Abstract

This background note serves to inform the “hot topic” session entitled ‘Sustainable Energy for All – What does it mean for Water and Food Security?’.

Energy is vital for human development. This is why the United Nations proclaimed 2012 as the ‘International Year of Sustainable Energy for All’. The goal is to ensure universal access to modern energy services by 2030. Today’s energy production, however, is already putting prohibitive strain on the global environment. In support of worldwide efforts to render energy systems sustainable, the UN has therefore called for two additional targets: to double the rate of improvements in energy efficiency and the share of renewable energy.

Besides energy, also food and water need to be universally provided to ensure human wellbeing and enable socio-economic development. Each of these targets is indispensable to improve people’s livelihoods and is a formidable challenge by itself. But taken together, they become an even more daunting task since they interfere with each other – while today human activities are already exceeding planetary limits.

The simultaneous expansion of energy, food and water requires a coherent approach based on integrated planning across these sectors. The management in each resource area is often done in isolation - with unforeseen and damaging consequences manifested in related systems. As a starting point, we focus on energy and consequently discuss Energy-Water-Food nexus relations. The beginnings of a ‘framework’ are presented that is useful to conceptualize these interrelations, and then applied to a preliminary case study. In that case study, integrated measures are considered as a means to improve the energy security of a climate-change-vulnerable small island developing state (SIDS). The case study assesses CLEW (Climate, Land-use, Energy and Water) strategies in an integrated manner, and was undertaken by organizations contributing to this special session.

1 FAO – Food and Agricultural Organisation
2 IAEA – International Atomic Energy Agency
3 IIASA – International Institute for Applied Systems Analysis
4 IRENA – International Renewable Energy Agency
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6 SEI – Stockholm Environmental Institute
7 UNDESA – United Nations Department for Economic and Social Affairs
8 UNIDO – United Nations Industrial Development Organisation
9 WBCSD – World Business Council for Sustainable Development
Relevance of integrated planning for water, energy and food security

At present, many parts of the world face energy, water, and food shortages. The theme of this session focuses on understanding how to sustainably meet energy requirements – including universal access - while concurrently meeting needs for water and food. Two aspects of this are emphasised. The first is that while production is growing, it is constrained by planetary, trade and political boundaries. The second is that access is inequitable, especially in developing countries. Provision of food, energy and water is at the heart of conflict. As disparities continue and supply becomes constrained, environmental, economic and social sustainability is threatened. Those problems are likely to accelerate in the future and are calling for new ways of planning, managing and allocating the available resources in an integrated way.

1.4 billion people are without access to electricity; 3 billion cannot afford to use modern fuels or technologies for cooking or heating in their home; 900 million people lack access to safe water; 800 million people are chronically hungry due to extreme poverty; 2 billion people lack food security intermittently. Energy, water and food all have rapidly growing global demand and are impacted by international trade; all suffer resource constraints leading to rivalry, even conflict and war, over their use; all have strong interdependencies with each other as well as with climate change and the environment; all have deep security issues as they are fundamental to the functioning of society; all feature heavily regulated markets. And yet policy-makers and technology developers often do not have toolkits at their disposal to make comprehensive, integrated and systematic assessment of policy or technological solutions. However, they need to make decisions urgently which will have long-term consequences. Acting in one of the three resource areas may unfold unintended consequences in the other areas. For instance, energy is required for food production as well as water management. In turn, water is required for energy production, and biomass provides a large and growing energy supply option. As our point of departure, we primarily focus on energy and then discuss nexus relations with the other resource areas.

An aim of the session is to identify synergies and potential tensions to better inform planning and management in all resource areas. This forms the basis of an analytical framework that is used for an integrated analysis and applied to a case study.

Without such integrated tools, providing affordable, appropriate and accessible supplies of energy, as well as water and food will not be possible. Nor will it be possible to develop complementary policies or incentives required to appropriately guide investments.

I. How does the water, energy, food security nexus perspective help in resource planning?

Providing access to energy can have strong and counter-intuitive outcomes. This can be because the interactions between Climate, Food (or “Land” as an underlying constraint), Energy, Water (“CLEW”) are held together by tight relationships. As these relationships can be quantified, they call for new integrated methods of assessing these resource systems: instead of using fragmented approaches (which have often been the “norm” in government, research, or development cooperation); integrated holistic resource assessments are needed.

Energy and its interactions with Water and Food analyzed

Energy, water and food supply, while likely to have numerous powerful synergies and co-benefits if approached through sensitive policy, also have natural tensions. Identifying appropriate levels of competition between these resources systems and at the same time increasing appropriate, affordable energy access and security requires careful modeling; integrating several elements of each system.

The following brief introduction into integrated modeling only gives a glimpse of the interactions between energy, water, and food (and land-use in general) as well selected interconnections with the climate. There are many more

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10 CLEWs is an abbreviation for Climate, Land-use, Energy and Water strategies and also refers to an integrated modelling methodology currently developed.
such inter-linkages. Identifying important interdependencies is of key importance for decision makers. Isolated approaches to adjust energy, (as well as water or agricultural) policies without investigating the impacts on other resources will often be insufficient as evidence shows that effects on the other resources are often likely.

Energy
Energy security has emerged as one of the fundamental challenges of the 21st century. In 2000, the global energy supply/demand balance was just over 400 exajoules per year. If projecting historical patterns of energy use driven by economic development, by 2050 the world would have an underlying demand for energy of about three times that. One may call this gap a "zone of uncertainty", which needs to be addressed by extraordinary measures on both sides: increased energy production and improved energy efficiency.

Today, there are still 1.4 billion people without access to electricity and 3 billion cannot afford to use modern fuels or technologies for providing essential energy services ranging from cooking, refrigeration and illumination to water pumping and operating power tools. For millions of people, traditional forms of biomass serve as the primary source of energy - with serious health impacts (indoor air pollution from smoke) and environmental implications (deforestation). Moreover, people without access to modern energy services often live in areas marked by water scarcity. In fact numerous linkages exist between energy and water as well as land-use; and all three areas affect or are affected by climate change. Thus GHG emissions from the combustion of fossil fuels increase atmospheric GHG concentrations, strong growth in biofuel production increases competition for arable land with the agricultural sector, and –also accelerates water requirements. The latter increases the need for water pumping - hence energy demand. The use of marginal lands often requires the application of fertilizers which are energy intensive and add to GHG emissions.

Water
Water is interwoven with energy, land and climate management. In the energy sector, thermal power plants use large amounts of water for cooling — much of which is lost to evaporation. Hydropower plants interfere with river water flows, affecting physical and biological resources in and near the river. Significant quantities of water are also required for other energy processing activities, such as refining oil products or manufacturing synthetic fuels. Pumping and irrigation requirements can lead to a significant share of electricity demand (in India it accounts for as much as 20% of electricity production). Desalination has become one of the most important sources of water for drinking and agriculture, especially in the Middle East and North Africa region. About 65.2 million m$^3$ water worldwide is desalinated per day (0.6% of global water supply), and rapid expansion is projected. As desalination increases, so too does related energy-demand as it is energy intensive. Renewable energy can play an important role in desalination. And desalination can support system integration: by enabling to use surplus energy production from intermittent sources (such as solar or wind) to run desalination processes ahead of demand, desalination facilities can be seen as “storing” energy. Furthermore, solar energy, notably CSP, produces large amounts of waste heat that is well suited for thermal desalination. Desalination is therefore one area where the use of renewable sources will become an important link between the energy and water systems.

An increasing world population will further stress water systems. Today, there are still 900 million people without access to safe drinking water and 2.5 billion people without access to sanitation. Water resources are unevenly distributed worldwide - efficient and sustainable water management systems are badly needed as demand for food and, hence, irrigation increases. Further, supplies of water are becoming increasingly vulnerable as climate change continues to affect the short term weather patterns, including rainfall levels, intensity and seasonality.

Food and Land Use
The provision of energy is interwoven with an important constraint that links it to food production, namely: available land$^{11}$. At present this land – and therefore its availability for food production - may be scarred by excessive mining or

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$^{11}$ Note that only limited quantities of land are in fact available for food production. Land that has the potential for cultivation can be classified into four categories: deserts, marginal land, cultivable land and forests or other natural vegetation such as savannahs. The
energy extraction, in some instances it is deforested and damaged due to overharvesting of fuel wood. It is also increasingly used for biofuel, in some instances displacing food-crop or animal feed production. Currently about 1 billion people are suffering from malnutrition and hunger. Agricultural production in many countries is still inefficient not only in terms of agricultural production per hectare, but is also often wasting energy and water (e.g. in outdated irrigation systems) sometime stimulated by false political incentives. Steering towards an efficient agriculture with locally proven technologies and which is adapted to specific climatic conditions avoiding the wastage of water and bio resources will be an important step not only to improve the food situation worldwide but will also be a necessity to cater for growing biofuel demand. As the biofuel industry expands, domestication and deployment of energy crops resources have to be suitable for the land of producing regions avoiding conflicts with food crops. (for further information see: FAO, “Climate Change, Water, and Food Security”, FAO Water Report 36, 2011, http://www.fao.org/docrep/014/i2096e/i2096e.pdf)

**Climate**

Finally, the largest share of anthropogenic emissions results from the production and use of energy. In turn, climate change is likely to significantly impact agriculture by increasing water demand, limiting crop productivity and by reducing water availability in areas where irrigation is most needed or has a comparative advantage. Global atmospheric temperature is predicted to rise by approximately 4°C by 2080, consistent with a doubling of atmospheric CO₂ concentration. Further, it is predicted that more extreme weather situations are likely to happen in the future leading for example to prolonged drought periods or severe storms/hurricanes. Amongst the greatest contributor to GHG emissions are the energy and agricultural sectors, with 28% of global GHG coming from electricity and heat production, 12.2% from transportation, 13.8% from agricultural and 12.2% coming from land use change, forestry and biomass burning (World Resources Institute, 2005 data, available under: http://cait.wri.org/).

II. **Key approaches/solutions**

It is our contention that better integrated modeling of Climate, Land, Energy and Water strategies (CLEWs), would help illustrate how to better manage and meet rising energy as well as food and water needs. Such a framework, if correctly implemented, could help underpin:

- **Policy assessment and harmonized decision making**: A well formulated integrated CLEWs approach would help decision makers to assess their policy options in terms of their likely effects on the broad CLEW system. Such a methodology should be able to transparently highlight the trade-offs associated with different resource strategies. Given limited resources, it is important for policy makers to ensure that policies are as cost-effective as possible. There are instances of contradictory policies, e.g. electricity subsidies that accelerate aquifer depletion – that in turn lead to greater electricity use and subsidy requirements. A CLEWS approach should help harmonize such potentially conflicting policies.

- **Technology assessments and scenario development**: Some technology options can affect multiple resources, e.g. intermittent wind generates electricity that is carbon free, but difficult to store. However, if coupled with water desalination, this intermittency may be far less difficult to integrate. A CLEWS approach should allow for a more inclusive assessment of technological options. Another goal is to elaborate consistent scenarios of possible socio-economic-technological development trajectories with the purpose of identifying future development opportunities as well as of understanding the implications of different development paths/policies. This is important for understanding whether current development is sustainable, and for exploring possible alternative development scenarios and the kinds of technology improvements that might significantly change development trajectories.

quantity of cultivable land increases as either forests are cleared or marginal lands and deserts are made cultivatable by irrigation and fertilization.
A Collaborative Approach and Case Study

A case study is presented that demonstrates the benefits associated with the application of a (very preliminary) Climate – Land Use – Energy – Water (CLEW) modeling approach. In the integrated study undertaken in a small island developing state (Mauritius) a detailed and high resolution application of an initial CLEW framework was implemented. The CLEW modelling approach included modelling techniques and inputs from a number of leading scientific and international organizations which were subsequently linked and updated in an iterative process.

Detailed energy\textsuperscript{12}, water\textsuperscript{13} and Land-Use\textsuperscript{14} models were prepared using high resolution data from local counterparts. Input data to all three models were harmonized with modelling results from one model being used as inputs to another in an iterative approach. All models were calibrated and run in an integrated fashion to determine (a) potential of meeting bio-fuel production targets, (b) the consequence of related crop changes and (c) measures to ensure adequate water supplies in the face of decreasing rainfall.

Results include a detailed energy balance of the country under different conditions (e.g. local biofuel production) as well as a GHG balance taking into account land use changes and fossil fuel substitution. Water demand projections were modeled and the influence of reduced rainfall on crop production and water supply simulated. Although the CLEW modeling still is in an early phase of development, the results were most promising; indicating that with a correct suite of measures, energy security and food security could be improved at a cost saving to the country. Even though vulnerable to changes in weather patterns, analysis indicated that this could be mitigated somewhat by potentially increasing water desalination. Further, by using intermittent renewables and storing desalinated water, this may be done with little effect on the national fuel imports or GHG emissions.

For future case studies a number of additional modelling tools (e.g. including AquaCrop developed by FAO\textsuperscript{15}, MESSAGE\textsuperscript{16} or OSeMOSYS\textsuperscript{17}) could be used to improve the robustness and accuracy of the results.

III. An enabling environment and incentives

The intricate links between energy, water, land use, climate and other features of the environment, are all relatively well documented but have not generally been incorporated into a common systematic framework. Governmental

\textsuperscript{12} For the energy sector “LEAP – Long-Range Energy Alternatives Planning System” developed by SEI was used (http://www.energycommunity.org/)
\textsuperscript{13} For the water model the “WEAP – Water Evaluation and Planning Systems” was used (http://weap21.org/)
\textsuperscript{14} AEZ – Agro Ecological Zoning (http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm) developed by IIASA was used to develop a land use model
\textsuperscript{15} AquaCrop - FAO’s crop water productivity simulation model (http://www.fao.org/nr/water/aquacrop.html)
\textsuperscript{16} MESSAGE – Model for Energy Supply Strategy Alternatives and their General Environmental Impact (http://www.iiasa.ac.at/Research/ENE/model/message.html)
\textsuperscript{17} OSeMOSYS – Open Source Energy Modelling System (http://www.osemosys.org)
administrative and decision structures tend to keep the management and development of these sectors separate from one another\(^\text{18}\). This allows options to develop a better enabling environment:

- As a first step, efforts must be made to identify clear and strong inter-linkages between different systems being planned for or assessed. This would help the development of a common framework for planning teams to communicate in a common vocabulary and metric. Such a framework harmonising the assessment of each CLEW resource may significantly improve information flows, and synchronize different departmental data collection, decision and policy making activities. Some assert that such a method is essential and that without such an integrated systems analysis tool, development, planning, policies and therefore development will not be sound and sustainable. Indeed many modelling approaches (e.g. in water and land-use modelling) require similar data sets (e.g. climate and soil data) and produce much better results when modelling efforts are combined. With a view on energy, this translates in a closer cooperation at the planning and policy level as well as on the level of energy producers (e.g. utilities) with “counterparts” at different ministries (land, water agriculture) and other utilities (water).
- Governments and planning organs should have access to tools that help to assess these integrated systems. This should include access to support and training.
- Importantly, while the methods (quantified systems modelling) are useful for developing consistent scenarios of how an integrated CLEW strategy may physically play out, it should be noted that these present only insights. The insights need to be translated into appropriate incentives and stable policy regimes in order to harness the power of end users as well as business, which are needed to innovate and invest. A careful review of available and suggested policy measures are therefore needed.
- Governments should facilitate the coordinated planning of energy, land and water through the systematic collection of data that are needed for this type of analysis. This includes stream flow, water table elevation, land use patterns, energy use and production, and meteorological data.

### IV. (Policy) Recommendations and suggested initiatives

Important next steps for an integrated Resource Policy:

- The development of new case studies including detailed stakeholder interactions to determine potential policy suites available to help address and incentivise the development and deployment of ‘nexus solutions’.
- These efforts should include key stakeholders, amongst others: UN and other international agencies and partnerships with a clear mandate to build capacity in and assist member states with sound policy formulation; Key national and regional policy making organs in member-states or regions involved in case study activities; Universities and technologists, who are key to developing technologies or systems of technologies for deployment; Business and investors, who ultimately help realise the implementation and the economic sustainability of the final solutions.
- The further development of integrated resource assessment toolkits is required: This may include a wider menu of tools than provided here. It is important that these tools are packaged behind user friendly interfaces and available with training and support as elements of a technical cooperation / development package (to developing countries in particular).
- It is suggested that governments and international organisations work to combine or develop interfaces between water, land, and energy planning efforts.

\(^{18}\) This is not only true for government but also for other institutions (e.g. development agencies, or universities) which often work with separate departments for water, agriculture and energy; making an integrated view on the “CLEW” interactions difficult.
V. Bibliography

