The Water-Energy-Food Nexus from the Food perspective

Alessandro Flammini and Manas Puri - FAO

Introduction

During 2012-14, around 805 million people were estimated to be undernourished globally and one in every nine people in the world had insufficient food to lead an active and a healthy life. (OECD/FAO, 2014). Making food available and accessible is one of the biggest challenge facing humanity today. With the rise in global population, it estimated that food production would need to increase by 60 percent by 2050 (FAO, 2014b) to ensure availability of food to all. Producing food is a resource intensive activity which requires extensive use of water and energy in primary production and processing. Currently around 70 percent of all fresh water, is used for irrigation to produce food. The total global water withdrawals for irrigation are projected to increase by 10 percent by 2050 (FAO, 2011a). Energy is required to produce, transport and distribute food as well as to extract, pump, lift, collect, transport and treat water. It is also estimated that today the food chain consumes about 30 percent of total global energy (FAO, 2011b). Around 70 percent of the energy required over the food value chain is consumed in food processing and preparation stages (but this depends very much on the specific food). As a consequence, an increase of the energy prices immediately reflects in an increase of the cost of food production, processing and preparation. Gradually introducing renewable energy (including bioenergy) along the agri-food chain and energy efficiency interventions can help decrease the energy costs associated with food. Access to modern energy can also help increase the value of the food produced from a value chain perspective, hence resulting in higher returns for farmers and food processors.

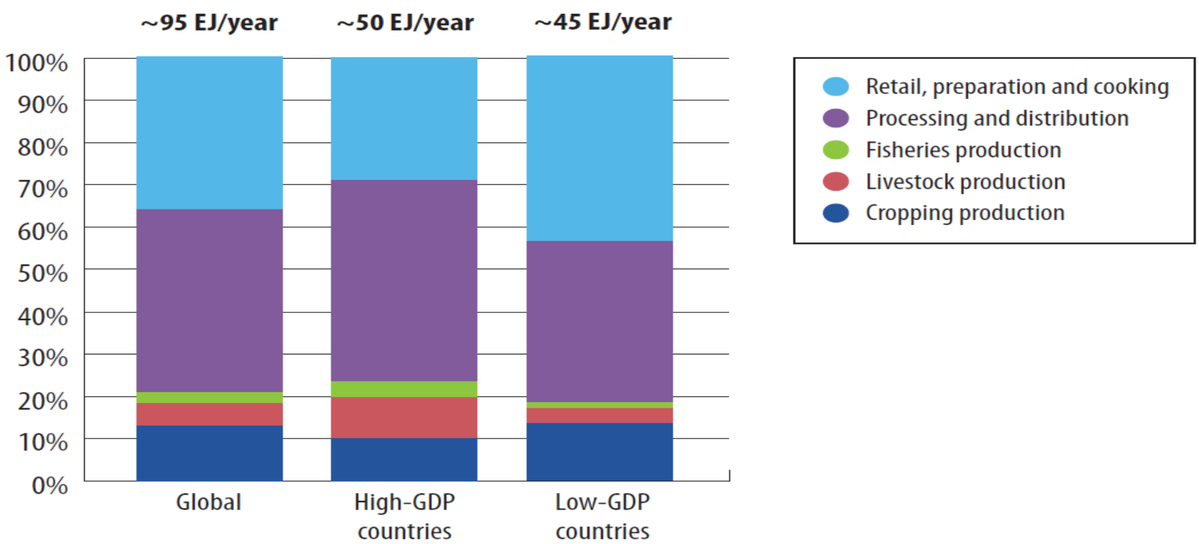

Figure 1: Energy use in food value chain.
Source: FAO, 2011b

Energy for and from food

Energy is needed along the whole food value chain. It is consumed directly in the form of fossil fuels and indirectly in the form of machinery and external agricultural inputs such as fertilizers, pesticides, herbicides and insecticides. Beyond the farm gate, energy is used in processing, storing and transport of food products.

Energy from fossil fuels (see figure. 1) is extensively used in agriculture and has increased farm mechanization, boosted fertilizer production and improved food processing and transportation. Consequently, movements in crude oil price have direct impact on food prices (see figure. 2) and, without proper stocks and access to modern energy and technologies to conserve food (for drying, cold storage, milling, packing, sterilizing, etc.), the small holder farmers are the first ones to be hit since their agricultural activities are much more dependent on external conditions than large/industrial agricultural producers with access to energy and modern technologies.

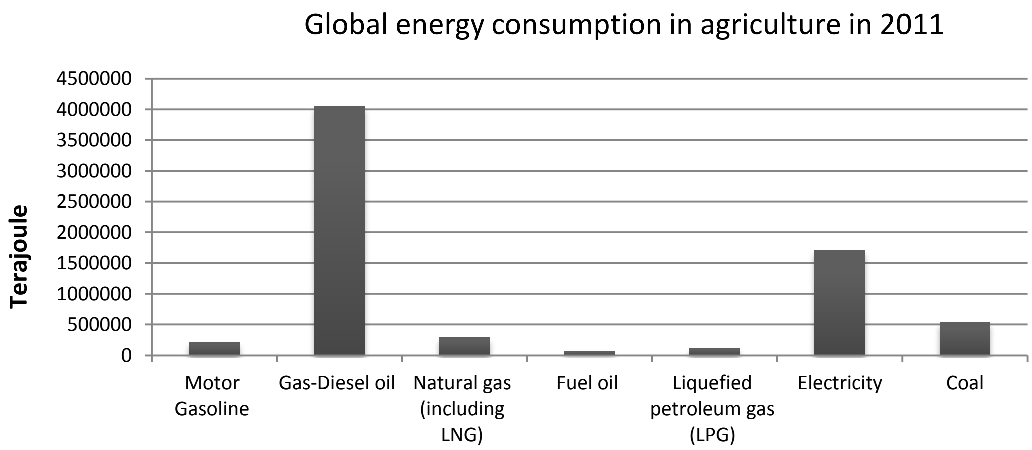

Figure 2: Global energy consumption in agriculture
Source: FAOSTAT (2015)

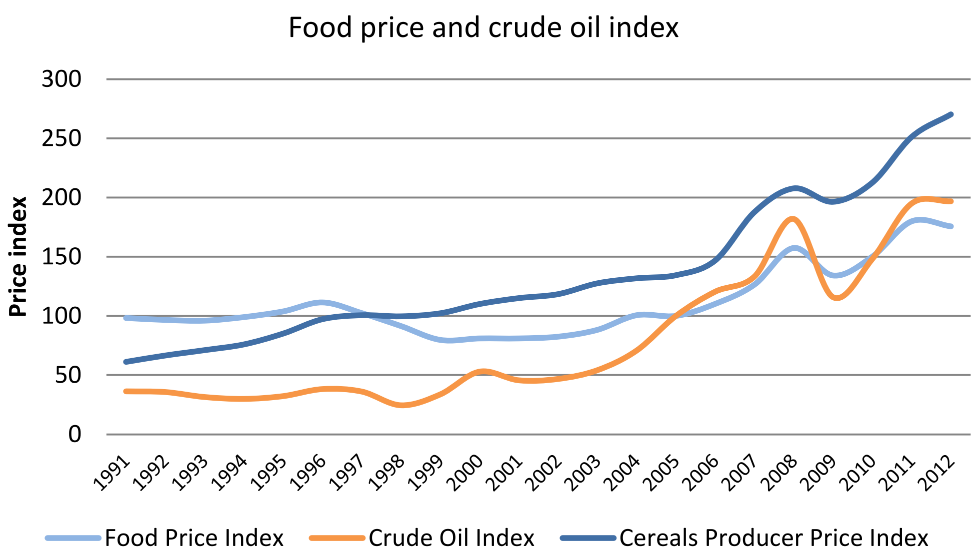

Figure 3: Food price and crude oil index.
Source: FAOSTAT (2015) and IMF (2015)

While agriculture is a large consumer of energy, and provides nutritional energy to humans through food, it can also provide energy in the form of biomass. Crop residues like rice and wheat straw are used as fuels in various parts of the world. Lignocellulosic biomass can be converted in to briquettes and combusted or can be processed to be used for gasification or pyrolysis to produce heat, electricity or other fuel oils. In many Asian countries where multiple growing season exist, the residues are often burned in the field to quickly prepare the field for subsequent cropping. It should be noted that not all biomass residue is available for bio energy generation. Crop residues can also be used as soil amendments and when left in fields after grain harvest, they enhance soil and water conservation, nutrient cycling and subsequent crop yield. Crop residues are also used for other purposes, such as livestock feed, fuel and construction material.

Although still an emerging technology, ethanol can also be produced from cellulosic biomass such as rice husks or wheat straw. The global potential of production of ethanol from rice husk is estimated to be in the order of 20.9 to 24.3 Gl per annum (Abbas and Ansumali, 2010) which can potentially satisfy around one fifth of the global ethanol bio-fuel demand for a 10% gasohol fuel blend.

FAO WEF Nexus approach

Due to global changes and interdependencies between natural resources, it is imperative to look at the current agrifood system as a constant interaction between water, energy and food resources (WEF nexus). A 'nexus' approach enables us to manage resources used for food more efficiently. There are many synergies and tradeoffs between water and energy use for food production. For instance, pumping water for irrigation may increase crop yield but it can also lead to a decline in water table resulting in a shortage of drinking water. Using fertilizers can also lead to increase in crop yields but it can also cause leeching and water pollution together with increasing the energy use on farm. Some synergies and trade-offs between energy and food are reported in Figure 4.

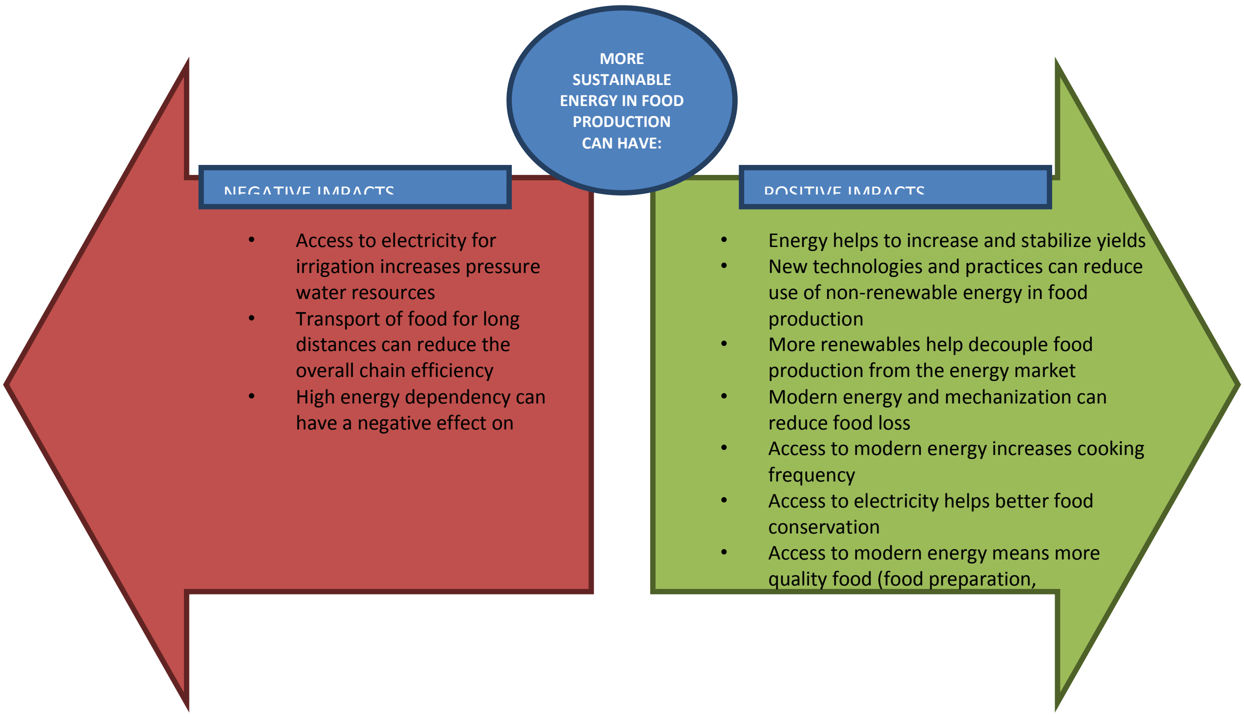

Figure 4: Some synergies and trade-offs between energy and food
Source: authors

The Nexus approach aims to systematically assess and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different (and sometimes competing) social, economic and environmental goals. It explicitly addresses complex interactions and feedback between human and natural systems (Figure 5).

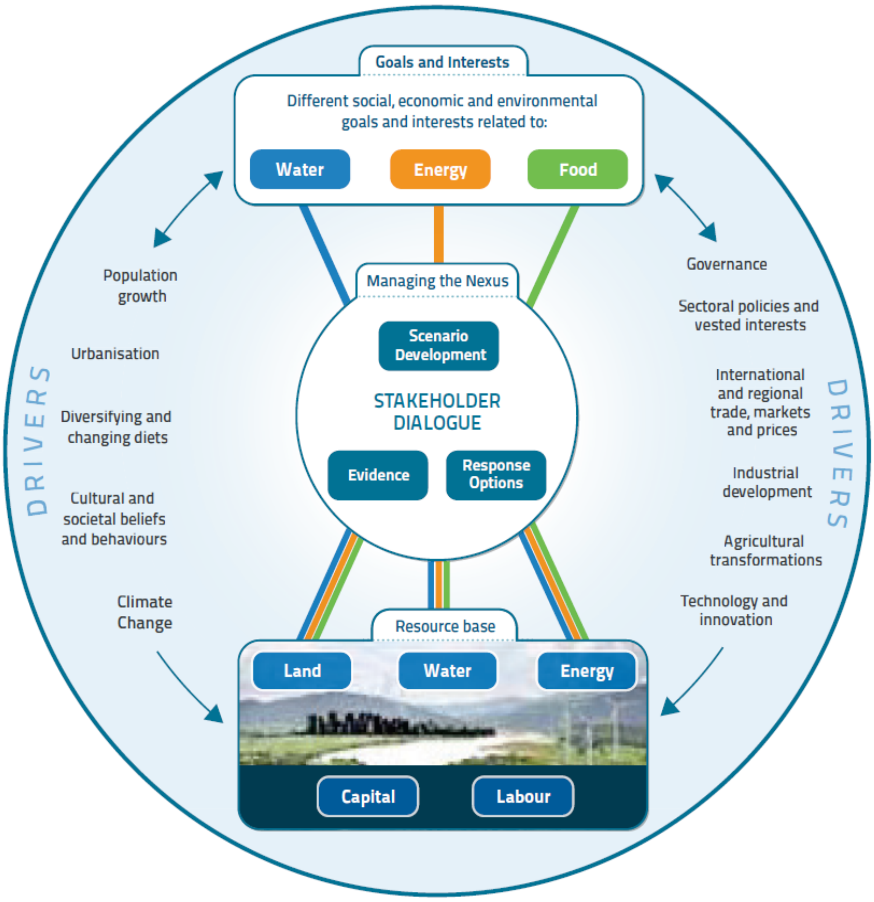

Figure 4: FAO approach to the Water-Energy-Food Nexus
Source: FAO, 2014a

Nexus interactions are complex and dynamic, and individual water, energy and food sectoral issues cannot be looked at in isolation from one another. They exist within a wider context of transformational processes – or drivers of change – that need to be taken into account. It is important to note that there are different conceptualisations of the Nexus that vary in their scope, objectives and understanding of drivers. It is a useful concept to describe and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic and environmental goals. The Water-Energy-Food Nexus is framed within the broader debate on sustainable development and as part of FAO's vision of sustainable food and agriculture to achieve its mandate of eradicating hunger, reducing poverty, and sustainably managing and using natural resources and ecosystems

Based on the Nexus approach FAO has developed a *Nexus Assessment* methodology which can help decision-makers evaluate the sustainability of specific water, energy and food interventions in a given context. Based on the analysis, response options can be developed which can be inter-sectoral like development of transparent and effective allocation mechanism but also intra-sectoral resulting in increase in resource uses efficiency and minimising wastes and losses.

The *Nexus Assessment* (FAO, 2014a) is a participatory process that helps understand critical situations, where resources (both human and natural) are under pressure, and which tipping points exist in terms of possible interventions (e.g. a new policy or a new plant). The nexus links are quantified at two distinct levels:

a. At the context level where prevailing water, energy and food nexus status is determined based on current pressure on natural and human resources.

b. At the intervention level where its performance is quantified. This is done by devising a set of indicators that measure its impact on the ecosystem and is measured as a percentage change.

The intervention level impact on the resources is then compared with the relevant nexus context status to understand the sustainability of an intervention in that specific context.

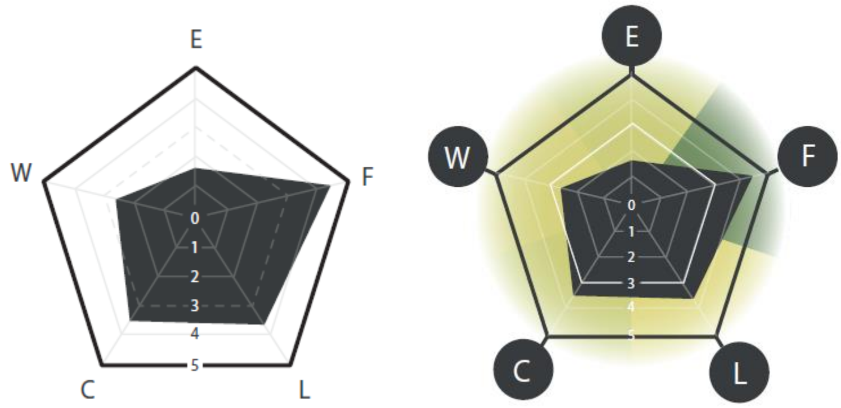

Figure 5: Intervention impact alone and intervention impact with context nexus status
Source: authors

This is important, as the same interventions may have different impacts in different contexts. They may or may not be sustainable when juxtaposed with the regional natural and socio-economic realities.

Leveraging the knowledge and tools developed on the nexus approach, FAO is involved in developing specific solutions within the agri-food sector. These include:

- Capturing resource use synergies in biorefineries. A biorefinery is a facility where biomass is used produce multiple products like fuels, heat and power and other co-products such as food that can be use for different purposes. A biorefinery is based on the idea of industrial ecology where the output from one process is used as input to another process resulting in optimization of resource use through reuse and reduction of waste. For instance, using algae to produce bioenergy along with other algal products to be used in the chemical industry or as fertilizers can be regarded as a biorefinery: algae can be used to produce liquid bio-fuels such as bio-diesel and bio-ethanol for the market to be used as fuels but also electricity to be used on site or sold to the grid. The same biorefinery can also produce high protein food supplements, algal oils and other chemicals that can be used in pharmaceuticals. The by-products can also be used as feed for livestock and aquaculture (FAO, 2010).

- Developing Integrated food-energy systems (IFES). An IFES stems from the principles of sustainable production intensification to build farming systems that incorporate agro-biodiversity and using waste or excess biomass or other form renewable resource to produce energy. Depending on the local resource base, generation of solar, thermal, geothermal, photovoltaic, wind and water energy can directly be integrated into the food production system. The simultaneous production of food and energy on the same farm offers opportunities to build on synergies between various natural resources resulting in a more sustainable food and energy production system. This can be achieved in broadly two ways, the first combines food and/or energy crops on the same field, such as in agro-forestry systems for example: growing trees for fuel wood and charcoal. The second type of IFES incorporates the use of by-products/residues from food production to produce energy. Examples include biogas from livestock residues, animal feed from by-products of corn ethanol, or bagasse for energy as a by-product of sugarcane production for food purposes.
- Solar energy for refrigeration, pumping water and for processing of food leading to reductions in food losses. Solar energy can be used extensively to replace fossil fuels required for processes like pumping water, drying crops for preserving food as well as in large industrial scale processing of food. In many parts of the world, lack of access to energy limits water withdrawal on-farm resulting in low yields. Additionally, a major factor resulting in food losses is often the lack of access to energy limiting food processing and storage infrastructure. Energy from the sun can be harnessed through photovoltaic, solar thermal and concentrating solar power systems to pump water, store and refrigerate crops as well as to process them. Solar pumping systems are increasingly being adopted in many developing countries as a way to irrigate fields. Solar dryer and refrigeration systems are also increasing becoming available and are used in developing countries where access to traditional forms of energy is limited. On an industrial level, solar energy can also be tapped to run processes like cooling and pasteurization of milk, milling of rice, drying tomatoes for increasing shelf life, heating water for cleaning etc.

Other effective nexus policies include:

- promoting the use of non conventional water and water harvesting, and
- promoting the reduction of food loss and waste which means saving energy, water, and land needed for the production of wasted food
- promoting certain consumption patterns which are healthy for people and the environment, such as reducing the consumption of animal based food products in affluent countries. Such behavioral changes can be an important way to use energy, water and land more efficiently, since animal proteins have the lowest natural resource use efficiencies (see fig. 7).

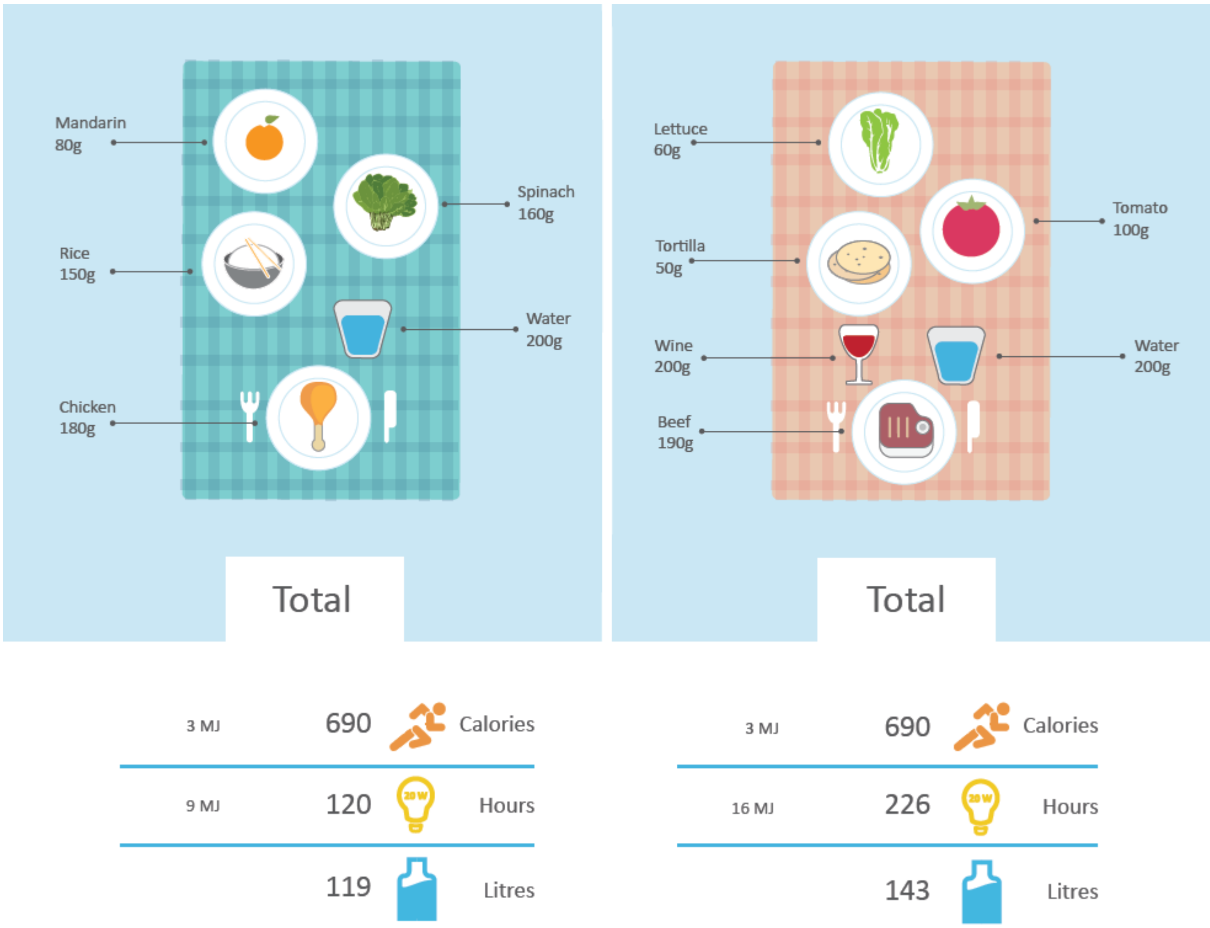

Figure 6: Comparison of energy and water use in two meals that provide the same amount of nutritional energy[1]
Source: authors

Conclusion

The water, energy and food nexus is a intricate system which requires constant knowledge sharing between the stake holders. FAO is committed to helping countries to build capacity in order to deal with nexus issues through developing partnership and engaging in dialog with countries and other international organization. The FAO *Nexus Assessment* needs to be tested by implementing it in countries to improve it over time as well as to derive lessons that can be replicated in similar environments.

[1] The values presented are indicative only and may vary considerably depending on the specific production system and location. Energy values were calculated comparing a large number of literature sources, but these are at time very specific by location and farming system. Water footprint values were taken from (Mekonnen & Hoekstra, 2011) and (Mekonnen & Hoekstra, 2010). Calories were calculated applying the conversion factors from the FAOSTAT Food Balance Sheets and, where not available, from the USDA National Nutrient Database for Standard Reference.

References

Abbas A and Ansumali S, 2010. *Global Potential of Rice Husk as a Renewable Feedstock for Ethanol Biofuel Production*. Bio Energy Research, 3(4), 328–334.

FAO, 2014a. *Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the Context of the Sustainable Energy for All Initiative.* Rome: Food and Agriculture Organization of the United Nations

FAO, 2014b. *The Water-Energy-Food Nexus: A new approach in support of food security and sustainable agriculture.* Rome: Food and Agriculture Organization of the United Nations.

FAO, 2011a. *The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk*. Rome: Food and Agriculture Organization of the United Nations

FAO, 2011b. *Energy-smart food for people and climate. Issue Paper*. Rome: Food and Agriculture Organization of the United Nations.

FAO, 2010. *Algae-Based Biofuels - Applications and Co-products.* Rome: Food and Agriculture Organization of the United Nations

IEA, 2014. *World energy outlook 2014: Executive summary.* Paris: International Energy Agency

OECD/FAO, 2014. *OECD-FAO Agricultural Outlook 2014*, OECD Publishing, Paris. Organisation for Economic Co-operation and Development and Food and Agriculture Organization of the United Nations