COLLABORATING TO ADDRESS SHARED RESOURCE RISKS

THE WATER-FOOD-ENERGY NEXUS: Insights into resilient development

Executive Summary

WWF and SABMiller have a shared interest in strengthening the institutions that govern the way society manages and develops water, food and energy resources. For WWF, this is close to the heart of our mission: conservation is inseparable from the challenges of changing patterns of resource use. For SABMiller, this is a question of the viability of our business: good quality drinking water and agricultural products are vital for a brewing company – and essential for the societies within which we operate.

So the risk of resource scarcity is a shared risk. We see that shared risk becoming more acute under changing consumption patterns and demographic pressures. The ambitious drive towards rapid development has often missed a fundamental dimension of progress, which we believe is essential to enable us to respond collectively to shared risks. Building the resilience of our water, food and energy systems is an essential and neglected part of development. Resilience is the ability to withstand shocks and pressures, whether economic, climatic or demographic in nature. Ultimately both national development strategies and business strategies need to be designed around resilience.

Nexus policymaking is about designing resilient government or business strategies in ways that take account of the connections between food, water and energy systems. It starts by recognising the interdependence of those systems, and hence challenges single-sector approaches that can have substantial unintended consequences for a country's future development options.

This report looks at 16 countries or states, comparing the ways in which their development patterns have managed their different mixes of resources and different capacities to make use of those resources. Nexus issues play out very differently in contexts with differing resource endowments, and this is only partially determined by the climate and physical availability of natural resources in a country. The country's ability to make use of its natural resource base can be at least as important.

Decisions made in the early stages of development may lead to weak resilience at later stages. This is particularly seen in the evolution of both infrastructure and institutions for governing the use of natural resources. Developing and emerging economies have the opportunity to build resilience in from the outset.

Trade has often enabled countries to manage their own resource scarcity, offering one strategy for building a nation's apparent resilience. However, in today's interdependent globalised world, in which resource scarcity has impacts on a global scale, trade is no longer a trump card that can enable rich countries to buy their way out of managing resource risks directly.

From our research we have concluded that the most resilient economic systems combine robust infrastructure, flexible institutions and functioning natural capital. The case studies propose areas in which policymakers have particular levers for responding to nexus challenges in order to bring about resilience. They suggest policymakers should:

- Integrate all aspects of development planning, in particular ensuring that water, energy and agricultural sector planning are not done in isolation, but consider how each can contribute to the resilience of the others;
- Design institutions for resilience, in ways that strengthen cooperation and coordinated decision-making;
- Use economic and regulatory instruments to strengthen the incentives and requirements for building resilience into water, food and energy systems;
- Use trade, regional integration and foreign policy to manage nexus trade-offs more effectively, and contribute further to resilience at both country and global levels.

Introduction

Water scarcity will only increase under new patterns of consumption driven by an additional three billion middle-class people by 2030.

WWF is the world's largest independent conservation organisation. Our mandate is to safeguard the natural world, conserving biodiversity and the vital benefits provided to humanity from natural systems. We see securing natural capital – the natural assets on which all our health and livelihoods depend – as an end in itself. But we were also interested in the business case SABMiller makes for thinking about water, food and energy systems in a different way.

SABMiller is an international brewer with operations in over 70 countries across six continents. Our business growth is closely aligned with the transformation of the global economy, in particular through growth in emerging markets and the expansion in their middle classes. We see great opportunities in this transformation – both for our business and for the societies within which we operate.

Yet those trends are entwined with great challenges for society and for all businesses. While hundreds of millions of people have been lifted out of poverty, many remain poor. Threats from the erosion of natural capital are challenging the basis of development, and these threats are particularly acute for businesses such as ours that depend so directly on the natural world – on good quality freshwater and the products of agriculture.

Business and the societies within which we operate rely on natural capital in ways that become acutely obvious when that natural capital base is eroded. On one level, SABMiller experiences resource scarcity in terms of rising costs and the volatility of prices of our raw materials, but the threat is more fundamental than this. Without sufficient supplies of good quality water, our business could not exist. If rivers run dry, some of our businesses would have to shut down operations. The risk of water scarcity is a risk we share with the communities around us: these interdependences demand a collaborative response.

More than 70% of the world's freshwater use is in agriculture. The pressure of water scarcity will only increase under new patterns of consumption driven by an additional three billion middle-class people by 2030, and a global population predicted to exceed nine billion soon afterwards. Much of the population growth and the middle-class growth will occur in countries that are already water-scarce. There are further pressures from competing need for land, and from the imperative to decarbonise our energy systems. Climate change means that rainfall and water availability are likely to become more uncertain.

These challenges are well understood and have already been written about extensively. We wanted to investigate whether it would be possible to offer more robust insights from cross-country comparisons, building on anecdotal local evidence of differences in how governments respond to these challenges.

We see good stewardship of water, food and energy resources as the foundation of resilient social and economic development. Starting from this viewpoint, this research aims to develop some new insights into how different decision-making can develop economies to deliver rapid reduction in poverty, enable sustainable business growth, and secure the natural systems that underpin social and economic progress.

What is this "nexus"?

Water is a critical limiting factor for food production. But it is also central to energy production.

Nexus policymaking is about designing resilient strategies in ways that take account of the connections between food, water and energy systems.

Food, water and energy systems are connected in some obvious ways, along with many less obvious links between them. Water is a critical limiting factor for food production. But it is also central to energy production – and not just in the countries with significant hydropower. The processing of fossil fuels, including newer sources such as shale gas, is water intensive, as is the electricity generation process itself.

Conversely, rich, dry countries can solve their most acute freshwater supply problems if they can generate energy cheaply enough to desalinate seawater or process urban wastewater to a high enough standard – at the expense of growing carbon emissions. Greenhouse gas emissions from energy generation are, in turn, likely to result in shifting rainfall patterns.

Food production requires energy – for fertiliser production, and for planting, weeding, harvesting and transport. Equally, there are tensions between the use of land for food and animal feed production and for energy production, and this is not a new trade-off. Before fossil fuels, fodder crops to generate the original "horsepower" occupied significant areas of northern European agricultural land. Feeding animals is a major user of cereals, oilseed and grazing land worldwide, and informal biomass is a major contributor to household energy security.

Nexus policymaking is about designing resilient strategies in ways that take account of the connections between food, water and energy systems. It starts with recognition of the interdependence of those systems, and hence challenges single-sector approaches that can have substantial unintended consequences for a country's future development options. As well as managing those kinds of risks, it points towards opportunities for each country to make the most of its particular mix of resource endowments, systematically aligning its development with the possibilities inherent in that mix.

An increasingly pressing agenda

Pressure on land and water availability will continue to grow – not only through the need to feed more people, but also from changes in their patterns of consumption.

16%

Since 2008 SABMiller has reduced its absolute water use by 16%, despite an increase in production volumes, and is on track to meet its efficiency target of using 3.5 litres of water per litre of beer by 2015.

We believe this approach to choosing development options is now essential, if governments are to adapt to the trends that are making trade-offs between food, water and energy systems ever more acute. As emerging markets continue to industrialise and develop, the demographic and economic impact will be faster and greater than the equivalent period in the Western economies, driven by the scale of these countries' populations and amplified by both globalisation and technology change.

In 2009, about 1.1 billion people in North America, Europe and the more developed economies in Asia-Pacific were classified as "middle class". According to the OECD, by 2030 the number of middle-class people in these countries will remain the same but a further three billion will have been created in the rest of the world – of which 90% will be in Asia, primarily in China and India. At the same time, there will still be around 3 billion low-income consumers in the world in 2030: that number includes an additional 1 billion in Africa and Asia, compared with 2009.

"By 2030 the world will need to produce 50% more food and energy, together with 30% more available fresh water, while mitigating and adapting to climate change. This threatens to create a 'perfect storm' of global events." Professor John Beddington, former UK Government Chief Scientist.

These changes will be accompanied by rapid urbanisation and greater concentration of wealth in cities. In simple numerical terms, all the new consumers in the world arising from population growth will be urban consumers. Urban growth and middle-class growth mean that the challenge of resource scarcity is more acute and more complex than simply providing for the food, water and energy needs of a growing world population.

The demand for increasingly scarce resources to fuel development is shaping commodity markets across the world. SABMiller and other companies experience the effects in terms of higher and more volatile input and raw material costs. Consumers experience this as fundamental changes in the patterns of their spending, driven by increases in the cost of essentials such as food and fuel.

"For the middle classes, [more expensive food] means cutting out medical care. For those on US$2 a day, it means cutting out meat and taking the children out of school. For those on US$1 a day, it means cutting out meat and vegetables and eating only cereal. And for those on 50 cents a day it means total disaster." Josette Sheeran, formerly Executive Director of the UN World Food Programme.

Pressure on land and water availability will continue to grow – not only through the need to feed more people, but also from changes in their patterns of consumption. Three billion more middle-class people will demand more meat, for example – and meat-rich diets will require far more land than the traditional diets they will replace. Choices over competing uses for land will become more acute. Land pressures also mean greater pressures on biodiversity and threaten the natural capital that underpins our ability to provide for the needs of a fully populated planet, even as middle class expectations of better environmental quality are on the rise.

Resilience and the nexus

Ultimately national development strategies and business strategies need to be designed around resilience.

70%

WWF's Living Planet Report 2012 showed a decline of 70% in measures of tropical freshwater biodiversity since 1970.

These trends matter for governments and businesses. They challenge the assumption that today's development strategies, which have delivered impressive poverty reduction and growth in prosperity over the past two decades, will continue to deliver into the future. They challenge a model of business growth based on competition for natural resources, since all businesses and communities share the risk of resource scarcity – a risk that is not solved by seeking to control a higher share of a rapidly shrinking resource base.

Many of the pressures that challenge us to think differently about joining up the management of food, water and energy systems will be exacerbated by climate change. There is already evidence of climate shifts putting greater stress on some river basins that are also damaged by pressures from the growing water needs of agriculture and industrialisation. Some of the regions where food security is most prevalent are also regions where climate change is expected to pose the greatest challenges for agriculture. And the rising energy needs of the growing world population are in tension with the urgency of the challenge to decarbonise and reduce the water intensity of our energy system.

The first priority in a response to these linked trends is to build resilience into national development strategies. We cannot predict in detail what the consequences of population pressures, changes in consumption patterns and climate change will be. A resilience-driven approach acknowledges this, recognising that there are multiple, complementary reasons for building flexibility into our design and management of food, water and energy systems, including into the infrastructure and institutions linked to them.

For example, many of the policies that help to keep a river flowing under pressures from rising population and industrial needs will also be beneficial resilience measures pre-empting some of the future likely impacts of climate change on that river system.

Ultimately national development strategies and business strategies need to be designed around resilience; they need to work under many different scenarios of the possible outcomes of the interacting trends described. They need to proactively optimise the resilience of food, water and energy systems at different scales. They need to build in the capacity to absorb climate- and population-driven shocks of many kinds, to reduce the impact of those shocks on people and on the natural systems on which we depend, and to mitigate the likelihood, depth and frequency of those shocks.

Even in rich countries that can well afford to make this kind of investment in the nation's future, such an approach is rare. Our comparative review of countries and states shows that, particularly at later stages of development, the inflexibility of institutions and the archaic state of infrastructure can be major risk factors undermining those countries' ability to respond to the climate-related and population-driven shocks that are already beginning. The lessons for countries at a different stage – those rapidly developing infrastructure and related institutions – could be critically important for their ability to sustain their development achievements into the future.

Resilience and the nexus *continued*

Nexus issues play out very differently in contexts with differing resource endowments.

This study uses three lenses in considering how to address the national planning of water, energy and food in a coherent and sustainable manner. These three lenses are:

- **Resource endowment** – what is the natural resource endowment of the country or region in relation to water, energy source, and agricultural land and food production potential? And what are the human, financial and institutional resources available to mobilise the natural resources?
- **Development status** – what is the level of development and the nature of the economic development trajectory of the country or area under consideration?
- How does **resilience thinking** inform nexus discussions and development planning in the country?

The first, simple insight from the country comparisons is that nexus issues play out very differently in contexts with differing resource endowments. Countries with abundant natural resources for food, energy and water, such as Brazil, face a different set of questions from countries with limited or unbalanced resource endowments. South Africa, for example, has limited water and agricultural land, but considerable reserves of coal and opportunities for solar power. The choices facing its government are quite different from those in Brazil. Even starker differences are presented by a comparison of Chad and Vietnam.

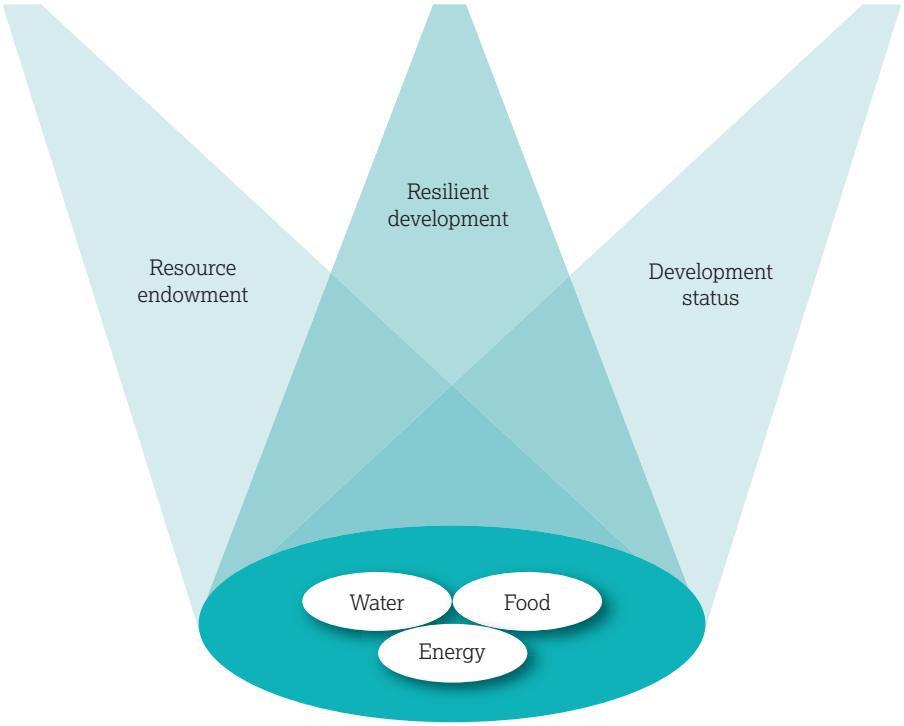


Figure A: A framework for understanding government nexus planning

A nexus comparison: Chad and Vietnam

Although Chad has substantial oil reserves in the Doba Basin in the southern part of the country, it is an exceedingly water-scarce nation, with low average annual rainfall (in the region of 320mm per annum). Lake Chad is the only permanent freshwater source in the country, but has been diminishing rapidly over the past 30 years: between 1982 and 1996, the lake's surface area shrank from 22,772km² to 2,276km². This phenomenon has been driven mainly by increased demands on the waters that feed the lake, largely by upstream countries. Its high water stress has translated into severe food insecurity and poor agricultural production potential. Almost a third of its population of 3.6 million people are considered to be at risk of food insecurity and a mere 0.03% of the country's land area is under permanent cropland. Constraints on transporting its oil to shipping have curtailed Chad's ability to earn foreign exchange and thereby import food.

Unlike Chad, Vietnam is a country rich in water resources; it is one of the world's highest rainfall countries. The climate thus provides highly favourable conditions for agricultural production in most parts of the country. The government of Vietnam has prioritised agricultural production to achieve food self-sufficiency. In doing so, the government has made significant investments into improving irrigation infrastructure to lengthen growing seasons. Currently, approximately 42% of all agricultural land is irrigated, with the majority of irrigation water and fish protein coming from the Mekong River. Increased pressure being placed on the Mekong River Basin by upstream countries, for example building of dams for energy generation in the middle reaches of the Basin, is likely to have profound impacts on both water flow and fish productivity for Vietnam downstream. Under these circumstances, maintaining food self-sufficiency may become more challenging in the future.

Workers harvesting tea leaf in Bao Loc, Vietnam

Resilience and the nexus *continued*

The climate and physical availability of natural resources in a country only partially determine its resource endowments. The country's ability to make use of its natural resource base can be at least as important.

Development priorities can only be met from a country's given mix of resources through the judicious and coherent development and management of those resources into the future.

Resource endowments include the natural water (rainfall, surface and ground water), energy (fossil fuels and renewables) and land (arable and grazing) available to that country. Many of these depend in part on climatic conditions. But the climate and physical availability of natural resources in a country only partially determine its resource endowments. The country's ability to make use of its natural resource base can be at least as important. So the country's skills base, infrastructure and institutions also play an important role in determining its effective resource endowment – and these in turn are closely linked to a country's stage of development.

For example, a country may have abundant water resources, but until it has reservoir storage and transfer infrastructure, it cannot ensure reliable supply for industry or domestic use during dry seasons. Similarly, a country may have underground fossil fuels, but until these are extracted, refined and transported, they cannot be exported or used to generate electricity. Arable land in the absence of cultivation and transport infrastructure is less productive, more vulnerable to climate variability and cannot be used to supply national or foreign markets.

Government decisions around the development and maintenance of water, energy and transport infrastructure fundamentally determine the nature of resource use, including access by households, allocation to manufacturing, or import and export to manage shortfalls and surpluses.

Development priorities can only be met from a country's given mix of resources through the judicious and coherent development and management of those resources into the future.

Interpreting national water, energy and food resource planning requires an understanding of the country's development and sustainability goals, overlain on a distinction between the natural resource endowment and the infrastructure and institutional systems set up to supply water, generate energy and cultivate food.

Reflecting development priorities in terms of the nexus

How a country defines its development priorities is determined, in part, by its resource endowment and level of development. Conversely, the use of its resources reflects its priorities, which help to focus resource allocation and infrastructure development.

Tanzania, for instance, has a relative abundance of natural resources but infrastructure and human and financial capacity challenges. Its National Development Plan identifies five strategic areas for intevention, two of which include infrastructure and human capital and skills development. For Tanzania, the national planning focus is currently on improving access to the country's key resources, rather than managing the trade-offs between them, or ensuring the long-term supply of those resources.

South Africa has substantial fossil fuel reserves but is significantly more constrained by its water and agricultural land availability. Water scarcity has implications for both energy generation and agricultural production. Important political issues are emerging around the constraints and opportunities for rural black farmers. Further agricultural development would need to be supported by irrigation which in turn would necessitate efficiency gains, regulation and new water infrastructure. Similar development, sustainability and efficiency issues are part of national energy policy debates.

For the highly developed but relatively arid region of Western Australia, public policy priorities are largely focused on increased efficiencies and growing energy supplies (including cleaner energy, as emphasised in the Government's Strategic Energy Initiative: Energy 2031). Although the State is water scarce, it has the financial capacity and relatively abundant fossil-fuel energy supply to produce freshwater through desalination. So Western Australia has options to overcome nexus constraints and achieve its objectives through capabilities linked closely with its highly developed state.

Stages in development and links to the nexus

Strategies to meet a country's development and sustainability goals are most resilient where they build on a clear analysis of the particular nexus resource challenges faced in that country context.

5 years

SABMiller and WWF have been collaborating for five years on water projects around the world.

In analysing the evolving choices available in managing nexus and resilience issues, we used three generalised (and in reality, overlapping) categories to describe countries' stages of development:

Developing economies with low levels of industrial and infrastructural development, focused primarily on resource cultivation or extraction, and with relatively low human development indices. Here the country's development goals typically focus on improving livelihoods, ensuring food security and developing commodity driven exports.

Emerging economies growing rapidly through a shift towards secondary manufacturing, with improved human development indices, increased urbanisation and development of economic and social infrastructure, often with considerable remaining rural poverty. The development focus is usually on ensuring sustained investment, diversification and bringing value added to economic activity and trade, while addressing livelihoods in rural and peri-urban areas. Water and air quality may be rising up the political agenda.

Developed economies have shifted to a consumption-based service-dominated economy supported by trade and by specialisation in manufacturing and commodities, with high rates of urbanisation. The focus here is on promoting growth through trade, sometimes seeking improved environmental quality, while maintaining employment, welfare and aging infrastructure.

Distinct water, energy and food resource-related challenges are faced by countries at different stages of development. Strategies to meet a country's development and sustainability goals are most resilient where they build on a clear analysis of the particular nexus resource challenges faced in that country context.

The focus for the nexus during the **developing stage** is on resource exploitation (energy extraction and food cultivation). This requires prioritisation of investment to overcome the infrastructural and other constraints on the use of these resources. The overriding need is for infrastructure to enable extraction, cultivation, distribution and export, while ensuring adequate consumption to sustain livelihoods.

Good systems of governance are needed to ensure effective and resilient development of this resource endowment, together with the mobilisation of adequate financial and human resource capacity to support more formalised commercial production.

Food security is an overriding nexus concern at this stage, as well as providing household access to safe water in urban and rural areas, together with adequate water supply to the primary economic activities (agriculture and mining). Energy reliability is a major challenge in meeting the needs of the economy, as is managing biomass harvesting by the majority of the population.

For **emerging economies**, the focus from a nexus perspective is on ensuring adequate availability of water, energy and food resources to support the growing domestic productive manufacturing economy and diversifying economic development for trade, while ensuring water, energy and food security for poor and rural households. Continued development and flexible management of infrastructure to supply water, generate energy and cultivate food may be necessary but there is now a greater focus on human and financial resource productivity and adding value to the primary resource production. Environmental challenges are also coming into focus, partly because of growing middle-class expectations of environmental quality and partly because of trade-offs made during earlier infrastructure development.

Chad, Tanzania, Mozambique and Vietnam

Despite their obvious differences, Chad, Tanzania, Mozambique and Vietnam all share a common need to develop infrastructure that will enable these countries to harness their water, energy and land resources. This serves the dual goals of catalysing their productive economies, while ensuring that their citizens have access to safe water, reliable heating and adequate nutrition.

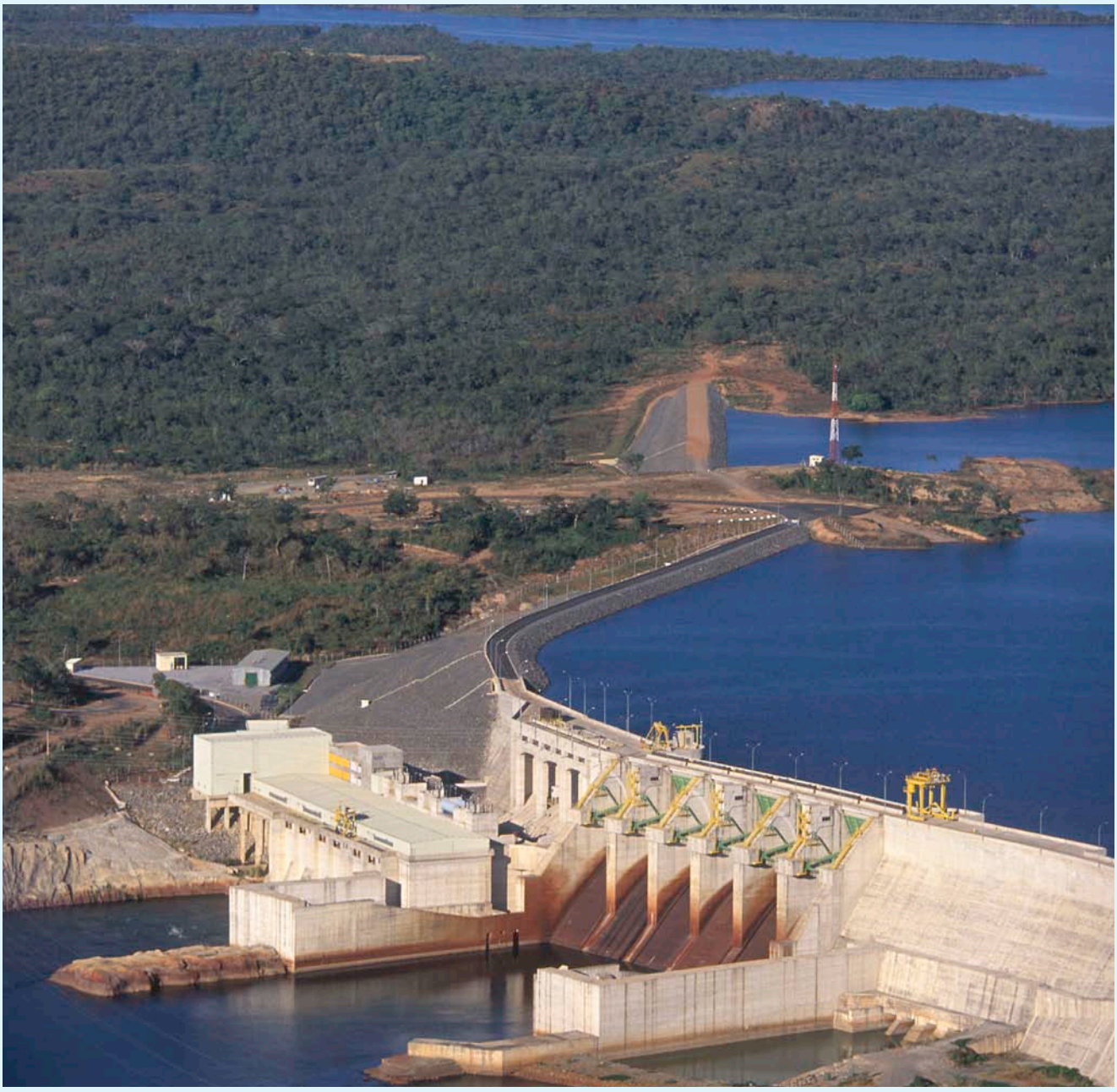
For these countries, developing infrastructure that is flexible and robust under different plausible futures, and which takes advantage of complementary opportunities across food, water and energy resources, is critical to building resilience to climate variability and other likely future pressures. Lessons can be learned by looking at the infrastructure challenges in emerging economies and developed countries.

Stages in development and links to the nexus *continued*

Comparison: Brazil and South Africa

Water abundance and energy resource abundance sometimes go hand-in-hand. This is the case in Brazil, a country that has a renewable freshwater resource endowment of almost 44,000m³ per capita, and where over 80% of the country's energy mix is hydropower. Due to its water abundance and fertile lands, Brazil's capacity for agricultural production is particularly large. As a result, the country is a net exporter of food and agricultural products that account for approximately 35% of total exports. These exports include water (rainfall) intensive crops.

South Africa, on the other hand, is an example of a country that does not have an abundance of water. It does have large proven coal reserves but water scarcity is a constraint for energy production. Despite its low level of renewable freshwater resources (about 640m³ per capita), South Africa is currently nearly food self-sufficient. Food imports represent approximately 6% of total imported goods while food exports form approximately 9% of total exported goods.



The Cana Brava Dam, Goias State, Brazil
Copyright: Edward Parker / WWF-Canon

The major need at this stage is for resilient institutions (including mandates, policies and mechanisms) that enable efficient, predictable development and allocation of nexus resources within the economy. These are prerequisites for supporting increasing domestic consumption and for promoting trade. Managing the associated scarcity trade-offs, resource use choices and disaster risk mitigation measures becomes an increasingly complex challenge in countries that have limitations in one or more of the nexus resources.

Planning for food, energy and water security plays out differently in these countries, depending upon the resource endowment and the past economic evolution of the country. Significant livelihood challenges remain in terms of access to adequate food, energy and water by peri-urban and rural households.

On the other hand, reliability and pricing becomes the overriding concern for urban household consumption and productive enterprises, and this typically frames the national approach to food, energy and water security.

Countries under transition have distinct and competing nexus challenges. These include national production and trade to support economic development; consistency of supply and pricing for urban consumers to support political stability; rural household access to support livelihoods; and rising expectations of environmental quality. At the same time, the traditional developing country focus on agricultural self-sufficiency in basic food cultivation is in tension with the requirements for reliable water and energy supply to the industrial economy.

India, Turkey, Brazil and Colombia

While the emerging economies of India and Turkey each have distinct water, energy and land resource endowments, they face trade-offs in scarce resource development and allocation to diversify economic development, increase urban consumption and respond to stagnating rural livelihoods.

On the other hand, Brazil and Colombia have more abundant (though spatially uneven) natural endowments of water, energy and food resources. This provides opportunities to support livelihoods and development goals, rather than requiring sharp trade-offs in resource allocation. Managing climate variability and extreme events in these countries needs flexible institutional mechanisms, robust infrastructure and functioning natural systems for disaster risk management and to ensure resilience.

Agricultural farmland and countryside, Turkey

Stages in development and links to the nexus *continued*

The transition to services and trade-based economies implies a degree of uncoupling of the economy from domestic resource constraints.

1.2 bn

Globally, the UN estimates that around 1.2 billion people already live in areas of water scarcity.

In **developed countries** the focus of the nexus shifts to improving efficiency in the use of water, energy and food resources to enable domestic consumption, production and trade, while dealing with climate and environmental challenges. Putting in place effective regulatory and economic instruments to achieve this is often a major challenge, along with the maintenance and adaptation of aging infrastructure and human resources to meet changing global conditions.

The transition to services and trade-based economies implies a degree of uncoupling of the economy from domestic resource constraints. National energy and food security are interwoven with trade and foreign policy, with increasing awareness of the risks associated with sourcing these resources from other countries and the volatility of global markets. Given the global power of these economies, shifting energy policy decisions, such as increasing self-sufficiency and growing renewables, may have profound impacts on global energy and agricultural markets.

A country's opportunities and required trade-offs in development and use of water, energy and food are clearly dependent upon its natural endowment of these resources. But these opportunities and trade-offs evolve over time as available resources are used, and they tend to converge as countries develop resource-delinked service and trade-based economies.

United Kingdom, Poland, California and Western Australia

While these developed countries differ in their domestic resource self-sufficiency, they are all to some extent shifting towards more resource-efficient, environmentally sustainable, low-carbon, consumption-based tertiary economies that are integrated into the global trade economy, albeit with aging infrastructure.

These countries tend to establish targeted regulatory and economic instruments, within the context of stable (and often inflexible) institutions, and in some cases remove existing infrastructure to rebuild natural system resilience. This implies a convergence between national and global resilience, which is appropriate given these economies' dependence upon global trade.

Changing energy endowments in Italy

Italy began its industrial development as an energy self-sufficient country. From the 1910s through the 1940s, Italy relied almost solely on domestic hydropower for its electricity generation, after an initial period of domestic fossil fuel-based electricity.

With post-war industrialisation, population and economic growth, the country's energy demands began to exceed the available hydropower supply, forcing Italy to import alternative sources of energy in the form of fossil fuels. Today Italy depends on foreign imports for over 80% of its primary energy needs, but is now starting a process of shifting to domestic renewable energy and efficiency gains. This pattern of moving from energy adundance to dependence, and later on to a shift towards renewables and efficiency, is a common feature of the development paths of many countries.

Climate change and global resilience

Resilient economies require coherent and effective planning of water, energy and food that balances consumption, production and trade requirements against the country's natural resource endowments.

Climate influences nexus resources as an underlying driver of water, energy and food endowments. Variations in temperature, precipitation, wind and sunshine can cause vulnerability in associated production systems. In particular, climate is closely tied with water resources, which are the underpinning dimension of the nexus resource endowment – because water abundance facilitates food abundance through irrigation, and energy abundance through hydropower, cooling water and, in some instances, biofuels.

Resilient economies require coherent and effective planning of water, energy and food that balances consumption, production and trade requirements against the country's natural resource endowments. That planning also needs to mitigate and manage the risks of climate-related variability and disasters. Resilient management of water, energy and food at a national scale is sometimes in tension with the needs of climate change mitigation and global resilience to the effects of climate change.

The multiple benefits of regulatory and market instruments that promote resource-use efficiency include a resilience dividend. Achieving greater resource productivity can clearly have a direct developmental benefit, with better outcomes achieved for a given cost in terms of resources required. The resilience benefit is in addition to these cost savings, and it occurs through reducing the most acute trade-offs in resource use. Those trade-offs are sharpest where peak resource need coincides with peaks in resource scarcity – a typical example being the need for more freshwater for agriculture and domestic use just when the dry season is at its peak. Efficiency, combined with appropriate regulation, can reduce both overall resource use and the size of peaks in consumption, hence reducing the vulnerability of the system to market or climate shocks that would otherwise be unmanageable at times of the highest resource use. When it comes to energy resource use, greater efficiency brings benefits both for national development and a reduced global threat of climate change.

46kms long Tehri Lake filling up after the construction of the New Tehri hydro electric project dam on the River Ganga in Tehri Garhwal Chamba, India

The importance of infrastructure, institutions and natural systems

Decisions made in the early stages of development may lead to weak resilience at later stages.

Resilient economic systems will be those that benefit from and reinforce the preservation of the natural systems on which they ultimately depend.

A recurring theme of this research is that decisions made in the early stages of development may lead to weak resilience at later stages. This is particularly true in the early formation of institutions and in the design of infrastructure. Consideration of the challenges faced by more developed economies around nexus resource development and resilience can enable developing and emerging economies to make planning decisions better suited to possible future scenarios. The systems they put in place have the potential to be more resilient and sustainable in the longer term, jumping a generation of outmoded infrastructure and institutions that were not designed with resilience in mind.

Countries that have historically developed extensive water, energy and food-related infrastructure without addressing coherence or resilience questions have significant financial maintenance challenges, while the infrastructure is frequently unsuited to current conditions of population pressure or climate variability. In some instances these countries have removed inappropriate or stranded infrastructure assets to improve natural ecosystem resilience and reduce the associated financial burden.

Strengthening institutions and ensuring flexibility in the management of water, energy and agricultural land resources (through coherent development planning) enables countries to adapt to evolving development needs and uncertain climate futures. This is closely related to the requirement for robust water, energy, agricultural and transport infrastructure to support economic production and household access, within the context of limited financial and human resources.

Another institutional dimension of nexus planning is in the relationship between national and local nexus responses. The interplay between water, energy and land resources is typically localised, so location and scale matter in considering the associated development opportunities or constraints. The enabling framework and policy context may catalyse or constrain local decisions. So it is essential to develop governance mechanisms and related institutions that support responsive and coherent local resource-use planning, while making the most of the opportunities to manage nexus trade-offs at a national level, where the trade-offs may be less acute.

The California case shows how over-reliance on extensive infrastructure development can create demands for natural resources (in this case, for water) that go far beyond the available supply from within natural systems. Damage to natural systems in turn undermines the resilience of the food system and hence of the wider economy. Similar issues arise in India, China and Turkey. In some countries, this sequence can lead to the resilience of political systems also coming under pressure. More broadly, public expectations of improvements in air quality, water purity and other quality-of-life indicators are increasingly important factors shaping political choices in emerging economies as well as rich nations.

Perhaps the greatest tension between a country's early development decisions and its later resilience lies in the stewardship of each nation's natural capital. Some depletion of natural assets may be an essential early strategy in finding pathways towards greater security of livelihoods. But soil quality, freshwater availability and forest resources all make fundamental contributions to a nation's productivity. New sources of insecurity and a permanent reduction in resilience emerge from continued economic dependence on the destruction of natural capital. Resilient economic systems will be those that benefit from and reinforce the preservation of the natural systems on which they ultimately depend.

National and state-level nexus planning – the example of California

In the United States, California is a major producer of food which is exported for consumption elsewhere. However, in order for the State to accommodate these demands, vast amounts of water (and energy) are required – arguably more than California can sustainably support.

The water and energy inter-linkages in the State are pronounced; coherent management of these will become increasingly important in the future, as climate change exacerbates the current problems. The government of California has established regulatory mechanisms and economic incentives to alleviate some of these constraints but whether these mechanisms are sufficient to maintain the State's economic and natural resource resilience is unclear.

The nexus at different scales and the role of trade

It will become harder for trade to remain a trump card enabling countries with resource scarcity to buy their way into resilience.

Clarity about scale is fundamental when responding to nexus challenges. In practice, the impacts of resource trade-offs occur primarily at the local level. The national level is where development objectives related to the nexus are conceived and managed. Climate change poses a risk to resilience at the global level.

Achieving coherence and resilience at one scale is not necessarily sufficient or even consistent with achieving resilience at other levels. Examples such as desalination of seawater using fossil-fuel reliant energy can make sense in building resilience at the local or national level, but can undermine resilience to climate change at the global level. Exploitation of fossil-fuel resources in the early stages of development, as in the Chad case, may be an essential precondition for building the nation's resilience in the medium term, while again undermining global resilience in the face of climate change. Global responses to climate change may in turn eventually make development strategies based on fossil-fuel extraction less economically resilient. For example, carbon prices could leave some forms of fossil-fuel extraction no longer economically viable in the future.

Trade can be an important mechanism for overcoming the resource bottlenecks that lead to acute trade-offs at the local or national level. To take the most extreme case example: a country such as Singapore has very limited availability of its own water, food and energy resources. But like other rich countries, it manages the nexus through an economic model relying on trade to provide for the country's water, food and energy needs. Singapore is still dependent on the successful resolution of nexus trade-offs, but these occur in other countries.

So trade can offer an effective strategy for building a nation's resilience. It can be mutually beneficial in nexus terms, where a country with one kind of resource scarcity trades with another country with a different mix of resources. But trade can also result in externalities that exacerbate resilience challenges elsewhere: for example, the water-abundant UK imports soft fruits from more water-stressed countries such as South Africa.

In today's interdependent globalised world, in which resource scarcity has impacts on a global scale (for example, through grain price spikes), there is a question about whether the strategy of building resilience through trade will come under pressure. With three billion additional middle-class people in developing and emerging economies by 2030, countries that have traditionally been global suppliers of natural resources will require more for domestic consumption. In the face of global resource shocks, those nations' own richer citizens will increasingly have the market and political power to demand first call on the resources originating within the country's borders. It will become harder for trade to remain a trump card enabling countries with resource scarcity to buy their way into resilience. Managing trade-offs locally and nationally may become more important in future.

Conclusions: putting the insights into practice

Nexus policymaking is not in itself complex. It requires the strategies of a government or a business to be designed in ways that take account of the connections between water, food and energy systems.

The risks and opportunities around water, food and energy resources are shared risks and opportunities. The vital challenge for policymakers is how to put in place a framework in which those risks and opportunities are engaged in a collaborative way by all who have a role to play. The alternative, competition to control resources, is one feature of today's incoherent responses to the water-food-energy nexus, which undermine resilience.

From our research we have concluded that the most resilient economic systems combine robust infrastructure, flexible institutions and functioning natural capital. The case studies propose areas in which policymakers have particular levers for responding to nexus challenges in order to bring about resilience. They suggest policy makers should:

- Integrate all aspects of development planning, in particular ensuring that water, energy and agricultural sector planning are not done in isolation, but consider how each can contribute to the resilience of the others;
- Design institutions for resilience, in ways that strengthen cooperation and coordinated decision-making;
- Use economic and regulatory instruments to strengthen the incentives and requirements for building resilience into water, food and energy systems;
- Use trade, regional integration and foreign policy to manage nexus trade-offs more effectively, and contribute further to resilience at both country and global levels.

Generic policy prescriptions under these headings will not work in every context. The first lesson of the country case studies is that the nexus plays out radically differently in different settings, and responses by both governments and businesses need to be similarly rooted in the context.

Resilient economies require coherent and effective planning of water, energy and food that balances consumption, production and trade requirements against the country's natural resource endowments. To achieve this coherence, one crucial and neglected part of development planning is to forge a shared perspective within government on where a country stands within the framework of resource scarcity and abundance, and how this relates to the country's development goals.

Some of the countries or states studied have clearly built a development strategy on a sound understanding of the opportunities and risks defined by their resource endowments. Others have appeared to pursue strategies in tension with those fundamental constraints. Particularly where a country has used trade to avoid confronting the risks inherent in its nexus resource availability, increasing global interdependence warrants a review of whether that kind of development strategy can be pursued indefinitely.

Given that the risks outlined in this report are shared risks, there is a central role in development policy for creating the conditions in which different actors collaborate to overcome the threats they face together. Examples of of such collaborative approaches include:

Water Futures partnership, of which SABMiller and WWF were founding partners. It brings together businesses, donors, governments, farmers, communities and others who all face risks of increasing water scarcity in an area, and builds a local alliance to put in place practical measures to secure the resource base on which they all depend. The third founding partner, Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, supports the German government in achieving its objectives in the field of international cooperation for sustainable development, and brings the crucial public sector perspective to the partnership. Policies that can catalyse and spread this kind of collaborative approach at scale are at the heart of a resilience-based development strategy.

The World Economic Forum and IFC have partnered with a number of private companies and official development agencies to establish the **2030 Water Resources Group** (WRG). In South Africa, the WRG has initiated the Strategic Water Partners Network, chaired by the South African Department of Water Affairs and co-chaired by South African Breweries; bringing together businesses and other organisations including the Development Bank of Southern Africa, the South African Water Research Commission and the South African Local Government Association to improve water efficiency and infrastructure. The network represents a unique and progressive multi-stakeholder platform for water resources management. It provides practical ideas to help deliver sustainable water supplies and, to date, has identified seven national projects on water conservation and efficiency and on effluent partnerships, now under development.

The World Economic Forum's **New Vision for Agriculture** (NVA) initiative facilitates coordinated, market-based action, harnessing the power of agriculture and its connection to other resources to drive food security, environmental sustainability and economic opportunity. Since its creation in 2009, the NVA platform has engaged over 250 organisations from a wide range of stakeholders and geographies, and has catalysed multi-stakeholder partnership platforms in 14 countries in Africa, Asia and Latin America.

Nexus policymaking is not in itself complex. It requires the strategies of a government or a business to be designed in ways that take account of the connections between water, food and energy systems. It involves a deep understanding of the interdependence of those systems, and of the consequences of climate change and demographic pressures for those systems. Resilience building becomes a central principle within any strategy founded on this understanding.