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Engineering Diplomacy for Water Sustainability: From Global Indicators to Local Solutions

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Abstract: Sustainable Development Goal 6.4 aims to improve water-use efficiency and reduce water scarcity, yet its implementation is hampered by ambiguities in definitions, limitations in metrics, and misalignments between global indicators and local realities. This paper introduces the **Engineering Diplomacy Framework (EDF)** as a principled yet pragmatic approach to address these implementation challenges. Building on the Water Diplomacy Framework, EDF integrates engineering reasoning with diplomatic negotiation to reconcile quantitative indicators with contested social values and institutional complexity. We analyze SDG 6.4 using three metaphorical heuristics— *"What is one plus one?"*, *"Where do we put the X?"*, and *"How do we divide 17 camels?"*—to diagnose key gaps in current monitoring frameworks and uncover context-sensitive paths to action. Through comparative analysis of Singapore, Denmark, the Democratic Republic of Congo, and Jordan, we show how EDF helps identify locally meaningful interventions where standardized metrics fall short. We conclude by outlining actionable steps for operationalizing EDF principles in SDG implementation, emphasizing the need to move beyond measurement toward negotiated, adaptive, and equitable solutions to achieve water sustainability goals.

Keywords: engineering diplomacy; sustainability; SDG 6.4; negotiation; complexity; ambiguity; decision-making

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1. Introduction

Sustainability has emerged as a unifying yet contested concept in global development discourse, signaling the urgent need to reconcile environmental limits with human aspirations for equity and well-being. While the Sustainable Development Goals (SDGs) provide a shared vision and roadmap for progress, the translation of these goals into meaningful action remains uneven. The breadth and ambition of sustainability—spanning natural and human systems with variables, processes, agents, and institutions across scales and sectors—make it both a powerful mobilizer and a source of analytical and practical complexity. Nowhere is this more evident than in the water domain, where technical challenges, social complexities, and related trade-offs intersect in deeply place-based ways.

Among the 17 SDGs, SDG 6— "Ensure availability and sustainable management of water and sanitation for all"—is a cornerstone of sustainable development. Water supports health, livelihoods, ecosystems, and resilient infrastructure, and is tightly linked to other goals such as food security (SDG 2), energy access (SDG 7), and climate action (SDG 13). Yet, despite widespread recognition of its importance, progress on SDG 6 remains far from adequate. Billions still lack reliable access to clean water and sanitation, and many water systems are stressed by overuse, pollution, and the growing impacts of climate change. As a result, sustainable water management has become a central priority—not only for engineers and hydrologists but also for decision-makers, political leaders, and communities.

Within this broader goal, Target 6.4 addresses a particularly complex aspect of water sustainability: scarcity. It calls on the global community to "substantially reduce the number of people suffering from water scarcity" and to improve water-use efficiency by 2030. However, while the indicators for SDG 6.4 rely on quantifiable data such as water withdrawal rates and renewable freshwater availability, the inclusion of the term "suffering" introduces an important social dimension that is harder to define and operationalize. What does it mean to suffer from water scarcity, and how do we measure and mitigate that suffering across diverse contexts? These questions

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highlight a fundamental implementation bottleneck: the tension between standardized global targets and the highly localized, often uneven, realities of water scarcity.

This paper responds to that challenge by introducing and applying the **engineering diplomacy framework**—an emerging approach that synthesizes technical expertise with creative problem-solving to co-create solutions that are scientifically credible, socially legitimate, and politically feasible. Rather than treating water scarcity as a monolithic global crisis, we argue for a multi-faceted, context-sensitive approach that emphasizes actionable progress at three interconnected scales: community, subnational, and international. Drawing on SDG 6.4 as a case, we explore how engineering diplomacy can facilitate adaptive learning, mediate competing interests, and build capacity for sustainable water management tailored to specific socio-ecological settings.

While this paper provides a structured and theory-informed critique of SDG 6.4 using the Engineering Diplomacy Framework, it does not present new empirical data or formal statistical validation. The analysis is grounded in qualitative synthesis, illustrative case studies, and comparative interpretation of publicly available indicators and policy documents. As such, its intent is not to test causal hypotheses, but to offer a conceptual lens for rethinking sustainability targets under conditions of ambiguity, complexity, and collective action dilemmas.

In doing so, we aim to contribute to cross-disciplinary dialogue by offering both conceptual and practical insights for scholars and practitioners working at the intersection of water governance, development policy, and systems engineering. Our goal is not only to assess the limitations of current approaches, but to propose concrete, inclusive pathways toward achieving SDG 6.4 in ways that make measurable and meaningful differences in people's lives. Future research could complement this work through in-depth field studies, participatory assessments, or quantitative modeling aligned with EDF principles.

2. From Water Diplomacy to Engineering Diplomacy: Framing a New Response to Address Sustainability Goals Framework

2.1. Evolution and Rationale

The Engineering Diplomacy Framework (EDF) builds on more than fifteen years of theoretical development and practical application of the **Water Diplomacy Framework (WDF),** which was originally conceived to address complex and often contentious water conflicts through a negotiation-based, context-sensitive approach (Islam & Susskind, 2012; Islam et al 2025). While WDF focused primarily on transboundary and regional water challenges, EDF extends these insights to **broader sustainability challenges and collective action problems.** It is motivated by the recognition that achieving global targets like SDG 6.4 is not just a technical or financial challenge, but also a political, institutional, and epistemic one.

EDF emerged from the observation that many sustainability initiatives stall not because of lack of data or resources, but due to **ambiguity in problem definitions, misaligned stakeholder goals,** and **inability to reconcile multiple worldviews** across disciplines and interests. EDF addresses these challenges by offering a structured, yet adaptive approach grounded in both **scientific principles** and **diplomatic pragmatism.** In contrast to rigidly technocratic or overtly normative frameworks, EDF seeks to **synthesize numbers and narratives,** and translate them into context-aware, stakeholder-informed, and politically feasible actions.

The Engineering Diplomacy Framework (EDF) evolves from the Water Diplomacy Framework (WDF) by retaining its core focus on complexity, adaptability, and stakeholder engagement, while expanding its scope beyond water conflicts to collective action problems across sustainability domains. While WDF emphasized resolving disputes through negotiated solutions in transboundary and regional water settings, EDF integrates engineering thinking and diplomatic practice to address ambiguous goals, pluralistic values, and systemic uncertainty. This evolution reflects a shift from managing specific water conflicts to enabling context-sensitive decision-making under dynamic and

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contested conditions—making EDF uniquely positioned to address implementation gaps in global sustainability agendas such as SDG 6.4.

2.2. Comparing Existing Frameworks: Why and How Engineering Diplomacy Framework Can Contribute?

Over the past two decades, multiple frameworks have emerged to help navigate sustainability challenges marked by uncertainty, complexity, and interdependence. Among the most influential are Adaptive Management, Resilience Thinking, Integrated Water Resources Management (IWRM), and Ostrom's Institutional Design Principles. Meta-level approaches such as Post-Normal Science, Multi-Level Governance, Strategic Environmental Assessment, and Mode 2 Knowledge Production have also expanded how knowledge is produced and applied to decision-making. Each of these frameworks offers valuable insights. Yet none, by itself, provides an adequately integrative, actionable, and context-sensitive approach to tackling collective action problems such as those posed by Sustainable Development Goals. The Engineering Diplomacy Framework (EDF) builds on the strengths of these approaches while addressing their key limitations—particularly when dealing with contested goals, multiplicity of interpretations, ambiguous metrics, and the need for negotiated problem-solving approaches to achieve desirable outcomes.

Adaptive Management (AM) provides a structured, iterative approach for managing ecological systems under uncertainty (Holling, 1978; Walters, 1986; Williams & Brown, 2012). It emphasizes experimentation, outcome monitoring, and learning by doing. These strengths are evident in resource management contexts such as fisheries, forestry, and river basin planning. However, AM generally presupposes that stakeholders share a baseline agreement on objectives and are willing to revise decisions as new data emerges. In more politicized or fragmented contexts, such as transboundary water allocation or domestic conflicts over water rights, these assumptions may not hold. AM is strong on uncertainty but limited in its capacity to address ambiguity and contested values. EDF complements AM by explicitly recognizing and engaging with multiple worldviews and value systems. It provides not only a process for technical learning but also a platform for negotiating what success means in context.

Resilience Thinking, grounded in social-ecological systems theory, focuses on a system's capacity to absorb shocks and reorganize while retaining core functions (Walker & Salt, 2006; Folke, 2006). It offers a powerful vocabulary for understanding dynamic systems, feedback, and tipping points. The widely referenced resilience principles—such as maintaining diversity, managing connectivity, and promoting polycentric governance—are valuable design heuristics for sustainability (Biggs, Schlüter, & Schoon, 2015). However, resilience as a concept is more descriptive than prescriptive. It provides limited guidance when stakeholders disagree on which systems should be made resilient, for whom, and at what cost. EDF adds value here by mediating among competing interests through diplomatic engagement. Rather than assuming consensus on system boundaries and desired futures, EDF builds legitimacy and feasibility through negotiated trade-offs.

Integrated Water Resources Management (IWRM) has long been promoted as a holistic approach to coordinating water, land, and related resources across sectors and scales (Global Water Partnership, 2000). It emphasizes participation, efficiency, and equity. In theory, IWRM provides a comprehensive governance model for water sustainability. In practice, however, it often suffers from overgeneralization, procedural overload, and difficulties in implementation. Critics argue that IWRM can become a normative ideal with little operational traction, particularly in politically contested or institutionally fragmented settings (Biswas, 2004; Molle, 2008). EDF shares IWRM's recognition of interdependence across sectors but shifts the focus from integration as an end goal to negotiation as a process. Rather than prescribing integration, EDF helps actors navigate institutional complexity and develop context-specific strategies for coordination.

Ostrom's Institutional Design Principles (IDPs), derived from extensive empirical research on commons governance, identify core features of robust institutions for managing shared resources. These include clearly defined boundaries, rules congruent with local conditions, collective-choice arrangements, graduated sanctions, and nested governance (Ostrom, 1990; Cox, Arnold, &

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Villamayor-Tomas, 2010; Baggio et al., 2016). The IDPs offer a powerful framework for evaluating institutional arrangements, particularly in localized settings. However, their application is often bounded by assumptions of relative social cohesion, local knowledge, and spatially defined resources. EDF extends the logic of the IDPs to more fluid, multi-scalar problems like those encountered in implementing SDG 6.4. It builds on the principle that no single institutional blueprint fits all contexts by facilitating co-created, negotiated rules that adapt to shifting capacities, actors, and incentives across scales.

More broadly, fields such as Multi-Level Governance (MLG; Tamtik & Colorado, 2022), Post-Normal Science (PNS; Funtowicz & Ravetz, 1993), Mode 2 Knowledge Production (Gibbons et al., 1994; Nowotny et al., 2001), and Strategic Environmental Assessment (SEA; Partidário, 1996) have sought to expand the epistemological and institutional foundations of science-policy engagement. Each of these approaches contributes valuable insights: MLG clarifies institutional complexity and cross-scale coordination; PNS and Mode 2 reframe knowledge production under uncertainty; and SEA integrates long-term environmental considerations into policymaking. Yet, while each enriches our understanding of sustainability governance, they often fall short in converting pluralistic knowledge and contested values into adaptive, negotiated action.

The EDF does not reject these established approaches but builds on them in a unique and actionable way. Where Adaptive Management fosters iterative learning, EDF adds the capacity to engage contested values. Where Resilience Thinking supports systemic robustness, EDF provides a path to reconcile competing interests. Where IWRM calls for structural integration, EDF supports dynamic coordination grounded in local realities. Where Ostrom's principles suggest durable governance designs, EDF operationalizes them under evolving and uncertain conditions. And where PNS and Mode 2 challenge the limits of traditional science, EDF translates pluralistic knowledge into context-sensitive interventions.

Framework	**Strength**	**EDF Contribution**
Adaptive Management	Iterative learning under uncertainty	Adds engagement with ambiguity and contested goals
Resilience Thinking	System robustness and tipping points	Adds negotiated legitimacy and framing of whose resilience matters
IWRM	Sectoral integration and participation	Replaces procedural idealism with adaptive coordination
Ostrom's IDPs	Institutional durability	Extends to fluid, cross-scalar contexts with co-created governance

The Engineering Diplomacy Framework extends the foundational insights of Water Diplomacy into a broader arena of sustainability challenges by emphasizing negotiated problem framing, adaptive learning, and action-oriented synthesis of numbers and narratives. The three core metaphors—"What is one plus one?", "Where do we put the X?", and "How do we divide 17 camels?"—function not merely as explanatory devices, but as operational heuristics for navigating complexity, ambiguity, and contested values. These principles offer a decision-centric and stakeholder-aware foundation for addressing the gaps between global sustainability targets and local realities. In the context of SDG 6.4, EDF provides the tools to reinterpret static indicators, recognize multi-scalar trade-offs, and reframe implementation from rigid compliance toward negotiated, adaptive, and co-created interventions with desirable outcomes.

2.3. Principles of the Engineering Diplomacy Framework (EDF)

At the core of Engineering Diplomacy is the synthesis of scientific and social facts. While scientific facts—such as the laws of physics governing water flow—are measurable and replicable, solutions implemented in a social context must address social facts—such as cultural values, political dynamics, and economic interests. For example, water in the American West "flows uphill toward

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money," reflecting how economic and political factors shape decisions that override purely technical solutions. The EDF recognizes that solutions must be negotiated, adaptive, and co-created with stakeholders to ensure long-term success. EDF embraces three key principles:

- **Fallibilism**: All solutions are provisional and must be open to revision.
- **Co-creation**: Solutions must be developed through inclusive stakeholder engagement.
- **Principled Pragmatism**: A balance between scientific rigor, societal acceptability, and political feasibility.

This triad enables EDF to go beyond technical fixes and normative ideals to create actionable pathways that are scientifically credible, socially legitimate, and politically feasible. To guide action in addressing collective action challenges, EDF draws upon **three metaphorical insights.**

2.3.1. Shared Understanding: What Is One Plus One

In collective action problems, meaning may matter as much or more than measurements. At first glance, one plus one equals two. Yet depending on context, the answer changes. A mathematician sees a universal truth; an engineer, aware of measurement uncertainty, may call it approximately two; a social scientist asks: are we adding apples, oranges, or both? For complex problems, **facts and values are intertwined**, and meaning of 'one plus one' depends on context, purpose, and perspectives.

Actionable Insight: Engineering Diplomacy treats "1 + 1" not as a fixed sum but as a **creative synthesis of scientific facts and social narratives.** Rather than seeking singular solutions, EDF fosters shared understandings that are scientifically defensible and socially acceptable. It frames problems as a negotiation between numbers and narratives, where "truth" is actionable and rooted in multiple perspectives. Practically, this means, for example, tackling sustainability challenges (such as SDG 6.4) by synthesizing diverse ways of defining water scarcity and human suffering to create pathways for desirable outcomes.

2.3.2. Strategic Intervention: Where Do We Put the 'X'?

Doing less sometimes can accomplish more if the "X" is well placed. This principle is captured by the metaphor "Where to put the 'X'?"—a reminder that skillful diagnosis, not scale of action, often determines impact. Charles Steinmetz solved a massive technical failure at General Electric by simply drawing a chalk mark of "X"—because he knew precisely where to put the "X" (Islam 2025). The lesson: **diagnosing the problem skillfully** is often more valuable than elaborate interventions.

Actionable Insight: In Engineering Diplomacy, the "X" symbolizes **principled pragmatism:** strategic diagnosis and minimal, high-impact interventions. EDF urges practitioners to engage early, listen deeply, diagnose precisely, and intervene strategically—especially critical in resource-constrained or politically sensitive environments.

In practice, rather than defaulting to costly infrastructure, EDF encourages pinpointing bottlenecks, misaligned incentives, or trust deficits, and designing small, meaningful adjustments for high impact. In the context of SDG 6.4, this could mean identifying a local water governance bottleneck or a misaligned policy incentive rather than defaulting to expensive infrastructure. EDF prioritizes insight over impulse, encouraging engineer-diplomats to pause, diagnose, and engage stakeholders before acting. The "X" becomes a symbol of principled pragmatism—a moment where technical knowledge intersects with systemic awareness to guide minimal interventions for maximum-impact.

2.3.3. Exploring Options: How Do We Divide 17 Camels into Halves, Thirds, and Ninths?

Sometimes creative problem-solving requires shifting the frame, not solving the old problem with existing procedures and protocols. n the fable, Ia seemingly impossible division problem is solved by finding the *"18th camel,"* making the division feasible (Islam 2025). **Reframing the**

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problem—not forcing the old frame—unlocked a solution. This insight draws from the metaphor of the "17 camels"—where introducing the 18th camel unlocked an otherwise impossible solution.

Actionable Insight: When conventional tools fall short, Engineering Diplomacy encourages the power of **creative reframing.** Sometimes the way forward is not to split the unsplittable but to introduce a bridging element—a temporary institution, a new metric, a reframed question—that unlocks new options.

In practice, solving the 17th camel puzzle represents the creative, often non-obvious element (finding the 18th camel) that breaks a deadlock: a temporary institutional arrangement, a shared indicator, a third-party facilitator, or a reframed question. For sustainability challenges, it might be a regional mechanism that makes resource sharing palatable to all sides, or a shared definition of "suffering" under SDG 6.4 that makes monitoring actionable. Engineering Diplomacy draws from this wisdom: when technical tools fall short, introduce a perspective shift. That's how complex, coupled systems become manageable—not through established protocols or procedural interventions, but through reframing and exploring options that were not considered before.

Together, these three insights highlight the core of Engineering Diplomacy: a principled, pragmatic approach that transforms abstract goals into grounded, context-sensitive actions that are scientifically credible, socially legitimate, and politically feasible.

3. Evaluating SDG 6.4 with Engineering Diplomacy Framework

The EDF offers a way to transform abstract global goals—such as those under the SDGs—into grounded interventions that recognize the messy, value-laden, and politically complex nature of real-world problems. It is not a static toolkit but a way of thinking, acting, and adapting. Rooted in decade long work on water diplomacy, EDF invites engagement from those seeking to make collective action work where neither technical certainty nor political consensus alone is enough. The EDF is designed for those who navigate contested, uncertain problems—engineers who must negotiate trade-offs, policymakers managing stakeholder conflicts, and practitioners facing plural narratives under resource constraints. The EDF **transforms problems into co-created interventions for desirable outcomes using the following three actionable ideas and shows how to apply EDF in practice.**

- **Shared Understanding - Synthesize** facts and values (1+1=?)
- **Strategic Intervention - Diagnose and act strategically** (where to put X)
- **Exploring Options - Reframe creatively** (find the 18th Camel)

3.1. Definitional Ambiguity and the Challenges of Measuring Human Suffering

Sustainable Development Goal target 6.4 aims to tackle water scarcity in a broad sense. It is officially stated as: "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity" (UN Water, 2023; UNStats, 2024). This definition notably blends objective measures (improving water-use efficiency, keeping withdrawals within sustainable supply) with a subjective, human-centric outcome (reducing the number of people "suffering from water scarcity"). The inclusion of the term "suffering" marks an explicit concern for human well-being, but it also introduces ambiguity: unlike efficiency or withdrawal rates, "suffering" is not straightforward to quantify. In fact, while two global indicators were agreed for efficiency and water stress (6.4.1 and 6.4.2), no direct indicator was adopted to measure "people suffering from water scarcity" (UN ESCWA, 2022). UN water experts have pointed out that this leaves "a target without a global indicator" for the human impact component (UN Water, 2023). Effectively, countries report on technical metrics under SDG 6.4, but there is no formal tracking of the population actually experiencing water scarcity. This gap between the phrasing of the target and its monitoring framework raises an important question: **are we measuring what truly matters?**

From an Engineering Diplomacy Framework (EDF) perspective, this is akin to asking ***"What is one plus one?"*** – a metaphor for ensuring all stakeholders agree on basic definitions and goals. If

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different parties sum up progress in different ways (e.g. engineers focusing on efficiency gains, policymakers on human livelihoods), the overall outcome can be misunderstood. Applying the "1+1" metaphor here emphasizes the need for a common understanding: How do improved efficiency and reduced human suffering add up to water security? Without a clear, shared definition of water scarcity that includes both physical supply and human experience, the target's ambition can be interpreted in divergent ways. For example, a technocratic view might celebrate gains in water-use efficiency even if local communities still lack water. Conversely, a humanitarian view might focus on access and equity, even if efficiency or sustainability metrics lag. EDF would first seek to reconcile these views, ensuring that the *"one"* of technical progress and the *"one"* of human well-being are measured in compatible units so that *1+1 indeed makes 2*. In practice, that could mean developing complementary indicators or qualitative assessments so that "suffering from water scarcity" is not lost in translation. In summary, SDG 6.4's wording is ambitious but internally inconsistent; clarifying this blend of objectives is the first step toward a coherent evaluation of progress. While the definitional ambiguity raises concerns about what is being measured, indicator reliability and reporting challenges may further complicate implementation.

3.2. Measuring What Matters: National Level Gaps and Consequences

Indicators 6.4.1 and 6.4.2 are central to evaluating water efficiency and stress. Indicator 6.4.1 tracks the economic output per volume of water withdrawn, effectively measuring how much value (in constant USD) is generated per cubic meter of water used (Hellegers et al., 2021). Change in water-use efficiency (WUE) over time is used for indicator 6.4.1. Its rationale is to decouple economic growth from water use, encouraging countries to produce more with less water. Indicator 6.4.2 monitors the fraction of renewable freshwater resources being withdrawn, accounting for environmental flow needs, with values above 25% suggesting water stress and over 100% indicating unsustainable withdrawals (FAO & Stockholm Resilience Centre, 2020; UN Water, 2023).

In practice, however, many countries struggle to measure these indicators consistently due to data gaps and weak reporting infrastructure. According to UN Water (2021) and UNStats (2024), methodologies exist but reporting remains uneven, especially among lower-income countries. Average national reports cover only five out of twelve SDG 6 indicators. Moreover, data are often aggregated at the national level, masking local and seasonal variability in water stress. For example, a country may report 20% national stress, while specific basins face over 50% (Liu et al., 2017). Meanwhile, no direct metric exists for the number of people suffering from water scarcity (UN ESCWA, 2022).

Beyond data gaps, 6.4.1 has been critiqued for its economic bias. It aggregates productivity in agriculture, industry, and services into one metric, inherently favoring economies with smaller agricultural sectors. Cross-country comparisons become misleading: for instance, Nepal may be more efficient in water use but still ranks lower than Serbia because Serbia's economy is less dependent on agriculture (Yale Water Management Initiative, 2022). The result is a distortion that privileges economic transformation over actual water-saving. WUE also overlooks non-economic values such as social or ecological benefits and omits reuse flows, leading to inflated efficiency estimates and possible perverse incentives (Hellegers et al., 2021). Consequently, a nation could score well on paper (high $\$/m^3$) while its rivers run may dry and communities downstream may suffer.

Water stress metrics (6.4.2) are more direct but still limited. While incorporating environmental flow requirements, they are reported annually and nationally, missing seasonal and spatial nuances. Analysts note that water stress assessment should distinguish net consumptive use from total withdrawals, especially in contexts with high reuse or desalination (Liu et al., 2017). For instance, Singapore, which depends on imported and desalinated water, would appear highly stressed if only internal renewable supply is considered. Yet SDG accounting omits these external sources, reducing apparent stress (PUB Singapore, 2020). In short, indicator 6.4.2 is a valuable gauge of national water balance. Yet it might not capture, for example, acute seasonal shortages or the dependence on shared rivers and non-renewable aquifers.

Given these issues, how tractable is SDG 6.4 at the national level? Countries can certainly report trends in WUE and water stress, and global data suggest mixed progress. Between 2015 and 2020, global water-use efficiency improved about 9% (from \$17.4 to \$18.9 per m^3) indicating a positive trajectory UNStats 2024). Water stress globally has crept up slightly (from ~17% to 18.2%), remaining "safe" on average but with dangerous regional spikes. For example, Northern Africa's water stress now exceeds 100% (meaning consumption of non-renewable or imported water) and rose 15 percentage points in five years (FAO and Stockholm Resilience Center (2020). These high-level numbers are informative, yet they hide vast internal disparities. Roughly *one quarter of the world's population faces extremely high-water stress* in their locale despite the global average stress being moderately higher. And notably, "none of the SDG 6 targets are on track to be met" as of 2022 (UNStats 2024). These aggregated statistics obscure internal disparities. In EDF terms, the metrics risk "putting the equals sign in the wrong place" – tracking efficiency and withdrawal figures without confirming their translation into human well-being.

3.3. Lessons from Practice: Singapore, Denmark, DRC, and Jordan

To appreciate the strengths and gaps of SDG 6.4, it is helpful to examine how it plays out in different country contexts. **Singapore**, **Denmark**, **Democratic Republic of Congo (DRC), and Jordan** offer a rich contrast: Singapore and Denmark are advanced economies known for proactive water management (one extremely water-scarce, the other water-rich but conservation-minded), whereas DRC is a developing nation with abundant water on paper but severe capacity challenges. We also draw on the case of Jordan – as a quintessential water-scarce country – where progress came not from a singular blueprint, but from pragmatic adaptations rooted in political feasibility, scientific diagnostics, and social legitimacy.

Singapore: Water Scarcity Met with Innovation and Diplomacy. Singapore consistently ranks among the most water-stressed countries by conventional measures. The World Resources Institute projected Singapore to be one of the world's top water-stressed nations by 2040, given its tiny internal catchment and high demand. Indeed, Singapore's renewable internal freshwater resources are negligible (it lacks large rivers or aquifers), so if it relied solely on rainfall, its 6.4.2 water stress would be astronomically high. However, Singapore illustrates how engineering and policy can overcome physical scarcity – a success that also exposes how SDG 6.4 indicators have limitations. Over decades, Singapore invested in a "Four National Taps" strategy: (1) local catchment rainwater, (2) imported water, (3) NEWater (high-grade recycled wastewater), and (4) desalinated water. Through innovation, it has built a diversified water supply that is largely climate resilient. As of the 2020s, five NEWater plants meet up to *40% of Singapore's current water needs*, and combined with seawater desalination, these non-conventional sources are set to provide *85% of Singapore's water by 2060* (PUB Singapore 2020). This is a remarkable feat of efficiency and sustainability – effectively finding the **"18th camel"** (extra water) to solve the scarcity puzzle. From a human perspective, Singapore has achieved universal access to safe water and sanitation; no one in the country "suffers" from water scarcity in the sense of lacking access to drinking water and sanitation.

Yet, Singapore's situation also highlights SDG 6.4's nuances. Its water-use efficiency (6.4.1) in economic terms is extremely high – by virtue of its developed, service-oriented economy, not just its water policies. A single cubic meter of water in Singapore supports many dollars of GDP (finance, electronics, etc.), far more than a cubic meter used in farming would. Thus, Singapore would score well on 6.4.1 by economic metric alone, even if it were not a model of water recycling. The target of "increasing water-use efficiency" is certainly being met, but one must ask: how much of that is due to deliberate efficiency measures versus the inherent advantage of having relatively little agriculture? This echoes the critique that cross-country WUE comparisons can mislead (Yale Water Management Initiative 2022). Singapore's water stress (6.4.2) is also a complicated story. If calculated naively as withdrawals over internal resources, it would exceed 1000% – but in practice Singapore mitigates stress via imports and desalination. Under SDG accounting, water imported from Malaysia or produced by desalination is not counted as "freshwater withdrawal," which *reduces* the stress ratio.

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By 2018, Singapore's reported water stress was around 67% (still "high" but not catastrophic), thanks to these external sources. The key point is that *national water stress can be managed by looking beyond national borders and natural endowments*. Singapore did exactly that through a long-term import treaty with Malaysia and heavy investment in technology. This kind of solution is not explicitly encouraged or captured by SDG 6.4, which focuses on within-border efficiency and withdrawals. However, it has been essential for Singapore's water security. In Engineering Diplomacy terms, Singapore knew *"where to put the X"*: it identified critical interventions – recycling, desalination, regional cooperation – and executed them to ensure water availability (Fu 2019).

While Singapore's innovation-led model shows how strategic engineering and regional diplomacy can overcome physical scarcity, countries with more moderate endowments but strong governance—such as Denmark—demonstrate how conservation and public values can drive efficiency from a different angle.

Denmark: Efficiency through Governance and Culture. Denmark provides a different angle – a country with moderate water resources that has chosen to use water very sparingly. With about 1,000 m³ of renewable water per capita, Denmark is not abundantly endowed (it borders the threshold of water scarcity by some definitions). However, Denmark experiences ample rainfall distribution and has modest water needs, so it does not face the kind of acute scarcity seen in arid regions. Its water stress (6.4.2) is low; for instance, Denmark withdraws a small fraction of its available freshwater (primarily for domestic and industrial use, with very limited irrigation). More striking is Denmark's achievement in water-use efficiency and conservation. Culturally and politically, Denmark treats water as a precious resource. The average Dane uses only ~100 liters of water per day at home (Smart Water Magazine 2021) far below the European average of 128 L and even below some much drier countries' usage. This has been accomplished through a combination of high-water pricing (among the highest in Europe, at over €8 per cubic meter) and public awareness . The high tariffs both incentivize users to conserve and provide revenue to maintain top-tier water infrastructure (leakage is very low, and tap water is of excellent quality). Notably, Denmark's example shows that efficiency is not only a technological matter but a governance one: regulation and societal values can drive down water waste significantly (Smart Water Magazine 2021).

On SDG 6.4's metrics, Denmark would report a continually improving or already high water-use efficiency, though again one must interpret that properly. Much of Denmark's economy is in services and industry, which yield high value per drop. But even within sectors like domestic use, Denmark has improved (per capita use was around 150 L/day a few decades ago, now ~100 L). In agriculture, farmers in Denmark use relatively little irrigation thanks to a temperate climate, but they also employ efficient practices when needed. In effect, Denmark may serve as a benchmark of "sustainable withdrawals" in an industrialized context: it uses water prudently, stays well within renewable supply, and ensures virtually the entire population has access to safe water and sanitation (thereby no one is "suffering" from lack of water services). However, one could argue Denmark's situation is somewhat *outside* the core concern of SDG 6.4 – Denmark doesn't have a water scarcity crisis to solve; it has already achieved a balance. The target of substantially increasing efficiency might be less urgent for countries like Denmark than for water-scarce nations. In fact, Denmark's per-unit cost of squeezing further efficiency gains might be high, given diminishing returns. Nonetheless, Denmark's approach offers lessons: effective institutions and public engagement can yield a high standard of water management that aligns perfectly with SDG goals (including integrated management and participation, as in SDG 6.5 and 6.b). It also underscores that high efficiency does not automatically impede economic development – Denmark's economy grew even as water use declined, exemplifying the decoupling that SDG 6.4 envisions. In EDF terms, Denmark's story reflects consensus on "1+1" (shared understanding that water saving is good for all) and an intuitive grasp of "where to put the X" (targeting leaky distribution systems and consumer behavior as key leverage points).

Yet, high-functioning governance and infrastructure are far from universal. In stark contrast, the Democratic Republic of Congo offers a paradox: abundant water resources coexisting with acute water scarcity at the household level—challenging the assumptions embedded in SDG 6.4 indicators.

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Democratic Republic of Congo (DRC): The Paradox of Plenty. The DRC presents a starkly different scenario – one that exposes a crucial gap in SDG 6.4's relevance. The DRC is water-rich: it holds over 50% of Africa's total renewable water resources in the vast Congo River basin (World Bank 2022). Per capita renewable water is on the order of 20,000–30,000 m³/year (among the highest in the world). By the SDG 6.4 definition of "addressing water scarcity," one might assume the DRC has little to worry about. Its water stress (6.4.2) is extremely low – only a tiny fraction of its freshwater is withdrawn annually. Agriculture is largely rain-fed, and industrial water use is minimal; most of the Congo's flow runs untouched to the Atlantic Ocean. But this abundance is tragically misleading. In reality, millions of Congolese *do* suffer from water scarcity in a practical sense: scarcity of access to clean and reliable water. Only about 52% of DRC's population has access to an improved water source and far fewer have tap water at home (World Bank 2022). The country's infrastructure is so underdeveloped that even basic needs aren't met, despite nature's bounty. This is often termed economic water scarcity – the lack of investment and institutions to make water available to people – as opposed to physical scarcity. The DRC highlights that SDG 6.4's indicators (efficiency and stress) can paint a very rosy picture that belies on-the-ground suffering. A DRC official could report to the UN that the country has nearly 0% water stress and that efficiency is increasing (not that the latter is even a priority when much of the water use isn't measured at all). Meanwhile, Congolese people face what one World Bank account calls *"daily challenges"* and a *"hygiene problem"* due to lack of running water, which severely impacts living conditions in cities like Kinshasa (World Bank 2022). This is precisely the kind of "suffering" that the SDG 6.4 target phrase implores to reduce – yet the global tracking framework would pick it up only indirectly, via other SDGs (e.g. SDG 6.1 on drinking water access). The DRC's case underscores the importance of connecting SDG 6.4 with the broader water agenda: efficiency and sustainable use at the national level mean little if they do not translate into water security for communities. In terms of EDF, the DRC exemplifies a situation where the technical numbers and the narrative of human well-being are completely out of sync. Bringing those together – making 1+1=2 – would require channeling the DRC's ample water through infrastructure and governance improvements so that people benefit from the resource. It's a reminder that achieving SDG 6.4 is tightly interlinked with achieving SDG 6.1 and 6.2 (water supply and sanitation for all). Ignoring that interdependence can lead to misleading victories on paper.

Where the DRC highlights economic scarcity amid resource abundance, **Jordan faces the inverse**: extreme physical water scarcity met with adaptive policy strategies. Jordan's experience brings the transboundary dimension into focus and reveals how regional cooperation—enabled by strategic diplomacy—can reframe even the most constrained conditions.

Jordan: Coordinated Action and Desirable Outcomes Despite Physical Scarcity - Jordan unlike the DRC, faces absolute physical scarcity. Jordan's renewable water per capita is under 100 m³ – among the lowest in the world (UNICEF 2020). By SDG 6.4 metrics, Jordan's water stress hovers around or above 100%, indicating it is extracting essentially all available water. This is a textbook case for the "sustainable withdrawals" part of the target. Jordan has tried to increase water-use efficiency across all sectors out of necessity: it has ambitious programs for improving irrigation efficiency, reducing municipal non-revenue water (currently still a high 52% lost through leakage or theft), and reusing wastewater (treated wastewater now constitutes a significant portion of water available for agriculture in Jordan). Despite these efforts, Jordanians still experience scarcity in daily life – most households receive water only once a week or less, storing it in roof tanks for use throughout the dry days (UNICEF 2020).

Facing mounting stress, the country implemented an integrated national strategy with political backing, technical innovation, and stakeholder engagement (UN Water, 2023). Jordan invested in wastewater reuse, expanded storage, adopted drip irrigation, and introduced decentralized water utilities to improve service delivery and accountability. Crucially, these technical interventions were matched by localized coping mechanisms (e.g., rooftop tanks, tanker regulations) and participatory rulemaking.

The three metaphors of EDF are evident in this success. First, the notion that "1 + 1 is not always 2" was embodied by the synthesis of centralized engineering plans with decentralized community

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responses. Jordan didn't rely solely on top-down projections or technocratic optimization; it framed progress as a negotiated blend of statistical goals and lived experience. Second, "putting the X" was evident in the strategic focus on wastewater reuse and utility reform—interventions that yielded the most impact for the least institutional friction. Rather than launching massive, politically contentious infrastructure, Jordan identified leverage points that restructured incentives and improved efficiency. Third, finding the "18th camel" metaphor came into play as the government created temporary arrangements to stabilize demand—such as tank systems in underserved areas and public-private partnerships—while building longer-term infrastructure.

The transboundary dimension may play an important role. Jordan shares the Jordan and Yarmouk rivers with neighbors and relies on cooperation (or sometimes lack thereof) which directly affects its water stress. As noted earlier, purely national indicators don't account for upstream usage or political agreements. For Jordan to "ensure sustainable supply," it can engage in diplomacy with Israel, Syria, and others. In 2021, a breakthrough regional deal was brokered (with the United Arab Emirates' help) between Jordan and Israel – a **"**water-for-energy" exchange that epitomizes an EDF approach. Under this plan, Jordan will build 600 MW of solar capacity to export power to Israel, and in return Israel will provide Jordan with 200 million cubic meters of desalinated water annually (Reuters, 2021). This creative arrangement effectively injects a new source of water (desalination from the Mediterranean) into Jordan's supply, an *18th camel* that makes the otherwise impossible division of scarce water a win-win solution. It shows how addressing SDG 6.4 in a place like Jordan may require going beyond one country's actions – it encourages regional cooperation and innovation. Jordan's example reinforces that without integrating the transboundary aspect, SDG 6.4 efforts can fall short. Globally, less than 20% of countries that share transboundary waters have fully operational agreements covering all shared rivers, lakes, and aquifers. This is a major gap, since water stress in one country often results from overuse or climate impacts in a shared basin. Jordan's progress (or lack thereof) on 6.4 is linked with how neighbors manage shared water (SDG 6.5.2 on transboundary cooperation). An engineering diplomacy viewpoint would encourage looking for mutual gains – like Jordan's solar-for-water trade – rather than zero-sum thinking.

Taken together, these national experiences illustrate not only the diversity of water sustainability challenges, but also the power of contextual diagnostics and negotiated problem-solving approaches. They lay the groundwork for the EDF framework's metaphors to be applied in evaluating how and why SDG 6.4 succeeds or falters across settings.

3.4. Translating EDF into Practice to Address Water Sustainability Goals

EDF helps make sense of SDG 6.4's inconsistencies and reveals opportunities to enhance its implementation:

- **"What is 1+1?"** EDF urges a common framing that aligns technical progress with reductions in human suffering. Countries might adopt supplemental indicators, like population experiencing water scarcity (UN ESCWA, 2022), to connect metrics to lived experiences.
- **"Where do we put the X?"** EDF helps prioritize interventions. In Jordan, fixing leaks yields large gains; in Singapore, recycling was key. In the DRC, building institutions is the first step. The "X" must also be socially and politically viable.
- **"How do we divide 17 camels?"** EDF supports fair and creative allocation. Israel-Jordan's desalination trade is one example. Reallocating water savings from agriculture to households or ecosystems is another. These arrangements, like the metaphor, seek win-win outcomes.

EDF bridges numbers and narratives, moving beyond indicator compliance toward actionable and trackable progress. With SDG 6.4 off track globally (UNStats, 2024), adopting EDF's interdisciplinary and diplomatic lens can help translate data into durable, equitable water security and desirable outcomes.

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3.5. Methodological Scope and Limitations

This paper offers a conceptual and integrative analysis of SDG 6.4 through the lens of the Engineering Diplomacy Framework (EDF), grounded in comparative case studies and qualitative synthesis. The methodological approach is interpretive rather than empirical: it draws upon existing global datasets, policy reports, and secondary literature to explore the operational and epistemological gaps in how water-use efficiency and scarcity are defined, measured, and addressed. By employing metaphorical reasoning ("1+1", "Put the X", and "17 Camels"), the paper introduces a heuristic structure for diagnosing sustainability challenges and identifying actionable entry points for negotiated solutions.

This approach has several strengths. It allows for cross-contextual comparisons across varied geographies (Singapore, Denmark, DRC, Jordan), each exemplifying different water-related constraints, governance logics, and institutional capacities. It also foregrounds issues often overlooked in indicator-based evaluations, such as stakeholder perceptions, institutional flexibility, and transboundary dependencies. However, several limitations need to be acknowledged.

First, the analysis is not supported by primary fieldwork, stakeholder interviews, or original statistical modeling. Its reliance on secondary data—though robust and diverse—means that certain claims, especially those related to governance behavior or user experience, are based on interpretations of existing accounts rather than direct observation. Second, the metaphor-based framing, while effective in illustrating multi-dimensional challenges, may not translate easily into formal policy design without further empirical grounding. Lastly, while the selected countries provide illustrative variation, they are not exhaustive; additional cases from other climatic, institutional, and geopolitical contexts could yield further insights.

Despite these limitations, the methodological intent of the paper is not to generalize universally, but to demonstrate how EDF can guide context-sensitive reasoning under uncertainty and ambiguity. It offers a framework that can inform both research and practice, inviting further empirical validation, participatory co-production, and refinement across disciplines.

4. From Diagnosis to Action—Operationalizing EDF for SDG 6.4

While global frameworks like SDG 6.4 provide a useful baseline for water governance, their effectiveness depends on how well they align with local realities and enable actionable change. The EDF, grounded in fallibilism, negotiated problem framing, and principled pragmatism, offers a pathway for bridging this gap. This section summarizes key takeaways from the earlier analysis into **three interrelated set of actions** that support the implementation of SDG 6.4 in ways that are **credible, feasible, and societally acceptable.**

4.1. Rethinking Metrics and Meaning: Synthesize Numbers and Narratives

- **Reexamine Indicator 6.4.2** to reflect *not just aggregate water stress*, but **functional access to water** at multiple scales. Reporting should distinguish between physical scarcity, economic scarcity, and institutional inaccessibility.
- **Integrate qualitative diagnostics** such as user perceptions, local knowledge, and governance bottlenecks into SDG reporting templates. For instance, community-defined thresholds for "suffering" may offer a better indicator of lived water insecurity than percentage withdrawal alone.
- **Account for scale and context** by supplementing national averages with subnational reporting and cross-sectoral disaggregation. Water-use efficiency in urban industrial zones cannot be directly compared to remote agrarian regions.

These shifts reflect EDF's ***"Where do we put the X?"***—they highlight how data needs to be targeted, contextualized, and decision-relevant rather than simply collected.

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4.2. Enhancing Governance and Participation: Whose Problems? Whose Solutions?

- **Foster multi-stakeholder dialogue** to build shared problem frames, especially in contexts where SDG targets are contested or disconnected from local narratives. This requires institutional platforms that encourage negotiation, not just compliance.
- **Embed participatory foresight** into water planning to move beyond reactive governance. EDF encourages looking forward while acknowledging ambiguity—opening room for scenario-based planning and iterative learning.
- **Link indicators to institutional accountability**, not just reporting. For example, where 6.4.1 shows improvement in efficiency, EDF asks: *Whose efficiency? At whose cost? To whose benefit?*

These actions reflect EDF's metaphor ***"What is one plus one?"***—building shared understanding and revealing pathways for mutual gain, even under conflict or constraint.

4.3. Engineering Diplomacy in Action: From Knowledge to Negotiated Action

- **Use metaphors as diagnostic and communication tools**. Practitioners can explore **"finding the 18th camel"** to discuss equitable allocation across ministries or regions without defaulting to zero-sum framing. These metaphors make ambiguity actionable.
- **Build capacities for adaptive decision-making**, not just compliance reporting. This includes empowering professionals who can synthesize numbers and narratives and translate global indicators into locally negotiated actions.
- **Design experiments** that test SDG implementation pathways under local constraints—mini "pilots" that blend technical design and negotiated agreement. EDF supports *learning by doing* rather than waiting for perfect plans.

This set of actions reflect EDF's ***"How do we divide 17 camels?"***—a reminder that creative solutions often emerge through negotiation, not optimization.

Taken together, these actions represent a shift from viewing SDG 6.4 as a fixed target to treating it as a **negotiated problem-solving approach**—one that must be co-constructed, tested, and adapted across multiple levels. By integrating metaphors, metrics, and negotiated engagement, the Engineering Diplomacy Framework offers a structured yet flexible approach to make sustainability indicators meaningful, trackable, and ultimately, actionable.

5. Concluding Remarks

Reducing the number of people who suffer from water scarcity (SDG 6.4) is a formidable challenge, but one that can be met through coordinated efforts across scales. **Community-level initiatives** demonstrate the power of grassroots action and local knowledge, while **subnational programs** show that supportive policies and innovation can significantly improve water outcomes in even the driest regions. At the **international level,** cooperation and shared commitment provide the overarching framework and resources needed to accelerate progress. The analysis highlights that sustainability issues like water scarcity cannot be solved by treating them solely as a homogeneous global crisis – context-specific, scale-dependent solutions are essential to address the complex mosaic of water problems around the world. Embracing approaches such as engineering diplomacy can bridge the gap between global science and local realities, forging consensus-driven solutions that are both technically and socially robust.

Crucially, as we advance toward 2030, refining how we **measure and define progress** will determine our success. We must develop metrics that truly reflect human wellbeing and ensure that no vulnerable community is hidden in the averages. By designing targets and interventions with local context in mind, by monitoring through both human and hydrological lenses, and by evaluating adaptively, the world can move beyond lofty goals to on-the-ground impact. In sum, achieving SDG 6.4 will require coupling global vision with local action – a blend of ambition and pragmatism. With sustained commitment at all levels and a willingness to learn and collaborate across disciplines and borders, we can substantially reduce water scarcity and secure a more sustainable and equitable water future by 2030.

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