Making Water the Business of Cities: Approaching Urban Water Governance Through the WEF Nexus

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Introduction

The evolution of cities will impact efforts to address climate change and ensure resource security, with policy, market, and human behaviour factors converging to determine outcomes in urban areas. Currently, 56 percent[1] of the global population reside in cities, a proportion that is expected to grow to 68 percent[2] by 2050, with 90 percent[3] of this growth concentrated in Asia and Africa. Despite occupying only 3 percent[4] of the world's land, cities consume approximately 75 percent[5] of global electricity and contribute 70 percent[6] of anthropogenic greenhouse gas emissions. India is anticipating an additional 416 million urban residents by 2050—[7] the largest projected increase worldwide. This urban surge will double the country's building space, with 70 percent[8] of new constructions located in urban areas.

The growing population and economic activity in Indian cities is straining freshwater supplies, sewage systems, and land use. Resource demands and capital converge in cities and highlight water, energy, and food (WEF) issues. Cities are also vulnerable due to their high population densities and critical infrastructures. The central role of cities in resource networks can create cascading security risks, as seen in the growing water, energy, and food security crises in Indian cities. By 2030,[9] global demand for food, water, and energy are projected to increase by 35 percent, 50 percent, and 40 percent, respectively, compared to 2012. Uncertainties in water availability, energy security, and food price stability also impact political and economic stability, which is essential for maintaining infrastructure and resource distribution systems.

Traditional sector-specific policymaking approaches are inadequate for managing the interconnected challenges of the nexus and often fail to account for detrimental cross-sectoral effects and synergies. A decade after the WEF nexus became a focal point of political and

research agendas, an integrated perspective on these resources has become crucial. India, the largest groundwater user globally, extracted 244.92 billion cubic metres in 2020,[10] surpassing the combined usage of the United States (US) and China. Nexus approaches aim to investigate critical linkages among food, water, and energy systems and their societal implications.

Cities are often seen as innovation hubs that are capable of leading sustainable transformations, with high densities promoting resource-use efficiency. However, urban-focused research on the WEF nexus is limited, often failing to capture urban complexities, being overly reliant on technical solutions, and rarely including stakeholder participation. By reimagining resource-efficient and sustainable cities, India can set a model for emerging countries in the Global South.

This report delves into the interplay of water, energy, and food issues in urban settings, emphasising the importance of the WEF nexus for Indian cities. By exploring the interdependencies and synergies among these resources, the report highlights how a nexus approach can enhance urban sustainability and resilience. Through a comprehensive analysis of current policies and the identification of existing gaps in the management of WEF resources, the report examines the challenges faced by Indian cities and offers strategic recommendations to optimise resource use, promote sustainable development, and ensure the well-being of urban populations.

WEF Issues in Indian Cities

Food Insecurity

India has made progress in agricultural production, achieving 3,296.87 lakh tonnes in food grain production in 2022-23,[11] up by 140.71 lakh tonnes from 2021-22 and 308.69 lakh tonnes from the previous five-year average. Despite this, as of 2023, nearly 200 million people in the country are undernourished.[12] Food insecurity in Indian cities remains prevalent despite economic progress and rapid urbanisation. Economic disparities, rising living costs, and shifting food consumption patterns have led to urban populations facing both food scarcity and dietary excess. Low-income groups, especially those in urban slums, are disproportionately affected by irregular employment, insufficient incomes, and limited access to affordable, nutritious food.

Studies highlight a high prevalence of food insecurity at the household level across urban areas. For instance, in an urban resettlement colony in Delhi, 77.2 percent of households were found to be food insecure.[13] Another study found that 17 percent of the 1,700 households surveyed in Bengaluru face food insecurity,[14] while 13 percent are experiencing severe food insecurity due to inadequate food quantity and variety. A cross-sectional survey in Mumbai[15] found that 60 percent of urban slum households were severely food insecure, with an additional 16.6 percent experiencing mild to moderate food insecurity. In eastern Uttar Pradesh,[16] 43 percent of households were food insecure, with many experiencing intense hunger. Research in Delhi and Chennai[17] showed 8.5 percent food insecurity among the lowest wealth quintile compared to 1.7 percent in wealthier households, with a higher prevalence in Delhi. A longitudinal survey in Bihar[18] noted an increase in severe food insecurity, from 25 percent in 2016 to 35 percent in 2021. Jharkhand exhibits similar levels of food insecurity, especially in priority districts. Both Bihar and Jharkhand, which face significant challenges in achieving food security, score the lowest[19] on Sustainable Development Goal 2 (Zero Hunger).

At the same time, the average citizen in urban India wastes 0.34 kg[20] of food per day, resulting in 153 gigagrams of food waste daily across these regions. According to the United Nations Food Waste Index Report, Indian households waste 78.2 million[21] tonnes of food annually. A report by the UN Environment Programme, released ahead of the International Day of Zero Waste in December 2024, places India's per-capita food waste at 55 kg per year[22] and highlights that rural India wastes less food compared to urban areas.

Water Insecurity

Achieving food sufficiency in India has come at the cost of increased water extraction and energy consumption in agriculture. India will need more food grains annually to sustain its growing population, which is projected to reach 1.7 billion by 2060.[23] However, challenges such as water scarcity and limited arable land complicate efforts to meet this demand.

The requirement for irrigation water in India is expected to grow by over 50 percent by 2050 while per-capita water availability continues to decline.[24] Annual irrigation requirement is projected to increase by 4.63-20.46 percent by 2050 even as climate change results in reduced crop yields by 4.5-9 percent and per-capita water availability continues to decline.[25] Climate change could lead to India's food production dropping by 16 percent while the population at risk for hunger increases by 23 percent by 2030.[26] The average annual per-capita water availability for the years 2021 and 2031 has been assessed at 1,486 cubic metres and 1,367 cubic metres, respectively.[a,27] Since Independence, India's annual per-capita water availability has declined by 75 percent,[28] from 6,042 cubic metres in 1947 to 1,486 cubic meters in 2021. This is expected to drop by another 20 percent by 2050,[29] making India the world's largest user of groundwater and a severely water-stressed country.

Cities like Bengaluru and Chennai have experienced severe water shortages in recent summers. Urban households consume only about 7 percent of the country's water,[30] with 6-8 percent of total water demand used for cooking.[31] Meanwhile, 85 percent of water demand

a Annual per-capita water availability of less than 1,700 cubic metres is considered as a water-stressed condition whereas annual per-capita water availability below 1,000 cubic metres is considered as a water scarcity condition. See: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2002726

comes from agriculture.[32] Climate change will exacerbate water scarcity in India, where large regions already suffer from limited water availability and rely heavily on groundwater for irrigation. A UN report[33] from March 2023 warned that India will be the most severely affected country as the global urban population facing water scarcity increases from 933 million in 2016 to between 1.7 and 2.4 billion by 2050.

Groundwater constitutes 48 percent of the urban water supply in India.[34] However, groundwater levels in seven of India's ten most populated cities have drastically declined over the past two decades,[35] often exceeding the annual limit of 20 cm of decline and reaching depths as low as 20 metres. The northwestern states of Punjab and Haryana, which produce most of the country's rice and wheat, are particularly water-stressed, with groundwater extraction rates surpassing 100 percent.[36] Over two decades, groundwater levels in these areas have dropped[37] from 3-10 metres to below 30 metres.

World Bank projections indicate that, with a global mean warming of 2°C above pre-industrial levels, India's food water requirements will exceed green water availability.[38] This gap between water demand and supply is likely to have serious implications for food grain production and food security in India. In Delhi,[39] the Delhi Jal Board struggles to meet the water and wastewater needs of the capital, providing an erratic and unequal water supply well below international standards. Mismanagement of water particularly affects the urban poor, with slum dwellers receiving only about 27 litres per capita per day.[40] Despite a third of India's population living in cities, less than half of the country's urban population has access to piped water supply.[41]

Energy Insecurity

Agriculture has the largest energy consumption in India, with the share of direct energy use in the form of electricity in the agriculture sector increasing from 28.75 percent in 2009-10 to 37.1 percent in 2019-20.[42] Energy is also essential in every stage of the municipal water supply system, including extraction, treatment, pumping, and recycling, making it a significant operational cost. Water and wastewater treatment plants are the most energy-intensive facilities operated by local governments, accounting for 30-60 percent of a municipality's total energy bill.[43]

With more than half of India's population expected to live in cities by 2036, millions of households are anticipated to purchase new appliances, air-conditioning units, and motor vehicles. In urban areas, energy consumption is primarily in the form of electricity. Consequently, the country's electricity demand has increased by 50 percent since 2014.[44] India's electricity demand grew by 7 percent in 2023 and is projected to grow by an average of 6 percent annually through 2026 due to higher economic activity.[45] A fourfold increase in commercial energy consumption is projected by 2025.[46]

As water shortages become more acute, unscheduled power cuts and outages have become common, causing housing and living standards to decline and making access to healthcare facilities challenging. To meet the growing electricity demand over the next 20 years, India will need to add a power system the size of the European Union to its current capacity.[47] The country's electricity demand is set to increase much more rapidly than its overall energy demand as the country's building space doubles over the next two decades, with 70 percent of new constructions occurring in urban areas.[48] The extent to which these new constructions follow energy-efficient building codes will influence energy use patterns.

The shift towards urban living is accelerating the transition in residential energy use from solid biomass to electricity and modern fuels. Rising appliance ownership and demand for cooling are driving the share of electricity in residential energy use to nearly triple. However, India relies heavily on coal for electricity supply (55 percent of energy needs[49]), and unscheduled power cuts and outages are common during shortages, particularly during heatwaves and higher temperatures; urban households in India experience power outages for at least two hours a day.[50]

Thermal energy,[51] which constitutes more than 70 percent of India's total electricity generation and 60 percent of its installed power capacity, is highly dependent on freshwater for cooling. Projections indicate that more than two-thirds[52] of the country's power plants will face high water stress by the end of the decade. During the 2016 drought, water-related outages[53] in thermal power plants were significant enough to cover Sri Lanka's annual demand, costing utilities billions in lost revenue. Between 2017 and 2021, there was approximately 8.2 terawatt-

hours (TWh) of lost energy production due to water shortages—enough to power 1.5 million Indian households for five years.[54]

Coal-fired electricity is another significant water consumer, with thermal generators requiring gigalitres of water from rivers to cool their turbine circuits. The power sector is estimated to account for more than a quarter of Karnataka's urban water consumption by 2030.[55] Much of this electricity is used in agriculture, with millions of grid-connected electric pumps adding further stress on the power system and accounting for about one-fifth of electricity consumption.[56]

Resource conservation, optimisation of use, and waste minimisation are crucial to meeting the growing demand for high-quality resources in sufficient quantities. To achieve the Sustainable Development Goals (SDGs) by 2030, it is crucial to urgently reduce the demand-supply gap (see Table 1) and make cities inclusive, resilient, and sustainable by implementing integrated policies and plans for efficient resource use and climate change adaptation.

Therefore, an integrated approach to managing water, energy, and food is necessary to balance resource use and reduce trade-offs among different sectors. The strong inter-relationship between water, energy, and food means that improving efficiency in one sector positively impacts the others. Enhancing resource security through technological interventions and policy measures would not only ensure adequate availability but also bring co-benefits in resource management.

The WEF Nexus and Its Importance for Indian Cities

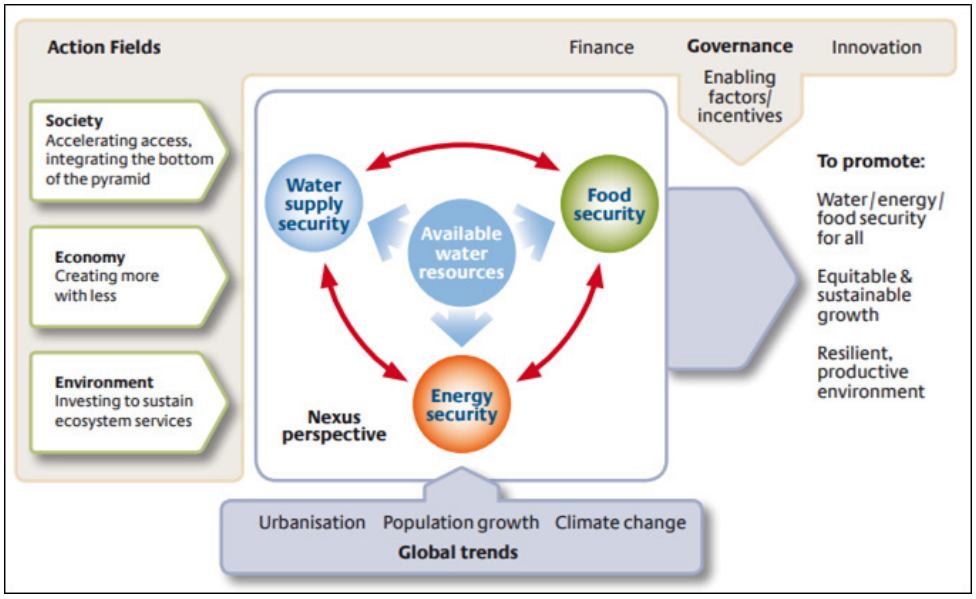
The WEF nexus captures the interdependencies[57] among the food, energy, and water sectors and emphasises the interconnected governance of WEF resources. Energy is essential for water treatment and supply, water is crucial for energy production, and food production requires both energy and water. Given the conflicting demands on WEF resources from a growing population, understanding the WEF nexus can help decision-makers avoid the unforeseen consequences of policy actions across these sectors.

The Food-Energy Nexus Programme, initiated by the United Nations University (UNU) in 1983, marked the beginning of nexus thinking.[58] It gained recognition at the 2011 Bonn Nexus Conference and is regarded as integral to achieving the SDGs. Among the 17 SDGs, Goals 2 (No Hunger), 6 (Clean Water and Sanitation), and 7 (Affordable and Clean Energy) specifically address WEF security, essential for human survival, economic growth, and development. Additionally, Goals 10 (Reduced Inequalities), 11 (Sustainable Cities and Communities), and 12 (Responsible Consumption and Production) emphasise resource efficiency and strengthening urban-rural linkages for sustainable development.[59]

The WEF nexus (see Figure 1) highlights the relationship between water, energy, and food, which evolves with resource availability, development priorities, and technological advancements. Therefore, it provides a platform to explore synergies for maximum benefits. Effective management of the WEF nexus requires a watershed approach at all municipal planning levels to optimise resource use. Incorporating a watershed perspective in micro-level planning can

reduce cities' reliance on external resources and enhance self-sufficiency through techniques like aquifer recharging and rainwater harvesting. Residential buildings should consider rooftop water harvesting, separate water-supply pipe connections, and renewable energy provisions to minimise their water and energy footprints while balancing food consumption needs.

Figure 1: The Water-Energy-Food Nexus



Source: Hoff, 2011[60]

India's rapidly growing population and rising energy demand present challenges in energy and food supply. Addressing these challenges requires an integrated management approach to ensure sustainable agriculture, energy production, and food and water security. This approach is important in existing as well as emerging urban areas to meet the needs of expanding populations. Megacities, characterised by urban slums, poverty, and inadequate infrastructure, contrast with slow-growing cities that offer opportunities for innovative, sustainable, and

inclusive infrastructure development. However, both megacities and slow-growing cities rely on rural areas to meet their resource needs.

Urban areas, as net consumers of food, water, and energy, draw resources from global and local hinterlands. Decentralised systems can address supply-demand mismatches, despite trade-offs. For instance, urban agriculture can increase access to healthy foods in "urban food deserts" and reduce ecosystem strain by recycling wastewater. However, challenges include water-intensive agricultural practices, carbon emissions, capital costs, land prices, and social acceptance of urban-grown food.

Food production intersects with water and energy systems. The WEF nexus framework posits that there are no externalities in this system, underscoring the interconnected nature of these resources in urban development and the achievement of the SDGs. The integration of WEF sectors at key stakeholder nodes can benefit urban populations, city regions, and supporting ecosystems. Recognising the intersectoral impacts of decisions, research underscores the need for improved data systems to quantify these interactions.

India's Urban Development Programmes for Synergising WEF Nexus Issues

Urban India needs to utilise available resources efficiently to improve the quality of life of citizens. The Indian government views urban development as an opportunity, with urban centres serving as engines of change. Water, energy, and food are managed by different ministries and departments across national, state, and district levels. Urban development, however, falls under the jurisdiction of state governments. The 74th Amendment Act further delegates many of these functions to Urban Local Bodies (ULBs) for city-level management.[61] Despite this decentralisation, the Ministry of Urban Affairs remains crucial for formulating policies, programs, and schemes for urban development.

Table 1: India's Urban Development Policies for Addressing WEF Issues

Sustainable Development Goals that Address Nexus Issues			India's Urban Development Policies			
Nexus Sector	**Goals**	**Salient Points**	**Smart Cities Mission**	**AMRUT**	**JNNURM**	**URDPFI**
Water	**Goal 6: Clean Water and Sanitation**	6.1. Universal and equitable access to safe and affordable drinking water	Yes	Yes	Yes	No
		6.3. Improve water quality, increasing recycling and safe use	Yes	Yes	Yes	No
		6.4. Increase water use efficiency, reduction in the number of people suffering water scarcity	Yes	Yes	Yes	No
		6.5. Implementation of integrated water resources management	Yes	Yes	Yes	No
		6.6. Protect and restore water related ecosystems - mountains, forests, rivers, wetlands, lakes and aquifers	Yes	No	No	No
Energy	**Goal 7: Affordable and Clean Energy**	7.1. Universal access to affordable, reliable and modern energy services	Yes	No	No	No
		7.2. Increase in the share of renewable energy	Yes	No	No	No
		7.3. Improvement in energy efficiency	Yes	No	No	No
		7.3.a. Enhance international cooperation to facilitate access to clean energy research and technology	No	No	No	No
Food	**Goal 2: Zero Hunger**	2.1. Access to safe, nutritious, and sufficient food	No	No	No	No
		2.4. Ensure sustainable food production and implement resilient agricultural practices	No	No	No	No
		2.5.c. Adopt measures to ensure that proper functioning of food commodity markets, access to market information, including of food reserves, and help limit extreme food price volatility.	No	No	No	No
	Goal 12: Responsible Consumption and Food Production	12.3. Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains	No	No	No	No

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Cross Cutting	**Goal 9: Industry, Innovation and Infrastructure**	9.1 Develop sustainable, resilient, and inclusive infrastructures	Yes	Yes	Yes	Yes
		9.2. Promote inclusive and sustainable industrialisation	No	No	No	No
		9.4. Upgrade all industries and infrastructures for sustainability	No	No	No	No
		9.5. Enhance research and upgrade industrial technologies	No	No	No	No
		9.6. Facilitate sustainable infrastructure development for developing counties	Yes	Yes	Yes	Yes
	Goal 11: Sustainable Cities and Communities	11.5. Significantly reduce the number of deaths and people affected by disasters, including water-related disasters	Yes	Yes	Yes	No
		11.7.b. Substantially increase the number of cities and human settlements with integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, and resilience to disaster	Yes	Yes	No	No
	Goal 13: Climate Action	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters	Yes	Yes	No	No
		13.2. Integrate climate change measures into national policies, strategies, and planning	Yes	Yes	No	No
	Goal 15: Life on Land	15.9. Integrate ecosystem and biodiversity into national and local planning and development processes	No	No	No	No

Source: Authors' own, based on open sources.

Smart Cities Mission

In 2015, the Government of India launched the Smart Cities Mission (SCM)[62] to transform urban areas into sustainable, technologically advanced, and citizen-responsive smart cities. The SCM aims to drive economic growth and enhance the quality of urban life through smart technology applications. The initiative uniquely integrates water and energy components alongside addressing other urban ecosystem issues. The mission focuses on water management through smart meters, leakage detection, maintenance, and water quality monitoring. Similarly, energy management under the mission includes smart meters, renewable energy sources, energy efficiency, and green building concepts. Notably, the initiative aims to ensure that 10 percent of the energy requirement for smart cities comes from solar energy.[63]

In the fiscal budget of 2014-15, the government allocated US$1.2 billion to the SCM.[64] Despite the mission's emphasis on improving water and energy use efficiency, less than 15 percent of the projects from the winning cities in the first round relate to water, and only 5 percent relate to energy. Only ten cities have implemented smart water management to reduce Non-Revenue Water (NRW),[65] indicating a lack of commitment from civic authorities.

The mission impact is difficult to assess due to the presence of over 4,000 urban settlements and significant project backlog in the country.[66] However, latest data indicates that 66 out of the selected 100 cities have yet to meet their physical targets, even after eight years.[67] Of these 66 cities, 25 have completed more than half of their originally planned projects, 19 have completed between 25 and 50 percent, and 22 have completed less than 25 percent of their projects.

Consequently, the deadline for completing the mission has been extended to July 2024. However, according to the Ministry of Housing and Urban Affairs (MoHUA), more than two-thirds of the 7,804 projects under the SCM have been completed as of January 2023.[68] While 34 cities have exceeded their project targets, some even by four times, the remaining 66 cities are yet to meet their targets, with some showing particularly poor performance.

ULBs often lack the core competencies, trained personnel, and financial resources to complete urban infrastructure projects. Despite doing reasonably well with targeted schemes such as AMRUT and SBM, ULBs have struggled with the comprehensive scope of the SCM.[69] Confusion and project drops further impede progress.

JNNURM

The Jawaharlal Nehru National Urban Renewal Mission (JNNURM),[70] launched in 2005, marked a significant shift in India's urban sector, emphasising the preservation of water bodies, adequate water supply, and the replacement of old and worn-out pipes in 63 identified cities. A component of JNNURM, the Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)[71] aimed to improve urban infrastructure, including water supply and sewerage in smaller towns. It positively impacts the WEF nexus by providing better quality water infrastructure services, minimising water loss during transmission, and introducing by-laws for the reuse of recycled water. Additionally, policies on user charges were formulated to achieve 100-percent cost recovery in water supply and solid waste management. Rainwater harvesting was also made mandatory to address depleting groundwater levels and promote water conservation.

However, the reforms envisioned under JNNURM did not yield the desired results due to poor implementation and weak monitoring and enforcement mechanisms. Among the projects aimed at improving water supply, less than one-third have been completed.[72] None of the projects for preserving water bodies have been finished. Although a toolkit to reduce NRW was developed under JNNURM, its usage has been limited due to the lack of capacity in municipalities.

AMRUT

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) scheme, launched on 1 October 2021 and with an implementation period of five years, aims to ensure that every household has access to a tap with an assured water supply and sewerage connections.[73] The scheme has covered about 60 percent of the urban population[74] and emphasises universal

metering, reduction of NRW, rainwater harvesting, rejuvenation of water bodies, and groundwater recharge. AMRUT 2.0[75] aims to achieve universal water supply coverage through functional taps in all statutory towns and sewerage and septage management in the 500 cities covered in the first phase.

Under AMRUT, the Energy Efficiency Services Limited (EESL) is working with the Ministry of Housing and Urban Affairs to deploy more efficient pumps in 500 cities.[76] These pumps, which will be replaced at no upfront cost to municipal bodies, promise uninterrupted water supply, lower energy bills, and reduced water wastage, backed by a seven-year repair and maintenance guarantee. Additionally, over 330 Indian cities will be audited for energy efficiency under the scheme.[77]

The scheme, however, has faced setbacks. The Centre's contribution to projects is just 50 percent, with the state and ULBs expected to cover the remainder. If a state fails to execute the project within a year, it must return the funds to the Centre, which will redistribute them to better-performing local bodies. In Kerala, projects worth INR 41 crores in the high-priority septage/sewerage sector were cancelled during the first phase of AMRUT, along with 58 projects worth INR 76.9 crores in various sectors.[78] The total expenditure in the sewerage/septage sector under AMRUT was just 20.6 percent over six years in Kerala.[79] The Local Self Government Department (LSGD) failed to properly utilise AMRUT funds, focusing more on consultancy engagements and seldom addressing irregularities in the scheme's implementation. Reports also indicate that many thrust areas proposed under the scheme are not feasible for the state, which lacks basic facilities.[80]

URDPFI

The Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines,[81] formulated in 2015, aim to address the emerging needs of planned urban development. These guidelines include provisions for rainwater harvesting, conservation of urban water bodies, water supply systems, wastewater management, energy efficiency, strategic planning for new and renewable energy, alternative energy sources, and smart grids to reduce electricity losses.[82] URDPFI uniquely incorporates food security within the urban context, emphasising the holistic integration of WEF systems.

The Ministry of Urban Development first introduced Urban Development Plans Formulation and Implementation (UDPFI) guidelines in 1996, which were later updated in 2015 to URDPFI.[83] The policy emphasises citizen partnership at every level of implementation. The 1996 guidelines suggested steps for public participation in development plan preparation, including public notification and display of draft plans, public meetings for comments and suggestions, public hearings, and submission of the final draft to ULBs for approval.[84] Direct participation was encouraged through various groups, including citizens, neighbourhoods, businesses, and consumer groups, with Non-Government Organisations (NGOs) and Community-Based Organisations (CBOs) acting as intermediaries. The 2015 URDPFI update introduced stakeholder consultation throughout the development plan process and emphasised revising state planning provisions to enhance public participation early in the planning stages, involving Residential Welfare Associations in Local Area Plans (LAPs), and using modern tools like websites by ULBs to increase public awareness and engagement during the preparation of urban development plans.[85] To date, however, only 2,100 master plans have been notified out of a total of 7,933 cities and towns under URDPFI.[86]

Public participation plays a pivotal role in democratic decision-making, supporting sustainability. In India, public participation is more evident during the implementation of plans rather than during their formulation.[87] Decentralised participatory spaces in megacities are fragmented,[88] and unlike the rural districts, cities lack platforms like the Gram Sabha to engage citizens.[89] Current practices for public involvement are limited to stakeholder consultations, primarily with expert groups, and lack robust methods to capture the input of the general public in the formulation of development plans.

The WEF Nexus in Indian Cities: A Review of Gaps and Policy Recommendations

Integrating WEF in Urban Systems

Current policies and interventions often work in isolation, leading to overlaps and conflicts that fail to address resource scarcity. The lack of integration and awareness of the WEF nexus results in policies that target the same objectives and populations, disproportionately affecting vulnerable groups through resource mismanagement. The absence of explicit national or international policies for coordinating the WEF nexus underscores the urgent need for institutional frameworks to address these constraints.

Embracing a nexus approach that acknowledges the interdependencies among the water, energy, and food sectors is essential for overcoming the limitations of silo-based methodologies. This approach is crucial for emerging urban spaces in India, which are already under tremendous stress. Unsustainable resource utilisation in the WEF sectors can further endanger millions of future city dwellers. Given the existing water scarcity in many parts of the country, climate change impacts in urban areas will be severe. Unplanned urban growth and excessive water from monsoons or flooding can also threaten city infrastructure if not climate-proofed.

It is important to note that for better water governance, along with the introduction of surface water pricing, a proper groundwater bill/act needs to be enacted. With rising population and incomes, there will be a need to not only produce more food but also save water for drinking, manufacturing and other needs of growing urbanisation. Once productivity is looked at from the water angle, the inefficiencies in allocation and use of water in agriculture could be identified and addressed.

The rapid urbanisation in India will accelerate transitions in residential energy use from solid biomass to electricity and modern fuels. Therefore, technological innovations, improvements in irrigation efficiency, and robust policy interventions with government incentives are imperative to navigate the complexities of the WEF nexus and achieve the SDGs.

The Need for a Definition and Understanding of the WEF Nexus

The vagueness in current definitions of the WEF nexus can hinder its application, while an overly restrictive definition can stifle development. Governance issues are further exacerbated by a lack of awareness and understanding of the nexus principle. Many professionals in the WEF sectors are not fully aware of the concept and its benefits. Additionally, some practitioners and researchers mistakenly compare the nexus approach with Integrated Water Resource Management (IWRM) without recognising the distinct advantages of each.

The key difference between the nexus and IWRM is that the latter is water focused, addressing issues primarily from a water-management perspective, whereas the WEF nexus considers water, energy, food, and ecosystems as part of an interrelated system and takes into account the interdependencies among these factors. This holistic perspective is crucial for addressing the complex challenges faced by emerging urban spaces in India.

Close Institutional Gaps

Each domain of the WEF nexus is currently individually handled by institutions, leading to fragmented and reactive decision-making. This approach often results in disjointed policies that fail to address the interconnected nature of the WEF sectors. Multiple ministries, including the Ministry of Jal Shakti, Ministry of Environment, Forests and Climate Change, Ministry

of Agriculture & Farmers Welfare, Ministry of New and Renewable Energy, Ministry of Coal, and Ministry of Power, contribute to the WEF nexus. While their involvement highlights the importance of these sectors, their siloed operations pose significant challenges to achieving a cohesive and integrated strategy. Bridging these silos is crucial for addressing the complex interplay between water, energy, food, and ecosystems. Urban and regional policymaking must shift from isolated sectoral planning to an integrated approach that enhances productivity, equitable delivery, affordability, reliability, and the overall quality of urban services. With the anticipated rise in resource demand, sustainably addressing resource scarcity is imperative for India's future cities.

Effective Stakeholder Integration

Balancing the interests of different sectors and stakeholders is a challenging task.[90] Different parts of the government often struggle to cooperate due to strict regulations, powerful interests, and established communication systems within their respective domains. For instance, the imbalance of power among sectors—such as the dominance of agriculture over water or water over the environment—and lobbying efforts pose significant barriers.

In India, as in many other countries, implementation and experience with the nexus principle are limited, primarily because of the lack of communication between engineers, scientists, policymakers, and the public. Senior-level decision-makers need to be sensitised to the advantages of the approach in policy formulation. Additionally, researchers must exert greater effort in translating nexus studies into actionable points to achieve a long-term, stable vision in policy and plans.

Community, industry and government must work together to improve water management. Proponents of private sector participation contend that if water were correctly priced, it would facilitate investment from the private sector and help find solutions to the water crisis facing vast regions of the developing world.[91]

Generating Data and Knowledge of Interconnected Sectoral Risks

India faces significant challenges in understanding and managing the interconnected impacts of the WEF nexus. The interdependencies among these systems are not well recognised, and the roles of related institutions remain poorly understood. Disruptions in one sector often trigger cascading effects in others, leading to compounded extreme events.

Climate change exacerbates these challenges, particularly in India's water resources, endangering not only water availability for consumption but also agriculture, which heavily relies on groundwater. Thermal power plants, which generate over 70 percent of India's electricity, depend on freshwater for cooling. Projections indicate that two-thirds of these plants will face high water stress by the end of the decade.[92] The evolution of Indian cities will be crucial in determining the country's success in combating climate change, especially as urban populations grow and are increasingly at risk due to poor planning and mitigation strategies. Therefore, integrated policy mechanisms and robust institutional frameworks are essential.

Way Forward

The interconnected challenges posed by the WEF nexus present a significant threat to sustainable urban transformation. The use of unsustainable resources exacerbates greenhouse gas emissions, which compromises water storage, energy generation, and food production. The lack of a WEF nexus approach can result in actions in one sector having unintended and adverse impacts on other interlinked sectors.

A review of policies and programs related to the water, energy, and food sectors in India as presented in this report highlights the need for greater integration and attention to the interconnectedness and interdependencies among these sectors through a nexus approach. The rapidly changing development scenarios in these sectors and the threat of climate change demand the adoption of nexus concepts to better address synergies and manage trade-offs.

It is imperative that relevant policies and programs are reviewed and updated to become nexus-compliant. Alongside developing coherent policies and programs in the WEF sectors, concerted efforts are required to create nexus-specific policy frameworks towards strengthening institutions and methods, including integrated risk and vulnerability assessments using a systems approach. This will enable informed policy development and effective management of interlinked challenges within the WEF nexus in Indian cities.

Endnotes

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