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CHAPTER 9

BRIDGING RESOURCES BRIDGING GOALS

Water-Energy-Food Nexus for Integrated SDG Advancement

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BRIDGING RESOURCES, BRIDGING GOALS

Water-Energy-Food Nexus for Integrated SDG Advancement

Xin Zhou, Bijon Kumer Mitra, and Vibhas Sukhwani

9.1 Introduction

As we passed the midpoint toward the 2030 Agenda, a sobering assessment of global progress on the Sustainable Development Goals (SDGs) confronts us: Of the 140 measurable targets, merely 15% are on track, while a concerning 37% are stagnating or regressing, and the remaining majority demand accelerated efforts (UNDESA, 2023). As we explore ways to accelerate SDG progress, it becomes increasingly clear that a siloed approach to managing resources falls short of addressing the multifaceted challenges our world faces. This chapter introduces a perspective that reconceptualizes resource management: the interlinkages between the water–energy–food (WEF) nexus and the SDGs. This integrated framework serves as a tool for holistic thinking, guiding us toward concerted SDG advancement.

The WEF nexus transcends traditional resource management, advocating for an integrative approach that considers the synergies and trade-offs between water, energy, and food systems. This chapter reflects on the evolution of the WEF nexus concept, exploring its potential to reshape our strategies for sustainable development. A core part of our discussion revolves around the intimate interlinkages between the WEF nexus and the broader SDGs. Through systematic mapping of the interlinkages between the WEF nexus and the SDGs, we provide an overall picture of the WEF–SDG system, highlighted by key SDGs and their linkages. To ground our discourse in reality, we present a practical case examining the water–energy nexus within the Ganges River basin—a vital lifeline for millions.

Further, we enrich this chapter with illustrative examples from the research works of the Institute for Global Environmental Strategies (IGES) which demonstrate the tangible benefits of the WEF approach. These case studies exemplify how the integrated management of water, energy, and food resources can not only propel resource efficiency but also fortify other development imperatives.

The purpose of this chapter is not merely to inform but to equip policymakers, researchers, and practitioners with scientific evidence and practical insights. By showcasing the interlinkages of the WEF nexus with the SDGs and illustrating how this approach can act as a lever for integrated SDG advancement, we aim to provide a practical tool to guide actions toward a future where resources are managed with a deep sense of interconnectivity.

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9.2 Understanding the WEF Nexus Approach

By 2050, the global demand for each of the WEF resources is estimated to rise by over 50% as compared with the 2015 level (Ferroukhi et al., 2015). Against the already-existing resource shortfalls, the optimal management and preservation of WEF resources has become one of the major challenges of the 21st century. Acknowledging the tight interconnections among the WEF systems, the nexus approach has emerged as a basis for integrated management and governance of WEF resources across sectors and different scales (Stephan et al., 2018). It provides an integrative strategy to balance and optimize the WEF sectors, which are competing but also complementary for the same scarce resources. For instance, water is required for energy production and supply, energy is required for water treatment and transporting, and both water and energy are vital for food production (Mohtar and Daher, 2012). While factors like changing climate, demographics, and economic growth continue to strain the limited WEF resources, the growing occurrences of drought situations, lack of fresh water, intensification of food crises, and shortages in energy supply pose a clear threat to social, economic, and environmental sustainability (de Andrade Guerra et al., 2021; Carmona-Moreno et al., 2021). The implicit interconnections between WEF resources further complicate the challenge of achieving resource security, as during any potential resource shortage situation, such intricate linkages can implicitly affect the whole resource supply nexus.

A number of studies have established the evolution of the WEF nexus approach, including Albrecht et al. (2018) and Sukhwani et al. (2020). After the initial attention gained through the United Nations University's (UNU) Food–Energy Nexus Programme, launched in 1983, the Bonn Nexus Conference in 2011 played a pivotal role in bringing the WEF nexus approach into the limelight of global policy and research (Hoff, 2011). Based on state-of-the-art review, Zhang et al. (2018) imply that the "nexus" concept is today gaining increasing attention, and it is explicit that ignorance of the WEF interlinkages may raise future uncertainties. Biofuel, for instance, was initially advocated as a good practice for mitigating climate change, but gradually its negative implications on biodiversity and land use are being realized. Thus, in regard to balancing different interests in WEF resource use, addressing conflicts, and capitalizing on the synergies, significant efforts are now being made to investigate the WEF nexus from different aspects, in terms of conceptual development, quantification of resource flows and their dependencies, as well as technology and policy application. Stephan et al. (2018) underscore that there is still a need to better quantify the WEF-related trade-offs for future planning and management.

In reference to the messages from the Bonn 2011 Nexus Conference, literature reviews, and expert knowledge, GIZ (2020) put forth ten core principles of the WEF nexus, namely: (1) equitable and balanced weighting of WEF sectors in decision-making; (2) leaving no one behind; (3) political will and commitment; (4) cross-departmental and multi-sectoral cooperation; (5) mechanisms and tools for data exchange and modelling; (6) capacity development of people, institutions, and organizations; (7) inclusive and participatory multistakeholder approach; (8) financing schemes and investments; (9) sustainable and efficient resource use and consumption; and (10) furthering peace and preventing conflict.

Clearly, the nexus approach promotes a rational, efficient, and balanced management of WEF resources, which widens its scope to also understand the interconnections between areas like health, gender, human mobility, and conflict management. In that manner, the WEF nexus provides a systemic and multi-sectoral perspective toward sustainable development and is vital for the integrated achievement of the SDGs, particularly in fast-growing developing countries (de

Andrade Guerra et al., 2021). Along with the direct connections to SDG 6 on water (Clean Water and Sanitation), SDG 7 on energy (Affordable and Clean Energy), and SDG 2 on food (Zero Hunger), the WEF nexus approach also links indirectly to several other SDGs, like SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), etc.

Through capitalizing on the synergies of multiple SDGs and addressing the trade-offs, the nexus approach lays emphasis on transitioning from a silo-based thinking to an integrated and transdisciplinary perspective (Ghodsvali et al., 2019). However, despite the growing dialogue, human societies are still confronted with the challenge of realizing an integrated WEF resource management for sustainable outcomes. A range of governance challenges restrain the localized implementation of the WEF nexus, like, for example, how majority of the policy decisions on WEF resource management continue to be made by separate institutions and departments, with minimal consideration to cross-sectoral impacts (Sukhwani et al., 2019). The practical implementation of WEF nexus solutions, even for the achievement of the SDGs and other global agendas on sustainability, has been limited. In regard to the integrated governance approach, Sukhwani and Shaw (2022) summarize the two key points that are consistent in the existing literature, namely, the fragmented policy approach on WEF nexus and the essence of achieving policy coherence by enhancing synergies and minimizing trade-offs.

9.3 WEF–SDG Interlinkages: Developing a Network Model

Beginning in the early 1980s with studies on the bilateral relationships among water, energy, and food systems, WEF nexus research has been actively developed since the early 1990s. It has since evolved to incorporate additional physical sectors—such as land, climate, and the environment—that are closely linked with the WEF systems. Nexus thinking has further expanded to cover broader development sectors, particularly the economic and social sectors, including economic growth, trade, employment, poverty, health, and justice. Just a few years before the adoption of the SDGs in 2015, the interlinkages between WEF and the SDGs began to attract attention. While research on WEF–SDG interlinkages has rapidly evolved, most studies have concentrated on the relationships between WEF and individual SDGs or a subset of the SDGs. There is a lack of scientific research mapping the interlinkages between WEF and all SDGs.

In this section, the interlinkages between the WEF nexus and the SDGs are mapped based on a systematic review. A network model is further developed to illustrate key SDG involved and their relationships within the WEF–SDG system.

9.3.1 A Systematic Mapping of WEF–SDG Interlinkages

A systematic review of the literature, selected from Scopus—a bibliographic database—was conducted to map the interlinkages between the WEF nexus and all the SDGs. Natural language processing (NLP) techniques were utilized to systematically process and synthesize the data following a transparent and replicable protocol.

A protocol with six processes was developed to guide an NLP-based systematic review and mapping of WEF–SDG interlinkages from selected literature (Figure 9.1). The methodology and processes are built upon existing studies (Zhou and Moinuddin, 2023; Zhou, Jain et al., 2022; Zhou, Moinuddin et al., 2022).

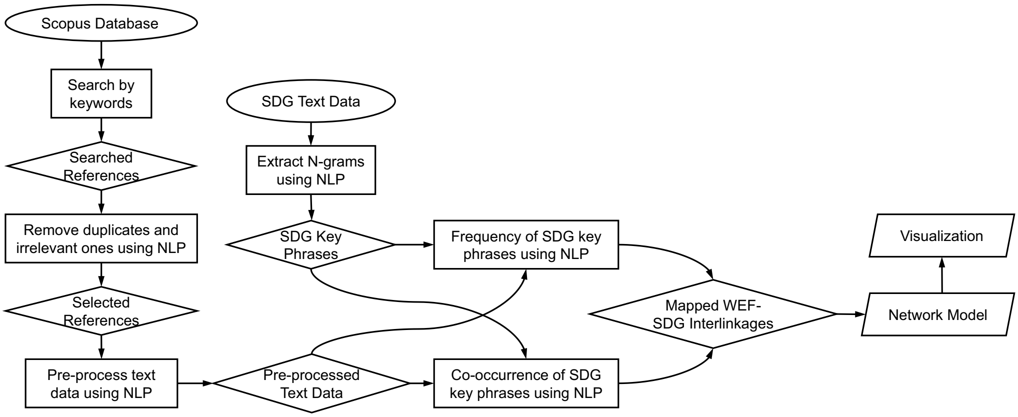

Figure 9.1 Workflow for NLP-based systematic review and mapping of WEF–SDG interlinkages.

Note: NLP = natural language processing; WEF = water–energy–food; SDG = Sustainable Development Goals.

9.3.1.1 Process 1: Selection of Literature

To conduct the literature search on Scopus, a combination of keywords was used to ensure comprehensive coverage of the topic. The search was structured around two sets of keywords: "water," "energy," or "food," in conjunction with "WEF" or "nexus." This approach allowed for a broad yet focused retrieval of documents related to the WEF nexus, capturing studies that specifically addressed any of these three critical resources in combination with nexus concepts.

A total of 11,775 references covering the time span from 1974 to 2023 were found. By removing references that lack an abstract and eliminating duplicates, 11,460 references remained. Using NLP, references that did not contain any combination of the previously mentioned sets of keywords were also removed. After these screening processes, a total of 9,359 references were selected for review.

9.3.1.2 Process 2: Pre-Processing the Text Data of Literature

The text data from the abstracts of selected literature was pre-processed using NLP techniques to remove punctuation and stop words, convert text to lowercase, and tokenize the content.

9.3.1.3 Process 3: Extraction of Key Phrases From SDG Text

In a parallel process to processes 1 and 2, N-grams—including single words, bi-grams, and tri-grams—were extracted from SDG texts using NLP techniques. The extracted SDG phrases were then manually screened to remove any that were irrelevant.

9.3.1.4 Process 4: Calculation of the Frequency of SDG Key Phrases From Literature Text Data

Using NLP techniques, SDG key phrases were extracted from the pre-processed text data of literature from process 2, and their frequencies were calculated.

9.3.1.5 Process 5: Mapping SDG Key Phrases and Calculation of Co-Occurrence Frequency

Using NLP techniques, SDG key phrases were mapped in pairs if they appeared simultaneously in the same sentence. The co-occurrence frequency of each pair was then calculated.

9.3.1.6 Process 6: Building a Network Model for the WEF–SDG Interlinkage System

Using NLP techniques, a network model was constructed and visualized to depict the interlinkages between WEF and SDGs, including SDG key phrases and their relationships within the context of the WEF nexus.

9.3.2 A Network Model of WEF–SDG Interlinkages

The network model illustrates the key SDGs and their relationships within the WEF–SDG interlinkage system. Key SDGs are displayed in a word cloud map based on the frequencies of SDG key phrases extracted from the literature (refer to Figure 9.2). Prominent SDGs identified in the network include "land" (Target 15.3), "resources" (cross-cutting SDGs 6, 12, 14, and 15), "renewable energy" (Target 7.2), "economic growth" (Target 8.1), "climate change" (Target 13.1), "trade" (Target 17.10), "health" (Goal 3), "agriculture" (Goal 2), and "technologies" (Target 17.7), among others.

The network model comprises 136 SDG targets that are linked with all 17 goals, featuring over 5,043 linkages among them. Figure 9.3 displays a simplified graph that describes the minimum

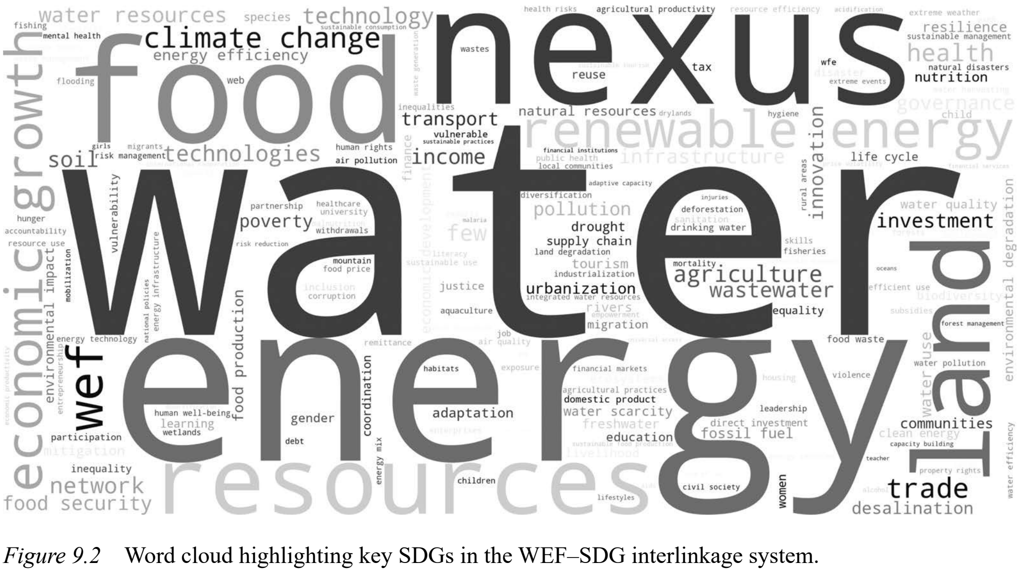

Figure 9.2 Word cloud highlighting key SDGs in the WEF–SDG interlinkage system.

Note: Each phrase represents either an SDG target (e.g., Target 15.3 for land) or a broader goal (e.g., SDG 6 for water).

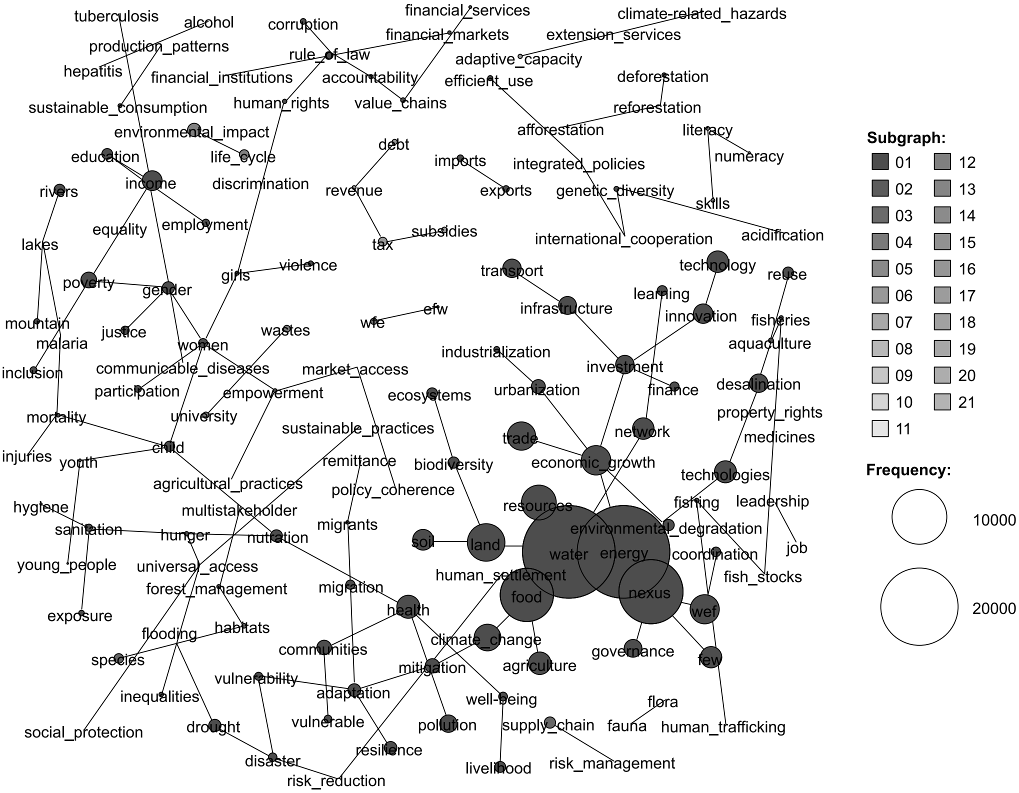

Figure 9.3 Network model of the WEF–SDG interlinkage system.

Note: Due to visualization constraints, a simplified network model featuring a minimum spanning tree is shown. Nodes represent SDG targets (e.g., Target 15.3 for land) or broader goals (e.g., SDG 6 for water), while edges illustrate the connections between nodes.

spanning tree of the top 200 key linkages based on their co-occurrence frequency. The top 50 key linkages are presented in Figure 9.4.

The results of key SDGs and key linkages in the network model provide a knowledge base on the WEF–SDG interlinkages. When planning WEF resource management and using the WEF nexus approach to leverage SDG progress, these key factors and linkages should be taken account together with the local context.

9.4 WEF Nexus at the River Basin Scale: A Case Study in the Ganges River Basin

Ganges, the most populous river basin in the world, is home to 600 million people of South Asia (World Bank, 2015), connecting three countries of the region, namely, India, Bangladesh, and Nepal. The Ganges River basin stands as one of the pivotal hubs of economic advancement in the region, contributing USD 700 billion to India’s GDP (World Bank, 2015). Over 40% of the population of the region is either directly or indirectly dependent on water from this river for drinking, agriculture, and energy generation purposes (Anand et al., 2018). For instance, agriculture alone

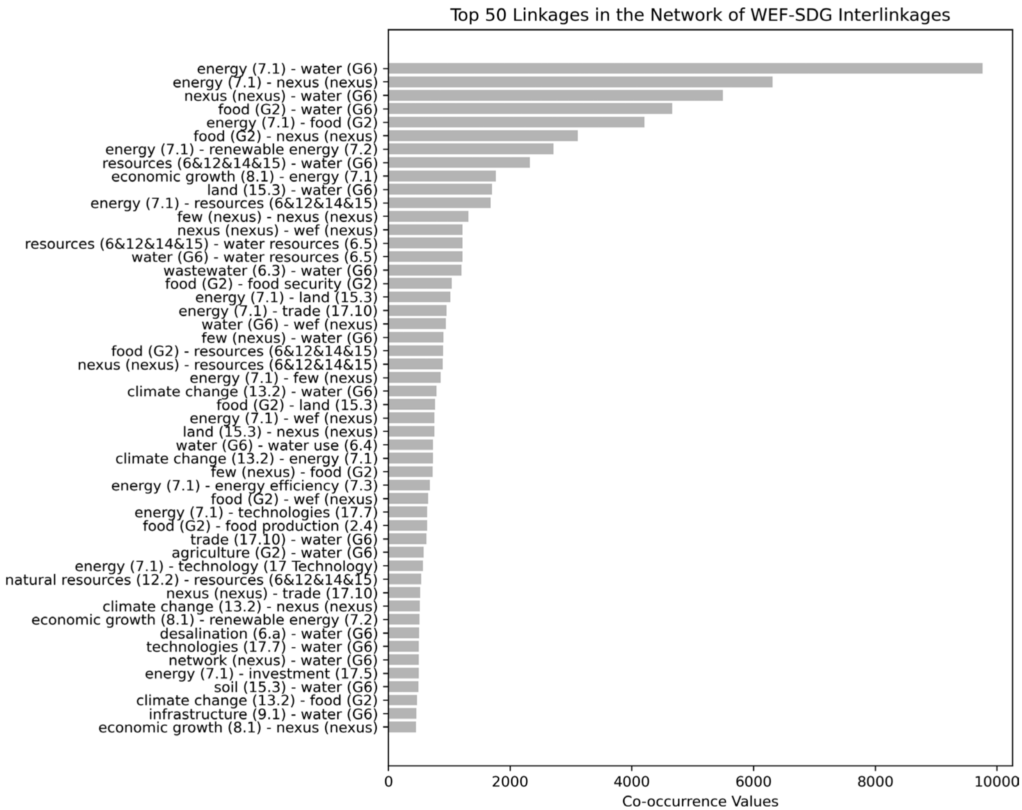

Figure 9.4 Top 50 linkages in the network of WEF–SDG interlinkages.

Note: Codes in parentheses represent specific SDG targets (e.g., Target 15.3 for land management) or broader goals (e.g., SDG 6 for water sustainability).

accounts for approximately 90% of the total water usage in the area (Sinha, 2014). The Ganges River is a vital water source for numerous thermal power plants, boasting a capacity exceeding 50 gigawatts (Sinha, 2014). Consequently, any fluctuations in water availability in the Ganges will profoundly affect the region's electricity security.

With a 40% share of the total electricity generation capacity in the area, the river basin plays a crucial role in power production (Sinha, 2014). However, per capita energy consumption in riparian countries remains comparatively low, with figures of 609 kilowatt-hours in Bangladesh (MOF, 2023), 1,327 kilowatt-hours in India (CEA, 2023), and 305 kilowatt-hours in Nepal (WECS, 2023), significantly below the global average of 3,130 kilowatt-hours (World Bank Database, on "Electric Power Consumption (kWh per capita)," available at https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC). This indicates considerable potential for growth in the electricity sector in riparian countries for years to come. Nevertheless, coal and gas-based thermal power dominates the electricity fuel mix in the region, comprising around 73% of the total electricity generation capacity (NPP, 2023; MPEMR, 2023). Thermal power plants (TPPs), relying on conventional cooling technology, demand substantial amounts of water for cooling purposes. The impact of cooling technology selection on water demand for power generation is vital for the optimization of water

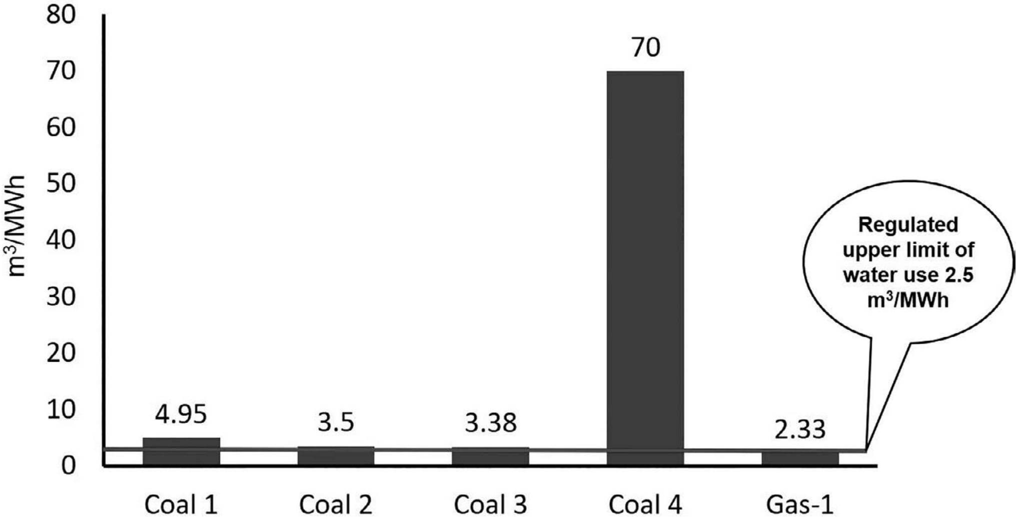

Figure 9.5 Water use intensity in the existing power plants.

Source: Mitra et al. (2021).

use in thermal power generation (Mitra et al., 2021). Power plants employing open-loop cooling systems exhibit a water use intensity of about 70 m^3/MWh (Coal 4), whereas those with closed-loop cooling systems range from 3.4 m^3/MWh to 5.0 m^3/MWh (Coal 1–3) (Figure 9.5). With ample reserves of indigenous coal and gas in India and Bangladesh, future power generation is expected to heavily lean on thermal sources. However, the sustainability of thermal power generation faces significant challenges due to climate-induced water resource variability (Gosain et al., 2011). For instance, drought events between 2013 and 2016 necessitated the shutdown of 14 major power plants due to cooling water scarcity, resulting in potential revenue losses of at least USD 1.4 billion (Luo et al., 2018). This highlights the precariousness of water availability for thermal power generation and underscores the operational risks faced by power plants in this river basin.

The future water risk situation in many sub-basins of the Ganges is alarming. For instance, the water surplus in the Damodar sub-basin will decrease by 15% in 2050, and the water deficit in the Yamuna is projected to surge by 86% by 2050 (Mitra et al., 2021). In contrast, in some basins, such as in Chambal and Damodar, water risks will diminish, where surplus water is anticipated in the future. As illustrated in Figure 9.6, among the 23 districts in the Chambal sub-basin, climate change is projected to have moderate to high positive impacts, reducing water risks in 19 districts by 2050. Conversely, power plants in the Yamuna and Gandak sub-basins are poised to face escalating water risks in the future. By 2050, the number of districts experiencing moderate negative impacts is projected to increase to 19. Notably, all existing and planned future power plants in the Yamuna and Gandak sub-basins are situated in districts where water risks are expected to rise. Particularly in the Gandak sub-basin, several planned thermal power installations are anticipated to encounter severe water risks during operation. Thermal power plants, whether existing or planned, situated in regions characterized by high water risks may encounter significant water shortages, thereby jeopardizing the stability of their operations. Districts within the Chambal and Damodar sub-basins experiencing moderate to high positive impacts on water risks from climate change could be deemed suitable locations for future electricity generation projects. This implies that the

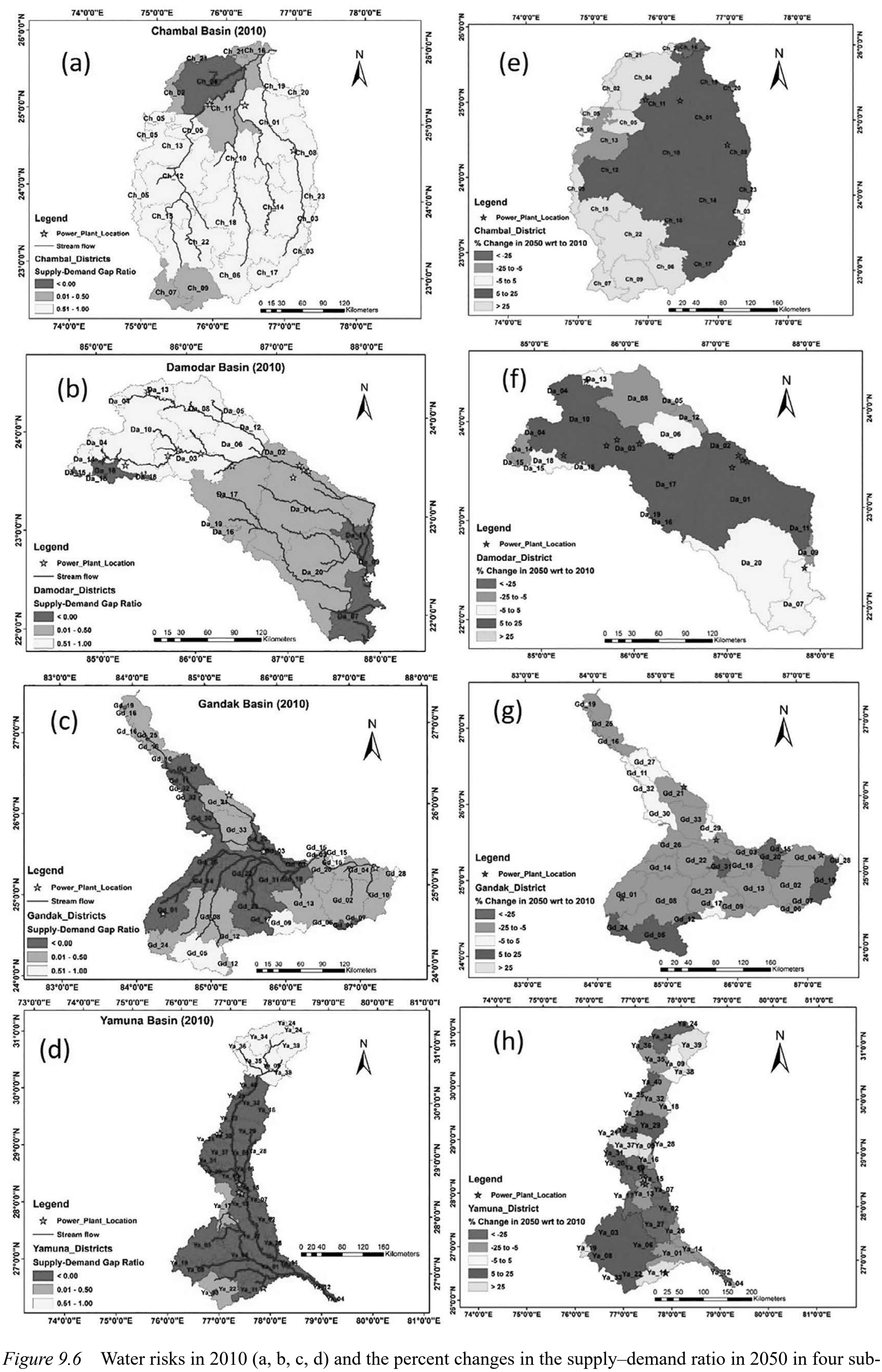

Figure 9.6 Water risks in 2010 (a, b, c, d) and the percent changes in the supply–demand ratio in 2050 in four sub-basins compared with 2010 (e, f, g, h).

Source: Mitra et al. (2021).

spatial distribution of the water–energy nexus risks should be considered as one of the key criteria for fuel and site selection of future power plants.

9.5 Case Studies on the Synergies of the WEF Nexus and the SDGs in Asia

As emphasized, a WEF nexus–based approach is imperative for the simultaneous achievement of diverse SDGs, as it helps capture synergies across different sectors of resource management, while also addressing the underlying trade-offs. Yet the grassroots-level implementation of nexus approach remains to be challenged by impediments, like discrete governance and lack of resources. Correspondingly, there is also a limited progress in the timely realization of the SDGs, especially in developing countries of Asia. In order to introduce resource-efficient pathways and cost-effective innovations, the following sub-sections present six case examples from Asia (summarized in Table 9.1) which reflect how the synergistical implementation of WEF nexus–based approaches can contribute toward the diverse SDGs. In reference to identified performance parameters, Table 9.1 presents a summarized description of the anticipated co-benefits through different nexus approaches and the corresponding SDGs.

9.5.1 Installation of Solar Power Systems at Agricultural Farms in Ulaanbaatar, Mongolia

9.5.1.1 Key Challenge

Ulaanbaatar, the capital city of Mongolia, is home to over half of the country's population. Between 2000 and 2017, an average of 19,000 persons/year migrated to the capital city (IOM, 2018). Despite the government of Mongolia's ban on migration into the capital city, the number of unregistered migrants may continuously increase, which is mostly driven by unequal economic and social development. Resultantly, the demands for basic services and infrastructure development are on the rise. In particular, the energy sector in Mongolia relies on coal-based power plants, which leads to large amounts of CO_2 emissions.

9.5.1.2 Nexus-Based Solution

To reduce its dependency on high-CO_2-emitting coal-based power generation, Mongolia has set up a target of generating 20% of total energy from renewable energy sources (GCF, 2019). As a nexus-based solution, a wholesale distributor, Everyday International LLC, initiated a solar power generation project which was registered by the government through bilateral cooperation under the Joint Crediting Mechanism as a mitigation project. The project aimed to improve power supply in the city and contribute in CO_2 mitigation by installing solar power systems at agricultural farms in the suburbs of Ulaanbaatar. These power plants can generate 3,352 MWh of electricity, which translates as a significant reduction in reliance on coal-fired thermal power, and thus avoidance of CO_2 emissions. Moreover, the solar power system also helps improve food supply by capturing synergies between agricultural and solar power generation technology.

9.5.1.3 Synergies With SDGs

The symbiotic use of agricultural lands to simultaneously yield food and solar energy not only helps in climate change mitigation but also harnesses clean renewable energy, together with improved protection of crops from extreme weather events. In that manner, this project not only

Table 9.1 SDG co-benefits of WEF-based solutions in selected cases of Asia

Performance parameters	*Anticipated co-benefits*	*Relevant SDGs*
1. Installation of solar power systems at agricultural farms in Ulaanbaatar, Mongolia		
CO_2 mitigation	2,682 tons CO_2/year	SDG 2
Renewable energy generation	3,352 MWh/year (estimated)	SDG 7
Agriculture production	Projected to improve	SDG 11
		SDG 13
2. Optimizing water, energy, and land resources in Ulaanbaatar, Mongolia		
Energy efficiency improvement	Heat energy consumption reduced by 50%	SDG 6
Wastewater management	Projected to improve	SDG 7
Awareness on nexus solutions		SDG 8
Partnerships between public and private actors		SDG 11
Value of land plots and economic growth		SDG 12
		SDG 13
		SDG 17
3. Capturing energy and reuse of treated domestic wastewater in Da Nang, Vietnam		
CO_2 mitigation	Captured methane from wastewater	SDG 2
Renewable energy generation	Energy generation from captured methane	SDG 6
Use of by-products	Use of treated wastewater for irrigation and processed sludge for urban agriculture	SDG 7
		SDG 11
Awareness on urban nexus solutions	Projected to improve	SDG 12
Cross-sectoral interactions		SDG 13
Cost performance		
4. Introduction of high-efficiency water pumps in Da Nang City, Vietnam		
Increased efficiency of pumps	Intake pump: from 50% to 83%; distribution pump: from 64% to 90%	SDG 6
		SDG 7
Improvement of supply capacity	Intake pumps: from 18 to 20 million m^3/year; distribution pumps: from 84 to 101 million m^3/year	SDG 11
		SDG 12
Electricity saving	Electricity consumption for water production reduced by 3,400 MWh/year	SDG 13
CO_2 mitigation amount	Contributes to annual reduction in emissions of approximately 1,145 tCO_2/year	
Reduction of operation cost	Total electricity costs of operating pumps in 2018 reduced by about 5.77 billion VND/year; estimated payback period only three years	
5. Energy-saving technologies for wastewater treatment in Palembang City, Indonesia		
GHG mitigation	Estimated CO_2 mitigation of 745 tons/year through energy savings; CH_4 emissions reduced through stimulated aerobic process (GEC, 2015)	SDG 6
		SDG 7
		SDG 11
Energy efficiency improvement	Estimated reduced energy consumption of 931 MWh	SDG 13
Effluent quality	Meets effluent standard of Indonesia	
6. Reuse of municipal wastewater in power plants to mitigate water crisis in Delhi, India		
Amount of wastewater treated and reused	20 MLD of wastewater	SDG 6
Amount of treated wastewater supplied for power generation	Intake of 20 MLD treated wastewater	SDG 7
		SDG 11
Cross-institutional collaboration	Annual operation and maintenance cost of sewage treatment plant borne by the power company	SDG 13

contributes toward multiple SDGs (SDG 2, SDG 7, SDG 11, and SDG 13) but also helps progress toward the NDCs of Mongolia.

9.5.2 Optimizing Water, Energy, and Land Resources in Ulaanbaatar, Mongolia

9.5.2.1 Key Challenge

More than 60% of Ulaanbaatar's 1.4 million residents live in disorganized ger-based settlements (*ger*: a portable round tent covered with skins or felt) on the city's periphery. As urban migration continues to rise, these settlements are expanding in a haphazard manner, exacerbating major socio-environmental problems, such as air pollution, as well as soil and groundwater contamination. Even though the residents of Ulaanbaatar's ger districts generally have legal titles to their plots, a majority desire to live in detached homes with basic infrastructure connections.

9.5.2.2 Nexus-Based Solution

Working with limited capacity and budgetary shortages, the city of Ulaanbaatar launched a community-driven land readjustment effort of about 180 participating households on 12 hectares of land to create an "eco village" in Khoroo No. 19 in the Bayanzurkh District, next to the "Tsaiz" wood market. Through this redevelopment, the city incorporated energy-efficient, ecological development principles and decentralized heating and wastewater management, with the objective of improving land use, raising the land value, and strengthening energy and waste management infrastructure. The redevelopment efforts are projected to reduce heat energy consumption and CO_2 emissions by 50%.

9.5.2.3 Synergies With SDGs

The creation of an eco village generates multiple co-benefits toward wastewater management, energy efficiency, land management, sectoral partnerships for economic growth, etc. It also contributes toward the simultaneous realization of multiple SDGs (SDG 6, SDG 7, SDG 8, SDG 11, SDG 12, SDG 13, and SDG 17), together with enhancing sustainable urban and regional development.

9.5.3 Capturing Energy and Reuse of Treated Domestic Wastewater in Da Nang, Vietnam

9.5.3.1 Key Challenge

Da Nang is one of the fastest-growing cities in Vietnam, with a current population of more than 1 million. The city has experienced stable and continued economic growth, mainly driven by rapid increase in the tourism and service sectors. In 2015, it had over 4.5 million visitors, and these numbers are expected to continue rising in the coming years. Da Nang's continued growth and expansion, however, has increased pressures on its infrastructure, including water and energy services, and wastewater treatment. As a coastal city, Da Nang also faces disaster risks associated with sea level rise, floods, and typhoons. In particular, access to adequate sanitation services has become a major challenge, with most households using septic tanks to dispose of wastewater. The wastewater collection system is inadequate, which increases environmental risks, including groundwater pollution and methane emissions.

9.5.3.2 Nexus-Based Solution

In collaboration with the Department of Planning and Investment, GIZ implemented a nexus project to improve wastewater management in the city. An innovative, flood-proof vacuum sewer collection system was introduced that can collect both black- and gray water, as well as capture biogas to produce energy. By-products such as processed sludge could then be used as fertilizer, and the treated gray water could be used for urban agriculture irrigation. The Da Nang People's Committee (DPC) established the Nexus Task Force to ensure institutional coordination, and a technical design was elaborated to install the vacuum sewer system and connect 110 households at an estimated cost of 416,500 euros. Subsequently, DPC expressed interest in the concept and agreed to implement the vacuum sewer system throughout the My An to My Khe area, covering 12,000 households, with support of the World Bank (GIZ, 2017).

9.5.3.3 Synergies With SDGs

The enhanced wastewater management system contributes to national and local climate actions while also enhancing the resilience of Da Nang toward flooding risks. It helps capture methane, generates renewable energy, and also contributes to improving adaptation capacity by supplying treated wastewater for irrigation and processed sludge for urban agriculture. Overall, it contributes to at least six SDGs (SDG 2, SDG 6, SDG 7, SDG 11, SDG 12, and SDG 13).

9.5.4 Introduction of High-Efficiency Water Pumps in Da Nang City, Vietnam

9.5.4.1 Key Challenge

Over the recent decades, the rapid growth of Da Nang for transportation, services, and tourism has increased pressure on the city's aging water supply infrastructure. In general, water demand is rapidly increasing from both local residents and tourists. It is anticipated that by 2030, the city's total water demand on the present water utility will have doubled. Simultaneously, the associated demand of energy for water supply will also increase; it is estimated to rise from 18 to 21 gigawatt-hours over 2015 to 2017 (Ninh, 2019).

9.5.4.2 Nexus-Based Solution

Acknowledging the water–energy interlinkages as well as the potential barriers in enhancing resource use, the Da Nang Water Supply Company (DAWACO) took an initiative to replace low-efficiency conventional pumps with higher-efficiency pumps at the Cau Do water treatment plant. Three existing conventional raw water pumps (50% efficiency) and six existing clean water pumps (64% efficiency) were replaced with higher-energy efficient pumps (83% for intake pumps, and 90.6% for clean water distribution pumps), which have been customized to the specific conditions and requirements of the recipient plants.

9.5.4.3 Synergies With SDGs

The introduction of high-efficiency pumps not only improved the water supply capacity of the pumps but also contributed toward energy saving, carbon mitigation, and cost-effectiveness. In that manner, it has a synergistic contribution toward multiple SDGs (SDG 6, SDG 7, SDG 11, SDG 12, and SDG 13).

9.5.5 Energy-Saving Technologies for Wastewater Treatment in Palembang City, Indonesia

9.5.5.1 Key Challenge

Indonesia has been among the world's largest emitters of GHGs (Climate Watch, 2024). After the Paris Agreement, the country strengthened its commitments to reduce global warming. It set an unconditional target to reduce CO_2 emissions by 32% by 2030 and, with international support, to 43% (Government of Indonesia, 2022). In its NDC, Indonesia identified energy use improvement as a priority area, and as cities are home to over half of the country's population and most economic activity is concentrated in urban areas, this revealed many energy-saving opportunities. Under Government Regulation No. 70/2009, private and industrial sectors are allotted major responsibilities toward energy conservation, and industry is one of the targeted sectors for enhancing energy efficiency through technological transformation. Besides, the government has implemented a set of incentives on energy conservation, including tax exemptions for energy-saving appliances, import tax reductions for energy-saving products, and low interest financing for energy conservation.

9.5.5.2 Nexus-Based Solution

To improve the performance of wastewater treatment facilities of a rubber company, an innovative project was initiated by PT. Aneka Bumi Pratama, located in Palembang City. As a result of the project, the company is now able to meet Indonesia's effluent–wastewater quality standards. Aerator technology is to be installed to improve the wastewater treatment facilities of the rubber company, which will accelerate the mixing of air from the blower to reduce methane emissions. Since there is no pressure loss at the blower, this will likely reduce the energy consumption of wastewater treatment facilities. Also, the aerator requires minimal maintenance to operate.

9.5.5.3 Synergies With SDGs

By increasing energy efficiency and avoiding methane emissions, the aerator technology directly contributes to national and local climate actions, while also helping mitigate water pollution, which can contribute to enhancing adaptation capacity in water management of Palembang City. This solution contributes simultaneously to SDG 6, SDG 7, SDG 11, and SDG 13.

9.5.6 Reuse of Municipal Wastewater in Power Plants to Mitigate Water Crisis in Delhi, India

9.5.6.1 Key Challenge

India's capital city, Delhi, is situated in the Yamuna River basin. The anticipated rapid population growth, and economic development, in Delhi is likely to intensify the water demand in this already water-stressed river basin, along with increased competition for the limited water resources. Concurrently, the demand for energy is also increasing. In Delhi, the power supply capacity has not kept pace with population growth and economic development. Further, the management of wastewater is also a big challenge for Delhi, as the sewage treatment capacity has also not kept pace with the rise in wastewater generation. Over the last four decades, while the treatment capacity increased sevenfold, the volume of wastewater increased twelvefold.

9.5.6.2 Nexus-Based Solution

While the limited water availability is an issue, reuse of wastewater can help mitigate the water crisis as well as reduce the pollution of natural water bodies. If Delhi's wastewater could be properly collected, treated, and reused in power plants, the freshwater demand of the power sector could be cut by up to 75%. Indraprastha Power Generation Co. Ltd. (IPGCL), the state-owned electricity provider of Delhi, is moving toward cleaner and water-smart power generation by using treated municipal wastewater instead of fresh water in the operation of its Pragati Combined Cycle Gas Turbine (CCGT) power plant. This represents a win–win solution for water crisis mitigation and wastewater management. A salient feature of the power plant is that the raw water requirement for operation of the power plant is met by a Delhi municipal sewage water treatment plant. As per an agreement between IPGCL and the Delhi Municipal Sewage Water Treatment Authority, in exchange for 20 million liters per day (MLD) of treated wastewater from the sewage treatment plant without charge, IPGCL covers the operation and maintenance costs of the sewage treatment plant.

9.5.6.3 Synergies With SDGs

The cross-institutional collaboration for the reuse of municipal wastewater in Delhi is a win–win solution which contributes toward several different SDGs, including SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

9.6 Conclusion

This chapter underscores the transformative potential of the WEF nexus as a pivotal framework for addressing the interconnected challenges of sustainable resource management. As we passed the halfway point toward the 2030 Agenda, it became evident that traditional approaches to resource management are insufficient in meeting the escalating demands and complexities posed by global sustainability objectives. The WEF nexus not only facilitates a deeper understanding of the synergistic and trade-off dynamics among water, energy, and food systems but also serves as a crucial lever for propelling the integrated advancement of the SDGs.

Through a systematic exploration of the WEF nexus, including a focused examination of the Ganges River basin and illustrative case studies from the research works of the Institute for Global Environmental Strategies (IGES), this chapter illuminates the tangible benefits and strategic importance of nexus thinking. These examples vividly demonstrate how integrated management can enhance resource efficiency and bolster other development imperatives, thereby contributing to a sustainable and resilient future.

As we look forward, the adoption of the WEF nexus approach should be seen not just as a strategic necessity but as an opportunity to reframe and deepen efforts toward the SDGs. It challenges us to move beyond siloed thinking and embrace a more interconnected and holistic perspective on resource management. By fostering cross-sectoral collaborations and enhancing policy coherence, the WEF nexus approach aims to optimize resource use, mitigate conflicts, and unlock synergies that can significantly propel sustainable development, particularly in rapidly developing regions.

Ultimately, this chapter aims to serve as a foundational guide for policymakers, researchers, and practitioners, providing them with the insights and methodologies to implement the WEF nexus framework effectively. In doing so, it seeks to catalyze actions that are not only informed by a deep understanding of the complex interdependencies but are also aligned with the overarching goal of achieving a balanced and sustainable future for all.

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