradigm.

However, technologies evolve with societies (Saviotti, 2005) and the externalities resulted from applications of some technologies like nuclear energy and the environmental degradation of ecosystems resulted in re-thinking the rationale and contribution of technology to sustainable development. The linear model of technological innovation (referred to as technological determinism) which is based on the concept that "*science invents, technology applies and market selects*" was replaced by theories like social construction of technology, where technological innovation is shaped by the meaning a society develops based on context and problem definition.

Technological developments influence society and vice versa. Lee and Mathews (2013) argues that STI play a critical role in expediting transition to a sustainable mode of development. They pointed out that latecomer countries can harness the positive outcomes of STI if they adopt appropriate strategies and policies such as leapfrogging, where they can integrate up-to-date technology and leap to a new paradigm. To do so, countries need to develop an enabling environment of STI systems and IP that supports and promotes technology transfer and use of Intellectual Property (IP).

Technology transfer models for SME in green technologies in the ESCWA region were operationalized at the national level through the establishment of Green Help Desk in selected countries including Lebanon, Oman, Jordan, Egypt and Tunisia supported by ESCWA. At the regional level the ESCWA Technology Center is mandated to provide the enabling systems for knowledge sharing, capacity building and technology transfer. Both ESCWA led initiatives are promising but need some time to assess lessons learned.

However, in any technology transfer endeavour, it is imperative for national authorities to have a strategic vision for technology adoption, technology policy, and systems for technology evaluation to ensure that the technology is appropriate, sustainable, and cost effective. Besides, international assistance and proper funding schemes are needed to support the transfer of clean technologies to the developing countries.

It is alarming to note that the Arab countries lag behind other regions in terms of both growth and STI. The indicators for STI are below other regions as manifested in many indicators including R&D. There is an untapped human potential and brain drain where unemployment is a key challenge for sustainability. However, the youth population should be viewed as an opportunity to overcome the "knowledge deficit" if necessary reforms are undertaken in education and STI. STI can play a vital role to reinvigorate development and unlock the untapped potential[1]. The key indicators for STI in the Arab region show limited contributions of the region in terms of R&D budget, patents, publications, and investments as indicated in Annex 1 and 2.

A. SUSTAINABLE DEVELOPMENT PRIORITIES AND STI INDICATORS IN THE ARAB WORLD

The notions of "technological fix" and the belief that "market forces determine the development of science and technology" were contested since they overlook the role of society and national policy in technology development. However, the role of technology to sustainable development was viewed from two perspectives, i.e., high-tech (nano-technology, bio-technology, advanced materials) and appropriate technologies (water harvesting and greywater reuse).

Figure 2 below illustrates a conceptual framework on the linkages between the three domains of sustainable development (social, economic, and ecological) and policies and technological innovation. Best Available Technologies (BAT) supported by ICT contributes to enhance water use and energy efficiency and enable social change through social media, e-learning and e-government models. Technologies to address climate change like carbon capture and storage is vital for sustainability. However, it is critical that this framework is supported by an enabling environment with sound institutional and human capital. The following will present an overview of technologies for sustainable development in water, energy and agriculture at the global and regional levels so as to draw some lessons learned for ESCWA region.

[1] A new Millennium of Knowledge, Lord (2008), Saban Center at Brookings

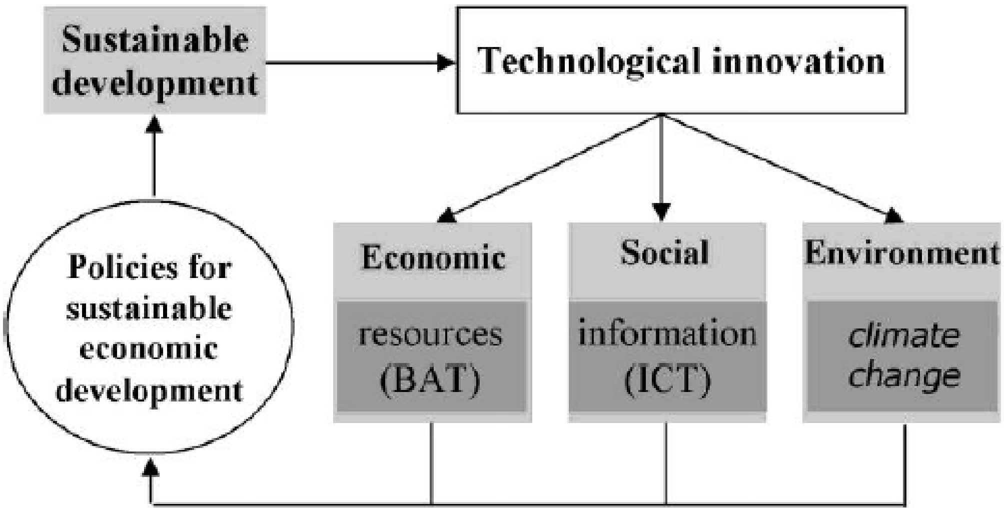

Figure 2. A framework for linking sustainable development and technology (Constantinescu and Frone, 2014)

The Arab region is challenged with a set of interlinked security challenges in water, energy, and food. This is coupled by poor governance and inability to harness technology for development.

Rapid urbanization is expected to increase vulnerability to natural disasters such as droughts, floods, earthquakes and storms. More than 37 million inhabitants in the Arab region were affected by natural disasters, and incurred losses exceeding $20 billion during the period 1980-2008.[1] ICT technologies like early warning systems and sector-based technologies in water, transport and sanitation can be utilized to mitigate the risks, challenges and threats of natural disaster.

In some countries, the influx of refugees from neighbouring countries due to conflict (such as Syrian refugees in Jordan and Lebanon) has impacted social cohesion in some areas and violations of the human rights of refugees have been reported.[2] In addition, refugee influx has put additional pressures to ensure access to already scarce water resources and other services in both urban and rural contexts. In fact, the Arab region had 7.4 million refugees in 2010, 9.8 million internally displaced and 15 million migrant workers from outside the region.[3] Technology can address the above urban and human challenges through harnessing the institutional capacity in the Arab World in STI institutions like KISR, RSS, KACST, and Qatar Foundation.

The Arab MDG report 2013 showed that due to unregulated disposal of wastewater in many Arab countries, water resources and coastal ecosystems are polluted, which leads to major health issues for the population. About 28 per cent of urban residents reside in slums in the region, and in the LDCs more than two thirds of urban residents live in slums. There is thus a need for an integrated approach in designing and provisioning of quality social services, in order to address concerns of rural and urban areas while taking account of environmental sustainability.

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[1] UNISDR, http://www.unisdr.org/arabstates/activities
[2] Human Rights Watch, World Report 2014 (http://www.hrw.org/sites/default/files/wr2014_web_0.pdf).
[3] UN-Habitat 2012.

While the collection rate of municipal solid waste in the region is fairly high, waste is inadequately disposed of in open or uncontrolled dumpsites rather than sanitary landfills, leading to the pollution of soil, air and water bodies and causing a threat to health and the environment. On the other hand, the per capita solid waste generation rate in the Gulf countries is among the highest in the world.

Solid waste management falls within the realm of local authorities, who implement local plans. However, there is potential in several Arab countries for delegating more powers to municipalities. The authority of local governments in most Arab countries is undermined by highly centralized governance structures and the roles of central and local governments are not coordinated.

There is a need in the Arab region for promoting sustainable transport, notably within large cities, in view of its importance in facilitating the movement of people and enabling economic activity in industry, commerce, tourism and agriculture. The sector consumes around 18 percent of primary energy in the Arab region[1] and produces air-polluting toxic gases, in addition to greenhouse gases. Demand for private cars is increasing in the Arab countries, triggered in part by limited availability of high-quality public transportation systems.

Technology can contribute to achieve all the SDGs at many forms and levels as illustrated in Annex 3. It is imperative to develop a *culture for green technologies* in the Arab world through purposeful reform of educational and development policies. What is needed in the Arab region is to develop a critical mass of scientists and researchers that work on joint relevant *regional R&D collaborative* projects for long term to leapfrog to green technologies. This requires an enabling environment for innovation and linkage to markets and industries. *It is imperative that STI is mainstreamed, defined and framed as an integral part of national development strategies for the Arab region.* Besides, we need a compelling and articulate green transformative initiatives and programs that harness and unlock the best human capital in the Arab region and abroad on regional flagship projects like a green transport and infrastructure connecting Arab capitals, a regional renewable energy project the demonstrate the role of green technologies in enhancing regional commons. Rooting the R&D agenda in the local context and forging a new social contract between science and society is critical to apply the notion of "Blue Ocean Strategy", i.e., to ensure that R&D agenda is informed and defined based on national and regional needs and priorities.

The role of advanced technologies in sustainability is substantial and is likely to make macro-shifts in economy and society. Bio-technology, nanotechnology, renewable energy, and ICT for green technologies can address the core insecurities in the Arab region in the domains of water, energy, and food. ICT for green technologies can contribute to address SDGs in the Arab region. For example, ICT for green technologies can contribute to new people-centred development models and new modes of social learning as in ESCWA project of ICT for rural development and the Knowledge Stations. ICT for green technologies can contribute to alleviate poverty through enhancing irrigation water use efficiency and enhancing crops productivity and resistance to disease as the results of R&D reveal in the work of ICARDA.

[1] UN-ESCWA, 2011, Policies and Measures to Promote Sustainable Use of Energy in the Transport Sector in the ESCWA Region (E/ESCWA/SDPD/2011/2).

Technology is unlocking possibilities for sustainable development and contributed to the achievements of MDGs as shown in Table 1.

Table 1. Examples of ICT initiatives helping to achieve MDGs in ESCWA member countries

Title	Location	Initiators	Description	MDGs
Knowledge Networks through ICT Access Points for Disadvantaged Communities[350] (see box 3)	EMCs	ESCWA, NGOs in various EMCs	The main objective of the project is to empower disadvantaged communities by transforming selected ICT access points/telecentres into networked knowledge hubs. The project sought to improve the living standards of the targeted communities by developing, organizing, sharing, and disseminating knowledge that is mainly related to employment, education, gender, and health.	1, 2, 3, 4, 5, 6, 8
Empowering Communities through Telecentre Networking[351]	Egypt	IDRC, UNDP, Telecentre.org	With over 1,300 telecentres (IT Clubs) under a national programme that dates back to the early 1990s, Egypt has the highest concentration of telecentre activities in a single country in the region. This project aims at allowing the Egyptian Ministry of Information and Communication Technology (MoCIT) and the IT Trust Fund to strengthen the current model of IT Clubs in Egypt by providing such support services as on-demand helpdesk services, telecentre staff training and online and offline knowledge-sharing platforms.	1, 3, 8
Acacia[352]	EMCs	IDRC	The Acacia programme works to help countries in Africa and the Middle East achieve social and economic change by applying ICT. The programme's objectives are to: (a) demonstrate how ICT can help communities tackle development problems with local solutions; (b) create knowledge about approaches that promote the use of ICT by such marginalized groups as women; (c) support researchers studying the impact of ICT on education and employment; (d) monitor policies that create equitable and inclusive access to knowledge through ICT; and (e) develop ICT to foster development and improve the delivery of social services.	1, 2, 3, 8
ICT for Education[353]	Iraq	UNESCO, ESCWA	The development goal and immediate objectives of this project are to: (a) reorient Iraqi educational policy objectives and strategies to maximize the effectiveness of the use of ICT in education; (b) build sustainable capacity in the Ministry of Education in Iraq to develop ICT-based curriculum instruction, learning and assessment; and (c) upgrade the school physical learning environment through the provision of ICT facilities.	2, 8
Lebanon Development Gateway (LDG)[354]	Lebanon	Collective for Research and Training on Development – Action (CRTD-A)	LDG seeks to address problems associated with poverty, illiteracy and unemployment. The project aims at strengthening knowledge-based interaction on gendered sustainable development between civil society organizations, Government organizations and the private sector. LDG uses ICT to foster exchange, dialogue and cooperation, and to promote accessibility to gender and social development information and resources in Arabic, English and French.	1, 2, 3, 8

Note: EMC stands for ESCWA member countries.

However, there are systemic challenges that limit STI to be part of the social fabric of the Arab world. Paradoxically, large amounts of public resources in the Arab world are allocated to military budgets, while comparatively less is spent on research and development for sustainable development. Public funding often subsidizes private sector research at times leading to the public being priced out of the benefits through disadvantageous licensing and patent. This also leads to frequent subsidies of innovations that are not aligned with promoting sustainable consumption and production patterns. The solutions that STI can generate, and the levels of access that they can enable, will be crucial to our vision for an Arab region beyond 2015. Besides, access to vital and environmentally sound technologies is today unevenly spread both within and between the Arab countries. Some Arab countries are categorized as LDCs (like Yemen and Sudan) and are locked out from STI.

Sustainable economic development includes, among other requirements the promotion of technological innovation. This completes the trinomial of knowledge, science and research, requiring society to favor conditions conducive to political decisions for sustainable development and for broadening the range of economic options. Thus, providing decision makers with more positive means of influencing economy, environment and society, technological innovation is likely to lead to achievement of sustainable development objectives. However, in order that technological innovation provides guarantees of sustainable economic development, *it is necessary that a transfer of technology to developing countries becomes a basic principle of national development policies.*

It is also necessary that developing countries, in turn, open to adopt an explicit long-term application of technological innovation. This will enable developing countries to promote use of sustainable technologies and more environmentally friendly materials. The science - policy interface implies that we see the synergy and connection between policy choices for sustainable economic development and technological innovation. In sum, a sustainable future in the Arab region will require that we *phase out* unsustainable technologies, to invest in green technologies for sustainable development.

B. ROLE OF TECHNOLOGY FOR WATER-ENERGY-FOOD NEXUS

1. Technology for integrated water resources management

The Arab region is quite unique in the combination of inter-linked challenges it faces in terms of water. The region has the lowest share of freshwater availability in the world and the largest proportion of its freshwater resources is trans-boundary. Furthermore, it is now fairly well documented that climate change will have negative effects on freshwater availability in the coming years, including through more frequent extreme events and seawater intrusion. There is evidently a growing competition on the demand for water between increasing populations, developing industries and expanding agricultural activities, and water scarcity will constitute a future development constraint and a threat to food and water security in the Arab region, especially that resources are unequally distributed and related governance and institutions are weak. Agriculture inefficiently consumes more than 85% of the region's water resources, and further losses are reported in water distribution networks. The agricultural sector is not only a major consumer of water, as it is also a major contributor to water pollution in the region due to uncontrolled use of chemical fertilizers and pesticides. The level of wastewater treatment remains low and untreated wastewater disposal is increasing. Gulf countries depend on desalinated water at considerable economic and environmental costs.

Lack of access to water and lack of improved sanitation, notably in rural areas, are other aspects of failure of public provisioning of social services. Providing access to water, as the MDGs aim for, is insufficient without looking at the quality of water and the cycle of water management. It is estimated that around 17% of the total population in the Arab region do not have access to improved drinking water sources (worse than the world average of 11%), and 20% do not have access to improved sanitation facilities. The majority of the populations lacking access reside in rural areas, and in LDCs in both rural and urban areas. [1]

The above-mentioned regional specificities in relation to water resources are not captured adequately in the MDG framework. As such, efforts have been exerted by ESCWA and partners to improve the monitoring and reporting on water supply and sanitation indicators (MDG+ initiative).[2]

Issues of water use efficiency and governance, adequate and equal access and water quality are top regional priorities that have important impact on human well-being, the environment and overall economic development efforts. The effect of climate change on water security needs to be well understood and appropriate adaptation measures should be adopted. The MENA region accounts for more than 54% of the world desalination capacity. Besides, wastewater reuse is the second option on the supply side and the more economical option as compared with desalination especially when energy consumption is compared.

Access and adoption of appropriate water technologies, including desalination, waste water reuse, water-saving and water treatment technologies, is an important enabler of water management and should be promoted. Besides, remote sensing and GIS technologies are utilized to predict the impact of climate change risks, rise of sea levels, and desertification so as to inform policies for development and investment[3].

2. Technology for food security

Improving food production in the Arab region faces both environmental and socio-economic constraints. On the environmental front, water scarcity, land degradation and desertification represent daunting challenges for Arab food producing countries. Agricultural policies, practices and support to farmers remain inadequate for the challenge, and inefficient irrigation technologies and expansion of agriculture into marginal lands are still pursued. It is estimated that three quarters of the agricultural exploitable land area have been affected by land degradation[4] including soil erosion and salinity, a phenomenon that will be exacerbated by climate change. Land degradation will impact natural grazing fields and reduce their carrying capacity. Irrigation technologies, crop

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[1] UN-ESCWA, 2013.
[2] UN-ESCWA, 2013.
[3] AFED (2009), A Remote sensing study of some impacts of global warming in the Arab Region. Chapter 3 by Ghoneim E. (2009).
[4] UN-ESCWA, 2007, Land Degradation Assessment and Prevention: Selected Case Studies from the ESCWA Region (E/ESCWA/SDPD/2007/4)

development and remote sensing and GIS technologies can contribute to control land degradation and enhance land productivity.

According to the Arab Organization for Agricultural Development (AOAD),[1] agricultural productivity in the region is below international levels for most crops. The level of food waste is estimated at around 1.3 billion tons yearly. As such, 13% of cereal production is lost at the post-harvest stage and 10-20% at the storage stage. The total food loss is valued at one trillion dollars.

Organic agriculture, bio-saline agriculture, bio-technology and genetic engineering technologies can play a key role in enhancing crop yield and resistance to severe weather conditions and diseases. Adopting a food-energy-water nexus approach to food security is expected to increase the sustainability of production systems.

3. Technology for energy security

Energy is a key enabler of economic and social development and job creation. It links growth to social justice and environment[2]. The Arab region presents wide divergence between oil and gas producing and non-producing countries. High and inefficient energy consumption patterns prevail in the Gulf countries, and electricity consumption more than doubled during the period between 1999 and 2011[3]. GCC countries should not remain complacent about their long-term supply advantage and alternatively seek to turn their oil resources into value-added products. This is especially true for natural gas, being more costly to export. On the other hand, non-producing countries are strained under a heavy energy bill and costly energy subsidy schemes.

Energy security in the Arab region is highly interlinked with water security for a number of reasons. One important factor that is of relevance to the GCC counties in particular is the cost of desalination. For example, water desalination using multi-stage flash technology typically consumes around 5kWh in total energy use to desalinate one cubic meter of water. Electricity consumption for desalination purposes is expected to triple in the next two decades.[4] For oil producing countries, increasing local consumption of oil to meet increasing water demand will translate into less oil and gas revenues with potential impact on economic growth. This constitutes an additional reason for the region to invest in renewable energy technologies.

The Arab region invested in renewable energy (RE) as shown in Table 2. Securing access to sustainable energy for all in the Arab region is greatly needed. It is important for all Arab countries, including the GCC, to invest more in energy efficiency and renewable energy applications (specifically solar and wind), both from a socio-economic perspective, but also in response to global concerns about climate change. Research efforts to develop or adapt locally appropriate energy technologies cannot be under-estimated. The choice of the appropriate renewable energy technology is critical, and will depend on national circumstances.

[1] http://www.aoad.org/eng/news-28-11-2013-1.htm
[2] UNSG's Sustainable Energy for All Initiative, http://www.se4all.org/our-vision
[3] IEA 2013, Energy Balance of Non-OECD Countries
[4] Water Desalination Using Renewable Energy (IEA-ETSAP and IRENA Technology Brief I12 – March 2012).

Table 2. Installed renewable energy capacity in the Arab countries September 2014. (RCREEE, 2014)

Countries/ Energy (MW)	PV	CSP	Wind	Total sun+wind	Biomass & Waste	Hydro	Total
Algeria	7.1	25	10	42.1	0	228	270
Egypt	15.0	20	550	585	0	2800	3385
Iraq	3.5	0	0	3.5	0	1864	1868
Libya	4.8	0	0	4.8	0	0	5
Syria	0.8	0	0	0.8	0	1151	1152
Djibouti	1.4	0	0	1.4	0	0	1
Jordan	1.6	0	1.4	3.0	4	10	17
Lebanon	1.0	0	0.5	1.5	0	282	284
Morocco	15.0	20	495	530.0	0	1745	2275
Palestine	1.0	0	0	1.0	0	0	1
Tunisia	4.0	0	214	218.0	0	66	284
Sudan	2	0	0	2.0	55.5	1590	1648
Bahrain	5.0	0	1	6.0	0	0	6
Kuwait	1.8	0	0	1.8	0	0	2
Oman	0.7	0	0	0.7	0	0	1
Qatar	1.2	0	0	1.2	40	0	41
S. Arabia	7.0	0	0	7.0	0	0	7
UAE	22.5	100	0	122.5	3	0	126
Yemen	1.5	0	0	1.5	0	0	2
Mauritania	15.0			15.0	0	48	63
Total GCC	38	100	0.5	139	43	0	182
Arab Countries	112 (1%)	165 (1.5%)	1271 (11.1%)	1549 (13.5%)	102 (1%)	9784 (85.6%)	11434

Solar stills are already cost competitive but wind RO, solar CSP and geo thermal are not far off the current fossil fuel desalination cost. However, cost is not the only consideration in relation to choice of renewable technology. Considering the issue of scale, solar stills only work at the individual level, solar PV at the household level and wind/geothermal at the village level. Only solar CSP at this point is capable of producing greater than 5000 cubic meter per day. Due to storage potential, CSP is also capable of being a base load desalination option. Table 3 shows the scale of investment in RE in various Arab countries.

Table 3. Renewable energy projects in Arab countries, 2013

Country	Solar (type)	Wind	Other (type)
Algeria	175 MW	20 MW	
Bahrain	3 MW	2 MW	25 MW (biomass and waste)
Djibouti	N/A	N/A	50 MW (geothermal)
Egypt	100 MW (CSP) 240 MW (PV)	1 070 MW	32 MW (small hydro)
Jordan	400 MW	360 MW	N/A
Kuwait	50 MW (CSP utility scale) 10 MW (PV utility scale) 3 MW (PV building integrated)	10 MW	N/A
Lebanon	<1 MW (PV)	60-100 MW	N/A
Libya	N/A	610 MW	N/A
Morocco	172.7 MW	1 553 MW	N/A
Palestine	10 MW (CSP); < 1 MW (PV)	0.35 MW	N/A
Saudi Arabia	125 MW	-	N/A
Sudan	20 MW	320 MW	N/A
Syria	N/A	290 MW	N/A
Tunisia	5 MW	100 MW	N/A
UAE	113.8 MW	30 MW	101 MW waste-to-energy
Yemen	N/A	60 MW	N/A
Total	= 1 846	= 4 531	= 208

Sources: Kuwait from EU-GCC Clean Energy (2013); Lebanon, Palestine and Sudan from RCREEE (2013); all other countries REN21 (2013).

V. HOW TECHNOLOGY CAN CONTRIBUTE TO THE ACHIEVEMENT OF THE SDGS

The intergovernmental process launched at Rio+20 initiated a process to develop global Sustainable Development Goals (SDGs). The global discourse had converged on the notion that poverty alleviation, human wellbeing, and environmental protection are to be integrated in a transformative framework[1].

At the global level, there was an initiative to develop indicators for monitoring of SGDs[2]. There are a set of goals that are interlinked to technology for sustainable development which address water and sanitation, sustainable growth, sustainable industrialization, sustainable cities, sustainable consumption and production, sustainable use of ecosystems, and combating desertification and climate change.

[1] ESCWA Discussion Paper, SDG Priority Conceptual Issues: Towards an Arab Approach for the Sustainable Development Goals, Tunisia, 18-19 November, 2013.
[2] Indicators and a monitoring framework for SDGs; A Report by the Leadership Council of SDSN, July 25, 2014.

The specific goals that the Arab region needs to consider include: transfer governance and technologies for sustainable development which is measured by the extent countries implement and report on systems of Environment-Economic Accounting (EEA) accounts. Besides, another goal is to accelerate the adoption of new technologies for achieving SDGs. This goal is measured by number of researchers and technicians (per million people) working on R&D and domestic expenditure on R&D as share of GDP. The Arab region needs to increase investment in R&D to be compared favourably to other regions as indicated in Annex (1).

This section outlines how technology can contribute to achieve sustainable development. It starts by a brief review on the STI landscape in the Arab world then it presents an overview of technologies in the Arab regions followed by a global review.

A. THE ENABLING ENVIRONMENT FOR STI

STI institutions, human capital, funding, governance and culture are the cornerstone for establishing infrastructure for sustainable development. A number of institutions and initiatives were founded in the last decade in the Arab world to promote and fund STI. These include:

- MASDAR initiative in UAE to promote renewable energy and energy efficiency;
- The Mohammad bin Rashid Al Maktoom Foundation;
- MEDRC for water desalination in Oman;
- International Center for Bio-saline Agriculture (ICBA) in UAE,
- Arab Science and Technology Foundation (ASTF);
- Qatar Foundation;
- King Abdullah City for Science and Technology (KACST) in KSA;
- King Abdullah University for Science and technology (KAUST) in KSA.

Besides, well-established R&D entities had a mandate to work on green technologies like green fuel energy (see Box 1). Common technologies in various sectors like water, food and energy constitute the R&D agenda in key institutions like KISR in Kuwait, RSS in Jordan and R&D institutions in universities and public and private sectors and many regional and international organizations like AUB, ACSAD, ICBA and ICARDA as shown in Table 4. The R&D agenda and strategic plans for STI in the Arab world focus on a set of common key technologies including ICT, water, energy, agriculture, health, and advanced technologies like genomics, nanotechnology, biotechnology, and advanced materials.

The Arab world does have key contributions on desalination technologies. The Middle East Desalination Research Center (MEDRC) in Oman developed a research agenda and supported research groups in the region and globe and it operates with a $2 million budget.

The contribution of technology to GDP is a good indicator of the significance of STI in development as indicated in Annex 1 and 2. In 2007, high technology exports were rising in Jordan, Morocco, and KSA at a rate of 77.8%, 31% and 161% respectively. Qatar, UAE and KSA invested in STI by establishing R&D hubs, universities, business parks, research labs and incubators. Jordan and Egypt were rated high in ICT products. In 2007, high technology exports in products like computers pharmaceuticals, aerospace, and electro machinery in Jordan, Morocco, and Tunisia accounted to about $200 million, $700 million, $360 million respectively[1], but still lack behind compared to Slovak Republic which exported $1900 million.

Table 4. Key technologies and in selected Arab countries

Region	Country	Technology
Levant	Jordan	Clean production, ICT for environment, RE, Nanotechnology, waste water reuse
	Syria	Food and water technology, biotechnology Bio-technology, health
	Lebanon	Bio-technology, health, nanotechnology
GCC	Kuwait	Water, Energy, Oil and gas, Marine Environment, , Desalination, RE,
	Saudi Arabia	Water, Energy, Oil and Gas, Petrochemicals, Desalination, RE
	UAE	RE, Agriculture, Advanced Technologies (nano, bio and advanced materials)
	Oman	Desalination, water and agriculture
	Qatar	ICT, Agriculture, health, water, energy and advanced technologies
North Africa	Egypt	RE, Biotechnology, Nanotechnology, Biotechnology
	Tunisia	RE, water, environment, and agriculture

A macro shift in the business model and operations of STI in the Arab world is needed to improve on STI indicators and unlock the immense potential. This requires strategic investment in R&D, ICT infrastructure, and technology transfer so as to transform the economic model in the Arab

[1] Word Bank development indicators, 2007

world and to achieve SGDs. Besides, it is imperative to build a critical mass of scientists, and regional research groups to bridge the gap of knowledge and innovation in the Arab region. Attracting human capital abroad is crucial to build science and technology base in the region. India and China are benefiting from brain regain and circulation of talents in the diaspora.

There is a broken cycle between academia, industry and markets[1]. This can be overcome through establishing an enabling environment for STI like technology parks, technology clusters, incubators, and business parks. Knowledge-based products can create high value goods and services and contribute to sustainable development. However, monitoring and assessing STI outputs and STI observatories are needed to measure assess and ensure results and impact. Besides, the Arab region can achieve SDG's through building regional and global networks, alliances, and cooperation with regional and international research institutions.

The Arab region has an opportunity to make a transition to green economy to satisfy the high electricity demand and reduce GHG emissions since solar technology in GCC presents a future for sustainable development as manifested in many initiatives in UAE, Egypt, Jordan, Morocco, and Saudi Arabia (*see insert Inboxes below*). Gulf oil export will total over 9 trillion dollar by 2020 according to McKinsey, 2008. This capital can fund science technology and innovation and help reach a critical mass for scientists. A number of funding sources were developed recently. These include:

- The Qatar foundation.
- Mohammad Bin Rashid Al Maktoom. Foundation in UAE.

Shift from R&D and S&T to innovation can be made through linkages with private sectors and through networks, technology transfer, funding start-ups and venture capitals. There are some good examples for developing an enabling environment for STI including Berytech in Lebanon, King Abdulaziz City for Science and technology (KACST), El Hassan Science City in Jordan, MASDAR, and Qatar Foundation.

There must be a new social contract between science and society. Science and technology is a source of progress for humanity and it's a public good and should be a responsibility of the state. Hence, it is imperative to define STI as a national development objective. There are some good national examples of technology parks like El- Ghazala Tech Pole in ICT, Tech Park in Morocco, and smart village in Egypt which aimed to link R&D to productive sectors.

[1] ESCWA (2014). The Broken Cycle: Universities, Research and Society- Proposals for Change.

Box 1- Sustainable transport and cleaner fuel vehicles

The city of Dubai created sustainable public transportation by establishing the subway network to induce a 30 per cent reduction in private car use, thereby cutting greenhouse gas emissions, especially in that the subway uses renewable energy. The initiative will improve and facilitate urban transport. With regard to cleaner fuel, natural gas vehicles are the most commonly used among cleaner fuel vehicles. Some countries in the region have started to introduce that technology into their means of transportation, notably cleaner fuel varieties including natural gas which has been increasingly used for taxi vehicles in some countries such as Egypt, followed by the Syrian Arab Republic and the United Arab Emirates. Since 1994, Egypt has adopted natural gas for transportation by establishing the first company converting vehicles engines to use compressed natural gas, and by 2009, Egypt had six companies converting vehicles to natural gas; around 114 natural gas supply stations were established, and the number of natural gas vehicles reached around 119.000 of which 79 per cent are taxi vehicles (ESCWA, Expert Group Meeting on Transport for Sustainable Development in the Arab Region, and its Relation to Climate Change Issues, Cairo, 29 September – 1 October 2009, Egypt paper). To support the shift to natural gas, Egypt introduced a set of incentives such as offering tax exemptions for companies using natural gas vehicles in the first few years, cutting conversion costs for vehicle owners, and introducing a competitive gas price compared to gasoline.

Source: ESCWA; 2009: *Transport for Sustainable Development in the Arab Region: Measures, Progress Achieved, Challenges and Policy Framework*, E/ESCWA/SPDP/2009/WP.1

B. ICT FOR SUSTAINABLE DEVELOPMENT

ICT can help in reducing rural-urban disparities and support green technology development as the MASDAR initiative in UAE (see Box 2). Besides, the ICT-led collaborative virtual research can capture the intellectual capital of scientists abroad and limit the negative impacts of brain-drain. E-business, e-communication, e-trade, e-health, e-government, e-media, and e-learning supported by ICT technologies are unlocking the human potential and creating an added value in exports, employment, and economic growth. For example, telecommunications sector employed about 150,000 workers in 2009 as illustrated in Table 5[1].

ICT technologies play an important role in supporting good governance, transparency, and accountability by enhancing citizen-government interactions, decentralization, provision of public services, and timely responses to citizens' demands. In 2013, ESCWA led a number of pioneering initiatives to support e-governance including the support for the Academy of ICT Essentials for Government Leaders, e-Government best practices documentation, and business models for Digital Arab Content[2].

Although it is recognized that ICT and e-governance programs can contribute positively to socio-economic development, it is imperative that strategies and objective of e-governance to explicitly include environmental sustainability as a key strategic objectives. Such alignment must take place

[1] ESCWA, Regional Profile of the Information Society in Western Asia, 2011.
[2] Commission on Science and Technology for Development (CSTD), 17th session, Geneva, 12-16, May, 2014.

in parallel at national and regional level and should be monitored at each stage of implementation in order to obtain the desired efficiency and effectiveness (Al-Khouri, 2013).

Although recent studies recognize significant growth due to ICT carbon footprint, they refer to the fact that this sector accounts for only about 2% of global CO_2. Specifically, International Telecommunication Union (ITU) estimated the contribution of ICT to climate change (except broadcasting) as being between 2% and 2.5% of total global carbon emissions. Main sectors contributing to ICT industry include: energy demand for personal computers and monitors (40%), data centers, which contributes another 23%, fixed and mobile communications, which contributes 24% of total ICT emissions (Al-Khouri, 2013).

Box 2- A Future Model City

Masdar city is a future model city and the first city aiming to be free of pollution and waste in the world. It is also the first city to adopt renewable energy sources. It is part of a very promising initiative called "One Planet Living" also known as "the Masdar Initiative". As mentioned earlier, Masdar city will need around 200 megawatts of clean energy compared with more than 800 megawatts for a conventional city of the same size. The city will also need around 8000 m^3 of desalinated water per day compared with more than 20,000 m^3 per day for a conventional city. It will include a solar power plant, and its water will be recycled for use in irrigation and agriculture.

Masdar city has two main roles, one economic and another scientific. Economically, Masdar city is expected to use renewable energy, thereby paving the way for the development of future technologies and creating effective balance in the global energy market which is still developing at high rates. As a result, Abu Dhabi will be able to harness its resources and expertise in global energy markets and build on them to reach new technologies. Scientifically, Masdar city is considered as a global compound of clean technologies that will be fully operational using renewable energy. This goal will be attained through the Masdar Initiative which is an effective joint action aimed at finding proper solutions to the most pressing issues affecting human life, such as energy security, and eventually developing human expertise. Masdar's urban model is expected to prove the suitability and economic feasibility of new technologies, thus encouraging the private sector to replicate them. Besides, the Masdar model will contribute to local capacity-building and use of local expertise, technologies and knowledge as a main pillar of sustainability.

Source: <www.masdar.ae >

It is projected that growth potential is higher in developing countries and LDCs; hence, it will be more efficient investing in these countries to reduce ecological footprints and GHG emissions. However, transition to developing and LDCs will be based of full utilization of ICT in order to achieve climate change adaptation, good governance, education, green development, prosperity and green jobs. For example, women and farmers can use simple forms of ICT, such as cell phones, to effectively manage water and agriculture systems in rural areas.

The research tools made available by Google and other search engines are helping to accelerate research in highly complex fields, such as genomics and genetic engineering, and helping scientists to better understand the full wealth of species and ecosystems on our planet. For example, the "Encyclopedia of Life" (www.eol.org) and "Conservation Commons" are open-access systems that intend to provide information on all of the known species on our planet (McNealy, 2009).

Technology can be considered the art of applying scientific knowledge to practical problems like green transport, green construction, and green building (see Box 3). Also, social networking sites and blogs also enable the public to organise themselves around key conservation issues (McNealy, 2009).

Box 3- Environment-friendly buildings

Saudi Arabia has established many environment-friendly buildings inspired by traditional architectural concepts to pave the way for future architectural achievements. King Abdullah University of Science and Technology (KAUST) is considered as a model building with innovative designs including the following::

(a) natural solar lighting, reducing the need for electrical lighting inside;

(b) "solar cooling" through solar towers retaining solar heat and hot air to facilitate air movement in buildings and therefore reduce the need for electrical cooling; and

(c) solar power which saves annual energy costs by 27.1 per cent.

Source: <www.kaust.edu.sa>

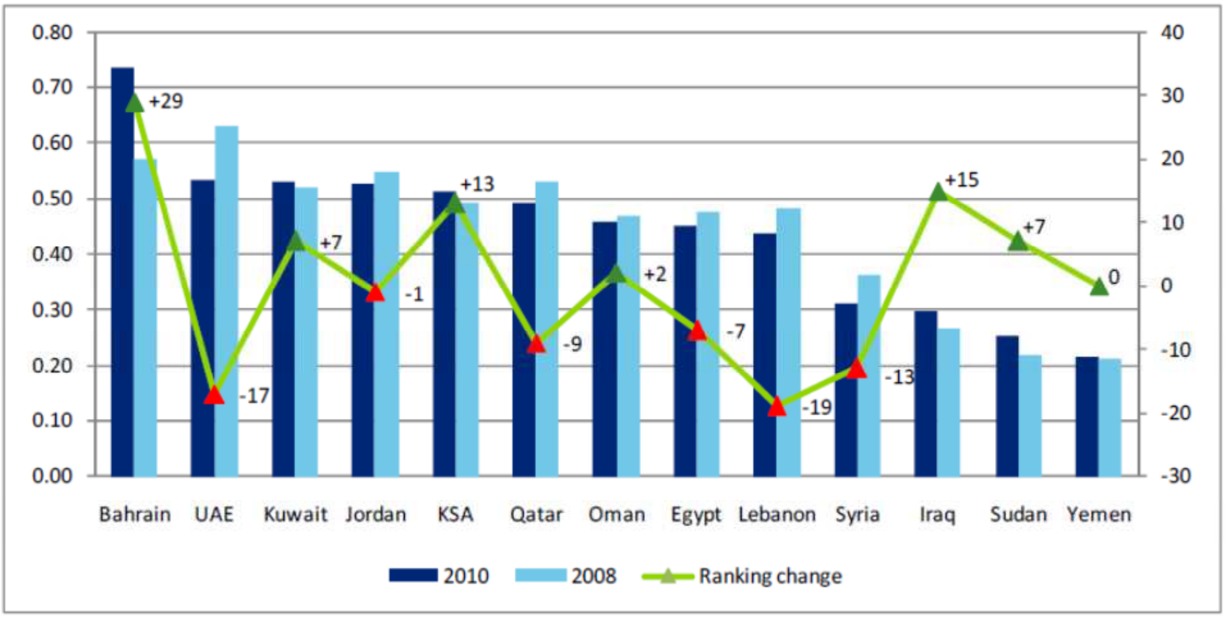
In sum, the emerging technologies in ICT, nanotechnology, bio-technology, genomics, bio-informatics, space technology, and renewable energy can provide huge opportunities for supporting human well-beings and livelihood through sharing best practices to save water, food and energy. Besides, for least developing countries and rural areas, green technologies can provide renewable solar energy as in the case in Yemen and Morocco and wind energy in Egypt (see Box 4 and 5).

Table 5. Employment in telecom sector in selected ESCWA member countries, 2008-2009

Country	Full-time telecommunications employees 2008	Full-time telecommunications employees 2009
Bahrain	2 470	2 500
Egypt	62 113	61 127
Iraq	16 957	21 000
Jordan	5 280	5 756
Oman	3 612	3 598
Qatar	2 048	2 414
Saudi Arabia	24 789	24 261
The Sudan	5 700	5 700
United Arab Emirates	11 759	11 890
Yemen	10 372	10 937
ESCWA total	**145 100**	**149 183**

Source: Compiled by ESCWA based on data from ITU. 2011a.

Technology can support good governance structures, transparency and accountability. Many countries in the Arab region adopted e-government strategies but with different levels of maturity and success as indicated in Figure 3 below.



Source: DESA. 2010.

Figure 3. E-Government Development Index scores of ESCWA member countries, 2008-2010

E-commerce use was the highest is the GCC countries with about 22 per cent per inhabitant while in Levant countries it was about 5 per cent as shown in Table 6.

Table 6. E-commerce users and penetration ratios in selected areas

Region or country	Population	Internet users	Internet penetration rate (*percentage*)	E-commerce users	E-commerce penetration per Internet users (*percentage*)	E-commerce penetration per inhabitant (*percentage*)
GCC	43 499 571	21 809 014	63.60	9 377 876	43	21.56
Levant[a/]	30 825 430	7 886 697	25.60	1 577 339	20	5.12
Egypt	81 121 077	21 691 776	26.74	3 904 520	18	4.81
Total/average	155 446 078	51 387 487	33.05	14 859 735	28.92	9.56

Sources: ITU. 2011a; and Effective Measure and Spot-on Public Relations.

Note: a/ The Levant countries covered by this research included Jordan, Lebanon and Syrian Arab Republic.

The introduction to computers and internet in schools varies across countries in the ESCWA region. The highest student-to-teacher ratio was in Bahrain, Kuwait and UAE and the lowest were Syria and Sudan as shown in Table 7.

Table 7. ICT indicators for selected ESCWA member countries, 2010

Country	Student-to-computer ratio *(ratio)*	Proportion of schools with Internet access *(percentage)*
Bahrain[a/]	6:1	100
Egypt	45:1	66
Jordan[a/]	16:1	72
Kuwait	..	100
Oman	12:1	87
Qatar	8:1	98
Saudi Arabia[b/]	30:1	56
Syrian Arab Republic	50:1	15
United Arab Emirates[a/]	17:1	93
Yemen	53:1	60
The Sudan	40:1	55

Source: ESCWA. 2011. National Profile of the Information Society for each member country.

Notes: a/ Data for 2008.

b/ Data for Saudi Arabia are estimated for 2010.

Two dots (..) indicate that data are not available.

Moreover, technology is supporting the markets to find the best talents in various countries through employment portals like Bayt.com, Akhtaboot and GulfTalent as shown in Table 8.

Table 8. List of selected employment portals in the ESCWA region

Country/region	Short description	Website
Regional	Bayt.com is one of the most prominent job portals in the Middle East covering all ESCWA member countries.	http://www.bayt.com
	Akhtaboot is an online career network currently serving Egypt, Jordan, Qatar, Saudi Arabia and the United Arab Emirates.	http://www.akhtaboot.com/jobs
	GulfTalent.com is an online recruitment portal, with a database of over 2,000,000 experienced professionals. Its services cover the GCC sub-region in addition to Egypt, Jordan, and Lebanon.	http://www.gulftalent.com
Gulf sub-region	The portal provides all advanced job search and resume management features which are available at monster.com, but specifically tailored to the region.	http://www.monstergulf.com
	Established in 2006, the portal allows job seekers to browse through listed jobs, apply online and self-register to be contacted by recruiters for relevant opportunities.	http://www.naukrigulf.com
	The portal provides job search for job seekers and allows recruiters and employers to place their vacancies online and search for a match from its database of registered candidates.	http://gulfjobseekers.com
Egypt	The portal avails a comprehensive suite of career-building tools in order to find a job in Egypt.	http://www.jobsinegypt.com
Lebanon	The portal is dedicated to finding potential Lebanese job seekers for employment opportunities in Lebanon and elsewhere.	http://www.hirelebanese.com
Kuwait	The portal provides jobs and employment search in Kuwait.	http://www.aywaa.net
Jordan	The portal provides recruitment services and career advice. Moreover, it assists students in choosing a specialization.	http://www.almanar.jo
Saudi Arabia	Glowork is the first portal in the region dedicated to providing career guidance for women. The site currently serves Saudi Arabia but will expand to other countries in the region as demand increases.	http://www.glowork.net
The Sudan	The portal offers the job seekers and employers in the Sudan to connect with each other in an online environment.	http://www.sudanjob.net

Source: Compiled by ESCWA from respective sites.

It is important to realize how ICT is perceived to have contributed to MDGs in many forms and at many levels from enhancing farming practices and water use efficiency, e-learning for women and youth to environmental monitoring using GIS and e-health services and hospital management. Table 9 highlights to perceived contributions of ICT in the achievements of MDGs. The Arab region witnessed great strides in ICT technologies in the last two decades and this can be a window of opportunity to develop *ICT to support green technologies to achieve SDGs.*

Table 9. Perceived role of ICT in the achievements of the MDGs

Goal/target[349]	Perceived role of ICT	Impact	Sample output indicators
G1/T1	Provide easy access to market information and reduce transaction costs	Make records and databases easily accessible to farmers	Number of farmers using ICT to conduct their daily business
G2/T3	Create virtual networks of trained teachers	Alleviate shortages of skilled teachers	Number of schools with computers
			Number of schools offering ICT-based education
			Number of new teachers trained per year
	Develop ICT-based education curricula	Enhance ICT skills of teachers and students alike	Evaluation of cost-effectiveness
			Number of primary school teachers trained through ICT-based education
	Encourage e-learning with the development of localized content	Increase distance learning opportunities to unilingual speakers	Number of primary school learning materials available on Internet
G3/T4	Use various ICT tools to raise awareness of general population on gender issues	Help reduce gender-based inequality	Number of women trained to perform technology-based jobs
			Number of jobs created for empowered women
	Educate disadvantaged girls and women on the use of new technologies	Increase the number of women working in the knowledge economy (Web, programming, data entry, etc.)	Number of women using telecentres for various purposes (education, access to data and information)
G4/G5/G6	Train health workers on the use of ICT	Improve administration and management of health institutions	Number of health workers using ICT in their jobs
		Better collection and management of health data	Number of clinics and hospitals with ICT access used for telemedicine
	Make telemedicine available at remote clinics and hospitals	Availability of health services in disadvantaged and remote areas	Percentage of registered or certified practitioners of telemedicine
G7/T9	Use geographical information systems (GIS) for water management	Better management of water resources, maximize access to safe drinking water	Number of polluted water supplies pinpointed by GIS
G8/T8F	Create telecentres in disadvantaged communities	Facilitate access to knowledge in disadvantaged areas	Percentage of population in disadvantaged areas using telecentres
		Educate disadvantaged groups on the use of ICT	Number of women and youth trained on the use of ICT

The ICT sector attracted new business ventures in the Arab region, thus contributing to address the unemployment challenge. About 4000 ICT companies were established in Egypt in 2011 as illustrated in Table 10. The revenue from the telecommunication sector amounted to 7.9 and 6.3 per cent of GDP in Lebanon and Jordan respectively as shown in Table 11. A 23.8 billion dollar was invested in the telecommunication sector in the ESCWA region in 2009 as shown in Table 12.

Table 10. Number of companies working in the ICT sector in selected ESCWA member countries

Country or territory	Number of ICT companies	Year
Bahrain	576	2010
Egypt	3,972	2011
Jordan	442	2009
Lebanon	559	2011
Palestine	150	..
Syrian Arab Republic	192	..
The Sudan	804	2011

Table 11. Telecommunication revenue in selected ESCWA member countries, 2008-2009

Country or territory	GDP in 2008 *(billions of US$)*	Telecommunications revenues 2008 *(percentage of GDP)*	Telecommunications revenues 2009 *(percentage of GDP)*
Lebanon	29 933	7.9	7.9
Jordan	22 696	6.7	6.3
Bahrain	21 902	4.1	4.1
Egypt	162 836	3.7	3.7
Iraq	86 523	3.5	3.5
Kuwait	148 023	3.5	3.5
The Sudan	60 299	3.3	3.2
United Arab Emirates	58 032	3.1	3.1
Syrian Arab Republic	261 347	3.0	3.0
Saudi Arabia	54 516	2.7	2.7
Oman	476 304	3.4	2.5
Qatar	110 712	1.8	1.7
Yemen	26 917	1.2	1.2
Palestine	11 950	0.8	0.8
ESCWA average		3.5	3.4
World average		**3.2**	**3.1**

Sources: World Bank. The Little Data Book on Information and Communication Technology. 2010 and 2011 editions.

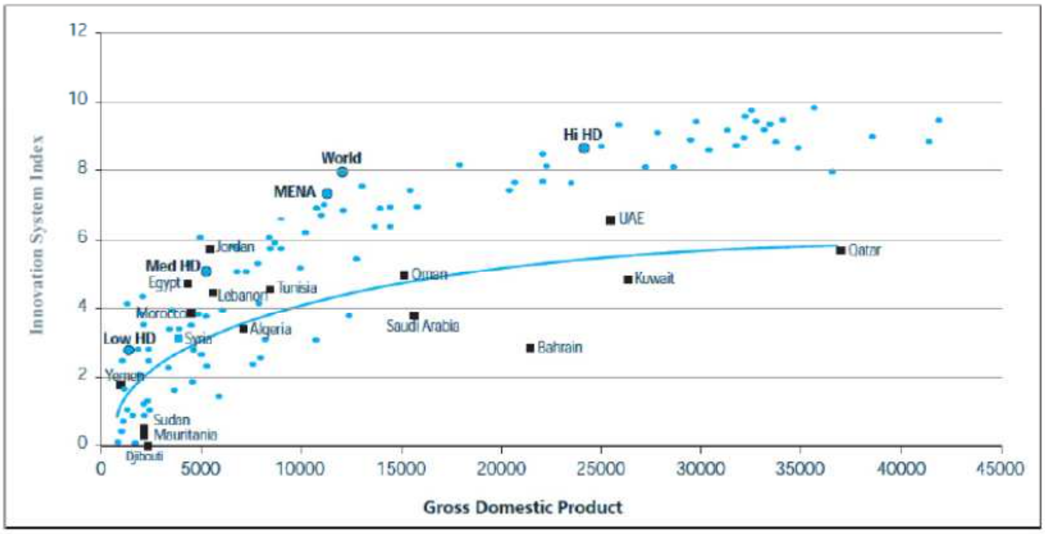
In terms of adoption of STI culture in the Arab world, Qatar, UAE and Kuwait show a high per capita per GDP along with high innovation index as shown in Figure 4.

Table 12. Telecommunication investments in selected ESCWA member countries, 2008-2009

Country	Telecommunications investments 2008 *(thousands of US$)*	Telecommunications investments 2009 *(thousands of US$)*
Egypt	2 737 143	3 117 169
Iraq	..	256 410
Jordan	161 971	247 183
Oman	200 130	396 548
Qatar	383 315	346 241
Saudi Arabia	10 771 175	10 561 218
The Sudan	7 708 325	7 708 325
Syrian Arab Republic	628 240	973 630
Yemen	267 700	243 257
ESCWA total	**22 590 303**	**23 849 983**

Source: Compiled by ESCWA based on data from ITU. 2011a.

Note: Two dots (..) indicate that data are not available.



Source: Mohammed bin Rashid al Maktoum Foundation. 2009. Arab Knowledge Report: Towards Productive Intercommunication for Knowledge. P. 183.

Note: Data source from World Bank database. Knowledge Assessment Methodology (KAM); available at: http://info.worldbank.org/etools/kam2/KAM_page5.asp.

Figure 4. Per capita GDP and Innovation System Index

Box 4- Solar energy use in Morocco and Yemen

It is very difficult to supply remote rural areas with traditional power installations in many Arab countries. In Yemen, ESCWA implemented a pilot project in Kaawa village in coordination with the Ministry of Electricity and Energy in Yemen and in cooperation with the Organization of the Petroleum Exporting Countries (OPEC) Fund for International Development. The project was aimed at achieving rural development and reducing poverty by ensuring better quality of life to rural population, minimizing the gap between rural and urban areas, and creating job opportunities. The project beneficiaries are Kaawa population, local authority and the Ministry of Electricity and Energy.

The project involved the following main activities:

(a) Procuring and installing photovoltaic solar systems in the village;

(b) Providing field training for Yemeni workers and technicians on the installation and maintenance of photovoltaic solar systems, in addition to training and familiarization of rural population about operating and maintaining combined systems;

(c) Conducting performance and project evaluation one year after the completion of operational works, at the technical and social levels.

In Morocco, a solar power plant was inaugurated in May 2010, the first of its kind in Africa and the Arab world. The plant is expected to generate an annual rate of 3538 gigawatts per hour and to cover around 13 per cent of Morocco's power needs.

Source: Deghaili, W.; 2009: *Improving Rural Livelihoods through Photovoltaic Electrification: the ESCWA pilot in Kaawa, Yemen,* Expert Group Meeting on Adopting the Sustainable Livelihoods Approach for Promoting Rural Development in the ESCWA region, 21 – 22 December 2009

Box 5- Wind energy use in Egypt

Egypt has developed a leading experience in using wind energy in the Arab region. In 2008-2009, hydroelectric power generation and wind energy reached 11.3 per cent and 0.7 per cent respectively, while combined power generation reached 11.9 per cent and 1.8 per cent respectively. The combined power generated by wind farms rose from 430 megawatts to 550 megawatts (August 2010). The Higher Council of Energy approved the strategy of the Ministry of Electricity to increase the renewable energy share of total electrical production to 20 per cent by 2020 (including 12 per cent from wind energy). The combined energy capacity should not be less than 7200 megawatts of which 66 per cent will be procured with the participation of the private sector.

The Egyptian government allocated an area of 7647 km^2 for wind farms with an almost free land access to investors. In 2009 and 2010, five wind farms with a production capacity of 5x250 megawatts were announced through Build-Own-Operate (BOO) contracts, and the first wind farm will be completed in mid-2014. The projects are expected to be successfully completed. The Egyptian government supports renewable energy power generation projects by giving top priority to linking them to the electrical network, providing investments, guaranteeing the price of energy purchased from the projects, though identifying long-term energy deals for 20 to 25 years at a price covering costs and returns on investment, while benefiting from low-carbon emission certificates, exploring local manufacturing opportunities and using local capacities to manufacture some of the equipments(iron structures, electrical equipments, pipes, etc), and technically cooperating with global companies under certain forms of partnerships to manufacture other equipments (air turbines, for instance). The private sector participates in wind power generation through competitive bids organized by the competent authority. This experience will allow for price identification and future transition to preferential tariff regimes.

Source: Deghaili, W.; 2009: Improving *Rural Livelihoods through Photovoltaic Electrification: the ESCWA pilot in Kaawa, Yemen*, Expert Group Meeting on Adopting the Sustainable Livelihoods Approach for Promoting Rural Development in the ESCWA region, 21 – 22 December 2009.

VI. INTERNATIONAL AND REGIONAL EXPERIENCES IN THE ROLE OF TECHNOLOGY IN SUSTAINABLE DEVELOPMENT

This section will review and compare how various technologies contribute to sustainable development at global and regional arenas. At the global level technologies in developed countries will be reviewed. These include US, EU (Denmark and Germany), Japan and Korea will be reviewed. On the other hand, selected countries will be studied from South East Asia, India and China. Besides, from the Least Developing Countries (LCDs), Yemen and Sudan will be reviewed. From the West Asia region, three categories will be studied. These include: Levant, GCC, and North Africa (Egypt) and Sudan and Yemen.

It should be noted that there were conceptual shifts in UN debates on the role of technology in development. This can inform new views on technology adoption in the Arab region in light of globalization. As a result, a number of paradigms and approaches had emerged as illustrated in Table 13.

Table 13. Overview of changing paradigms in UN debate on technology since the 1960s

		1960s	1970s	1980s	1990s	2000s
Dominant perceived	Causes of poverty	Lack of science and technology to increase production	Lack of capacity to benefit from technology	State intervention	State intervention, protectionism	Implementation gaps in terms of capacity, funds, technology; low political commitment
	Paradigms, solutions	Big push, technology transfer; techno-optimism; stages of development.	Technology gaps, equitable access; indigenous capacity; NIEO, Neo-Keynesianism, dependency theory.	Neoliberalism and self-regulating markets.	Washington consensus (globalization, liberalization), sustainable development (intergov. agreements, global funds)	Global problems approach: international cooperation to set goals and raise resources
UN	Approach	Scientific-technical level. Authoritative content provided by UN staff and experts.	Political level. Strictly intergovernmental process. Global and regional plans of action.	Increased involvement of public and private stakeholders.	Intergovernmental Summits. Global Forum of stakeholders. High-level panels.	High-level political panels. Expert assessments with stakeholder participation. Transnational alliances, public-private partnerships.
	Meetings	UN Conference on S&T for Development (Geneva, 1963).	UN Conference on S&T for Development (Vienna, 1979).	None	Earth Summit (Rio, 1992)	UN MDG Summits (2000 and 2010), Rio+20 (2012)
	Institutional change	ECOSOC established Advisory Committee (ACAST)	World Plan for Action (1971). Vienna Program of Action (1979). GA created Inter-governmental Committee	IPCC	Rio Conventions; GEF, UN CSD. Donor funding through UN programmes and funds.	Millennium Task Force, IIASTD. Global funds. CDM and emissions trading; "One-UN"; Global Compact.

A. CUTTING-EDGE TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT

Technology development has been the result of interplay of many factors including scientific discoveries, changing business interests, changing consumer demand, and government regulation.

There are a number of advanced technologies that are likely to induce macro-shifts in economy, society and environment. These include nano-technology, bio-technology, renewable energy, genomics, bio-informatics, space science, and advanced materials. Many countries in the developed (US, EU, India and China) and developing world (KSA, Qatar, UAE, Egypt, and Jordan) had research programs and strategies on these cutting edge technologies.

In contrast to the cutting edge or high-tech technologies, local knowledge and culture can inform locally rooted or appropriate technologies. Appropriate technology is a model of people-centred development that is based on small scale, energy efficient, and environmentally sound technologies.

1. Biotechnology and health technology

Transformative discoveries and breakthroughs are taking place in biotechnology. Genetic modification of crops has increased the agricultural yield and enhanced plants resilience and resistance to diseases. However, side effects or externalities were identified due to possible contamination of seeds, access to non-modified food, and reduction of biodiversity.

2. Nanotechnology

The nanotechnology entails the design of technology at the molecular level and includes two types of products, i.e., optical techniques and "scanning probe microscope" and molecular engineering which are used for absorption and lubrication. The most important current applications, as measured by the number of patents, are in micro-electronics: massive storage devices, flat panel displays, electronic paper, extended semiconductor approaches, information processing, transmission, and storage devices. Beyond this, there are more far reaching ideas about: "DNA-computing" and computational self assembly. The main drivers for these developments are computing, telecommunications, consumer electronics, and military applications.

Besides, nanotechnology promises new forms of drug development and delivery, medical diagnosis and cancer treatment. Nanotechnology in combination with biotechnology underpins rapid advances in genomics, drug discovery, gene sequencing, and bioinformatics. Application of nanotechnology in energy and lighting technologies could reduce the energy demand for lighting and raise energy efficiency.

3. Information and communication technologies

GPS, GIS, remote sensing, and the Internet enable unprecedented exchange of information and knowledge across the globe. In the realm of technological innovation, it is expected that the development of small memory chips and microprocessors will support brain research and the merger of human and machine computational intelligence.

Many countries developed green growth strategies to respond to both the environmental and economic challenges. Globally, key sectors and green technologies were identified as shown in Annex 4[1]. Green innovative technologies are common to the developed countries since they work on frontier and cutting edge technologies that address national industries and needs. On the other hand, the developing world and LDCs are mainly dependent on appropriate technologies and technology transfer.

B. THE EXPERIENCE OF DEVELOPED COUNTRIES

1. The United States of America: The US is leading in terms of number of patents in green technologies which include renewable energy, green buildings, advanced technologies, and ICT. IT can be an engine for an efficient and green economy as manifested in cloud computing like Google and Yahoo industries that use renewable energy to operate their power plants and data centers so as to reduce carbon footprint[2]. Besides, the US is leading in developing technologies for sustainable green aviation by increasing the efficiency and seeking alternative carbon neutral fuel like bio-fuel and solar energy[3].

In terms of Green technology patent intensity during (1990-2010), the top ten countries worldwide are: Germany, Japan, Denmark, Switzerland, Taiwan, U.S, Netherland, Norway, Sweden, and South Korea. The main sectors for patents in green technology are solar, bio-fuel, fuel cells, and wind energy[4]. It was evident that the renewable energy is the main catalyst for green investment. The Green agenda in the U.S policy was reflected in federal funding and research agenda in renewable energy. It was found out that a carbon tax is a driver to green technological innovations and to

[1] The 2012 Brookings Blum Roundtable Policy Brief
[2] Greenpeace (2012). Make IT Green- Cloud Computing and its contribution to climate change.
[3] Agarwal, 2012, Review of technologies to achieve sustainable (green) aviation; www.intechopen.com
[4] Bierenbaum, 2012.

address climate change risks[1]. The National Science Foundation (NSF) is the main source of funding basic science, engineering and university R&D in the U.S. It was founded by Congress in 1950 with a mandate to promote progress of science and advance national health, prosperity, national security, and welfare. NSF budget for 2014 was $7.17 billion[2].

2. **Denmark:** Danish invested in wind energy and biogas technologies and they linked them to energy chain for 2020 vision. Denmark has 24 large centralized biogas plants with a total capacity of 50-600 cubic meter of manure per day[3]. Denmark 2020 vision is to use 30% of renewable energy including wind energy, biomass, solar and geothermal. Denmark adopted *technology foresight* to integrate science and technology policy with environmental policy. Three types of technologies were assessed these include: end of pipe solutions, cleaner technology, and system changes for sustainability. Cleaner technologies include: recycling, new energy sources, energy saving technologies.

Besides, smart cities are being studied as a future model for sustainable development that harnesses system thinking in infrastructure, green buildings, green transport along with green IT by using cloud computing, e-governance, smart cars, real-time transport information systems, smart grid, electric trains, and smart water and energy metering[4].

3. **Germany:** There were a set of policies and incentives to support green growth strategy in Germany. These include High Tech Strategy 2020 which focuses on R&D for energy and climate change and Bio-fuel Quota Act 2006, and Renewable Energy Heat Act. Germany is one of the world largest PV markets and it installed 25 GW of renewable energy in 2010[5]. Germany has the world largest wind energy manufacturing cluster. Innovative green technologies include: silicon water technologies, and thin film technologies. The key green technologies in Germany include: power generation and storage, energy efficiency, material efficiency, waste management, sustainable mobility, and sustainable water management.

Besides, combining ICT expertise with R&D in green technologies can help lay groundwork for major green growth opportunities. Green IT in Germany includes green public procurement, green energy storage, automotive electronics, energy-efficient home appliances, and adaptation techniques for climate change.

Employment in renewable energy sector increased in 2010 by 129% in comparison to 2004, amounting to 367,400 jobs[6]. Germany's 2012 *technology foresight* process identified key technologies like sustainable energy solutions, nanotechnology, space program, and green innovation.

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[1] Meltzer (2014), A carbon tax as a driver to green technological innovation, Energy Law Journal. pp.14-45.
[2] The NSF (2014)- Background and Selected Policy Issues, July 5, 2014.
[3] Lybaek, 2013. Enhancing the transition capability of Danish Biomass technology. European Journal of Sustainable Development, pp. 37-50.
[4] Climate Action in Megacities (ARUP, 2011)
[5] Grigoleit and Lenkeit (2012). The renewable energy industry in Germany.
[6] BMU, (2011). Development of renewable energy sources in Germany.

4. Japan: Japan is the third largest economy in terms of GDP after US and China. In 2010, 2.49% of GDP was allocated to R&D. It accounted to 32% of OECD patents and has a strong ICT infrastructure coupled with clean technologies. In Japan, green innovation is viewed as a priority. S&T is the foundation for national survival, knowledge creation and S&T are intrinsic parts of the culture. The country's aim is to create over $468 billion of new demand and 1.4 million jobs in the environment sector by 2020. Its green growth strategy includes key sectors like energy, energy efficiency, transport, agriculture, and trade.

After Fukushima nuclear incidence in 2011, EU and Japan established dialogues to cooperate on Science and Technology in the domain of wind technology and bio-energy by supporting SMEs[1].

Japan green technologies include the core products, i.e., hybrid vehicles, renewable energy, energy-efficient home appliances, and green certification schemes. S&T policy is created in partnership with society. Japan's environmental technologies include: resource efficiency in smart grid engineering, waste management using plasma technology, wastewater purification, and rainwater storage.

5. South Korea: Green growth is conceived as a pillar for Korea's Green New Deal which focuses on climate change adaptation, energy efficiency, eco-system restoration, and green technologies. Korea developed plan for green industry complexes to support SMEs for renewable energy, nuclear energy, bio-energy and biomass technologies. Besides, Korea is investing in cutting edge technologies including advanced nano-products, IT convergence high technology, bio-medicine, and ICT[2].

C. THE EXPERIENCE OF COUNTRIES IN TRANSITION

1. **China and India:** In Southeast Asia, there is a mix of applying local small-scale technologies and the development of new technologies to address both poverty and climate change. Rural agriculture and organic farming are vital for ensuring food security. On the other hand, climate change adaptation technologies are applied in various development sectors like water, energy and agriculture.

It is recognized that implementation of Carbon Capture and Storage (CCS) will reduce CO_2 emissions by to a third by 2050. However, CCS has not been added to the list of technologies in which industrial countries can invest in order to balance their emissions as part of the Clean Development Mechanism (CDM) (COM, 2011, b). The development of emerging economies like China and India is coupled by a high use of fossil energy. Hence, development of climate change adaptation and green technologies is a key element of EU-China Partnership on Climate Change.

Major agro-technological changes have been noticed in both India and China as emerging global economic powers. This includes water and irrigation technology. Other green technologies include:

[1] Lambrecht, 2014. The Clean Energy sector in Japan.
[2] Korea- five year plan green growth.

solar photovoltaic technology and bio-fuel as bio-ethanol and bio-diesel have a potential to assume and important portfolio in future energy scene in Southeast Asia. However, food security concerns and risks are to be assessed when analyzing the feasibility of bio-fuel.

For India and China, the new knowledge in ICT, precision farming, and biotechnology had brought about major technological changes in agriculture. The challenge is to determine the most suited and affordable technology in a market economy.

India initiated biotechnology as a tool for the growth of agriculture and health sectors since the sixth five year (1980-1985) plan. Biotechnology in India has helped sustaining cotton production and also the development of virus-free potato seed, banana and micro-propagation of sugarcane through tissue culture. Almost 70 per cent of Indian population depends on agriculture, which is one of the energy intensive sectors. Agriculture consumes about 35 percent of the total power generated through electrically operated pump sets. It is expected that about 30 per cent of savings is possible through appropriate green technology. India had about 3.1 million hectares of Jatropha plantations in 2009. One hectare of plantation in average soil gives 1.6 tons of oil. Biogas qualifies on the merits that this technology utilizes organic agricultural waste and converts it to fuel and fertilizer. Direct impacts of biogas are fuel-wood agriculture residue, livestock manure, and kerosene savings. Hydropower plants ranging from maximum capacity of 500 kW in Nepal to 25 MW in India are conceived renewable. Generally used in rural electrification, hydropower plants can take an equally important role in facilitating irrigation and value addition at source of agricultural products.

Geothermal technology has potential in China. A geothermal power plant not only generates electricity but also produces hot water for cold storage and crop drying. Genetically Modified Organizations (GMO) has been growing at 45% per annum in developing countries which now account for 39% of 103 million hectares plated worldwide. In India and China, 9.2 million farmers planted GMO cotton on 7.3 million hectares in 2006. In India and China, precision agriculture uses ICT to cover the various aspects of production, including data collection of information input through options as Global Positioning System (GPS) satellite data, grid soil sampling, and yield monitoring.

2. Malaysia: The economy of Malaysia had undergone transformations from resource-based to innovation-based. Besides, Malaysia commercialized new green and ICT-based technologies through establishing a model called "bio-valley" which is a centralized development area for bio-tech with linkages to industry and academia and incentives for entrepreneurship. The ICT application in environmental governance in Malaysia project has proven the best practice in the application of information and communications technology (ICT) for monitoring the quality of air and water on–line. Green technology in Malaysia revolves around renewable energy and bio-fuel. Agriculture is heavily dominated by oil palm that is largely produced for bio-fuel. The new energy policy promotes new sources of renewable energy to supplement to the conventional supply of energy. The fuel diversification policy which includes oil, gas, hydro and coal will be extended to include renewable energy, particularly biomass, biogas, municipal waste, solar and mini-hydropower.

D. Technologies in the Developing World

1. West Asia: The Levant

- **Jordan:** Jordan transformed its economy from agriculture-based in the 1950s to a knowledge-based and service economy in 2000 and beyond[1]. Jordan ICT sector contributes by about 14 per cent of GNP and exported about $202 million in 2010. Also, high tech exports amounted to 5.3 % of the total exports in 2004[2]. ICT sector supported Jordan in rural development through e-learning, e-government, business, and e-health technologies. Beside ICT, health, pharmaceuticals, services, education sectors are among the key contributors to economic growth and prosperity. In 2003-2004, 42000 staff was employed in the science and technology sector. This implies a 1.9 researcher per 1000 people which is higher than Egypt and Tunisia but still lower the global figures.

The key priority sectors are water, energy and food. Hence, The STI system in Jordan defined key strategic objectives to support technologies related to water, food and energy. The Royal Scientific Society (RSS) was founded in 1970 with research centers for energy, water, environment and industrial development. RSS developed and introduced renewable energy technology, ICT technologies for hazardous waste management and water monitoring, cleaner production center and Green Help Desk supported by UN ESCWA in 2013. In 2009, the RSS was expanded to be El Hassan Science City which included Business Park, Intellectual Property Office, and Queen Rania Center for Entrepreneurship to develop an enabling environment that links R&D outcomes to the market and industry. Moreover, the Higher Council for Science and Technology (HCST) was established in 1987 with a mandate to develop R&D and technologies in the domain of ICT, bio-technology, nano-technology, and advanced materials. Scientific Research Support Fund (SRSF) was initiated based on 1% levy on the profits of public listed companies. The areas of SRSF include: engineering, ICT, renewable energy and medicine[3].

In 2011, ESCWA established a regional technology center based in El-Hassan Science City, Jordan. ESCWA Technology Center (ETC) has a mandate to support national technology transfer and national-global knowledge sharing. Also, ETC objectives are to facilitate the initiation of business incubators, support reverse engineering, investment ventures, regional partnerships in STI, and match science-business in diaspora with national needs of Arab countries. ETC identified key promising technologies to meet sustainable development challenges. These include: renewable energy, desalination, nano-technology and bio-technology[4]. Still, ETC results and impact are to be seen to measure the role of technology in sustainable development.

- **Lebanon:** Lebanon has a diverse and dispersed S&T community which is mainly based on public institutions and universities. However, the limited funding, brain drain, and political instability constrained the development of STI. The American University of Beirut (AUB) has a niche in R&D in medical sciences and engineering. The National Council of Scientific Research

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[1] Mahroum et al. (2012). Jordan- The Atlas of the Islamic World- Science and Innovation: Country Case Study.
[2] Same as above.
[3] Same as above.
[4] ESCWA –ETC Newsletters, 2012-2013.

(NCSR) and the Lebanese Agriculture Research Institute are the main public R&D entities. The private sector has a potential to contribute to STI. The science and technology base was early established in Lebanon. In 1962, the National Council for Scientific Research (CNRS) was established under the authority of prime minster office. CNRS had a budget of about $6 million in 2005 and manages four research centers; i.e., geophysics, marine sciences, remote sensing, and atomic energy commission. In 2001, CNRS with support from UNESCO and ESCWA developed Science, Technology, Innovation and Policy (STIP) program for Lebanon. Lebanese STI policy for 2006-2010 focused on linkages of "science to society" to address national needs. The priority R&D areas identified include: water and energy efficiency, ICT for development, technology for industrial development, water and coastal management, and bio-medical industry. In 2006, a program for Science, Technology and Culture was launched to promote diffusion of science to society[1].

- **Syria:** Despite the fact that higher education started in the early 20th century by the establishment of Damascus University, the centralized governance of S&T, limited funding, low pay, and investment in the human capital resulted in low contributions to innovation and patents. The registered patents in 2000 were only 100 and 161 were registered. R%D expenditure was 0.20 % of GDP during 1996-2002[2]. In 2005, the Science and Technology system was reformed and a supreme council for scientific research was established to address national priority needs in agriculture, industry and energy through national research institutions. A number of private and international organizational were hosted in Syria including ICARDA and ACSAD to address agriculture productivity and arid land issues. Science and technologies are important to achieve food, water and energy security which are part of SDG's.

ICARDA had conducted research programs that showed evidence in the role and impact of the role of science and technology in water and food security[3]. These include: improved crop varieties that are more water use efficient, higher yielding and are resistant to draught, increased water productivity, improved water use efficiency, intensified and diversified production systems that increase the returns to water and land used and reduce climate change risk. Other examples for the role impact for ICARDA include[4] science and technology in sustainable development include: conservation and Utilization of crop genetic recourses, crop improvement using biotechnology, integrated pest management that combine resistant varieties with improved crop management practices, optimal supplemental irrigation, and conservation agriculture is an affective technology that increases productivity and improve environmental sustainability in dry land.

Besides, several organizations were established which had a scientific mandate like Atomic Energy Organization and General Organization of Bio-technology. The ICT contributed to foster regional and global linkages in STI and supported partnerships with UN, Japan, France, and EU which were led by the Higher Institute of Applied Sciences. International alliances with EU addressed R&D

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[1] Same as above.
[2] Satti, N. (2005). S&T Development Indictors in the Arab Region: Science and Technology Society. 10:2 (2005). Sage Publications. pp. 249-275.
[3] El Solh(2012)
[4] El Solh(2012)

agenda on waste water reuse, biological treatment, and water management. However, the recent regional instabilities in many countries in West Asia and North Africa confined the role of STI in national development.

2. GCC

The six oil-rich countries in the GCC (Saudi Arabia, Kuwait, UAE, Oman, Bahrain, and Qatar) had invested in the last two decades in establishing a science infrastructure for STI. This is reflected in many science and technology investments in higher education and infrastructure.

In 2006, UAE established a green city in Abu Dhabi, MASDAR, as a model for a green and sustainable (low carbon) city. The key research areas in MASDAR include: energy systems, water, environment, health, micro-systems, and advanced materials.

Besides, in Saudi Arabia King Abdul-Aziz City for Science and technology (KACST) is an impressive integrated model for STI ecosystem with sound funding model that aims to translate R&D outputs into patents and products and services[1]. KACST R&D agenda is comprehensive and ambitious but is similar to R&D and technology agenda of other countries which includes: ICT, water and energy technology, electronics and communications, space and aeronautics technology, petrochemicals, and advanced materials. Also, King Abdullah University for Science and Technology (KAUST) is a new promising model that attracts human talents worldwide to work on cutting-edge research on areas like wastewater technology, electronics, environment, fuel cells, organic solar cells, and marine.

Moreover, Qatar initiated a model for technology diffusion and adoption as manifested in Qatar Foundation[2]. Qatar 2012 National Research Vision consisted of an ambitious R&D agenda with well-defined targets to develop technologies and innovations in the fields of energy and environment, infrastructure technology, and health. Qatar set a target of 2.8 percent of general budget to support research in 2008[3].

Besides, Qatar National Vision 2030 defined strategic priorities in STI which include oil and gas, renewable energy, climate change and sustainability, ICT, solid waste, nanotechnology, bio-informatics, and genomics. Qatar also developed a global food security program with R&D and technology transfer focus. The Qatar Science and Technology Park mandate is to develop e-health technologies, water desalination, ICT modeling and simulation, and health technology with a focus on diabetes R&D[4]. Qatar and all GCC countries, Egypt and Jordan are strategically and purposefully planning to develop an enabling environment for STI the links basic sciences to applied sciences to industry and policy as illustrated in Figure 5.

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[1] www.kacst.sa
[2] www.qf.org.qa
[3] Lawnumber24/2008
[4] Qatar National Vision 2030.

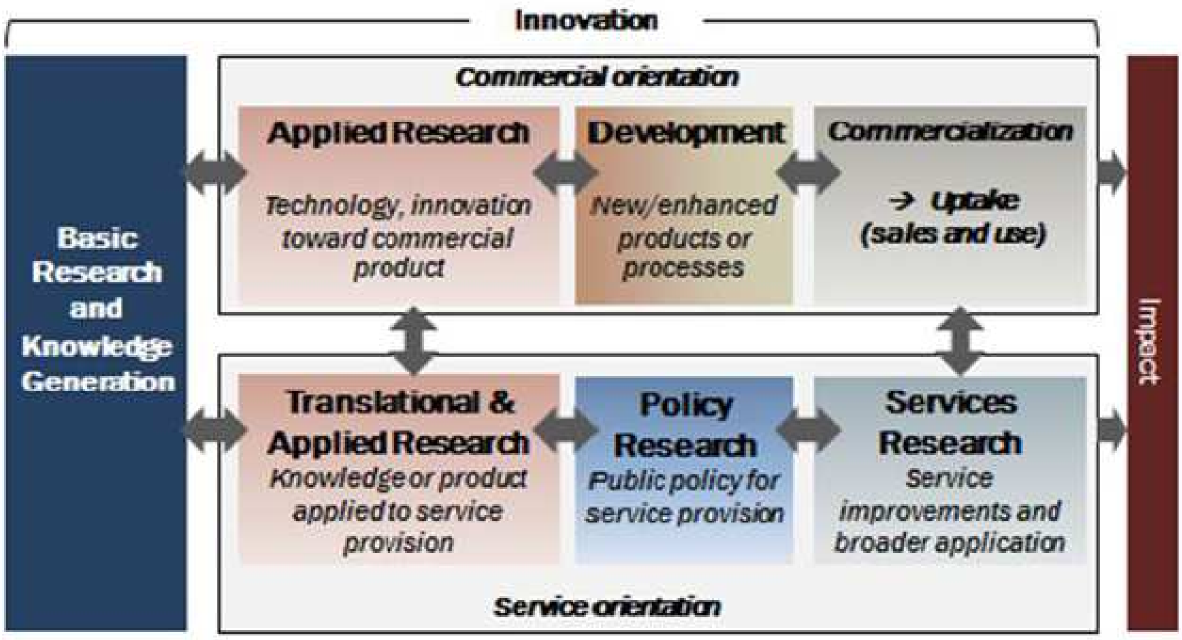

Figure 5. The Ecosystem for STI in Qatar, (Qatar National Research Strategy, 2012).

In Kuwait, the science base was established in 1967 by the Kuwait Institute for Scientific Research (KISR)[1]. KISR was mainly focusing on petroleum technology transfer and developed later to address a wide R&D agenda including water, energy, marine an life sciences, green buildings, and desalination. Middle East Desalination Research Center (MEDREC) in Oman funds joint research in desalination technology since GCC region accounts for about 38 percent of the global desalination capacity, with Saudi Arabia being the largest user of desalinated water [2].

Besides, there are several regional and international R&D agricultural entities in the Arab region are ICARDA and ICBA. ICARDA had programs on agriculture extension and advisory services and link between research and end users. ICARDA developed high yielding of wheat (9 ton per hector compared to 6.5 ton per hector). Many international organizations have a mandate and programs to support STI including ESCWA, EU, OECD, UNISCO, UNIDO, and ALECSO.

In sum, it is evident that GCC countries have an opportunity to make a transition to green technologies and green growth and jobs to satisfy the high electricity demand and reduce GHG emissions since solar technology in GCC presents a future for sustainable development. Gulf oil export will total over 9 trillion dollar by 2020 according to McKinsey, 2008. This capital can fund science technology and innovation and help reach a critical mass for scientists. A number of funding sources were developed recently. These include: The Qatar Foundation and Mohammad Bin Rashid Al Maktoom Foundation in UAE. Shift from S & T to innovation can be attained

[1] www.edu.kisr
[2] IRENA, technical brief 112, 2012.

through building linkages with private sectors and civil society through networks, technology transfer, funding start-ups and venture capitals. There must be a new social contract between science and society. Science and technology is a source of progress for humanity and it's a public good and it's a responsibility of the state. It is recommended to make STI and innovation as a national development objective.

3. North Africa

-Egypt: Like many countries in the Arab region, there is evidence on lack of a coherent and mainstreamed STI agenda and infrastructure. This is manifested in lack of a science and technology culture, poor governance of R&D entities, under-investment, limited incentives for scientists and researchers, and poor linkages between academia and industry. This resulted in brain drain and limited production of knowledge and patents. Egypt's science community is mindful of the need to reform STI system which entails a set on interlinked actions, such as, a merit system for employment, investing in human capital, brain circulation of scientists in diaspora, sufficient funding for R&D, addressing national development needs, and commercialization of research results.

Rooting STI culture in the local context, building home-grown capacity, and bridge building initiatives will be needed to rekindle the private sector appetite for science and technology. Egypt faces a huge challenge in water, energy and agricultural development. The key question is how harness the intellectual capital of 98,000 scientists in 19 governmental agencies and the 198 research centers so as to improve crop yield, reclaim deserts, build more efficient irrigation systems, improve water systems, and utilize renewable energy[1]. The ICT sector is a promising income-generating sector. Egypt attracted global ICT firms like Microsoft, Ericson, Intel, and IBM. ICT industries grow at a rate 13.5 % per year. Egypt plans to spend 1.4 billion dollars in 2010 to generate 2.6 billion in 2014, hence it is becoming the fastest growing ICT economy in the world. There are some good Egyptian examples of ICT technology parks like El- Ghazala Tech Park and smart village.

It is imperative that the governments and policy makers have faith in STI as an engine for sustainable development. This should be reflected in the amount of investment in R&D, however, only 0.25% of GDP was invested in R&D during 2004-2010 which is about one-tenth of what is spent in OECD countries. In contrast, military expenditure amounted to be 2-3 % of GDP per year during 2000-2009[2].

There are a number of pioneer STI initiatives at various levels like SEKEM mode which is a grass-root model for green culture, education, and appropriate technologies and Zuwail City for Science and Technology and Smart Village at Nile University focuses on cutting edge IT technologies.

Egypt established strategic alliances and partnerships with many countries including Europe, Japan, Australia, and US to support R&D and technology transfer and adoption in the domain of renewable

[1] Bond, M. et al. (2012). Science and innovation in Egypt, Atlas report of OIC.
[2] World Development Indicators, World Bank.

energy, ICT, nanotechnology, biotechnology, agriculture, water, and pharmaceuticals. Besides, the institutional set up for STI is well-established. The Academy of Scientific Research and Technology (ASRT), which was established in 1972, is mandated to oversee and guide the STI system and serves as a think-tank and policy advisor to the Ministry of Scientific Research (MOSR)[1].

The 2007 reform of STI governance structures was modeled after Japan and South Korea. This resulted initiation of Supreme Council of Scientific Research Centers and Institutes, science and technology fund, and defining core R&D programs in renewable energy, water, food, ICT, health, and space technologies[2].

In sum, to transform STI in Egypt and the Region, there is a need for more research-oriented students along with incentives to enable them to stay in their countries. Besides, it is imperative to assess and oversee R&D activities and monitor STI indicators, and to invest in infrastructure for new technologies, re-define the role of universities, promote business linkages through incubators, procurement supporting technology development and protected IP.

4. Least Developed Countries (LDCs)

- **Sudan and Yemen:** Improved access to technology and science is critical to enhance the LDCs (like Sudan and Yemen) livelihood and human well-being. In Sudan and Yemen, the science and technology base, and R&D culture are constrained by lack of an enabling environment for knowledge creation and adoption, limited funding and poor governance. The models of technology transfer were limited in rooting a local culture for STI and in promoting organizational learning. Brain drain is another challenge for many LDCs since there is no enabling R&D environment and a national STI agenda to unlock the human potential. South-South cooperation for technology transfer is critical for developing a culture for technology, home-grown appropriate technologies, organizational learning and assimilation of local knowledge[3]. Besides, in many LDCs there is a lack of deliberate technological learning and implementation of policies that respond to national needs and priorities[4]. To overcome the barriers of technology transfer, technology for LDCs must be appropriate in terms of relative advantage and complexity.

In Sudan, renewable energy (bio-mass, hydropower, wind, and solar) are used in the rural areas. The National Council of Research was established in 1970 and focus on agriculture, medical and renewable energy. R&D also exists in the public sector in ministries of higher education, agriculture, and industry.

In Yemen, the use of ICT was evident to support economic development as manifested in applications in e-government, e-leaning, and e-health and in water and agriculture technologies. Besides, to address climate change, a set of technologies were identified for LDCs including, climate change mitigation through agriculture, off-grid energy access, and water use efficiency.

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[1] Bond, M. et al. (2012). Science and innovation in Egypt, Atlas report of OIC
[2] Same as above.
[3] UNCTAD, The LDCs Report, 2013.
[4] Ahmad A. (2004). Science, technology and sustainable development: a worldview. World Review of Science, Technology, and Sustainable Development, Vol.1, No. 1, 2004

VII. Policies and STI systems for technology for development

A critical review of STI policies in the Arab world reveals that Science and Technology in the Arab region follows a national mandate rather than an integrated regional system. There is substantial variation in the level of maturation, mainstreaming and consolidation of STI systems in national development plans and programs.

Besides, the financial constraints limit the spread of STI systems and culture in a structured and sustainable manner. One of the key aspects to be developed is the enabling environment to develop sound STI institutions and governance structures[1]. One key observation is that STI policies are not mainstreamed in the national development strategies and policies and there is no emphasis on innovation as a driver for economic growth. In many Arab countries the STI model does not address the local needs for industry and local development. It is imperative to align and coordinate the various STI programs and initiatives in the public and private sectors to support and respond to the needs of the different production sectors in the economy.

Policies for S&T should focus on harnessing regional and global partnerships and strengthening the enabling environment to transform knowledge to products and services. There are two types of STI policies. These include implicit STI policies which entail stable macro- economic environment, appropriate climate for trade and investment, credit policies and adequate IPR regime. On the other hand, explicit policies for STI include:

- Support for industry based training to encourage technology deepening.
- Increase industry-academia linkages
- Stimulate clusters of knowledge based industries
- Enhance public role in setting priorities, funding, governance and M&E
- ICT policies should seek to maximize the access and flow of ICT to a wider range of users
- Focus on providing platforms for cutting-edge technologies, such as ICT, bio technology, nano-technology, genomics, space technology, and advanced materials.

Most countries in the Arab world developed Intellectual Property (IP) and S&T policies and strategies except Iraq, Libya and Palestine. Table 14 shows some STI systems for selected countries in the ESCWA region.

[1] UNESCO and ALESCO, Arab Plan of Action for S&T (in Arabic), p.9, (2009).

Table 14. STI institutions and policies for selected ESCWA member countries

Country	STI Policies/ Systems	Date	Status	STI System Institutions*	Coordination	Funding
Jordan	▪ National Scientific and Technological Policy and Strategy, and Executive Plan (2006-2010) ▪ National Policy for Science and Technology	2005 1995	Functional	▪ Higher Council for Science and Technology (HCST) ▪ Ministry of Higher Education and Scientific Research (MHESR)	HCST	Through HCST
Kuwait	▪ National Science, Technology and Innovation Policy for the State of Kuwait	2007	Functional	▪ Kuwait Institute for Scientific Research (KISR) ▪ Kuwait Foundation for the Advancement of Science (KFAS) ▪ Supervising and planning bodies ▪ Bodies providing or receiving science and technology	-	Through KISR
Lebanon	▪ Science, Technology and Innovation Policy (STIP) for Lebanon	2006	Functional	▪ National Council for Scientific Research (NCSR)	-	CNRS
Oman	▪ National Science and Technology Strategy (2008-2020)	2007	Functional	▪ The Research Council ▪ Ministry of Higher Education ▪ Higher Education Council ▪ Ministry of Manpower ▪ Oman Accreditation Council ▪ Ministry of Commerce and Industry	Led by the Research Council	Public
Palestine	▪ Palestine Academy for Science and Technology (PALAST)	1998	Functional	▪ PALAST ▪ Ministry of Education and Higher Education ▪ Ministry of National Economy	-	International and regional organizations
Qatar	▪ Qatar Foundation	1995	Functional	▪ Qatar Foundation ▪ Qatar Science and Technology Park ▪ Qatar National Research Fund ▪ Other Education and Research bodies	-	Public
Saudi Arabia	▪ Science and Technology National Policy (STNP)	2002	Functional	▪ King Abdulaziz City for Science and Technology (KACST) ▪ Ministry of Economy and Planning (MEP) ▪ Ministry of Communications and Information Technology (MCIT)	KACST, with national and external cooperation committees and programmes.	Public
Syrian Arab Republic	▪ Establishment of the Higher Council for Scientific Research (HCSR)	2006	Functional	▪ HCSR ▪ Ministry of Communication and Technology (MoCT) ▪ National Planning Council	HCSR is lead institution. National committee coordinates between research and industry stakeholders.	Public

* *The list of institutions and information in this table is preliminary and would be updated based on further access to information.*

VIII. GAPS, CHALLENGES, AND PRIORITIES

The Arab region is characterized by many paradoxes; a region rich in oil supplies but poor in water resources, high growth of youth population along with high unemployment, low expenditure on R&D compared to high expenditure on military, and rich human capital but limited institutional, intellectual, and manufactured capital (technology), and rich heritage of STI but detached from present adoption of the culture of science. However, gaps, challenges, and priorities can be grouped under the following categories as outlined in Table 15 below:

- *Political commitment, policy integration, and planning and coordination.*
- *Infrastructure, funding, and human capital.*
- *STI culture, partnerships, and M&E*

It is recommended that science must become more policy relevant and research agendas must be defined through broad-based participatory approaches. The S&T community called for a new contract between S&T and society, including the following crucial components: (i) improving education and capacity building, (ii) bridging the North-South divide in scientific and technological capacity, (iii) developing clean technologies and sustainable production and consumption patterns, (iv) transforming governance institutions to ensure incorporation of the best available scientific and technological knowledge, (v) establishing long-term monitoring systems, and (vi) augmenting financial resources for S&T for sustainable development.

To address the systemic challenges in STI in the Arab world, a new social contract for STI to sustainable development is imperative to make a transition to a culture of green technologies. A transformative regional vision and development plan for a new Arab region that enjoys dignity, justice, and sustainability is highly needed. The following are a set of gaps and challenges:

The limited science base and inadequate socio-ecological systems: The focus of much of the R&D needed to promote sustainable development will have to be on the complex, dynamic interactions between nature and society (socio-ecological systems), rather than on either the social or environmental sides of this interaction. S&T will have to reach beyond the formal entities of knowledge creation to include grass-root innovation, culture, and local knowledge.

The need for credible, relevant, and legitimate STI systems and institutions: People-centred STI development models are needed in the Arab region to transform to a sustainable society. The interdependence of relevancy and credibility is critical to develop confidence in the ethics and methodologies of technology evolution, diffusion and adoption. In globalized markets, technologies work on both ends of the production consumption chain, hence, a better understanding of local culture, development models and consumption patterns is vital for guiding STI policy and appropriate technology based on people's needs.

There is limited institutional learning in the Arab region. It is noted that the ability of Arab STI institutions to deal with the cross-scale aspects of interactions among society, economy and ecology is limited. It will be insightful to identify how and under what conditions some STI institutions advance sustainability goals better than others based on global and regional experiences.

Social and organizational learning in STI: The Arab region needs to strengthen its ability scale up and learn from locally-based initiatives and to harness science and technology from around the world in terms of STI culture, science ethics, agenda setting, business and funding models. It is crucial to build sound STI governance models and to foster a process of science-policy interface to develop regional funding opportunities for common research agenda on *ICT for green technologies* in water, food, and energy.

Table 15. Gaps and priorities for STI systems in the Arab region

STI Domain	Gaps	Priorities
Political commitment, policy integration, and planning and coordination	Limited political commitments, coordination, and policy integration for STI in many countries.	Develop regional R&D teams to work on joint common priority areas (ICT for green technologies in water, energy, food, and health)
	Insufficient policy integration at national and regional levels.	Enhance policy dialogues across sectors and disciplines
	Limited STI strategic planning and coordination among various entities.	Mainstream STI in national development plans
Infrastructure, funding, and human capital	Inadequate STI infrastructure in Levant and North Africa and LDCs (Yemen and Sudan)	Harness ICT technologies to develop regional virtual hubs of STI networks and communities of practice
	Below global average funding for STI	Prioritize and consolidate regional funding mechanisms
	No retention policy for brain-regain and circulation for scientists	Harness the human capital of diaspora on national needs
STI culture, partnerships, and M&E	Limited mainstreaming of the culture of science and technology	Develop programs on Science for Society
	Limited partnerships with business and civil society	Support new partnerships with business and society
	Insufficient STI observatories and M&E systems	Support STI observatories and STI audit

A. STI PRIORITIES FOR T4D

1. Science-policy interface

Mainstream STI on national development agenda is the cornerstone for profiling STI for green technology in the Arab region. This requires developing a new contract between science and society for sustainable development. Under the contract, the S&T community would devote an increasing fraction of its overall efforts to R&D agendas reflecting socially determined goals of sustainable development. This in turns will require changes in both the demand and supply sides of science and technology for sustainable development. Increasing the demand for S&T will require increasing public and political awareness of the nature and magnitude of the challenges posed by transitions to sustainability.

Creating links between knowledge generation and enterprise development is one of the most important challenges facing developing countries. There are a variety of ways in which governments can help stimulate small and medium-sized enterprises: for instance, by supporting business and technology 'incubators', export processing zones, and production networks that allow small enterprises to pool business services and labor pools. Targeted taxation regimes and market-based instruments, and a wide variety of strategies for unlocking financial capital, are needed to create and sustain enterprises that contribute to sustainable development.

2. Ecosystem for innovation

A culture for green technologies supported by ICT (*as a core competence*) requires institutional coherence and coordination at both vertical and horizontal levels. Achieving a transition to sustainable development is inconceivable without meaningful dialogue and partnerships among the STI community. There is a need to develop technology foresights and to support observatories to develop metrics and STI mapping and indicators. Besides, it is critical to establish networks for innovation parks and regional hubs for STI and green technologies so as to enhance the attractiveness for the R&D infrastructure for financing regional projects, and support starts up and SMEs under a regional enabling conditions, such as, a regional strategic framework for green economy for the industrialization in the Arab region, CSR, and IPR legal frameworks.

3. A critical mass of human capital and tipping points

International organizations such as UN ESCWA, ICSU, ISTS, and TWAS should develop alliances scientists abroad along with grass root and national STI entities to co-develop the most appropriate R&D activities that address specific sustainability problems in the Arab world. Collaborative joint research at the regional level among R&D entities like KAUST, KISR, MASDAR, RSS and others is likely to create a critical mass and a tipping point in technologies for sustainable development. For example, Qatar Foundation developed regional funds for R&D that can be harnessed to address regional priorities in STI.

4. STI institutions and good governance

There is a need for new participatory mechanisms for different groups to share perspectives about critical gaps in knowledge and technical capabilities, to develop common agreement on priorities for future R&D efforts, and to develop frameworks under which research can be organized as effectively as possible. The outcome of these efforts would be an R&D agenda that is primarily targeted towards the research community and the individuals and institutions that influence R&D funding priorities. Ranking R&D institutions, regional awards in excellence in STI, and supporting regional funding mechanisms can provide incentives for branding R&D institutions. Also, linking

R&D to society and national priorities as key performance indicator can provide some accountability and responsibility to science to society.

Besides, this requires a strategic intent to harness Direct Foreign Investments (DFI) to ensure appropriate technology transfer and to negotiate STI under FTA and international agreements and conventions.

5. Regional initiatives with compelling vision like green regional transport and regional green energy flagships

A key characteristic of harnessing STI for sustainable development is the need to go beyond generating new knowledge towards applying this knowledge to real world problems. The Arab region needs a compelling and transformative vision that creates linkages and shared infrastructure like an Arab regional green transport network (green regional Arab train network), regional renewable energy mega-projects, and regional desalination plants. Brain re-gain and virtual R&D teams on national and regional priorities. The Arab League and GCC can provide the regional mandate and political commitment to co-create a regional transformative vision.

Circulation of the Arab human capital in diaspora and linking R&D and patents providers with investors worldwide can help establish a critical mass of science community to address national and regional needs in water, energy, food and health. To address the needs of this generation, it is a priority to strengthen programs for training young individuals using ICT technologies and e-learning models in interdisciplinary research and assessment approaches central to harnessing science and technology for sustainable development.

IX. PARTNERSHIPS IN TECHNOLOGY FOR DEVELOPMENT

The Arab region hosts many national, regional and international R&D organizations. These include ESCWA, IRENA and RECREE for renewable energy. Besides, South-South collaboration is already taking place as in the case of ICARDA, ACSAD, and the International Center for Bio-saline Agriculture work on enhancing crop productivity and control desertification.

At the International level, ESCWA, UNESCO, CHOMSTEC, ICSU[1], ISTS[2], and TWAS[3] support and facilities knowledge diffusion and adoption for many national R&D institutions. Pioneer institutions like MASDAR in UAE, Qatar Foundation, KAUST, and KACST, KISR in Kuwait, RSS in Jordan, and the Zuwail Science and Technology City in Egypt play a valuable role in knowledge co-creation by opening channels for dialogue between the producers and the end-users of scientific knowledge, and by fostering new types of systems thinking in STI. These organizations have unique role along with the international S&T community to stimulate locally-driven initiatives and technologies for sustainable development.

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[1] - The International Council for Science (ICSU): www.icsu.org/
[2] -The Initiative for Science and Technology for Sustainability (ISTS): sustainabilityscience.org/
[3] - Academy of Sciences for the Developing World (TWAS): www.twas.org/

These STI global partnerships are instrumental to inform new ways of developing home-grown technologies through participatory processes by integrating indigenous knowledge and grassroots technological innovation into formal research and development (R&D) initiatives.

Climate change risks and threats are shaping new global partnerships in STI. The S&T enterprise is already evolving towards new paradigms for harnessing green technologies and ICT to transform to green economy. For instance, advances in complex system modeling and integrated assessment methodologies are providing new opportunities to overcome traditional disciplinary R&D. International and interdisciplinary scientific assessments (such as the Intergovernmental Panel on Climate Change, the Millennium Ecosystem Assessment, and Arctic Climate Impact Assessment) offer opportunities for integration of knowledge across a broad range of disciplines and development experiences, and involving an array of stakeholders. ICT technologies offer new opportunities for knowledge sharing, transparency, and science advocacy.

Over the past two decades, global change research has led to countless new insights about the magnitude and rate of human-driven changes to the Earth System. Among the key players in this work are the four Global Change Research Programmes - the International Geosphere-Biosphere Programme, the International Human Dimensions Programme in Global Environmental Change, and the World Climate Research Programme.

In recent decades, considerable attention and resources have been devoted to technology-oriented approaches to reduce pollution and increase efficiencies of material and energy use. These are critically important efforts, but in terms of achieving transitions to sustainability, it is necessary to develop a more holistic understanding of production/consumption systems and population dynamics in a region plagued with poor governance, unemployment, conflicts and refugees. The United Nations Environment Programme (Division of Technology, Industry, and Economics) has numerous activities for promoting environmentally-sound technologies and industrial management practices, and building worldwide linkages among industry leaders and experts in clean, efficient production technologies.

The Arab region can benefit from various forms of partnerships, such as, south-south partnerships with South Africa, Latin America and countries in transitions like India and China. Moreover, north-south alliances in the form of technical assistance or technology transfer with EU and US in green technologies. The experience of South Korea and Malaysia in green technology can inform new business models for technology adoption and localization of appropriate green technologies.

In conclusion, there is a need for strengthening and re-orienting science and engineering systems to inform a new science-policy discourse. Moreover, a macro shift in the business model and operations of STI in the Arab world is needed to improve on STI indicators and unlock the immense potential. This requires strategic investment in R&D, ICT infrastructure, and technology transfer so as to transform the economic model in the Arab world and to achieve SGDs. Besides, it is imperative to build a critical mass of scientists, and regional research groups to bridge the gap and knowledge and innovation deficit in the Arab region.

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ANNEXES

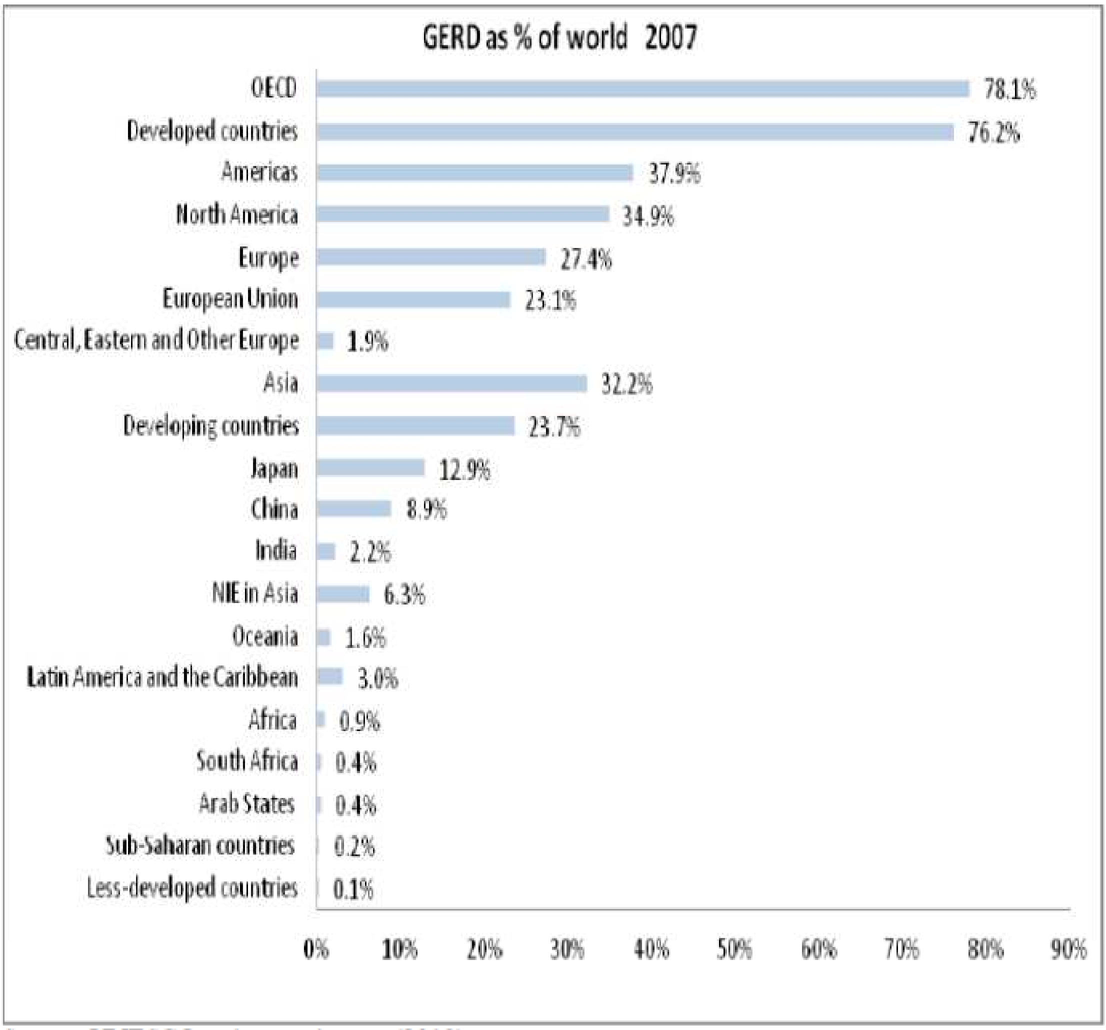
Annex 1: STI Indicators in the World including the Arab region

Annex 2: STI Indicators in the Arab region

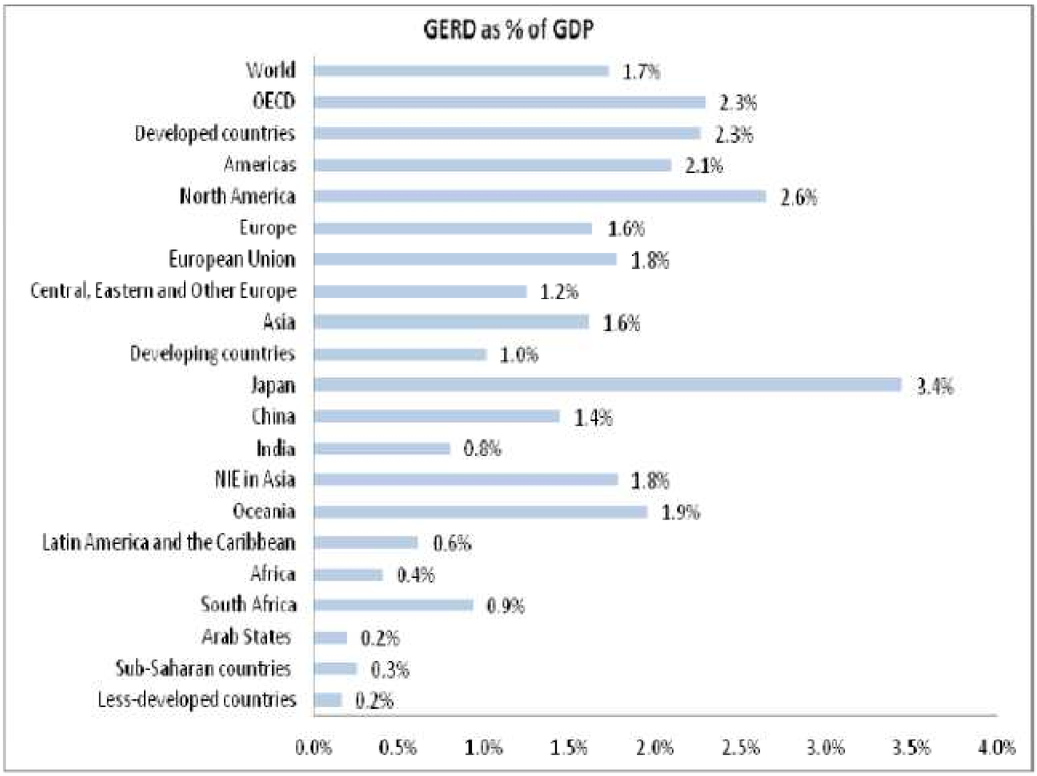
Annex 3: Examples of how technology contributes to sustainable development goals

Annex 4: Key sectors and technologies for green growth innovations

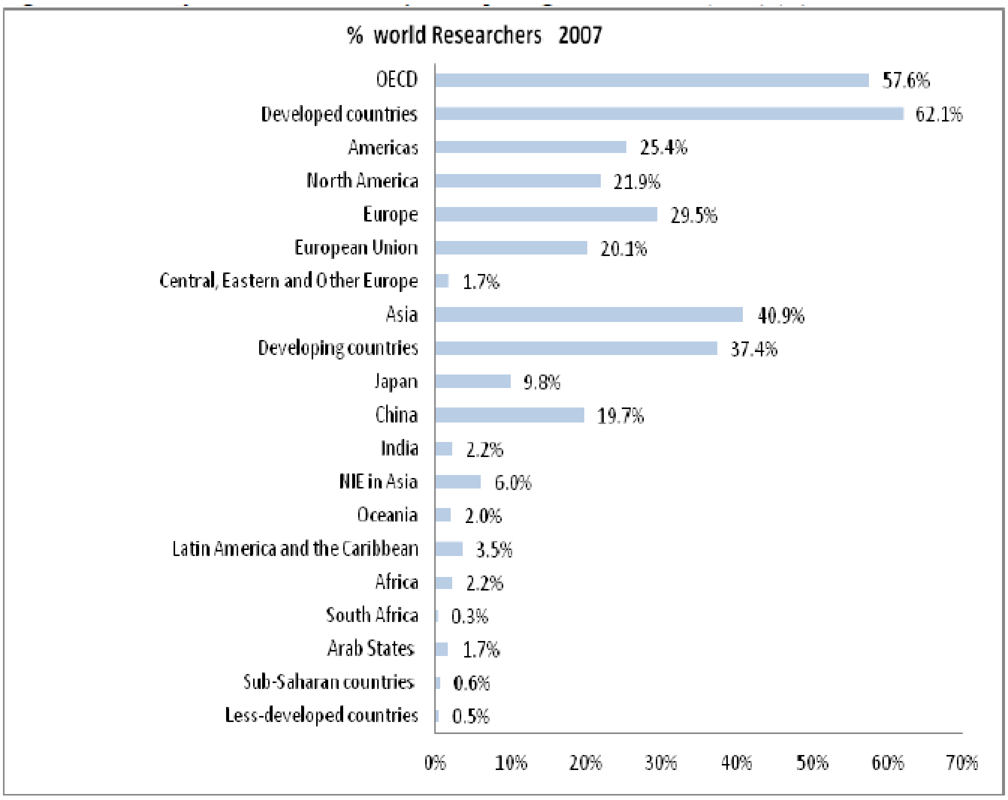
ANNEX 1. STI INDICATORS IN THE WORLD INCLUDING THE ARAB REGION



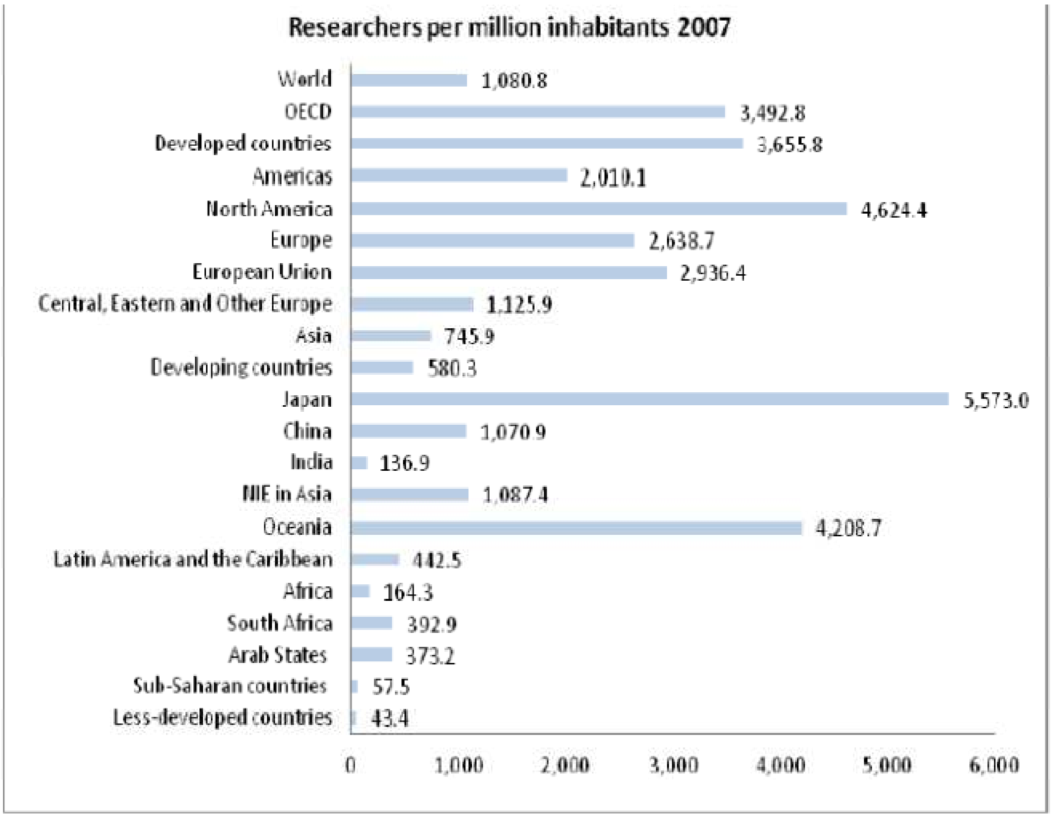
Source: UNESCO estimates August (2010)



Source: UNESCO estimates August (2010)



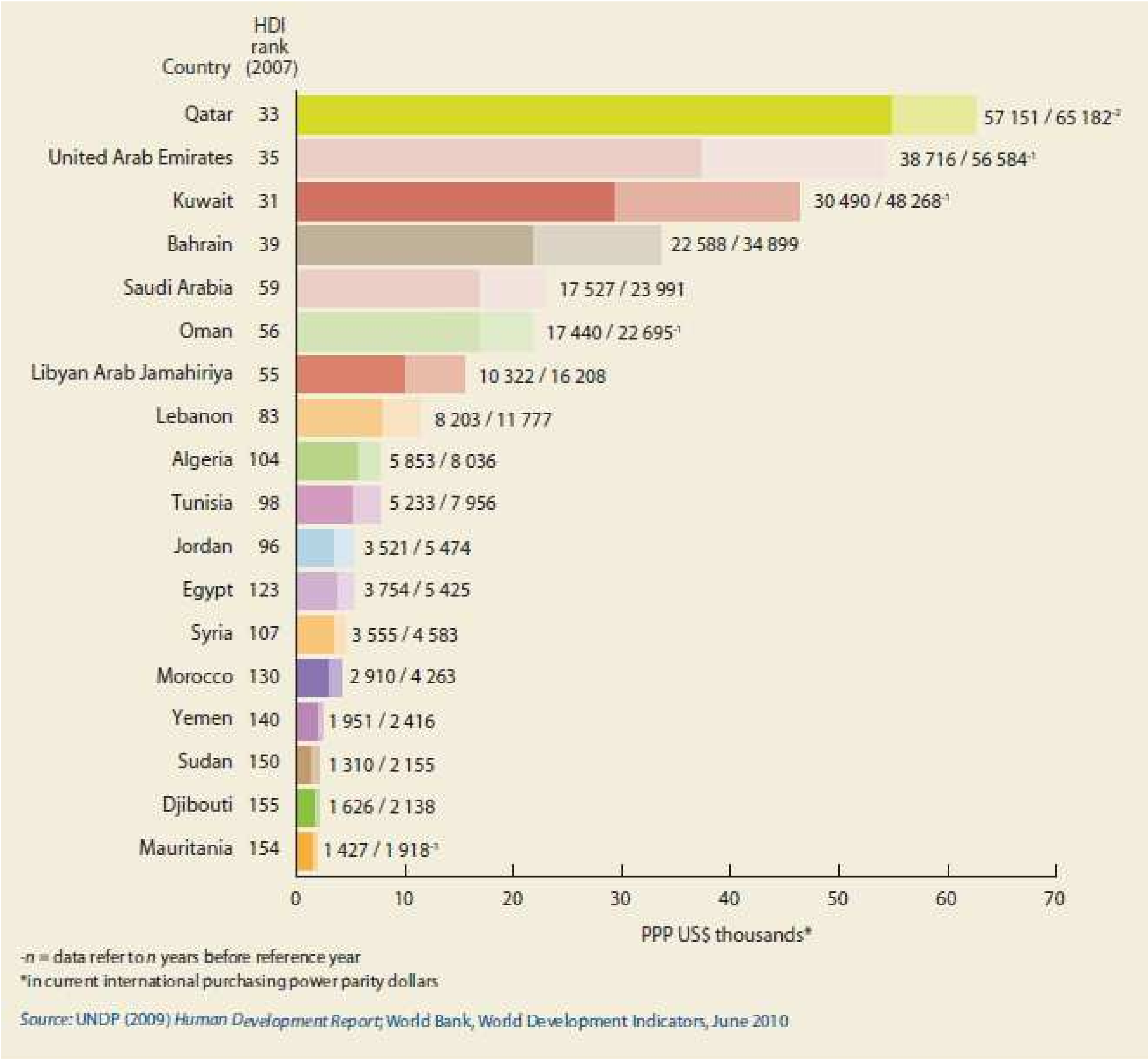
Source: UNESCO estimates August (2010)



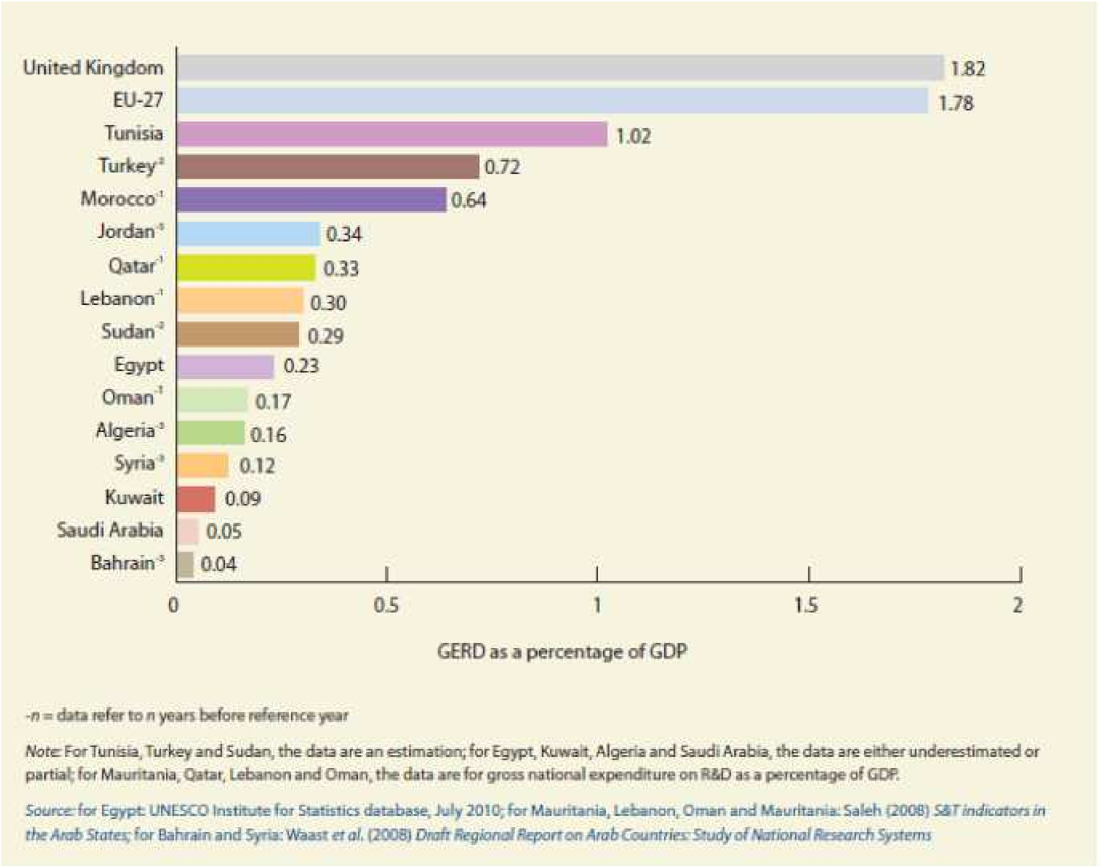
Source: UNESCO estimates August (2010)

Annex 2. STI Indicators in the Arab region

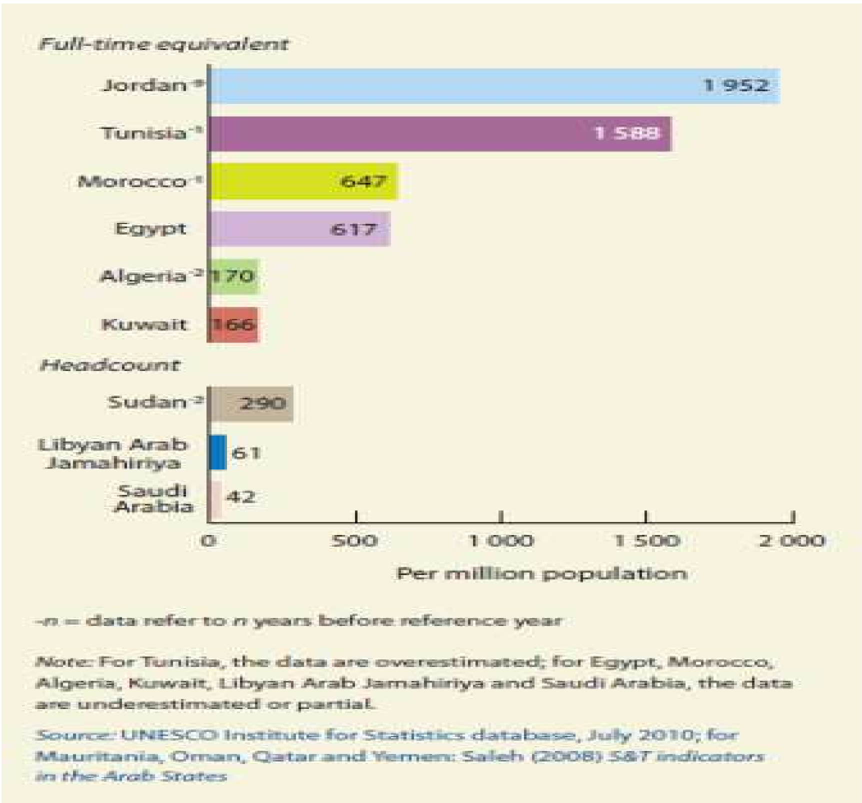
GDP per capita in the Arab region



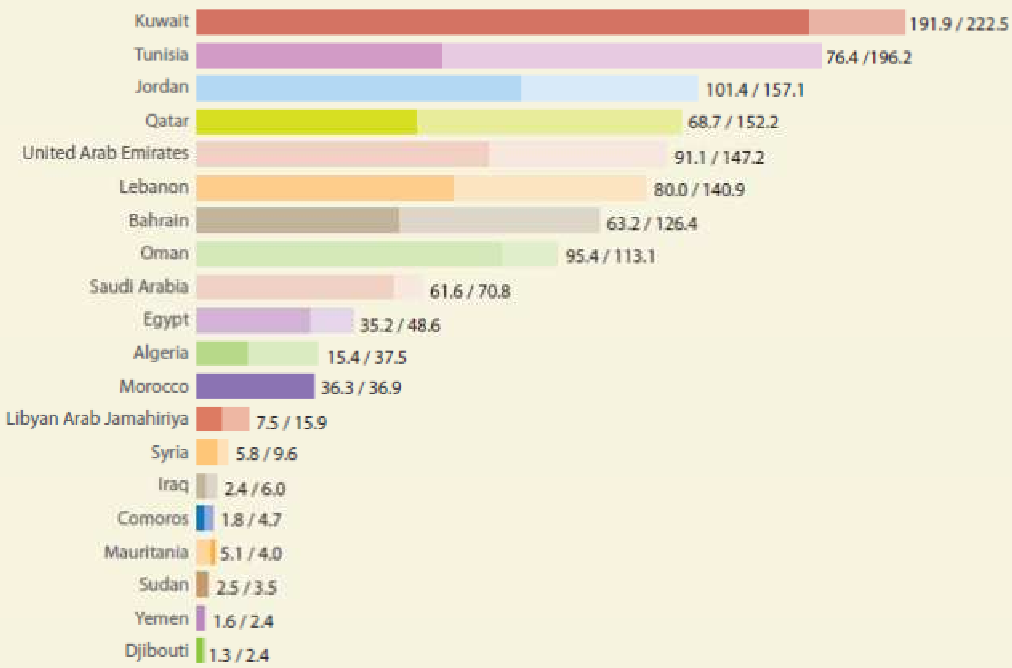
GERD as % of GDP for the Arab countries



Researchers per million in the Arab world, 2007

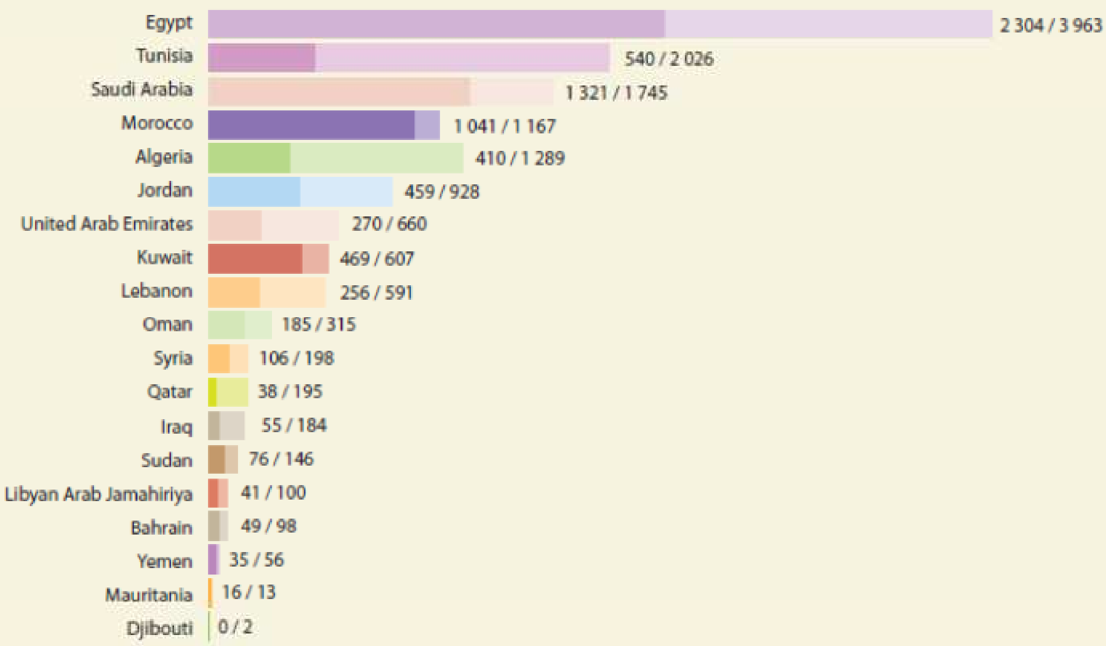


Scientific publications per million population in the Arab world, 2002 and 2008



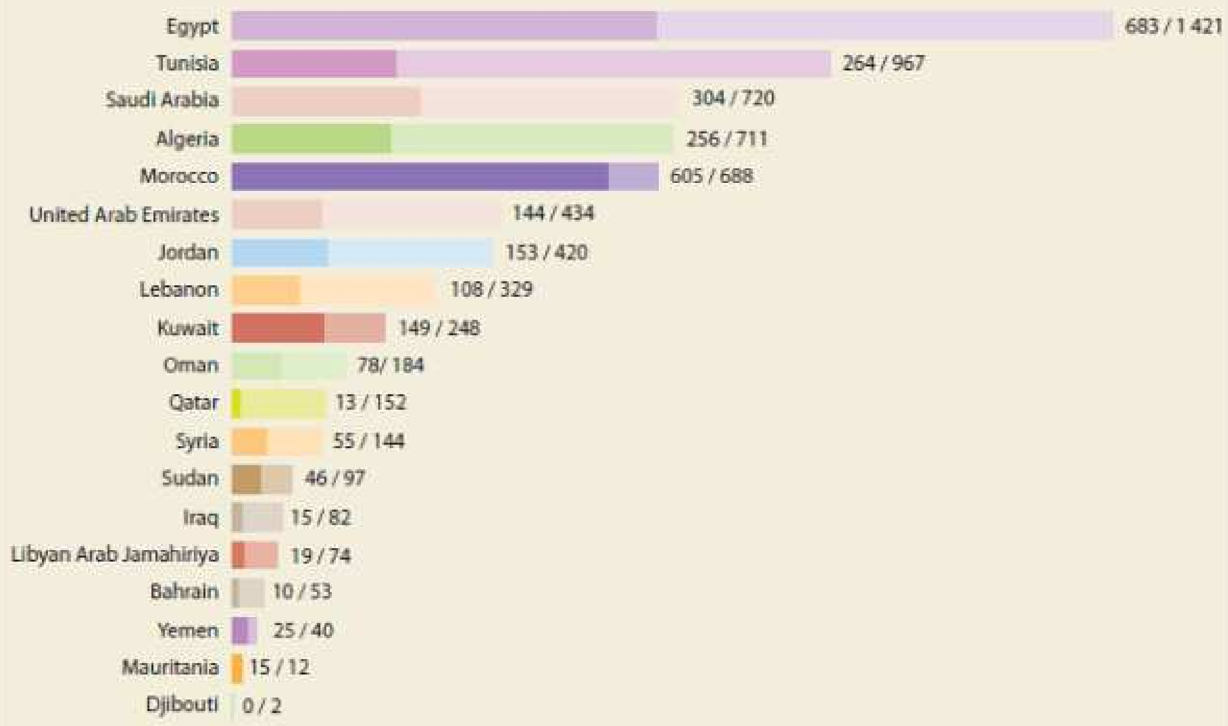
Source: Thomson Reuters (Scientific) Inc. Web of Science. Science Citation Index Expanded, compiled for UNESCO by the Canadian Observatoire des sciences et des technologies; for population data: World Bank, World Development Indicators, June 2010

Scientific articles published in the Arab world, 2002 and 2008



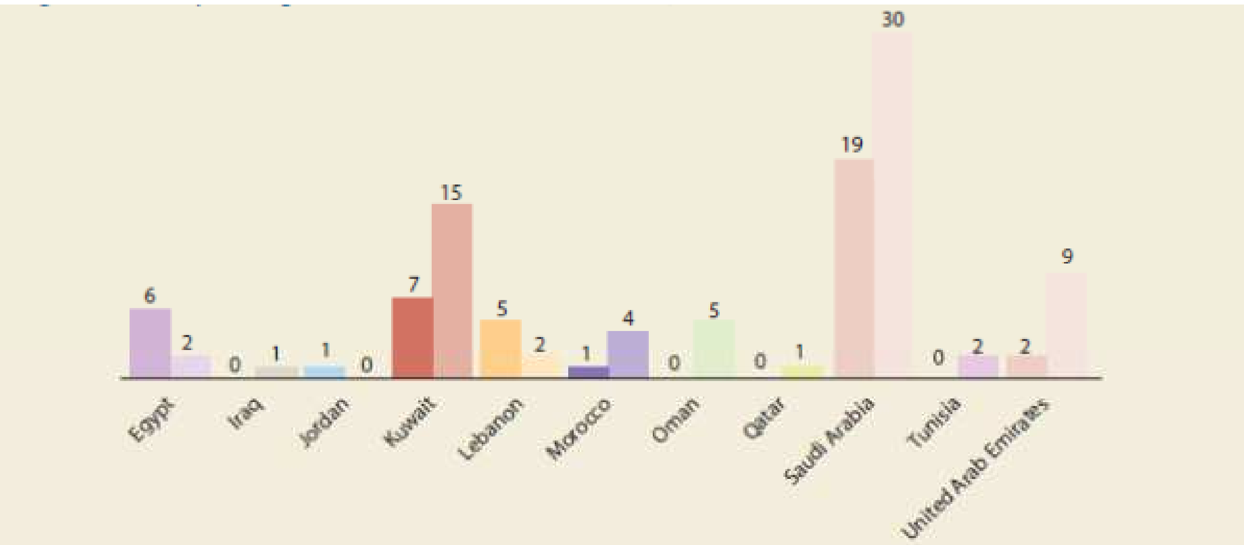
Source: Thomson Reuters (Scientific) Inc. Web of Science, Science Citation Index Expanded, compiled for UNESCO by the Canadian Observatoire des sciences et des technologies

Scientific co-publications in the Arab world, 2000 and 2008



Source: Thomson Reuters (Scientific) Inc. Web of Science, Science Citation Index Expanded, compiled for UNESCO by the Canadian Observatoire des sciences et des technologies

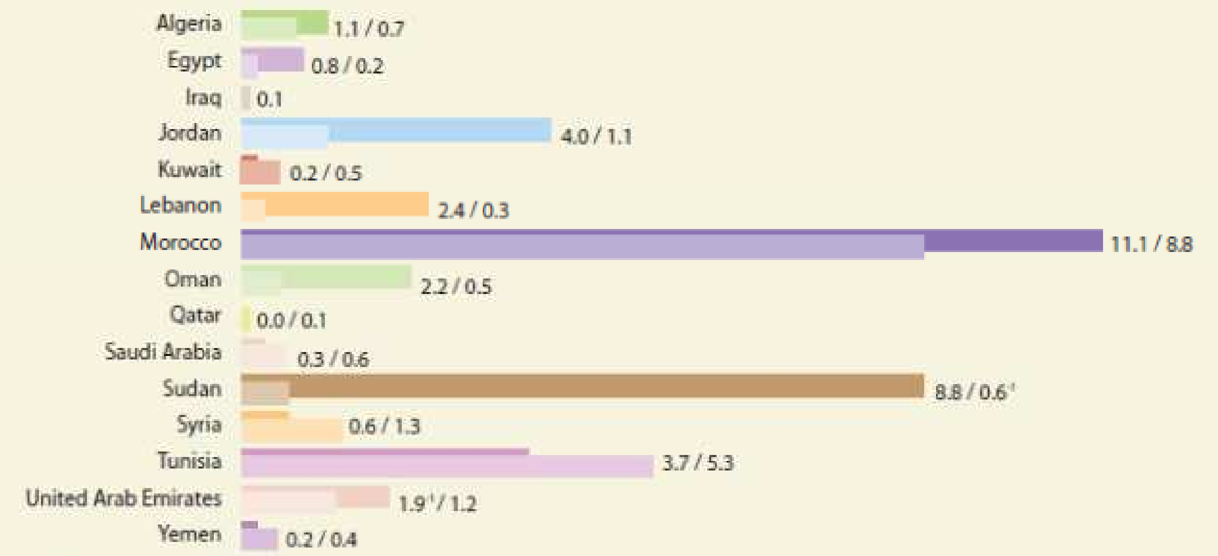
USPTO Patents granted to residents of Arab countries, 2003 and 2008



Note: The country of origin is determined by the residence of the first-named inventor. No patents were granted to residents of Algeria, Bahrain, Libyan Arab Jamahiriya, Mauritania, Sudan and Yemen in 2003 and 2008.

Source: United States Patents and Trademark Office

Share of Arab High-tech exports in total manufactures exports, 2002 and 2007



-n = data refer to *n* years before reference year

Note: The relatively high share of high-tech exports for Sudan in 2002 can be explained by the fact that overall export figures for Sudan are very low, so a single large order in a given year may represent a large share of the total.

Source: World Bank, World Development Indicators, June 2010

Internet penetration, 2002 and 2009

Country/ territory	Internet users per 100 population		Growth 2002–2009
	2002	2009	(%)
United Arab Emirates	28.3	82.2	272
Bahrain	18.1	82.0	429
Oman	6.9	43.5	624
Saudi Arabia	6.4	38.1	600
Kuwait	10.3	36.9	340
Tunisia	5.3	34.1	592
Morocco	2.4	32.2	1 371
Qatar	10.2	28.3	470
Jordan	6.0	27.6	466
Lebanon	10.3	23.7	150
Egypt	2.7	20.0	739
Syria	2.1	18.0	978
Algeria	1.6	13.5	840
Sudan	0.4	9.9	2 525
Palestinian Autonomous Territories	3.1	8.3	239
Libyan Arab Jamahiriya	2.2	5.5	183
Comoros	0.6	3.6	659
Djibouti	0.5	3.0	600
Mauritania	0.4	2.3	650
Yemen	0.5	1.8	320
Iraq	0.1	1.1	1 200
World	10.7	26.8	140

Source: International Telecommunications Union, World Telecommunications/ICT Indicators, July 2010

ANNEX 3. EXAMPLES OF HOW TECHNOLOGY CONTRIBUTES TO SDGS

Goal	SDGs targets	Technology Applications	Institutional hubs for Technology to address SDGs
End extreme poverty	Reduce high inequality within and across countries and rural-urban. Protection against natural and human-induced shocks	Food technologies Water technologies Energy technologies ICT for green industries. E-business, e-trade. ICT for DRR	ICARDA, IFAD, FAO, Un-Habitat, ICBA
Create decent jobs	Reduce women and youth unemployment	ICT for green technology Renewable energy Green buildings Recycling	Business parks, iParks, ICT for green business Clean Production Centers
Provide quality education and lifelong learning for all	Reduce inequality in education opportunities between regions Entrepreneurship and research and development in technology	E-learning technologies	ESCWA Knowledge stations, UNESCO ESD,
Empower girls and women, achieve gender equality and the full realization of women's human rights	Prevent and eliminate all forms of violence against women and girls	Social media, e-media Health technologies (bio-engineering, nano-technology)	NGOs. CBOs
Ensure healthy lives			
Secure access to water and sanitation for all and promote the sustainable use and management of natural resources	Secure access to safe potable water, sanitation and hygiene Promote access to appropriate water technologies	Water saving technologies	ACWA,
Secure access to sustainable energy for all	Increase the share of solar and wind energy in the energy mix Improve energy efficiency indicators in all activities and uses Promote access to appropriate energy technologies	Water saving technologies	IRENA, RECREE, NERC and universities
End food insecurity and malnutrition and promote sustainable agriculture	All food and agriculture production systems become more productive, sustainable, resilient and efficient – minimizing adverse environmental impact without compromising food and nutrition security	Water use efficiency technologies and agriculture technology	FAP, IFAD, ICARDA, Bio-saline center

Promote sustainable and inclusive cities and human settlements and ensure quality housing	Promote sustainable transport and ensure the right to a decent, safe, inclusive and affordable public transportation network Increase the proportion of recycled waste	Green building technologies Recycling technologies Bio-engineering Environmental technologies (soil remediation, waste treatment and management, air monitoring) Earth quake prevention technology	GBCs, private sector, NGOs
Secure peaceful societies and effective institutions	Improve transparency and accountability in public finances management Leverage ICT and promote e-government services	Social media and e-government, e-business, e-trade	Public sector and Private sectors.
Advance global partnerships for sustainable development	Ensure greater cooperation on environmentally sound technology transfer and support action on both climate change mitigation and adaptation and natural disaster risk management	Climate change technologies., MIS and DSS in water and environment, Carbon capture and storage (CSR)	Public and private sectors

ANNEX 4. KEY SECTORS AND TECHNOLOGIES FOR GREEN GROWTH INNOVATIONS

Sector	Examples of Technologies
Electricity Access	• Smart power grids • Indoor cooking stoves using renewable energy (for example, solar, wind) • Off-grid technologies such as local wind turbines
Water Management	• Desalinization plants • Wastewater treatment facilities
Climate Change/ Reducing Emissions	Mitigation technologies: • Smart power grids • Renewable energy technologies: wind, solar, geothermal, marine energy, biomass, hydro power, etc. • Electric and hybrid vehicles • Carbon capture and storage Adaptation technologies: • Higher-yield seeds (for more arid and saline soils) • Drought resistant crops and cultivation practices • Climate resistant infrastructure: sea walls, drainage capacity, water, forest and biodiversity management, etc.
Transport	• Bus rapid transit • Low emission vehicles and fuels: biogas, hybrid and plug-in electric vehicles
Building Energy Efficiency	• Smart power grids and smart meters • Thermal insulation • Energy efficient lighting: energy-efficient compact fluorescent lamps, electroluminescent light sources • Energy recovering stoves using thermoelectric generators
Agriculture	• Genetically modified crops • Mechanical irrigation and farming techniques

Source: The 2012 Brookings Policy Brief