



TOPIC GUIDE :

Managing the Water, Energy,
Food and Land Nexus in the
context of Climate Change
and Food Security

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About Topic Guides

Welcome to the Evidence on Demand series of Topic Guides. The guides are produced for Climate, Environment, Infrastructure and Livelihoods Advisers in the UK Department for International Development (DFID). There will be up to 40 Topic Guides produced 2013-2016.

The purpose of the Topic Guides is to provide resources to support professional development. Each Topic Guide is written by an expert. Topic Guides:

- Provide an overview of a topic;
- Present the issues and arguments relating to a topic;
- Are illustrated with examples and case studies;
- Stimulate thinking and questioning;
- Provide links to current best 'reads' in an annotated reading list;
- Provide signposts to detailed evidence and further information;
- Provide a glossary of terms for a topic.

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The Topic Guides, and key texts referred to in the guides, cover the latest thinking on subject areas. If you think that a specific issue might be raised when you are under the spotlight, you can scan a Topic Guide dealing with that issue to get up to speed.

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- Send an email to the Evidence on Demand Editor at enquiries@evidenceondemand.org with your recommendations for other Topic Guides.

Report Summary

Objectives

The purpose of this Topic Guide is to assemble a set of learning resources that will contribute to the development of the professional competence of DFID advisers on the issue of managing water, energy, food and land linkages in the context of climate change and urban resilience.

The specific objectives are to provide:

- The background to the emergence of the nexus approach to water, energy, food and land in the context of sustainable development planning
- A summary of the underlying issues surrounding water, energy, food and land linkages
- An overview of how nexus linkages impact on infrastructure projects, climate change and vulnerability
- A summary of opportunities for effectively considering water, energy, food and land linkages in DFID infrastructure programmes.

Rationale for a nexus approach

The combination of population growth, urbanisation and rising consumption are placing pressure on water, energy, food and land resources. The production and use of these resources results in greenhouse gas emissions. Climate change is in turn putting pressure on the available supply and demand for resources. These pressures prompt a need to consider more effective solutions for the equitable management of resources.

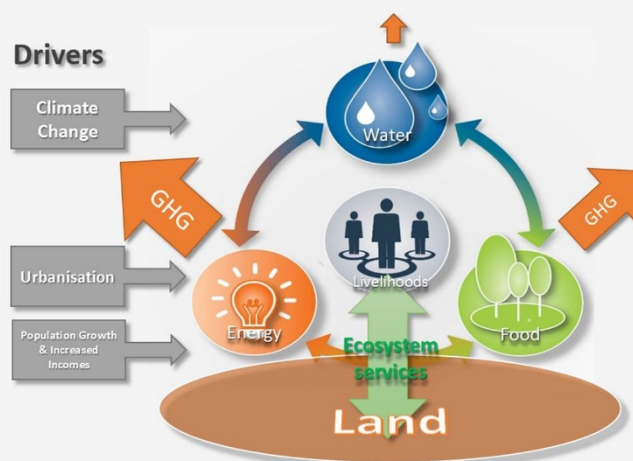
Approaching management of the vital resources of water, energy, food and land as a nexus, (the core of a linked system) can provide a base for governments to re-appraise their approach to water, energy and food security and identify how they can move to sustainable resource use.

The focus on the links and interconnections between management of water, energy, food and land is what differentiates a nexus approach from “integrated” approaches to resource management which consider each resource separately and integrate plans on a spatial, temporal and institutional basis.

The approach guides a wide variety of stakeholders to identify and pursue possible synergies between sectors, jurisdictions, and technical domains. It encourages the breaking down of traditional responsibilities and business as usual thinking that often results in poorly coordinated investments. Taking a nexus approach can therefore enhance what could be achieved by managing water, land and power resources individually but requires new governance structures that will be tailored to individual circumstances and be, by definition, innovative in nature.

Thus, although the outcomes from a nexus approach can be measured, demonstrating the internal efficiency of a project, it would be extremely unlikely that a counterfactual could be constructed for comparison purposes.

The water, energy, food and land nexus is the resource base for human livelihoods which have co-opted land use to human functions with consequences for the ecosystem services we are dependent on. This process is being driven by further development and urbanisation, is modified by climate change and in turn is causing climate change.



The rationale and issues driving the need to consider the nexus can be framed as follows:

- Water, energy and food are vital resources that support human livelihoods.
- These three elements are in an inter-dependent nexus relationship. Each is required in order to produce the others. Society must continually produce and renew each to survive.
- We need land, shelter and the physical and social infrastructure to get the water energy and food, and the waste products of their use to us and away from us.
- Food, but also water and energy require land to produce them. Land is also needed for urban infrastructure, nature and the ecosystem services that support life. There are competing pressures on land use.
- Changing land use, extracting resources and generating energy to support livelihoods causes greenhouse gas emissions. The atmosphere's capacity to absorb GHG emissions without causing catastrophic climate change is a limit to fossil fuel use and changes in land use.
- Climate change is driving change in land use and how we manage the water energy food nexus
- Water, energy and food are each renewable and can potentially be made abundant but changes in our infrastructure and social organisation are required to achieve sustainable livelihoods. The means for renewing water, energy and food resources should minimise the use on finite fossil fuels.
- As well as water, energy and food, land provides a range of ecosystem services for purifying water and air, and has intrinsic natural value. These services have an economic value. In managing land for food production, urban development or conservation we should seek to maximise all the services provided (in multiple sectors) rather than focusing on a single function per area based on maximising economic returns in a narrow sense.
- Nexus-based tools incorporating the linkages between resources can help formulate and economically justify plans that will result in diverse, mixed land uses that provide multiple services, such as water, energy and food as well as provide other benefits in terms of climate mitigation and aesthetic beauty. These tools and resulting plans must account for pressures from urbanisation and climate change and quantify the costs and benefits against indicators and budgets.
- The nexus approach can inform policy making and inter-sector dialogues. It also provides a framework for applying analytical and technical tools to appraise impacts and consider implementation options with economic justification.

Recommendations

Change requires leadership. It is therefore important that every opportunity is taken with the top leadership of a country, cities and regions to ensure that the basic principles of a need to move to more sustainable development models are accepted. Implementation of resource management policy can be more effective if top leaders understand the linkages between water, energy, food and land management.

There are 10 key recommendations that advisers should consider:

- **Recommendation 1: Guide sustainable and inclusive growth.**

Analysis of the resource nexus has widespread potential to help find effective and sustainable routes to inclusive growth and better livelihoods. Advisers should consider the approach in connection with programmes and projects which have significant implications for natural resource use or where there is complexity and uncertainty regarding possible impacts and trade-offs between resource sectors.

- **Recommendation 2: Policy Appraisal.**

Advisers should advocate the use of the nexus approach to encourage appraisal of policy frameworks and plans and the impact of unsustainable practices.

- **Recommendation 3: Stakeholder mapping and governance.**

Advisers should undertake an initial appraisal of governance capacity to identify what the conditions are for using a nexus approach. Relevant institutions and stakeholders who could be engaged should be identified.

- **Recommendation 4: Develop evidence base.**

Advisers should analyse data and information to frame the existing situation and challenges as a key first step to making the case to take action on the nexus approach and support efforts to strengthen the information base.

- **Recommendation 5: Legal and regulatory issues**

Advisers should consider how legal and regulatory frameworks may influence the effectiveness of possible actions. Diagnosing these issues through analysis of the links between resource areas can be used to identify possible entry points for multi sector approaches.

- **Recommendation 6: Links to finance.**

Advisers should consider how the nexus approach can be linked to mobilising investment and finance in support of projects and options to support implementation of the nexus solution.

- **Recommendation 7: Engaging private sector.**

Advisers should consider engaging the private sector to advocate for change. Opportunities could exist for forging partnerships with both government and civil society.

- **Recommendation 8: Using nexus to enable economic growth and urban development.**

DFID should consider fully embedding the nexus approach in policies and strategies. The added value which a nexus approach can bring is highlighted in Section 2. The approach can help DFID deliver its existing policy objectives.

- **Recommendation 9: Need for additional research.**

There is a need for further research in monitoring and evaluation to quantify the impact of applying the nexus approach on demonstration or pilot studies. DFID should consider opportunities to develop new tools and appraisal methods for identifying the costs and impact of nexus-related solutions on a transparent basis.

- **Recommendation 10: Mechanisms for engaging stakeholders.**

Advisers should review potential entry points to support national partners in exploring the water-energy-food-land nexus. Advocacy, support for applying and developing tools, contributing to strategy and investment planning and reviewing opportunities to address nexus in existing projects are examples of potential entry points which should be considered.

Structure of the guide

In Section 1 we describe how an approach focusing on the linkages between the use of resources can inform the development of analytical approaches and tools, which in turn can inform policy development and support implementation leading to changes in behaviour and construction of appropriate infrastructure.

In Section 2 we differentiate this nexus approach from more established integrated resource management approaches to understand how it can be used to enhance existing methods to move more rapidly to secure and sustainable societies. This section sets out how analysing governance and administrative processes through a nexus lens can help to identify where to build and support linkages and communication between parts of government responsible for the management of each resource.

In Section 3 we review some of the available tools and the requirements for the development of new tools. A range of analytical tools can be used to appraise options, consider the potential costs and benefits, and make the case for change.

In Section 4 we present examples which tackle two or more interrelationships within the nexus concept.

Section 5 sets out the nexus issues in the context of programme design for DFID advisers with recommendations on how to put the findings into practice.

This is followed by an annotated bibliography and list of references.

Added value: The increased value or benefits achieved by adopting an efficient approach without increasing the initial estimated costs or efforts.

Circular economy: A circular economy is one that is restorative by design, and which aims to keep products, components and materials at their highest utility and value, at all times.

Climate change: The United Nations Framework Convention on Climate Change defines climate change as ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods’.

Ecosystem services: The benefits people receive from ecosystems including products like clean drinking water and processes such as the decomposition of wastes.

External drivers: Conditions and events that change the trajectory of proceedings outside the sphere of influence of a location, sector or organisation.

Food security: Reliable access to sufficient quantity of nutritious food.

Governance capacity: Capability of governmental institutes and actors to respond positively to risks.

Green growth: Fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our wellbeing relies (OECD).

Natural resources: materials found in nature that can be exploited for financial gain.

Nexus: The nexus is an integrated approach to governance and management across sectors and scales which delivers improvements in water, energy and food security for the benefit of all.

Self-sufficiency: Condition of relying on one’s own resources.

Socio-economic benefits: Positive impacts arising from change in terms of social and economic wellbeing such as employment and income, housing, public services and quality of life.

Sustainable resource planning and use: Process that links available resources to the current needs of a population and economy without compromising the ability to meet future needs.

Value for money: Maximum benefit from the goods and services the government both acquires and provides, within the resources available.

Water security: Sustainable and equitable access to water of sufficient quantity and quality for health (e.g. drinking and sanitation), productive activities (e.g. agriculture, industry), the environment (e.g. wetlands) and reduced vulnerability to water related risks (e.g. floods, drought and pollution).

SECTION 1

Context

1.1 The challenge

Increasing demands are placing pressure on water, energy, food and land resources creating a daunting challenge. But humans are innovative and adaptable and solutions can be found. The way forward is not by continuing the ways of the past - new approaches need to be implemented.

Global population growth, rising social expectations, urbanisation and climate change are pushing global resources to their limits (Figure 1). Many regions are increasingly over-exploiting scarce resources, resulting in extreme energy poverty, water scarcity, food shortages and environmental damage. Demands will intensify in the future.

As stated by Beddington (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.”*

Currently more than one-third of the world’s population (roughly 2.8 billion people) lives in water-stressed countries and by 2025 the proportion is expected to rise to two-thirds. Around 2.5 billion currently have unreliable or no access to electricity. Approximately 790 million people in the developing world are chronically undernourished.

Governments will need to adapt to changing temperatures, rainfall patterns and more frequent extreme events such as flooding and drought. These climate change impacts will affect water availability, agricultural food production and possibly energy production.

The capacity of governments to act and respond to the challenge may be limited. Most countries have governance arrangements along sector lines with limited arrangements for coordination between institutions.

In addition, decisions taken by one institution may be made in isolation without recognition of the social or economic consequences this may have for particular groups or other areas of government spending.

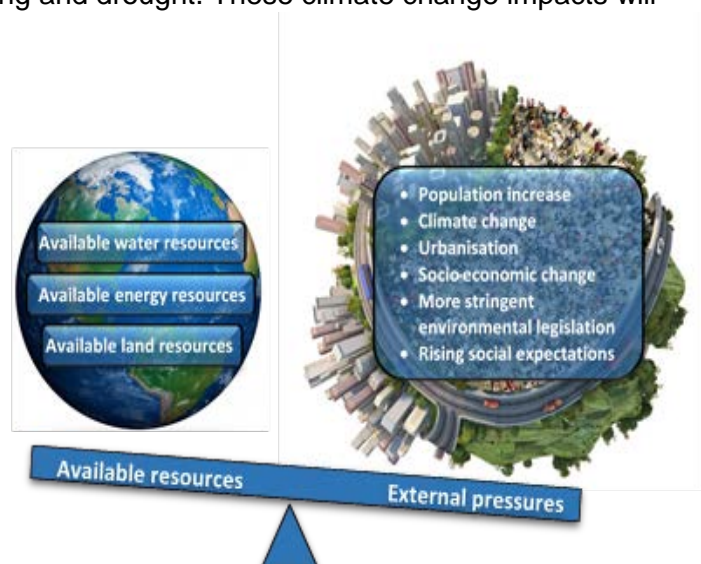


Figure 1 The global resource challenge

This Topic Guide shows how a nexus approach to managing the linkages between water, energy, food and land resources can be helpful in supporting decision making. The approach can be used to highlight the linkages between these issues and make the impact on society

more explicit than before. It can also be used to improve coordination and planning across sectors and mobilise change for a multi-sector response to the challenges of urbanisation and climate change.

The potential benefit on offer is more effective projects and programmes, which deliver improvement of livelihoods while managing national resources more sustainably. This in turn will increase resource security and reduce crisis and conflict.

1.2 Evolution of the water, energy, food and land nexus conceptual framework

The idea of the nexus has risen to prominence over the last ten years and has increasingly been taken up by the scientific and policy community, multilateral and bilateral development agencies as well as national governments in the developed and developing world.

What differentiates the nexus concept from other integrated and holistic approaches to policy making is the focus on viewing beyond individual sectors and focusing on the linkages and interdependencies between land, resources and people. (Bizikova, L. et al., 2013 provides a review of nexus frameworks).

The research and underpinnings of the concept have a longer lineage. It builds upon research and practice in a wide range of fields including those relating to the wider field of sustainable development, social-ecological systems, resource management, and ecosystem services.

Different emphasis has been given to the nexus by different organisations. Most common is the use of the nexus term to frame interlinked challenges around energy, water and food security. However, organisations such as the European Union (EU), World Economic Forum and Transatlantic Academy have taken a wider definition to focus on land rather than just food and to include mineral resources and climate change. This Topic Guide focuses on the links between water, land and energy which is consistent with the framework developed by the EU (Overseas Development Institute et al., 2012). However, the guide draws upon research and initiatives relating to water, food and energy nexus.

“The rush for land is a rush for water and energy.”

Source: Nairobi Nexus Dialogue, Outcome Document, Nov. 2012.

The reason for including land use in addition to food resources within the nexus is to recognise the multifunctional role of land and soils in supporting a range of often overlapping functions and to recognise the critical role which ecosystem services play linking natural systems and economic use of land.

While agriculture represents the most extensive and significant economic land use in many countries, other land uses can also be significant. For example, forest areas are more significant than agriculture in a number of countries and subject to conflicting demands and objectives over their management. Natural habitat and protected areas as well as being of intrinsic value represent an important economic resource in view of their role which natural habitat and biodiversity plays in connection with tourism. Also urbanisation, transport and energy systems are taking ever more land and, even if still small by total area, urban development is often competing heavily for the most valuable and productive land.

While the word nexus just means linkages or a focus point of linkages, for the purposes of this report, the nexus approach is defined as:

“An integrated approach to governance and management across sectors and scales which delivers improvements in water, energy and food security for the benefit of all”.

Nexus solutions are those plans, policies and strategies which have been informed by a cross sector, cross scale view, where a coordinated approach has been taken to addressing resource security challenges and where the linkages between sectors and the potential impacts and benefits of potential options have been considered.

Historically the links between water, land and energy have received little attention from government and the private sector, in part because of governance and institutional frameworks which do not recognise how the issues are inter-related or who is responsible for coordination. There are wide differences between water, energy, and land in terms of regulation and the economic benefits of addressing the linkages are generally ignored.

1.3 Interpretation of the water, energy, food and land nexus in this guide

Population growth, rising social expectations, urbanisation and climate change are all putting pressure on global resources. Some resources are finite and depleted through use while others are renewable. Securing peaceful development in the future means changes are needed in behaviour and infrastructure to make the most of the finite resources as we transition to sustainable social and economic systems based on maximising access to renewable resources.

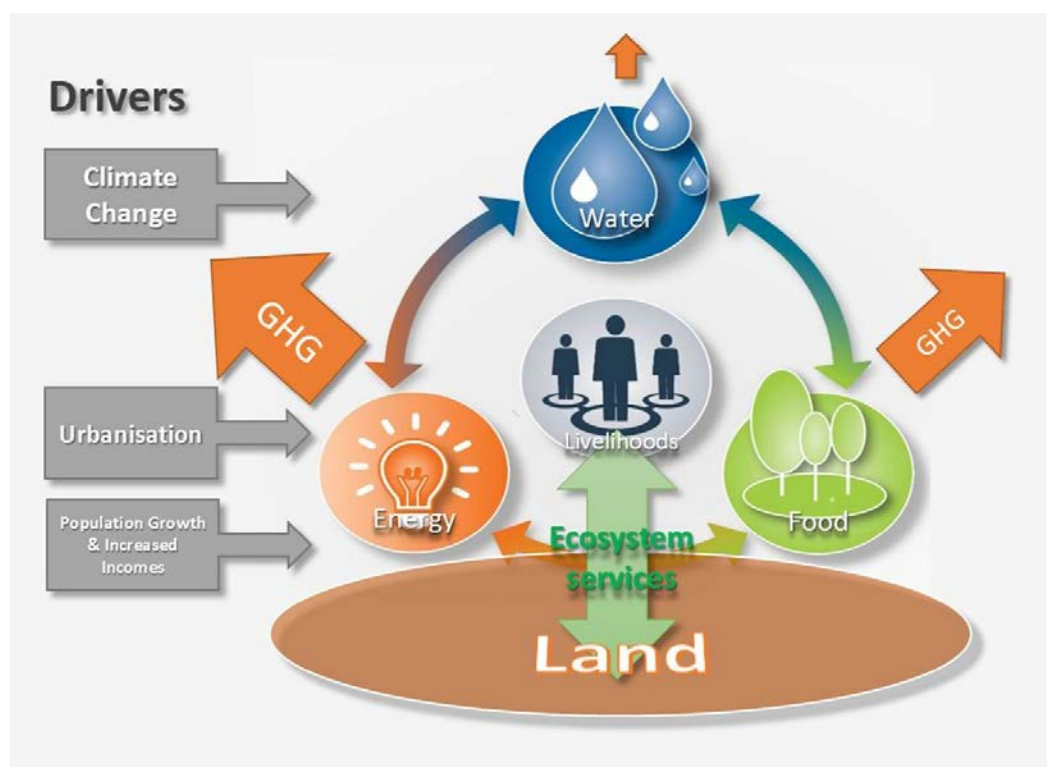
Water, energy and food are the most vital resources that support human livelihoods. These three elements are in an inter-dependent nexus relationship by which each is required in order to produce the others. Society must continually produce and renew each to survive. While each is potentially renewable, in most cases finite resources are used in production steps.

Each of these elements requires land to produce it and so the water, energy, food nexus can be viewed in the context of competing pressures on land use. Land is also needed for urban infrastructure and the ecosystem services that support life. The economic value of land is one of the most important elements of wealth of individuals and nations.

People are at the centre of the nexus. The relevance of nexus to development is the relationship between people, their needs, livelihoods and environment. Those living in multidimensional poverty are frequently most vulnerable to the impact of climate events and food and energy price shocks.

The water, energy, food nexus is the resource base for human livelihoods which have co-opted land use to human functions with consequences for the ecosystem services we are dependent on. This process is being driven by further development and urbanisation, is modified by climate change and in turn is causing climate change. These relationships are illustrated in Figure 2.

Figure 2 Water, energy, food and land nexus and drivers



This guide seeks to identify how these concepts can be used to plan more effective interventions and support better use of resources.

The nexus approach is about focusing not so much on the absolute resources of water, energy or food but on the linkages between them and how better understanding of the role of one resource in the availability of another can lead to formulating more sustainable solutions. As such, nexus planning is more focused on the linkages between resources and how to adapt governance to produce cross-sector solutions.

The nexus approach provides a concept which can inform policy making and inter-sector dialogues. It also provides a framework which can be used for appraisal by applying analytical and technical tools to identify impacts and consider implementation options. Through this guide we will focus on the nexus linkages and build on three key principles to help identify practical solutions:

1. **The vital resources of water, energy and food are potentially renewable and in most regions scarcity can be overcome:** Obtaining the vital resources of water, energy and food for human livelihoods has led to the exploitation of much of the land and the fossil resources of the planet, but water, energy and food themselves, though they may be locally scarce or abundant, are potentially renewable resources. Overcoming scarcity in one resource requires using more of the others – typically more energy if water is scarce or more water where food is scarce – energy is most often the limiting and non-renewable resource. The key is to manage land use and behaviours better for the long-term sustainable production of these resources at the local scale, minimising consumption of concentrated fossil resources taken from finite sources at the global scale.
2. **Land management is the key when considered with ecosystem services:** As well as water, energy and food, land provides a range of ecosystem services for

purifying water and air and has intrinsic natural value. These services have economic value. In managing land for food production, urban development or conservation we should seek to maximise the overall services provided (in multiple sectors).

3. **To justify nexus-based solutions you need to convince at inter-ministerial level.** Though many stakeholders will be involved in the final decision it is vital that a sound economic and financial case can be made for any project investment. Nexus-based tools incorporating the linkages between resource areas can be employed to formulate and economically justify proposals. These tools and resulting plans must account for pressures from urbanisation and climate change and quantify the costs and benefits against indicators and budgets.

Nexus solutions are those plans, policies and strategies which have been informed by a cross sector, cross scale view, where a coordinated approach has been taken to addressing resource security challenges and where the linkages between sectors and the potential impacts and benefits of potential options have been considered. Table 1 below, describes linkages between these resources and gives some examples of policy responses.

Dependency	Examples of linkages	Policy responses
Energy for water	<p>Energy is needed to power water abstraction, treatment, distribution and sanitation. It is also needed to heat water for end-uses such as cooking, washing and domestic appliances, which in UK uses 89% of energy associated with the domestic water cycle. Much of the energy added to water goes to waste but more can be recovered and reused. This energy use increases though the development cycle from village agriculture to urbanized living.</p> <p>In water scarce areas more water can always be obtained by the use of infrastructure and energy – but the difference in cost compared to taking more from existing resources is normally prohibitive so over exploitation is perpetuated.</p>	<p>Energy efficiency and carbon foot printing in the water industry. Energy saving in household and industrial settings – appliance specifications and behavioural change. Promote recycling and leakage reduction. Pumped storage and scheduling of energy consumption in water industry to balance energy supply temporal variation from increased renewables. Energy recovery using heat pumps. Increased solar thermal energy use. Careful design of inter-basin transfers</p>
Water for energy	<p>Water may be used directly for hydropower. Huge quantities of water are consumed in the extraction and processing of fossil fuels, and even more in the thermal generation of electricity whether from coal, oil, gas, biomass or nuclear fuel. Much of this water is “Lost” as a useable resource through evaporation to the atmosphere in cooling cycles and from hydropower reservoirs.</p>	<p>Integrated River Basin management – flow and storage allocation (between hydropower, water resource, flood protection and environment). Regional water resources allocations. Water saving and pollution control in extractive industries. High efficiency power cycles (super/ultra-critical) and dry cooling.</p>
Water for food (land)	<p>Water is crucial for agriculture whether rain fed or irrigated. Irrigation from surface and groundwater. Runoff from agriculture contains nutrients, pesticides and other contamination. Agriculture and especially irrigation impacts groundwater recharge and contamination. Water taken for food impacts the natural environment and biodiversity. Virtual water is traded in agricultural products.</p>	<p>Advanced water allocation (e.g. Evaporative planning) for agriculture. Appropriate crop selections and urban planting. Management of runoff and irrigation return water-integrated catchment management. Groundwater protection zones. Water rights trading between agriculture and urban/industrial water users. Investment in water efficient irrigation.</p>
Energy for food	<p>Energy is needed to power agricultural machinery such as ploughs and milking equipment. Energy is crucial in fertilizer and pesticide production. Energy needed to pump water for irrigation. 95% of global food production is highly dependent on oil. More energy can allow much more intensive farming and greater yields.</p>	<p>Crop selections and intensive agriculture practices. Nutrient recycling and reduction of excess fertilizer use. Energy efficiency in irrigation and farm mechanisation. Construction of greenhouses for controlled climates, higher productivity and reduced evaporation</p>
Land for food	<p>By far the greatest land use is taking land from natural use and adapting to food production (and timber and fibre). Increasingly this is competing with land demands for urbanisation. All of these can detract from land providing ecosystem services.</p>	<p>Agricultural, urban and rural development and land-use planning. Conservation areas and green belt protection. Integration of provision of ecosystem services to development planning. Agricultural policy. Incentivising adoption of farming methods that also provide greater</p>

Dependency	Examples of linkages	Policy responses
Land for water	<p>Land use can be managed for watershed protection and water storage. Managing land for flood storage is critical to secure development. Hydropower and water resources dams and reservoirs. Water must also be considered and protected in aquifers under the ground.</p>	<p>ecosystem services. Integrated river basin management; Integrated catchment management. "Room for rivers" and flood zoning. Groundwater protection policies. Environmental and social impact assessment. Urban development to be required not to increase flood risk by having more permeable areas and green, absorbent features in buildings and urban landscapes.</p>
Land for energy	<p>Land is needed for mining, fossil fuel extraction energy infrastructure, hydropower reservoirs and increasingly to grow produce for biofuel. Deforestation of land sometimes takes place to provide charcoal for cooking. Use if land for solar arrays and wind farms can compete with agriculture and conservation areas.</p>	<p>Land use and development planning. Integrated river basin management. Energy policy and subsidies. Regulation of energy development e.g. shale gas. Balancing biofuels and food production.</p>

Table 1 Water, Energy, Food and Land Nexus Linkages and Example Policy Responses

The consequences of not addressing the problems of equitably providing vital resources is an increased threat to peace and security and increased vulnerability to the shocks of climate change. Better managing the water-energy-food-land nexus is vital to lifting developing countries from poverty; even where the basic resources are plentiful.

Example: Resources for Beijing: The city of Beijing is short of water resources and atmospheric pollution is limiting the capacity to locally produce energy from fossil fuels. In common with most cities worldwide food is brought into the city from far away. Now the same is applied for water with the South-North transfer using massive canal infrastructure to convey water 1200 km from the Yangtze basin, by gravity in the middle route and also using energy to pump in the Eastern route. Almost all the coal stations in Beijing have now been mothballed and power is transmitted from other provinces, or coal is to be converted to gas (SNG) for cleaner consumption in Beijing (but dirtier production at a distance) (Thomas 2015). Together these solutions improve the environment and water security locally but result in far greater energy consumption and higher wastage of resources globally. The wealth of the city reaches out to buy the resources from distant poorer areas, but the result may be inequitable.

A pro-poor approach to addressing nexus challenges needs to be designed in from the outset in order that proposals for land development, energy and water projects can benefit all and do not disadvantage the poorest groups. Increasing resilience through enabling access to water, promoting decentralised and renewable energy projects, enhancing land and property rights and facilitating the urban transition can build resilience to future uncertainty and strengthen the conditions needed to support development.

1.4 Finding solutions

The first area is to look at how we can slow down the wheel of change while still meeting the needs of growing societies. This means conservation and efficiency. Making better use of what we have at each step to achieve the same outcome with less and with less waste.

The second is in moving to sustainable resource management. Water, food and to some degree energy are renewable and constantly replenished but some resources used in their production and the consequences of using them are not. Most important in this is the move away from the use of fossil fuel. Water and food can be produced in huge quantities almost anywhere if enough energy is available. The temptation is to use more and more fossil fuel to overcome restrictions in other resources. This would be fine in the medium term (until fossil fuels run out) if it were not for the dangers of climate change which are facing us in the short term. The emissions of greenhouse gases consume the capacity of the atmosphere to absorb them without dangerous changes making the atmosphere a finite resource. This means that we need to leave most of the fossil fuel in the ground and move as rapidly as possible to renewable and low carbon energy sources.

In addition to the fossil energy we also need to preserve and make the best use of, fossil groundwater, and of minerals that have taken geologic time to concentrate. Thus solutions should focus on maximising the renewable resources of water food and energy production capacity, yielded from the least possible consumption of finite resources. This is effectively applying the principles of a circular economy but by looking at it from a nexus linkages perspective, as it is in the transition between resources where much consumption occurs where we can be more effective in identifying solutions.

Land management is mostly a balance between natural areas, food production and urban/industrial use. The natural landscape and ecosystem has its own inherent value which is of great importance and in certain places needs to be preserved in a pristine condition. The unchanged natural environment provides certain ecosystem services that are vital to human society, but in most cases there is a balance in the human productive factor and the ecosystem service and biodiversity function. We need to avoid land-use change that reduces ecosystem services or depletes the soil health and future capacity for production. Instead we need to develop land to both meet our needs and sustain us and a natural environment in the long term.

Applying this thinking to achieve sustainable and harmonious development will require structured mechanisms for cross-sector communication as shared agendas and goals are difficult to achieve. Instead a nexus approach can be used to encourage integrated river basin, energy sector or food security plans to consider the issues related to linkages to other resources, balancing land use requirements and quantifying affected ecosystem services.

1.5 Next sections of this report

In the next sections of this report we look in more detail at how the nexus linkages can be identified and used to help develop appropriate policy responses in the context of existing integrated planning approaches.

We then go on to look at tools that have been developed or could be developed further to help this process. These tools can help to quantify the benefits of decisions about land use that account for all three vital resource usages and their linkages under different scenarios. These can be used to build the economic case. If economic models do not show advantages in taking a sustainable approach then policy makers will need to consider introduction of measures that will drive the economics of sustainability during transition, e.g. renewable energy feed in tariffs, increased water and mineral abstraction fees, financial incentives for agricultural nutrient management.

The tools can also be used to calculate the greenhouse gas emissions impacts of different options and therefore how they fit within wider climate change policy objectives. The scenarios considered can also take account of major drivers of change such as climate change and increasing urbanisation.

We assess each of the nexus linkages and put these into context with case studies before moving on to formulate a set of recommendations for policy advisers to consider.

1.6 Key messages

This section has highlighted that considering the water, energy, food and land nexus as an analytical concept can provide a basis for governments to re-appraise their approach to water, energy and food resource security issues and to identify how they move to a sustainable model of resource use which reflects absolute and economic resource scarcity for the benefit of all. The focus on the linkages and interconnectedness between water, land and energy nexus issues is what differentiates the nexus from other “integrated” approaches to sustainable development and resource management.

The rationale and issues driving the need to consider the nexus have been framed as follows:

- **External drivers are prompting a need to consider resource use and its implications differently.** Increasing demands from population growth, urbanisation, and rising consumption are placing pressure on water, land and energy resources. In the context of climate change these pressures are becoming ever more critical and threatening security and peace. Thus we need to consider more effective solutions to managing resource use more effectively and equitably.
- **Strong interrelationships between water, energy and food mean they should be considered together.**
- **The nexus approach provides a concept which can inform policy making and inter-sector dialogues. It also provides a framework which can be used for appraisal by applying analytical and technical tools to identify impacts and consider implementation options.** In considering application of the nexus concept for policy land management is a factor in successfully considering nexus solutions as it is linked to energy, water and food and land supports a range of ecosystem services.
- **There is a need to consider the financial and economic case to justify nexus solutions.** The range of tools highlighted in Section 4 can be used to appraise options and make the case for change considering the potential costs and benefits.

SECTION 2

Nexus linkages and policy responses

2.1 Introduction

How is using the nexus concept for resource planning and management different from traditional integrated planning and resources management approaches? In Table 1 we applied the identification of some water, energy, food and land nexus linkages to looking at some appropriate policy responses. In some cases these were about efficiency and minimisation of resource wastage, in other cases they were about incorporating policy into “integrated” planning and management processes. This section explores the relationship between nexus and integrated planning further and looks at factors to consider for implementing the required change in governance to realise benefits.

2.2 The resources nexus and integrated resource management

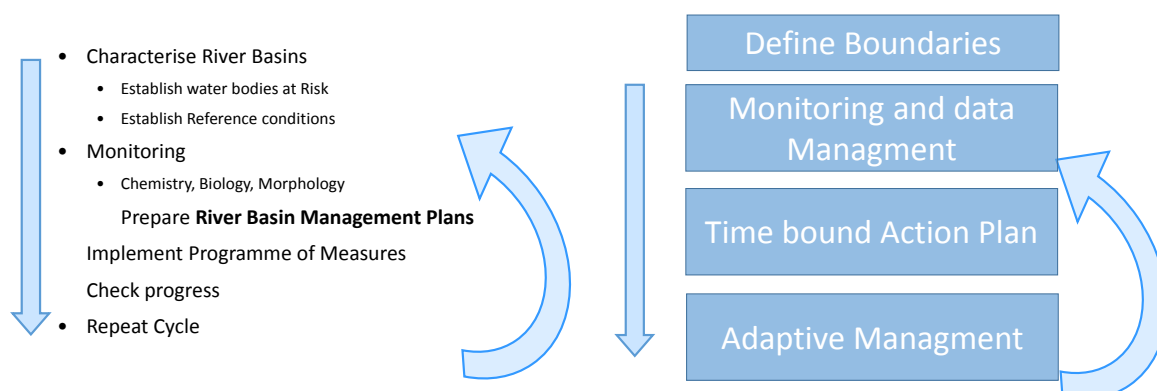
Integrated resource management is about consideration of all of the factors (stakeholders, environmental needs and policy implications) for a defined area, to come up with solutions that adapt to feedback from monitoring systems of the natural and human environments. These integrated approaches can be applied in situations such as; integrated river basin management; integrated natural resource management; integrated agricultural policies and integrated energy policies, each with a different scale and wider or narrower focuses. For example, in the water sector, there can be integrated water resources management, integrated pollution control, integrated catchment management – each of which are implemented in different ways in different territories. The box gives an example of the process of integrated resource planning applied to water management in the EU and compared to similar processes in China.

How does nexus thinking affect the integrated approach? Integrated planning tends to focus on one particular resource and then builds out the geographical, social, and economic and governance implications of managing that resource. Nexus thinking focuses on the linkages between the resources and on the geographical implications for optimising resource efficiency and sustainability across sectors. Solutions with multiple benefits can then be justified systematically in comparison to individual sector plans.

Integrated planning is the vehicle for the implementation of solutions – especially where the time bound action plans are incorporated with policy and legislative frameworks. A nexus analysis can be an enhancement of this process, providing useful analytical tools, for communication across sectors and justifying solutions that have multiple benefits under different resource headings. Economic modelling tools can be extended to consider these more complex cost benefits.

Example: Integrated Water Resources Planning – EU Water Framework Directive

The EU Water Framework Directive is an example of the implementation in policy and law of integrated resources planning at local, national and European Union levels. There is a process set out in EU Directives (and implemented in member state law) to undertake cyclical planning over 6 year periods to define the river basins, setup monitoring and undertake analysis to prepare a time bound action plan and then to review through the process of adaptive management and repeat.



This process is supported by stakeholder engagement – both with member state policy makers and with the mass of people who will be affected in each river basin. Implementation of integrated resource management also requires regulatory processes such as permits for abstractions and discharges which have formal procedures based on monitoring, data analysis and reporting. The whole process is enforced at local levels through courts that can prosecute breach of permits and at member state level by the Commission which can hold states, who have not implemented the directives in a timely manner, to be in infraction and impose significant national fines.

In the EU and USA these processes are defined in legislation and enforced through environmental courts and economic regulation. In developing countries these processes may be politically rather than judiciary led and enforced. For example in China for integrated water resources management there are processes set out in policy documents such as the 2011 No.1 policy document on water reform, the enforcement of which is through the party cadre assessment system (the annual performance assessment of senior officials by the Communist Party of China (CPC)). This political process is more important than the legal process that was set out in the 2002 water law because that has no clear implementation process through the environmental courts, which are very weak. Thus advisors need to understand the real levers of power that drive behaviour and not just the official legal processes.

An important practical consideration when looking at the nexus between resource management plans is to structure the communications and the interactions between sectors. The people responsible for developing their own integrated plans have a big enough challenge already without having to spend long periods in workshop discussions of multiple goals and unifying agendas that will end up confusing and demotivating everybody.

Thus the structure of nexus integration should be appropriate to the level within the governance systems: the goal being to use integrated planning principles as the means for the implementation of better resource management and to coordinate this using nexus principles. This will lead to different messages for different levels of government.

For high level messages to influence senior civil servants and political decision makers, the focus should be about increasing recognition of the importance and potential of nexus thinking, especially the principles of resource abundance to support better livelihoods.

For the mid-levels of administration the messages need to be about the practical steps and tools that can be taken to move towards the long-term goal. This will require working on development of country specific tools and mapping of the key planning documents of each sector and the most efficient exchange of information that would allow for nexus understanding without causing complexity and confusion.

Example: Cross-ministerial initiatives in China “Sponge Cities”

An example of implementing cross sector action is in evidence in the announcements in June 2015 by the Chinese government on “Sponge Cities” a pilot programme of new urban design principles aiming to incorporate water and energy saving features to the design of buildings and urban spaces; to save and recycle water; reduce storm-water runoff and improve the ecology and micro climate of cities. This draws on European Sustainable Urban Drainage (SuDs) or American Low Impact urban design but also has local characteristics. The action plan, investments and pilots are coordinated principally between two ministries (Water and Urban Construction), consults with several other ministries in a structured manner and is to be implemented through Provincial and Municipal governments giving both horizontal and vertical institutional integration.

Example references: <http://canadawood.org/reports/china/news/3885/>
<http://jjs.mof.gov.cn/was5/web/search?searchword=海绵城市&channelid=292129&image.x=-776&image.y=-125>

When undertaking analysis of national policy frameworks the nexus approach can be applied to indicate where a focus on linkages will help understand how sector plans will interact and on maximising the provision of renewable water, energy and food resources which can best lead to improved livelihoods.

The practical implementation of nexus thinking can then be through instruments such as permits, planning guidelines, planning approvals, environmental impact assessments, etc. which tend to be sector specific but can be extended to require consideration of impacts between resource areas.

2.3 Pro-poor and gender solutions

Resource scarcity generally has a disproportionate impact on the poor. The interests of the poorer members of society should be considered in the goal of improving livelihoods for all. Having productive but labour intensive multi-output activities should help to underpin rural development while recognising migration and urbanisation patterns. Solutions also need to consider gender issues in design, implementation, stakeholder engagement and outcomes.

Gender is also a key cross cutting issue. The connections between gender and water and food security linkages were highlighted in a speech at the 2012 World Water Week in Stockholm (see box below).

Example: The gender dimension of nexus linkages and impact on women and girls.

The linkages between water and food security are most significant in four ways:

Firstly, in gendered patterns of production: women dominate subsistence agriculture and unpaid water collection tasks while men dominate the cash crops. Women are involved both in irrigated and non-irrigated agriculture. However a larger number of women than men are engaged in rain-fed agriculture, which puts them more at risk of changing weather patterns. In addition, water rights are often related to land rights, which preclude women smallholder farmers from accessing irrigated water.

Secondly, in gender entitlement systems: looking at gender differences in the access and control over water and other productive resources, assets, services and opportunities for ensuring food and nutrition security. Due to pervasive gender norms and behaviours, women and girls have restricted access to productive resources, such as water, land, agricultural inputs, finance and credit, extension services and technology. This, in turn, limits the efficiency of the agricultural sector to deliver food security for all.

Thirdly, in the gendered division of labour, women and girls are the most overburdened with managing water, food and energy scarcity with their unpaid work, especially in developing countries. Entrenched gender roles mean that women and girls often bear the brunt of the associated hardships as growers and processors of food, responsible for the nutrition of their family, and water collectors. They spend a disproportionate number of hours on time-consuming and unpaid domestic tasks. This leads to their drudgery, reducing their opportunities to education, decent work, political engagement, and perpetuating the intergenerational transfer of poverty and disempowerment.

Finally, in gendered patterns of governance and leadership, which exclude women from policy making and management in the water and agricultural sectors. Although women carry most of the water related tasks, play a key role in food production, especially in subsistence farming and perform most of the unpaid care work, their participation in decision making processes on water and food management remains very low”.

Source: edited closing remarks Lakshmi Puri, Deputy Executive Director of UN Women, Stockholm, World Water Week 2012.

See more at: <http://www.unwomen.org/en/news/stories/2012/8/gender-perspectives-on-water-and-food-security#sthash.9hOo8chY.dpuf>

2.4 Development of tools

The principles of nexus thinking need to be expressed through technical and economic modelling tools so that plans with multiple goals can be quantitatively planned and economically justified. This will require working with treasury/finance ministry officials to agree the acceptable principles and tools that can be used in the processes of approving policies and projects. There are tools that can help in this process and these are discussed further in Section 4.

Economic assessments need to take account of the value of both ecosystem services and non-traded resources used. For example the poor often receive water from wells and energy from firewood at no financial cost and may utilise open land to sustain their livelihoods. If this is ignored in the value assessments of policy options, then perverse outcomes that are damaging to poorer people can arise.

The socio-economic consequences of decisions that may have great economic benefit at national scale, but dire social impact locally must be quantified.

2.4.1 Resource planning

Taking a nexus approach to the planning of natural resources and ensuring that resource allocations relating to water, land and energy are considered across economic sectors helps countries ensure that their resources are used efficiently and equitably and are aligned with national policies and objectives.

Traditionally where there is resource scarcity the first thought is to increase supply, second is demand management. However under the water, energy, food and land nexus thinking the long-term goal is to move to systems that provide abundance of renewable resources while preserving finite resources. Thus demand management should focus on particular non-renewable steps of the resource cycle.

Resource planning is essential and should take place before infrastructure planning. A water policy must reflect the reality of conflicts in the allocation of water under conditions of scarcity. That is the critical new factor and that is what is missing nearly everywhere.

Case Study Benefits which can be gained from improving governance processes addressing nexus links

The Government of Malawi used the nexus approach for sustainable resources management in order to achieve both economic and social development targets and to make investments that meet a range of water needs for productive purposes in agriculture, industrial/commercial, energy and water supply. Using water as an entry point, the government embarked on a systematic review of water use across energy, agriculture and water sectors. The study found that current sector plans had been developed in silos and did not consider other users. For instance, large consumptive irrigation schemes were planned upstream of new hydropower plants. Through nexus based water resource planning, the Malawi government was able to use resources more efficiently by tackling water and energy issues together and improve resource productivity of the agriculture sector. The trade-offs and their impact on different groups in society was considered and plans included a series of priorities which were achievable and implementable. (World Bank, 2011).

In Lake Naivasha in Kenya a nexus approach has helped stakeholders to manage competing short, medium and long term interests from tourism, agriculture and energy provision. In this example strong partnerships and collaborations between private companies, small scale farmers, local government and international organisation have created innovative and workable management arrangements to achieve a balanced water, energy, food and land nexus. (Nyangena and te Velde 2011).

2.4.2 Knowledge and awareness

To aid resource planning and manage nexus linkages, consistent data sets are needed across sectors to understand the existing position. Data are often less available in low income countries making it difficult to make informed decisions about allocations. The need for data is often overlooked in nexus discussions and is an important consideration in the implementation of the nexus approach.

Data on energy, water resources and supply capacity are generally available but information on efficiency and waste can be much harder to obtain. Water data which includes different water uses within sectors, including energy sector users, facilitates decision making and helps ensure that water resources are allocated to the most appropriate uses. Any opportunity to encourage this level of data recording should be encouraged.

The framework for interpreting data and using it as a tool for management is as important as the availability of information. The frameworks and tools identified in Section 4 highlight the opportunities for bringing green resource accounting tools and techniques to bear on nexus issues in order to highlight the most significant priorities for action.

2.4.3 Joint procurement

Joint projects and procurement between ministries can help to ensure that nexus objectives are followed through in practice.

Multi-purpose dams are an example of how use of the nexus approach to procure common infrastructure jointly between sectors. From just one investment, multiple benefits across many sectors may be realised, provided operating procedures reflect stated priorities during shortages. Multi-purpose dams can provide water for irrigation for food productions, hydropower for energy production and for potable water but these uses often compete in time of scarcity. They are compatible with climate change adaptation strategies, providing flood and drought protection through increased storage facilities. However, in practise although the infrastructure can provide multiple benefits the operating procedures are different for each requirement. Thus there will be ongoing tension between users for control of the operation of the asset. Quantitative tools may help in finding and justifying optimal balance between the needs of different users.

The development of procurement guidelines can be used to define how nexus principles can be operationalised. In many countries the current financing and regulatory frameworks for water and energy infrastructure investments are focused on a single-sector approach and not designed to consider multi-sector investments. Multi-sector financial models can consider existing and new finance streams for investment into water resilience.

2.5 Making the case

To support business case development the range of benefits which a nexus approach can help to deliver should be considered. Examples of the range of benefits which projects and programmes have the potential to deliver are described below.

Sustainable resource use and improved natural resource efficiency

A nexus approach provides a basis to achieve efficiencies in the use of water, energy and other natural resources.

For example effective agricultural land management policies and use of modern irrigation methods can help to more effectively manage scarce water resources and reduce the need for pumping which normally requires energy from fossil fuels.

A nexus approach can reduce the energy intensity of development and lead to reductions in CO₂ emissions. There are examples of multi-sector interventions which can be combined to achieve this objective.

Example: Delhi Mumbai Industrial Corridor Project in India includes developing multi-modal development corridors which can be used to provide a focus for development accommodating power transmission systems to carry electricity from renewable energy power fields, rail and road systems to improve agricultural logistics networks and the creation of new townships which include planned provision of water and energy systems. Several of the towns have incorporated demonstration projects to pilot new water and energy efficient technologies

Source: <http://www.dmicdc.com/>

In responding to the challenge of urbanisation pressures, many countries are reviewing their policies to identify how urban development can be managed in a way that responds more effectively to energy, climate, resource and security risks. DFID research on Future Proofing Cities highlighted that there are more than 100 policies many of which can deliver multiple benefits to address climate and energy risks in parallel with reducing vulnerability and delivering socio-economic benefits. The report highlighted the need to develop approaches which consider the capacity of institutions to act. (Godfrey, N.; Savage, R. 2012) <http://www.futureproofingcities.com>

Increased socio-economic benefits

The case for adopting a nexus approach can be supported by developing green growth packages of solutions which can deliver socio-economic co-benefits such as employment opportunities, increased incomes, and health benefits. Evidence to underpin the economic benefits which could be secured has been highlighted by several recent studies including the work of the OECD and the reports of the Global Commission on the Economy and Climate (OECD, 2013) <http://newclimateeconomy.report/>

Opportunities linked to innovation

The work of the Global Commission on the Economy and Climate provides a positive message of the role innovation can play in responding to climate risks and environmental challenges and highlights examples of technological innovations which address linkages between water, land and energy. However, there is a need for innovation to be considered carefully. Debates around geoengineering, and genetically modified crops, for example, highlight the need to take a holistic view of the potential impacts of particular solutions over the long term and highlight the importance of addressing issues of uncertainty (The Economist, 2010). Opportunities for innovation can apply to governance and institutional processes. There is a growing body of research highlighting the role that social innovation can play in developing solutions to environmental challenges (Nicholls et al., 2012).

Improved resilience to energy and food price shocks

Implementing policies which address water, energy, food and land linkages can play a key role in building resilience to energy and food price shocks by enabling countries to aim towards greater resource self-sufficiency and enhance energy and water efficiency. Countries can reduce the impact on the poor and the political and social instability which events of this type can cause. The Annual Global Risk Report produced by the World Economic Forum highlights the interconnectedness of environmental drivers and their linkages to social, economic, political and technological risks (World Economic Forum, 2014).

2.6 Key messages

This section highlighted a range of opportunities for addressing the nexus through the entry point of national natural resource planning and management.

Resource management currently, typically, focuses on the development of resource management plans implemented sector by sector through formal structures defining boundaries, gathering and analysing data from which time bound action plans may be developed and implemented. After which there is a review and a process of adaptive management before repeating the cycle.

Several opportunities were identified for applying the nexus. These include:

- Raising awareness among senior decision makers and civil servants is a first step to initiating action. However, to follow through in taking action organisational capacity needs to be in place among civil service cadres.
- Infrastructure planning should identify the sectoral infrastructure plans for energy, water, agriculture and forestry, transport and urban development. Policy appraisal can compare the difference between programmes and projects formulated to deliver nexus objectives and a business as usual approach.
- Reviewing existing data and identifying potential data gaps as a first step to sound resource management and planning.
- Developing policies for managing land recognising the multifunctional roles which land performs. Within this policy framework should be a national policy for guiding and maximising the opportunities associated with urbanisation and industrialisation while reducing its environmental footprint.
- Consider opportunities for joint procurement for projects which can meet multiple nexus issues (e.g. water, food and energy). Procurement guidelines can be used to set performance criteria and objectives across multiple nexus issues to drive outcomes which meet multiple objectives.
- The nexus business case needs to convince the Finance Ministry, as well as other stakeholders. An economic as well as technical and ideological case will need to be made. The value and benefits which a nexus approach can bring include:
 - Policy - improved governance of natural resources leading to support sustainable use;
 - Effective resources planning to inform infrastructure priorities and programmes responding to environmental limits and distributional issues;
 - Improving resilience to energy and food price shocks by improving resource self-sufficiency; and
 - Opportunities to support innovation and diversification of the economic base.

The next chapter provides further details of the tools which are currently available to support analysis of nexus issues.

SECTION 3

Developing tools for nexus analysis

3.1 Introduction

To integrate the multi-sector approach, the linkages between resource areas outlined in Section 3 will require the application of analytical tools. This section sets out some of the tools available and also some of the requirements for the development of new tools.

For the mid-levels of administration the messages need to be about the practical steps that can be taken to move towards the long-term goal of sustainable resource management. This will require different sectors working together on development of country specific tools, mapping the key planning documents of each department and the most efficient channels of communication and exchange that would allow for nexus understanding to be incorporated in the processes, without increasing complexity and causing confusion.

3.2 Assessing the benefits and added value that a nexus approach could bring

Traditional approaches to planning resource use tend to follow models of predict and provide to deliver an effective supply without considering resource limits. Often there are mismatches in the availability of resources and the level and location of final demand.

Accounting for natural resources using natural capital accounting tools and frameworks that identify and consider existing stocks and flows as a first step to understanding how improvements in resource efficiency can be made. As well as analysis at national level there has been increasing attention to cities and city regions as a scale of analysis and for taking action (World Bank, 2011; UNEP, 2013). The impacts relating to environmental problems often manifest themselves at a local level and it can be more effective to engage end users at this scale.

Once the position is known on existing resource stocks and flows, a scenarios approach can be used to explore existing deficiencies and future needs and the drivers and pressures which may impact the system. These alternative futures can be used to define and build flexibility into the development of infrastructure programmes.

Through examining the issues together new solutions and opportunities can be revealed which can align programmes for different infrastructure sectors and lead to the formulation of programmes which are complementary. The design of combined or multi-sector programmes may also be a possibility which can bring additional benefits beyond bringing issues together at the level of individual projects.

Use of the nexus approach in integrated resource planning is becoming a necessity in order to ensure that plans are achievable and resources are distributed equitably. Trade-offs can

be resolved, accounting for the needs and priorities of the region, country or local area and mitigating the unsustainable use of resources¹.

3.3 How can nexus issues be measured and monitored?

There are various tools and frameworks that can be applied to individual links of the nexus (see Table 2) but far fewer which consider the nexus as a whole (Table 3). Choosing the right tools for the right assessment is essential and depends on data availability and needs. Approaches span a continuum from qualitative approaches such as index building to more data driven and quantitative modelling or scenario approaches which combine both approaches.

For example, index building addresses the macro-regional scale using a core set of representative parameters to identify key insecurities within the nexus. Positive gains that can be generated and shared will be identified, plus barriers to development and preferred development options. This kind of assessment would be a first step towards more quantitative analyses of resource use. To consider the nexus at the macro-region and in-country levels, sector specific, data-intensive modelling approaches are available. These approaches need to be stakeholder driven. In this way, these techniques can provide sustainability criteria for investments and support national and local planning (Hoff and Karlberg, 2013).

Further examples of nexus assessment tools can be found here:

<http://www.water-energy-food.org/en/practice/assessment.html>

By unpacking the water, energy, food and land nexus at different scales using different methodologies it is possible to identify measures for cooperative governance and management that support outcomes which tackle key nexus linkages.

Sophisticated accounting and measurement tools have emerged over the last 5 years which are more focused. These have utility in assessing components of the nexus as well as framing nexus choices. However, often the underlying assumptions are not clear, or transparent, and care is required to consider the science base underpinning the tools.

In addition to the tools already available there is a need to develop a wider range of tools suitable for assessing a broader set of nexus projects and programmes and to enable improved assessment temporally and at different geographic scales.

¹ Effective engagement and multi-stakeholder dialogue can be used to mediate and resolve areas of disagreement.

Type of tool	Examples
Ecological foot-printing tools including carbon and water foot-printing tools	<p>Energy and carbon foot printing Ecological foot printing Water foot printing</p> <p>Sources: http://www.footprintnetwork.org/en/index.php/GFN/ http://www.waterfootprint.org/ http://www.cdp.net</p>
Water risk	<p>The World Resources Institute (WRI) tool, Aqueduct, can be used to map water scarcity risks in comparison to other resource demands such as energy, agriculture and urbanisation to understand relationships.</p> <p>http://www.wri.org/our-work/project/aqueduct</p>
Material flow analysis	<p>Material flow analysis is a systematic assessment of the flows and stocks of materials within a system defined in space and time.</p> <p>Examples: WRI (2000) The Weight of Nations: Material Flows from Industrial Nations.</p>
Whole-life or life-cycle costing	<p>Whole life cost, or Life cycle cost, refers to the total cost of ownership over the life of an asset. This technique is commonly used for project appraisal and asset management.</p> <p>Costs considered include the financial cost which is relatively simple to calculate and also the environmental and social costs which are more difficult to quantify and assign numerical values to.</p> <p>Typical areas of expenditures that are included in calculating the whole life cost include planning, design, construction and acquisition, operations, maintenance, renewal and rehabilitation, depreciation and cost of finance and replacement or disposal.</p>
Economic Input-Output Life cycle Analysis	<p>The Economic Input-Output Life Cycle Assessment (EIO-LCA) method estimates the materials and energy resources required for, and the environmental emissions resulting from, activities in the economy.</p> <p>A free online tool developed by Carnegie Mellon University is available here: http://www.eiolca.net/</p>

Type of tool	Examples
Natural resource accounting	<p>Natural resource accounting is an accounting system that deals with stocks and stock changes of natural assets, comprising biota (produced or wild), subsoil assets (proved reserves), water and land with their aquatic and terrestrial ecosystems.</p> <p>It is frequently used in the sense of physical accounting as distinguished from monetary (environmental) accounting.</p>
Ecosystem services assessment and valuation	<p>Refer to DFID Topic Guide on this subject (Roe, 2014 http://www.evidenceondemand.info/topic-guide-ecosystem-services).</p> <p>Ecosystem services are defined as services provided by the natural environment that benefit people. While there is no single, agreed method of categorising all ecosystem services, the Millennium Ecosystem Assessment framework is widely accepted and is seen as a useful starting point.</p> <p>Ecosystem services provide outputs or outcomes that directly and indirectly affect human wellbeing. These considerations can link well to taking an economic approach.</p> <p>The underlying case for the valuation of ecosystem services is that it will contribute towards better decision making by ensuring that policy appraisals fully take into account the costs and benefits to the natural environment and human wellbeing (DEFRA, 2007).</p>
State of the Environment Reporting and Driving forces-Pressure-State-Impact-Response model.	<p>The causal framework for describing the interactions between society and the environment has been adopted by numerous agencies and is widely used as the conceptual framework for State of the Environment Reporting.</p> <p>The model was adopted by the European Environment Agency: driving forces, pressures, states, impacts, responses (an extension of the Pressure-State-Response model developed by OECD). Examples of recent assessments have include assessments for Zambia and Kenya.</p>
Abatement mitigation cost curves	<p>Policy appraisal tool used to compare the cost of abatement/mitigation options against impact. Most recently the technique has been used for assessing climate change mitigation and adaptation options.</p> <p>A review and assessment of this family of techniques provides the issues and pitfalls to be considered (Kesicki, 2011).</p>
Planetary boundaries	<p>In 2009, a group of 28 internationally renowned scientists identified and quantified a set of nine planetary boundaries. Crossing these boundaries could generate abrupt or irreversible changes. Respecting the boundaries reduces the risks to human society of crossing these thresholds. (See Rockström J. et al., 2009).</p>

Table 2 General tools and approaches commonly used for resource accounting, and measurement of systems and linkages in environmental and socio-environmental systems.

Tool	Institution	Description	Limitations
A water-energy-food nexus tool	Qatar Environment and Energy Research Institute (QEERI)	<p>Platform for different decision-making entities to create various scenarios and predict their resource demands. Calculates a sustainability index for a proposed scenario, based on:</p> <ul style="list-style-type: none"> • Resource requirements (water, land, energy, finances, carbon); • Relevance factors for each resource type defined by stakeholders; • Food self-sufficiencies, choice of water and energy sources and countries of import. <p>Output provides a financial cost to a given scenario, quantifies water requirements (m³), local energy requirements (kJ) and carbon emissions (tonne CO₂), land requirements (ha), energy consumption through import (kJ), carbon emissions through import (tonne CO₂).</p> <p>Further details can be found in (Mohtar R. and Daher B. 2012). Available at: http://www.wefnexustool.com/login.php</p>	Currently the application is limited to Qatar.
Foreseer tool	University of Cambridge, UK	<p>A scenario generation tool which investigates the ‘nexus’ of water, energy and land resources. The tool is based on a set of linked physical models for natural resource supply, transformation, and use, as well as the ways in which they affect each other. The Foreseer tool also calculates greenhouse gas emissions and other measures of stress, such as groundwater depletion, in response to user-defined scenarios.</p> <p>A set of Sankey diagrams show the flow from basic resource (e.g. coal, surface water, and forested land) through transformations (e.g. fuel refining and desalination) to final services (e.g. sustenance, hygiene and transportation). The user of the tool is able to change future scenarios by choosing different parameters such as estimated population growth, climate change scenarios and others.</p> <p>Examples and evidence from applying the tool include: Bajželj B, Allwood JM, Cullen JM. (2013); Bajželj B, Richards K, Allwood J, Smith P, Dennis JS, Curmi E, and Gilligan CA. (2014); Bajželj B and Richards K (2014); Curmi E, Richards K, Fenner R, Allwood JM, Kopec GM, Bajželj B. (2013).</p> <p>Tool available at: https://www.foreseer.group.cam.ac.uk/foreseer-tool/</p>	Currently developed for California. It is being developed for China and the United Kingdom.
Nexus in trans-boundary basins	United Nations Economic Commission for Europe (UNECE)	Focus on interdependencies and trade-offs in trans-boundary water basins through a step by step approach which breaks down the complexity of the object of study. Every step contains specific questions to be answered and will draw upon different kinds of sources to locate and identify specific information. There are four main steps:	From a water perspective. In the context of trans-boundary

Tool	Institution	Description	Limitations
		<ul style="list-style-type: none"> • Identification of the main sectors of activity involved within the nexus: to gain a broad understanding of the institutions and governance systems alongside the potential evolution of the different sectors. • Analyse the main regulations at the sectoral and inter-sectoral levels: Aims to identify the regulations of the resources within the nexus (water, land, energy and ecosystems). This analysis is at two levels; legal provisions framing one resource's use in particular and interactions between the different users identifying the regulation of shared resources and potential rivalries. • Configuration of actors involved: aims to analyse what kind of actors are involved in the management of resources (e.g. private, public, national, international, users associations and NGOs) and the nature of the links between actors. • Identify specific hot spots: Through case studies identifies main rivalries at different institutional levels, how they are regulated and the governance structure. Salient characteristics of the institutional framework are identified by calling upon four analytical variables: extent, coherence, robustness and flexibility allowing the analyst to grasp the functioning of the system, identify its regulation and adaptive capacities. <p>Further details available at: http://www.water-energy-food.org/en/news/view_1184/nexus-in-transboundary-basins-a-unece-initiative.html</p>	basins this approach considers water as the point of entry to a nexus analysis.
Nexus assessment	FAO	Provides a stepwise process to address policy-making interventions and identify trade-offs at country level. Combines quantitative and qualitative assessment methods based on integrated accounting. The assessment proposes interlinkage matrices as a tool to identify clear nexus synergies and trade-offs in terms of the sustainability of the ecosystem and human system at different scales. This context analysis should guide the assessment towards the relevant 'nexus issue' and a quantitative assessment of the context nexus status through the use of a set of sustainability indicators relevant for water, energy and food in relation to human resources. This is achievable by either developing specific indicators or undertaking a rapid appraisal, relying on existing indicators and making use of country typology (to derive benchmarks). Refer to (FAO, 2014) in annotated bibliography.	
Multi-Scale Integrated Analysis of Societal and Ecosystem	FAO and LIPHE4	Initially designed for energy matters as an integrated accounting framework for the energy, food/land, and water nexus. Simultaneously characterises the metabolic pattern of energy, food and water in relation to socio-economic and ecological variables. It can be used for diagnostic purposes or to	

Tool	Institution	Description	Limitations
Metabolism (MuSIASEM)		<p>simulate scenarios. As a diagnostic tool, the accounting system is used to characterise the existing metabolic pattern of the socio-economic system. This provides information on the ratio between elements (e.g. population, work force, technological capital) and flow elements between food, energy, water and money. Flow elements consider the total requirements, the fractions for internal consumption, and the losses, the degree of self-sufficiency and imports and exports for each flow. As a simulation tool it can be used to explore feasibility, viability and desirability of proposed scenarios. For example see (Sorman AH. and Giampietro M., 2011).</p> <p>A web portal has been established by the MuSIASEM group available at: http://societalmetabolism.org/?page_id=11</p>	
Water Evaluation and Planning and Long Range Energy Alternative Systems Planning (LEAP)	SEI	<p>Modelling approach with GIS-based land-use models. Provides quantitative outputs on water resources, food production, land-use, power production and environmental impacts. Can be used to explore trade-offs between water, land and energy needs for various applications such as agricultural intensification or food, biofuels and hydropower production in relation to other sectors, such as tourism and water for industry and domestic use. Examples available at: http://www.energycommunity.org/default.asp?action=47</p>	

Table 3 Tools developed for assessing nexus-related issues

3.4 Key messages

This section has considered some of the issues and challenges associated with analysing the nexus and reviewed a range of tools which represent the current “state of the art”.

- **A range of resource accounting tools and approaches is available and can be used for examining interrelationships between the nexus and the links with socio-environmental systems.** These techniques remain useful but may need to be used in combination depending on the nature of the challenges being examined.
- **A scenarios approach can be used to explore alternative futures relating socio-economic needs to resources availability and management.** Scenarios should explore the implications for key drivers affecting the demand and supply of resources such as rising incomes and climate change. The trade-offs and distributional impacts of the scenarios for locations and socio-economic and gender groups should be considered. The results should be used to formulate objectives for resource management policies and infrastructure planning.
- **More sophisticated accounting and measurement tools have emerged over the last 5 years which are more focused.** These have utility in assessing components of the nexus as well as framing nexus choices. However, often the underlying assumptions are not clear or transparent and care is required to consider the science base underpinning the tools.
- **There is both a need and opportunity to support the development of the science underpinning nexus tools.** This can be used to develop further tools and metrics which can be applied at a practical level so that nexus principles can be applied tackle a wider range of challenges than the existing tools allow.

SECTION 4

Opportunities for applying a nexus approach: case studies

4.1 Introduction

This section highlights case studies and some of the opportunities where a nexus approach can be utilised. We focus on inter-sectoral linkages as identified in Table 1. Wherever possible examples are drawn from case studies and the existing literature. In a number of cases examples of emerging practices are drawn from the UK and China which represent opportunities for learning and adapting approaches across regions. In these cases comparable examples of nexus practices could not be identified in DFID target countries.

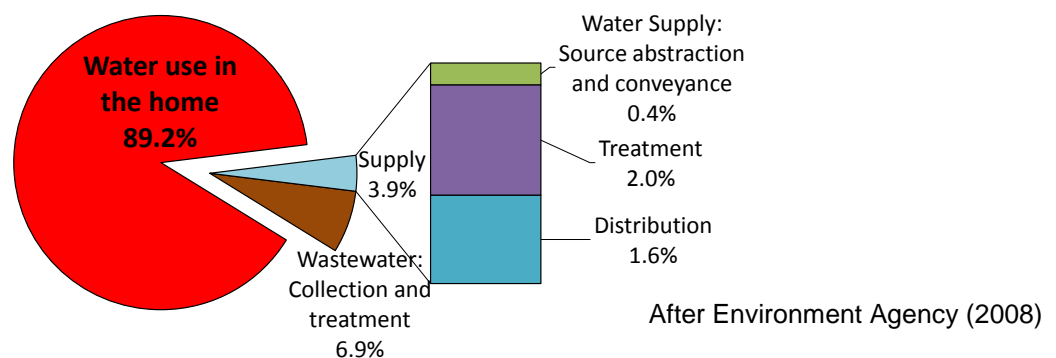
Though there are linkages between all of the resources of water, energy, food and land, the linkage with energy is most vital when it comes to overcoming scarcity. Energy can be used to make water and food more abundant in any situation and, with limitless energy, so land can be developed and made productive to a greater degree. But it is energy that is currently most dependent on finite fossil resources, the use of which uses up atmospheric capacity for absorption of greenhouse gases. Thus the most vital task when analysing linkages is to find ways to transition to energy sources that are renewable or do not cause climate change.

Many of the issues in this section are merely flagged as being relevant to the debate. They are major topics in their own right but for reason of length, cannot be covered in detail here.

4.2 Energy for Water

Energy is required as electricity for lifting and pumping water as well as for water and waste water treatment where is mostly used for pumping and running blowers for aeration treatment. The energy embedded in chemicals used in treatment processes should also be considered. In the UK around 6% of total energy use is used in the water cycle for water resources, water supply and distribution, wastewater collection and treatment and domestic water heating. However nearly 90% of this energy is used in water heating for washing and domestic appliances such as washing machines and dishwashers.

Figure 3. Where is the most energy used in domestic water cycle?



Thus when considering the energy use in the water cycle it is very important to keep a perspective of where most energy is actually used and how this changes as water and sanitation systems develop – Water falls from the sky, can be collected from a stream and waste can be disposed of in a latrine all with no energy use at all.

In developing countries supplying energy to villages to run pumps for groundwater abstraction and irrigation is often one of the primary drivers of rural electrification. The energy use for water production will rise rapidly if water is scarce. Even where water is abundant, wastewater treatment is normally more energy intensive than water supply and becomes necessary as urbanisation and industrialisation increases. As a country develops further and urbanises so it is the domestic use of energy to heat water that will increase rapidly to use by far more energy than the water supply and wastewater networks.

When looking at energy efficiency in the water supply cycle, the selection of water resources can impact on the amount of energy used. In most cases abstraction from a nearby clean river, requiring simple treatment by chemical sedimentation, sand filtration and disinfection is a relatively low energy process. Groundwater sources may be naturally cleaner and so only require disinfection, saving on chemicals and treatment processes, but the groundwater may need to be pumped from depth, requiring greater energy. Poorer source water quality leads to higher treatment costs. Stricter standards for drinking water quality may require removal of trace pesticides, endocrine disrupting chemicals, colour, iron or cryptosporidium in which case more energy intensive activated carbon, dissolved air flotation, UV or ozone treatment stages may be required.

In water scarce areas, water may need to be transported long distances, increasing pumping costs and scale of infrastructure. A good example is China's South–North water transfer scheme. There are also now increasing numbers of inter-basin transfer schemes in the UK. These can be energy efficient means of providing additional resource and relief of over exploitation of local resources in main population centres so increasing water security, but can also cause problems of inequality, vulnerability and dependence of one regional or national area on another (e.g. Singapore dependence on Malaysia for water, Hong Kong to China).

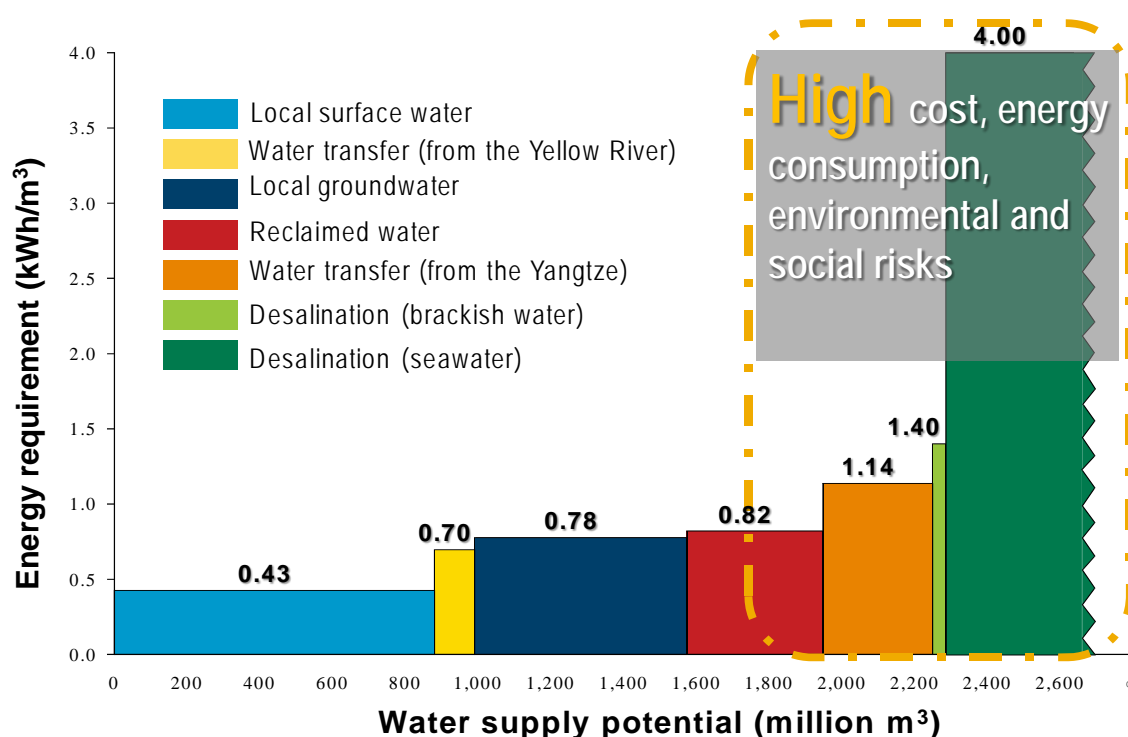
In extreme areas of water scarcity, water may need to be obtained by desalination of sea water – this is very common in the Middle East. There are various processes of different efficiencies with regard to thermal or electricity use which may be appropriate for different settings. All desalination processes are more energy intensive than other water treatment processes, though the efficiency of these processes is constantly improving.

The same reverse osmosis processes as used to desalinate seawater if used to treated wastewater effluent will yield far more pure water for the given amount of energy. Though there is a natural (though not fully justified) reluctance to directly use this water it can be put back to the raw water supply reservoirs completely safely. This is done on an increasing scale in Singapore's NEWater scheme. An example of an analysis of the energy use of different options for water supply is given in the box on the Qingdao water energy nexus study carried out for the FCO in China.

Qingdao water energy nexus study

An analysis considering the effects of water resources selection was undertaken for Qingdao in Shandong, China, a water scarce coastal city of around 10 million population. This highlighted how the water resources options for future supply scenarios would impact on energy consumption and greenhouse gas emissions in the future. Qingdao has a very wide range of water sources including local rivers, reservoirs and groundwater as well as long distance transfers from the Yellow River and the South – North Transfer from the Yangtze River and also some desalination plants.

Energy requirement for water production by sources in Qingdao



Source: Wen, W. Zhong, L., Fu, X. (2014).

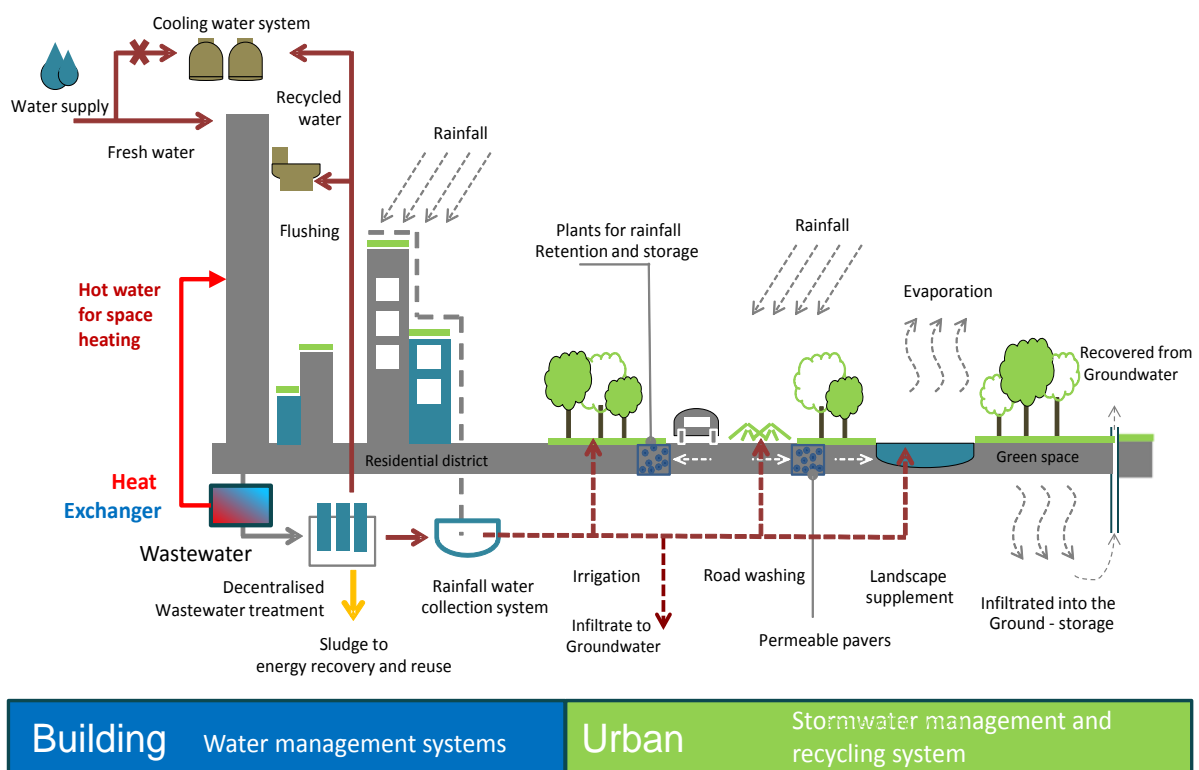
<http://www.wri.org.cn/en/publication/water-energy-nexus-urban-water-source-selection-case-study-qingdao>

The water cycle is also very well suited to integrate with the renewable energy production cycle (refer to Figure 5). There are many energy intensive tasks in the water cycle such as pumping water up to storage reservoirs which can operate with a degree of flexibility in their timing. Renewable energy such as wind and solar are intermittent in their production and at times there may be spikes of excess energy production. Water companies can enter agreements with electricity producers to utilise this excess energy at a reduced rate to balance supply. Where there is irrigated agriculture or pumped land drainage so the water, energy and food areas can fully integrate – this was of course one of the first uses, hundreds of years ago for windmills in the Netherlands, the fens of the UK and elsewhere.

The loss of water in the supply network through leakage can also be considered a waste of energy. The supply networks can also be optimised for energy efficiency by more intelligent pressure management and supply on demand telemetry systems to develop smarter water networks. Better pressure management can also reduce leakage and the incidences of burst

pipes and requirement of asset replacement. In hilly regions energy may be recovered from water networks and fed back to the local grid.

Looking to future solutions, energy can be further saved in the urban water cycle by better integrating into urban infrastructure. This can be a combination of collecting wastewater in buildings, treating and recycling locally and collecting rainwater, storing and reusing in the urban setting. These solutions can reduce water use in the city by 30%, reduce flood risks, reduce pollution impact on the environment and create a cooler, greener and more pleasant urban environment. This can also integrate with thermal energy recovery. Figure 4 illustrates this after methods developed in the eco-low carbon planning methodology (ELC), jointly developed with the Chinese Ministry for Rural and Urban Development supported by FCO (see www.atkinsglobal.com/FPC)².



The integration of urban infrastructure and urban water cycles through the planning of blue-green infrastructure has been studied and taken up by various cities around the world. The approach takes into account the management of the urban micro-climate and so adapting to climate change. London and Durban are examples of cities that have been active in integrating the approach in urban planning.

4.3 Water for energy and industry

Hydropower and the cooling requirements of conventional thermal power production, nuclear and waste to energy have major implications for water.

“As almost all energy generation processes require significant amounts of water, and water requires energy for treatment and transport, these two resources are inextricably linked. This relationship is the energy-water nexus.” (World Bank, 2013)

Furthermore, industry especially heavy and extractive industries are often major users of water as well as power which can impact on the environment and nearby communities. A

² <http://www.atkinsglobal.com/en-GB/group/sectors-and-services/services/future-proofing-cities/china>

nexus approach can be used to better understand the implications of projects and inform development.

When calculated in absolute terms the abstraction of water resources to use in the power sector can be massive in a developed country and represent more than 40% of all water use in the USA. But differentiation should be made between the use of water in the energy cycle and its immediate return to the environment, where it is available for reuse and consumptive use and where it is evaporated and will not be available again (until eventually recycled as rainwater).

4.3.1 Hydropower

Hydropower projects are viewed as a double edged sword. They can help to address needs for water and energy and can help to drive agricultural production by providing water resources for irrigation. However, the development of projects has a large land take and may require the loss of existing productive land and biodiversity. Resettlement disrupts existing communities and their way of life. From a nexus perspective it is critical that decisions to improve access to one resource (electricity) do not have detrimental impacts on others (water, food, livelihoods, biodiversity). Hydropower consumes a considerable amount of water, through the evaporation from the reservoir surface.

The multiple function of the dams produces challenges in itself in the form of conflicts of interests between uses for instance flood regulation would require low storage levels in dry months and water supply would want to maximise storage in case of a drought. Divergence in common goals means it is often difficult to attract private investment and mean that strong regulation is required so that water allocations are divided equitably among users.

Democratic Republic of Congo is highlighted in the literature as a country with abundant natural resources but lacking some of the complementary infrastructure elements to turn this to its advantage. For example the Grand Inga Dam area has the potential to install hydro power systems that could yield 39 GW of capacity – nearly twice which of the Three Gorges Dam in China.

Case Study The Himalaya's: Balancing energy and climate change mitigation benefits with water and food security

In South Asia, 51% of the population is in food and energy poverty whilst 20% do not have access to safe drinking water (Babel and Wahid, 2008). The Himalayan mountain system provides ecosystem services that are integral to the agricultural production, water security, and clean energy development of South Asia. The hydropower potential of the Himalayas exceeds 500GW so could provide energy security for the majority of South Asia. Also, the resultant reduction in traditional fuels would reduce CO₂ and help mitigate climate change. To sustain these benefits that the Himalayas provide, a strategic, inter-sectoral management approach must be taken to watersheds, forests, wetlands and rangelands. In turn, this will provide more resilient food, water and energy supply for South Asia improving the livelihoods of the population. Given the trans-boundary nature of resources in the Himalaya's, multi-lateral agreement is required to manage competing priorities and sustainable use of resources.

Case Study Using Integrated Water Resources Management (IWRM) to balance the needs of competing users in the context of a hydropower project

The Nam Ngum River in Lao PDR is the main water and hydropower source for the Vientiane plain which is the country's main rice production region. The basin is also a major region of large-scale gold mining, cassava processing, steel making, potash mining and fertiliser production. Pollution and flooding are major challenges in the basin affecting downstream users and rural communities. The environmental flow is critical for downstream users and ecosystems in the Lower Mekong Basin. The livelihoods of approximately 60 million people depend on the river system as source of food and income generation (ICEM, 2010). The impact of the hydropower developments on local livelihoods and fish catchments (the main source of protein for people in the area) alongside the competition between water, energy, agriculture and other productive sectors highlights the importance of a forward looking nexus approach. In 2011, a large flood highlighted this need for a more integrated approach to water management in the Nam Ngum Basin. The flood devastated many rural settlements, crops and cattle.

The Lao Government recognised this need and invested in an integrated water resources management plan (IWRM). The Lao IWRM plan brought together different stakeholders with competing needs and interests. By openly sharing information with and between all stakeholders this allowed future risks to resource security to be recognised. To engage stakeholders, sub basin committees have been formed which are governed by a Nam Ngum River Basin Committee led by the Ministry of Natural Resources and Environment. The Lower Mekong Basin has conflicting demands between the high capacity for energy production upstream but food production downstream. This link with national government has enabled wider monitoring and management aiding the integrated management of the basin and these competing demands. The Lao Government has recognised the importance of a nexus approach to integrated water management and is continuing to restructure their governance and policy to fully incorporate the nexus approach into basin management. For example, a Hydropower and Mining Forum is being developed to facilitate cooperation between the government and the hydropower and mining companies. This forum consists of Ministry of Natural Resources and Environment, the Ministry of Agriculture and Forestry, Ministry of Energy and Mining and private developers.

Case Study Eskom Power Stations, South Africa

Water resources are under considerable pressure in South Africa however they are critical for the production of electricity. Eskom is a government owned electricity supplier and provides almost 95% of all end users in South Africa, and close on 60% of the entire electricity consumption on the African continent. The Eskom Power Stations are coal powered requiring highly purified water for steam. Eskom have recognised that their medium and long-term water resource is threatened by climate change, population and economic growth, competing demands and depleted environmental flows. To increase energy resilience Eskom have taken a more innovative approach. They have moved to a zero discharge policy through the use of new technologies such as dry cooling technology to reduce water losses during condensation. As an example, Limpopo Province is one of South Africa's richest agricultural areas but is very dry and unable to meet its water needs from its local supplies. Matimba Power Station is the largest direct-dry-cooled station in the world, with an installed capacity of greater than 4,000 MW.

4.3.2 Industry

In many developing regions of the world, water is the limiting factor to industrial expansion as it is used in many processes of mining, energy generation and processes such as cooling as well as in lighter industries such as food processing and textiles. Measures supporting more water efficient production, reviewing opportunities for recycling water for heating and cooling and adopting practices which lead to the sustainable long-term management of water resources are all important. It is necessary to consider water management issues at the basin scale and to ensure that the needs of water for industry are considered in parallel with other uses. The nexus approach encourages cooperation and cross-sector sharing such as cooling waste water and reuse for industrial processes. Most importantly water is the main medium for carrying energy, in the form of heat and steam power, in many industrial processes. Saving water, especially hot water, is also saving energy and the high value of energy saving can pay for the investments in the water saving.

Case Study Improving the energy and water efficiency of industrial processes

Steel production

Major power plants and steel production facilities are clustered in the Gujarat region of India. These abstract huge volumes of water from the River Tapti whilst discharging large amounts of effluent to the sea. Amongst these sites is the Essar steel facility, the fourth largest steel factory in the world. The sites have collaborated to reduce their water footprint. Innovative efficiency measures such as retrofit of condenser process and its material specification have reduced the freshwater demand of the power plant cooling system and its discharge has been transferred and reused by the steel plant. Wastewater from the steel plant is now treated for re-use in the power plant and used for localised irrigation of land. Combined these interventions have reduced the demand on freshwater by 1.5 million m³ per year. The project has reduced the chemical dosing requirements, freshwater abstraction, and water treatment costs and has provided sludge for horticulture.

Water allocation trading along the Yellow River

In North and Western China there is huge demand from industry and growing cities for the scarce water resources of the Yellow River. This is an arid area and the glacier fed waters of the river are the only major year round source of water. More than 70% of water use in the Yellow River is still for agricultural irrigation and with very low levels of investment in this sector there is huge scope for water saving and greater efficiency. The Yellow River basin also contains some of the greatest coal reserves in China and electricity produced there is transmitted to major cities such as Beijing on the East coast. Extracting and generating power from coal is very water demanding, and now synthetic natural gas production, which has nearly 10 times the water demand of direct coal use is growing in the region.

New energy producers want to abstract water from the river. However, because the water abstraction permits already issued considerably exceed the available water resources the Yellow River Commission will not issue any new water drawing rights. Therefore they have piloted a scheme for the trading of water rights. The idea is that an industry invests in water saving irrigation technology with the farming community – for example canal lining, spray irrigation, drip irrigation etc. and in return the water savings mean that the farmers can transfer some of their water rights to the new industry and still attain the same yields. (Squires 2014).

Managing water and energy resources in mining

The Lomas Bayas Copper Mine, Chile, highlights the benefits of taking a nexus approach to

propagate technological innovation and develop alternative, less financially and environmentally costly, solutions to industrial expansion. The Lomas Bayas Mine is located in a desert but is highly water intensive, largely due to their heap leaching processes for extracting minerals from copper ore. Annual rainfall in the region is approximately 1mm and evaporation rates are high. Water for operations is pumped 100km to site from the Loa River. Regulatory limits for abstraction prevent the mine increasing its production therefore Xstrata Copper and Chilean Corfo Innova Mining Programme funded a project with support from local academic centres to reduce evaporative water losses. The mine implemented measures to optimise its water use which included replacing their leach pad sprinkler with a drip system which has reduced the water lost to evaporation by 54% between 2008 and 2013. Savings in evaporative loss have been utilised for mine expansion. By optimising their water use the mine has been able to expand its production without relying on additional water sources. The alternative to this project would have been to invest in a blue green plant to provide water for the leach pads. Instead, the \$1.1 million investment in the project for research into innovative methods to reduce evaporation has led to technological advancements for the mining industry.

4.4 Water for food

Globally 70-90% of freshwater demand is used in food production, of this 40-60% of water is utilised in agriculture and the balance in processing. Around 30% of land globally is used for agriculture with forests (30%) and savannah (20%) representing other significant shares. Most of the remaining land is barren or unproductive (Hertel, 2010).

Increasing global population, combined with rising incomes and changing lifestyles is leading to increasing demand for water intensive meat production as well as inputs used in the production of processed foods such as palm oil. There is pressure for more land to be dedicated to agriculture evidenced by deforestation and the trend of transnational land deals.

The crops selected to be grown in particular areas should be suitable to the water resources availability. It is unwise to try to grow very water intensive crops in arid areas in open fields fed by fossilised ground water resources. But for political and short-term economic reasons this often happens.

Integrated Watershed Management is a tool that addresses issues of managing land use to sustain the soil and water resource potential. This tends to focus more on issues such as forestation and terracing to prevent soil erosion and to encourage water retention in the catchment. This can have direct impacts on the regional climate especially in prevention of dust storms and also in reducing flood risks.

Much of the water use in irrigated agriculture is inefficient and has potential to be greatly improved. There is a need for policy makers to make water for agriculture more efficient in terms of water use. The use of Evapotranspiration (ET) calculations can help in the improved management of agricultural water use (see case study).

Case Study Water resources planning using evapotranspiration quotas

Water management in China, based on water abstraction only, has encountered only limited success because the saved water was used to irrigate more land; that is, more water was consumed and less water returned to the surface and underground water systems. Recent advancements in remote sensing and geographic information system (GIS) technologies have made it feasible to manage water resources in terms of the amounts of water actually consumed through evapotranspiration (ET).

This approach encourages farmers to reduce the evaporation and transpiration that does not contribute to plant growth. For example, they will reduce evaporation by changing crop choices, reducing waterlogged areas, irrigating when evaporation is lowest (at night instead of during the day), using moisture-retaining mulches and films, and replacing open canals and ditches with pipes. Where excessive fertilizer and pesticides runoff is a problem, they will be encouraged to reduce non-point pollution, since return flows that are not reusable downstream will be deducted from their ET quota.

ET technology thus makes it feasible for China to adopt a more scientific approach for its water rights allocation. This has been piloted in the Hai River Basin in Eastern China under World Bank/GEF programmes (Wang 2005) and in the Turpan Basin in Western China.

Source: <http://blogs.worldbank.org/water/china-innovation-water-rights-leads-real-water-savings>

The calculation of proper water balances and pollution discharge control through industrial enterprises and urban centres can help reduce water wastage and better understanding of how human activity results in water moving from one source (e.g. ground water reservoir) to another (e.g. river flows downstream of wastewater discharge) and assess whether that water is still of sufficient quality to be regarded as a resource that can be used in food production.

4.4.1 Beyond integrated water resources management

The Global Water Partnership, established in the 1990s, promotes the sustainable management of water resources and the integrated water resources management approach (IWRM) through projects and programmes³.

The partnership has established country and regional platforms for dialogue. Taking water as the entry point the partnership has a focus on six thematic areas which explore nexus issues around climate resilience and water security, food and water security, energy and water security, ecosystems and water security, urbanisation and water security as well as exploring trans-boundary water security issues. Work is most developed on water for food and there is an established and growing body of research supporting the approach through partners such as CGIAR – the global agricultural research partnership⁴. The CGIAR research programmes on water, land and ecosystems and climate change, agriculture and food security are focused on building climate resilience across multiple sectors.

In most efforts to create a regional integrated water management plan, segregation of users, transparency of knowledge and monitoring between stakeholders can be major barriers. Nexus frameworks stress the importance of identifying, adopting and implementing evidence-based policy decisions, sound governance and institutions, cost-effective water investments and best management practices that can significantly improve agriculture

³ <http://www.gwp.org/>

⁴ <http://www.cgiar.org/>

productivity and food security. A key success of the IWRM approach is the focus on explicitly considering responsibilities for water management and development engaging the public and private sectors as well as civil society. Incorporation of a focus on demand management and incentivising efficient use of water by assigning a cost to water can shift behaviour and help to allocate scarce resources. The public sector has a responsibility for resolving trade-offs, regulating prices and managing the public interest in terms of environmental issues and the needs of poorer water users.

IWRM is not uncontested. The approach has been criticised in some quarters for the approach being formulaic and not being applied in a pragmatic way⁵.

Case Study Improving the effectiveness of Integrated Water Resources Management practices

An IWRM approach was used to tackle the constraint of water to increasing food production to increase agricultural resilience and food security.

In cooperation with the World Bank and Tanzanian Ministry of Water, Atkins prepared an IWRM and Development Plan for the Ruvuma River and Southern Coast Basin. The key objective of this project was to provide a blueprint for sustainable development and management of Tanzania's water resources considering current and future water demand.

Stakeholder workshops enabled a comprehensive cross-sector water demand assessment to be undertaken which informed the water allocation and development action plan for each sector at a basin scale. Guidelines for water management governance, policy and legal framework were developed to provide an effective regulatory structure including Urban Water and Sanitation Authorities and Water Users Associations. The final plan responded to population and economic growth and considered the needs of planned development projects like Mtwara Development Corridor and the oil and gas industry which are driving urbanisation as well as an increase in irrigated area for food crops and commercial farming for coffee and cashew nuts.

4.5 Land for food

4.5.1 Large scale land deals

The rise of large scale land deals to secure land for food production highlights the existing gap in governance relating not only to productive land used for food production but the associated water and energy resources required to support food production.

In recent years, large scale, often transnational, land-based investments have been made by governments and business, typically involving acquisition of land for agribusiness, industry or urban development. The phenomenon is contentious because of reported environmental and social impacts leading to use of the phrase "land grabs" (Oxfam International, 2010).

In a multi-country study the polarised nature of the debate was highlighted. Proponents emphasise the developmental benefits of agricultural intensification and opponents document cases where habitats have been threatened and local communities marginalised (see Azadi, H. et al., 2013; Cotula, L. and Oya, C. 2014).

⁵ Refer to (Jeffrey and Geary 2006) and <https://globalwaterpartnership.wordpress.com/2013/04/10/iwrm-not-pragmatic-enough>.

The study also raises fundamental problems related to availability of data, government record keeping is varied and researchers struggle to access sensitive data held by governments; furthermore the negative externalities, outcomes and benefits of many land deals have yet to materialise given the early stages of implementation⁶. Regardless of the scale, the cultural, socio-economic and environmental transformations they bring about may be significant for recipient localities.

4.5.2 Scale and geography of land deals

The evidence remains patchy and databases reveal significant variability in recorded land deals (Cotula and Oya, 2014). Consequently caution should be exercised when reporting the scale of land deals due the variation that often exists between the size of project reported in official documents (memorandums of understanding are most common) and area of land eventually leased for the project. Land deal sizes range in size up to several million hectares, reflecting a broad range of uses and scales of investment, the largest projects being linked to biofuel and palm oil production as well as food production (Grain, 2014)⁷.

The drivers for land deals differ between countries, but to a greater or lesser extent demand for biofuels, non-food crops (such as cotton) and food crops (including edible oils and cereals) dominate. Cotula and Oya (2014) noted that typically land deals have the following characteristics:

- Land leasing is preferred over land purchase, particularly state owned land;
- National government is involved in the majority of land deals;
- Government socio-economic policies drive land deals - realising potential of agribusiness to help increase foreign exchange reserves through export promotion;
- Local communities typically lack any form of control related to land deal investment because decision making and contractual negotiations are exclusive and thus public interest is often not represented;
- Projects are typically large and take time to scale up and reach maturity, thus longer term impacts may not materialise until projects are well into operational stages; and
- Many displaced communities come from land under customary tenure.

4.5.3 Nexus and land deals

Large scale land deal projects may have significant footprints and thus occupy large biophysically productive systems. Vulnerable groups, subsistence farms and local communities can be adversely affected if their access to essential biophysical systems is restricted. Increasing competition for land means that there is a pressure on the utilisation of land and water resources. This is likely to impact on the poor as traditional farming practices come under pressure for intensification or modernisation. The issue of land and property rights is significant, given the frequent lack of land ownership records and legal frameworks regarding use of open land.

⁶ Despite the paucity of reliable and comprehensive data there are online resources tracking publicly available information on land deals. These include: Landportal.info <http://www.landportal.info/>; GRAIN; and Land Matrix Consortium <http://www.landmatrix.org/en/>

⁷ At the time of writing the *Online Public Database on Land Deals* hosted by Land Matrix held data on over 1,000 deals totalling 38m hectares covering Africa (15 million ha), America (2.7 million ha) Asia (6.5 million ha), Europe (2.9 million ha) and Oceania (2.5 million ha). The USA (7.7 million ha), Malaysia (3.5 million ha), Singapore (2.9 million ha), UAE (2.8 million ha), UK (2.4 million ha) are the largest investors. Papua New Guinea (3.8 million ha), Indonesia (3.6 million ha), South Sudan (3.5 million ha), DRC (2.7 million ha), Mozambique (2.2 million ha), Congo (2.1 million ha) and the Russian Federation (1.7 million ha) are main target countries for land deal investors. It should be noted that the land subject to deals of this nature represents a very small share of total agricultural land in percentage terms.

Teklemariam et al. (2015) raise the challenge of better governance around land deals in light of the changing international agricultural context. To mitigate negative externalities associated with land deals the authors advocate use of an Inclusive Land Deal Framework which recognises the needs of a broader stakeholder group and the interactions with the biophysical environment, putting sustainable land use at the core of what would constitute inclusive land deals.

4.5.4 A drive for increased water resource efficiency

The primary step of any attempt to improve resource security is to ensure efficiency in its consumption and to minimise waste. A nexus approach considers opportunities at every stage of the supply chain including considering opportunities for reducing food waste during production, and through improved logistics to end usage.

There is a wide body of established evidence of practices which can support this approach. Examples include the work of the World Economic Forum Water Resources Group (2030 Water Resources Group, 2013) and the ESCAP report highlights the current position and possible and solutions focused on the Asia-Pacific region (UNESCAP, 2013) (refer to annotated bibliography).

Case Study Improving water efficiency along with supply chain from field to factory

The impact of water insecurity on food production was evidenced in 2010 when drought in the Western Cape region of South Africa led to water stress throughout the country and threatened operation of the Nestle factory in Mossel Bay. With climate projections suggesting increasing frequency of droughts, Nestlé financed a \$145,000 project to increase water resilience and hence reduce business risk.

The water use reduction strategy involved active monitoring of water use, recovery and use of condensate from the milk evaporation process alongside water efficiency initiatives such as retrofit of water use fixtures and employee engagement. The strategy was successful in reducing the plant's water consumption by approximately 50% in 2010 compared to 2009. The reduced water usage at the factory has resulted in reduced water withdrawal from the Wolvedans Dam and more water availability for the Mossel Bay area. Nestlé are currently engaging with their supply chain and in particular farmers in the catchment to promote water efficiency measures to save water and reduce their electricity bills. The aim is to make the factory a zero municipal water intake factory by 2015. Engagement between the different interests was seen as a critical factor behind the success of the approach.

4.6 Land and water

Water resources are not only important for agriculture but also to sustain natural capital and ecosystems including forests and biodiversity as well as towns and cities. Natural habitats and protected areas are important for tourism to underpin economic growth in many countries.

Case Study Contrasting approaches to harnessing innovation

Combining renewable energy to address irrigation and power needs. Unreliable rainfall, volatile energy prices and lack of access to expensive modern farming equipment all lead to insecure crop yields and unreliable income for the 2.9 million smallholder farmers in Kenya. Only six percent of small farms are irrigated in Kenya due to lack of access to energy. The inter-linkages between water, energy and food targets are substantial. Small-scale irrigation systems based on renewable energy, such as the Sunflower Pump, could provide a viable alternative to manual pumping and environmentally polluting fossil fuel powered generators. Sunflower Pump (solar irrigation pumps) pilot studies offer a key example of innovation to tackle the nexus of challenges that face many farmers across developing countries. In 2013 and 2014 field trials were performed in Kasikeu in Kenya. It was found that the technology provides a cost effective and convenient way to provide smallholder farmers with irrigation with negligible impact on land or energy usage to harness the solar power. Added benefits are the improved quality of life for children and women in the regions as they are not required to manually pump and carry water. Moreover, the solar powered pumps could increase local employment in remote areas by encouraging small business in manufacturing and service industries. However, the pilot study did highlight the risk of over abstraction of water resources and consequential long-term risk to local and global food production if abstractions are not governed correctly.

Developing new technology to improve resource efficiency. The Sahara Forest Project piloted in Qatar and showcased at the UN Climate Conference in 2012 (COP 18 in Doha), highlights how integrated approaches to land management can minimise energy and freshwater use whilst optimising food production. The project is a prime example of how the nexus approach to challenges can develop innovative technological ways of managing nexus efficiency and resilience whilst creating opportunities for social and economic growth. The Sahara Forest Project has designed an interconnected technological system which links up the waste from one system as a resource for another system. This is done through saltwater-cooled greenhouses, solar power technologies and technologies for establishing outside vegetation in arid environments. Furthermore, the project has promoted restorative growth and created green jobs through profitable production of food, freshwater, biofuels and electricity. Importantly, this project has actively encouraged innovation and environmental solutions within the food, water and energy sector. To do this the project collated an interdisciplinary team of experts from different professions to try and eliminate the sector barriers to technological innovation in the nexus.

The nexus approach requires that the importance of ecosystems services is properly considered including its role in sustaining livelihoods and sustainable use of resources. There is increasing recognition that a systems view is helpful in framing pressures and competing demands on land which provides a starting point for defining an effective approach to management (Foresight, 2010).⁸

⁸ The Foresight Land Use Futures report highlights the conception of land as a system and the key linkages and opportunities to be managed. Although developed for the UK the system and comparable range of choices and trade-offs are relevant to developing countries.

4.7 Land and energy

The linkage between land and energy is a critical relationship in view of the need to enhance energy security and to maximise opportunities for energy efficiency.

4.7.1 Biofuels

Land required to support energy production competes with other land uses such as food. The growing trend of allocation of land for production of transport biofuels highlights the trade-off between how land is managed for food and for fuel.

Energy security, climate change mitigation, foreign exchange savings and rural development are commonly identified as justifications for biofuel expansion. However, the promotion of energy from biomass for reducing greenhouse gas emissions has led to increased usage of fresh water, especially during the cultivation of biomass such as sugar cane. The picture of the potential impact is not clear cut and is sensitive to context and the net energy impact of growing biomass needs to be carefully considered. The issues concerning land deals for food are equally relevant to biofuels. However, utilising secondary biofuels (i.e. fuel from waste products including spent oils etc.) can help close resource loops and may be viewed as part of the solution.

4.8 Food and energy

The energy consumption of the food production and supply chain represents around 30% of total global energy demand. Energy is embodied in the production of inputs such as water and fertilizer, through to irrigation, transport and food processing and manufacturing and retail and logistics (Hoff, 2011).

In rural areas, agriculture is often a major energy user linked to the consumption of fossil fuels. Ground water extraction and irrigation typically rely on generators and transport is also a fossil fuel user. Land is also a source of fuel for households through wood and animal dung. The effect of climate change is likely to increase the demand for energy. Projects to introduce and scale up the use of small scale solar photo voltaic systems (PVs) represent an important opportunity. In areas where there is sufficient intensity of need rural electrification schemes can also provide a cost-effective solution which is more efficient than production from generators and could represent a source of clean energy. Other examples linking energy use associated with the water required to support food production have been highlighted earlier in this section.

4.8.1 Urbanisation and climate change

With urbanisation increasing rapidly in many developing countries demand for energy is becoming concentrated on urban areas. Building the wrong infrastructure – energy inefficient buildings, sprawling cities with poorly integrated transport systems and urban landscapes that are unapproachable and lack green spaces and are prone to flooding – sets the framework for a poor and unsustainable future. Instead urban planning needs to centre on future proofing, laying down infrastructure that will be efficient and resilient to change and will create liveable cities. Whilst the development of each city must build on the cultural and architectural heritage, it must also address the particular risks and pressures that the city faces – the future proofing cities programme (Godfrey, N and Savage, R. 2012) sets out guidance on how to achieve this with policy recommendations appropriate to the different contexts of cities in developing countries around the world.

New infrastructure and buildings should be planned not just to be low carbon impact to reduce greenhouse gas emissions but also to be resilient to climate change able to provide shelter and services even under more extreme climate conditions.

There is a wide range of policies and measures which can be deployed at building and urban scales such as:

- Preparing visions of where the city wants to be by certain future horizons. The city leaders and Mayors invest political capital in leading the administration, public and private sector towards better choices and engaging the people in this change;
- Preparing eco-low carbon urban planning guidelines that for each country set out how eco city planning and design best practice can be integrated into the statutory planning processes;
- Developing country specific green building standards and enforcing with building inspections on new construction;
- Formulating incentives to implement green buildings;
- Incentivising micro generation and smart grids by support funding to make solar PV thermal and energy recovery solutions (e.g. heat pumps, solid and wastewater energy recovery) economically viable through the gap between development and becoming commercially competitive with conventional energy sources;
- Transit oriented design for integrated transport systems – combining urban planning with the design of the transport systems such as air, rail, cars, trams, BRT, taxis cycling and walking;
- Making walking and cycling viable and safe and pleasant transport options; in part by improvements to the streetscape but more importantly by having mixed use developments that don't require long journeys to meet every day needs; and
- Circular economy – encouraging production by clean technologies that eliminate waste at source and that reuse or fully recycle materials and recover and reuse energy.

There are many different dialogues on better urban planning, mostly focused on “Eco Cities” for better resource efficiency and “Smart Cities” for information and technology solutions to make cities operate more efficiently and enable better solutions. A combination of these approaches is required and will evolve as the enabling technologies and experience grows.

India is embarking on a programme of “Smart Cities” and a concept has been formulated to capitalise on opportunities for integration including linking concerns around energy, water and food⁹. Recent research highlights the scale of opportunities and mechanisms for combining action across sectors for two Indian cities at city and urban township level¹⁰.

4.9 Key messages

This section has highlighted a wide range of opportunities available which tackle two or more interrelationships within the nexus concept highlighted in Section 1.

Examples included quantifying the energy use at each stage of the water cycle to identify where choices about water sources and treatment processes can save energy. How energy can be recovered from the water cycle through not just hydropower but also the use of heat pumps and recovered from bio-solids of wastewater. The energy use in the water cycle can also be integrated with renewable energy production to help to absorb and balance the intermittent renewable energy sources and the need for energy storage.

⁹ http://indiansmartcities.in/downloads/CONCEPT%20NOTE-13-10-2014_mkgnew.pdf

¹⁰ http://www.atkinsglobal.co.uk/~media/Files/A/Atkins-Corporate/group/sectors-documents/urban-development/LCC_Report_March%202013%20LowRes.pdf

Examples of improvements to productive efficiency highlighted in the case studies, included changes to subsidies/tax treatment/charging mechanisms, innovation of management practices and processes (e.g. intercropping in the field of agricultural production), or new/more efficient technologies (e.g. drip feed irrigation, solar energy projects)

There are governance mechanisms such as quota allocation systems combined with the use of water trading systems that can help to balance the needs of different water users.

The example of land deals where ownership is transferred from local to foreign institutions highlighted that, in considering the nexus, resource efficiency issues cannot be considered in isolation from questions linked to the distribution of uses.

The drivers and trends associated with demographic change, urbanisation, rising incomes and global climate change mean that there is a need for focused and sustained investment to develop the quantity and quality of resources in a sustainable way, in order that absolute resource scarcities can be avoided. Some general findings can be drawn:

- **Adequate information and knowledge around resource scarcity and resource efficiency is required to understand the existing position.** There is a need to manage demand to reflect scarcity values also to ensure that investments in infrastructure lead to greater abundance of renewable resources where these can be made available. This section made reference to a range of tools and best practice which can be drawn upon.
- **Nexus policy requires an informed approach by stakeholders. Often poor management of natural resources results from poor governance and coordination failures.** Coordination is required between public, private and civil society to make sure all voices are heard as well as between central and sub-national government. In many cases cooperation between national governments at a regional scale may be required in terms of managing transnational water resources and imbalances in opportunities for energy or food production.
- **A pro-poor approach to addressing nexus challenges needs to be designed in from the outset in order that proposals for land development, energy and water projects can benefit all and do not disadvantage the poorest groups.**
- **Increasing resilience can be a useful strategy where there is uncertainty around the nexus linkages.** Enabling access to water, promoting decentralised and renewable energy projects, enhancing land and property rights and facilitating the urban transition are all measures which can build resilience and provide some of the conditions needed to support development.

SECTION 5

Implications for programme design: recommendations

5.1 Introduction

This section builds upon the findings from the previous sections. It clarifies how a nexus message can be communicated to government and highlights some of the criteria which may be helpful in determining when a nexus approach could be most effective and recommends specific actions that advisers could consider.

Traditionally where there is resource scarcity the first thought is to increase supply, second is demand management. However, using water, energy, food and land nexus thinking the long-term goal is to move towards systems that provide ample renewable resources while preserving finite resources. In this context, demand management is focused on particular non-renewable steps of the resource cycle and attention is given to increasing supply where that can be achieved sustainably.

The process for Advisors communicating the nexus message and helping to incorporate to governance should consider the following:

- The water, energy, food and land nexus message needs to be communicated conceptually to the higher levels of government, a message of hope to be achieved by changing to a more structured and careful resource management regime and by planning infrastructure based on renewable resources.
- This may be encouraged by Advisors working with high level policy advisers (institutes to ministries, academies of science, policy think tanks etc.) to provide training and workshops on nexus methods; the aim being to influence the leaders to form the high level policy framework that enables nexus solutions and actions.
- For the mid-levels of administration the messages need to be about the practical steps and tools that can be taken to move towards the long-term goal. This will require working together on development of country specific tools and mapping of the key planning documents of each department and the most efficient channels of communication that would allow for nexus understanding to be incorporated to the processes without causing complexity and confusion. This would extend current integrated resource management systems to incorporate nexus issues.
- The water, energy, food and land nexus approach is inherently decentralised in its approach to land management, aiming for more granulated and varied land use which should be more conducive to pro-poor policies rather than single use or mono-culture solutions.
- When undertaking analysis of national policy frameworks the nexus approach can be applied to indicate where focus on linkages will help to understand how sector plans will interact and on maximising the provision of renewable water, energy and food resources which can best lead to improved livelihoods.
- Formalising water, energy, food and land nexus solutions within policy could be a goal to demonstrate commitment and to formalise the approach. However, this is not a pre-condition for considering the approach.

5.2 Criteria for defining when a nexus approach could be needed.

The nexus provides a framework which can be used to optimise the balance between water, land and energy leading to sustainable management of key resources. This extends the integrated resources management approach to governance.

Nexus issues are relevant to all countries supported by DFID rather than just a sub-set. However, a differentiated approach to policy is needed. No two countries have the same “signature” of water, energy, food and land nexus issues and policy needs to recognise absolute and economic resource scarcities as well as the opportunities for achieving sustainable resource abundance. The approach taken needs to work with existing governance capacity and take opportunities to build from this. The approach requires a different way of approaching and solving problems which may require a new outlook and behaviour.

Recommendation 1: Guide sustainable and inclusive growth.

Analysis of the resource nexus has widespread potential to help find effective and sustainable routes to inclusive growth and better livelihoods. Advisers should consider the approach in connection with programmes and projects which have significant implications for land use and other natural resource use or where there is complexity and uncertainty regarding possible impacts and trade-offs between resource sectors. The concept should be linked to specific action steps to be taken.

A range of opportunities to consider are highlighted in the remainder of this section.

5.3 Assess alignment with existing policies

The nexus approach can be used as a way to re-appraise existing policy approaches and frameworks. Existing policies may unintentionally encourage unsustainable resource use practices. The nexus approach can help diagnose these and identify steps that will move to better resource usage.

Consideration of existing national and regional development plans and policies across sectors will help establish the baseline provision and help identify at what level to engage policy and decision makers around nexus issues.

The effect of the existing development trajectory should be framed and quantified as far as possible to provide an initial call to action.

Those regions which are more advanced and are making progress on “integrated” approaches to development are likely to be best positioned to extend and improve existing practices. For example if existing policy integration is limited it would be difficult to introduce a reform to de-couple land and water rights or to remove subsidies for energy.

A branching point either due to a crisis or where there is political change could provide an environment for a fresh response to longstanding development challenges.

Recommendation 2: Policy Appraisal.

Advisers should advocate the use of the nexus approach to encourage appraisal of policy frameworks and plans and the impact of unsustainable practices.

5.4 Assess governance capacity to help establish what type of actions could be effective

The institutional framework to support a nexus approach will require cooperation and collaboration between a range of government agencies and stakeholders. A first step is to consider the governance capacity and possible coordination gaps:

- Is there political commitment and leadership to an integrated, cross-sector approach?
- Are there mechanisms in place for enabling exploration of resource questions between public, private and civil society sectors to ensure that all voices are heard?
- Are there structures to support inter-ministerial dialogue and action?
- Is there sufficient organisational capacity to deliver a more integrated approach?
- Is there an effective regulatory framework and institutional capacity to enforce decisions?
- Is there an effective dialogue between national and sub-national government?
- Is there coordination with neighbouring governments where there are trans-boundary issues?
- Could awareness among academia and the private sector (especially resource intensive industries) be used as a lever?

For policies to be implemented effectively, systems need to be developed to enable nexus thinking to be followed through to delivery, implementation and operation. The debate and focus of the strategy should not be confined to policy-making circles but have a practical focus.

Ideally, the debate and formulation of strategies and programmes to deliver a nexus approach should involve stakeholders from outside government policy makers, including the academic community, civil society, the private sector and other groups who represent the largest users of energy, water and land.

The nexus approach requires technical capacity to be developed in cross-sector policy analysis and programme and project formulation to enable a coherent approach. Where technical cadres already exist the approach will find most fertile ground but skills may need to be developed or expanded.

Recommendation 3: Stakeholder mapping and governance.

Advisers should undertake an initial appraisal of governance capacity to identify what the conditions are for using a nexus approach. Relevant institutions and stakeholders who could be engaged should be identified.

5.5 Define the scale and scope of action

Reviewing the existing evidence base at national and sub-national level should be used to assess the most significant nexus linkages to be addressed. A review of data should consider the full range of issues concerning environmental reporting and indicators; energy and water resources and usage; agricultural production and food consumption; socio-economic indicators and drivers; information on land use and demands; climate data; future projections and trends to establish long-term and short-term changes.

The economic, social and environmental significance should be identified to help draw out the most critical issues which could impact on the future trajectory of the country. Adapting or applying one or more of the tools and frameworks highlighted in Section 4 could provide a

starting point (for example through using foot-printing tools to highlight water-land-food, energy- water, energy land-food linkages).

A focus on what the opportunities could be, together with evidence of the benefits, could provide an incentive to move forward. Frameworks for monitoring and evaluation should be established to help measure impact from the outset.

Recommendation 4: Develop evidence base.

Advisers should analyse data and information to frame the existing situation and challenges as a key first step to making the case to take action on the nexus approach and support efforts to strengthen the information base.

5.6 Legal and regulatory environment

The legal and regulatory framework should support the goal of managing demand to reflect resource scarcity. The pricing of resources is often inadequate (e.g. free water for irrigation), and distortions which do not incentivise sustainable resource use (e.g. fuel subsidies) should be reduced where possible. This process, some is likely to be politically sensitive and will require time to implement.

Inclusive land policies and recognised property rights (whether individual or collective) are necessary to provide protection of livelihoods. This is especially so for marginalised groups who may use land on a customary basis.

To implement a sustainable approach to tackling the nexus, effective regulation and incentives are required for water, land and energy markets. Sometimes legislation and policy may unintentionally favour maximising output from particular natural resources to the detriment of others without considering the impact on consumers and long-term sustainability.

Recommendation 5: Legal and regulatory issues

Advisers should consider how legal and regulatory frameworks may influence the effectiveness of possible actions. Diagnosing these issues through analysis of the links between resource areas can be used to identify possible entry points for nexus solutions.

5.7 Links to investment and finance

A goal of government should be to mobilise investment to address those gaps in infrastructure provision giving priority to those which can make the greatest beneficial impact.

A nexus approach provides the opportunity and incentive to look at cross-sector impacts and actions. At one level framing programmes and projects to tackle multiple sectors could be used to deliver economies of scale and scope. There is potential to enhance the catalytic and transformational effect of projects and to ensure the additional benefits are delivered.

Coordination and greater emphasis at the planning stage can also provide opportunities for securing improved value for money through avoiding waste and co-ordinating action. The nexus approach can be used to help align support from the multilateral and bilateral donors with public investment programmes in order to improve the quantity and quality of available natural resources in a sustainable way while increasing access to the poor.

Raising finance for nexus projects and programmes could represent a challenge as increasing the ambitions of projects, the sectors and range of institutions involved adds to complexity. Simpler more straight forward programmes are more likely to attract finance particularly from the private sector, but bankable bids and programmes can be offered directly to the private sector.

Further research and analysis is required to investigate how the financing of nexus projects and programmes tackling multiple sectors should be approached, what options have been effective so far and how the structuring and delivery of projects may need to change in the future.

Recommendation 6: Links to finance.

Advisers should consider how the nexus approach can be linked to mobilising investment and finance in support of projects and options to support implementation of the nexus solution.

5.8 Mobilising the private sector through establishing partnerships to deliver change

As highlighted in a number of the case studies in Section 4 private sector resource users may have greater incentive to act on resource questions than the public sector and can be engaged to take action individually or in partnership with government. The rationale for the private sector taking action includes:

- Cost efficiencies;
- A need to secure access to sustainable and reliable inputs;
- Part of the licence to operate or an effective way of managing reputational risks in the context of future resource conflicts;
- A possible requirement of government to enable market access;
- Innovation to support resource efficiency, leading to commercial and consumer benefits and wider economic development benefits; and
- Partnerships can be successful in helping to overcome coordination problems.

Recommendation 7: Engaging private sector.

Advisers should consider engaging the private sector to advocate for change. Opportunities could exist for forging partnerships with both government and civil society.

5.9 Implications for DFID policy

The water, energy, food and land nexus agenda has emerged over the last decade. However, it represents the alignment and integration of parallel agendas around areas such as integrated water resources management, environmental management, sustainable urban development and energy efficiency and low carbon development which have a longer lineage and are now seen as part of the mainstream.

Closer alignment between these areas is likely to deliver additional gains some of which may represent a series of incremental marginal gains. However, there are also likely to be transformational opportunities where the approach is considered in connection with large scale projects which have a wide geographical and sectoral reach. In these cases the impact

of these projects could be enhanced by framing the project more broadly to deliver a wider range of benefits and opportunities for economic development.

Recommendation 8: Using nexus to enable economic growth and urban development.

DFID should consider embedding the nexus approach in policies and strategies for economic growth and urban development. The added value which a nexus approach can bring can help DFID deliver its existing policy objectives.

5.10 Next steps

Throughout the preparation of this Topic Guide, limited evidence was identified of “new” nexus programmes which had been fully conceived to tackle nexus issues from the outset, completed and subjected to evaluation. However, there is a wide range of programmes and projects which have delivered components of a nexus approach across at least two resource areas.

While this report has highlighted existing frameworks and tools in Sections 3 and 4, many of the frameworks were focused at a particular scale or were geared towards particular nexus challenges (e.g. food security). Few of the tools currently provide the full capability or well defined processes to identify and work through changes between environmental and social systems. The current tools also do not generally consider nexus-related shocks in a dynamic way considering implications over time or at different geographic scales. Developing the scientific basis to work towards such an approach focused upon the key nexus linkages could be an area for future work.

The current state of the art is to piece together the outputs from various domain and sector specific models and then to use a scenario building approach to explore the implications and cumulative impacts of changes to more than one (of the three) resource components.

There is a need to develop frameworks, toolkits and guidance which can provide an easier basis for translating the approach to support the take up by policy makers and practitioners. A starting point would be to review the application of existing frameworks and tools from a conceptual and practical standpoint in order to help to define the improvements needed.

These tools need to be tested and demonstrated in their utility with real data from pilot studies.

DFID should consider embedding nexus approaches within existing project appraisal frameworks. They should also consider opportunities to develop new tools and appraisal methods which can be used for identifying the costs and impact of nexus-related solutions on a transparent basis.

Recommendation 9: Need for additional research.

There is a need for further research in monitoring and evaluation to quantify the impact of applying the nexus approach on demonstration or pilot studies. DFID should consider opportunities to develop new tools and appraisal methods for identifying the costs and impact of nexus-related solutions on a transparent basis.

5.11 Entry points

There is a range of potential entry points for DFID to engage stakeholders:

- **Advocacy tools, policy gap analysis and roadmap.** DFID could engage stakeholders to explore and identify opportunities for adopting a nexus approach through policy advocacy around evidence which highlights the potential offered by a nexus approach. Stimulus for engagement could include a policy and gap analysis to identify which countries are already undertaking elements of a nexus approach, the areas which could be scaled up and areas where progress has been more limited. The results could help to highlight where the nexus could be an area to be considered in connection with existing and future government programmes and DFID country operational plans.
- **Provide support for applying existing available tools.** Supporting the development and application of existing frameworks and tools identified in Section 4 of this document at a practical level could be used help to scope out in a tangible way with stakeholders the range of issues and opportunities relevant to a particular context to develop a roadmap or action plan.
- **Strategy development and investment planning.** The review and update of existing plans and strategies provides an opportunity for introducing and embedding a nexus approach and widening the debate around trade-offs and challenges. The focus need not necessarily be confined to cross cutting “national plans” and strategies. A starting point could be to use sector plans for water, energy, agriculture or urban development as basis to pilot and scale action if traction can be gained.
- **Existing projects and programmes.** Existing programmes and interventions provide a basis to explore and pilot mechanisms and policies linked to nexus. Even if nexus was not considered at the outset, at the detailed level there could be opportunities for exploring nexus solutions as a response. For example, tools such as CEEQUAL explore the resource use questions in relation to the construction stage of projects.

Recommendation 10: Mechanisms for engaging stakeholders.

Advisers should review the potential entry points to support national partners in exploring the water-land-energy-food nexus. Advocacy, support for applying and developing tools, contributing to strategy and investment planning and reviewing opportunities to address nexus in existing projects should be considered.

Annotated bibliography

What added value could a nexus approach bring

Andrews-Speed, P., Bleischwitz, R., Boersma, T., Johnson, C., Kemp, G., VanDeveer, S. D. (2012). The Global Resource Nexus: The Struggles for Land, Energy, Food, Water and Minerals. Translantic Academy, Washington, D.C. Available at: http://www.gmfus.org/wp-content/blogs.dir/1/files_mf/ta2012report_apr12_web.pdf

This report identifies that five resources, land, energy, food, water and minerals are essential for human security and international trade. It highlights that if these resources are not managed in synergy then it could lead to inter- and/or intra-regional conflict. Importantly, this report calls for leadership on the nexus challenges and unprecedented global demand for resources from United States of America, Canada and Europe.

Hoff, H. (2011). Understanding the Nexus. Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm. Available at: <http://www.water-energy-food.org/en/conference.html>

This paper introduces the Bonn conference on the global nexus issues which has been a landmark event in the global nexus discussions. It provides a good introduction and overview of the main nexus challenges. The author promotes a reduction of trade-offs and the generation of additional benefits that outweigh transaction costs. Initial evidence of the opportunities for improving water, energy and food security through a nexus approach are presented. Evidence is provided for opportunities in various policy areas such as: increased productivity of resources; waste as a resource in multi-use systems stimulating development through economic incentives; governance, institutions and policy coherence and integrated poverty alleviation and green growth.

Roderiguez, D. J., Delgado, A., DeLaquil, P., Sohns, A. (2013). Thirsty Energy. World Bank Water Partnership Program (WPP), Washington, United States of America. Available at: <http://documents.worldbank.org/curated/en/2013/01/17932041/thirsty-energy>

This comprehensive report contributes to the World Bank global initiative entitled “Quantifying the Trade-offs of the Water and Energy Nexus” and focusses on the inextricable linkages between water and energy. The report considers the potential opportunities for synergies in water and energy infrastructure for the developing world. Importantly, this report, discusses the institutional, policy and financial barriers to cross-sectoral planning offering guidance on integrated energy and water system planning.

UN ESCAP. (2013). Water, Food and Energy Nexus in Asia and the Pacific. A position paper commissions by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Bangkok, Thailand. Available at:

http://www.worldwatercouncil.org/fileadmin/world_water_council/documents/programs_hydro_politics_sdgs/Water-Food-Nexus%20Report.pdf

This report provides a ‘go to’ synthesis of water-energy nexus debates, frameworks, conferences and policy up to 2013. It also reviews the resource challenges that the nexus presents for Asia and the Pacific including: biofuel; hydropower; thermoelectric production and water security; irrigation and food security; irrigation and energy security; food trade and virtual water, land and food security; and the intertwining effect of water production and energy security. Case studies of Central Asia and Mekong Basin are presented to unpack the nexus challenges, solutions and opportunities. These case studies reveal that existing policy frameworks consider water and energy policy in isolation, limiting the ability to tackle the nexus challenges. The authors present areas of policy interventions needed to mainstream the nexus concept in Asia and the Pacific region such as, analytical

comprehensiveness, scale-specific assessment, policy salience and an ecosystem approach.

World Economic Forum. (2011). Global Risks 2011 report Available at:

<http://reports.weforum.org/global-risks-2011/>

This annual report brought the water-food-energy nexus to global political attention at the Davos Summit. The water-food-energy nexus features as one of the World Economic Forum's three most important risk clusters that emerged from the analysis undertaken during 2011. The report highlights that short-term production responses to water, food and energy demand undermine long-term sustainability. The report stresses that shortages could cause social and political instability, geopolitical conflict and environmental damage. The need to fully consider the interconnected risks of the nexus to avoid unintended consequences is highlighted. The report recommends that investment and research is focused on transformative technologies, risk management tools and efficiency improvements via new operational management models.

How can nexus issues be measured and monitored – brief overview of available tools and techniques

Asian Development Bank. (2013). Thinking about Water Differently – Managing the Water-Food-Energy Nexus. Asian Development Bank, Manila, Philippines. Available at: <http://www.adb.org/publications/thinking-about-water-differently-managing-water-food-energy-nexus>

This report provides a high level synthesis of current challenges surrounding the water-food-energy nexus in the context of water security issues. Issues are considered at both policy and project levels. Interestingly, examples of emerging nexus opportunities are provided. The report also presents a concise but accessible introduction to new water accounting and how to manage, plan and respond to the nexus challenges. To tackle the nexus challenges the Asian Development Bank (ADB) advocates 'systems thinking', looking at a whole system rather than its individual parts. In this way, countries can improve efficiencies and ensure their environmental and social sustainability. To do this the ADB advises that developing member countries compile a 'country water assessment' to help them understand their current and future supply-demand balance, introduce good governance and adopt new ways to manage water security risks. This report provides an introduction to country water assessments but more detail of practical implementation should be sought from additional sources. Although the report is focused on developing member countries in Asia and the Pacific the overview and guidance is applicable globally.

Bizikova, L., Roy, D., Swanson, D., Venema, H. D., McCandless, M. (2013). The Water–Energy–Food Security Nexus: Towards a practical planning and decision-support framework for landscape investment and risk management. International Institute for Sustainable Development, Winnipeg, Canada. Available at:

http://www.iisd.org/pdf/2013/wef_nexus_2013.pdf

This paper provides a comprehensive summary of key arguments, approaches, frameworks and lessons learned from global water-energy-food initiatives. Also, a summary table of global and regional water-energy-food nexus conferences, workshops and meetings held in 2011-12 as preparation for Rio+20 is presented. The author's main argument focuses on operationalising the nexus concept stating that land investments made with broader social, environmental and economic objectives will perform better due to improved socio-ecological risk management. Ecosystems and decision-making systems are nested and act at different spatial and temporal scales, the linkages between natural and human systems are an important practical means of optimising water-energy-food security. An ecosystem based, spatially explicit framework to design, monitor and manage land investments which deliver increased water, energy and food security is presented. The basic participatory planning

process adopts four main stages: Assess the water-energy-food security system, envision future landscape scenarios, invest in water-energy-food secure future and finally transform the system.

Food and Agriculture Organization. (2014). The Water-Energy-Food Nexus: A new approach in support of food security and sustainable agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy. Available at:

http://www.fao.org/nr/water/docs/FAO_nexus_concept.pdf

The main content of this report outlines the key stages of a nexus assessment approach developed by the Food and Agriculture Organization of the United Nations (FAO). As outlined in this report, the nexus assessment constitutes evidence-based analysis of nexus interactions, scenario development, strategic visions and response options. The approach should be used by practitioners to identify, assess and manage nexus interactions and evaluate the wider impact of any proposed regulatory, practice or infrastructural change. This report states that the assessment should be carried out through stakeholder dialogue suggesting that this will reconcile any differences in uses or interests of stakeholders create a sense of ownership to legitimise decision-making processes and raise awareness of the interlinked nature of global resources. This report provides an introduction to the structure of the FAO nexus assessment however, in practise, users will require additional more detailed information.

Food and Agriculture Organization. (2014). Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the Context of the Sustainable Energy for All Initiative. Food and Agriculture Organization of the United Nations, Rome, Italy. Available at:

<http://www.fao.org/3/a-i3959e.pdf>

The main content of this report outlines the key stages of a nexus assessment approach developed by the Food and Agriculture Organization (FAO). The approach should be used by practitioners to identify, assess and manage nexus interactions and evaluate the wider impact of any proposed technical or policy intervention in the given context. The assessment focuses on the context analysis and provides examples of some problem-specific tools for more in-depth quantitative analysis of the impacts and development of scenarios and strategic visions. The report also considers the performance of technical and policy interventions, their resource use efficiency and productivity. It is suggested that the performance of interventions should be assessed in relation to the nexus context status. This report states that the assessment should be carried out through stakeholder dialogue suggesting that this will reconcile any differences in uses or interests of stakeholders create a sense of ownership to legitimise decision-making processes and raise awareness of the interlinked nature of global resources. It provides a stepwise process to address policy making and intervention in a nexus manner and provides indicators to carry out a nexus rapid appraisal or generate context specific information, combine quantitative and qualitative assessment methods and links.

Granit, J., Fogde, M., Hoff, H., Karlberg, L., Kuylenstierna, J. L. and Rosemarin, A. (2013). Unpacking the Water-Energy-Food Nexus: Tools for Assessment and Cooperation Along a Continuum. Stockholm International Water Institute, Report 32.

Available at: <http://www.sei-international.org/mediamanager/documents/Publications/SEI-2013-WWW-Nexus-article.pdf>

This article was developed as part of a thematic report for Stockholm World Water Week (2013). The authors suggest that nexus analysis should be applied across a continuum of scales and sectors. Examples of methods and tools ranging from qualitative approaches to more data driven and quantitative modelling approaches are presented. For example, index building addresses the macro-regional scale using a core set of representative parameters for key sectors to identify sensitivities of the nexus. Whereas, sector-specific and data-intensive modelling approaches provide an in-country level analysis. This multi-scale, multi-sector approach enables measures for cooperative governance and management that

support outcomes to be identified along multiple value chains within the nexus. The authors argue that, applying a nexus analysis at different scales strengthens collaboration between stakeholders. This approach also enables and encourages cooperative management.

Rasul, G. (2012). Contribution of Himalayan ecosystems to water, energy, and food security in South Asia: A nexus approach. International Centre for Integrated Mountain Development. Available at: <http://circleofblue.org/waternews/wp-content/uploads>

Presents a framework centred on ecosystem services developed by the International Centre for Integrated Mountain Development (ICIMOD). The paper focuses on the Himalayas, South Asia. The framework adopts a system-wide, rather than a sectoral approach to the nexus arguing that this can help reduce trade-offs and generate additional benefits. Integral to the framework are ecosystem goods and services as they contribute to the security of water-energy-food nexus and agriculture. The ICIMOD stress that ecosystems must be protected and enhanced to ensure their resilience and their support for production., the paper recommends policies to enhance food, water, and energy security in South Asia, such as: restoration of natural water storage capacity; development of climate-smart, environmentally and socially sound infrastructure; and incentive mechanisms for managing Himalayan ecosystems.

World Economic Forum. (2011). Water Security – The Water-Food-Energy-Climate Nexus. The World Economic Forum Water Initiative, Washington, United States of America. Available at: <http://www.weforum.org/reports/water-security-water-energy-food-climate-nexus>

Comprehensive insight from government leaders, religious groups, business, NGOs, academics, entrepreneurs, financial experts, journalists and trade specialists on common water issues and challenges to meet future social and economic needs for the next two decades. The report explores different sectors such as agriculture, energy, and cities to develop a better understanding of how water is linked to economic growth across a nexus of issues. Chapter 10 and 11 are particularly useful as they outline a step by step economic framework for decision making with fact-based analysis as a platform for action. In this framework, food and water security are linked to economic disparity and global governance failures causing chronic water and food shortages and crises. Chapter 11 focuses on guidance to create multi-sector, public-private coalitions to develop water reform programmes in reaction to a clear fact base of the challenge. This framework aims to help decision makers better understand risks so they are able to respond proactively and mobilise quickly in times of crises.

World Bank. (2015). Water Security for All: the Next Wave of Tools, 2013/2014 Annual Report, Water Partnership Programme. Available at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/02/12/000350881_20150212155839/Rendered/PDF/942940WSP0Box30rt0201301400low0res0.pdf

This report outlines the Water Partnership Programme initiatives and assesses progress and results to date under its second Phase (2012-2016) and assesses its performance for the year 2013-2014. Using a number of case studies looking at activities that have been implemented in 44 countries it focuses on three key areas: Water in Agriculture and Energy; Tools and Knowledge; and Geographic Priority areas where challenges within the water supply and sanitation and water resources management sub-sectors are addressed.

Lessons from applying a nexus approach

Hellegers, P., Zilberman, D., Steduto, P., McCornick, P. (2008). Interactions between water, energy, food and environment: evolving perspectives and policy issues. *Water Policy*, 10, 1-10. Available at: <http://test.iwaponline.com/wp/010S1/0001/010S10001.pdf>

Introduction paper to a special issue that brings together 8 papers by 21 authors who examine the water related policy issues surrounding the nexus from a variety of disciplinary contexts and professional backgrounds. This paper is a useful summary paper as it provides an overview and synthesis of the papers included within the special issue. The special issue assesses three issues related to the nexus. These are the water–hydropower interactions and their effect on food and the environment, energy-water interactions and their implications for groundwater depletions and rural livelihoods and finally water–biofuel linkages and their consequences for water allocation, food security, farm income and the environment. Both a global level review and a practical context of in-country case studies for China, Ethiopia, India, Jordan, Pakistan, Sri Lanka and the USA are provided. The paper finishes with some recommendations for future research needs.

Hussey, K., Pittock, J. (2012). The Energy-Water Nexus: Managing the Links between Energy and Water for a Sustainable Future. *Ecology and Society*, 17(1), 31. Available at: <http://www.ecologyandsociety.org/vol17/iss1/art31/>

Guest editorial as part of a special feature on the energy-water nexus. This paper highlights that although the urgency around the links between energy and water sectors for security of supply are widely accepted, existing water and energy policy frameworks are developed in isolation from one another. Drawing on case studies from Australia, Europe, and the United States, this special issue identifies where policy and management strategies could be integrated better. Also, the special issue explores the barriers to integration of water and energy management policies and highlights available solutions or where solutions are needed.

Glassman, D., Wucker, M., Isaacman, T., Champilou, C. (2011). The Water-Energy Nexus, adding water to the energy agenda. *World Policy Paper*, World Policy Institute, New York, USA. Available at: http://www.worldpolicy.org/sites/default/files/policy_papers

This policy paper provides the context needed to evaluate key trade-offs in the water-energy nexus. Importantly, this paper provides a comprehensive guide to the most credible available data about water consumption per unit of energy produced across a spectrum of traditional and alternative energy technologies. Usefully, the data sources are provided in the report appendices. The review of available data allows the authors to conclude that both emerging petroleum and alternative transportation fuels consume more water than conventional petroleum-based fuels and also the picture on electricity generation is mixed. Also, data holes and important issues that merit further attention are identified.

McCornick, P. G., Awulachew, S. B., Abebe, M. (2008). Water-food-energy-environment synergies and trade-offs: major issues and case studies. *Water Policy*, 10, 23-36. Available at: <http://test.iwaponline.com/wp/010S1/0023/010S10023.pdf>

This paper provides an analytical overview of the linkages between water, energy, food and environment and their economic, social and environmental implications. It provides both a brief global overview and closer review of four case studies from India, Ethiopia, Jordan and the USA. These case studies provide country and basin-specific experiences in managing the synergies, conflicts and trade-offs under different hydrological, energy, agricultural and environmental contexts. Also, the authors provide some anecdotal evidence and illustrative cases of available policy options for minimising conflicts while maximising synergies between water, energy, food and environment.

United Nations. (2015) Conceptual Frameworks for Understanding the Water, Energy and Food Security Nexus by the United Nations Economic and Social Commission for Western Asia (ESCWA) Available at <http://css.escwa.org.lb/SDPD/3581/WP1A.pdf>

This recent working paper provides an overview of the main conceptual framework for understanding the nexus provided by the World Economic Forum (WEF), the Bonn 2011 Nexus Conference, UNEP, IIISD, ODI—ECDPM-DIE, the Transatlantic Academy, FAO, BMZ, and how the definition and scope has evolved over the years and links it with the latest work down for the sustainable development goals and the post-2015 development agenda. The latter part of the paper considers how work on the examining of the water-energy-food nexus has been linked with regional priorities and projects in Western Asia, before putting forward a number of key questions for consideration for developing a regional vision for the WEF Security Nexus.

United Nations Water. (2015). The United Nations World Water Development Report: Water for a Sustainable World. Available at

<http://unesdoc.unesco.org/images/0023/002318/231823E.pdf>

This latest edition of the United Nations World Water Development Report focuses on how water resources are critical to achieving global sustainability starting with a 2050 Vision of the world in which water resources managed efficiently and shows how dedicated SDG for water would create social, economic, financial and other benefits that would extend to poverty alleviation, health, education, food and energy production, and the environment. The report also includes regional perspectives outlining challenges faced in different parts of the world such as in Europe and North America, Asia and the Pacific Region, Latin America and the Caribbean, Africa and the Arab Region.

World Bank. (2013). Thirsty Energy. Available at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/06/27/000333037_20130627121240/Rendered/PDF/789230REPLACEM0sty0Energy0204014web.pdf

This report is the first publication coming out of the World Bank Initiative 'Thirsty Energy' which focuses on increasing awareness, building capacity, fostering interdisciplinary collaboration and introducing tools for political decision makers and other public and private stakeholders in relation to water requirements for the energy sector. This first report introduces the energy-water nexus, examines the water demand of thermal power plants and hydropower including present and future challenges using Southeast Asia as an example of future change in water stress and power plants, and outlines some potential technical and institutional solutions for improving the management of the nexus.

References

- Azadi, H et al. (2013). Agricultural outsourcing: a two headed coin? *Global Planet*, 100, pp20-27.
- Babel, M. and Wahid, S. (2008) *Freshwater under threat South Asia*. Asia Institute of Technology and UNEP, Nairobi. Available at: http://www.unep.org/pdf/southasia_report.pdf
- Bajzelj B, Allwood J.M., Cullen J.M. (2013) Designing climate change mitigation plans that add up. *Environmental Science and Technology*, 47(14), pp.8062–9.
- Bajželj B, Richards K, Allwood J, Smith P, Dennis JS, Curmi E, and Gilligan CA (2014). 'Importance of food-demand management for climate mitigation'. *Nature Climate Change* (4) 924-929.
- Bajželj B and Richards K (2014) The Positive Feedback Loop between the Impacts of Climate Change and Agricultural Expansion and Relocation. *Land*, 3(3), 898–916
- Beddington, J. (2009). "Perfect Storm" Presentation, UK Chief Scientist Advisor. GovNet SDUK09 Conference, Westminster, UK, March 2009.
- Bizikova, L., Roy, D., Swanson, D., David Venema, H., McCandless, M. *The Water–Energy–Food Security Nexus: Towards a practical planning and decision-support framework for landscape investment and risk management*, IISD, Winnipeg. Available at: http://www.iisd.org/pdf/2013/wef_nexus_2013.pdf
- Cotula, L and Oya, C. (2014) Testing Claims about Large Land Deals in Africa: Findings from a Multi-Country Study. *The Journal of Development Studies*, 50:7, pp903-925.
- Curmi E, Richards K, Fenner R, Kopec G, Bajzelj B, (August 2014). Balancing the needs of all services provided by global water resources, Chaper in Book '*The Global Water System in the Anthropocene, Challenges for Science and Governance*, Springer
- Curmi E, Fenner R, Richards K, Allwood J.M, Kopec G, Bajželj B (2013). Visualising a stochastic model of California water resources using Sankey diagrams. *Water Resources and Management*, 27:3035-3050.
- Curmi E, Richards K, Fenner R, Allwood J.M, Kopec G.M, Bajželj B (2013). Effective and integrated management of the services provided by global water resources. *Journal of Environmental Management*, 129(2013), 456-462
- Curmi E, Richards K, Fenner R, Allwood J.M, Kopec G.M, Bajželj B (2013). *Understanding the importance of the services that water provides and their connections with energy and land resources; a case study of California*. Abstract submitted for presentation at the Water in Anthropocene conference in Bonn.
- DEFRA (2007) *An Introductory Guide to Valuing Ecosystem Services*. DEFRA, London.
- The Economist, 31st March 2010. *We all want to change the world. Dealing with climate change might mean tinkering with the oceans and the atmosphere. Those who could do so would like the regulations to be clear.*

- Foresight (2010) *Land Use Futures: Making the most of land in the 21st century*, Cabinet Office, London. <http://www.gov.uk/government/publications/land-use-futures-making-the-most-of-land-in-the-21st-century>
- Jeffrey, P and Gearey, M. (2006) Integrated water resources management: lost on the road from ambition to realisation? *Water Science Technology*, 53 (1) 1-8. Also refer to: <https://globalwaterpartnership.wordpress.com/2013/04/10/iwrm-not-pragmatic-enough/>
- Godfrey, N.; Savage, R. *Future proofing cities: risks and opportunities for inclusive urban growth in developing countries*. Atkins, Epsom, UK (2012) 188 pp
- Grain (2014). *Planet Palm Oil: Peasants pay the price for cheap vegetable oil*. [online] Available from: <http://www.grain.org/article/entries/5031-planet-palm-oil>
- Hertel, T. (2010) *The Global Supply and Demand for Agricultural Land in 2050: A Perfect Storm in the Making?* GTAP working paper No. 63. Purdue University, West Lafayette, IN.
- Hoff, H. (2011). *Understanding the Nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus*. Stockholm Environment Institute, Stockholm. Available at: <http://www.water-energy-food.org/en/conference.html>
- Hoff, H., & Karlberg, L. (2013). *A Nexus Approach for the Lake Tana and Upper Blue Nile Basin*. Stockholm Environment Institute – Policy Brief
- ICEM (2010) *Strategic Environmental Assessment of Hydropower on Mekong Mainstream*, International Centre for Environmental Management. Available at: <http://icem.com.au/portfolio-items/strategic-environmental-assessment-of-hydropower-on-the-mekong-mainstream/>.
- Kesicki, F. (2011) *Marginal abatement cost curves for policy making – expert-based vs. model-derived curves*. UCL Energy Institute. Available at: http://www.homepages.ucl.ac.uk/~ucft347/Kesicki_MACC.pdf
- Mohtar, R. and Daher, B. (2012). Water, Energy, and Food: The Ultimate Nexus *Encyclopedia of Agricultural, Food, and Biological Engineering*, Second Edition DOI: 10.1081/E-EAFE2-120048376. Available at: [http://wefnexusool.org/docs/water,%20energy,%20and%20food_the%20ultimate%20Onexus%20\(mohtar,%20daher,%202012\).pdf](http://wefnexusool.org/docs/water,%20energy,%20and%20food_the%20ultimate%20Onexus%20(mohtar,%20daher,%202012).pdf)
- Nicholls, Alex, Moore, Michelle-Lee and Westley, Frances (2012) The Social Finance and Social Innovation Nexus. *Journal of Social Entrepreneurship*, 3 (2). pp. 115-132.
- OECD (2013), *Putting Green Growth at the Heart of Development*, OECD, Paris.
- Oxfam International. (2010). *Land Grabbing in Africa: A review of impacts and the possible policy responses*. [online] Available from: <http://www.oxfamblogs.org/eastafrica/wp-content/uploads/2010/11/Land-Grabbing-in-Africa.-Final.pdf>
- Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute, European Union, Brussels (2012) *The 2011/2012 European Report on Development, Confronting Scarcity:*

Managing Water, Energy and Land for Inclusive and Sustainable Growth. Overseas Development Institute (ODI), European Centre for Development Policy Management (ECDPM), German Development Institute, European Union, Brussels.

- Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society* 14(2): 32. Available at: <http://www.ecologyandsociety.org/vol14/iss2/art32>
- Roe, D. *Topic Guide: Ecosystem services*. Evidence on Demand, UK (2014) vii + 34 pp. [DOI: http://dx.doi.org/10.12774/eod_tg.september2014.roed]
- Sorman AH, Giampietro M (2011) Generating better energy indicators: Addressing the existence of multiple scales and multiple dimensions. *Ecological Modelling*, 223 (1):41-53.
- Squires V, Milner H, Daniell K,. (2014) *River Basin Management in the Twenty-First Century: Understanding People and Place*, CRC Press ISBN 9781466579620, Chapter 11 “Sustainable Management of Water Resources in the Yellow River Basin: Main Issues and Legal Approaches”, Du, Zhuang, Spooner
- Teklemariam, D. et al. (2015). Transnational land deals: Towards an inclusive land governance framework. *Land Use Policy*, 42, pp781-789.
- Thomas H, Aveyard B, Spooner S (2015) *Managing water risks in China's unconventional natural gas development*, Atkins, FCO SPF project in press
- UKWIR (2008) *Guidance for operational emissions (08/CL/01/5)*, UKWIR, London.
- UKWIR (2008) *Carbon Accounting in the UK Water Industry: Guidelines for Dealing with ‘Embodied Carbon’ and Whole Life cycle Accounting (08/CL/01/6)*, UKWIR, London.
- Swilling M., Robinson B., Marvin S. & Hodson M. (2013) *City-Level Decoupling: Urban resource flows and the governance of infrastructure transitions*. A Report of the Working Group on Cities of the International Resource Panel. Swilling M., Robinson B., Marvin S. and Hodson M. UNEP, 2013.
- Wang J, Liu S, Maitani T, Bastiaanssen W, Pelgrum H, (2005) Monitoring Actual Evapotranspiration with Satellite Remote Sensing in the Hai River Basin of China [Journal of Agricultural Meteorology](http://www.cas.ac.cn/journal/ENGLISH/01/2005/60(5):565-568) 01/2005; 60(5):565-568.
- 2030 Water Resources Group (2013) *Managing Water Use in Scarce Environments: A Catalogue of Case Studies*. Water Resources Group.
- Wen, W. Zhong, L., Fu, X, Spooner, S. (2014) “Water Energy Nexus in the Urban Water Source Selection: A case study from Qingdao”, World Resources Institute. Available at: <http://www.wri.org.cn/en/publication/water-energy-nexus-urban-water-source-selection-case-study-qingdao>
- Suzuki, H., Dastur, A., Moffatt, S., Yabuki, N. & Maruyama, H. (2011) *Eco2 Cities Ecological Cities as Economic Cities*. Suzuki, H. Dastur, A.; World Bank, Washington.

World Economic Forum (2014) *Global Risks 2014, Ninth Edition*, World Economic Forum, Geneva. Available at:
http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2014.pdf

WRI (2000) *The Weight of Nations: Material Flows from Industrial Nations*. World Resources Institute, Washington.