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Justifying, extending and applying "nexus" thinking in the quest for sustainable development

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Introduction

There was a time, not very long ago, when scholars, policy makers and those engaged in private enterprise were consumed by the quest for sustainable development. Gaining prominence after the 1987 Brundtland Report and subsequent UN-sponsored conferences, the concept of sustainable development demanded and received enormous attention over several decades, and in many ways, the achievements of those heady days are remarkable. For example, the key tenets of sustainable development – notably, the principles of precaution, policy integration, inter- and intra-generational equity, and the polluter pays principle – were incorporated into significant international law and into the domestic policies of almost every country on earth. The sense of urgency and import generated in that period also ushered in a suite of initiatives and instruments to support the process towards sustainable development, from 'triple bottom line reporting' and 'corporate social responsibility', through to the mainstreaming of environmental impact assessments and third-party certification of environmental practices. Not surprisingly, the momentum generated from the late 1980s onwards was matched by a concomitant rise in the representation of pro-environment parties in many countries, the establishment of national and state departments of the environment, and the proliferation of sustainability-related professions and associated educational offerings.

But somewhere along the way sustainable development – the ideological concept, process and goal – has almost disappeared from the international stage. Indeed, notwithstanding its rebadging to a green economy by UNEP, 'green growth' and the post-Rio+20 emergence of Sustainable Development Goals, it is fair to say that the global effort expended on 'sustainable development' has faded, replaced by similar levels of zeal and activity targeted at climate change. Why is that the case? Perhaps because the all-encompassing scope of 'sustainable development' made it unwieldy and intractable in practice? Or was it a consequence of the characteristic boredom that humanity exhibits when a concept lurks too long or is too difficult to achieve? Or perhaps it was the sense of urgency generated about climate change and the comparative ease with which carbon emissions can be measured and, arguably, reduced, that was just too seductive to resist? Whatever the reason, by the mid-2000s climate change had replaced sustainable development as the big environmental issue of our time.

The subjugation of sustainable development by climate change is anathema to those who recognise the latter as a subset of the former (eg Dovers and Hezri 2010). Yet the shift to the single focus of climate change, away from the all-encompassing focus of sustainable development, quickly gave way to a curious and welcome consequence: the re-emergence of 'nexus' thinking. What started as the realisation that to combat climate change was to transform, predominantly, the energy sector, became the further realisation that changes to the energy sector would have consequences for the water sector. Most recently, that link has led to the further realisation that developments in the climate, energy and water sectors all have implications for agricultural production, specifically, food. And biodiversity, and health, and on it goes. The fundamental tenet of sustainable development remains: policy integration and co-ordination across sectors to attend to linkages and interdependencies.

In many ways, conceptual framing using a nexus 'approach' is a natural extension of the earlier, well-known concept of Integrated Water Resource Management (IWRM). Espousing as it does "the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP 2000), IWRM is, by its very definition, combining nexus language with the broader objectives of sustainable development. However, like sustainable development, IWRM is a somewhat nebulous concept that has proven hard to implement in practice. It is perhaps not surprising then that much of the research and literature on the nexus has been generated from the water sector (Hussey and Pittock 2012; Hussey et al. 2013), which has recognised that while there is evidence of broad acceptance of IWRM principles, success has been limited and a fresh approach is needed (Biswas 2004). The exception is the work generated in the United States on water demand in the energy sector, which has been driven by the extreme vulnerability felt by the energy sector in that country to increasingly dire water scarcity (Rogers et al. 2013; Hussey et al. 2013).

All that said, in the course of our research for this book and other projects, we have regularly questioned the usefulness of the 'nexus' approach. What is the benefit of restricting our thinking to two or three sectors when we know that important connections exist with other sectors, and that a holistic, systems approach is optimal? Why the inclusion of 'climate' in the climate-energy-water nexus, when it serves mostly as a driver of change in the other two, in the same way that changes in population and economic development act as drivers? And perhaps most pervasive is the genuine concern that 'nexus' research will follow the path of other conceptual frameworks by being intellectually interesting for a time only to be replaced by the next intellectual fad in a few years (leaving aside sustainable development and IWRM, the interesting discourses on environmental security, ecosystem services and green growth, everything under the rubric of 'earth systems science', and more recently the prevalence of scholarship dedicated to the concept of resilience, is also relevant.)

Our answer to the first question is simple: thinking about individual sectors and their relationships to each other is easier, more amenable to systematic analysis and can be applied more readily in policy and investment decision making. At various fora, scholars have described the nexus approach as a 'pedagogical tool' and a 'dialectical apparatus' but, again, we put it more plainly: you can 'get your arms around' the relationship between two or three sectors in a way that is impossible with the broader concept of sustainable development. Sustainable development demands integrated or 'whole system' research and policy approaches that may well extend beyond our capacities, including too many variables and imperatives: the 'nexus' between three or so sectors is within our intellectual and policy reach.

Our justification for including 'climate' as the third pillar in the climate-energy-water nexus in this book lies in the fact that developments in climate policy are so rapid, urgent and significant that it is a powerful policy driver in its own right, but with many 'levers' available to shift its direction; the same cannot be said for population growth and economic development which are both seemingly on steady trajectories. In truth, though, the inclusion or exclusion of one sector over another can easily be justified; indeed, to argue about which two or three sectors are paramount and should thus be favoured is to miss the point entirely.

Much scholarship has emerged in recent years illustrating the benefits to be gained from a 'nexus approach' or 'nexus language' (Rogers et al. 2013; IEA 2013; Pittock et al. 2013), which brings us to the focus of this book. Our purpose in this volume is to extend earlier work on the nexus in four very distinct ways.

Our first objective in this book is to extend the existing technical knowledge of the links between the climate, energy and water sectors. Much research has been undertaken in the water sector over the last few decades – thanks to the traction gained by IWRM and most recently that of water footprinting – but very little work has been done to focus attention on the interrelationships between climate change per se, climate change policy and the transformations it drives in both the energy and water sectors. Chapters 2 and 3 go a long way to filling that deficit. Chapters 3 to 7 provide detailed accounts of the implications for water resources from the full suite of fossil fuel and renewable energy sources. Importantly, these chapters focus not only on the negative or perverse trade-offs that exist in the energy-water nexus, but also on the many opportunities that can arise when the links between the sectors are better understood. The next two chapters explore the dynamics of the climate, energy and water nexus in rural (Chapter 8) and urban (Chapter 9) settings. In doing so, they expose not only new linkages between the two settings, but also the distinct policy and institutional arrangements that govern urban and rural contexts. In a similar vein, Chapter 10 provides valuable insight into 'the nexus' in four countries, specifically with respect to the generation of electricity. Combined, the first ten chapters of this book provide a comprehensive overview of the many links that exist between the climate, energy and water sectors.

In essence, efforts to pursue sustainable development are a matter of co-ordination and integration, and 'unpacking' the integration challenge into two or three sectors through a nexus approach exposes where the fundamental disjunctures between policy spheres lie, as well as where existing or new integration tools could be used to achieve better outcomes. Recognising this, our second objective for the book is to critically explore the range of governance mechanisms available to better account for, and integrate, the climate-energy-water nexus in policy and investment decisions. In various ways, Chapters 11 to 17 tackle this objective. Chapter 11 begins by examining the institutional dynamics within each sector and the implications of those dynamics for cross-sectoral co-ordination. In doing so, Chapter 11 sets the scene for the next three chapters, which explore the role of regulation in managing the nexus (Chapter 12), the opportunities and limitations of markets to integrate across the three sectors (Chapter 13), and the importance of knowledge, education and enabling skills amongst key stakeholders to make decisions that both reconcile trade-offs and seize opportunities in the nexus (Chapter 14). Importantly, Chapter 15 returns to the central question of governance to explore the extent to which a nexus approach to policy integration can or should be embedded in a broader systemic governance framework. Collectively, these chapters shed new and critically important light on the opportunities and limitations of existing policy and institutional arrangements to better govern the nexus.

Our third objective in this book is to identify and explore some of the knock-on consequences of dynamics in the climate-energy-water nexus for other sectors, most notably biodiversity (Chapter 17) and food (Chapter 18). We see this as a way of testing whether efforts to manage the nexus between two or three sectors leads to benefits in other sectors.

Our final objective is to attempt to distil this book’s wealth of knowledge so as to identify where important ‘win-win’ opportunities can be seized in the short term, but also where gaps in our understanding remain and demand attention. Thus, in the concluding chapter, we endeavour to ‘add it all up’ to see where it gets us: the ultimate test of the nexus conceptual frame is whether it can lead us to positive possibilities. We believe that this volume moves beyond a catalogue of problems to identify practical means of minimising perverse actions from one sector on others and seize positive synergies across sectors to benefit people and the environment. Thus, in Chapter 19, we present our conclusions and insights for where the nexus has taken us, and where we ought to go with it next.

Which brings us back to our last concern, namely that our and others' scholarship on the nexus – including scholarship presented in this book – will mark another decade of important and intellectually exciting research but that, ultimately, the conceptual framework of ‘nexus’ thinking will not endure. We have come to the conclusion that to worry about the longevity of any one conceptual or analytical tool is to overlook the cumulative nature of research and the human experience it informs. The outstanding research contained in this volume builds on the sustainable development research that has come before it, and the use of ‘nexus’ framing serves only to provide a fresh perspective. In doing so we highlight where existing research can be useful, or conversely, expose the research gaps. In this way, our thinking ought to evolve over time with new ideas and understandings racing to overtake those before but always cognisant of the dangers of ignoring the accrued insights developed under previous frames of reference, topicality and analysis.

Our plea, if we may be so bold, is simply that the normative goal of sustainable development – ambitious, unwieldy and often intractable though it might be – ought not to be lost sight of in the race.

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Water resources, climate change and energy

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Introduction

The objective of this chapter is to summarise our understanding of the physical interactions between water resources, energy use, and climate change and mitigation. The distribution and pressures on our water resources will be reviewed, as well as our current understanding of observed and projected changes due to climate change. By addressing a set of relevant questions, the aim is to provide a framework within which we can interpret which interactions are likely and which less likely; which are desirable and which not desirable. The questions addressed include the following:

- *What are the characteristics, drivers and challenges of water resource management?* Why do water resource management challenges vary between countries? Are concepts like green and blue water, embedded water, peak water and integrated water resources management useful in managing the relationship between water, climate and energy?
- *What are the observed and projected impacts of climate change on water resources?* Why does it seem that climate change makes water management harder everywhere? Does it matter whether climate change is man-made? How do melting ice caps and glaciers affect water resources? What is the relationship between drought and water resources? How do climate change, floods and water resources interact? Will climate change affect water use?
- *What are the potential impacts of water management on climate and energy security?* What adaptation measures are considered in water management? What is their influence on energy security and climate mitigation measures? For example, can changes in water management change climate? What do water management changes mean for energy use?
- *How can climate mitigation and energy security measures impact on water security?* Can switching between energy sources affect water security? What impact do the by-products of energy generation have on climate and the water cycle? What is the impact of climate mitigation measures such as landscape carbon storage?

In this chapter, ‘water management’ refers to all the activities designed to balance the supply and demand of water. It refers to structural as well as non-structural measures, and natural as well as man-made water systems. The goal is to achieve human and environmental benefits, including water supply, wastewater service, flood control, hydropower, recreation, navigation and environmental protection (Grigg 1996).

Water management: A challenge even without climate change

Water has traditionally been thought of and managed as a local issue, or at least one that does not extend beyond river or groundwater basin boundaries. While this is to a large extent still the case, the challenges to water management are increasingly taking on a global dimension, influenced by global processes like population growth and movement, international trade and climate change. For example, Vörösmarty et al. (2010) estimated that 80 per cent of the global population now lives in catchments with threatened surface water supplies and river health, with more than two billion people regularly having to face severe water scarcity (Hoekstra et al. 2012). The situation is no better for groundwater, which is mined at unsustainably high rates almost everywhere where livelihoods critically depend on it (eg Wada et al. 2010). Thus, water security has become a problem of global scale that only a few relatively wet and sparsely populated countries have been able to escape, and one that is contributing to political conflict between countries and regions within countries.

So far, the main stresses on water availability have not been from climate change but from increased water use, the modification of river channels and water pollution (UN 2003). In many countries increases in population, irrigation, urbanisation and household water consumption drive water use and the regulation of river systems. According to the United Nations, the increase in global water use over the last century has been two times greater than the rate of global population growth. Most of this increase has been to satisfy the increasing demand for crop products. Globally, irrigation accounts for about 70 per cent of water withdrawals and 90 per cent of consumptive use (ie water that evaporates or is too polluted for reuse; Shiklomanov and Rodda 2003). Global irrigated area has doubled since 1961 and is projected to increase another 10 per cent by 2030 (Bruinsma 2003); competition for water can be expected to increase further.

A local problem of global proportions

Water is essentially an inexpensive resource but one that requires much energy to transport. For this reason, natural surface and groundwater systems are often the logical unit of management. This is less true for municipal water systems, because the higher economic value of water in these cases can justify costly 'unnatural' water movements such as long-distance pipelines and desalinisation. Urban water use constitutes less than 20 per cent of total extractions in most countries, but managing these water supplies has its own challenges. For example, there may not be sufficient nearby and accessible river or groundwater, or the water may be of poor quality or polluted (for example, ironically, due to flooding). Many of the world's largest cities face occasional or on-going risks to water supply – even those in wet climates.

Because of the costs of water transport, considering water availability and use at global aggregate scale provides limited insight into the challenges that face water managers. National scale information still hides major transport obstacles but does illustrate the vast differences in water management challenges between countries (Fig. 2.1).

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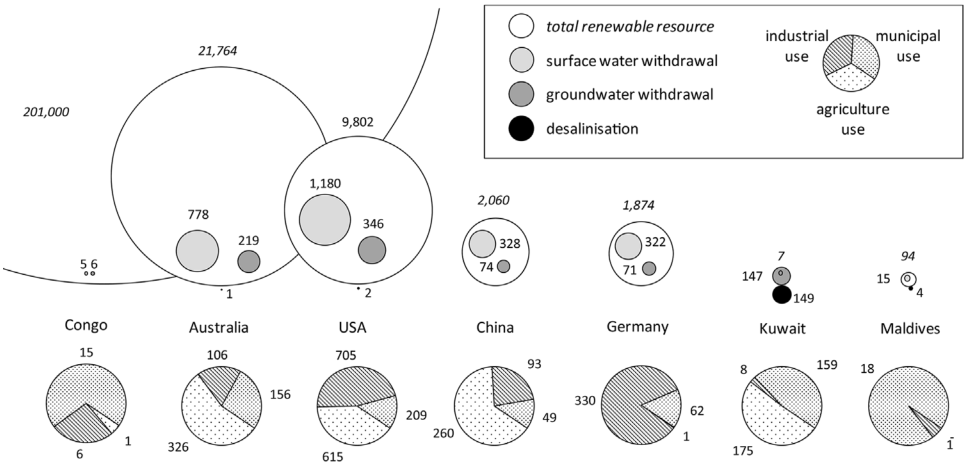

Figure 2.1 Comparison of water availability and use in a selection of countries. All numbers are expressed in m^3 per person per year. Data are from AQUASTAT (FAO n.d.).

Figure 2.1 shows the water available, withdrawn and used in seven countries, expressed in cubic metres (or thousands of litres) per person and year (FAO n.d.). The total renewable resource includes the annual average amount of water that is added naturally to surface and groundwater sources, as opposed to non-renewable water contained in glaciers or so-called fossil groundwater reservoirs. Expressed per person, the renewable resource available is the combined result of climate conditions and population density. Thus, wet and sparsely populated Congo can boost a comfortable 201,000 cubic metres (thousand litres) of renewable resources per year per person, compared to a mere 7 cubic metres in arid Kuwait. This does not include desalinisation, which theoretically creates a near infinite and renewable water source but at high-energy costs. Figure 2.1 illustrates some other points:

- Municipal water use is typically not the main part of total withdrawals. Exceptions are non-industrialised countries with a climate that is sufficiently wet to make irrigation unnecessary (eg Congo) and countries where water is so scarce that any other uses are uneconomical (eg Maldives). Usually, only municipal water use can economically justify desalinisation. It provides more than 20 per cent of total water use for several Middle Eastern countries (Kuwait, Qatar, Bahrain, United Arab Emirates, Lebanon) and small islands (Malta, Antigua and Barbuda, Maldives; FAO n.d.).
- Irrigation is often the largest use of water in countries with dry regions. Water is usually drawn from surface water sources, but groundwater can be another important water source. Groundwater is the primary water source in the Middle East and Northern Africa (where fossil groundwater reserves are used) and several countries with high yielding groundwater sources, often in limestone ‘karst’ aquifers (eg Slovakia, Denmark, Portugal and Jamaica).
- In most European countries, Russia and the United States, industry is the largest water user. Unlike irrigation water use, much of these withdrawals (eg for power station cooling) are not evaporated and returned to the rivers.

- At face value, several countries known to face water management challenges (eg, the United States, China, and Australia) would appear to have sufficient renewable resources available to meet demand. Indeed, at the national level, no more than ten countries withdraw water at a rate that exceeds natural renewal (nine Middle Eastern countries and Barbados). This again emphasises that the cost of water transport is a major constraint on effective water management, and one that links it directly to energy use.
- The sensitivity to climate change varies widely between countries and regions. Thus, in Congo water availability is unlikely to be a major challenge, but flooding might. In Kuwait, climate change may influence water demand but will not affect water availability. In the Maldives, climate change per se may not be the main problem but sea-level rise certainly does pose a threat to many aspects of life, including water.
- The large differences in water availability and scarcity between countries and regions can be attributed to the large amount of energy required to supply water by artificial means.

'Blue' versus 'green' water

The surface and groundwater sources from which water is drawn have been categorised conceptually as 'blue' water: water in sources from which it can in principle be extracted and transported with relative ease. This contrasts with 'green' water, which can be thought of as the water in the soil and which cannot easily be extracted other than by vegetation (eg Rockström et al. 2009). Water management tends to focus on blue water, while green water is the domain of land and crop management. This separation has a longstanding pragmatic use, but can lead to important oversights, even more so in stressed water systems. For example, green water is critical for dry land cropping, but irrigated crops, too, rely on green water; blue water is only added when rainfall is insufficient. Also, any precipitation onto the landscape will largely go towards replenishing the ('green') soil water first, before flowing over to fill ('blue') groundwater and surface water sources. The main implication of this is that an increase in green water use in the landscape can lead to a reduction in blue-water renewal. The two water types interact closely and this can lead to complex management questions. Some of these will be discussed later in this chapter.

Embedded water

A concept illustrating the link between water transportability and energy is that of 'embedded' or 'virtual' water (Allan 1997), which quantifies the large volumes of water that can be involved in the production of any particular product. The concept of a 'water footprint' captures a very similar idea. Accounting for embedded water makes it clear that transporting the product is usually more cost efficient than transporting the water required for its production. For example, for many Middle Eastern countries it makes more sense to import food and use the saved irrigation water resource to increase water security for other users. The concept also has some problems. Often no distinction is made between embedded green and blue water. This can lead to the interpretation that all embedded water that is 'freed up' can be used for other purposes, which is usually incorrect. Also, using water from geographically different sources is likely to have quite different associated outcomes, both wanted (eg food sufficiency, economic activity) and unwanted (eg environmental degradation). Accounting for these outcomes is not straightforward. Nonetheless, the concept of embedded water illustrates that water, food and energy can in fact be substituted for each other, through transport, trade and technology.

Peak water

Water resources share some characteristics with fossil fuel resources, and some resource availability concepts apply to both. For example, the concept of 'peak oil' has been extended to 'peak water' (Gleick and Palaniappan 2010). Peak oil refers to the initial exponential increase in oil production in the United States during the twentieth century (because of growing demand and extraction efficiency) and the subsequent decline after 1970 (because the remaining oil was increasingly difficult and costly to extract). The concept has been applied at local, regional, national and global scale. The concept is directly transferable to non-renewed or 'fossil' groundwater reserves in arid regions. With some modifications, the concept can be extended to renewable water resources used at an unsustainable rate. Important groundwater reservoirs that have reached 'peak water' are found in the California Central Valley, the US Great Plains (the Ogallala Aquifer), the North China Plains, and Northern India. Similarly, river water extractions can become so large that streamflow no longer reaches the river mouth for much of the time. This is the situation for the Murray River in Australia, the Colorado River in the United States, the Yellow River in China, the Jordan River in the Middle East, and the Nile River in Egypt. In a less literal interpretation of peak water, the concept may be used to describe the point at which the overall societal benefit of increased withdrawal is undone by the damage to all other water resource functions – however these are quantified.

Features of the peak oil concept that apply to water are the role of the (energy) costs of extraction and the ability to substitute one water source with another. An important difference is, again, the vastly higher cost of resource transport. Gleick and Palaniappan illustrate this with a simple sum: the oil contained in a tanker ship may be worth around US$250 million, which leaves enough margin to justify long-distance transport and encourage global trade. The same tanker but full of drinking water would be valued at US$500 thousand at most. Overall, peak water probably remains a local or regional phenomenon. In some cases, changes in climate can bring forward or delay peak water.

Integrated water resources management

Integrated water resources management (IWRM) is a widely used and broadly interpretable term. It may be used to imply that integrate management measures should be integrated, for example:

- across different water system components or management aspects (eg flood protection and water security, green and blue water, surface and groundwater, water quantity and quality);