Istituto Affari Internazionali

The Water-Energy-Food Nexus in Libya, UAE, Egypt and Iraq

by Martin Keulertz and Rabi Mohtar

ABSTRACT

Libya, Egypt, Iraq and the United Arab Emirates (UAE) have a strong renewable energy potential in solar power and energy sourced from feed stock. At the same time, these countries have limited water resources and food production capacity. Integrated management strategies centred on the "Water-Energy-Food Nexus" framework provide a useful way to address resource challenges. Energy innovation potentials are assessed in line with suggestions on governance obstacles and partnership opportunities for these four countries. This must however also be harmonised with new strategies for water and food security in order to strengthen rural livelihoods.

Water | Energy | Food security | Libya | UAE | Egypt | Iraq

keywords

IAI PAPERS 22 | 01 - FEBRUARY 2022

ISSN 2610-9603 | ISBN 978-88-9368-238-1

IAI PAPERS 22 | 01 - FEBRUARY 2022 ISSN 2610-9603 | ISBN 978-88-9368-238-1

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by Martin Keulertz and Rabi Mohtar*

Introduction

At the beginning of the 2020s, the world is entering a new development phase. Climate change has become a top priority for governments around the world. The Paris Agreement of 2015 has set out a global framework to address climate change by limiting global warming to well below 2°C, ideally to 1.5°C. The Glasgow Climate Pact at COP26 further strengthened these goals by agreeing to reduce global carbon emissions by 5 billion tonnes in 2030 and to achieve net-zero by 2050.[1] Central to achieving these ambitious targets will be the orderly transition from fossil fuels to renewable energy. At the same time, the energy sector must undergo a just transition in line with other resources such as water and food. Therefore, the Water-Energy-Food Nexus (WEF) concept will have to be at the heart of any strategies related to energy innovations. This especially applies to countries in the Middle East and North Africa (MENA), where a very significant renewable energy potential is owed to abundance of solar radiation and alternative energy made from feed stock. However, the MENA region is conspicuous for its lack of several resources, including water, necessary to energy production.

Libya, Egypt, Iraq and the UAE, in particular, are subject to a resource conundrum, thus representing interesting cases to analyse in this context. While the four countries are richly endowed with fossil hydrocarbons such as oil and gas, they are among the most water-scarce countries in the world with the consequence of food production limitations. As Allan noted at the turn of the last century, these countries as well as the entire MENA region have effectively run out of sufficient water resources since the 1970s.[2] At the beginning of the 2020s, the four – like

[1] UKCOP26, *COP26: The Glasgow Climate Pact*, November 2021, https://ukcop26.org/cop26-presidency-outcomes-the-climate-pact.

[2] Tony Allan, *The Middle East Water Question. Hydropolitics and the Global Economy*, London/New

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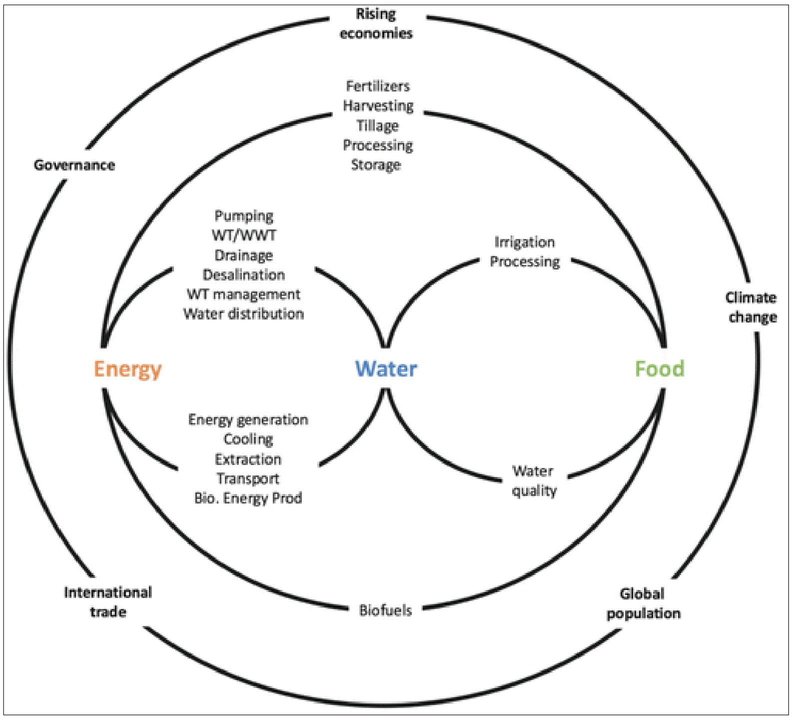
many other countries in the region – must identify strategies to cope with water challenges while at the same time maintaining or improving livelihoods for their populations through new, low-carbon-dioxide energy technologies whilst maintaining food security. This will be one of the biggest challenges in the history of Libya, Egypt, Iraq and the UAE.

In most countries in the world, water, energy and food have been managed separately in "sectors" since the introduction of modern statehood. The Water-Energy-Food Nexus seeks to change this mode of "silo" governance.[3]

Figure 1 | Schematic representation of the WEF Nexus and its interdependencies



Source: Robi H. Mohtar and Bassel Daher, "Water, Energy, and Food: The Ultimate Nexus", cit.

The WEF Nexus has its intellectual foundations in the assumption that water, energy, agriculture and also natural ecosystems are strongly interlinked. Under the traditional sectoral approach, the goal of achieving security of one resource

York, I.B. Tauris, 2001.

[3] Tony Allan, Martin Keulertz and Eckart Woertz, "The Water–Food–Energy Nexus: An Introduction to Nexus Concepts and Some Conceptual and Operational Problems", in *International Journal of Water Resource Development*, Vol. 31, No. 3 (2015), p. 301-311; Martin Keulertz et al., "The Water-Energy-Food Nexus in Arid Regions: The Politics of Problemsheds", in Ken Conca and Erika Weinthal (eds), *The Oxford Handbook of Water Politics and Policy*, New York, Oxford University Press, 2016, p. 167-196; Robi H. Mohtar and Bassel Daher, "Water, Energy, and Food: The Ultimate Nexus", in Dennis R. Heldman and Carmen I. Moraru (eds.), *Encyclopedia of Agricultural, Food, and Biological Engineering*, 2d ed., Boca Raton, CRC Press, 2010.

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independently of the other resources often threatens the sustainability and security of one or more other sectors. The WEF Nexus approach analyses interlinkages, synergies and trade-offs in order to identify solutions for all sectors to reduce negative impacts on the economy, nature and social development at large.[4] It is therefore reasonable to expect that the "system of systems" approach that the WEF Nexus brings to the table can enable a better understanding of the resource nexus and better manage these primary resources with system sustainability and synergy in mind (see Figure 1).

1. An assessment of the natural and institutional environment in the four countries

Egypt, Iraq, Libya and the UAE are highly diverse in terms of economic and political development. While Egypt and Iraq have a long agricultural history, being amongst the earliest "food bowls" in human history, Libya and the UAE have very small agricultural sectors due to the arid climate and the proximity to deserts. The limiting resource for agricultural production is water. While Egypt and Iraq have access to key global river systems such as the Nile and the Euphrates and Tigris, Libya and the UAE have to rely on groundwater or desalination systems to cater for the hydrological needs of their populations. We will therefore provide a summary of the water situation in the four countries.

1.1 Water

Water availability is a major challenge in all studied countries. Table 1 provides the total renewable water resources per capita (m3/inhab/yr). A country is experiencing absolute water scarcity if it has below 500m3 per inhabitant per year according to the Falkenmark water stress index.[5]

Although Iraq is way above this threshold, the available data must be treated with extreme caution. Recent dam constructions by Turkey in the headwaters of the Euphrates and Tigris river basin have led to severe water shortages in southern Iraq with Basra experiencing unprecedented water shortages.[6] Obtaining transparent and valid hydrological data for Iraq is next to impossible even for the United Nations from which the data originates, hence the disparity of official numbers vis-à-vis the situation on the ground. The same applies to Egypt, which is concerned about less inflow from the upstream Nile due to the filling of dams by Ethiopia, notably the Grand Ethiopian Renaissance Dam (GERD). Egypt and Iraq do not possess full

[4] Global Water Partnership (GWP) website: *SEE Nexus project*, https://gwp.org/seenexus.

[5] M. Falkenmark, "Fresh Water: Time for a Modified Approach", in *Ambio*, Vol. 15, No. 4 (1986), p. 192-200.

[6] Tom Peyre-Costa, "'We Have No Options': How Water Scarcity Is Changing South Iraq", in *The Guardian*, 19 March 2020, https://www.theguardian.com/p/dc4ta.

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autonomy over their water resources as they are downstream riparians of the Nile and Euphrates and Tigris river basins.[7] This could mean further variability in water availability depending on future inflows from upstream riparian countries.

Table 1 | Renewable water resources availability per capita from 2003 until 2017 in Egypt, Iraq, Libya and the UAE

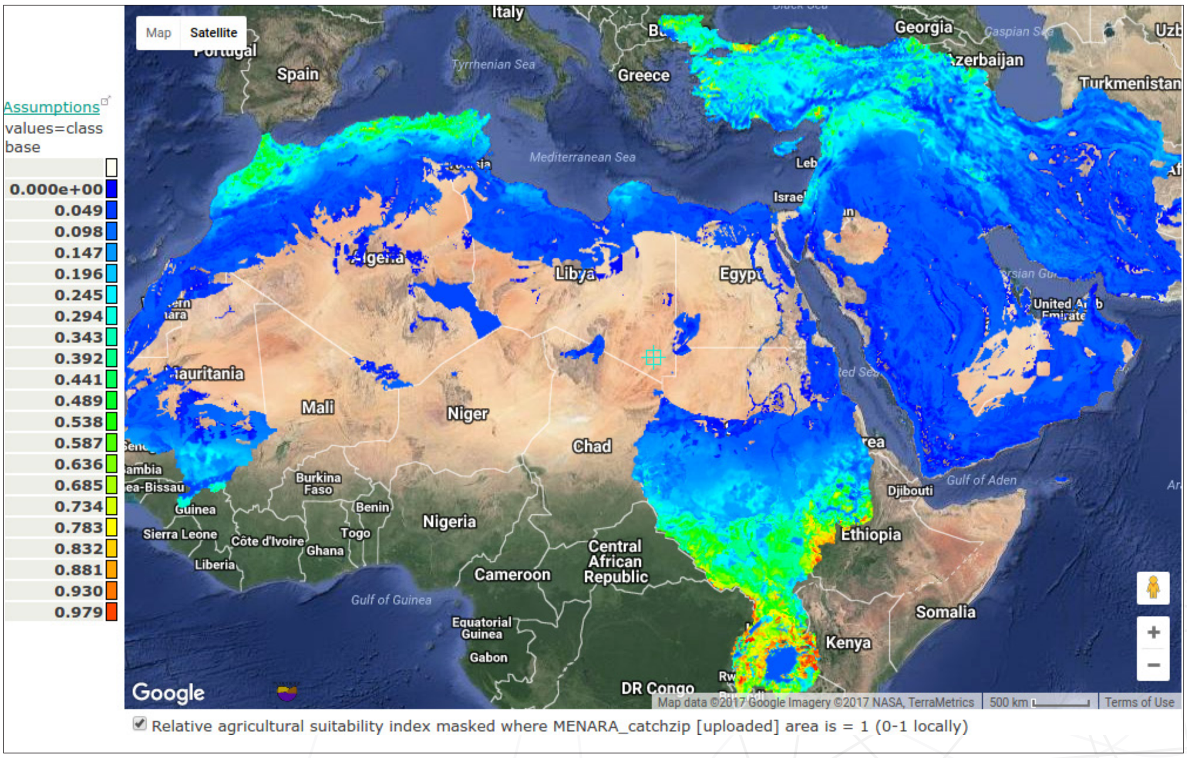
	2003–2007	2008–2012	2013–2017
Egypt	735.0	665.3	596.2
Iraq	3219.0	2818.0	2393.0
Libya	117.2	111.4	106.4
UAE	24.32	16.41	15.81

Source: FAO Aquastat, 2021.

1.2 Food

The water predicament directly feeds into the dismal food production capacity of the region. Figure 2 shows agricultural suitability on the regional scale.

Figure 2 | Relative Agricultural Suitability Index from the MENARA Policy Tool



Source: MENARA Policy Tool, 2021, http://www.policysupport.org/menara.

[7] Tony Allan, *The Middle East Water Question*, cit.

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Agriculture, which is the greatest user globally of water with 70 per cent of water withdrawals and 92 per cent of water consumption, faces a near impossible struggle to provide the four countries with domestically produced food. In addition, due to high levels of fertiliser application, the agricultural areas in all four countries are severely degraded, with salinisation levels of more than 75 per cent (see Figure 3).

Figure 3 | Land degradation in the Arab world

Source: Arab Spatial, 2021, https://arabspatial.org.

As a result, more than 90 per cent of the food in Libya, Iraq and the UAE is imported from the rest of the world. Only Egypt produces about 30 per cent of its domestic food requirements and acts as an important provider of food to other Arab and international markets.[8] Given Iraq's history as one of the earliest agricultural producers in the world alongside the availability of land, it could also increase its food production. Iraq is also a special case as its agricultural sector has suffered badly due to the political developments affecting the country since the 1980s, such as the politically motivated drainage of the marshlands and protracted and generalised insecurity due to conflict. Hence the picture from these four countries

[8] United Nations Economic and Social Commission for Western Asia (UNESCWA), *Arab Horizon 2030: Prospects for Enhancing Food Security in the Arab Region. Technical Summary*, Beirut, United Nations, 2017, https://archive.unescwa.org/node/149461.

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is twofold: while Libya and the UAE have severe agricultural limitations, Egypt and Iraq possess important agricultural opportunities to at least provide a portion of the domestic food needs to their populations.

1.3 Energy

Egypt, Libya, Iraq and the UAE are endowed with considerable natural resource assets such as natural gas and oil (see Table 2). In total, the four countries possess 6.6 per cent of the world's natural gas resources and 17.71 per cent of global oil reserves. They have explored further gas reserves such as in the Mediterranean Sea (Egypt and Libya), in Western Iraq and in the Indian Ocean/Persian Gulf area (UAE). Energy production has been the most important business model in Iraq, Libya and the UAE for the past fifty years, with hydrocarbons bringing up to 90 per cent of revenues to the countries. Only Egypt has a more diversified economy, with a strong industrial base in food processing, textiles, telecommunications, automotive and pharmaceutical production as well as agriculture.[9]

Table 2 | Natural gas and oil reserves in UAE, Iraq, Egypt and Libya, 2016

	UAE	Iraq	Egypt	Libya
Gas reserves (MMcf)	215,098,000	111,522,000	77,200,000	53,183,000
World share	3.1%	1.6%	1.1%	0.8%
Oil reserves (billion barrels)	97.8	143.069	4.4	48.363
World share	5.9%	8.7%	0.21%	2.9%

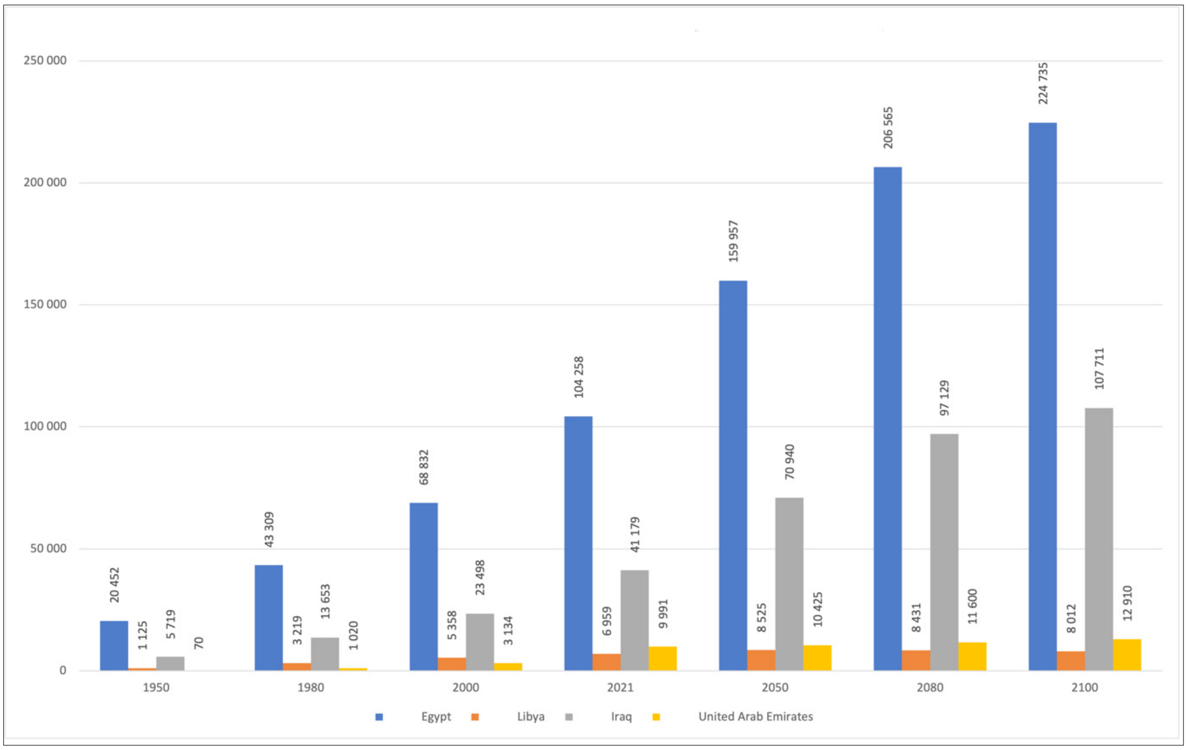
Source: World Bank, 2021.

1.4 Demography

Population growth acts as another major burden for resource management. All four countries' populations are growing fast. Egypt and Iraq will have among the largest populations in the entire MENA region by the end of the century, whereas Libya and the UAE will grow by approximately one third of the current population. All countries combined will grow from today's total population of 130 million to 255 million by 2100, according to UNDESA calculations (see Figure 4).

[9] Egyptian Embassy in Berlin-Economic and Commercial Office (ECRG) website: *Economic Sectors*, https://www.ecrg.de/en/doing-business-in-egypt/economic-sectors.

Figure 4 | Population growth in Egypt, Libya, Iraq and the UAE, 1950–2010



Source: United Nations Department of Economic and Social Affairs (UNDESA), 2021.

1.5 Political stability and governance

Arguably the most crucial feature for the governance of water, food and energy is located in political stability. While the UAE is a highly developed economy with strong access to global markets and firm political stability, government effectiveness, rule of law and control of corruption, Egypt has witnessed severe political unrest in the past decade with a now strongly securitised state tightly controlled by the military. Voice and accountability as well as corruption control have seen a gradual decline. Iraq has been in troubled political waters for at least 30 years, and these challenges were severely exacerbated by the US-led invasion in 2003. The country is on a very slow recovery path. Political stability indictors are amongst the lowest in the world. However, voice and accountability are slightly better than in, for instance, Egypt. Libya is in a similar predicament to Iraq. While it was relatively stable until 2010, the conflict that broke out thereafter led to a decline in good governance indicators, with only voice and accountability in a better shape than ten years ago (see Figure 5).

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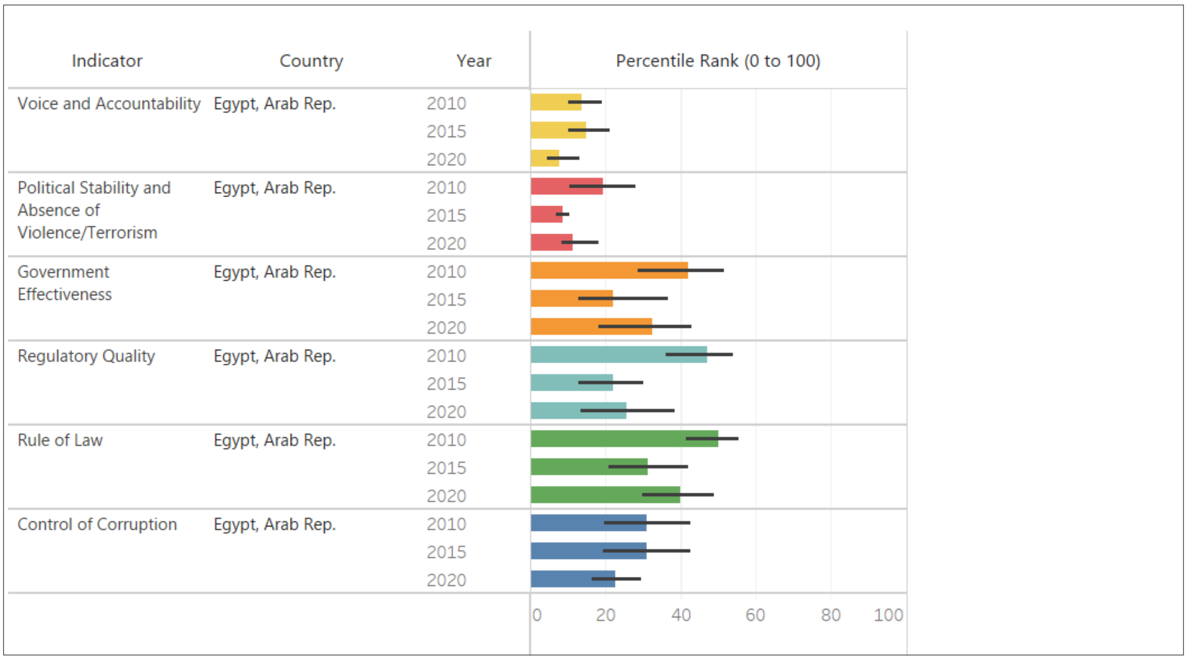
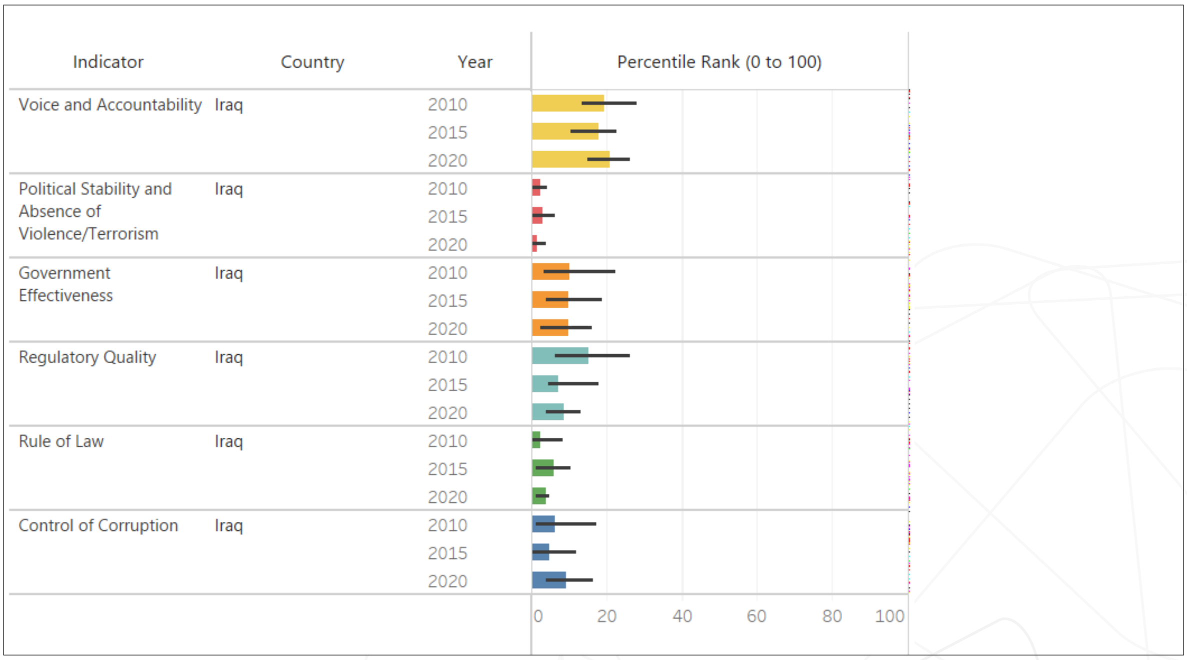
Figure 5 | Political stability indicators for Egypt, Libya, Iraq and the UAE





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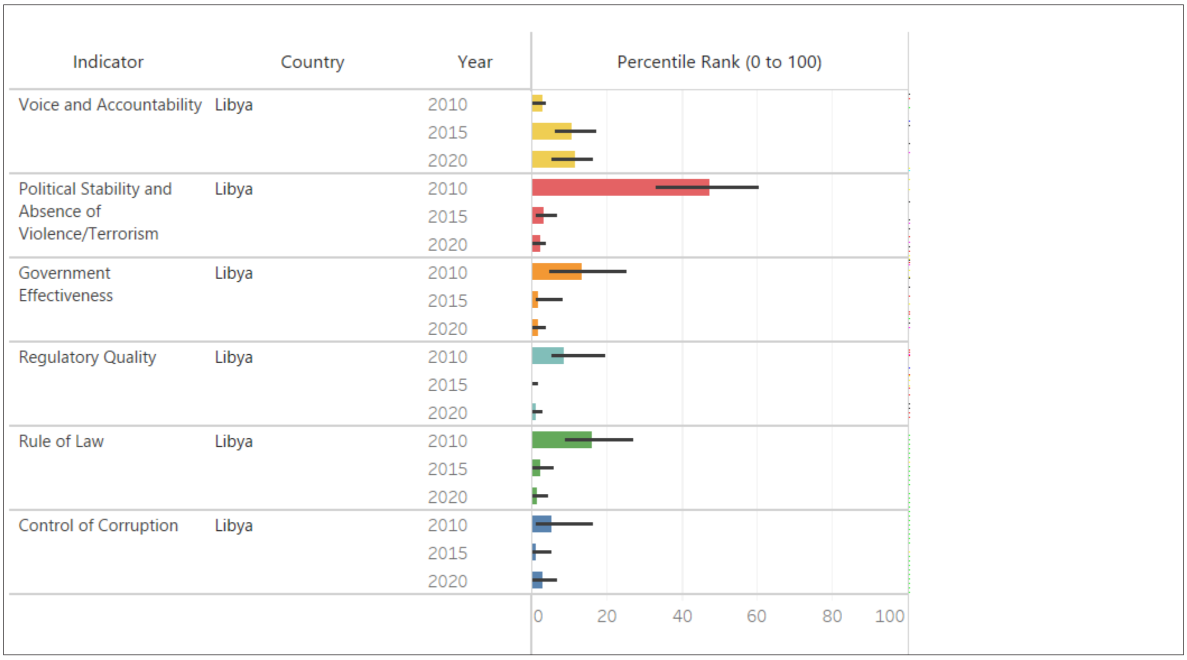

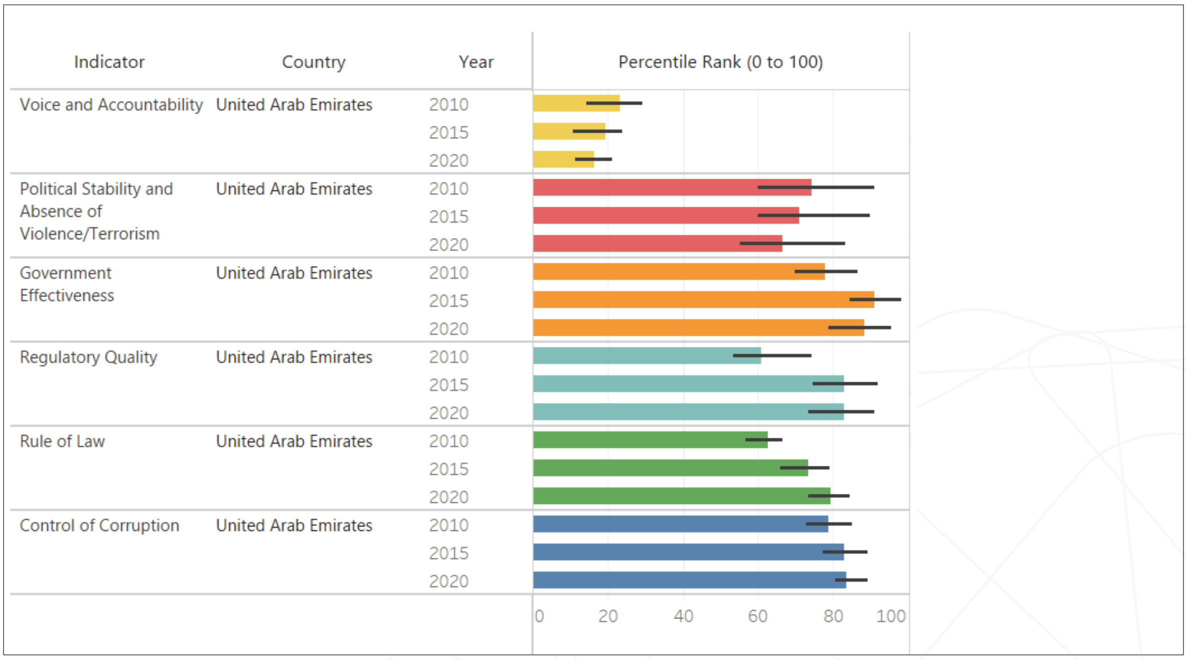

Source: World Bank, *Worldwide Governance Indicators*, http://info.worldbank.org/governance/wgi/Home/Reports.

1.6 Climate change

Climate change is further exacerbating the resource situation in the four countries. The most recent report of the UN Intergovernmental Panel on Climate Change projects decreasing precipitation and more fire hazards as well as a higher

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frequency of drought and aridity by mid-century.[10] Higher temperatures will lead to higher water vulnerability in the entire region and thus also in Libya, Egypt, Iraq and the United Arab Emirates. Crop water requirements will increase resulting from higher temperatures.[11] Egypt and Iraq will however see more water inflows due to higher precipitation in upstream countries of the Nile and Euphrates and Tigris rivers. Libya and the UAE will be severely affected in the coastal areas, which may lead to a further salinisation of groundwater aquifers and subsequent reductions in water availability.

In sum, all countries are subject to a mounting water crisis while being important providers of hydrocarbons. Most of their food is imported due to land and water shortages. Population growth and climate change will add to the challenges in the four countries, which – with the exception of the UAE – are also subject to poor governance and low political stability. Finally, the four will require more water to maintain food production. The environmental, political and social data presented above paint a grim picture. Yet is this reason for despair or are there opportunities?

2. The imperative to manage these resources in an integrated manner

Energy production requires water, food production requires energy and water, and water requires energy for moving it from the source to the production site. In addition, these resources are influenced by external social and political factors such as population growth and governance amongst others. As the use of these resources is interlinked, their management should be integrated.

2.1 Water and energy

Water use and availability and energy production are strongly interconnected. Almost all types of energy production require water: for processing the raw material processing used in the energy facilities, for constructing and maintaining electrical plants, or just for generating electricity itself. Although renewable energy sources such as photovoltaic solar power and wind power have low requirements, they still need water for extracting raw materials, such as sand, to build the plant and clean photovoltaic systems. While energy production withdraws substantial amounts of surface and ground water (blue water), it has a small water footprint due to lower water consumption rates. It is of high importance to distinguish between water withdrawals and water consumption in this context: water withdrawals mark the total volume removed from a water source, such as surface and ground water.

[10] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021: The Physical Science Basis. Working Group I contribution to the Sixth Assessment Report of the IPCC*, Geneva, 2021, https://www.ipcc.ch/report/ar6/wg1.

[11] Ibid.

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However, depending on the way water is used, a portion of this water is returned to the source and is available for reuse. Water consumption on the other hand is the amount of water removed for use without being returned to its source.

2.2 Water and food

While water used for energy production is often subject to pollution, it does not fully perish. Cooling of power plants is by far the largest user of water in energy production. For all other energy-related water uses, water can be recycled through technology such as wastewater treatment. It can then be reused for other sectors, in particular agriculture. Agricultural water consumption related to biomass production is by far the highest across the world due evapotranspiration, which leads to little or no return flows. The agricultural sector is by far the largest consumer of water in any economy as the plants use the applied water to grow and do not return the water to its source (see Table 3).

Table 3 | Withdrawals vs. consumption in water use

	Gross withdrawals (A)	Return flow (B)	Consumptive use (A x B)	Consumptive use (%)
Agriculture	70%	50%	0.35	92%
Industry	20%	10%	0.02	5%
Drinking water	10%	10%	0.01	3%
Total			0.38	

Source: Jippe Hoogeveen et al., "GlobWat – A Global Water Balance Model to Assess Water Use in Irrigated Agriculture", in *Hydrology and Earth System Sciences*, Vol. 19, No. 9 (2015), p. 3829-3844, https://doi.org/10.5194/hess-19-3829-2015.

2.3 The role of energy in the food system

The Food and Agricultural System (FAS), beside its direct reliance on water supply, needs an extensive amount of energy. Energy is needed for farm agricultural practices such as tillage, planting, fertiliser, harvesting and storage. Energy is also needed for transport and processing. Access to safe and affordable energy sources is the enabler of the FAS, and must accordingly be provided. Renewable energy can be a source for much of this requirement, although not in remote rural areas due to the poor state of grids and longer transport routes.[12]

[12] Food and Agriculture Organization (FAO), *The Water-Energy-Food Nexus: A New Approach in Support of Food Security and Sustainable Agriculture*, Rome, FAO, 2014, https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/421718.

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2.4 From sectoral to systems thinking: How the WEF Nexus can address critical challenges for energy-producing countries

According to the Food and Agriculture Organization, the WEF Nexus describes the complex interactions between the three systems water, energy and food. It highlights the interrelatedness between these resource systems.[13] The WEF Nexus is about balancing different resource user goals while maintaining the wider ecosystem. Decisions in one sector may have detrimental effects on other sectors. It is therefore of great importance to anticipate trade-offs and synergies while keeping the three systems – water, food and energy – in mind in an integrated manner. In other words, the WEF Nexus approach forces decision-makers to think about the economy and the environment at large before reaching decisions.[14] As shown above in Section 1, water scarcity, as the case in the four countries analysed above attests, leads to broader consequences on the political, social, environmental and economic levels. Energy production is by far the most profitable and economically viable way of using the comparative solar radiation advantage in Libya, Iraq and the UAE. Egypt as the biggest country by population also holds an important agricultural advantage, which it has thus far very impressively managed to utilise, as it is the largest food producer in the Arab world.

2.5 Solar production and ammonia

Solar energy presents a major opportunity for generating synergies in all four countries. These are endowed with a comparative advantage due to ample solar radiation for nearly 12 months of the year. The photovoltaic power potential (PVOUT) for Libya ranges from 1,753 to 2,045 kwh per person per year. The same applies to Egypt. In Iraq it is between 1,534 and 1,899, and in the UAE the potential has a range of 1,680 to 1,899 kwh per person/year (see Figure 6). Except for the UAE, the solar potential alone could generate sufficient electricity to match current consumption rates. Solar energy's water use has long been known to be minimal. Although some water is required for the cooling and cleaning of the solar panels, the consumptive use of water is very low, hence solar energy serves as a strong opportunity for water-scarce economies. Polluted water from cleaning or cooling of the plants can be recycled and used for agricultural production. However, it must be noted that especially large-scale solar farms may have a detrimental effect on desert habitat and thus biodiversity as they may lead to a displacement of plant and animal species underneath the solar farms.

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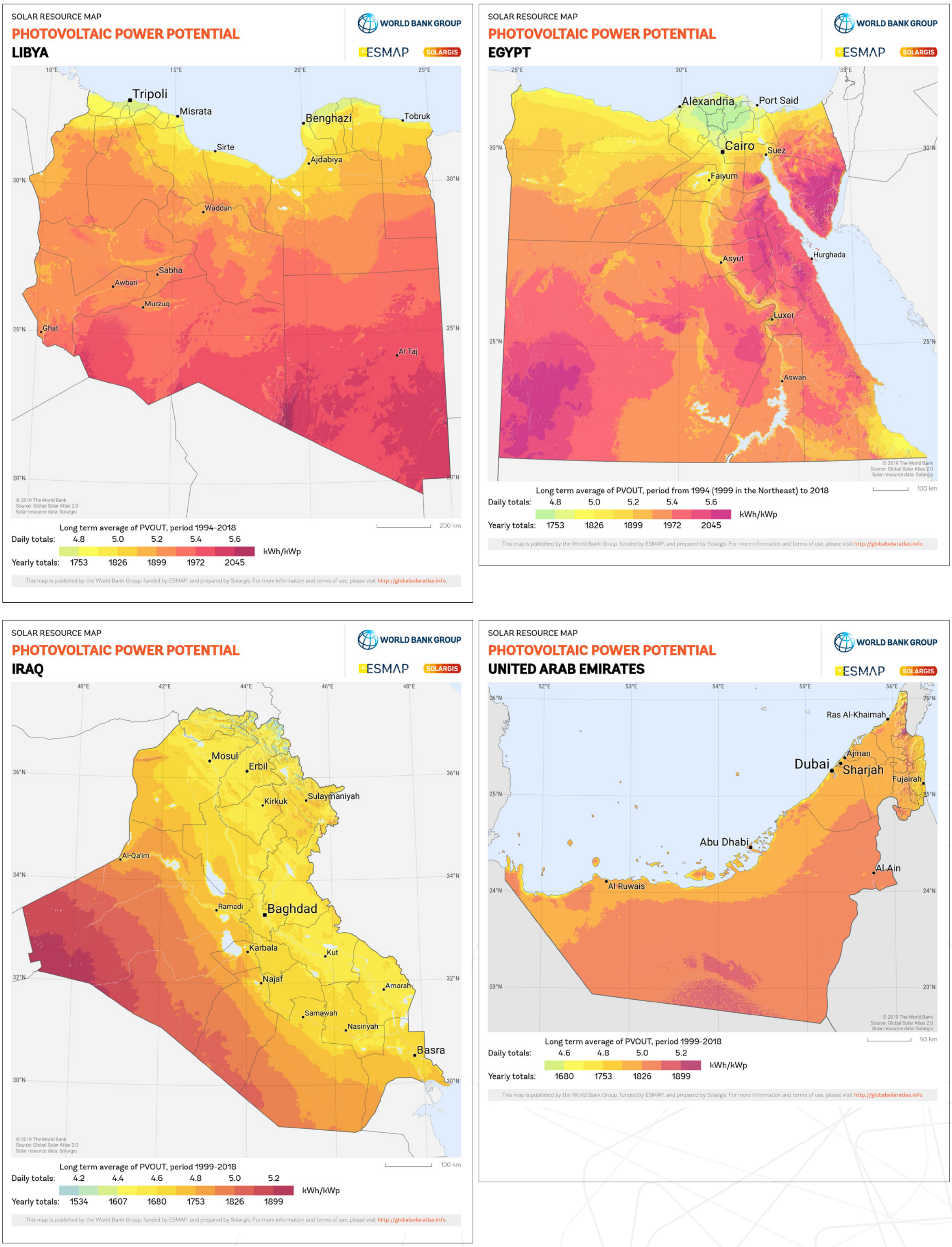
[13] Rabia Ferroukhi et al., *Renewable Energy in the Water-Energy-Food Nexus*, Abu Dhabi, International Renewable Energy Agency (IRENA), January 2015, https://www.irena.org/publications/2015/Jan/Renewable-Energy-in-the-Water-Energy--Food-Nexus.

[14] Cara Giaimo, "Can Desert Plants and Solar Panels Live in Harmony? Sometimes, Yes", in *Anthropocene Magazine*, 8 April 2020, https://www.anthropocenemagazine.org/?p=68139.

Figure 6 | Photovoltaic potential in Libya, Egypt, Iraq and UAE



Source: World Bank, *Global Solar Atlas*, https://globalsolaratlas.info.

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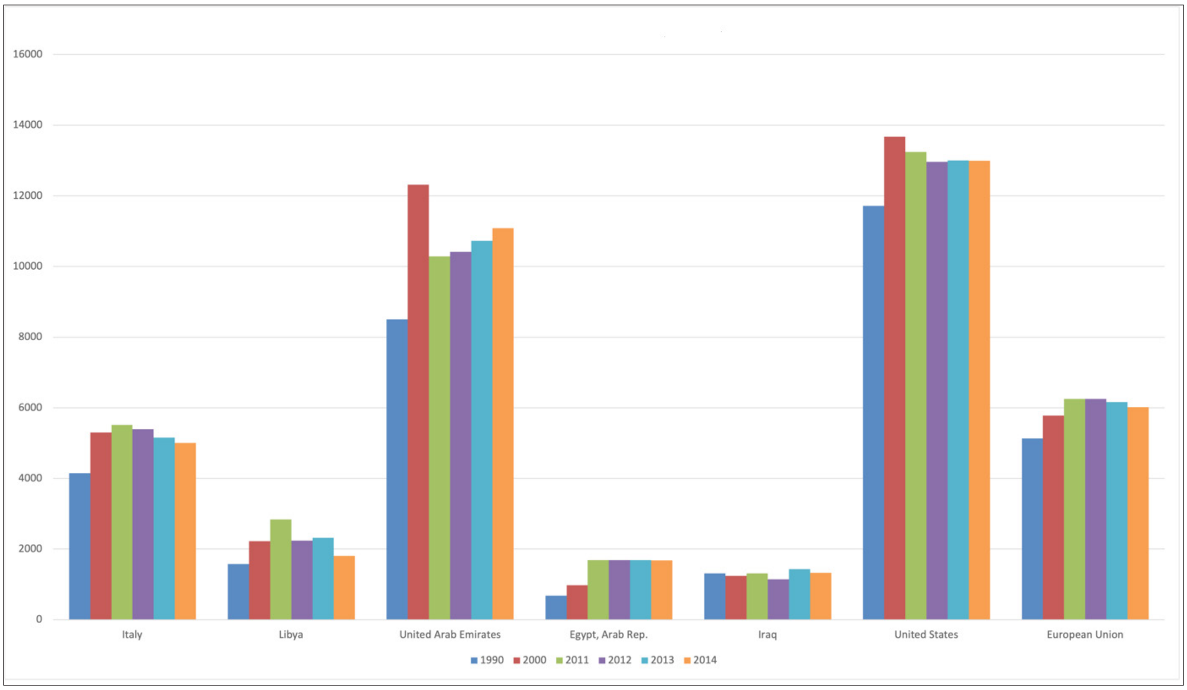
Figure 7 | Electric consumption per capita in kwh



Source: World Bank, 2021.

Solar energy has been around for several decades, but has found limited application in all four countries (see Table 4).

Table 4 | Energy generation by source in Libya, Iraq, Egypt and the UAE in 2019

	Natural gas (GWh)	Oil (GWh)	Solar (GWh)	Hydro (GWh)
Libya	22.560	11.151	8	0
Iraq	53.039	40.902	57	1.181
Egypt	150.205	25793	1.471	13.121
UAE	133.871	804	3.550	0

Source: IEA, 2021.

This is partly due to their dependency on hydrocarbons but also more recently political public investment shortages. Yet, a recent focus by industrial players on ammonium nitrate, a new source of alternative energy made from feedstuff such as fertilisers, may generate renewed interest in solar energy. Ammonia was one of the very first fuels for engines. For example, ammonia engines were used as early as in the 1870s in New Orleans for the St. Charles Streetcar Line.[15] However, given

[15] Agustin Valera-Medina et al., "Ammonia for Power", in *Progress in Energy and Combustion Science*, Vol. 69 (November 2018), p. 63-102 at p. 74, https://doi.org/10.1016/j.pecs.2018.07.001.

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the cost advantage of fossil fuels such as oil, it was not competitive. Yet considering climate change and global strategies for decarbonisation, new types of ammonia production may provide a clean fuel to power the maritime industry or aviation.

Current commercial ammonia production is predominately based around the Haber-Bosch process, which involves the catalytic reaction of hydrogen and nitrogen at high temperature and pressure. This is called brown ammonia, an energy-intensive type of energy consuming 8 MWh of energy per tonne of ammonia. Brown ammonia is predominantly used as a fertiliser for agriculture. It may pose storage risks in case of unsafe handling as seen in Beirut on 4 August 2020, when an ammonia-caused blast killed more than two hundred people causing large-scale destruction.[16] The production of brown ammonia is also not an environmentally friendly one as most of the energy consumption and around 90 per cent of the carbon emissions are from the production of hydrogen, which is generated almost exclusively via steam reformation of fossil fuels. At present, the majority of ammonia plants rely on the steam reformation of natural gas to produce hydrogen and carbon dioxide, but there have also been uses of coal, heavy fuel oil and naphtha, whose carbon footprint is even higher.[17]

However, there are also two innovative options to produce ammonia, which are low in carbon dioxides and may provide alternatives for energy needs of industries where electrification is not possible. First, blue ammonia using blue hydrogen from steam methane reforming (SMR) with carbon capture and storage (CCS) may serve as a low carbon alternative especially in countries with natural gas reserves such as in Libya, Egypt and the UAE. If natural gas prices and carbon taxes remain low, steam methane reforming with carbon capture and storage would be a useful option for reducing the carbon footprint of ammonia production. However, the blue ammonia production would become more expensive if global carbon taxes increase and if carbon capture technologies are incorporated into the steam methane reforming process. This would lead to an increase of natural gas consumption and a consequent increase in the operating cost of hydrogen production compared to brown ammonia production. However, carbon emissions in the process of natural gas extraction limit the life-cycle emission reductions for combined steam methane reforming and carbon capture and storage to 60–85 per cent, which is not the most optimal hydrogen production in order to reach a net-zero goal.[18] Nevertheless, if natural gas is replaced with a renewable energy source coupled with higher carbon taxes, the benefits could be enormous.

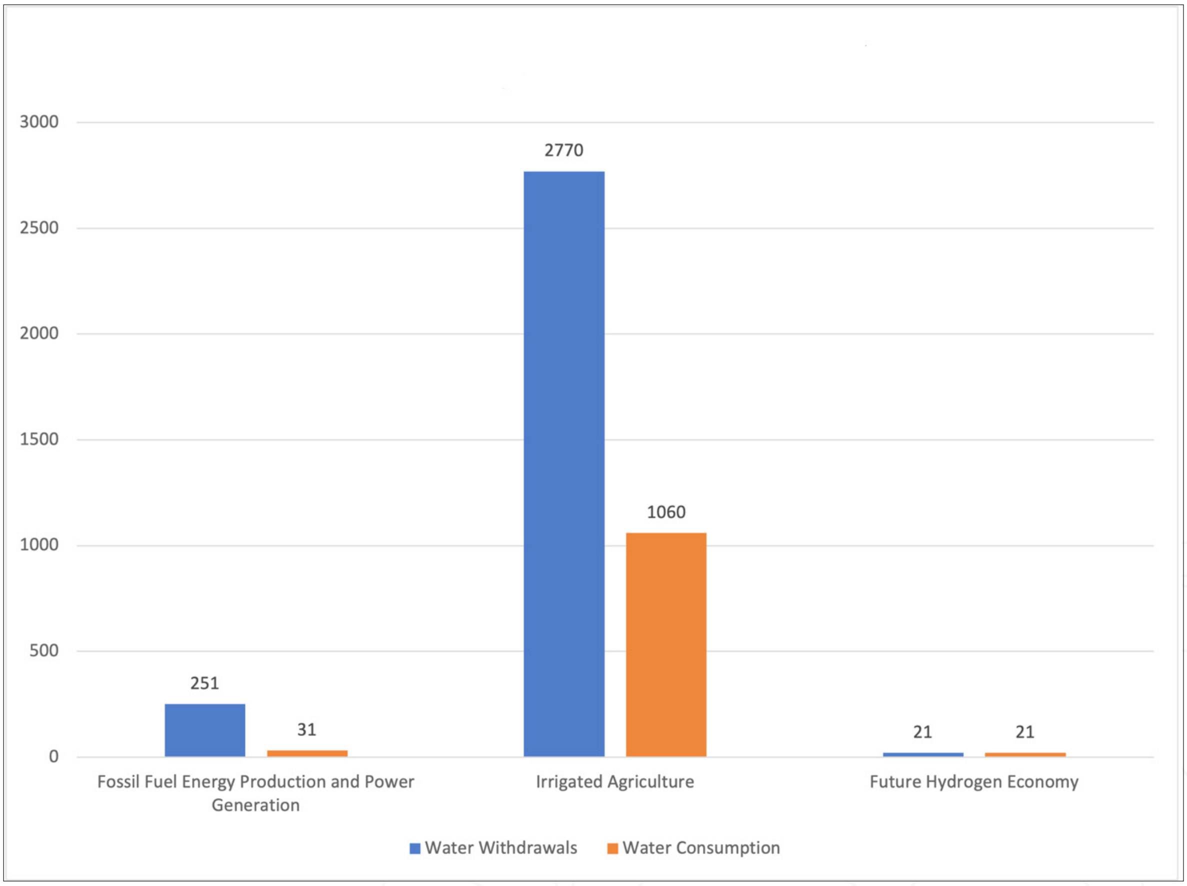
[16] "What Is Ammonium Nitrate and Why Is It Dangerous?", in *Reuters*, 5 August 2020, https://reut.rs/3gDGXYm.

[17] The Royal Society, *Ammonia: Zero-Carbon Fertiliser, Fuel and Energy Store*, London, February 2020, p. 12, https://royalsociety.org/-/media/policy/projects/green-ammonia/green-ammonia-policy-briefing.pdf.

[18] Ibid., p. 14.

A more promising process is green ammonia production, whereby the hydrogen is produced through the electrolysis of water. Nitrogen is obtained directly from air using an air separation unit which accounts for 2–3 per cent of the energy used in the process. Ammonia is produced using the Haber-Bosch process using renewable energy for the hydrogen component, such as solar energy. The main challenge is cost. About 85 per cent of this is electricity, which in most parts of the world is still significantly more expensive than natural gas.[19] From a water perspective, both blue and green ammonia have a lower consumptive water use than brown ammonia (see Figure 8).

Figure 8 | Water withdrawals vs. consumption of different sectors (billion cubic metre)



Source: Rebecca R. Beswick, Alexandra M. Oliveira and Yushan Yan, "Does the Green Hydrogen Economy Have a Water Problem?", cit., p. 3168.

However, while actual water consumption to produce energy from foodstuff such as ammonia is generally low, it still presents challenges to water-scarce economies such as Libya, Egypt, Iraq and the UAE. Water-scarce economies may need to

[19] Ibid.

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further invest in new water desalination plants such as those using reverse osmosis to provide sufficient water for hydrogen generation. Using desalinated water would lead to a minor increase of the cost of overall hydrogen production, adding approximately 0.01 US dollar per kilogram.[20] Blue and green hydrogen production therefore must go hand in hand with strategies to upscale water desalination and treatment to ensure water needed for energy production doesn't harm other sectors such as agriculture.

This will especially impact the two countries with a significant agricultural potential, namely Egypt and Iraq. In both countries, any harm to water availability for farmers could have very detrimental social effects. It is therefore important to scrutinise the institutional challenges and actors in the water-food-energy nexus.

3. Institutional challenges and requirements

The actors involved in the water-food-energy nexus in Libya, Egypt, Iraq and the UAE are manifold. Apart from national institutions, international organisations and businesses, there are also external actors involved. These include technology partnerships and governance.[21]

3.1 Libya

Libya doesn't have a systematic WEF Nexus strategy due to recent political instability. The Ministry for Water Resources, the Ministry for Agriculture, Livestock and Marine Resources and the Ministry of Electricity and Renewable Energy are important actors as regards the WEF nexus. In the energy sector, the National Oil Company, a holding company owned by the state, the Libyan Post Telecommunications and Information Technology Company and the Central Bank of Libya should be added to the list. International companies active in oil extraction are Italy's Eni and Spain's Repsol. Oil has been marketed and sold around the world under the Tamoil corporation, of which the National Oil Company is the main stakeholder.

Water supply in Libya is in the hands of tribes in the desert areas in the south and the Great Man-Made River Project Authority in the coastal areas, which provides the coastal cities with drinking water. Despite several breakdowns during the

[20] Rebecca R. Beswick, Alexandra M. Oliveira and Yushan Yan, "Does the Green Hydrogen Economy Have a Water Problem?", in *ACS Energy Letters*, Vol. 6, No. 9 (2021), p. 3167-3169, https://doi.org/10.1021/acsenergylett.1c01375.

[21] Global Water Partnership (GWP) website: *SEE Nexus project*, https://gwp.org/seenexus; Rabia Ferroukhi et al., *Renewable Energy in the Water-Energy-Food Nexus*, cit.; Waleed K. Al-Zubari, "Understanding the Nexus and Associated Risks", in *The Water-Energy-Food Nexus in the Arab Region Policy Briefs*, No. 1 (2017), https://uploads.water-energy-food.org/legacy/policy_briefs_1_english.pdf.

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2014–2020 civil war, the system is still in place. Agriculture is a small sector in the economy with the Ministry of Agriculture having recently been downgraded to an authority. Since the majority of food is imported, the Ministry of the Economy and Trade and the Price Stabilisation Fund are highly important stakeholders to provide subsidies to keep food prices low and affordable for consumers.[22]

3.2 United Arab Emirates

The UAE is the most advanced economy of the four studied countries. This also applies to the governance of the WEF Nexus. The country has embraced the nexus concept in recent years through various policy innovations such as merging ministries charged with water, food and energy management. Significant institutional investment has been made in food and water security in the past ten years, with an Emirates Council for Food (ECF) overseeing the implementation of the food security strategy. The ECF is led by the Ministry of Environment and Climate Change including representatives from the Ministry of Economy, Ministry of Energy and Industry, Ministry of Health and Community Protection, Ministry of Education, and the National Authority for Emergency, Crisis and Disaster Management.[23]

Energy has traditionally been a means for the UAE to secure geopolitical support. The Abu Dhabi National Oil Company (ADNOC) contract area covers Abu Dhabi's onshore and near-shore areas and is the largest oil concession in the Middle East. The contract was renewed in 2015 providing international corporations with shares of the natural resources of the country. ExxonMobil (US), Total (France), Eni (Italy), BP (UK), Inpex (Japan) and GS (South Korea) are the main multinationals in the energy sector, with oil field operators like Halliburton, Fluor and Schlumberger (all from the United States) doing the extraction work. In 2021 ADNOC announced its plan to build the largest blue ammonia plant in the MENA, in Ruwais, to move its business further into renewable energy production.[24] This is likely to further reaffirm the pivotal position of the UAE in global energy markets.

3.3 Egypt

Egypt is the most industrialised economy of the four countries. As noted in Section 1, its agricultural sector is a regional powerhouse, contributing approximately 30 per cent of agricultural output in the region.[25] Water, food and energy are governed by three different ministries under the auspices of the cabinet. The strong oversight

[22] FAO and World Food Programme (WFP), *COVID-19 Impacts on Agri-food Value Chains*. Libya, Cairo, FAO, 2021, https://doi.org/10.4060/cb3089en.

[23] UAE Government website: *Food Security*, https://u.ae/en/information-and-services/environment-and-energy/food-security.

[24] ADNOC, *ADNOC to Build World-Scale Blue Ammonia Project*, 24 May 2021, https://www.adnoc.ae/news-and-media/press-releases/2021/adnoc-to-build-world-scale-blue-ammonia-project.

[25] UNESCWA, *Arab Horizon 2030*, cit.

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of the cabinet is the closest to Nexus governance as it gets in Egypt. As the largest non-OPEC oil producer, Egypt is the second-largest fossil fuel producer on the African continent and in addition to this it is also a key transit country due to its geostrategic location along the Suez Canal, through which the majority of energy supplies are channelled. The energy sector is characterised by the presence of similar companies as in Libya with Eni, BP and Total playing key roles in energy production. Through German financing, Egypt has constructed the fourth-largest solar farm in the world, called the Benban Solar Park, which is operated by more than 30 companies from around the world.[26] Eni as well as Siemens have recently signed agreements to produce hydrogen in Egypt, signalling a further transition to renewable energy.

Since Egypt is highly reliant on the Nile for its water requirements, the recent filling of the Grand Ethiopian Renaissance Dam poses significant hydrological challenges. This especially applies to the agricultural sector as farmers in the Nile Delta almost exclusively rely on water from the river to produce commodities. As a result, the government of Egypt has embarked upon a very ambitious irrigation reform strategy to upscale irrigation technology to higher efficiency systems.

The Ministry of Agriculture is the second-largest employer in the country, with about 100,000 employees. It plays a major political role as agriculture is also a social question due to millions of small farmers depending on agriculture as a livelihood. The use of ammonia for energy therefore also poses a social question as less fertiliser may be available for agricultural inputs. This may be a key bottleneck as energy production may be in conflict with food producers, of which there are several million in Egypt.

3.4 Iraq

Iraq is by far the most challenged of these countries in terms of water, energy and food sectors. While the country notionally has access to an abundance of water resources, dam construction in the upper Euphrates and Tigris basin by Turkey and Syria has led to a decrease of water inflows. Water, energy and food are governed by federal ministries, yet the ethnic diversity of the country, with Arab Sunnis, Kurdish Sunnis and Arab Shias vying for power and control of resources, has led to political fragmentation since the 2003 US-led invasion.[27] The energy sector is characterised by steady growth in oil production. However, low oil prices in recent years have left the government unable to pay its public administration. At the same time, a patchy energy grid is leaving Iraq with the challenge of bringing energy to the whole territory, especially rural areas. China may be able to provide investments in the grid as Beijing has become a very active player in the energy

[26] Bassem Aly, "Benban Solar Park Opens", in *Ahram Online*, 17 December 2019, https://english.ahram.org.eg/News/357970.aspx.

[27] Oxford Analytica, "Water Scarcity Will Boost Turkey-Syria-Iraq Tensions", in *Oxford Analytica Daily Briefs*, 6 October 2021, https://dailybrief.oxan.com/Analysis/DB264557.

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sector since Iraq signed on to the Belt and Road Initiative in 2015.[28]

The agricultural sector is in a dire state. Major constraints include restricted access to land due to violence; internal population displacement; reduced availability and increased cost of farming inputs; physical damage to land, farming equipment and infrastructure including storage facilities; the disruption of markets; increased cost of and reduced access to animal feed sources; and reduced veterinary supplies and services. It is therefore of paramount importance to increase the output of the agricultural sector. At present, any diversion of agricultural inputs or price increases could lead to further conflict.

3.5 Public-private partnerships as a future development model?

As shown in the previous sections, public governance in especially Libya and Iraq is in a difficult state. At the same time, renewable energy is largely underdeveloped. A model to increase urgent actions to improve water, food and energy systems in the four countries would be to mobilise private money in partnership with public funds. While such developments have seen a considerable uptick in recent years in Egypt and the UAE, Libya and Iraq are lagging. Public-private partnerships (PPPs) to fund water, energy and food projects, including through projects with Israel on tech innovation for urban and agricultural water supply, are well underway in the UAE.[29] The Dubai Department of Finance has allocated US$ 272 million to fund PPP projects with the aim of reaching net-zero by 2050.[30] Egypt, which has a mixed record in attracting PPP finance for infrastructure projects, has partnered with the European Bank for Reconstruction and Development (EBRD) to promote PPP schemes in logistics and the power sector. This has led to the instalment of 900 MW of renewable energy, with a further 400 MW of capacity under construction and 4,000 MW in the planning and development stages.[31] Moreover, the EU's Water Stars programme has provided funding for PPPs in relation to irrigation infrastructure modernisation. Despite some announcements on PPPs in the energy and water sector, little progress has been made so far in Libya and Iraq, largely owing to political instability in the two countries.

[28] Anchi Hoh, "Covid and China's BRI in Iraq and Syria", in *Middle East Policy*, Vol. 28, No. 2 (Summer 2021), p. 31-47, https://doi.org/10.1111/mepo.12559.

[29] "UAE's Al Dahra, Israel's Watergen Sign Strategic Partnership on Water Security", in *WAM*, 26 November 2020, https://wam.ae/en/details/1395302890325.

[30] Bakatjan Sandalkhan, "UAE: Driving Net-Zero Aspirations with Public-Private Partnership Support", in *Gulf Business*, 18 September 2021, https://gulfbusiness.com/?p=194225.

[31] Hossam Abougabal, "Logistics and Power Sectors Drive Progress on PPPs in Egypt", in *MEED*, 12 June 2018, https://www.meed.com/logistics-power-ppp-projects-egypt.

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4. Europe's role in transitioning to a low-carbon future in Libya, Egypt, Iraq and the UAE

Europe can play an important role in support of the four countries' transition from hydrocarbon economies to renewable energy producers. As shown above, all four countries are subject to significant water challenges, which however should not come in the way of producing more renewable energy due to the low water consumption of solar power and hydrogen, at least in the countries where the agricultural sector plays a minor role in the economy and social composition. Libya and the UAE are therefore best suited to transition into a low-carbon future. Egypt and Iraq not only have a significant agricultural sector, but farmers play a key role in the social composition of their population.

Investments in water infrastructure and sustainable, high-value agricultural production systems are key to address WEF Nexus challenges in these countries. The UAE's investment needs are lower than in Egypt and in the two post-conflict countries, Iraq and Libya. In order to successfully produce solar power and blue and green ammonia, the water and food systems of Egypt, Libya and Iraq require significant attention. Libya could be best supported through investment in water and energy infrastructure as well as water management, whereas Iraq and Egypt require an upscaling of not only water and energy infrastructure but also the agricultural sector. Europe could therefore offer its assistance with financing desalination, wastewater treatment plants and water delivery systems to increase water availability to all sectors. Especially the reuse or reclamation of wastewater could be useful. In Israel, almost 90 per cent of municipal wastewater is recycled for reuse in agriculture. Treated wastewater provides approximately 45 per cent of Israel's agricultural water.[32]

Iraq and Egypt could be further provided with assistance in agricultural capacity and value chain development to ensure the agricultural sectors – regardless of their size – are not affected by the energy transition. Another potential opportunity could be investing in more organic food production, as organic agriculture does not permit agricultural inputs such as ammonia. Organic agriculture is a system that relies on ecosystem management rather than external agricultural inputs such as fertilisers and pesticides among others.[33] Granted, a switch to organic agriculture would mean a reduction of 15–20 per cent of yields compared to conventional agriculture.[34] However, given the advanced levels of soil degradation especially in countries such as Iraq and Egypt, it remains questionable whether the current yield levels can be maintained through conventional high-input agriculture. From a

[32] Karyn Simpson, "What the World Can Learn from Israel's Water Reuse Programs", in *Medill Reports*, 18 October 2018, https://news.medill.northwestern.edu/chicago/?p=72191.

[33] FAO website: Organic Agriculture, https://www.fao.org/organicag.

[34] Samuel Knapp and Marcel G.A. van der Heijden, "A Global Meta-Analysis of Yield Stability in Organic and Conservation Agriculture", in *Nature Communications*, Vol. 9 (2018), Article 3632, https://doi.org/10.1038/s41467-018-05956-1.

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WEF Nexus perspective, a wider shift towards organic agriculture would benefit the three resources water, energy and food as well as the ecosystem at large, allowing for a regeneration of natural resources. If such strategies are to be successful, they must involve another level, which is trade.

As shown above, the lion's share of the water deficit in the four countries is due to food security and population growth. This trend will only intensify in the coming decades. Trade-based solutions to provide affordable food for growing populations will therefore depend on future food trade relationships. In this respect, Europe may have the best means to support countries with efforts aimed at integration into its favourable global food trade agreements such as those with Canada or Latin America, where key global agricultural commodities are produced. This could involve the establishment of an agricultural customs union with the four (but not exclusively) countries to ensure that food security concerns do not get in the way of the transition to clean energy. This would mean bringing the WEF Nexus up to the trade level, entailing greater imports of food funded by greater renewable energy exports to, for instance, Europe.

Conclusions

This report has analysed WEF Nexus challenges in Libya, Egypt, Iraq and the UAE to explore whether a greater focus on renewable energy could provide future alternatives. Using the WEF Nexus concept to steer economies towards new solar, green or blue ammonia and hydrogen has a significant potential to establish itself as a new development model. Renewable energy and new energy sources (e.g., green and blue ammonia) could enable these economies to generate new income by becoming renewable energy exporters to especially Europe.

The water-energy linkage does not affect greater production of renewable energy due to the low water consumption of such new energy sources. However, greater renewable energy production must go hand in hand with food security strategies to avoid negative impacts and spill-overs on the agricultural sector and farmer livelihoods. Countries like Egypt and Iraq have strong agricultural sectors, which mean that WEF Nexus trade-offs need to consider synergy effects such as providing more treated wastewater and avoiding any competition over agricultural inputs such as ammonia. Any ammonia produced through cleaner alternatives must not deprive farmers of their input needs.

At the same time, the countries have stark governance differences, which leads to little policy coordination in water, food and energy issues. The state must play a proactive role in establishing and harmonising strong policy institutions to induce an intersectoral governance of water, food and energy, which means the ministries and institutions charged with governing these resources must collaborate effectively. At present, only the UAE stands out as incorporating the Nexus concept through various policy initiatives and partnerships with external actors and countries. Yet, the UAE hosts a small agricultural sector. Egypt has made some important steps towards realising its renewable energy potential together with external partners such as from Europe, yet the dependency of the economy on agriculture makes governance innovations challenging. Libya and Iraq have not made great policy and partnership leaps so far, not least due to their troubled recent political history.

A potential major driver for change could be the collaboration of national and international private sector entities through partnerships with governments to invest in new renewable energy developments. These PPPs have a great growth potential, but they also require good governance. The private sector is ideally placed for systems thinking, as companies have to adopt "nexus thinking" to avoid supply chain problems. PPPs are still largely at an infancy stage in the four economies. While the UAE and Egypt have pursued several PPPs with international partners in recent years, Libya and Iraq have not sufficiently adopted such opportunities.

The WEF Nexus in the four countries is no longer a choice but a mandatory policy framework if these economies want to prepare themselves for a water-scarce future that can still provide significant opportunities for economic growth and development. An adoption of new renewable energy pathways combined with "nexus thinking" in government and the private sector could be a major opportunity in the years and decades ahead.

Updated 26 February 2022

IAI PAPERS 22 | 01 - FEBRUARY 2022 ISSN 2610-9603 | ISBN 978-88-9368-238-1

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ISSN 2610-9603 | ISBN 978-88-9368-238-1

ISSN 2610-9603 | ISBN 978-88-9368-238-1

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