Economic and Social Commission for Western Asia

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ESCWA

Developing the Capacity of ESCWA Member Countries to Address the Water and Energy Nexus for Achieving Sustainable Development Goals

Water-Energy Nexus Operational Toolkit
Technology Transfer Module

Economic and Social Commission for Western Asia

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Abbreviations and explanatory notes

BOT	Build operate transfer
BTUs	British thermal units
CO_2	Carbon dioxide
CSP	Concentrated solar power
CTF	Clean Technology Fund
CTO	Cooling tower only
CWET	Centre for Wind Energy Technology
DEWA	Dubai Electricity and Water Authority
EIB	European Investment Bank
ENPI	European Neighbourhood and Partnership Instrument
EOR	Enhanced oil recovery
EPRI	Electric Power Research Institute
FDI	Foreign direct investment
FO	Forward osmosis
GCC	Gulf Cooperation Council
GCF	Green Climate Fund
GDP	Gross domestic product
GEF	Global Environment Facility
GFCF	Gross fixed capital formation
GHG	Greenhouse gases
GIZ	Deutsche Gesellschaft for Internationale Zusammenarbeit (German International Cooperation Agency)
GW	gigawatt
GWh	gigawatt-hour
Hg	Mercury
IEA	International Energy Agency
IKI	Internationale Klimaschutzinitiative (International Climate Initiative)
IRENA	International Renewable Energy Agency
KWh	kilowatt-hour
LDCs	Least developed countries
MED	Multiple-effect distillation
MED-ENEC	Energy Efficiency in the Construction Sector in the Mediterranean
MENA	Middle East and North Africa
MW	Megawatt
MWe	Megawatt electrical

MWh	Megawatt-hour
NGO	Non-governmental organization
NOx	Nitrogen oxides
NRS	Natural reclamation systems
ODA	Official development assistance
OECD	Organisation for Economic Co-operation and Development
PDO	Petroleum Development Oman
PPP	Public-private partnership
PV	Photovoltaic
R&D	Research and development
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
RE	Renewable energy
ReACT	Regenerative Activated Coke Technology
RO	Reverse osmosis
SDGs	Sustainable Development Goals
SMEs	Small and medium-sized enterprises
SOx	Sulfur oxides
TCHS	Thermosyphon Cooler Hybrid System
TSC	Thermosyphon cooler
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WTO	World Trade Organization

Technology Transfer and the Arab Region

Introduction

The Economic and Social Commission for Western Asia (ESCWA), as part of its efforts to help member countries find an integrated approach to the Sustainable Development Goals (SDGs), is implementing a United Nations Development Account project to develop the capacity of member States to examine and address the water and energy nexus.

To achieve this, ESCWA is using two parallel and complementary tracks. The first targets high-level officials in water and energy ministries for training on how to incorporate the nexus in national and regional policy by means of a regional policy toolkit. This is comprised of seven modules based on priorities identified during an intergovernmental consultative meeting in 2012. The seven priorities, which were endorsed by the ESCWA Committees on Water Resources and on Energy, are as follows: Knowledge and awareness-raising; increasing policy coherence; examining the water and energy security nexus; increasing efficiency; informing technology choices; promoting renewable energy (RE); and addressing climate change and natural disasters.

The second track targets water and energy service providers by means of three technical interventions addressed through an operational toolkit made up of the following modules:

a. Resource efficiency: to improve efficiency during the production and consumption of water and energy resources and services.
b. Renewable energy: to assess costs and benefits related to applying RE technologies in the region.
c. Technology transfer: for water and energy considerations when pursuing the transfer of new technologies regionally.

This document presents the third module of the operational toolkit, on technology transfer.

Background

Technology transfer is the "broad set of processes covering the flows of know-how, experience and equipment, and is the result of many day-to-day decisions of the different stakeholders involved".[1] It can take place through many different channels, such as from the public to the private sector, from a big firm to a smaller one and between universities or countries (such as from developed to technologically less developed countries). It is also described as the conversion of research output into products on the market. It is much more than just hardware transfer, for effective technology transfer considers many factors, such as the raising of awareness among all stakeholders in a project. In this module, we look primarily at the transfer of technology from universities and research centres to the private sector and from the country of development and production to countries where it can be used. Transfers can take various forms, such as public-private partnerships and joint ventures. Such arrangements play a crucial part in the determination of the path to be followed during the transfer process.

The energy and water sectors, and the associated technology, often require substantial investment. That can only be attracted, and technology transfer can only be implemented successfully, in countries with suitable economic, regulatory and institutional conditions and the necessary infrastructure. That, in turn, requires the support and cooperation of local governments. Technology transfer projects that fail tend to do so due to economic and

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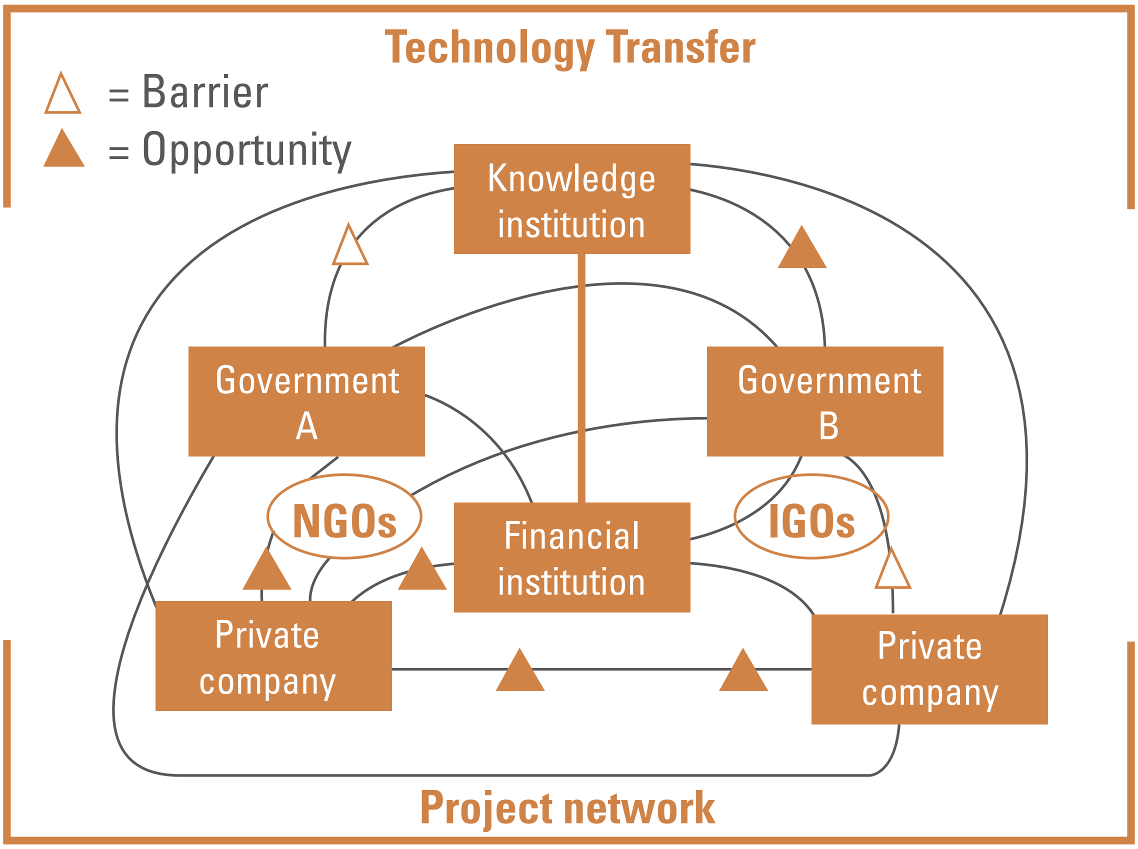
institutional factors; rarely does the failure have to do with the technology being transferred. Barriers may include inadequate infrastructure, insufficient public incentives, the lack of a market, or the absence of a technological development plan on the part of the recipient country. Conflict and limited financing options for the developing countries can also impede transfers.

Access to technical, management, business and regulatory skills locally, access to information, consumer and corporate awareness, and robust policy and regulatory frameworks all contribute to the success of technology transfer projects, which must target local needs and be adapted to conditions in the recipient country.

Technology transfer within countries is easier to carry out than that between countries, because there are fewer barriers and costs are lower (see figure 1). Trade policy, for instance, can serve as a barrier. That may have something to do with why technology transfer between the Arab countries is scarce.

Developing countries frequently partner with developed countries to obtain access to technology. Many such projects are carried out under the aegis of organizations such as the International Energy Agency (IEA), International Low-Carbon Energy Technology Platform and the Clean Energy Ministerial (CEM). Increasingly, knowledge transfer is taking place between countries that are not members of the Organisation for Economic Co-operation and Development.

Figure 1. The technology transfer/innovation system



Source: Metz and others 2000.

The technologies that can be deployed in the Arab region in order to achieve water and energy efficiency and RE targets are described in the previous two modules of this toolkit. Many have already been introduced in to various Arab countries by means of technology transfer. More can be done as new and more efficient technologies are developed.

The technologies involved must support sustainable development and thereby help countries to achieve the SDGs. Technology transfer is a means of combating climate change, especially in the case of technologies that address the water and energy nexus. The adoption of eco-friendly technologies can be aided by "leapfrogging", whereby state-of-the-art technology is applied in an area where immediate prior technology had not been adopted. Technology transfer regimes should also encourage the development of clean technologies.

Table 1. Assessment of technology transfer framework options for the water and energy nexus

1.	**Potential for large-scale resource efficiency improvement and RE deployment across the world.** The degree to which an option will enhance water and energy efficiency and is universally applicable. Emphasis will be given to facilitating the use of the technology and associated management practices and changes in consumer behaviour.
2.	**Relevance to needs of countries at different development stages.** Options are evaluated based on their cost-effectiveness and the extent to which they can be tailored to the varying needs of least developed countries (LDCs), developing countries with more advanced economies, and developed countries.
3.	**Effectiveness across sectors and consistency with sectoral strategies.** Evaluation of options on potential effectiveness across sectors associated with the water and energy nexus.
4.	**Mobilization of private investment.** Options are assessed based on their potential to attract the private investment needed to achieve large-scale deployment in markets around the world.
5.	**Potential to be self-sustaining and replicated.** Options are assessed on the extent to which they could lead to self-sustaining investment in, and the use of, the technology and replication (without ongoing government or donor funding).
6.	**Cost-effectiveness.** The benefit–cost ratio for the use of public funds (by national governments or international donors) needs to be assessed.
7.	**Ease of implementation.** This criterion covers the relative complexity and transaction costs associated with managing and implementing the various options.
8.	**Effective governance structure.** The options are evaluated to determine the extent to which they will inspire confidence and foster cooperation between the parties.
9.	**Promotion of indigenous technologies.** Indigenous or traditional technologies for the water and energy nexus could play an important role in LDCs and developing countries where the capacity for investment is low. There is a need to develop, promote and transfer indigenous technologies that may be applicable in other countries with similar circumstances.
10.	**Sustainability.** The impact of the options under study on the recipient country's environmental and societal sustainability is assessed.
11.	**Monitoring, reporting and verification.** The ease with which progress in achieving goals can be transparently tracked and verified over time is assessed.

Source: United Nations Framework Convention on Climate Change, 2009.

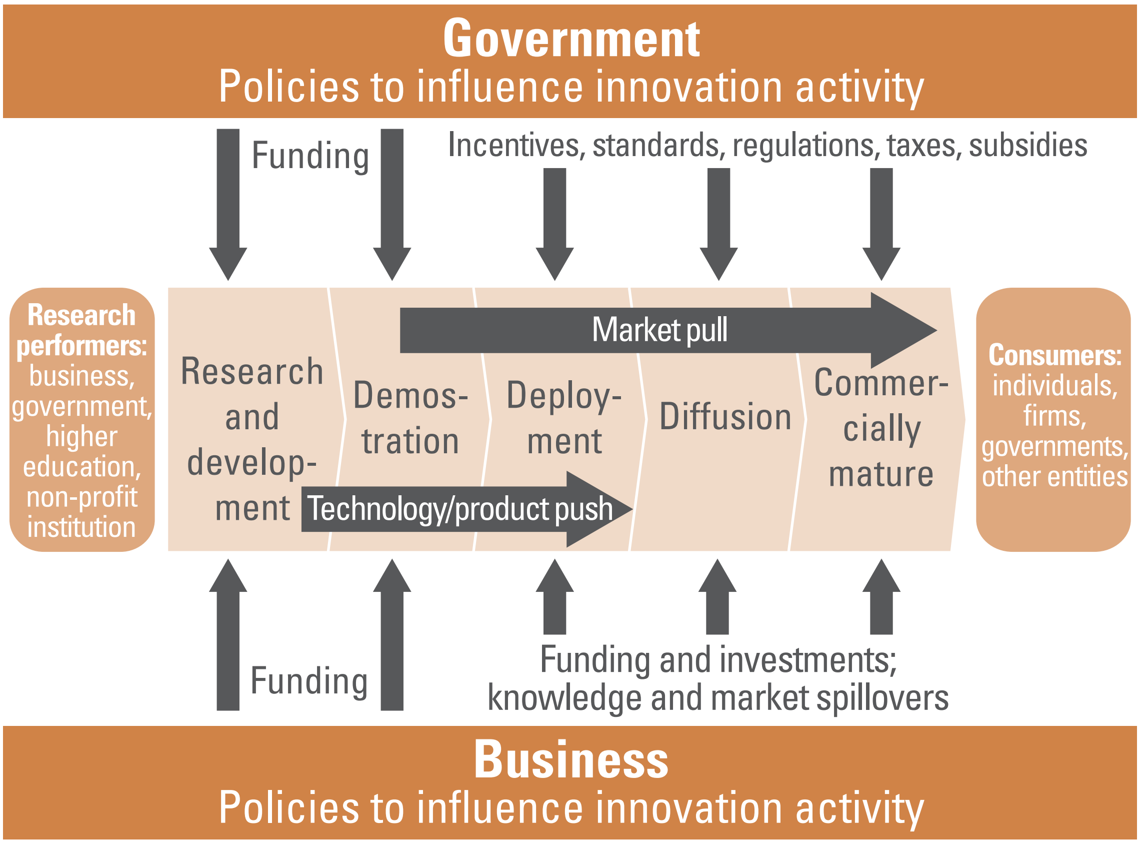
The technology transfer and innovation process consists of various stages: assessment, agreement, implementation, evaluation and adjustment, and replication. The replication is once again followed by assessment and so it is a continuous cycle. Figure 2 illustrates the processes involved in projects between governments and the private sector.

Table 1 sets out the considerations to be taken into account when assessing technology transfer for water and energy nexus projects, with a view to obtaining optimal and sustainable results. There may be trade-offs: a given technology may, for example, lead to reduced water consumption while consuming greater amounts of energy. The table also touches on the importance of monitoring and verification.

Objectives

The primary objective of this toolkit is to help ESCWA member countries to improve integrated and sustainable management of water and energy resources. It aims to provide government officials who manage water or energy services with strategies for integrating water and energy nexus considerations into their activities, and with information to help them make informed decisions regarding technology. This module discusses technology transfer with regard to resource efficiency (module 1) and RE (module 2), and is designed to assist Arab countries in the process of building capacity for exchange and collaboration across industrial and other

Figure 2. The innovation process



Source: United Nations Framework Convention on Climate Change, 2009.

sectors based on a common set of assessment tools. It also aims to assist authorities in the creation of an environment that is more conducive to, and supportive of, technology transfer.

Technology transfer principles

Concepts

Table 2 sets out technology transfer options, the choice of which will depend on a given institution's stage of technology development. Some initiatives may involve the diffusion of technologies already in use in other regions. In that case, only the options mentioned under the diffusion section would be relevant. Others may seek to launch recently developed

Table 2. Technology transfer options by stage of technology development cycle

Stage of the technology development cycle	Technology transfer options
Research and development	Global technology research and development (R&D) fund Globally coordinated research programmes International networks or alliances of relevant research institutes Researcher and scholar exchange programmes Increasing public-sector investment in R&D for targeted technology areas Increasing private-sector investment in innovative technology R&D
Demonstration and deployment	Technology demonstration and scale-up partnerships Technology standards, testing, verification and certification Technology life-cycle cost and impacts assessment, and outreach Community and regional sustainable design and infrastructure investment Training and workforce development
Diffusion	Enabling environments Education and awareness Regional networks and country focal points Intellectual property (IP) access and protection Technology assessment and clearing house Investment matchmaking and technical assistance Investment risk-mitigation incentives for emerging technologies Investment credits and incentives Coordinated trade and economic policies Technology diffusion partnerships Sectoral goals and road maps Supporting business plan development Setting national goals and action plans and provision of the necessary financial resources

Source: United Nations Framework Convention on Climate Change, 2009.

technology in a local market, whereby options under "demonstration and deployment" and "diffusion" would be relevant. For any given project, the option(s) chosen will depend on its characteristics and context.

Table 3. Stakeholders in technology transfer

Stakeholders	Motivations	Decisions or policies that influence technology transfer
Governments • National/federal • Regional/provincial • Local/municipal **Civil society**	Development goals Environmental goals Competitive advantage Energy security	Tax policies (including investment tax policy) Import/export policies Innovation policies Education and capacity-building policies Regulations and institutional development Direct credit provision
Private-sector business • Transnational • National • Local/ microenterprise including producers, users, distributors and financiers)	Profits Market Share Return on investment	Technology R&D/commercialization decisions Marketing decisions Capital investment decisions Skills/capacity development policies Structure for acquiring outside information Decision to transfer technology Choice of technology transfer pathway Lending/credit policies (producers, financiers) Technology selection (distributors, users)
Donors • Multilateral banks • GEF • Bilateral aid agencies	Development goals Environmental goals Return on investment	Project selection and design criteria Investment decisions Technical assistance design and delivery Procurement requirements Conditional reform requirements
International institutions • WTO • UNCSD • OECD	Development goals Environmental goals Policy formulation International dialogue	Policy and technology focus Selection of participants in forums Choice of modes of information dissemination
Research/extension • Research centres/ labs • Universities • Extension services	Basic knowledge Applied research Teaching Knowledge transfer Perceived credibility	Research agenda Technology R&D/commercialization decisions Decision to transfer technology Choice of pathway to transfer technology
Media/public groups • TV, radio, newspapers • Schools • Community groups • NGOs	Information distribution Education Collective decisions Collective welfare	Acceptance of advertising Promotion of selected technologies Educational curricula Lobbying for technology-related policies
Individual consumers • Urban/core • Rural/periphery	Welfare Utility Expense minimization	Purchase decisions Decision to learn more about a technology Selection of learning/information channels Ratings of information credibility by source

Source: Metz and others, 2000.

Table 3 shows how different stakeholders aim to benefit in different ways from technology transfer, highlighting potential areas of conflict. Governments and the private sector play the leading roles in policy and decision-making.

Technology transfer can be classified in various ways. For example, it can be either vertical or horizontal in nature. “Vertical technology transfer occurs when information is transmitted from basic research to applied research, from applied research to development, and from development to production. Such transfers occur in both directions and the form of the information changes as it moves along this dimension. Horizontal transfer of technology occurs when technology used in one place, organization, or context is transferred and used in another place, organization, or context.”[2] It can also be formal or informal. Formal transfer can take place through technology services and consultancy, training and education, and sponsored R&D activities. Informal transfers take place, for example, through conferences and exchanges between researchers.

Intellectual property rights (IPR) constitute a key factor where cutting-edge research is part of the technology transfer process. There is a need for IPR regimes, the strength of which is generally measured through an index. There are many such indexes, including the Ginarte and Park patent index, which calculates a score based on five national components: extent of coverage, membership in international agreements, loss of protection, enforcement mechanisms and duration of protection. Other indexes are more general, addressing trademarks and copyright.

Conflicts between stakeholders regarding their joint objectives or the ownership of innovations can bring technology transfer processes to a halt. For example, where researchers at academic institutions and in industry work together, the former may wish above all to publish their results, while the latter may prefer to keep them classified so as to obtain the desired patent or be the first to commercialize a certain technology. Appropriate policies must be in place to deal with those situations when cooperation between such groups is formalized. Similarly, formal agreement is needed from the outset on any profit resulting from the transfer project, particularly if public institutions are involved.

The World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) aims to harmonize national IPR regimes, which is essential for technology transfer between countries. It also describes a dispute resolution mechanism. Stronger national IPR regimes with conflict resolution mechanisms are likely to attract more intellectual products to a country. One study found “strong evidence that US multinationals respond to changes in IPR regimes abroad by increasing technology transfers”.[3] However, IPR regime reform can face significant resistance in developing countries, where, for instance, many people employed in industries manufacturing unauthorized products could face unemployment. There are also concerns that stronger IPR regimes can support monopoly pricing, reduce access to technological information and lead to higher costs associated with the use of new technologies, which would primarily benefit the foreign IP owners.[4] Strengthening IPR regimes in developing countries, including those in the Arab region, is thus not always straightforward.

Over time, barriers encountered in the technology transfer process can be resolved in various ways (table 4). Technology transferred to achieve water and energy nexus goals, for instance, can encounter challenges in terms of climate change mitigation. Solutions to many issues involve increasing awareness and training, or networking between entities whose cooperation can help to make processes more transparent and overcome problems encountered. Each situation is unique, but two broad areas of intervention can facilitate technology transfer.

Table 4. Addressing local barriers to technology transfer

Activity	Gap/need addressed	Benefits
Applied R&D Grant funding, open and/or directed at prioritized technologies	Inadequate support for applied research for technologies, where existing efforts are minimal or non-existent because of lack of market signals or existing (technical and other) capacity	Adapt existing technologies or develop new technologies to meet local needs, leveraging local knowledge base, where possible Applied research and product development for potential commercial relevance Promote North-South and South-South technical cooperation
Technology accelerators Design and funding of projects to evaluate technology performance (such as demonstrations, field trials)	Uncertainty, lack of information and scepticism about in-situ costs and performance, and lack of end-user awareness	Reduction in technology risks and/or costs by independent collection and dissemination of performance data and lessons learned
Business incubator services Strategic and business development advice to start-ups	Lack of seed funding and business skills within research/technology start-ups and the "cultural gap" between the academic research and private sectors	Investment and partnering opportunities created by building a robust business case, strengthening management capacity and engaging the market
Enterprise creation Creation of new businesses by bringing together key skills and resources	Inertia and rigid market structures that impede development of start-ups or new corporate products and services	Creation of new high growth businesses to meet and stimulate market demand Development of local commercial and technical capabilities
Early stage funding for water and energy nexus technology ventures; co-investments, loans or risk guarantees to help viable businesses attract private-sector funding	Lack of financing (typically first or second round) for early stage technology/product development due to classic innovation barriers combined with perceived energy technology market and/or policy risks	Enhanced access to capital for emerging businesses that demonstrate commercial potential Increased private-sector investment in the sector by demonstrating potential investor returns
Deployment of existing resource efficient technologies Advice and resources (such as interest-free loans) to help organizations to achieve sustainability goals	Lack of awareness, information and/or market structures, which limits uptake of cost-competitive, resource efficient technologies	Improved use of energy and water resources by enabling organizations to implement efficiency measures and save costs
Skills and capacity-building Training of human resources in areas related to technology innovation Design and running of training programmes	Lack of capacity to research emerging water and energy nexus technologies, develop appropriate products, and install, maintain and finance emerging resource efficient and RE technologies	Enhancement of technical, policy and market analysis and implementation skills Growth in business capacity and employee capabilities to enable more rapid uptake of sustainable technologies
Domestic policy and market insights Analysis and recommendations to inform domestic policy and businesses	Lack of independent, objective analysis drawing on practical experience to inform the local government and the market	Enhancing the policy and market landscape to support the development of a water and energy nexus technology economy

Source: United Nations Department of Economic and Social Affairs, 2008.

Institutional mechanisms and legal frameworks

Technology transfer would not be possible without the appropriate policies and regulatory frameworks. Table 5 outlines policies, frameworks and potential barriers to be overcome, and the corresponding pathways, sectors and stages. "Pathways" are the means by which stakeholders interact to enable the transfer of technology, while "stages" represent the different steps of the transfer/innovation process. The policy tools contained in the table can be classified into the following 10 categories:

a. National systems of innovation: the organizational and institutional structures that support innovation and technological development.
b. Social infrastructure and participatory approaches: social networks, such as NGOs, that can play a pivotal role in enabling technology transfer.
c. Human and institutional capacities: technical and scientific skills development, and capacity-building in business, management and finance.
d. Macroeconomic policy frameworks: direct and indirect financial support, energy tariff policies, trade and foreign investment policies, and financial sector regulation and strengthening,[5] all aimed at promoting an economic environment propitious for technology transfer.
e. Sustainable markets: policy tools designed to make technology transfer a sustainable process and framed by addressing the supply of and demand for technology.
f. National legal institutions: institutions and policies to prevent corruption and reduce regulatory, property and contract risks.
g. Codes, standards and certification: means for ensuring and maintaining the quality of the technology.
h. Equity considerations: policy tools to ensure that weaker social groups are not adversely affected by technology transfer processes.
i. Rights to productive resources: tools to address the impact of technology transfer on the rights of people to productive resources, such as land and factories, and to resolve disputes amicably.
j. Research and technology development: policy tools designed to strengthen R&D institutions, possibly taking the policies of OECD countries as a model, with the due flexibility to adapt them to local circumstances.

Table 5. Policy tools and frameworks to facilitate technology transfer

Policy Tool	Barriers addressed	Relevance
National systems of innovation and technology infrastructure		
• Build the capacity of firms for innovation • Develop scientific and technical educational institutions • Facilitate technological innovation by modifying the form or operation of technology networks, including finance, marketing, organization, training and relationships between customers and suppliers	• Lack of technology development and adaptation centres • Lack of educational and skills development institutions • Lack of science, engineering and technical knowledge available to private industry • Lack of research and test facilities • Lack of information relevant for strategic planning and market development • Lack of forums for joint industry-government planning and collaboration	Pathways driven primarily by the private sector Primarily buildings, energy and industrial sectors All stages

Social infrastructure and recognition through participatory approaches		
• Increase the capacity of social organizations and NGOs to facilitate appropriate technology selection • Create new private-sector-focused social organizations with the technical skills to support replication of technology transfers • Devise mechanisms and adopt processes to harness the networks, skills and knowledge of NGOs	• Technology selection inappropriate to development priorities • Legacy of technology transfer in development • Problems of scaling cultural and language gaps and fostering long-term relationships	All pathways Particularly adaptation technologies, but applies to all sectors Particularly assessment, evaluation and replication stages, although NGOs are increasingly involved in implementation stages
Human and institutional capacities		
• Build capacities of firms, NGOs, regulatory agencies, financial institutions and consumers	• Inability to assess, select, import, develop and adapt appropriate technologies • Lack of information • Lack of management experience • Problems of scaling cultural and language gaps and fostering long-term relationships • Limited impact of technology in the absence of long-term capacity to maintain innovation • Lack of joint-venture capabilities for learning and integrating	All pathways All sectors Particularly assessment and implementation stages
Macroeconomic policy frameworks		
• Provide direct financial support like grants, subsidies, loans and loan guarantees • Provide indirect financial support, like investment tax credits • Raise energy tariffs to cover long-term economic costs • Alter trade and foreign investment policies, such as trade agreements, tariffs, currency regulations and joint-venture regulations • Reform financial sector regulation	• Lack of access to capital • Lack of available long-term capital • Subsidized or average-cost (rather than marginal-cost) prices for energy • High import duties • High or uncertain inflation or interest rates • Uncertainty of tax and tariff policies • Investment risk • Excessive banking regulation or inadequate banking supervision • Incentives for banks that are distorted against risk-taking • Banks that are poorly capitalized • Risk of expropriation	Particularly private-sector-driven pathway, but relevant to all pathways Trade and foreign investment policies, particularly those relevant to private-sector-driven pathways Particularly assessment and repetition stages All sectors; energy tariffs relevant to building, industry and energy sectors

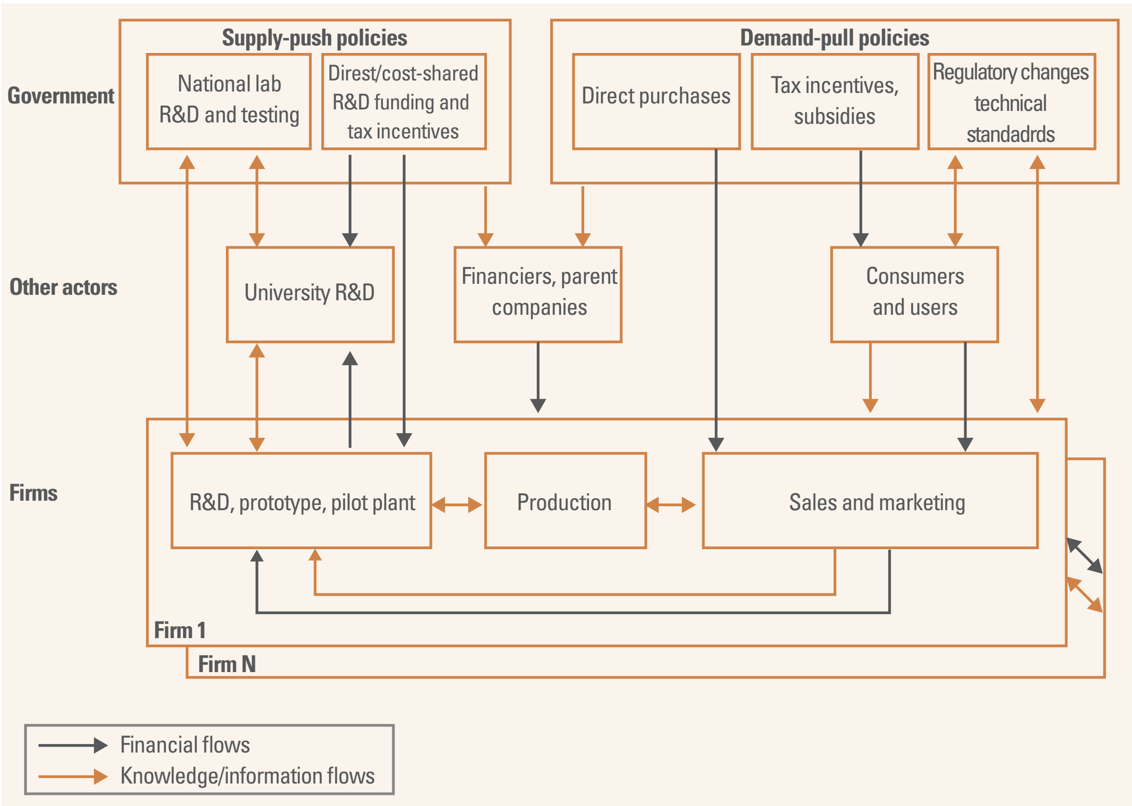
Policy Tool	Barriers addressed	Relevance
Sustainable markets for environmentally sound technologies		
• Conduct market transformation programmes focussing on technology supply and demand • Develop capacity for technology adaptation by small and medium-sized enterprises (SMEs) • Conduct consumer education and outreach campaigns • Carry out targeted purchasing and demonstrations by public sector	• High transaction costs • Weaknesses of smaller firms • Uncertainty of markets for technologies, preventing manufacturers from producing them • Lack of consumer awareness or acceptance of technologies • Lack of confidence in the economic, commercial or technical viability of a given technology	Private-sector-driven pathways Building, industry and energy sectors All stages
National legal institutions		
• Strengthen national intellectual property protection frameworks • Strengthen administrative and legal processes to ensure transparency, participation in regulatory policymaking and independent review • Strengthen legal institutions to reduce risks	• Lack of intellectual property protection • Contract risk, property risk and regulatory risk • Corruption	All pathways All sectors Particularly the agreement stage
Codes, standards and certification		
• Develop codes and standards and the institutional framework to enforce them • Develop certification procedures and institutions, including test and measurement facilities	• High user discount rates that do not necessarily result in adoption of the most efficient technologies • Lack of information about technology or producer quality and characteristics • Lack of government agency capability to regulate or promote technologies • Lack of technical standards and institutions for supporting the standards	All pathways Building, transport, industry and energy sectors Assessment stage
Equity considerations		
• Devise analytical tools and provide training for social impact assessment • Require social impact assessments before technology is selected • Create compensatory mechanisms for "losers"	• Social impacts not adequately considered • Cases in which stakeholders are left worse off by technology transfer	All pathways All sectors Assessment stage
Rights to productive resources		
• Investigate impact of technology on property rights • Test that impact through participatory approaches • Devise compensatory mechanisms for "losers"	• Inadequately protected resource rights	All pathways Most sectors where land use is involved

Research and technology development		
• Develop science and educational infrastructure by building public research laboratories, providing targeted research grants and strengthening technical education system • Invest directly in R&D	• Insufficient investment in R&D • Inadequate science and educational infrastructure	Government-driven and community-driven pathways Assessment and replication stages Building, industry, energy, and waste management and treatment sectors

Source: Metz and others, 2000.

Figure 3 shows how the development of new, environmentally friendly technologies is affected by supply-push and demand-pull factors. Government R&D funding is an important push factor, since it facilitates the processes by which innovative technology may be supplied. R&D centres that focus on sustainable technologies are key members of the energy innovation scene in many Arab countries. The intermediary status they tend to have means that they can benefit from public funding while also enjoying some of the independence characteristic of private-sector entities. Such centres also facilitate push and pull forces.

Figure 3. Supply-push and demand-pull policies in energy innovation



Source: Margolis, 2002.

Capacity-building (human and organizational), an enabling environment and mechanisms for technology transfer are three areas to be addressed in order to make technology transfer more effective. A country's human resources need to be capable of responding to continuous technological change and working with the latest innovations. That implies continuous learning and acquisition of new skills. Technology transfer assistance programmes between OECD and non-OECD countries generally include a training and human resource development component. Most of that training focuses on technical matters, but training should ideally also include units on finance and management, which are essential for the effective transfer of technology. Improving organizational capacity is also vital, given many different entities, in addition to the main parties, tend to be involved in technology transfer projects, including consultancy firms, energy service providers, solicitors and finance companies.

"Mechanisms for technology transfer are designed to facilitate the support of financial, institutional and methodological activities."[6] Such mechanisms may include:

National Systems of Innovation: When such national structures integrate access to information, capacity-building and an enabling environment into their approach, it leads to innovation support. National systems of innovation benefit from working with international consortiums, which tend to involve public and private stakeholders, given that they are system-oriented and involved in all stages of the technology transfer process. Pertinent case studies are discussed in part 2 of this module.

Official Development Assistance (ODA): ODA is one of the available financing options that can be mobilized to achieve the Sustainable Development Goals (SDGs). Monitored by the OECD, ODA is a crucial component of the financing portfolios in many developing countries. The total official support for sustainable development (TOSSD) framework, recently developed by the OECD, complements ODA.

ODA is an important mechanism for transferring technology supported by local governments, particularly in the most vulnerable developing countries and from developed to developing countries.[7] SDGs immediately relevant to the water and energy nexus and the facilitation of technology transfer are Goals 6 and 17. Target 6.A (and its corresponding indicator 6.A.1) addresses water and sanitation-related activities, while target 17.2 (and its corresponding indicator 17.2.1) addresses ODA provision targets for developed countries as a proportion of gross national income.

Support for technology transfer can come from international development banks and through multilateral, regional and bilateral trade and investment agreements and organizations. Such foreign direct investment (FDI) can be used to transfer technology between any countries. FDI has been found to be more significant than ODA in sectors such as electricity, gas, water and manufacturing in many developing countries. FDI flows accounted for between 9 per cent and 18 per cent of gross fixed capital formation, which is essentially net investment, while ODA only accounted for a maximum of 4 per cent (and in many sectors less than 2 per cent).[8]

The Global Environment Facility (GEF), Clean Technology Fund (CTF) and Green Climate Fund (GCF): The GEF, founded in 1991, is an entity of the United Nations Framework Convention on Climate Change (UNFCCC) Financial Mechanism. It "targets incremental, one-time investments in mitigation projects that test and demonstrate a variety of financing and institutional models for promoting technology diffusion, thus contributing to a host country's ability to understand, absorb and diffuse technologies."[9] Climate change projects funded by the GEF Trust Fund tend to be related to facilitation of the initial introduction of technologies to developing countries or the dissemination of technologies in such countries and the broadening of their applications. Algeria, Egypt, Jordan, Lebanon, Mauritania, Morocco, Tunisia and Yemen have benefitted from the GEF for RE projects, such as a solar water-heating project in Tunisia, which led to a tripling of solar water heater

Modern Communication Technology. © kentoh. Fotolia_ 123708582.

installations in the country, and a solar thermal power project in Egypt, which led to an annual increase of renewable electricity generation by 35.1 gigawatt-hour (GWh).[10]

The CTF and the GCF, founded in 2008 and 2010 respectively, tend to be used more for large-scale projects. While the CTF and GEF are used for climate change mitigation projects, the GCF is also used for projects designed to help countries to adapt to the climate change already taking place.[11] It was selected to serve the Paris Agreement. The CTF is associated mostly with projects in middle-income countries.[12]

Multilateral Development Banks: Such banks partner with national systems of innovation to fund technology transfer projects.

Financial implications

The roles of public and private finance in technology transfer differ, with the former especially important in long-term and infrastructure projects. Public finance continues to be a prime funding source for energy infrastructure projects, given that they cater to the public good and due to the "positive externalities" resulting from such facilities.

However, as the ratio of public debt to GDP and public deficits have grown, private finance has taken on greater significance and, in some countries, surpassed public funding as the principal source of finance. Examples in the region include water and energy nexus projects in Jordan and the United Arab Emirates.

The shift from public to private finance does not come without risks. Where there are no competitors for private energy companies, for example, a monopoly distributor could influence the supply price excessively and affect the risk-return profile of the energy infrastructure investment. A substantial proportion of the energy purchasing costs could also be passed on to consumers.

Public-private partnerships (PPPs) can, by contrast, come with the benefits of both types of funding and mitigate the corresponding downsides. PPPs are playing an increasingly important role in technology transfer. They can consist of entities such as NGOs, private companies, private financial institutions and government entities at the local and national levels. Examples of PPPs include technology partnerships and projects to facilitate the development of innovative financial instruments. Many such partnerships have received financial backing from multilateral development banks or the GEF.[13]

In the Arab region, and especially in oil-exporting countries, subsidies for non-RE sources distort the market and make RE options less attractive due to price. RE projects, therefore, continue to rely mainly on government funding and assistance from development banks.[14]

Technology transfer and the Arab countries

Current trends and gaps

Arab countries are aiming to diversify their economies, meet RE targets and address water and energy challenges more efficiently. Demand in the Arab countries for expertise in RE technologies and resource efficiency is growing and the following trends have been observed in recent years:

- Increased funding for RE and resource efficiency-related businesses and products, and for the environment that supports the corresponding new technologies.
- More research in local institutions related to RE technologies and resource efficiency.
- Greater availability of funds for researchers outside individual countries (through, for instance, the Qatar National Research Fund and the Arab Science and Technology Foundation).

Many Arab countries are members of the International Renewable Energy Agency (IRENA). IRENA works closely with the Regional Center for Renewable Energies and Energy Efficiency (RCREEE) on several projects, including one on energy subsidies and another, involving the League of Arab States, aimed at improving cooperation and facilitating technology transfer between the Arab region and South America. In April 2016, ESCWA and IRENA organized a meeting, in the context of the sixth Middle East and North Africa Renewable Energy Conference, to discuss the manufacturing of renewable energy equipment in the Arab region.

The Arab countries can be classified roughly into four groups by size (in terms of geography, economy and their research systems) and growth (in terms of technology and innovation):

Group 1. Large research systems with slow growth (Algeria, Egypt, Morocco and Saudi Arabia). The research systems of these countries tend to suffer from a degree of inertia.

Group 2. Small, dynamic and integrated (Jordan, Lebanon and Tunisia). They are the best performers in the region in terms of publications and production growth. By regional standards, they boast a considerable numbers of researchers and some niches of innovation-related activity.

Group 3. Very small and rapidly expanding (Bahrain, Qatar and the United Arab Emirates). These small countries enjoy very high GDP and run aggressive technological development policies. They have established universities with a strong sense of purpose resulting from being associated with certain "brands".

Group 4. The remaining 12 countries tend to have rather modest and poorly integrated research systems. While some may perform well in some areas, such as the development of academic institutions, their overall performance leaves much to be desired.

The Gulf Cooperation Council (GCC) countries have planned for the investment of $200 billion in 120 RE projects between 2010 and 2030.[15] Such plans require technology transfer and the United Arab Emirates is leading the way. It has designated water and renewable and

Abstract of world network, internet and global conection concept. © taw4. Fotolia_ 142867489.

clean energy as innovation priority sectors, with particular focus on water management and economics, solar and alternative energy technology, and petroleum geosciences. Specific themes under those three focus areas include, respectively, the treatment of water from oil and gas exploration, solar desalination, and non-potable water treatment. The country's science, technology and innovation policy specifically mentions the need to support "institutions for technology transfer and incubating innovation". [16]

Saudi Arabia is working to ensure that local industry and companies benefit more from technology transfer, for instance by stipulating that local R&D must be involved. That also means involving local staff.[17] Successful projects tend to have strong institutional support, even if funding is inadequate. In 1984, the Government launched the Economic Offset Programme (EOP), under which a certain portion of the value of contracts (mostly related to defence) awarded to international contractors is supposed to be reinvested in Saudi Arabia.[18] Advanced research in areas of key economic interest is channelled through the National Science, Technology and Innovation Plan (NSTIP). In that context, for example, Saudi Aramco and the King Abdulaziz City for Science and Technology are together researching advanced technologies for the oil and gas sector, particularly in producing clean fuels. Saudi Basic Industries Corporation (SABIC), the largest manufacturer of petrochemicals in the world, is taking part in a project to "transfer and localize petrochemicals technology in communities across the Kingdom". [19]

Morocco, meantime, has singled out natural resources and RE, and agriculture, fisheries and water as national priority areas for research.[20] The diffusion of research institutions means that some industries receive inadequate attention, while others, such as agronomy and mining, benefit more from technology transfer.

Technology transfer and innovation centres in Egypt come under the umbrella of the Ministry of Industry and Foreign Trade and are primarily concerned with the transfer of new technologies from abroad to local industry. Egyptian universities, meanwhile, house technology, innovation and commercialization centres under the aegis of the Academy of Scientific Research and Technology. They focus on technology transfer from universities to local industry.

In many Arab countries, specific institutions deal with technology transfer and research in the water and energy sectors. They include: the Solar Energy and New Energies Research Institute (Morocco), the Energy Research Institute for Energy (the Sudan), the Egyptian Petroleum Research Institute, and the Institut Pasteur de Tunis (Tunisia). In addition, ESCWA launched a three-year project in 2015 in Egypt, Lebanon, Morocco, Oman and Tunisia to establish national technology transfer offices, boost R&D and commercialize research results.

Much remains to be done, however. Funding for technology-targeted R&D in the Arab region is inadequate. RE technologies from outside the region are not always suited to its harsh environment. The need to integrate them with existing technologies and supply chains also presents challenges. Academic and vocational training has been neglected, technical centres designed to respond to the needs of particular industries are often wanting,[21] and the spread of technologies and technological cooperation within and between countries could be improved. The lack of cooperation between RE research centres in the region is holding back the development of a "critical mass of scientists and research teams, community of practice, patents, and innovations or breakthrough".[22]

National and regional consulting, contracting, engineering and industrial firms play an important role, obtaining the required technologies, organizing the bidding procedure for contracts, and finding foreign companies interested in working with local establishments. These activities must be performed in a transparent and competitive manner. States need to provide frameworks to facilitate the work of those firms, and the ESCWA Technology Centre works with member countries to that end.

While joint technology transfer projects between academic institutions and industry in GCC countries have proven increasingly successful and efficient in terms of commercializing technologies, the experience in Maghreb countries has been quite different, in part because of the lack of support for such collaborative efforts. Most support for R&D and innovation is directed at SMEs, which make up the bulk of companies and generate the most jobs. The European Union has been keen to assist them with "upgrading programmes" to help them to improve their operations, productivity and competitiveness through innovative technology. They have largely been ineffective, however, mostly because of how they have been managed. An alternative strategy would target several sectors simultaneously, with support for large investment projects in highly competitive areas (including direct support to big companies); for innovative projects in smaller firms, whatever the sector, on a regular basis and in tune with company growth; and for solid medium-sized companies (of around 300 employees) that lack investment capacity but have a proven record of technical success.

Technology transfer units created in universities in Maghreb countries have proven a disappointment. Lacking effective support from the universities themselves, unable to work effectively with the private sector and industry and generally seen in a poor light, many have either ceased operations or stagnated. One exception is the unit in Settat, Morocco, which facilitates local start-ups and provides support services to the country's largest corporation, the OCP Group. Morocco is now promoting a different model: clusters focussing on computer science, robotics and electronics. Although closely linked to academic institutions, they have full administrative independence and have thus far been found to be more successful than the transfer units.[23]

Examples abound of the repercussions of the failure to transfer technology and know-how. The application of water-efficient irrigation technologies in North Africa, for instance, has been minimal, with poor knowledge transfer processes, a gap in local expertise and the absence of solutions to adapt technology to local factors (such as rainfall, soil fertility and water delivery methods). Egypt and France have similar agricultural added value. However, while France uses only 12 per cent of its fresh water withdrawals for agriculture, Egypt consumes 86 per cent.[24] In fact, half of Egypt's fresh water withdrawals are lost due to factors such as poor infrastructure, pollution and distribution problems.[25]

Innovation

In the Arab region, innovation has historically been viewed as an extension of research, unlike in OECD countries, where it is undertaken in response to particular demands. Nevertheless, in recent years the Arab region has seen a perceptible shift in funding from research to innovation, due in part to improved communication between the public sector and industry, and to the promotion of innovation in the public sector. Arab governments have increasingly funded the creation of industrial clusters, technology parks and technopoles, and incubators, often closely linked to local universities. Several countries in the region have adopted innovation policies, but often with a limited view to short-term success. Where that has not been realized, the policies have withered.

There is usually a positive correlation between a country's GDP and "innovation ranking". That holds true for Western industrial nations and appears to be so in Arab countries. The region's oil-producing countries with strong GDP perform better on the Global Innovation Index (table 6) than their non-oil producing counterparts with a significantly lower GDP. The 2016 Index had

Table 6. Global Innovation Index values for some Arab countries

	2016		2017		
Country	**Ranking**	**Value**	**Ranking**	**Value**	**Net Rank Change**
United Arab Emirates	41	39.4	35	43.2	+6
Saudi Arabia	49	37.8	55	36.2	-6
Qatar	50	37.5	49	37.9	+1
Bahrain	57	35.5	66	34.7	-9
Kuwait	67	33.6	56	36.1	+11
Lebanon	70	32.7	81	30.6	-11
Morocco	72	32.3	72	32.7	0
Oman	73	32.2	77	31.8	-4
Tunisia	77	30.6	74	32.3	+3
Jordan	82	30.0	83	30.5	-1
Egypt	107	26.0	105	26.0	+2
Algeria	113	24.5	108	24.3	+5
Yemen	128	14.6	127	15.6	+1
Average		**31.28**		**31.68**	

Source: Cornell, INSEAD and World Intellectual Property Organization, 2017.

Table 7. Intuitive institutional models in Arab countries

Type	Countries	Main Features
The Gulf model	Gulf countries	Decentralized, trade-oriented governance Public universities open to foreign teachers/researchers Research based on international cooperation Foundations for research
The Middle East model	Syrian Arab Republic	Centralized type of governance
	Egypt	Research in large public research centres and universities, as well as in international and private universities
	Iraq	Large public universities
The Mashreq model	Lebanon Jordan	Decentralized governance Research concentrated in private universities
The Maghreb model	Algeria Morocco Tunisia	Centralized governance Large public universities Research mainly in universities and public research institutes

Source: ESCWA, 2013.

the Western Asia and North Africa region in fourth place, with an average index value of 33.9, behind North America (58.1), Europe (46.9) and South-East Asia, East Asia and Oceania (44.6), and even behind the global average (36.73). However, it performed better than Latin America, the Caribbean, Central and South Asia, and sub-Saharan Africa. The average value for the Arab countries rose slightly in 2017. Table 6 shows the value and rankings of the Arab countries, according to the Global Innovation Index for 2016 and 2017. No values were provided for Iraq, Libya, Palestine, the Syrian Arab Republic or the Sudan.

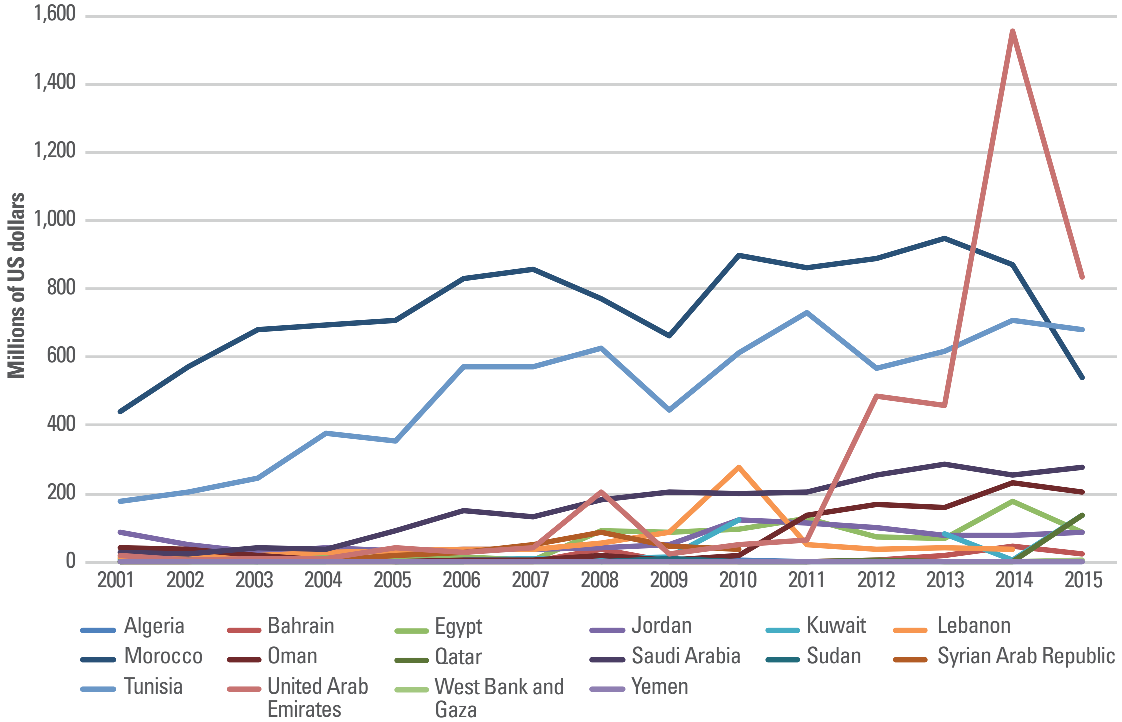
One survey in recent years found that successful entrepreneurship and innovation in Morocco and Tunisia were more widespread than commonly thought. Similar trends are expected to emerge in other parts of the region too.[26] In Egypt, however, a similar survey reported the opposite: little innovative activity and an economic environment that was tougher than that of the Maghreb countries.[27]

Quantifying technology transfer is not straightforward. One ideal parameter is the number of academic spin-offs in a certain area. However, such data tends to be available only for high-income countries. Measures taken in the Arab region to facilitate innovation cannot be assessed effectively due to a lack of comparative standards. Even assessing initiatives like incubators and technology parks is difficult, due to a dearth of appropriate industrial sector statistics. Other indicators, such as data on the number of patents filed by a country, can be used. Such indicators are discussed below. In addition, table 7 categorizes the Arab countries according to their intuitive institutional models.

Technology transfer indicators

The World Bank DataBank has various technology-related indicators, such as R&D expenditure (as a percentage of GDP), researchers in R&D (per million people) and numbers of scientific and technical journal articles. However, relevant data is often either unavailable or only partially available for Arab countries. In this section, we examine indicators for which the most complete data sets relating to technology transfer are available and compare them with corresponding OECD values as appropriate.

Figure 4. High-technology exports of Arab countries



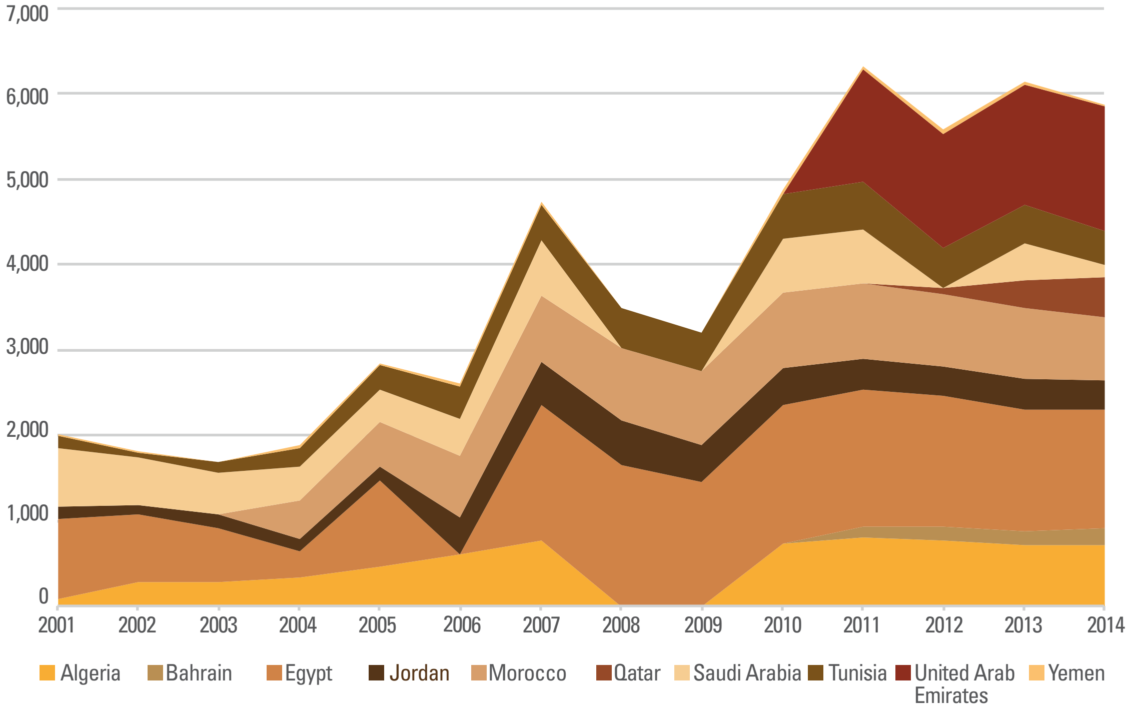
Source: World Bank, 2017.

The World Bank defines high-technology exports as "products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery".[28] Although most Arab countries experienced an increase in such exports between 2001 and 2015 (figure 4), only a few are performing well in this area. Leading the way was the United Arab Emirates.

Figures 5 and 6 quantify patent applications by non-residents and residents[29] respectively in selected Arab countries, while figure 7 compares Arab with OECD countries. It emerges that the GCC countries, where expatriates make up a larger portion of the population, account for a greater volume of patent applications by expatriate researchers than residents, while the opposite is true in the remaining Arab countries. The drop in patent applications in 2008 and 2009 can be attributed to the global financial crisis and decline in oil prices at that time, which demonstrates the link between economic and technological growth.

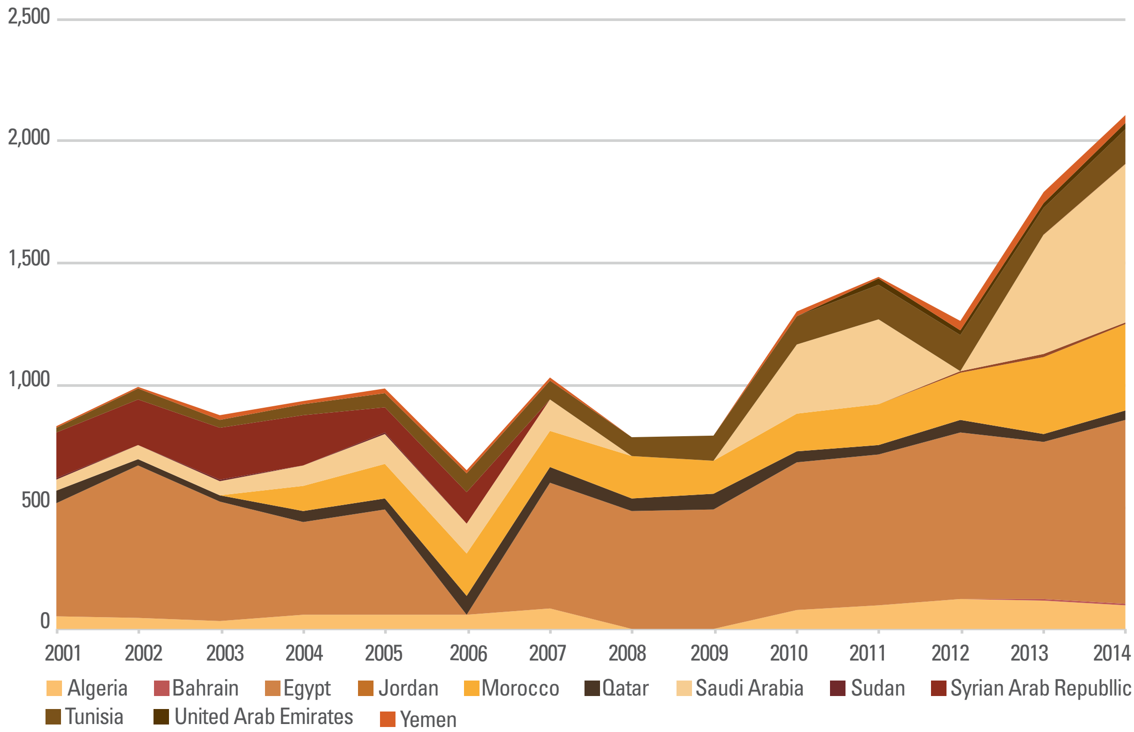
Figure 7 shows that the volume of patent applications by OECD countries is much greater than in Arab countries, that there are more patent applications by residents than non-residents in the OECD countries and that the differences in volume between resident and non-resident applications are fairly constant over time. In the Arab countries, non-resident applications outweigh those by residents and the difference between the two categories undergoes much greater variation over time than in OECD countries. While it is positive that patent applications in the Arab countries are increasing overall, the fact that most come from non-residents is a source of concern from the perspective of the long-term sustainability of R&D, particularly in the GCC countries.

Figure 5. Patent applications by non-residents in the Arab countries



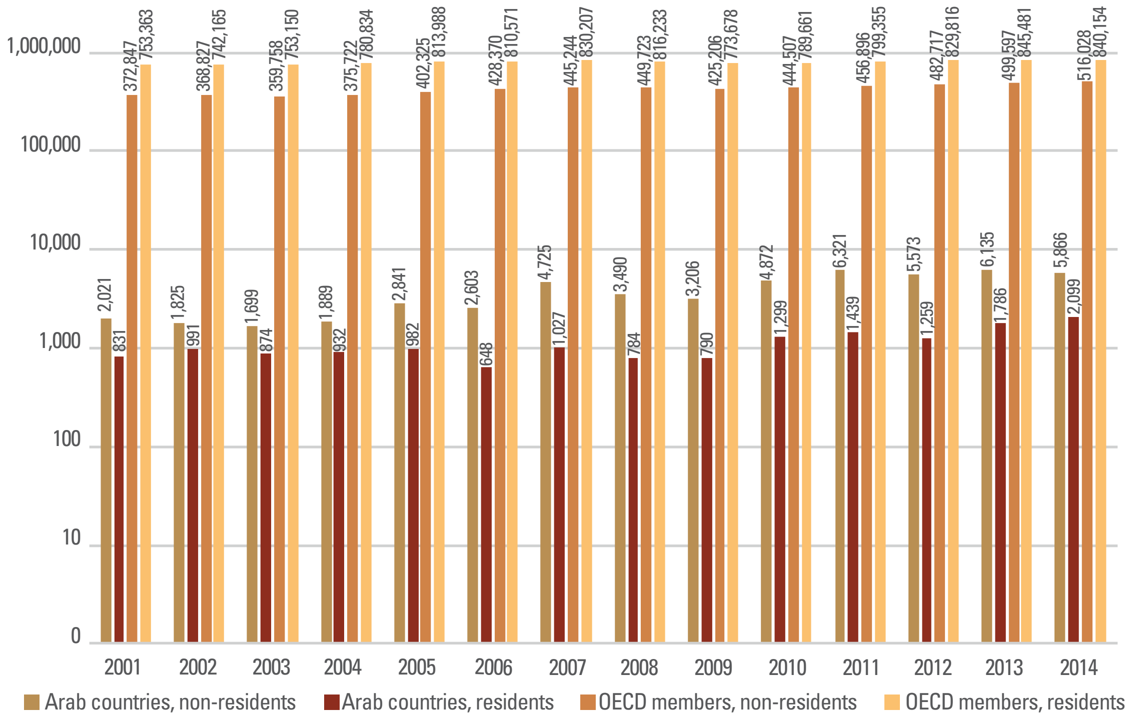
Source: The World Bank, 2017.

Figure 6. Patent applications by residents in the Arab countries



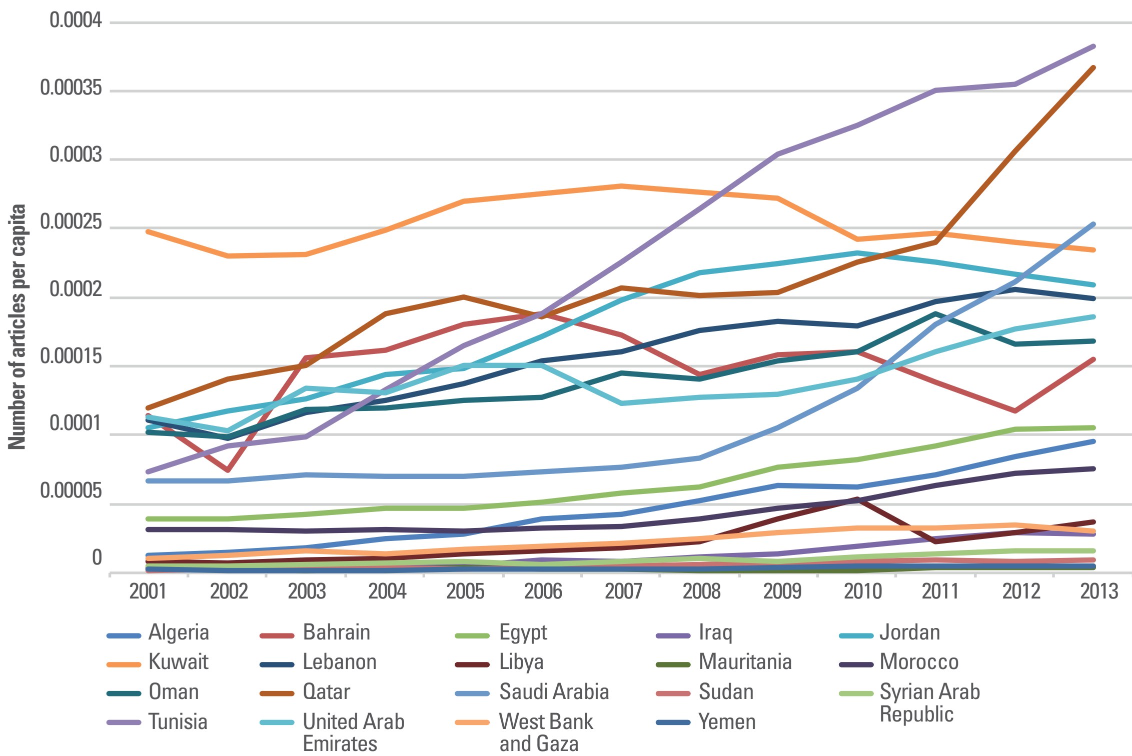
Source: World Bank, 2017.

Figure 7. Patent applications by residents and non-residents in OECD and non-OECD countries



Source: The World Bank, 2017.

Figure 8. Articles published in scientific and technical journals in Arab countries



Source: World Bank, 2017.

Kuwait, Qatar and Tunisia have outperformed their neighbours in the Arab region in recent years in terms of the number of articles published on a per capita basis in scientific and technical journals (figure 8). Qatar, in particular, has shown a noteworthy improvement. However, such data does not necessarily correlate to rates of success in technology transfer and innovation, as in the case of Tunisia (see table 6). Thus, a more holistic picture is required.

Table 8, based on an ESCWA evaluation released in 2013, attempts to provide such a picture.[30] It was carried out for each Arab country with the help of a SWOC (Strengths, Weaknesses, Opportunities and Challenges) analysis and discussion of different innovation indicators. Tunisia got the best overall rating, and, in general, the Maghreb countries seem to have been performing best at the time of the study, followed closely by the GCC countries and then countries of the Eastern Mediterranean region. Libya, Mauritania, the Sudan and Yemen scored very poorly in all categories and thus stand to benefit most from technology transfer from the

Table 8. Science and technology in the Arab countries

Country	STI strategy	R&D Expenditure	Universities	Publications	International collaboration	Incubation	Private sector innovation	Human resources	Involved diaspora
Algeria	2	2	2	2	2	1	1	2	2
Bahrain	2	2	1	1	1	1	2	2	1
Egypt	3	1	1	2	2	1	2	2	1
Iraq	2	1	1	1	1	1	1	2	1
Jordan	3	2	2	2	2	2	1	2	1
Kuwait	2	2	2	2	1	2	1	1	1
Lebanon	2	1	3	3	3	2	1	3	2
Libya	1	1	1	1	1	1	1	1	1
Mauritania	1	1	1	1	1	1	1	1	1
Morocco	2	2	2	2	3	2	2	2	2
Oman	3	2	2	1	1	1	1	1	1
Palestine	2	1	2	2	2	2	1	2	2
Qatar	3	3	3	2	2	2	2	1	1
Saudi Arabia	2	2	3	2	1	3	3	2	1
The Sudan	1	1	1	1	1	1	1	1	1
Syrian Arab Republic	2	1	1	1	1	1	1	1	1
Tunisia	3	3	3	2	3	1	2	3	1
United Arab Emirates	3	2	2	2	2	1	1	1	1
Yemen	1	1	1	1	1	1	1	1	1

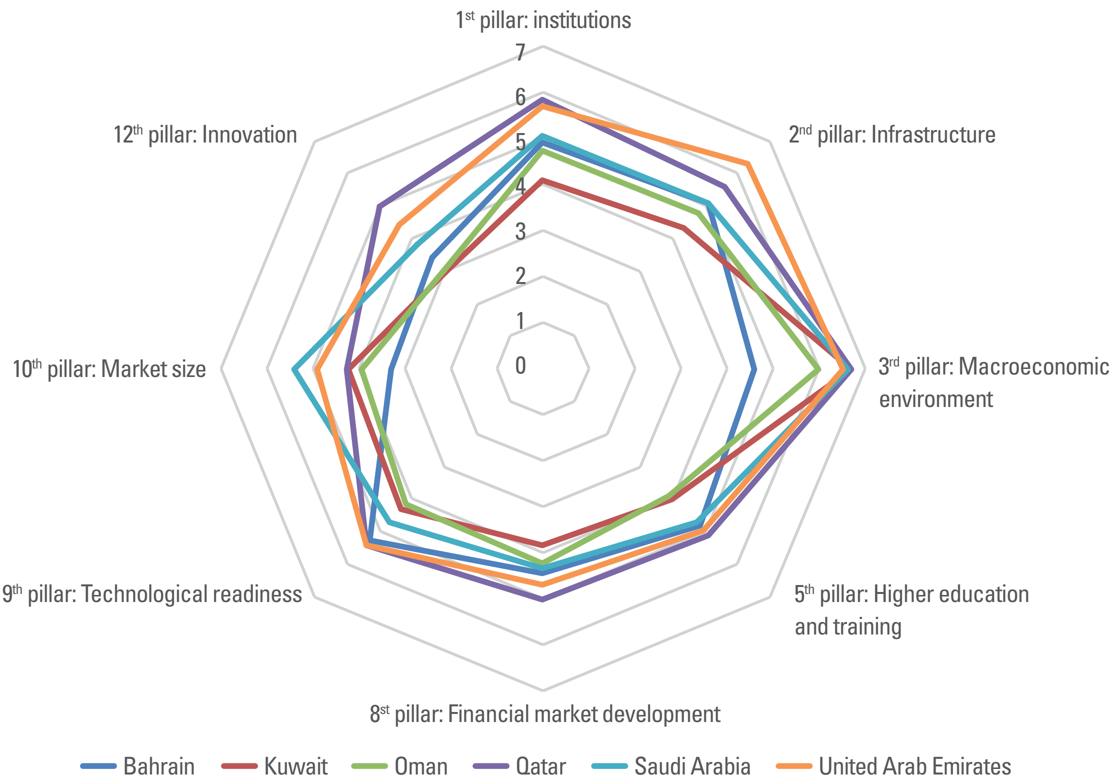
Source: ESCWA, 2013.
Notes: 1 = weak; 2 = average; and 3 = strong.

strongest Arab countries. Only Saudi Arabia was rated as strong in "private sector innovation" and "incubation", and only Lebanon with regard to "publications".

Such a table compiled today would no doubt produce different results, since many Arab countries have undertaken ambitious programmes and projects in recent years related to science and technology development, entrepreneurship and innovation, all of which facilitate technological transfer. Kuwait, for instance, saw great improvement in its Global Innovation Index ranking between 2016 and 2017 (table 6), but has an average score in table 8. Nevertheless, the table sheds some light on the situation in Arab countries, in general, and how they compare with one another.

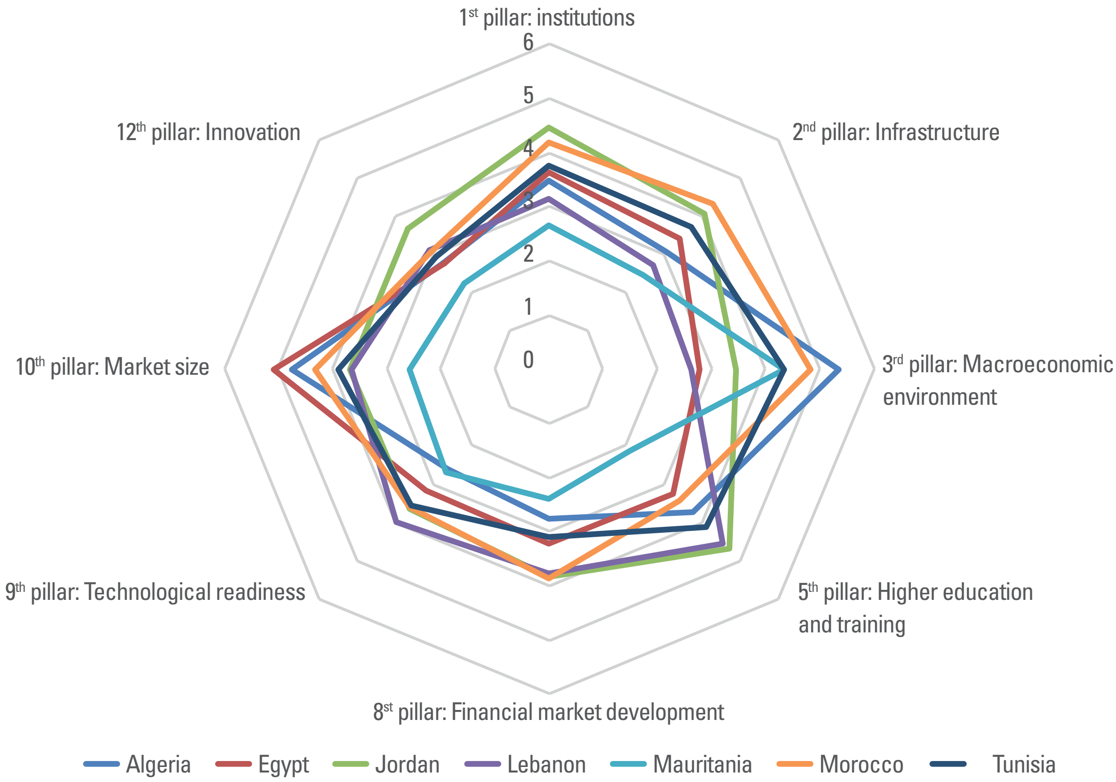
Another way of assessing technology transfer capacity is through the data compiled for the "12 pillars of competitiveness" of the World Economic Forum (WEF). The Forum defines competitiveness as the "set of institutions, policies and factors that determine the level of productivity of an economy, which in turn sets the level of prosperity that the country can achieve". [31] The pillars most relevant to technology transfer are analysed with regard to the GCC countries (figure 9) and non-GCC Arab countries (figure 10). The GCC countries are performing much better in terms of infrastructure and institutions, technological readiness and innovation than the non-GCC countries. The Maghreb countries do not stand out in figure 9 the way they do in terms of technology transfer in table 8. That may be due to the fact that the data in figures 9 and 10 is more recent (2016). At any rate, the table and two figures, taken together, provide an idea of the rapid pace of change in the technology and innovation scene in the Arab countries over the past five years.

Figure 9. Performance in selected pillars of competitiveness: GCC countries



Source: Schwab, 2016.

Figure 10. Performance in selected pillars of competitiveness: non-GCC Arab countries



Source: Schwab, 2016.

Case Studies

This part of the module presents case studies that describe successful examples of technology transfer for projects related to the water and energy nexus. Although most of the studies are drawn from Arab countries as recipients of technology, some on countries beyond the region are included for the lessons to be learned for implementation of similar transfer projects in Arab countries. An attempt has been made to select case studies representative of the different sectors covered by the toolkit.

Technologies for energy efficiency

Electricity

In 2004, a turbine modernization project was launched in China, which is keen to improve resource efficiency for power generation, and carried out by the German company KfW Entwicklungsbank with funding of 38 million euros. The efficiency of six 20-year-old coal-fired power stations was improved by decreasing the amount of coal needed per kilowatt-hour (kWh) of energy provided, which also led to a drop in the amount of water consumed by the plants. The efficiency gains came with optimization of the combustion process and improved resource efficiencies, and employed low-pressure technology. Mobile measuring systems, which provided the data needed to optimize the combustion process, were subsequently used in other power stations, providing benefits to the Chinese power industry beyond the scope of the initial project.[32] The project, which built on the success of similar technology used in Europe, involved little R&D and is an example rather of the wider dissemination of proven technologies.

Global demand for "clean coal" is expected to rise by 15 per cent by 2040[33] and some Arab countries see coal as a means of diversifying their energy sources. Dubai Electricity and Water Authority (DEWA) is planning the construction of a 2,400 megawatt (MW) coal-fired power plant, a step towards fulfilling its goal of 7 per cent electricity production from coal by 2030. The plant should be completed by March 2023. It is envisaged as a joint venture, with 51 per cent stake to be held by DEWA and 49 per cent divided between ACWA Power of Saudi Arabia and Harbin Electric of China.[34]

Desalination

In the largest joint project between the Russian Federation and Egypt since the 1960s, the former will provide technology for a nuclear-powered desalination plant in El-Dabaa. The plant is expected to have four 1,200 Megawatt electrical (MWe) nuclear units, each producing up to 170,000 m^3 of fresh water per day. The project will make Egypt the only country in the Arab region to have Generation III+ nuclear technology.

In February 2015, the Nuclear Power Plant Authority of Egypt and Rusatom Overseas (a subsidiary of Rosatom, the Russian State nuclear corporation) signed an agreement on the project. That was followed by an intergovernmental agreement in November 2015 regarding cooperation on construction and operation of the plant. The two sides also signed a memorandum of understanding on the development of further nuclear infrastructure as required by the initiative. Together, those documents address the supply of nuclear fuel to the reactors, management of used fuel, plant operation and maintenance, and assistance to the Egyptian authorities in the development of regulations and standards related to the use of nuclear power.

The building of a nuclear plant in Egypt was first mooted in 1964. Plans to construct one at El-Dabaa in the 1980s were shelved after the Chernobyl disaster. Then, in 2010, a tender was completed on the selection of the technology for the country's first nuclear power plant. The Arab uprisings of 2011 and ensuing political instability brought that work to a halt. One asset Egypt enjoys is a good number of nuclear technology specialists.[35] As important as human capacity is for technology transfer, poor regulatory capacity on the part of the State can constitute a significant barrier. A stable government is needed to put the required standards and codes in place.

In the Russian Federation, a council was set up in 2014 to determine suitable technologies for nuclear-powered desalination, with the aim of working with international partners on the construction and financing of such technology. According to IEA, "small reactor technology may be key to expanding clean, nuclear energy-based desalination," and such technology could help decrease costs.[36] However, safety needs to be considered. For example, an

Businessman hand pressing innovation button on a touch screen interface. © twobee. Shutterstock_ 75461950.

isolation loop may be used to ensure that no radioactive material reaches the drinking water produced.[37] There are different ways to isolate the desalination system, but they all mean greater capital costs.

The desalination technology to be used in the El-Dabaa project will be hybrid: reverse osmosis (RO) and multiple-effect distillation (MED). Such hybrid combinations help to decrease energy consumption and produce both process water and drinking water.[38] Energy and water efficiency are both targeted by this project. Other advantages of the hybrid system are that post-treatment can be made easier by mixing the product water from both plants, the temperature of the RO plant feedwater can be optimized with the use of cooling water from the MED plant, and the MED plant can be operated in base mode, facilitating the covering of consumption peaks by the RO plant. The optimal contribution of each plant depends on the particular situation in El-Dabaa: social, regional, environmental and technical features must be taken into consideration.[39]

This project, an example of technology facilitating water and energy security, describes technology transfer that is as yet in the pipeline. The only nuclear technology presently in use in Egypt are two research reactors: a 2 MW reactor obtained from the then Soviet Union in 1961 and a 22 MW reactor bought from Argentina in 1998. Once complete, this project could set an example for other Arab countries, particularly those such as Jordan, which have no significant fossil fuel resources. Countries such as Morocco, Saudi Arabia and Tunisia have taken part in nuclear desalination studies in the past,[40] which demonstrates the interest of Arab countries in the technology. Nuclear desalination in the region could be facilitated through cooperation between countries in areas such as R&D, legal frameworks and manpower development.

Water and wastewater treatment

The three-year DEPURANT programme, established in February 2003, was an initiative of the European Water Framework Directive. Its goal was to achieve sustainable wastewater management for rural areas in the European Union, providing decentralized technology for the treatment and reuse of wastewater, along with other products of the treatment process. The technology needed to be cheap (including low energy costs),[41] be easy to install and use, and come with a tool to guide its operators.

Twelve pilot projects were carried out in France, Portugal and Spain. Another goal of the programme was the direct involvement of the population in target areas. A network of institutions was therefore engaged to develop strategies, facilitate the training of future technology users, disseminate information about the technology and prepare materials for distribution.[42] Co-financed by the European programme INTERREG IIIB "Atlantic Area", the project involved research centres, local authorities and private companies and associations. The Canary Islands Institute of Technology played a leading role. The technology used is referred to as the Natural Reclamation Systems (NRS).

DEPURANAT was divided into four parts: experimentation and demonstration of the technological, social and environmental aspects of wastewater reclamation by NRS; market study, and economic and environmental feasibility study of the NRS; methodology to define the potential application of the NRS in any given territory; and development of support tools for decision-making.[43]

The programme has helped to facilitate cooperation between researchers, the authorities and end-users of the NRS technology. Such connections make possible the continued success of this technology transfer process and have contributed to social integration in the communities in which it has been employed. The DEPURANAT experience underlines that sound communication with stakeholders and ensuring that technology meets local requirements improve the effectiveness of technology transfer.

The NRS provided sufficient treatment of wastewater in terms of the removal of solids and nutrients. The quality of the effluent was such that it could be used for the irrigation of crops, environmental purposes and the recovery of natural wetlands. The effluent was found to integrate satisfactorily into the local ecosystem, without disturbing wildlife or causing odours.

Operational costs, of which labour made up a significant part, were found to be lower than for conventional systems. Investment costs did not vary significantly with the type of technology employed, and equipment accounted for only a fraction of those costs. Additionally, the variation in investment and operational costs decreases as the number of people served by the NRS increases. The use of reclaimed water and other by-products in irrigation and agriculture creates sources of extra income for the local community, such as commercial flower-growing.

The execution of DEPURANAT led to the development of new software. By taking into consideration the different variables associated with small-scale wastewater treatment systems (such as effluent quality requirements as per intended destination/function and average costs), the software can help to determine the ideal technology for treatment.[44]

The results of the DEPURANAT project show "a high potential for implementation of low-cost energy wastewater treatment plants"[45] in rural areas of the European Atlantic. It could equally be used to address issues of water and energy nexus security in rural areas of Arab countries such as Egypt, Morocco and Yemen.

Industrial, commercial and institutional sectors

The Energy Efficiency in the Construction Sector in the Mediterranean (MED-ENEC) programme was designed to boost energy efficiency measures and the use of RE in the construction sector in southern and eastern Mediterranean countries (among them Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Palestine and Tunisia). Funded by the European Union, the project was designed to aid countries under the European Neighbourhood and Partnership Instrument (ENPI) and also to facilitate cooperation between those countries themselves. A similar initiative is the Mediterranean Association of the National Agencies for Energy Conservation (MEDENER), which has an observatory for energy efficiency.

The work took the form of policy dialogue between stakeholders, such as energy utilities and energy ministries, funding schemes, knowledge management initiatives and other activities. MED-ENEC worked to build institutional capacities, develop technology and business cooperation, initiate pilot projects, address building codes in the region, and offer technical training.[46] MED-ENEC consortium partners included the German International Cooperation Agency (GIZ), the French Environment and Energy Management Agency (ADEME) and Ecofys (an energy efficiency, RE and climate change consultancy company).

The programme was designed in two phases. During the first phase, from 2006 to 2009, MED-ENEC supported pilot projects in which 10 low-energy buildings were constructed in all partner countries. Six of them received the National Energy Globe Award. The findings of those pilot projects were disseminated extensively through regional workshops, investor meetings, national consultations and fairs. The second phase, which ran from 2010 to 2016, was aimed at the implementation of energy efficiency and RE measures in buildings. In addition to work on business development and regulatory frameworks, training and expertise were provided in support of major building programmes.

One of the projects backed under MED-ENEC was the Mobile Energy and Environment Clinic in Jordan. This project, implemented by the Amman Chamber of Industry, aimed to improve water and energy efficiencies in factories. Partners included energy consultancies, energy service companies, and the Jordan Enterprise Development Corporation. The idea was for the Clinic to perform detailed water and energy audits on factories and assess the potential for improvement. Where appropriate, it would then recommend means for improving a given factory's energy efficiency, including information on costing, indicators and investment.

The duration of audits varied, as did the cost, half of which was covered by the Amman Chamber of Industry. The Jordan Enterprise Development Corporation provided grants to cover 50 per cent of implementation costs, up to a ceiling of 10,000 Jordanian dinars. The factories concerned were also exempt from tax and customs duties on energy efficiency and RE equipment. It was estimated that the project would lead to savings of JD 11 million Jordanian dinars by 2014. The impact of the project was evaluated through questionnaires given to the participating factories. The project helped to build awareness, for instance through workshops and Amman Chamber of Industry newsletters.[47]

The example set by Jordan could be replicated in the industrial sectors of all Arab countries. More generally, MED-ENEC confirmed the viability of technology transfer through collaboration between Mediterranean countries. With similar climates, Arab countries such as Algeria and Tunisia can benefit from the experience of countries such as Italy and Spain.

binary stream. © Photobank gallery. Shutterstock_ 9623992.

Water pumping and transport

Another initiative associated with MED-ENEC was a 32-million euro project to improve the energy efficiency of the Jordanian Water Authority. The Authority joined private entities to improve energy performance using technical, economic and institutional innovation. Pilot studies were carried out at pumping stations and help was provided to develop and test an operator model for energy performance contracting at pumping stations. The idea was that the Water Authority would lower its energy costs, while facilitating greenhouse gas reduction efforts and reducing electricity generation demands.

The project was funded primarily by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety as part of its International Climate Initiative (IKI), which plays a key role in meeting the country's climate funding commitments under the Convention on Biological Diversity and can thus fund technology transfer projects designed to mitigate greenhouse gas emissions. The ministry, GIZ and the Japan International Cooperation Agency provided grants, and the private sector contributed investments that would be repaid using energy performance contracting.

The first phase of the project involved an energy audit at major pumping stations in three governorates. The resulting recommendations were implemented through contracts signed between the relevant entities. The second phase of the project, in which the private sector was also engaged, involved the implementation of recommended strategies at some pumping stations.

The cost per kilowatt-hour (kWh) saved for the overall project was $0.07/kWh, with a saving of more than 500,000 Megawatt-hour (MWh) of energy. The annual electricity bill of the Water Authority fell by almost 16 million Jordanian dinars, and carbon dioxide (CO_2) emissions decreased by about 60,000 tons a year. GIZ and the Water Authority monitored and evaluated project operations. External evaluation also took place. The new equipment installed as part of the project greatly facilitated the collation of electricity consumption data needed for accurate evaluation of the project's impact.

All Arab countries could benefit from this kind of technology transfer to make their water-pumping systems more energy efficient. Indeed, it could now become the subject of transfer between Arab countries.

Technologies for water efficiency

Electricity

ReACT™ technology

The use of coal-fired power plants is increasing in the Arab region, particularly in GCC countries. ReACT™ (Regenerative Activated Coke Technology) is one way forward for cleaner coal-fired power. Developed in Germany in the 1970s, and thereafter commercialized in Japan, ReACT™ achieves the simultaneous capture of mercury (Hg), Sulfure oxides (SOx), and Nitrogen oxides (NOx) in a single vessel.[48] Removal efficiency rates reach 98 per cent for SOx, more than 90 per cent for Hg, and between 20 per cent and 40 per cent for NOx.[49]

ReACT™ is a completely dry scrubbing system. Consumption of water is just 1 per cent of the amount needed in conventional wet flue gas desulfurization (wFGD) systems. It has the additional advantages of: producing sulfuric acid, which is a valuable by-product; not generating the solid waste produced in conventional systems, thereby avoiding disposal costs; requiring minimal plant modifications because of its easy integration into existing plants; providing a range of options for NOx reduction; and repeatedly recycling the activated coke as part of the process. Indeed, the performance of the activated coked improves with time.[50] Power stations using ReACT™ technology include Nordjylland in Denmark and the Isogo thermal power station in Japan. A 2015 report found Isogo to be the world's cleanest coal-fired power plant in terms of the intensity of its emissions, which are comparable to those of a natural gas-fired combined-cycle facility.[51] The 21 MW Wisconsin Public Service Weston Power Plant will be the first built in the United States of America with ReACTTM technology.[52]

Just as ReACT™ technology has been successfully transferred from Japan to the United States, it can be transferred to Arab countries, helping to address the water and energy nexus in their emerging coal-based power sector. It could greatly improve the water efficiency of plants in the pipeline, such as those being built or planned in Egypt and the United Arab Emirates,[53] as well as of plants already in operation, primarily in Morocco. Oman scrapped plans for a coal-based water and power project around 2010 due to environmental concerns, but is now once again planning a coal-fired power project.[54]

Thermosyphon Cooler Hybrid Heat Rejection System

In 2011, the California-based Electric Power Research Institute (EPRI) started the Technology Innovation Water Conservation Program, funded by EPRI's Technology Innovation Office as a long-term strategic programme. The project aims to reduce the dependence of steam power plants on local supplies of freshwater by identifying and developing innovative technologies that would help to expand available water resources or conserve water. In 2011 and 2012, EPRI dispatched requests for information on technologies related to, for instance, water-efficient cooling and usage of waste heat. It received 114 proposals from around the globe. In the end, five technologies dealing with the cooling process in power plants were selected for funding.

One of those technologies was the Thermosyphon Cooler Hybrid System (TCHS) for water savings in power plants, now rebranded the BlueStream™ hybrid cooling system. EPRI developed the technology with Johnson Controls. The thermosyphon cooler (TSC) is placed right after the steam condenser unit to precool the hot water before it is cooled further in the evaporating tower, thereby leading to lower water consumption in the tower. The TSC is a dry heat rejection device, which contributes to a reduction in water consumption. The system is easily installed in new or existing power plants, including nuclear power plants, in modular, incremental phases as required, necessitating minimal plant outages in the process. Feasibility and pilot studies are addressing potential drawbacks related to the selection of refrigerants, and the economical design, construction and implementation of the technology on a commercial scale.[55]

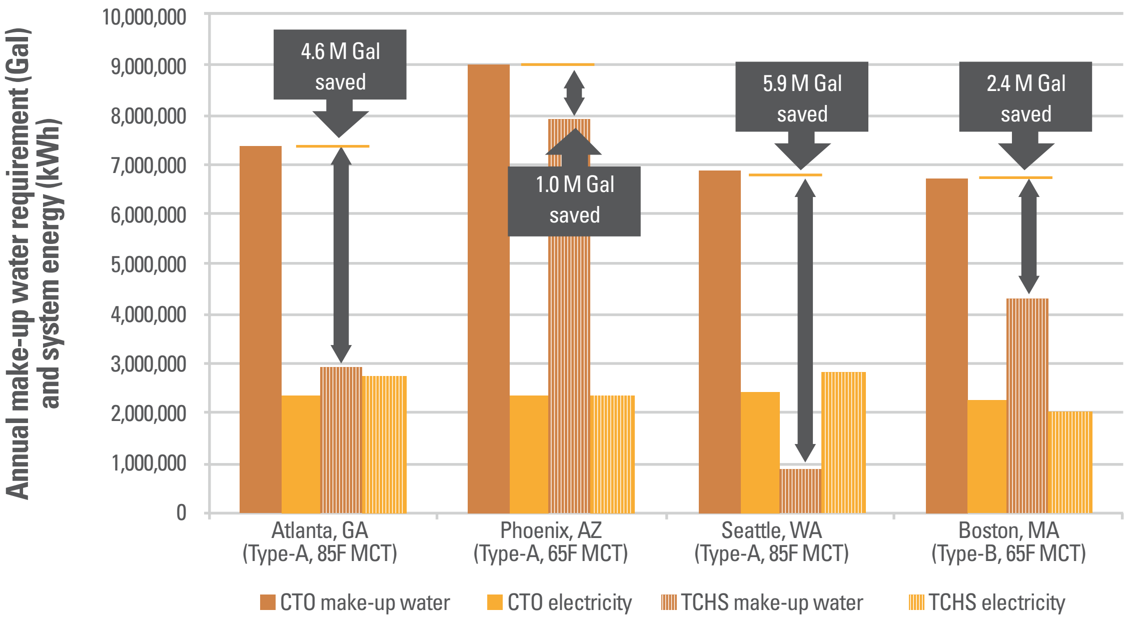
EPRI provided Johnson Controls with technical guidance and oversaw a feasibility study that involved testing the system in a 500 MW power plant. The allocation of specific roles to all partners is a key to successful technology transfer.

The technology has been applied at power stations in the United States cities of Atlanta, Boston, Phoenix and Seattle. In all cases, water consumption has decreased substantially as a result (figure 11). Energy use, however, appears to have increased somewhat (figures 11 and 12). Nevertheless, overall utility costs have decreased as a result of applying the technology.

There is much potential for the use of BlueStream™ in the Arab region, especially in the more populous countries, such as Algeria and Egypt. In addition to power plants, the technology can be used to provide water-efficient cooling systems for chiller plants (which are present in all Arab countries), data centres (present in most Arab countries, above all in Egypt and Saudi Arabia) and even petrochemical processing plants.

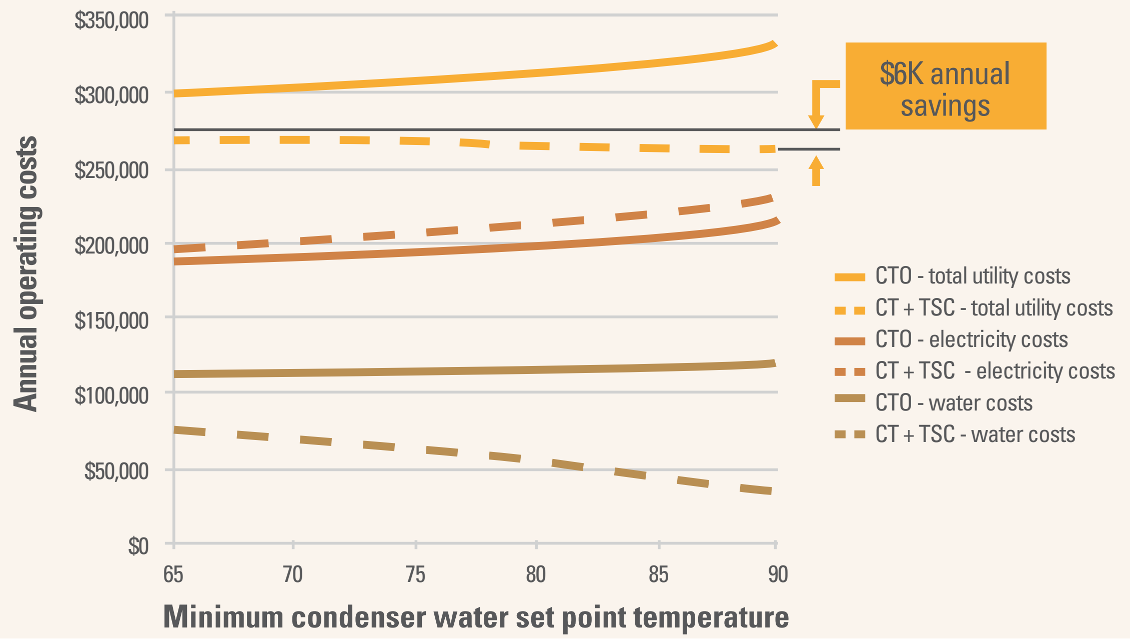
EPRI not only supports technology transfer projects, it presents annual Technology Transfer Awards to EPRI members around the world who, by applying EPRI R&D, have led technology transfer projects in the areas of power delivery and utilization. Similar awards could be initiated in the Arab region as a way of encouraging an environment more conducive to technology transfer.

Figure 11. Annual water and energy savings of cooling tower only (CTO) and TCHS systems



Source: Carter, 2014.

Figure 12. Annual operating costs of CTO only and CT+TSC hybrid systems



Source: Carter (2014).

Oil and gas

In 2016, Oasys Water, a world leader in membrane solutions for the treatment of industrial wastewater, announced its new ClearFlo™ technology. The ClearFlo MBCˣ platform improves the forward osmosis (FO) process by more than doubling the system flux, which in turn improves energy efficiency and helps to reduce life-cycle costs. The technology also facilitates greater reuse of wastewater. Oasys Water has been working closely with the oil and gas industry since 2014, for example partnering with National Oilwell Varco and thereby providing technology to the oil and gas sector in the Gulf of Mexico. In 2016, the company opened an office in Dubai to support its activities in the Arab region, where the number of conventional and unconventional oil and gas recovery projects is expanding.

Gradiant Corporation, a spin-out company started by two Massachusetts Institute of Technology (MIT) alumni, also worked with industry partners to commercialize its proprietary carrier gas extraction technology. The technology treats flow back and produced waters generated by gas extraction for reuse, by evaporating water from a wastewater stream and subsequently condensing it at another location. In 2014, the technology was being used to treat produced water at an unconventional gas extraction facility in West Texas and obtain fresh water through desalination. Water quality may be optimized according to the plant's requirements. Unlike the Oasys Water technology, the system does not use membranes, making it more thermally effective. It also enables lower overall energy consumption.[56]

Such technologies would also make the oil and gas sector in the Arab world more water-efficient. Arab countries need to support such spin-out companies to facilitate technology transfer.

Renewable energy technologies

Desalination

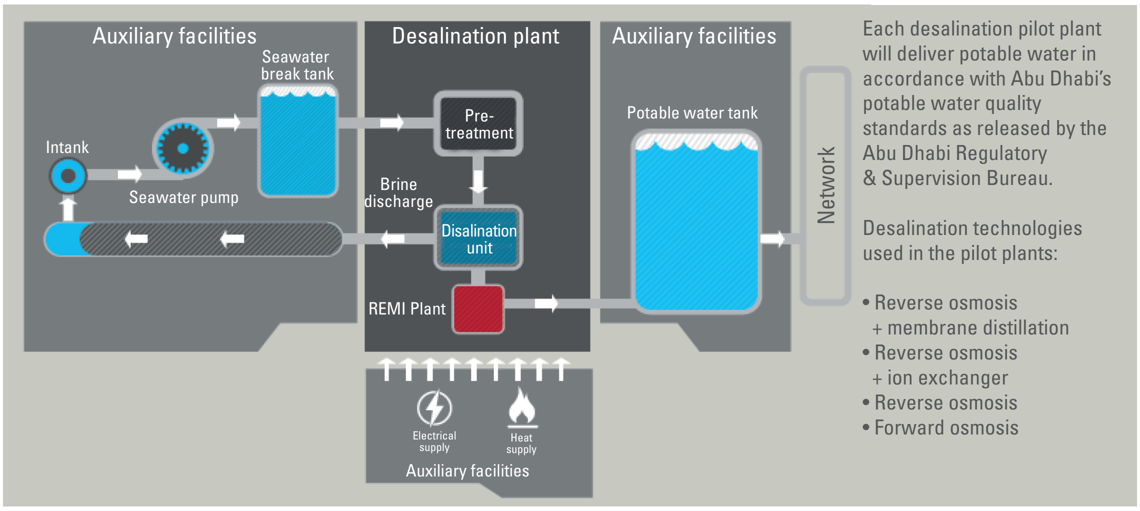
In 2013, Masdar, an Abu Dhabi company, launched its Renewable Energy Desalination Pilot Programme, a notable example of successful technology transfer. Work began in Ghantoot, Abu Dhabi, in 2015. The programme, co-funded by the Government of Abu Dhabi and industry partners, aims to develop desalination technologies that are energy and cost efficient. It is planned to have a commercial facility up and running by 2020, and thereafter to build RE-powered desalination plants in the United Arab Emirates and other Arab countries.

Masdar is working with various partners on a range of advanced seawater desalination technologies, all of which could be powered by solar energy (table 9). Each partner is testing its technologies in the same conditions (figure 13). A fifth partner, Mascara NT, is testing an off-grid solution without batteries, ideal for remote areas. Masdar is managing the project and coordinating with Abu Dhabi stakeholders. The Masdar Institute of Science and Technology is supporting the programme with research projects.

During the pilot phase (2015-2017), each partner tested technologies in small-scale desalination pilot plants (each producing 1,500 m^3 of potable water a day). The implementation and development phase, scheduled to take place after 2017, will commercialize successful technological configurations in line with predefined criteria. For instance, an energy consumption target of no more than 3.6 kWh per cubic metre of produced water has been set, and plants would preferably be powered solely by RE.

Full-scale implementation is expected to lead to energy and cost savings of about $94 million annually for Abu Dhabi, assuming that 15 per cent of new desalination capacity is met through the RE-powered energy-efficient technology. The partners benefit from Masdar financial support

Figure 13. Schematic representation of Masdar pilot plant for testing desalination technologies



Source: Ramahi, 2016.

Table 9. R&D studies associated with Masdar renewable energy desalination pilot programme

Country	Abengoa Water, Spain	Veolia Water, France	Suez Environment, France	Trevi Systems, United States
Scope	Evaluate scaling and fouling processes in membrane distillation modules	Develop capacitive deionization of RO product water (after first pass) to avoid double-pass RO systems	Develop optimized design of solar energy powered RO plant using most practical and economical technologies	Develop and test high-temperature FO membranes and manufacturing techniques
Anticipated results	• Strategies to reduce scaling and fouling • Evaluation and troubleshooting report for commercial plants	• Demonstration of 100l/h unit in lab environment • Identified improvements in electrode materials • Evaluation of bio-fouling propensity • Basic design for 20,000 m^3/d RO+CapDI plant	• Optimized processes and configurations for solar RO plants • Optimized cost of water by solar RO plants • Multiple design scenarios of solar RO plants (grid connected and off-grid)	• A recipe for composition and structure of advanced FO membranes* • Experimental verification of prototype membranes • Novel manufacturing techniques*
Expected completion	June 2017	March 2017	January 2017**	March 2016**

Source: Ramahi, 2016.
Notes: *Results already obtained; **Already completed.

and the opportunity to demonstrate that their technology works in an arid region relying on desalination for a continuous water supply. Masdar plans to invite more companies to develop and test their advanced RE-powered desalination technology, thereby extending the technology transfer process. The benefits of addressing the water and energy nexus in this manner are clear. In a region where almost half of the world's desalination capacity is located,[57] there is great potential for the technologies tested in Masdar programme. Similar programmes could be set up in other Arab countries in order to transfer the technology.

Wind energy

Wind energy technology can be transferred through various mechanisms. Components may be imported via international trade; component manufacturers can create subsidiaries in the recipient country using FDI; local and foreign companies can form joint ventures; or local companies can be licensed to produce the components.

In India, international trade has been most often used to import wind energy technology. However, due to high customs duties, the other options have also been employed in order to transfer the required technology.[58]

In 2009, India ranked fifth in the world in terms of cumulative wind power installations and the size of its wind market. The Indian Government easily met its target of 10,500 MW of wind energy installed in the country by 2012. Potential capacity for wind energy in the country has been estimated at 45,000 MW at least.

The Centre for Wind Energy Technology (CWET) provides high-quality training on "wind resource assessment, design evaluation and certification and full-scale type testing of wind turbine generators". Private entities (mostly wind turbine manufacturers) are allowed to perform their own wind resource assessment, subject to vetting by CWET, which has led to the discovery of more potential sites suitable for wind energy generation.[59]

The history of wind energy development in India since the early 1990s has been uneven, but the Indian Government is working to create favourable conditions to attract public and private sector investment, including tax exemptions and a tariff paid per kWh to grid-connected wind energy projects of less than 49 MW. The Government has also endeavoured to promote the manufacture of wind turbines. Customs duties have been revised to make it more attractive to import wind turbine components than completely assembled turbines. A national certification programme for wind turbines, reflecting global standards, has also been devised.

The country's dominant manufacturer of wind turbines, Suzlon, sells turbines worldwide. Based in Denmark, Suzlon has created a global learning network through licensing arrangements with international firms, and R&D and manufacturing facilities. Although it takes part extensively in international R&D efforts, it relies mainly on its Indian manufacturing base to produce turbine components.

Suzlon began operations in 1995, when it obtained wind turbine technology through a technical collaboration agreement with Südwind, a German firm. Südwind shared technical knowledge in return for royalties. In 2001, Suzlon obtained a license from Aerpac B.V. to manufacture rotor blades. It also obtained the moulds and technical support from Enron Wind Rotor Production B.V., allowing it to manufacture another model of rotor blade. In 2006, it purchased Hansen, a Belgian company that, at the time, was the world's second-largest gearbox manufacturer. Suzlon also signed an agreement with Winergy AG, the leading gearbox supplier in India. By focusing on the expansion of its production capabilities, Suzlon has been able to produce more competitive products, giving it an edge as it expands to such markets as the United States.

Other foreign wind companies, such as the Enercon, Vestas, Pioneer Wincon, Ghodawat Energy, General Electric and Siemens, have set up turbine manufacturing facilities in India, operating in joint ventures, under license, or through subsidiaries. As an indication of the health of the industry in India, some international companies manufacture more than 80 per cent of their turbine components in India and export them around the world.

Arab countries such as Algeria and Libya have considerable wind potential. Egypt is achieving onshore wind prices that are among the lowest in the world.[60] Indeed, in 2016, installed wind power generation capacity (2,020 MW) in the Arab countries accounted for a greater share (0.87 per cent) of the overall installed capacity than solar power (880 MW; 0.38 per cent).[61] Wind atlases, which assist in the evaluation of the wind resource potential of different locations, are available for many Arab countries.

The Indian case shows how RE manufacturing and deployment can be facilitated when the right conditions are created. Those conditions could also be created in Arab countries. Egypt and Morocco are already following the lead of India.

The case of Jordan is also instructive. The National Energy Research Center facilitates the transfer of wind energy technology in a variety of ways. It provides training and workshops to bolster workforce skills, provides laboratory facilities, works with local and international organizations to carry out projects, and offers technical consulting services on wind energy. It is also working with the European Union to set up a station for the calibration and monitoring of fans and their components. The Center has deployed water pumping and treatment systems powered by wind energy and maintains such systems for the local water authority. It also "works to design and manufacture small fans and their parts, and transfer the manufacturing technology to the industrial private sector".[62]

Oil and gas

One of the world's biggest solar energy plants is being built in Oman to power a significant portion of the country's enhanced oil recovery (EOR) operations. When fully operational in 2022, the Miraah solar energy facility is expected to be the largest EOR project in the world. It will also deliver the greatest peak energy output of any solar plant in the world, producing 6,000 tons of solar steam a day for use in EOR in the Amal oilfield, in southern Oman.[63] In addition to the economic and environmental benefits, the project has also led to the development of a skilled local workforce.

Oman is a world leader in EOR, a process for extracting oil from low pressure reservoirs. At present, the country uses about 20 per cent of its natural gas supply for EOR processes. The country's natural gas supplies are dwindling, and so Petroleum Development Oman (PDO), which is expected to obtain more than a quarter of its petroleum through EOR by 2025, decided to look at the solar option.

In 2012, PDO, which is a joint venture between the Government of Oman, Total, Royal Dutch Shell and Partex, partnered with GlassPoint Solar to launch a pilot project using solar steam generators in the Amal field. Their use in the EOR process led to a decrease in gas consumption of up to 80 per cent. In the light of that success, work on the Miraah project, also in the Amal field, began in 2015.

When it is complete in 2022, the plant will cover 3 km^2 and provide 1,021 MW of peak thermal energy. The solar array will be housed in 36 glasshouses and the steam generated for EOR operations will lead to a saving in natural gas of 5.6 trillion British Thermal Units (BTUs) a year. The first two phases of the three-phase project are expected to be complete by 2018, by which time the plant should be producing 2,000 tons of steam daily.[64]

GlassPoint Solar's enclosed trough technology is designed specifically for oilfields. Batteries of curved mirrors focus sunlight onto a water-filled pipe, turning water into steam that is transported to the steam distribution network in the oilfield. The solar field is encased in a glasshouse to protect it from the harsh climate (dust storms and humidity), giving the system an expected lifespan of 30 years. The protective housing also means that the solar equipment can be made of lightweight materials and kept clean with a water-efficient automated washing system, all of which helps to keep costs down. Such plants can be scaled up easily, as several standard glasshouse modules may be constructed in parallel.

Bangkok business area with Chao Phraya river at night with business connection concept at Bangkok, Thailand. © Namthip Muanthongthae. Shutterstock_ 663363148.

Miraah illustrates the potential for the use of clean energy, particularly solar energy, in oil and gas sector operations. It also sets a benchmark for future solar EOR projects. As a result of joint R&D, PDO was able to announce in 2016 that the cost of the Miraah project had been reduced by 46 per cent.

The potential for solar EOR projects in other oil-producing Arab countries is clear. At present, a thermal EOR project is being developed in the Wafra field, which is located in the Partitioned Neutral Zone between Saudi Arabia and Kuwait. Kuwait, Saudi Arabia and the United Arab Emirates are all looking into expanding oil production through EOR.

Water and wastewater treatment

The As-Samra wastewater treatment plant (WWTP) project in Jordan is exemplary in that 80 per cent of the energy required for its operations is generated by the plant itself. It is also a fine example of technology transfer at work and innovative financing, and addresses the water and energy in several ways.

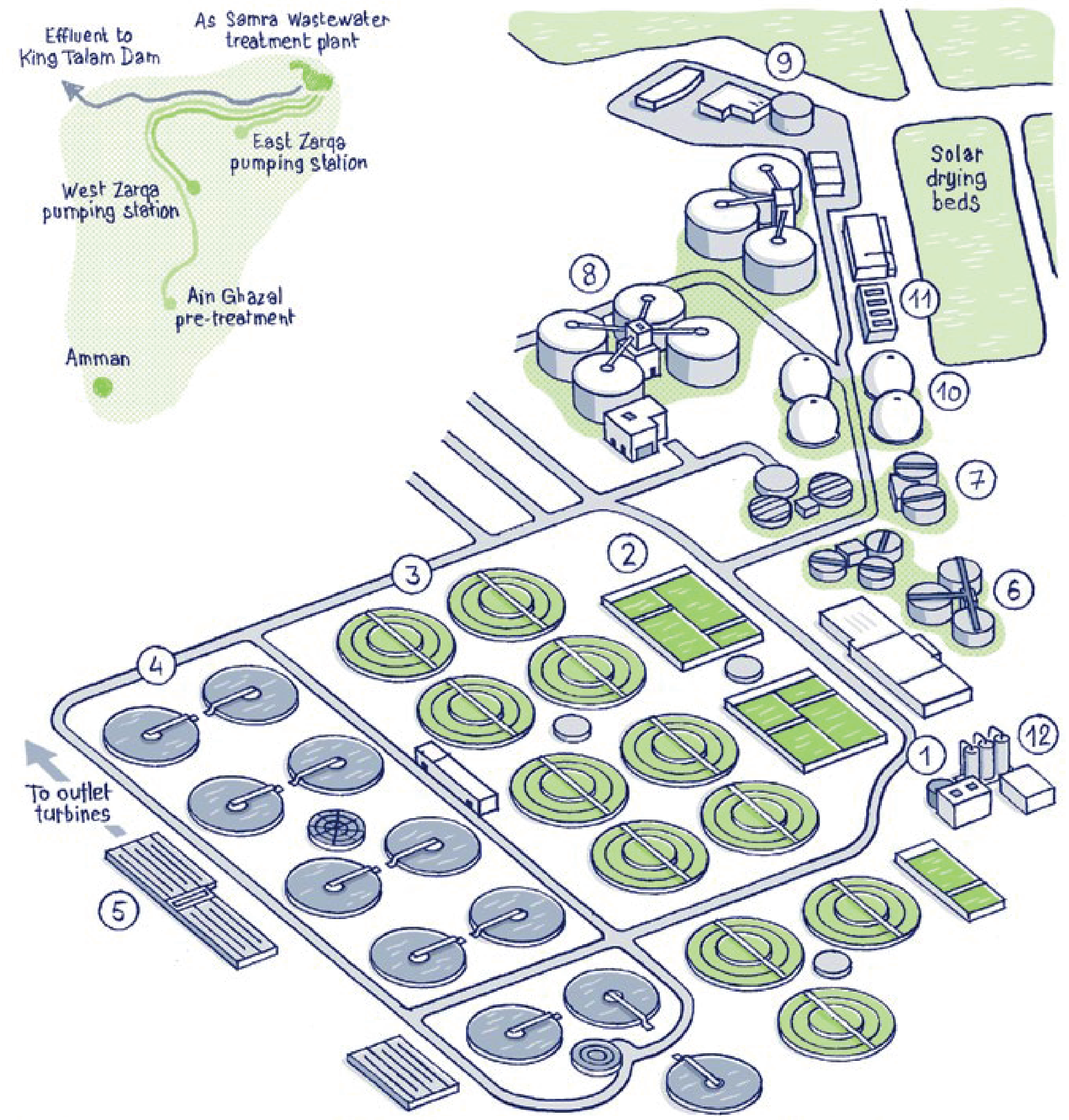
The plant is the largest of its kind in Jordan (see also figure 14). It can treat up to 267,000 m^3 of wastewater a day, more than 70 per cent of the total treated throughout the country. The sludge produced as part of the treatment process is used to produce biogas, which is stored in tanks with a combined capacity of 18,000 m^3. It is subsequently treated to remove hydrogen sulfide (H_2S) and used in 10 biogas generators to produce electricity, which helps to power the plant. In addition, hydraulic energy is generated at the plant inlet (using Pelton turbines) and outlet (using Francis turbines). Combined, the two sources of RE generate 230,000 kWh a day.[65]

The plant also produces 133 million m^3 of high quality treated water a year, which is used for agriculture and represents 10 per cent of the country's water consumption. Water pollution has been drastically reduced as a result and has helped to transform the once heavily polluted Jordan River into one of the cleanest rivers in the country.[66]

Completed in 2008, the plant is being expanded in order to increase water-line and sludge-line capacitates by 37 per cent and 80 per cent respectively, thereby catering to the wastewater treatment requirements of the 3.5 million people living in Greater Amman and the surrounding areas.

The plant was the first in the Arab region to benefit from a combination of private, donor and government finance and grant funding known as viability gap funding. This unique setup has

Figure 14. As-Samra wastewater treatment plant



1- Raw water inlet
2- Primary settling
3- Biological treatment
4- Clarification
5- Final disinfection
6- Primary sludge thickening
7- Activated sludge flotation
8- Anaerobic digestion
9- Mechanical dewatering system
10- Biogas holders
11- Gas power generation
12- Odor control

Source: Vieille and SUEZ, 2016.

led to an affordable tariff for the community and the country. The plant is a public-private partnership for financing the construction and operation of public infrastructure based on a build operate transfer (BOT) approach over 25 years.[67] It was the first BOT project in Jordan and the first to be supported by the United States Agency for International Development (USAID). The Swedish International Development Agency (SIDA) financed the technical assistance required during the preparation, construction and commissioning phases, as well as during the first 18 months of commercial operation. The Ministry of Water and Irrigation awarded a new 25-year BOT contract for the expansion project.

The bulk of the funding came from USAID ($78 million), a consortium of 10 local banks led by the Arab Bank ($60 million), the Samra Plant Consortium (SUEZ, Morganti Group and Infilco Degrémont Inc.; $17 million). The banks provided a 20-year commercial loan, the longest maturity ever offered by Jordanian banks (as of 2016) for a Jordanian dinar-denominated limited-recourse loan, which can be repaid as deferred payment.

The As-Samra project sets an example for the region. It employs technology that can be integrated into new and existing wastewater plants.

Local manufacture of RE components

The fact that RE technologies tend not to be very capital intense and can be transferred with relative ease from producing to newly producing countries facilitates the creation of RE manufacturing facilities and encourages R&D in developing countries.[68] However, there are challenges.

The market for RE is growing in the Arab region as countries strive to diversify their energy portfolio and depend less on fossil fuels. Should they achieve their national RE targets, the Middle East and North Africa (MENA) countries will increase capacity in the 15 years to 2030 by 107 gigawatt (GW).[69]

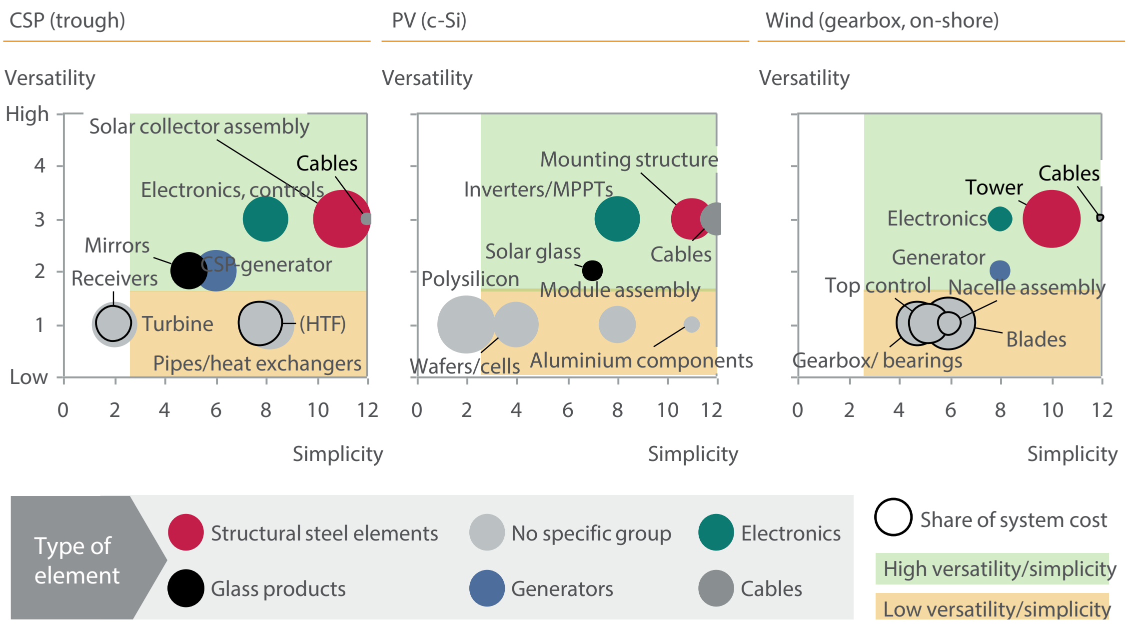
A growing market enhances the potential for local RE manufacturing. For instance, 66 United Arab Emirates companies took part in construction of the Shams 1 concentrated solar power (CSP) plant in Abu Dhabi. Morocco has set a target of 42 per cent local production for components of its planned 160 MW CSP plant. In Egypt, 40 per cent of the equipment for the Kuraymat CSP plant was sourced locally. In Jordan and Tunisia, solar water heating systems are made locally, and up to 30 per cent of the equipment in wind farms in Egypt is provided locally. Factories in Algeria produce photovoltaic (PV) panels.

Arab Governments are also keen to promote local RE manufacturing as a vehicle for job creation, especially given that it creates more jobs directly per value added than the oil and gas industry.

Parts, such as cables and electronic components, are often not specific to a certain type of RE technology. Their versatility means that they can be manufactured at a single location for supply to various RE installations (see figure 15). A new RE manufacturer is therefore probably better off concentrating on the manufacture of less complex and more versatile components.

Most of the RE technology components already manufactured in the Arab countries are limited in complexity and for them markets can be developed fairly quickly. It is expected that all the components required for photovoltaic and, especially, wind energy systems should be being produced locally in the mid-term. CSP technology, on the other hand, requires a long-term investment, given the complexity of CSP generators and turbines.

Figure 15. Versatility and simplicity for components of RE power plants



Source: Zickfeld and Wieland, 2013.

Concentrated solar power (CSP) technology

CSP systems could be manufactured in many Arab countries. The MENA CSP Technical Assistance Program is an investment plan, supported by the World Bank and the African Development Bank, that aims to use concessional finance provided by the Clean Technology Fund (CTF) to accelerate the expansion of CSP generation capacity in Algeria, Egypt, Jordan, Libya, Morocco and Tunisia.

The plan has triggered the installation of 1.2 GW of CSP capacity in the Arab region, and it is expected to lead to the installation of at least 5 GW by 2020. That growth, and the position of the United Arab Emirates as a regional leader in the deployment of CSP technology, should help to foster the spread of a CSP industry across the region, thereby lowering the technology's costs to a point where it may compete with PV technology, which dominates the solar industry in the region today.[70]

The percentage of locally manufactured CSP technology components could rise to as much as 60 per cent of requirements in the region, provided that the market for CSP grows. Various industrial sectors could integrate the CSP value chain into their operations, and they are already competitive at a regional and sometimes even at a worldwide level. However, since the key components are technically complex, that would be best achieved either through joint ventures between local and international companies or the establishment by the latter of local subsidiaries.

Either approach would encourage more local R&D and, thereafter, the production of components more suited to local conditions. That can only be accomplished through greater cooperation with international entities. In the short run, local manufacturers should focus on producing electronics, control systems, pipes, cables, mirrors, heat exchangers and solar collector assembly (including mounting structures). Existing factories can produce most of those items.

Photovoltaic (PV) technology

The potential for promoting local manufacture of solar PV equipment in Arab countries is great. Again, much depends on the size of the market. A substantial initial outlay is required to build facilities for the production of complex parts (such as wafers and cells). Given the competition from largescale manufacturers in China, local manufacturers should focus on niche technologies, working closely with national and international R&D partners. They also need to equip employees with the skills required to make such parts.

With 270 MW of power capacity based on PV technology already installed, and another 416 MW in the pipeline, Algeria is a regional leader in the sector. In Palestine, 70 per cent of domestic water heaters are solar, and 90,000 had been installed in Tunisia as long ago as 2009. Solar water heater factories operate in most MENA countries.[71]

In the short term, local manufacturers should focus on more versatile and less complex parts, such as aluminium components, mounting structures, cables, module assembly and solar glass.

Wind energy technology

The limited market for wind energy in the region makes the local manufacture of critical components unlikely, even though the size of components such as towers, which are difficult to transport, makes them ideal candidates for localized production.

Even where the market is small, there is an argument for manufacturing parts for smaller wind turbines locally. To effect the initial necessary transfer of knowledge, local manufacturers cans license the technology from international partners. Critical components such as blades and gearboxes could be manufactured locally through joint ventures, as in the case of complex CSP components.

High standards of quality must be met and local manufacturers need to factor in up to 15 months in order to obtain the necessary approvals.[72] In the short term, the focus should be on the production of nacelle assembly and housing, blades, towers, cables and generators.[73]

In the Arab region, Egypt and Morocco are taking the lead when it comes to wind energy. They are seeking to become regional manufacturing hubs, providing wind energy components to other Arab countries. The prominence given to wind energy in those two countries has encouraged and facilitated the establishment of local component manufacturing facilities.

Egypt plans to have installed 2,000 MW of wind energy capacity by 2022. General Electric is building a $200 million wind energy components manufacturing facility in the country, and Siemens plans to build a rotor blade manufacturing plant. El Sewedy Electric, a local firm, plans to produce blades and rotors for export.[74]

In Morocco, Siemens plans to open a wind turbine rotor blade production plant in 2017. The blades would be used for onshore wind energy installations. The country plans to meet 52 per cent of its energy needs with RE sources by 2030, with one fifth of that capacity coming from wind energy.[75]

Challenges

Sustained local demand for parts is a prerequisite for viable local manufacturing of RE components. By the same token, the absence of local manufacturing capacity could itself be an obstacle to the spread of a given technology. Strong international competition and, in some countries, the lack of political stability can also hinder the creation or expansion of local manufacture.

Disincentives for investing in such manufacture in the Arab region include the lack of clear regulatory frameworks, a sufficiently skilled local workforce or promising forecasts for the rollout of such technologies, and uncertainty regarding the future development of new RE projects and the security of investments. Arab countries also need to do more to facilitate investment in R&D, upgrade industrial capacity to deal with complex processes and foster market dynamism.

Particularly in the case of more complex RE components, local manufacturing can only take off through cooperation with companies and entities from outside the region. Local manufacturers may require international certification to produce parts that meet quality and safety standards. That approval process can take time and may deter local companies. Another market entry barrier is the large investment needed to fund RE manufacturing operations.

Aside from a lack of skills, local workforce problems can also include an aversion to work in labour-intensive manufacturing jobs, particularly in GCC countries. Yet it is exactly such labour-intensive RE manufacturing that has the greatest potential in the region, especially in the short term. A further obstacle is that labour costs in the Arab region are generally higher than in Asia.

In addition to parts factories, local service companies with adequately skilled staff are needed to maintain plants and systems. Success in that regard can bring an employment dividend for engineers, management staff and other high and low-skilled workers. Local researchers could develop the means of modifying components to suit local conditions.

All of the above factors could simply render components made in the region uncompetitive with those manufactured in countries like China.

A key consideration is the need to align industrial and supply chain policies, which requires consensus between policymakers and all sectors involved. There must be coordination along the entire supply chain and between all stakeholders, even in separate industries, for the integration of RE manufacturing operations in a country’s economy to succeed.

Fossil fuel subsidies distort the energy market and make the investment costs for RE technology components and the costs for service providers, comparatively unattractive to investors and, by extension, consumers.

Specific attempts to localize manufacture have not always worked. In 2014, the United Arab Emirates company Masdar reissued an engineering procurement construction (EPC) tender for a solar PV project with a capacity of 100 MW, dropping an earlier condition that half of the panels used in the project had to be manufactured by Masdar when it realized that the target was not feasible.[76]

Recommendations

The above challenges can be overcome. The European Investment Bank (EIB) and IRENA have identified some key factors that could contribute to the success of future RE manufacturing in the Arab region (table 10).

Investment capacity and strong financing infrastructures can be achieved by encouraging local banks to provide low-interest loans and grants. The As-Samra wastewater treatment plant project in Jordan (see above) demonstrates how such an approach can facilitate the installation of state-of-the-art technology. However, such approaches to funding need to be part of a broader strategy. Investing in manufacturing components is pointless in the absence of a market for them.

The Arab countries should focus initially on making the most versatile and least complex parts. That would provide those countries with the greatest immediate benefit and enable them to increase local value creation before they dive into the manufacture of more complex parts. In many cases, production of those less complex parts could be enabled by expanding extant manufacturing facilities.

Table 10. Success factors for local RE manufacturing in the Arab region

	Success factors			
	Substantial political support aimed at creating a long-term, stable market	**Competitive local players in the global market**	**Strong industry innovation potential and skilled workforce**	**Investment capacity and strong financing infrastructures**
Classes of recommendation	Formulate a long-term RE strategy with national targets	Conduct awareness-raising activities	Support R&D	Encourage local banks to provide low-interest loans and grants
	Define an extensive RE regulatory framework	Assess the feasibility of production line upgrades	Educate and train a highly skilled workforce	Implement investment support mechanisms to adapt or create production lines
	Define a national plan for manufacturing RE equipment	Foster business links, in particular through joint ventures with international companies	Upgrade specific industries	Implement price, tax and other incentives
	Reform fossil-fuel subsidies	Support the structuring of the sector	Identify niche technologies and set up national centres of excellence	

Source: European Investment Bank (EIB) and International Renewable Energy Agency (IRENA), 2015.

Cooperation with international producers is also key. The main CSP technology manufacturers in the world are already helping to set up CSP plants across the region. Should the market in Arab countries develop sufficiently, they could become interested in building local factories.

The deployment of RE manufacturing capacity in the Arab region could well benefit from the substantial increase in concessional climate financing envisaged under the UNFCCC.

In 2010, it was decided at the Cancún Climate Change Conference to set a goal of mobilizing $100 billion a year for the GCF by 2020, to be garnered from public, private, bilateral, multilateral and other alternative sources. Accredited entities facilitate the transfer of GCF resources to assist with the management of different programmes and projects. As of July 2017, 43 projects had been approved, the forecast result of which will be 981 million tons of CO_2 avoided and greater resilience for 125 million people. Africa accounts for 42 per cent of those projects and Asia 35 per cent.[77]

In the long term, Arab countries will, however, need to cut back dependence on concessional financing. That will only happen if investment costs decrease, which in turn depends on factors such as the cost of power generation and manufacturing. A combination of technical innovation, economies of scale and the learning curve effect can bring about such a situation. Moreover, the presence in some Arab countries of a strong automobile parts industry indicates an industrial capacity that could be tapped and adapted to encourage the growth of a new, high value-added industry in the region: RE manufacturing.

The authorities in Arab countries should provide local firms with the technical support and resources they need to formulate standards and codes for RE technologies and to obtain internationally recognized certification in the manufacture of principal RE technology components. Science and technology parks can be used to encourage R&D, especially in the private sector, and to facilitate knowledge transfer. Exchange programmes between local and international students at all levels can be activated. In addition, a "marketplace for private-sector, for profit vocational training should be enabled in RE-relevant subjects" in the Arab region.[78]

As described in the case studies above, initiatives such as the MED-ENEC have been working to achieve some of the above. Another example is an EIB-IRENA study aimed at promoting RE manufacturing in the Arab Mediterranean countries of Egypt, Morocco and Tunisia. The study assessed existing RE technology manufacturing capability and proposed ways of facilitating its expansion.[79]

Countries in the Arab region show varying degrees of potential for particular types of RE. Egypt and Morocco, for instance, have greater potential to develop wind energy than other countries in the region. Such countries can work together to design policies to facilitate manufacturing of components for the RE technology in which they have a common interest and capacity. Arab countries could follow the lead of Tunisia and look at developing solar water heating, especially given the simplicity of the technology involved.

Another option is to promote off-grid applications of RE technology that can provide electricity in rural and remote areas. That is of particular interest at a time when parts of the region are affected by war and hosting significant populations of refugees and internally displaced people. Aside from promoting economic development and electrification in the region, the use of such applications would stimulate the spread of RE technology and manufacturing.

Positive green bulb in business world transfer network vector illustration. © Adam Vilimek. Shutterstock_ 181974071.

The scaling up of RE manufacturing could also encourage increased trade, particularly with the European Union, thereby providing countries in the region with opportunities to generate export revenue and helping them to become more energy secure and meet emission targets.

Conclusions

Technology transfer will be a key to helping the Arab countries to achieve the SDGs. Goal 6, on clean water, and Goal 7, on affordable and clean energy, are the most relevant to the water and energy nexus. Each includes a roadmap, with targets and indicators. Improved efficiency in water use is of prime importance in achieving both goals, and technology, whether RE technologies or others specifically designed to improve existing devices or processes, will enable those efficiency gains.

Many are already being implemented in different parts of the world, including in some Arab countries. That is where technology transfer, whether to Arab countries from other regions or between them, comes in. It is a broad and multifaceted process and the choice of financing option, policies and regulations, and how transfers are carried out, depends greatly on the circumstances of each recipient country.

Many applications of relevance to the entire region have already been set in motion in various countries. The potential for growth and improvement across the region is therefore considerable, and in some cases should be relatively straightforward. Newly developed technologies could bring great resource efficiencies when applied to, for instance, the oil and gas sector and cooling processes. The technology transfer required would strengthen water and energy security.

National policies regarding technology in the water and energy sectors should address the complete technology transfer chain. They could require large businesses to contribute to local research funds. More support could be provided to university spin-outs and tech start-ups. The public and private sectors should be encouraged to become more involved in basic and applied research, skills development, and pilot projects. Transparency should be bolstered, with improved data reporting that would help to calculate indicators and quantify progress, as well as raising awareness of examples in the country and region that can be emulated. Transparency in terms of policy objectives is also important, as it enhances communication between stakeholders and ultimately results in more efficient and effective technology transfer processes.

Technology transfer should also take into account the rights of recipient countries, including in the context of climate change negotiations. All too often, countries providing technology do not take those rights into consideration. Saudi Arabia, for example, has demanded that intellectual property rights should not hinder the transfer of climate change mitigation technologies.[80]

The gap between countries in the Arab region performing well with regard to technology transfer and those lagging behind is widening. The stronger countries should do more than hitherto to partner with their weaker counterparts to help them to develop through, for example, leapfrogging. Such cooperation would be mutually beneficial and strengthen the region as a whole.

The use of technology transfer within the region to spread RE technologies related to the water and energy sectors would create a positive loop, encouraging growth in local markets for RE components and thereby creating opportunities for local manufacturers. Growth in such manufacturing would in turn lead to more affordable parts through economies of scale, and thereby reinforce the cycle. The entire region would experience greater water and energy security, and more sustainable development and prosperity.

Endnotes

1. Metz and others, 2000.
2. Mansfield, 1982.
3. Branstetter and others, 2004
4. Maskus, 2000.
5. Metz and others, 2000.
6. United Nations Department of Economic and Social Affairs, 2008.
7. Metz and others, 2000.
8. Brewer and Mani, 2008.
9. United Nations Department of Economic and Social Affairs, 2008.
10. Yang and others, 2012.
11. Amerasinghe and others, 2017.
12. Trabacchi and others, 2016.
13. Metz and others, 2000.
14. EIB and IRENA, 2015.
15. Ghaddar, 2010.
16. United Arab Emirates, 2015.
17. El-Khayat and others, 2014.
18. Ramady, 2004.
19. Alsodais, 2013.
20. El Amrani, 2016.
21. Economic and Social Commission for Western Asia (ESCWA), 2013.
22. Al-Jayyousi, 2015.
23. ESCWA, 2014.
24. European Commission, 2015.
25. Ibid.
26. United Nations Economic and Social Commission for Western Asia (ESCWA), 2014.
27. Ibid.
28. World Bank, 2017.
29. According to the World Intellectual Property Organization (WIPO), the term 'resident' refers to filings made by applicants at their home office while the term 'non-resident' refers to filings made by applicants at a foreign office. 'Residents' refers to nationals of an Arab country and 'non-residents' refers to expatriates living in that country.
30. ESCWA, 2013.
31. Schwab, 2016.
32. Ionita, 2011a.
33. Turner, 2016.
34. French and Torchia, 2016.
35. Khlopkov, 2016.
36. Dalton, 2015.
37. Muralev, 2016.
38. National Research Nuclear University, 2017
39. Muralev, 2016.
40. Megahed, 2007.
41. Vera and others, 2009.
42. Kimeraa, 2011.
43. Vera and others, 2009.
44. Ibid.
45. Ibid.
46. Energy Efficiency in the Construction Sector in the Mediterranean (MED-ENEC), 2017a.
47. Becker and Tawalbeh, 2013.
48. Peters, 2010.
49. Hamon Research-Cottrell, Inc., 2016.
50. Ibid.
51. Turner, 2016.
52. Hamon Research-Cottrell, Inc., 2016.
53. Avis, 2017.
54. Prabhu, 2017.
55. Shi, 2012.
56. Williams, 2014.
57. Clean Energy Business Council, 2014.
58. Lema and Lema, 2013.
59. Gomathinayagam, 2011.
60. Philibert, 2015.
61. Ibid.
62. Al-Jayyousi, 2015.
63. GlassPoint Solar, 2016.
64. Oman News Agency (ONA), 2016.
65. SUEZ, 2016.
66. Ibid.
67. SUEZ and Degrémont, 2014.
68. El-Katiri and others, 2014.
69. EIB and IRENA, 2015.
70. EIB and IRENA, 2015.
71. Kordab, 2009.
72. EIB and IRENA, 2015.
73. Zickfeld and Wieland, 2013.
74. Graves, 2016.
75. Weston, 2016.
76. Davies and others, 2016.
77. Green Climate Fund, 2017.
78. Zickfeld and Wieland, 2013.
79. EIB and IRENA, 2015.
80. Teehankee and others, 2012.

Bibliography

Abouelhassan, N. (2017). Overview of Egypt's nuclear power program. Available from https://www.iaea.org/NuclearPower/Downloadable/Meetings/2017/2017-01-31-02-03-NIDS/Session_1_-_Considerations_for_Nuclear_Energy_Programme_Implementing_Organizations_(NEPIOs)/Session_1_-_Considerations_for_Nuclear_Energy_Programme_Implementing_Organizations_(NEPIOs)/Overview_of_Egypts_Nuclear_Power_Program_-_N._Antar_-_Egypt.pdf.

Al-Jayyousi, O. (2015). *Renewable energy in the Arab world: Transfer of knowledge and prospects for Arab cooperation* (al-Ṭabʽah al-ūlá). Amman: Friedrich Ebert Stiftung.

Alsodais, S. (2013). Science, technology & innovation in Saudi Arabia. *WIPO Magazine*, September. Available from www/wipo_magazine/en/2013/05/article_0006.html (accessed 8 June 2017).

Amerasinghe, N. M. and others (2017). *Future of the Funds: Exploring the Architecture of Multilateral Climate Finance.* Washington, D.C.: World Resources Institute (WRI). Available from http://www.wri.org/sites/default/files/The_Future_of_the_Funds_0.pdf.

Avis, P. (2017). Is the Middle East the new home for coal? *Energy Analyst*, 6 March. Available from http://energyanalyst.co.uk/is-the-middle-east-the-new-home-for-coal.

Becker, D. and M. Tawalbeh (2013). *MED-ENEC support on National Energy Efficiency Action Plans (NEEAPs): Jordan.* No. ENPI/2009/224-969. Available from www.rcreee.org/sites/default/files/plans_neeap_jordan_2013_en.pdf.

Bellini, E. (2017). Aurés Solaire commissions Algeria's second module factory. *PV Magazine*, 25 April. Available from https://www.pv-magazine.com/2017/04/25/aures-solaire-commissions-algerias-second-module-factory.

Branstetter, L. G., R. Fisman, and C. F. Foley (2004). Do stronger intellectual property rights increase international technology transfer? Empirical evidence from US firm-level panel data. Available from www.cb.cityu.edu.hk/ef/PastEvent/Sem2004_24May2004/pdf/session%201_2.pdf.

Breeze, C. (2017). Miraah takes solar EOR in Oman to the next level. *Shell World Joint Ventures*, February, pp. 3-5. Available from www.shell.ae/en_ae/about-us/shell-world-jv-magazine/shell-world-jv-10/_jcr_content.stream/1489073360594/b9c8dfc4b2bc495e52e4d236b673756cefee0d7f5816f1f1df163dc2d1a533cb/Shell-World-JV-v10.pdf.

Brewer, T. L. and M. Mani (2008). Technology transfers and climate change: International flows, barriers, and frameworks. *Brookings Trade Forum*, pp. 93-119.

Burns, M. (2012). A sustainable framework for international green technology transfer. *Colorado Journal of International Environmental Law and Policy*, vol. 23, No. 2, pp. 405-432.

Carter, T. P. (2014). Water savings using the thermosyphon cooler hybrid heat rejection system: Case studies from Atlanta, Phoenix, Seattle, and Boston. Johnson Controls, Inc.

Clean Energy Business Council (2014). Water and energy in MENA: Challenges, opportunities, and potential. Available from www.cleanenergybusinesscouncil.com/site/resources/files/Energy-and-Water-in-MENA.pdf.

Cornell, INSEAD and World Intellectual Property Organization (2017). Analysis, Global Innovation Index. Available from https://www.globalinnovationindex.org/analysis-indicator (accessed 27 July 2017).

Croce, R. D., J. Paula and A. Laboul (2015). *Infrastructure Financing Instruments and Incentives*. Organisation for Economic Co-operation and Development (OECD). Available from www.oecd.org/finance/private-pensions/Infrastructure-Financing-Instruments-and-Incentives.pdf.

Dahlberg, Neil, Buzz Reynolds and Royce Warnick (2016). ReACT™ Regenerative activated coke technology. Somerville, New Jersey: Hamon Research-Cottrell, Inc. Available from www.hamonusa.com/sites/default/files/attachments/brochure%20-%20hrc%20-%20react.pdf.

Dalton, David (2015) Russia and Egypt sign agreement to develop nuclear desalination plant. *NucNet*, 3 March. Available from www.nucnet.org/all-the-news/2015/03/03/russia-and-egypt-sign-agreement-to-develop-nuclear-desalination-plant.

Darcy, Jacques and others (2009). Financing technology transfer. Working Paper No. 2009/002. Luxembourg: European Investment Fund. Available from www.eif.org/news_centre/publications/eif_wp_2009_002_financing-tt_fv.pdf.

Data Center Research (2017). Colocation Middle East. Available from www.datacentermap.com/middle-east/ (accessed 25 July 2017).

Davies, Michelle and others (2016). *Developing Renewable Energy Projects: A Guide to Achieving Success in the Middle East* (third ed.). Eversheds and PwC. Available from https://www.pwc.com/m1/en/publications/documents/eversheds-pwc-developing-renewable-energy-projects.pdf.

DNV.GL (2016). Middle East waking up to EOR. Available from https://www.dnvgl.com/oilgas/perspectives/middle-east-waking-up-to-eor.html.

El Amrani, Ali (2016). National innovation system: Enabling technology transfer in Morocco. Beirut: United Nations Economic and Social Commission for Western Asia (ESCWA). Available from https://www.unescwa.org/sites/www.unescwa.org/files/page_attachments/morocco_science_technology_and_innovation_landscape_analysis_0.pdf.

Electric Power Research Institute (EPRI) (2015). Information, communication, & cyber security newsletter. Palo Alto, United States of America: EPRI. Available from http://smartgrid.epri.com/doc/EPRI%20ICT%20Newseltter_Mar2015.pdf.

__________ (2016). Technology transfer awards. Palo Alto, United States of America: EPRI. Available from www.eskom.co.za/news/Documents/EPRI_Awards.pdf.

El-Katiri, L. and B. Fattouh (2014). *A Roadmap for Renewable Energy in the Middle East and North Africa.* Oxford, United Kingdom: Oxford Institute for Energy Studies. Available from www.oxfordenergy.org/wpcms/wp-content/uploads/2014/01/MEP-6.pdf.

El-Khayat, M. and others (2014). *Pan-Arab Renewable Energy Strategy 2030: Roadmap of Actions for Implementation.* Abu Dhabi: IRENA. Available from https://www.irena.org/DocumentDownloads/Publications/IRENA_Pan-Arab_Strategy_June%202014.pdf.

Energy Efficiency in the Construction Sector in the Mediterranean (MED-ENEC) (2017a). Background. Available from www.med-enec.com/background.

__________ (2017b). Consortium Partners. Available from www.med-enec.com/about/consortium.

__________ (2017c). Objectives, Activities & Outputs. Available from http://www.med-enec.com/about/objectives-activities-outputs.

ESCWA Technology Centre for Development (2007). Detailed assessment of regional needs and priorities and identification of implementation mechanisms. New York: United Nations. Available from https://www.unescwa.org/sites/www.unescwa.org/files/publications/files/ictd-07-tp6-e.pdf.

European Commission (2015). Inception impact assessment: Partnership for research and innovation in the Mediterranean area (PRIMA). Available from http://ec.europa.eu/smart-regulation/roadmaps/docs/2015_rtd_009_prima_en.pdf.

European Investment Bank (EIB) and International Renewable Energy Agency (IRENA) (2015). *Evaluating Renewable Energy Manufacturing Potential in the Mediterranean Partner Countries*. Available from www.eib.org/attachments/femip_study_evaluating_renewable_energy_manufacturing_potential_en.pdf.

Fawkes, Steven, Kit Oung and David Thorpe (2016). *Best Practices and Case Studies for Industrial Energy Efficiency Improvement: An Introduction for Policy Makers*. Copenhagen: UNEP DTU Partnership. Available from http://orbit.dtu.dk/en/publications/best-practices-and-case-studies-for-industrial-energy-efficiency-improvement(6ff49b1b-9683-4d7d-9b42-ab2b0c7955a4).html.

Fong, M. W. L. (2009). Technology leapfrogging for developing countries. IGI Global. Available from https://journalistsresource.org/wp-content/uploads/2013/04/Technology-Leapfrogging-for-Developing-Countries.pdf.

Fraunhofer ISE and Ernst & Young (2011). Middle East and North Africa region assessment of the local manufacturing potential for concentrated solar power (CSP) projects. Washington, D.C.: World Bank. Available from http://siteresources.worldbank.org/INTMENA/Resources/CSP-Job-Study-Eng-Sum.pdf.

Frazer, Lance (2004). Low water consumption: A new goal for coal. *Environmental Health Perspectives*, vol. 112, No. 5, pp. A296-A299. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241941/pdf/ehp0112-a00296.pdf.

French, David and Andrew Torchia (2016). Dubai's DEWA gets finance for $3.4 bln coal power plant. Reuters. 11 December. Available from http://af.reuters.com/article/commoditiesNews/idAFL5N1E606Z.

Ghaddar, Nesreen (2010). Research in the Arab region from a development lens. Presented at Panel III: Knowledge and technology transfer, The Climate Change Impacts in the Arab Region: Towards Sustainable Energy – Resources, Challenges and Opportunities, held by UNDP-RBAS, Bahrain. October.

GlassPoint Solar (2016). Miraah project fact sheet. Petroleum Development Oman (PDO). Available from https://www.glasspoint.com/wp-content/uploads/Miraah-Fact-Sheet.pdf.

Gomathinayagam, S. (2011). A case study on Indian wind power programme for technology transfer and sharing best practices. Islamabad: SAARC Energy Centre. Available from www.saarcenergy.org/wp-content/uploads/2016/02/Indian_Wind_Power_Program_2011_2.pdf.

Graves, LeAnne (2016). Egypt revives wind turbine plans. *The National*, 24 January. Available from www.thenational.ae/business/energy/egypt-revives-wind-turbine-plans.

Green Climate Fund (2017). Portfolio dashboard. Available from www.greenclimate.fund/what-we-do/portfolio-dashboard (accessed 24 July 2017).

Indra, Rajani Kant (2012). GEF & GCF. 31 October. Available from http://rajanikantindra.blogspot.com/2012/10/gef-gcf.html.

Ionita, R. (2011). Modernisation of turbines in six Chinese power stations. United Nations Framework Convention on Climate Change (UNFCCC). Available from http://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/IMS_BLS/a70e62d7861e4f1c9a6fb250af63d1c2/dac36acd0be24afd9ac79e83be007c33.pdf.

IRENA (2016). Renewable energy in the Arab region. Overview of developments. Abu Dhabi. Available from www.irena.org/DocumentDownloads/Publications/IRENA_Arab_Region_Overview_2016.pdf.

Johnson Controls (2017). Hybrid Cooling Systems. Available from www.johnsoncontrols.com/buildings/hybrid-cooling-systems.

Kaye, Jen (2016). Oasys water's next-generation technology platform extends the impact of membrane solutions for industrial wastewater reuse. Boston, United States: Oasys Water. 12 October. Available from http://oasyswater.com/news-post/oasys-waters-next-generation-technology-platform-extends-the-impact-of-membrane-solutions-for-industrial-wastewater-reuse/.

Kessides, Ioannis. N. and Vladimir Kuznetsov (2012). Small Modular Reactors for Meeting the Electricity Needs in Developing Countries. Washington, D.C.: World Bank; Vienna: International Atomic Energy Agency. Available from https://openknowledge.worldbank.org/handle/10986/23186.

Khan, Mosahid and others (2013). *2013 World Intellectual Property Indicators*. Geneva, Switzerland: World Intellectual Property Organization (WIPO). Available from www.wipo.int/edocs/pubdocs/en/intproperty/941/wipo_pub_941_2013.pdf.

Khanfir, Mondher (2016). How to harness the national innovation system in Tunisia. Amman: ESCWA Technology Centre. Available from https://www.unescwa.org/sites/www.unescwa.org/files/page_attachments/tunisia_science_technology_and_innovation_landscape_analysis.pdf.

Khlopkov, Anton (ed.) (2016). Prospects for nuclear power in the Middle East: Russia's interests (grantees report). Moscow: Valdai Discussion Club. Available from http://ceness-russia.org/data/doc/REPORT_ENG_prospectsfornuclearpowerME.pdf.

Kimeraa (2011). European initiatives to excellence in maritime cluster. KIMERAA (Knowledge Transfer to Improve Marine Economy in Regions from the Atlantic Area). Cardiff, United Kingdom. Available from http://kimeraa.eu/gestor/upload_files/Documentos/European_Initiatives_to_Excellence_in_Maritime_Cluster.pdf.

Kordab, Mohamad (2009). Solar water heaters development in MENA region. Presented at the conference on Solar Thermal Application in Egypt, Palestine, Lebanon, Syria and Jordan: Technical Aspects, Framework Conditions and Private Sector Needs. Cairo, 23-25 March 2009. Available from www.solarthermalworld.org/sites/gstec/files/Session1_Solar_Water_Heaters_Development_In_MENA_Region_MKordab.pdf.

Lema, Adrian and Rasmus Lema (2013). Technology transfer in the clean development mechanism: Insights from wind power, *Global Environmental Change*, vol. 23, No. 1, pp. 301-313. Available from https://doi.org/10.1016/j.gloenvcha.2012.10.010.

Lesser, W. (2012). Measuring intellectual property "strength" and effects: An assessment of patent scoring systems and causality. *The Journal of Business, Entrepreneurship & the Law*, vol. 4, No. 2. Malibu, California: Pepperdine Libraries. Available from http://digitalcommons.pepperdine.edu/jbel/vol4/iss2/4.

Lewis, J. I. (2011). Building a national wind turbine industry: Experiences from China, India and South Korea. *International Journal of Technology and Globalisation,* vol. 5, No. 3/4, p. 281. Available from https://doi.org/10.1504/IJTG.2011.039768.

Makiver, Meghan (2016). Oasys water continues expansion of global operations to deliver much needed industrial water treatment innovation to the Middle East. *Oil & Gas 360*, 23 February. Available from https://www.oilandgas360.com/oasys-water-continues-expansion-of-global-operations-to-deliver-much-needed-industrial-water-treatment-innovation-to-the-middle-east/.

Mansfield, E. (ed.) (1983). *Technology Transfer, Productivity, and Economic Policy.* New York: W. W. Norton & Company, Inc.

Margolis, Robert M. (2002). *Understanding Technological Innovation in the Energy Sector: The Case of Photovoltaics.* Princeton University.

Masdar (2017). Renewable energy water desalination programme. Available from www.masdar.ae/assets/downloads/content/3588/desal_factsheet-final-jan_10,_2017.pdf.

Maskus, Keith E. (2000). Intellectual Property Rights and Economic Development. University of Colorado, Boulder.

Mazurkiewicz, Adam and Beata Poteralska (2017). Technology transfer barriers and challenges faced by R&D organisations. *Procedia Engineering,* vol. 182, pp. 457-465. Available from https://doi.org/10.1016/j.proeng.2017.03.134.

Megahed, M. M. (2007). *Nuclear desalination activities and prospects in the Arab countries.* Presented at the International Conference on Non-Electric Applications of Nuclear Power: Seawater Desalination, Hydrogen Production and Other Industrial Applications, held from 16 to 19 April 2007 at O-Arai, Japan. Available from www-pub.iaea.org/MTCD/Meetings/PDFplus/2007/cn152/cn152p/Megahed%20Egypt%20ND%20in%20ArabCountries.pdf.

Metz, Bert and others (eds.) (2000). *Methodological and Technological Issues in Technology Transfer.* Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Mukasa, Alli. D. and others (2013). Development of wind energy in Africa. Working Paper Series, No. 170. Tunis: African Development Bank. Available from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Working%20Paper%20170%20-%20Development%20of%20Wind%20Energy%20in%20Africa.pdf.

Muralev, Y. (2016). Proposal of desalination technology selection for nuclear power and desalination plant. Presented at the Technical Meeting on the User-Vendor Interface in Cogeneration for Electricity Production and Seawater Desalination, held from 14 to 16 March 2016 in Vienna. Available from https://www.iaea.org/NuclearPower/Downloadable/Meetings/2016/2016-03-14-03-16-NPTDS/Kazakhstan2.pdf.

Nagy, B. (2009). IPR protection strength and the market for knowledge, *Regional Competitiveness, Innovation and Environment,* pp. 183-197. Szeged, Hungary: JATEPress.

National Research Nuclear University (2017). Researchers develop hybrid nuclear desalination technique with improved efficiency. Phys.Org, 24 January. Available from https://phys.org/news/2017-01-hybrid-nuclear-desalination-technique-efficiency.html.

Negewo, B. D. (2012). *Renewable Energy Desalination: An Emerging Solution to Close the Water Gap in the Middle East and North Africa.* Washington DC: World Bank.

Oman News Agency (2016). PDO's Miraah solar project costs cut by 46%. *Times of Oman*, 30 July. Available from http://timesofoman.com/article/89031/Business/PDO%27s-Miraah-solar-project-costs-cut-by-46.

Organisation for Economic Co-operation and Development (OECD) (2013). *Increasing Private Participation in the Southern African Development Community's Infrastructure: Policy Bottlenecks and the Way Forward.* Available from https://www.oecd.org/daf/inv/investment-policy/IncreasingPrivateParticipationInSADCinfrastructure.pdf.

_______ (2017). OECD and the Sustainable Development Goals: Delivering on universal goals and targets. Retrieved June 7, 2017, from http://www.oecd.org/dac/sustainable-development-goals.htm.

Passut, Charlie (2014). Texas plant deploys promising technology to clean produced water. *NGI's Shale Daily,* 11 June. Available from www.naturalgasintel.com/articles/98981-texas-plant-deploys-promising-technology-to-clean-produced-water.

Peters, H. James (2010). ReACT reduces emissions and water use. *Power*, 1 July. Available from www.powermag.com/react-reduces-emissions-and-water-use/.

Philibert, Cédric (2015). Renewables in the MENA region. Presented at the 21st Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in December 2015. Available from www.iea.org/media/workshops/2015/cop21/otherevents/5DecPhilibert.pdf.

Polity (2017). Eskom scoops coveted global award. 23 February. Available from www.polity.org.za/article/eskom-eskom-scoops-coveted-global-award-2017-02-23.

Poulton, Wendy, Steve Lennon and Laurie Steenkamp (2000). What are the options of technology transfer for South Africa? Johannesburg and Pretoria, South Africa: Eskom and Department of Trade and Industry. Available from http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=4FD9AFD4CF52F6E7609987EB66076FBE?doi=10.1.1.199.8363&rep=rep1&type=pdf.

Prabhu, Conrad (2017). Advisers sought for Oman's first coal-fired power project. *Oman Daily Observer*, 10 April. Available from http://omanobserver.om/advisers-sought-omans-first-coal-fired-power-project/.

Ramady, M. A. (2004). Components of technology transfer: A comparative analysis of offset and non-offset companies in Saudi Arabia. King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Ramahi, M. E. (2016). Masdar's renewable energy desalination program. Presented at the Singapore International Water Week 2016. Available from www.siww.com.sg/sites/default/files/Desalination%20and%20water%20reuse_Mr%20Mohammad%20El%20Ramahi.pdf.

Santamarta, J. (2017). Middle East leaders seek concentrated solar power to support growth. *Helioscsp*, 2 May. Available from http://helioscsp.com/middle-east-leaders-seek-concentrated-solar-power-to-support-growth/.

Schwab, Klaus (ed.) (2016). *The Global Competitiveness Report 2016–2017*. Geneva, Switzerland: World Economic Forum. Available from www3.weforum.org/docs/GCR2016-2017/05FullReport/TheGlobalCompetitivenessReport2016-2017_FINAL.pdf.

Shi, J. (2012). Program on technology innovation: New concepts of water conservation cooling and water treatment technologies. Technical update No. 1025642. Palo Alto, California: Electric Power Research Institute (EPRI). Available from https://www.epri.com/#/pages/product/1025642/.

SUEZ (2016). As Samra wastewater treatment plant: A major asset for Jordan. Available from www.degremont.com/document/?f=engagements/en/as-samra-r-er-020-en-1510-web.pdf.

SUEZ and Degrémont (2014). Samra Wastewater Treatment Plant Jordan. Available from www.fogevaporator.com/pdf/samra-wastewater-treatment-plant.pdf.

Teehankee, Manuel. A. J., Ingrid Jegou and Rafael Jacques Rodrigues (2012). Multilateral negotiations at the intersection of trade and climate change: An overview of developing countries' priorities in UNCSD, UNFCCC and WTO processes. Issue paper No. 2. Geneva, Switzerland: International Centre for Trade and Sustainable Development (ICTSD). Available from https://www.ictsd.org/downloads/2012/06/multilateral-negotiations-at-the-intersection-of-trade-and-climate-change.pdf.

Toscano, A. and others (2016). Recent trends in the world gas market: Economical, geopolitical and environmental aspects. *Sustainability*, vol. 8, No. 2, p. 154. Available from https://doi.org/10.3390/su8020154.

Trabacchi, Chiara and others (2016). The role of the climate investment funds in meeting investment needs. Climate Policy Initiative (CPI). Available from https://climatepolicyinitiative.org/wp-content/uploads/2016/06/The-role-of-the-Climate-Investment-Funds-in-meeting-investment-needs.pdf.

Turkenburg, Wim and others (2012). Renewable Energy. In *Global Energy Assessment - Toward a Sustainable Future*, pp. 761–900. Cambridge, United Kingdom: Cambridge University Press and Laxenburg, Austria: International Institute for Applied Systems Analysis. Available from www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter11_renewables_lowres.pdf.

Turner, Julian (2016). Lean and clean: Why modern coal-fired power plants are better by design. *Power-technology.com*, 22 June. Available from www.power-technology.com/features/featurelean-and-clean-why-modern-coal-fired-power-plants-are-better-by-design-4892873/.

United Arab Emirates (2015). Science, technology & innovation policy in the United Arab Emirates. Available from www.uaeinnovates.gov.ae/docs/default-source/pdfs/science-technology-and-innovation-policy-en.pdf.

United Nations Department of Economic and Social Affairs (2008). Climate change: Technology development and technology transfer. Paper prepared for the Beijing High-level Conference on Climate Change. Available from http://climatestrategies.org/wp-content/uploads/2009/09/isda-ghana-country-study-september-2009-report-2.pdf.

United Nations Economic and Social Commission for Western Asia (2007). The ESCWA Technology Centre for Development: Detailed assessment of regional needs and priorities and identification of implementation mechanisms. New York: United Nations. Available from https://www.unescwa.org/sites/www.unescwa.org/files/publications/files/ictd-07-tp6-e.pdf.

__________ (2012). Intergovernmental consultative meeting on the water and energy nexus in the ESCWA region. E/ESCWA/SDPD/2012/IC.1/2/Report.

__________ (2013). Strengths and weaknesses of science and technology institutions in Arab countries. Beirut. Available from https://www.unescwa.org/sites/www.unescwa.org/files/page_attachments/sti_national-swot_arab1.pdf.

__________ (2014). *The Broken Cycle: Universities, Research and Society in the Arab World - Proposals for Change.* Beirut. Available from https://www.unescwa.org/sites/www.unescwa.org/files/page_attachments/broken_cycle_study_-_english_version.pdf.

__________ (2015). *Policies for the Establishment of an Efficient System of Innovation and Technology Transfer in Egypt*. Beirut. Available from https://www.unescwa.org/sites/www.unescwa.org/files/page_attachments/egypt_technology_transfer_legislative_analysis_0.pdf.

__________ (2016a). Developing the capacity of ESCWA member countries to address the water and energy nexus for achieving Sustainable Development Goals: Regional policy toolkit. E/ESCWA/SDPD/2016/Manual.

__________ (2016b). Expert group meeting on the potential of manufacturing renewable energy equipment in the Arab region. E/ESCWA/SDPD/2016/WG.11.

__________ (2016c). Innovation system landscape in Sudan. Beirut. Available from https://www.unescwa.org/sites/www.unescwa.org/files/page_attachments/sudan-ntto-innovation-landscape-study-en.pdf.

__________ (2016d). *Innovation System in Lebanon*. Beirut. Available from https://www.unescwa.org/sites/www.

unescwa.org/files/page_attachments/lebanon_technology_transfer_legislative_analysis_0.pdf.

United Nations Framework Convention on Climate Change (2009). Strategy paper for the long-term perspective beyond 2012, including sectoral approaches, to facilitate the development, deployment, diffusion and transfer of technologies under the convention.

___________ (2016). Green Climate Fund. Available from http://unfccc.int/cooperation_and_support/financial_mechanism/green_climate_fund/items/5869.php.

United Nations Statistics Division. (2017). SDG Indicators. Available from https://unstats.un.org/sdgs/metadata/ (accessed 27 July 2017).

Vera, Luisa and others (2009). Depuranat project: Sustainable management of wastewater in rural areas. *Desalination and Water Treatment*, vol. 4 No. 1–3, pp. 59–68. Available from https://doi.org/10.5004/dwt.2009.356.

Wahab, Sazali Abdul, Raduan Che Rose and Suzana Idayu Wati Osman (2011). Defining the concepts of technology and technology transfer: A literature analysis. *International Business Research*, vol. 5, No. 1. Available from https://doi.org/10.5539/ibr.v5n1p61.

Walley, Stuart (2011). Enhanced oil recovery technology gains momentum. *Arab News*, 12 December. Available from www.arabnews.com/node/400807.

Wang, Brian (2016). Gigawatt scale solar thermal generates steam for enhanced oil recovery. Next Big Future, 13 November. Available from https://www.nextbigfuture.com/2016/11/gigawatt-scale-solar-thermal-generates.html.

Weinberg, Josh (2015). Making water-energy-food nexus approaches operational to support sustainable urbanization. Presented at the Sustainable Megacities: Food, Energy, Water and the Built Environment Workshop: Food, Energy, and Water Nexus in Sustainable Cities, held in Beijing on 21 October. Available from https://www.nyit.edu/files/special_events/FewWorkshop_2015_Presentation_WeinbergJosh.pptx.

Weston, David (2016). Siemens to open Moroccan blade plant. *Wind Power Monthly*, 10 March. Available www.windpowermonthly.com/article/1386863.

Williams, Andrew (2014). Oilfield produced water management: Which technologies will gush to success? Water & Wastewater International. Available from www.waterworld.com/articles/wwi/print/volume-29/issue-5/technology-case-studies/oilfield-produced-water-management-which-technologies-will-gush-to-success.html.

Wood, Alex, and Kelsey Tamborrino (2015). United Arab Emirates plans to increase crude oil and natural gas production. United States energy Information Administration, 23 October. Available from https://www.eia.gov/todayinenergy/detail.php?id=23472.

World Bank (2017). DataBank: World Development Indicators. Washington D.C. Available from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed 24 August 2017).

World Nuclear News (2015). Russia formalises deal to build Egypt's first reactors. 20 November. Available from www.world-nuclear-news.org/NN-Russia-formalises-deal-to-build-Egypts-first-reactors-20111501.html.

Yang, Ming, David E. Rodgers and Karan Chouksey (2012). *Investing in Renewable Energy: The GEF Experience.* Global Environmental Facility (GEF). November. Available from https://www.thegef.org/sites/default/files/publications/gef_renewenergy_oct2012_r16_0.pdf.

Zaleski, Andrew (2015). A start-up that solved fracking's dirty problem. CNBC, 17 February. Available from www.cnbc.com/2015/02/17/a-start-ups-that-solved-frackings-dirty-problem.html.

Zickfeld, Florian and Aglaia Wieland (2013). *Desert power: Getting started the manual for renewable electricity in MENA.* Munich: Dii. Available from https://www.db.com/cr/en/docs/Desert-Power-Getting-Started-Full-Report-English-Screen(1).pdf.

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