THE FUTURE OF THE WESTERN CAPE AGRICULTURAL SECTOR IN THE CONTEXT OF THE 4TH INDUSTRIAL REVOLUTION

Review: Internet of Things (IoT)

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USB
University of Stellenbosch Business School

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1. Renewables in Agriculture

Introduction

Agriculture is intricately tied with energy. Agriculture is responsible for approximately 2.4 per cent of electricity consumption in South Africa[1] and about 3% of energy consumption[2]. Because of its intensive fossil energy use, global agriculture contributes between 14% and 30% of the world's greenhouse gas (GHG) emissions[3]. Increasing agricultural production will increase emissions which, in turn, will impact the industry negatively. Mitigating climate change may require reducing agricultural production. Agriculture is therefore seemingly faced with a double edged sword.

But agriculture is fortunately capable of also providing solutions. Much potential exists for the generation of energy and production of fuel from agriculture. This chapter will provide an overview of the agriculture-energy nexus.

2. RE is at early adoption phase

The agricultural industry is experiencing, and will experience, a significant shift because of a changing renewable energy landscape. De Wilde[4] maintains that agriculture may shift to renewable energy because the world is running out of fossil fuel. However, we believe the shift will happen for far more virtuous reasons.

Firstly, the industry will experience an increased demand for agricultural products for the production of biofuels. Caution, in this respect, should be taken to avoid biofuels to impact on food production.

At the same time, renewable energy can reduce the environmental impact of agriculture substantially while also making farming much more competitive.

Cost is of paramount importance in any industry. It is therefore not surprising to find that the declining cost of renewable energy is a major driver for the increased adoption of the technologies. Many farmers make use of diesel engines to provide electricity on their farms. In many instances, renewable sources can reduce the need for diesel fuel and hence reduce costs substantially. Figure 1 illustrates the globally observed levelized costs of a number of energy sources. What is important to state is that electricity only represents 0.6 per cent of costs in agriculture[5]. A much larger component of costs come from fuels like diesel. In the figure, we point to the cost saving that is possible with solar PV compared to using diesel fuel. Figure 1 shows that PV could represent as much as a 75% saving in energy costs. This cost saving is likely to increase more with and increasing fuel price, weakening currency and decreasing cost of solar PV installation.

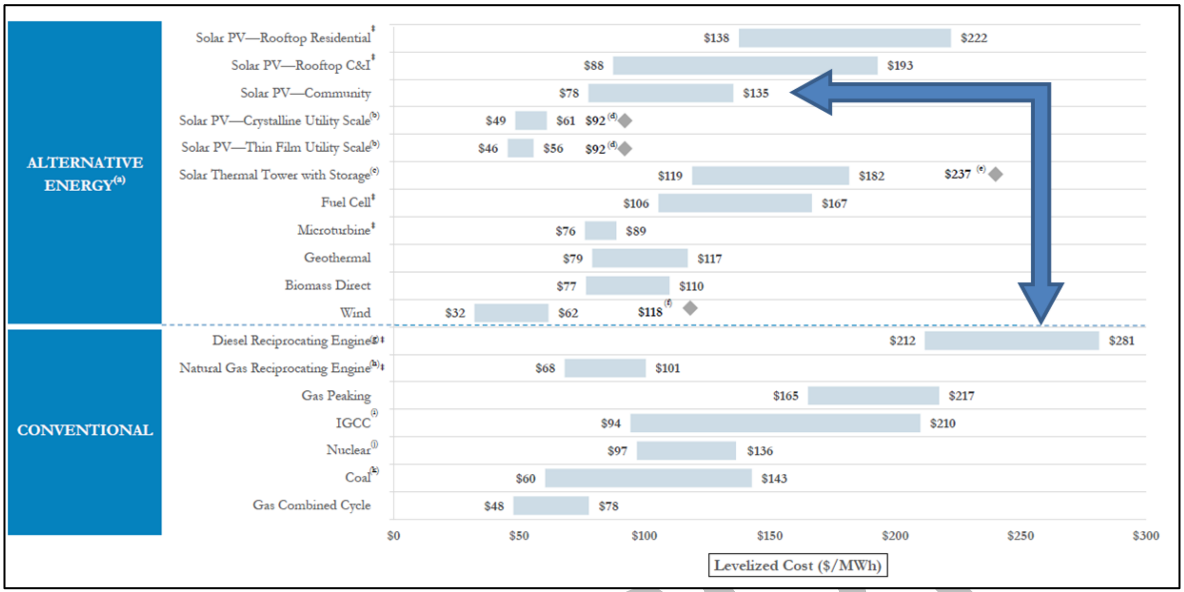
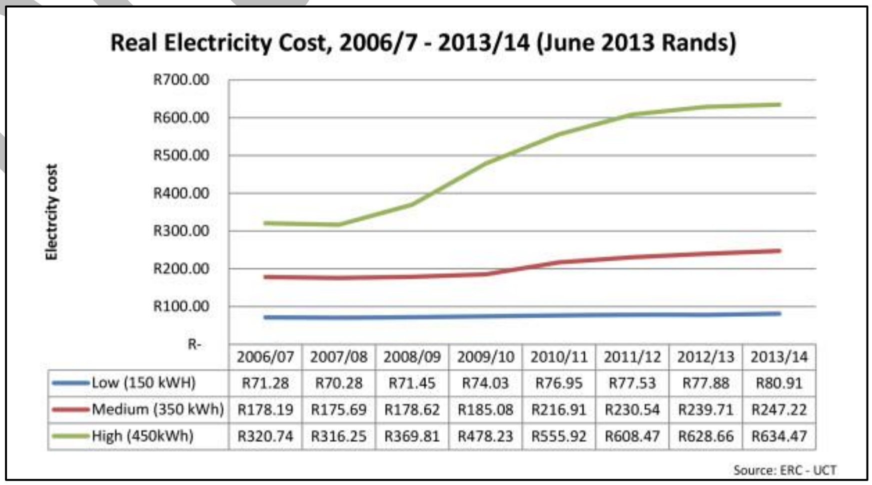


Figure 1: Unsubsidised Levelised cost of Energy comparison Source: Lazard, 2016:26

Despite its small contribution to total costs, the cost of electricity provides further support for growth in renewable energy. The cost of energy for large electricity users has more than doubled between 2006 and 2014 (Figure 2), while "low" users are typically accepted to be low income households and therefore are subsidised through a free basic electricity grant. What makes the "high" line all the more significant is that large users are incentivised to switch to cheaper sources of electricity because of an increasing price, but also because they consume more electricity than other users.



	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Low (150 kWH)	R71.28	R70.28	R71.45	R74.03	R76.95	R77.53	R77.88	R80.91
Medium (350 kWh)	R178.19	R175.69	R178.62	R185.08	R216.91	R230.54	R239.71	R247.22
High (450kWh)	R320.74	R316.25	R369.81	R478.23	R555.92	R608.47	R628.66	R634.47

Figure 2: Increases in the real cost of electricity in South Africa
Source: Chehore, 20147

The cost of utility scale wind and solar PV energy has respectively declined 59 and 83 per cent between 2011 and 2016 (Figure 3). Much of this is due to the declining cost of the hardware, although some of the cost reduction is due to lower financing costs and the industry's learning curve.

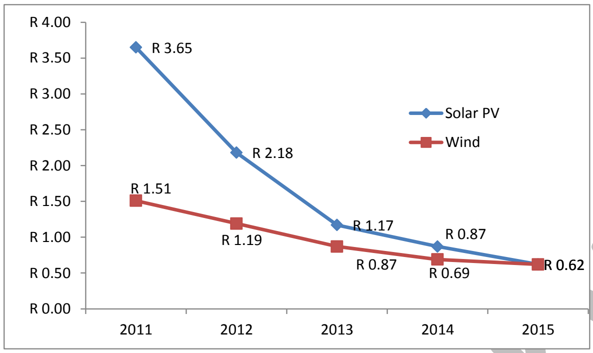


Figure 3: Average tarrifs of wind and solar PV have declined in R/kWh (Apr-2016-R)

Even though renewable energy at domestic and commercial level is much smaller, the cost reductions are similar. This decline in cost will increasingly be a driver for farmers to adopt RETs on their farms.

Particularly for electricity, the tariff per kilowatt-hour (kWh) only tells a fraction of the story. The real saving for farmers can often be seen in the "demand charge". The demand charge reflects the maximum load that the farmer may require in a period. For instance, the maximum demand in Figure 4 is just below 36 000 megawatt (MW). By lowering the peak demand, the farmer will pay a lower demand charge. In a case (like in Figure 4) where the peak demand is after sunset, it may be beneficial for a farmer to use a renewable energy source that can deliver energy at the time of the peak, or alternatively, store energy in order to provide power at the time of the peak demand.

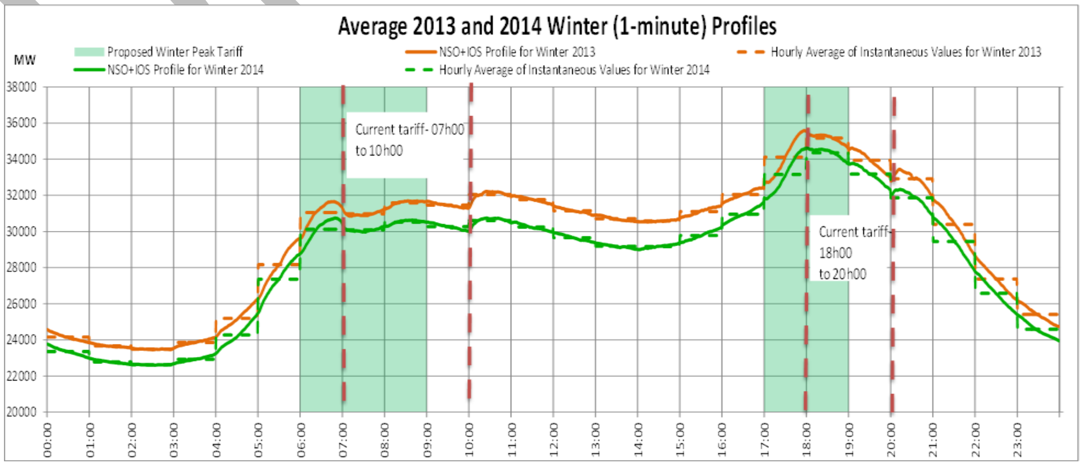


Figure 4: Illustration of a typical 24 hour demand cycle

3. Smart grids, net metering and distributed generation

Smart grids that allow net-metering represent a movement towards the democratisation of energy generation by allowing energy-generators, regardless of size, to be rewarded for energy that they provide to the grid. In some cases, the “feed-in tarrif” is set at the same price as drawing from the grid, but in the majority of cases, micro-generators are paid a reduced fee. Time of use (TOU) net metering employs a meter that rewards an electricity generator with different tariffs at different times of day. Recently, a number of municipalities have opened up their electricity network for net-metering for Small Scale Embedded Generators (SSEG). In order to qualify as a SSEG,

1. the total capacity of the system must be less that 1 megawatt-ampere (MWA) and
2. the generator must be a net user of electricity in any consecutive 12 month period[8].

The opening of the electricity grid poses challenges to Eskom and municipalities due to already existing excess capacity in South Africa and potential erosion of their income from electricity sales. The SSEG tariffs have therefore been set up in such a way that it benefits generators more to first use all available capacity to reduce their own consumption of electricity from the grid.

No.	Municipality	Allow SSEG	SSEG tariffs	SSEG policies
1	Beaufort West	Yes	Yes	In progress
2	Bergrivier	Yes	No	In progress
3	City of Cape Town	Yes	Yes	Yes
4	Drakenstein	Yes	Yes	Yes
5	George	Yes	Yes	Yes
6	Mossel Bay	Yes	Yes	Yes
7	Oudtshoorn	Yes	In progress	In progress
8	Overstrand	Yes	Yes	In progress
9	Stellenbosch	Yes	Yes	Yes
10	Swartland	Yes	Yes	Yes
11	Theewaterskloof	Yes	Yes	Yes
12	Langeberg	Yes	Tariff consultant appointed	Yes
13	Breede Valley	Yes	In progress	No

Table 1: Western Cape municipalities that allow small scale generators to feed back into the grid.
Source: Greencape, 2017b

4. Renewable Energy Technologies in agriculture

Many renewable energy technologies are well suited for smaller installations as would be the case in agricultural applications, regardless of whether it is at large or small scale farming. Technologies that are worthwhile in terms of cost savings are the following technologies:

- Micro wind
- Solar PV
- Solar heating
- Micro hydro
- Biomass

We have included biomass in the list of renewable energies, even though it is a resource that could potentially be over-exploited. We included it for three reasons. Apart from the potential from agriculture to produce biofuels, the agriculture sector has secondary potential for energy generation. The agricultural sector creates significant volumes of biomass that is often viewed as waste. Where such residue-streams can be identified, much potential exist to process these into value-added products. Thirdly, even though biomass is not considered a zero carbon solution, biomass has a footprint that is comparable

The following section will explore the different renewable energy technologies in more depth.

Micro wind

Wind energy is one of the oldest renewable sources of energy. Wind pumps have been used extensively by farmers in drier regions of South Africa to pump water for animals from underground sources.

Micro wind is very easy to set up, and typically can operate with very low wind speeds. Most of the Western Cape is suitable for wind energy (See Figure 5).

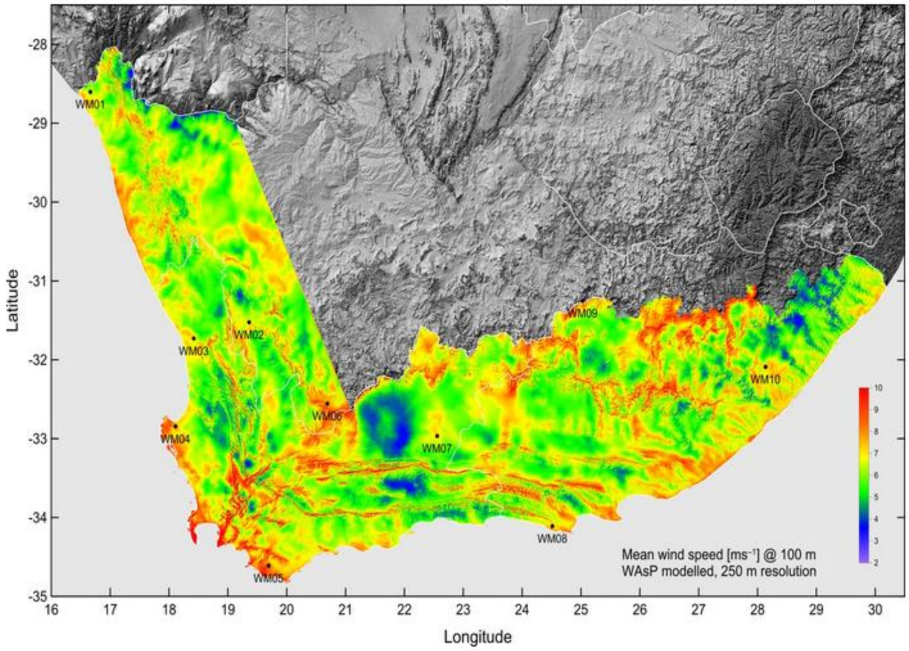


Figure 5: Wind resource in South Africa
Source: SANEDI, WASA project

Wind energy has many benefits. In a water scarce environment, it is important to note that wind energy does not require any water to operate. Wind energy also has low operational costs, although it is not as low as for solar PV. Furthermore, wind energy is the energy technology with the quickest energy payback, meaning it offsets the energy that it took to make the turbine in the shortest time. Lastly, wind energy is an old technology, and hence micro-wind turbines can be serviced and repaired by most people with a rudimentary understanding of electric dynamos/ motors.

Unfortunately the benefits of wind energy are offset by the disadvantages in most situations. Without battery backup, wind energy is unable to provide uninterrupted energy, or dispatchable (i.e. can be turned on or off, or can adjust their power output accordingly to an order) energy. This makes wind-energy unsuitable for applications that need a constant supply of power such as lighting or refrigeration. Battery backup is becoming cheaper though, making wind energy ideal for applications that has sufficient wind but no grid connection.

Solar Photo-Voltaic (Solar PV)

Agriculture is the second biggest non-utility-scale user of solar PV in South Africa. In November 2016, Greencape[9] found the total capacity of PV to be just over 30 MW (Figure 6). Adoption of PV in all sectors were driven by, amongst other factors, the electricity shortages in 2015. Agri-businesses like dairy need a constant and stable supply of energy and are severely impacted by power outages[10].

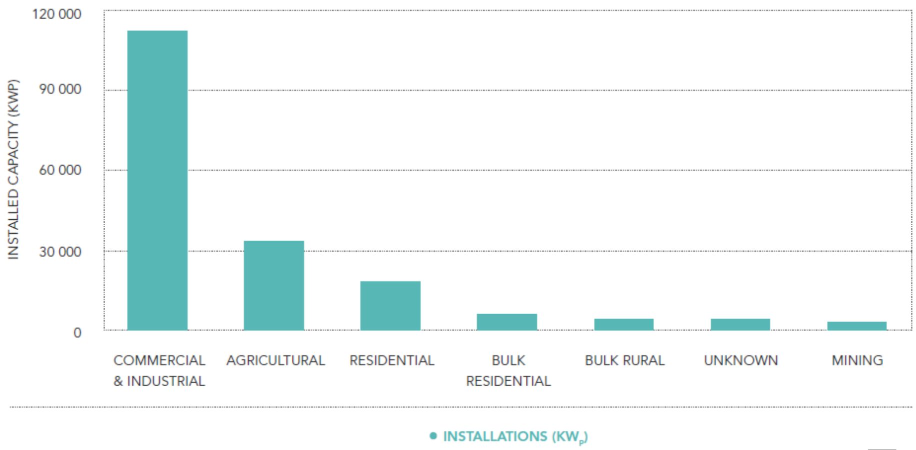


Figure 6: Distribution of solar PV installations across end-user segments
Source: GreenCape, 2017 b: 19[11]

The Northern Cape and Western Cape of South Africa is endowed with very high levels of solar irradiation, making it ideal for solar energy applications such as solar PV. It should be noted that extreme heat is counterproductive for solar PV as the efficiency of panels decline at very high temperatures[12].

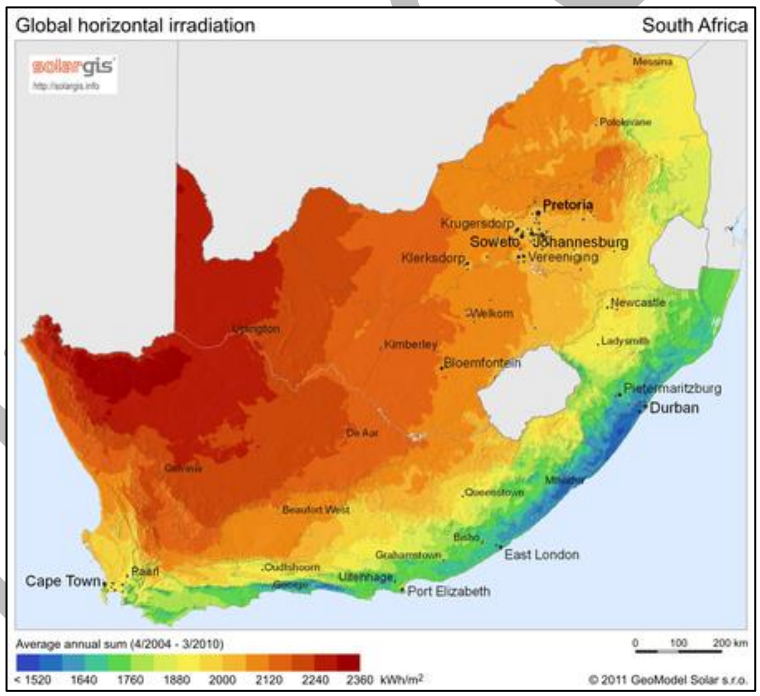


Figure 6: Horizontal irradiation in South Africa

Solar PV is an ideal solution for applications that require energy at daytime or when it is hot (such as cooling for warehouses and packhouses) or applications where the time of use is unimportant and only required for some hours of the day (such as pumps to fill water-troughs). One study found that solar PV on an apple packhouse resulted in a 15 per cent saving on electricity[13].

Although a diesel-driven waterpump is cheaper than a PV-based alernating current (AC) pump, diesel pumps are expensive to maintain and require constant monitoring and refuelling. PV pumps can easily be controlled through smart-phone technology and requires little additional attention. One issue with PV-pumps though is that the pump should not run without water for any extended period. Solar pumps are ideal for arid areas.

The saving attainable through the use of solar PV and other renewables will continue to increase with declining cost of PV, and the increase in the price of electricity from Eskom (as illustrated in Figure 7). According to the graph, power parity for non-utility scale PV could be achieved by 2019. It is important to note that Figure 7 compares the price of Eskom electricity, and not the price for building a new coal plant. That parity was already reached in 2013.

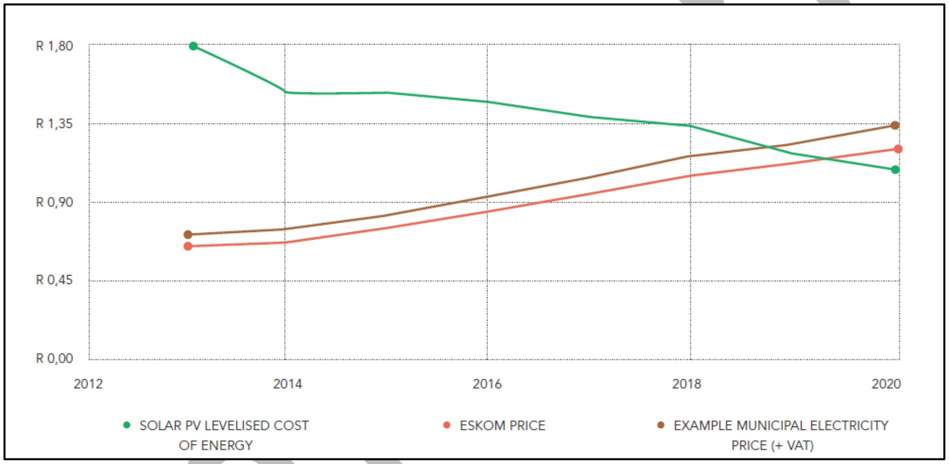


Figure 7: Expected price of electricity provided by a >100 kilowatt-peak (kWp) solar PV system
Source: Greencape[14]

Figure 8 provides further evidence of the cost reductions in solar PV. Solar PV is not a mature technology like hydro, and costs are expected to continue declining. Figure 8 shows the relative reductions in cost of different components of a utility scale PV system. Smaller systems are more expensive, but have typically the same components.

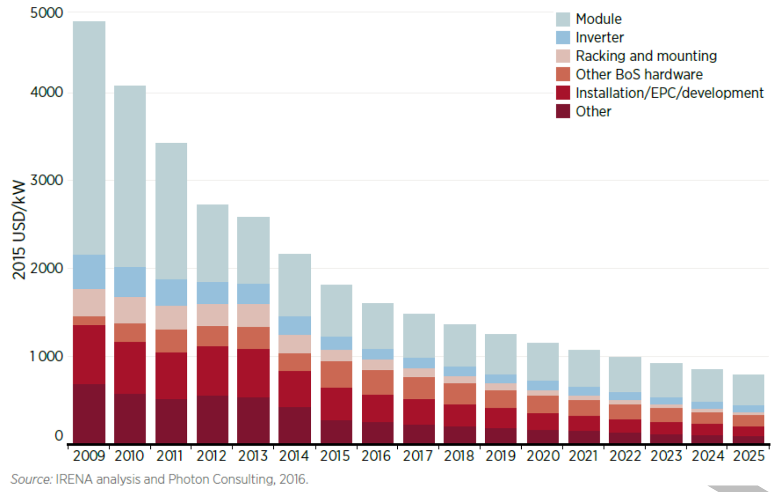
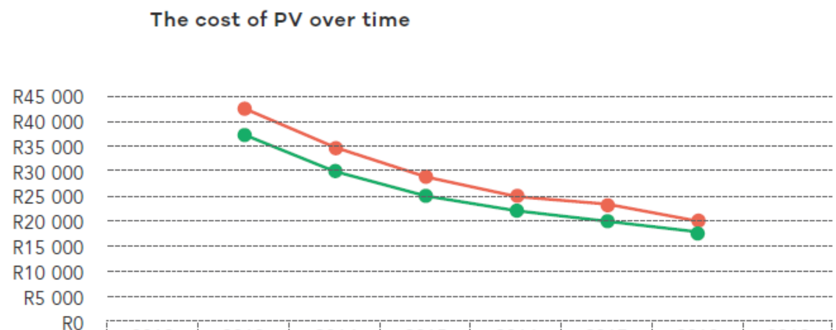


Figure 8: Global weighted average total costs breakdown of utility scale solar PV systems, 2009-2025
Source: IRENA, 2016[15]

Figure 8 only shows the upfront capital cost of solar PV. Once installed, solar PV has the lowest maintenance expenses of any renewable energy technology. The fact that it has no moving parts, means that the only maintenance that remains is to clean the panels sporadically (a bigger expense in drier regions). Unless the panels are cleaned with water, solar PV requires no water.

On the downside, solar PV requires space. Panels do not work in the shade, which implies that panels must be set so that the panels do not cause a shadow on other panels. Fortunately, agricultural environments usually have space available on shed rooftops or in unused fields. Although solar PV is also more predictable than wind, without battery backup, it is restricted to providing electricity only in daytime. Hence, electricity production from solar is much lower in winter than in summer, reinforcing the early point that it is ideal for cooling (not needed in winter). Figure 9 shows the additional cost of battery backup. The most critical aspect of Figure 9 is not only the reduction in costs (already made explicit in previous figures), but the narrowing cost difference between PV with and without battery storage.



	2012	2013	2014	2015	2016	2017	2018	2019
Rooftop Solar PV system without battery storage (R/kW)		R37 000	R30 000	R25 000	R22 000	R20 000	R17 750	
Rooftop Solar PV system with battery storage (R/kW)		R42 500	R34 500	R29 000	R25 000	R23 250	R20 000	

Rooftop Solar PV system without battery storage (R/kW)
Rooftop Solar PV system with battery storage (R/kW)

Figure 9: The cost differential of battery storage is decreasing

Battery storage allows a much wider array of applications of solar PV, such as security lights, power supply for computer systems and heating applications. However, it should be noted that heating needs should ideally be met with solar thermal applications.

Solar thermal

Solar thermal installations are a relatively low-tech but high efficiency technologies. Solar thermal technologies include many different technologies, but it typically involves the heating of water, which in turn may be used for food processing, greenhouse heating or even for under-floor heating. But solar thermal application also include solar fruit driers, space heating and sometimes also cooling. Solar thermal is a broad terms that is used to describe application that produce heat rather than electricity.

Solar water heating (SWH) or solar geyser systems often use panels (or collectors) through which water circulates. The warm water can then be used for applications that require hot water. SWH systems can also be used for pre-heating of water where steam may be needed. SWH technology is a mature technology and is well understood (compared to PV). There are therefore many providers of technology, and the cost is much lower for heating than it would be if one would use solar PV to heat water. In that respect, solar thermal collectors are far superior.

A second and similar technology uses mirrors to heat water or another carrier for the energy in order to provide steam. This is sometimes referred to as Concentrated Solar Power (CSP). However, CSP is often expensive and requires scale. It is therefore not suitable for smallholding farmers.

Solar thermal applications have relatively short payback periods, but this could depend on the supplier, the particular technology, etc. However, it must be said that the low technical knowledge required for solar thermal means that it holds far greater potential for job creation among previously disadvantaged communities.

Maintenance for solar thermal systems may vary, but it would typically be higher than that of solar PV due to the presence of water. At the same time, the low tech need for maintenance services could be a significant job creator in rural areas.

A further future application of solar thermal energy is for desalination of seawater. As with the previous example, desalination can be done during daytime and does not require an uninterrupted source of electricity. A greenhouse in Australia will produce 15 000 tonnes of tomatoes using no soil, pesticides, fossil fuels or groundwater[16].

Biomass

Agriculture is both a potential producer and consumer of biomass-based energy. Energy can be extracted from biomass in a number of ways, and can be delivered in a number of forms (see Figure 10).

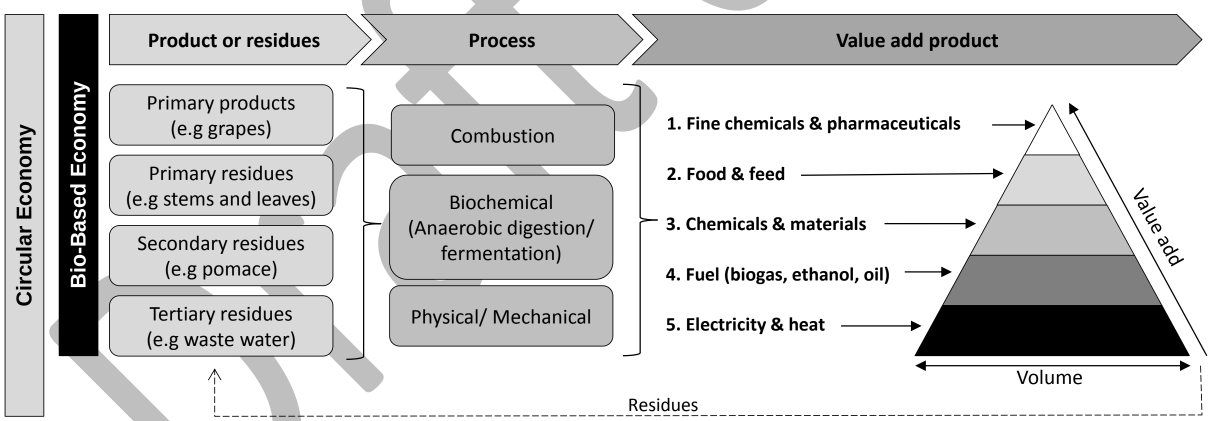


Figure 10: From waste management to resource management
Source: Adapted from Pineo, Gogela, Janse van Vuuren, Williams, Lyons, Kuschke & Basson, 2016[17]

Some forms of biomass have typically been used for heat through direct combustion. This makes sense for waste wood but, in some instance, organic waste can be processed to provide higher value added products (Figure 10). For instance, residues of wine production can be combusted to generate heat or electricity, or alternatively, it can be processed in a biodigester to make biogas. Biogas can be used further for heat or even to run an engine.

For combustion, it is important that the fuel is dry (i.e. have a low moisture content. Wet organic material (such as manure or abattoir waste is much better suited for wet applications, such as anaerobic biodigestion.

Biodigesting technology is easily understood, but due to a lack of experience, it is not abundant in South Africa. Recent reports estimate that there are about 300 biogas plants in South Africa[18]. The growth potential for biogas is highlighted by the fact that China has 17 million plants, and India has 12 million[19]. The biggest biogas plant in South Africa is on a dairy farm in the Western Cape. This plant produces 1.5 gigawatt-hour (GWh) electricity per year, and reduced the farm's electricity bill from R110 000 to only R12 000 per month[20].

Biogas energy has many advantages over solar and wind energy. Biogas based energy is dispatchable at any moment of the day. Capacity factors for biomass plants typically are higher than eighty per cent, provided enough feedstock. A big advantage is that biogas energy is often generated from waste streams and therefore has the potential of solving two problems, namely removing waste and providing energy security. An example of such "industrial symbiosis" is the use of abattoir waste (considered a hazardous waste stream) in a biodigester owned by a fruit processing company. Abattoir waste is considered ideal for biodigesters. Furthermore, the digestate (residue from biodigesting) is often a good and safe fertilizer.

An important consideration for biodigester applications is the availability and sustainability of raw materials such as manure, fruit residues and other fine organic material. Reliability of supply is one of the most important considerations.

Heat pumps and exchangers

Heat pumps and heat exchangers are often also mentioned as renewable energy technologies. These technologies extract heat from one environment and release it into another. Such technologies can therefore either heat or cool a space or water. Heat pumps are regarded as more efficient for heating than pure solar technologies and it does not require sunshine, but rather uses ambient heat. However, heat pumps still require electricity to operate, unlike some solar geysers.

Micro hydro

Micro-hydro represents a relatively poorly exploited renewable energy technology in South Africa. Yet, micro-hydro provides reliable and despatchable power at a price that competes well with solar and wind[21].

The Western Cape has some of the best resources for hydro-power in South Africa. Figure 11 shows the potential for micro-hydro in South Africa, as well as the current state of micro-hydro plants in the Western Cape.

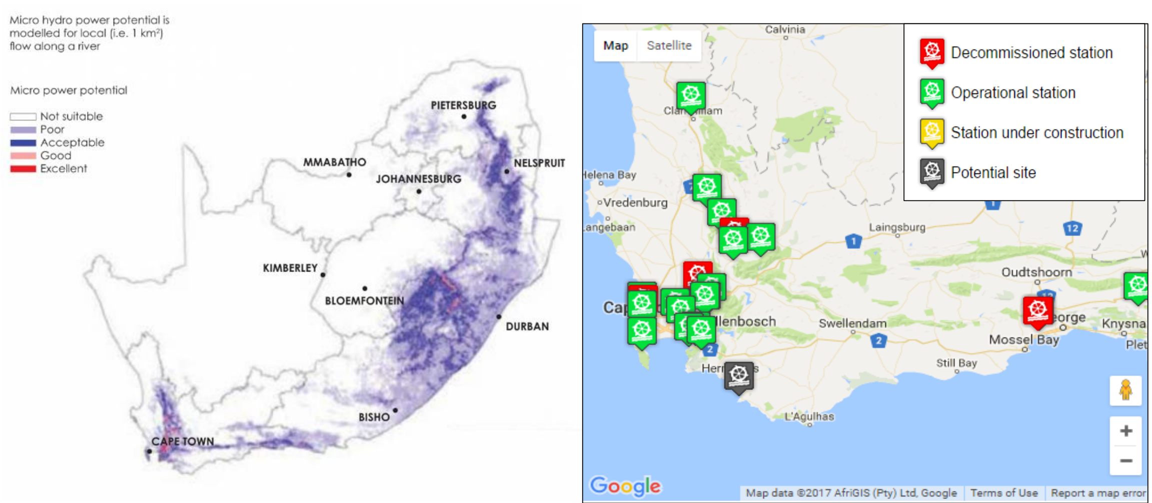


Figure 11: Hydro-power plants in the Western Cape
Source: hydro4africa.net[22]

The capacity for a stream to generate hydro-power is based on the flow and drop in the stream at the point of generation. In increase in either variables increases the potential.

5. Storage technology

One of the biggest criticisms against wind and solar energy is the intermittent nature of supply. Storage capacity and the economics of storage plays a major role. For that reason it is briefly covered in this report.

Combining renewable technologies with deep cycle lead-acid batteries enable the expansion of potential uses. Such applications could include water pumps, security lights, electrical fences, communication, and remote control and monitoring

6. Partnering with Independent Power Producers (IPPs)

One last aspect of energy to consider in the agricultural sector is the role played in providing space for Independent Power Producers (IPPs) on farm-land. Apart from generating their own power, farmers can earn substantial rent from IPPs that require sites with particular characteristics.

7. Overall benefits of RETs

In order to gain a sense of material benefits of different renewable energy technologies, we rated a number of technologies against criteria that is generally regarded as decision drivers at operational as well as policy level. What is important to note is that no technology ticks all the boxes. It is therefore important to understand the applications that may align with the relative weaknesses and strengths of the different technologies.

Table 2: Potential Economic, Social, Ecological and Political Dimensions of selected RETs

	Good = 3 Neutral = 2 Bad = 1 (Not that these scores are subjective)	Micro wind	Solar PV	Solar thermal pumps/exchangers	Solar thermal CVP	Solar thermal water heating (Thermal)	Micro hydro	Biomass: Combustion	Biomass: Biochemical	Biomass: Physical (pressed oil)
	Capital cost	2	2	2	1	3	3	3	2	1
	Operations & maintenance cost	3	3	3	2	2	2	1	1	1
	Dispatchability	1	1	3	2	2	3	3	3	3
	Small scale application ability	3	3	3	1	3	3	3	3	2
	Complexity of integration	2	3	2	2	1	2	1	2	1
	Job creation	1	1	1	1	2	2	3	3	2
	Technical skills development	3	3	3	3	3	2	1	3	3
	Industry creation/ local production	2	1	1	3	3	3	3	3	1
	CO_2 reduction	3	3	3	3	3	3	2	2	2
	Environmental concerns	3	3	3	2	3	3	2	3	2

8. Aggregated impact of Renewable Energy Technologies

Renewables as a whole will have a moderate impact on agriculture. However, certain technologies are better suited for certain applications. Table 3 provides a granular view of renewable energy technologies and where certain technologies may have a relative strength to other technologies.

Table 3: Impact potential of different RETs in agriculture

Technologies in Agriculture	Impact Potential: 1 = low impact; 2 = medium impact; and 3 = high impact												
	WC Agricultural Commodities			Infrastructure									
	Horticulture	Animals	Field crops	Abattoirs: red meat	Abattoirs: white meat	Agri processing plants	Chicken batteries, broilers, layers & hatches	Cool chain facilities	Dairies	Fruit/pack packers house	Pigeries	Silos	Tunnels
Micro wind	2	2	2	1	1	2	2	1	1	1	2	2	2
Solar PV	**3**	**3**	2	2	2	**3**	**3**	**3**	**3**	**3**	2	2	2
Heat pumps/exchangers	1	2	1	**3**	**3**	**3**	2	**3**	**3**	**3**	2	1	1
Solar water heating (Thermal)	1	2	2	2	2	2	2	2	**3**	1	1	1	**3**
Micro hydro	2	1	1	1	1	1	1	1	1	1	1	1	1
Biomass: Combustion	**3**	1	2	1	1	1	1	1	1	1	1	1	1
Biomass: Biochemical	**3**	**3**	2	**3**	**3**	**3**	**3**	2	**3**	**3**	**3**	1	2
Biomass: Physical (pressed oil)	2	1	0	0	0	0	0	0	0	0	0	0	0
RETs collectively	**2.1**	**1.9**	**1.5**	**1.6**	**1.6**	**1.9**	**1.8**	**1.6**	**1.9**	**1.6**	**1.6**	**1.1**	**1.5**

Solar PV is well suited for water pumps that supply animals with water or drip irrigation is used. It is also well suited for applications that require electricity in daytime and that has ample (roof) space.

Heat pumps and heat exchangers are efficient at providing thermal (heating or cooling) needs, such as those of agri-processing and abattoir facilities.

A technology that is rather underutilised is biochemical conversion of waste to energy. Any environment that provides wet organic waste could benefit from creating methane or another fuels from waste. This is true for both plant and animal waste. Abattoirs in particular can benefit.

Overall it seems that horticulture in the Western Cape can benefit greatly from renewables.

9. Conclusion

Compounding forces, including climate change, decreasing prices and potential economic benefits, are driving an increasing appetite for renewable energy internationally, as well as in African, South Africa and the Western Cape.

Renewable energy, combined with storage technologies, is already cheaper than fossil fuels in some instances, and will continue becoming cheaper. Policies that enable renewable energy adoption may allow lower cost of production in the long term.

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