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Nexus Regional Dialogues Programme & Energy Efficient Water Sector

Development of Framework for the Governance of the Water, Energy, Food and Environment (WEFE) Nexus in Jordan

Governance and institutional frameworks analysis and global lessons learned

Revision (Final)

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Table of Contents

List of abbreviations

ABH	River Basin Agency, Morocco
AMEE	Moroccan Agency for Energy Efficiency
ANME	National Agency of Energy Conservation, Tunisia
ANRE	National Energy Regulatory Agency, Morocco
APIA	Agricultural Investment Promotion Agency, Tunisia
CEM	Climate and Energy Model
CNE	National Council for the Environment, Morocco
CRDA	Regional Commissariats for Agricultural Development, Tunisia
CSEC	High Council for Water and Climate, Morocco
EAP	Environmental Action Program
EC	European Community
EMA	Energy Market Authority, Singapore
FTE	Energy Transition Fund, Tunisia
FTI	Tunisian Investment Fund
GDA	Agricultural Development Group, Tunisia
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IMCCC	Inter-Ministerial Committee on Climate Change, Singapore
MARHP	Ministry of Agriculture, Water Resources and Fisheries, Tunisia
MASEN	Moroccan Agency for Sustainable Energy
ME	Ministry of the Environment, Tunisia
MEE	Ministry of Equipment and Water, Morocco
MENA	Middle East and North Africa
MIEM	Ministry of Industry, Energy, and Mines, Tunisia
MSE	Ministry of Sustainability and the Environment, Singapore
MTEDD	Ministry of Energy Transition and Sustainable Development, Morocco
MTI	Ministry of Trade and Industry, Singapore
NCCS	National Climate Change Secretariate, Singapore
NEA	National Environment Agency, Singapore

NPD	National Policy Dialogue
OCP	Cherifian Phosphate Office
OECD	Organization for Economic Cooperation and Development
ONAS	National Sanitation Office, Tunisia
ONEE	National Office of Electricity and Drinking Water, Morocco
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PUB	Public Utilities Board, Singapore
PV	Photovoltaic
RBMP	River Basin Management Plan
SECADENORD	Northern Water Canal Supply Company Tunisia
SoCU	Statement on Common Understanding
SONEDE	National Society of Water Exploitation and Distribution, Tunisia
SPIS	Solar Pumping and Irrigation System
STEG	Tunisian Electricity and Gas Company
STIR	Tunisian Company of Refining Industries
UNECE	United Nations Economic Commission for Europe

List of tables

List of figures

1. Introduction

1.1 Overview of interconnected Water-Energy-Food-Environment (WEFE) Nexus challenges globally

Water, energy, and food systems are tightly interconnected, and the way in which they are managed has direct impacts on the environment and eco-systems in which they exist. Water, energy, and food security are critical for economic growth and human development. Globally, water demand is expected to increase by 1% each year for the next 30 years, which will exacerbate pressures on water resource systems, jeopardizing the livelihoods for the estimated 4 billion people living in areas that experience water scarcity (UNESCO WWAP 2022). Energy demand is expected to double between 2015 and 2050 as a result of economic development and growing populations (IRENA 2015). At the same time, moderate and severe food insecurity has been on the rise since 2014, soon after the shocks on the food markets in 2007 and 2008 (Wiggins, Keats, and Compton 2010). Due to the impact of the COVID-19 pandemic the increase in global food insecurity in 2020 equaled the increases of the previous five years combined (FAO 2021).

Understanding the interconnections between water, energy, and food systems, and their impact on the environment is critical as new management and governance approaches are developed in response to the growing demands and pressures they face (Figure 1). In 2014, energy consumed 10% of total water withdrawals, and energy-related water consumption was estimated to increase by 60% between 2014 and 2040 (IEA 2016). The water sector consumed about 4% of the world's electricity to pump, treat, and distribute water in 2014, a proportion that is expected to more than double by 2040. Much of this increase is attributed to increasing desalination, water transfer, and wastewater treatment (IEA 2016). The global food system is highly dependent on water, with irrigation for agriculture making up 70% of global water withdrawals (UNESCO WWAP 2022).

Global trends, such as climate change and growing populations, result in additional strains to WEFE-Nexus systems. The effects of climate change include unpredictable weather patterns, fluctuating surface water resources, and decreased agriculture potential. According to UN Water, fluctuations in surface water availability have been observed in over a fifth of the world's basins, making water resource management more challenging and unpredictable (UN Climate Change News 2021). Population growth and urbanization trends have had notable impacts on water, energy, and food consumption patterns. Population growth and food production forecasts estimate a 100-110% increase in global crop demand between 2005 and 2050 (Tilman et al. 2011). Additionally, increasing demand has highlighted areas where infrastructure dedicated to providing and distributing water, energy, and food is unable to keep up with increased demand (Bakirtas and Akpolat 2018; Wu and Tan 2012). Increasing production to meet demand could have a variety of effects on the environment, including desertification, water contamination, air pollution, and ecological damage.

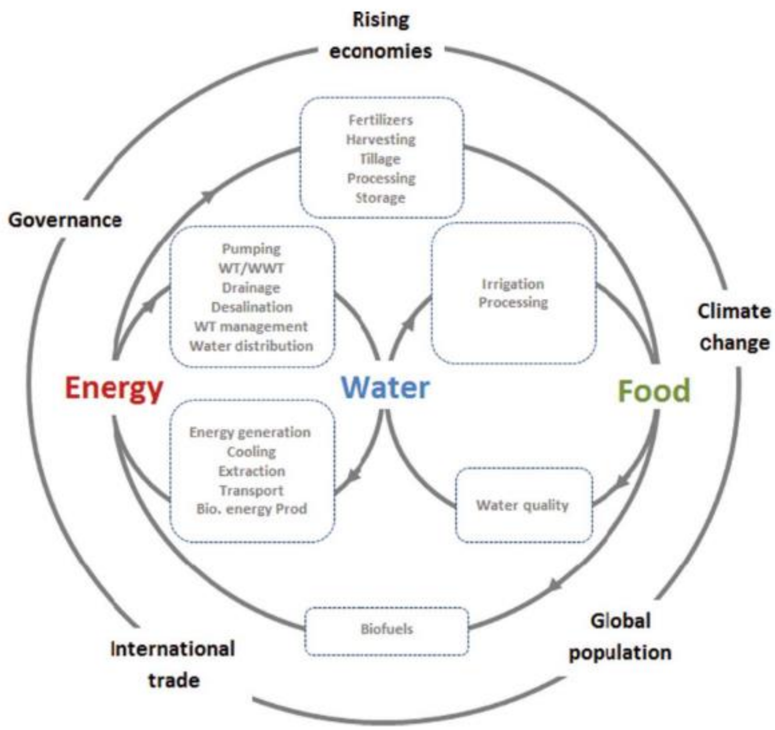

Figure 1. Water-Energy-Food system interconnections. Source: (Mohtar and Daher, 2012)

1.2 Overview of interconnected Water-Energy-Food-Environment challenges in the MENA region

Two-thirds of countries in the MENA region are expected to be in absolute **water scarcity** (less than 500 m3 of renewable water resources per capita per year) by 2050, and at least ten countries in the MENA region are considered absolutely water scarce now, based on most recent available data (Mendonca et al. 2019; The World Bank 2018). A comparison of MENA countries' renewable water availability per capita can be found in Figure 2. The MENA region has around 1% of global freshwater resources, much of which is made up of non-renewable groundwater (GW), which worsens the consequences of overexploitation (Hibrawi 2019; UNESCO WWAP 2022).

Energy resources, although present in many countries, often come with concerns about security, sustainability, and affordability for countries that are not self-sufficient energy producers. Petroleum production and consumption in MENA countries is shown in Figure 2. Energy demand in the MENA region is high due to inefficient insulation, heating and cooling technologies, and distribution infrastructure. Furthermore, energy demand in the region is expected to increase by 2% a year until 2040 (Ersoy and Terrapon-Pfaff 2021).

Food security is a critical issue in the MENA region, where the arid climate and water scarcity make food production a costly, and often insufficient, endeavor. MENA's high dependence of imported food, especially for water-intense food products, is a national security and economic issue. About 50% of food in the MENA region is imported, and areas in conflict have additional challenges with procuring and distributing food (Howey 2021). Environmental factors affect each of the other parts of the WEFE Nexus. Climate change has led to more extreme weather, which has affected water availability and crop production. Other issues, such as locust outbreaks, desertification, and air quality interact with water, energy, and food and affect the ability of systems to meet demand (Belhaj and Soliman 2021).

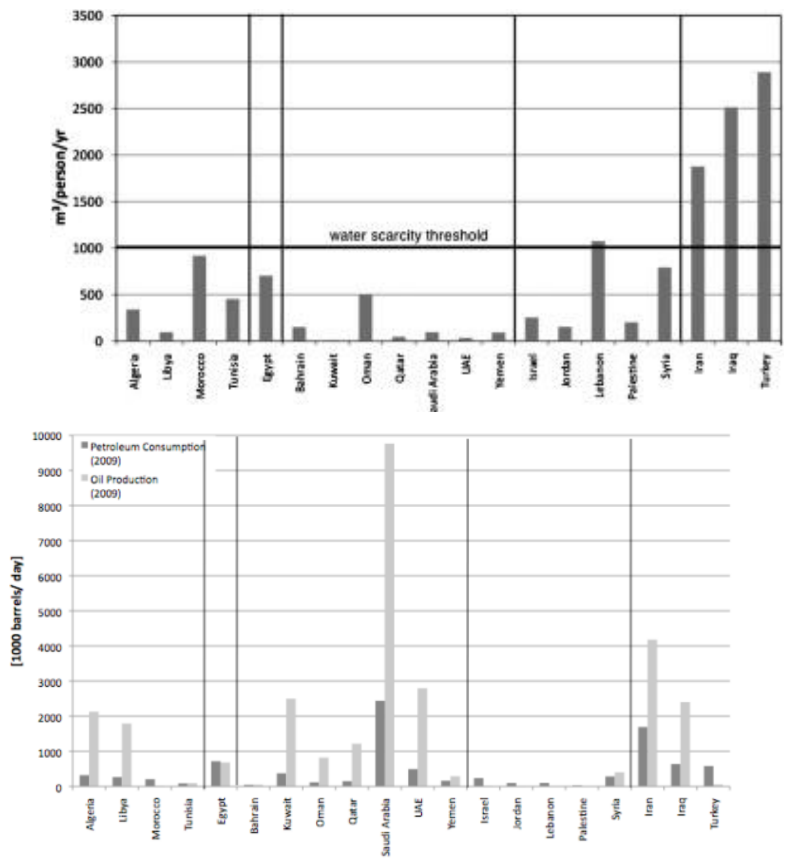

Figure 2. Annual per capita renewable water availability (as of 2010) and Petroleum production and consumption as of 2009 by MENA countries. Source: (Siddiqi and Anadon 2011)

Social factors are also challenging water, energy, food and environment in the MENA region. Population growth in the region is one of the main drivers of increasing water, energy, and food demand. Although the population growth rate is slowing, the MENA region's population is expected to double during the first half of the twenty-first century (Mendonca et al. 2019, 16). Similarly, the MENA region is facing changing demographics and patterns of consumption due to high youth unemployment rates and urbanization. The MENA region has long had the highest youth unemployment rate in the world, with rates higher than 24% since 2011 (Kabbani 2019; International Labor Organization and World Bank 2022). As youth go to urban areas in search of employment, pressures on urban water and energy demands increase accordingly.

Solutions. Many alternative water solutions being considered by the water sector across the region are energy intensive. Desalination, treatment of wastewater and storm and return waters, and deep groundwater exploration/pumping require significant energy inputs. In 2016, the water sector consumed 9% of total electricity consumption in the Middle East, which is expected to increase to 16% by 2040 (IEA 2016). The MENA region has more desalination capacity than any other region, and this capacity is expected to increase by over five times between 2015 and 2030. This increase will raise total electricity demand for desalination by three times in the same time period (IRENA 2015). In response to this and other growing demand challenges, the MENA region has implemented solutions that have significant implications for water and energy resource balances. Countries with little indigenous energy resources are focusing on renewable energy options, such as solar and wind energy. Although renewable energy can have low water requirements, countries that originally relied heavily on imported energy will see a rise in water demand as part of their transition to renewable energy production. Growing energy and water requirements for the MENA region highlight the need for system-minded solutions.

1.3 Overview of Water-Energy-Food-Environment interconnected challenges in Jordan

Jordan faces extreme water scarcity, limited freshwater resources, high energy dependence, and a growing population to feed. Jordan had just 68 m3 of renewable freshwater resources per capita per annum in 2018, far below the threshold for severe water scarcity (World Bank 2018b; UNICEF n.d.). Demand for water in Jordan regularly outweighs supply, which leads to overexploitation of water resources and necessitates alternative water solutions. By 2025, demand is forecasted to outweigh supply by over 26% (MWI 2016). Jordan is also highly reliant on energy imports, having imported 84% of its energy needs in 2021 (MEMR 2021). Furthermore, demand for electricity has consistently risen around 2.4% each year to reflect a growing electricity usage (JREEEF and MEMR 2018). In addition to growing demand, the high cost of energy is one of the driving forces for establishing the intersectoral water-energy committee and technical working group in Jordan. In 2021, Jordan spent 6% of its GDP on energy imports, at a cost of nearly 2.6 billion USD (MEMR 2021). It is reported that the electricity bill of the water sector constitutes almost half the operational and maintenance cost.

Jordan’s demand for food has grown in recent years due to population growth, which led the King to declare 2021 as the year of food security for Jordan. The subsequent food summit and national food security plan that included highlighting the multi-disciplinary and multi-institutional nature of the food system with the goal of reconsidering the roles and responsibilities of related actors (GoJ 2021). Jordan’s agriculture sector represents a key feature of the water-energy-food-environment system: 50-60% of Jordan’s water goes toward agriculture, and 15-16% of Jordan’s electric energy each year goes toward agricultural and water pumping activities (MWI 2016; MEMR 2020).

To address these challenges, Jordan has explored renewable energy production and sources for alternative water supply and water reuse. Water treatment is one clear example; 30.9% of water used by the agriculture sector is treated wastewater, which utilizes 98% of Jordan’s available treated return and storm water (MWI2023; MWI and MoEnv 2020). Building new desalination plants and pumping deeper ground water are also water supply sources Jordan has pursued (GoJ 2015).

These water initiatives represent significant strains on both the water and energy sectors. As it presently stands, 50% of the water sector’s operational costs go towards electricity. At the same time, Jordan has committed to providing affordable water to its citizens, which can contribute to financial pressures on the government (MWI and MoEnv 2020).

Jordan's Ministry of Water and Irrigation and the Ministry of Energy and Mineral Resources have adopted strategies and plans to increase energy and water efficiency, finance investments into renewable energy sources, and explore new water resource options. These sector-specific plans are useful, but further integration and coherence of such plans is yet to be realized (JREEEF and MEMR 2018; GIZ 2017).

The water, energy, and food sectors have environmental effects. Livestock represent over 50% of agricultural production in Jordan, which has led to consistent overgrazing. The result of this is desertification and a decrease in the amount of cultivatable land over the past few decades (MoEnv 2021). Jordan's water and food sectors also contributed to pollution. Over 50% of household waste is food waste, while the average municipal recycling rate is only 7%, which is low for the region (MLA and MoEnv 2020). Transboundary and national industrial pollution have led to high pollution of Jordan's rivers, and overdrawing of Jordan's groundwater has increased salinity and deteriorated water quality (MWI and MoEnv 2020). Jordan has acknowledged intersectionality of the environment through its ***Green Growth National Action Plans 2021-2025***, which encompass the water, waste, energy, and agriculture sectors. These plans highlight the necessity of environmental sustainability to ensure a sustainable economy and prioritize cross-sector collaboration and support of the environment through technical and financial initiatives (MWI and MoEnv 2020).

Need for integrated planning. Despite growing evidence of the tight interconnectedness between water, energy, food, and environment systems and the interdependence of the challenges they face at different scales, little coordination exists for planning, financing, and governing these sectors (Daher et al. 2019). Plans are often developed within institutional silos with little recognition to the interdependencies. Given the growing pressures on water and energy resource systems, there is a need for developing new innovative frameworks and coordination mechanisms that allow a proper evaluation of the synergies and trade-offs associated with different technical and policy interventions being considered across sectors. This requires the development of a common vision and success metrics to ensure coherence between cross-sectoral policies. It also requires the development of innovative shared financing and governance models that can ensure the implementation of solutions that address the tight interconnectedness between sectors.

This report aims to review available literature on experiences of other countries, good practices and lessons learned that can inform the process of developing new governance mechanisms and sustainable business models to ensure greater resilience of the water, energy, and food sectors in Jordan. Specifically, the report will**: 1)** introduce criteria for selecting country case studies that offer best practices; **2)** identify countries based on selection criteria and multi-stakeholder consultation process; **3)** outline the decision-making processes, governance and institutional structures, methods to ensure policy coherences, and examples of best practices from each of the three selected countries and other global examples; **4)** reflect on lessons learned which could be considered within the Jordanian context.

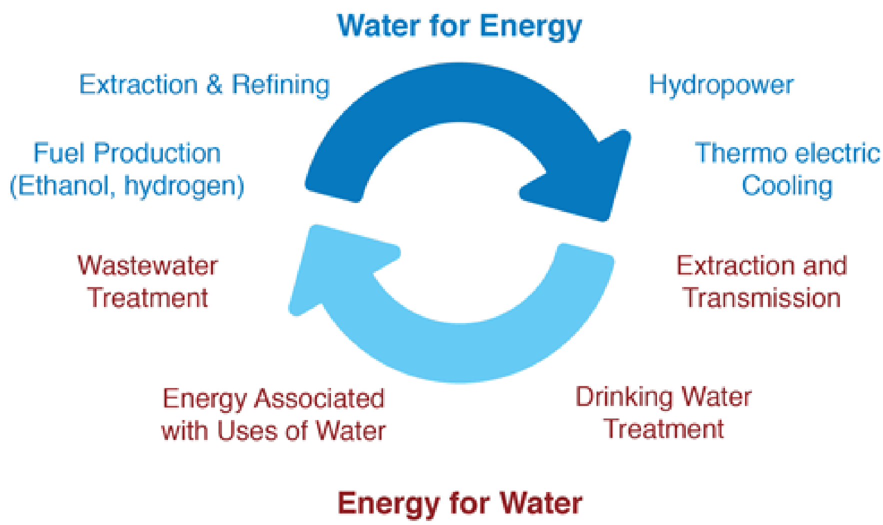

Figure 3. Water-Energy interconnections
Source: (WBCSD 2009*)*

This report will specifically focus on the Water-Energy nexus interconnections within the context of the broader Water-Energy-Food-Environment nexus framework. Addressing the challenges that face water and energy will require new solutions that are consistent with the tight interconnections between these resource systems (Figure 3). In addition to focusing on managing water demand and reducing non-revenue water, many solutions to increase water supply, such as desalination and water re-use and recycling are energy intensive; it is expected that desalination projects will account for 20% of water-related electricity demand by 2040 (IEA 2016). Solutions to develop renewable energy or conventional domestic energy resources can also be water-intensive; although some renewable energy production methods require very little water, others (e.g., some methods of solar power (e.g. solar heaters), biofuels, and nuclear power), can have significant water requirements (IEA 2016). Developing water and energy solutions must take a variety of factors into account; water and energy needs to be coherent with national security, policy making, and international relations **while taking into account the interconnections with food and the environment** (Simpson and Jewitt 2019; Dubois 2015; Hogeboom et al. 2021).

2. Methodology

2.1 Criteria identification and country selection process

i. ***Email correspondence.*** The GIZ project team developed an initial draft of country selection criteria which was circulated with governmental stakeholders, where feedback and input was requested. The draft included a list of resource availability, climate, economic, financial, and governance criteria, among others. The engaged stakeholders included members of: Ministry of Energy and Mineral Resources, Ministry of Water and Irrigation, Water Authority of Jordan, Jordan Valley Authority, Energy & Minerals Regulatory Commission.

ii. ***Virtual stakeholder consultations.*** Following the email request, the consulting team organized a series of virtual meetings with the same stakeholders to learn about the key challenges facing different sectors. These interviews were also used to get further feedback about countries which could offer lessons learned and best practices to be considered in the case of Jordan. These virtual interviews included additional non-governmental and international development stakeholders including EDAMA Association, GIZ-Jordan, German Development Bank, World Bank, EU delegation to Jordan, and Friedrich-Ebert-Stiftung Jordan & Iraq.

iii. Literature review and analysis. Based on the input provided by stakeholders in response to the country selection criteria and the shortlist of countries to be considered, the consulting team conducted an initial analysis based on reviewing the literature to determine the alignment of the countries of choice with the criteria of interest.

2.2 Country selection criteria

To identify best practices and lessons most relevant to the Jordanian context, a set of criteria was developed to guide country selection. These criteria emphasized similarities in contextual features while also examining a variety of water and energy system characteristics, as well as different economic, governance, and regional cooperation situations. Specifically, it was determined that the selected countries should be part of, or have similar characteristics to the Mediterranean Sea (MED) basin and have regions with similarities to Jordan in terms of the challenges they face (see Table 1):

Table 1. Co-created country selection criteria

Water and Energy Resources Criteria (availability, dependence, losses, infrastructure services)	1. Water scarcity 2. Energy dependence 3. Water per capita 4. Energy per capita 5. Non-revenue water 6. Water losses	7. Energy losses 8. Climate (dry, hot with large number of sunny days) 9. Infrastructural development 10. Services coverage (%) 11. Desalination plans 12. Renewable energy plans
Economic/Financial Criteria	1. Level of development 2. Sources of financing 3. Energy costs of the water sector	4. Electricity tariffs differentiated by time of use (TOU) 5. Water cost
Governance Criteria	1. Relevance and how topical for the country is WEN/ existing WEN sector coupling and planning 2. Water and Energy governance structure 3. Role of central government agencies versus basin organizations 4. Operators of energy and water systems (centralized vs. decentralized)	

Regional Cooperation Criteria	1. Neighboring countries' cooperation in water and energy
Food/Agricultural related Criteria	1. Agriculture water needs 2. Agriculture energy needs 3. The prevalence of desertification, soil erosion, overgrazing
Environmental Criteria	1. Fresh water quality and quality of treated wastewater

2.3 Country selection

During the stakeholder consultation meetings, there was a general agreement that Jordan has a number of specific peculiarities that would be challenging to find in another country or region. Each country has its unique context in terms of water and energy sources availability, geography, population density and culture, among others. Keeping that in mind, the identified criteria was used to select three countries that have a reasonable level of similarity in terms of challenges, while offering a diverse range of lessons learned and best practices which could be considered for the Jordanian context.

Several countries were initially considered and shared with stakeholders. Following feedback from the consultations, and after collecting information about resource availability, climate conditions, governance structures, and technological availability, among others, the level of similarity or suitability for each criterion was determined as either 1) very similar to Jordan (green), 2) somewhat similar to Jordan (yellow), or 3) far from being similar to Jordan (red). More details on the mapping can be found in Table 1 in Appendix 1. The most eligible countries were then discussed until consensus was reached regarding the countries that would be most instructive to examine further. The project team, upon consultation with local stakeholders, determined **Tunisia**, **Morocco**, and **Singapore** to be the best candidates for further study based on their similarities and alignment with the criteria. The following sections explore each of the selected countries.

3. Country 1: Tunisia

3.1 Context

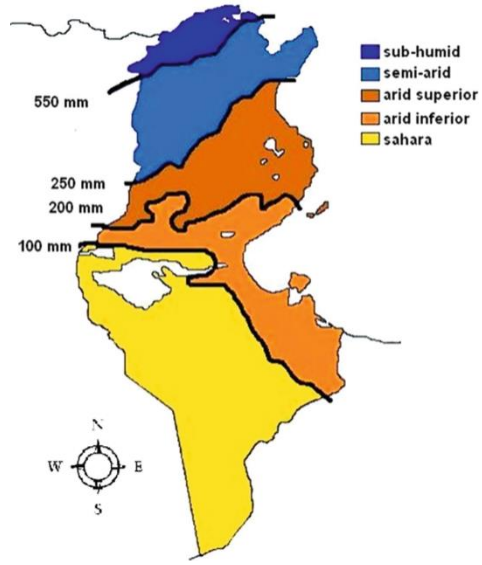

Figure 4. Climatic and rainfall map of Tunisia (Source: Hentati 2010)

Water. Despite Tunisia's limited renewable water resources, it has succeeded in providing universal drinking water service in urban areas and managing water demand during times of drought since the implementation of its first water mobilization strategy in 1990 (MARHP 1998). Tunisia's water resources are unevenly distributed throughout the country, with northern areas receiving more rainfall (594 mm a year on average) than the southern, Saharan climate (156 mm a year on average) (Figure 3). Due to the variability of water resources, Tunisia's highly populated coastal areas and southern desert areas require transfers or water from alternative sources to meet demand (Nexus Dialogue Program 2018). To combat water scarcity and inconsistency, Tunisia has mobilized over 90% of its water resources for the past decade, storing much of it in dams, lakes, and wells (IUCN ROWA 2019). Although Tunisia captures seasonal rainfall, 60% of Tunisia's water consumption is from groundwater, which has led to overexploitation of groundwater resources (Nexus Dialogue Program 2018). Tunisia treats 83% of sewage from urban areas, and 78% of its wastewater treatment plants are equipped to produce reusable water. 75% of treated wastewater is discharged into the receiving environment, and the remainder is mostly used in the tourist and agricultural industries, or to refill groundwater reservoirs (Caucci 2018; Hamida 2017).

Energy. Tunisia has transitioned from an energy exporter to an energy importer over the past two decades, mostly due to increasing consumption and declining fossil fuel production (Ersoy and Terrapon-Pfaff 2021). In 2018, Tunisia imported 60% of its energy consumption (IRENA 2021b). 96.7% of Tunisia's energy comes from natural gas, most from an Algerian tax agreement that provides Tunisia with 10% of the natural gas that flows through pipelines running through Tunisia (Nexus Dialogue Program 2018; GIZ 2019b). Tunisia's energy production by source is mainly by combined cycle heat and power generation at 69.9% of production, followed by 15.2% gas turbines, 12.4% thermal steam, 2.4% wind, and 1% hydropower (Nexus Dialogue Program 2018). Tunisian electricity consumption has grown together with growing industrial demand and increasing populations. Furthermore, seasonal demand has shifted significantly over the past two decades, driven by air conditioning use in the summer (Ersoy and Terrapon-Pfaff 2021).

Water-Energy. The growing and interdependent demand for water and energy in Tunisia makes the need for adopting a nexus approach particularly relevant. In 2020, freshwater pumping and pumping for sanitation services made up 12% of the national energy company's electricity sales through their high tension and medium tension lines (STEG 2021a). Tunisia's initiatives to address growing water needs are highly energy dependent. The National Office of Sanitation (*Office National de l'Assainissement*) spends 60% of its operating costs on energy (Drechsel and Hanjra 2018). The oil and mining sector consumes 3-4% of total water consumption in Tunisia. The oil sector consumes water through the drilling and production processes. (GIZ 2019b). Tunisia has made early steps toward integrated water and energy management through a variety of initiatives, including desalination of sea water and brackish water, hydro storage, wastewater treatment, and residential solar power (GIZ 2019b). A summary of water and energy interconnections in Tunisia can be seen in Figure 5.

There are differences between Tunisia and Jordan. Tunisia has more surface water resources due to its climate with higher precipitation in the north, which allows it to store water in dams and lakes. Tunisia also produces more indigenous energy, primarily from oil and natural gas (IRENA 2021b). The agriculture sectors in both countries represent different proportions of energy consumption. Tunisia's agriculture consumes 6% of the national total final energy consumption (IRENA 2021b). Jordan's agriculture sector consumes 3.2% of the national total final energy consumption (MEMR 2015). Jordan's political situation has been more stable than Tunisia's over the past decade, given Tunisia's 2010-2011 revolution, change of power in 2015, and new constitution (GIZ 2019b).

Tunisia shares similarities with Jordan. Both are highly water scarce; in 2018 Jordan had 68 m^3 of renewable water resources per person per annum, Tunisia had 363 m^3 (World Bank 2018b; 2018e) – also well below the 500 m3 threshold. In addition to water scarcity, both countries face uneven water availability in different geographic regions, which requires energy intensive water conveyance projects over long distances. Both Jordan and Tunisia face high levels of non-revenue water stemming from aging water infrastructure; more than a quarter of the Tunisia's drinking water network is more than 37 years old, and in 2017 the network efficiency (measured as 100% minus the percentage of water lost in the network) was only 71.5%. In Jordan, the non-revenue water (NRW) rate was 50%, due to aging infrastructure and illegal withdrawals (GIZ 2019b; Al-Sheriadeh and Amayreh 2020). In 2020, freshwater pumping and pumping for sanitation services made up 12% of the Tunisia's national energy company's electricity sales through their high tension and medium tension lines (STEG 2021a). Similarly, about 10% of Jordan's electric energy each year goes toward water pumping and wastewater treatment processes.

Both countries experience overexploitation of groundwater resources, tumultuous regional politics, and reliance on imported energy. Jordan and Tunisia both use treated wastewater, although Tunisia's reused wastewater makes up about 1% of their irrigated agriculture needs, much less than Jordan. Furthermore, Tunisia's treated wastewater is often not in compliance with water quality regulations; in 2013 80% of

Tunisian wastewater treatment plants were not compliant with at least two water quality parameters, and all were not compliant with phosphate and nitrate requirements (Caucci 2018).

The agriculture sector in both countries makes up the majority of water demand: 48.6% of Jordan's water goes toward agriculture and 77% of water goes toward agriculture in Tunisia (MWI 2023; World Bank 2017). Desertification and overgrazing are issues in both countries; in Tunisia, desertification mostly affecting the rangelands in the south of the country (Gamoun, Belgacem, and Louhaichi 2018). Jordan and Tunisia are facing many similar challenges, and both have had significant successes. 98% of Jordan's population has access to a safely managed water source, and Tunisia has achieved universal urban access to water (MWI 2016; GIZ 2019b). However, in both countries, water supply is intermittent, and rural areas populations have less access to safely managed water sources (GIZ 2019b; Al-Ansari et al. 2014; OHCHR 2022).

Both Tunisia and Jordan see desalination, improving energy and water use efficiencies, and renewable energy as opportunities for improving the sustainability of both sectors. Jordan aims to have renewables make up 31% of its electricity generation by 2030; Tunisia aims to have renewable energy make up 30% of electricity production by 2030 (IRENA 2021a; 2021b). Although Tunisia has more opportunities for hydropower, both countries are highly focused on solar energy possibilities. Both Tunisia and Jordan prioritize ensuring affordable and available water and energy for their citizens (GoJ 2015; IUCN ROWA 2019).

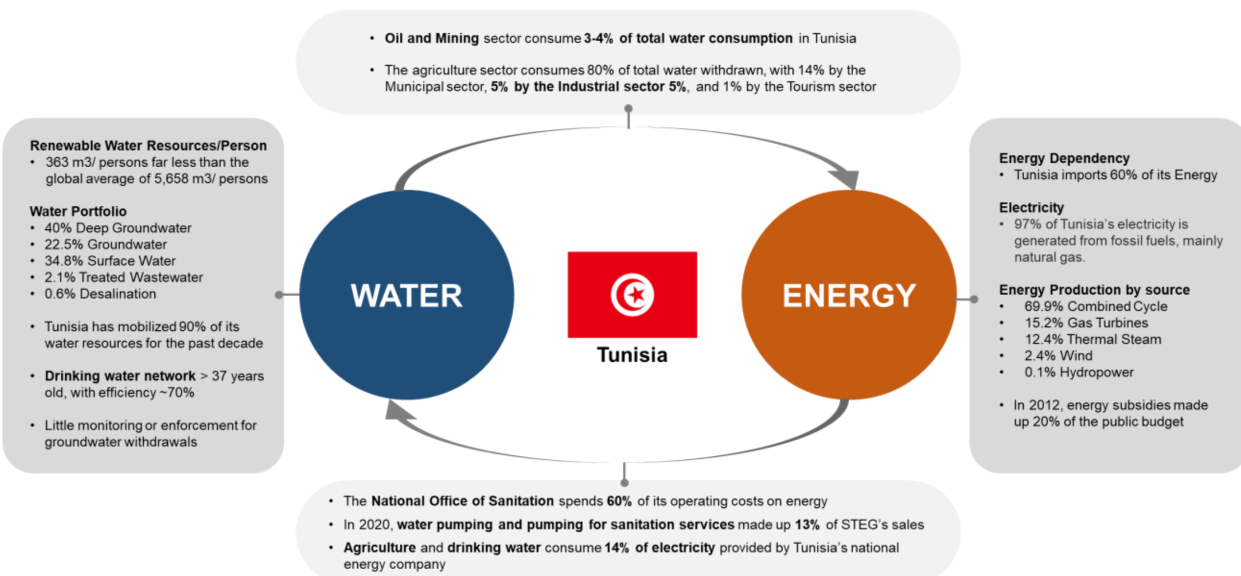

Figure 5. Key water-energy interconnections in Tunisia
Source: Authors

3.2 Governance and Institutional Structures

a. Governance of the Water and Agriculture Sectors

The *Ministry of Agriculture, Water Resources and Fisheries (Ministre de l'Agriculture, de Ressources Hydrauliques et de la Pêche, MARHP)* is the main actor responsible for water and land resources and manages small dams, water sector monitoring, water supply, and drinking water production. Additionally, MARHP governs development of the agricultural sector and facilities for agricultural production. (GIZ 2019b). The ministry is also responsible for creating and implementing national water strategies, research and development, and acquiring financial resources (MARHP 2001). MARHP is guided by the *National Water Council (Conseil National de L'eau)*, a strategic advisory body made up of representatives from various ministries and national organizations, although no *Agricultural Development Groups (Groupements de Développement Agricoles*, GDAs) or local representation is included (Closas, Imache, and Mekki 2017).

MARHP has many departments that manage specific areas of national water resources. The *General Directorate of Water Resources (Direction Générale des Ressources en Eau)* is the most over-arching entity, responsible for developing operational methods for managing water resources, developing mobilization plans, and managing water quality measuring stations. Operating under the General Directorate is the *Bureau of Inventory and Hydraulic Research (Bureau de l'Inventaire et des Recherches Hydrauliques)*, an administrative unit that is responsible for research, monitoring, and managing water data (CEDARE 2014). The *Bureau of Planning and Hydraulic Equilibria (Le Bureau de Planification et des Equilibres Hydrauliques)* is a public establishment under the General Directorate of Water Resources that schedules annual water allocations, plans water mobilization, and develops non-conventional water resources to manage supply and demand. The Bureau also coordinates between water resources production institutions and water users in different sectors.

The *General Directorate of Dams and Hydraulic Works (Direction Générale des Barrages et des Grands Travaux Hydrauliques)* is another directorate under MARHP that develops and researches topics relating to dams and water mobilization, and the *General Directorate for Development and Conservation of Agricultural Land* manages water guidelines and coordination relating to agricultural water (CEDARE 2014).

The *Directorate General of Rural Engineering (Direction Générale du Génie Rural et de l'Exploitation des Eaux)* is another directorate under MARHP that is responsible for small and medium water supplies in rural areas (IUCN ROWA 2019). Its responsibilities with rural water and agriculture include monitoring and evaluation, increasing water efficiency, and monitoring and evaluation of projects and drinking water programs (CEDARE 2014).

Two public companies are supervised by the MARHP. The *National Society of Water Exploitation and Distribution (Société Nationale d'Exploitation et de Distribution des Eaux, SONEDE)* is a public company created in 1968 in charge of drinking water production, supply systems, and distribution for all urban areas and major rural centers in Tunisia (SONEDE 2021). In 2020, SONEDE serviced 100% of urban areas and 53.4% of rural areas (SONEDE 2021). The Northern Water Canal and Supply Company (SECADENORD) is responsible for the management and operation of water piped from northern dams to the rest of the country (CEDARE 2014).

Also encompassed by MARHP are regional and local water governance entities. Since a push for decentralization in 2005, the *Regional Commissariats for Agricultural Development (Commissariat Régional au Dévelopement Agricole, CRDAs*) have been responsible for authorizing access to water for irrigation purposes. *Agricultural Development Groups* (*Groupements de Développement Agricoles, GDAs*) are responsible for managing public irrigated perimeters (PPIs), including maintaining irrigation infrastructure and collecting fees (GIZ 2019b).

Decentralized water management through regional and local authorities has seen inconsistent results. There are over 2,800 GDAs managing irrigation or drinking water in Tunisia (GIZ 2019b). Although some GDAs are able to engage with their communities and provide appreciated services to local constituents, many GDAs frequently experience financial challenges, as farmers rarely pay GDA water fees due and frequently connect to water networks illegally to avoid paying water fees. CRDAs are similarly ineffective; they have the authority to fine users who do not receive permission to drill for water, or even block the illegal wells, but this is rarely enforced. In additional to a growing number of illegal wells, there are no meters monitoring authorized wells and therefore no way to control the volume of water withdrawn (GIZ 2019b).

Other ministries govern water quality and a few other aspects of the water sector. The *Ministry of the Environment (Ministère de l'Environnement, ME)* is responsible for sanitation and all environmental aspects of water. The ME oversees the *National Sanitation Office (L'Office national d'assainissement, ONAS)*, the *National Waste Management Agency (Agence Nationale de Gestion des Déchets),* and the

National Environmental Protection Agency *(L'agence nationale de protection de l'environnement)* (MoE 2020a). The *Ministry of Public Health* controls drinking water standards, while the *Ministry of Equipment* manages flooding in urban areas (MPH 1974; MoEH 2018).

Because the water and the agrifood industry are managed under the same national entity, many of the offices and actors within MARHP are involved in the governance of both sectors. Other agri-food focused entities include the Agricultural Investment Promotion Agency, Agricultural Extension and Training Agency, the Institution of Agricultural Research and Higher Education, the National Council for Agriculture and Fisheries, and the Agriculture, Food Security, Trade and Services Committee, which operate or advise on different aspects of sector governance (GIZ 2019b).

b. Governance of the Energy Sector

The *Ministry of Industry, Energy and Mines* (*Ministère de l'Industrie, des Mines et de l'Energie, MIEM*) governs the energy sector by overseeing and implementing energy policies and strategies. The ministry promotes research, ensures national energy security, develops policies and laws, and negotiates with private actors to promote energy projects and optimize market conditions (Ersoy and Terrapon-Pfaff 2021). The ministry administratively oversees the *National Agency for Energy Conservation (L'Agence Nationale pour la Conservation de l'Énergie, ANME)*, an independent public non-profit organization that designs and implements Tunisia's national energy policies (IUCN ROWA 2019; AMNE 2022). Two commissions in MIEM, the *Interdepartmental Commission of Independent Power Generation (Commission Supérieure de la Production Indépendante d'Electricité)* and the *Technical Commission of Private Renewable Power Generation (Commission Technique de Production Privée d'Électricité)*, are responsible for renewable energy projects, analysis, and negotiations with independent energy producers. Other actors related to the energy sector are the *Tunis International Center of Environmental Technologies (Centre International des Technologies de l'Environnement de Tunis)* and the *National Agency for Environmental Protection (L'agence Nationale de Protection de l'Environnement)*, which build sustainable skills and assess environmental impacts of power production, respectively (Ersoy and Terrapon-Pfaff 2021).

The *Tunisian Electricity and Gas Company* (*La Société Tunisienne d'Electricité et du Gaz, STEG*) was created in 1962 with the responsibility to produce, transport, and distribute electricity and gas (STEG 2021b). Although the electricity market was opened in 1996, STEG continues to be the producer of majority of energy in Tunisia (Ersoy and Terrapon-Pfaff 2021). One power plant was managed by

Carthage Power Company and it produced 18.6% of energy in 2017, but the plant was returned to STEG after the 20-year power purchasing plan ended in May 2022 (ITA 2022a). Individuals generating solar power are able to sell up to 30% of any excess electricity they produce from photovoltaic systems back to STEG (GIZ 2019b). STEG suffers from financial difficulties, in part due to significant unpaid customer bills due, and physical losses in about 18% of the energy it produces (GIZ 2019b).

c. Water and Energy Institutions

From a national legal perspective, water and energy usage have long been written into law. Tunisia's constitution enshrines citizens' rights to water and the authorities' responsibility to provide water. The standing Water Code was issued in 1975, although a new water code has been in progress since 2011 to reissue the water code to incorporate amendments and better reflect expectations of governance (GIZ 2019b). Energy is less institutionalized as a right, but Tunisia strives to provide affordable and accessible electricity for all its consumers through subsidies and affordable pricing (GIZ 2019b).

Tunisia's water — drinking water and water for irrigation — is priced so that to ensure affordability (OHCHR 2022; Chebil et al. 2022; GIZ 2019b). The lack of enforcement or clear legislation on groundwater pumping leads to illegal withdrawals and unpaid water fees. Currently, revenues from drinking water only cover 89% of SONEDE's operating and distribution costs (GIZ 2019b). Tunisia's pricing method for electricity is more detailed: each year, MIEM, the Ministry of Finance, the General Directorate for Energy, the Tunisian Enterprise of Petroleum Activities, the Tunisian Company of Refining Industries (STIR), and the Ministry of Commerce agree on a price rates based on international oil and gas prices, finances of national energy companies, and the government's ability to provide subsidies (Ersoy and Terrapon-Pfaff 2021). Tariffs for subscribers on the low-voltage (90 kV) network are based on the sector, monthly consumption, and power level. Tariffs for the medium-voltage (150 kV) network are based on the time of day and the season (AfDB 2021).

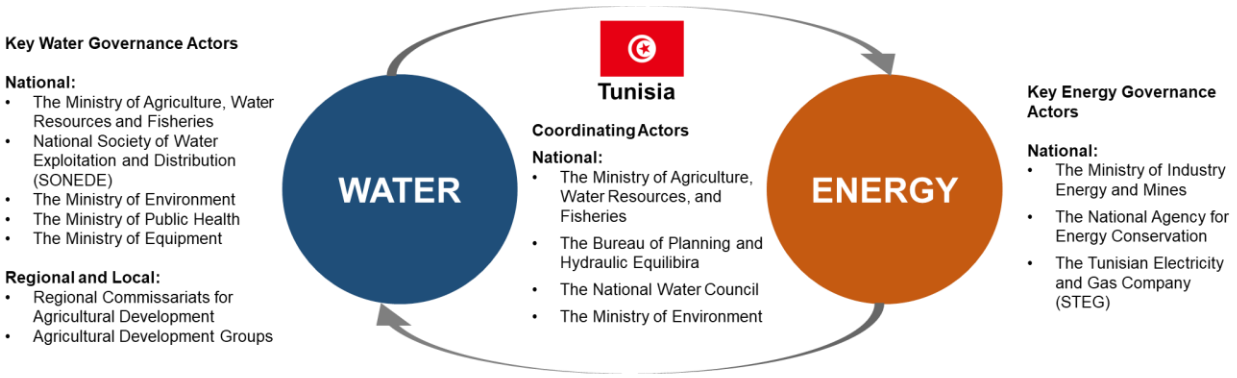

Figure 6. Key water and energy governance actors in Tunisia
Source: Authors

Electricity for water pumping is sold to farmers at a lower rate (IRENA 2021b). Although the pricing system accounts for many factors, because of subsidies, energy tariffs do not reflect true production costs. The two main energy providers, STEG and STIR have annual deficits that are covered by the state's budget (Ersoy and Terrapon-Pfaff 2021). Although some subsidies have been removed over the past few years and some prices increased, the overall subsidization of energy has increased over the past decade and now makes up around 13% of total the expenditures of the two main energy providers (STIR and STEG), which is covered by the State's budget. In 2012, energy subsidies made up 20% of the public budget or 9% of Tunisia's GDP (Ersoy and Terrapon-Pfaff 2021). A summary of the key actors governing water and energy in Tunisia can be found in Figure 6.

Tunisia has established legislation to encourage public-private partnerships in the water and energy sectors, with notable laws passed in 2015 and 2019 (OECD 2016; EIB n.d.). However, little progress has been made in implementing further private involvement, due to political volatility and the COVID-19 pandemic (USDoS 2022).

3.3 Methods to ensure policy coherence and integration

Although Tunisia does not have specific government entities that formally coordinate water-energy-food nexus areas, there is a number of entities that have mandates, members, or responsibilities relating to interconnected nexus issues. The most notable feature is the combination of water and agriculture under MARHP. This combination highlights the interconnected nature of agriculture demand for water, and for energy to pump water. MARHP plays an important role in promoting efficient agricultural practices through its directorates of agricultural land and of rural water exploitation. Many of MARHP's departments have research responsibilities that can lead to water-energy solutions, but the Bureau of

Planning and Hydraulic Equilibira’s role is unique in that it includes analysis of water resources and coordination between water production institutions and water users in different sectors. The bureau’s responsibilities include appropriately allocating water and ensuring sustainable resource mobilization, which corresponds with energy-for-water analysis (CEDARE 2014).

The National Water Council was established to update water policies and strategies (World Bank Group 2021). The council’s composition includes representatives from a variety of sectors and highlights an opportunity for coordination, although the Council has only an advisory position (CEDARE 2014). The council is required to meet twice a year, or more often whenever necessary. The council is chaired by the Minister of MARHP and is made up of representatives from eight other ministries, including the Ministry of Industry, Energy, and Mines, as well as 9 other officers from various organizations and ministries. The chairman can call on any other experts for consultation and can set up technical commissions. The council assists MARHP on topics related to general water resource mobilization and development principles, developing programs and plans for the water sector, and developing and presenting sustainability and non-conventional water plans and policies (GoT 2010).

SONEDE has an energy efficiency strategy that acknowledges the energy intensity of supplying drinking water and aims to optimize performance of WSS. The strategy highlights both energy efficiency in production and pumping processes, and the integration of renewable energy. SONEDE’s implementation of this strategy includes projects to improve seawater desalination technologies, acquiring pumping equipment that uses less energy, and others. Renewable energy projects include plans for solar powered desalination projects and small hydroelectric power stations (SONEDE 2021).

The *Agricultural Investment Promotion Agency* (*Agence de Promotion des Investissements Agricoles, APIA*), a department under MARHP, has worked with ANME to investigate the potential of solar power in agriculture for water pumping and irrigation. This partnership highlights an area of particular importance for water and energy systems (GIZ, APIA, and ANME 2016). A related initiative to encourage the adoption of Solar Pumping and Irrigation Systems represents one of the clearest interdependencies of the Water-Energy-Food Nexus. The Energy Transition Fund (*Le Fonds de Transition Énergétique, FTE*) and the Tunisian Investment Fund *(Le Fonds Tunisien de l’investissement, FTI)*), run through ANME, have subsidized the adoption of these new systems, making pumping much more efficient (GIZ 2019b).

The *Ministry of the Environment* is the main actor outside of the two-line ministries that integrates water and energy. The *National Strategy for the Green Economy in Tunisia* clearly targets energy efficiency, renewable energy, water conservation, and water reuse as areas that together can lead to a sustainable economy (MoE 2020b). Although the Ministry of Environment's governance over natural resources is less tangible than the two main line ministries, its responsibilities are system-oriented, making it a unique actor for coordination.

Additional water-energy nexus solutions are being addressed through small-scale projects, studies, and pilot programs. Tunisia has planned and implemented renewable energy initiatives such as solar power plants, solar powered desalination, rooftop solar panels, and hydro storage, among others (IRENA 2021b). Many of these initiatives are motivated by cost efficiency; SONEDE's program and MARHP's energy efficiency goals expressly seek to decrease energy costs (SONEDE 2021; GIZ, APIA, and ANME 2016). The one-way nature of water energy connections is representative of the financial motivations of each sector; many water and agriculture entities have made steps to implement energy saving—and therefore energy cost-saving—opportunities, but the energy sector has no cost-oriented motive to pursue energy cost saving opportunities in the water sector. Instead, the energy sector financially benefits from inefficient water usage. The highly silo-ed orientation of the energy sector reflects this dynamic.

3.4 Good practices and lessons learned

a. Variable energy pricing

Tariffs are differentiated between low-voltage (90 kV), medium-voltage (150 kV), and high-voltage (225 kV) networks (AfDB 2021). *The low-voltage* network is split into two tariff categories, economic and normal. The category of tariffs a consumer falls under depends on their monthly consumption and whether they are residential or non-residential (STEG 2022). Billing is organized into progressive tranches based on monthly consumption (IRENA 2021b). Tariffs are subsidized most for households with lower consumption per month (STEG 2022).

For the *medium voltage* network, tariffs can be uniform or four-shift tariffs. The four-shift tariffs are broken down into the day shift, morning peak summer shift, evening peak, and night. Furthermore, the time of each shift differs to adjust to different seasons, with one set of times from September to May, and a different set of times (which includes the morning peak summer shift) from June to August. For the *high-voltage* network, only the four-shift tariff is available, and emergency services using high-voltage network have an alternate tariff rate (IRENA 2021b). Two other tariffs are used for agricultural irrigation, and emergency services. There are also tariff rates specific to natural gas for grey cement industries that differ for high pressure and medium pressure gas lines. Electricity for water pumping for irrigation is the least expensive, which could potentially contribute to overexploitation of groundwater (IRENA 2021b).

Increasing natural gas imports have caused electricity prices to increase several times in Tunisia — for the medium voltage network, the uniform tariff has increased by three times since 2010. These price adjustments have affected all electricity consumers except low-consumption households (IRENA 2021b).

Despite a complex pricing scheme, Tunisia's energy providers run annual deficits due to excessive subsidization. These subsidies are done through the yearly price setting done by the government, who sets prices far below international market rates (Ersoy and Terrapon-Pfaff 2021; Eibl 2017). In the 1990s, Tunisia was an energy exporter and could provide cheap domestic energy to consumers. Presently, with growing energy demand and decreasing production, these high energy subsidization rates are much more costly (Eibl 2017).

Tunisia's framework for electricity pricing strengthens the ability to manage consumer demand and overcome the renewable energy variability challenge. Furthermore, variable tariffs allow the government to determine which sectors should have to pay for the true production cost of energy and which sectors are eligible for cheaper rates (e.g., emergency services and low-consumption households). As a result, energy prices can better reflect true value and encourage optimal patterns of usage across sectors while maintaining prioritization of equity and affordability for the most vulnerable.

Variable energy pricing can help reduce peak demand for electricity, which can lead to lower water consumption. This is because peak demand for electricity often occurs during times of high water use, such as when people are using air conditioning or heating. By shifting energy use to off-peak hours, variable electricity pricing can help to reduce the amount of water that is used to generate electricity. It can also help to encourage the use of renewable energy sources, which can have a positive impact on water resources. This is because renewable energy sources, such as solar and wind power, do not require the use of water to generate electricity. By making renewable energy more affordable, variable electricity pricing can help to increase its use and reduce reliance on fossil fuels, which can have a negative impact on water resources. Variable energy pricing can further help improve the efficiency of energy use. This is because it can give consumers an incentive to use energy more efficiently, such as by turning off lights when they leave a room or unplugging appliances when they are not in use. By reducing energy consumption, variable electricity pricing can help to conserve water, as water is often used in the production and distribution of energy.

b. Subsidies

Subsidies have successfully encouraged the adoption of efficient technologies. Solar pumping stations have been adopted primarily in rural regions of Tunisia, mostly in the south of the country (IRENA 2021b). A framework allowed the Energy Transition Fund (FTE) and the Tunisian Investment Fund (FTI), run through ANME and APIA, to subsidize the installation of off-grid Solar Pumping and Irrigation Systems (SPIS) in 2009, which has led to improved levels of technology adoption in rural areas (GIZ 2019a).

SPIS have become more economically viable as diesel subsidies diminish, making SPIS a more lucrative choice in rural areas far from the STEG electricity grid. Grid-connected SPIS have long term returns on investment, since electricity for water pumping from the electric grid is still highly subsidized (GIZ 2019a). Off-grid SPIS, however, are viable and reliable options for rural irrigation under the condition that water abstraction does not violate water allocation rules and quotas and does not result in over-exploitation of freshwater resources. Between 2010 and 2017, 124 SPIS projects were carried out through ANME's subsidy program. In 2017 alone, the 56 projects were carried out, highlighting the growing popularity of SPIS technology (GIZ 2019b).

Subsidies should carefully consider trade-offs and unintended consequences. One notable lesson learned highlights the behavioral consequences of subsidies, which can incentive overuse. SPIS subsidies significantly decrease the installation cost of these systems, leaving maintenance and electricity costs almost non-existent. This, paired with the tendency of farmers not to pay water fees and the lack of proper monitoring of water abstraction and GW levels, leads to a high likelihood of over-pumping. Without motivations to conserve water or limitations from electricity costs, farmers may choose to irrigate more land, over-irrigate crops, or switch to more lucrative and more water-intensive crops. As a result, SPIS systems may lead to a higher volume of water consumption in exchange for lower energy consumption (GIZ 2019b).

Analysis suggests that the number of SPIS actually installed is higher than the official statistics suggest (GIZ 2019a). This implies that many SPIS systems have been installed at illicit wells. One reason for this may be that the official subsidy process is administratively cumbersome and includes many terms and conditions, which incentivizes illicit usage (GIZ 2019a). Additionally, SPIS subsidies are limited to farmers using drip irrigation. This is meant to encourage water efficiency, but may also lead to illicit well usage (Kiprono and Llario 2020). Furthermore, the inherent water savings from drip irrigation is also not proven (GIZ 2019b). Although illicit installation reinforces the popularity and efficiency of these systems, it also highlights challenges with monitoring commonly accessible resource consumption and concerns over abstraction of limited water resources.

c. Agriculture and water are under the responsibility of one ministry

The agriculture sector is highly interconnected with water and energy in Tunisia and that is reflected in the way these sectors are governed. The feature most applicable to water-energy, and food nexus management in Tunisia is the combination of water resources and agriculture under MARHP. This combination highlights the interconnected nature of agriculture demand for water and energy for pumping water. MARHP plays an important role in promoting efficient energy and water practices in the agriculture sector through the General Directorate for Development and Conservation of Agricultural Land and the Directorate General of Rural Engineering. These departments are able to take a multi-sectoral approach for resource management. Furthermore, they are appropriately motivated to manage both water and energy efficiently. Tunisia's medium-term and long-term strategies emphasize the need for water saving efforts and the use of nonconventional waters, and the corresponding stakeholders involved in the agricultural sector benefit from water supply conservation and cost-efficiency measures (IUCN ROWA 2019). Additionally, MARHP departments are financially motivated to increase cost-efficiency through energy savings and renewable energy solutions. These motivations, mandates, and strategies reflect the interconnectivity of the agriculture sector with the water-energy nexus and highlight an opportunity for nexus-minded decision making.

4 Country 2: Morocco

4.1 Context

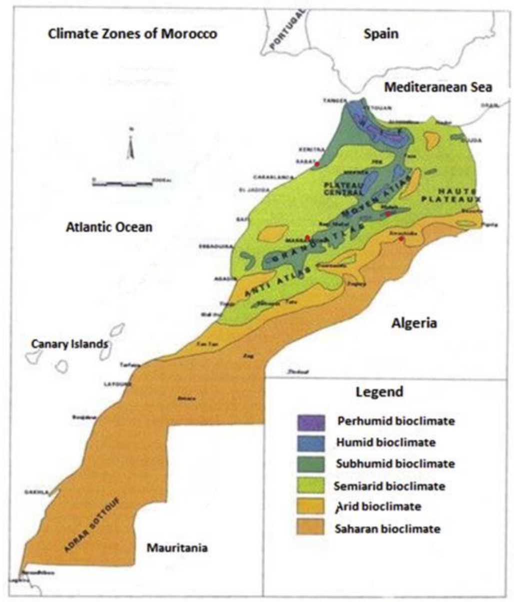

Figure 7. Climate Zones of Morocco (Source: Ouali et al., 2020)

Water. Morocco’s strategy to provide water for all began in earnest in 1995, when the right to water, aim for rationalizing water use, and the goal of water security became law. Morocco has focused on increasing water storage capacity through dams and storage infrastructure, regulating water development and distribution, and widening water availability since the 1995 Water Act, with a heightened focus on water and sanitation rights for all after the royal speech on the topic in 2001. (Sadeq 2020; Legrouri, Sendide, and Kalpakian 2019). Morocco’s water availability differs greatly geographically and annually; the mountainous northern region receives 800mm of rainfall a year, while the southern Sahara region receives about 100 mm of rainfall a year (Langenberg et al. 2021). A climate map of Morocco can be seen in Figure 7. In 2018, Morocco had an average of 815 m^3 per capita of available renewable freshwater resources, far less than the global average of 5,658 m^3 per capita (World Bank 2018c; 2018f). Challenges to surface water resources include aging dam infrastructure, which leads to significant water losses, and high evapotranspiration rates (Langenberg et al. 2021). Groundwater supplies 40% of the irrigated area in Morocco and provides drinking water to most of the rural population. This has led to overexploitation of non-renewable water resources where groundwater levels have declined by between 0.5 to 2 meters per year on average, with an annual average of 3 meters in the most exploited aquifer (Langenberg et al. 2021; Faysse 2011).

Energy. Industrial and economic development contribute to Morocco’s growing energy demand (UNESCWA 2018). Morocco imports about 90% of its energy needs in the form of oil and coal (ITA 2021a; IRENA 2022b). Total energy supply is made up of 56% oil, 30% coal, 10% renewables, and 4% gas (IRENA 2022b). Morocco’s electricity production methods are 80% thermal steam, 10-11% wind, 6% hydropower, 1-3% solar (METDD 2018). Morocco receives a portion of the natural gas that passes through it on an Algeria-Spain natural gas pipeline (EIA 2019). The agriculture sector makes up about 7% of Morocco’s total consumed energy, far less than the most energy-intensive transportation (38%) and industry (22%) sectors (Meir, Opfer, and Hernandez 2022; AMEE n.d.; n.d.).

Morocco is striving to become one of the most renewable-energy oriented states in the MENA region. The state-owned Moroccan utility company has set a target to generate 52% of electricity needs from wind and solar energy by 2030 (EIA 2019). Of the 52%, Morocco plans for 20% to come from solar energy, 20%, from wind energy, and 12% from hydraulic energy (KOM 2016). Morocco also plans to reduce energy consumption by 15% by 2030 (MEMDD 2009). In 2019, only 10% of Morocco's total energy supply was from renewables (IRENA 2022b).

Water-Energy. Growing demand has been met with different strategies for water and energy. Until recently, Morocco's water strategy has focused on capturing domestic surface water resources and providing water for agriculture and other industries (Langenberg et al. 2021). Energy planning has focused on investing in new technologies for renewable energy and stronger pushes for improving energy efficiency. Hydro/Marine energy contributed 37% of Morocco's renewable energy capacity in 2021 (IRENA 2022b).

One of Morocco's main industries is phosphate production, which is a key input to fertilizer production and agricultural productivity. Over 75% of global phosphate reserves are located in Morocco, which represent over a quarter of the global market share (Daher and Mohtar 2021). Morocco plans to increase its fertilizer output by nearly 70% to counter the drop in global availability resulting from the Russia-Ukraine war in 2022. Russia is the world's largest fertilizer exporter, foremost of nitrogen and potassium fertilizers, and price increases have strained agricultural production in Europe and Africa (Tanchum 2022). Morocco's essential role as a phosphate producer interacts greatly with the Water, Energy, and food nexus, as mining and chemical processing are water and energy intensive processes. Managing phosphate production's local and national effects on Morocco's water and energy resources requires dynamic, system-oriented management (Lee et al. 2020). The energy sector makes up 3-4% of Morocco's water consumption (MEM 2018).

One key area where the water-energy nexus is visible is Morocco's agriculture sector. Through the Green Morocco Plan and forthcoming Green Generation Plan, Morocco has committed to making its agriculture sector into a "lever of socio-economic development" (Ministère de l'agriculture 2008). The agriculture sector contributes about 15% to Morocco's GDP, but employs some 40% of Morocco's population, which makes the sector both socially and economically significant (Taheripour et al. 2020). Agriculture consumes 87% of Morocco's water. As such, Morocco has invested in drip irrigation, solar powered water pumping technology, and desalination. The national climate plan highlights the goal of renewable energy-powered desalination plants for agriculture (MEMDD 2009). A summary of Morocco's water and energy features can be found in Figure 8.

There are differences between Morocco and Jordan. A majority of Morocco's water resources come from surface water, with only 20% coming from groundwater (Langenberg et al. 2021). This leads to different challenges than Jordan, including water losses due to aging water storage infrastructure, high evapotranspiration rates, and water pollution (Langenberg et al. 2021). Furthermore, similar challenges have different consequences in Morocco, where decreasing aquifer levels leads to saline infiltration (Faysse 2011). Morocco has some hydropower production associated with its dams. Although agriculture is an important consumer of water and energy in both countries, in Morocco the agriculture sector consumes 87% of national water resources, while in Jordan it is only 48.6% (Langenberg et al. 2021; MWI 2023). Regarding governance, Morocco governs the water sector with a far more decentralized manner compared to Jordan, with much of the responsibility at the regional level. Additionally, Morocco has greater private sector involvement in the energy sector compared to Jordan.

Morocco shares similarities with Jordan. Morocco and Jordan are both water scarce countries, though at different scales. In 2018, Jordan had 68 m^3 of renewable water resources per person, compared to 815 m^3 in Morocco (World Bank 2018b; 2018c). In addition to water scarcity, both countries face more unpredictable and uneven water availability due to climate change, making long-term water planning more difficult. Desertification is a challenge in both countries; in Morocco, desertification mainly affects highly populated plains and areas with livestock pressure (Mirzabaev, et al. 2019).

Both countries have issues with aging infrastructure: although Jordan is mostly concerned about aging distribution infrastructure, while Morocco is concerned about aging dams and inefficient irrigation conveyance (Langenberg et al. 2021). Both countries face overexploitation of groundwater resources, illegal or unmetered groundwater withdrawals, and reliance on imported energy, with both countries importing about 90% of their energy needs (MEMR 2020; IRENA 2022b).

Morocco and Jordan have both prioritized water for all as a human right — 98% of Jordan's population has access to a safely managed water source, and 91% of Morocco's urban population has access to a safely managed water source (MWI 2016; World Bank 2018a). In both countries, the rural and more arid areas have the least consistent water provision. Both countries see treated wastewater and rainwater runoff as an opportunity to increase water supply. Morocco reuses relatively little of its treated wastewater, and 79% of the generated wastewater was not treated to acceptable standards (MFA 2018). Both Morocco and Jordan see desalination, water efficiency, energy efficiency, and renewable energy as opportunities for improving the sustainability of both sectors.

4.2 Governance and Institutional Structures

a. Governance of the Water Sector

Water and utility governance in Morocco is a complex system, with many players at both the national and regional levels. Morocco's decentralized water management system reflects pre-colonial decision-making structures and customs (Legrouri, Sendide, and Kalpakian 2019; Machrafi et al. 2022).

The *1995 Water Act* created the framework for water management that Morocco still uses today. This act sought to rationalize water use, provide universal water access, ensure water security, and set limitations on access to groundwater (Langenberg et al. 2021). Additionally, the 1995 law set the stage for decentralized water management by drainage basin, which was further supported by another law in 2016. Since 2016, Morocco has had a two-tiered system of governance; at the national level, an inter-ministerial commission manages water strategy, and at the hydrologic basin level, basin committees manage basin water strategy and operations (Sadeq 2020).

There are many players at the national level responsible for water management. There are *five advisory bodies*: The *High Council for Water and Climate (Le Conseil Supérieur de l'Eau et du Climat, CSEC)*, which is responsible for coordination and consultation, the National Council for the Environment, the General Council for Agricultural Development, the Permanent Inter-Ministerial Council for Rural Development, and the National Drought Observatory (Legrouri, Sendide, and Kalpakian 2019). The *National Council for the Environment* (Conseil National de I'Environnement, CNE) was established in 1995 to protect and improve the environment and prevent pollution and environmental harm. In practice, the National Council for the Environment has been responsible for preparing an annual inventory of national environmental issues (Machrafi et al. 2022). The *General Council for Agricultural Development (Conseil Général du Développement Agricole)*, the *Permanent Inter-ministerial Council for Rural Development (Le Conseil Interministériel Permanent du Développement Rural)*, and the *National Drought Observatory* (*Observatoire National de la Secheresse*) provide advice and decision-making support for issues relating to drought and agricultural development (Iglesias, Moneo, and López-Francos 2007). In addition to these advisory bodies, the *Inter-ministerial Water Commission (la Commission Interministérielle de L'eau)* is the sole coordinator body for the water sector.

Responsibility for Morocco's water sector at the national level has been marked by transition since 2002 (Machrafi et al. 2022). In 2002, the water sector was separated from the Ministry of Public Works and Equipment and was put under the Ministry of Land Management, Water and the Environment and directly administered by the Secretariat in charge of Water. In 2007 it was merged with the environment, energy, and mining sectors in the Ministry of Energy, Mines, Water, and Environment (now the Ministry of Energy Transition and Sustainable Development (MEMDD) (Machrafi et al. 2022). Finally, in 2017, the water sector was placed under the Ministry of Equipment, Transport, Logistics and Water, which is now known as the *Ministry of Equipment and Water (Ministere de l'Equipement et de l'Eau. MEE)*. It is responsible for government policy relating to port, water, and meteorological infrastructure. It comprises the General Council for Equipment and Water (*Conseil Général de l'Equipement et de l'Eau*), and the General Directorate of Hydraulics (*Direction Générale de l'Hydraulique*), which includes the Water Research and Planning Department and the Department of Hydraulic Developments (MEE n.d.).

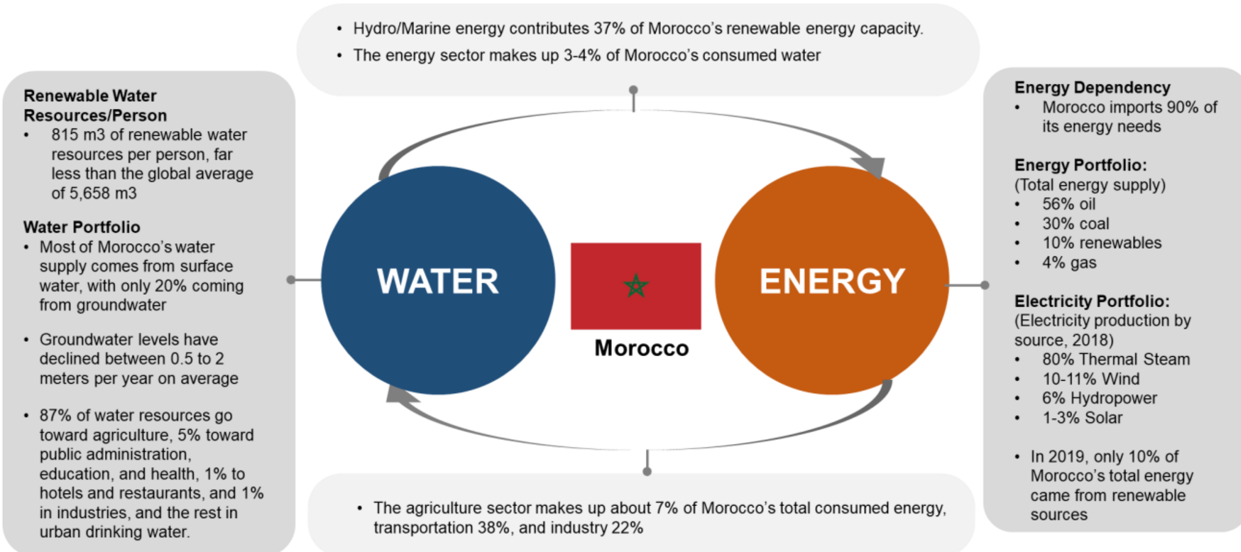

Figure 8. Key water-energy interconnections in Morocco (Source: Authors)

The *Ministry of Energy Transition and Sustainable Development (Ministère de la Transition Energétique et du Développement Durable, MTEDD)* is still involved in water governance through its Secretariat of State for Water, while the Ministry of Finance's *Water, Energy, and Mining Division* monitors public water companies (Machrafi et al. 2022). METDD also oversees ONEE, Morocco's state-owned water and electricity utility company. The Ministry of Interior's *Water and Wastewater Direction* assists municipalities with water and sanitation issues, planning, implementation, and budgeting. Other directorates supervised by the Ministry of Interior are responsible for monitoring and regulating local utilities. Additionally, a Ministry of Interior representative from the Directorate of Public Utilities and Concessions is on the board of each municipal utility (MFA 2018).

The *Secretariate of State* is in charge of the ten *Water and River Basin Agencies (Agence de Bassins Hydrauliques, ABH)* and drafts laws and regulations related to the development and operation of water resources. It steers the national policy for water by researching and planning for water management (MFA 2018). Responsibility for water in Morocco is largely in the hands of the River Basin Agencies, with relatively little governance at the national level. Instead, national entities are consultants and coordinators for the regional bodies (Machrafi et al. 2022).

b. Governance of the Energy Sector

The *Ministry of Energy Transition and Sustainable Development (Ministère de la Transition Energétique et du Développement Durable, MTEDD)* is responsible for most energy-related governance on the national level, including electricity, renewable energies, energy efficiency, hydrocarbons, nuclear, fuels, and mining. In particular, METDD develops and implements government policies, applies legislation and regulations to public establishments under its jurisdiction, guarantees the security of energy supplies, and strengthens coordination with other administrations and partners involved in the development of the energy and mining sectors (METDD 2019). Additionally, the ministry implements energy efficiency aspects of the National Energy Strategy, including energy audit plans and research and development, and oversees ONEE.

In addition to METDD, a handful of ministries are involved in other aspects of energy governance. The Ministry of the Interior supervises private electricity distribution companies and cross-subsidies and participates in designing and implementing electricity tariffs. The Ministry of Finance and Economy financially supervises state-owned energy enterprises, and the Ministry of General Affairs and Governance is involved with implementing tariff adjustments and setting prices (Usman and Amegroud 2019). The Ministry of General Affairs and Governance chairs the Inter-ministerial Price Commission, which includes the ministry of Finance and Economy, the Ministry of Trade and Industry, and the Ministry of Agriculture, as well as any department related to the specific service or product on the commission's agenda (MEF 2014).

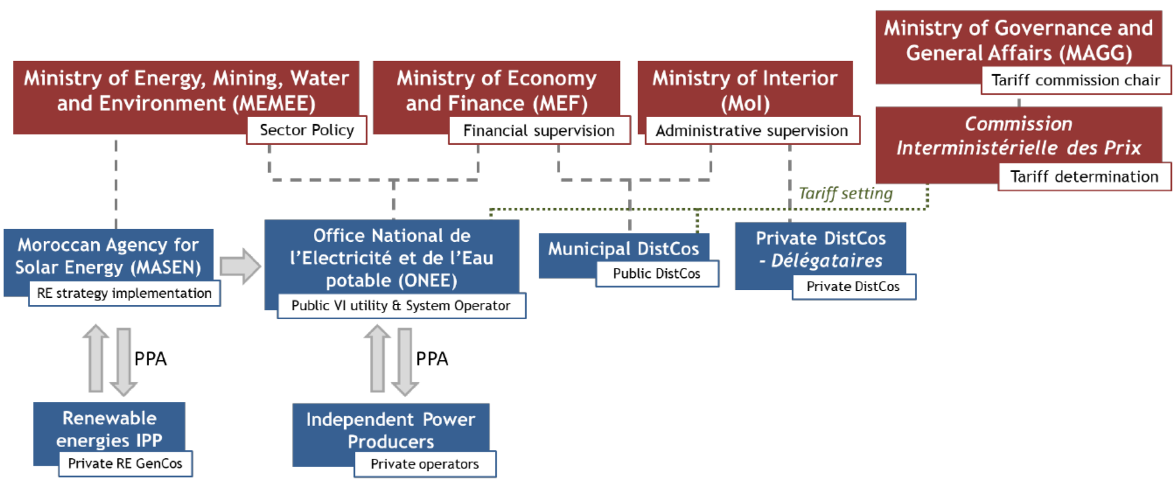

Figure 9. Public and Private Entities in the Energy Sector. Source: (Usman and Amegroud 2019)

Other entities assist in areas specific to energy efficiency and renewable energy. *The Moroccan Agency for Sustainable Energy* (*L'Agence Marocaine de l'Énergie Durable, MASEN*) was established in 2010 to lead and manage renewable energy projects. It raises funds and conducts assessments with ONEE (Usman and Amegroud 2019). The *Moroccan Agency for Energy Efficiency* (*Agence Marocaine pour l'Efficacité Energétique, AMEE*) implements and coordinates energy efficiency programs and proposes national, regional, and sectoral plans for energy efficiency. A 2016 law introduced the *National Energy Regulatory Agency* (ANRE), which held its first board meeting in 2021 (AMRE 2022). Its responsibilities include regulating access to networks, setting tariffs, and ensuring the electricity market functions efficiently. The agency is not yet in operation (Usman and Amegroud 2019). A summary of Morocco's key energy actors can be found in Figure 9.

c. Governance of the Agri-food Sector

The agricultural sector in Morocco employs 45% of its population, so the national strategic plan for agriculture—laid out in the Generation Green plan—prioritizes stabilizing and developing jobs within the sector (ITA 2020). Morocco's agricultural sector has a history of significant state intervention in production decisions, imports and exports, and price regulation (Arndt and Tyner 2003). Reform since 2009 has led to a focus on governing to specific national goals, decentralized institutions, and delegating operation functions to non-state actors. Three offices exist at the national level under the Department of Agriculture—National Office for Food Safety, the National Agency for the Development of Oasis and Argan Zones, and the National Agricultural Council Office Regional. Additionally, nine Regional Agricultural Development Offices and a variety of training and production centers allow for more decentralized services and administration (MoA 2022).

d. Water and Energy Institutions

Morocco has long been a champion of climate adaptation and renewable energy. Since its first Intended Nationally Determined Contribution in 2015, Morocco has intensified its goals with additional Nationally Determined Contributions in 2016 and 2021 (NDC Partnership 2021). These goals have been further institutionalized by climate change laws, national implementation and adaptation plans, and sector-specific roadmaps. Expanding renewable energy deployment has been a part of numerous national plans and strategies focused on climate and energy efficiency.

Of Morocco's national plans and strategies, few mention water-energy nexus topics. The *National Water Strategy* (2009) only mentions hydroelectric power opportunities, while the *Ministry of Equipment and Water Plan* (2017) and *Climate Change Policy* (2017) do not explicitly mention water-energy interconnections. The *Green Morocco Plan* (2009) and the *National Irrigation Water Saving Plan* (2007) highlight the interconnectivity between making irrigation more efficient and subsequently increasing the area of irrigated land, which allows for farmers to produce more crops and more valuable crops (Ministère de l'agriculture 2008).

The *National Climate Plan* (2020) highlights some areas, including the goal of using renewable energy to support desalination projects to increase irrigation water supply. Morocco's *National Energy Strategy* includes goals of optimizing water use, encouraging drip irrigation, using solar water heaters, fighting desertification, and the use of nuclear energy for desalination (MEMEE 2009).

The energy tariff increases that began in 2017 included a shift to a selective pricing structure that priced energy according to the level of consumption. Overall, these price increases led to less electricity consumption. Until the recent introduction of ANRE, Morocco's complex tariff and cross-subsidization system was a result of inconsistent accounting and data reporting, which complicated cost-recovery and price setting (Usman and Amegroud 2019). Although different renewable energy and energy efficiency programs have subsidized equipment, such as drip irrigation systems, there are few other subsidies for water (Assouli et al. 2019).

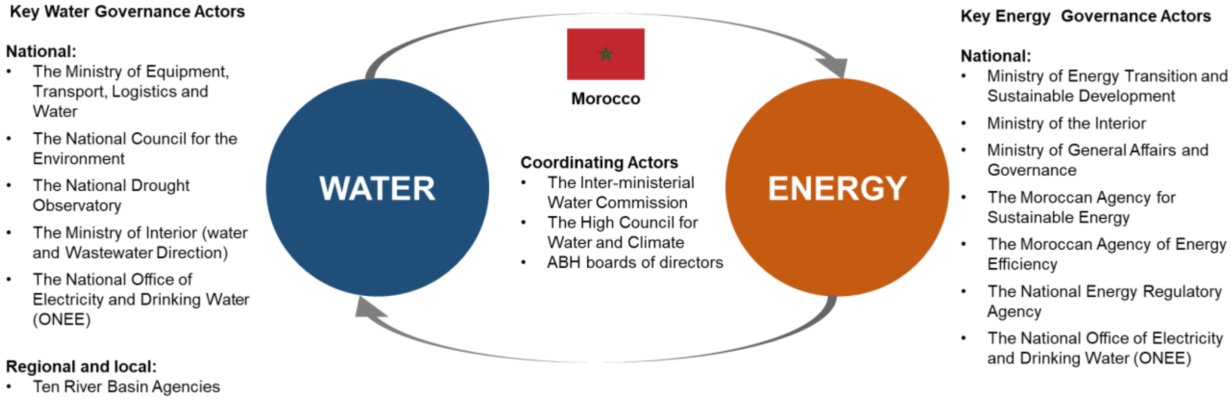

Figure 10. Key water and energy governance actors in Morocco

4.3 Methods to ensure policy coherence and integration

A variety of institutions overlap with water and energy governance at the national level. The Secretariat of State in charge of Sustainable Development interacts with energy, water and wastewater wherever environmental concerns or environmental data is involved (MFA 2018). A summary of key actors governing water and energy in Morocco can be found in Figure 10

Many of Morocco's *inter-ministerial boards* and *commissions* offer opportunities for coordination at the highest level, such as the *Inter-ministerial Water Commission* and the *High Council for Water and Climate*. Additionally, Morocco's government entities related to renewable energy and sustainable development (AMEE, AMRE, METDD, and a number of research entities) have the ability to overlap in areas where water usage and energy efficiency overlap, such as CSPs, desalination, and irrigation. However, these coordination mechanisms are mainly found at the highest level, which inhibits operational and regional coordination. Outside of national entities, basin-oriented water management and the role of the private sector led to the establishment of coordination mechanisms to accomplish smaller scale water-energy projects.

4.4 Good practices and lessons learned

Morocco's past decades of transition in both the water and energy sectors have created a number of lessons from which water-energy-food nexus governance principles can be learned. The two distinctive features that generate these trends are Morocco's shift toward decentralized water governance and the role of private actors in the water and energy sectors.

a. Inter-ministerial commissions and their role in improved policy coherence

Morocco has high-level inter-ministerial bodies that coordinate between water, energy, and other related sectors. Similar coordinating mechanisms are needed at all levels of governance to complement Morocco's decentralized governance structure.

Part of Morocco's transition to including a variety of stakeholders in the governance process has led to the **prioritization of cross-sectoral discussion and coordination at the highest levels of government.** The **Inter-ministerial Water Commission** is the main water body in charge of coordination for the sector. It is made up of representatives of all the ministerial departments related to water, including the ministry in charge of energy. This commission is to act as a coordinating discussion body to ensure agreement between sectors. However, the commission had a 10 year period of inactivity between 2005 and 2015, when it was decreed into law (Machrafi et al. 2022). The commission was re-established to examine drinking water and irrigation water shortages.

The ***High Council for Water and Climate (CSEC)*** is one of the older and more impactful entities. Meetings of this council in 1989 and 2001 served as the basis for basin authority and the focus on water for all, respectively. CSEC was established by the 1995 water law to reflect the law's focus on coordination and intersectoral dialogue. The Council was created in 1981 to be in charge of formulating the orientations of national water and policy. The founding law established the permanent committee, which meets at least twice a year and whenever necessary (Machrafi et al. 2022). Half of the Council is made up of representatives of state and public establishments involved in the water sector, including the King. The other half is made up of regional and local representatives, scientific and academic experts, and professional associations. The council has held nine sessions since its creation, with the most recent being in 2001. The findings of the council are impactful for long-term national strategy in the water sector (MEE n.d.).

These commissions highlight important cross-sectoral coordination and consultation mechanisms, which could assist with water-energy nexus decision making. CSEC,in particular, is able to set up technical commissions to ensure proper research and evaluation is done on complex issues. Furthermore, the central and high-level nature of these bodies allows their decisions to have wide-ranging and long-term effects.

It Is worth noting, however, that "oroc'o's" decentralized organization leads to asymmetrical coordination: Coordinating entities at the top can speak to national, long-term issues, but ABHs are left without official and consistent mechanisms for coordination with other sectors and actors. ABHs, municipalities, and government offices with topically specific mandates are the entities most frequently entrusted with implementing and enforcing practical water management. Because Morocco's institutionalized coordination is found only at the highest levels of the national government, regional and day-to-day coordination is lacking (Legrouri, Sendide, and Kalpakian 2019; Al-Alaween et al. 2016).

b. National Office of Electricity and Drinking Water (ONEE)

Morocco's public utility manages both electricity and water, but there is still limited coordination between the water and energy branches. The main public institution related to water and energy utilities in Morocco is the *National Office of Electricity and Drinking Water (Office National de l'Electricité et de l'Eau Potable ONEE),* which is overseen by MEMDD. ONEE is a legislated merge of two separate national offices — the National Office of Electricity and the National Office of Drinking Water in 2012. The law specified that ONEE ensures the missions and activities that had been assigned to each office (Machrafi et al. 2022). The water branch of ONEE guarantees the country's drinking water supply, ensures water quality, and plans and researches water management and water projects (ONEE 2022). ONEE provides 80% of Morocco's drinking water.

ONEE's mission in the energy sector revolves around the public production, transmission, and distribution of electricity and managing electricity demand (METDD 2019). ONEE currently produces 20% of Morocco's electricity, with another 72% produced by concessionary production (Selmi 2021).

The National Office of Electricity was created in 1963, and the National Office of Drinking Water was created in 1972. The 2012 merger of the national water and electricity utilities did not entail any changes in organization structure or financial accounts, and the branches of water and energy are still siloed in practice (Usman and Amegroud 2019). This example highlights the need for additional coordination mechanisms to initiate analysis and discussion on water-energy topics, but also acknowledges the abundance of institutional knowledge found in well-established national offices.

c. Decentralized water governance

Decentralized governance in Morocco creates the opportunity for integrated water management involving a variety of stakeholders, but success requires appropriate support and resources. Beginning with the 1995 water act and implemented in 2016, the River Basin Agencies (ABH) have been the major entities responsible for water quality, sanitation, monitoring, and the development of local water management and water shortage management plans in Morocco (Langenberg et al. 2021; METLE 2020). ABHs are administered by *boards of directors*, which are chaired by the Secretariat of State in charge of Water and are composed of a maximum of two-thirds – representatives of government authorities related to drinking water, hydroelectric energy, and irrigation, and at least one-third – representatives from the river basin council, regional councils, professional organizations, and water user organizations (METLE 2020; MFA 2018). National entities provide assistance and guidance to the ABHs through their roles on the boards of directors and through advisory and consultative entities.

In addition to ABHs, other decentralized entities govern related water and food issues in Morocco. Nine regional offices of agricultural development, under the *Ministry of Agriculture and Fishery (Ministère de l'Agriculture, de la Pêche Maritime du Développement Rural et des Eaux et Forêts)* are involved with the management of irrigation waters supplied from large hydraulic systems (Legrouri, Sendide, and Kalpakian

2019; Choukr-Allah 2011). Wastewater services are the responsibility of the municipalities, who can choose to manage wastewater through independent communal utilities, a concession to the private sector, some other legally supported management system, or direct municipal management. In most large urban areas, water supply utilities also provide wastewater services and electricity distribution. Currently, there are *12 autonomous inter-communal utilities* — seven of which manage water, wastewater, and electricity—and four private concessions, in addition to the National Office of Electricity and Drinking Water (ONEE), which operates in 112 urban centers, including the largest cities (MFA 2018).

Although the structure of ABHs shifts Morocco toward IWRM principles and aligns with national priorities, currently ABHs do not have the resources necessary to adequately manage, coordinate, and monitor water consumption (Machrafi et al. 2022; Legrouri, Sendide, and Kalpakian 2019). Furthermore, most of the coordination and communication responsibilities are at the highest levels of governance, which makes it difficult for regional and local entities to properly coordinate (Legrouri, Sendide, and Kalpakian 2019). Furthermore, jurisdiction and responsibility is often unclear between the ABH, neighboring entities, or the national government (Al-Alaween et al. 2016; Machrafi et al. 2022).

Additionally, ABHs have generally not been equipped to carry out the variety of responsibilities assigned to them. The original role of the river basin agencies before the 2016 decentralization law was focused mainly on hydrological engineering. As such, ABHs had little experience engaging with farmers and local populations as clients. With little training on human relations and communication, many farmers are unfamiliar with their ABH, its role, or the regulations surrounding water usage (Al-Alaween et al. 2016).

Morocco's ABH structure is innovative and cognizant of the traditions and needs of local communities. Despite setbacks relating to training and a lack of resources, ABHs are poised to play an important and integrated role in water resource management while taking into account the full range of stakeholders involved.

d. ***Privatization and Public-Private Partnerships in the energy and water sector***

Public-Private Partnerships (PPPs) and Power Purchase Agreements (PPAs) can be either successful enterprises or costly agreements. Morocco began privatizing parts of its energy sector in the 1980s, and ONEE ceased to have a monopoly of private electricity in the 1990s, when legislation was passed to allow private producers to enter the market (Selmi 2021). Prior to a 2015 law on public-private partnerships (PPPs), power purchase agreements (PPAs) allowed independent producers to sell energy to ONEE. ONEE was required to purchase all electricity produced at a fixed price for the entirety of the 25–30-year agreement. In 2015, new legislation on PPPs allowed private renewable energy developers to connect to the grid and directly access end users. Provisions in the law codify the protection of developers and cover any losses by private distributors by requiring ONEE to purchase any excess energy produced. As a result, ONEE frequently buys energy it does not need, and in cases of low demand, sometimes shuts down public power plants to avoid blackouts, which is a costly practice. Consequently, risks are borne by the state, while private actors benefit from full capacity utilization rate (Selmi 2021).

Simultaneously, PPPs and PPAs have resulted in many successful ventures in the water and energy sectors in Morocco. Morocco hosts the Guerdane Irrigation project, which is the world's first PPP irrigation project for citrus farmers. The project is a 30-year concession initiated in 2004 that ensures participants receive access to water that would be cheaper than the alternative groundwater, which was necessary due to the overexploitation of the groundwater supply. The Guerdane Irrigation project was successful in raising financing and providing water to over 1,900 individual farmers (Naughton, DeSantis, and Martoussevitch 2017). Another example is the Oum Er Rbia Basin, which has been experiencing a chronic water deficit. To alleviate demand, the Cherifian Phosphate Office (OCP), the Ministry of Interior, Ministry of Agriculture, Ministry of Water, ONEE, and the Oum Er Rbia ABH collaborated on an agreement, in which the OCP will geographically relocate its surface water withdrawals and cease using groundwater from local aquifers. To make up for the industrial water demands, wastewater treatment plants will cover 60% of OCPs water needs, and desalination will cover the remaining portion, thus removing any additional demand for conventional water. Joint investments will lead to less surface water demand and nearly 10 Mm^3 a year of treated wastewater and nearly 25 Mm^3 a year of desalinated water (METLE 2020). Another example is a 2012 partnership between the Energy Earth Company, ONEE, and the Moulouya Hydraulic Basin Agency to rehabilitate and modernize the Flilo micro hydroelectric power station. The station produces 9.2 GWH a year and increases water flows available for irrigation (METLE 2020).

5. Country 3: Singapore

5.1 Context

Water. Singapore's focus on water has been an integral part of its existence: the water agreements with Malaysia that provide much of Singapore's water were enshrined alongside the Separation Agreement which established Singapore's independence in August 1965 (MICA 2003). Singapore has experienced water vulnerability since its independence, with a heavy reliance on rainwater during its early years that sometimes resulted in inconsistent water provision (PUB 2018a). Although Singapore has abundant annual rainfall, it is considered a water scarce country, with 106 m^3 of renewable water resources per capita per annum (MSS 2020; World Bank 2018d). Singapore has no large rivers, natural springs, or aquifers, yet demand for water is expected to double by 2060 (MSE 2022b; PUB 2018a). Singapore has had around 5% unaccounted-for water losses for the past two decades (Vincent et al. 2014). A map of Singapore can be seen in Figure 11.

Figure 11. Map of Singapore

Singapore has had two water agreements with Malaysia since 1961 and 1962. The 1961 agreement allowed Singapore to draw water from Malaysia at a rate of 3 sen per thousand gallons. In return, Singapore treated the water and sold at least 12% of the imported water to Malaysia at a rate of 50 sen per thousand gallons. The treatment plants were built and maintained by Singapore but owned by Malaysia and located on Malaysian land (MFA 2022).

In 1998, during the 1997-98 Asian financial crisis, Malaysia and Singapore began water talks to consider loans, long-term water supply, and other topics of mutual interest. The water talks lasted until 2003, with Malaysia and Singapore growing more uncooperative as Malaysia continued to offer increasing water prices. In 2003, Singapore released a document detailing the correspondences and pushing back against some of Malaysia's claims (MICA 2003). In October 2002, water ceased to be part of the negotiations. In 2011, the 1961 Water Agreement expired and the infrastructure that had been operated by Singapore was handed back to Malaysia (MFA 2022).

The failed water talks pushed Singapore to strengthen its existing **goal of water self-sufficiency**. Although the 1961 Water Agreement expired in 2011, the 1962 agreement is still in effect and will expire in 2061. It allows Singapore to draw 250 million gallons of water and provide 2% of the treated water back to Malaysia (MFA 2022). Singapore's water supply is made up of the "Four National Taps;" one of which is water imported from Malaysia. The other taps are local water catchments, NEWater (Singapore's brand of highly treated wastewater), and desalinated water (PUB 2018a). Currently, imported water makes up about half of Singapore's water supply, and while the 1962 agreement is in effect, imported water is more cost-effective than some of the other taps (Taylor 2019).

Local water catchments take advantage of Singapore's rainfall. Two-thirds of Singapore is a water catchment, and there are plans to make 90% of Singapore a water catchment (IWA n.d.). Singapore is able to capture urban rainwater for consumption by using a collection system that is separate from the sewerage system to prevent contamination (PUB 2018a).

NEWater began development in the 1970s. The NEWater process involves microfiltration, reverse osmosis, and disinfection by ultraviolet light in five plants to recycle treated wastewater into high-grade reclaimed water (PUB 2018a). Currently, NEWater can supply up to 40% of Singapore's water consumption. NEWater meets drinking water guidelines from the World Health Organization and United States Environmental Protection Agency (US EPA) and is mostly used for industrial and cooling purposes, although it is mixed with reservoir water during dry periods (PUB 2022d; 2018a). NEWater has a high public acceptance rate: in 2002, a survey found that 98% of Singaporeans would drink NEWater, out of which 16% would if it was mixed with reservoir water and 82% would drink it directly (WHO 2022).

Desalinated water is the fourth tap that provides Singapore's water. Currently, five desalination plants operate in Singapore, one of which began operation in 2020 and the other that began operation in 2022 (PUB 2022c). In 2017, when only two desalination plants were operating, desalinated water would still make up 25% of Singapore's water needs (PUB 2018a).

Although Singapore has non-conventional water options, **imported water** is still more cost-effective and makes up about half of Singapore's water needs. In 2012, water catchments made up 20% of the country's water needs, recycled water made up 30%, and desalinated water made up 10% (WWF 2012). Today, water supply figures are reported in potential: NEWater can supply 40% of Singapore's water needs, and desalinated water can supply 25%, although imported water is still preferred when possible (Taylor 2019; PUB 2018a). When dry weather reduced Malaysian supply in 2016, Singapore was able to meet demand (Bloomberg 2016).

Energy Singapore is also an energy-scarce country; it has no hydrocarbon resources and limited opportunity to generate renewable energy. However, Singapore is a major energy trading and refining hub for Asia (EIA 2021). Singapore's total energy supply in 2019 was made up of 48% oil, 46% gas, 4% coal and others, and 2% renewables (IRENA 2022a). Singapore has three petroleum refineries and is the world's largest bunkering (ship fueling) port (EIA 2021). Additionally, Singapore receives natural gas through pipelines from Malaysia and Indonesia, as well as liquefied natural gas (LNG) from other countries. Many natural gas import contracts are set to expire in 2024, after which Singapore plans to use liquified natural gas to meet its energy needs. Singapore has made changes to turn itself into a liquified natural gas bunkering hub as well (EIA 2021).

Energy consumption in Singapore decreased during the pandemic but increased again by around 2% in 2021. The industrial sector consumes 41.8% of electrical power, commerce and service-related industries consume 37.1%, households consume 15.3%, and the transportation sector 5.3% (EMA 2022b). Because Singapore has limited opportunities for renewable energy production, energy efficiency to reduce and manage demand is a key focus. Energy efficiency strategies are focused on adopting efficient technologies, raising awareness and capability, and supporting efficiency research and development (NCCS 2022a).

Singapore plans to harness Four Switches of low-carbon energy. The first switch is natural gas, which makes up about 95% of Singapore's electricity generation. Singapore's switched from oil to natural gas over the past 50 years (EMA 2022d). The second and most promising switch is solar, which Singapore has invested in through initiatives such as solar panels on reservoirs, roofs, and floating solar farms (NCCS 2022d; ITA 2022b). Additionally, Singapore has plans to increase energy storage systems by 200MW over the next ten years to balance solar energy supply and energy demand (ITA 2022b). The next two switches are regional power grids, which Singapore intends to use to import 4GW of low-carbon electricity by 2035, and emerging low-carbon alternatives, such as hydrogen technologies and carbon capture, utilization, and storage (CCUS)technologies. Although hydrogen technology supply chains have not yet been established, Singapore has recognized hydrogen as a key potential decarbonization pathway. It hopes to diversify its fuel mix in applications such as electricity generation and transportation (EMA 2022d). To support hydrogen deployment, Singapore has five key goals: to experiment with the most advanced hydrogen technologies available, to invest in research and development, to pursue international collaborations and enable supply chains, to undertake long-term land and infrastructure planning, and to support workforce training and development (MTI 2023). CCUS technologies face many challenges in Singapore; there are no geological formations that are suitable for permanent storage, and costs are high (EMA 2022d). Nonetheless, Singapore sees CCUS has an important avenue for long-term emission reduction and has pursued research and international partnerships to facilitate collaboration (IEA 2021).

Water-Energy. Because desalination is one of four main water sources, Singapore is particularly aware of the integrated nature of water and energy resources. Singapore's desalination plants use reverse osmosis technology. The energy consumption for this desalination technology is expected to quadruple by 2060. In Singapore's national water plan: "Our Water Our Future," new technical innovations in desalination, including electro-deionization and biomimicry, are highlighted as technologies that could lead to more energy efficient desalination (PUB 2018a). Singapore's goal is to reduce energy requirements for desalination by over half (PUB 2022c). In 2014, it was estimated that 2% of Singapore's energy went towards water and wastewater treatment processes (Vincent et al. 2014). Around 10% of Singapore's water demand comes from the petroleum, petrochemical, and specialty chemical industrial island. Singapore has researched and encouraged the use of seawater for industrial purposes where possible (PUB 2018a).

Singapore has also shown water-energy nexus initiatives at smaller scales. The Tuas Water Reclamation Plant and the Integrated Waste Management Facility harness synergies to make the plant energy self-sufficient. Integrating food waste and used water sludge will increase biogas production by 40% and optimize land use (NEA 2020). In 2018, Singapore's National Water Agency moved to digitalize the national water systems in hopes to improve operational efficiency. This plan used artificial intelligence and automation to improve water quality monitoring and planned to incorporate smart technology to better manage resources as well as find disruptions in the system (PUB 2018b). Refer to Figure 12 for a summary of water and energy interconnections in Singapore.

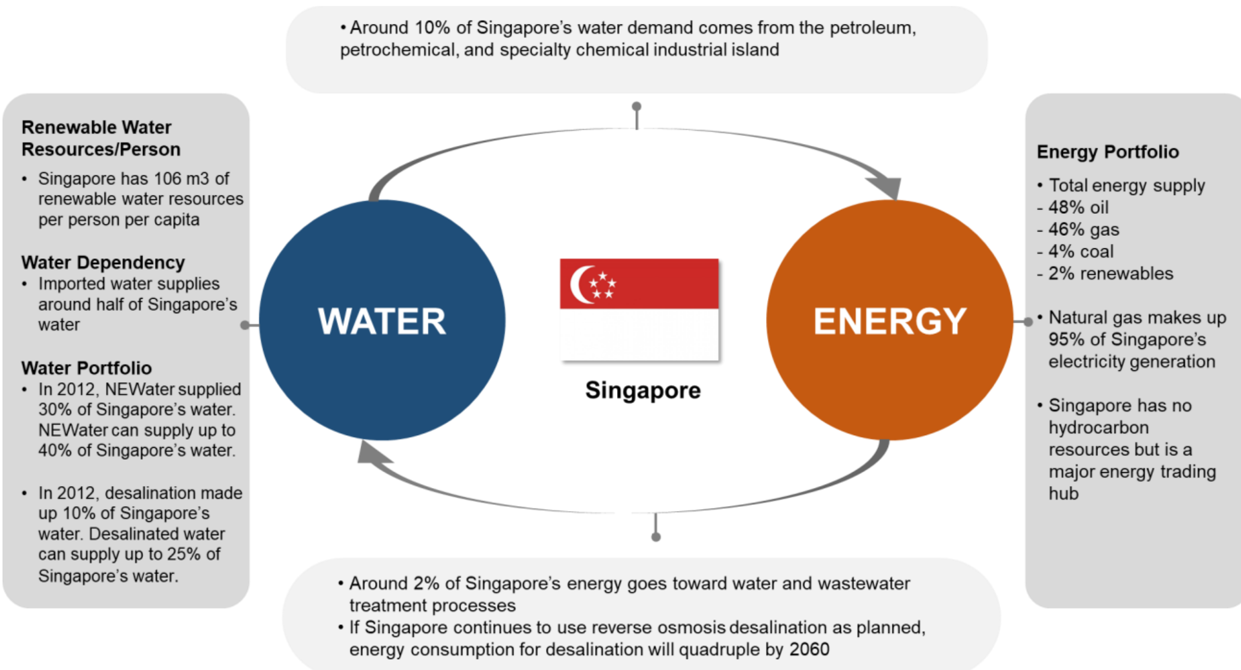

Figure 12. Key Water-Energy interconnections in Singapore (Source: Authors)

There are differences between Singapore and Jordan. Unlike Jordan, Singapore receives considerable rainfall—2,200 mm a year (MSS 2020). Jordan's primary source of water is groundwater, which Singapore does not possess. Singapore does not have an agriculture industry, so most of its water resources go towards industrial uses. Furthermore, Singapore's smaller size, more densely populated urban area, higher level of per capita income, and its position as an energy trading hub, all lead to different challenges and benefits. For example, Singapore must be much more cautious with water quality because of its reliance on catchments that are near urban areas, However, Singapore is part of many trade relationships from which it can import petroleum, liquified natural gas, and water. While Jordan's energy market is managed by the state completely, Singapore's energy market is fully liberalized.

Singapore shares similarities with Jordan. Both Jordan and Singapore are extremely water scarce; Jordan has 61 m3 of renewable water resources per person, Singapore has 106 m3. Additionally, both Jordan and Singapore import most of their energy supply, and both have a history of tension with neighboring trade partners. Jordan and Singapore aim to provide water to all residents and consider nonconventional water sources as a key to future water security.

5.2 Governance and Institutional Structures

a. Governance of the Water Sector

Water is overseen by the Ministry of Sustainability and the Environment (MSE), whose strategic directions are focused on economic, resource, and climate resilience. MSE oversees three statutory boards: the Public Utilities Board, the National Environment Agency, and the Singapore Food Agency (MSE 2022a). Water-related divisions in the MSE are the Water Food Policy Division, which manages policies to ensure reliable supply of quality water and food, manages flood risk and drainage planning, and regulates demand by controlling tariffs and costs. The Communications and Private Public Partnership Division manages public communications and engagements related to water, food, and the environment. Moreover, the Research, Futures, and Planning Division coordinates strategic planning and research for MSE (MSE 2022a).

The main actor in the water sector is Singapore's Public Utilities Board (PUB), which is a statutory board under MSE and the national water agency. It manages water supply, catchment, and wastewater. PUB also leads and coordinates issues relating to rising sea levels and flooding. PUB is the national entity responsible for all water collection, production, distribution and reclamation, as well as sanitation and sewerage. It was instituted in 1963 to coordinate the supply of electricity, piped gas, and water, and was reconstituted as Singapore's national water authority in 2001. Also in 2001, the sewerage and drainage departments were reconsidered as departments working under PUB, and the task of electricity and gas regulation was transferred from PUB to the new Energy Market Authority (PUB 2022b). In 2016, PUB accounted for more than a quarter of MSE's operating budget (Bloomberg 2016).

The National Environment Agency manages water quality in the sewerage system, inland water bodies, and coastal areas. It also enforces pollution regulations and quality standards for water discharged into catchment and drainage systems (NEA 2021). The Ministry of Foreign Affairs is involved in Singapore's international water agreements with Malaysia, as is the Ministry of Information, Communications and the Arts (MFA 2022; MICA 2003).

b. Governance of the Energy Sector

The Ministry of Trade and Industry (MTI) is the line ministry responsible for energy in Singapore. Due to the open electricity market in Singapore, one of MTI's main responsibilities is to oversee the Energy Market Authority. The MTI's Energy Division is responsible for formulating national energy policies and strategies to ensure a sustainable future. The Energy Division works with the Energy Market Authority and other government agencies to develop competitive energy markets, alternative energy sources, and international and regional cooperation (MTI 2022).

The Energy Market Authority (EMA) was established in 2001 to ensure a reliable and secure energy supply and promote competition as the energy market opened. The same year, Singapore's power company was divested, and companies with electricity demand of 2MW or above could buy electricity from whichever retailer. Over the next 17 years, the electricity demand threshold was lowered, and the natural gas market was also liberalized. In November of 2018, the Open Electricity Market was rolled out to all remaining households and small businesses (EMA 2019).

Currently, power generation companies bid to sell electricity in the wholesale electricity market every half hour. Electricity retailers buy the electricity and compete to sell it to consumers. Consumers can buy from an electricity retailer at a set price plan, buy from the wholesale electricity market at the wholesale price set each half-hour, or buy from SP Group at the regulated price. SP Group provides services such as data management and facilitating customer interactions between retailers, in addition to operating the national power grid (Open Electricity Market 2022b). In 2021, three electricity providers exited the market, citing difficulties with the volatile electricity market, leaving nine retailers still providing services (Open Electricity Market 2022a; Reuters 2021).

EMA is the main energy operator, regulator, and sector developer in Singapore. As the power system operator, EMA is responsible for ensuring reliable electricity supply and maintaining the power system, including the control center, which runs the electricity generation and transmission system. The EMA also oversees the operation of the natural gas transmission system and carries out studies to assess and monitor said system (EMA 2022c). The EMA also acts as the main electricity and gas industry regulator. The EMA's multifaceted role allows it to ensure stability in the energy market while Singapore transitions to an open market. Although the EMA is a significant player, the national priority is to shift to private sector operation (Tan and Tan 2021). Singapore's national priority ensures security, reliability, and adequacy of electricity supply while promoting competition and protecting consumer interests. The EMA also plays a role as the industry developer and works to foster the energy sector and catalyze innovation (EMA 2022c).

In addition to the MTI and the EMA, there are other national bodies whose responsibilities overlap with the field of energy, especially as it relates to climate change and environmental matters. The National Climate Change Secretariate (NCCS) was established in 2010 to develop and implement climate change policies. It supports the Prime Minister and his cabinet to develop priorities and strategies that cover multiple ministries and agencies. The NEA also works toward energy efficiency by encouraging efficiency in different sectors. In the industrial sector, for example, NEA requires an energy efficiency improvement plan each year which describes energy efficiency measures that have been completed or are planned, as well as the status of any previously reported energy efficiency measures (NEA 2022). The Ministry for Sustainability and the Environment is responsible for sustainability and resilience in a variety of areas—although MSE specifically oversees water, food, and environment, it also has priorities and policies for energy, including improving energy efficiency (MSE 2022c).

c. Agri-Food Governance

Singapore's food policy goal is to achieve self-reliance rather than self-sufficiency, so reducing wastage and increasing industry production are major goals to the country (Tortajada and Hongzhou 2016). Historically operated farms, especially pig farms, were phased out by 1990 and replaced with space-conscious agrotechnology parks that grow a variety of products, with a focus on high-value items such as cut orchids and ornamental fish.

Until 2019, the agri-food industry was managed by the Veterinary Authority of Singapore; a statutory board that ensured food supply and safety, and the National Environment Agency, which governed food safety after retail distribution, monitored production establishments, and inspected imported food (Tortajada and Hongzhou 2016). In 2019, the Singapore Food Agency was created to consolidate food-related governance functions under one entity (SFA 2022). The Singapore Food Agency operates under the Ministry of Sustainability and the Environment. The Inter-Ministry Committee on Food Security, formed in 2012, coordinates and analyzes food security risks, and proposes mitigation strategies. Because 90% of Singapore's food is imported, there are many regulations and laws set in regards to food safety and import requirements (Tortajada and Hongzhou 2016).

d. Water and Energy Institutions

The National Climate Change Secretariate's scope spans over many sectors, including water and energy. NCCS's mitigation effort areas include power generation—specifically the transition to low-carbon energy sources—and energy efficiency, which includes promoting the adoption of new energy efficient measures and technologies, building capacity for energy efficiency efforts, raising awareness, and supporting research and development efforts to enhance energy efficient technology capabilities (NCCS 2022a). Additionally, NCCS works to reduce the energy used by desalination and maximize energy recovery from waste through biogas production (NCCS 2022c).

Overseen by NCCS is the Inter-Ministerial Committee on Climate Change (IMCCC), which enhances holistic coordination within the government to ensure Singapore is prepared for the effects of climate change. Members of this committee include the Minister for Sustainability and the Environment and the Minister for Trade and Industry, as well as the Minister for Transport and the Minister for National Development among others. Five working groups exist under the IMCCC to coordinate and develop strategies for different aspects of long-term sustainability, such as the Long-Term Emission and Mitigation Working Group, the Resilience Working Group, the Sustainability Working Group, the Green Economy Working Group, and the Comms and Engagement Working Group. The emissions and resilience working group have to do with emissions and planning for resilience against climate change, while the Green Economy and Comms and Engagement group are mostly climate change or economics-focused. The sustainability group is the most related to WEN, since it focuses on building resource resilience and cross-cutting issues. (NCCS 2022b).

Research and innovation are key areas where water and energy interactions are explored. The 2020 Research Innovation Enterprise Plan, developed by Singapore's National Research Foundation, lists lowering the energy consumption of used water treatment, seawater desalination, and NEWater production as one of its key strategic goals for urban solutions and sustainability. In particular, the Research Innovation Enterprise aims to "take an integrative approach to reap synergies at the intersection of the energy-water-land nexus." The plan lists a set of schemes available to public researchers who can also partner with urban sustainability agencies (NRF 2020).

Water is closely managed, and most governance and planning responsibilities fall under MSE or PUB. In contrast, energy generation and distribution are largely left for EMA and the open market. As a result, many entities, such as the Ministry of Transportation, the Ministry of National Development, the Ministry of Sustainability and the Environment, and the Ministry of Trade and Industry have energy efficiency and low-carbon energy transition policies and priorities for their own sectors. Refer to figure 13 for a summary of key energy, water, and coordination actors in Singapore.

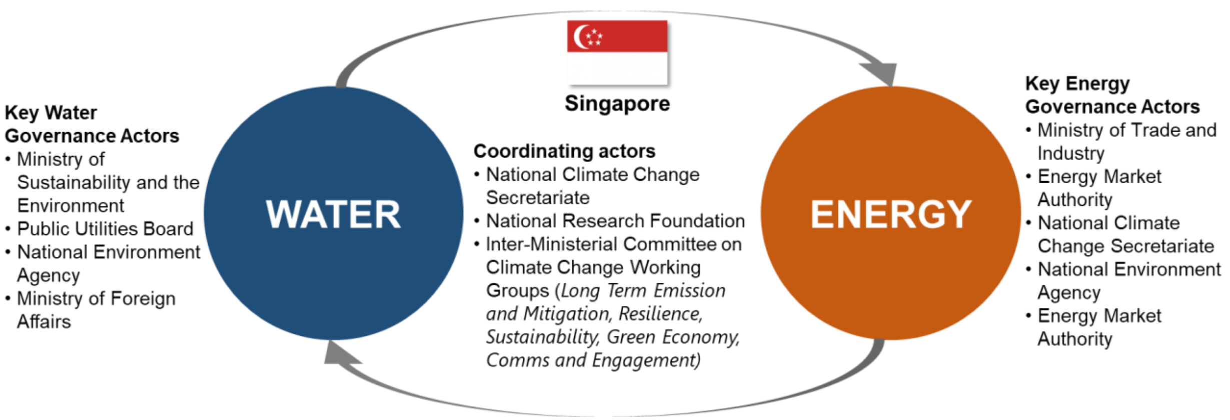

Figure 13. Key water and energy actors in Singapore (Source: Authors)

5.3 Methods to ensure policy coherence and integration

There are several coordinating bodies and mechanics within Singapore's government. The Inter-Ministerial Committee on Climate Change is a high-level body that coordinates between ministers. MSE's Research, Futures and Planning Division coordinates strategic planning and research within the ministry, and the Energy Division of MTI coordinates many of its responsibilities with EMA. Under the Research Innovation Enterprise Plan, close integration of research, especially across disciplines and stakeholders, is listed as a major strategy (NRF 2020). Water quality and pollution challenges are closely integrated with the water supply, since so much of the water supply sources are in close proximity to urban areas. The National Environment Agency coordinates between pollution regulations and the PUB's water governance responsibilities. PUB and NEA both operate under MSE.

Singapore also ensures cohesion and inter-sectoral integration through clear, purposeful strategies by directing goal-oriented, pre-planned actions. In the case of its water sector, Singapore has had the goal of water self-sustainability since the failed water talks with Malaysia. This goal was purposeful by addressing clear national needs, and its parameters—achieving self-sufficiency by 2060—clearly align with the expiration of its water agreements with Malaysia. In the energy sector, Singapore's focus has been on innovation and efficiency, which is pursued through opening the market between 2001 and 2018. These plans and strategies highlight Singapore's national priorities and help different ministries and agencies to create strategies that align with those pre-set priorities.

5.4 Good Practices and Lessons Learned

a. Clear and actionable strategies with measurable targets

Singapore ensures policy coherence and inter-sectoral integration by setting out simple yet specific goals and strategies for its development. Singapore's "Four Taps" of water supply are standing strategies for water supply, not limited by end years or cut-off times. Similarly, the "Four Switches" of low-carbon energy aim to give the same stability of prioritization in the energy sector. These planned supplies for water and energy help dictate where development, time, and finances should be prioritized, thus allows Singapore to commit to large infrastructure plans. For instance, two new desalination plants have kicked off operation in the past two years. Similarly, Singapore has committed to large sewerage and water treatment projects because of the clearly described role of treated wastewater for its future water supply. The deep tunnel sewerage system will be used in conjunction with Singapore's NEWater plants to increase the amount of treated wastewater. The deep tunnel sewerage system began construction in 1987 and is expected to be completed by 2025 (Freyberg 2014; PUB 2018a).

Singapore clearly streamlines its water strategy. Although MSE and PUB have many priorities and efforts that they work toward, the national water strategy is easily distilled into three long-term actionable strategies: i. collect every drop of water, ii. reuse water endlessly, and iii. desalinate more water. These targets account for expected demand increases (PUB 2018a). While its energy strategy is less succinct, Singapore's open energy markets allow government priorities to be focused on energy efficiency strategies and low-carbon transitions.

Simultaneously, clear targets for each tap and switch allow Singapore to measure and communicate progress while being clear on sector goals. Singapore has set clear aims for the proportions that NEWater and desalinated water will provide for the national water supply by 2060. The country has also set quantified targets for the amount of low-carbon energy imports and energy storage capacity it plans to achieve by 2035 (PUB 2018a; ITA 2022b).

b. Long-term planning with strict enforcement

Many of Singapore's strategies are long-term, for example, the *Our Water Our Future* strategy document covers 50 years ahead. The goal of self-sustainability was set with an even longer time frame (PUB 2018a). In the energy sector, the transition from petroleum to natural gas also occurred over a 50-year period. These time frames allow Singapore to make necessary plans for its future that stand through global challenges and changes.

Additionally, Singapore commits to strict enforcement of its policies to achieve its goals. Fines for water pollution are strictly enforced, and there are several energy efficiency standards and requirements in a number of sectors (NEA 2021; 2022; EMA 2022a). This commitment to every-day policies allows Singapore to make consistent progress in its long-term national goals.

c. Use of new technology to improve efficiencies

Singapore has utilized new technology to ensure the efficiency and longevity of its systems. In 2020, Singapore began using leak monitoring sensors, inline pipe inspection tools, and smartphone acoustic sensors for early leak detection. These technologies make leak detection easier and faster, especially in pipes that are far underground (PUB 2020a). In 2022, PUB adopted a digital thermodynamic pump efficiency monitoring system at a pumping station to monitor the performance of the pumps. The data collected from this monitoring system allows PUB to optimize operation conditions and prioritize the most efficient pump combinations (PUB 2022a). In the energy sector, the adoption of energy efficient machinery is encouraged through minimum energy performance standards and efficiency grants and funds. In the household sector, EMA encourages energy efficiency through advanced electricity meters, solar panels, and LED lighting (EMA 2022a).

Singapore has long relied on new technology to achieve its goals. NEWater was first explored in the 1970s, when treatment technology was found to be too inefficient to implement. However, after more research, new membrane technology made water reclamation feasible by 1998. Similarly, Singapore is pilot testing unproven technology to make desalinated water's energy cost feasible. One method being explored is electro-deionization, which has been piloted in small scales, but, if successful, could use less than half the energy needed by the current reverse osmosis method. Biomimicry and synthetic water channels are also energy-efficient desalination technologies that PUB has explored. New processes, such as upflow anaerobic sludge blankets and anaerobic membrane bio-reactors, could allow the biogas production methods utilized during water treatment to bypass the energy-intensive aeration phase (PUB 2018a).

d. Good relationship with and ownership by the public

Singapore strives to share its water challenges and achievements with the public. Although Singapore has mitigated water scarcity and does not experience any breaks in tap water supply, the public is still informed and involved in water conservation and demand management. Awareness campaigns in elementary schools, tips and tricks for saving water, and water pricing are the ways in which the Singaporean government impresses the importance of water on the public. One indicator of success is the average household water use per person per day, which decreased from 165 liters in 2003 to 148 liters in 2016 and is further forecasted to reach 140 liters by 2030 (PUB 2018a). MSE has established energy efficiency labels and minimum energy performance standards for appliances to push energy conservation in households (MSE 2022c). Additionally, MSE, NEA, and MTI all have communication or public engagement divisions. Singapore's campaign with NEWater has also been effective; 92% of Singaporeans would drink NEWater, one of the NEWater plants maintains a visitor center to encourage engagement (PUB 2022d).

Singapore's Active, Beautiful, Clean Waters program (ABC Waters) aims to bring the public closer to their water resources under the belief that residents are more likely to prioritize and contribute to water-conservation measures if they can see and appreciate water resources. By integrating Singapore's 8,000 km of waterways and 17 reservoirs parks, gardens, and water activity spaces, the country hopes to make its functional water infrastructure a scenic part of the national environment (PUB 2020b).

6. Global examples of best practices

Example 1: The Ministry of Energy and Infrastructure in the United Arab Emirates

The UAE presents an example of water and energy governed jointly under one national entity. In 2020, the Ministry of Energy and Industry was merged with the Ministry of Infrastructure Development and the Federal Transport Authority for Land and Maritime to create the one Ministry of Energy and Infrastructure (MOEI 2022b). Within the Ministry of Energy and Infrastructure (MOEI), The Undersecretary of Energy and Petroleum Affairs oversees the Assistant Undersecretary for Electricity, Water, and Future Energy Sector. Departments under the Undersecretary for Electricity, Water, and the Future Energy Sector include the Electricity and Energy Trade Department, the Future Energy Department, the Productivity and Demand Management Department, the Regulations and Monitoring Department, and the Water Resources Department. Notably, even at the department level, both the demand management and regulatory departments are managing both water and energy, rather than separating the sectors (MOEI 2022d).

The MEI's strategic objectives cover both water- and energy-specific issues, as well as many objectives that cover the interlinkages between both resource systems. The ministry's 2020-2021 strategic plan specifically highlighted increasing the efficiency of water establishments through technical studies and inter-authority coordination; adopting best practices to reduce water losses; implementing the National Program for Demand Management of Energy and Water; and promoting research and working groups in the field of energy and water (MOEI 2022e). The MOEI has won a number of awards for its innovative approaches, methodologies, and green growth, including winning the Harvard Business Council International Green Award and Innovation Award (MOEI 2022c; 2022a).

Example 2: The Ministry of Environment, Water, and Agriculture in Saudi Arabia

The Ministry of Environment, Water, and Agriculture in Saudi Arabia (MEWA) was founded in 2016, when the Ministry of Water and Electricity was abolished, and the Ministry of Agriculture took on water- and environment-related duties. The Ministry oversees five agencies which govern land and survey, planning and institutional excellence, economic affairs and privatization, agriculture, water, and the environment. Additionally, MEWA has seven directorates pertaining to the Environment, Water Affairs, Water Services, Agriculture, Land and Survey, Animal Resources, and Planning and Development. The Ministry also oversees 14 regional administrative bodies under the directorates of water as well as 13 general administrations responsible for agricultural services.

The ministry's duties include supervising development, providing agricultural subsidies, providing guidance on best farming practices, developing and preserving cultivatable lands, providing irrigation water, managing food supply and food exports, implementing irrigation and drainage projects, and research (MEWA 2020). Additionally, Saudi Arabia's National Transformation Program highlights the water, agriculture, and environmental sectors, which MEWA helps to implement. The objectives of the transformation program cover ensuring a sustainable water supply, managing water demand, turning agriculture into a more water efficient sector, and addressing food security risks (MEWA 2022). As part of the program, MEWA launched a water rationalization program in 2019 to significantly decrease Saudi Arabia's high water per capita consumption rate. MEWA's Water Rationalization Division has put on public water conservation campaigns and distributed water consumption rationalization tools. The program hopes to decrease water usage by 43% by 2030 (MEWA 2019).

Example 3: Identified barriers for cooperation between water, energy, food sectors in San Antonio, Texas

San Antonio, Texas, is one of the fastest growing cities in the United States. The region surrounding the city includes major areas of irrigated cotton, citrus and nut trees, and other agricultural crops. The region lies over the Eagle Ford shale play and is increasingly becoming home to oil and natural gas production, as hydraulic fracturing technology becomes more prevalent. The San Antonio region thus represents a hotspot whose stakeholders across sectors compete for its limited water, land, and financial resources. Despite the tight interconnectedness between water, energy, and food challenges, a very low level of communication was identified between the different cross-sectoral decision-making entities within the region (Daher et al., 2019). When asked about the barriers leading to this low level of communication across different sectors as part of a stakeholder engagement meeting (Rosen et al., 2018), stakeholder cited the following:

- Legal and procedural barriers: Limited institutional mandates and lack of coordination mechanisms
- Financial: who will pay for the time and effort involved in pursuing increased communication?
- Uniformity of Language: units, abbreviations, syntax and context of problems and solutions
- Differences in planning horizons; which differ for water, energy, and food (10 to 50 years) causing ideological differences and creating barriers
- Self-interest versus collective goals - silo mentality
- Lack of common goals and collaborative projects

This list includes some of the common challenges that need to be addressed to develop more coherent strategies and coordinated action across the different interconnected sectors.

Example 4: Multi-stakeholder dialogues towards participatory governance

There is growing evidence from various countries that it is possible to base energy policies on co-creation processes (Haddad et al. 2022; Komendantova, Neumueller, and Nkoana 2022). The water-energy-food-environment nexus is a complex policy problem that requires upgrading of existing infrastructure and techniques in use, changes in legal and institutional frameworks, new technological solutions, and new forms of cooperation between various stakeholders involved in the energy, water, and agri-food sectors' policy development and implementation (Komendantova et al. 2020). Without the development of cooperation schemes and compromise solutions, such complex policy process, can lead to conflicts or inefficiencies. Additionally, benefits from synergies in water and energy efforts are lost. Therefore, a participatory governance methodology that integrates views, visions, and opinions of different stakeholder groups is a useful practice (Komendantova, Neumueller, and Nkoana 2021). Participatory governance could facilitate the negotiation of compromise solutions involving a large variety of stakeholders with heterogeneous and difficult to reconcile views, interests, visions, plans, and policy targets. Furthermore, developing and implementing robust ("no-regret") water policies is of high importance for sustainable development of any country (Danielson et al. 2022).

Frequently, such participatory governance involves ***multi-stakeholder dialogues or platforms*** that aim to create and support spaces in which meaningful conversations can take place among diverse stakeholder groups. Managing the flow of technical information through a dialogue process could help lift the quality and substance of debates by allowing the focus to move from points of shared understanding and agreement to more difficult issues related to differences in assumptions, interests, and values. At the same time, a mixture of participants that is too large or diverse leads to significant challenges in creating appropriate spaces for all participants to meaningfully contribute. The aim of the dialogue is to identify contested spaces relating to socio-economic and political power, including whose voices are heard and how the feedback is being integrated. Additionally, the dialogue often should identify how knowledge is constructed and legitimized. For example, to what extent technical or scientific discourses integrate with local knowledge and experiences.

While the following do not necessarily cover all sectors of the WEFE nexus, they offer examples of multi-stakeholder dialogues at the international, national and river basin levels which can be applicable to WEFE nexus contexts:

- **The World Commission on Dams** (WCD) was one of the first major examples of a multistakeholder dialogue in the water sector. The WCD was initiated in 1997 by the World Bank and World Conservation Union to review the effectiveness and development of large dams as well as create international guidelines for planning, building, and operating large dams. The main stakeholder forum itself included 68 members, and a total of 1,400 individuals from 59 countries performing a variety of roles took part in consultations. The review process also included hearings, 125 surveys of dams across the world, 8 independent case studies, and 17 thematic reviews from the perspectives of engineers, governing bodies, and victims of dam disasters. Several hundred people contributed to the final report produced by the commission (World Commission on Dams 2000).
- **Kyrgyzstan:** The preparation of the Strategy of Sustainable Industrial Development of Kyrgyzstan was one of the optimal practices of ***participatory design of the planning process*** and involvement of various stakeholders. It included the review of existing strategic documents and in-depth interviews with various experts and stakeholders. Additionally, multiple-choice questionnaires, a set of four surveys with national and integration experts, focus groups with private companies in various regions

  of the country, and scenario development with involvement of key stakeholders contributed to the planning process. Furthermore, four regional roundtable discussions took place between May 2018 and July 2018 (Strelkovskii et al. 2020). Such procedures allowed the development of scenarios and identification of risks and benefits. Afterwards, based on these scenarios a matrix of actions was developed to utilize Kyrgyzstan's natural resources and geographic location while considering its geopolitical and economic context. Eventually, a matrix of actions, indicators of success, an action plan, and budgetary measures were developed (Strelkovskii et al. 2020).

- **Rhine Basin:** Another example is the IJsseldelta case in the Rhine Basin. Public and stakeholder participation took place during the process of ***developing the masterplan*** for IJsseldelta South, in the Overijssel province of the Netherlands. The dialogue surrounding the new masterplan began when then-Minister of Housing, Spatial Planning and Environment (VROM) requested examples of pilot projects that could be included in the National Spatial Strategy. Spatial planning in the IJsseldelta involved a variety of complex and often conflicting challenges: At first, residents were wary of participating in the decision-making process due to a history of exclusion. However, once trust between the residents of the region and VROM was built and the legitimacy of the residents' role was established, the residents were fully bought in to the decision-making process. Four design groups with stakeholders and citizens were created. Each group included at least one spatial planner, urban developer, or architect to carry out the technical aspects of visualizing stakeholder input. Five scenarios were developed by the project staff and stakeholders and served as the starting point of the groups' dialogue. A sixth scenario was created by one group that opposed the preexisting five scenarios. The sixth scenario gained support from the other groups and stakeholders and went on to form the basis of the masterplan. The masterplan has been widely supported by the public, as it was created by farmers and residents that are directly affected by it (Huntjens, Lebel, and Furze 2017).

Example 5: Local community participation and bottom-up decision-making mechanisms

Water and energy resources are closely linked, meaning that managing them locally has global repercussions on resource usage and consumption patterns. Conversely, local developments can also have an impact on a larger scale. This underscores the importance of involving stakeholders in the governance of water and energy infrastructure projects at the local level to assess their impact. When water or energy supplies are inadequate or development patterns are unsustainable, the negative consequences are most felt at the local level.

Austria presents one example of a best practice which facilitates the participation of local communities in decision making processes regarding infrastructure needs or details of its deployment (Komendantova and Neumueller 2020). The ***energy groups*** in Austria promote the participation of local level energy stakeholders in energy policy (Komendantova and Neumueller 2020). For example, energy groups in the region of Freistadt act as a link between regional level management, national authorities, residents, and local authorities. The groups also trouble-shoot; they interact with the public and implement site-specific projects with the support of the locals (Reusswig, Komendantova, and Battaglini 2018).

In efforts to establish the energy groups, local residents who had already been interested in energy policy issues (e.g. organic farmers, residents applying for subsidies for PV, thermal energy and other renewable energy sources etc.) were contacted and invited to partake in the decision-making process by regional managers of official entities, more specifically the representatives of the Austrian Climate and Energy Fund, founded by the Austrian Federal Government. During this process, the authorities adopted a procedure of discharging moderation and coordination duties, while the participants negotiated the thematic focus. In this meeting, working groups on various topics were deployed, one of which was a group dealing mainly with energy issues. The bottom-up initiative of local resident participation arose through this procedure, led mainly by the current energy policy manager. Afterwards, the energy management installed a network of energy groups, following the previously mentioned procedure. The decision-making process on infrastructure needs and deployment was steered by the regional management for the duration of two years in efforts to establish an organizational structure and promote regular meetings. Overall, 21 energy groups are currently active in the region of Freistadt (Komendantova, Riegler, and Neumueller 2018).

The energy groups are also a vehicle to implement strategies and targets developed on the national governance level. The Federal Government of the Austrian Republic has determined decarbonization targets for Austria's energy sector, including that of energy generation, energy transportation, and the industry overall. Regional, urban, and local authorities in Austria are considered vital partners in achieving decarbonization targets. To avoid duplication, the collaboration between governing bodies at different levels is required in a "cost-efficient manner" and "with clear division of responsibilities and powers" (Komendantova 2017). Consequently, these requirements also apply to coordination of decarbonization efforts in Austria. (Komendantova 2017). Various initiatives of the Austrian government lay stress on bottom-up approaches while emphasizing the role of local governance and the engagement of various stakeholders. Such initiatives also highlight the importance of providing laypeople with the opportunities to engage in the decision-making process regarding the decarbonization of the energy sector.

The participation of local communities can provide key inputs for the implementation of the WEFE nexus governance models through participatory mechanisms that allow for horizontal integration (between various ministries and sectors) and for vertical integration (involving local level stakeholders). That is especially relevant when evaluating the impact of WEFE infrastructure whose impact is more pronounced at the local level in terms of land use or impact on environment. The developed energy groups are discussing projects from this perspective while providing feedback to the national ministry which is managing the program whose evaluating possible impacts of different interventions.

Another example of energy and climate security policies being implemented at both the local and regional levels in Austria are ***climate and energy model (CEM) regions***. CEM is a concept that brings together goals of climate change mitigation, energy security and socio-economic development policies at the regional level. CEM regions are an initiative by the Austrian Climate and Energy Fund with the goal of fostering independence away from fossil fuels with a regional bottom-up approach. Currently, Austria has around 100 CEMs (Komendantova, Neumueller, and Nkoana 2021).

There are two phases in the decision-making process on energy transition in CEM regions. The first phase is to develop implementation concepts and exploration plans based on regional potential. This step often includes definitions and targets relating to energy independence. The second phase is concerned with the development of concrete projects funded by the Austrian Climate and Energy Fund. There exists a funding threshold for the projects, and the CEM region is required to co-finance 25% of the project. Since 2015, 10 million Euro of fund were made available to all regions for investment into a variety of renewable energy and energy efficiency initiatives (Komendantova, Riegler, and Neumueller 2018). Funds are provided by the Austrian Federal Ministry for Transportation, Innovation and Technology, and the Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management. The economic, social, legal, and technical feasibility of the ministries' energy transition activities are researched by scientific stakeholders and academics. At the state level, the main stakeholders are regional development agencies and the provincial government whose role is to develop and carry through legal frameworks and regulations on the energy-transition process. A CEM manager resides at the regional level and is joined by representatives of municipalities, including such stakeholders as mayors, environmental committee officers, and leading officials at the local level. The stakeholders are responsible for implementing and partly financing the projects (Komendantova, Riegler, and Neumueller 2018). The energy groups provide residents with an opportunity to provide their feedback on the goals and the projects. Residents are also able to act as links between their community, CEM management, and the authorities. The CEM manager is responsible for the organization of the energy group meetings. and the CEMs together with energy groups represent a bottom-up incentive where many residents and stakeholders can participate.

In Austria, ***Urban Renewal Offices and of Neighborhood Management Offices*** are an example of participation in water-energy decisions at the urban level. Originally more focused on technical support, today, Urban Renewal Offices act as coordinators and organizers of urban participation. They have created platforms for the public to participate in local decision-making. This allows residents to have a direct transmission of local perspectives into political decision-making processes. They also provide information and advice on topics most relevant to the local community. Furthermore, a Master Plan for Participatory Urban Development has been developed to balance local interests with the overall requirements of the city. This plan defines procedural principles based on existing successful examples of urban planning (IRECH 2016).

Example 6. National Policy Dialogues

Experiences of many countries suggest that establishing and conducting policy dialogue (**PD**) on WEFE issues might be instrumental in addressing challenges. In 2004-2020, such dialogues on had been conducted in 10 countries in the EECCA region. The dialogues were institutionalized by establishing respective management structure (Coordination Council) and procedures. In several countries, management of the Coordination Council was supported by a dedicated secretary - a full-time officer hosted by one of participating ministries. Ad hoc working groups were created to prepare ground for informed discussion and recommendations.

The PDs were sponsored by the EU (under the *EU Water Initiative*) and several other donors (e.g., Austria, Finland, Germany, Norway, Sweden, Switzerland) and were facilitated by the OECD and UNECE (OECD and UNECE 2016). *Ad hoc* dialogues on topical policy issues facilitated by the OECD were conducted also in Brazil, the Netherlands and other countries.

Though initially the focus of PDs was on water for various uses (domestic WSS, water for irrigation, water for eco-systems etc.), water-food and water-environment, as well as water - health inter-linkages were discussed through the dialogues from the very beginning. In some instances, country dialogues specifically addressed topical nexus issues (e.g., Kyrgyzstan).

On top of that, several **regional dialogues** were held in EECCA discussing PPP/PSP in water infrastructure and reform of rural WSS; applying economic instruments for WRM; water- and nexus related SDGs as well as results of the UNECE-led **nexus assessmen**t in trands-boundary river basins (e.g. in Syr-Darya basin in Central Asia where the water-for-food *versus* water-for-hydro-power trade-off is very topical).

Building on the existing country and regional policy dialogue processes and accumulated positive experience, recently a **regional policy dialogue on nexus was launched in Central Asia**, supported by Germany and EU Delegations to countries and facilitated by the OECD, UNECE, EBRD and their regional partners. The scope of national policy dialogues was extended respectively. However, **water is still in the center** taking into account its key role in agri-food production and in the energy sector in the region (especially in Kyrgyzstan and Tajikistan where most of electricity is generated by hydro-power), as well as in ensuring sustainability of eco-systems in the Lake Aral Basin shared by all 5 countries of Central Asia.

A variety of lessons have been learned through these dialogues. They concern:

Focus on priority issues. Typically, key objectives and tasks of the policy dialogue are country specific. Initial objectives should be defined by top level decision-makers when establishing the dialogue and platform for it. The ministries and agencies leading, and participating in, the dialogue should also be clearly defined.

Ability to adapt to the evolving policy agenda. Policy dialogues initially (in 2006-2010) focused more narrowly on domestic WSS and water-health inter-linkages, proved to be able to extend their scope firstly to broader water management agenda (incl. Irrigation and multi-purpose water infrastructure systems; incl. water reservoirs, hydropower plant, irrigation canals, etc.) and then to the fully-fledged nexus, also in transboundary context. As most stakeholders were involved in the dialogue from the very beginning, the extension of the scope required only marginal changes in the PD management and in the composition of *ad hoc* working groups.

Stakeholder engagement and ownership. Previous experiences have shown that the PD on nexus should be **multi-stakeholder and cross-sector**, taking account of trans-boundary issues where necessary. In addition to the top representatives of key stakeholders in the water, energy, environment and agri-food sectors, other relevant parties should also participate in the dialogues. This includes ministries of economy and finance, ministry of foreign affairs (responsible for regional cooperation on transboundary issues, not least on the aforesaid water-for-food *versus* water-for-hydro-power trade-off) ministry of emergencies; bodies subordinated to the ministry of environment (like hydro-meteorological service), water and energy tariffs regulators; ministry(ies) responsible for public health and social issues; ministry(ies) responsible for territorial (urban and rural) development, housing and utility services; line ministries responsible for water intensive industries (from mining to processing); representatives of respective parliamentary committees or departments of the prime-minister's office; representatives of basin councils (incl. trans-boundary ones, where exist); representatives from academia and civil society organizations active in the nexus domain; and representatives of development partners (DPs) assisting the country, region, or basin in addressing key challenges and issues in the nexus domain.

Strong continuous leadership and institutional sustainability. As achieving policy targets in the water, agri-food and energy sectors, typically requires quite a few years (sometimes, several decades), it is of utmost importance **to ensure strong and continuous leadership** over the period at a proper senior level. At a minimum, a deputy minister, a deputy chair of state committee, or a head of an agency shall be involved. While involvement of medium-level officers (e.g., heads of departments) can help ensure the preservation of an institutional memory about the PD in their respective organizations.

In each country, a special *ad hoc* inter-agency **coordination council** has been established: either by a government decree (e.g., Kyrgyzstan) or an ordinance of the lead ministry, or a joint ordinance of interested ministries (e.g.in Moldova) and its regular meetings has provided the platform for the dialogue. Respective legal regulatory acts established key tasks and objectives of the dialogue, the composition, and the mode of work of the council.

In Kyrgyzstan, a **National Council on Water and Land Resources** was recently established as a top level decision-making body on water-land/agriculture nexus related issues, incl. their environmental dimension, covering also the aforesaid water-for-food *versus* water-for-hydro-power trade-off. It is chaired by the President of Kyrgyzstan (elected national leader), with the Prime-minister and the Minister of Environment as deputy-chairs (the latter ministry is *inter alia* responsible for managing water resources and state irrigation systems). Top management of the Council is supported by a dedicated Secretariat. Lifting the discussion of acute water-land/agriculture-environment nexus issues to the top level of the national governance system helped to finally find acceptable solutions of several long-lasting politically sensitive issues, adopt the National Water Strategy (adopted in February 2023, by Decree of President) and make a few other decisions.

Selected model examples from 2018 until 2020 of what was achieved through the NPDs include:

Regional dialogue on nexus assessment in Syr-Darya basin: it helped develop a common understanding of: (i) key inter-linkages and trade-offs in the water-energy-food-environment nexus domain, as well as (ii) costs of the lack of co-operation between sectors and countries; and also develop some basic local capacity for nexus assessment.

Belarus, where support was provided inter alia to: (i) draft a new 2030 national Water strategy in the context of climate change; and (ii) adopt new norms regarding water consumption and wastewater discharges by most water intensive enterprises, incl. 3 food-processing ones, in one pilot rayon (i.e. administrative district); and (iii) develop training materials on economic instruments for managing water resources, bodies, and infrastructure systems (used for domestic water supply and irrigation; water transport and hydropower) .

In Kyrgyzstan, support was provided *inter alia* to develop: (i) a **national framework for water, food and energy security indicators**; (ii) training materials on economic instruments for managing water resources, bodies, and infrastructure systems; and (iii) foster trans-boundary co-operation in Chu-Talas basin where water is used mostly for agriculture.

In Moldova, support was provided inter alia to draft RBMPs for two river basin districts (the plans cover all water uses, incl. agriculture and food processing, and domestic water supply).

In all previously mentioned examples, the discussion at national policy dialogue meetings helped to improve the quality of, and mobilize broad political support to, respective draft strategies and plans that were ultimately officially approved by decrees of the government or ordinances by relevant ministries or other government agencies.

7. Conclusions

Water, energy, food, and environment system challenges are tightly interconnected. Therefore, they must be addressed in an integrative manner. A systems approach is necessary to account for these interdependencies and ensure coherent and effective actions are adopted across sectors. Adopting a systems approach ensures the consideration of cross-sectoral perspectives, allowing for a better understanding of the trade-offs and synergies associated with different pathways and interventions being considered across sectors.

Adopting such a systems approach needs to be context-specific and may yield different types of interventions in different regions. Resource availability, governance structures, institutional infrastructure, local human capacity, technological availability, stakeholder engagement mechanisms, and available traditional and indigenous practices can all affect the nature of interventions to address interconnected resource challenges. Examples from Tunisia, Morocco, and Singapore, among other global examples, highlight a variety of strategies, lessons, and principles that may be applicable to other contexts. Understanding the contexts surrounding water-energy nexus management and governance within the broader WEFE nexus framework in different regions reveals good practices and lessons learned to be considered.

This report presents good practices of example countries selected based on key economic, social, governance, and resource-related criteria developed in consultation with stakeholders in Jordan. Additionally, global good practices in water-energy nexus applications were reviewed. Through this analysis, the report highlights patterns, strategies, and structures that demonstrate successful approaches as well as highlight key challenges in implementing water-energy nexus system management and governance. Table 2 presents a list of the key economic, governance, and policy and engagement interventions identified across the different case studies explored.

Table 2. Economic, governance, and policy practices

	Economic & Operational	**Governance, institutional and regulatory frameworks**	**Policy and stakeholder engagement**
Tunisia	• Variable energy pricing • Subsidies	• Agriculture and water under one ministry	
Morocco	• Privatization and Public Private Partnerships	• Inter-ministerial commissions and their role in improved policy coherence • National Office of Electricity and Drinking Water • Decentralized water governance	
Singapore	• Use of new technology to improve efficiencies	• Long-term planning and strict enforcement	• Clear and actionable strategies with measurable targets • Good relationship with and ownership by the public
United Arab Emirates		• Water and energy under managed and governed under one ministry	

Saudi Arabia		• Environment, Water, and Agriculture under one ministry	
San Antonio, TX, USA	• Need for developing collective goals and collaborative projects across sectors	• Need to address legal and procedural barriers through expanding institutional mandates and developing cross-sectoral coordination mechanisms	
Other Global Practices		• Multi-stakeholder dialogues toward participatory governance	• Local community participation and bottom-up decision-making mechanisms • National Policy Dialogues • Development of coordination mechanisms with appropriate allocation of financial and human resources

Source: authors' own elaboration

The economic practices identified in this analysis serve to steer demand and promote long-term cost-effective investments. Findings from Tunisia highlight the value of **variable energy pricing** (i.e. variable energy pricing by time, season, or industry): energy should be priced in a way that incentivizes responsible, economic consumption. Variable energy pricing can help reduce peak demand for energy, which can lead to lower water consumption. This is because peak demand for energy often occurs during times of high water use, such as when people are using air conditioning or heating. By shifting energy use to off-peak hours, variable energy pricing can help reduce the amount of water that is used to generate electricity. Variable energy pricing can also help to encourage the use of renewable energy sources, which can have a positive impact on water resources. This is because renewable energy sources, such as solar and wind power, do not require the use of water to generate electricity. **Subsidizing the adoption of new technologies** or processes can be an impactful way to incentivize change, but the full ramifications of the technology or behavior must be analyzed and coordinated with both water and energy needs in mind, to avoid unintended consequences. There is a major potential in exploring **opportunities for public-private partnerships**, especially at the project level, where the players, goals, and contributions can be clearly defined. Finally, **national investment in new technologies** has significant potential to increase efficiencies across both sectors, especially when the resulting technologies are focused on the nation's specific needs and challenges.

The structure and role of government institutions is a common area where water-energy management is explored. Although water and energy are two highly interconnected sectors, there are other relevant sectors that must also be considered as part of a wider systems approach that includes agriculture, waste management, economy, finance, and others. Each country reviewed here has different combinations of sectors governed differently. **Mechanisms (committees, commissions, and boards) to facilitate coordination between sectors** (i.e. between relevant line ministries, departments, or local entities) can effectively increase communication and coordination, if the right stakeholders are involved and the mechanism is given the time and authority necessary to effect change.

The governance structure for water and energy management should reflect the traditions and communities of the specific context. In Morocco, for instance, a decentralized structure of water management embraced both traditional methods and national priorities. **Decentralization and local empowerment** can be an effective way to encourage responsible resource management but must be combined with appropriate local community commitment and national support and should be tailored to fit the specific local context. The inclusion of the voice of local stakeholders is a key piece in improving public engagement while also gaining a valuable perspective on the day-to-day effects of water-energy challenges.

Finally, water and energy policies can be useful tools for fostering engagement and cooperation with stakeholders. Strategies and targets for water and energy management are most useful when they are clear, measurable, and actionable. Overarching strategies and targets for water and energy management need to be aligned with long-term implantation time frames, with strict enforcement of regulations and policies. In the case of Singapore, **long-term plans and strict policy enforcement** have allowed considerable success in water management considering the country's low natural water resources and proximity between waste systems and water collection systems. Finally, **fostering a good relationship with, and ownership by, the public** of water and energy challenges allows for better demand management and can contribute to shifting patterns of consumption.

Table 3 outlines a list of advantages and considerations that need to be accounted for as different practices are being considered within different contexts.

Table 3. Summary of good practices

Good Practices	Advantages	Considerations
TUNISIA		
Variable electricity pricing	-Better reflects the true value of energy -Can encourage more efficient patterns of consumption - Reduce peak demand for electricity, which can lead to lower water consumption	-May be unpopular to transition to -Requires efficient metering

	- Help to encourage the use of renewable energy sources with lower water footprint	
Subsidies	-Subsidies can effectively encourage the adoption of new, efficient technologies, which can improve infrastructure and encourage more efficient consumption patterns	-Making one resource more accessible (e.g. energy through solar technology) can lead to easy access and overuse of another resource (e.g. pumped groundwater) unless proper regulations are put in place
Agriculture and water are under one ministry	-This structure can encourage coordination between two interconnected sectors	- Must have mechanisms to ensure actual coordination in practice
MOROCCO		
Inter-ministerial commissions and their role in improved policy coherence	-Councils and commissions coordinate and communicate at the highest level to ensure long-term water strategies are coordinated with other relevant ministries	-These bodies are primarily consultative, political will is required to use their recommendations -There is an absence of coordinating bodies between sectors and areas at the local and technical level
National Office of Electricity and Drinking Water	-The combination of water and energy utilities acknowledges the connection between two sectors and integrates the abundance of institutional knowledge within well-established offices	- Must have mechanisms to ensure actual coordination in practice
Decentralized water governance	- Decentralized water governance allows for more local decision-making and can help to better align water and energy management at the local level. - Facilitate greater stakeholder engagement in decision-making processes to build consensus around water and energy management decisions. - Improve accountability by providing more transparency and opportunities for public participation in decision-making processes.	-Success of decentralized governance requires appropriate national support and resources
Privatization and PPPs	-PPPs and PPAs represent opportunities for efficient concessions and technical expertise	-PPPs and PPAs often include high levels of risk that the government takes on, such as assurances of purchasing all energy produced by

		private entities. This can be costly to the state.
SINGAPORE		
Clear and actionable coherent strategies with measurable targets	-Clear and measurable targets facilitate intra-governmental and public engagement with transparent measures of success -Coherent and actionable strategies set forth clear priorities for water and energy initiatives to focus on	-Creating measurable and transparent targets requires sound analysis of national capabilities and trajectories
Long-term planning and strict enforcement	-Long-term planning facilitates commitment to infrastructure and plans with long term time frames -Strict enforcement shows commitment and helps achieved intended effects of policies and regulations	-Long-term planning requires sound analysis of national capabilities and trajectories -Strict enforcement of regulations requires political will and monitoring infrastructure -Strict enforcement of regulations may be unpopular
Use of new technology to improve efficiencies	-New technology has the potential to increase efficiencies	- The development of new technologies requires financial and time investments
Good relationship with and ownership by the public	-Public engagement and ownership of water and energy challenges can help with demand management and encourage more efficient consumption patterns	- Requires time and financial resources
United Arab Emirates		
Water and energy under managed and governed under one ministry	-Can catalyze coordination and planning between two interconnected sectors guided by collective outcomes	-Coordination mechanisms need to be in place to ensure meaningful coordination happens
SAUDI ARABIA		

Environment, Water, and Agriculture under one ministry	-Can catalyze coordination and planning between two interconnected sectors guided by collective outcomes	-Coordination mechanisms need to be in place to ensure meaningful coordination happens
SAN ANTONIO, TX, USA		
Addressing legal and procedural barriers through expanding institutional mandates and developing cross-sectoral coordination mechanisms	-More coherent planning and evaluation of interventions through collective indicators	- This will require stakeholder buy-in and investment in financial and human resources
GLOBAL EXAMPLES		
Multi-stakeholder dialogues toward participatory governance	-Stakeholders from different levels (local, regional, and national) have valuable insights on water and energy challenges -Organized dialogues provide a medium for structured and pointed discussion with clear themes	-Including too many stakeholders without clear processes can diffuse the dialogue and its intended outcomes
Local community participation and bottom-up decision-making mechanisms	-These mechanisms involve the perspectives of the residents who are often most affected by national decisions and often create solutions that are publicly favorable	-Careful organization and planning must go into establishing, supporting, and engaging with local and provincial-level groups
National Policy Dialogues	-National Policy Dialogues can lead to clear national decisions on complex topics	-The leaders, objectives, and results of the policy dialogue must be clearly thought out and kept in institutional memory - NPD is primarily consultative, political will is required to use its recommendations.

Source: author's own elaboration

Applicability in Jordan. Many of the good practices and lessons shared in this report have potential for application in Jordan. These would need to be further discussed and evaluated as part of the envisioned WEFE governance structure. Economic and regulatory practices, such as strict enforcement of regulations, variable energy pricing, developing actionable targets, and investing in new technologies to improve efficiencies need to be considered.

Challenges to the application of those practices in Jordan include financial limitations and lack of existing cross sectoral WEFE governance framework.

Other good practices are focused on involving or influencing other stakeholders, including the public and private sectors. Providing subsidies and generating public ownership to influence consumption and production patterns, utilizing PPPs and PPAs, and involving a variety of stakeholders in organized dialogues have both positive and negative potential outcomes. Any of those practices could be considered in Jordan, but careful analysis of their implications on various social, economic, and environmental metrics, while ensuring alignment with national plans and goals is necessary.

Many practices and lessons focus on governance and management structures. Some consider consolidation, while others consider decentralization of responsibilities. In Morocco, decentralization in the water sector shows potential to allow communities to make decisions for themselves, which has roots in Morocco's geography and traditions. Tunisia's ministry of agriculture and water shows the potentials of more centralized governance, which can allow for easier coordination. Some of the presented practices and lessons highlight the role of coordinating bodies, such as committees, commissions, and boards in facilitating coordination and communication without changing existing structures. Further evaluation and analysis are needed to develop context specific governance structures and mechanisms that facilitate cross-sectoral coordination and decision making, that respond to the Jordanian context.

Developing an integrated WEFE nexus governance framework is well aligned with Jordan's **Economic Modernization Vision**, which calls for the establishment of a WEFE Nexus Council. Further, this framework can build on the ongoing Water-Energy inter-sectoral technical working group and steering committee. More details about the governance structure will be shared in a subsequent report following rounds of consultations with representatives of the concerned ministries and other stakeholders including the Prime Minister's office. Many of the advantages and potential challenges and barriers communicated through consultations and conversations with stakeholders can be summarized in the table below (Table 4).

Table 4. Establishing a new Water-Energy-Food-Environment Nexus Entity

Advantages	Potential Challenges and Barriers
Holistic approach to managing resources: provide a more integrated and holistic approach to managing water, energy, food and environmental resources, leading to better coordination and more efficient use of resources.	**Resistance to change:** establishing a new governance entity may face resistance from existing institutions, who may be hesitant to relinquish their control or responsibilities.
Improved risk management: help in identifying and managing risks associated with resource management, such as climate change impacts, water scarcity, and energy insecurity.	**Institutional capacity building:** establishing a new governance entity would require significant capacity building efforts to ensure that the entity has the necessary expertise, skills and resources to effectively manage the nexus.
Enhanced policy coherence: leading to better decision-making and alignment of policies.	**Coordination challenges:** coordinating across different sectors and institutions will require dedicated time and effort to achieve effective coordination.
Better stakeholder participation: provide a platform for better stakeholder participation and engagement, ensuring that the needs and concerns of all stakeholders are considered in decision-making processes.	**Political challenges:** establishing a new governance entity may face political challenges and opposition, particularly if it involves changes to existing power structures or interests.
Improved social and environmental outcomes & Enhanced resilience: ensure that resource management is conducted in a way that is socially and environmentally sustainable, leading to improved social and environmental outcomes and enhanced resilience of communities to environmental**,** social, and economic shocks and stressors.	**Lack of data and information:** collecting and managing data across different sectors and stakeholders can be challenging, and there may be gaps in data and information that could hinder effective decision-making and planning.

Moving forward, these considerations need to be addressed to ensure effective operationalization of the developed governance structure. Developing such a WEFE governance framework and demonstrating its effectiveness for resource planning improved resilience would be a unique model and reference for the region and globally.

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9. APPENDIX I – Mapping Country Selection Criteria

Table 5. Mapping country selection criteria

Criteria	Jordan	Tunisia	Morocco	Singapore
1.How topical is WEN	• Additional water resources will require more energy and financial resources than the traditional ones	• Relevant - additional water resources will require more energy and financial resources than the traditional ones	• Relevant - conversations on Hydropower and the energy cost of alternative water sources	• Relevant - many of Singapore's water sources are fairly energy intensive
2. Climate	• Dry, hot, desert[1]	• South semi-arid to desert, north and center are Mediterranean/ mountainous[2]	• Coast is Mediterranean[3] • South is desert[3]	• Tropical, hot, humid, with high temps[4]
3. Water Scarcity	• 68 m3 of water per capita (2018)[5] • 88.95 mm water in 2021[5]	• 363 m3 per capita (2018)[6] • Rainfall 158 mm per year, less than 100 mm in the south[6]	• 805 m3 water per capita (2018)[7] • 1,200 mm rainfall along the coast[7] • 100 mm rainfall yearly in the south[7]	• 106 m3 per capita per year (2018)[8] • Has been decreasing, was 144 m3 in 2002[8]
4.Energy Resources	• .7 toe energy consumption per capita (2020)[9] • 1850 kWh per capita (2020)[9] • Imported 93% of energy in 2018[10]	• 0.9 toe per capita in 2020[11] • 1405 kWh per capita electricity in 2020[11] • Imports 66% of supply[12]	• .56 toe energy consumption per capita (2020)[13] • 900 kWh per person electricity consumption annually (2020)[13] • Imported 90% of total primary energy between 2017 and 2020[14]	• 5.8 toe per capita of energy consumption (2020)[15] • 8900 kWh of electricity per capita (2020)[15] • Has no hydrocarbon resources and only generates 2% renewable energy[16]

5. Development	• HDI .720 (2020)[17] • 4,405.80 USD GDP per capita (2021)[18]	• HDI .731 (2020)[17] • GDP per capita 3,924.30 USD (2021)[18]	• HDI .683 (2020)[17] • 3,496.80 USD GDP per capita (2021)[18]	• HDI of .939 (2020)[17] • GDP per capita 72,794 USD (2021)[18]
6. Governance Structures	• Ministry of Water and Irrigation is responsible for water policy, strategy, planning, and regulation[19] • Water authority of Jordan, Jordan Vallely Authority, and three water utility companies are under the MWI[19] • The Ministry of Energy and Mineral Resources administers and organizes the energy sector[20] • There are two generation companies, one state-owned buyer and seller, and three distribution companies[20]	• One ministry over agriculture and water policies, water supply authority is a public entity under the ministry of agriculture[21] • One ministry over energy, industry, and mines, the Tunisian Company of Electricity and Gas is a public company[22] • Ministry of Environment governs sanitation, wastewater, and environmental planning[23]	• The High Council for Water and Climate helps coordinate across different actors/agencies[24] • River basin agencies and local agencies play a significant role[24] • Water services are primarily provided by the National Office for Electricity and Potable Water, which provides public electricity, sewage, and water[25] • Other service providers include four private concessions and 12 autonomous intercommunal utilities[26]	• Ministry of Sustainability and Environment manages water through PUB, a statutory board that provides water services[27] • Ministry of Trade and Industry oversees the EMA, a statutory board that creates energy policies and regulates the liberalized energy market[28]
7.Financing	• Jordan subsidizes water heavily[29] • The water sector sustains financial losses each year. GOJ absorbs deficits and debt	• Water tariffs strive for full cost recovery of water services, but national budget	• In addition to public funding, some urban water services have been privatized, PPPs often play roles	• Water tariffs reflect cost of water services-households that use less water have cheaper rates[32]

	through annual cash subsidies and liability transfers[29] • Electricity tariffs increased from 2010 to 2018, which helped to lower energy sector deficits, although electricity tariffs are still costly[30]	subsidizes the water sector[21] • Energy subsidies are costly but have improved recently[22]	in water and energy projects.[31]	• Energy is a liberalized market[33] • Vouchers for low-income and public housing[32,33]
8.Desalination	• Desalination is a planned method for additional water supply[1]	• Desalination is a current and future plan for increasing water[21]	• Desalination is a current and future plan for increasing water[34]	• Desalination is one of Singapore's four "taps" of water and is expected to provide at least 30% of water needs by the mid-21st century[35]
9.Renewable Energy	• 20% of the electric grid is powered by renewables • Goal for 30% of energy in 2030[20]	• Aims to generate 30% of its electricity from RE by 2030, currently only 3-5%, mostly hydro[36]	• Renewable energy covered 35% of electricity (2019)[37]	• Solar is considered to be the only viable renewable energy option[38]
10. Other-Neighbor countries	• Relies on trade partners for energy and neighbors for some water resources[39]	• Receives energy from neighboring countries through natural gas pipelines[40]	• Relies on neighbors for energy[41]	• Relies on imported water from neighbors[42] • History of tension with Malaysia[42]
11. Other-Agriculture	• 50-60% of water goes to the agriculture sector[1] • Overgrazing livestock has led	• 86% of water withdrawals goes to agriculture[43] • Desertification and overgrazing	• 85% of water resources go toward agriculture[44] • Desertification mainly affects	• Agriculture is not a major sector • Desertification and

	to desertification[45]	are issues in the southern rangelands[46]	highly populated plains and areas with livestock pressure[47]	overgrazing are not issues
12. Fresh water quality and quality of treated wastewater	• Transboundary and national industrial pollution have led to high pollution of Jordan's rivers, and overdrawing of Jordan's groundwater has increased salinity and deteriorated water quality[29]	• In 2013 80% of wastewater treatment plants produced water that was not compliant with at least two water quality parameters, and all were not compliant with phosphate and nitrate parameters[48]	• Morocco reuses relatively little of its treated wastewater, and 79% of the generated wastewater was not treated to acceptable standards[49]	• NEWater meets international drinking water guidelines and is mostly used for industrial and cooling purposes, although it is mixed with reservoir water during dry periods[50]

Notes: 1) (MWI 2016) 2) (Hentati 2010) 3) (Ouali et al. 2020) 4) (MSS 2020) 5) (World Bank 2018b) 6) (World Bank 2018e; Hentati 2010)7) (World Bank 2018c; Langenberg et al. 2021) 8) (World Bank 2018d; MSS 2020) 9) (Enerdata n.d.) 10) (MEMR 2020; ITA 2021b) 11) (Enerdata n.d.) 12) (IRENA 2021b) 13) (Enerdata n.d.) 14) (ITA 2021a; IRENA 2022b) 15) (Enerdata n.d.) 16) (EIA 2021) 17) (United Nations n.d.) 18) (World Bank 2021) 19) (MWI 2016) 20) (IRENA 2021a) 21) (GIZ 2019b) 22) (Ersoy and Terrapon-Pfaff 2021) 23) (MoE 2020a) 24) (Machrafi et al. 2022) 25) (ONEE 2022) 26) (MFA 2018) 27) (MSE 2022a; PUB 2022b) 28) (MTI 2022; EMA 2022d) 29) (MWI and MoEnv 2020) 30) (MoEnv and MEMR 2020) 31) (METLE 2020) 32) (PUB 2021) 33) (EMA 2022a) 34) (MEMEE 2009) 35) (PUB 2022c) 36) (IRENA 2021b) 37) (IRENA 2022b) 38) (NCCS 2022d) 39) (MEMR 2020) 40) (Nexus Dialogue Program 2018; GIZ 2019a) 41) (ITA 2021a; IRENA 2022b) 42) (MFA 2022) 43) (World Bank 2017) 44) (MEMDD 2009) 45) (MoEnv 2021) 46) (Gamoun, Belgacem, and Louhaichi 2018) 47) (Mirzabaev, et al. 2019) 48 (Caucci 2018) 49) (MFA 2018) 50) (PUB 2022c; 2018a)

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