Chapter 6.

Special theme: The climate-land-energy-water--development nexus

"Land, energy and water are our most precious resources..." (Howells et al., 2013)[284]

Sustainable development highlights the need for integrated approaches to finding solutions that are commensurate with the challenge of achieving economic, social and environmental goals that are often interlinked. The climate–land–energy–water–development (CLEWD) nexus is of great importance for sustainable development.

Water, energy and land are needed to grow food. Some food crops can also be used as biofuel. Power plants require water. Energy-intensive seawater desalination increasingly provides water for drinking and agriculture. Water and energy infrastructure is needed to spur development and vice versa. In many parts of the world, a changing climate exacerbates some of these already strained links. Increasing droughts call for increased energy inputs for irrigation and limit the use of hydropower plants. In some SIDS, as well as in drought-sensitive areas, these impacts of a changing climate are already a reality. In many cases, these links are so significant that they cannot be neglected by policy and call for integrated approaches.

The case studies presented in this chapter highlight the importance of scientific evidence in supporting sustainable development policy.

6.1. From integrated assessment to the climate-land-energy-water-development nexus

There are many relevant sustainable development issues that need to be considered in principle (see Table 2 in chapter 1). Integrated sustainable development assessments aim to capture all of these issues and to take into account the interlinkages among them. This can be daunting task, as the interlinkages are complex and context-specific and depend, inter alia, on the issues under consideration, the geographic and temporal scales, population density and the existing technology systems.

Since the 1970s, quantitative models and other decision-support tools have been increasingly used to better understand the trade-offs and synergies of various policy options. Scenario models and related tools allow a systematic analysis using scientific findings and data from all relevant disciplines. They provide decision-makers with access to scientific knowledge in an actionable way without requiring a full understanding of the underlying science.

In practise, however, there is a limit to what can be modelled, what can be easily understood, and what will be trusted by decision-makers. For example, changing the scope of issues to be considered can greatly alter the findings and the resulting policy conclusions. In the example of the IPCC process, various series of emissions scenarios have informed climate policy over the years. These scenarios were developed with sophisticated global scenario models, which typically captured the energy, land/food and air pollution issues, but which did not model in detail issues surrounding water, materials use, biodiversity issues, poverty, trade and others. [265] As a result, these IPCC scenarios were not designed to identify integrated solutions that can resolve trade-offs and build on synergies across the wide range of sustainable development issues. Instead, they were developed to explore alternative emission trajectories and emissions mitigation options. If goals other than emission targets were considered, such as energy, water and food resource targets and development objectives, then the overall results would change.

Clearly, fully integrated assessment continues to be a complex and challenging undertaking. This partially explains why it has not been used to the extent that was originally envisaged in *Agenda 21*, as was agreed by Governments in 1992. In fact, at the national level, planning and assessment continue to follow exclusively sectoral and/or thematic lines in most countries.

Consequently, an increasing number of scientists have started to promote a second-best option to fully integrated assessment in recent years. They suggest focusing initially on smaller clusters of interlinked issues that are considered most important for policy action.

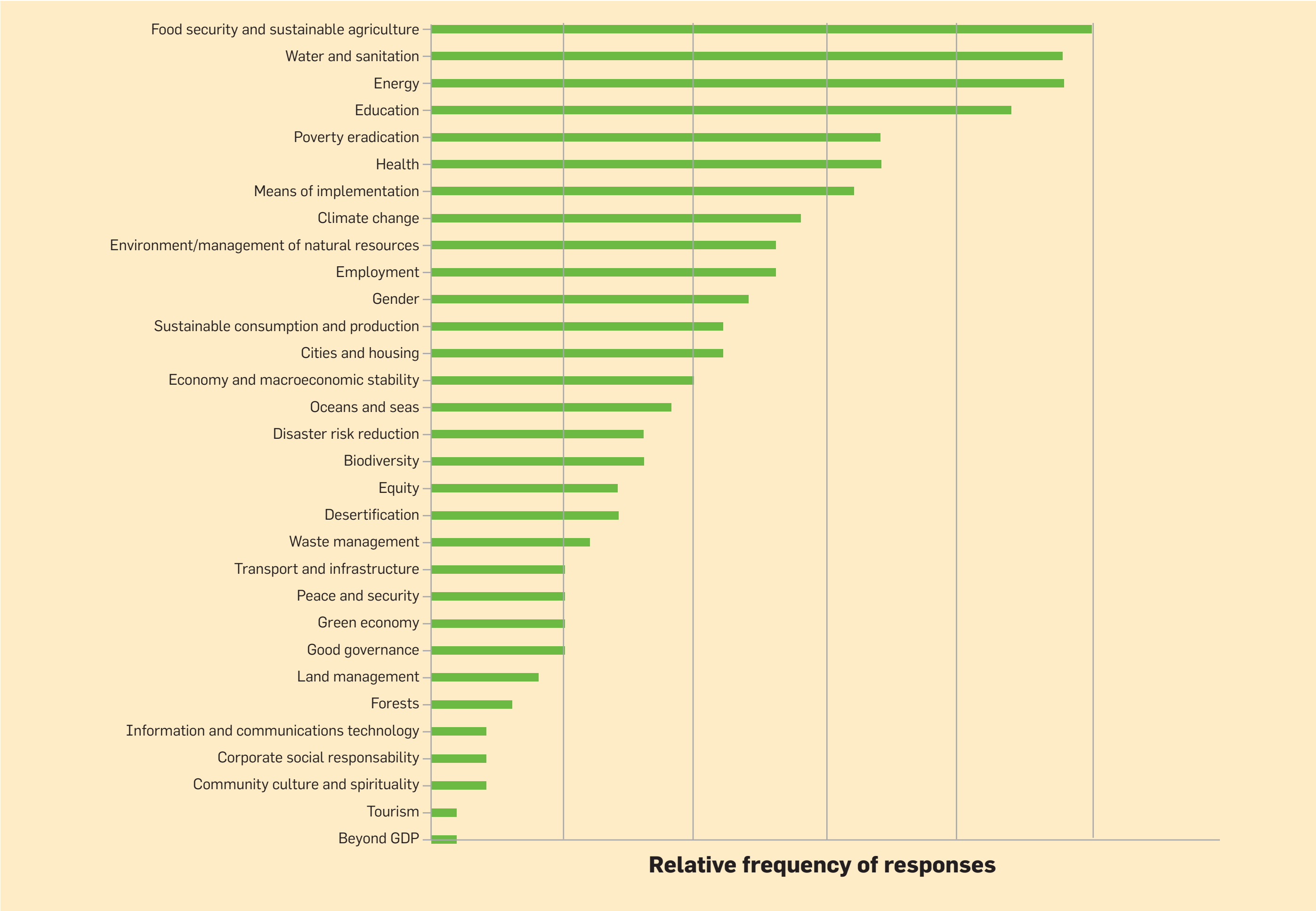
Food, water, energy, poverty eradiation and climate change are issues in the top-10 of the priority areas that were suggested by Governments for the SDGs in December 2012 (Figure 28). They are also some of the key issues that were highlighted by Governments in the Rio+20 outcome document. Similarly, according to the *State of the Planet Declaration*, climate, land, energy and water are central to development.[266] The World Economic Forum outlined several interrelated global risks arising from the interconnected food, water and energy security issues.[267] It should be noted, in particular, that Governments have engaged in a number of nexus initiatives in recent years. For example, a Task Force on the Water-Food-Energy-Ecosystem Nexus was created under the UNECE Water Convention; [268] the German Government launched a water, energy and food security resource platform; [269] and a series of international "nexus" meetings has been convened. [270] Against this background, the CLEWD nexus was chosen as a special theme for the present prototype report.

It is important to note that different terminologies are being used to refer to similar CLEWD nexus approaches. For example, energy analysts typically refer to climate–land–energy–water strategies (CLEWS) or energy–food–water strategies, whereas water analysts tend to refer to "the nexus", in particular the water–energy–food security nexus (WEF). Analysts with a food security perspective as a starting point have used a combination of the above.

Ideally, the strength of interlinkages among issues and the policy priorities of Governments might define the most suitable cluster of issues to be analysed. Hence, the "right" cluster of issues is case specific. In some cases, the cluster can be narrower (e.g. energy–water) or wider (e.g. to include biodiversity).

At the same time, energy, water and food resources have a number

Figure 28. Priority areas for SDGs officially suggested by Governments in December 2012



Source: Responses by United Nations Member States to a questionnaire on priority areas for the SDGs carried out in December 2012. The results are summarized in the Report of the United Nations Secretary-General (A/67/634 of December 2012).

of important common characteristics: there are billions of people without access to modern sources; global demand for these resources has increased rapidly leading to concerns over resource limits; all are "global goods" and involve international trade; all operate in heavily regulated markets and are linked to security issues; all are closely linked to environmental issues including climate change. [271]

Finally, it should be noted that the CLEWD nexus is but one of a number of clusters of strongly interlinked issues of great relevance for sustainable development. Future editions of a global sustainable development report could address these clusters in turn.

6.2. Interlinked issues: climate, land/food, energy, water, materials and development

Many of the national submissions in preparation for the Rio+20 Conference in 2012 highlighted food, energy, water and development among the highest priority areas. Yet the mentioned national plans and initiatives were primarily along sectoral or thematic lines, as were the proposed solutions and recommendations contained in the submissions. This is illustrated for eight developing countries (Table 36). These and other countries would benefit from an integrated assessment of the CLEWD cluster.

There are complex interconnections between resources, such as groundwater and biomass availability, and processes such as climate change or geochemical flows.[272] Changes in resource availability typically have their worst effects on poor people.[273, 274, 275, 276] On the other hand, increasing wealth alters consumption and production patterns, and this has impacts on resource consumption and GHG emissions. Yet it should be noted that providing universal access to clean and affordable energy services would not significantly increase global pollution loads. In fact, it would reduce indoor air pollution and not significantly increase global GHG emissions, which are almost exclusively the consequence of "excessive" resource consumption by a minority.[277, 278] Various types of extreme events, such as droughts, floods, or energy crises, have impacts on poverty, food security and the potential for conflicts.[279]

Table 37 lists important interlinkages in the CLEWD nexus, as well as linkages with material consumption. An extensive list of relevant interlinkages has been assembled by the United States Pacific Northwest National Laboratory. [280]

Table 36. Selected climate–land–energy–water–development nexus content in national submissions in preparation for Rio+20

Country	Priority challenges	Policy plans	Identified gaps and recommendations
Jamaica	• *Energy:* high energy intensity, low efficiency, 90% of energy needs come from imported oil • *Water:* contamination of water resources by industry and human activity • *Food:* weakening capacity of local food supplies by agriculture losing land to other sectors such as housing and tourism	• Vision 2030 Jamaica • National Energy Policy 2009-2030	• Have developed countries renew their commitments for the transfer of financial resources and affordable technology to support all sustainable development • Reduce dependence on exports and diversification of the economy • In the energy field, implement technological innovation
Dominica	• *Energy:* high cost of electricity • *Water:* growing demand for water, inadequate institutional structure, ineffective land-use management, limited public understanding of integrated water resource management, a lack of data and information to support decisions, climate variability, legislation that needs updating, and a lack of adequate human and financial resources • *Food:* fundamentally an agrarian economy but declining banana exports	• While there is not a Sustainable Development Ministry in Dominica, sustainable development initiatives are commonplace	• The main gap in the implementation of sustainable development in Dominica is the absence of a coordinating mechanism
Tanzania	• *Water:* high degree of water resource variability, particularly from rainfall, both spatially and temporally • *Energy:* low per capita consumption of commercial energy and high dependence on non-commercial energy including biomass fuels (90%) • *Food:* lack of mechanization and inadequate support services to the agricultural sector	• Tanzania Development Vision 2025 • National Environmental Policy (NEP), 1997	• Encourage financial institutions to support farmers to finance irrigation projects • Be aware of biofuel's threats to food security • Strengthen implementation of policies and strategies in agricultural production
Lebanon	• *Water:* vulnerable to water contamination, unsustainable water management practices, population growth, urbanization, pollution • *Energy:* net energy importer, rely on dirty fuels and heavy fuel oil in primary energy mix • *Food:* global rise in food price, low food subsidies	• National Water Sector Strategy (NWSS) • Four initiatives related to the energy sector: Electricity Sector Policy Paper, 12% Renewable Energy pledge, National Energy Efficiency Action Plan, and Energy Conservation Law	• Encourage R&D, offer subsidies to organic farming, reduce taxes on sustainable products • Designate each governorate a prosecutor • Improve crops and irrigation
Bhutan	• Tremendous hydropower, highly vulnerable to the impacts of climate change • Lack of access to affordable clean technology due to high cost • 5.9% of the population is at subsistence level and under the food poverty line	• Block tariff pricing system of power consumption for low-income group • Bhutan Sustainable Hydropower Development Policy 2008 • National Framework for Organic Farming in 2007	• Develop clean energy by harnessing hydropower and renewable energy resources • Strengthen local government institutions and service delivery • Create/encourage partnerships with civil society and private sector
Ethiopia	• Population growth pressure • Chronic food insecurity in rural Ethiopia • Conflict between keeping the trends of increasing agricultural productivity to meet food security and attaining the green economy strategy	• National Growth and Transformation Plan (GTP) • Climate Resilient Green Economy (CRGE) Strategy	• Continue on development programmes and projects by committing own financial sources • Collaborate with development partners and deal with financial issues • Develop natural resources such as water, geothermal, solar and wind resources
Cambodia	• *Energy:* Increasing gap between supply and demand, high cost of electricity, difficulty attracting investors to non-hydro-renewable energy, low levels of electrification • *Water:* Low access to urban drinking water and rural sanitation • *Food:* Lack of proper milling infrastructure, storage facilities and irrigation systems	• An Institutional Development Plan for Water and Sanitation (2003-2012) • The Strategy for Agriculture and Water (SAW) for the period 2010-2013	• Develop policies to foster investment in energy resources; Hold regional discussions on energy gaps; Continue building capacities • Improve the efficiency of water management on existing water resources • Develop rules, regulations and institutional mechanisms for effective and integrated management of water resources
Nepal	• *Energy:* huge hydro potential, but share of renewable energy and hydropower is less than 3% • *Water:* water shortage and increasing contamination of drinking water • *Food:* among the countries worst affected by the global food crisis due to deteriorating quality of imported foods and rising costs	• The energy programmes include Promotion and Development of Renewable Energy, Energy Sector Assistance Program and Energy Conservation Programs • Nepal has formulated various policies and strategies for hydropower, such as the Task Force Reports for Generating 10,000/25,000 MW Hydropower in 10/20 Years • The Agricultural Perspective Plan (APP) (1995-2015)	• Nepal needs additional international support in financing, technology transfer and capacity-building • Nepal should provide incentives and attract foreign as well as domestic investors in hydropower generation

Source: Authors' compilation

Table 37: Selected interlinkages between climate, land/food, energy, water and materials

Impacts of the issues listed below on those listed on top	Climate	Land/food	Energy	Water	Materials
Climate		Climate change and extreme weather affect crop productivity and increase water demand in most cases	Climate change alters energy needs for cooling and heating, and affects hydropower potential	Climate change alters water availability and the frequency of droughts and floods	Climate change alters material demand choices due to GHG emissions mitigation efforts, adaptation and changing technology choices
Land/food	GHG emissions from land-use change (vegetation and "soil carbon") and fertiliser production		Energy is needed for water pumping, fertilizer and pesticide production, agricultural machinery and food transport	Increased water demand due to intensification of agriculture, and effects on the nitrogen and phosphorus cycles	Land-use regulation and other uses of land compete with extraction of resources and materials
Energy	Fuel combustion leads to GHG emissions and air pollution	Land use for biofuels and renewable energy technologies (solar, wind, hydro, ocean), crop/oil price correlation		Changes in river flow, evaporation in hydropower dams, biofuels crop irrigation, fossil fuel extraction (especially unconventional)	Materials used in energy sector for construction, operation, transmission and distribution
Water	Changes in hydrological cycles affect local climates	Changes in water availability for agriculture and growing competition for it affect food production	Water availability for biofuels, energy use for desalination but also storage of renewable energy as fresh water		Materials needed for water sector (extraction, desalination, purification, pumping etc.)
Materials	Emissions from materials fabrication and resource extraction	Land degradation due to extraction of resources and pollution and yield increases due to fertilizer/pesticide availability	Material-embedded energy and high energy intensity of new materials	Mining, refining and production processes lead to water consumption and pollution	

Source: Adapted by authors from Weirich (2013)[281] based on Rogner (2010), Hoff (2011)[282], and Howells and Hermann (2011)[283].

The scale of the CLEWD issues affects billions of people. There are 1.4 billion people without access to electricity, 3 billion without access to modern energy services, 0.9 billion without access to safe water, 2.6 billion without improved sanitation, 0.9 billion who are chronically hungry and 2 billion who lack food security from time to time.[270]

The scale of interlinkages between CLEWD issues is also large. At the global level, seven per cent of commercial energy production is used for managing the world's freshwater supply, including for extraction, purification, distribution, treatment and recycling.[270] About 70 per cent of human water use is for irrigation, and 22 per cent is for industry, most of which is for thermal cooling in power plants and manufacturing.[284, 285] Roughly four per cent of final energy use is in agriculture,[286] and food processing and transportation uses an increasing additional energy amount.[287] About half of the demand increase for maize and wheat has been due to biofuel production.[288] Energy use for desalination and pumping for irrigation constitutes a large share of energy use in some developing countries.

Correlations between energy, water and food prices are further evidence for close interconnections. In particular, the fuel and food crises of recent years have illustrated a close relationship between food and oil price indices, which reflects the use of oil for fertilizer production and agricultural machinery, as well as the impact of oil price increases on biofuels demand.[270]

6.3. Hierarchy of assessments

In 1992, in *Agenda 21*, Governments agreed to promote integrated assessment that would encompass economic, social and environmental dimensions. However, 22 years later, truly integrated approaches are not yet common, except in certain niches. Table 38 provides a stylized overview of today's assessment practises at various levels in the world.[289] It shows that CLEWD assessments at the national level fill an important gap in the existing hierarchy of assessments.

At the national level, planning and assessment has followed primarily sectoral lines in most countries. There are only a few national multisector applications, some of which are presented in this chapter. However, SEA has become mandatory In Europe and the comparative assessment of development options (CADO) is being piloted in some developing countries.

At the regional and global levels, a moderate number of multisectoral integrated assessments have been carried out.[290] Most energy, land-use and water models continue to be sectoral. The United Nations system is actively engaged in environmental and poverty impact analysis and various types of integrated assessment at the programme level. At the international level, integrated assessment of projects is still more the exception than the rule, but has been increasingly used for cross-border projects.

At the subnational level, most assessments are carried out at the project level, as environmental impact analysis has become mandatory almost everywhere. In contrast, there are only isolated examples of subnational assessments at the programme or policy level. Interestingly, there is a significant number of academic studies that include a multisectoral assessment at the subnational level.

To ignore interlinkages among sectors and across national borders, however, has meant that success in one area or location has often come at the expense of increasing problems elsewhere. The links among food, fuel and climate crises are a case in point. Energy, water and food security, land-use issues, development policy and climate policy continue to be addressed in isolation. The result has been a trial-and-error approach by policymakers, who have had to muddle their way through addressing trade-offs. A prime example is the early promotion of highly ambitious biofuel targets in many developed countries and changes in sugar policy in Europe, only to be followed by food prices shocks and concerns about global food security.

In conclusion, a hierarchy of assessments has evolved that focuses on the project level at the expense of a strategic higher-level (Table 38), which has caused unnecessary costs. Opportunities have been missed, as a significant part of (suboptimal) infrastructure has already been built in developing countries. The window of opportunity is decreasing. Case studies of the CLEWD nexus at the national level fill an important gap in the assessment hierarchy and could potentially replace some of the lower-level assessments.

Sustainability science provides evidence of the interaction of sustainability issues at various spatial and temporal scales. Hence, it is true that sustainable development is essentially local, but it has interrelated aspects at various geographical levels all the way up to the global level. Hence, a human geography perspective using big data approaches might also be adopted for analysing the CLEWD nexus (see chapter 6).

Table 38. Stylized review of integrated assessment practices

	Subnational	National	Regional and global
Project	EIA, ESIA, almost universal and mandatory		Ad hoc IA of cross-border projects
Programme Policy	Isolated examples	SEA mandatory in Europe and selected countries; CADO in selected countries	EIA and PIA by United Nations, development banks and global funds. IA by OECD, UNEP and G20
Sector	Conventional sectoral planning	Conventional energy and infrastructure planning	Many energy, land-use and water models
Multisector	Significant number of academic applications	Few examples. Recent CLEWD case studies	Moderate number of IAs

Note: CADO (comparative assessment of development options); CBA (cost–benefit analysis); EIA (environmental impact assessment); ESIA (environmental and social impact analysis; HIA (health impact assessment); IA (integrated assessment); PIA (poverty impact assessment); SEA (strategic environmental assessment); SIA (social impact analysis).
Source: Howells et al. (2013)[284] based on UN ESCAP (2006)[291] and OECD (2006)[292].

6.4. Global climate-land-energy-water-development nexus (CLEWD) model - an open source, open-data approach

In preparation for the present report, a global CLEWD model was developed as an open-source, open-data tool for research cooperation on global sustainable development, and to support the emerging national and regional applications: The Global Least-cost User-friendly CLEWs Open-Source Exploratory (GLUCOSE) model. The model is currently being further developed. The result will be a user-friendly web interface and a widened scope of the model to capture all the goals that will eventually be agreed by the OWG on SDGs. The envisaged user interface follows the approach used for the 2050 Pathways Calculator of the United Kingdom's Department of Energy and Climate Change, in order to enable access to the model for a non-technical audience.[293] The original model was developed by researchers from KTH in Sweden in cooperation with the United Nations Division for Sustainable Development.

Annex 5 provides a description of the GLUCOSE model and of a number of global integrated scenarios that were developed, including a baseline scenario, CO_2 tax scenario, and 2°C, 4°C and 6°C scenarios. Most importantly, results are compared between the global integrated model and a separate energy model. Interestingly, when CLEWD interlinkages are taken into account, GHG mitigation costs turn out to be much less than currently suggested by separate global energy models. When we are realistic about trade-offs between different resources under a changing climate, most of the cheaper sectoral baseline scenarios will not be feasible. Feasible baseline scenarios without climate mitigation policies will require higher investments, and integrated approaches that achieve a range of sustainable development goals may turn out to be cheaper than the feasible business-as-usual alternatives.

6.5. Landscape of CLEWD nexus applications: subnational, national, regional and cross-border river basins

A pioneering pilot assessment of the CLEWD nexus in Mauritius has shown the practical benefits of integrated analysis for policymaking. The assessment of the nexus has helped in identifying innovative policy that avoids costly mistakes of isolated sectoral policymaking. This is a good example of a strong science–policy interface in action.

In a very short time, the Mauritius case study has inspired many similar CLEWD nexus applications. The expert group meeting held in Stockholm in support of the present report assessed case studies in Australia, Brazil, Burkina Faso, California, Canada, Chile, China, Comoros, Cuba, Germany, India, Jamaica, Lithuania, Madagascar, Mauritius, Qatar, Seychelles, South Africa, Syria, Tarawa/Kiribati, Thailand, United States, United Kingdom and Zanzibar, and the river basins of the Danube and the Nile, as well as a number of local applications. These applications use different entry points - energy security, water security or food security - but they share the same overall integrated approach. Selected cases are presented in this chapter.

It should be noted that recent initiatives to apply the CLEWD approach are being carried out by a number of organizations within and outside the United Nations system. In particular, a coordinated research project of the International Atomic Energy Agency (IAEA) supports cooperation among 10 national entities. KTH has carried out an impressive number of applications in various world regions and has also provided technical support to various United Nations initiatives. The Stockholm Environment Institute (SEI) has a long tradition in nexus applications, especially with a water perspective as a starting point. FAO has leveraged cooperation between different departments within the organization that focus on the various CLEWD resources. FAO and LIPHE4 (a spin-off of the Autonomous University of Barcelona) have developed a Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism approach to assess 'nexus' problems in Mauritius, the Punjab region of India, and South Africa. UNECE supported the creation of a task force under the UNECE Water Convention which aims to support CLEWD applications for river basins. And the Secretariat of the United Nations Convention on Biological Diversity has worked on the CLEWD nexus and biodiversity. UNESCO has carried out nine local (subnational) case studies[294] of the nexus in the context of the Sustainable Management of Marginal Drylands (SUMAMAD) project.

Table 41 provides an overview of ongoing or recently completed CLEWD case studies at the national level. While all these applications share the same overall integrated analysis framework, their focus and model implementations vary greatly (Table 39 and Table 40). Some of the case studies are summarized in the following pages.

Table 39. Coverage of CLEWD issues in selected national case studies

Country	Bioenergy		Climate vulnerability		Energy and water		Water for agriculture and bioenergy	Land use representation	Development
	Liquid biofuels	Solid biofuels	SIDS	Other	Water for power generation	Energy for water			
Australia									
Brazil	X			X			X	X	X
Cuba		X	X		X	X	X	X	X
Germany	X	X		X	X		X	X	
India									X
Mauritius	X	X	X		X	X	X	X	X
Lithuania	X	X			(X)			X	
South Africa				X	X	X	X	X	
Syria									X
Thailand	X						X	X	X
Qatar				X		X	X	X	X

Source: Authors and IAEA input.

Table 40. Tools and models used in the selected CLEWD case studies

Country	LEAP	WEAP	MESSAGE	MAED	MAWD	GAEZ	CROPWAT	CGE	Climate	WEF
Australia										
Brazil	X						X	X	X	
Cuba	X?	X	X	X	X?	X			X	
Germany									X	
India										
Mauritius	X	X				X	X		X	
Lithuania	X?	X?	X	X		X?	X?			
South Africa	X	X						X	X	
Syria			X							
Thailand	X					X	X			
Qatar										X
Nile basin	X	X				X				

Source: Authors and IAEA input.

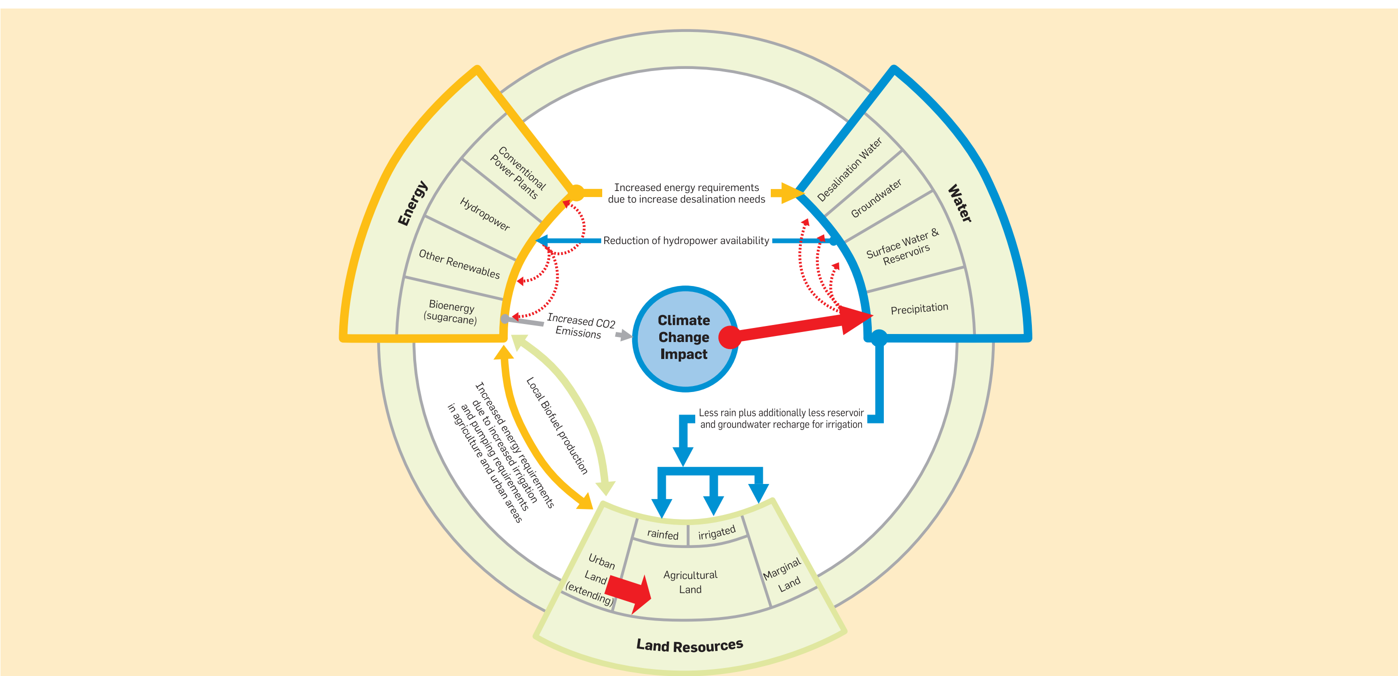
Table 41. Selected national and subnational CLEWD applications (ongoing or recently completed)

Case study	Research	Innovative	Approach/models	Partners	Sources
Australia *(ongoing)*	Australia case study	Governance issues	Qualitative	University of Technology, Australia	Sharma (2013)
Brazil *(Ongoing, preliminary results)*	CLEW analysis of sugar cane cultivation for bioethanol production in Brazil	"Product-focused" CLEW analysis	Set of models (LEAP, Cropwat, CGE, own climate and land-use models)	Energy Planning Program, COPPE/UFRJ; Sponsor: IAEA	Pereira (2013)
Burkina Faso *Country report finalized and published - scope for more detailed analysis*	Looking at CLEWs, what are sustainable development pathways for a resource constrained country taking into account population growth and potential effects of climate change?	National resource strategy relevance	Set of models (LEAP, AEZ)	IAEA, KTH	Hermann et al. (2012)[295]
Canada (and rest of world) *(completed, ongoing)*	Water–energy–food nexus	Highly sophisticated systems model	ANEMI model with 8,000 feedbacks	University of Western Ontario, Canada	Simonovic (2013)
Chile *(ongoing)*	Energy–water nexus in Chile	Designed for policy advice	Set of models	Universidad Diego Portales, Santiago, Chile	Minoletti (2013)[296]
China *(preliminary results)*	Water–land–energy–climate nexus		Surveys	Centre for Chinese Agricultural Policy, Chinese Academy of Sciences; various universities	Wang et al. (2012)[297]
Cuba *(Ongoing)*	CLEW analysis of Cuba based on securing energy supply	Coordinated policy	Set of models (MESSAGE, MAED, LEAP, WEAP, AEZ)	Cubaenergia, Cuba Several ministries Sponsor: IAEA	

Case study	Research	Innovative	Approach/models	Partners	Sources
Germany *(ongoing)*	Integrated assessment of climate impact, land, energy and water use (CLEW systems) in Germany against the background of the United Nations green economy model and Germany's sustainability strategy	CLEW indicators	Own indicator based approach	Jülich Research Centre Sponsor: IAEA	Schlör and Hake (2013)[298]
India *(Ongoing)*	CLEWs in India: An analysis focusing on the Climate Change drivers and effects (mitigation and adaptation) on different CLEW resources	Climate change-centred CLEW	Set of models	Bhabha Atomic Research Centre, Mumbai Sponsor: IAEA	Pandit (2013)[299]
Jamaica *Country briefing and first results available*	Sugar cane cultivation in Jamaica under potential CC and increased irrigation efficiency efforts - influences on the water and energy balance	"Product-focused" CLEW analysis	Set of models (LEAP, AEZ)	KTH	Morrison (2012)[300]
Lithuania *(Ongoing)*	CLEW analysis of bioenergy potentials in Lithuania: a detailed analysis of different biofuel feedstock in Lithuania - an environment that is not water but temperature constrained	CLEW using the MESSAGE energy systems model	MESSAGE, MAED	Lithuanian Energy Institute, Lithuania. Sponsor: IAEA	Galinis (2013)[301]
Mauritius *Completed*	Which implications does shift to local biofuels (sugar cane) have on other CLEW resources? What is the influence of potential climate change on CLEW resources (water, agriculture, energy) in the future?	First ever national case study	Set of models (LEAP, WEAP, AEZ)	Agricultural Research and Extension Unit, Mauritius. Various ministries. Sponsors: IAEA, KTH	Ramma (2013)[302] Howells et al. (2013)[284] Welsch et al. (2014)[303]
Thailand *(Ongoing)*	CLEW analysis different biofuel solutions for Thailand: This analysis investigates different biofuel crop options in the country. The impact (and resilience) of different biofuel feed stocks (ethanol and biodiesel options are considered) on other CLEW resources is evaluated	Support for policy implementation	LEAP, AEZ, CROPWAT	Naresuan University, Thailand. Sponsor: IAEA	Wattana (2013)[304]
Cape Town, South Africa *(first results and regional report available)*	CLEW analysis at subnational level focusing on the Cape Town region in South Africa	"High resolution"	Set of models (LEAP, WEAP, CGE)	Energy Research Centre, University of Cape Town. Sponsor: IAEA	Stone et al. (2013)[305]
Syria *(ongoing on hold due to difficult political situation)*	CLEW analysis of Syria focusing on highly constraints water resources	Water-focused CLEW	Set of models, (MAED, MAWD, MESSAGE)	Atomic Energy Commission of Syria. Sponsor: IAEA	Omar et al. (2013)[306]
Qatar *(completed)*	Integrated food self-sufficiency scenarios, taking into account the water–energy–food nexus	Food security perspective; web tool	WEF web tool	Qatar Environment and Energy Research Institute (QEERI)	Daher and Mohtar (2013)[307]
Tarawa/Kiribati	Water–land–energy nexus	Water efficiency	?	IRENA	Skwierinski (2012)[308]
United States *(completed)*	Climate and energy–water–land system interactions	Comprehensive review		Pacific Northwest National Labs. Sponsor: USDOE	Skaggs and Hibbard (2012)[309]

Source: Authors' elaboration.

Figure 29. Mauritius CLEW interlinkages considered in the case study



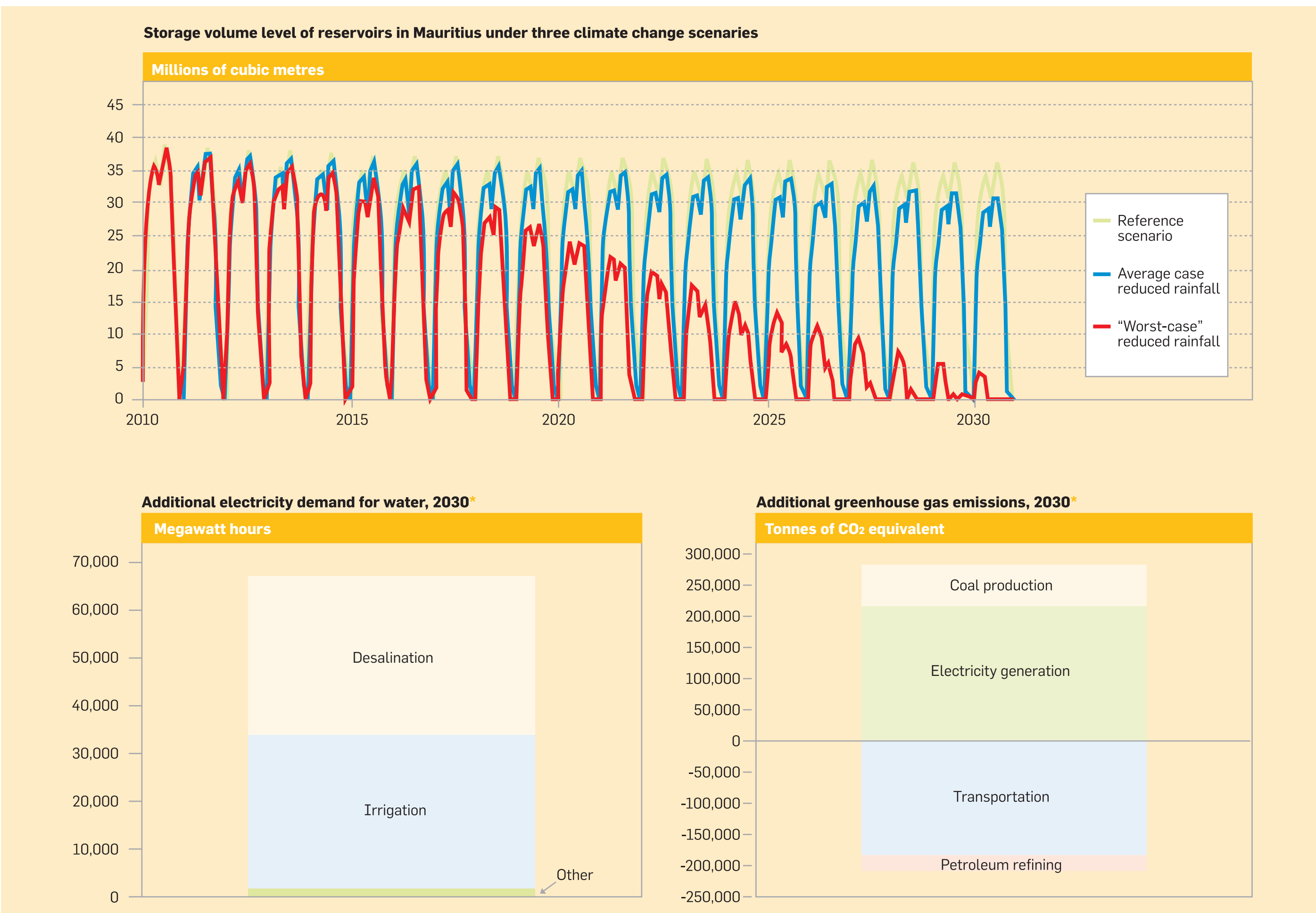
Source: Ramma (2013)[302], Howells et al. (2013)[75], Welsch et al. (2014)[303].

Mauritius

In Mauritius a national biofuel policy that made sense from a best-practice energy, land and water planning point of view was shown to be strongly inconsistent. This was only discovered when government and international analysts modelled these systems in an integrated manner - especially in response to climate change-induced reductions in precipitation (Figure 30). The change in rainfall patterns led to an increase in water withdrawals that in turn led to higher demand for energy to drive pumps to bring the water from its source to the fields and to power water desalination plants. A positive feedback loop meant that this led to increased demand for cooling of thermal power plants and thus additional withdrawals of water (unless they are cooled by seawater). If the increase in electricity demand is met with coal-fired power generation as planned, then the GHG benefits of the ethanol policy are eroded by increased emissions from the power sector. Higher coal imports also have a negative impact on energy security. The benefits of this policy - aimed to reduce energy import costs and emissions - are thus clearly vulnerable to the impacts of climate change, and the long-term viability of this strategy is at risk if rainfall were to decrease further and droughts continue. In this event, producers would either have to scale back production or resort to expensive water desalination. Both of these options negatively impact the expected climate and energy security benefits of the policy, and both would be detrimental to the sugar and ethanol industry.

The water-constrained scenario does, however, lead to better prospects for renewable electricity generation. Wind and photovoltaic electricity generation is typically much less water-intensive than fossil fuel generation. Further, if power consumption for water desalination facilities makes up a significant share of total system load, intermittent resources such as wind could be integrated more easily. Since water is cheap and easy to store, it is

Figure 30. Predicted impact of climate change on water availability in Mauritius, water-related energy consumption and GHG emissions, predictions for year 2030



Notes: Upper graph: Storage volume levels in reservoirs in Mauritius under 3 climate change scenarios (in million m^3).
Left graph: Additional electricity demand (compared to scenario without climate change impacts) under worst-case climate change scenario (in MWh). The additional water requirements in the "worst-case" climate change scenario led to an increase in energy demand, mainly due to additional desalination requirements and the need for irrigation in sugar cane plantations.
Right graph: Additional GHG emissions (compared to the scenario without climate change impacts) under worst-case climate change scenario (in ton CO_2 equivalents). The additional energy demand leads to an overall increase in GHG emissions. The additional demand is largely met by coal-based electricity generation. The resulting emissions outweigh the emission benefits of the second generation ethanol production.
Sources: United Nations (2013) and Howells (2013).

not important that it is produced at a specific time. It could therefore be treated as an interruptible load and shut down in the event that wind generation is unavailable during times of high system load.

In response, the Government of Mauritius appointed a high-level CLEWs panel to ensure consistency between its climate, land, energy and water strategies.[284]

Burkina Faso

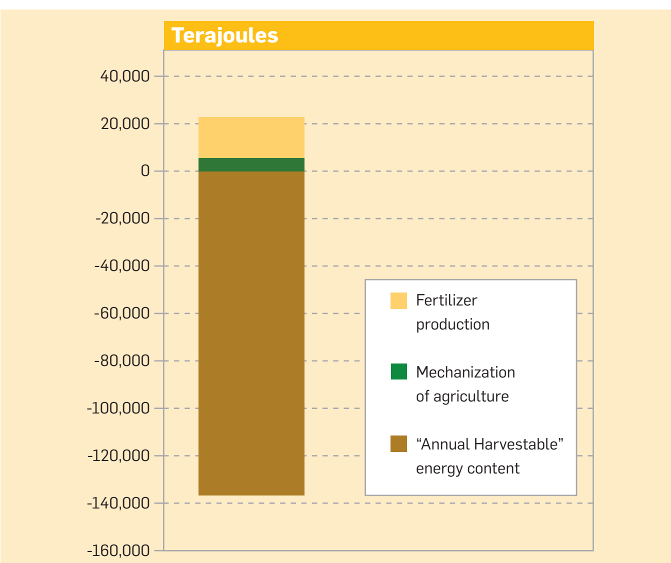
In Burkina Faso, a country with rapid deforestation, growing energy insecurity and GHG emissions, we found that a measure with direct negative effects on each of these has disproportionately positive knock-on effects. This solution is uncovered as integrated modelling of a system where nationally appropriate development actions are possible.

Agriculture is expanding rapidly, eating into forests, which are a natural carbon sink. Forests supply vital fuelwood used for cooking and heating. With forests being displaced, people are forced to use oil for their energy needs - which is expensive and imported. Emissions are rising as a carbon sink is disappearing and oil use is increasing. Energy security is reduced as more oil is imported, and energy poverty is increased as the price of the new energy source (oil) is relatively expensive.

However, agriculture in Burkina Faso is not intensive. The land requirements for similar outputs can be significantly reduced by changing practices. Those changes would include higher application of fertilizer and mechanization. Incidentally, the conventional production and application is highly GHG-intensive and increased mechanization requires higher volumes of oil for use in tractors and other equipment.

Figure 31 illustrates the altered energy balance due to reduced land-use change in the scenario for Burkina Faso in 2020. An intensification

Figure 31. Changed energy balance due to reduced land-use change in Burkina Faso in 2020



Notes: Based on the following assumptions: an additional energy input for mechanization of 1 GJ/ha; an additional fertilizer input of 50 kg N/ha; a fuelwood yield in savannah and mixed vegetation of 35 m^3/ha and 250 m^3/ha in forests.
Sources: United Nations (2013) and Hermann et al. (2012).

of agriculture associated with "intermediate input levels" would require an increased energy input for mechanization and as well for the production of fertilizer. This increase is small compared to the biomass energy that could be sustainably harvested from the land that would otherwise have been converted to crop land. The biomass energy potential is calculated based on harvestable yields of different land types (e.g. forest, savannah, meadows) which are subject to potential future change into agricultural land.

Qatar

Qatar is a nation currently enjoying a period of unprecedented growth and advancement, governed by set national visions and goals. The country is well recognized for its oil and gas abundance, yet also known for its aridity, water scarcity and harsh environmental conditions. Qatar has an arid desert type climate with hot and humid summers. Average annual rainfall is only 75 mm. Permanent surface water is practically non-existent. Agricultural development is limited by water scarcity, low water quality, unsuitable climatic conditions, unfertile soils and poor water management, all of which contribute to low crop yields. Most agricultural food products are being imported. Population and GDP have grown rapidly (9.6 per cent and 8.6 per cent, respectively, in 2010). Qatar has one of the highest energy consumption and carbon emissions per capita.

Qatar's General Vision 2030 issued by the Secretariat for Development Planning aimed to choose "*the development path that carefully balances the interests of the current generation with the interests of future generations*". The Qatar National Food Security Program highlighted the necessity of reducing the nation's food imports which currently represent about 90 per cent of the total national consumption.

The starting objective of the case study was to identify water, energy, agricultural and economic strategies to achieve food self-sufficiency. Present agricultural practices use exclusively fresh groundwater, with extraction rates more than 100 times the natural replenishment rate. Therefore, agricultural intensification to increase food self-sufficiency would require energy-intensive desalination as an alternative source of water.

The case study initially looked at eight locally produced food products, grown with different water and energy sources, and imported from several countries. The food products are typical of a Middle Eastern diet: tomato, eggplant, lettuce, carrots, watermelon, cucumber, potato and green onion. Multiple scenarios showed that increasing the self-sufficiency of the studied food products by only 10 per cent would increase land requirement by 153 per cent and water requirement by 82 per cent(Figure 32).

Throughout the case study, the scientific discussion and the policy narrative changed from trying to achieve national full self-sufficiency to searching for the right mix of local production and international trade.

Thailand

The Thai case study focused on analysing bioenergy policies.[310] The Thai Government developed an Alternative Energy Development Plan (AEDP) for the period 2012-2021. The aim is for biofuels to eventually replace 44 per cent of national oil consumption. According to the AEDP, ethanol production (primarily from cassava and sugar cane) would increase from 1.3 million litres per day in 2012 to 9 million litres per day in 2021. The production of biodiesel (primarily from crude oil palm) would

Figure 32. Qatar case study of the water–energy–food nexus

Combined self-sufficiency = 15% (2010)

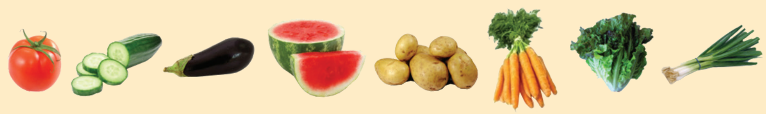
Tomato and **Cucumber** are partially done in protected agriculture

Groundwater is main source for agriculture

Natural Gas is main source of energy

Imports secured from **15 different countries**

WATER (m^3)	5,783,797
LAND (ha)	792
E1 (kJ)	24,699,706,932
E2 (kJ)	15,000,733,177
C1 (ton CO_2)	3,039436
C2 (ton CO_2)	1,089
F Local (QAR)	48,940,200
F Import (QAR)	3.36E+08
E IMP (kJ)	1.2117E+12
C IMP (tom CO_2)	92,987



Source: Daher and Mohtar (2013)[307].

increase from 1.62 million litres per day in 2012, to 5.97 million litres per day in 2021. The expectation is also to produce 25 million litres per day of new fuel for diesel substitution in 2021. The new fuel development strategies include new energy crop development, including jatropha and micro algae, the development of oil-conversion technology, and ethanol blending for diesel oil.

Baseline scenarios were developed for ethanol and biodiesel following the AEDP assumptions. Alternative scenarios explored a range of assumptions regarding energy crops for biofuel production (leaving all other assumptions fixed). The baseline scenarios (following AEDP) suggest that in order to meet ethanol target, demand for sugar cane and cassava production in 2021 will grow by 8 per cent and 26 per cent, respectively, from 2012. Future land requirement for growing sugar cane and cassava in 2021 will increase by 16 per cent. To achieve the biodiesel target, demand for oil palm production in 2021 will rise by 82 per cent from 2012. Future land requirements for growing oil palm would increase by about 106 per cent, i.e. more than double from 2012.

Regional case studies and river basins

A number of regional case studies are being undertaken in Africa, Central Asia, Europe, the Indian Ocean and the Pacific (Table 42). Several case studies focus on river basins, including for the Danube, the Mekong and the Nile basins. In the context of the nexus task force under the UNECE Water Convention, assessments of another 13 river basins have been proposed in Africa, Asia and Europe (Table 43).

Table 42. Regional CLEWD case studies and river basins (ongoing or recently completed)

Case	Research	Approach	Partners	Source
Nile basin *(ongoing, first results expected in 3rd quarter 2013)*	Assessing trans-boundary water–energy interlinkages and options to optimize water resources	Interlinkages of LEAP and WEAP	Sponsors: KTH, SEI (Cooperation between SEI (responsible for water modelling) and KTH (responsible for energy) with connections to FAO	Hoff (2013)
Pacific Islands *(initiated)*	Development of a CLEW model for SIDS to address multidimensional resource shortages	Indicator based approach (AEZ, LEAP)	KTH, IRENA	
ISLANDS project in the Eastern and Southern African and Indian Ocean Region	Integrated case studies in Comoros, Madagascar, Mauritius, Seychelles, Zanzibar	Systems dynamics model. Nesting learning-by-doing, multi-stakeholder approach	Indian Ocean Commission; Ecological Living In Action Ltd (ELIA); Sponsor: European Union' European Development Fund	Deenapanray and Bassi (2014)[311]
CLEWs in Africa *(ongoing)*	Indicator based CLEW approach to define resource constrained regions	geographic information system (GIS)-based approach (AEZ)	KTH	Howells (2013)
Trans-boundary CLEW Analysis in Europe and Central Asia *(initiated)*	Looking at CLEWs from the water perspective: finding ways of integrating resource assessments from the perspective of trans-boundary river basin regions	Set of models	UNECE (together with FAO, SEI and KTH)	
Middle East *(ongoing)*	Water, energy, drought and climate change	Technical cooperation project, WEF web tool	Qatar Environment and Energy Research Institute (QEERI)	Daher and Mohtar (2013)
Danube basin *(ongoing)*	Water–agriculture–energy–ecosystems nexus; biophysical and economic assessment	Set of models; participatory scenario building; POLES model	Joint Research Centre of the European Union (JRC-IES), IPTS, IET	Bidoglio (2013)[312]
Mekong basin *(ongoing)*			Mekong River Commission	

Source: Authors' elaboration.

Table 43. Proposals for basins to be assessed (water–food–energy–ecosystems nexus) under the UNECE Water Convention

River	Riparian countries	Proposed by
Sava	Albania, Croatia, Bosnia and Herzegovina. Montenegro, Slovenia	Sava River Commission
Narva	Estonia, Latvia, Russian Federation	Ministry of the Environment of Estonia
Dniester	Republic of Moldova, Ukraine	Moldovan Environment Ministry
Alazani	Azerbaijan, Georgia	State Agency for Water Resources under the Ministry of Emergency Situations of Azerbaijan
Araks	Armenia, Azerbaijan, the Islamic Republic of Iran, Turkey	State Agency for Water Resources under the Ministry of Emergency Situations of Azerbaijan
Ural	Kazakhstan, Russian Federation	Water Resources Committee
Chu and Talas	Kazakhstan, Kyrgyzstan	Water Resources Committee
Aral Sea Basin	Afghanistan, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan	Executive Committee of the International Fund for Saving the Aral Sea, Scientific Information Centre of the Interstate Committee for Water Coordination
Vakhsh, Pyanj, Kunduz (upper Amu Darya)	Afghanistan, Kyrgyzstan, Tajikistan	Ministry of Land Reclamation and Water Resources, Tajikistan
Mejerda	Algeria, Tunisia	Ministry of Agriculture, Tunisia
Niger	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger and Nigeria	Niger Basin Authority and the Wetlands International
Sesan, Srepok and Sekong rivers (Mekong)	Laos, Vietnam and Cambodia	Conservation International
Marowijne	Suriname, France (Department of French Guiana)	Conservation International

Source: UNECE (2013)[313].

6.6. Conclusion

Innovative, pragmatic solutions

The CLEWD case studies illustrate the benefits of integrated approaches. In particular, they helped identify innovative and better solutions. CLEWD results also provide important lessons for the ongoing discussions on the definition of SDGs. In fact, they indicate a need to include clusters of strongly interlinked issues in the SDG discussions, beyond the sectoral and thematic approach.

Concerns have been voiced about an increasingly complex hierarchy of assessments, which is perceived as burdensome by some parts of many Governments and the private sector. In order to make scenario modelling relevant and sustainable at the same time, this problem must be acknowledged and some of the lower-level (project) assessments might be replaced by fewer higher-level, strategic assessments.

The CLEWD nexus approach is a pragmatic approach to integrated assessment for selected clusters of strongly interlinked issues. It is not specific to the particular set of issues. It should be noted, however, that the "right" cluster of themes is case specific. In some cases, these clusters can be narrower (e.g. energy-water), in others they need to be wider (e.g. to include biodiversity). Carrying out a CLEWD-type nexus assessment requires cooperation among different disciplines and various parts of government, with potentially important overall governance and economic benefits.

Financing the nexus

A number of simple lessons can be learned from CLEWD nexus case studies presented above. Integrated approaches that focus on clusters of strongly interlinked issues, such as the CLEW nexus, can help identify innovative and sustainable solutions. Innovative CLEW nexus solutions are "cheaper" in terms of mitigation costs, but may mean shifts of investments across sectors. There are typically both "winners" and "losers" from integrated solutions, potentially leading to political economy issues. Since components of CLEW nexus solutions depend on what happens in other parts of the system, investors may face additional uncertainty and risks, which might make nexus solutions less attractive to them. Benefits of integrated approaches differ greatly between and within countries, and thus good financing strategies have to be tailored to country situations. CLEW nexus projects are expected to face important challenges in tapping into financial resources provided by local and international financing institutions and funds due to the existing fragmentation by narrowly defined sectors and activities.

Hence, the following may be considered for effective financing of the CLEWD nexus:

- Coordination risks can be mitigated, compensated or shared by a range of actions, such as sustainability certifications and risk guarantees
- Small islands and countries in water-stressed regions that are subject to significant additional stresses from climate change would benefit the most. The CLEWD nexus could justify preferential access for these countries to international public funds
- CLEWD nexus solutions may require rethinking the international public finance architecture in support of development and climate change, as well as a reconsideration of current practices of local and international financial institutions, including in terms of financial engineering
- Efforts at the national and subnational levels to build financial engineering and financial management capacities will be required to enable integrated solutions to emerge in practice. Bottom-up networks of practice, supported as necessary by the international community, could help in this regard
- The intergovernmental follow-up to Rio+20 and the post-2015 development agenda should consider the issue of financing CLEWD and other relevant, interlinked issue clusters. There may also be a need for a technical support mechanism for financing CLEWD.