Food and Agriculture Organization of the United Nations

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

International Workshop:

Prospects for solar-powered irrigation systems (SPIS) in developing countries

Final Report

FAO HQ | Rome, Italy | 27-29 May 2015

Jointly Organized by the Food and Agriculture Organization (FAO) and the German Agency for International Cooperation (GIZ)

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1. Workshop Background

The Food and Agriculture Organization of the United Nations (FAO), in partnership with the German Agency for International Cooperation (GIZ), organized an International Workshop on 'The prospects for solar-powered irrigation systems in developing countries" from 27 to 29 May, 2015 at FAOHQs in Rome, Italy. There were over 60 participants representing a variety of institutions and organizations, both private and public, from a range of sectors: water, energy, agriculture etc., from across the globe. Country representation at the workshop covered India, Egypt, South Africa, Kenya, Burkina Faso, Ethiopia, Ghana, Lebanon, Yemen, China, Turkey, Germany, The Netherlands, Austria, Sweden, Italy, The United Arab Emirates, Thailand, Chile, Mexico, and the USA.

The workshop programme comprised an introduction session, four thematic sessions and a final discussion dedicated to concluding session outcomes and ideas for the way forward. A total of **19 presentations** were made and each was followed by discussion. Finally, there were welcome and closing remarks by both FAO and GIZ colleagues, including the Director of the Land and Water Division (NRL), Moujahed Achouri and the Director of the Climate, Energy and Tenure Division (NRC), Martin Frick.

2. Rationale: Why now?

Agriculture drives the world's water use as it accounts for 70 percent of total global freshwater withdrawals. Around 56% of global irrigated land requires energy and that number is growing with significant GHG emissions. Cities, industry and other users, too, claim increasingly more water, energy, and land resources, and simultaneously face problems of environmental degradation and, in some cases, resources scarcity. This situation, which has unpredictable impacts for livelihoods and the environment, is expected to exacerbate in the near future as 60 percent more food will need to be produced in order to feed the world population by the year 2050.

Solar-powered irrigation systems (SPIS) are increasingly in demand in developing countries as they can provide a cost-effective and 'clean" solution to increase agricultural productivity. Access to water for irrigation is key to farmers, particularly in order to sustain their livelihoods and food security. However, operating irrigation systems efficiently often calls for the adoption of local irrigation techniques and this in turn requires a source of energy. In the absence of a reliable electricity supply in many rural areas in several developing countries, farmers have to resort to diesel-based pumping systems. These systems

create high operating costs particularly in remote areas, require frequent servicing which is not always available, contribute to GHG emissions, and contribute to the energy bill in countries that do not produce such fuels.

Renewable energy options, in particular solar power, offer promising and reliable solutions for sustainable agriculture in regions with high-incident solar-energy. Solar energy has environmental advantages, low operation and maintenance costs and increasingly low investment costs. Until recently, the use of solar energy for irrigation had not generated a lot of interest amongst governments, farmers and development agencies because of its high investments costs. As these costs are being reduced, and with growing concerns of climate change, there is renewed attention to this technology. Many countries are testing and promoting the solar technology for irrigation in the framework of national action plans, as a solution to climate change and the lack of access to electricity and fossil fuel in rural areas.

It was therefore timely to take stock from existing experiences on solar energy for irrigation in order to derive sound conclusions and recommendations regarding its future use in general and in particular in developing countries.

Objective

The overall goal of the workshop was to take stock of experiences and existing tools and practices for the use of solar power for irrigation and to identify the key challenges and constrains for the development of this technology in developing countries. The three-day workshop brought together a large number of authorities, experts, and researchers associated with SPIS or who have had direct experiences on it in different countries and regions.

3. Key Messages

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 know-how requirements, that depend on site-specific conditions and specific needs and skills of farmers. Irrigation systems that rely solely on solar energy are rather rare. Such systems often combine solar and other types of energy sources, because solar energy is often adopted as a backup to the other which are either not reliable or because diesel is too expensive. Implementing successfully is not just a technology fix or a financial solution; it concerns farmers' livelihood conditions and strategies and considers impacts on farming systems (e.g. crop pattern, income, costs) as well as social acceptance. As a result there is no 'one-size-fits-all" solution.

Currently a knowledge and information gap surrounding SPIS still persists. The gap concerns benefits, sound financial mechanisms and business plans, best practices, technology options, etc. More communication and exchange regarding SPIS experiences at different levels is needed to scale-up efforts and to promote SPIS use. The high investment costs may largely explain the fair amount

of resistance to SPIS; however, systematic M&E of SPIS performance is also crucially missing, resulting in a lack of lessons and possibilities for comparative analysis to be able to provide guidance on how to develop sustainable systems. Integrated approaches such as the water-energy-food nexus and sustainable livelihoods should also be used to help fill the information gaps regarding SPIS performance and feasibility.

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. More research regarding SPIS models suitable for small-scale farmers would help up-scale the technology. The technology has also proven valuable in humanitarian crisis situations for providing drinking water supply.

Capacity building is needed for all actors involved in the design and implementation of SPIS, including users, service providers and where appropriate, local manufacturers. The GIZ handbook and toolbox on SPIS is welcomed as an important element of capacity building.

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. Considerations about the high initial costs of SPIS must be balanced with the fact that their operating costs are often much lower than other irrigation systems. Possible ways to reduce costs include:

- Subsidies (see next point);
- Adding other uses of the energy produced;
- Selling extra energy;
- Cost sharing by organizing farmers; and
- Carbon credits (although there is little experience to date on this point).

Subsidies to SPIS constitute a particular issue that has generated a lot of debate. On the one hand, they do not promote quality or innovations, and, on the other, the entailed 'low-cost' energy for users can result in over use of both water and energy. But it is also true that subsidies to other forms of energy hamper the interest in SPIS and agriculture itself is also subsidized in many countries. Moreover, experience shows that subsidies are usually needed when promoting new technologies; in fact most cases presented included subsidies. **A consensus emerged 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.

There is currently a lack of policies that account for the above considerations and also a lack of regulations regarding quality insurance and control. In fact most policies in favour of SPIS have included subsidies, with a dearth of policies related to market-based financing mechanisms.

Different institutional arrangements exist regarding the implementation of SPIS. In some cases individual farmers manage their own systems, in other cases the systems are managed by groups of farmers, yet in other cases, they are managed by a specialised entity with farmers paying for the energy they get – so a division of labour and responsibilities. No conclusion was reached on the pros and cons of these different arrangements.

Pilot SPIS might be needed to convince decision-makers to develop the right policies and institutions to scale up SPIS. However in order for them to fulfill this awareness raising and show casing role, the pilots should involve relevant stakeholders at both local and national levels from their onset.

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

4. Sessions 1-4 Coverage

Session one: state of the art of SPIS in different regions and countries.

<u>The water-energy-food nexus</u> at FAO is a holistic vision of sustainability that recognizes and tries to strike a balance between the different goals, interests and needs of people and the environment. It explicitly addresses complex interactions and feedback between human and natural systems, such as does 'free' energy and water exist?; is solar energy free compared to diesel and/or electricity?, etc. Making these resources available cost money so the question is at what costs and, if free, for whom. Integrated approaches such as the water-energy-food nexus and sustainable livelihoods can help ensure that all relevant aspects are taken into consideration in assessing the feasibility and performance of SPIS.

<u>Although SPIS has been successfully piloted it is not clear whether or not small-scale farmers can benefit from SPIS technology.</u> Due to high initial capital cost constraints and technological know-how requirements, SPIS better caters for market-oriented medium to large scale farming since it is mostly accompanied by an intensification of agricultural production. For SPIS to be

affordable in subsistence farming contexts, it would require an increase in the production of high income crops. Carefully designed 'smart' subsidies for SPIS should be designed to serve as temporary solutions, as we think about water scarcity, over-abstraction, GHG emissions, poverty reduction, and viable business models for SPIS application.

Twenty-five years of experience in water pumping with solar energy in **Mexico** sees pay-back within 4-6 years for simple systems (i.e. PV pumps, well-controller). Half of the systems were installed by farmers without subsidies and involved key participation of women. Durable and efficient life-cycles of SPIS means investing in parallel activities such as technical assistance, capacity development/training and R&D. Sagarpa and Firco in Mexico have prepared such training manuals for water pumping, PV O&M to support SPIS activities.

Irrigation is a major energy consumer in many countries. For example, nearly 23% of electricity and 15% of diesel use in India is for irrigation pumping. In Bangladesh, 15% of installed capacity is utilized for pumping. This poses a number of challenges for the energy sector. Solar-powered irrigation pumping offers a technically-proven and cost-effective option for replacing grid-connected and diesel-based pump sets, as well as for expanding irrigation. The case for their adoption is strong for both farmers and governments. Nevertheless, it should be remembered that SPIS is not the only solution towards sustainable irrigation practices. The **IRENA** presentation supports that an enabling ecosystem to scale-up solar irrigation needs to be established to create favorable conditions for its implementation. Overall, an integrated approach to promoting solar water pumping for irrigation is necessary to realize the multiplier effect on benefits. IRENA analysed the benefits of solar pumping for irrigation in a report published in 2015.

Session two: techno-economic feasibility and environmental impacts of SPIS.

In recent years, thousands of PV water pumps have been sold and manufacturers gained extensive field experience to further improve their products. The **GIZ** presentation explored SPIS components and plant configurations. Depending on the results of site data collection and the specific needs and skills of the farmer, different technical SPIS configurations are possible. Defined standard system packages which are limited in size are not an appropriate solution. The design of government funded programs should include a standard monitoring program to provide the farmer with a minimum of system information and a possibility to check the system performance after installation.

In **Bangladesh**, there are 1.77 million irrigation pumps of which 300 are solar. The government has targeted to install about 15,000 solar pumps by 2025. There is 61% irrigation coverage in the country out of which 82% operate on a diesel engine and 18% on electric motor operated pumps. Governments are now providing more financial support to solar-irrigated projects, especially for irrigation in high value crops like fruits and vegetables where solar pumping is economically feasible. Although initial capital costs are high, with the help of subsidies, the operating cost of a solar pump is about half that of a diesel operated pump and has almost zero carbon emissions.

In the **Egypt** case study, solar powered water lifting for irrigation is looked at closely in a pilot project titled, 'Coping with water scarcity—the role of agriculture—Phase III," that is financed by the Italian government and managed by FAO. Current challenges related to existing water resources and their management are creating conflicts between sectors of society, farmers and the environment and result in negative effects on irrigation efficiency in the country.

The presentation titled **Environmental Performance of Solar Photovoltaic Technologies** highlights how solar energy technologies present tremendous environmental benefits when compared to the conventional energy sources. Practical examples were taken from two case studies, one in Pakistan and the other in South Africa, to show the benefits of using PV systems for irrigation, even in cloudy weather conditions (in the case of SA), and the positive impacts it has for farmer livelihoods in the remotest areas with no access to grid. It is considered beneficial and suitable for long-term investments as compared to diesel powered engines.

The deployment of photovoltaic (PV) powered irrigation poses several socio-environmental considerations that require planning and management. PV modules have a lifetime of 20 to 40 years and pose end of-life waste management issues even earlier as some modules fail early. PV modules have the perfect recipe for e-waste, a valuable metal (silver, indium, tellurium) found with a toxic one (lead, cadmium, indium tin oxide). PV modules also rely on some rare metals that limit the total amount of solar that can be deployed. They also are made of materials that are

easily recycled such as aluminium and glass, and using recycled inputs can reduce energy requirements to make PV modules. It is critical to develop recycling and extended producer responsibility policies early, as done in Europe with PV Cycle. Development projects too should have end-of-life management strategies in place before commencing to ensure the environmental injustices seen in the global e-waste trade are not reproduced.

Session three: policies, institutions and financing mechanisms that would enable conditions for the development of SPIS in developing and emerging countries.

The IFC has conducted three in-depth and very different market assessments for solar-powered irrigation in Morocco, South Africa and Yemen. In Morocco, the government plans a subsidy programme to support the development and access to a market for solar irrigation. This is partially a response to the government's commitment to improve agricultural productivity, and partially to the gradual reduction of unsustainable subsidies for fossil fuels. In South Africa, the motivation to support solar irrigation is slightly different. The agriculture sector is dominated by commercial farms that are highly dependent on surface water resources. Solar irrigation could provide a solution to expand production and water productivity. Nevertheless, electricity rates in the agricultural sector are still competitive compared to the costs associated with solar irrigation. The situation is quite different in Yemen, which is confronted with extreme water scarcity, low public service provision and individual water pumping solutions. Solar irrigation there could play a significant contribution in improving access to basic water and energy services, and in increasing water use efficiency if combined with appropriate technologies and practices.

Rajasthan has acute irrigation water shortage, erratic rainfall, recurring droughts, deteriorating ground water, heavy dependence on agriculture for livelihoods, inefficient grid/diesel based irrigation methods, long queues for electricity connections; but excellent solar insolation. Rajasthan's composite off-grid irrigation package - creating water harvesting structures, drawing water through solar-powered pump, irrigating through drip, made available at large scale, in remote areas of the State - is conserving groundwater and conventional energy and creating livelihood for rural folks. The strategy has been to converge programs and subsidies via a **Solar Water Pumpset Programme**; develop regulatory framework; involve Central and State governments and field functionaries. Starting from just 34 installations in the year 2010-11, more than 10,000 have been installed in the next three years thereafter, between April 2011 and March 2014, making it the largest solar water pump program implemented in the world.

In **China** there are great potentials for developing and applying SPIS which are cost effective. 18 PV pilot areas have been created in Northeast and Northwest China, as well as in other locations, for irrigating pasture areas and crops. China is switching to policies in support of larger farms and subsidizing up to 50% of total investments. Despite existing policies and Chinese government promotion of SPIS, there is still more that could be done to scale up current efforts. For example, it was suggested that special funds be established for the application of SPIS in remote areas without electricity supply and where diesel costs are high, and the creation of more dedicated policy and financial incentives.

In **Chile**, there are institutions dedicated to scaling up total investments in irrigation and drainage projects and the use of Non-Conventional Renewable Energies (NCRE), across the country. The National irrigation commission (NIC), with a budget from the national treasury, is making a concerted effort to support small-scale farmers and build their capacities to better compete with big farmers. The idea of SPIS was first introduced in 2008. National biddings, following in 2012, helped to establish this technology. Management improvement programmes in 2015 aimed to improve the public management by linking goal attainment to employees' monetary rewards. The goal is that starting in 2015, 30% of projects must incorporate NCRE. Given its novelty, the task of promoting SPIS and upscaling pressurized irrigation systems, through improved policy and institutional arrangements, remains a challenge.

A pilot project plans to install, operate and maintain Solar Concentrated Photovoltaic Systems (CPV) for pumping and irrigation stations in the Kebili Governorate, in **Tunisia**, an area which receives high levels of direct sunlight. It is a pioneer initiative in which for the first time farmers are going to produce their own electricity from solar energy, under the framework of Tunisian law on self-production. This project supports the Agricultural Development Groups (ADG) of Kebili by providing a sustainable solution to manage their operating costs. Using the mechanism of self-production, the ADGs will partially reduce the amount of the bill from the Tunisian Company for Electricity and Gas (STEG) and this will also protect them from rising prices of fossil fuels, thus impacting the electricity tariffs in Tunisia. A contract for self-production has been established between the self-producing ADG and STEG. The contract also provides the opportunity for the ADG

to sell any excess energy produced back to the STEG when it produces surplus electricity.

An **initiative** by the International Water Management Institute (IWMI-TATA) in India, called SPARC, is helping farmers increase their incomes by 'growing' Solar Power as Remunerative Crop (SPaRC). This is done by giving farmers solar irrigation pumps with a power-purchase guarantee that megawatt-scale generators get. SPaRC income is free of risk from droughts, floods, pests and diseases; needs no fertiliser or pesticides and is an ideal 'farm income insurance.' Perverse farm subsidies on grid power have left all stakeholders worse off: electricity utilities bankrupt and aquifers depleted. Switching from grid-connected pumps to solar pumps would provide a smart way out of the deadweight of power subsidies. There is a risk that solar pumps may accelerate groundwater depletion but in the SPARC proposal, a credible power purchase guarantee makes it attractive to sell solar power to the grid rather than to use it to pump groundwater. A pre-condition to a power-purchase guarantee means surrendering to grid-connection.

Session four: capacity development, via training programs and tools, to promote SPIS in developing countries.

The Solar Electric Light Fund's (SELF's) long running solar drip irrigation project in **Benin** – since 2007- has been built on a steady process of capacity building for both the 400+ women growers in their 11 half-hectare gardens and their local NGO partner, ADESCA. From the beginning, SELF has provided training in solar and pump installation and maintenance and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has provided training in the installation and use of drip irrigation systems as well as all horticultural aspects of optimizing gardens to produce high value fruits and vegetables. In terms of building local organizational capacity, ADESCA started as a small inexperienced organization and through the assistance of SELF and others, has grown to be well-functioning and well-respected NGO that provides weekly assistance to all 11 gardens through the services of 3 solar and irrigation technicians and 3 agro-technicians. Beyond the technical and horticultural considerations, each of the gardening collectives has also been assisted in organizing themselves and marketing and in collecting their own fees for operating and sustaining their gardens. SELF continues to be involved by helping to optimize garden output to assure full sustain-

ability and by helping to enable ADESCA to raise its own funds for maintaining and expanding the program.

A 3.3 million euro SIDA-GIZ project started in response of the severe drought that hit Kenya in 2010. The goal is to improve self-sufficiency of food-aid dependent Arid and Semi-Arid Lands (ASAL) communities in Kenya through a combination of business development, capacity development and smart technologies. PV technologies are adopted in two communities for water abstraction and distribution, and their design adapted to local farming systems. A key for success is the incubation process which supports the development of, i) capacity at different institutional levels and, ii) entrepreneurs entities by creating linkages between dealers and vendors. Another important lesson learnt through **this project** is the need to adapt not only to bio-physical but also social context, as shown by the different level of adoption reached in the two targeted communities.

GAP is a regional development project in South-eastern Anatolia, Turkey that has been implementing the 'Utilization of Renewable Energy Resources and Increasing Energy Efficiency' since 2009. One of the main activities of the project is to demonstrate solar powered irrigation systems. Within this specific project component, four different pilot micro-scale irrigation systems have been installed, each with different technical characteristics and locations. Performance parameters of the installed micro-scale solar irrigation systems are currently being measured through data collection. Until 2018, GAP RDA will conduct further studies with an integrated resource management approach, to support the development of regional and national support programs and incentive schemes in the application of solar-powered irrigation systems and to improve energy efficiency in existing pump stations.

The **GIZ manual** and toolbox for solar-powered irrigation systems, a work in progress, is welcomed as an important element of capacity building in SPIS implementation. The information from the manual is based on lessons from stocktaking: the lack of know-how on demand based and site-specific design. It was primarily designed for those who give advice to agricultural enterprises or who offer financing products. The manual is not meant to be 'perfect" as its application is case-specific. It should be widely available and accessible for its use. Suggestions on how to update and/or improve the manual are welcomed.

5. Concluding Remarks and Recommendations for Next Steps

Until recently, solar irrigation did not generate significant interest among governments, farmers and development agencies. As investment costs are decreasing, however, solar irrigation is becoming a viable technology to address a range of issues: a) the access to groundwater resources for irrigation, especially in arid and semi-arid areas; b) the pressurization of water for localised irrigation; c) provision of energy, including for remote rural communities; d) the cost of grid supply, which is often subsidized heavily, and e) the mitigation of climate change impacts through low-carbon sources of energy. Nevertheless, there still are many questions to explore.

1. **What are the real costs and benefits of SPIS compared to other technologies?** The costs of infrastructure, water and energy vary from context to context. A wide variety of technology options are available, such as hybrid models of solar and diesel, or different designs and sizes of SPIS, that need to be adapted to the given context.

2. **What are appropriate business models to make SPIS viable?** During the workshop, a number of cases were presented, ranging from government grants for small-scale systems to grid-connected feed-in tariffs for the solar energy generated. There still is great scope to think about innovative and adaptive solutions, considering subsidy schemes, tax exemptions and other financial incentives, private funding, pay-as-you-go schemes, etc.

3. **What policies are needed to reduce the risks and enhance opportunities of SPIS development?** Policy briefs on the use of SPIS as well as detailed assessments of the policy environment can be useful in identifying incoherence between, and potentially distorting impacts of, different sectoral policies. Inter-sectoral collaboration of relevant Ministries is crucial when designing new policies to promote SPIS.

4. **How can the risk of groundwater depletion be addressed effectively?** There are concerns that the unregulated supply of energy may lead to groundwater overexploitation and wasteful use of water and energy resources. It thus requires a careful assessment of techno-economic feasibility, social and environmental impacts, policy and regulatory frameworks and cultural contexts in which solar irrigation is to be used. Combined systems – for example with drip irrigation – and subsidy can potentially play a regulatory role.

5. **How can small-holders benefit from SPIS technology?** The workshop demonstrated that SPIS is viable for commercial farms, like in Morocco. Whilst the SPIS technology itself is mature, the use of SPIS by small-scale farmers still faces several challenges, concerning the financing and usability of solar systems. There is a need to explore how this technology can become interesting for small-scale farmers, providing them with training on the operation and maintenance of the systems, as well as ensuring access to solar markets and relevant services.

6. **How can SPIS help to empower women and promote gender equity?** A focus on gender divisions of labour, responsibility, rights and interests can be considered as a means to start identifying differences between farmers as well as a way of highlighting women in their important role as food producers and water managers.

7. **What type of capacity development programmes are needed to support farmers, extension workers, local private sector and others?** Effective capacity development programmes are key to ensure that SPIS technology is appropriated and maintained by the users. More training material and tools would promote the uptake and upscaling of SPIS.

8. **What are the opportunities for knowledge exchange and technology transfer?** Countries, like India and China, already have several years of experience with SPIS technologies. Other countries could benefit significantly from South-South cooperation to share experiences and learn from each other.

The above conclusions mean that, in terms of recommendations for next steps/future work, priority should be given to fill the knowledge gap in terms of what makes SPIS work or not work and be sustainable.

a) Re: Big picture

- More in-depth case studies on SPIS performance should be carried out in order to compare and contrast SPIS life cycles/costs in different environments/countries, and also to consider integrated approaches such as the water-energy-food nexus and sustainable livelihoods;
- More assessments of cost-effective and harmonised M&E systems would provide a clearer picture for policy-makers and practitioners;
- Similarly, integrated approaches should be used in assessing the feasibility of SPIS and the feasibility and performance should consider both the farm and national levels;
- Additional discussion/exploration regarding what could be the drivers for integrated planning and design of SPIS since there is a lack of know-how on demand based and site-specific design.

b) Re: Financing mechanisms and business plans

- Much clearer guidelines on how to develop 'smart' subsidies are currently lacking. More broadly, much more work on different sound financial mechanisms/business plans is needed, perhaps based on a case-study approach to keep things close to and be able to draw lessons from reality;
- Further explorations/data needed regarding innovative business models, economic viability of the technology.

c) Policies and institutions

- More information is needed on current policies that seem to have worked in the promotion of sustainable SPIS;
- Innovative policies should be developed based on the results of the stock taking regarding financial mechanisms/ business plans, in particular 'smart subsidies'. One could also explore the possibility to certify SPIS;
- The same applies to institutional arrangements. Innovative arrangements such as PPPs and farmer groups, strengthening should be explored.

d) Capacity building

- More attention should be paid to capacity development of all relevant actors involved in SPIS implementation;
- A first step would be to improve the quality of information on SPIS in terms of performance, good practices and options;
- The development of information systems to make the above-mentioned information more accessible and transparent could be an option;
- Participants were requested to provide feedback on the draft of the GIZ handbook and toolbox – several committed to do so.