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Technology Opportunities

For Sustainable Development in Arab countries

Full Report

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ABBREVIATIONS

AGT	Appropriate Green Technologies
AUB	American University of Beirut (Lebanon)
CBDR-RC	Common But Differentiated Responsibilities and Respective Capabilities
CCS	Carbon Capture and Sequestration
CDM	Clean Development Mechanism
CNRS	"Conseil National de Recherche Scientifique" (Lebanon)
COP	Conference of the Parties to the UNFCCC
CSP	Concentrated Solar Power
CTCN	Climate Technology Centre and Network (part of the UNFCCC TM)
CTF	Clean Technology Fund
EOR	Enhanced Oil Recovery
ESCWA	United Nations Economic and Social Commission for Western Asia
ETC	ESCWA Technology Centre
EU	European Union
GCF	Green Climate Fund
GE	Green Economy
GHG	Greenhouse Gas
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions (under the UNFCCC)
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change (under the UNFCCC)
IPO	Inter-decadal Pacific Oscillation
KACST	King Abdul-Aziz City for Science and Technology (Saudi Arabia)
MASEN	Moroccan Agency for Solar Energy
MDG	Millennium Development Goals
MENA	Middle East and North Africa
MHESR	Ministry of Higher Education and Scientific Research (Algeria)
MIST	Masdar Institute of Science and Technology (United Arab Emirates)
MRV	Measurable, Reportable and Verifiable (For actions taken under the UNFCCC)
MW	Megawatts
NAMA	Nationally Appropriate Mitigation Action (under the UNFCCC)
NAPA	National Adaptation Plan (Under the UNFCCC)
NDA	National Designated Authority
NGO	Non-Governmental Organization
PPM	Parts Per Million (measures GHG concentrations in the atmosphere)
PV	Photovoltaic (Solar Cell)
QSTP	Qatar Science and Technology Park
RE	Renewable Energy
R&D	Research and Development

RICCAR Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region

RSS Royal Scientific Society (Jordan)

SE Sustainable Energy

SD Sustainable Development

SDG Sustainable Development Goals

SE Sustainable Energy

STI Science, Technology development, and Innovation

SWH Solar Water Heating

TEC Technology Executive Committee (part of the UNFCCC TM)

TM Technology Mechanism of the UNFCCC

TT Technology Transfer and Adaptation

UAE United Arab Emirates

UN United Nations

UNCED United Nations Conference on Environment and Development

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

UNESCO United Nations Educational, Scientific and Cultural Organization

UNFCCC United Nations Framework Convention on Climate Change, or "Paris Agreement"

UNGA United Nations General Assembly

USJ Saint-Joseph University (Lebanon)

Executive Summary

The Arab Region stands on the brink of a radical socio-economic change. This change is partly due to the ongoing "Fourth Industrial Revolution". As technologies "fuse" and blur the lines between various fields of expertise, they are creating unprecedented challenges, and offering new possibilities, and fundamentally changing the way people live, work, and relate to one another. In addition, the region faces the dual challenge to adapt to climate change while still ensuring its sustainable development.

The region's future Sustainable Development will require it to adapt to those changes, and thus meet both its Sustainable Development Goals (SDGs), and the stated goals of the "Paris Agreement". This will require it to develop, adapt, manage, and transform the most promising technologies, and will depend on policies to promote Science, Technology Development, and Innovation (STI). This report focuses on how STIs that can contribute in implementing effectively and efficiently the SDGs in Arab Countries. The report first (1) outlines the current regional context, then evaluates the capacity for innovation, before (3) investigating STI options for Sustainable Development and (4) outlining the way forward.

The "Paris Agreement" was reached on December 12, 2015, in Paris, at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC). It outlines the current consensus on the efforts necessary to combat climate change. IT also clarifies the central role of STI in meeting both adaptation and mitigation targets. It therefore supports two critical objectives of the Arab Region; (1) achieving the Sustainable Development Goals (SDGs), and (2) meeting its mitigation commitments.

STI is therefore crucial to promote sustainable economic growth. It offers an opportunity to the region; thanks to its young and dynamic population, it may be well positioned to develop or adapt those new technologies, unburdened by "legacy" systems that tend to evolve slowly. In addition, the region's STI ecosystem is nimble, and can therefore adapt faster to an ever-accelerating technological environment. This technological revolution is unlike previous ones, as it promotes a "winner takes all" whereby it exacerbates income disparities and inequality. STI requires policies that balance economic development with social cohesion. Successful policies would promote wider support and involvement in research and innovation to accelerate the transfer, exploitation and commercialisation of public research.

الملخص التنفيذي

تقف المنطقة العربية على حافة تغيير اقتصادي واجتماعي كبير يعود بالدرجة الأولى الى التأثير المستمر للثورة الصناعية الرابعة والتي تتميز بدمج التقنيات التي تطمس الخطوط الفاصلة بين مختلف التخصصات وما يصاحبها من تحديات وفرص غير مسبوقة والتي تتداخل بصورة مباشرة مع طرق العيش والعمل والعلاقات الاجتماعية عامة. بالإضافة الى ما تواجهه المنطقة العربية جراء آثار التغييرات المناخية وتداعياتها ناهيك عن مسؤولياتها تجاه دعم التنمية المستدامة.

هذا الواقع يفرض على دول المنطقة التكيف لهذه التغييرات من اجل تحقيق أهداف الأمم المتحدة للتنمية المستدامة والأهداف المنبثقة من اتفاقية باريس، والعمل على تطوير، واعتماد، وإدارة ونقل التقنيات الواعدة ووضع السياسات الهادفة لتعزيز دور العلوم والتكنولوجيا والابتكار(STI). يركز هذا التقرير على الكيفية التي يمكن ان تساهم بها العلوم والتكنولوجيا والابتكار (STI) في تنفيذ أهداف التنمية المستدامة بصورة فعالة وعملية. حيث سيلقي الضوء اولا على الوضع الراهن في المنطقة العربية ومن ثم تقييم القدرة الابتكارية من أجل بحث الخيارات المتاحة لبلوغ هذه الأهداف والمضي قدما في هذا المجال.

تم التوصل إلى "اتفاقية باريس" في ١٢ ديسمبر ٢٠١٥، في باريس، في المؤتمر الحادي والعشرين للأطراف (COP21) إلى اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ (UNFCCC) والتي من خلالها تم تحديد ملامح الجهود الرامية لمكافحة تغير

المناخ وكذلك توضح الدور الرئيسي الذي تلعبه العلوم والتكنولوجيا والابتكار في بلوغ الغايات المرجوة. وعليه فان هذه الاتفاقية تدعم غايتين رئيسيتين في المنطقة العربية الا وهما تحقيق أهداف التنمية المستدامة (SDGs) والوفاء بالالتزامات الخاصة بهذه الاهداف.

فالعلوم والتكنولوجيا والابتكار (STI) تعتبر من المقومات الرئيسية لتحقيق النمو الاقتصادي المستدام لما توفره من فرص للمنطقة العربية الغنية بالطاقات الشابة المتسمة بالديناميكية والتي من الممكن استغلالها لامتلاك وتطوير التقنيات الحديثة، لا سيما أن ليس لصناعتها الكثير من الآليات "القديمة" الموروثة التي يصعب تطويرها. وبالإضافة إلى ذلك فإن النظام الإيكولوجي في مجال العلوم والتكنولوجيا والابتكار في المنطقة يتميز بالمرونة، وبالتالي يمكن أن يتكيف بسرعة أكبر مع البيئة التكنولوجية المتسارعة. فالثورة التكنولوجية الرابعة هذه تختلف عن الثورات السابقة، لأنها تعزز مبدأ "الفائز يأخذ كل شيء"، مما يزيد من التفاوت في الدخل وعدم المساواة. لذلك تتطلب العلوم والتكنولوجيا والابتكار (STI) سياسات ناجحة توازن بين التنمية الاقتصادية والتماسك الاجتماعي والتي من شأنها دعم البحث والابتكار لتسريع نقل واستغلال وتسويق البحوث العامة.

I. INTRODUCTION

The Arab Region stands on the brink of a radical change, as the world's economy undergoes a "fourth industrial revolution" that is fundamentally altering the way people live, work, and relate to one another. It adds to the impact of a changing climate and the many challenges to the region's sustainability. The change is partially due to a technological revolution that, if properly leveraged, could both solve the region's many sustainability challenges, and create unprecedented development opportunities.

Sustainable Development, going forward, will therefore require a vision that acknowledges both the interconnectedness of development's economic, social, and environmental dimensions, and the importance of multi-sector solutions. This is recognized by the universality of the Sustainable Development Goals (SDGs), and is reflected in the Paris Agreement's stated goals.

The SDGs extend beyond a focus on poverty eradication in developing countries, and tackle issues relevant to all countries at all levels of development. In this manner, they offer a perspective that completely alters the construction of the policy agenda, one that addresses the multifaceted challenges facing peace, stability, economic progress, and human development in the Arab Region. One key factor in fulfilling them SDGs is Science, Technology Development, and Innovation (STI). This is the focus of this report; to help identify priority areas in STIs that can contribute in implementing effectively and efficiently the SDGs in Arab Countries. The report first (1) outlines the current regional context, then (2) evaluates the capacity for innovation. The report then (3) investigates STI options for Sustainable Development and the implications of the latest climate change agreement (the "Paris Agreement"), and then (4) outlines a suggested way forward.

The Paris Agreement was reached on December 12, 2015, in Paris, at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC)[1]. It outlines the current consensus on the efforts necessary to combat climate change. It also clarified the central role of STI in both adaptation and mitigation efforts, and will inform strategies for the transfer, adaptation, and development of technologies. It offers an opportunity to the Arab regional efforts to promote STIs and implement appropriate and adapted technology transfer mechanisms. STI would allow the Arab Region to meet two critical objectives; (1) achieving the Sustainable Development Goals (SDGs), and (2) meeting its commitments under the recent "Paris Agreement" on climate change.

Going forward, the ability of countries to achieve sustainable development is largely defined by their capacity to develop, adapt, manage, and transform the most promising technologies for optimization and productivity in a multi-sector context. The Arab Region has many new opportunities, the new environment challenges policy-makers to ensure planning accounts for changing technologies, without trying to "forecast the future".

[1] In this document, the terms UNFCCC, COP21, or "Paris Agreement" will have one and the same meaning.

II. SCIENCE, TECHNOLOGY AND INNOVATION IN ARAB COUNTRIES

One key factor in fulfilling the SDGs is Science, Technology Development, and Innovation (STI). It is therefore important to help identify priority areas in STIs that can contribute in implementing effectively and efficiently the SDGs in Arab Countries. This is done by first (1) outlining the current regional context, then (2) evaluating the capacity for innovation, before (3) investigating STI options for Sustainable Development and (4) outlining the way forward.

A. SCIENCE, TECHNOLOGY DEVELOPMENT, AND INNOVATION IN THE ARAB CONTEXT

STI plays a central role in the SDGs because of the need to "upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes[2]".

The SDGs include all dimensions of Sustainable Development, and therefore require a wider perspective that (1) deepens Policy Coherence for Development and (2) improves horizontal coordination at the national level. This requires a "long-term", holistic perspective, where STI is relied upon to develop new and more sustainable ways to satisfy human needs. This is shown in Table 1 below, which outlines the main SDGs whose fulfillment STI play a central role.

Table 1. THE UNITED NATIONS' STI MOST RELEVANT SDG TARGETS.

	SDG Targets
1.4	Ensure that all men and women, in particular the poor and the vulnerable, have [...] ownership and control over […] appropriate new technology.
2.a	Increase investment in rural infrastructure, agricultural research and extension services, and technology development [notably in] plant and livestock gene banks, [often] through enhanced international cooperation.
3.b.2	Total net official development assistance to medical research and basic health sectors
4.b	Substantially expand globally the number of scholarships available to developing countries […] for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes.
6.a	Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes.
7.b	expand infrastructure and upgrade technology for supplying modern and sustainable energy services [in accordance with national priorities]
8.2	Achieve higher levels of economic productivity through diversification, technological upgrading and innovation
9.4	upgrade infrastructure and retrofit industries to make them sustainable,
9.5	Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries
9.b	Support domestic technology development, research and innovation in developing countries,
12.a	Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
13.2	Integrate climate change measures into national policies, strategies and planning
13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
13.b	Promote mechanisms for raising capacity for effective climate change-related planning and management.
14.a	Increase scientific knowledge, develop research capacity and transfer marine technology

[2] UN, 2017, SDG 9.4.

17.6	Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing
17.7	Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms.
17.8	Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology

While the challenges to achieving the SDGs remain country-specific, there are common elements. Those challenges take into account (1) the local context and the current status in which (2) applied sciences have been taking an increasingly important role, as various Arab countries strive to address a set of common (3) priority areas, but with differing (4) mechanisms of implementation. The evaluation of how well the challenges are met depends, in part, on (5) STI relevant Key Performance Indicators.

1. Current STI Structures

The positions of the Arab countries differ with respect to the SDG to "fully operationalize the technology bank and science, technology and innovation capacity-building mechanism", and "enhance the use of enabling technology, in particular information and communications technology[3]". According to a 2013 review of the strengths and weaknesses of their STI institutions, the systems differ in the way the way are organised, but share some key characteristics.

On one hand, the STI ecosystem is not uniformly structured across the Arab Region. The various systems fall in three categories, depending on their prevailing Research and Development (R&D) environment[4]:

1) **Large** R&D systems in **Algeria**, **Egypt**, **Morocco**, and **Saudi Arabia**. **Iraq** and **Syria** would have been part of this group were it not for the destruction of their research systems as a result of war. The growth of such large groups is slower relative to other countries, and the systems tend to change little, and to focus on consolidating existing international collaborations. Except for Morocco, research is generally focused on specific areas, around mining and petrochemicals.
2) The R&D systems of **Tunisia**, **Jordan**, and **Lebanon** are generally **small, dynamic and integrated**. To some extent, **Kuwait** is also similar. They tend to have a proportionally large scientific production, with "niches of innovative activities" in spite of low overall innovation.
3) In the Gulf States, R&D systems are **small but rapidly expanding**. Thanks to an active R&D policy, those countries aggressively leverage their resources to develop strong Technopoles. This is the case of the **UAE**, **Bahrain**, **Qatar,** and, to some extent, **Oman**.

Other counties in the Arab region tend to have small and less integrated R&D systems.

Box 1 Barriers to Entry and "Late Mover Advantage"

Traditionally, businesses faced "**barriers to entry**" when entering new market segments, or implementing new technologies. This is because of costly initial equipment or licenses, or lengthy Research and Development (R&D). Established firms are at an advantage, especially when new technologies imposes "supply restrictions" that limit transfer of new materials, tools, or know-how.

Recently, however, global economic development led to both an acceleration in new scientific advances, and an increase in the number of technology suppliers. As result, initial investments is lower, and performance is higher. This benefits new entrants who, unburdened by "**sunk costs**", now have a "**late mover advantage**".

This plays to the advantage of late market entrants who can then "pay off" any new equipment while market "pioneers" still struggles to deal with older, "legacy" systems. As a result, Arab Countries may often be correctly positioned for opportunities to change and adapt new technologies.

[3] UN, 2017, SDG 17.8
[4] ETC, 2013, pp. 61-63.

On the other hand, the various R&D ecosystems of Arab countries generally share two characteristics;

1) While some universities have developed R&D systems, there is little overall coordination or scientific production among universities. Collaboration with businesses is still in early stages.
2) There are few overarching themes. Except for a few "flagship" projects, the various centers are "islands", with few programs in common.

This is illustrated by the case of Tunisia, where there is a nationwide push to spend up to 1% of GDP on R&D. Yet businesses and universities still do not collaborate much, in spite of such a high rate of public investment. In addition, in spite of the centralization in STI governance, the ecosystem remains fragmented among various ministries, each with "its own strategy and agency to implement it". There are "very few common programs, except for" a national-wide "ambitious national program of digitalization[5]".

2. The Growing Importance of Applied Sciences

Innovation paradigms are undergoing a shift. The institutional model, traditionally "top-down" and dominated by publically-funded academic institutions, is making way to a more "networked" model, with growing private sector involvement[6].

In the Arab Region, policy is shifting away from fundamental R&D in "basic" sciences such as Math, Physics and Chemistry. New policy focus is showing an increasing emphasis on "applied" sciences:

1) In **Algeria**, scientific research reflects the relative importance of its petrochemical sector. Output is focused on "organic chemistry, chemical engineering and physiochemical characterisations of specific materials[7]";
2) **Egypt** is increasingly focusing on developing applications in agriculture, medicine, biology and especially bio-technologies. There is also a strong push in "renewable energy, nanotechnology, biotechnology, agriculture, water resources and pharmaceuticals[8]";
3) Through the "Qatar Foundation and the Qatar Science and Technology Park" (QSTP), **Qatar** has been "executing applied research and delivering commercialized technologies in four themed areas: Energy, Environment, Health Sciences, and Information and Communication Technologies[9]";
4) **Saudi Arabia** is devoting an increasing share of the science budget to the applied sciences. An example is the King Abdul-Aziz City for Science and Technology (KACST), the country's main "Technopole", which devotes more than 75% of its budget to applied science fields such as medicine (31%), engineering (27%), and agriculture (16%)[10];
5) In general, Arab countries tend to prioritize R&D based on immediate trade's needs. This is the case of **Tunisia**[11], which prioritizes application to specific industries such as machines and control systems, packaging, agro-alimentary, materials (mostly in construction). The industries concerned are both large-scale manufacturing (textiles, chemicals) and smaller-scale industries (wood and furniture, leather and shoes)[12];

Such a wider private sector involvement would allow countries to better promote "the development, transfer, dissemination and diffusion of environmentally sound technologies[13]" that would "support

[5] Khanfir, 2016, p.21.
[6] ETC, 2013, p.6.
[7] ETC, 2013, p. 8.
[8] ETC, 2013, p. 14.
[9] ETC, 2013, p. 39.
[10] As of 2012, Ref: ETC, 2013, p.43, 44.
[11] Khanfir, 2016.
[12] ETC, 2013, p. 52.
[13] UN, 2017, SDG 17.7

domestic technology development, research and innovation in developing countries[14]". Greater involvement of the private sector, if it materializes, would go a long way towards facilitating collaboration across various key areas, within "a conducive policy environment" that facilitates economic diversification[15]".

3. Priority Areas

Arab Countries share most priority areas for Sustainable Development (SD), and much progress is still needed in SDG relevant areas. In spite of some achievements in the run-up towards 2015 and the Millennium Development Goals' (MDG) endpoint, the Arab Region still "failed to transform its wealth into a commensurate improvement in human wellbeing for all its member countries[16]".

Further progress towards Sustainable Development requires improvements in key areas of; poverty and inequality, health, gender, institutional capacity, education, urban planning and land degradation, as well as International cooperation for trade, technology, and finance. STI relevant SDG targets relate to those areas in the following manner;

1) The eradication of **poverty and inequality** is directly linked to the ambitious SDGs 1 (eradicate poverty by 2030) and 2 (zero hunger). STIs contribute to either goal through advances in both resource use efficiency and waste reduction. This is achieved through greater access to technology and innovation (SDGs 1.4, 2.a, 6.a, 8.2, 17.7, 17.8), either home-grown (SDG 9.b) or through international cooperation (SDGs 6.a, 17.7), as well as infrastructure improvements (SDG 2.a), expansion (SDG 7.b), and upgrades (SDG 9.4). This will contribute to enhance resilience (SDG 13.1), especially if climate change measures are integrated into "national policies, strategies and planning" (SDG 13.2).
2) Innovation and technology can contribute to "ensure **healthy lives** and promote well-being" (SDG 3). This comes with greater access to "appropriate new technology" (SDG 1.4), "development assistance to medical research and basic health sectors" (SDG 3.b.2), as well as "water- and sanitation-related activities and programmes" (SDG 6.a). This also promotes enhanced resilience (SDG 13.1) to climate change, especially when "environmentally sound technologies" are implemented (SDG 17.7).
3) STIs link directly to the goal of greater **gender** equity through greater "ownership and control over […] appropriate new technology" for "all men and women, in particular the poor and the vulnerable" (SDG 1.4). Technological implementations can create positive feedback loops through investments in infrastructure and research in rural areas (SDG 2.a), and development in "medical research and basic health sectors" (SDG 3.b.2). This leads to stronger "resilience and adaptive capacity to climate-related hazards and natural disasters" (SDG 13.1). Local capacity for research and innovation will also benefit from enhancements to education and training (SDG 6.a, 13.1).
4) Stronger **institutions** will benefit from STIs thanks to increased investments in infrastructure and research (SDG 2.a), notably in teaching, training, international scientific cooperation, and knowledge sharing (SDGs 4.b, 6.a, 13.3, 13.b, 14.a, 17.6). STIs promote the "technological upgrading and innovation" that can lead to "higher levels of higher levels of economic productivity through diversification" (SDG 8.2).
5) STIs promote **Education** through increased investments in agricultural research and technology development (SDGs 2.a, 3.b.2, and 17.8), as well as education (SDG 4.b, and 13.3). Local capacity for STI will also greatly benefit from enhanced capacity for domestic technology development in both academia and industry (SDG 8.2, 9.5, 9.b, 12.a, 17.8), as well as enhanced "North-South, South-South and triangular regional and international cooperation" (SDG 17.6). The Arab Region has a comparative advantage in this field, thanks to its young and relatively well educated workforce.

[14] UN, 2017, SDG 9.5
[15] UN, 2017, SDG 9.b
[16] UNDP, 2011, p.21.

6) Infrastructure improvements (SDG 2.a, 6.a, 7.b, 9.4) will both improve **urban planning** and mitigate **land degradation**. The necessary retrofits, and upgrades will require an expansion of STI activities (SDG 2.a, 6.a, 7.b, 9.4), empowered through local and international cooperation and capacity-building (SDG 2.a, 6.a, 7.b, 14.a, 17.7).

7) Overall, **International cooperation** will benefit **trade**, **technology**, and **finance**. In the Arab region, there is a comparative advantage thanks to its relatively high integration in the global economy, and to the relative wealth of some countries in the region. This is illustrated by the case of Saudi Arabia, the second largest source of remittances by foreign workers in the world; together with the other Gulf Cooperation Council (GCC), it "accounted for $98 billion in outward remittance flows in 2014[17]".

   a) **Trade** will benefit from infrastructure investments. The expansion of STI activities will further facilitate the necessary upgrades and retrofits (SDG 2.a, 9.4), especially in conjunction with the enhancement of local capacity for science and technology (SDG 12.a) and resilience and adaption (SDG 13.1).

   b) The SDGs have a wide **technology** focus, including the needs of business applications (SDG 1.4, 2.a, 8.2) and academic research (SDG 4.b, 6.a, 9.5), both at the formal (SDG 4.b, 6.a, 9.5, 14.a, 17.6) and informal (SDG 1.4, 2.a) level.

   c) **Finance** will fund the necessary economic diversification. STIs will enable the necessary upgrades and improvements (SDG 8.2), often through domestic technology development (SDG 9.b). This will lead to strengthened adaptive capacity and resilience (SDG 13.1, 13.2).

Table 2 below shows relationship among priority areas, SDGs and STI relevant SDG Targets.

Table 2. PRIORITY AREAS AND SDGS.

Issue	STI Relevant SDG Targets	Sustainable Development	Climate Change	Comparative Advantage	Resilience
Poverty & inequality	1.4; 2.a; 4.b; 6.a; 7.b; 8.2; 9.b; 9.4; 12.a; 13.1; 13.2; 17.7; 17.8	x	x		x
Health	1.4; 3.b.2; 6.a; 9.b; 13.1; 17.7; 17.8	x	x		x
Gender	1.4; 2.a; 3.b.2; 4.b; 6.a; 13.1	x			x
Institutional capacity	2.a; 4.b; 6.a; 8.2; 13.b; 14.a; 17.6; 17.7; 17.8	x	x		x
Education	2.a; 3.b.2; 4.b; 4.b; 8.2; 9.5; 9.b; 12.a; 13.3; 14.a; 17.6; 17.8	x		x	x
Urban Planning	2.a; 6.a; 7.b; 9.4; 14.a; 17.7	x	x		x
International cooperation for:					
Trade	2.a; 9.4; 12.a; 13.1	x		x	x
Technology	1.4; 2.a; 4.b; 6.a; 8.2; 9.5; 9.b; 12.a; 14.a; 17.6	x	x	x	
Finance	8.2; 9.b; 13.1; 13.2	x	x	x	x

[17] World Bank, 2016, p.vi.

a) Sectors Essential to Sustainable Development

From a perspective of Sustainable Development, most Arab Countries share similar priorities for STI. Those priorities are similar to those identified by Jordan's National Policy[18]. Those areas are; (1) water, (2) energy, (3) food security, (4) social justice, livelihoods, and healthcare, as well as the needs for (5) climate change adaptation, (6) urban planning and land management, and (7) waste and wastewater management.

1) **Water** technologies are an important SDG. The SDGs link water and wastewater issues, focusing on "water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies". They also call for more reliance on STIs and "international cooperation and capacity-building[19]".

2) The SDGs call for infrastructure expansion and technology upgrades **"**for supplying modern and sustainable **energy** services" in accordance with national priorities[20]". In the Arab region, future energy plans may not account for current realities.

    a) Future plans show an **increasing focus on Renewable Energy** (RE), as shown by such initiatives as the "Masdar" Institute of Science and Technology (MIST), established to focus primarily on Sustainable Energy (SE) and green technologies.

    b) However, present problems may as much managerial as technological. Indeed, in regions were most households are connected to the grid, supply can often be unreliable. This happens in regions removed from main population and business centers, such as rural areas. Not only are most of the inhabitants of those areas "without full access to energy", they also often struggle with "low buying power and **high delivery cost for energy**[21]".

3) Agriculture in the Arab region is about both **livelihoods** and **Food security**. The sector generally contributes around 13% to the region's GDP and 20% of its exports. Farming employs about 40% of the population in some Countries[22], mostly low skilled rural labor. In spite of this, planners often miss the rural aspect of farming, and may thus be misinterpreting the SDGs' holistic approach to STI. The SDG's approach takes into account the potential of both new technologies and local innovation, and recognize:

    a) The potential for STIs in farming, through the call for increased investment "in rural infrastructure, agricultural research and extension services, technology development", and notably in "plant and livestock gene banks", often "through enhanced international cooperation[23]". However, those techniques have limitations:

        i) In general, both seed and gene banks require periodic evaluations to ascertain the viability of the stored material. They also struggle to store the genetic variability of any given species, let alone of their associated micro-organisms.

        ii) Those "banks" are exposed to power failure or environmental changes. For example, in mid-2017 the otherwise robust Svalbard "Global Seed Vault" in the Arctic Circle experienced an unexpected meltwater intrusion[24].

[18] ETC. 2013, p.18.
[19] UN, 2017, SDG 6.a.
[20] UN, 2017, SDG 7.b.
[21] ECA, 2013.
[22] World Bank, 2012.
[23] UN, 2017, SDG 2.a.
[24] The Guardian, May 19, 2017.

iii) In the case of livestock gene banks, there is no evidence that DNA alone is sufficient to - preserve an animal species. Indeed, bringing back any extinct animal still requires related parent species.

b) That the agricultural sector is an "**entry level**" sector of activity, often employing people with limited skills who cannot easily move to other occupations. It is not clear how various economic studies, when evaluating the flexibility of the economy, can take this critical factor into account.

4) Higher levels of economic productivity can enhance **employment and livelihoods** (SDG 8), provided the economy, at the local level, has (1) high value-added sectors, and (2) diversified, with "technological upgrading and innovation[25]".

   a) This would address key "zones of concern[26]" in social protection, poverty and food security; Health care; empowerment of women and gender issues, particularly pertaining to social justice, participation and enhancement of the judicial environments.

   b) Furthermore, STI could enhance development in remote rural areas, where domestic agriculture remains "a major source of food, despite the fact that 50% of the" Arab Region's food is imported[27]. Livelihoods enhancement would further consolidate existing cooperative networks, and promote wider, stronger value chains of businesses.

5) Appropriate technologies are needed to confront the impact of **Climate Change** on the Arab Region, through strengthening "education, awareness-raising" as well as local "capacity on climate change mitigation, adaptation, impact reduction and early warning", in part by "focusing on women, youth and local and marginalized communities[28]". This is highlighted both by the relevant SDGs and by the United Nations Framework Convention on Climate Change (UNFCCC)

   a) SDGs recognize the need to "integrate Climate Change measures into national policies, strategies and planning", in a way that strengthens "resilience and adaptive capacity to climate-related hazards and natural disasters in all countries[29]".

   b) The UNFCCC subsidiary bodies now consider that SDGs are "closely linked to climate change", and recognize "the importance and inter-linkages of the climate and the post-2015 development agenda processes[30]".

6) **Land management and urban planning** would help address rising demographics and growing urbanisation. This could also promote progress on social issues such as poverty eradication and women empowerment, thus ensuring "that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over [???] appropriate new technology and financial services, including microfinance[31]".

b) Leverage Comparative Advantage

The Arab Region has a natural **comparative advantage** in (1) conventional energy, (2) Sustainable Energy (SE) potential, and (3) the adaptability of its population.

The First comparative advantage is the Arab region's conventional energy sector. The field has a proven history of using STIs to deliver significant results, both "upstream", in oil fields, and "downstream", in chemical manufacturing.

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[25] UN, 2017, SDG 8.2.
[26] ESCWA, 2017.
[27] ESCWA, 2011, p.1.
[28] The Guardian, May 19, 2017.
[29] The Guardian, May 19, 2017.
[30] UNFCCC, 2015-b, No. 92, p.22
[31] UN, 2017, SDG 13.1, 13.2, 13.3, 13.b.

1) Thanks to heavy investments in R&D and innovation, producers have been able to significantly increase the "recovery rates" from existing oil reservoirs. The lessons learned and the technologies developed can now be used in a wider range of applications.
2) The region's producers have traditionally marketed basic chemical products, and need to diversify away from marketing such commodities and towards more specialised products. This move "downstream" requires partnership with research centers, and would thus further help develop regional STI ecosystems.

The Arab Region owes its second comparative advantage to its geology, the Arab Region has a natural comparative advantage in **Sustainable Energy** (SE), in solar, wind, and geothermal energy, in addition to second-generation biofuels. SE in the region is at the beginning stages, accounting for "6% of the region's total power generation capacity, mostly in the form of hydropower (4.7%), wind (0.9%) and solar energy (0.4%)[32]" in 2015.

1) **Solar Energy** has two main uses in the Arab Region, Photovoltaic (PV) systems, or Concentrated Solar Power (CSP).
    a) PV systems that directly convert sunlight into electricity through semiconducting surfaces, generally silicon. There is a need to develop more versatile types of semiconducting surfaces, such as polymer-based. This is an area where regional experience with chemical manufacturing can be effectively leveraged.
    b) CSP systems captures the sun's heat directly, either for **low temperature** Solar Water-Heating (SWH), or for **high-temperature** applications in power generation, where the heat is converted into mechanical energy to operate power-generating turbines. Regional experience with the management of complex fluids and refining can be leveraged in this field, because of the need to develop better heat-transfer fluids and more efficient turbines.
2) The Arab Region has significant potential for **Wind Energy**, but a more detailed mapping is needed to determine the locations of highest potential.
    a) Wind turbine yield depends mainly on **location**. Because generated energy is proportional the cube of wind power, a turbine located in an area with 10% faster wind can generate 33% more energy. Current wind turbines require wind speeds of 6 to11 m/s (~20 to 40 km/h) to begin generating electricity, and 13 to16 m/s (~45 to 60 km/h) to operate at full capacity. Most turbines are turned off for wind speeds greater 25 m/s (90 km/h) to avoid blade damage[33].
    b) Overall, the strongest winds in Arab Region is found mostly in desert areas. Measured at 200 m/s, average wind speeds in the region can reach 12 m/s at 200 m height in the Saharan Desert, and 11 m/s in the interior of the Arabian Peninsula[34]. However, more **detailed mapping** is required, to demarcate both (1) the locations with strong and sustained winds, and (2) the elevations of smooth and laminar airflows (typically 25-35 m above ground).
3) Systems that rely on "**waste-to-energy**" follow either of three processes; (1) **thermochemical**, burning residues for heat recovery, (2) **biochemical**, "feeding" biodegradable residues to anaerobic bacteria to generate "biogas", or (3) **physicochemical**, turning some solid wastes into fuel pellets. In the Arab Region, the use of such systems is limited, and only now spreading in remote rural areas where organic residues are a common problem.
    a) In the Arab Region, rural farmers are installing biochemical systems such as "digesters" that generate biogas and fertilizers. In some areas, such systems have been successfully expanded to

[32] IRENA, 2016-A, p.9.
[33] energy.gov/eere/wind/how-do-wind-turbines-work
[34] irena.masdar.ac.ae/gallery/#map/103

use municipal waste; in Jordan, a test facility near Amman was successful, and later expanded from 1MW to 3.5 MW in 2010. An extreme case is in Syria, where biogas is helping meet the energy needs of areas isolated by the war.

b) The disposal of olive oil residues is more difficult, but farmers developed traditional processes to turn some of olive oil waste into a form of fuel pellets used for heating. STIs could help improve those processes, both to make it less laborious, and to help eliminate all the wastes that remain.

4) G**eothermal** energy's potential has yet to be mapped in detail. The development either high temperature or low temperature applications can greatly benefit from the expertise gained in the oil industry.

a) The zones with highest potential for **high temperature** geothermal energy generation extend along the main fault lines near the edge of the Arabian plate. Those regions are:

i) To the West, Arabian and African tectonic plates move away from one another, along the "Red Sea Rift" that runs from Yemen to the Saudi Hejaz, West of Djibouti, Sudan, and Egypt. This rift extends northwards, becoming the "Dead Sea Transform" in Jordan, Palestine, then further splitting into Lebanon's "Yammouneh fault", and Syria's "Parlmyra Fold Belt" in Syria. Along this rift are volcanic regions in Yemen, Djibouti, Western Saudi Arabia, Souther Egypt/Northern Sudan, as well as Southern and Northern Syria, and Northern Lebanon.

ii) To the East, the Arabian plate is thrusting up the Eurasian plate, forming the Zagros and Makram thrust zones. This seismic active region extends along the Arabian Gulf, with zones of high potential extending along the Eastern Arabian peninsula in Oman, the UAE, Qatar, Bahrain, and Kuwait.

b) The potential for **Low temperature** geothermal was limited until recent innovations. In July 2015, the Akça "low-enthalpy geothermal plant" came online in the Denizli region of Turkey, generating 4 MW for a fluid temperature of 105°C[35]. Further technical developments may "open up" the potential of other sources, such as in Tunisia's southern Kebili Region, where geothermal sources do not exceed 85°C[36].

Finally, the Arab Region's own population is a source of unique comparative advantage, thanks to very specific characteristics. On one hand, the population's common language and culture facilitates day-to-day business operations across the wider Arab Region. On the other hand, a significant portion of its workforce is educated or skilled, and thus well able to operate in today's complex technical globalized world.

Across the wider Arab Region, the workforce is highly mobile, able to move more with great ease in its different markets. This promotes a deep **regional integration** that doesn't require extensive state-to-state agreements. Expatriate workers' remittance thus make for a high volume of financial flows that contrast with low inter-Arab trade. Oil-producing Gulf States are the source of remittances to various other Arab countries, mostly in the Mashreq and North Africa. Destination countries' economies came to significantly rely on remittances from both other Arab Countries and the rest of the world, as shown in Table 3 below.

Table 3. GLOBAL REMITTANCE INFLOWS IN SOME ARAB COUNTRIES.

Country	Global Remittances	
	Billion USD*	% GDP**
Egypt	20.4	6.8
Jordan	3.8	10.3

[35] Webb, 2015.
[36] Ben Mohammed, 2003.

Lebanon	**7.5**	**16.2**
Morocco	**6.7**	**6.4**
Palestine	**2.3**	**17.1**
Syria	**1.6**	**-**
Tunisia	**2.3**	**4.8**
Yemen	**3.4**	**9.3**

(*) as of 2015: World Bank, 2016, p.49.
(**) as of 2014: World Bank, 2016, p.49

A sizeable portion of the Arab workforce is also well integrated in the modern economy, in terms of education and skills.

1) On one side of the spectrum are academic researchers. Many demonstrated an ability to do "more with less". This is the case of countries such as **Tunisia**. **Jordan**, or **Lebanon**, with high output research systems, in spite of limited funds and fewer researchers.

2) On the other side of the spectrum are local or rural communities that managed to thrive for generations through **local innovation** by using local resources, often relying on one another's skills and experience, and based on a shared understanding of their problems and their environment. Examples abound in the region, from the ancient deployment of "Qanat" Systems, or "Aflaj", to modern day olive oil repurposing or biogas generation[37]…

Innovation in the Arab Region is therefore the result from the combination of the region's competitive advantages, especially with new systems and technologies, notably collaborative technologies. However, this needs government support, especially in remote or rural regions where no business case can be made for wider private sector involvement. The current needs of many in the Arab Region may not stem from lack of local skills and experience, but rather from a side-effect of their "**enhanced access to markets**". In theory, they have access to wider markets for their goods. However, in practice, it "exposes them to stiffer competition[38]" from better funded competitors.

Box 2 Government 2.0:

The concept of "Government 2.0" is not a new kind of government, but one that empowers one of its key aspects; collective collaboration and action. This concept leverages collaborative technologies to establish a platform through which policy makers and communities can address challenges in a participatory manner.

- As platforms, businesses tend to adhere to open standards, building simple systems that can evolve, based on a development process that "feeds on" participation and user inputs. While they measure extensively, they strive to lower barriers for innovation without attempting to "reinvent to wheel";
- Governments, on the other hand, operate in an inherently more regulated environment, and adhere to stricter confidentiality. While they require greater participation, they still need to focus on national priorities. They benefit from lowering barriers for innovation, but still need to "reinvent the wheel" and thus support research avenues with low immediate returns.

The Arab region can greatly benefit from such collective knowledge sharing and decision making process to help guide innovation. They allow various stakeholders to collaborate and collectively participate in the process of research and innovation.

c) Sectors that Enhance Resilience

As climate change becomes more pronounced, vulnerable communities need to adapt and increase their resilience. The Arab Region, which is already predominantly arid and semi-arid, "is a prime example of the potential adverse impacts of climate change on a number of social, economic and environmental levels". As heat stress reaches expected "thresholds" that hinder human activity, "the challenge for the region is

[37] ESCWA, 2015-a.
[38] ESCWA, 2015-a, p.2.

[…] to live the reality that is climate change[39]". The challenge can be met through adaptation and mitigation:

1) On the longer term, only **mitigation** can minimize the main drivers of climate change such as human Greenhouse Gas (GHG) emissions, which appear to be the main factor exacerbating Climate Change On the long-term, this could offer opportunities for the Arab Region, because of the need to develop and implement innovative solutions to mitigate GHG emissions.

2) In the short to medium term, only **adaptation** can address the impacts of climate change. Many countries in the Arab Region have taken measures to adapt to climate change in spite of funding limitations and technology needs.

The main impacts of climate change in the Arab Region are[40]; (1) increased temperatures; (2) shifting precipitation patterns; (3) sea level rise along the coast; (4) land degradation in the interior; and (5) the increased frequency of extreme events such as floods and droughts. In theory, there are three ways in which resilience to those impacts could be enhanced; avoiding the adverse impacts of climate change, limiting their impact; or enhancing coping mechanisms or means of recovery. However, in practice, the impacts described cannot be avoided in the short term, even if they may be mitigated on the long term.

1) If no mitigation efforts are undertaken, average **temperatures** may increase by 2ºC in the 2011-2041 period, and by 3-4ºC by 2070[41]. Threshold values for ambient temperature and humidity are already observed adjacent to the Arab Gulf and the Red Sea areas of the region and, to some extent, in the desert interior of the Arabian Peninsula[42].

    a) Under current technologies, temperature increase cannot be mitigated or avoided, and require adaptation measures.

    b) Through technical innovations, temperature-resistant crops could be developed for agriculture, or more adapted greenhouses could be constructed. In cities, infrastructure could be developed to help avoid "heat island effect", and district systems could be constructed to improve cooling efficiency.

2) Greater **precipitation** variability would adversely impact countries where agriculture is an important means of livelihood, such as Lebanon, Iraq, Jordan, Morocco, Mauritania, Tunisia, Palestine, Sudan, and Syria.

    a) Innovations could promote adaptation by enhancing irrigation efficiency, changing agricultural techniques, or developing drought-resistant crop varieties. Water recycling could help cope with shortages.

    b) Water shortages may be exacerbated by management strategies that focus solely on expanding water storage and conveyance networks, and increasing dam capacity. Such a strategy, while adapted to smoothing out variability, it cannot do much to compensate for the lack of supply caused by precipitation decrease.

3) Under the various emission scenarios, the mean **sea level** rise would reach between 0.32 m to 0.45 m in the 2046–2065 period, and between 0.63 m and 0.82 m in the 2081–2100 period[43]. Coastal areas in the Arab Region will be differently affected by sea level rise, and is expected to be highest

[39] UNEP/ROWA, 2015, p.2.
[40] UNEP/ROWA, 2015.
[41] UNEP/ROWA, 2015.
[42] Pal and Eltahir, 2015.
[43] IPCC, 2013. Comparison with 1986–2005.

along Morocco's Atlantic coast, and lowest along the Mediterranean coast. Sea levels will continue to rise beyond 2100, but mostly in the southern ocean[44]. A measure of adaptation to rising sea level

Adaptation measures for those cases include improvements to community infrastructure and individual structure, so they can withstand storm surges and high winds. Continuity plans would help businesses for the aftermath, but they would need to diversify their suppliers, and expand their value chain to ensure continued operations.

1) The Arab Region's **land degradation** is mostly the result of ill-adapted land management practices whose impact may be exacerbated by climate change[45]. Land degradation can be mitigated, or even reversed, by installing better infrastructure that helps combat soil erosion, using irrigation techniques that minimize soil salinization, or implementing better livestock management. There is also much potential for innovation in selecting and breeding crop varieties better suited to the prevailing environment.

2) The Arab Region is likely to experience an increased frequency of **extreme events** such as floods and droughts, as well as cyclones.

   a) Flooding can have a disproportionate impact on poorer areas of the Arab Region, as in the case of the 2006 Nile flooding in Sudan, which caused 600 deaths and left 35,000 homeless[46].

   b) The increased frequency of cyclones may have a significant economic impact over the region, especially in the southeastern part of the Arabian Peninsula. The extent of the potential damage was highlighted in 2010 when Cyclone Phet hit Oman, causing USD 700 Million in damages and 44 deaths. Adaptation measures for those cases include improvements to community infrastructure and individual structure, so they can withstand storm surges and high winds. Continuity plans would help businesses for the aftermath, but they would need to diversify their suppliers, and expand their value chain to ensure continued operations.

   c) The region is also vulnerable to extreme events from outside. An example is the Nile, which may experience much greater variability due to its sensitivity to the Indian Monsoon, particularly in the case of its Blue Nile tributary[47].

Adaptation measures would allow humans to endure when the impacts of climate change occur, and to continue work and operate effectively. An outline of the possible impact and the associated resilience measures are shown in Table 4 below.

Table 4. CLIMATE CHANGE IMPACTS AND SOME RESILIENCE MEASURES.

Impact	Resilience Measure:		
	Avoid	Limit	Cope
Temperatures	-	• Temperature-resistant crops; • Infrastructure to avoid "heat island" effect; • Cooling systems, either local or district; • Greenhouses;	-
Precipitation	-	• Water storage; Water-Efficient irrigation; • Crop varieties; • Agricultural techniques;	• Wastewater recycling

[44] IPCC, 2013.
[45] UNEP-ROWA, 2015, p.5.
[46] World Bank, 2012.
[47] Hemming et al., 2007; Marriner et al, 2012.

Land Degradation	-	• Land infrastructure; • Adapted animal husbandry; • Crop varieties; • Wastewater and waste management; • Adapted irrigation techniques;	-
Extreme Events	• Relocation; • Switch to suppliers from outside vulnerable areas; • Change value chain partner	• Community Infrastructure; • Upgrade/Retrofit buildings as applicable; • Continuity plan; • Diversify suppliers.	• Evacuation plans; • Back-up resources; • Adapt value chain;

4. Mechanisms of Implementation

The investment required in STI is hard to determine, and finding the appropriate mechanism of implementation is more difficult. While **science** and **technology** may appear obvious once it is developed, the **innovative** process that lead to them is a complex, non-obvious process that involves investment, organization and technology.

In general, innovation remains a hazardous "path-dependent[48]" process, where "today's success" stems partly from "yesterday's effort", and partly from luck. This may be the reason why, in spite of the best efforts, successful innovations do not necessarily translate into positive economic results. Given this system uncertainty in innovation, no wonder different Arab countries follow different approaches and models of organisation.

Across those various models of organization, implementation of STI strategies requires investments, following strategies that take into account each country's national priorities and its comparative advantage. Those would be further reinforced by enhanced regional and international cooperation, supported by greater availability of official data and statistics.

1) **STI Funding** is unevenly distributed across the Arab Region. There is a trend for strong institutional change in policy toward research funding, and a diversification of funding sources

   a) Across the Arab region, R&D funding is an average of 0.25-0.30% of GDP, but still lags behind the rest of the world (2.00-2.20%)[49]. Economic strength does not always translate into higher rankings on innovation and scientific research indices, and Arab countries with lower incomes still generate significant STI in many cases.

   b) Regional trends are changing since 2010, as some Arab countries started committing a higher proportion of their GDP to R&D since 2010. As % of GDP, R&D funding increased to 0.27% in 2007 to 0.72% in 2015 in Egypt and from 0.1% to 0.3% in Kuwait. Based on published data, the largest R&D investors are Saudi Arabia (0.88% of GDP in 2012) and the United Arab Emirates (0.87% of GDP in 2015).

2) Many Arab countries have clearly **established STI strategies** that take into account both their **national priorities** and their own specific advantages. This is the case of Algeria and Tunisia;

   a) **Algeria**'s strategy has two components: (1) a fiscal policy to promote investment in R&D, and (2) public funding for research, mostly under the supervision of the Ministry of Higher Education and Scientific Research (MHESR)[50].

[48] ETC, 2014.
[49] World Bank, 2017.
[50] ETC, 2013.

b) **Tunisia** established a well-structured research systems in the Arab Region, with a "system of nationally recognized label for research laboratories and research units", where "evaluation done by a national committee of research[51]". However, in practice, this organization is hindered by a dispersion of Technopoles, with various projects that do not seem to take into account local capabilities[52].

3) The SDGs call for stronger "means of implementation", through enhanced "North-South, South-South and triangular **regional and international cooperation**", to enhance developing countries' "respective capabilities[53]". Many countries in the Arab region have made progress towards this goal;

a) One example of successful collaboration in the field of knowledge sharing is found in **Saudi Arabia**, in the collaboration between KACST and Springer, a major scientific publisher. The fruits of this collaboration are "international high impact open access" technical journals of subject areas that "complement existing publications[54]" and drawn on the country's comparative strength in R&D in 6 topics; Applied Water Science, Journal of Petroleum Exploration and Production Technology, Applied Petrochemical Research, Applied Nanoscience, Biotech, Materials for Renewable and Sustainable Energy.

b) Another example is the high level of co-authorship of research publications, even if international cooperation represents a small proportion of national expenditure on R&D. This is evidenced by the high proportion of articles co-authored with international researchers[55] in countries such as **Morocco** (70%). However, such a research focus could also hinder greater practical application of the research carried out; when "the objective of research is to publish its results", this tends to limit these results' capacity for transfer and commercialization[56].

4) **Data** is a key element of research and collaboration, and its dissemination is often a concern. Even in cases when data is widely available, access can be limited, and it tends to be licensed to "value added" providers.

a) By properly leveraging Information and Communication Technologies (ICT), a more **open platform** can be established to enable a wider distribution of data, and allow policy-maker to engage more directly with various stakeholders. This would take into account distinctions between types of data, such as public, personal, confidential, seasonal, others.

b) There are limitations to any data-driven approach; while facts and data can be easily used to refute mistaken ideas or falsehoods, they cannot establish theories or methods. Indeed, because a reliance of data is necessarily "backward reasoning", excessive reliance on empirical data and analysis can only serve to reinforce inherent biases, and potentially recreate mistakes.

Box 3 The Limitations of "Big Data" and "Data-Driven Decision-Making"

In theory, with enough related information about a large data set, algorithms derive a best possible answer to a given question. However, in practice, they tend to either reinforce biases inherent in the dataset, or to oversimplify physical/real-world interactions. This causes embedded biases that can best be addressed through an "audit*" of the dataset and the algorithm;

- A data integrity check can be carried out to address data biased by the way it is collected, recorder, and analyzed;

[51] ETC, 2013, p.52.e
[52] Khanfir, 2016.
[53] UN, 2017, SDG 17.6
[54] http://www.nature.com/press_releases/npj-climate-atmosphere.html
[55] ETC, 2013; El-Amrani, 2016.
[56] El-Amrani, 2016, p.36.

- Documentation should (1) outline how does the algorithm make a "successful match" and what defines a "positive outcome"; and (2) determine whether it contradicts known physical or real-world interactions;
- The algorithms should be frequently tested to determine (1) accuracy and (2) error range, in addition the impacts of "false positives", both in the short term and over the long term.

This approach would help ensure algorithms' role in guiding decision-making. Algorithms, by themselves, cannot be "arbiters" of complexity, but "translators" of the relationships within a dataset, which is merely a subset or model of this reality.

(*) O'Neill, 2016

Many innovations, once applied and proven, can be expanded to other sectors. However, this would require Intellectual Property (IP) protection that accounts for **traditional knowledge**. Indeed, in spite of the complementarities, there is an inherent tension between the Intellectual Property (IP) regime and the indigenous knowledge of local communities.

1) **IP protection** is designed to grant protection for "non-obvious" and specifically **documented** "creations of the human mind" such as inventions or innovations[57].

2) **Traditional Knowledge** is a "**diffuse**" body of conventions, traditions, methods, and knowledge. It develops and evolves constantly, and is therefore hard to document.

The tension can be partially diffused protecting traditional knowledge. In theory, this could be done either through (2) **Positive Protection**, by pre-emptively gaining rights beforehand, or simply (1) **Defensive Protection**, by stopping people outside the community from acquiring its IP rights. In practice, it is the latter form of protection that is easier to achieve; this is the case of India, which has compiled a searchable database of traditional medicine that can be used as evidence of "prior art".

The focus in the Arab region appears to be now on "conventional" IP, as there is already a high amount of "imported" IP through licensing. This form of Technology Transfer plays an important role as a "Knowledge Enabler[58]", and may have promoted the region's relatively active patent activities.

Box 4 Intellectual Property (IP), Traditional Knowledge, and Biodiversity

The tension dates back to the development of genetic engineering, when the use of biological systems expanded. Because of the increasing number of "non-obvious" inventions that were based on genetic resources, it became increasingly critical to determine whether the new "creations of the human mind" were actual novel innovations, or simply derived from Traditional Knowledge.

This was the case of a US Patent granted, then withdrawn, for a medical application for turmeric, a spice whose role had been well established in traditional Indian medicine.

http://indiatoday.intoday.in/story/patents-india-wins-a-victory-over-turmeric-but-the-war-is-on/1/277014.html

5. STI relevant Key Performance Indicators (KPI)

Innovation Metrics can be based on Key Performance Indicators that measure 3 categories relevant for Science, Technology Development, and Innovation (STI); (1) Inputs, (2) Processes, and (3) Outputs. Each of those categories is further subdivided into 7 subgroups:

1) The "**Inputs**" category captures the main "drivers of innovation", which can be either "Resources" or "Enablers". The indicators represent educational parameters as well as economic parameters;

2) The "**Processes**" category measures the efficacy of the innovation process, and is expressed by indicators in 3 subgroups; (1) quality of educational or private sector systems involved in

[57] http://www.wipo.int/pressroom/en/briefs/tk_ip.html
[58] ISESCO, 2016.

innovation; (2) policies designed to stimulate the innovation process; and (3) investment in R&D and new business startups;

3) The "**Output**" category represents the "effect" of innovation activities, which is represented by both (1) their direct "impact" on the economy, and (2) the intellectual assets that they generate.

The KPIs will be derived from data obtained from international agencies (UNESCO, WIPO, ITU, IMF, World Bank) and national organizations. ESCWA member countries are expected to establish sustainable statistical systems for indicators related to Science, Technology and Innovation (STI), involving relevant ministries and National Statistical Offices to overcome the lack of data and close the gaps with other countries.

Box 5 A Successful National Innovation System (NIS):

The mission of a successful National Innovation Systems (NIS) is to ensure that STI has priority share in the policy agenda*. The NIS should include a sustainable funding organ, and be led by a team enabled to set aims, take actions, and coordinate regional and international benchmarking exercises. The team would seek to ensure that (1) the private sector is actively involved in policy and decision-making; and (2) a policy-learning process is maintained, through workshops, awareness raising, and continued training in strategic and operational management of innovation, benchmarking, and evaluation.

(*) ETC, 2015.

In the Arab Region, there are some challenges in collecting data on Science, Technology Development, and Innovation (STI), posing a challenge to policy analysis and evidence-based policy making. In most countries, National Innovation Systems (NIS) remain at early stages, and indicators are often not a priority, especially since most suffer from underfunding and high staff turnover.

However, there is recent progress in data collection, even if availability of "timely" data remains limited[59]:

1) In **Egypt**, the Egyptian Science, Technology and Innovation Observatory (ESTIO) has been active since February 2014. Established by the Academy of Scientific Research and Technology (ASRT), it restarted the publication of the Egyptian STI indicators on annual basis, last published in 2008. The report covers 3 main sets of indicators; (1) Higher Education, (2) R&D input, and (3) R&D output, in addition to (4) Composite Indicators.

2) The **Qatar** Foundation has been using 18 Key Performance Indicators (KPI) developed in 2014. The data is generally updated quarterly, and measures 4 different stages of the research process: (1) inputs into research; (2) processes involved in conducting research; (3) the direct outputs of the research; and (4) the longer term outcomes of the research.

[59] ETC, 2015.

B. Capacity for Technological Development

The focus is on STI systems that facilitate transformation, and help change existing, clearly unsustainable, pathways. In order to move the region's development towards a more sustainable path, there is no "silver bullet". Rather, progress will depend on (1) the scaling of existing technologies that prove to be appropriate for the transition towards a Green Economy; (2) "leapfrogging" by developing or adapting radical innovations; while (3) developing capacity for innovation.

1. "Scaling-Up" Existing Technologies

In many cases, it is not necessary to wait for new technology to emerge; the needed technologies are often available, but their deployment has been limited. Once proven, those technologies could be implemented on a larger scale.

The "scaling up" of proven technologies, would allow time for (1) marginal improvements, and (2) determining which improvements or implementations would "stay the course".

1) Improvements to mature technologies are generally marginal. However, through the "aggregation of marginal gains", continuous and small improvements add-up to the initial design, and the succession of "**micro-inventions**" results in a new innovation. In addition, as the technology's use spreads, people get increasingly used to it and "learn by doing", and thus add their own improvements.
2) While it is possible, early on, to identify the transformative technology, it is much harder to identify the best **implementation**. When the automobile came along, many could have grasped the importance of the technology, but still found it hard to decide whether the car's engine would use gasoline, diesel, or electric.
3) The real impact of new innovations is hard to grasp early on, even by the people at the heart of the process. The computer age illustrates this; when electronic computers first came along in the 1940's, even the leading manufacturers at the time did not expect their product to become so widespread[60]. They were too focused on their vacuum tube technologies and failed to grasp the transistor's potential. Even later, when computers were becoming ubiquitous in the workplace, manufactures failed to realize the mass-market potential[61].

Box 6 From Radical Innovation to Dead End

The history of human technology is filled with radical innovations that turn into dead ends; as soon as new paradigm shifts come along that undermine the foundations of the old technology.

In the 19th Century, a "hydraulic semaphore system" in which pressure applied at one end of a water-filled pipe would be transmitted to convey codes was immediately superseded by the electric telegraph. Later technologies lasted a bit longer, but all would vanish; the Polaroid instant camera succumbed to digital cameras, the fax and telex are now all but replaced by digital communications, and so on…

In the Arab Region, there are many efforts to "scale-up" successful technologies, notably in mature Sustainable Energy (SE) technologies such as solar and wind power.

1) By 2015, large scale projects had already been undertaken in the Arab Region, as in the case of Morocco and the United Arab Emirates.
    a) In Morocco, the Moroccan Agency for Solar Energy (MASEN) identified five potential sites suitable for Concentrated Solar Power (CSP) and Photovoltaic (PV) plants. It selected one of them, in Ouarzazate, for the construction of 160 MW CSP plant, and construction was initiated

[60] Thomas Watson, president of IBM, 1943: "I think there is a world market for maybe five computers"
[61] Ken Olsen, founder of Digital Equipment Corporation (DEC), 1977: "There is no reason anyone would want a computer in their home."

in 2013[62]. Its innovation potential is supported by extensive research involvement in solar power[63].

b) In 2013, the United Arab Emirates (UAE) launched the 13 MW Mohammed bin Rashid Al Maktoum Solar Park. The park is designed to serve as a hub for technical training and innovation. It is designed to scale up, with largely automated systems that rely on "very little manpower and water[64]". The UAE plans to expand the park to 1,000 MW by 2030 and generate about 15% of the country's projected demand.

2) Most other Arab countries have smaller-scale implementations of SE.

a) Most of the effective implementations are in solar power, viewed by businesses as a mature technology. As a result, this is increasingly drawing private investment in the region, as in the case of Lebanon, where the level of private sector investment tripled the local photovoltaic solar energy market between 2014 and 2015[65].

b) In some Arab countries, SE technologies are being more actively promoted by the government. This is the case of Morocco, which launched a program in 2010 to install a 1,000 MW capacity from wind energy sources, with an objective to achieve 2,000 MW by 2020. By 2015, the installed capacity was 787 MW, with another 1,400 MW is under development[66].

Going forward, newer technologies build-up on the progress made in proven technologies. This will allow more effective implementation and more confident benefit from scale. Newly introduced technologies would then better leverage regional integration and complementarity in all areas related to STIs such as investments, talents, markets, resources, opportunities, and capacity.

Some technologies are not defined along industrial or academic R&D. Those technologies are improved through an innovation process that remains largely **informal**, and therefore generally undocumented. As such, this grassroots innovation is often dismissed by formal learning and "conventional" processes. However, this does not make it less valuable, not least because it is centered on an informal culture of "**learning to learn**". It is such a mindset that needs to be cultivated, and it can be done through simple measures that promote the documentation of informal knowledge, and encourage businesses to become, in part, "learning organisations" that operate in a "network of institutions" to leverage current technologies. Those measures would;

1) Aim to establish a platform that promotes "connectivity" among various actors, and help drive "one-to-one" engagements. Such platform can help build on government efforts at promoting local empowerment, by helping to find areas where the private and public sector can complement each other. The "boundary" of the platform would depend on specific local conditions, due to both the "structure" of region, and the role of governments. The role of government is central, as "solution provider", both because of (1) the many domains where no business case for others to be involved, and (2) the need to maintain a focus on national needs and priorities. At present, this approach is mostly followed by some Non-Governmental Organizations (NGO). An example is the Lebanese NGO "Arc-en-Ciel" that, as part of its mission to offer job opportunities for people with special needs, has developed recycling networks through both a "municipal waste management plan" and network for "infectious healthcare waste". The organization has a growing involvement with agriculture and ecotourism, and is pioneering the use of sustainable energy and design[67].

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[62] http://www.masen.ma/en/projets/
[63] El-Amrani, 2016.
[64] UNDP, 2014, p.52.
[65] https://en.annahar.com/article/478260-lebanons-solar-power-sector-reports-triple-digit-growth
[66] http://www.invest.gov.ma/?Id=67
[67] http://www.arcenciel.org/en/

2) To focus on a "value chain" of complementary businesses that work add "value to a particular marketable product on its way from raw material to the final consumer". The innovations from one business would then transmit across the value chain. In the Arab Region, the necessary "support provided to actors in agricultural value chains is insufficient, and it may be limited to the same field of activities while other areas may be overlooked[68]". As a result, only a "high performing agricultural systems, including their related value chains, have been successfully developed". For example, in Morocco, systems focus on vegetable exports, but the "majority lack efficiency and effectiveness[69]".

3) Map various skills and knowledge to strengthen the network. The advent of participatory information and communication technologies allows for wider sharing of knowledge and skills. Measurable "metrics" that can track "what matters", and better quantify local business innovation in "technologies that are more appropriate to the prevailing situation[70]" in their area.

Box 7 Humans and Machines

In 2005, an online chess-playing website sponsored a competition where "anyone could compete in teams with other players or computers" to win significant prize money.

When the competition started, it became very clear that teams of humans and machines would dominate the event, but the "the surprise came at the conclusion of the event", when "the winner was revealed to be not a grandmaster with a state-of-the-art PC but a pair of amateur American chess players using three computers at the same time".

This demonstrated that, expertise still matters for problem solving, computer literacy is the determining factor.

First, the best teams are those that **combine** the power of "**human strategic guidance** [...] with the **tactical acuity of a computer**". Even the most powerful machine proved "no match for a strong human player using a relatively weak laptop".

Second, the stronger teams where those where humans were skilled "at manipulating and 'coaching' their computers", and only had a basic understanding of the problem. Such teams proved able to outperform "several groups of strong grandmasters working with several computers at the same time".

Ref: Discussion by Garry Kasparov, former World Chess Champion, at: http://www.nybooks.com/articles/2010/02/11/the-chess-master-and-the-computer/

2. Leapfrogging

Thanks to the accelerated pace of change, technology "leapfrogging" may be possible, whereby developing countries could be able to acquire and adapt the newest technologies, skipping intermediate steps. Indeed, this may be possible in some fields such as computer science, where the improvements are so fast that "capabilities pass from the realm of science fiction to the realm of the mundane not over the course of a human lifetime, but rather well within the span of one professional's career[71]".

As computers grew in power, their efficiency also improved, doubling about every 1.5 years from 1975 to 2009 (Figure 1 below). As this trend continues, the power needed to perform computing tasks will decrease by the same rate, thus allowing ever smaller devices to carry out an increasing range of tasks with increasing performance. Some applications (personal computers and mobile phones) will grow in power and performance. Other applications (sensors and control systems) will become smaller, more efficient, and less power hungry, and thus more ubiquitous[72]. The use of computers will therefore continue to expand to a wider range of applications, in various sectors.

[68] ESCWA-GIZ; 2013, p.18.
[69] ESCWA-GIZ; 2013, p.9.
[70] ESCWA, 2011, p.7.
[71] McAfee, 2010.
[72] Koomey et al., 2011.

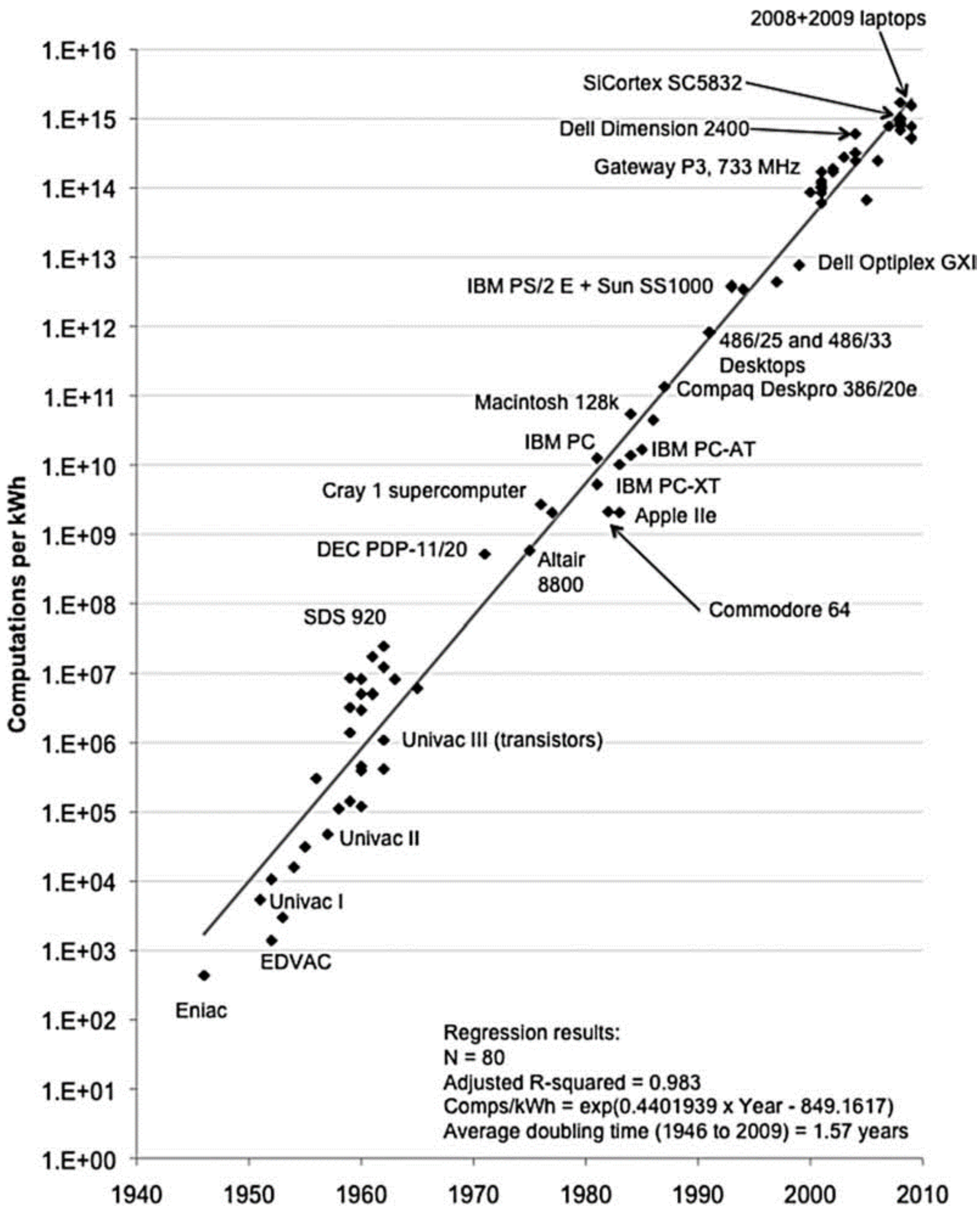

Figure 1. Increase in Computations per Kilowatt-Hour Over Time[73].

In such a new environment, the current technological revolution is likely to bring about a significant transformation in human society, unprecedented in scale, scope, and complexity.

1) Businesses would generally benefit from "**late-mover**" advantage, whereby new entrants benefit from the most cost-effective technology;

[73]Koomey et al., 2011, Figure 3, p.49.

2) Penetrating new markets would be far less risky, as it would require less capital in cheaper and more performing equipment.

However, leapfrogging still requires an infrastructure of existing technologies and technical abilities. Indeed, for all its uses, supercomputer system would be a dead box without reliable electrical supply. For this reason, in many developing countries, while new technologies are often adopted by a small minority of people, they fail to gain wider diffusion with limited benefits.

Therefore, with a solid foundation of intermediate technology, the latest technologies can become widely diffused, allowing developing countries to "**leapfrog**" over lesser efficient technologies. Such leapfrogs occurred both in the developing and the developed world.

Leapfrog in **developing countries**, tend to be "**accidental**", as people and businesses adapt emerging technologies to their own specific conditions, as in communication and power industries:

1) In the field of Information Technology and Communication, the cellular and wireless systems enabled many economies to "skip" over the fixed line technologies, towards practical mobile networks.
2) The adoption of decentralized renewable energy production systems such as solar and wind, allowed local electrification without the need for grid expansion into remote areas.
3) "Leapfrogging" may not be possible for all industries. Innovation in the healthcare industry, for example, generally needs a solid foundation of existing, intermediary technologies. The adoption of new methods is slow because of the need for caution. Indeed, in spite of the rapid adoption of new diagnostics tools, the interpretation of results still relies on accumulated experience, and any potential treatments requires tested methods.

Developed countries generally have more central vision and planning, but **no guaranteed success**. An example is the French "Minitel" online service; after an initial successful innovation between 1978 and 1982, the system had become too rigid and failed to "scale-up[74]". It was completely superseded by the accidental advent of the internet and the World Wide Web.

Box 8 From "Makers" to "Mass Customization"

New technologies are making it ever easier to leapfrog various production systems.

In manufacturing, individuals can already create, develop, and manufacture small batches of customized items. Those "**Makers**" can sidestep the business model of traditional large-scale manufacturing and its financial "bets" on high-volume, factory-scale production.

The nascent "Do-It-Yourself Bio" (**DIY Bio**) movement is trying to replicate this approach in biology-related sectors. The technologies relied upon by "DIY Bio" makers would allow them to cost-effectively manufacture small batches of medicine, and thus (1) take **low financial risks**, and (2) easily provide **customizable** options.

Ref: Landrain et al., 2013

A successful leapfrogging requires an enabling policy environment, without imposing mandates. Such an environment:

1) Builds upon existing capacity and "indigenous knowledge relevant to green economy and technology". Then, by identifying "visionary regional projects" that promote "a leapfrog approach" to address local challenges;
2) Allows for technology transfers without artificial hindrances, such as restrictive Intellectual Property laws or hefty import duties. Jordan, for example, recently updated its import laws to facilitate the import of some essential parts for start-ups[75].

[74] http://www.bbc.com/news/magazine-18610692
[75] Furman et al., 2002.

3) Deals with the effects of unforeseen consequences. An example is the "Internet of Things" and unintended consequences regarding security and system reliability;

   a) The most publicised one is related to security, as many devices are being hacked and hijacked. This was the case of the recent attack by the "Mirai" botnet, which shutdown parts of the internet on the US East Coast in November 2016.

   b) Many negative effects may appear later, as more devices are connected, the haphazard networks may prove increasingly hard to manage, and the resulting interactions among devices are likely to undermine the reliability of some operations.

Another concern is related to very fast advances in genetic engineering, most notably in gene editing techniques such as CRISPR/Cas9 that are poised to revolutionize not only genetic engineering and biology, but also the agriculture, pharmaceuticals, and the chemical industry.

Box 9 CRISPR/Cas9

The CRISPR/Cas9 system was discovered as part of the immune system of bacteria. The system has two components; (1) the "Clustered Regularly-Interspaced Short Palindromic Repeats" (CRISPR) that "stores" genetic sequences obtained from previous virus (or bacteriophage) infections, and the (2) nuclease or helicase protein "CAS", that cutting or unwind DNA.

In bacteria, the system is such that, when the same or similar virus invades again, it is able to recognize it immediately based on the stored DNA segment. The bacteria can unleash a protein such as the "cas9" (isolated from the Streptococus pyogenes bacterium) that targets precisely the bacteriophage's DNA and cuts it at the site corresponding to the stored CRISPR sequence.

It was later determined that the system could be modified to literally "cut and paste", removing specific DNA sequences and replacing them with alternatives, thus allowing for targeted modification of the genome in living beings. However, it remains unclear how the human system may react to those new systems, because it has evolved to recognize them as part of pathogenic bacteria's arsenal*.

(*) Charlesworth et al., 2018.

3. Innovation

Formally speaking, innovative capacity is the ability of any group "to produce and commercialize a flow of innovative technology over the long term", and depends on an infrastructure of "interrelated set of investments, policies, and resource commitments[76]". This defines a process beyond the (1) capacity to innovate and the national systems for innovation, and the (2) mechanisms through which innovation takes place.

Box 10 What is Innovation?

Innovation can be defined as "the implementation of a new or significantly improved production (good or service) or process, a new marketing method, or a new organization method in business practices, workplace or organization or external relations*" that brings about "change that creates a new dimension of performance**".

This definition focuses on Technological Product and Process (TPP), and is implemented either through market introduction (product innovation), or by its incorporation within a production process (process innovation). The innovation itself can be of either (1) **incremental**, that builds upon existing technologies, or (2) **radical**, that brings about a shift in technology or conceptual paradigm.

(*) OECD, 2005.
(**) http://www.druckerinstitute.com/wp-content/uploads/2015/04/Drucker-on-Innovation-reading.pdf

[76] Stern et al., 2000, p.1.

a) Capacity to Innovate

The capacity to innovate is not measured by a single parameter, at a single point in time, but by the evolution of various parameters across (1) regions and (2) time. As such, the national innovation capacity results from those three critical components, and is greater than the sum of their parts[77]:

1) **Endogenous idea-driven growth**, in which the rate of innovation in a national economy depends on two key factors, the (1) "prior stock of knowledge accumulated in the economy", and (2) the amount of R&D. This would require "a strong common infrastructure", and a cumulative "stock" of knowledge and skills;
2) **Cluster-based**, in which the focus is not on specific industrial segments, but rather "country-specific industrial clusters" such as those for Information and Communication Technology (ICT). In this model, the rate of innovation is critically dependent on (1) the "knowledge spillovers" between various groups, (2) the actual interdependencies across various sectors and, critically, on (3) a business culture that promotes risk taking and does not penalize failure;
3) **National innovation systems**, empowered by (1) policy environments such as intellectual property or trade policies, (2) the education sector and research organisations, and backed by (3) strong and integrated set of mechanisms. They are essential to the productivity of the national innovation infrastructure, as they facilitate the migration of ideas from the common infrastructure into commercial practice.

In the Arab region, National Innovations Systems are currently being established as part of a drive to update STI related policies, and set up offices to link universities and research institutions, and facilitate the partnership between the research community and economic development sector, the industry and relevant governmental and nongovernment actors. One of those implementations is through a project with the ESCWA Technology Centre, for National Technology Transfer Offices (NTTO) and networks established in Egypt, Lebanon, Morocco, Tunisia, and Oman. Once established, those offices will work on linking and matching local capacity with multinational corporations seeking local partnerships, with shared development and production values.

Box 11 Does Science Advance One Funeral at a Time?

Science progresses through knowledge accumulation, a process highly influenced by established researchers whose enduring influence could prevent the emergence of new entrants. This led famous physicist Max Plank once quip that any new idea triumphs when "opponents eventually die, and a new generation grows up". A recent review of publications validated his hunch.

The review tracked the publication records of 452 "elite scientists" who passed away prematurely, covering about 40,000 papers published during the period between 1975 and 2003. The findings demonstrated that, after the passing of the "star scientist", the publications by collaborators decreased by about 40%, while accepted publications by non-collaborators increased by about 8%.

In addition, within 5 years, those "new entrants" had offset the productivity decline of the collaborators of the new defunct "star scientist". These "additional contributions [were] disproportionately likely to be highly cited", and were "more likely to be authored by scientists who were not previously active in the deceased superstar's field*". The "boost" did not necessarily appear when competing researchers or labs picked up the mantle of deceased "star researchers", but mostly when newer ideas were used, often incorporated from other domains of scientific inquiry.

In a similar manner, newly established research centers are unhindered by the legacy of established practices and accepted ideas, and are free to explore new avenues of inquiry.

This appeared to validate the quip by famous physicist Max Planck that "a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its that is familiar with it."

[77] Stern et al., 2000, p.2.

(*) Azoulay, Fons-Rosen, and Graff Zivin, 2015.

b) Measuring Mechanisms of Innovation

The mechanisms of innovation depends on the linkages between local capacity, industry, and multinational corporations seeking partnerships. Those linkages are described partially by parameters such as the amount of R&D spending, and patent activity.

The importance of **R&D spending** depends as much on its composition than its amount. While (1) public R&D leverages national systems to builds up the common innovation infrastructure, (2) private R&D enhances the dynamic of clusters and stems from endogenous idea-driven growth. An imbalance in the "mix" of R&D expenditure can lead to missed opportunities. When budgets are too focused on "academic" R&D, this can even lead to outright financial losses, as other countries "pick up" the research and develop their own commercial applications. This was the case of the development of VCR technologies in Japan, which was initiated on the basis of research carried in the United States[78]. It is not necessary to focus all research in Academia away from addressing rigorous "fundamental" questions. While such research may not have direct relevance to businesses, it could still lead to unexpected practical applications. By regularly engaging with business and industry, academic researchers can therefore regularly ascertain whether their research questions (1) are relevant to organizational practitioners, and if (2) they are applicable in any specific organizational situation, or generalized to other settings.

The **number of patents** reflects R&D spending, IP protection, openness to international trade, the relative share of research carried out by academic and private sectors, and economic significance of ideas.

The mechanisms of innovation are acting within a context of enabling common institutions and policies. In the context of a trading group such as the Arab Region, those policies need to build upon national integration, to facilitate spillover effects. While spillovers tend to be localized to clusters or geographic regions at first, their medium to longer term impact may not remain circumscribed to national borders. Policies designed to promote innovation would differ from country to country, but they do share two key minimum requirements:

1) The central importance of R&D manpower;
2) The need for an established and "deep, local technology base", with "skilled scientists and engineers operating in an environment with access to cutting-edge technology[79]";

Box 12 Academic Disincentive

In the business world, there is a concern that Academic research may generally be of little relevance to practice, in spite of its scientific and methodological rigour. This is borne out by data on publication metrics:

- Most published papers are not cited in other publications, or even patents. As of 2010, at least 56% of the articles published in 4500 top scientific journals were cited within the first 5 years of publication. Furthermore, only 42% of the papers cited receive more than one citation. Even then, "self-citations", where the authors refer to themselves may represent* up to 25%
- A majority of publications may merely be focused on addressing established questions; this is the case of 60% of the 6.4 million biomedical and chemistry publications from 1934 to 2008. Furthermore, it appears that researchers who pursue innovative approaches are less likely to be published. However, when they are published, their research is cited more frequently**.

This data also confirms that the "**publish or perish**" is stifling innovative and fundamental research, a feeling shared by many academics, and echoed by the 2013 Nobel Prize in Physics, Peter Higgs.

(*) Bauerlein et al., 2010; **(**)** Foster et al., 2015.

[78] Cusamo et al., 1992.
[79] Stern et al., 2000, p.9.

C. STI Options for Sustainable Development

Science, Technology Development, and Innovation (STI) are key for the promotion of Sustainable economic growth, decent work, and well-being. It requires a coordinated policy effort to enhance learning capabilities, and promote lesson-sharing.

For STI to be successful, it has to be part of a broad effort that promotes the capabilities of the wider segment of the population for learning, investigating, and innovating. Such a focus will outline the general policy orientation, and help orient STI policies towards meeting goals of sustainable development for all.

1. General Policy Orientation

A successful policy should encourage people to keep a **focus** on the problem or issues that need to be resolved, maintain the **discipline and rigor** in the analysis, and have the patience to overcome short-term setbacks and keep a **long-term outlook**.

In the Arab region, there is a shift towards more applied sciences, policies are increasingly enticing researchers to be focused on the need to solve specific problems. However, the "long-term outlook" is not always there, and much progress remains to be made in promoting greater linkages among academic institutions, businesses, and laypeople. This results in an imbalance between R&D expenditures and their spillover effects on the economy at large.

a) Enhancing Impacts of Science, Technology Development, and Innovation Policy

This is done, in part, through "a policy shift from support to research toward innovation", mostly through "measures promoting innovation in the public sector and interaction between the public sector and the productive companies in many forms: engineering networks, promotion of technology transfer units, fiscal measures, promotion of start-ups and venture-capital funding[80]". However, most local research efforts have yet to return significant economic impact. This could be due to a variety of factors:

1) Research may still be excessively "focused" on **academic pursuits**, as evidenced by the weak link between the IP generated in university and the one needed by socio-economic sectors. Patent activity in Morocco is an illustration of this[81]. In spite of the large number of national patents, there is little or no international patent applications. More than 80% of the patent applicants are international actors, for patents related to their investment in their localized manufacturing operations. This may be due to the lack of tax incentives for local companies to fund industry-academic R&D projects. As a result, most of the research in the country is carried out in universities (65%), and about half of the of the country's R&D spending (0.7% to 0.8% of GDP) is taken-up by researchers' salaries[82].

2) Yet another reason could be related to the prevalence of **short-termed policies**, where success is expected to be easy and immediate. The result is a lack of long-term focus, after "more than 10 years of systematic efforts in various countries", and therefore an effective underfunding of R&D, in spite of any given country's economic potential. This is illustrated by the lack of correlation between any given Arab country's "position on some 'innovation index' and the growth of their GDP". Indeed, in spite of their high GDP, the scientific research index of oil-producing countries still remains relatively low compared to the other Arab countries[83].

However, the main factor may not be related to specific policies as much as to the "policy mix", with linkages that extend far beyond financial support", to promote an "ecosystem conductive to technological development". Exceptions were such cases as Lebanon's "Berytech" incubator and Tunisia's El-Ghazala

[80] ETC, 2013, p.5.
[81] Based on data for 2009, 2010 (ETC, 2013, p.29)
[82] El-Amrani, 2016, p.35.
[83] ETC, 2013, p.5.

Technopark, whose success rested not financial support as much as on "creating an institutional background[84]".

There is already a focus on business incubators in the Arab region; of 40 incubators reviewed in the Arab Region, the highest proportion of existing incubators (80%) followed a non-profit business model, and their objectives are generally to promote entrepreneurship and graduate profitable enterprises[85]. Going forward, their non-profit motive should allow incubators to focus beyond their own bottom line, and let the Start-up be the "product[86]". This can best be done by:

1) Focusing on developing local businesses **beyond the main centres**, in what is conventionally considered "non-bankable" regions. In any case, the focus on "bankable" center proves to be counterproductive on the long run. Indeed, too many startups, after a short period of time and once their success is assured, move to the relatively "greener pastures" of the Arab Gulf states.
2) Few incubators realize that **not all technology is new technology**. There is too much of a focus on Information and Communication Technologies (ICT). Incubators need to move beyond the "app store" and to diversify into the various sectors of the economy.

Box 13 Incubators

Business incubators are designed to help new companies "start-up" by providing them with subsidised essential services such as management training, administrative and financial services, business infrastructure and office space, marketing and networking, mentoring, others. They act as catalysts for local business development, and are of varying types, depending on the institutional setup: (1) academic "technoparks", (2) non-profit corporations; (3) development ventures; (4) venture capitalist.

b) Fixing the Imbalance in R&D

On the long run, this imbalance between R&D expenditure and economic "spillover effects" creates a risk. Indeed, the importance of R&D spending depends as much on its composition than on its amount. Public R&D only grows national systems of innovation, but economic activity is enhanced by private R&D, especially in the presence of clusters. Otherwise, any imbalance in one country risks creating "gaps" where competitors can come in and exploit "unused" ideas. The best alternative is diversification among the three components of the national innovation capacity; (1) **Endogenous idea-driven growth**, (2) **Cluster-based**, (3) **National innovation systems**. This would be done within a general policy orientation for STI that would:

1) Take into account **both current business and livelihood activities**. It is in those existing activities that trust and tacit knowledge have been established, and can be built upon to promote further innovation, as in the case of product innovations that suppliers make for their partners in the value chain.
2) Avoid **overemphasis on science-based institutions**. While fundamental science has a role to play, it cannot be pursued "in a vaccum", and requires the capacity to sustain long-term endeavours that may or may not "pan out". This can only be achieved in a context of an active and thriving sustainable economy.

It is with such a focus that one can optimally "enhance scientific research, upgrade the technological capabilities of industrial sectors", and promote a sustainable economy that can support a substantial increase in "the number of R&D workers", as well as in "public and private R&D spending[87]".

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[84] ETC, 2013, p.5.
[85] iPark, 2013.
[86] ETC, 2017.
[87] UN, 2017, SDG 9.5.

2. Orient STI Policies Towards SDGs

From a perspective of Sustainable Development, the objectives of Science, Technology Development, and Innovation (STI) aim to support the path towards an economic development that can grow on the long run in the face of diverse challenges including Climate Change.

To ensure STI's proper alignment with SDGs, two sets of specific measures need to be taken at the policy level; one conceptual, one practical.

1) At the **conceptual** level, perspective, STI should be approached as an "ecosystem" that represents the web of complex relationships among the various entities facilitating sustainable development. Those entities are the (1) material resources needed by the (2) human personnel working at the (3) various institutions that are part of this ecosystem. The material resources are: land and related facilities, funds, equipment, and raw materials. Concerned human personnel extends from the farmer, labourer, factory worker or artisan, to the factory manager, engineer, various business staff members, industry researchers, industry representatives, policy makers, others. The institutions of the local Small and Medium Businesses or the local school/vocational college, to the larger business conglomerates, the universities, financial institutions and venture capitalists, funding agencies, economic development and business assistance organizations…
2) At the **practical** policy level, the focus of policy should be switched towards reorienting mindsets and behaviours towards Sustainable Development. In this manner, STI problem statements would be rephrased from Sustainable Development challenges, and the focus of education and research policy would be more on building innovative capacity than on simple conventional detached technology transfer. This can be achieved through partial subsidies, as in the case of solar power in Tunisia, where the government has introduced subsidies to lower the cost of solar panels by around 30% to encourage commercial and residential installations, in addition to a "a tax-exemption policy for locally produced solar modules[88]". In addition, practical policies should enhance an environment where the private sector is engaged and incentivized in the formulation of STI objectives. Furthermore, the practical policy must be "evidence based", focused on policy-making, to (1) better benefit from the current "data science" through the set-up of monitoring, evaluation and assessment tools, and thus (2) improving policy coherence and effectiveness.

Doing so will define a policy to meet the challenge of climate change, while still addressing the needs for both sustainable development and greater scientific and technical development. Hence, Technology Transfer and Adaptation will help develop a stronger, more resilient economy, and thus to incentivize the private sector. STIs would then help meet the main challenges of climate change; (1) raising temperatures; (2) shifting precipitation patterns; (3) land degradation; and (4) the increased occurrence of extreme events such as flooding and droughts.

1) STIs can greatly contribute to measures that limit the adverse effect of **increased temperatures**, by deploying currently available and future technologies. Electricity generation is one example where currently available technologies can help enhance resilience to climate change. This is especially the case since demand for electricity is set to increase with increased temperature and humidity. At present, the electricity generation sector is slowly transiting from "conventional" diesel-powered generation and towards more sustainable renewable energy systems. Initially, the development of this field occurred to cover a need for additional energy demand, since electricity supply is generally unreliable in spite of the large number of people connected the grid in most Arab countries. In **Lebanon**, for example, private generators account for about 40% of the electricity supply in 2016[89]. Some of local businesses that developed to service such sector have grown to become industrial enterprises, and are now leveraging their experience to expand other markets, especially in Africa

[88] IRENA, 2016-b, p.51.
[89] Bouri and El-Assaad, 2016.

where a "bring-your-own-infrastructure" business environment thrives. In addition, they are now increasingly diversifying in Renewable Energy (RE) systems such as solar and wind, to help meet Lebanon's stated objective of generating 12% of total electricity supply through renewable energy by 2020[90].

2) **Shifting precipitation patterns** will mostly affect climate-sensitive sectors such as agriculture. In the Arab Region, there are already many areas where agricultural productivity is threatened due to land degradation and water supply variations. Those can be also addressed with a mix of existing tools and future technologies. Existing tools such as water-efficient irrigation and hydroponic farming are already being deployed. Hydroponic farming, whereby plants are grown indoors in controlled environments, is now a growing business in the Arab Region, and the activity centers mostly around the production of vegetables. In the future, more development is needed, both on the "production" of water and its consumption. To a certain extent, the "production" of freshwater is now becoming increasingly possible and cost-effective, for example in air-moisture harvesting. Current techniques are now used in such Arab Countries as Morocco, but they have limitations; "fog harvesting" requires very high relative humidity (close to 100%), and "dew harvesting" can work with much lower levels (down to 50%), but is very energy-intensive. However, since 2017, nanotechnology applications were being tested for air moisture harvesting that operates effectively at even lower levels (20%), with no energy input other than sunshine[91]. On the "consumption" side, much has been done in efficient irrigation techniques. More could be done through the development of water-resistant crop varieties.

3) There are many ways to help address **Land degradation**, while there are direct applications based on current technologies, there are also beneficial side-effects from the implementation of newer technologies. One example of the beneficial impact of new techniques is in **biogas**, a technique that not only addresses issue of energy shortages, but also goes a long way to mitigating land degradation and water pollution. In one of the projects applied in **Jordan**, even an apparently simple technology implementation demonstrated the need to ensure that proper technologies are being transferred. Indeed, imported **biogas generators** were in fact Natural Gas generators that got repurposed by locals for this specific application[92].

4) Managerial measures can be deployed to address the impact of **extreme events**, but they can do much more. Indeed, beyond the most obvious crisis management, the application of Information and Communication Technologies (ICT) tools can be also adapted to improving daily interactions. One "low hanging fruit" is to enhanced logistics management of supply. ICTs can, for example, facilitate the establishment and management of value chains of complementary and collaborating businesses that each add more "value" to a product as it makes its way to market. A value chain involved in the production and marketing of olive oil, for example, would focus on both using renewable energy in the production process, and recycling waste products for energy generation or other purposes. ICTs can also help identify "Energy Management Opportunities" (EMO), to coordinate a supply chain where the "outputs", or waste of one business or process can serve as "inputs" into others. These technologies can improve supply chains by coordinating logistics. Indeed, by managing product databases and related shipping management, software tools could greatly help addressing the price of transportation to remote areas.

3. Focus Areas for STI

The main focus areas for STIs should parallel those for Sustainable Development; water, energy, food security, social justice, livelihoods, and healthcare, as well as the needs for climate change adaptation, urban planning and land management, and waste and wastewater management. STI areas would be lead to

[90] LCEC, 2016.
[91] Kim et al., 2017.
[92] http://www.wisions.net/projects/biogas-demonstration-units-for-small-animal-farms

solutions to the identified problems, by bringing to bear the latest developments in (1) computing and artificial intelligence; (2) manufacturing and the related fields in applied physics and nanotechnology; (3) biology; and (4) resource utilization and energy production.

1) Computing power is accelerating with more miniaturization at a sustained pace, so much so that they are now increasingly embedded items of daily usage. This advancement in the raw power of **computing** is leading to a "**data revolution**" that may finally unlock the promise of **artificial intelligence**. The Arab Region stands to greatly benefit from this change, since the cost of systems is steadily decreasing with each advance, giving new entrants a "late mover advantage". This leads to undermining businesses with labour-intensive models, and therefore the **employment** and the **livelihoods** of the unprepared. This change will only benefit those that can leverage the skills of their workforce and their innovation potential. Consequently, capacity building and **education** would need to focus on technical training in addition to scientific pursuits, but also. Schools and universities can best nurture innovation and help cultivate entrepreneurship skills by nurturing analytical skills and providing "hands on" technical knowledge.

2) In other technologies, progress is starting to follow a similar path to the progress in computers. This is the case of **manufacturing**, which is making more use of **applied physics and nanotechnology**. There, it is becoming increasingly easier and more affordable to design and construct complex components and machines. This progress is occurring in three phases. The first phase is already underway, as additive manufacturing is driving a paradigm shift in industry. In many cases, major manufacturers are now exploring the methods of the "maker movement", leading to a new drive to "**mass customization**", in which they combine the flexibility of custom-made products while still leveraging their capacity for mass production and thus generating even lower unit costs. The next step would be to go to smaller scales, since "there's plenty of room at the bottom[93]". At the "**nanoscale**", where items and devices can be built "from the atom up". In the immediate, this is leading to resource efficient manufacturing. Later, nanotechnologies could lead to more efficient tools for resource extraction. The third phase would involve greater **integration with biological systems**. There are already examples in the field of medicine and pharmaceutics, particular in diagnostics, such as the "lab on a chip", or in implantable devices that can be powered by blood glucose.

3) Considerable advances in **biotechnology** are making it increasingly possible to carry out gene editing, and thus modify living organisms. In many ways, the tools of genetic engineering are now well known, and the scientific applications well established, even if there still are issues about efficacy. There is now a growing body of work that strives to learn from living organisms, and to implement the solutions they have devised. Going forward, there are already some proposals to extend into uncharted waters, with "germ line modifications" that not only affect one organism, but also its descendants. This is the case of programs aimed at eradicating mosquito-borne diseases[94].

4) The issues the Arab world faces today with respect to water and energy are essentially related to resource utilization and energy production. In addition to new technologies, **water** availability could be potentially resolved through process management that leverages traditional knowledge. This will both strengthen livelihoods, and help identify comparative advantages for value-added production. It is important also to ensure that the global intellectual property regime does not hinder tech transfer and local innovation. New technologies make possible cheaper access to **Energy**, not only by allowing for new implementation of renewables, but also by allowing for more efficient use of energy resources such as hydrocarbons. The promise of renewable energy would be fully realised once storage technology has improved, something that new technologies are only now beginning to

[93] Feynman, 1959.
[94] Gantz et al., 2015.

tackle[95]. Pollution that results from the use of hydrocarbons would greatly diminish with the use of filters to cheaply capture or extract pollutants from the air.

Going forward, to ensure sustainable economic growth and decent work, policies should focus on ensuring the Arab Region is ready for the move away from a labour-intensive "perspiration" economy to a more resource-efficient "inspiration economy.

4. The Entrepreneurial Culture

Entrepreneurial activity can generate spillover effects on national employment, in addition to social and cultural impacts. Not all entrepreneurial activity is the same; it ranges from self-employed "subsistence entrepreneurs" and their micro-businesses, to "social entrepreneurs" who mostly create value for others. Economically significant entrepreneurs are those who manage to create significant value for themselves and others[96].

In the Arab region, entrepreneurial activity appears robust, with about 13% of its "working population engaged […] far more than in the US, Germany or Japan". However, most of those businesses are "subsistence entrepreneurs" with a very small-scale businesses; about 80% of businesses appear to be established out of necessity and generally employ family members, and are valued at less than USD 15,000[97]. However, in aggregate, they do create significant value, as their overall share of the economy is often significant, since they generate a large proportion of private sector employment in various countries, from Morocco (65%) to Saudi Arabia (40%).

The data therefore reflects more the lack of opportunities than any "entrepreneurship vigour". But it also highlights the population's high adaptability and resilience, and hints at the possibility that, provided the right environment, those enterprises can potentially grow beyond the subsistence needs of their owners.

Some countries are indeed trying to further cultivate this entrepreneurial spirit, and launching targeted initiatives, as in the case of Oman's SANAD programme and Tunisia's "Centre des Jeunes Dirigeants d'Enterprise". Overall, "innovation policies, understood as this complex set of institutions and measures not as a unique form of intervention, have been developed and sustained quite firmly in the last few years by some governments[98]". However, while there is growing support for the "bottom" to help them rise up, there is little for Small and Medium Enterprises. This "yawning funding gap" affects businesses valued between USD 500,000 and USD 8 Million, a "missing middle[99]" that can rely on no identifiable financial or support institutions, as shown in Figure 2 below.

[95] WEF, 2011, p.15.
[96] Ahmad and Seymour, 2008.
[97] WEF, 2011, p.15.
[98] ETC, 2013, p.4
[99] WEF, 2011, p.9.

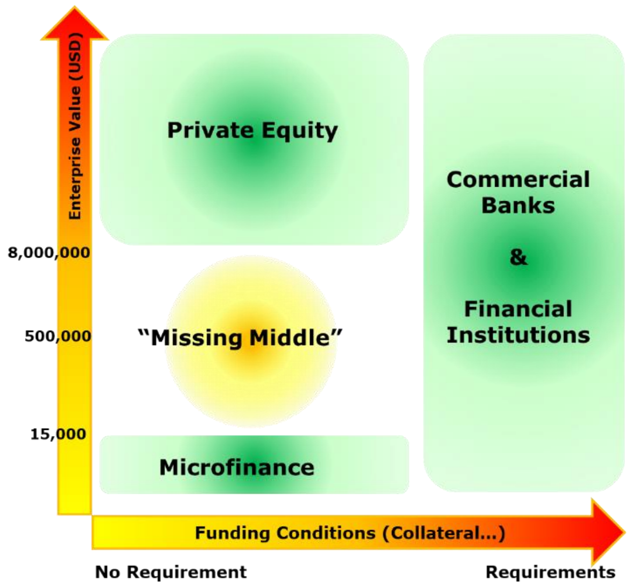

Figure 2. Funding Gap: The "Missing Middle"[100].

In general, policies and initiatives are greatly benefiting from the growing importance of technology, as STI have been steadily growing in importance in the region; between 1970 and 2010, Arab R&D output has already increased 33 fold. Since the 1950s, the countries in the region have been expanding "the number of scholarships available […] for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes[101]". As a result, the number of universities grew from only 10 in 1950 to more than 500 in 2010, with no shortage of recruits, thanks to a growing and young population.

Going forward, innovation and entrepreneurship in the private sector would best be reinforced by an educational system that focuses on skills training and retraining, in an academic context that prioritizes industry collaborations over peer-reviewed publications.

[100] WEF, 2011, Exhibit 7, p.15.
[101] UN, 2017, SDG 4.b

III. Technology Transfer and Adaptation and the Paris Agreement

The "Paris Agreement" was reached on December 12, 2015, in Paris, at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC)[102]. The document has two main outcomes; it outlines the current consensus on the efforts necessary to combat climate change, and clarifies the central role of STI in both adaptation and mitigation efforts.

The Paris Agreement therefore informs strategies for the transfer, adaptation, and development of technologies. It offers an opportunity to the Arab regional to meet two critical objectives; (1) achieving the Sustainable Development Goals (SDGs), and (2) meeting its mitigation commitments. This can best be done as part of efforts to promote STIs, and implement appropriate and adapted technology transfer mechanisms.

A. The Paris Agreement

The "Paris Agreement" entered into force on November 4, 2016, 30 days after instruments of ratification were received by the secretariat from "at least 55 Parties to the Convention, accounting in total for at least an estimated 55% of the total global greenhouse gas emissions[103]". By September 2017, 191 countries had submitted 164 INDCs, detailing their plans to both reduce emissions and enhance their resilience[104].

The Agreement covered both adaptation and mitigation to confront climate change. Both approaches are complementary; while adaptation addresses short-to-medium term impacts, mitigation targets climate change contributing factors.

1) **Adaptation** is a pressing need in developing countries, and particularly in the Arab Region, home to 5 of the 10 countries most at risk of climate change. Recent regional simulations confirmed that the region's prevailing aridity and water scarcity will be exacerbated by temperature increases, greater rainfall variability, and increasingly frequent extreme events.
2) On the longer term, **mitigation** efforts are essential, and focus on reducing human emissions of Greenhouse Gases (GHGs), the main factor exacerbating climate change. Under the Paris Agreement, mitigation is achieved through emission-reduction pledges by individual countries.

The Paris Agreement mainly focuses on mitigation actions, through emission-reductions pledged by countries, or "Intended Nationally Determined Contributions" (INDCs). INDCs therefore outline the parties' mitigation targets, and whether they have any specific adaptation needs. Mitigation targets outline how far each country intends to reduce its Greenhouse Gas (GHG) emissions, and describe pre-conditions such as finance, technology, or technical capacity. The current INDCs are not yet ambitious enough (see bleow). However, it is still technically possible to make them more "ambitious" and ensure that agreed-upon mitigation targets are met through "proven technologies and policies[105]".

Box 14 Co-Benefits

Some mitigation actions can also have positive implications for adaptation efforts. For the Arab Region, it is important that mitigation is approached in this way, primarily as a co-benefit of adaptation. Adaptation is key in the Arab region, especially since the changing climate may already be adversely affecting development, particularly in regions under growing risk of hyper-aridity.

Furthermore, a single focus on mitigation in Arab countries may not have a significant impact at the global level. Indeed, not only have Arab countries made negligible cumulative emissions since the onset of the industrial age, but they also make comparatively negligible current emissions. This was implicitly recognized by the Kyoto

[102] In this document, the terms UNFCCC or "Paris Agreement" will have one and the same meaning.
[103] UNFCCC, 2017-a.
[104] http://cait.wri.org/indc/
[105] UNEP, 2016, p.

Protocol, under which Arab countries were not required to have commitments to contribute to global mitigation efforts.

1. Climate Change: Probable Outlook for the Arab Region

Climate change will impact Arab countries proportionally more than other regions in the world. The general extent of those impacts was highlighted in Global Climate Modeling results, and it was mapped in further detail thanks to the recent Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR), a collaborative regional initiative between the United Nations and the League of Arab States[106].

Climate forecast are based on possible pattern of human GHG emissions, represented by a "Radiative Concentration Pathway" (RCP). The Intergovernmental Panel on Climate Change (IPCC) has identified 4 such pathways; while the first 3 represent cases where emissions decrease after a given peak date for GHG emissions, the fourth one considers that emissions continue to rise throughout the 21st Century. From a perspective of policy planning for adaptation, the most relevant RCPs are RCP 4.5 and RCP 8.5:

1) Under RCP 4.5 mitigation efforts cause GHG emissions to start decreasing after a peak in 2040;
2) Under RCP 8.5, no significant mitigation efforts are undertaken. Under such "Business-As-Usual" (BAU) conditions, GHG emissions continue to rise throughout the 21st Century.

The forecasts are carried for the time periods 2046-2065 (middle of the century) and 2081-2100 (end of the century), and compared with the baseline period 1986-2005. The impacts will result in sea-level rise, temperature increases, as well as lesser and more variable precipitation.

1) By the end of the century, **sea level rise** is expected to increase by 0.47-0.62m, if the rate of ice-sheets melting remains relatively constant[107]. This will worsen land degradation and seawater intrusion. In the Arab Region, the areas mostly affected would be low-lying coasts in the Arabian Gulf and Palestine, as well as the densely populated Nile Delta, in Egypt. Adapting to those conditions requires significant infrastructure work, and may necessitate the development of specific technologies[108].
2) Average **temperatures** in the Arab Region are expected to increase by 2.4-3.4°C by the middle of the century[109], reaching 4-5°C by the end of the century. The region's infrastructure generally relies on imported equipment that may not be designed for high average temperature environment, and may therefore be further challenged. Already, there are concerns that a "**tipping point**" may be reached at the global level, when temperature increases exceed the 2-3°C range, leading to **lower annual economic** output compared to the 1990 baseline[110]. Under most projections, highest increases in the Arab Region are forecasted for non-coastal areas, mostly in the Sahara desert of Africa, affecting parts of Algeria, Morocco and Mauritania. Under RCP8.5, high temperature increases would also occur along the westerns shores of Yemen and Saudi Arabia.
3) Under higher temperatures, both the frequency and intensity of **heatwaves** are expected to increase[111]. When ambient air becomes too hot and humid, outdoor activity is limited, as human cannot sustain physical work when outdoor temperatures reach around 46°C and humidity levels are at 50%[112]. Such conditions are forecasted to occur with increased frequency in the Arab Gulf Region. Already, in summer 2015, as temperatures in some Gulf countries peaked to 50°C, **extremes**

[106] https://www.unescwa.org/climate-change-water-resources-arab-region-riccar
[107] IPCC, 2015-a.
[108] IPCC, 2015-b.
[109] ESCWA, 2015-b. Ranges are expressed as follows: lower values for RCP4.5, higher value for RCP8.5.
[110] Stern, 2007.
[111] IPCC, 2015-a; ESCWA, 2015-b.
[112] Pal and Eltahir, 2015.

of heat and humidity were almost reached in the Bandar Mahshahr region of the Khuzestan province, in Iran. Under those conditions, air conditioning systems may struggle to cope; their **energy efficiency** decreases by 2% for every 1°C increase in outside temperature. Most systems cannot operate under outside temperatures of 38-50°C, except for some compressors that can tolerate up to 55°C[113].

4) The forecasts show a marked decreasing trend in **precipitation**[114] amounts over the Arab Region, with an expected reduction in Monthly precipitation rates of about 8mm by the middle of the century, down to about 10mm by the end of century. By the middle of the century, the regions experiencing the largest decrease appear to be the Atlas Mountains in Morocco. By the end of the century, significant decreases are expected over most of the coastal areas of the Mediterranean, and the Euphrates and Tigris river basins. The region's current water supply infrastructure is designed for a different environment, and would need to be updated and, in some cases, redesigned.

Box 15 Threshold for Survivability: Health and Economic Impacts

The human body maintains its temperature to a very narrow range, its ability to cool itself defined by the difference between skin temperature and inner temperature. When ambient air exceeds specific thresholds of heat and humidity, metabolic heat can no longer be dissipated and the human body's ability to cool itself is reduced, and physical and cognitive functions are thus impaired. Many of the animal feedstock that humans rely on for food are similarly affected.

When a heatwave struck India in summer 2015, by June 3, about 2,500 people had died as temperatures reached as high as 48°C in some cities. That same heatwave caused the death of 17 Million chicken, driving up the price of poultry by more than 35% over the course of a single month.

2. The Paris Outcome

The "Paris Outcome" was a comprehensive document in which all parties agree to two common goals of reducing GHG emissions.

1) The goal of limiting warming to 1.5°C was included in the agreement as an **aspiration**. The parties would simultaneously focus on "holding the increase in the global average temperature to well below 2°C above pre-industrial levels", while pursuing "efforts to limit the temperature increase to 1.5°C". Efforts to limit the increase in temperature to below 2°C will likely require either the active removal of GHGs from the atmosphere, or limiting incoming solar radiation. Both would require the development of specific technologies whose efficacy has yet to be evaluated.

2) The final agreement would **not be legally** binding. However, when a party ratifies the agreement, its "Intended Nationally Determined Contribution" (INDC) would become a "Nationally Determined Contribution" (NDC), with a **binding commitment for transparent reporting**, every 5 years, on meeting mitigation targets. The potential for coercive interference or enforcement on the longer term is however mitigated since the text "welcomes" rather than "invites" all actors to scale up and demonstrate efforts.

Box 16 The Principle of Equity

The "Principle of Equity" recognizes; the (1) need for global action, the (2) respective capabilities of various countries, and their (3) specific national circumstances, capacities and priorities. This forms the basis of a principle of **Common But Differentiated Responsibilities and Respective Capabilities** (CBDR-RC). This was enshrined in the "Rio Declaration", in which "developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command[(1)]". However, there was little follow-up in later agreements, as the 2011 Durban Platform made no direct reference the principle of CBDR, nor of the concept to Respective Capabilities.

[113] Im et al., 2017.

[114] ESCWA, 2015-b.

(1) UNGA, 1992, Principle 7.

When the agreement was signed, most of the pledged mitigation contributions focused on defining emission targets for GHGs and non-GHGs (72% of submissions). The rest of submissions either included a mix of non-GHG targets and actions (14%), or made only reference to intended climate actions (6%)[115]. The agreement entered into force on November 4, 2016, when 55 parties to the convention ratified the agreement, representing 55% of human GHG emissions.

Globally, the "level of ambition" of the INDCs defines the amount of emission reduction, and thus determines whether the Paris Agreement would meet its stated climate warming "targets". By April 4, 2016, a total of 161 INDCs were submitted in time for the COP22, in Marrakech, Morocco, covering 189 Parties to the Convention. Adaptation components were incorporated in 83% of the INDCs, and most parties submitted additional information on market-based mechanisms, support needed and pre-conditions, response measures, plans for economic diversifications…

The countries who submitted INDCs account for about 99% of emissions (the entire Arab Region accounts for less 5%)[116]. The level of ambition is generally significant; if implemented, "the communicated INDCs would lead to sizeably lower aggregate global emission levels than in pre-INDC trajectories[117]". However, those emission reduction are still insufficient to avoid overshooting the Paris Agreements 2℃ target, let alone its 1.5℃ "aspiration". Furthermore, the more time passes by, the higher the emission reductions required to meet those targets and the more uncertain the outcome, thus leading to greater expenditure on infrastructure, as well as much larger investment in Science, Technology Development and Innovation (STI).

Box 17 Response Measures

For any given policy decision, any beneficial effect in one country or region may cause adverse impacts in another country. This could be the case of climate change mitigation measures and new environmental policies; such Response Measures (RM) may affect the biophysical, social, economic, and cultural environments.

In theory, RM should not result in adverse impacts, since the Rio Declaration recognize that some standards "applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries[(1)]".

In practice, however, the principle is much harder to apply because of the interlinked nature of the sustainability challenge; while our scientific tools are well suited to understand "linear" problems, climate and the environment are essentially chaotic, "non-linear" system, with many feedbacks. Our understanding will therefore largely remain "formative", in continuous development, and our policy measures would need constant monitoring and frequent updating.

(1) UNGA, 1992, Principle 11.

a) Intended Nationally Determined Contributions

The Paris Agreement calls for a global effort to combat climate change. It enjoys "developed country Parties [to] continue taking the lead by undertaking economy-wide absolute emission reduction targets", and "developing country Parties [to] continue enhancing their mitigation efforts[118]". Those efforts are documented by the INDCs, initially an outcome of the 19th Conference of the Parties (COP19) in Warsaw. Every member state, regardless of its development status, was called upon to outline their "nationally determined contributions" to climate change mitigation for the post-2020 period. The scope of those

[115] WRI, 2017
[116] www.carbonbrief.org/paris-2015-tracking-country-climate-pledges
[117] UNFCCC, 2016-a, Item 38.
[118] UNFCCC, 2015-a, Article 4.4.

contributions was later clarified at the Lima COP20, and expanded to include "an adaptation component[119]" in addition to their mitigation commitments.

Each party's INDC documents were due for submittal by the end of first quarter 2015, in time for the Paris COP21. Now that the Paris Agreement has come into force, INDCs would then become "Nationally Determined Contributions" (NDCs) once a country would submits its ratification documents to the UNFCCC convention's secretariat. By June 2017, 146 countries had ratified the Paris Agreement, including most Arab countries who signed the agreement, except for Iraq, Kuwait, Lebanon, Libya, Oman, and Yemen (Table 5 below).

Table 5. PARIS AGREEMENT RATIFICATION: ARAB REGION STATUS[120].

Country	Signature	Ratification	Entry into Force
Algeria	22 Apr 2016	20 Oct 2016	19 Nov 2016
Bahrain	2 Apr 2016	23 Dec 2016	22 Jan 2017
Egypt	22 Apr 2016	29 Jun 2017	29 Jul 2017
Iraq	8 Dec 2016	-	-
Jordan	22 Apr 2016	4 Nov 2016	4 Dec 2016
Kuwait	22 Apr 2016	-	-
Lebanon	22 Apr 2016	-	-
Libya	22 Apr 2016	-	-
Mauritania	22 Apr 2016	27 Feb 2017	29 Mar 2017
Morocco	22 Apr 2016	21 Sep 2016	4 Nov 2016
Oman	22 Apr 2016	-	-
Palestine	-		
Qatar	22 Apr 2016	23 Jun 2017	23 Jul 2017
Saudi Arabia	3 Nov 2016	3 Nov 2016	3 Dec 2016
Sudan	22 Apr 2016	2 Aug 2017	1 Sep 2017
Syria	-	-	-
Tunisia	22 Apr 2016	10 Feb 2017	12 Mar 2017
United Arab Emirates	22 Apr 2016	21 Sep 2016[(a)]	4 Nov 2016
Yemen	23 Sep 2016	-	-
Notes: (a) Acceptance			

Both INDCs and NDCs are designed to facilitate climate change action coordination between national and international decision-making. However, their evaluation remains a challenge, because various parties selected "a wide variety of forms and contributions", mainly because of the lack of "agreed formats for reporting on mitigation contributions, including on the units in which those might be expressed[121]". Still, in aggregate, those contributions outline practical steps necessary to achieve "net zero emissions" by 2050. They outline:

1) The "level of ambition" in meeting climate mitigation targets. This helps determine the necessary means to enhance national mitigation efforts, be it financial, technological, or technical capacity.

2) How parties can hope to achieve mitigation "co-benefits" in coordination with their National Adaptation Programmes of Action (NAPA). For the Arab Region, the link between NAPA and INDCs is "a strategic necessity for purposes of development planning, because of the cross -cutting implications of climate change adaptation[122]".

Box 18 Binding Commitments

[119] UNFCCC, 2014, No. 12.
[120] UNFCCC, 2017-a.
[121] UNEP, 2015, p. xvii.
[122] ESCWA, 2017.

In spite of the wish of major negotiators such as the European Union, the Paris Agreement did not mandate that INDCs be made into hard "commitments", as the text "welcomes" all actors to scale up and demonstrate efforts, but does not "invite" them to do so. However, Article 4 of the Paris Agreement still contains an effectively "binding commitment" for countries to report every 5 years on their mitigation targets under their submitted INDCs. However, evaluation of INDCs impact remains a challenge, because of the variety of contribution types and parameters. They can be economy-wide absolute reduction from historical base year emissions; emissions reduction relative to a baseline projection for the emissions associated with energy consumption; trajectory target for specific sectors or gases; specifying a peaking year; emissions intensity of GDP; fixed level target…

In addition, the Paris Agreement contains provisions for enhanced transparency (Article 13), to help "self-differentiate" amongst the various mitigation intentions. Indeed, due to differing national development needs and capacities, current INDCs and NDCs differ in various aspects such as; (1) target years and baselines; (2) treatments for market mechanisms, carbon offsets, or carbon sinks; (3) approaches for setting emissions targets; (4) types of GHGs measured and tracked; (5) level of ambition. The difference is greatest regarding emissions, as pledged mitigation contributions focused on defining emission targets for GHGs and non-GHGs (72% of submissions). The rest of submissions either included a mix of non-GHG targets and actions (14%), or made only reference to intended climate actions (6%)[123]. Transparency ensures information is well-organized, quantifiable, comparable, and publically available. This will provide clarity for businesses, and thus guide investment in any "Green Infrastructure" by ensuring projects are properly targeted.

b) Limiting Warming: Technical Aspects

The current climatic change is largely the result of past technologies and policies. It results from continued accumulation of human GHG emissions, which exacerbate a "greenhouse" effect that increases surface temperatures. Those emissions have been accumulating since the onset of the industrial age, around 1840, and can be broadly attributed to the United States (~30%), European Union (~25%), followed by Russia and China (each about 10%), and Japan and India (each less than 5%)[124]. The solution will also require technology development and policy coordination. Any mitigation effort should either curb or stop the GHG emission growth, and therefore address the following physical facts[125]:

1) The effect of GHGs will persist for centuries, because they remain a long time in the atmosphere. Effective mitigation therefore requires a sustained, a long-term effort.

2) The current climatic change is directly linked to the profile of emissions, which have been increasing rapidly since the onset of the industrial age. The main emitters, at the time of Paris Agreement (December 2015), were[126]: China (22.7%), the United States of America (15.6%); the 28-member European Union (10.9%), India (5.7%); Brazil (2.6%); Russia (5.4%); Japan (2.9%); Canada (1.7%). The entire Arab Region accounts for about 4.9%.

3) Any temperature "target" implies a maximum amount of GHGs accumulated in the atmosphere.

    a) Every tonne of CO_2-Equivalent emitted causes about the same amount of warming, regardless of when and where it is emitted.

    b) Overshooting this GHG "budget" will also overshoot the temperature "target".

The Paris Agreement states two goals to limit climate warming with respect to pre-industrial levels. In addition to the 2°C target "inherited" from the Copenhagen COP19, it has an even lower aspirational goal of 1.5°C. Both these goals will not be met under either the BAU of the INDCs, as shown in Figure 3 below. Under BAU, the carbon "budget" would be insufficient to keep the Paris Agreement's 2°C target. It implies

[123] WRI, 2017
[124] WRI, 2014.
[125] IPCC, 2013.
[126] WRI, 2017. Numbers to do not take into account land-use change and forestry.

a "budget" of about 270 Gigatonnes of Carbon Equivalent that will be exceeded within 20-32 years of the agreement's date, by 2035-2047, long before the end of the Century[127]. The 1.5°C aspiration's carbon budget is even smaller, and would be depleted[128] by 2020-2030. Under INDCs/NDCs, a significant "emissions gap" remains. Intended mitigation measures are "most consistent with scenarios that limit global average temperature increase to below 3.5°C until 2100 with a greater than 66% chance[129]".

Box 19 IPCC: Likelihoods and Model Simulations

When the IPCC AR5 estimates carbon budgets for any given target, it provides "likelihoods" of staying below the temperature increase over a certain period of time (66%; 50%; 33%). This represents the proportion of all model simulations that generate this result. As an example, a probability of 50% of overshooting the 2°C within by 2035 under BAU scenario means that about half the models simulations gave this result.

[127] Friedlingstein et al., 2011; Rogelj et al., 2011.
[128] The IPCC's "Special Report on 1.5°C Global Warming" (SR15) is due in mid-2018.
[129] UNEP, 2015, p.xvii.

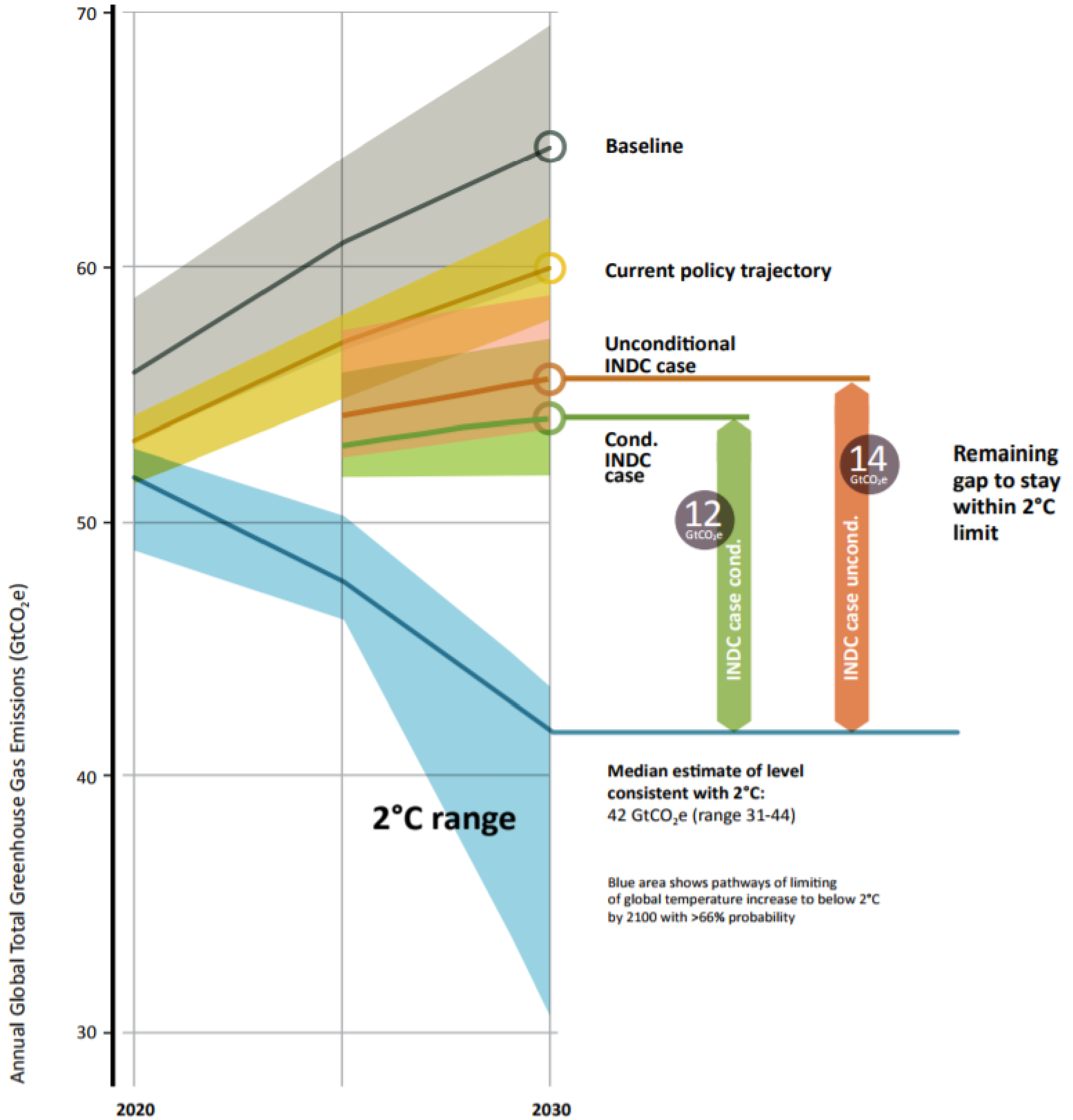

Figure 3. The Emissions Gap[130].

It is technically possible to cost effectively close this "ambition gap" in time to ensure warming does not "overshoot" the target. However, computer modeling suggest that delays in increasing the level of ambition would require "economically less attractive options", featuring "higher and/or later [emission peak] with steeper declines afterwards[131]". Until 2020-2030, it is possible to enhance mitigation through proven technologies and policies, and thus meet the Paris Targets. Those technologies focus on energy production and use, land use, and human settlements, in an attempt "decouple" GHG emissions from economic development and population growth. The risks associated with a heavily technological approach are

[130] Adapted from UNEP, 2015, Figure ES2, p.xix.
[131] Rogelj, 2016, p.416.

unclear, as "even the most sustainable technologies have had unintended and known adverse impacts[132]". Beyond this, risks will increase, as effective mitigation would require unproven technologies.

This will be further clarified going forward, as part of the Paris Agreement's "ambition mechanism", a process to continue "strengthening" mitigation action through 5-year "cycles of action". This is an ongoing process to increase mitigation action, whereby a "Global Stocktake" of progress is made at 5-year intervals, and new NDCs are updated and submitted. The Parties are now set to reconvene for a "facilitative dialogue" in 2018. They will then will review progress made and outline any next steps; either they will submit new mitigation contributions, or they will update their existing NDCs. This will clarify technology needs and possibilities.

Box 20 Geo-Engineering: Reversing Climate Change?

Geoengineering is a proposed attempt to reverse Climate Change not through emission reductions, but through technological means. The methods remain largely speculative, and follow either of two types ;

(1) Affect directly the increase in temperature by reducing the "forcings" that contribute to the increase, such as the incoming solar radiation, the reflectivity of the surface and the oceans, the rate of absorption of GHG through the oceans; the mix of gases or particulate matter in the atmosphere…

(2) Remove the GHGs that have already been released into the atmosphere, and thus decrease their concentration. The GHGs would then be sequestered away into underground reservoirs or rock formations, though there are suggestions that it be dumped into the deep ocean.

An obvious limitation of such proposed interventions is their scale and the related policy implications. The main limitation is related to the fact that, for most of these methods, the concept is extremely speculative and the underlying science remains poorly understood, and the effects far too complex to model effectively and safely. However, many of the proposals are advance to promote scientific debate and help understand atmospheric dynamics better.

B. Technology Transfer and Adaptation, and SDGs

The Paris Agreement and the SDGs are complimentary. Its agreement's ambitious goals could only be met through concerted efforts from national governments and significant support for developing countries. There are, however, areas where the agreements can conflict, due to improper implementation. The success of both the agreement and the SDGs therefore rests on coordinated technology transfer and appropriate support mechanisms for developing countries.

Box 21 What is Technology Transfer?

Technology transfer generally involves some transfer of knowledge, whether "hard" (technical), or "soft" (managerial).

Technology is transferred with the purchase of new equipment. In theory, technology transfer would include skills and capabilities for (1) operation and maintenance, (2) production or adaptation, or (3) improvement or development. In practice, however, "Technology Transfer" often means only purchase of new equipment that only a few countries develop and manufacture.

1. The Paris Agreement and SDGs

UNFCCC principles clearly state that "the Parties have a right to, and should, promote sustainable development[133]", and SDGs specifically acknowledge the UNFCCC as "the primary international, intergovernmental forum for negotiating the global response to climate change[134]". The development of the SDGs is "closely linked to climate change", because of "the importance and interlinkages of the climate and the post-2015 development agenda processes[135]". Indeed, the 2030 Agenda for Sustainable

[132] UN, 2016, p.52.
[133] UNFCCC, 2015-a, Article 3.4.
[134] UN, 2017, SDG Goal 13.B.
[135] UNFCCC, 2015-b, No. 92, p.22.

Development is unlikely to succeed under BAU, because of the comparatively higher impacts on the economies of developing countries.

This alignment is concretely reflected in the Paris Agreement through specific references. The text calls for the parties to collaborate "in the development, application and diffusion, including transfer, of technologies, practices and processes" that serve to reduce GHG emissions, in the sectors of energy, transport, industry, agriculture, forestry and waste management[136]". Those sectors correspond to SDG 7 (energy), SDG 11 (cities), SDG 9 (industrialisation), SDG 2 (zero huger), and SDG 15 (forests). Furthermore, the agreement requires the parties to "promote sustainable management" of such resources as "biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems[137]", which correspond to SDG 14 (oceans, seas and marine resources) and SDG 15 (terrestrial ecosystems, forests, desertification, land degradation and biodiversity).

This is reflected in the INDCs/NDCs, where both conditional and unconditional climate actions align with at least 154 of the 169 SDG targets (Figure 4 below). The Paris Agreement further facilitates such linkages through "a mechanism" that promotes "the mitigation of greenhouse gas emissions while fostering sustainable development[138]", recognizing that "mitigation co-benefits resulting from Parties' adaptation actions and/or economic diversification plans can contribute to mitigation outcomes[139]".

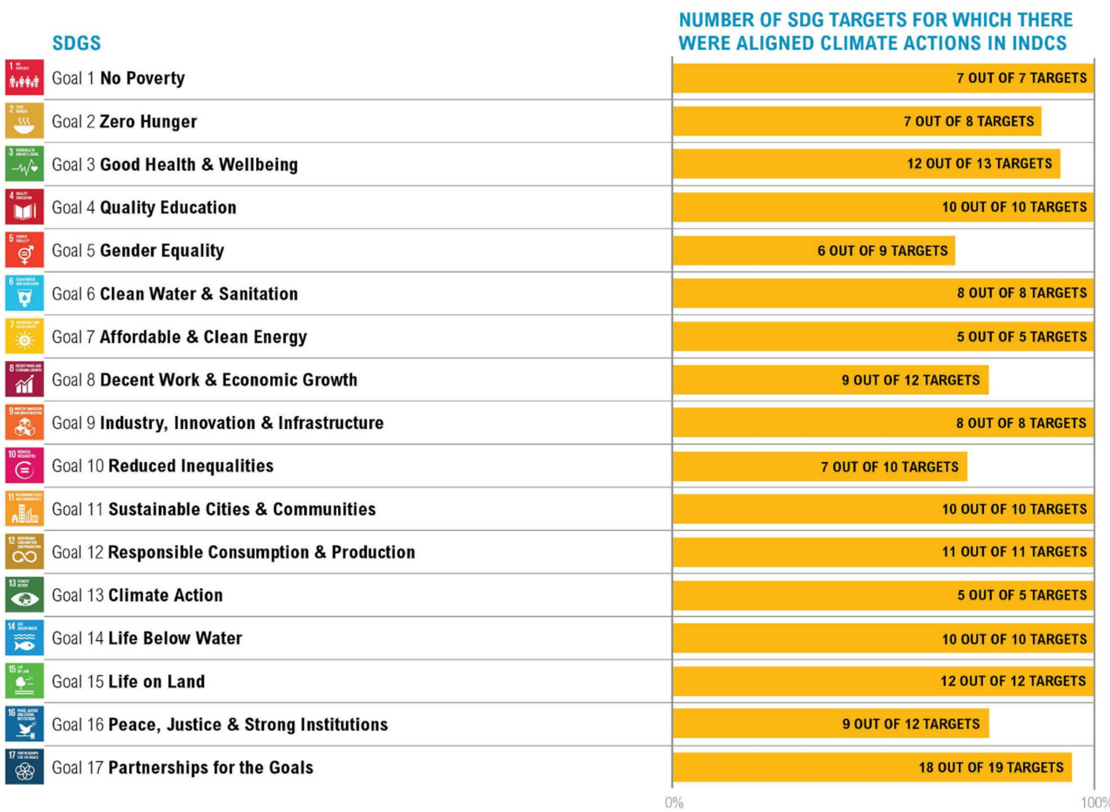

Figure 4. Alignment between the SDGs and the INDCs/NDCs[140].

[136] UNFCCC, 2015-a, Article 4.1.c.
[137] UNFCCC, 2015-a, Article 4.1.d.
[138] UNFCCC, 2015-a, Article 4.6.a
[139] UNFCCC, 2015-a, Article 4.7.
[140] WRI, 2016, Figure ES1, p.3.

In spite of the alignment, there are areas of conflicts and trade-offs within the SDGs, and between them and the Paris agreement. In some cases, progress towards one target unintended effects on others. For example, without the proper technology transfer, rushing to expand the food supply (SDG 2) could lead to unsustainable agricultural practices. Those practices would undermine efforts conserve and restore ecosystems, endanger water supplies, but also increase GHG emissions through inefficient energy usage and damage carbon sinks through soil erosion. Furthermore, without appropriate technologies, "circular effects" can reinforce conflicts between the objectives. For example, expanding access to transportation (target 11.2) "is likely to lead to higher greenhouse gas emissions (target 13.2)" and undermine efforts to reach the Paris targets, "while measures taken to reduce greenhouse gas emissions can constrain transport access[141]".

2. Technology Transfer and Adaption, and SDGs

Technology is an important tool for both combating climate change and for the achievement of the SDGs. It is also "a double edged tool" that providing solutions while also adding new challenges. Some technologies contributed to human emissions and climate change, while other developments help solve this challenge and sustain economic development.

As Science, Innovation, and Technological Development (STI) "co-evolve", the changes are non-neutral, and often "biased toward capital and skilled labour[142]". The resulting distributional effects could then increase inequalities, unless knowledge and tools are shared. The transfer and adaptation of technologies is therefore vital to secure the goals of the Paris Agreement while still achieving Sustainable Development.

Technology is generally **transferred** and adapted through (1) new equipment acquisition, and the transmission of skills sufficient to operate and maintain it, and can lead to (2) the ability to produce similar equipment domestically or adapt the technology to local conditions.

1) Technology transfer through **trade** or **Foreign Direct Investment (FDI)** is generally limited to skills sufficient enough to operate and maintain the new equipment. When equipment is purchased, there is often little interaction with the supplier beyond turnkey projects or service contracts. In the case of a wholly owned subsidiary of a multinational firm, technology is transferred form the parent company.
2) **Joint Ventures** or **Licensing** provide the ability to produce similar equipment domestically or adapt the technology to local conditions. Joint ventures are more "hands on", involving multinational corporations and local firms with market reach. In Licensing, local firms simply acquires Intellectual Property (IP).

A significant amount of technology transfer and adaptation already occurs in the Arab Region as part of normal business operations[143]. The resulting accumulation of technological capabilities is facilitated by modern Information and Communication Technologies (ICT). However, ICT also magnifies the risk "technology loss", because newer information storage media and formats are increasingly "backward incompatible" and cannot access obsolete systems. This risk is compounded by the fact that a technical knowledge is "informal" and thus undocumented. This "**ten-year-itis**" occurs gradually, over the course of 10 to 15 years, as staff quit or retire, and the key documentation becomes hard to access.

Box 22 "Ten-year-itis": Technological Change and "Legacy" Knowledge

In 2000, the United States Navy needed to upgrade its W76 thermonuclear warheads. However, the plans were delayed because the US National Nuclear Security Administration (NNSA) had "**forgotten**" how to manufacture a critical component, codenamed "Fogbank". Even after the NNSA managed to rebuild the production systems, it struggled to fully replicate the process and re-manufacture the component. Whenever a

[141] ICSU, 2017, p. 26
[142] UN, 2017, p. 42.
[143] Lema and Leman, 2013.

> successful batch was produced, "personnel still did not know the root cause of the manufacturing problems". The NNSA had to carry out detailed investigations to fully re-establish production, and it took about 8 years to complete a 1 year project. The upgrades were only delivered in February 2009.
>
> Modern technologies such as the W76 design can be more easily "forgotten" than in the past. In this case, the design dated back to the 1980's. However, by 2000, little-used manufacturing plants had been dismantled, undocumented knowledge was lost when key personnel retired or passed on, and existing, formal documentation was incomplete, or inaccessible to modern systems.
>
> **Ref:** "Lost Knowledge Regained", Nuclear Weapons Journal, Issue 2 / 2009, Los Alamos, NM.

The transfer and adaptation of technologies also needs to focus on the SDG's main objective to "**leave no-one behind**". Otherwise, technology risks exacerbating inequalities among countries, and thus hindering sustainable development. To avoid such a risk, technology transfer and adaptation should be simultaneous with progress on equity, overall infrastructure, and institutions. The most promising policy actions therefore require (1) strengthening national innovation systems and (2) establish supporting institutions that can (3) develop plans and implementation roadmaps in a (4) socially inclusive manner[144].

1) National systems of innovation aim to accelerate technology progressand promote infrastructure performance improvements. This will also strengthen STI literacy, and promote a knowledge-based economy, multidisciplinary collaboration, and evidence-based policy-making;
2) Supporting institutions would promote R&D and leverage community knowledge. They would collect, share, and analyse data openly.
3) An increase in technology investments, to support plans and actions, with countries following "their own desired paths of economic diversification based" on their specific needs and national priorities. During the COP21 negotiations, developing countries had partially conditioned their INDCs on clear mechanisms for technology transfer and adaptation. This is reflected in their Nationally Appropriate Mitigation Actions (NAMAs) and National Adaptation Plans (NAPs).
4) Inclusive innovation policies would promote equity by facilitating access to technology for developing countries. Those policies can be based on an ecosystem approach, to address continually arising technology gaps.

This approach will help ensure that, as technology is transferred, any associated risks are not transferred as well. As "**there are no risk-free technologies**[145]", National Innovation Systems should be structure in such a way as to manage and mitigate any adverse impacts. At present, there are no clear provisions in the Paris Agreement to address this issue.

3. Mechanisms of Support

The UNFCCC has a formal mechanism specifically aimed at technology transfer, as well as a set of supporting instruments. The Technology Mechanism (TM) had been established in 2010 in support of climate change mitigation and adaptation. It has two components: a policy arm, the Technology Executive Committee (TEC), and an implementing institution, the Climate Technology Centre and Network (CTCN). A set of instruments also support technology transfer and adaptation, such as the Clean Development Mechanism (CDM) and the Green Climate Fund (GCF).

Under the **Clean Development Mechanism (CDM)**, developing countries' emission-reduction projects can earn certified emission reduction credits. As of June 2010, there were 4,984 projects in the CDM pipeline, in 81 countries, 3,778 of which formally involved technology transfer. A review of those projects revealed the following salient facts[146]:

[144] UN, 2017, p.45.
[145] UN, 2017, p.52.
[146] Murphy et al., 2013.

1) Most of the projects (85%) obtained technology from developed countries and China, the top suppliers being Germany, the USA, Japan, and Denmark. technology transfer tends to be lower for mature technologies.
2) A limited number of countries develop climate mitigation technologies relevant for CDM projects. Together, the US, Germany, and Japan generate 60% of patents.
3) Technology Transfer is often associated with larger projects, and 25% of the projects were limited to equipment imports.

It appears that "conditional funding" may be dominant in the CDM, as shown by a strong link between emission credit purchases in developed countries and technology supply (equipment purchases) for projects in developing countries[147]. **Transparency** would partially resolve this issue, by ensuing that Measurable, Reportable and Verifiable (MRV). As part of the Paris Agreement, transparency will be supported by a "capacity-building Initiative for Transparency", aimed at building "institutional and technical capacity, both pre- and post-2020[148]". This will clarify what type of technology is being transferred and how, and show where the funding is coming from.

The **Green Climate Fund (GCF)** became formally active in 2015, following the Paris Agreement. Established formally in 2010, at the Cancun COP16, the GCF had been first mentioned in the 2009 Copenhagen Accord. It had been established to support mitigation and adaptation action in developing countries. The Paris Agreement recognizes the need for mitigation actions to have adaptation co-benefits, as parties prioritize their "ability to adapt to the adverse impacts of climate change and foster climate resilience" while pursuing "low greenhouse gas emissions development […] in a manner that does not threaten food production[149]".

The GCF is updated regularly, through a "Global Stocktake" that occurs every 5 years, when parties communicate their adaptation priorities, needs and efforts. Every **2 years**, the parties also submit information on available climate financing provided or received. In this manner, the GCF facilitates "finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development[150]". This is consistent with either the 2°C goal or the 1.5°C aspiration. Funding is expected from both developed and developing countries. The Paris Agreement not only **requires developed countries** to update their expected "level of support" every 2 years, but also **encourages developing countries** to do so as well.

This level of support should amount to USD 100 Billion a year, at least till 2025. In order to minimize the risk of "conditional support", the Marrakech COP22 "encouraged" the increased "collaboration between national designated authorities for the Green Climate Fund and national designated entities for technology development and transfer[151]". However, developing countries generally struggle to secure funding because the GCF's accreditation process makes it hard for many public or private institutions to qualify.

C. The Arab Region Status with Respect to the Paris Agreement

To most countries in the Arab Region, the Paris Agreement appears to be an opportunity. For the most part, their submitted INDCs generally reflect the need for support on Technology transfer and adaptation.

1. Intended Nationally Determined Contributions of the Arab Region

All countries in the Arab Region had submitted their INDCs by October 4, 2017, with the exception of Libya, Syria (not a signatory to the Paris Agreement), and Palestine (not a party to the convention). Most

[147] Murphy et al., 2013.
[148] UNFCCC, 2015-a, No. 85.
[149] UNFCCC, 2015, Article 2, No.1.b, p.22.
[150] UNFCCC, 2015-a, Article 2.1.c.
[151] UNFCCC, 2017, Item 16.

looked post-2020, except for Algeria, Egypt, Jordan, Mauritania, Morocco, and Tunisia. Those countries submitted pledges for the pre-2020 period, focusing on mitigation co-benefits of their Nationally Appropriate Mitigation Actions (NAMAs). Additional emission reductions pledges were submitted for non-GHGs by Mauritania, Morocco, and Tunisia.

Arab countries' INDCs suggest different types of actions, with some setting specific targets, and others focusing on mitigation as a co-benefit of adaptation. Not all of them specify emission-reduction targets (Table 6 below).

1) Specific targets for emission reductions were set by Algeria, Iraq, Jordan, Lebanon, Mauritania, Morocco, Oman, and Tunisia. The main GHG gases targeted were Carbon dioxide (CO_2), Methane (CH_4), and Nitrous Oxide N_20. Additional targets were specified by Jordan and Oman for Perfluorocarbons (PFC) and Hydrofluorocarbons (HFC), and by Yemen for Perfluorocarbons (PFC) and Hydrochlorofluorocarbons (HCFC).
2) No specific targets for emission reduction were set by any of Kuwait, Qatar, Saudi Arabia, Sudan, and the United Arab Emirates.
    a) Kuwait stated that it will be operating under the BAU scenario for the period of 2020-2035, while still working on diversifying sources of energy for production. Qatar and Saudi Arabia specifically stated that they would be pursuing "adaptation actions with mitigation co-benefits" in various sectors, as well as economic diversification.
    b) Saudi Arabia made it clear that it intended to work on "reducing the impacts of response measures", in addition to implementing "Carbon Capture and Utilization/Storage" technologies.
3) The desire to undertake adaptation actions with mitigation co-benefits in various sectors was specifically expressed by Egypt, Bahrain, Qatar, and Saudi Arabia. Furthermore, Qatar and Saudi Arabia, stated that their mitigation actions would include economic diversification.

Box 23 Carbon Capture and Sequestration (CCS)

It is possible to capture carbon dioxide (CO_2) and store it into an underground geologic formation. The Carbon can be captured from either point sources (easier), or from the atmosphere (harder, and more energy intensive), and then injected into an underground geological formation such as a hydrocarbon reservoirs or salt formations. An application of this technique is used for Enhanced Oil Recovery,

Most Arab pledges are conditional on assistance in means of implementation such as external finance and technical capacity building. They link the success of mitigation efforts rests to technology transfer and adaptation.

INDCs that approach mitigation is a "co-benefit" of adaptation do so because of the cross -cutting implications of climate change. This lead to coordination between National Adaptation Programmes of Action (NAPA) and INDCs, which guides "green Infrastructure" investments, and ensures projects are properly targeted. Since there is apparently more funds for mitigation, any linked adaptation actions also qualify. , and thus funding would be easier. Furthermore, this is consistent with the spirit of the Paris Agreement, which calls for "finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development[152]".

[152] UNFCCC, 2015, Article 2, No.1.c, p.22.

Table 6. ARAB COUNTRIES' INTENDED NATIONALLY DETERMINED CONTRIBUTIONS (INDCS).

Country	Emission Reduction Target			Adaptation Measures	Notes / Implementation Conditions	GHG Share[(a)]
	Unconditional	Conditional	Year			
Algeria	7%	22%	2030	-	External financing; Technology development & transfer; Capacity building.	0.34%
Bahrain	-	-	-	Yes	"depends highly on the level of international support in means of implementation"	0.06%
Egypt	-	-	-	Yes	Aims at reaching "high CO_2 mitigation levels" by 2030, conditional on: External Financing (~ USD 73.04 Billion), and aid for both adaptation and mitigation.	0.56%
Iraq	1%	12%			National Security;	0.30%
Jordan	1.5%	14%	2030	-	External Financing: ~ USD 5,157 million; Support to means of implementation.	0.05%
Kuwait	-	-	-	-	Until 2020-2035, "move to a low carbon equivalent economy" by diversifying sources of energy for production, and avoid an increase in emissions above BAU projections, conditional on international support	0.19%
Lebanon	15%	30%	2030	-	Additional external support	0.04%
Libya	No INDC submitted as of October 2017.					0.16%
Mauritania	7%	22.3%	2030	Yes	External financing: ~ USD 9.3 Billion	0.03%
Morocco	13%	32%	2030	Yes	"gaining access to new sources of finance and enhanced support, compared to that received over the past years, within the context of a new legally-binding agreement under the auspices of the UNFCCC"	0.15%
Oman	-	2%	2030	Yes	"Assistance will be provided by the UNFCCC on finance, capacity building and transfer of technology."	0.12%
Palestine	Not a Party to the Convention					No Data
Qatar	-	-	-	Yes	"seeks to enhance the diversification of its economy away from hydrocarbon"	0.20%
Saudi Arabia	-	-	-	Yes	"to achieve mitigation co-benefits ambitions of up to 130 million tons of CO2eq avoided by 2030 annually"	1.05%
Sudan	-	-	-	Yes	Aims at ensuring "deviation from the current development trajectory to a low carbon development", conditional on: External funding for adaptation (USD 1.2 Billion); External funding for mitigation (USD 11.68 Billion); Technology transfer and capacity-building.	0.94%
Syria	No INDC submitted as of October 2017.					0.15%

Tunisia	13	41	2030[a]	-	External funding for adaptation (USD 2 Billion); External funding for mitigation (USD 18 Billion); Capacity Building; Technology Transfer.	0.08%
United Arab Emirates	-	-	-	Yes	"will pursue a portfolio of actions, including an increase of clean energy to 24% of the total energy mix"	0.39%
Yemen	1	13	2030	Yes	Financial assistance; Capacity Building; Technology Development and Transfer	0.08%
					Arab Region Share of Global Emissions:	4.89%

Notes: **(a)** Share of Total Greenhouse Gas Emissions (GHG) as of Dec. 2015. Ref: www.carbonbrief.org/paris-2015-tracking-country-climate-pledges
(b) Mitigation target is the 2010 baseline. Other Arab countries use their BAU projections as mitigation target baseline.

2. Technology Needs and INDCs

Technological change is proceeding at an accelerating pace in the current industrial revolution. Progress in research is increasingly relying on multi-disciplinary teams, as more than 30% of the references in scientific papers cite work in other disciplines[153]. In this increasingly complex environment, it is highly likely that, "by 2030, many new technologies will emerge, while current nascent or immature technologies will reach the commercialization stage and may help addressing some of the SDGs[154]", as well as the challenge of climate change.

While there is no way to predict which new technology will emerge, it is possible to outline technology clusters are crucial for the SDGs and the Paris Agreement's targets. Those clusters were identified by the Global Sustainable Development Report team through a survey of scientific communities around the world (Table 7 below). Those clusters involve many disciplines, and are centered on nanotechnology, Information and Communication Technology (ICT), biotechnology, and energy.

1) The cluster around **nanotechnology and material sciences** has the most far reaching implication. It affects many sectors; energy, manufacturing, resource extraction, water, waste management… and has the potential to enhance mitigation efforts. It also brings about unprecedented risks to human health (toxicity) and the environmental (nanowaste).

2) **Energy** technologies focus on two areas, renewable and sustainable technologies, and developments that enhance mitigation. Development in renewable energy technologies is already lowering the cost of clean, emission-neutral technologies. Concerning mitigation, there are some recent developments in the Arab Region through innovative, large-scale projects.

    a) In its INDC, Saudi Arabia's stated its "promote and encourage actions" in the field of "Carbon Capture and Utilization/Storage" technologies. The country plans "to build the world's largest carbon capture and use plant" to (1) "capture and purify about 1,500 tons of CO_2 a day for use in other petrochemical plants", and (2) test its use in "Enhanced Oil Recovery (CO_2-EOR)", in order "to assess the viability" of GHG sequestration "in oil reservoirs".

    b) There are investigation underway to determine methods to optimally use the unique rock formation in the Southern Arabian Peninsula to absorb CO_2, the main GHG. Those formations, apparently centered on the Oman's Al-Hajjar Mountains, contain high concentrations of Peridotite minerals that permanently absorb the carbon in the air. Omani Peridotite formations could be naturally absorbing anywhere between 10,000 to 100,000 tons of carbon every year, a process that could be accelerated significantly through means that leverage the region's experience with oil and gas drilling[155].

3) The **ICT** cluster is often enabling to other technologies such as manufacturing (automation, 3D printing or "additive manufacturing"), transportation (networking, tele-presence, and logistics planning), agriculture (farm management, hydroponics system control), as well as biology, energy… The cluster has branched out into various technologies, most recently into "Big Data" and networked tools and appliances, and has significant implications for all SDG targets. The main risk, however, is job losses at it skills are rapidly rendered obsolete and value chains are disrupted.

4) **Biotechnology** cluster is rapidly evolving around technologies such as proteomics, gene-editing technologies and genetic engineering and, in addition to bio-catalysis, synthetic biology, and sustainable agriculture tech. Biotechnology offer opportunities in SDGs areas such as food crops and human health, but also affect other technology fields such as material sciences. Biotechnologies can help mitigation efforts through its impact on fuel generation and waste recycling. However,

[153] van Noorden, 2015.
[154] UN, 2016, p.52.
[155] Kellemen and Matter, 2008; Streit et al., 2012.

some technologies in that cluster can create unprecedented and irreversible changes to the environment.

Further developments along those sectors will help the deeper development of a “green tech” cluster and a more “circular economy”. Resources would be optimally used and re-used or repurposed with resource-efficient manufacturing and agriculture, and infrastructures would be integrated, with multi-modal transportation systems.

Table 7. SOME CRUCIAL EMERGING TECHNOLOGIES FOR THE SDGS UNTIL 2030[156].

Cluster	Crucial Emerging Technology	SDG Opportunities	Threats
Biotech	Biotechnology and proteomics; Genomics; gene-editing technologies and custom-designed DNA sequence; genetically modified organisms (GMO); Stem cells and human engineering; bio-catalysis; synthetic biology; sustainable agriculture; Mass-customization of pharmaceutics;	Food crops, human health, pharmaceuticals, materials, environment, fuels	Military use; irreversible changes to health and environment.
Digital	Big Data and Data mining; "Internet of Things" and networked tools and appliances; distributed and "cloud" computing; open data and open source development; data sharing and online learning; mobile telephony; 3-D printing/additive manufacturing; micro-simulation; e-distribution; Integrated data acquisition and remote sensing systems; Virtual reality and tele-presence; Smart power grid and digital monitoring & security.	Development, employment, manufacturing, agriculture, health, cities, finance, governance, participation, education, citizen science, environmental monitoring, resource efficiency, social networking and collaboration	Unequal benefits, job losses, skills gaps, social impacts, poor people priced out; global value chain disruption; concerns about privacy, freedom and development; fraud, theft, cyberattacks.
Nanotech	Nano-imprint lithography; Applications for decentralized water and wastewater treatment, desalination, and solar energy (nanomaterial solar cells); artificial photosynthesis Organic and inorganic nanomaterials, metamaterials, and memory alloys; Enhance resource extraction and waste treatment;	Energy, water, chemical, electronics, medical and pharmaceutical industries; high efficiencies; resources saving; CO2 mitigation.	Human health (toxicity), environmental impact (nanowaste)
Neurotech	Digital automation, including autonomous vehicles (driverless cars and drones); robotics; smart technologies; cognitive computing; e-discovery platforms, personalization algorithms, enhanced artificial intelligence and machine learning; Handicap mitigation; brain-machine interface; augmented reality.	Health, safety, higher efficiency, resource saving, new types of jobs, manufacturing, education.	Unequal benefits, de-skilling, job losses and polarization, widening technology gaps, military use, conflicts.
Greentech	Circular economy: technologies for remanufacturing, technologies for product life-cycle extension such as re-use and refurbishment, and technologies for recycling; multifunctional infrastructures; technologies for integration of centralized systems and decentralized systems for services provision; CO2 mitigation technologies; low energy and emission technology. **Energy**: off-grid electricity systems, mini-grids, and smart grids; energy storage; heat pumps; for space heating, heat and power storage and electric mobility; enhanced energy recovery; biofuel supply chains; renewable energy systems; salinity gradient power technology; energy-efficient lighting; **Transport**: integrated public transport infrastructure, energy efficient vehicles; **Water:** water and wastewater management water technology, advanced metering; **Buildings**: sustainable/smart building, passive heating/cooling. **Agriculture**: Sustainable agriculture; hydroponics; bio-based products and processing; low input processing and storage; horticulture techniques; efficient irrigation; application of biotech;	Environment, climate, biodiversity, sustainable production and consumption, renewable energy, materials and resources; clean air and water; energy, water and food security; development, employment; health; equality.	New inequalities, job losses; concerns about privacy, freedom and development.

[156] Adapted from UN, 2016, Table 3.3, p.53.

Other	Assistive technologies for people with disabilities; alternative social technologies; fabrication laboratories; radical medical innovation; geo-engineering technologies (e.g. for iron fertilization of oceans); new mining/extraction technologies (e.g., shale gas, in oceans, polar, glacier zones); deep sea mining technologies;	Inclusion, development, health, environment, climate change mitigation, resource availability	Pollution, inequalities, conflict.

IV. TECHNOLOGY OPPORTUNITIES FOR SUSTAINABLE DEVELOPMENT

Technological breakthroughs are already having significant socio-economic impacts, as various production sectors evolved from labour-intensive and resource-hungry "perspiration economy" to a more productive and resource-efficient "inspiration economy[157]". The resulting "Fourth Industrial Revolution", through "a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres", is disrupting "almost every industry in every country", and heralding "the transformation of entire systems of production, management, and governance[158]".

A. TECHNOLOGY AND INVESTMENT

The Implementation of the SDGs is both a technological and social challenge, and rapid technological development may already be driving changes in the Arab Region perpetually. This accelerating pace of change will require more adaptation, planning, design and control from individuals, governments, community institutions and enterprises. As a result, both policymakers and business managers need to plan ahead, and try to account for future trends in technology.

1. Forecasting Science and Technology Development

Specific technological developments remain hard to forecast. However, the general foresight of successful future technologies can be understood as a balanced act between missing speedy risky opportunities and conservative slow adaptation. Those frontier technologies are expected to consume resources responsibly, deliver expected performance effectively, empower people inclusively, and reward investments generously which will support Sustainable Development (SD). However, they will also be less labour-intensive, requiring input from a talented labour. Furthermore, markets in developing countries may settle for "turn key" purchase and struggle to "absorb" the new technologies, as they may lack developed infrastructures and skilled talents.

Therefore, SDG targets relevant for STI require improvements in many key areas such as poverty and inequality, health, gender, institutional capacity, education, urban planning and land degradation, as well as International cooperation for trade, technology, and finance. The main technology clusters that will affect are crucial for the SDGs will affect resource management, and are likely to involve many disciplines, centered on nanotechnology, Information and Communication Technology (ICT), biotechnology, Artificial Intelligence and Robotics.

The challenge remains in the detailed policy formulation, which would require both quantitative and qualitative forecasts. Even those specific issues are hard to define well enough to quantify parameters and establish benchmarks; the market penetration of solar power, for example, does not only depend on cost of production, but also on cost of storage, a domain in which progress is only starting. Furthermore, qualitative techniques that rely on human judgement could be mistaken, since expert consensus can often miss the real impact of specific technological applications, let alone technological evolutions. This is because the challenges are "entangled", with any given process influencing others in ways that cannot be foreseen, and are only obvious "after the fact".

Box 24 Why Forecasts Fail

A review of various experiences suggests the following facts about forecasts (*):

- Forecasts cannot rely on extrapolating patterns and relationships from the past to the future. While the future often appears similar to the past, there remains enough differences;

[157] Krugman, 1994; Mahadevan, 2007.
[158] Schwab, 2016.

- Models can be misleading; while statistical models can very well describe "past data", there is no guarantee that they will "fit" future data. In many cases, simple models can provide more accurate forecasts than more complex models, albeit still with large errors.
- Human judgement is also a poor guide to forecasts. Experts are more likely to fail at forecasting than average persons, but still tend to overestimate their own accuracy.

However, it appears that the "averaging" of various independent predictions leads to better forecast. Forecasts used in climate change modeling rely on such an approach, using "ensemble" predictions of various, independently developed models.

(*) Makidrakis et al, 2010.

2. Technology's Impact on Business

In this new technology environment, both business leaders and policy makers face a similar challenge. They operate rapidly in a fast changing world by altering their "concept of business" or "scope of activities" to adapt to the new environment.

Traditionally, businesses "partition" problems, drawing a "virtual box" around the part that they control, and focusing minimally on effects that "propagate" beyond this box. This allows them to concentrate on design ramifications within their organizational and technical "boundaries". This approach, while practical, has limitations as the pace of technological change accelerates. As organizations struggle to get the latest technologies "out in the field" in time to effectively benefit their bottom line, they find that investments made in previous business cycles are as much hindrance as help. Indeed, from cycle to cycle, businesses build up a "legacy" of applications and systems that require ongoing maintenance and support before any further innovation can be considered. In many cases, this problem is compounded by the fact that many of those systems are not always compatible with each other. Furthermore, the skills required to maintain a relatively recent system do not "transfer" well to the newer system.

The net result is that businesses increasingly have to manage a set of competing priorities, which may distract them away from the adverse impact of disruptive technologies.

1) On one hand, advanced technology appears to be a "game changer" that will pull leaders and laggards apart. It creates "runaway winner" effects, where the few companies that make it across the "technology divide" grow rapidly, while the rest reach the limits that their original business structure imposes on them.
2) On the other hand, many other businesses remain shielded from technological change by regulation, geography, or other happenstance.

However, most businesses are not shielded from "winds of change". In order to remain competitive, they struggle to leverage their own business ecosystem. An example is Information Technology (IT); by 2015, many enterprises were allocating as much as 20% of their organization's revenue on IT investment, compared with 2% in previous years[159]. Those were not productive investments, as they were often devoted mostly the maintaining "legacy" systems, due to the growth in complexity of new enterprise products and platforms. Many organizations may find themselves spending more and more, with no guarantees they would not "fall behind" the technology race.

The way forward is for businesses to operate in a business ecosystem where they can focus on their own critical path for market differentiation, while their partners assist them in the day-to-day running of other systems. This is best done in a context where a public-private partnership is reinforced, and where R&D and business development are well coordinated.

[159] Tennant, 2015.

Box 25 "FANG" Stocks and "Legacy" firms

Among the best performing firms are advanced technology companies grouped in the much touted "FANG" stocks (*); Facebook, Apple, Amazon, Netflix, and Google. Their market capitalization of together make up more than USD 2 Trillion as of June 2017. However, there are "legacy" firms that perform just as well. An example is the risk-averse Berkshire Hathaway conglomerate, whose market capitalization, as of June 2017, was high as any of the much touted high technology firms, and is still growing.

(*) www.wsj.com/articles/the-growing-peril-of-index-funds-too-much-tech-1514457003

3. Technology's Impact on Society

Together with its many opportunities, technology imposes risks on society. One of such risks is "technological unemployment", whereby the introduction of more productive machines causes short-term job losses as the labour force struggles to adjust.

Because of the accelerating pace of technological change, many will likely struggle to retrain and adapt, as shown in the case of the US oil industry. Since 2014, there has been "divergence between trends in rig counts and employment on the one hand and oil and the trends of natural gas production on the other". As shown in Figure 5 below, employment declined by 26% between 2014 and 2016 while rig count increased. In addition, production also increased, from about 6 Million Barrels Per Day in 2013, to more than 9 Milllion Barrels Per Day in 2016[160]. To a large extend, this was achieved thanks to greater automation, with new automated oil rigs doing, with 5 workers, a job that had required 20 previously[161].

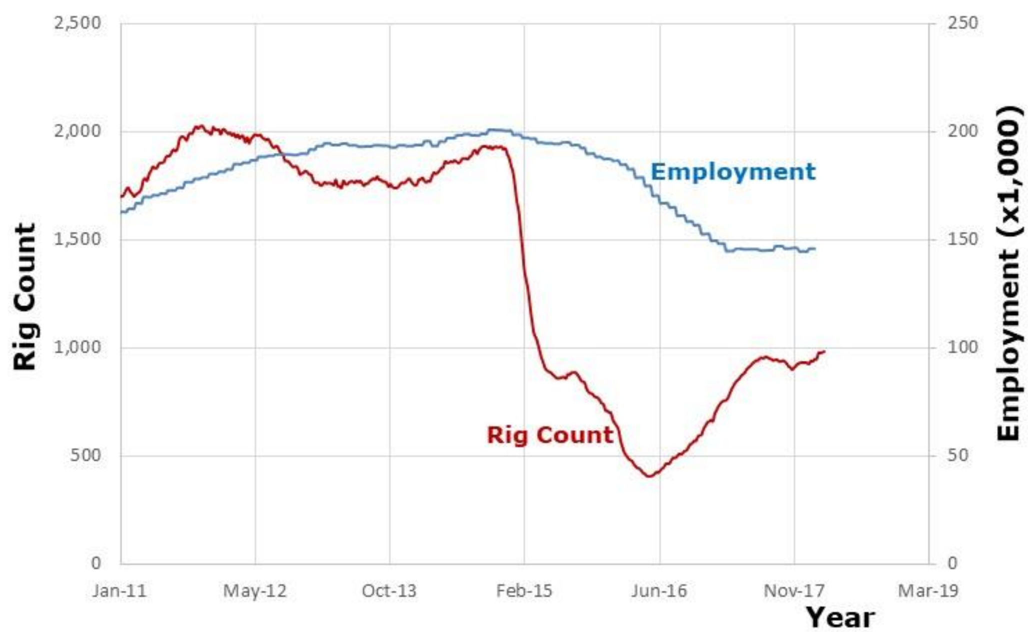

Figure 5. Employment and Rig Count in the US Oil and Gas Sector[162].

While it is unclear whether "technological unemployment" will be a lasting effect of increased automation, it is certain that the mix of jobs in the marketplace will change. This will require an integrated policy approach that takes into account the need for educational innovation and retraining. Planners would therefore need to ascertain whether there are net technologically-driven job losses and to map them, taking

[160] https://www.eia.gov/todayinenergy/detail.php?id=27392
[161] https://www.nytimes.com/2017/02/19/business/energy-environment/oil-jobs-technology.html
[162] Adapted from: Baker and Hughes, 2018 and US Bureau of Labour Statistics, 2018.

care to identify any related underemployment, precariousness. In some cases, inequality may arise due to lack of relevant skills, while some jobs remain immune to technological change, and some occupations may therefore expand at the expense of another. The planning horizon will also change as longevity continues to increase, as the pattern for old-age dependency continues to evolve.

4. Meeting the STI Challenge

The technological, financial, and social nature of SDG implementation poses a unique challenge. Technically, the knowledge available is generally “formative”, and many technical problems are interconnected, with often incomplete or contradictory information. In addition, the level of complexity is such that the challenge may involve a large and diverse set of stakeholders, and impose large economic burdens. Socially, aspects are often interconnected; while poverty is linked to education, so are food and health, Technologies can help address those problems, but require a holistic approach that involves policymakers, business managers, and researchers.

The challenge of developing and harnessing STIs to further the SDGs has an indeterminate scope and scale. It has the following characteristics.

1) There can be no definitive formulations for various aspects of social issues. For example, while poverty can be understood in terms of household income, it differs across countries and locations for any given level of income. There are therefore many possible explanations for any given challenge, each hinting at different solution “pathways”.
2) Success is often hard to define. Any given STI deployment cannot be strictly “designed” to implement a specific SDG. As social challenges “bleed into” one another, so will the impact of any specific STI. A consequence is that there is no specifically guaranteed “steady state” of the “system” once a solution is implemented.

This challenge therefore needs to be approached not as a simple infrastructure design problem, but through a methodical and rigorous iteration that “stays the course” to generate incremental improvements. This approach requires perseverance through interdisciplinary collaboration across all the fields of applied sciences, both technical and socio-economic.

B. Technology and Sustainability

STIs are critical for progress towards the SDGs, just as they “were critical in achieving” the previous Millennium Development Goals (MDG). The role of STIs extends “beyond industrial growth”, and is expected to prove “critical at each and every stage of development[163]”.

In spite of the difficulty in forecasting technological development, it appears that multi-disciplinary research is key to progress in the post-2015 agenda. Such multidisciplinary technological innovations will form the basis of the move towards sustainable development, and efforts to support climate change mitigation and adaptation. Progress will focus on “clusters” around Digital technologies, nanotechnology, biotechnology, Robotics and Artificial intelligence.

Digital technologies were ushered in with the invention of the transistor in 1947, the seminal technology that made possible the electronics revolution. This allowed two revolutions that shaped the rest of the century. First, the **electronics** revolution that brought about sweeping changes in electrification and industrialization. Second, the resulting emergence of **Information and Communication Technologies (ICT)**, which ushered massive economic, social and technological shifts. Progress in ICTs, materiel science, and instrumentation are enabling a “Fourth Industrial Revolution” characterized by a “transition to

[163] UNESCO, 2015.

a new set of systems, bringing together digital, biological, and physical technologies in new and powerful combination[164]".

Nanotechnology is not a single technology, but rather an enabling and potentially disruptive set of technologies. The applications center on the physics of very small scales, which allow for direct control over fundamental properties of matter. At the small scale, the resulting "nanomaterials" have novel properties, and the field of application has been fast growing. The effects are felt at the large scale, and nanotechnology cluster have disrupted various fields and sectors, from manufacturing, resource mining, energy generation, medicine, biology and agriculture, desalination and water treatment, to telecommunications and electronics…and others. There is not yet a classification of the nanotechnology firms. However, based on the current mix of applications, nanotechnology companies can be grouped into at least 6 categories; (1) nanomaterials processing, (2) nano-biotechnology, (3) nano-chemistry, (4) nano-photonics, (5) nano-electronics and nano-instrumentation, and (6) nano-energy. They follow either of two approaches; most are focused on "**dry nanotech**" based on electronics and materials engineering, but there is a growing number of companies that follow "**wet nanotech**" approaches, building structures using proteins or DNA and using the machinery of life.

1) Companies that focus on **nanomaterials manufacturing** build the technology's "infrastructure", creating products that are either (1) new structures (such as fullerenes, carbon nanotubes and nanofibers), or (2) nano-scale forms of familiar materials (such as nano-silica or nano-aluminum). The techniques are still under development, and research is interdisciplinary, involving not only materials science and engineering, but also physics, chemistry, and biology. Production methods are either "top-down" or "bottom-up":
    a) **Top-down** manufacturing methods start from large size "bulk" materials, and decrease the size to the required scale. By 2017, this was still the most common method of manufacturing nanoscale materials, with techniques such as etching or lithography used to make electronic circuits, and mechanical milling used to create nanoparticles. Those techniques tend to be resource-intensive and generate waste byproducts.
    b) **Bottom-up** approaches have the potential to be far more resource-efficient, since they arrange atoms or molecule building blocks into larger scale nanostructures. They also result in nano-materials with more precise structure, shape, size, and chemical composition.
2) **Nano-chemistry** is a hybrid field that combines nanotechnology with chemistry (new alloys or catalysts). The technology has immediate implications for coatings and fibers, and will have long term applications in resource extraction and manufacturing.
    a) Many applications are currently available thanks to a growing variety of additives or surface treatments. Fabrics are being made resistant to wrinkling, staining, bacterial growth, more resistant to tears. Nanoscale films are now available for lenses, windows, and displays to make them self-cleaning, resistant to ultraviolet or infrared light, fogging, antimicrobial, scratch-resistant, and electrically conductive for solar power applications…
    b) Thanks to the addition of peizofibers or thermocells, "smart fabrics" may gain the potential to generate energy or power electronics.
    c) Nanotechnology has many applications already changing the management and consumption of natural resources such as water. In one case, "solar steam devices[165]", initially developed to increase the efficiency of steam generation in power plants, can be used to generate steam from

[164] WEF, 2016, p.4.
[165] Boyd, 2012.

direct sunlight to purify water or disinfect instruments. More recently, a system is being developed that allows efficient water capture from air[166] at humidity levels as low as 20%.

d) The manufacturing sector will greatly benefit from applications of "3D Printing" and catalysis. In the petrochemical industry, nano-catalysts allow significant improvements in process efficiency by reducing the amount of catalytic materials needed, as well as any process-related pollutants.

3) **Nano-biotechnology** is another hybrid field that combines nanotechnology with biology for applications in such fields as medicine or agriculture. In medicine, nanoparticles are being clinically investigated as potential tools to treat disease or support surgery. Currently investigated applications focus on nano-assemblages that either target disease directly, or elicit an immune response. Nano-scale assemblages can carry medication to target and "mop-up" cancerous stem cells[167], or diseased body tissue[168]. In another role, those assemblies are built to resemble human molecules such as HDL Cholesterol, specific antibodies, or even to serve as a vaccine scaffolds[169], which will allow them to easily elicit, in a targeted manner, either the body's repair mechanisms[170] or its immune response[171]. In some cases, those assemblies make use of unique small-scale physics to act as nano "robots" to carry out specific tasks inside cells[172].

4) **Nano-photonics** focus on applications in optics, some of which has implication for the next generation of computers and communication networks. Already, applications are being developed to improve current devices, such as high efficiency light bulbs that are both shatterproof and compact, based on specially engineered polymer matrices, or organized material structures[173].

5) Continuing miniaturization of transistors and computer memory is now leading to **nano-electronics** and **nano-instrumentation**. In principle, transistors' decreasing size and thickness could lead to "2-D electronics[174]" made up of a single layer of atoms; from 130 to 250 nanometers (nm) in size at the onset of the 21st Century, the scale went down to 14-nm in 2014, 7-nm in 2015, and then 1 nm in 2016[175]. However, because of the behaviour of electrical current at the very small scales, it was not clear if a limit was reached beyond which electrical leakage would render the circuits useless. By 2018, the potential for one-atom layer thick "atomristor[176]" for computer memories is now demonstrated. What remains to be seen is what material those circuits would be made of, as there is a variety of materials that can form honeycomb structures; graphnene, silicene, phosphorene and stanene, in addition to atom-thick allotropes of silicon, phosphorus, or tin.

6) Nano-energy applications focus on improving key elements of energy; production, efficiency, storage, and transmission.

a) The technology can benefit energy **production** in a variety of ways. One example is flexible piezoelectric nanofibers can generate electricity when bent, suggesting they could even be included into clothing. Another example is "thermocells" that generate electricity when differentially heated, as in the case of processes that generate waste heat. Nanotechnology can also enhance fuel production by allowing for more efficient processes; this will not only increase

[166] Kim et al., 2017.
[167] Misra et al., 2017.
[168] http://www.imperial.ac.uk/news/180347/nano-sized-drug-carriers-could-future-patients/
[169] Xiaowei, et al., 2012.
[170] Yi et al,. 2016.
[171] Leneghan et al., 2017.
[172] Gu et al., 2010.
[173] Chen et al., 2013; Zhou et al., 2014.
[174] Kolodziejczyk, 2015.
[175] Desai et al., 2016.
[176] Ge et al., 2018.

the efficiency of traditional processes, but also allow access to low grade raw materials that would not otherwise be cost-ineffective.

b) **Efficiency** benefits from new lubricants based on nanomaterials such as inorganic "bucky balls" to significantly reduce friction[177].

c) In **solar** energy, the use of nanomaterials allows for: (1) lower manufacturing costs through novel processes such as low temperature "printing" or "painting" processes; (2) easier and cheaper installation by replacing fragile rigid crystalline panels with more durable flexible polymer rolls or silicon thin films; (3) increased efficiency of converting light to electricity, thanks to "quantum dot" technology refer. In **wind** energy, carbon nanotubes allow to improve strength-to-weight ratio of fan blades, thus increasing a turbine's efficiency. refer

d) The technology has the potential to improve energy **storage**, both for novel fuel cells and for electrical batteries. Thanks to hydrogen fuel cells based on grapheme or sodium borohydride that allow to store more fuel for less weight. In electrical batteries, nanotechnology can help improve existing design through (1) better, less flammable electrodes; (2) enhancing available power and recharge speed, thanks to coatings that increase electrode surface areas; or (3) improving separation among component materials, thus preventing low level discharge. refer

e) Nanotechnology can help reduce **transmission** losses, as in the case of wires upgraded with carbon nanotubes to give them significantly lower resistance than traditional materials. refer

7) **Biotechnology** now applies to a wider sector, beyond the focus on food production. This sector has been playing an increasingly important role since the "Green Revolution" that multiplied worldwide agricultural production in the middle of the 20th Century through the various R&D and technology transfer initiatives. In the post-2015 agenda, progress is expected to extend beyond past improvements to agricultural yields and food security, to future developments in human health, and even in waste-to-energy applications[178].

a) Biotechnology is expected to impact human health thanks to progress in biopharmaceuticals, gene therapy, and pharmacogenetics. Unlike current synthesized pharmaceuticals, **biopharmaceuticals** are produced from biological sources, and a more akin to the body's own molecular compounds. Gene therapy has the potential to treat or prevent diseases by targeting genes for removal or inactivation, or by adding new ones. The same advances allow to map drug metabolism at the individual level; pharmacogenetics allow the determination of the genes that define key drug metabolic pathways.

b) Biotechnology may contribute to solving waste management problems, a key sustainability challenge. It would allow "waste-to-energy" through the conversion of cellulose into ethanol. Research is proceeding on engineered bacteria or enzymes to break down cellulose into sugars that can then ferment into ethanol.

8) Nanotechnology in **Robotics** is opening-up entirely new avenues, based on both "dry" and "wet" nanotech.

a) In the medical field, "wet" nanotech allow for more precise drug delivery mechanisms and new medical sensors. For example, microscopic bacteria-powered robots have been demonstrated that can navigate a complex environment[179].

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[177] St.Denis et al., 2011
[178] UNESCO, 2015.
[179] Kim and Kim, 2015.

b) In "dry" nanotech, nanorobot motors use energy far more efficiently. The force per unit-weight of some systems far exceeds those of motors or muscle[180], and the size of the demonstrated nano-engines have been decreasing steadily, from 10,000 particles to little more than a single atom[181].

9) **Artificial intelligence** could greatly benefit from nanotechnology application, not least thanks to improvements in information storage and retrieval. DNA-based information storage devices have been demonstrated with 700 Terabytes of data stored in a single gram of material[182]. Information storage and encryption was demonstrated by the "DNA Storage Bitcoin Challenge", where an encrypted bitcoin was encrypted in DNA, and later recovered[183].

C. Technology Opportunities in Arab Countries

The Arab region is making inroads in the main STI areas relevant for the SDGs. In many cases, this progress was at the same pace as the developing world, and current advances therefore can contribute to the achievement of SDGs.

1. Current Status

The business environment is improving in many countries of the Arab Region, as suggested by surveys of global competitiveness[184].

1) Gulf countries such as the United Arab Emirates, Qatar, and Saudi Arabia tend to rank high in global competitiveness, thanks to their institutional framework, infrastructure, macroeconomic stability, and ICT sectors that are gathering strength.
2) Countries with fewer resources, such as Jordan and Morocco, were still able to rank high thanks to their educated population and efforts to diversify the economy. This would allow countries to build-up a "critical mass" of people trained for the new technologies, such as the "next tech leaders" launched in 2016 in Egypt, which has already graduated 5,000 youths.

Thanks to this relatively developed base, the region may be better served by focusing more on "scaling up" current technology implementations than leap-frogging. This is already being done through establishing techno-parks, and building-up human capacity for the new skills required.

Since the mid-1990s, an increasing number of initiatives to promote STIs have been established, such as techno-parks and incubators. Initially, the focus had been excessively on "real estate", and is now moving towards a model more akin to "innovation centers", often around a campus model where people can communicate and cooperate more directly. Those techno-parks allowed the region to make progress not only in ICTs, but also in biotechnology, nanotechnology, and green technologies.

ICT is an enabler technology essential to sustainable development, because of its importance for the management of natural resources, water, and energy. The Arab Region is well positioned in this field, with the UAE, Qatar, and Bahrain ranked, respectively, 26th, 27th, and 28th in the world in the World Economic Forum's (WEF) Networked Readiness Index (NRI), a key indicator of progress towards a digital economy[185]. Over the course of a single year, many of the region's other countries have made significant progress, such as Lebanon (moving to 88th from 99th) and Kuwait (61st, up from 72nd).

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180 Ding et al.. 2016.
181 Roßnagel et al., 2016.
182 Church et al., 2012.
183 news.bitcoin.com/scientist-deciphers-instructions-to-claim-bitcoin-in-a-dna-sample/
184 WEF, 2016 .
185 WEF, 2016.

There is a large potential for **biotechnology** development in the Arab Region. There are many initiatives under way, both in agriculture and health. In the health sector, there is a large potential for improvement in the manufacturing of both conventional drug and biotechnology products.

1) In conventional drug manufacturing, local production generally accounts for about half of the total regional market. Manufacturing focuses on patent-expired generic or branded generic medicinal chemicals and pharmaceutical preparations; about 40% of drugs are produced under licence, and 90% of the raw materials are imported[186].
2) The production of pharmaceutical raw materials remains limited. Some of those materials are produced in Egypt and, to a lesser extent, in Oman and Algeria. However, this local production only accounts for 10% of regional demand. It appears that R&D generally focuses on improvements to manufacturing processes and quality control[187].
3) Efforts are currently underway in Egypt, Saudi Arabia, Jordan and the UAE to start the production of biotechnology products such as vaccines. However, the production of vaccines can be expanded, only tenth of shots are produced locally. In addition, there is little or no production of advanced drug delivery systems and therapeutic groups. In spite of local demand, products such as hormones, antineoplastics and immunosuppressive agents are imported.

An enabling technology, **nanotechnology** is essential to advance sectors such as manufacturing, resource mining, energy generation, pharmaceuticals, and biology. The development of this field requires a sustained strategy, because of the many dead-ends, whereby once promising firms do not live up to expectations. In addition, there are many safety and ethical concerns that need to be addressed locally. In the Arab region, there have been a growing number of initiatives, in both the public and the private sectors.

1) A growing number of Arab initiatives have been aimed at encouraging development in this technology cluster. An example is Morocco's third InnovAct support programme (2011), or the efforts by King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia to foster ties between academia and private sector. It is one of the priority areas for cooperation of the new Arab Strategy for Science, Technology and Innovation, as well as of UNESCO's Network for the Expansion of Convergent Technologies in the Arab Region (NECTAR).
2) The private sector is also investing in the development of nanotechnologies. An example is Saudi Aramco's Exploration and Petroleum Engineering Center - Advanced Research Center (EXPEC ARC) and its investigations of nanotechnology applications in the petroleum industry, both in extraction (enhanced oil recovery) and in refining (nano-catalysts).

Those initiatives will undoubtedly add to the nascent applications of nanotechnology. As shown in Table 8 below, there are currently available applications, with many others in the "pipeline".

Table 8. SOME NANOTECHNOLOGY APPLICATIONS.

Companies / Institutes	Description
Currently Available on the Market	
Bayer AG: Durethan	Hybrid plastic made up of polyamide (PA) and layered silicate barriers (clay). Applications where conventional PA is too permeable (soft drinks, juice, beer).
Honeywell: Aegis OX	Polymerized nanocomposite film with an oxygen-scavenging barrier resin, for bottle applications (soft drinks, juice, beer).
Sharper Image: FresherLonger A-DO Korea: Food Containers Baby Dream Co: Milk Bottle	Nanosilver for antimicrobial action to preserve foodstuff Examples include "™ Miracle Food Storage Containers" and "FresherLonger™ Plastic Storage Bags" from Sharper Image® USA and "Nano Silver Baby Milk Bottle" from. (South Korea)

[186] Saleh, 2015; Sackman, 2013.
[187] Saleh, 2015; Sackman, 2013.

A123 Systems, LLC	Lithium-ion battery based on Nanophosphate, with faster recharge times and better power density.
Luminex Corp: Verigen System	Pathogen-detection system based on DNA-coated gold nanoparticles that help identify some proteins and genes
Nanosolar	Solar panels based on nanoparticle layer printed on metal foil.

The **Neurotechnology** cluster emerges from the convergence of nanotechnology with neuroscience. It would allow the development of computer systems with brain-like characteristics such as self-learning Artificial Intelligence (AI), energy efficiency, and fault-tolerance. This could also lead to neuro-inspired computers or brain-machine interfaces, and thus to "cognitive enhancement" opportunities for improved attentiveness, memory, decision making, and control. Progress in that field is motivated by initiatives such as the US Defense Advanced Research Projects Agency (DARPA) and its "high-fidelity" brain interface initiative. A few companies have already been active in this technology cluster, as shown in Table 9 below.

Table 9. SOME NEUROTECHNOLOGY INITIATIVES.

Companies / Institutes	Description
Neuralink([a]) San Francisco, CA	Ultra high bandwidth brain-machine interfaces to connect humans and computers. Founded in 2016.
DARPA([b]) Lawrence Livermore National Laboratory([c]) Cognionics	Brain sensor technology as part of the Restoring Active Memory (RAM) program to combat memory loss by reading brain signals and stimulates neurons. An implantable neural device will stimulate and record from neurons in the entorhinal cortex and hippocampus, regions of the brain associated with memory.
Kernel, Cambridge, MA([d])	General-purpose technology for recording brain signals and stimulating it, to help treat neurologic diseases, with the longer term goal remains to "develop technologies to understand and treat neurological diseases", and "interpret the brain's complex workings in order to create applications towards cognitive enhancement".
Neurable, Boston, MA([e]) Intheon, San Diego, CA([f])	Brain-controlled software platform for immersive computing developers to support applications in Augmented Reality and Virtual Reality.
(a) www.neuralink.com/ (b) www.darpa.mil/program/restoring-active-memory (c) www.llnl.gov/news/darpa-taps-lawrence-livermore-develop-worlds-first-neural-device-restore-memory (d) kernel.co/ (e) www.neurable.com/ (f) intheon.io/	

In spite of much progress, too many initiatives remain confined to isolated technology "islands", which little cooperation across disciplines. Going forward, greater cross-disciplinary should be promoted through greater integration between industry and universities, to better enable technology development and transfer. Such an increased cooperation would promote more technical risk taking, with a market-oriented focus.

2. Suggested Way Forward

In promoting SDG relevant STI, policy making should not focus on picking "winners". Indeed, it would be futile to try to forecast technological progress, especially in the modern context of rapid technology development. Furthermore, a single focus on research is insufficient; R&D, by itself, is not enough. Rather, it may best to focus on establishing a balanced policy portfolio that both encourages greater R&D collaboration between industry and academia, and promotes the knowledge and deployment of new technologies.

The successful "policy mix" would have the following key elements:

1) Support for education and technical training to supplement R&D activities.

2) Support for capacity building in the public sector, to better ensure science policy interface.

3) Ensure that policies, in general, do not hinder future market for technical innovations. A stable policy environment would reassure investors and prevent short-term political pressures, and that can have long lasting, unforeseen effects.
4) Avoid "picking winners", and generally support a suite of options. Funding is best channeled through a variety of complementary entities, to better promote competition between actors and technologies.
5) Involve stakeholders, document opinions, and communicate the national vision and priority; focus on action; and adopt a "feed-forward" orientation.

The **involvement of stakeholders** is an essential element to managing the complexity of an STI strategy. Indeed, such "social-planning processes" that document opinions, and communicate ideas are better adopted than systematic processes to the ever-changing technology environment. The focus is to develop a shared understanding of the challenges, and to foster a joint commitment to possible policies and programs. The process extends beyond obtaining facts and opinions from stakeholders, and involves them in mapping out a "way forward". While this would increase the complexity of the policy making process, it would also increase the scope of options, and nurture wider creativity. The main objective would not necessarily be to generate agreement as much as it is to (1) outline the different interpretations of the challenges, (2) map the various stakeholders that can collaborate together towards a solution, and (3) identify their respective capabilities and needs. This would be part of an ongoing process of engagement that continuously "feeds into" the policy making process information about the evolving business and technology environment.

While the ever-evolving technology environment may create many diverse opportunities, they have to serve the sense of purpose as stated in a country's **national visions and priorities**. This sense of purpose, as stated in national visions and priorities, would serve as a "touchstone" against which those choices are evaluated, and will help direct any related policies. Those policies usually (1) maintain the focus of what is fundamentally important to the country; (2) identify national "comparative advantage" and its population's core competencies; (3) define success and develop benchmarks to measure it.

While the realm of technology possibilities is ever growing, their complexity is also increasing. There is little assurance that any given strategy is appropriate or will result in success. This could lead to "paralysis by analysis", where too much time and energy is wasted on "thinking through all options" rather than experiment with feasible strategies. It is better to **focus on possible actions** rather than on the myriad of options, thus quickly analyzing options and making decisions to meet the goals of several constituents. By constantly making small policy changes, progress can be achieved.

In addition to traditional feedback practices, policy makers need a "**feed-forward**" orientation that tries to envision the future. Collecting feedback, while a very valuable tool, is necessarily "backward" looking; it helps to learn from the past, and refine sound strategies. However, modern challenges are likely to arise from unanticipated, uncertain, and unclear technological evolution, and would require novel strategies to address them. Those strategies rely primarily on scenario planning. This is done first by identifying the desired set of external and internal circumstances for the next 10, 20, or 50 years. The strategies can then be defined that will increase their likelihood. Relevant policies can then be outlined. This is a difficult approach that cannot be carried out "according to a timetable", and requires constant monitoring of the business and technology environment, to "scan" for small alterations rather than large scale business changes. In the new environment, evolutions are not confined to any given sector, and small changes in one industry often affect other segments of the economy.

V. CONCLUSION

The Arab region faces the dual challenge to adapt to climate change while still ensuring its sustainable development. Concurrently, the modern economy is undergoing a "fourth industrial revolution", in which technologies "fuse" to blur the lines between various fields of expertise, create unprecedented challenges, and offer new possibilities[188]. In this age, The Arab region has an opportunity and many assetsthanks to its young, enterprising population.

STI is therefore crucial to promote sustainable economic growth. Indeed, while climate change poses many challenges to the region's future development, technology offers many opportunities that the region's young and dynamic population is eager to exploit. The governance structure can play a large role in the promotion of STI, and the Arab countries tackle this issue with diverse approaches, ranging from large research systems, to small and integrated clusters, to rapidly expanding and well-funded institutions. Such a non-uniform STI ecosystem is more nimble, and can therefore adapt faster to an ever-accelerating technological environment. Furthermore, because of the relative young age of the region's research establishments, they are not hindered by any established "legacy" modes of thinking that need to be overcome before any progress is made. They are often able and leverage international collaborations, to achieve wider aims. In some cases, institutions have been effective at leveraging their comparative advantage and "punching above their weight", to achieve high impact research.

Those various systems are now increasingly pursuing applied sciences, prioritizing sectors essential to sustainable development and that enhance resilience to climate change in water, energy, food security. While relative investment in STI still lacks behind the rest of the world, progress is being made in this regard. This is facilitated by two factors; the region's own capacity to innovate and "scale-up" existing technologies, and the fact than many of those new technologies afford businesses a "late mover" advantage, thus allowing them to "leap-frog" and bypass intermediary technologies.

Technology transfer and adaptation is key to the successful implementation of both SDGs and the Paris Agenda. Indeed, "there is no limit to the number of innovations that could help nations accelerating implementation of SDGs[189]". The Arab Region therefore has an opportunity to seize many available synergies by tackling both SDGs and INDCs together. Through an integrated approach to planning, budgetary and monitoring processes, the countries in the region can optimise resource use, enhance information-sharing, and promote greater development of capacities, skills, and technologies.

As new ideas come along, they drive new enterprises, create new products that better meet market demands and social needs, and generate better efficiencies. As a growing economy creates a more complex value, the benefits affect wider segments of society. A successful STI policy therefore focuses on providing both stable appropriations and outlays for R&D, and a predictable policy environment and a wide dissemination of innovation. The focus of STI programs and policies should not be on picking winners, but rather on promoting the innovation process itself by bringing together innovators, investors, and entrepreneurs. This can be done through National Technology Transfer Offices (NTTOs) such as the initiative to establish those in selected ESCWA Countries (Egypt, Lebanon, Morocco, Tunisia, and Oman). This would allow policy makers to plan ahead without attempting to "forecast the future". Investment programs would then aim not only to promote innovative projects, but also to improve the quality of the business environment, and enhancing national positions in global value chains. Policies would target broad technology clusters that have competitive applications in sustainable development such as ICT, nanotechnology, biotechnology, and Artificial Intelligence. Depending on national needs and priorities, policies could highlight "grand challenges" or outline action plans to jumpstart strategic sectors that strengthen national competitiveness. The approach would require a four-step feasibility evaluation:

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[188] Schwab, K.; 2016.
[189] UN, 2017, p.52.

1) Review and classification of (1) relevant technologies, and (2) socio-economic potential. This will be carried out in coordination with established organisms such as NTTOs, in two parts. A desk review to establish the benchmarks and types of data needed.

   a) Emphasis should be placed on field research, not least because much of the relevant information is "informal". The focus in Arab Region is already tilted towards academic research, which often has little practical applications. More effort therefore needs to be done to ensure greater involvement from business and industry with R&D, by mapping (1) existing National Innovation Systems and (2) growing number of business incubators and their functions.

   b) Outline any existing mechanisms in place that aim to greater private sector involvement in STI. This will show how best to promote greater linkages among the academic institutions' drive for intellectual inquiry, the businesses need for specific process improvement, and laypeople's needs of everyday life. When this linkage is made, the Arab Region would be able to properly leverage STIs towards meeting the SDGs, the Arab Region could not only solve its many sustainability challenges, but also benefit from the new opportunities for development.

2) Assessment of the risks are related to (1) technology, the (2) implications of its implementations in the current context of climatic change. In general, policymakers already recognize that there are "**no risk-free technologies**". The risks posed are of two types; technological, and socio-economic.

   a) Technology risks are "systemic", resulting from the ongoing technological change itself. An example is the case of the recent discovery of human immunity to the promising new CRISPR biotechnology[190]; it has implications not only for health, but also for business strategies. The risk assessment would first establish the categories of risk (environmental, technical, financial, social…), then it would determine the benchmark by which they are measured. This risk assessment would be regularly updated and revised.

   b) The current accelerating pace of technology changes adds a new layer of risk. Indeed, the current technological revolution is so far reaching that it may prove extremely disruptive to current modes of production and consumption. The change is so transformational that it reinforces an adverse distributional effect that could well lead to a "winner takes all" technology ecosystem.

3) Mapping the need for STI implementations across (1) sectors of activity, and (2) regions, before drilling down to identify specific types of businesses and sources of financing.

   a) Most of the focus would be a "field" study with starting point the "problem" that needs solving, to (1) ensure that the solutions can be implemented using current technologies, (2) determine any administrative hurdles, and (3) outline any need for capacity building.

   b) The current climatic change may add complexity to the socio-economic environment, and exacerbate any adverse distributional effects, as it tends to disproportionally impact the more vulnerable. The change is transformational to such a wide array of sectors that some development paths risk becoming "dead ends" in the long term. The solution rests in developing the best adapted type of technologies, and in managing the transfer of skills and knowledge to promote local empowerment.

4) Outlining an implementation strategy that recognizes the interactions between the SDGs and the need to confront climate change. This will allow for a clearer "pathway" for the effective transfer and adaptation of relevant technologies. The implementation of any strategy would be done in continuous coordination with NTTOs or similar organisms. Because of the ever-evolving nature of the technology and its changing socio-economic implications, the first three steps would be regularly updated and revised.

[190] Charlesworth et al., 2018.

With this information, STI policies would be able foster long-term innovation capacity. They would not be limited to "supply-side" such as public R&D spending, but also include "demand-side" policies such as specifications. However, this requires a dynamic policy formulation that is regularly updated to reflect changing realities. Unlike previous industrial revolutions, the current 4^{th} edition fosters a "winner takes all" situation whereby it exacerbates income disparities and inequality. This will also have an effect on policy formulation, as it would need to balance economic development with social cohesion. One way to achieve this is to promote wider support and involvement in research and innovation, which will also "widen" the science base and accelerate the transfer, exploitation and commercialisation of public research.

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