CHAPTER 7

ENERGY AND AGRI-FOOD SYSTEMS: PRODUCTION AND CONSUMPTION

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The objective of this chapter is to present the role of energy in the Mediterranean agri-food sector and to discuss the possibilities. Agri-food chains require large amounts of energy and produce various wastes that can be utilised for energy generation. Therefore, these chains are both consumers and producers of energy. Additionally, rural areas can explore their renewable energy potential in order to increase energy supply and create additional incomes to the farmers. Improvements in energy efficiency and higher use of renewable energies in this sector can increase its sustainability. Considerations regarding how developed and developing countries differ in terms of energy efficiency and bioenergy are very relevant to discuss links between energy and agri-food systems in the Mediterranean Basin because the region includes both types of countries.

After a presentation of global issues, this chapter provides an overview of energy mix and discusses challenges and opportunities regarding energy efficiency and increased renewable energy in the Mediterranean agri-food sector. We briefly address the relevance of the water-energy-food nexus approach to tackle energy issues in the agri-food sector in the region before stressing the importance of gender equality in the production and consumption energy in the sector in order to enhance its sustainability.

Global considerations on energy in agri-food systems

Current energy consumption in agri-food systems is unsustainable on the long term (FAO, 2011). Food systems currently consume 30% of the world's available energy, with more than 70% occurring beyond the farm gate, and produce over 20% of the world's greenhouse gas emissions (around 31% if land-use change is included). At the same time, about one-third of the food we produce is lost or wasted, and with it about 38% of energy consumed in food systems. Moreover, modern food systems are heavily dependent on fossil fuels. According to estimations, in the next decades there will be significant and simultaneous increases in water, energy and food needs. These will lead to a degraded and depleted natural resource base, and increasing climate change challenges (FAO, 2014a).

Modernising agri-food systems by increasing the use of fossil fuels, as in the past, will be neither an affordable nor a sustainable option because of climate change and the impact of high and volatile fossil fuel prices on production costs and food prices. As a result, due consideration to energy and its links with water and food production and its use in agri-food systems development is crucial. In particular, the agri-food value chain will have to become gradually decoupled from fossil fuel dependence so that it can deliver more food with less and cleaner energy. To address these challenges, "Energy-Smart" agri-food systems are required including improved access to modern energy services through integrated food and energy production, improved energy efficiency, an increased use of renewable energy and the promotion of a water-energy-food nexus approach throughout agri-food chains.

Improvement in energy efficiency is generally considered as the best strategy to reduce CO_2 emissions, to limit energy dependence and to alleviate the effect of oil prices increase (MEDENER, 2013). Energy intensity is a useful indicator of energy efficiency. The evolution of this factor in recent decades provides some interesting findings (Schneider and Smith, 2009). Globally, energy intensity in agriculture significantly increased until the mid-1980s; after which it decreased. This is a crucial change as it shows that in recent years agriculture has managed to produce more food per energy input. However, this global trend masks important differences between industrialised/OECD and newly-industrialised or developing countries: while both types of countries have experienced a reduced intensity in land and workers' use, the energy intensity of fertilisers and agricultural machinery has decreased in industrialised countries since the beginning of the 1980s, whereas it has steadily increased in developing countries since 1965. These differences can be explained by two factors. Regarding OECD countries, a combination of the collapse of high input agriculture for example in the USSR countries in the mid-1980s, more efficient use of inputs through increased adoption of "precision agriculture"[1] starting at the same period, and the increase in the implementation of *low* or *zero tillage* techniques. "Precision agriculture" technologies are often rather "high tech" and involve significant capital investment. Therefore, even if farmers in developing countries had access to them, these technologies are generally too expensive for smallholders and only viable for middle-to large-scale farmers.

Regarding newly industrialised and developing countries, the steady increase in energy intensity has been dominated by high external inputs farming systems, especially in China and India. However, it is also important to mention low external input systems that may have a relatively high energy intensity in case of low production associated with limited external energy uses, or obtain good results in terms

1 - "Precision agriculture" (also called "precision farming" or "site specific management") is defined as the application of a holistic management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with agricultural production, marketing, finance and personnel.

of energy intensity where low levels of external inputs are associated with energy inputs coming mainly from human or animal labour. In this case good performance is explained by a more integrated use of resources (crops and livestock for example), and the more systemic use of agricultural residues as inputs to the farming system – hence reducing the need for external and fossil fuel-dependent inputs. Such farming systems all over the world (Pretty *et al.*, 2006), are therefore a valid option for farmers who cannot afford "precision agriculture".

Changes in energy efficiency are often difficult to explain because. 1) They depend on the technical performance of the energy used, the importance of energy transformations, climate conditions (heating and cooling needs), the structure of each economic sector that uses energy (MEDENER, 2013). 2) The data available on energy efficiency in agriculture does not consider post-harvest stages; although in many cases, especially in industrialised agriculture, most of the energy consumed in agri-food chains occurs at those stages. This is also partly because a significant proportion of food losses and waste – and related energy losses – occur at post-harvest stages. In developing countries, these losses often occur at storage, transport and processing stages. Adequate access to energy at these stages, including from the use of agricultural residues, can significantly contribute to reducing such losses. 3) Different causes can lead to similar trends. Indeed, the increase in precision agriculture, the collapse or underdevelopment of the agricultural sector, but also low input agriculture can result in low energy intensity. Table 1 presents possible ways to improve energy efficiency in agri-food systems.

Agriculture has a unique link with energy as it can both consume and produce energy, the latter through bioenergy whose use is very old (wood for heating and cooking for example). It currently accounts for about 10% of the world energy mix. Bioenergy being the only renewable source of energy that can replace fossil fuels in all energy markets (heat, electricity and transport) its share in the future energy mix is bound to substantially increase up to 25-30% according to the latest estimates (IEA, 2010).

Again, here, a distinction should be made between developed and developing countries. In many developing countries, bioenergy is the most accessible source of energy in rural areas. It is therefore often used for domestic purposes (cooking and heating) and when it is done in an unsustainable way it can lead to forest degradation and deforestation. So far, production and use of modern bioenergy is not very common. On the other hand, in developed countries and some emerging economies (e.g. Brazil, India, China), modern bioenergy is much more common, be it in the shape of biofuels or the industrial use of woody biomass.

Among the different types of bioenergy, liquid biofuels (often simply called biofuels) have been the most controversial ones. The most controversial aspects – at least for first generation ones based on sugar, starch and oils – concern their environmental and food security risks, more particularly when produced on a large scale. These risks are mainly related to possible biodiversity loss and increase in GHG emissions caused by land conversion; the latter with possible competition for land between energy and food crops, and the impact on food prices caused by the diversion of crops to biofuel production. However, as with many products based on land and natural resources, liquid biofuels are not bad or good *per se*. It all depends on how they are managed, including feedstock and land choice, farming practices, and other stages of the biofuel supply chain. Based on some recent work conducted by the FAO[2] and others, knowledge on good practices to minimise risks and harness the opportunities associated with liquid biofuels has been shared: agro-ecological zoning, sustainable yield increase, integrated food energy systems and outgrower schemes.

Table 1 - Examples of energy efficiency improvements in the agri-food sector through direct or indirect interventions

	Directly	Indirectly
Pre-harvest	Fuel efficient engines/maintenance Precise water applications Precision farming for fertilisers Adopting no-till practices Controlled building environments Heat management of greenhouses Propeller designs of fishing vessels	Less input-demanding crop varieties and animal breeds Agro-ecological farming practices Reduction of water demand and losses Energy efficient fertiliser and machinery manufacture IT identification of fish stock locations
Post-harvest	Truck design and operation Variable speed electric motors Better lighting and heat processes Insulation of cool stores Minimised food packaging Technology transfer and education Improved efficiency of cooking devices	Improved road infrastructure Reduction of food losses at all stages Matching of food supply with demand Promotion of diets with a lower consumption of meat Decrease in obesity levels Labelling of food products

Source: FAO (2011a).

Residues from agriculture and forestry are often considered as a win-win solution regarding the production of bioenergy. However, great caution is needed concerning possible competing uses of these residues. In particular, for small-scale producers, such residues are often the most accessible source of fertiliser and soil protection,

2 - FAO's work includes a project on Bioenergy and Food security (BEFS), Bioenergy and Food security Criteria and Indicators (BEFSCI), a decision Support Tool on Sustainable Bioenergy (with UNEP), and Integrated Food Energy Systems. More details can be found on the FAO bioenergy website (www.fao.org/bioenergy).

as well as animal feed. The FAO has developed tools that allow the assessment of how much residue would be available for bioenergy purposes, both at territorial and farm levels.

Energy availability and energy trends

The Mediterranean region is far from being homogeneous when it comes to energy. Firstly, there are differences between NMCs that are all developed countries and SEMCs, which are at different stages of development (from very wealthy to relatively poor). This matters a lot from an energy point of view as emerging economies and developing countries will experience significant increase in energy needs in the future. According to the estimations, energy needs in SEMCs will double from 2000 to 2020 (GEF, 2008). Secondly, while some countries are oil producers and exporters, several Mediterranean countries are energy dependent and energy importers. Moreover, this situation has been changing in several countries of the eastern Mediterranean region including Cyprus, Israel, Jordan, Lebanon, Syria and the Palestinian territories. Recent discoveries of large hydrocarbon resources, particularly natural gas, are going to alter their energy landscape: they might be able to cover their energy demands and probably export hydrocarbons to European countries, as in the case of Algeria and Libya. Moreover, it seems quite probable that large offshore hydrocarbon reserves will be discovered soon in the territories of Greece and Turkey thus reducing their energy dependence. However, all Mediterranean countries will have to decarbonise their agri-food systems by reducing their use of fossil fuels – be it domestic or imported – in order to address climate change challenges. Finally, an additional differentiation can be made between countries that enjoy political stability and those, mainly SEMCs, which have faced political instability and social uprisings.

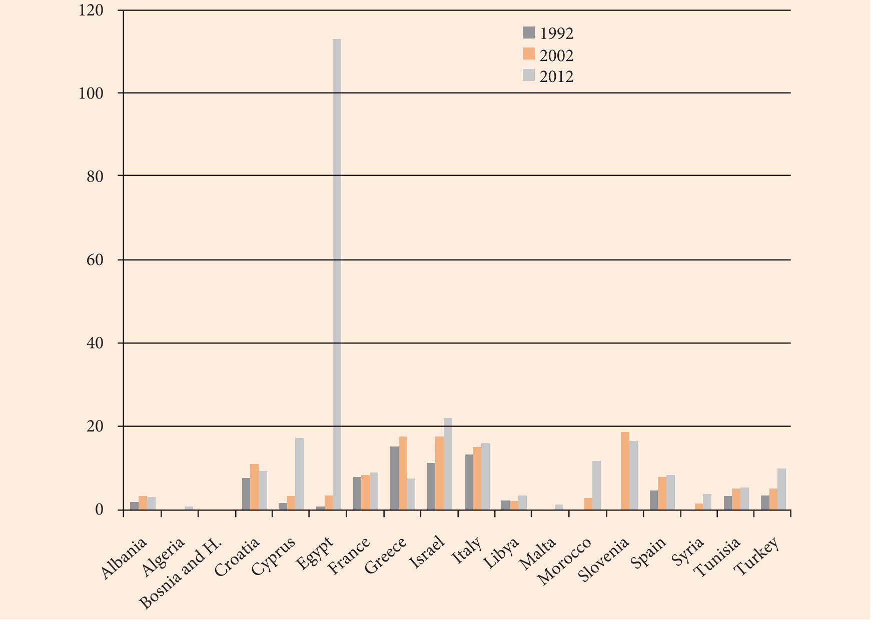
The above-mentioned differences do not allow for generalisations regarding the energy situation in agricultural sector in the region as a whole. However, one can reasonably say that Mediterranean countries: 1) Heavily depend on fossil fuels regarding their energy supply – this dependency is estimated at 75-90% (Fader *et al.*, 2014); 2) In the SEMCs, energy demand in the Mediterranean Region as a whole may increase by 65% during the period 2010-2025 (ENPI, 2014) due to population growth and economic development; 3) All countries have a high potential for improving energy efficiency and using renewable resources.

Energy efficiency

As regards energy efficiency, over the period 2000-2010, the primary intensity of most countries has decreased, except in Morocco and Algeria (that is also an oil exporter) where fossil fuel use in agriculture is subsidised. In southern countries, this decline was 2.5 times slower than in EU countries, except in Tunisia and Lebanon (MEDENER, 2013). This situation is less clear regarding the agricultural sector, as illustrated in Figures 1, 2 and 3 which present energy intensity of agriculture (up to the farm gate) in a sample of countries for the years 1992, 2002 and 2012 per unit of land, monetary value and food supply, respectively (FAOSTAT, 2012)[3].

A few interesting observations emerge from these Figures. Broadly speaking, energy intensities in agriculture (i.e. pre-harvest) are higher in SEMCs than in NMCs. In some cases there are different trends when one compares energy intensity per hectare and energy per value added and food supply (Israel, Italy and Tunisia). With the exception of France, all NMCs show a reduction of energy intensity in agriculture between 1992 and 2012. The picture is more varied regarding SEMCs. Water pumping for irrigation is a key factor in energy intensities. For instance, in 2010, energy consumption for pumping was close to 1 toe per irrigated (toe/ha) hectare in Morocco against 0.6 toe in Tunisia (MEDENER, 2013). In the fisheries sector, energy intensity depends a lot on the fishing technique: for example in Tunisia, in 2010, fire fishing was less energy consuming (0.3 toe/tonne of fish) than trawler fishing (2.2. toe/tonne) (MEDENER, 2013).

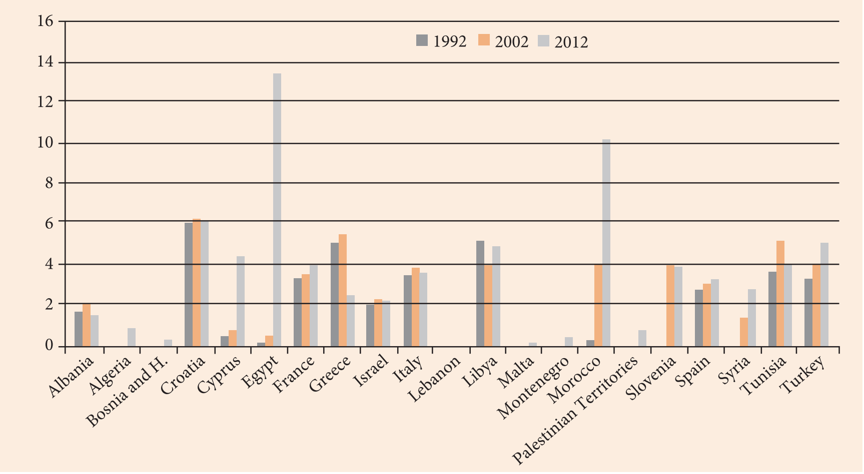
Figure 1 - Energy intensity according to arable land (GJ/ha)



Source: FAOSTAT (2012).

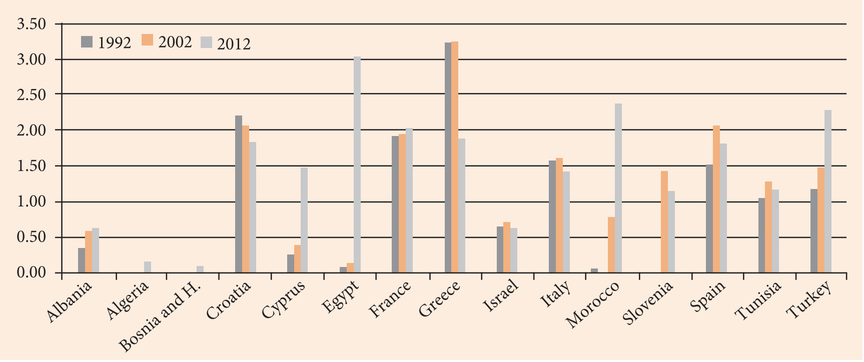
3 - The value for Egypt in 2012 seems abnormally high and might therefore result from a reporting error.

Figure 2 - Energy intensity according to the monetary value of agricultural production (MJ/$)



Source: FAOSTAT (2012).

Figure 3 - Energy intensity according to food supply (MJ/kcal)



Source: FAOSTAT (2012).

Many of the barriers that prevent investments in energy efficiency are common across all sectors: limited knowhow of policy makers, little awareness of energy efficiency of consumers and the financial sector, lack of technical capacity to develop and implement energy efficiency projects, limited access to affordable financing, subsidised energy prices and organisational and institutional gaps and overlaps (IEA, 2014). Governments can improve energy efficiency results by adopting a cross-sectoral approach to addressing implementation barriers, such as the lack of private-sector capacity and/or insufficient institutional coordination. IEA (2014) makes the following recommendations to improve energy efficiency in SEMCs:

– Establishment of energy data collection capacity;
– Development of national energy efficiency plans;

– Facilitation of private investment;
– Designation of lead energy efficiency institutions; and
– Progressive removal of energy price subsidies.

A recent study showed that most Mediterranean countries have implemented energy efficiencies programmes at different stages (Blanc, 2012). It foreseed that energy intensity in the Mediterranean should fall perceptibly by approximately 13% over the next twenty years. However, given the programmed energy mix (mostly fossil fuels), this will not limit emissions of CO_2, which are likely to increase by more than 90%. This is where the promotion of renewable energy in the region comes as a useful complement to energy efficiency.

Renewable energy

Exploitation of renewable energy is one pathway for Mediterranean countries to minimise their dependence on imported fossil fuels and reduce GHG emissions. Their potential for deployment in the Mediterranean Basin is very high but it is still largely underexploited, especially in non-EU countries. Renewable energies, particularly biomass, solar and wind energy are more used in NMCs compared to SEMCs.

Wind energy. With a long coastline, the Mediterranean region has an abundant potential for wind energy. As shown in Table 2, northern countries have many more wind farms compared with southern countries. Among the countries that have not yet developed wind farms, some are situated in areas with high wind potential and can easily increase their power generation thanks to this energy.

Table 2 - Wind power capacity and number of wind farms by country (2010)

Country	Number of farms	Capacity (MW)
Morocco	15	286
Algeria	1	14
Tunisia	3	20
Libya	1	20
Egypt	8	550
Jordan	3	2
Israel	1	6
Turkey	54	1,329
Greece	102	1,208
Italy	266	5,797
Spain	881	20,676
Portugal	245	3,702

Source: Bloomfield *et al.* (2011).

The integration of wind energy projects in the agri-food sector is an interesting economic opportunity for agricultural enterprises in the region. However the development of wind energy projects require heavy capital investments and attractive financing mechanisms for farmers need to be established. Capacity-building in terms of wind project development and management is also necessary. The next Box briefly describes a project in the Canary Islands where wind energy is used to desalinate water for agriculture.

On-grid wind energy for water desalination in the Canary Islands

The Canary Islands have neither local fossil fuel resources, nor abundant fresh water natural sources. However, there is plenty of wind, sun and seawater. The main water demand comes from the agricultural sector, which has a long tradition in the archipelago (fruits and vegetables are the main crops). The guarantee of a reliable and good quality water supply at competitive costs for this sector in the eastern islands is only possible with the production of desalinated water (in some islands, there is almost a 100% dependence on desalination for the water supply).

The location of crops in windy areas close to the shore is a clear advantage when considering the combination of electricity generation from wind power and water production from desalination plants. The local government has been a pioneer in creating a specific regulation to promote the simultaneous implementation of a wind farm associated with the energy consumption of a local industry. Firstly, it was the public water companies on the eastern islands (Lanzarote and Fuerteventura) that owned SWRO (seawater reverse osmosis) desalination plants. According to regional legislation, the nominal power of the desalination plant must be at least 50% of the installed wind power and the annual balance of electricity consumed by the SWRO unit must be 50% or more of the electric energy generated by the wind farm.

An illustrative example is the initiative of a local agriculture cooperative (Soslaires Canarias S.L.) which installed a 5,000m^3/d SWRO plant associated to a grid-connected 2.64MW wind farm (4 x 660kW wind turbines) in Playa de Vargas (East of Gran Canaria Island), with a total investment of 5.2 million euros (wind farm 46%, SWRO plant 21%); both installations were commissioned in 2002. The desalination plant occupies an area of around 450m^2 and is able to produce up to 1.5 million cubic meters per year for the irrigation of more than 150 hectares. The water produced is of high quality (slightly over 400ppm) and the plant has an excellent specific energy consumption (approx. 7.9MJ/m3, equivalent to 2.85kWh/ha of irrigated land). The annual electric energy balance (wind energy production minus energy consumption due to water production) is positive, avoiding the emission of more than 6,000 tonnes CO_2/year.

The management and technical staff for the tasks related to the wind farm and desalination plant is composed of seven technicians with a total personnel cost of around 150,000 euros/year. Thanks to the water quality and the constant water supply, the diversification of crops and ratio of productions has changed drastically. Prior to this investment, tomatoes were the only crop. Now more than fifteen types of vegetables (gourds, beans, kidney-beans, cucumbers, etc.) are being cultivated. Although the cost of the desalinated water is higher than the existing (low quality) groundwater, the income increment has been significant for local farmers.

Source: FAO (2014b).

Solar energy. The Mediterranean region receives one of the highest solar radiation in the world. Large availability of unexploited lands in the region, especially in SEMCs, makes solar energy systems, especially photovoltaics an attractive proposition for regional countries. Agricultural farms in the Mediterranean region can use PV systems for domestic as well as commercial power generation. Solar energy is often used in greenhouses and irrigation.

Controlled environment agriculture such as greenhouse horticulture is an interesting farming system as it can increase sustainable food production and food safety by, *inter alia* simultaneously reducing the use of natural resources such as land and water to produce food, allowing cultivation in unsuitable land and environments, stabilising seasonal productivity and reducing risks resulting from extreme events and climate change and increasing the income per unit of land, hence raising the revenue of small family farms (Adami and Battistelli, 2015). However, control of the agricultural environment requires energy and average energy use accounts for 10% to 30% of total production costs, depending on the region (FAO, 2013). If the required energy can be produced onsite from renewable sources in a cost effective way, then the overall system can be self-sustaining.

Vegetable growers can adopt a range of greenhouse system technologies including solar energy to improve climate control and energy use. However, there are numerous obstacles and constraints to overcome. The existing technology and knowhow developed in northern European countries are generally not directly transferable to the Mediterranean: high-level technology is beyond the means of many growers in SEMCs due to the high cost compared with the modest investment capacity; and knowhow from northern European growers is often inappropriate with regards to the problems encountered in the Mediterranean region (FAO, 2013). The next box briefly presents the case of photovoltaic energy in Greece.

Photovoltaic energy in Greece

The rapid development of solar-PV in Greece during the last six years led to the achievement of the national targets for photovoltaic energy set for 2020, seven years in advance. Currently Greece covers 5% of its electricity needs with PV power and is ranked 5th in the world in terms of installed PV power per capita. The Greek government provided various incentives to promote these investments, thus supporting the rapid growth of this energy in the country: capital subsidies to the investments but mainly attractive feed-in tariffs for the generated power (initially the feed-in tariffs were in the range of 0.40 to 0.55 euro per kWh but later the tariffs decreased substantially) coupled with contracts to sell the generated power according to a grid of predefined prices for twenty to twenty-five years. This has pushed thousands of people to invest in this technology. Most of the photovoltaic parks have been installed in agricultural areas; which can be categorised as follows: PV installations with nominal power of over 200kWp; PV installations with nominal power of 20-200kWp and PV installations of 3-10kWp placed on the roofs of various buildings. It is estimated that over 50,000 companies and individuals have invested in PV cells in Greece creating around 50,000 direct and indirect new jobs. The total invested capital in solar-PVs in Greece currently exceeds a few billion Euros.

Residents in agricultural areas have benefited from the growth of solar-PVs in Greece. They have increased their income by investing in this sector. Nevertheless, in recent years, changes in the common agricultural policy of EU have led to the reduction of solar-PVs. Due to relatively high irradiance, electricity generation from PV in Crete is approximately 1,500kWh per kWp installed. In addition to the feed-in tariff initiative, in the end of 2014, the government offered a new initiative related to net-metering: this measure promoted the installation of PVs in residential buildings or in enterprises in order to balance the generation of electricity produced and consumed by the network; the household or enterprises had therefore the possibility to zero their electricity bills and thus make energy savings. The growth of PVs and other renewable energies for the generation of electricity such as small hydro, wind parks and biomass power plants will allow the transformation of the existing power system in a decentralised mode where electricity will not only be generated in few large plants using mainly fossil fuels but it will be generated in many decentralised plants using various renewable energy sources. In Crete, electricity is currently generated by over a thousand decentralised power plants compared with two central plants, which operated in the island two decades ago. Decentralised power plants using local renewable resources will obviously be mainly located in agricultural areas where the inhabitants will significantly benefit from this transformation.

Source: Vourdoubas (2015).

Irrigation is widely used in the Mediterranean region, and it is a major consumer of energy in agriculture. A lot of attention has therefore been focused on how to achieve better energy efficiency and promote the use of renewable energy (solar in particular) in irrigation activities. A recent study on solar irrigation in the Mediterranean concluded that (Fader *et al.*, 2014):

– Climate change will very likely increase irrigation requirements.
– Improved irrigation technology and distribution systems have a large potential for saving water.
– More energy will be needed for irrigation in future, whether because of higher irrigation water requirements or due to more extensive pressurised systems.
– Photovoltaic panels could produce the energy needed for irrigation.
– The areas needed for photovoltaic panels are small enough to be placed on roofs of agricultural buildings without hindering agricultural production.

Summary of the key messages of the FAO-GIZ workshop on "Prospects for Solar-Powered Irrigation Systems (SPIS) in developing countries"

1) *Solar energy for irrigation is a technically mature option and can constitute an alternative to the conventional sources of energy.* There are however, preconditions for investing in SPIS, such as tenure security, right investment and technological knowhow requirements that depend on site-specific conditions and specific needs and skills of farmers.

2) *Currently a knowledge and information gap surrounding SPIS still persists.* More communication and exchange regarding SPIS experiences at different levels is needed to scale-up efforts and to promote their use.

3) *Under the right circumstances, SPIS technology can benefit small-scale farmers.* SPIS has been successfully piloted at small-farm levels and can substitute non-solar irrigation solutions, depending on the socio-economic and political conditions of the local context.

4) *Capacity building is needed for all actors involved in the design and implementation of SPIS*, including users, service providers and where appropriate, local manufacturers.

5) *Finding the right financial mechanisms and business models to support SPIS is a major challenge.* Many types of mechanisms exist and there is no agreement on which systems work better. *There is however consensus around the fact that while necessary, subsidies should be "smart" i.e.* it should be clear from the beginning that they are a temporary solution and should lead to market-based financial mechanisms.

6) *There is currently a lack of policies that account for the above considerations and also a lack of regulations regarding quality insurance and control.*

7) *Different institutional arrangements exist regarding the implementation of SPIS.* No conclusion was reached on the pros and cons of these different arrangements.

8) *Pilot SPIS might be needed to convince decision-makers to develop the right policies and institutions to scale up SPIS.* Such pilots should involve relevant stakeholders at both local and national levels from their onset.

9) *The above considerations clearly show that action to promote sustainable SPIS*: should occur at both farm and national levels and adopt an integrated and inclusive approach (e.g. nexus and sustainable livelihoods); and takes time – often up to 3-4 years – between concept and implementation.

Source: FAO/GIZ (2015).

In May 2015, FAO and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the German international cooperation agency for development organised a workshop on "The prospects of solar-powered irrigation systems in developing countries". The previous Box presents a summary of the key findings as they are relevant to SEMCs.

Bioenergy. The Mediterranean region has abundant biomass energy resources, which have remained largely unexplored. According to conservative estimates, the potential of biomass energy in the Euro-Mediterranean region is about 400TWh per year (Zafar, 2015a). Traditionally, biomass energy has been widely used in rural areas for domestic purposes in the MENA region, especially in Egypt, Yemen and Jordan. The escalating prices of oil and natural gas, the resulting concern over energy-security, have led the MENA countries to explore alternative sources of energy.

Large quantities of crop residues are generated in the region every year and they are vastly underutilised. Currently, these residues are usually ploughed back into the soil, or they are burnt, left to decompose, or grazed by cattle. These residues can be processed into liquid fuels or thermos-chemically processed to produce electricity and heat in rural areas. Use of residues of vineyards and wine have been used successfully in an existing winery in Sicily for power generation (Corona *et al.*, 2010): the nominal power of the plant is 950kW. The generated power in injected to the grid and sold at an attractive feed-in tariff that is higher than the buying price. The electric efficiency of the plant is 22% and the annually generated power is higher than the annual plant consumption. As demonstrated the above-mentioned example, biomass use for energy generation results in many environmental, economic and social benefits. The first Box presents a biogas project in Jordan while the second explains the case of use of olive tree by-products for heat generation in Crete.

Biogas Plant at Rusaifeh Landfill

In collaboration with the United Nations Development Programme (UNDP), the Global Environment Facility (GEF) and the Danish government, the Jordanian government established a 1MW biogas plant at the Rusaifeh landfill near Amman in 1999. The plant has been successfully operating and its capacity has recently been increased to 4MW. The project consists of a system of twelve landfill gas wells and an anaerobic digestion plant based on 60 tonnes of organic wastes per day from hotels, restaurants and slaughterhouses in Amman. The successful installation of the biogas project has made it a role model in the entire region and several big cities are striving to replicate it.

Source: Zafar (2015b).

Utilisation of olive tree by-products for heat generation in Crete

Olive trees grow across the Mediterranean enabling the production of excellent edible olive oil. Olive tree byproducts produced during the processing of olives like olive kernel wood are very good solid fuels used extensively today for heat generation. Olive paste from olive mills after the extraction of olive oil is further processed in olive kernel oil producing plants where olive kernel oil and olive kernel wood are produced. Olive kernel wood has very good burning qualities and heat content 3,700-4,100 kcal/kg at moisture content of 12%. It is used as heating fuel in olive mills, various small and medium enterprises, greenhouses and various residential and other buildings. The current total olive kernel wood production in Crete is approximately 110,000 tonnes/year and its price about 0.08 euro per kg, which is significantly lower (compared with its heating value) than the price of heating oil. Burnt according to locally manufactured simple systems with an efficiency of about 70-80%, it is a preferable fuel for heat generation in Crete and in Greece particularly in the present context of severe economic crisis. Olive kernel wood is not currently used for power generation in Crete although there are projects for the cogeneration of heat and power. Olive tree wood is also an excellent solid fuel used for heat production in open fires and wood stoves mainly in residential buildings. Various efforts have been recently made in Crete for the production of wood pellets from olive kernel wood and "olive biomass" produced from the processing and refining of olive kernel wood is available on the market.

Table 3 - Prices of various energy sources in Crete (2015)

Energy source	Price (€/1,000kcal)	Efficiency (per cent)	Price (€/1,000kcal delivered)
Olive kernel wood	0.022	70	0.036
Fuel oil	0.045	0.095	90
Heating oil	90	0.050	0.106
Electricity	0.116	100	0.116
Electricity/heat pump	0.116	200-250	0.046- 0.058

Source: Vourdoubas (2015).

The high potential of biomass, solar and wind energy in the Mediterranean basin and the current developments in solar-PV and wind energy technologies allow the generation of additional incomes for farmers due to the production of electricity with governmental support and various policies. In areas facing economic problems due to low food production or low food prices, the possibility of generating biomass, sun and wind energy offers the local population new ways to increase its income and standard of living. Attractive feed-in tariffs for electricity generated from these renewable energies with a low nominal capacity of 5 and 100kWp combined with the decrease in installation costs (for solar devices) have the potential to boost their investments. Additional incomes resulting from energy savings can also be obtained from households or small and medium enterprises with a net-metering policy allowing them to install renewable energy systems with capacities of 3 and 50kWp in their premises. The high potential of solar, wind and biomass in the region allows the establishment of energy cooperatives at local and national level. This practice that is already common in many European countries ensures the exploitation of renewable energy locally, generating electricity and selling it to the grid. Therefore, together with agricultural cooperatives, energy cooperatives can bring additional economic benefits to local populations.

More broadly, the establishment of or the support provided to producer associations and consumer associations promoting access to modern energy in rural areas creates opportunities to gain experience in the running of civil society organisations representing and involving rural people and communities. The latter will therefore participate more actively in decision-making processes. Moreover, providing a feeling of modernity, access to energy has a transformational effect: their involvement in a successful small business activity, the co-operative management and sustained income generation develop their self-confidence. Producer organisations and cooperatives can also reduce investment and operations costs regarding renewable energy systems and improve access to knowledge. All these factors are likely to have knock-on effects on entrepreneurship, community organisation and give way to new future ventures. This is especially the case for decentralised bioenergy production and use, as this type of energy lends itself more easily to the development of local value chains (Practical Action Consulting, 2009).

The water-energy-food nexus

The production of food and energy as well as the use of water, energy and land that it involves, are closely interwoven. Referring to the Mediterranean region, more specifically to SEMCs, many of the development issues are related to water, energy and agriculture and food issues because many people in the region do not have access to satisfactory services in these areas. In this context, the water-energy-food Nexus has emerged as a useful concept to describe and to address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic and environmental goals.

In practical terms, the Nexus Approach helps to better understand and systematically analyse the interactions between the natural environment and human activities, and to work towards a more coordinated management and use of natural resources across sectors and scales. This can help to identify and manage trade-offs and to build synergies through our responses, allowing for more integrated and cost-effective planning, decision-making, implementation, monitoring and evaluation (FAO, 2014a).

In order to make the Nexus concept operational, three non-sequential sets of activities should be undertaken through adequate stakeholder involvement (FAO, 2014a):
– Evidence refers to the collection and analysis of data to discuss and identify the interlinkages of water, energy and food systems and the impacts that any change can have on the system;
– Scenario development refers to the possible impacts of interventions or policies on the natural environment and society. Specific interventions are identified, assessed and discussed;
– Response Options where different stakeholders engage in an open and participatory dialogue to build consensus among themselves on specific policy issues and to decide on how to intervene.

The symposium "Agrosym 2014" has raised the issue of the crucial importance of understanding the complex relationship between water, energy and food systems and the necessity to develop a sustainable and secure future for the Mediterranean region (Hamdy *et al.*, 2014). This study suggests that, in order to achieve water, energy and food goals, there is need for a coordinated harmonised Nexus knowledge base and data base indicators and metrics that cover all relevant spatial and temporal scales and planning horizons. A full life cycle analysis across the nexus is also required. Such an improved nexus understanding could underpin new decision and policy making in a green economy framework. The next Box presents two typical cases where a water-energy-food Nexus Approach helps address trade-offs and foster opportunities in energy for agriculture.

Nexus examples that are relevant to the Mediterranean Region

Solar energy for irrigation

The irrigated area in the Mediterranean region has doubled over the last forty years and now represents a fifth (21%) of the total cultivated agricultural land in the region (Plan Bleu, 2008). Shifting from rain-fed to irrigated production would increase irrigation demand by 137% (166 km^3/yr) whilst CO_2 emissions would rise by 270%. At the same time, clean energy solutions like solar irrigation that provide energy at limited or no operational costs bear the risk of depletion of water tables due to over-pumping. They also face other challenges and bear opportunities. In order to support the sustainable intensification of agriculture, particularly in the Mediterranean region, there will be a need for low cost, reliable, efficient irrigation systems that avoid excessive groundwater pumping supported by policies that recognise trade-offs but also promote synergies between saving water, reducing CO_2 emissions and intensifying food production.

Wind energy for water desalination

Many arid zones of the southern and eastern Mediterranean face simultaneously population growth leading to the depletion of underground water reservoirs due to irrigation and drinking water increasing needs and pollution of surface waters. Water desalination has been tested as a possible solution to address these challenges. However, water desalination is quite energy intensive. Therefore, conventional desalination systems consume a lot of fossil fuel to produce electricity to run the operation. Solutions involving the use of renewable energy exist. However, these schemes are often knowledge and capital intensive. There is a trade-off between the use of capital and knowledge for sophisticated technologies versus using more conventional ones.

The Nexus Approach is most useful in situations where at least one of the elements (water, energy or food) is scarce. It is therefore of particular relevance to the southern and eastern countries of the region, as most of them face water scarcities and several challenges in terms of energy and food security. The GIZ has started to support the Arab League regarding nexus regional dialogues and the EU will also provide its support as from 2016.

Gender considerations in the agricultural production and consumption of energy

According to the FAO (2011c), closing the gender gap in agriculture would generate significant gains for the agricultural sector and for society. If women had the same access to productive resources as men, they could increase yields on their farms by 20 to 30%. This could raise total agricultural output in developing countries by 2.5 to 4%. Production gains of this magnitude could reduce the number of hungry people in the world by 12 to 17% (FAO, 2011c).

In developing countries, men and women experience the lack of access to modern energy in a very different way. In particular, in rural areas, traditional socio-cultural roles make things more difficult for poor women when compared to men. Many women are compelled to spend a lot of their time in drudgery (fetching water, carrying wood, and processing food by hand) due to the lack of water pumps, modern fuel sources and grain mills. Access to energy can therefore free women for more rewarding and productive activities. As a result, they could become more interested in creating energy cooperatives using local renewable energies (such as solar and bioenergy from the waste generated during farming and cattle breeding) and increasing energy supply (such as the use of solar-PV energy for collective water pumping) since they experience the difficulties when carrying wood fuel from long distances. Women might also be keener to use energy-saving techniques in their homes and their working facilities particularly if they gain access to micro credit to support their investments in renewable sustainable energy, which is necessary to promote sustainable energies among them. According to a recent study by the International Centre for Research on Women (ICRW) (2012), engaging women in the development and distribution of a (renewable energy based) agricultural technology, which in turn enables their access and use of technology, generates a positive chain reaction with extensive outcomes. This process unlocks two key pathways to economic progress for women by enhancing women's productivity in existing economic activities and by creating new economic opportunities for women. The same report makes the following recommendations regarding gender aspects related to energy and agriculture:

– Gender responsiveness must become a core practice;

– Complementary services that facilitate consumers access to technologies should be tailored to ensure that women can benefit from them and that facilitate the pathways to women's economic advancement;

– Technology development efforts that seek to economically promote women must recognise the buyer/end user distinction when marketing technologies. Men often make decisions about technology purchases and control family finances, even if women are end users. Thus, expressed demand for technologies among women may not translate into realised demand if female users have little control over household spending;

– Demand generation efforts should appeal to larger numbers of female users by targeting marketing and awareness-raising efforts at women, as well as men, and making clear the potential economic benefits of using technologies;

– Technology development and distribution initiatives must measure their efforts to reach women and address their constraints in accessing and using technologies for their economic advancement;

– Investors and donors should attempt to create networks that enable technology investees and enterprises to exchange knowledge and best practices on achieving scale and economically advancing women; and

– In order to ensure that self-employed women are able to access and effectively use the powerful tools of technology, there needs to be an emphasis on economic empowerment, in addition to economic advancement.

Conclusion

The agri-food sector is both a consumer and a potential producer of energy. While the highest priority should be to ensure adequate access to modern energy services along agri-food chains, this should be as much as possible achieved concomitantly with improvements in energy efficiency and gradually, increased use of renewable energy, in order to decouple their development from their current high dependence on fossil fuels. The FAO Energy-Smart Food for People and Climate Programme addresses these challenges.

While Mediterranean countries display diverse energy situations, they all depend heavily on fossil fuels; many eastern and southern countries will experience a significant increase in energy needs due to important and simultaneous population and economic growth. All countries in the region have significant potential for improvement in terms of energy efficiency and use of renewable agriculture. These considerations also apply to the agri-food systems in the region.

Combining energy efficiency with more use of renewable energy would reduce the dependency of agriculture on fossil fuels and contribute to the reduction of GHG emissions from the sector. However, this will require improvement in policy and institutional measures, in particular regarding financial support, better considerations of gender aspects and support to producer organisations, standards and guaranteed markets. Promotion of gender equality in energy issues particularly in poor areas is very important in order to support and mobilise women in sustainable energy production and consumption. Women are likely to be keen in promoting energy and water sustainability and if they have access to micro-credit, they could increase energy sustainability using energy-saving techniques and local renewable energies. Combined with political stability in some countries in the region, all these measures are required to promote investments and sustainability in "Energy-Smart Food" in the Mediterranean. Currently, there is international support to promote both improved energy efficiency and increased use of renewable energy in the region. Such support should also be adequately provided for the agri-food sector.

Since many people in SEMCs do not have access to adequate energy, food and water resources, securing adequate levels of these resources is very important in order to ensure sustainable development. This requires a water-energy-food Nexus Approach, especially because scarcity means that trade-offs have to be addressed, and that possible synergies should be explored. The FAO Nexus Approach reflects this willingness to promote dialogue between water, energy and food in southern and eastern Mediterranean countries.

Due to the increasing overlap of the water-climate-energy Nexus and the strong link between agriculture and energy consumption, the CIHEAM has decided to confer a significant place to energy issues in its Post-2015 Agenda, particularly through the implementation of the MED-SPRING. Moreover, the highly complementary mandates and actions of the FAO and the CIHEAM paves the way for the establishment of a partnership between the two organisations involving both the expertise of the CIHEAM and its Institutes and the knowledge of the FAO on this matter.

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