TOOLBOX ON SOLAR POWERED IRRIGATION SYSTEMS (SPIS)

POWERING AGRICULTURE:
AN ENERGY GRAND CHALLENGE FOR DEVELOPMENT

Module 8: Market

The Toolbox for SPIS Advisors is made possible through the global initiative Powering Agriculture: An Energy Grand Challenge for Development (PAEGC). In 2012, the United States Agency for International Development (USAID), the Swedish International Development Cooperation Agency (Sida), the German Federal Ministry for Economic Cooperation and Development (BMZ), Duke Energy, and the Overseas Private Investment Cooperation (OPIC) combined resources to create the PAEGC initiative. The objective of PAEGC is to support new and sustainable approaches to accelerate the development and deployment of clean energy solutions for increasing agriculture productivity and/or value for farmers and agribusinesses in developing countries and emerging regions that lack access to reliable, affordable clean energy.

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ABBREVIATIONS

USAID	United States Agency for International Development
PAEGC	Powering Agriculture: An Energy Grand Challenge for Development
Sida	Swedish International Development Cooperation Agency
BMZ	German Federal Ministry for Economic Cooperation and Development
OPIC	Overseas Private Investment Cooperation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
FAO	Food and Agriculture Organization of the United Nations
RISE	Regulatory Indicators for Sustainable Energy
SPIS	Solar Powered Irrigation Systems
SDGs	Sustainable Development Goals
DEMs	Digital Elevation Models
GIS	Geographical Information System
AEZs	Agro-ecological zones
GAEZ	Global Agro-ecological Zones
IIASA	International Institute for Applied Systems Analysis

MARKET

1. Identify a potential market
2. Evaluate geophysical parameters
3. Evaluate the business environment
4. Decide on market potential

1. MODULE AIM & ORIENTATION

The **MARKET** Module aims to provide high level theory on how to conduct market potential assessments for solar powered irrigation systems within a country or region. It provides parameters for consideration that may be applied by varying stakeholders (including private SPIS companies, policy-makers, financial institutions and development practitioners) in assessing the market potential of SPIS.

The Module recognizes that, in order to carry out the market potential assessment, the user must have identified a target area for evaluation. **Chapter 1: Identifying a potential market** provides factors for consideration in identifying the market and provides tools that can be used.

Additionally, the Module identifies two over-arching categories of parameters that are key to conducting a high-level assessment of the market potential for SPIS in a target country or region: 1) geophysical attributes and 2) business environment. **Chapters 2 – evaluate geophysical parameters** and **Chapter 3 – evaluate the business environment** expound on the specific parameters under each category. These chapters provide the definitions of the parameters and highlight why these parameters are considered key to the market assessment.

The parameters identified under geophysical attributes include: land cover land use, solar radiation, water availability, topography, crop and livestock and ambient temperature.

Parameters affecting the business environment include: government and non-governmental interventions, financing, cost and availability of alternative sources of power, level of SPIS related technical capacity, awareness levels of solar PV and irrigation technologies, significance of agriculture to the economy, land use rights and tenure and transport and communication infrastructure.

The Module is also supplemented by the **MARKET - Market Assessment Tool**, which considers basic geophysical parameters, and provides guidelines and weights to evaluate parameters that inform an enabling business environment for SPIS.

2. IDENTIFYING TARGET MARKETS

Identifying a market of interest is a pre-cursor to assessing the market's potential for SPIS. Key to the identification process, and which affects the evaluation of the market, is **WHO** is interested in the promotion and adoption of SPIS, and **WHY** they are interested. For instance, a private SPIS company may be looking to break into new markets, developing agencies may want to advance sustainable development goals (SDGs) within a region, and policy makers and government agencies may be interested in growing or diversifying their country's economy. The parameters presented in this module and their associated weights, may therefore be seen as parameters for both market assessment and gap analysis.

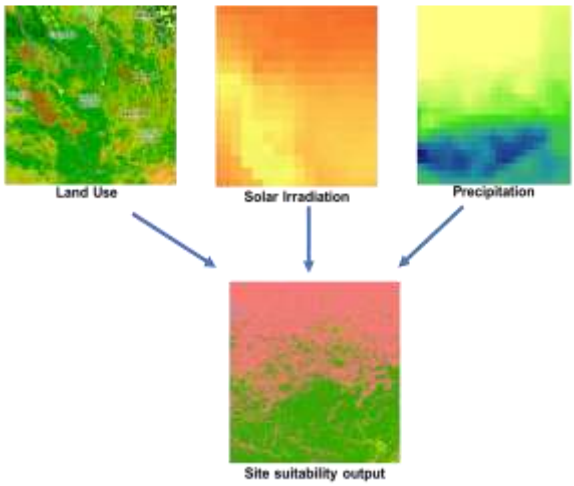
Identification of target markets for SPIS involves the evaluation of numerous parameters. These may include various geo-physical and business environment parameters. For stakeholders who do not have a set target market in mind or who merely want a high-level overview of potential areas where systems could be set up or utilized, this could prove to be a daunting and time-consuming task.

As the guidelines provided in Chapters 2 and 3 help to determine whether a pre-identified location has potential for SPIS rather than identify a target market, this chapter aims to ease the identification process by providing some key considerations in market identification.

Three geophysical parameters are considered core to the viability of SPIS within an area: solar irradiation, precipitation and land cover/land use. These parameters are highlighted below and elaborated on in the geophysical parameter section of the module.

- **Solar irradiation** refers to the energy incident per unit area on the earth's surface measured in Kilowatt hour per square meter (kWh/m^2). While advancements in solar PV technologies have enabled tapping into low levels of irradiation, it is generally concluded that the lower the irradiation levels, the less the economic viability of SPIS due to prohibitive capital costs.
- **Precipitation** is considered a core factor based on the premise that areas receiving rainfall above a certain rain threshold do not require irrigation. For instance, sugarcane is seen to have the highest seasonal water requirement of 1500-2500mm translating to an estimated average water requirement of 200mm per month according to the FAO. It may therefore be said that, areas receiving higher rainfall volumes than 200mm per month have limited application viability for SPIS.
- **Land cover/land use** allows for the elimination of unsuitable areas including but not limited to forests, urban settlements and snow-covered areas.

Suitability maps provide a high-level overview of countries or regions that have large land areas that are suitable for solar powered irrigation. This can act as a guide for stakeholders to conduct further evaluation on geophysical parameters and business parameters within the identified countries.



Core geophysical parameters for suitability mapping

(Source: EED Advisory, Kenia, 2018)

OUTCOME / PRODUCT

- Target market for SPIS

DATA REQUIREMENTS

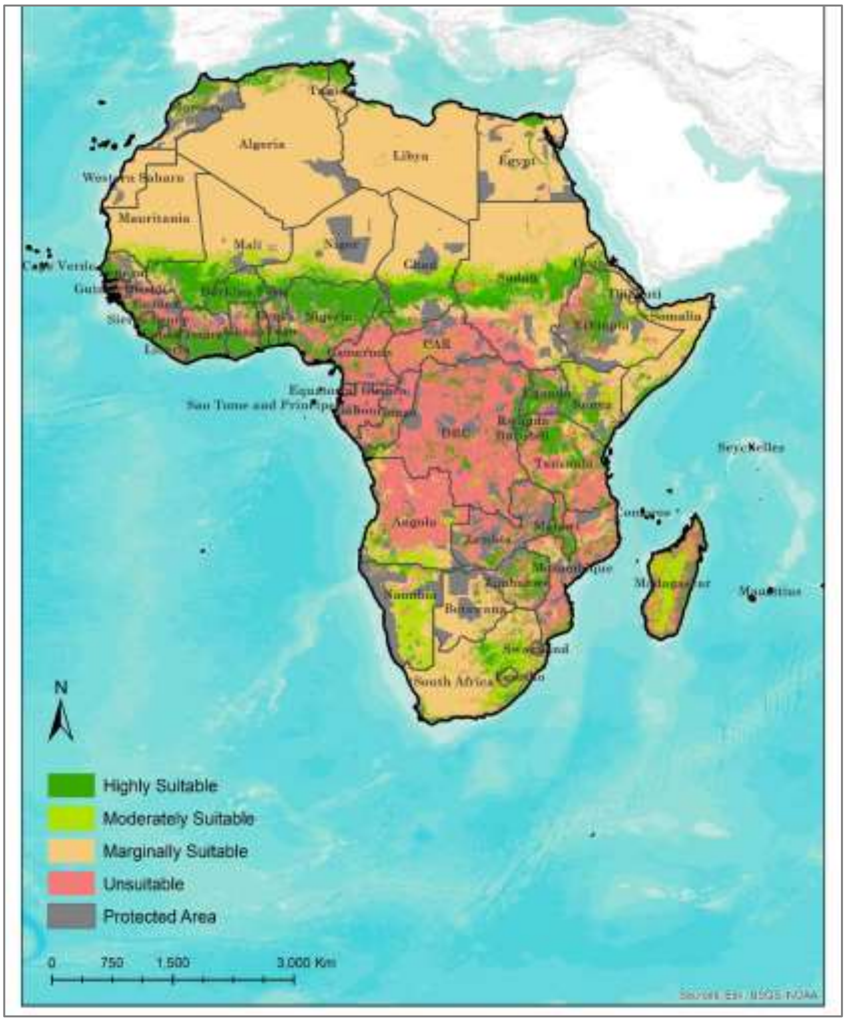
- Precipitation data
- Land cover land use data
- Solar irradiation data

PEOPLE / STAKEHOLDER

- Private SPIS companies
- Policy-makers
- Financial institutions
- Development practitioners
- National and local governments

IMPORTANT ISSUES

- The guidelines provided in the follow up chapters help to determine whether a pre-identified location has potential for SPIS, rather than identify a target market.
- The Suitability Maps tool provides high levels analysis by layering solar irradiation data, precipitation and land cover-land use.



Sample suitability map for SPIS (Esri, USGS, NOAA data)

(Source: EED Advisory, Kenia, 2018)

3. EVALUATION OF GEOPHYSICAL PARAMETERS

Several geophysical parameters can be used to assess SPIS markets. This module highlights 3 that are crucial to the viability of SPIS applications as discussed in Chapter 1: Land cover-land use, solar irradiation and precipitation (under water availability). If the state of these three parameters is unfavourable in the area under assessment, SPIS is unlikely to be practical. An additional 4 parameters that are key to the market assessment for SPIS are also identified – these do not affect the viability of SPIS; they affect the success of SPIS adoption on a case by case basis. The 7 parameters are expounded on below.

LAND COVER/ LAND USE

Land Cover refers to the physical and biological cover over the surface of the earth including water, bare surfaces, forests, and artificial structures among others. Land use on the other hand refers to how people utilize the land whether for recreation, agriculture or wildlife habitats among others.

Land cover/land use is one of the fundamental parameters to be considered during the identification of potential markets for SPIS as it helps determine feasible locations for agriculture from which other parameters may be considered. Land cover is measured either through direct field observations or through remote sensing techniques involving the analysis of satellite and aerial imagery. Based on the land cover analysis, land use data can be inferred through ancillary data. The data assists decision makers and stakeholders in cross-cutting sectors to understand the dynamics of a changing environment and ensure sustainable development.

Land cover data typically consists of eight classes including wetlands, water bodies, urban, shrubs, grassland, forests, bare land and agricultural land. These may, however, be classified into varying classes depending on the source of data. The FAO framework for land suitability for instance, divides land into four classes ranging from highly suitable land for agriculture (S1) to currently not suitable land (S4). For the 8 classes listed above, 'agricultural land' can be classified as highly suitable (S1) and 'grassland', which requires land clearing and levelling, as moderately suitable (S2). 'Shrub land' and 'bare land', which require higher initial investment for land preparation can be classified as marginally suitable (S3) while 'forest', 'water', 'urban', and 'wetlands' can be categorized as not suitable (S4).

In assessing market potential for SPIS for a given country or region, stakeholders need to assess the irrigation viability of their target location from a land cover-land use perspective. For example, areas that are mostly classified as S1 land would have higher potential for SPIS compared to those that are highly urbanized or classified as wetlands.

It should be noted that desktop analysis of land cover/land use data through application of remote sensing techniques should be followed by ground truthing to ascertain the land cover/land use in the selected regions prior to investment.

OUTCOME/PRODUCT

- Classification of land based on agricultural suitability
- Selection of optimal sites to promote solar powered irrigation

DATA/REQUIREMENTS

- Land use - land cover data
- Land suitability classification frameworks (e.g. FAO)

PEOPLE/STAKEHOLDERS

- Land Surveyors
- Remote sensing analysts

- Government land ministries

IMPORTANT ISSUES

It is always important to follow up desktop analysis of landcover with actual on-ground visits to the selected areas. Satellite and aerial images are typically very accurate however if one is not using up to date datasets it becomes important to verify the selection.

SOLAR IRRADIATION

Solar irradiation is a key factor in gauging the market potential of SPIS within a region. It refers to the amount of energy incident per unit area on the earth's surface in units of watts hours per square meter. PV systems use Global Horizontal Irradiation (GHI) which is the total amount of radiation received from above by a horizontal surface. GHI consists of both Direct Normal Irradiation (DNI) – the amount of solar radiation received per unit area by a surface that is always held perpendicular to the incoming rays and; Diffuse Horizontal Irradiation (DHI) – the amount of radiation received per unit area by a surface that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere.

Solar radiation can be categorized into four classes: levels less than 2.6kWh/m^2 are classified as low solar radiation while solar irradiance between 2.6-3kWh/m^2 is moderate solar radiation; irradiance of between 3-4kWh/m^2 is high solar radiation and irradiance higher than 4kWh/m^2 is very high radiation. It is important to note that the classification is used for purposes of distinguishing the efficiency of systems as advances in solar technologies have allowed for the set-up of systems in almost all areas that receive radiation. In areas of low radiation, system efficiency will be compromised due to lower panel output. Additionally, set up of solar panels in regions of low solar radiation could lead to high set up costs resulting from the use of a greater number of panels to generate the same output as regions with higher insolation. It is therefore noted that, because of technological advances, solar irradiation is more of an economic consideration than a question of technical feasibility.

OUTCOME / PRODUCT

- Classification of regions based on GHI or PV system output
- Identification of optimal sites for SPIS

DATA REQUIREMENTS

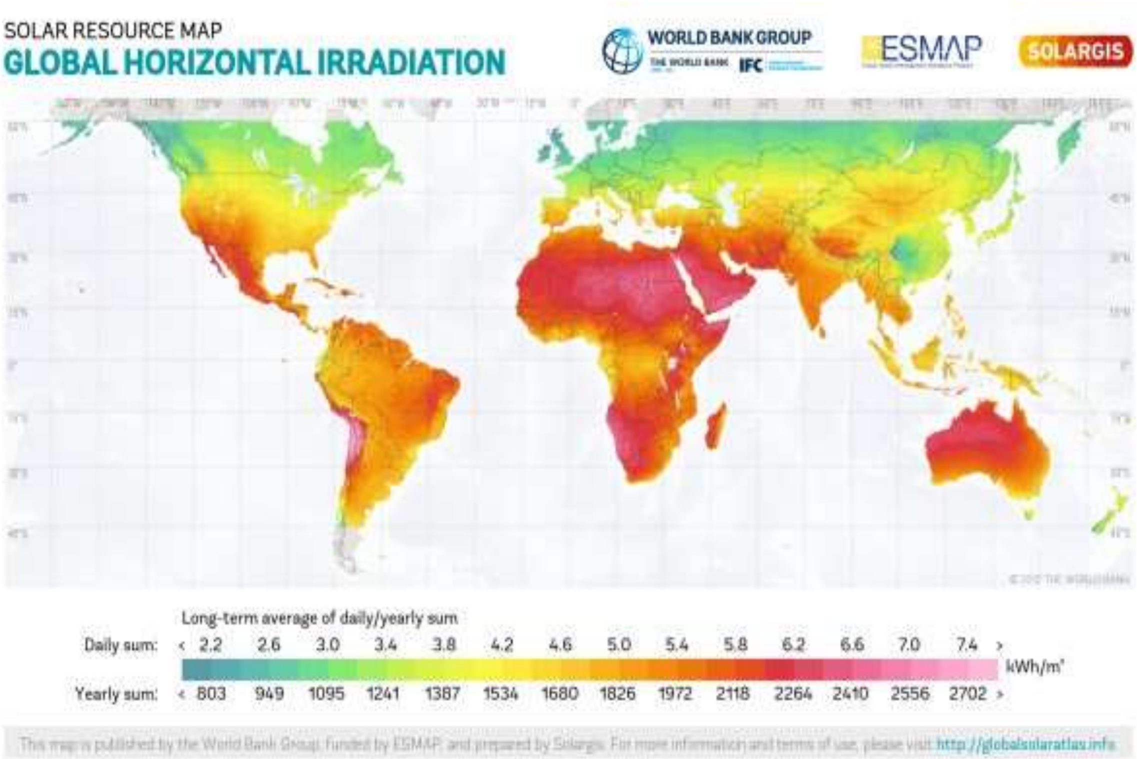
- Global horizontal irradiation data

PEOPLE / STAKEHOLDERS

- Solar PV system installers
- Meteorological service providers
- Solar equipment suppliers

IMPORTANT ISSUES

- There are various other factors that affect the functionality of a PV system in addition to solar irradiance. Two of the most important include temperature and aspect which are further expounded on in the ambient temperature and topography sections of the module.



Global Horizontal Solar Irradiation

(Source: World Bank Group, 2018)

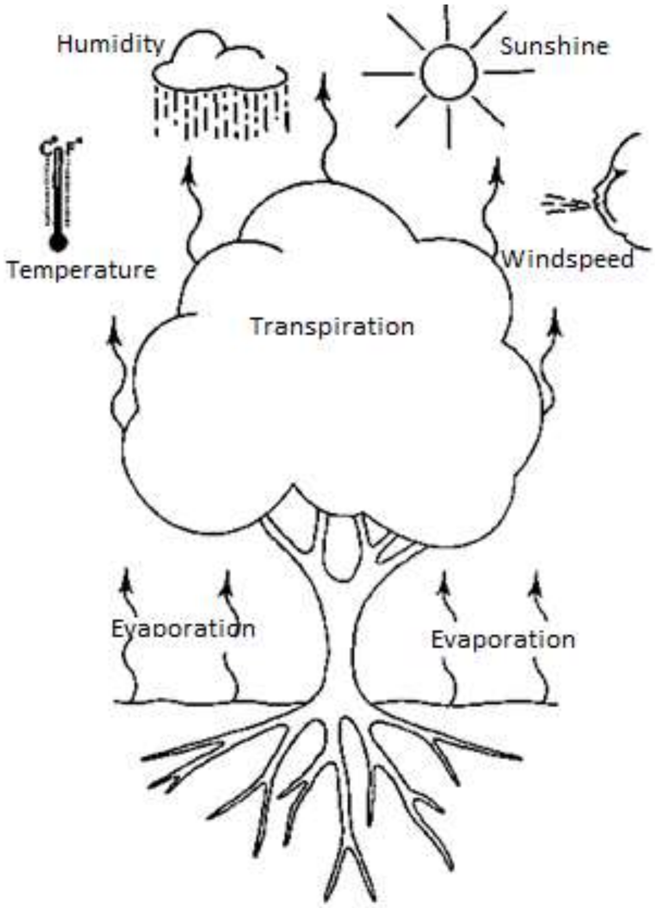
WATER AVAILABILITY

This parameter investigates the amount and quality of water available for irrigation at a potential SPIS area. Irrigation water requirements depend on the balance of the crop water demand against the water availability.

Crop water demand may generally be defined as the amount of water needed for a plant to live and grow and is measured in milimeters per day, month or season. It is affected by various factors including:

1. ***Climatic conditions*** including temperature, humidity and windspeeds. Consequently, water needs for one crop will vary with varying climatic conditions, with the highest demand seen in areas that are hot, dry, windy and sunny;
2. ***The type of crop*** affects its water demand, both in the short term (daily water demand) and the longer term (seasonal water demand);
3. ***The stage of growth*** for a particular crop also affects its water demand. For instance, a mature maize plant may demand more water than one at the shooting stage. Local data on crop water needs is often available with agricultural extension offices. The Water requirement tool under the **SAFEGUARD WATER Module** as well as resources provided by the FAO may also be used in estimating water demand.

Water availability for crop growth is dependent on three main sources: precipitation, ground water and surface water resources.



Major climatic factors affecting crop water demand

(Source: Food and Agriculture Organization of the United Nations)

Precipitation, the amount of rainfall received in an area, has a direct influence on the need for irrigation within an area. If the amount of precipitation received within a region is enough to meet the water demands of the crops grown, irrigation is not necessary; when precipitation volumes are not adequate, water supply through irrigation from ground or surface water resources becomes critical for crop growth. The adequacy of precipitation may be evaluated by comparing the effective rainfall against the crop water demand using the **SAFEGUARD WATER – Water Requirement Tool**.

Effective rainfall – this looks at the amount of water from rainfall received within an area that is available for utilization by crops. This volume is affected by various factors including soil texture and structure, climate, topography and the depth of crops' root zone[1] among others. These factors consequently affect the rate of surface run-off and water percolation / infiltration beyond the root zone. The amount of rainwater retained in the root zone of plants that can be used by plants is referred to as effective rainfall. Most countries have developed tools to determine effective precipitation. However, in the absence of data (e.g. lack of prevailing soil type, rainfall reliability and topography data), the FAO provides rough estimates for effective rainfall per rainfall received.

Ground and surface water sources – the need to tap into these resources to meet the water deficit from rainfall introduces the market potential for SPIS. However, it is important to note that factors such as water source proximity and yield, aquifer recharge rates, water quality, water permits or rights required for abstraction among others must be taken into consideration when identifying and designing SPIS for specific areas. Water source yield, for example, has a direct influence on the type of irrigation method selected. In situations of inadequate water supply, sensitive soils or poor quality water (sedimentation, salinity and water hardness) appropriate methods like drip and sprinkler irrigation are preferred. Surface irrigation is preferred if the irrigation water contains large amounts of sediment which may clog the drip or sprinkler irrigation systems. This is expounded on in the **DESIGN module**.

OUTCOME / PRODUCT

- Classification of regions based on crop water demand vs effective rainfall.
- Identification of ground and surface water sources.

DATA REQUIREMENTS

- Monthly Precipitation data
- Data on surface water bodies and ground water aquifer systems
- Water licensing and abstraction rights
- Water source flow rates
- Crop water demand

PEOPLE / STAKEHOLDERS

- Meteorological Service Providers
- Water resource management authorities and abstraction licensing authorities
- Agricultural advisors and extension officers
- Irrigation boards and organisations

IMPORTANT ISSUES

- Desktop analysis of precipitation and ground and surface water sources should be followed by verification of data from the relevant government bodies (e.g. national meteorological centres and water resources management authorities) prior to investment.
- Determination of crop water requirements can be done using the

[1] Rootzone may be defined as the region within which a plant's roots extend within the soil, and from which it can absorb water.

WATER REQUIREMENT TOOL in the Safeguard water module.

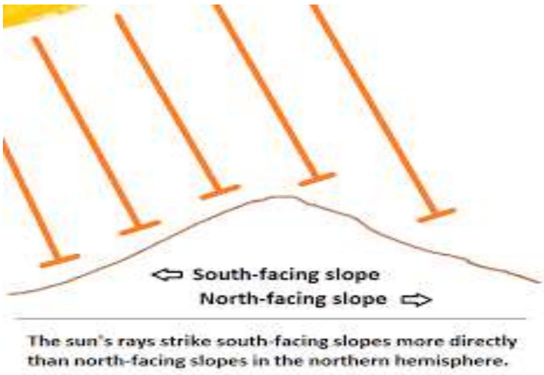
- Adoption of SPIS should ensure sustainable abstraction of water from identified water sources. The SAFEGUARD WATER module provides information on water resource management and sustainable water abstraction and provides a water resource management checklist.

TOPOGRAPHY

Topography describes the elevation and the relief features on the earth's surface. Relief features include both natural and man-made landforms such as roads, hills, valleys, railways among others. Key topographical features in evaluating market potential for SPIS are slope and aspect.

Slope is a measure of the change of elevation over a certain distance. It answers the question of how steep an area is and is a determining factor for the type of irrigation system to promote. This in turn determines the cost and labour requirement (e.g. erosion control practice and water conveyance channels). For instance, surface irrigation is more suitable in undulating areas and is cheaper compared to sprinkler and drip irrigation which are more suited on steeper or unevenly sloping land. Therefore, coupling steep lands with a factor like low access to finance (discussed in Chapter 3) would lead to weak market potential for SPIS.

Aspect describes the direction which a slope faces. It is especially relevant for systems located in higher latitudes and rarely affects systems close to or along the equator. Aspect influences the amount of solar radiation that the slope receives as well as the daily range of temperature and the relative humidity on the slope.



The effect of aspect

(Source: http://www.explorenaturalcommunities.org)

Generally, more direct sunlight tends to fall on the south and southwest slopes while North aspects of slopes are more shaded in the northern hemisphere. The converse is true in the southern hemisphere where more direct sunlight tends to fall on the north and northwest slopes

Topographic analysis for potential SPIS sites can be determined through use of topographic maps that depict the physical configuration of the earth's surface using contour lines as wells as symbols for man-made and natural features. Users can also use Digital Elevation Models (DEMs) that are specialized databases that represent the relief of a surface between points of known elevation. DEMs can be used on Geographical Information System (GIS) platforms. This should be followed by a ground-truthing exercise to determine the exact slope and aspect of the area of interest.

OUTCOME/PRODUCT

- Determination of slope and aspect of potential SPIS markets
- Selection of suitable irrigation systems based on the topography of the potential SPIS market

DATA REQUIREMENT

- Topographic Maps
- Digital Elevation Models(DEMs)

PEOPLE/STAKEHOLDER

- Lands and Survey Authorities

IMPORTANT ISSUES

- Care must be taken when designing irrigation systems on steep slopes as such areas are prone to erosion and runoff.

CROPS AND LIVESTOCK

An overview of the prevailing types of crops and/or livestock in the country or region of interest serves to understand which SPIS are most suitable and is also indicative of the market potential for SPIS technology. This is particularly relevant for SPIS system suppliers and entities seeking to promote adoption of SPIS by farmers. This information can be sourced from government ministries in charge of agriculture, global research studies on cultivated areas, FAO databases on crop cultivation among others.

Additionally, stakeholders interested in promoting or setting up SPIS schemes can use agro-ecological zones (AEZs) to determine the most suitable crops to be cultivated and animals to be reared in an area. AEZs define areas based on combinations of soil, landform and climatic characteristics and match suitable crops and animals to regions. The zones can also be used to determine the potential yields of the main crops grown within the zone thus helping with income projections of the target market. As discussed under Finance in Chapter 3, access to finance is a key parameter in evaluating a market's potential for SPIS.

The Global Agro-ecological Zones (GAEZ) portal by FAO and the International Institute for Applied Systems Analysis (IIASA) provide a comprehensive online portal with details on land resources, agro-climatic resources, suitability and potential yield, actual yield and production and yield and production gaps. Stakeholders interested in SPIS can refer to this or similar tools to determine important characteristics that influence the type of crops or livestock in an area.

OUTCOME/PRODUCT

- List of crops grown and animals reared in selected countries or regions
- AEZ classification for selected areas
- Potential crop/livestock yield within the area of interest

DATA REQUIREMENT

- Global AEZ by FAO and the International Institute for Applied Systems Analysis

PEOPLE/STAKEHOLDERS

- Ministry of Agriculture

AMBIENT TEMPERATURE

As the name suggests, this parameter looks at the temperature of the areas surroundings. This has two main effects on SPIS potential: **1) affects the efficiency of SPIS and 2) affects the crops and livestock found in an area**.

On **efficiency of SPIS**, temperature is a key factor in the design of pumping systems as it affects the functionality and life span of solar PV equipment. The flow of electricity and the voltage output of solar panels depend linearly on the operating temperature of the panels. Lower temperatures produce reduced resistance to electricity flow resulting in higher voltage outputs; higher temperatures increase resistance and subsequently lead to lower voltage outputs. High ambient temperatures also affect the performance of the system's inverter by reducing its frequency which in turn reduces its efficiency and the flow rate of the pump.

Due to the variability of climate in different regions, most panels do not operate under ideal temperature conditions. To correct this, panels in hotter regions of the world are often designed with cooling systems to keep the panels within certain temperatures. Additionally, PV systems in different temperature environments must be sized to ensure that the output voltage is not too high, which could damage the equipment.

The range of crops and livestock that are suitable in an area is often affected by ambient air temperature. Analysis of thermal regimes using agro-ecological zoning discussed in the previous section can reveal crops and livestock suited to a region based on its temperature. This may then inform the need for SPIS for the said region.

OUTCOME/PRODUCT

- Determination of ambient temperatures in potential SPIS markets
- Selection of suitable solar technology based on temperature regimes
- Determination of suitable crops and livestock based on temperatures

DATA REQUIREMENT

- Global AEZ by FAO and the International Institute for Applied Systems Analysis

PEOPLE/STAKEHOLDERS

- Meteorological service providers

IMPORTANT ISSUES

- Panel selection should be done with ambient air temperature in mind to maximize efficiency of the system and to ensure adequate voltage output.

DEMOGRAPHICS

An understanding of demographic characteristics including population density, age, migration levels and patterns and household income provide additional information when making decisions on potential SPIS markets. These characteristics can be used as proxy indicators of poverty levels, labour availability, prevailing agricultural practices, urban settlements among others.

This parameter cannot be used standalone, but in combination with other parameters can assist in a deeper understanding of social dynamics and cultural conditions for a target region. For example, as earlier mentioned, coupling topography with poverty levels could help infer market potential. Also, analysis of population density and land cover-land use data could highlight densely populated areas or urban settlements which could be a factor in determining the viability of a potential SPIS market. SPIS sites cannot be in densely populated urban settlements however they could be located close to such areas as they provide market for produce.

Evaluating demographic characteristics such as household income alongside business parameters such as financing and incidences of poverty can serve to highlight the capability of households to take up SPIS systems.

OUTCOME/INCOME

- Correlation of demographic characteristics with SPIS geophysical and business parameters to identify relevant issues in determining potential SPIS markets

DATA REQUIREMENTS

- Census Reports
- Satellite imagery on global population

PEOPLE/STAKEHOLDERS

- Government Ministries including Ministries of labour and migration
- Statisticians

4. EVALUATION OF THE BUSINESS ENVIRONMENT

While adoption of SPIS within a region may be feasible from a geophysical perspective, the operative business environment plays a key role in the actual uptake of the technology. There are various factors that contribute to an enabling environment for the adoption of SPIS, and whose significance varies with the entity promoting SPIS adoption. The 9 parameters presented in this chapter are seen to play the most significant role.

GOVERNMENT INTERVENTIONS

Government interventions as a business environment parameter for SPIS looks at policies, rules and regulations that govern the irrigation and solar sectors in a country.

Together they provide a complete picture of the strength and breadth of government support and the actions taken to turn that support into reality. Typically, government policies and regulations vary from country to country, but can be assessed in terms of:

1. ***promotion of renewable energy systems*** specifically solar,
2. ***programs promoting irrigation devices*** and in particular SPIS and
3. ***presence of relevant government bodies*** that are providing support to the sector.

An important indicator for an effective policy and regulatory environment for SPIS is the existence of programs to implement and support the frameworks in place. For instance, if the programs have an indicative or projected budget and target, it signals the government's commitment to implementing the policies. Additionally, presence of government bodies to keep track of the progress in implementation and adherence to standards are good indications of implementation of policies and regulations.

By way of example, contrast country X that has a clause in their Energy Act on the country adopting renewable sources of energy including solar to country Y that has the same clause but has also developed Solar PV regulations, has set standards for equipment and has designed a subsidy program to promote adoption of SPIS among small scale farmers. Country Y is seen to have a better environment for promotion and adoption of SPIS.

OUTCOME/PRODUCT

- Determine the regulatory landscape of a region and its appetite to SPIS

DATA/REQUIREMENTS

- Data on government regulations and policies in solar and irrigation equipment
- List of government programs that promote SPIS
- List of government bodies involved in solar and/or irrigation
- World Bank's Regulatory indicators for sustainable energy (RISE) help in comparing national policy and regulatory frameworks for sustainable energy

PEOPLE/STAKEHOLDERS

- National and local governments
- Energy and irrigation ministries

IMPORTANT ISSUES

Some of the policies may cut across different government ministries. For example, a policy on trade may remove custom duty on solar. This would still be a government intervention but focused on finance. This is covered in the financing parameter of the business environment module.

DEVELOPMENT ORGANIZATIONS INTERVENTIONS

Development organizations may introduce an agenda or programs that present a significant influence on the adoption of SPIS within a country or region. Most of these organizations build their agendas around the Sustainable Development Goals (SDGs) necessitating an understanding of SPIS within the SDGs. SPIS falls in an interesting cross-section of several SDGs including:

- ***SDG #2*** which is aimed at ending hunger, achieving food security and improved nutrition and promoting sustainable agriculture;
- ***SDG #7*** on ensuring access to affordable, reliable, sustainable and modern energy for all and;
- ***SDG #13*** on taking urgent action to combat climate change and its actions.

It is therefore important to understand the target areas of action for development organizations working in a country or region to identify opportunities for SPIS.

Development organizations may vary as civil society organizations, research institutions, and bilateral and multilateral development organizations. It is observed that involvement of these organizations in SPIS at a localized level is often well positioned to bring the various elements needed to promote SPIS uptake together in a systematic, integrated way to empower individual actors and create market momentum.

Ordinarily, development organizations vary from country to country, but they can be assessed in terms of:

i) organizations that have national programs that promote adoption of irrigation systems

ii) development agencies that have national programs that specifically promote adoption of SPIS.

Development organizations differ in knowledge, experience, needs and capacity. They each assess the market situation differently, and their specific areas of expertise can address different market development hurdles. Taken together, a comprehensive picture of the market potential for SPIS emerges, including the barriers that currently impede its adoption and the incentives needed to move forward.

Countries or regions with national interventions on irrigation and/or SPIS are more likely to create a positive atmosphere which is more likey to work in to the advantage of SPIS uptake.

OUTCOME / PRODUCT

- Assessment of national development agencies interventions in irrigation and SPIS within a country or region.

DATA REQUIREMENTS

- List of possible development agencies in irrigation and/solar system

PEOPLE / STAKEHOLDERS

- Civil society organizations
- Research institutions
- Bilateral organizations
- Multilateral organizations

IMPORTANT ISSUES

- For an agenda or program to be a significant parameter in influencing the SPIS market potential, it needs to be of a size significant enough to shift market dynamics. For instance, a program implemented at a national scale is likely to have a more significant impact on SPIS operations than one implemented at a very localized level.

FINANCING

Uptake of SPIS is associated with substantial upfront costs which often limits their adoption, especially among low income farmers. For some, farming is the only source of livelihood and investing in SPIS equipment would take away finances from other household needs. The ability to meet the high capital cost of SPIS is therefore seen as a significant barrier to SPIS even though its lifecycle costs are lower than alternative solutions. Facilitating adoption of these systems would therefore require support in terms of financing.

Some governments, development agencies and the private sector have developed various mechanisms in different regions to offer this support. Financing for SPIS can be looked at from two perspectives:

a) End-users financial ability

b) Availability of financial institutional support

End-users financial ability

This parameter assesses the purchasing capacity of the end-users as a key indicator of the market potential of SPIS within a region. It helps determine the amount of capital available and/or accessible to an end-user, including options for external market based financing. This informs their financial empowerment and consequently, ability to purchase SPIS.

A population's general financial ability and access to financial services may be inferred from factors such as incidence of poverty, income and employment indices and the prevalence of financial institutions within an area. Other factors could include number of individual accounts in financial institutions, value of customer savings and borrowing rates at financial institutions, and ease of access to loans. The Gross National Income (GNI) may also be used.

Availability of institutional support

Institutional support can either be from government, development agencies, or private sector. These influence the rate at which an end-user can raise external finance. Government financial support may be in terms of subsidies, tax incentives, rebates, customs and duty incentives. Typically, government support is most effective at the early stages of market development and is phased out as markets mature. Development agencies may also offer subsidies, result based financing (RBF), grants and soft loans. The more the mechanisms available in a country or region the better for the market potential.

It is also critical to evaluate financing mechanisms towards competing sources of power for irrigation. For instance, government support may, directly or indirectly, promote the use of competing sources of fuel such as diesel or electricity. For instance, a rural electrification subsidy or subsidizing of butane gas for cooking may negate adoption of SPIS in a country or region if the recurrent costs of energy are insignificant compared to the upfront cost of SPIS.

OUTCOME / PRODUCT

- Assessment of the financial landscape of the region

DATA REQUIREMENTS

- Incidence of poverty among the rural population
- Ratio of formal bank accounts to population in rural areas
- Value of savings and access to loans among the rural population
- GNI per capita
- Employment figures
- Government fiscal policy on solar and irrigation
- Development agency that finance irrigation and SPIS

PEOPLE / STAKEHOLDERS

- Government
- Civil society organizations
- Research institutions
- Bilateral organizations
- Multilateral organizations
- Financial institutions

IMPORTANT ISSUES

- Evaluation of the financial landscape should go beyond the financial empowerment levels of end users (individual financial ability and available institutional support) to include financing options for competing sources of power for irrigation.

AVAILABILITY AND COST OF ALTERNATIVE FUELS

The economic viability of SPIS within a region may be affected by the availability and cost of alternative fuels. In most cases for the same size of pump, SPIS normally require higher initial capital investment as compared to either diesel or grid-electricity powered pumps. However, the latter two have life-cycle fuel costs while SPIS does not hence the need to evaluate the life-cycle fuel savings and payback periods of SPIS within the target market.

An availability assessment should determine the quantity and quality of alternative fuels for water pumping. For instance, if a country or region is exploiting fossil fuels, it is likely that fossil fuel based power will compete favourably against solar. For electricity, the rural electrification rate can help to determine the availability of electricity for pumping. Holding other factors constant, the more electrified a rural area is (where most farming is carried out), the higher the likelihood that a notable proportion of the population will use electricity for pumping. The cost and quality of the electricity, however, are among the factors that affect actual use of electricity for irrigation. For instance, there might be high penetration rates but frequent outages, that make electricity unreliable,present an opportunity for SPIS.

In some regions, wind can also be seen as a competing resource for irrigation pumping. Some studies have shown that wind applicability and economic viablility of wind competes with solar power at speeds greater than 8 m/s.

In addition to the financing considerations presented in the previous section, cost of alternative fuels may have a significant effect on the potential of SPIS within a market. One way to conduct a **cost assessment** of available fuels is to standardize the unit of measure– determine the per unit market prices (cost / kwh) of the competing fuels in the market. This allows estimation of the amount of fuel needed for a specific pump size, and consequently the cost to power the pump. It is often observed that the lower the costs of alternative fuel compared to the capital investment of acquiring SPIS, the less the market potential of SPIS.

OUTCOME / PRODUCT

- Availability of alternative fuels in the region or country
- Cost analysis per unit of the alternatives

DATA REQUIREMENTS

- Data on energy resources in the country
- Per unit market prices of diesel, petrol
- Market prices of electricity per kwh
- Electrification rate in rural areas
- Quality of electricity in the rural areas

PEOPLE / STAKEHOLDERS

- Government agencies in energy

IMPORTANT ISSUES

- It is important to determine if there are any government subsidies offered to the alternative fuels presented. These may be a deterrent to uptake SPIS in the country or region.

TECHNICAL CAPACITY

A successful intervention to promote and upscale adoption of SPIS would require technical capacity for solar solution providers to design, implement and maintain the systems. Lack of such capacity makes it difficult to sustain the SPIS market in the country or region. The availability of this capacity is especially crucial at the infancy stages of a market – this is the time when end users are introduced to the technology and when first impressions are critical to long-term adoption. As an example, poor installations leading to frequent SPIS breakdowns and lack of timely repairs on SPIS may result in a negative attitude towards SPIS by end users, limiting the market potential for SPIS.

Technical capacity evaluates the availability of skilled personnel for installation and maintenance of SPIS. It may be inferred from:

i) availability of training courses on solar systems;
ii) number of accredited institutions offering solar courses and;
iii) licensing of solar technicians.

In addition to the presence of skilled technicians, presence of a licensing and regulating body for SPIS practitioners is key. Licensing indicates the existence of standards of professionalism and a regulator for the market. For instance the energy regulator in Kenya – Energy Regulatory Commission (ERC) – registers all solar practitioners who have to adhere to a certain code of conduct and standards. It also maintains a members database that acts as a pool for obtaining qualified technicians for installation and maintenance of solar PV systems.

OUTCOME/PRODUCT

- Assessment of level of skilled capacity in the country/region

DATA REQUIREMENT

- List of solar training institutes and courses
- List of licensed technicians

PEOPLE/STAKEHOLDER

- Energy agencies

AWARENESS OF SOLAR PV TECHNOLOGY

General awareness of solar technologies (solar lighting and solar water heating) and irrigation systems, mainly pumps, may be indicative of a population's willingness to adopt similar technologies. The converse is also likely - lack of knowledge and information about solar technologies can pose a barrier to public discussion and decision making on use of solar as an alternative energy solution. By way of example, high levels of awareness among end-users about the benefits, long-term costs and payback periods, and performance of solar lighting compared to use of alternative fuels for lighting (e.g. kerosene) can act as an enabler in the adoption of SPIS. Lack of exposure to real-life solar PV installations, on the other hand, is likely to lead to low confidence in new solar technologies.

Awareness of solar PV technologies may also affect the public's access to market based financing. For instance, financial service providers who are not well-versed with SPIS and its related benefits may be hesitant in disbursing loans for their acquisition, and where loans are available, they may be under limiting conditions (e.g. high interest rates). This hinders the technology adoption due to lack of financing for the high capital costs associated with SPIS.

The level of awareness of SPIS in a region or country can be deduced from various factors including:

1. **Trends in adoption of irrigation pumps**.
    a. Presence of suppliers and distributors of global brands of irrigation pumps and their associated spare parts may be considered a key indicator of market potential. This is especially relevant for SPIS suppliers where presence and growth rate of competitors may be indicative of the markets appetite for SPIS.
2. **The percentage of solar energy in a country's energy mix**
    a. A significant proportion of solar power may be indicating of an enabling environment for adoption of solar PV technologies.
3. **Solar PV adoption trends** over a period of time, say 5 years can be assessed to determine uptake of the technology in the country/region.

OUTCOME/PRODUCT

- Assessment of awareness level of the country/region

DATA REQUIREMENT

- Trends in solar technology adoption
- Number of distributors and suppliers of global brands of irrigation pumps
- Number and distributors of global brands of solar equipment
- Solar energy proportion to the country's energy mix

PEOPLE/STAKEHOLDERS

- Government bodies in energy and trade
- Research institutions

SIGNIFICANCE OF AGRICULTURE IN THE LOCAL ECONOMY

This parameter examines the contribution of agriculture to a target area's economy. Relevant indicators would include:

1. ***Proportion of population engaged in agriculture*** – the higher the proportion of the population practicing agriculture, the higher the probability of good market potential for SPIS. This is because there is a higher population that may be seeking to ensure their water security for farming. Also, there is a higher probability of favorable government and non-governmental interventions to ensure employment opportunities within the sector.
2. ***Existing irrigation culture*** – practice of irrigation farming that is mostly powered through fossil fuels and electricity presents a ready market to shift to solar energy.
3. ***Proportion of the GDP attributed to agriculture*** – regions with a significant proportion of GDP attributed to agriculture are likely to offer an attractive market for SPIS as agriculture would be an established economic driver. It is, however, important to take note of the main crops or livestock contributing to the GDP. For example, coffee and tea could be significant contributors but these do not present obvious avenues for SPIS uptake. This could be contrasted to export of horticultural products (e.g. flowers and vegetables) which are water intensive and therefore ready markets for SPIS.

OUTCOME/PRODUCT

- Contribution of agriculture to the GDP

DATA REQUIREMENT

- GDP figures
- Agricultural output numbers
- FAOstats

PEOPLE/STAKEHOLDERS

- Government ministries in agriculture

IMPORTANT ISSUES

- Although the economic contribution of agriculture to a country's GDP may be steadily declining it may be in sight of the country's broad-based economic growth and agriculture may still be the broadest economic sector in terms of demographics, and plays a significant role in the nation's overall socio-economic fabric.
- In addition to agriculture's contribution to the GDP, the type and method of agricultural practice should be assessed. Areas that practice irrigated farming would be more ideal markets for SPIS.

LAND ACCESS AND TENURE

As SPIS is an agribusiness, land is at its foundation and it is therefore important to determine land rights, land access and land tenure terms in an area under assessment. Therefore, it is key for an area to have a pragmatic land policy environment. A desirable land policy is one that has emphasis on land access and development, secure property rights, is backed by reliable information and has clear permitting processes. A proper land policy has the land administration services including surveys and mapping, land use planning, rural and urban development, housing and market information service providers well established. Paucity of information about the laws, procedures and/or information required to safely and legally complete land and real estate transactions creates uncertainty and discourages investments.

Land access is defined by the availability of land with the required security of ownership, desirable physical and economic attributes and level of transparency and fairness in transactions.

Land tenure is the institutional structure that determines the political, economic and social framework by which individuals and groups secure access to land and associated resources. The absence of reliable information to guide rapidly expanding land market is, by far, the most persistent bottleneck undermining long-term development in most countries.

Clear tenure rights are an important consideration when investing into SPIS. Not only do they provide investment security, but may also serve as collateral when applying for loans. For some countries there are clear demarcations between commercial land (with fixed title deeds) and communal lands (with only informal land use rights and agricultural practices limited to subsistence farming).

OUTCOME/INCOME

- Country land ownership patterns and statistics

DATA REQUIREMENTS

- Land access and tenure rights in the country

PEOPLE/STAKEHOLDERS

- Government Ministries especially that of land

TRANSPORT AND COMMUNICATION INFRASTRUCTURE

Infrastructure is an organizational system of resources that is needed for a society or business to run. Transportation infrastructure such as roads, harbours, airports and rail, and telecommunication infrastructure are physical systems that are needed for efficient operations within a country or region.

Transport infrastructure determines the ease of movement of goods and people.

Lack of transportation infrastructure (e.g in deep rural areas and islands) can have significant cost impacts - inefficient transport systems make it difficult to obtain inputs and to deliver products to customers affecting scalability and quality of services. For SPIS market potential, good transport infrastructure would mean reduced costs of system installation as well as easier access to skilled labour for installation and maintenance. Additionally, lower transportation costs could lead to better allocation of funds in running businesses and ease of access to new markets. Good physical connectivity in the urban and rural areas is therefore essential for SPIS users.

Communication infrastructure (especially mobile phone connectivity) would be relevant to SPIS as indicative of access to mobile banking in rural areas and implementing monitoring devices in SPIS. Mobile phone use can also be used as a proxy indicator for income levels. Mobile phone usage in rural areas also shows the users can access services such as agricultural information and financial services such as mobile remittances and loans.

OUTCOME/PRODUCT

- Assessment of transport and communication infrastructure

DATA REQUIREMENT

- Data on transport network especially roads in rural areas
- Data on mobile penetration particularly in rural areas

PEOPLE/StAKEHOLDERS

- Government ministry of transport and communication
- World bank ease of doing business report

5. DECISION ON MARKET POTENTIAL OF SPIS

This module presents parameters that are key to assessing the market potential of SPIS for any target area. The evaluation of these parameters should be done in consideration of **WHO** is evaluating the market and **WHY** they are evaluating the market.

The evaluation of the parameters presented in this module should be in a sequential order.

EVALUATION OF WEIGHTED GEOPHYSICAL ATTRIBUTES

While several geophysical parameters are identified to guide the assessment of SPIS markets, 3 are considered crucial to the viability of SPIS applications as highlighted in chapter 1. If their state is unfavourable in the area of interest, SPIS is unlikely to be practical. These parameters should therefore be weighted on a binary scale of 1 if conditions are favourable and 0 if unfavourable. Where any of the parameters is scored at a 0, it is then concluded that the target area is not feasible for SPIS.

#	Parameter	Weight
1	Land cover – land use	0 or 1
2	Solar irradiation	0 or 1
3	Water availability (Precipitation)	0 or 1

1. Evaluation of additional geophysical parameters

These are geophysical parameters that are key to market assessment for SPIS but unlike the parameters in Table 1, they do not critically affect the viability of SPIS; they affect the success of SPIS adoption on a case by case basis. The significance of their impact of the SPIS market is dependent on the needs of the user. The parameters are expounded on in chapter 2 and listed below.

#	Parameter
1	Water table
2	Topography
3	Ambient temperature
4	Crops and livestock

2. Evaluation of the business environment

The first and second steps of the evaluation look at the practicality of implementing SPIS within a target country or region. Parameters on the business environment seek to establish the economic and operational feasibility of SPIS within the said market.

The table below highlights the Modules proposed weighting criteria. However, evaluation of these parameters can be weighted based on the user's areas of interest and consideration of most critical factors.

#	Parameter	Weight
1	Government interventions	15%
2	Development Organizations Interventions	10%
3	Financing	15%
4	Availability and cost of alternatives	10%
5	Technical capacity	10%
6	Awareness of solar PV and irrigation technologies	10%
7	Significance of agriculture to the local economy	10%
8	Land Tenure	10%
9	Transport and communications infrastructure	10%
	TOTAL	**100%**

OUTCOME / PRODUCT

- Decision on the SPIS uptake potential for a target market.

DATA REQUIREMENTS

- N/A

PEOPLE / STAKEHOLDER

- Private SPIS companies
- Policy-makers
- Financial institutions
- Development practitioners
- National and local governments

IMPORTANT ISSUES

- The parameters presented in this module present key issues of consideration in conducting a high-level assessment of the SPIS uptake potential for a target market. A detailed market assessment is, however, needed before investment.

FURTHER READINGS, LINKS AND TOOLS

Links

1. Photovoltaic Efficiency: The Temperature Effect- https://www.teachengineering.org/content/cub_/lessons/cub_pveff/Attachments/cub_pveff_lesson02_fundamentalsarticle_v6_tedl_dwc.pdf

2. A.W Worqlul, J. Jeong, Y. Dile, J. Osorio Assessing potential land suitable for surface irrigation using groundwater in Ethiopia, Applied Geography 85 (2017) 1-13

3. N.G. Dastane, FAO Irrigation and Drainage Paper No 25-Effective Rainfall -FAO,1978

4. M. Masri, R. Badishah, Solar Radiation Potential as Energy Source of Photovoltaic Powered Uninterrupted Power Supply in Perlis, Northern Malaysia- IOSR-JEEE PP 31-36, 2014

5. European Wind Energy Association, 2009, The Economics of Wind Energy, http://www.ewea.org/fileadmin/files/library/publications/reports/Economics_of_Wind_Energy.pdf

6. SNV, 2014, Renewable Energy for small holder irrigation, https://www.practica.org/wp-content/uploads/2014/10/Renewable_Energy_for_Smallholder_Irrigation.pdf

SPIS tools

MARKET – Market Assessment Tool

Other relevant tools:

- **PROMOTE and INITIATE – SPIS Rapid Assessment**: includes a (financial) market analysis for financing of SPIS components
- **INVEST – Payback Tool**: to calculate the financial viability of a SPIS and compare that to other alternative pumping systems (diesel and grid power)
- **SAFEGUARD WATER – Water Requirement Tool**: calculator to determine monthly water of different crops and livestock
- **IRRIGATE – Impact Assessment Tool**: to determine the social and environmental impacts of a SPIS project

TECHNICAL GLOSSARY

Aquifer	Underground geological formation(s), containing usable amounts of groundwater that can supply wells or springs for domestic, industrial, and irrigation uses.
Chemigation	The process of applying chemicals (fertilizers, insecticides, herbicides, etc...) to crops or soil through an irrigation system with the water.
Conveyance loss	Loss of water from a channel or pipe during transport, including losses due to seepage, leakage, evaporation, and other losses.
Crop coefficient	Ratio of the actual crop evapotranspiration to its potential (or reference) evapotranspiration. It is different for each crop and changes over time with the crop's growth stage.
Crop Water Requirement (CWR)	The amount of water needed by a plant. It depends on the climate, the crop as well as management and environmental conditions. It is the same as crop evapotranspiration.
Current (I)	Current is the electrical flow when voltage is present across a conductor, or the rate at which charge is flowing, expressed in amperes [A].
Deep percolation	Movement of water downward through the soil profile below the root zone. This water is lost to the plants and eventually ends up in the groundwater. [mm]
Drawdown	Lowering of level of water in a well due to pumping.
Drip irrigation	Water is applied to the soil surface at very low flow rates (drops or small streams) through emitters. Also known as trickle or micro-irrigation.
Emitter	Small micro-irrigation dispensing device designed to dissipate pressure and discharge a small uniform flow or trickle of water at a constant discharge which does not vary significantly because of minor differences in pressure head. Also called a "dripper" or "trickler".
Evaporation	Loss of water as vapor from the surface of the soil or wet leaves. [mm]
Evapotranspiration (ET)	Combined water lost from evaporation and transpiration. The crop ET (ETc) can be estimated by calculating the reference ET for a particular reference crop (ETo for clipped grass) from weather data and multiplying this by a crop coefficient. The ETc, or water lost, equals the CWR, or water needed by plant. [mm]
GIWR	The Gross Irrigation Water Requirement (GIWR) is used to express the quantity of water that is required in the irrigation system. [mm]
Fertigation	Application of fertilizers through the irrigation system. A form of chemigation.
Financial viability	The ability to generate sufficient income to meet operating expenditure, financing needs and, ideally, to allow profit

	generation. It is usually assessed using the Net Present Value (NPV) and Internal Rate of Return (IRR) approaches together with estimating the sensitivity of the cost and revenue elements (See Module **INVEST**).
Friction loss	The loss of pressure due to flow of water in pipe. It depends on the pipe size (inside diameter), flow rate, and length of pipe. It is determined by consulting a friction loss chart available in an engineering reference book or from a pipe supplier. [m]
Global solar radiation (G)	The energy carried by radiation on a surface over a certain period of time. The global solar radiation is locations specific as it is influenced by clouds, air humidity, climate, elevation and latitude, etc. The global solar radiation on a horizontal surface is measured by a network of meteorological stations all over the world and is expressed in kilowatt hours per square meter [kWh/m^2].
Gravity flow	The use of gravity to produce pressure and water flow, for example when a storage tank is elevated above the point of use, so that water will flow with no further pumping required.
Head	Value of atmospheric pressure at a specific location and condition. [m]: Head, total (dynamic) Sum of static, pressure, friction and velocity head that a pump works against while pumping at a specific flow rate. [m]; Head loss Energy loss in fluid flow. [m]
Infiltration	The act of water entering the soil profile.
Insolation	The rate at which solar energy reaches a unit area at the earth measures in Watts per square meter [W/m^2]. Also called solar irradiance.
Irradiation	The integration or summation of insolation (equals solar irradiance) over a time period expressed in Joules per square meter (J/m2) or watt-hours per square meter [Wh/m^2].
Irrigation	Irrigation is the controlled application of water to respond to crop needs.
Irrigation efficiency	Proportion of the irrigation water that is beneficially used to the irrigation water that is applied. [%]
Irrigation head	Control unit to regulate water quantity, quality and pressure in an irrigation system using different types of valves, pressure regulators, filters and possibly a chemigation system.
Lateral	Pipe(s) that go from the control valves to the sprinklers or drip emitter tubes.
Latitude	Latitude specifies the north–south position of a point on the Earth's surface. It is an angle which ranges from 0° at the Equator to 90° (North or South) at the poles. Lines of constant latitude, or parallels, run east–west as circles parallel to the

	equator. Latitude is used together with longitude to specify the precise location of features on the surface of the Earth.
Leaching	Moving soluble materials down through the soil profile with the water.
Maximum Power Point Tracking (MPPT)	An important feature in many control boxes to draw the right amount of current in order to maintain a high voltage and achieve maximum system efficiency.
Net Irrigation Water Requirements (NIWR)	The sum of the individual crop water requirements (CWR) for each plant for a given period of time. The NIWR determines how much water should reach the crop to satisfy its demand for water in the soil. [mm]
Power (P)	Power is the rate at which energy is transferred by an electrical circuit expressed in watts. Power depends on the amount of current and voltage in the system. Power equals current multiplied by voltage (P=I x V). [W]
Photosynthesis	Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organisms' activities (energy transformation).
Pressure	The measurement of force within a system. This is the force that moves water through pipes, sprinklers and emitters. Static pressure is measured when no water is flowing and dynamic pressure is measured when water is flowing. Pressure and flow are affected by each other. [bars, psi, kPa]
Priming	The process of hand-filling the suction pipe and intake of a surface pump. Priming is generally necessary when a pump must be located above the water source.
Pump	Converts mechanical energy into hydraulic energy (pressure and/or flow). Submersible pump: a motor/pump combination designed to be placed entirely below the water surface. Surface pump: pump that is not submersible and placed not higher than about 7 meters above the surface of the water.
Root Zone	The depth or volume of soil from which plants effectively extract water from. [m]
Salinity (Saline)	Salinity refers to the amount of salts dissolved in soil water.
Solar panel efficiency	Solar panel efficiency is the ratio of light shining on the panel, versus the amount of electricity produced. It is expressed as a percentage. Most systems are around 16% efficient, meaning 16% of the light energy is converted into electricity.
Suction lift	Vertical distance from the surface of the water to the pump. This distance is limited by physics to around 7 meters and should be minimized for best results. This applies only to surface pumps.

Surface irrigation	Irrigation method where the soil surface is used to transport the water via gravity flow from the source to the plants. Common surface irrigation methods are: Furrow irrigation – water is applied to row crops in small ditches or channels between the rows made by tillage implements; Basin irrigation – water is applied to a completely level area surrounded by dikes, and Flood irrigation – water is applied to the soil surface without flow controls, such as furrows or borders.
Transpiration	Water taken up by the plant's roots and transpired out of the leaves. [mm]
Voltage (U or V)	Voltage is the electric potential between two points, or the difference in charge between two points, expressed in Volts [V].