CASH Paradox, ReWASH, Bronze-2-Gold and JEDI AWAKENS: introduction of new concepts to enhance the sustainability of the water-energy nexus

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ABSTRACT: Amidst the escalating impacts of climate change and extreme weather events, participatory decision-making in water management stands out as a sustainable approach for disaster risk reduction. Hydrological disasters, such as floods and droughts, are increasing globally due to anthropogenic activities, necessitating adaptation in water infrastructure. The OECD projects severe water stress for 2.3 billion people by 2050 without new policies, affecting production and triggering conflicts. Water management solutions, employing participatory socio-hydrology, provide a sustainable framework. Thus, this article introduces three segments - Bronze-2-Gold, ReWASH, and JEDI AWAKENS - reconciling energy, water demand, and socio-hydrology. Bronze-2-Gold focuses on zero emissions and sustainable development. ReWASH addresses scarcity by recycling water, promoting a circular economy. JEDI AWAKENS emphasizes climate justice, equity, and inclusion in sustainable management, advocating for knowledge dissemination and social participation. The CASH Paradox highlights interdependencies between ecosystems, climate, and human systems, emphasizing the need for balanced policies. This multidisciplinary effort advocates for a future with zero emissions, mitigating risks, and promoting resilience.

KEYWORDS: Water-Energy Nexus. Virtuous Water Cycles. Sustainable Water Access. Environmental Justice. Adaptation knowledge Exchange.

Introduction

In the face of escalating climate change impacts, including a heightened frequency and intensity of unprecedented extreme weather events, participatory decision-making in water management is becoming an alternative for sustainable disaster risk reduction. According to Singh (1996), hydrological disasters refer to any kind of natural or man-made events that result in extreme floods and droughts, mudflows, landslides, and other water-related hazards. For example, in 2022, there were 176 reported instances of flood disasters and 22 cases of drought disasters worldwide, impacting over 164 million people, causing 10,555 deaths and resulting in economic losses exceeding US$79.1 billion (CRED, 2023). Climate change has contributed to increasing risks of hydrological disasters, leading to the need for adaptation and to develop safety measures in water infrastructure in order to ensure the safety of stakeholders (Carneiro et al., 2022).

Warmer climate with increased climate variability is increasing the risk of floods and droughts, as it intensifies water cycling and rainfall, making extreme events more frequent (Putra, Dewata and Gusman, 2021). Anthropogenic activities, such as greenhouse gas emissions, have also contributed to the increased risk of floods (Sabatino et al., 2020). Frequency of disasters is driven by aggregate CO2 emissions, while the severity is influenced by the trend in regional real GDP per capita (Chavez-Demoulin, Jondeau and Mhalla, 2021). As we grapple with the repercussions of climate change, understanding these intricate relationships is imperative for formulating resilient strategies and policies to mitigate the impact of extreme weather events on communities and ecosystems.

According to the OECD (2012), by 2050, without any new policy measures, freshwater availability will be further strained, with 2.3 billion more people than today projected to be living in watersheds under severe water stress, especially in the northern and southern parts of Africa, and South and Central Asia. As consequences, the water vulnerability can impose several consequences to society, impacting food and industrial production, increasing poverty, decreasing ecosystems services and life quality, inducing water-seeking migration, and triggering conflicts and protests for water (Gleick and Shimabuku, 2023). Thus, there is a necessity to formulate public policy measures aimed at ensuring water management safety and advancing sustainability, in line with the Sustainable Development Goal (Song and Jang, 2023).

Water management solutions, considering socio-hydrology approach with participative decision making, can be used to provide a framework to understanding the complex interactions between human activities and hydrological processes, allowing strategies for sustainable water management in the future (Xia, Dong and Zou, 2022). By studying multiple hazards in a joint framework and integrating results from qualitative and quantitative analyses, socio-hydrology can improve our understanding of human-water interactions and support Disaster Risk Reduction (DRR) in the short and long term (Vanelli and Kobiyama, 2021). Also, it allows society to search for new and renewable energy sources, minimizing the effects of climate change.

This paper endeavors to elucidate the intricate dynamics within water-energy demand pathways, shedding light on the coexistence of both deleterious and beneficial cycles. These cycles, whether vicious or virtuous, exert profound influences on both society and the environment, potentially culminating in unsustainable practices and heightened risks of hydrological disasters. Furthermore, this study pioneers the introduction of novel concepts, aiming to establish a groundbreaking framework for integrating socio-environmental-economic perspectives. This integrative approach seeks to navigate the paradoxical relationship between society and the economy's imperative need for natural resources and the simultaneous threat of environmental degradation.

The currently hydrological risks and disasters and the future perspective

It is widely known that the number of people affected by extreme weather events such as floods, droughts, storms, and wildfires has increased significantly in recent decades. For example: the 2008 Kosi River flood in India displaced 3 million people and destroyed several assets (Rajeev, 2020); in 2014, the rainfall patterns change from the Amazon basin induced a severe drought in São Paulo city, Brazil (Gesualdo et al., 2019); and the impacted Pacific Northwest forests in the USA due to wildfires (Halofsky et al., 2020).

Climate change is exacerbating disasters and the hydrological sensitivity, making it crucial adaptive measures for water infrastructure as a way to improve the resilience from unprecedented extreme weather events (Carneiro et al., 2022). As pointed out by Vörösmarty et al. (2021), this improvement has to be complemented with green alternatives in order to achieve more sustainable practice. Additionally, the adoption of non-structural measures, such as environmental insurances, new policies and co-participative approaches for making decisions, are needed to cope with extreme events such droughts or floods (Roslan et al., 2019; Andjelkovic, 2001).

Generating resilience also requires a bottom-up participative process. Here, the socio-hydrology methodology is essential, with community participation and strategies to sustainably manage water amidst complex human-hydrology interactions. This includes vulnerability assessments, inclusive decision-making, and adaptive policies that strengthen water systems against intensifying hydrological disasters (Xia et al., 2022). Furthermore, more research is still needed to fully understand these interactions and inform evidence-based policies that promote equitable and sustainable water management.

Vicious and virtuous cycle into the water and energy demand

The pathway of the water and energy demands by society are important and current factors that lead to two different types of cycles and can improve or deteriorate the relationship between the consumption of natural resources, as also the human’s life quality and the planet's health (Maddock, 2019). On the one hand, as shown in Figure 1, vicious cycles can be considered all non-sustainable responses for water or energy demand, relating to an increase of non-renewable energy and pressure on water resources, people and biodiversity. This performance triggers degradation and imbalance to the environment - as intensification of the climate change, loss of biodiversity and pollutants spreading - that returns back to the society with a bigger intensity and more challenges than before (Kamboj et al., 2020), generating interest conflicts between the stakeholders and increasing the risks to the human’s quality life and to the environment.

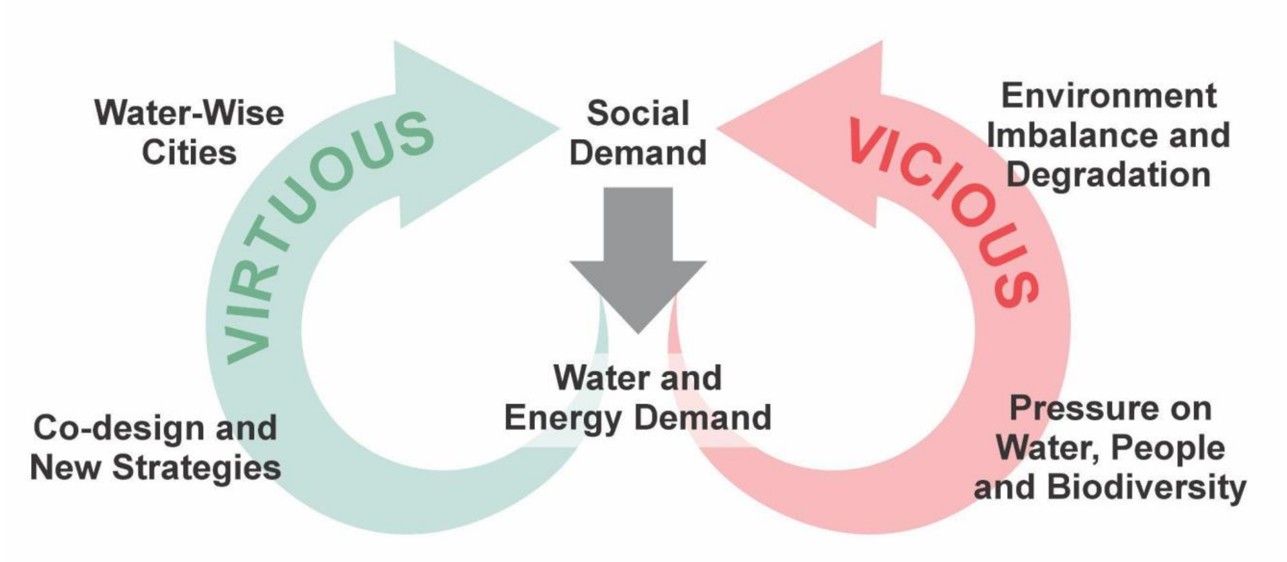

Figure 1 - Vicious and virtuous cycles related to water and energy demand by human society.

On the other hand, virtuous cycles can be considered as all the practices that contribute to sustainability of the water and energy demand, considering stakeholders in the decision making and the cogeneration of knowledge, promoting sustainable practice and wise-cities, improvements in the human's life quality and enhancement of the planetary's health. Thus, this approach search for new designs to overcome water and energy supply problems (Panagopoulos, 2021), with co-participation strategies (Li et al., 2022), as a way to achieve the balance between the stakeholders, using engineer tools and socio-hydrology thinking to minimize the impact of disasters and climate change on society (Venelli and Kobiyama, 2020).

Furthermore, new approaches for water management are being explored the achievement of sustanable goals, reducing water and carbon footprint. Therefore, there is a focus on macroscopic level for water management, which involves strategies such as recycling, reusing, and regeneration of water sources (Garcia and Ortega, 2016). Notwithstanding, the consideration of different stakeholders in the decision making for water management, knowing critical points and feasible solutions, thus avoiding losses in biodiversity and interest conflicts, contribute to increase nature's contribution to people and create a resilient society upon climate challenges (Lukasiewicz and Baldwin, 2014).

In this study, aiming to integrate the different approaches, as described before, reducing vicious cycles in the water and energy demand from different stakeholders, we present three segments that conciliate energy, water demand and socio-hydrology (Figure 2) to promoting virtuous cycles: (i) Broad Offsets of Net-Zero Emissions towards Goals for Leveraging Development (Bronze-2-Gold); (ii) Recycling Water Assets for Sustainable Habitats (ReWASH) and (iii) Climate Justice, Equity, Diversity and Inclusion Accelerate Water security and Adaptation Knowledge Exchange towards Net-zero and Sustainability (JEDI AWAKENS). All of those are grounded in the intricate interplay between watersheds, society, weather, and biodiversity, as elucidated by the Coevolution Assets of Symbiotic Habitats Paradox (CASH Paradox).

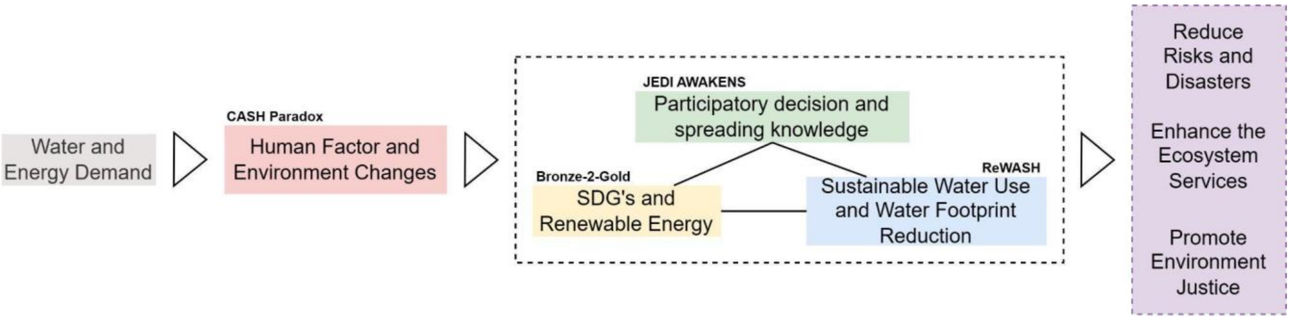

Figure 2 - Diagram representing the new approaches to conciliate energy, water demand and socio-hydrology.

CASH Paradox: Coevolution Assets of Symbiotic Habitats Paradox

The CASH concept focuses on describing the beneficial association between two or more ecosystems and how the disruption of this can lead into a paradox (i.e., natural and urban environment). Here, we highlight that the complex and evolutionary relationship between natural capital services and socio-economic interdependencies, encompass a wide range of factors that can significantly affect both ecosystems' sustainability. A negative interaction will be reflected on the availability and quality of ecosystem services, with implications for both environmental sustainability and human well-being (Hernández-Blanco et al., 2022). For example, as early mentioned, the Amazon rainforest and São Paulo case, changes in the Amazon can significantly disrupt rainfall patterns in São Paulo, influencing the transcontinental “flying river” of water vapor, and triggering droughts, water shortages, and economic challenges (Ferrante et al., 2023).

This approach exemplifies the paradoxical interdependencies between human and environmental systems. As human development leads to overexploitation of natural resources, it can undermine the ecosystems that sustain habitats and human well-being (Banuet, 2013). The environmental response by the degradation, in turn, drives back to the human and the natural habitats as a way of natural disaster, like unprecedented floods and droughts. For example, the deforestation in the Amazon disrupts a vital moisture source for the Cantareira system in São Paulo (Xu et al., 2022). Hence, sustainable techniques to manage these complex, paradoxical relationships require understanding the interdependencies between ecosystems, climate, and human system. Thus, there is a need for more research in this field, able to assist policies that can balance human development and the protection of natural capital assets This can help mitigate the cascading impacts of human activities on increased hydrological disasters.

JEDI AWAKENS: Climate Justice, Equity, Diversity and Inclusion to Accelerate Water security and Adaptation Knowledge Exchange toward Net-zero and Sustainability

The consequences of climate change pose a significant threat to society and the livelihoods of more than 3 million people living in highly vulnerable conditions (Birkmann et al. 2022). This marginalized group, in which the vast majority correspond to low-income communities or racial and ethnic minorities, faces the impacts inherent to climate change without efficient minimum support (Braga, Oliveira and Givisiez, 2016). Thus, climate adaptation should deliver triple benefits by preventing future humanity, nature and economic losses, facilitating economic growth by driving innovation in specific sectors crucial for water-energy management and achieving enhancements in both social and environmental aspects (Wang et al., 2021).

The possibility of the threat of sea level rise, extreme storms, forest fires and smoke from forest fires, heat waves and other events, trigger changes in ecological water flow regimes, as well as loss of ecosystem services due to the extinction of biodiversity, reiterating the adverse impact on the disadvantaged population, leading to further setbacks (Birkmann et al. 2022). Therefore, there is a critical need to confront the challenges within the water and energy resources sector, specifically addressing the issues of diversity, equity, inclusion, and justice in water governance and management (World Bank, 2019; Katusiime and Schutt, 2020).

The essence of JEDI AWAKENS, denoting climate **J**ustice, **E**quity, **D**iversity, and **I**nclusion to **A**ccelerate **W**ater security and **A**daptation **K**nowledge **E**xchange toward **N**et-zero and **S**ustainability, is intricately intertwined with the unwavering pursuit of justice and equality in water, energy and environmental matters, mindful of the needs of underserved communities. It involves the widespread dissemination of knowledge and the active encouragement of social participation (Pérez-Orellana et al., 2019). Hence, it is pertinent to link it to water inequality, signifying variations in water distribution and access influenced by factors like geography, infrastructure, resource availability, and financial capacity. (Cole et al., 2018; Rubin et al., 2023).

For example, Cole et al. (2018) presents the importance of measuring and monitoring water inequality to achieve the SDGs, which include goals related to clean water and sanitation for all. The universalization of basic sanitation means that all citizens should have access to proper water supply, sanitation, urban cleanliness, and solid waste management services (Batista, 2021). According to the World Health Organization (WHO), 2.3 billion people are still excluded from basic sanitation services. Furthermore, water and sanitation access inequality is pervasive in developing nations, particularly impacting marginalized communities such as slum dwellers, riverine populations, and indigenous communities (Bayu et. al, 2020).

Considering this issue, one of the possible solutions, encompassed in the acronym "Adaptation Knowledge Exchange towards Net-zero and Sustainability," is the development of social technologies to bring basic water access and sanitation to the well-being of the communities. This involves the development of social technologies aimed at enhancing basic water access and sanitation for the well-being of communities (Batista, 2021). Social technologies, encompassing cost-effective products, techniques, or methodologies, play a pivotal role in promoting social transformation and empowering specific communities. Through the democratization of basic sanitation, these technologies address community-specific issues, consider the desires and needs of the community, foster knowledge exchange, and contribute to sustainable local development (Kumar et al., 2020). The integration of socio-hydrology and participative sustainability approaches ensures a holistic and community-centered strategy for achieving water access and inclusion goals.

Bronze-2-Gold: **Broad Offsets of Net-Zero Emissions towards Goals for Leveraging Development**

Concerns related to the emissions of greenhouse gasses (GHGs) are a top priority, arising from the unsustainable lifestyles that are prevalent in our modern society. The methods of production and the ways we consume water and energy have been adversely affecting the environment and contributing to the rise in global temperatures, thus amplifying the impacts of climate change, including severe droughts and floods. Reports from the Intergovernmental Panel on Climate Change (IPCC) underscore the pressing need to curb the rapid temperature increase, emphasizing the critical importance of keeping global temperature rise below 1.5 °C in the coming years (Birkmann et al. 2022). As a result, reducing GHG emissions is a crucial global objective that aligns with Sustainable Development Goals (SDGs), and this can be achieved through adaptive measures by socio-hydrological approach.

Thinking about how we can address strategies to overcome these problematics, the concept of **Br**oad **O**ffsets of **N**et-**Z**ero **E**missions **to**wards **Go**als for **L**everaging **D**evelopment (Bronze-2-Gold) refers to a strategy in which the world looks to the equilibrium or compensation for its carbon emissions, through initiatives and actions that support achieving net-zero emissions and fostering sustainable development. This concept involves an integrative approach of activities, policies, or projects that not only reduce the GHGs emission but can contribute to reach the development goals linked to the Agenda 2030 (UN, 2015). In essence, it underscores the idea that environmental sustainability and socio-economic development can be mutually reinforcing, with emissions reductions and developmental progress going forward.

To reach that purpose, Shared Socioeconomic Pathways (SSP) play a key role (O'Neil et al., 2016). The SSPs comprise a textual description of how the future might unfold in terms of broad societal trends. It helps to complement quantitative model projection by associating causal relationships, including description of trends that are traditionally difficult to capture by models (Riahi et al, 2017). According to the authors, the pathways for the energy and land-use systems in the SSP scenarios translate into a wide range of GHG and pollutant emissions, which are correlated to the future challenges and adaptation for mitigation emissions of GHGs. SSP1 and SSP4 are related to the low fossil-fuels dependence and lower GHG emissions; SSP2 is an intermediate pathway, leading to high emissions; SSP3 and SSP5 are related to higher emissions and higher mitigation challenges. Therefore, actions and strategies towards a sustainable pathway will lead to a future with low GHG emissions and lower mitigation challenges for water supply and energy sectors.

Some projects and initiatives are being developed worldwide, trying to propose ways to decrease carbon emissions and increase the water resources disponibility. Ahmari & Mufti (2022) demonstrate the successful operation of the Carbon Capturing & Injection (CC&I) Project. The analysis of the financial and economic results in Montenegro shows that due to the thermal power reconstruction, increased use of renewable energy sources, contributed in reducing GHG emissions (Ćetković et al., 2021). In Brazil, in terms of public policy, we have a draft law number 572/2020 that creates the National System for Reducing Emissions from Deforestation and Forest Degradation (REDD+), whose main objective is to reduce national emissions of greenhouse gasses resulting from deforestation (Brasil, 2020). Another national example is the reports of the Energy Research Company (EPE), which have pointed out the necessary transition to a more "green" energy portfolio, contributing to reducing GHG emissions (MME, 2020).

Nonetheless, despite these examples, the road to a net-zero future, related to the water-energy nexus, remains far, needing more integrative approaches, combining multidisciplinary efforts of sectors, researchers and experts.

ReWASH: Recycling Water Assets for Sustainable Habitats (ReWASH)

The increase of water's demand due to population growth and the necessity to provide potable water for human activities and environmental purposes is getting worse by the intensification of climate change effects (Zhou et al., 2015). Thus, the reuse of water for non-potable applications or potable substitution has been proven internationally in water stressed regions to be a drought proof source of water and one of the most effective water scarcity solutions (Angelakis and Durham, 2006). This approach can help alleviate water scarcity and pollution issues, leading to social, environmental, and economic benefits.

The concept of **Re**cycling **W**ater **A**ssets for **S**ustainable **H**abitats is proposed to mitigate (or at least reduce the impact) of the drinking water, food and energy security, to achieve the goals of responsible consumption and production for sustainable management of freshwater resources. By recycling water assets (e.i. wastewater) and reusing it for potable and non-potable purposes, recycled water can become a significant source to handle water scarcity (Chen et al., 2013). In this context, two approaches have been considered: (i) the circular economy focused on the reuse of the water resources and (ii) the decentralized solutions for potable water and stormwater use.

In recent years, the first approach has garnered considerable interest, driven by the depletion of water sources in close proximity to largest metropolises, which has highlighted the imperative for sustainable water management. Consequently, the substantial generation of wastewater has pushed the exploration of water reuse as a viable alternative source (Berbel, Mesa-Pérez, and Simón, 2023). The implementation of circular economy principles in the water sector involves reducing, reusing, recycling, and recovering bodies of water (Fernandes and Marques, 2023). However, this transition towards the new paradigm of reuse wastewater faces challenges such as technological limitations, institutional barriers, and social acceptance (Nguyen et al., 2022). To attain this transformation, researchers must emphasize both technology development and the study of risk management (Ran and Nedovic-Budic, 2017). This dual focus is crucial to demonstrate to society that the exploration of this resource is not only feasible but can be accomplished through transparent regulation.

In contrast, decentralized solutions for potable water and stormwater management have garnered attention as a means to enhance water supply reliability, foster energy efficiency, and diminish the necessity for importing and exporting water across diverse watersheds. (Sharvelle, 2019). These local water sources can be treated within the community to remove contaminants and provide a secondary supply of potable water (Warsinger et al., 2018). Furthermore, a modeling approach incorporating decentralized options for stormwater and urban water supply management can evaluate management options like restrictive irrigation policies and rainwater harvesting (Sample and Heaney, 2006; Martín-Dato et al., 2023). This approach has shown that water reuse infrastructure investments, including managed aquifer recharge coupled with water reuse, are safe and sustainable solutions for water resource planning, particularly in the context of climate change (Chaudhry and Harper, 2023).

Conclusion

The escalating impacts of climate change, particularly hydrological disasters like floods and droughts, necessitate adaptive measures and sustainable strategies in water management. The socio-hydrology approach with participatory decision-making emerges as a promising framework to understand and address the complex interactions between human activities and hydrological processes. Thus, this paper introduced three innovative segments – Bronze-2-Gold, ReWASH, and JEDI AWAKENS – to reconcile energy, water demand, and socio-hydrology, with the aim of promoting virtuous cycles.

The CASH Paradox highlights the intricate relationships among ecosystems, climate, and human systems, emphasizing the need for balanced policies. JEDI AWAKENS focuses on climate justice and water inequality, advocating for inclusive governance. ReWASH promotes recycling water assets for sustainable development. Bronze-2-Gold outlines the necessity of strategy for net-zero emissions and socio-economic progress through environmental sustainability.

In essence, this paper urges for a multidisciplinary, collaborative effort to realize a net-zero future in the water-energy nexus. By fostering virtuous cycles, embracing participatory decision-making, and integrating innovative approaches, society can mitigate the risks associated with hydrological disasters, ultimately paving the way for a more resilient and sustainable future.

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