



Appropriate Technology



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Green Technology

**Needs Assessment and Appropriate
Policy Tools**

Distr.
LIMITED
E/ESCWA/SDPD/2016/Guide (Part I)
19 August 2016
ORIGINAL: ENGLISH

Economic and Social Commission for Western Asia (ESCWA)

Green Technology

Needs Assessment and Appropriate Policy Tools



United Nations
Beirut, 2016

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16-00201

Contents

	<i>Pages</i>
Abbreviations	iv
I. Outline.....	1
II. Implementing Appropriate Green Technologies (AGTS).....	1
II.1 Mapping energy flows through the production process	3
II.2 Energy flows through the value chain.....	8
III. Case Histories.....	8
III.1 Outlining the problem	9
III.2 Condition survey	10
III.3 Profile of energy	14
III.4 Energy management opportunities (EMOs).....	18
III.5 Mapping energy flows through the value chain	19
IV. Appropriate Policy Tools	21
IV.1 Promoting sustainable energy	21
IV.2 Policy implementation and sustainable local engagement.....	23
IV.3 Finance.....	24
V. Technical Background.....	26
V.1 The methodology	26
V.2 Types of sustainable energy solutions	29
V.3 Appropriate green technologies	30
<i>References</i>	36

List of tables

Table 1. Example: process summary	6
Table 2. Example layout of a simple building heat loss calculator	6
Table 3. Energy management opportunities in a small residential house	8
Table 4. Process summary: typical aluminium workshop, Jordan	15
Table 5. Process summary: typical olive mill, Jordan.....	16
Table 6. Process summary: typical Alfalfa, Jordan.....	17
Table 7. Process summary: typical dry clean and laundry, Jordan	17
Table 8. Process summary: butcher shop and restaurant, Jordan.....	18
Table 9. Stakeholder roles: the Four Rs	23
Table 10. Energy uses and sources	30
Table 11. Energy solutions and their applications in rural settings	31
Table 12. Wind speed and windmill applicability.....	32
Table 13. General parameters for biogas digester design	35

List of figures

Figure 1. Some product and energy flows in a simplified olive oil value chain	2
Figure 2. Example of energy flows in small residential house.....	3
Figure 3. Power situations and the quality of agreements	23
Figure 4. Mapping the production process	28

Abbreviations

AGT	appropriate green technology
CSP	concentrated solar power
EE	energy efficiency
EGS	environmental goods and service
ESCWA	Economic and Social Commission for Western Asia
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GE	green energy
GG	green growth
GT	green technology
ICT	information and communications technology
LPG	liquefied petroleum gas
MDG	Millennium Development Goals
MW	megawatt
NGO	non-governmental organisation
PV	photovoltaic
RE	renewable energy
RESCO	rural energy services company
SE	sustainable energy
SD	sustainable development
SHS	solar heating system
SME	small and medium enterprise
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WtE	waste-to-energy, also referred to as energy-from-waste (EfW)

I. Outline

Sustainable economic development prioritizes essential needs, taking into account limitations imposed by natural resources and available technology. Sustainable development, therefore, is based on utilizing resources efficiently. Appropriate green technologies (AGTs) address the limitations of resource availability either by tapping into new resources or increasing the efficiency of existing resource use.

Energy is at the heart of all production processes. That has two implications for implementing AGTs successfully in rural areas.

1. AGT implementation needs to focus on sustainable energy (SE), which comes mostly from either the:
 - (a) Use of new, renewable energy sources;
 - (b) More efficient utilization of existing, conventional sources.
2. AGT implementation is useful only if it generates additional value to businesses. Each business becomes part of a value chain that links suppliers, producers and markets. Such integration is taken for granted in urban areas but often is lacking in rural areas. Any implementation of AGTs in rural areas should ensure that:
 - (a) There is an operational value chain;
 - (b) SE is used within each individual production process and throughout the value chain.

Proper implementation of AGTs, therefore, depends on sustainable energy use from the level of individual production processes right up through the value chain. The guide is designed to help practitioners and policy makers implement AGTs. It comprises three parts.

1. The first part (chapter II) focuses on practical implementation by practitioners.
 - (a) Implementation is based on an energy assessment (EA) regarding the sustainability of energy use from individual production processes to the end of the value chain;
 - (b) Case histories are provided as examples.
2. The second part (chapter III) focuses on policy implementation. It discusses appropriate policy environments and tools to help mainstream AGTs. Chapter III might also be useful for practitioners in terms of identifying key issues relevant to policymakers.
3. The third part (chapter IV) provides the technical background for the guide. Chapter IV serves three purposes.
 - (a) It outlines the methodology on which the guide is based;
 - (b) It outlines the value chain concept linking suppliers, producers and markets;
 - (c) It discusses the main available renewable energy (RE) solutions that could form the basis of AGT implementation in rural areas of the Economic and Social Commission for Western Asia (ESCWA) region. Those solutions are wind energy, solar power, hydropower and biomass.

II. Implementing Appropriate Green Technologies (AGTs)

Businesses work together rather in isolation. That is the case in both urban and rural areas, even more so in today's integrated world, where products comprise many components, each manufactured or extracted by a separate business. As the product moves from raw material to final consumer, it goes through a value chain, networks of businesses with complementary skills. Each step of the process consumes its own amount of

energy. The production of each member of the chain adds value to the result of previous steps as the steps lead towards marketing and the end user.

Across that network, the implementation of AGTs in rural areas centres on sustainable energy (SE). For implementation to be successful, energy use must be sustainable. Implementation, therefore, is based on an energy assessment, a systematic overview of the energy flows within the small-scale production system of specific businesses and within the later segments of the value chain.

1. At the individual business or process level an energy assessment is made to identify any opportunities for AGT implementation. Such energy management opportunities (EMOs) might be improvements to the process itself, modifications with regard to waste management, or finding ways to use waste generated as an energy source, either in that or another part of the value chain.

2. At the macro level, the energy assessment looks at the value-chain process, to determine the energy sustainability of the chain as a whole and to identify EMOs in a way that:

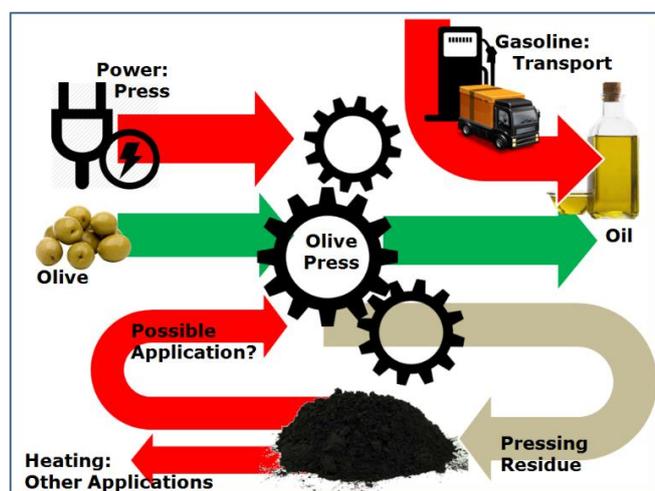
(a) Focuses on the value chain, finding partnerships between businesses that improve total energy efficiency. The outputs of some processes often can serve as inputs for others;

Example: olive oil waste products
 After the first pressing of olives in olive mills, subsequent pressings of the residue yield lower-quality oil that can be used for such non-cooking purposes as making soap. Remaining solid residues can be burned to provide energy.

(b) Ensures that there are no net negatives and that the process does not undermine existing business relationships. Most rural areas of the ESCWA region depend on transportation for access to markets. It is not practical to require the transportation system itself to use renewable energy. However, it is critical to ensure optimal functioning of the chain as a whole.

Olive oil provides a typical case. Olives might be picked and pressed locally but they require the involvement of other parts of the value chain. For example, seasonal labour might need to be transported to the region, housed and fed. The presses must be maintained and powered. The final product must be stored in purpose-built containers before being transported to market. Each step is provided by specific businesses that form the value chain from olive tree to final consumer. Figure 1 illustrates part of the energy flows of the value chain.

Figure 1. Some product and energy flows in a simplified olive oil value chain



Each production process in the value chain requires energy and will benefit from the implementation of AGTs at the macro level of the chain.

II.1 Mapping energy flows through the production process

The EA is a systematic overview of the energy flows through a business process. That business process can be at the micro level of a small production operation or the macro level of the entire value chain.

Example: transportation and renewable energy

There are no currently available feasible AGTs for effective transportation of rural production in the ESCWA region. It is not practical, therefore, to focus on renewable energies for the transportation segment of the value chain. Chains involved in producing and marketing olive oil or bread, for example, should focus on using renewable energy in the production process and recycling waste products for energy generation or other purposes.

The way the EA maps the energy flows in and out of the system is similar to the financial auditing of cash flow. The EA determines:

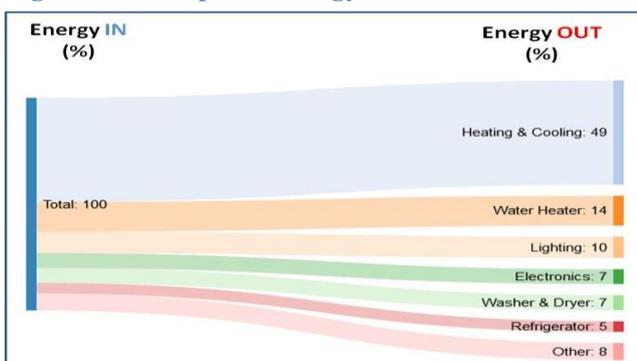
1. How and where energy enters the system. For example, in the case of a bakery:
 - (a) The EA that focuses on the business itself looks at fuel sources needed to make bread and operate machinery;
 - (b) The EA that considers the entire value chain looks at the supply and distribution network for fuel and raw materials (inputs) plus distribution and waste generated (outputs).
2. Where energy goes and how it is used. For example, in the case of a bakery:
 - (a) Fuel is needed to heat ovens. Electricity is required to power motors, air conditioning units and refrigerators;
 - (b) At the macro level, fuel is required for transportation, which uses the largest amount of energy within the system.
3. Variations between inputs and uses, as energy needs might vary during the day and/or by season. Different bakery products have different resource needs in terms of raw materials and cooking time, for example.
4. How it can be used more efficiently or effectively.

The map of energy flows depends on the actual case.

1. At the macro level, energy flows are mostly between the value chain's partner businesses.
2. At the micro level, energy flows are between the component processes involved in individual businesses.

In the case of a small residential house powered by the grid, energy used for different purposes can be calculated as a percentage, shown in figure 2.

Figure 2. Example of energy flows in small residential house



Source: <http://sankeymatic.com/build/>.

The review is conducted at the small and medium enterprise (SME) level and the value chain as a whole. The steps are:

1. **Preparing** for the EA, to clarify business objectives and expected outcomes of any AGT implementation.
2. Conducting a condition survey, to determine the current status of the business. That evaluation is in two parts, covering energy usage and financial returns. The survey helps identify the limitations under which the business operates and determine the most cost-effective sustainable energy (SE) solution. Solutions can include:
 - (a) Increasing energy efficiency (EE);
 - (b) Deploying a RE solution;
 - (c) Integrating with another value-chain possibly as a waste-to-energy (WtE) factor.
3. Developing a more detailed understand of energy usage, which might be necessary for some businesses. This is more demanding technically because it involves determining the profile of energy use patterns, focusing on the entire process and, if necessary, on some key elements in it.
4. Determining the possible EMOs, based on information gathered in Steps 2 and 3.,The EMOs should help define any AGTs or, at the very least, opportunities for saving energy.
5. Developing an Implementation Plan that outlines what needs to be done and the means available to do it.

(a) Outlining the problem

The scope of the EA needs to be determined. This is done by defining:

1. The EA's objectives, after listing current problems, justifying AGT implementation in terms of benefits, plus any assumptions used.
2. The financial means available. Implementing RE takes time to pay for itself. The actual time depends on such factors as initial system cost and value of energy generated. In general, that could be up to 15 to 20 years but could be reduced to a more manageable six to nine years if external funding is provided.
3. The methodology and standards to be followed. That includes measuring energy flows, observing and reviewing existing operating practices, reviewing tasks undertaken as part of the EA, plus listing the EMOs that are technically feasible.
4. The possible implementation timeline, identifying potential sources of delays and what their business impact would be.

By the time Step 1 is complete, everybody involved should be thoroughly familiar and comfortable with the purpose and expected outcome of the EA. Any revisions or adjustments needed later are likely to be minimal.

(b) Condition survey

The second step of the EA is the condition survey, to assess the state of the business and its environment. The survey helps determine the limitations under which the business operates and the type of SE solution best suited to it.

The extent of the condition survey depends on the size of the business and the region in which it operates. The survey should look at the regional setting in which the business operates before looking at the business itself.

1. Understanding the regional setting helps identify relevant external factors and potential partners. The survey should include information about:

- (a) The socioeconomic structure of the region, including population numbers, levels of education and employment, plus main sources of employment and revenue;
- (b) The resource base and main activity sectors, including agriculture, industry and services;
- (c) The access to infrastructure, including water, electricity and transportation.

2. Understanding how the individual business operates helps determine any problems and possible solutions. The survey should:

(a) Map the energy usage of the business, looking at levels of maintenance, housekeeping and operational practices;

(b) Ascertain the current economic performance, in terms of economic returns and social benefits, which are crucial because almost all rural businesses are family owned and operated. That includes assessing resource efficiency, including consumption and costs, plus comparing performance and returns with similar processes or businesses in similar environments.

(c) Profile of energy use

An energy profile can be a useful tool to establish how much energy a business needs, when and for what processes. Most rural businesses do not require a detailed energy profile, but some might. The energy profile comprises three steps.

1. By revealing which process uses how much energy to accomplish its task, a demand profile can be established for such elements as lighting, air conditioning and ventilation, refrigeration, motor power, plus heat for cooking or drying. Energy usage priorities can be determined.

Example: lighting and architecture

An excessive demand for lighting in a sunny region could suggest that a business might benefit from larger windows or better layout, reducing energy usage or at least preventing increases.

2. By showing how much energy is being used and when, a time-relationship of energy can reveal variations in energy usage by time of day, week or season. The optimum type of renewable energy can be determined.

Example: solar energy and storage

If a business does not need power at night, a photovoltaic (PV) power system could provide sufficient power for day use, without the need for batteries.

3. By mapping transport energy needs for importing resources and delivering products to market, the energy profile can help identify any barriers to expansion and/or access to wider markets, given that transportation costs are linked to energy prices.

Energy profiles for specific processes of specific businesses can be combined to create energy profiles for each partner business and the value chain as a whole.

The profile of energy use should be undertaken at the optimum level of detail for any given case.

General energy use profile

A general energy use profile of process and energy flows can be mapped to show:

1. Key processes. In the case of a small residential house, the processes that generate energy are internal and external. Internal processes include heat from equipment, lighting and occupants. External processes include heating systems and the sun.

- Main sources of energy and materials. In the case of a small residential house, the main source of energy would be the power used to run various appliances, plus elements of the heating, ventilation and air conditioning (HVAC) system.
- Waste generated. In the case of a small residential house, waste includes that generated by residents. It also includes heat lost through such external components of the house as walls, doors and windows, plus infiltration (air leakage) and ventilation. Such energy loss can be measured by well-placed thermometers over time.

Table 1. Example: process summary

Process	Description
Final product(s)	Main marketable output or product
Main inputs	Raw materials and energy type
Technology/process:	Parts of the processes where energy is used
Market:	Local, regional, global
Energy	Description
Input type	Type of energy source, including primary (fuel), secondary (electricity)
Amount:	In terms of kilowatt hours (kW/H)
Energy cost	Monetary amount per month or year
Waste	Description
Type	The raw waste products, whether they can be used as inputs for other processes and, if so, whether they require filtering
Amount/quantity	In terms of units of volume or mass
Cost/unit	Monetary amount per month or year
Total monetary value	Monetary amount per month or year

Detailed energy flow mapping

It might be necessary to undertake a detailed mapping of energy flows. There are different standard evaluation checklists available for such large business elements as the building envelope and such component elements as HVAC, lighting and refrigeration. Most calculations can be made with accuracy reasonable enough for mapping, using spreadsheets with basic formulas, assumptions and rules of thumb that can be adjusted for local conditions (Natural Resources Canada (NRCAN), 2015, p. 144).

In the case of the building envelope, energy flows relate mainly to heat transfer and include three types: conduction through and between materials, convection through air circulation, plus radiation through sunlight. The flows can be traced across the main elements.

Table 2. Example layout of a simple building heat loss calculator

Building Envelope														
		Length	Height	Slab	U-Val	Window Qty				Door Qty				
		m	m	W/m ² C	W/m ² C	1.	2.	3.	4.	5.	1.	2.	3.	Schedule
Walls														
1.	Main External	180	6	0.1	0.6	30	8				2	4		24h 7d
2.	Covered Balcony	120	10	0.3	0.9						3		1	Other
3.														24h 7d
4.														24h 7d
5.														24h 7d
Roofs		Length	Width	n/a	U-Val	1.	2.	3.	4.	5.				Schedule
1.	Main	50	40	n/a	0.6				1					24h 7d
2.	Covered Balcony	30	30	n/a	1									24h 7d
3.				n/a										24h 7d
Windows		Length	Width	Infilt.	U-Val									
1.	Large Th'pane	1	1	2	3.3									
2.	Small Th'pane	0.3	1	2	3.3									
3.														
4.														
5.														
Doors		Length	Width	Infiltration	U-Val									
1.	Steel Doors	1	2.5	5	2.5									
2.	Glass Doors	1	2.5	5	4.5									
3.	Overhead Doors	3	3	10	2.5									

Source: NRCAN (2015), extracted from spreadsheet envelope.xls.

(d) Energy management opportunities

When considering the way energy is managed, people should keep an open mind and evaluate all practices critically, no matter how widely accepted they are. It is with a fresh look, combined with imagination and technical know-how, that people can identify the best opportunities for improvement.

The energy management opportunities (EMOs) can lead to better production and energy consumption. In general, the opportunities are of three types: balancing production and demand to control energy expenditure, controlling energy savings, or improving processes.

1. Determine the need, by documenting the loads on the system, mapping energy production and demand at every stage of the process.
2. Match the need, by answers a few questions:
 - (a) What is being done?
 - (b) Why is it being done?
 - (c) What is the energy currently consumed at each stage of the process?
 - (d) What energy optimally should be consumed at those stages?
 - (e) When are the idle times? What energy is consumed during those times and why?
3. Maximize efficiency, usually by eliminating waste. Such housekeeping is carried out by answering the following questions for each process:
 - (a) Are there other ways to carry out the process? Are they more or less effective in time and/or energy? What explains the difference?
 - (b) Is the principle behind the process well understood? If there are more effective ways to manage the process, why are they not being used?

Note: non-process energy

In all businesses, energy is used for purposes other than the given production process. Such non-process energy is used for HVAC, lighting, electronics, cooking and water heating, plus onsite transportation in large production units. Even if the efficiency of main processes cannot be improved, the business could benefit significantly from improvements to non-process uses.

In the case of transportation, better thermal insulation could reduce air conditioning usage, resulting in lower overall fuel consumption. That non-process factor is now increasingly recognized by the car industry, with some companies offering specially coated vehicles. However, there are many simple, readily available solutions, including painting a truck's roof white to allow it to reflect as much as 70 per cent of the sun's energy, reducing the need for air-conditioning within the truck..

4. Optimize the energy supply, in which RE solutions are applied. Processes can be improved through SE solutions that typically include:
 - (a) Process or behavioural changes to eliminate sources of waste. That is the simplest, cheapest approach;
 - (b) Heat-recovery systems that utilize streams of waste energy through such means as warm air ducting, water heating using waste heat from a furnace, or more complex heating pump systems;
 - (c) Cogeneration, through combined heat and power (CHP) systems that take advantage of waste energy in cases where there is a need for both heating or hot water/steam and electrical power. By taking advantage of what would otherwise be waste energy, CHP systems convert fuel to electricity and use waste heat to enhance heating efficiency;
 - (d) Fuel switching, in which one source of energy replaces another, converting water boilers from electricity to gas being one example.

The measures listed form the basis of an implementation plan.

Table 3. Energy management opportunities in a small residential house

Steps	Actions
Determine the need	<ul style="list-style-type: none"> • Document the load on the heating/cooling system, accounting for different sources of energy used for space heating/cooling • Determine design end-use requirements, including temperature and fresh air
Match the need	<ul style="list-style-type: none"> • Determine end-use requirements, verifying that they do not differ significantly from the design, adjusting if necessary • Reduce temperature stratification in rooms that have high ceilings • Ensure that cooling and heating systems are coordinated rather than competing
Maximize efficiency	<ul style="list-style-type: none"> • Minimize leaks from windows, doors, vents and other openings • Verify or install optimal building insulation • Consider modifying windows and other openings to minimize summer heat gains and winter heat losses
Optimize supply	<ul style="list-style-type: none"> • Maximize solar gains when heating and minimize losses when cooling • Use solar heating technology for heating space passively, through solar walls or heat recovery from vented air and through active solar water heaters
	<ul style="list-style-type: none"> • Assess the load on the heating/cooling system, separating fuel energy used for space heating/cooling, because the load will change once energy management improvements have been made

Source: NRCan (2015), adapted from table 1. example: process summary, p. 146.

II.2 Energy flows through the value chain

To understand the value chain, an EA requires three steps.

1. Establishing the value chain's sustainability by assessing the sustainability of individual businesses, identifying long-term challenges they could face. Such challenges could include reliance on subsidies that meet the needs of individual businesses but expose the value chain to risks in terms of potential policy changes.
2. Identifying EMOs between businesses, especially where process outputs can serve as inputs for later processes. For example, organic wastes could be collected for use in a biogas digester to generate energy.
3. Ensuring that any process changes do not result in undermining existing business relationships, which could lead to net negatives. In many value chains, some parts might not be energy efficient but are critical to the chain as a whole. Transportation is a key example. Most rural areas in the ESCWA region rely on vehicles powered by gasoline, diesel or gas to get goods to market. In Jordan, the transport sector uses approximately 41 per cent of total energy consumption, a figure typical for the ESCWA region. Better transportation management by consolidating shipments in the fewest trips possible is one solution but could negatively affect the transport business, especially in rural areas, thus destabilizing the chain.

III. Case Histories

Surveys using the methodology outlined above were undertaken in four ESCWA member States: Jordan, Morocco, the Sudan and Tunisia. All regions were well equipped for AGT initiatives, having good access to land, resources and markets.

1. In Jordan, three regions with similar socioeconomic structures were surveyed: Al-Hashemyah, Al Husayneiah and Al-Ramtha (Alamouh, 2014).

2. In Morocco, two areas similar socioeconomically but different geographically were surveyed: Delmate, at the foot of the Atlas mountains, plus Safi, on the Atlantic coast (Lamrini, 2015).
3. In Oman, the survey considered the country as a whole rather than specific regions. Oman's rural population is 26 per cent, spread across a vast landscape in population centres distant from one another.
4. In the Sudan, the survey covered two very different areas: Soba and Al-Halla Al-Jadida, relatively close to Khartoum, plus Musalamia, a prime agricultural area in which implementation of AGTs could be hindered by long-standing disputes on property rights and water (Kamal, 2014).
5. In Tunisia, the survey covered three regions: Tataouine, an important agricultural area with good access to national and global trading networks, Rmada, where agricultural income is supplemented by unregulated trade at the Libyan border, plus Rchache, where access to markets is limited half the households lack reliable electricity (Chemlali, 2015).

Information gathered from the surveys can be used to show how to undertake a typical EA.

III.1 Outlining the problem

Most businesses in the regions surveyed were well adapted to working in their environments. However, they generally faced limitations to expansion, plus high costs for energy and other resources, business supplies and services, including marketing.

1. The objectives of the EA:

- (a) The initial goal was to validate the methodology described above by mapping the processes of different businesses in rural areas, to identify ways of participating optimally in the value chain and implementing AGTs;

- (b) Each survey was conducted by a local expert on sustainable development, who selected the regions and businesses;

- (c) The survey mapped the main processes and functional units for each selected business, identifying local markets and providing an energy profile;

- (d) Many businesses in rural areas rely extensively on expensive, inefficient ways to extract resources. They could benefit greatly from SE solutions by implementing AGTs. The highest priorities for businesses in rural areas was to:

- i. Reduce their costs and enhance their resource use. In Jordan, most water comes from groundwater sources, the extraction of which consumes about 15 per cent of electricity produced (Alamouh, 2014);
- ii. Expand their market access beyond local environments.

2. In most of the regions surveyed, financial means were limited. Private finance was not easily accessible in rural areas, which left non-governmental organizations (NGOs) or public finance to support local businesses in their efforts to implement AGTs and undertake other improvements.

- (a) In Jordan, there was no clear financing available for AGTs by 2016. However, there were some helpful regulations, including “a statutory guarantee of access for renewable energy to the grid” (http://solargis.info/doc/_pics/freemaps/1000px/dni/SolarGIS-Solar-map-DNI-Oman-en.png);

- (b) In Morocco, funds could be available from a government programme to install 2,000 megawatt (MW) capacity from solar energy sources by 2020, using both large-scale and small-scale power sources. A national programme for low-voltage photovoltaic (PV) systems was announced but by 2016, was still waiting for regulatory and financial frameworks to be established;

(c) In Oman, most rural areas have electricity and access to public financial support. There is also a significant effort to invest in RE, but mainly in large-scale projects;

(d) Rural areas in the Sudan are hampered by a general lack of access to power. Even though the Sudan more than tripled its power generation capacity between 200 and 2011, only 29 per cent of the population had access to electricity by 2011 (<http://www.eia.gov/countries/cab.cfm?fips=su>). By 2016, rural areas had little financing available to implement AGTs;

(e) In Tunisia, in spite of much public support, there is little public financing available for small-scale AGT implementation. One of the main public sources of support is the National Council for Enterprise Creation and Innovative Projects, aimed at helping to create micro, small and medium enterprises (ESCWA, 2011). The Government introduced subsidies to lower the cost of solar panels by about 30 per cent in order to encourage commercial and residential installation (Chemlali, 2015).

3. In most of the ESCWA region, there are clear national standards for AGT implementation. By identifying what units of measurement are most useful in a particular case, an EA can serve to measure energy flows objectively, plus observe and review existing operating practices. It is helpful, at this stage, to have:

(a) A checklist for each of the tasks undertaken as part of the EA: condition survey, profile of energy, plus usage patterns;

(b) The EMOs that are technically feasible in the ESCWA region. In practical terms, the most readily available energy sources are:

- i. Solar water heaters, which have gained wider acceptance across the region because of their high efficiency and low maintenance costs;
- ii. Water pumping, using wind power for shallow aquifers or solar PV systems for deeper aquifers. In PV systems used for water pumping, additional small-scale applications can be provided, including recharging cell-phones in areas where electrification rates are low, as is the case in the Sudan's Kordofan region;
- iii. Biogas systems, which are readily available in rural areas of the ESCWA region. The systems can be implemented with resources found locally, provided the right know-how is available;
- iv. Solar power and PV wind power for small-scale electricity generation, which are technically feasible but not widely utilized for domestic or production use because they require expensive batteries that require frequent replacement.

III.2 Condition survey

In general, the various rural areas surveyed were structurally similar. All had access to wider markets. In the various businesses surveyed, production processes faced similar challenges in terms of energy usage and economic returns.

(a) Regional setting

1. In Jordan, the three regions surveyed were Al-Hashemyah, Al Husayneiah and Al-Ramtha (Alamoush, 2014).

(a) The Al-Hashemyah sub-district is located in the Zarqa governorate, in the middle part of Jordan, at the main cross roads linking Al-Zarka, Irbid and Al-Mafraq governorates. Trading is a key activity. The area has good access to national, regional and global markets. Al-Hashemyah accounts for approximately 60 per cent of the of Zarqa governorate's economic activity. The population of Al-Hashemyah depends largely on activity outside the region, mostly through government and military employment. The region has the following main characteristics:

- i. The population of 30,000 has an unemployment rate of 13.9 per cent and a poverty rate of 14 per cent;
- ii. The area has strong agricultural potential, with 45 per cent of its 140 square kilometres (km²) suitable for farming. However, agriculture is underdeveloped, with only 70 per cent of its total viable area of 44 km² devoted to irrigated or rain-fed agriculture;
- iii. The industrial sector is dominated by major industrial groups. Those include the Jordan Petroleum Refinery, which produces most of the country's fuel oils, plus the Al-Hussein Thermo-Power Plant, one of the region's main electrical power plants. The region also contains steel factories and the Al-Samra Sewage Natural Purification Plant;
- iv. The commercial activity in Al-Hashemyah is represented by malls, shops and stalls spread throughout the sub-district;

(b) The sub-district of Al-Husaynyeh is a 5 km² area in the Maan governorate, southern Jordan. The area has good access to national, regional and global markets. Most of the economic activity in Al-Husaynyeh is concentrated on small-scale businesses. The sub-district is relatively poor in terms of resources. It is mostly desert, with average temperatures of 36°C in summer, and 2°C in winter. The annual rainfall of 50 mm is relatively low, but the area has access to groundwater, as evidenced by numerous wells;

- i. The sub-district's 8,000 inhabitants are among the poorest in Jordan, with a poverty rate of 52.5 per cent. The average family size, at 6.4, is higher than Jordan's 5.7 average. The Al-Husaynyeh sub-district is a rural community whose population (47.6 per cent of whom are men) depend mostly on government and military work;
- ii. Economic activity remains limited, particularly in the case of agriculture. Until recently, agricultural activity in the district was limited to self-sufficiency. It provides little employment to the region's inhabitants. The main products are vegetables, alfalfa and olives, mostly rain fed. The local community depends totally on the Maan market for supplies and basic needs;
- iii. The area has at least two key advantages, however. It is a transit area for tourists and pilgrims, being located near the international highway that links the north and south. Second, it has a wealth of livestock. Because of that, it is considered a business hub for surrounding governorates, and the sub-district is home to some businesses unique in the region, including a factory bottling mineral water;

(c) The Al-Ramtha sub-district of 276 km² is located in the northern Irbid governorate, near the Syrian border. The area has good access to national, regional and global markets. It is a key transit area to trade with Syria. Most of the economic activity in Al-Ramtha comprises small-scale businesses. Al-Ramtha is an extension of the arable Horan Plains, a region where agriculture relies mainly on rainfall of about 400 mm per year. The rain fills the wells that provide most of the region's freshwater needs. The sub-district has a low population density, at 496 inhabitants per square kilometre. Its 87,446 inhabitants depend primarily on trading, agriculture and livestock (sheep and cattle), plus government and military jobs. However, there are relatively few employment opportunities. The district's poverty rate is 24.3 per cent. Family size is 5.6, compared to 5.7 at the national level. Population growth is estimated to be around 2.2 per cent.

Note: the effect of neighbouring political instability on northern Jordan

During the past few years, some rural areas of northern Jordan have been adversely affected by the Syrian crisis. The Al-Ramtha sub-district is facing two unprecedented stressors: an influx of Syrian refugees that doubled the number of its inhabitants, plus interruption of trade with the Syrian Arab Republic.

Of the 1.3 million refugees in Jordan (47 per cent of the Jordanian population), 63,000 live in the Al-Ramtha district.

Trade and transportation-related work with the Syrian Arab Republic have been interrupted, greatly diminishing an activity that represented 39 per cent of the local economy. Of all Al-Ramtha's cross-border 61 taxis, none are fully active.

2. In Morocco, the two areas surveyed were the region around Delmate, at the foot of the Atlas mountains, plus Safi, on the Atlantic coast (Lamrini, 2015).

(a) Delmate is located in central Morocco, 110 km east of Marrakech. An ancient trading hub, it is today a mid-sized city of 40,000 inhabitants;

- i. Delmate has many diverse small businesses but is best known for textiles, pottery and farm products, plus tourism-related activities. The strong pottery tradition arose because of extensive deposits of red clay;
- ii. Tourism is a growing business in the area. Apart from the Atlas Mountains surrounding it, Delmate is near such unique geological features as the Iminifery natural land bridge, dinosaur traces and the Ouzoud Falls;

(b) Safi is located in western Morocco, on the Atlantic Ocean. The city itself has a population of 280,000. Its agglomeration has a population of 793,000. Safi is a regional centre, home to some large-scale industries, particularly textiles, ceramics and phosphates. Its port is the main fishing port for Morocco's sardine industry. It is also a popular tourist destination.

3. In Oman, the survey did not consider specific regions. Oman's 26 per cent of rural inhabitants are spread across the country's vast landscape, in centres that are distant from one another.

4. In the Sudan, the survey covered two very different areas: Soba and Al-Halla Al-Jadida, relatively close to Khartoum, plus Musalamia.

(a) Al-Halla Al-Jadida is a new village in the southern province of Jabal Awliya in Khartoum state. The village is about 45 km from Khartoum, the Sudan's capital city. Located on the shores of the Jebel Aulia Dam, the village survives mostly from fishing and tourism, thanks to the Jebel Awliya Dam on the White Nile;

- i. Built in 1937, the Jebel Awliya Dam was the largest dam in the world at the time. It holds an estimated 3.5 km³ of water in a reservoir 500 km long, with a width that varies between 6 km and 7 km, plus a depth that reaches 12 m (van der Knaap, 1994). The Jebel Awliya Dam was upgraded between 2003 and 2005. By 2007, 80 new hydroelectric turbines had been added to give the irrigation dam a new hydroelectric capacity of 30.4 MW (Bihlmayer, 2005);
- ii. Many fishing villages are dotted around the 1,246 km² area. An estimated 1,500 fishermen live around the reservoir, working on about 500 boats. Their fishing yield is estimated at 2,829 kg/day. The reservoir is estimated to have a sustainable yearly yield of 7,300 tons/year (van der Knaap, 1994);
- iii. The dam and its reservoir attract local tourists on holidays and weekends, when Khartoum residents travel in their thousands to its shores;
- iv. Agriculture is a secondary activity, mostly for sustenance. It is seasonal, for eight to nine months of the year, starting after autumn, when the Nile flood ends;

(b) Musalamia village is located 150 km from Khartoum, in the middle of an important agricultural state, the 27,549 km² Aljazeera state in the east-central region of the country, between the Blue Nile and the White Nile. The state, has a population of 2.6 million people. The region employs more than 130,000 farmers with large family sizes, 6 to 7 people on average, plus many herdsmen. It provides about 60 per cent of the country's agricultural output;

- i. In general, personal income is directly related to the area of land owned or managed. A five-acre lot would generate a monthly income of 1,500 Sudanese Pounds (SDG). Daily income for itinerant herdsmen ranges between 10 SDG and 20 SDG;
 - The main activity is farming. Farmers import large amounts of fertilizers, pesticides and moisturizers. Most winter crops are wheat, onions and lentils. Most summer crops are beans. The region exports bread. Crops are grown for local sustenance all year round, including tomatoes, watercress and portulaca;

- The secondary activity is livestock for export, mostly goats, sheep and cows, with some camels. Poultry is raised for local use;
- ii. The region has undergone much economic change since the 1920s, when Aljazeera state became the Sudan's major agricultural region. The development in the 1920s was initiated as part of the Gezira Scheme, a cotton-farming plan that led to the construction of the Sennar Dam on the Blue Nile, near the town of Sennar, and the digging of numerous canals that allowed for irrigation of more than 10,000 km². Production now increasingly focuses on wheat cultivation, a trend that probably accelerated after the 2005 Act that ended the obligatory plantation of cotton;
- iii. Energy usage is related to agriculture, the area's main activity. It comprises mainly gasoline and natural gas. Most of the fuel used is gasoline for transportation and farm tractors. Water pumps increasingly are needed during the summer months, to remedy the shortcomings of the irrigation network, which has maintenance problems. Domestic energy needs are met principally through natural gas for cooking. Firewood is used for making traditional bread and pastries.

Note: property rights and agricultural productivity in the Sudan

Investment in the Aljazeera region is affected by the controversy over fees and property rights in the Gezira scheme. Starting in the late 1970s, insufficient funds meant that there was no possibility "to finance the considerable recurrent operations and maintenance costs of the Gezira scheme and to replace machinery and equipment". This led to decreased yields "two to three times below those achieved at the research stations" (Plusquellec, 1990, p. 8).

In the Gezira scheme, 40 per cent of the area is registered as free property for individual Gezira inhabitants, while 60 per cent is government owned. Despite the 2005 Gezira Scheme Act, questions remain as to specifics of land ownership, the amount of fair compensation and who is to be liable for it, particularly concerning rent arrears that have accumulated since 1967, when the 1927 lease contract expired.

5. In Tunisia, the survey covered three regions: Tataouine, Rmada and Rchache.

(a) The Tataouine governorate is the southernmost of Tunisia's 24 governorates, the only one to border both Algeria and Libya. The largest governorate, it covers an area of 38,889 km², with a population of 143,524;

- i. The regional economy is based on agriculture, with the 200,000-hectare agricultural area dominated by olive trees, legumes, potatoes and asparagus for export, in addition to the production of red meat and milk. All of the industrial activities in the region are traditional and carried out by SMEs;
- ii. Tataouine is divided into Tataouine North and Tataouine South. Tataouine North has 59,396 inhabitants, 31 per cent of whom live in rural areas. There is high unemployment among the more highly educated population, 50 per cent of those who hold degrees and other certification;

(b) Rmada is located 80 km south of Tataouine. The population is 10,239 inhabitants, of whom 53.2 per cent live in its rural area. The economic activity in Rmada is currently based on agriculture and smuggling on the border with Libya. The district has diverse and rich natural resources, from hydraulic resources to gas and petrol. The economy is based on agricultural activities, mainly livestock, and fruit;

(c) Smar is a rural area 50 km east of Tataouine. Its 13,684 inhabitants rely for their livelihoods on agriculture, including olives, sheep, cows and chickens. Rhache is a small village in Smar comprising 30 families or so;

- i. The village has little access to infrastructure, although 50 per cent of its inhabitants who have no access to electricity are able to use solar PV systems for lighting;
- ii. The economic activities of the village are based on livestock and olive farming. Pastoralists rely mainly on sheep and goats and, more recently, on free-range chicken. The village is very poor and faces challenges irrigating the land nearby, relying on rare rain to grow small amounts of barley and wheat.

Geothermal energy in Tunisia

In southern Tunisia, the confined deep Continental Intercalaire aquifer has a low-enthalpy geothermal resource that does not appear to exceed 80°C. That resource currently is being used in the southern part of the country, in the regions of Gabes, Kebili and Tozeur, near Tatouine.

Tunisia has a long tradition of using geothermal power, particularly in the south. Traditionally, the usage for such temperatures was limited to direct utilization in agriculture (greenhouse heating and irrigation) and, to some extent, tourism (bathing). However, because of water scarcity, the relatively saline water was often used for irrigating oases, which resulted in excessively saline soils, especially in the fourth year after that practice began. (Ben-Mohamed, 2003).

There is potential to use the geothermal resource for other value-added applications, while still using the cooled water for agricultural applications. At present, such sources are often disregarded or underexploited because they are low enthalpy, with temperatures ranging from 45°C to 85°C. However, thanks to the advancement of drilling technology, the development of efficient heat exchangers, plus the availability of highly sensitive binary fluids, it might be possible to expand the usage, even if not currently used for energy generation. Similar geothermal sources that range between 80°C and 150°C can already be used to generate energy.

(b) Business condition

1. Most businesses reviewed employ fewer than five people. Many rely on seasonal labour. They are generally family businesses that operate individually, integrating little with other businesses in the regions surveyed.
2. In the regions surveyed, there were few efforts to increase energy efficiency. The deployment of RE solutions remains limited, in spite of a need for alternative sources. Many businesses already rely on alternative sources of power and use generators to supply additional power during outages or to help extract groundwater. The main reasons for limited implementation of RE solutions appear to be:
 - (a) Lower upfront costs of traditional generators, a critical factor for businesses that cannot afford to plan long term. That could be the case in the small businesses reviewed in rural areas of Jordan, Morocco and Tunisia;
 - (b) The fact that most RE systems still provide intermittent power that is difficult to control. That might be the relevant factor for businesses in many rural areas of Oman.
3. There is room for improvement in most businesses reviewed in terms of efficiency and/or enhanced waste management. However, it should be noted that most of the rural areas appeared to be under economic strain, due to conditions outside their control. That is particularly the case in the rural areas of Jordan, where there is a large refugee population, and Tunisia, where the economy has yet to recover from its economic downturn.

III.3 Profile of energy

The processes in the rural areas surveyed were relatively simple but varied. They included industrial workshops, food production, food processing, plus general services.

(a) Industrial workshops

The industrial businesses surveyed included small workshops for aluminium, iron, carpentry, tiles and building blocks, brickworks, plus pottery and crafts. Except for pottery and crafts, the main inputs for most of the shops are imported from outside the region in bulk, with components of standard shape and size.

Aluminium workshops across the rural areas of the ESCWA region provide a typical example. In Jordan, such workshops are family owned businesses that employ between two and five permanent workers. They tend to specialize in producing goods for the construction industry like aluminium doors and windows, plus kitchens.

The main inputs are imported aluminium tubes, glass, PVC sheets, screws, rubbers, sealing materials, locks and hinges. The production process focuses mainly on machining imported standard parts to form window and door panels.

1. The process starts by cutting the aluminium parts, mostly in the form of rectangular tubes.
 - (a) That is done using a table saw, according to the measures taken;
 - (b) Punch presses are used to punch through holes, locks and fittings;
 - (c) Another type of press is used to fit tube endings of the frame;
 - (d) The wastes during the process are mainly scrap and aluminium chips that are generally discarded.
2. The process uses plastic or metal parts for inserts fixed at corners of the frame using screws. The waste during that process comprises mainly discarded, ill-fitting parts and screws.
3. Glass or PVC screening is added.
 - (a) Glass is delivered on site and cut on site according to measure before inserted into the aluminium frame, along with a rubber sealing. The waste during this process comprises mainly small, unusable glass panels;
 - (b) PVC sheets sometimes are used instead of glass, especially for kitchens. The waste during this process comprises mainly scraps of PVC panels.

Table 4. Process summary: typical aluminium workshop, Jordan

Process	Description
Final products	Aluminium doors, windows and kitchens
Main inputs	Aluminium tubes, screws, hinges, handles, glass, PVC boards, silicon and rubbers (about 50 per cent of inputs are available locally)
Technology/process	Cutting, framing and assembly
Market	Local
Energy	Description
Input type	Electricity
Amount	200-250 kWh/month
Cost of energy:	Grid Electricity: 300-350 Jordanian Dinar (JOD)/year (1 JOD = \$1.4 at August 2016) Electricity Backup Generator: 200 JOD/year Transportation 10 JOD/trip
Waste	Description
Type	Aluminium chips and scraps
Amount/quantity	1,200 kg (15 per cent chips)
Cost/unit	1 JOD for scrap and 0.3 JOD for chips
Total monetary value:	1,074 JOD

(b) Food processing

Food processing businesses surveyed included bakeries, slaughterhouses, butcher shops, olive mills and presses, dairy mills, plus water purification. A typical case of food processing is the olive mill. Olive mills exist across much of the ESCWA region, particularly in Jordan, Morocco and Tunisia.

The olive mills reviewed in Jordan were typical of many. They employ about five to six people. They increase operations during the olive harvest season, from September or October, when olives are harvested after the first rainfall, until February or March, when harvest season ends.

The main inputs of the production process are olives, water, energy and the containers needed to store the oil produced by the mill. The oil production process is a staged process, in which 1,000 kg of olives result in 200 kg of olive oil.

1. Olives are collected from different locations, 30 per cent from within the region. If need be, they can be grouped at this stage by quality and/or region. The olives are cleaned with freshwater.

2. Olives are ground together using grinding stones and mixed into a homogeneous pulp. A small quantity of water is added during grinding to the mix, about 100 to 150 litres for each 1,000 kg of olives.

(a) Whenever possible, the pressing is powered by electric motors, to avoid affecting the oil. In some cases, diesel motors are used, but that results in lower-quality oil;

(b) In some poorer rural areas where electric supply is insufficient or non-existent, camels or donkeys are used to power the presses. While that provides better quality oil than diesel, it is less productive. That is the case in poorer rural areas, including the Tunisian Berber villages in the Rmada district.

3. The olive pulp is mixed/beaten in downstream-arranged *malaxeurs*. Up to 100 per cent of water, by volume, is added to the mix, to allow it to be pumped to a decanter. Sea salt generally is added at that stage in order to further promote osmotic breakdown of olive cells and separate oil droplets from water.

The main marketable products are:

1. The extracted oil, which is collected in containers, and cleared through sedimentation.

2. The olive pulp, which can be extracted by being repeatedly beaten and heated and further extracted through centrifuges. That results in lower quality olive oil that can be used for making soap and for other applications.

3. The dried residues, which can be made into charcoal used for heating.

Table 5. Process summary: typical olive mill, Jordan

Process	Description
Final product	Olive oil
Main inputs	Olives, to which the process adds freshwater and salt
Technology/process	Cleaning, grinding extraction and purification
Market	Local 30 per cent
Energy	Description
Input type	Electricity
Amount	20,000 kWh/year
Cost of energy	Electricity: 15,000 JOD/year Waste: 21,000 JOD/year Additional cost: waste water transportation, 500 JOD/month during season
Waste	Description
Type	Waste water, olive press paste
Amount/quantity	1,500 tons of waste water, and 1,500 tons of waste paste
Cost/unit	30.0 JOD/ton dried waste paste. If, wastewater is not sold, it should be dumped at cost
Total monetary value	30,000 JOD/year

(c) Food producing

Food production surveyed in rural areas included products from farms, pastoralists and fisheries. The processes were typical of small family farming operations, usually employing two or three family members. Their labour is supplemented with seasonal workers, some of them expatriate.

The alfalfa farm in the Tel Burma agricultural zone of Al-Husaynyeh of Jordan is typical of many such farms, with a yearly turnover of 10,500 JOD. It employs two family members plus one expatriate worker. Such farms

often supplement their production by relying on animal husbandry, mostly poultry but also sheep and goats, often in cooperation with local pastoralists.

The process starts with ploughing the land, seeding and fertilizing, then watering the crop. Seeds and fertilizers tend to be imported from outside the region.

The energy flow throughout the process reveals two areas where improvements can be made: the power source for irrigation systems, plus transportation energy used to import fertilizers and seeds.

Irrigation is the main limitation because most water is derived from groundwater, which has to be extracted by electric or diesel pumps. When the cost of diesel is too high, farmers cannot irrigate the fields and have to rely on, rainfall. That is the case in some areas of the Rmada district in Tunisia, where farmers were able to irrigate only part of their fields. Solar-powered pumps were not a panacea, because of shortfalls in terms of maintenance and spare parts, and/or the failure of the ill-adapted solar panels themselves.

Table 6. Process summary: typical Alfalfa, Jordan

Process	Description
Final product	Alfalfa
Main inputs	Water, seeds and fertilizers
Technology/process	Plough the land, seed the land, add fertilizers, cut crops and prepare them for market
Market	50 per cent locally
Energy	Description
Input type	No direct inputs
Amount	0 kWh/year
Cost of energy	Fuel for transportation (1,400 JOD/year) and water pumping (800 JOD/year)
Waste	Description
Type	Hay
Amount/quantity	140 sacks of hay
Cost/unit	3 JOD
Total monetary value	420 JOD/year

(d) Services: energy-intensive dry cleaners

Several types of service businesses were surveyed in rural areas, including restaurants, pastry shops, dry cleaners, plus such artisan businesses as tailors. The dry cleaners are among the most energy-intensive services. They tend to be small family businesses that employ no more than one or two additional workers. The main inputs are plastic wraps and hangers for clothes, plus laundry detergents. The main energy source used is electricity, either through the grid or a diesel generator.

Table 7. Process summary: typical dry clean and laundry, Jordan

Process	Description
Final products	Clean and ironed clothes
Main inputs	Plastic wraps and hangers for clothes, plus laundry detergents
Technology/process	Washing, drying, ironing and wrapping
Market	Local
Energy	Description
Input type	Electricity
Amount	1,000-1,100 kWh/month
Cost of energy	120-130 JOD/month
Waste	Description
Type	None
Amount/quantity	
Cost/unit	
Total monetary value	

Dry cleaning and laundry consume a relatively high amount of electricity and water for washing, dry cleaning and ironing. The washing cycle consumes energy to generate hot water and to power the machines, but most of the cost comes from using freshwater, amounting to 72 m³/year, at a cost of 250 JOD/year.

(e) Services: restaurant/butcher shop

In rural areas, businesses often combine many services, an example being a restaurant/butcher shop. Those businesses generally are located in areas with decent access to transportation, so that they can cater to both locals and passing travellers. They are generally family owned and operated, with few outside workers other than those recruited temporarily if required.

Such shops generally provide various fresh meat products like cooking meat, mince, plus meat for kebab and kafta preparation. Sometimes there are chicken meals and side dishes like fried potatoes. The main inputs are locally sourced meat and chicken, coal for barbeque and gas for cooking, plus pre-processed foods and seasonings from outside the region.

Such shops consume large amounts of electricity compared to other businesses, because of the need for kitchen automation, including mincing/grinding machines, refrigerators and freezers.

Table 8. Process summary: butcher shop and restaurant, Jordan

Process	Description
Final products	Fresh cooking meat,, barbequed meat like kebab
Main inputs	Fresh meat (mainly lamb and goat), coal for barbequeing, plus seasonings. About 50 percent of inputs produced locally
Technology/process	Slaughtering, cutting, mincing/grinding
Market	Local
Energy	Description
Input type	Electricity from cooking charcoal
Amount	500-700 kWh/month
Cost of energy	Diesel for transportation: 45 JOD/month Electricity: 60-80 JOD/month; Cooking Charcoal: 70 JOD/month
Waste	Description
Type	Skin and leather, internal digestion organs, coal
Amount/quantity	20-30 skin and organs
Cost/unit	0
Total monetary value	0 JOD

III.4 Energy management opportunities (EMOs)

Notwithstanding a detailed cost-benefit analysis for each specific case, measures to promote AGT fall into two categories: energy production and energy savings.

(a) Energy production

1. Solar power through PV panels is a feasible SE solution for all geographic areas surveyed but suffers from at least two main limitations:

(a) The need for financing, to pay for the cost of installation and ongoing maintenance costs. While solar power would save the cost of diesel and provide much-needed off-grid electricity, financial returns in many poor rural areas are insufficient to cover installation and operating costs;

(b) The need for local technical know-how to ensure proper maintenance and operation of the PV panels, plus the need to cope with the system's limitations;

- i. Solar water heaters could be used to provide hot water. Boilers then could be made larger. That would need to be based on operational needs, with burners properly modulated;
- ii. Some applications of concentrated solar power (CSP) could be implemented to allow insulation to be used for both low- and high-temperature applications:
 - For low-temperature needs, the region’s high rate of insulation means that drying by solar power does not need special equipment. The sun’s heat is used directly in the region, with little or no special installation, as in the case of pottery shops in Delmate and Safi, Morocco;
 - For high-temperature applications, significant heat can be generated through specific innovative adaptation of CSP systems. In the surveyed geographic areas, that could apply to pottery workshops in Morocco and the brick makers in the Sudan because CSP systems can already generate heat greater than that required by the processes. However, such a system, if it were developed, would require a more centralized approach where ovens are clustered together.

2. Significant energy savings could be made by using more energy-efficient equipment in manufacturing and/or better insulation for refrigeration. Some production processes utilize the sun’s heat as an essential element.

(a) Many shops use machine tools and electrical equipment that might not be energy efficient. Measures to help replace those tools with energy-rated equipment would go a long way to ensuring SE. An example is more energy-efficient cutting/drilling power tools and machines for the small industrial unit;

(b) In the geographical areas surveyed, there is a strong need for refrigeration, especially in the spring and summer. Significant energy savings could be made from more energy-efficient refrigeration systems and/or better thermal insulation of part or all of the facilities;

(c) For some manufacturing processes, the sun’s heat can be used directly:

- i. For some cooking needs, solar cookers are a readily available technology that can be developed and built locally (Zein, 2014);
 - In domestic applications, it can be a useful cooking technique in many rural areas with high insulation, as is the case of most countries in the region. In the Sudan, solar cooking is already being deployed to help internally displaced people meet their cooking needs. Whenever it is used, solar cooking can supplement charcoal or propane gas, and thus potentially save 5 to 6 SDG, a significant sum in many rural areas;
 - In commercial applications, the technique can be applied as a supplemental cooking technique in many restaurants throughout the countries surveyed. It might not be applicable to all restaurants. In the case of Al Kahla Butcher Shop and Kebab Restaurant in Al-Hashmyeh, Jordan, charcoals are needed for a critical part of the process. Solar cookers, therefore, are not applicable;
- ii. For drying, or to help the drying process:
 - Solar dryers are currently used for agricultural applications but can easily be manufactured locally to help in the drying process. “Experience in developing countries has demonstrated that simple, locally manufactured solar dryers can be economical” (Zein, 2014, p. 37).

III.5 Mapping energy flows through the value chain

Further savings can be generated through a greater integration among businesses in a wider value chain. That can be helped by methods to promote AGT in at least two categories: process management and better waste management.

1. The implementation of Information Technology and new production techniques can help, at the very least, to enhance process management. Process management could generate significant energy savings through stock management, process re-engineering, plus developing alternative products.

(a) In many cases, stock management would lessen the need for transportation, a large component of the energy footprint of many of the shops surveyed;

(b) Some processes are, by their nature, extremely energy-intensive. In those cases, it is best to address energy efficiencies. Few savings can be made through the use of RE sources, unless new alternative techniques are developed that generate more power. That is the case of processes that require a lot of heat, as in the case of a dry clean and laundry business;

(c) Significant gains can be made by developing alternative versions of existing products that have lower energy requirements. However, that has to be done in coordination with all the members of the value chain.

Example: manufacturing of firebricks in the Sudan

Mud bricks can be made suitable for most housing applications. Local manufacturers need to let the products dry in the sun for about 90 days. Such farming waste products as husks and straw can be added to the mixture of loam, mud, sand and water to enhance mudbrick integrity and strength. While those mudbricks would be far more heat resistant than firebricks, they would cost far less to manufacture.

2. Improvements to waste management can lead to a waste value chain, where the waste of one partner is used as input into another of the chain's partner processes. That is the case of the cooperative collection of wastes and the generation of biodiesel or biogas, which creates new producers and consumers.

(a) There are many potential producers, large scale and small scale:

- i. There is a high potential for improving waste management in such agricultural areas as the Sudan's Gezira region, where there is a large amount of easy-to-recycle plant biomass and animal waste;
- ii. Something similar is being done on a smaller scale as part of such operations as olive mills, where the dried residues of olive pressing can be made into a type of charcoal for heating;

(b) Consumers also would benefit, especially in cases where there appears to be no alternative to conventional fuel.

Example: when there are no alternatives to conventional fuels

Biogas and biodiesel are crucial when there are no alternatives to natural gas or diesel.

- The need for biogas is illustrated by the case of such bakeries as the Al Kawther Bakery in Al-Hashmyeh, Jordan and the Pâtisserie Erramli in Tidili, Morocco. The use of natural gas allowed large increases in productivity compared to traditional fuels. It generated far less waste, and was healthier. Biogas could be made available locally as part of regionally planned waste reduction measures.
- The need for biodiesel is illustrated by the case of the Alfalfa Farm in the Tel Burma agricultural zone of Al-Husaynyeh, Jordan, and the Filahat Adil farms near Safi, Morocco. The farms could supplement the diesel for their tractors with second-generation biodiesel generated from farm waste products.
- Cooking has benefited greatly from the development of gas and electric stoves. Biogas could be a useful substitute fuel source.

IV. Appropriate Policy Tools

In order to enable the implementation of AGTs, policy would need to overcome barriers to RE technologies and to promote an enabling environment for AGTs. Policy should address three main elements:

1. A technical perspective, focused on a clear vision of actively promoting SE and AGTs in a context that facilitates access to wider markets. Policy must incorporate incentives and support for integration within a wider value chain, to provide access to a wider market where there could be larger profit margins.
2. A managerial perspective, designed to promote local engagement and stabilize power equilibrium. Rural development often entails multi-stakeholder processes, which involves negotiations between stakeholders of varying powers and different relationships.
3. A financial perspective, to facilitate financing and financial management, helping rural businesses deal with both upfront costs of implementing AGTs and long-term maintenance expenses. That could be done by promoting greater integration within local value chains, providing incentives, plus promoting greater awareness.

IV.1 Promoting sustainable energy

Policy should take into account the objective of development, which is directly linked to energy. The Arab region has gone through all three stages of the energy-use ladder, an evolution of energy levels that starts from basic survival to meeting the needs of economic development (FAO, 2000).

1. At the most basic level of meeting survival needs, energy use focuses on cooking, lighting and space heating. Households, use such traditional biomass fuels as wood cuttings and animal dung, the energy content of which is limited. Economic productivity is low.

- (a) There is little industry and agriculture only on a small scale, because power is limited to the labour of beasts of burden;

- (b) Transportation is local, relying mainly on animals, whose range and speed is limited.

2. The use of conventional hydrocarbon sources in households provides an increased level of comfort. Such fuel sources as coal, kerosene, plus liquefied petroleum gas (LPG) increase economic productivity from low to medium.

- (a) In some cases, industrial activity relies on mechanical power provided by windmills and small-scale hydropower. However, those are static sources, the operation of which depends on environmental conditions. The needs to store power for later and to transmit power for use elsewhere remain;

- (b) Increased agricultural activity requires more energy and more portable sources of power. Transportation, becomes an essential element of development.

3. Energy and mechanical power increase rural development significantly, because of higher productivity and increased flexibility. That is made possible by the advent of a centralized electrical power supply; gasoline and diesel fuels to support agricultural and industrial activity; and transportation. However, the use of non-renewable sources of power is unsustainable in the long run.

Policies to promote AGTs should ensure that implementing SE solutions is done in such a way so as to continue promoting an increased level of comfort and providing higher productivity while not undermining the flexibility necessary for farming and transportation.

At that stage, SE can continue to increase comfort and productivity. Various technologies can generate electric power effectively, including solar, wind, small-scale hydropower, plus biogas.

Note: product quality and the wider market

In the wider market, where quality sells at a premium, many rural products can generate higher profit margins. That is the case with olive mills, where such investment in production as introducing solar power and electric presses help improve product quality. However, there is little incentive to implement such systems for the local market if consumer demand is low and price sensitive.

However, SE solutions are not flexible enough for transportation purposes. In most cases, transportation remains dependent on the portable sources of power that gasoline and diesel fuels provide. Biogas is portable enough to support powered tractors and some local transportation.

Based on those factors, policies to promote the implementation of AGTs should focus on measures that can be dealt with at local community level. Those measures relate to energy production, waste management, the need for new skills, plus training and enhanced awareness, while assessing potential side effects of implementing new technology implementation in a rural environment.

1. Energy production can be promoted at the local level by establishing a local rural energy services company (RESCO), a power cooperative. In that way, decentralized energy systems and services could be developed to serve rural areas. Such an approach is emerging but at the moment is commercially experimental.
2. Significant energy gains can be made in waste management through reducing waste and/or using waste to produce energy.
 - (a) Decreasing waste can help diminish transport costs significantly. Optimal use of parts and raw materials requires fewer transportation trips. In industrial businesses, stocking standardized parts decreases waste, because of less machining and, therefore, less scrap from, for example, punching holes;
 - (b) In the regions surveyed, wastes from plant processing and meat byproducts could be used to make second-generation biodiesel or biogas. While the wastes from a single shop might not be sufficient to justify establishing a plant, wastes could be collected from many smaller operations by a RESCO or a dedicated local enterprise.
3. AGTs require local know-how to manage and maintain them, plus awareness of their usefulness and limitations. The implementation of AGTs requires a balance between two types of skills:
 - (a) Technical skills pertaining to the engineering implementation of AGTs;
 - (b) Business skills needed to manage implementing the AGTs in a way that ensures ongoing finance, possibly including marketing and sales skills to enable greater integration within a value chain.

Example: technical training and local adaptability

Proper training can have positive unforeseen consequences, as in the case of the Kordofan area of the Sudan, where tech-savvy users were able to use solar power to recharge mobile phones and other low-power devices, especially during production downtime, when surface water was more abundant and groundwater pumping not required

Policy must consider potential adverse consequences utilizing any new technology on a wider scale. It must be flexible. In many cases, better management could be enough without the need for new technology. The implementation should be gradual, even after a successful pilot scheme, to allow time to develop optimal management policies. For example, introducing solar-powered water pumps needs to be monitored closely, especially in cases where it will be used to pump groundwater. Management must be conducted at the regional level, to ensure that the water is not depleted by too many pumps. Farmers benefiting from greater access to water should be encouraged to deploy water-saving irrigation systems.

Note: the need for technology

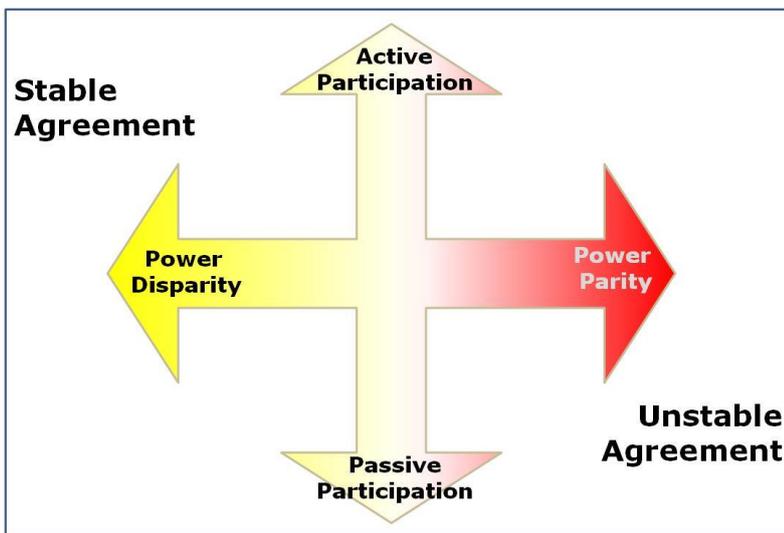
The use of solar-powered water pumps in the ESCWA region has proven very effective, but a close inspection could reveal that such technology is not always necessary. That is the case with regard to water pumps in the Gezira region of the Sudan. The pumps are used in summer, when the flow of the irrigation slows. It could, therefore, be more energy effective to enhance the irrigation network or improve its management. That could obviate the need for much of the pumping. In fact, the region is struggling with water management issues, which it did not have during the heyday of the Gezira Scheme, when fees collected efficiently financed the system’s upkeep.

IV.2 Policy implementation and sustainable local engagement

Any policy implementation process should be based on a stepwise approach, in a collaborative framework that promotes an enabling environment. In the short-to-medium term, control and command strategies appear to require less significant transaction costs, but they become cost ineffective and prove difficult to enforce in the longer term, making them less likely to succeed.

Stable agreements occur in situations where power is balanced and participation is active, illustrated in figure 3. However, as that often is not the case in rural areas, policies must be designed to take that into account.

Figure 3. Power situations and the quality of agreements



Source: Dubois, 2016.

However, for any collaboration to result in a stable and sustainable agreement, there should be a way to strike a balance between the various stakeholders and their different roles. One way to strike that balance is through the Four Rs framework, which strives to strike a balance between Rights Responsibilities and Returns/Revenues, “both within and between stakeholder groups” (Dubois, 2016, Slide No. 7). That balance is defined largely by the status of the mutual relationships, as shown in table 9.

Table 9. Stakeholder roles: the Four Rs

Role	Description
Rights	1. Obtain information on the local context through background research
Responsibilities	2. Understand the various stakeholders, their potential roles and capacity needs
Returns/revenues	3. Map technical capacities, related to adequacy of resources
Relationships	4. Quality (good/medium/fair) 5. Type (financial, social, technical) 6. Degree of formality (formal/informal)

Policy formulation, under the Four Rs is based on a four-stage process:

1. Determine the balance of Rights, Responsibilities and Returns/Revenues within and between stakeholders.
2. Evaluate the status of relationships between stakeholders.
3. Negotiate the rules, to ensure that stakeholders envisage and agree on a successful future scenario for a sustainable value chain with sustainable management of natural resources. That should be done gradually, by applying the framework first to a specific, simple issue. The “build-up to a more general picture” should start with “piecemeal negotiation first around hunting issues, then tree rights, then product processing and marketing relationships” (IIED, 2005, p. 4).
4. Map the Capacities, by identifying “the capacities needed to bring about the desired Four Rs as identified through the role negotiation phase”, then obtain agreement from stakeholders.

Example: the Four Rs in the case of the olive oil value chain			
	Rights	Responsibilities	Returns/revenues
Farmers	Usage rights	Custody of land	Harvest
Olive mills	Pressing	Quality of pressing waste disposal	Pressing
Marketers	Trading	High-value customers	Sales
Local government	Collection of taxes	Secure property rights; law enforcement	Taxes

Policy should be based on the findings from each of the phases outlined above. Policy should not be issued as a single recommendation but designed to create a framework that can be updated easily. It should ensure that:

- Wealth issues are documented and well understood;
- Stakeholder interaction is encouraged, in order to maintain momentum;
- Any options and agreed next steps are documented and understood.

An example of a policy to implement AGTs is setting up a RESCO. That collaborative energy-generation effort is a member-owned electrical generation business operated as a not-for-profit organization in order to meet members’ needs. It is built upon long-term relationships with end users who are, in effect, partners. Successful RESCOs are collaborative efforts that share the following four characteristics (UNIDO, 2006):

- Focus on energy applications, considering all renewable energy sources.*
- Offer a number of rural energy options.*
- Take a long-term view operating as an ongoing service rather than a one-off sale.*
- Remain mindful of rural market difficulties and avoid unfocused or aggressive expansion.*

The success of a RESCO relies on promoting local skills in the organization’s technical maintenance, plus ensuring good ongoing management of the organization generally.

IV.3 Finance

Finance is a key element of implementing AGTs successfully, with regard to short-term installation costs and long-term maintenance costs.

Example: sustainable energy and the cost of maintenance

In many areas, while such RE sources as solar power would save the cost of diesel and provide much-needed off-grid electricity, their deployment fails because financial returns in many poor rural areas are insufficient to cover running costs. That was the case with some poorer villages in the Rmada district of Tunisia, where many solar-powered water pumps fell into disuse because of lack of maintenance.

Despite the need, finance is not easily available to rural businesses because they are often considered unbankable (insufficiently profitable as bank customers). Instead of conventional banking, customers in those areas can rely on micro-lenders, which are able to offer small loans for small business purposes. Typically, those lenders tend to be charities, cooperatives, unions or associations, plus administrative or semi-administrative public bodies. They use banking techniques, including interest-bearing loans and guarantees, which might involve savings schemes (savings into loans), capital participation, or refinancing through credit within the conventional banking system.

In order to make rural businesses more bankable, policies should promote a form of banking that can be referred to as social micro-lending. It has four key aspects:

1. Financial, as banking services are extended on a small scale.
2. Labour market, as credit provisions aim to reduce unemployment and poverty.
3. Community development, with capital channelled to under-served rural communities.
4. Social welfare, reducing the need for direct subsidies.

There are three general approaches for regulating micro-lending: the market approach, the welfare State approach and the social lending approach (Reifner, 2016).

1. The market approach leaves lending to the financial sector and thus requires the minimum amount of supervision. That is the most traditional approach.
2. The welfare state approach promotes social objectives, providing finance through guarantee schemes, tax subsidies and state administrative funds. That approach often is taken in Germany and the Netherlands.
3. The social lending approach is linked to non-profit employment programmes and social welfare activities, either through direct support (in France, for example), or through the promotion of certain types of lenders assumed to engage in social lending (in Italy and Belgium, for example).

Policymakers can facilitate micro-lending in two ways: granting exemptions from bank law to certain institutions or granting micro-lenders a special legal status. In many cases, the scale of loans required could matter more than the type of lending institution when it comes to implementing AGTs. Some intermediation could be necessary to consolidate amounts that are too large for micro-lenders but too small for traditional banks. That could make the projects attractive to finance agencies by converting cash flows in a form that conventional retail finance could manage. Such financial intermediation (UNIDO, 2006, p. 24) could extend beyond ensuring funding and would need to cover:

1. The transaction costs of assembling the equity and securing loans.
2. The procedures for obtaining subsidies.
3. The assessment and assurance of the financial viability of schemes, plus the financial credibility of borrowers.
4. The management of necessary guarantees and the loan conditions, ensuring adequate collateral.
5. The management of loan repayment, plus any payment of dividends to equity holders.

V. Technical Background

The success and extent of any implementation of AGT initiatives depends greatly on economic dynamism, mainly of SMEs at the local level, supported by SE practitioners and policymakers.

1. Local SMEs understand their own economic needs. Given access to those green technologies (GT) that are appropriate to them, they will be able focus on local economic development.
2. Practitioners are well informed and possess the right tools to ensure sustained implementation. Their primary intent is to find an optimum energy supply/demand scenario for a pre-defined location and thus identify mechanisms by which that solution might be achieved. They should focus on SE, ensuring that local SMEs have access to, and understanding of AGTs, and that policymakers receive appropriate feedback.
3. Policymakers have a clear vision of SE in their own national context and tend to be well aware of their own specific rural context. Provided with the appropriate feedback from local SMEs and practitioners, they can come up with enabling policies that are essential for the mainstreaming of appropriate green technology. Those policies need to take into account the complex nature of rural areas and energy, plus align with national needs and priorities.

It is this interaction that will drive the transition towards a GE in rural sectors of the Arab region. However, those sectors face three main limitations:

1. Limited access to:
 - (a) Markets, due to a small local customer base, a significant distance to larger markets, plus lack of available funds to expand transportation;
 - (b) Infrastructure and centralized power supply, due to lack of available funds for grid expansion or the high cost of doing so in vast, sparsely inhabited areas;
 - (c) Skills and know-how, due to lack of technical training.
2. Strained ecosystems, because development puts increasing pressures on scarce resources.
3. Climate change, which adversely affects scarce water supplies and increases temperatures, thus increasing local energy needs.

The key to addressing those limitations to sustainability lies in a comprehensive strategy that tackles the various facets of the problem.

V.1 The methodology

The implementation of AGTs is best done using a methodology that recognizes that sustainable development (SD) is predicated on energy security through SE and linkage with such development issues as water security and food. The basic premise should be that:

By adopting AGT to enhance productivity of the income-generating activities in productive sectors, the technologies should be in tune with market forces, and local communities should play an active role in helping finance those technologies.

AGT initiatives are those technologies that can be adopted in the rural sectors of the Arab region as the region transitions towards a GE.

(a) Mapping the production process

The methodology was applied to selected rural communities in the ESCWA region. In general, rural areas were considered to be those areas that were remote. Remoteness was defined as being infrastructural, geographic and/or economic (International Energy Agency – Renewable Energy Technology Deployment (IEA-RETD), 2012).

1. In infrastructural approaches, the remoteness of an area was related to whether or not it was connected to central infrastructure.
2. Geographic definitions of remoteness generally relate to population density or to the “distance from anchor points such as major population centers” (IEA-RETD, 2012).
3. In economic terms, the focus was on energy remoteness, with remote areas classified as those where energy services were neither affordable nor cost effective.

In the context of the Arab region, none of those approaches is sufficient by itself. A combination of the three approaches is needed. That is especially the case now that rural areas are far less isolated and far more exposed to global markets than during the past century. Most rural areas now have enhanced access to markets and much greater integration in the global economy. However, that exposes them to stiffer competition, as even “smallholder producers now compete in markets that are much more demanding in terms of quality and food safety, and more concentrated and integrated than in the past” (OECD, 2006, p. 10).

The rural areas surveyed differed in their ability to produce goods and services, plus in their access to national, regional and global markets.

1. The regions surveyed in Jordan, Morocco and Oman all had access to national, regional or global markets. That was also the case with most of the regions reviewed in Tunisia and the Sudan. Some economies were dominated by large-scale businesses, as in the case of Zarqa governorate in Jordan, but most were dominated by small-scale operations.
2. Two of the surveyed regions had limited access to land and resources, with food security the primary concern.

(a) In the Musalamia village of Gezira state, productive capacity is hindered by problems related to land ownership and property rights;

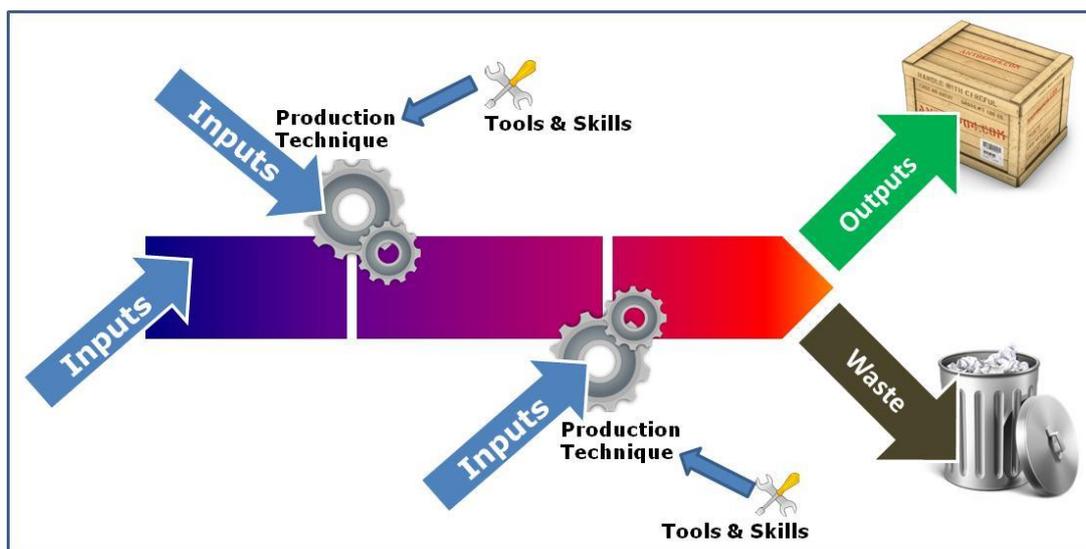
(b) In the Rmada district of Tunisia, productive capacity is undermined by the unfavourable economic situation. The region is likely to need more social assistance before it can focus on further development.

The methodology is valid for the wider macro-economic context in which rural economies operate, based on a logical flow of the production process, as shown in figure 4. The methodology maps the entire flow from inputs to outputs, to reflect how productive it is. As energy flows through the process, producers strive to strike a positive balance where the useful outputs (goods and services) are greater than inputs (energy, raw materials, labour and know-how) and waste outputs (waste materials and inefficiencies).

Mapping assesses those flows, to determine if the production process has high enough returns on energy and material inputs, and to determine how and where those returns could be improved. The aim is to find positive returns on energy, ensuring that energy produced is higher than energy consumed.

For that purpose, it is best to rely, to the extent possible, on alternative and SE sources. That would provide income that would otherwise be spent on fuel. However, SE sources have limitations that need to be taken into account.

Figure 4. Mapping the production process



(b) The value chain

The success of businesses in rural areas depends greatly on their access to markets. Those business can no longer be content to survive by focusing solely on their own regional context, because of increasingly stiff competition.

1. In theory, those businesses can overcome such challenges by collaborating in a manner that helps them increase their access to national, regional and global markets. There is an increasing “economic, financial and ecological case for beginning to transition” towards “a greater reliance on more local and sustainable forms of energy”, especially in the context of decreasing RE costs (IEA-RETD, 2012, p. 13). One way to do so is through the establishment of a value chain.

2. In practice, however, rural areas face “generic factors limiting [their] market participation” (Springer-Heinze, 2007, p. 19). In those cases, producers find themselves stuck in a poverty trap of high costs and low returns. The most obvious limiting factor is that the location has limited access to resources, goods and services, and/or markets. However, there are other, less obvious limiting factors, such as:

- (a) A comparatively higher risk of doing business, particularly SMEs;
- (b) The lack of access to diversified services, which are vital to ensure the maintenance of any new technology;
- (c) Property rights that might be unclear and/or laws that might be poorly enforced;
- (d) Lack of relevant technical skills obtained through vocational rather than formal education.

The value chain helps determine what GT is appropriate. The GTs appropriate for rural areas of the Arab region need to rely, as much as possible, on local, renewable resources. The technology selected focuses on the integration among businesses, where the waste of one business can become an input of another. That ensures that AGTs minimize the financial and technical burden associated with energy production, allowing businesses to focus on income generation.

Example: farming value chain that markets animal products

The animal waste from one business can be used as feedstock into a biogas generation plant. The plant would provide both energy for the partner businesses and fertilizer.

A successful value chain needs the following key elements:

1. Commitment from all members and a clear vision of objectives, which allows for the formulation of compelling goals.
2. Careful selection of partners with complementary skills and needs, to ensure interdependence and cohesion. Strong business relationships are built on trust. They are nourished by interdependence, a balanced power structure, and a fair decision-making process that leads to equitable returns
3. Clearly planned and validated logistics.
4. A neutral facilitator, if possible, perhaps a dedicated chain manager working for the value chain as a whole rather than for an individual business.

V.2 Types of sustainable energy solutions

Sources of SE differ with respect to three main technical factors: generation, usage and waste. A fourth factor is the level of skills (from basic, medium to advanced) required to implement and maintain the solution.

(a) Energy generation

Different energy sources have different power limitations, so it is optimal to combine sources with different types of power limitations. In general, energy sources are either energy limited or power limited.

1. Power sources that are energy limited (EL) generate a fixed amount of energy for a given production unit over a given period of time. To obtain more power from the system, more units must be added that is often the case with RE. To get more power from solar or wind installations, for example, more solar panels or windmills are required.
2. Power limited (PL) sources are more flexible: more energy simply requires more fuel. That is the case with diesel-electric generators, biodiesel generators combined with biogas plants, or car/truck engines.

Availability is a further limitation. The availability factor varies. Most RE sources are intermittent sources of power. Energy produced is not continuously available, due to such external factors as the weather.

Differences between RE and conventional sources are discussed below.

(b) Energy usage

The main energy applications relevant for rural areas of the ESCWA region are lighting, pumping, information and communications (ICT) systems, plus cooling and refrigeration.

1. The amount of lighting required depends on use. For example, more light requires more batteries. Lighting differs in relation to needs for ambience, general use, or tasks requiring high contrast and precision.

(a) Ambient lighting requires, the lowest amount of energy. A lighting level of about 5 lux is enough to provide a minimum amount of illumination for people to see one another and move about. Ambient lighting is used in waiting rooms, hospital wards and restaurants. The lighting required is comparable to that provided by wicks, candles, kerosene and gas lamps;

(b) Most applications require general lighting, with levels between 5 and 50 lux. That provides enough illumination for reading or viewing objects. It is adequate for reading/studying, cooking, security, plus illuminating shops and classrooms;

(c) Fewer applications require lighting greater than 50 lux. Such task lighting needs to be bright enough for high viewing detail. It is used primarily for close work required in anything from sewing rooms to medical operating theatres.

2. The irrigation need in rural areas defines the type of water supply required. Water in rural areas is used for community use, livestock, plus crop irrigation. Sources of RE might be well suited for the first two applications but might struggle to meet crop irrigation needs. That is because the amount of water required in irrigated farms varies widely during the day and differs for different crop types. Intermittent power sources generally are ill suited for those purposes unless combined with sufficient storage.

3. The ICT systems that can be powered by PV energy can be grouped into three categories: (a) educational and office equipment, including computers; and monitors (b) communication equipment; and (c) audio-visual equipment. The power usage of ICT equipment ranges from about 60 watts for a colour television set to 400 watts for a computer system, for about eight hours of operation each.

4. In order to power cooling and refrigeration systems in off-grid settings, the cost for a power system might be as high as for the refrigeration system itself. The type and cost of the system depends on whether or not freezing is needed, the size of refrigeration space, how often access is needed, prevailing heat, plus how critical the refrigeration requirement is.

Table 10 shows the applicability of different energy uses and sources.

Table 10. Energy uses and sources

	Energy uses			
	Lighting	Irrigation	ICT	Refrigeration
Solar	✓	(2)	✓	(2)
Wind	✓	✓	✓	(2)
Small hydro	✓	✓	✓	✓
Biogas	(1)			(2)
Conventional	✓	✓	✓	✓

Notes: (1) Fire hazard: requires frequent smell checks to detect biogas leaks.
 (2) More applicable for smaller scale applications.

(c) Waste

Waste is a problem of all economic activity. The generation and use of energy is no exception. However, there are cases in enhanced SE services where waste can be minimized or serve as a source of WtE.

1. Solar and wind power minimize waste generation. They generate energy from the sun and wind respectively. The only resulting waste is from activities related to maintenance.

2. Waste can be diminished through WtE processes. Those processes generate biogas and other combustible fuels that can be used to generate heat or provide motor power to produce electricity.

V.3 Appropriate green technologies

The technologies considered do not include systems powered by human or animal effort because, while those technologies are used extensively in rural areas where survival is at stake, they cannot generate enough energy for increased economic development. There has been some progress in devising human-powered electricity generation systems, but those systems are physically limited to about 50 watts, which is suitable for such low-energy needs as recharging cell phones, radios and small lamps.

Table 11 shows the main differences between renewable and conventional power technologies.

1. Different types of RE technologies utilize wind, solar, small-scale hydropower and biomass resources.
 - (a) Wind energy is used for pumping water and generating electricity;
 - (b) Solar power is used for drying crops, heating water (using solar heaters) and generating electricity (using PV systems);
 - (c) Small-scale dams are used to store water. They can be coupled with hydropower units to generate electricity;
 - (d) Technologies that utilize biomass include improved cooking stoves for burning traditional energy sources more efficiently, plus digester tanks to generate biogas. Biogas also can be used in small power plants to generate electricity, the waste products often used as fertilizer.
2. Conventional sources might not be readily available locally. However, they offer a complete solution because they provide good energy storage, good transportability, and can be used in many different ways. Their main downside is the waste products they leave behind.

From the perspective of energy generation, the main difference between conventional and RE technologies is in the flow of energy through the respective systems. Conventional sources offer a complete solution but RE technologies often need to be coupled with other systems, mainly because of current storage limitations within those technologies.

Table 11. Energy solutions and their applications in rural settings

Energy stage	Solar PV	Solar heater	Wind electric	Wind pump	Small hydro	Biogas	Conventional
Generation							
Intermittent	✓	✓	✓	✓			
Limitation	EL	EL	EL	EL	EL	PL	PL
Availability (%)	20-30	30-40	20-40	30-40	30-40	50-60	70-90
Storage		✓		✓	✓	✓	✓
Use							
Industry	✓			✓	✓	(1)	✓
Agriculture	✓			✓	✓	✓	✓
Household	✓	✓		✓	✓	(1)	✓
Waste							
Generated						(2)	Greenhouse gases, oil
Minimized	✓			✓	✓		
Waste-to-energy						✓	
Skills required	Advanced	Medium	Advanced	Basic	Advanced	Basic	Medium

Notes: (1) Requires large amounts of organic wastes of the type generated by agricultural operations.
 (2) Solid sludge left over, part of which can be used as fertiliser.

(a) Wind energy

Wind energy is used mainly for pumping water and generating electricity. The applicability for either solution differs in terms of prevailing climatic conditions and resource availability.

Prevailing climatic conditions define the average wind speed and, therefore, the type of windpower that can be used, as shown in table 12.

1. Water pumping is feasible with prevailing winds starting from 2 m/s to 5 m/s (7 km/h to 20 km/h). For any given wind speed, the pumping rate depends on the pumping head, the height that the water must be lifted from the ground. The further away the water, the slower the pumping rate. Water pumps generally operate adequately in cases where there is no more than 100 m difference between the top of the groundwater table

and the top of the water surface in the water tank to be filled. Most cost-effective wind pumps are placed 7 m to 25 m above ground.

2. Electric wind power is feasible with prevailing winds starting from 6 m/s to 11 m/s (25 km/h to 40 km/h). Higher wind speed are needed because of physical limitations. With current blade designs, wind turbines generally capture only 12 per cent to 30 per cent of wind energy. Larger turbines tend to be more efficient than smaller ones. Nevertheless, even at low wind levels, wind power can still be effective for such low-power applications as battery charging.

The availability of local resources is a second limiting factor for the construction and use of windmills, especially in rural areas. Low wind speeds and limited resource availability mean that it is easier to deploy windmills for water pumping than for electric power. Since the 1980s, there were attempts to develop steel wind pumps that would keep the virtues of older designs while being lighter. Those attempts led to the Kijito design in Kenya and the Tawana design in Pakistan. Thanks to such developments, costs are kept low enough to allow for installation, while providing the durability of traditional designs.

However, such windmills still face physical limits because weaker winds generate weaker mechanical power. That restricts them to shallower water. Deeper wells need to be electric powered.

Table 12. Wind speed and windmill applicability

Wind speed		Naming and definition		Minimum applicability
Force (beaufort scale)	m/s			
0	0	Calm	Smoke rises vertically	
1	1	Light air	Direction shown by smoke but not wind vane	
2	2-3	Light breeze	Wind felt on face, leaves rustle	Water pump
3	4-5	Gentle breeze	Leaves, small twigs and flags move	
4	6-8	Moderate	Dust and paper raised, small branches move	Electricity
5	9-11	Fresh breeze	Small trees with leaves sway	
6	11-14	Strong breeze	Large branches move, wires whistle	
7	14-17	Near gale	Whole trees move, walking slightly impeded	
8	17-20	Gale	Branches break off trees, walking difficult	

(b) Solar power

Solar power is used in rural areas of the ESCWA region for drying crops, heating water and generating electricity.

1. Solar driers can be used to dry clothing and prepare dried foods. Traditional designs have been improved recently, with drying racks and solar tents being used.

2. Solar water heaters (SWH) for domestic use are becoming increasingly common. There are design variations, but all devices are based on a solar thermal collector that uses sunlight to heat water directly. Some designs are more susceptible than others to dissolved solids in water, so do not perform equally well in all regions.

3. Solar PV systems are based on panels that convert solar energy directly into electricity. The technology has demonstrated its ability to supply basic increments of electricity in off-grid rural areas but is inappropriate for electricity needs of more than 5 kWh/day.

(c) Hydropower

Hydropower captures the source of energy from running water to generate a rotating motion that can provide direct energy through the use of water wheels, or to generate electricity through electric generators coupled with water wheels or hydropower turbines.

Hydropower can be generated directly or as part of a pumped storage scheme.

1. Direct hydropower comprises two types:

(a) Conventional small-scale dams connected to river streams that capture and store runoff. When water is plentiful, it can be released to power mechanical devices;

(b) Micro-Hydro devices that rely on specific topographical configurations to capture the run-off energy from non-river streams, including:

- i. Irrigational channels and conveyers that capture the excess potential energy of flowing water;
- ii. Wastewater treatment plants, where the excess potential energy of treated effluent can be captured at the plants' outlets;
- iii. Outfall pipes from existing large plants that rely on large amounts of cooling water;
- iv. Excess pressure in large potable (drinking) water networks, where there is a need for pressure reduction.

2. Wherever regional topography allows it, hydropower could be used in conjunction with other energy generation sources to provide for power storage. Such pumped storage relies on energy trading, using any power available at off-peak times to store water in elevated reservoirs. At peak time, when power is needed, stored water flows through turbines and generates power.

(d) Biomass

Gas from decaying biomass, or biogas, provides a feasible and ready source of gas for cooking needs. Provided the right know-how is available, biogas systems are easy to implement with local resources. They are particularly useful and versatile in areas where access to market is restricted or, worse, disrupted. A recent example is in 2015 in Syria, where the residents of the eastern Ghouta agricultural area in the Damascus countryside turned to biomass fuel extraction to compensate for disruptions in the supply of gas and electricity.

Biogas is a mixture of gases that result from the anaerobic digestion by bacteria of a slurry comprising organic wastes in a hermetically sealed container. In a biogas plant, that slurry is stored in an insulated fermentation tank, the reactor. Biogas systems have two main outputs: (a) biogas that can be used for domestic use or small power plants to generate electricity; and (b) solid waste that often can be used as fertilizer, thus enhancing agricultural productivity.

Biogas is mostly methane but also contains carbon dioxide and traces of hydrogen sulfide (which gives biogas a distinct smell, akin to rotten eggs). Like methane gas, biogas can be compressed to form Compressed Natural Gas, for use in gas engines.

Basic designs

A biogas system centres on a digester or reactor inside which the gas is generated. As the gas is generated, its pressure increases. The pressure helps the gas flow into pipes, towards where it is needed. As the gas is removed, most of the slurry flows back into the reactor, leaving a residue, the digestate that can be used as fertilizer. There are three main types of biogas systems: rubber balloon, fixed dome, plus flexible or moving dome.

(a) The simplest type of biogas plant is made of a rubber balloon, a hermetic bag made of rubber or plastic and partly buried. The system is simple to construct and use, with easy control of gas pressure. However, it requires more maintenance than other designs and has a shorter lifespan;

(b) A more complex type is the fixed dome reactor, usually placed underground to save space and provide better thermal insulation. The system often has an expansion chamber into which part of the slurry flows. The expansion chamber allows for continuous use of the biogas reactor, with less frequent need to access it. That type of system lasts longest and is easiest to maintain. However, because all the components are fixed, the gas pressure fluctuates and cannot be controlled directly;

(c) A flexible or moving done is an intermediate design that provides for better gas control. The top of the reactor is equipped with either a flexible membrane or a floating drum that moves up or down depending on the amount of gas stored. The system is more expensive to build, and maintain. It also is more prone to malfunction.

Types of organic waste

The tank is connected to an inlet where various types of organic waste are placed. The wastes used in biogas plants comprise mainly livestock manure and some types of farm residue. Kitchen waste and, in some cases, human waste also are used.

(a) Livestock manure, plus non-cellulosic residues from food processing and agriculture. Livestock usually generate daily amounts of manure representing 3 per cent to 5 per cent of their body weight;

(b) Kitchen wastes, excluding lignin (straw and wood chips). In general, most waste from green plants is suitable for bio-digesters, and might, in fact, yield more gas than animal or human waste;

(c) In some cases, toilets can be directly linked to biogas units. Provided that no household detergents are used in the toilets, human wastes can be digested along with other waste products. That option does not significantly increase the amount of biogas generated, because humans generate daily wastes of only about 1 per cent of their body weight. Human wastes are generally not as rich as animal dung in the material that can be converted to biogas. However, the option provides a safe and effective treatment of human waste, reducing pollution to groundwater and the wider environment.

General design parameters

In the hermetically sealed fermentation tank, the slurry is digested by anaerobic bacteria, which thrive in oxygen-free environments, feeding by breaking down organic matter. When the reactors are first filled, the bacterial community can take some time to get started. For that reason, some reactors are seeded with sludge from a septic tank or from another anaerobic reactor. The entire process results in two end products:

(a) A methane-rich biogas that contains varying proportions of carbon dioxide, hydrogen and ammonia. The gas can be used for cooking and lighting;

(b) The digestate, an enriched organic manure in the form of digested slurry, which can be used as fertilizer;

The size of the reactor depends on two parameters: a hydraulic retention time (HRT) and the volume of the slurry that will be fed into the reactor. The required volume is obtained by multiplying the HRT by the daily amount of slurry.

(a) The HRT depends on the prevailing temperature. In hot climates, it should be at least 15 days. In more temperate environments, it would be 25 days. The temperature of the reactor itself should be in the range of 30°C to 38°C for effective biogas production;

(b) The amount of slurry is estimated based on the source of input.

If properly designed, a biogas plant should be easy to operate. The main maintenance requirements are to check regularly for corrosion and leaks, and to clean up grit and sand accumulation at the bottom of the reactor. If properly designed and constructed, the reactor should need to be emptied only about every 5 to 10 years. General design parameters are summarised in table 13.

Table 13. General parameters for biogas digester design

Design parameter	Value
Slurry retention time	40 to 100 days
Biogas energy	0.55 to 0.65 litres of diesel fuel
Cooking requirements	0.30 to 0.90 m ³ /person/day
Gas lamp requirement	0.10 to 0.15 m ³ /hour
Daily yield	0.30 to 0.50 m ³ /m ³ of reactor volume

(e) Combined systems

When implementing RE solutions, it is best to combine them with other energy sources, because renewables have two main limitations: they provide intermittent power and tend to be EL.

1. Power is provided by RE whenever the source is present: PV systems can generate power only when the sun is shining, and windmills are productive only when the wind is blowing above a minimum speed. The output of those systems varies across the year, from season to season.

2. Renewables relying on EL systems generate a fixed maximum amount per unit. Solar panels cannot be made to increase power output. More output requires more solar panels to be installed.

To meet those two limitations, it is best to combine EL sources with PL sources that can make up for any shortfall, or that can be cranked up to meet peaks in demand. An additional combination is possible, in which the waste of one power source can be used as an input for another. That is the case with Combined Heat and Power systems, also known as micro-CHP systems.

1. Micro-CHP systems can use biogas to generate heat and electricity simultaneously.

2. There is no standard micro-CHP system design: each design must address local needs in order to utilize the biogas mix available and to generate the required ratio of heat to electricity.

(a) While micro-CHP systems are powered by biogas, some models can be designed or adapted to use waste oils or other bioliquids. There are three main types of technologies:

- i. The most proven technology is the internal combustion engine-CHP, essentially a modified truck diesel engine design. While the engine generates the electricity, any heating is collected from the waste heat of the cooling water and exhaust manifold;
- ii. A new technology coming to market is based on the Stirling engine design. The Stirling engine micro-CHP is optimized for heating, with a comparatively small electrical output;
- iii. More recently, fuel cell designs have been adapted to use biogas. As of 2015, the technique is still experimental but has the potential to generate comparatively more electrical energy;

(b) The ratio of heat to electricity depends on the type of micro-CHP system. Most domestic systems are similar in size and shape to standard boilers. The ratio of energy generated for heat and electricity is 6:1.

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