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Climate change impacts on current WEF Nexus challenges: A comparative assessment of WEF Nexus adaptation in developed and developing countries.

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Abstract

With global projections indicating a growing demand for freshwater, energy and food, the formation of the Water-Energy-Food Nexus approach seeks to cohesively address causes and effects and promote sustainable solutions. However, with climate change impacts threatening to exacerbate vulnerabilities and further disrupt ecosystem services, the pre-existing challenges of the WEF nexus are expected to worsen. This paper seeks to examine the current challenges of the WEF nexus and how climate change may intensify these challenges. To help understand effects and adaptation strategies, a comparison of case studies from the developed world (Korea, and the Danube River Basin) and the developing world (the SADC, and Tanzania) will be examined in order to identify the new challenges.

Key words: WEF nexus, climate change, climate change adaptation, challenges of WEF nexus, climate change induced vulnerabilities, developing countries, developed countries, SADC, Tanzania, South Korea, Danube River Basin, capacity-building, cooperation, SDG 6, SDG target 6.4, SDG target 6A

1.0 Introduction

Water scarcity and management are important topics in the discourse of development. In the past few years, methods of water management have been introduced into the discourse surrounding it, including Integrative Water Resource Management (IWRM). The WEF nexus (water-energy-food) became prominent in 2008 and onwards as it was increasingly recognized that there exist synergies and trade-offs between the water, energy, and food sectors. In this way, the WEF nexus approach is in line with the goals of SDG 6, particularly target 6.4 which promotes the sustainable and efficient use of water across all sectors. By acknowledging the interlinks, the WEF nexus approach allows for a more holistic management of the trade-offs, synergies, and interlinkages of the water, energy, and food sectors, and can allow for the creation of policies that are cognizant of these links.

The WEF nexus is fraught with pressures and challenges. With population growth, ecological factors, urbanization, changing consumer patterns, and the drive for economic growth, there are increasing pressures on the WEF nexus; with a growing population there's a greater demand for water, energy, and food for personal, industrial, and national use. Furthermore, the need for extensive data, and the lack of a transferable model to implement WEF approaches to different contexts makes it a difficult approach to put into practice. To make matters more difficult, the incumbent pressures of climate change -- such as changing weather patterns, glacial melt, heat waves, flooding etc. -- serve as an additional challenge to the nexus.

The effects of climate change are context-specific, and therefore require different adaptation strategies to cope with the new pressures on the nexus. This however does not negate the importance of global and regional cooperation and capacity building. In fact, in light of climate

change, it becomes more important to expand coordination and cooperation, and build adaptive capacity (target 6A). This is because climate change is a global phenomenon that affects people indiscriminately; without global cooperation or coordination, there is no sizeable or tangible adaptation or mitigation that will take place to counter the effects of climate change. Furthermore, while effects of and adaptation to climate change may be context-specific, the lessons derived from adaptation strategies in various areas can be used to design solutions for different contexts. Lastly, through coordination, it is more likely to find varying solutions as the involvement of more actors in solution-building can yield ideas that may not occur to those who operate in only a very specific geographic and political context. This will allow for idea sharing and idea generation that can be useful to build capacity. The cross-sectoral approach to resource planning and management that the WEF nexus propagates makes it an apt strategy for climate change adaptation. (Mpandeli et al., 2018).

In this paper, we discuss some of the existing challenges that the WEF nexus faces and argue that they will be exacerbated by the variabilities brought by climate change. We look at some of the adaptation mechanisms adopted by developed countries (by looking at the example of South Korea, and the Danube river system), and developing countries (by looking at the SADC, and Tanzania). In the last part of this essay, we provide recommendations based on the findings from our research and thorough analysis. The paper posits that having assets and creating expensive technological solutions may not always be the best course of action for sustainability; smaller, vulnerable communities may have to press for solutions from local service providers; actors outside the immediate WEF nexus premises can be employed to change consumer consumption patterns and reduce pressures on the nexus. In addition, developing countries need

to simultaneously deal with building sustainable capacity and countering vulnerabilities; and in the case of shared watershed where cooperation is lacking, micro and multi-purpose projects along with conflict resolution exercises may be beneficial to build sustainable capacity.

2.0 The WEF Nexus

The WEF nexus became a topic of discussion in water management since 2008, and became particularly important after the Bonn Conference, when it was understood that interlinkages between water-energy-food were key areas to focus on in order to attain sustainability. The WEF nexus is a method based on a systems approach which uses the socio-ecological system as its point of reference (Nhamo et al., 2018). It is a useful approach especially in light of resource interlinkages due to growing scarcities, resource supply crises, and failures of 'siloed 'management strategies (Al-Saidi and Elagib, 2017).

The WEF nexus is a framework, that can act as a complement to the IWRM framework (Giupponi and Gain, 2017), as it accounts for the "interactions, synergies, harmonization, and trade-offs between water, energy, and food when undertaking the management of these resources" (Mpandeli et al., 2018). Whereas the IWRM is more water-centric, WEF nexus is more multi-centric. The Nexus approach "promotes efficiencies in resource development and allocation, calls for greater coordination between inter-linked resource producing/consuming sectors, emphasizes the need to change the way policy and decision-making occurs in order to improve human welfare and social equity" (Mohtar and Lawford, 2016).

Energy security is defined as securing the availability of energy sources at a price which is economically affordable; water security is defined as being within a population's capability to

safeguard the adequate use of necessary qualities of water, such that it sustainably supports livelihoods, human well-being, and socio-economic development; food security is defined as sustainable access to sufficient quantities of safe and nutritious food, which also meets dietary needs such that it fosters healthy living (Zisopoulou et al., 2018). The water-energy-food nexus allows policymakers to work towards sustainable solutions to resource management, keeping synergies and trade-offs in mind, in order to secure energy, food and water (Mpandeli et al., 2018).

One of the tools available for WEF nexus resource management is the 'WEF nexus Tool 2.0', which enables users to explore different scenarios based on data, and allows for comparability between scenarios (Holtermann and Nandalal, 2015)

2.1. Current Challenges of the WEF Nexus

The challenges to the WEF nexus are numerous and consist predominantly of human factors, ecological factors, and (in terms of methodology and implementation of the WEF) research and analysis factors.

The human factors that pose a challenge for the WEF nexus include population growth, economic development, urbanization, and changing consumer patterns (Terrapon-Pfaff et al., 2018), which add pressures particularly in MENA countries, Asia, and Central America (which bear the brunt of population growth (Mohtar and Lawford, 2016)). On a global scale, 1 billion people lack access to safe drinking water, and 1.1 billion have no access to modern energy services; furthermore, in most cases, the people who lack access to both these facilities tend to be those who depend on agriculture as their source of income (Terrapon-Pfaff et al., 2018). Studies project that by 2050 the energy demand will nearly double, and the demand for water and food will

increase by 50% (Zisopoulou et al., 2018). By 2030 urban population will have increased from 29.1% (in 1950) to 60.8% (Zisopoulou et al., 2018), with a large portion attributed to the developing world.

Another set of challenges faced by the WEF nexus are the ecological factors such as over-withdrawal of surface water and groundwater, water pollution, depletion of underground water and the inability to control excess flows (Giupponi and Gain, 2017). Water extraction is linked to economic growth and is a primary contributor to food security (Zisopoulou et al., 2018); 55% of the operating costs of water utilities go to energy, and food production utilizes between 70% and 90% of total water used for human activities (Mohtar and Lawford, 2016).

The value of water is also a factor that negatively influences decision making in the WEF nexus. The price paid by consumers for the use of water in homes is quite understated in comparison to the actual costs of water provision, and the opportunity costs of water use in other sectors (Holtermann and Nandalal, 2015). This could lead to "questionable resource use decision in the WEF nexus" (Holtermann and Nandalal, 2015). Bates et al. (2008) posit that the value of water is the "prioritization of domestic and industrial water supply over irrigation water supply and the efficient use of water, including the application of water-saving technologies and water pricing". Due to this prioritization, the food production sector is likely to be ignored in favor of the energy and domestic use sectors.

Biofuels are an example of this, wherein the production of biofuels is heavily emphasized in certain countries; since they require large amounts of water input per unit of energy output, the low price of water is a major factor in encouraging biofuel production (Holtermann and Nandalal, 2015). However, biofuel production usurps resources from food production, and also

the heavy demand of water could mean that some segments of society are being denied water for domestic use. 10% biofuel shares in global transport would increase the risk of lack of food by 15% (Huq, 2015). In Tanzania, increasing biofuel plantation is leading to threats to local livelihoods, land grabbing, and destruction of biodiversity coupled with a lack of water for domestic use (Huq, 2015). In Cambodia the effects of biofuel plantations are even worse (Huq, 2015). If the price of water was increased to reflect its actual costs, biofuel production would become much more expensive, thereby making biofuel production less attractive and financially less viable (Holtermann and Nandalal, 2015).

Scope and scale are also important considerations in nexus thinking, because "actions in one geographic region often influence and are influenced by actions in other geographic regions" (McCarl, Yang, and Srinivasan, 2017). Sectoral and resource scope are also important considerations. Global oil price for example can cause strains on WEF nexus in different parts of the world. The issue is made all the more complex in WEF considerations because there exists a range of scales and "the scales that matter to each component systems vary in importance. For example, water supply and sewage systems tend to be more localized than food supply systems, that have extensive global supply chains for both inputs (e.g., fertilizer) and outputs (i.e., food)" (Hoolohan et al., 2018). The effects of any intervention will be felt on the various scales. Temporal scales are another challenge for the WEF analysis. According to Hoolohan et al. (2018), studies of the WEF that focus on long term impacts tend to undermine the short and medium term impacts of policies, and conversely, studies that focus on short term policy impacts ignore the long term management issues that can arise due to climate change.

Addressing nexus issues thereby requires a holistic thinking in time as well, integrating both short and long term goals. Furthermore, the discussions of the WEF nexus have focused on global or national levels, often discounting that many challenges are faced by communities, households, institutions, and even small businesses at a local level (Terrapon-Pfaff et al., 2018). Using WEF nexus thinking in a localized context is necessary in order to understand the connection between access to sustainable energy, nutritious food, and safe water; without this understanding, analysis of global WEF problems is likely to be incomplete (Terrapon-Pfaff et al., 2018). In addition, the transference of global practices into a local level can pose challenges (Terrapon-Pfaff et al., 2018). A tousle exists between national versus regional goals: shared resources are better dealt with at a regional level, however involving cooperation of actors would be a challenge when most governments want to act in national interests (Nhamo et al., 2018).

In addition, data collection, analysis, interpretation, and visualization are challenges faced by the WEF framework, which doesn't have any set models, indicators, or indices with which to guide research. Nexus data that is desirable in order to foster better management across resources include regional economics, income distribution, water-energy-food needs and prices, technology mix, emissions of CO2e and soil health, water contamination levels, allocation of land and water, export and imports (along with possibilities and needs in the future), groundwater stock, potential alternative energy and water sources and their viability, population growth, sprawl, and associated WEF demand increase, energy use by sector (particularly food production), utilities pricing, and agricultural production (McCarl, Yang, and Srinivasan, 2017). The complexity and expansiveness of data required for optimal decision making shows the challenge faced by the WEF nexus method of resource management. There is a need for data

unifying and modeling, in order to better understand the challenges to the WEF nexus, and also to better create local solutions (McCarl, Yang, and Srinivasan, 2017). There is also a need to improve how that data is relayed and presented (McCarl, Yang, and Srinivasan, 2017). Finally, climate change also puts pressure on the WEF nexus and creates a series of challenges that will be exacerbated due to unpredictable changing weather patterns.

3.0 Climate Change impacts on WEF Resources

There is a strong consensus among the scientific community, supported by ample evidence that the Earth's climate is warming in response to increasing greenhouse gas emissions caused by human activity. Other changes are emerging from a warming climate and threaten to profoundly affect the resources on which the human and the natural world depend. Specifically, climate change is identified as an additional stressor to the WEF nexus (Leck et al., 2015). Climate is an important determinant of water availability and potential agricultural production, and can influence greatly energy provision and demand (Leck et al., 2015). Changes in precipitation patterns, increase in extreme weather events such as floods, droughts and storms as well as sea-level rise, will drive fluctuations in WEF resources while simultaneously generating secondary effects to the nexus (Leck et al., 2015; Mpandeli et al., 2018).

3.1 Climate Change Impacts on Water Resources

The impacts of climate change on water supply and water quality are a fundamental concern of the WEF nexus. Lakes, rivers, aquifers, oceans and the hydrological cycle will be undergoing severe disturbances from climate change. Impacts on the hydrological cycle and systems involve changes in precipitation patterns, more frequent and extreme occurrences, widespread snow

melting, ice and permafrost thawing, increased evaporation, and changes in soil moisture (Bates et al., 2008). Changes in rainfall patterns will cause some areas to become wetter, while others will become drier (Mpandeli et al., 2018). According to climate projections, areas experiencing monsoon regimes, areas of the tropical Pacific and high latitude regions will observe a general increase in intense precipitation events, during both summer and winter seasons (Bates et al., 2008). Increased annual precipitation and widespread snowmelt will modify stream and river-flow, increasing chances of floods and compromising water quality. Indeed, more intense precipitation and runoff can impact river and lake water quality by increasing sediments, nitrogen, and other pollutants (Georgakakos, et al., 2014).

Inversely, sub-tropical regions such as tropical Central American-Caribbean, the Mediterranean as well as mid-continental areas are projected to experience decrease in mean precipitation (Bates et al., 2008). Direct negative impacts would affect food production and energy generation, causing further consequences on nutrition, health and wellbeing, and sanitation (Mpandeli et al., 2018). In addition, reduced annual rainfall and increased evaporation from warmer temperatures will cause unreliability of surface water resources which can increase in groundwater use, in both rural and urban areas (Bates et al., 2008; Mpandeli et al., 2018). The water quality of coastal freshwater aquifers and surface water resources may also be compromised by saltwater intrusion caused by rising sea-levels, storms and storm surges, further exacerbating water insecurity (Bates et al., 2008; Georgakakos, et al., 2014).

3.2 Climate Change Impacts on the Energy Sector

Climate change is projected to act as an additional stressor to the energy sector by increasing energy use and pose further risks to energy production, reliability, supply and costs (Mpandeli et al., 2018; Mabhaudhi et al., 2016; Dell et al., 2014). Changes in water availability, extreme weather events, rising temperatures, rising sea levels and intense storm surges are among the main climate change impacts that will affect the energy sector (Dell et al., 2014; IRENA, 2015).

Decreasing water availability combined with changes in precipitation patterns and more frequent droughts will threaten the various stages of the energy supply process. Hydropower generation and biofuels production are highly vulnerable to these impacts since they are dependent on rainfall and runoff (Mpandeli et al, 2018; Schaeffer et al., 2012). Fossil fuel and nuclear power remain however the largest users of water for extraction, processing, power plant cooling and transportation purposes (Mabhaudhi et al., 2016). Rising atmospheric temperatures can impact negatively the efficiency of power plants and weaken the capacity of distribution infrastructures (IRENA, 2015; Schaeffer et al., 2012). Higher temperatures will also influence energy demand globally as warmer summers will increase cooling demand (Dell et al., 2014; Schaeffer et al., 2012). Extreme weather conditions, rising sea levels and more intense storm surges may cause damage to power plants and other infrastructures interrupting the production, transmission, transportation and distribution of all types of energies. More frequent and intense droughts, frosts and storms can also affect crops needed in the production of biofuels (Schaeffer et al., 2012).

3.3 Climate Change Impacts on Agriculture

Climate change is already severely impacting the performance of the agriculture sector since food production is highly dependent on climate conditions (Hatfield et al., 2014; Mpandeli et al., 2018). In many regions, climate change is posing additional challenges in achieving food and nutrition security by reducing crop production and causing significant increases in food prices (Hatfield et al., 2014; Mpandeli et al., 2018). Crops and livestock consume large amounts of water. A warmer climate will increase water evaporation rates leading to more frequent water shortages (Kantor et al., 2017). Combined with declining rainfall, warming temperatures increase the potential for more frequent and longer droughts which will affect both crop production and the health of livestock. Inversely, more frequent and intense precipitation events such as flash floods can lead to crops drowning and accelerated soil erosion (Kantor et al., 2017). Other extreme weather events such as intense storms and hurricanes, frost and hail can exacerbate soil erosion, ravage crops, harm livestock, and significantly damage infrastructures necessary to the transportation and storage of food (Hatfield et al., 2014).

It is important to note that the agriculture sector is a major source of greenhouse gas emissions and that the intensification of agricultural activities as a response to climate change will result in the enhancement of the greenhouse effect, thereby exacerbating global warming and other climate change impacts (Mpandeli et al., 2018).

4.0 Current Adaptation to Climate Change Impacts of the WEF Nexus

In attempting to collect data about the progress and challenges faced across the world in relation to the WEF nexus, it is found that the breadth of information makes it necessary to adequately relate and consolidate the different data that is retrieved from many research methodologies across sectors. Understanding and planning adaptation strategies with

information provided from different fields is believed to be the way forward in ensuring that the most comprehensive water, energy and food policies are developed and enacted (Srinivasan et al, 2015, p.5). In addition to the importance of consolidation, it is also found that stakeholder elicitation of adaptation priorities and responses are successful in some cases. Stakeholders are asked to come together to develop adaptive strategies. Other times experts develop adaptation models together with various stakeholders, or independently and those are subsequently introduced to stakeholders with culturally appropriate tools to maximize their understanding and contributive capacity (Srinivasan et al, 2015, p.5).

4.1 WEF Nexus Opportunities and Progress in Developed Countries (eg. South Korea, Central Europe)

4.1.1 South Korea

The WEF interactions in South Korea, a fairly developed country dealing with water basin issues, center the processes of desalination and inter-basin transfers. Water insecurity in the region manifests as a result of growing population and urbanisation, climate change and the nature of its landforms (OECD, 2018 p.15). It is described as a mature water economy, in that it recognises that its existing systems can be changed, connected and further enhanced to improve the quality of water distribution while still holding environmental conservation important. The country relies on surface water use and its current supply is affected by low annual precipitation, limited precipitation time intensified by climate change, causing intense competition for water resources (Holtermann and Nandalal, 2015). This is especially true in rural areas where water infrastructure is not as extensive or up-to-standard as the infrastructure in urban areas.

As a result of the growing water scarcity in the region, there was a widespread adoption of energy-intensive, high-emission operations to remedy the situation. The two main procedures; inter-basin transfers and desalination technology, while necessary WEF-centric interventions, pose a hazard to the long-term health of the WEF nexus in Korea. Desalination in particular is a cause for concern because the residual toxic brine is not properly treated or disposed of. In cases where it is left to evaporate from land cachements, it threatens to increase the salinization of the soil and jeopardise agricultural activities (Radford, 2019; Jones et al., 2019). In addition, Korea faces issues in the field of food production and land use. High-intensity agricultural production approach requires large volumes of water, for cultivating crops and rearing animals as detailed by the OECD report (2018). Intensive exploitation of the soil coupled with climate change-driven acidification and an increase in the occurrence of pest attacks and disease outbreaks poses a danger to the stability of the agricultural sector. It is noted that environmental taxes and charge rates on land development are low, and could be increased accordingly to support efforts to establish stronger environmental regulations and encourage more sustainable policies.

Korea's energy-intensive economy could be in jeopardy if water efficiency is not enhanced. This is because while hydro-electric power is the smallest source of energy (contributing approximately 1% as compared to the 30% contribution of nuclear energy, 40% portion that comes from the use of coal and the 22% from natural gas according to the KEPCO 2017 Annual Report), water is still important in industry because it is used to cool down production plants, and a projected increase (World Nuclear Association, 2018) implies that this particular water use will increase substantially.

4.1.2 The Danube River Basin

The Danube river takes its source from the Alps and runs across Europe; through Ukraine, Moldova, Romania, Serbia, Croatia, Hungary, Bulgaria, Slovakia, Austria, and Germany. Some of the capital cities along the sprawling banks have harnessed the river's flow for their economic growth, as detailed by the Danube Region Strategy. Water is dammed at 59 points along the river for hydroelectric power generation. This high number of dams makes it such that there are disruptions to the ecosystem, with Brears (2017) citing disconnections of floodplains and wetlands as the main manifestations of this. Much like other parts of the world, climate change intensifies the occurrence of flood and drought, in addition to changing rainfall patterns, average temperatures and the like, which will negatively affect the production of hydropower.

Additionally, the water in the river has become unfit for irrigation and drinking as it is heavily polluted by activities related to the dams. Agricultural production as a source of bio-energy material (as an alternative to fossil fuels) is also slated to become more intense, and without proper sustainability measures in place, this could negatively impact food security for communities, townships and cities along the river.

Uzbekistan has developed an energy efficiency labelling scheme aimed at diversifying energy production away from hydropower. The integration of thermal energy resources into the energy provisioning systems that supply Uzbekistan, Turkmenistan, and Kazakhstan provides some relief and creates assurance of energy that is not from hydropower. In addition, there is legislation in place to prevent the importation of appliances that are not labelled as satisfactorily energy efficient by the State Electric Industry Inspectorate (Akhmetov, 2015, p. 30-31). They take this one step further by banning appliances found unworthy in stages. This is a potential area for cross-sector collaboration, where international policy being enacted at a national level affects

corporate behaviour by incentivising firms in the market to provide acceptable appliances from early on, and gain public trust. As this continues, appliances that do not meet the approved standards may be recycled or repurposed, giving companies the opportunity to enhance their products, range of services and on a larger scale, reduce the amount of electronic waste they are inadvertently responsible for.

4.2 WEF Nexus Opportunities and Progress in Developing Countries (eg. the SADC & Tanzania)

4.2.1 SADC

The South African Development Community (SADC) started out as a regional entity formed to stand united against the politically and economically antagonising apartheid government of South Africa, and so has some political links upon which they can build a stronger alliance. Most of the water used in the region is from rainfall as well as rivers and water bodies that exist along country boundaries. Seeing as the water is a main supportive resource for many of the industries in this area (mining and agriculture as detailed by Conway et al., 2015), it is understandable that the alliance would be formed and maintained through the years.

The recently projected 20% annual precipitation is a cause for concern for multiple members of the SADC. The climate in this region varies, but is largely arid and semi-arid (Bates et al., 2008; Mpandeli et al., 2018). Water as a central resource is fugitive, and coupled with the extremities of climate change, access within this region could be greatly compromised. Indeed, we find from multiple sources of evidence that, “dependence on climate sensitive WEF resources in southern Africa worsens vulnerabilities. Consequently, the region is classified as a climate

change hot spot," (Mpandeli et al., 2018). The changes in crop growth patterns being noticed in agricultural cycles within the region have been seen to put their economic system in jeopardy (Holtermann and Nadalal, 2015).

Members of the SADC are also highly susceptible to climate change effects, largely more so because economies are largely built on agriculture, unlike South Korea. Primary products do not attract as much capital as finished products do, and so differences in export revenue and the subsequent contribution to development are noticeable. The inherent possibility of water insecurity also endangers the energy security of countries that depend on hydroelectric sources (essentially, all of them).

4.2.2 Tanzania

Tanzania, one of the members of the SADC, is home to 52 million people, a thriving agriculture sector and productive industries that source their water supply from a multitude of water bodies that form seasonally in depressions caused by the East African Rift System. Chirisa & Bandauko (2015) highlight that the increasing effects of climate change are calling into question water management and sanitation systems, provided at local government level. The increasing occurrence of droughts, reduced rainfall and predicted changes in rainfall patterns also heighten the likelihood that water scarcity is going to become a reality for a larger number of people across the country. In addition, the aforementioned lack of rainfall will create restrictions within the production of hydroelectric power and limit the amount of solid fuel (i.e.; wood) that can be gathered, especially by citizens in rural areas that do not have the same access to electricity as urban areas.

Yang & Wi (2018) highlight that the frequency of zero flow days will be more noticeable in Tanzania because of the increase in droughts, high temperatures and reduced rainfall.Currently, efforts are being made to integrate infrastructure, but these efforts must combat the issues of poor leadership, resource limits, weak institutions and a general inability to implement plans in the long-term.

5.0 Discussion

Climate change is already affecting WEF resources in most regions which requires that adaptation strategies be implemented in order to achieve greater water, energy and food security. Through the examination of a range of case studies from developed and developing countries, it was possible to identify successes and failures in addressing WEF nexus challenges within the context of climate change.

Climate change impacts on the WEF nexus are context-specific, therefore strategies to address them will vary greatly from country to country. While adaptation strategies might be different, there is room to learn from the driving forces that encourage adaptation in different countries, and using those to encourage climate change adaptation in different contexts.

We could conclude that wealthy countries are better able to adapt to change than poorer countries, however building assets that enhance people's ability to exploit WEF resources may increase vulnerabilities to climate change and therefore impede on WEF nexus interconnections (Cinner et al., 2018). South Korea’s decision to turn to desalination demonstrates that costly, highly advanced and energy-intensive technologies, do not necessarily represent an adequate solution, even if the necessary financial and technological resources are readily available. Indeed, according to Rasul and Sharma (2015), technological measures can often fail to focus on issues

affecting the local population, or lead to maladaptation. Smaller communities facing similar water scarcity situations as rural South Korea should focus on enhancing the efficiency of water supply systems by insisting on a certain form of collaboration and association between small service providers. This would provide an opportunity to reduce the vulnerability of these systems to climate change while at the same time targeting the most vulnerable groups of people (Holtermann and Nandalal, 2015, p.119).

Furthermore, as learned from the desalination example, it is not enough to create adaptation measures that only focus on one aspect of the WEF nexus. Projects, particularly energy projects, that focus only on one aspect of the water-food-energy nexus are sub-optimal (Terrapon-Pfaff et al., 2018). To have optimal use of resources, projects need to incorporate multi-layered aims at the project planning stage and not as an afterthought (Terrapon-Pfaff et al., 2018). This can be successfully achieved with both micro-level projects such as co-production of energy and food through 'solar sharing' (Institute of Science in Society, 2013), or with mega projects such as multi-purpose dams that promote small-scale irrigation through solar-powered pumps or hydroponics to reduce trade-offs that exist within the food production sector (Mpandeli et al., 2018). In addition to irrigation, power generation and agriculture, multi-purpose dams could also provide additional services such as aquaculture and eco-tourism activities.

In developing-country contexts, adaptation to climate change should focus on two action pathways simultaneously: mitigating climate change impacts and addressing other drivers of vulnerability such as poverty, gender, structural weaknesses and social equity to also build resilience (Rasul and Sharma, 2015). Regions such as the SADC that still heavily rely on fossil fuels as an energy source are perpetuate counterproductive behaviours that go against climate change

mitigation. Furthermore, by adding to greenhouse gas emissions and exacerbating climate change impacts, the use of fossil fuels such as coal, only adds to the vulnerabilities of these communities (Conway et al., 2015). By shifting away from carbon and water-intensive energy sources, and opting for renewable energies, developing countries are provided with an opportunity to simultaneously mitigate climate change, increase water security, reduce poverty by overcoming cost volatility of fossil fuels and increase access to more secure and affordable energy (IRENA, 2015).

One lesson from the Danube river system suggests that industries operating outside the WEF nexus can also be used to encourage better adaptation to climate change, within the WEF nexus. The production and use of appliances that use lesser per unit energy than regular appliances is an example of such methods; by decreasing the overall demand of energy through more energy efficient appliances, or even through promoting energy efficient lifestyles, some pressure can be put off from the water-energy nexus. Thus, one way that countries can adapt the WEF nexus in lieu of climate change is to promote more energy efficient, and water-use efficient lifestyles.

Lastly, it is observed that multi-actor cooperation is essential to building adaptive capacity, particularly in the case of shared watersheds. This can be seen in the case of the Danube River Basin, and the SADC shared watershed. However, in cases where cooperation is lacking, or where different stakeholders are in a deadlock over the decision-making of using the watershed sustainably and efficiently, other methods need to be adopted in order to adapt to climate change pressures on the WEF nexus. Firstly, it is suggested that in these cases it might be more beneficial to engage in micro-level, multi-purpose projects to cater to the vulnerabilities of the

local communities. At the same time, actions need to be taken to encourage and incentivize better cooperation amongst different stakeholders and the national and multinational level; it is necessary to even out power asymmetries and incentivise interactions that prioritise the well-being of others in order to build a culture of collectively beneficial decision-making. Working on conflict resolution strategies, whilst avoiding tokenism, should be done in tandem with micro-projects so that the immediate needs of communities can be met in sustainable ways, and cooperation can be built up for a more national and multinational solution. Mpandeli et al. (2018) suggest that shared power grids that generate electricity from shared watercourses represent an opportunity for regional and transboundary integration and cooperation; while this is a good idea in theory, it is questionable if this can work in contexts where ethnic, or national interests obtrude over the ideal of sustainable water solutions. Therefore it is suggested that cooperation be built up before macro-level water management policies can be put into place.

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