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A review of Energy and Water Use for Processing by Horticultural Micro, Small and Medium Enterprises

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Abstract

Micro, Small and Medium Enterprises (MSMEs) account for over 99% of companies and about 60% of employment opportunities can be attributed to them in most countries globally. MSMEs uses energy and water intensively, is a major driver in the economy with respect to innovations, Gross Domestic Product, investments as well as exports. Despite MSMEs key role in the economy, they have not been the focus in the energy and water policy actions of the majority of countries in spite of their intensive usage of energy and water for horticultural processing. Thus, to address this gap the paper undertook a systematic literature review of energy and water for horticultural processing. Out of the 486 articles retrieved from the various databases, 18 publications met the inclusion criteria. From the literature synthesis, it's evident that energy conservation opportunities lie in the use of renewable energy. The food processing sector globally utilizes 200 exajoules of energy annually. This consumption causes decreasing resources and large levels of greenhouse gas emissions. Processing operations consume 78% of the water supplied to a processing plant. The study recommends utilization of the best available technologies so as to ensure energy and water use efficiency. Efficient use of energy and water by MSMEs is largely dependent on a country's legal and regulatory framework.

Keywords: *Energy Use Efficiency; Water Use Efficiency; Legal and Regulatory framework; Horticultural processing; MSMEs*

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Introduction

The Oslo Symposium of 1994 defined sustainable consumption and production as, "*the use of services and related products, which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of further generations*". It is imperative that societies undergo transformation in the manner in which they consume and produce if global sustainable development is to be attained (UNEP, 2014).

Over the last 20 years, sustainable consumption and production (SCP) has become the prime concern of governments as the globe adapts to more economical, environmental and social sustainable sequence of development (UNEP, 2014). Unsustainable patterns of consumption and production have been acknowledged to be the major cause of environmental deterioration. This was also confirmed in the Rio Summit of 1992 and in all other susbequent sustainability meetings ever since. SCP aims to change these patterns thus it's a policy agenda for tackling the underlying causes of humanity's ecological dilemma while also providing for human well-being and prosperity (Akenji & Bengtsson, 2014).

SCP is a holistic approach that uses a life cycle perspective, therefore, it takes into consideration the total use of resources as well as the resulting emissions, effluents and waste; aiming to minimise negative environmental impacts and promoting inclusive well-being (UNEP, 2012a). SCP focuses on promotion of resource and energy efficiency, sustainable infrastructure, green jobs and better quality of life (UNEP, 2012b). The globe in 2015 approved the 17 globally recognised Sustainable Development Goals (SDGs). Connected to the 17 goals are the 169 targets and SCP was singled out as a separate SDG as well as a fundamental constituent of the numerous other goals and targets agreed to (Statistics Sweden, 2016). In general SCP is all about producing more while using less hence promoting resource use efficiency in MSMEs.

Energy and water interact in several ways in the production and processing of food. Water and energy are both complements and substitutes; each is an input in the generation of the other and this is one of the most energy intensive industries (FAO, 2015). The food processing sector is a big consumer of energy. According to the US Census Bureau (2010), the total cost for the purchase of elecricity and fuel in this indusrty amounted to $9.92 billion USD in 2006 which was 9.57% of the total energy costs for all manufacturing industries. In the European Union and Netherlands, the total energy demand in the food industry was 8% and 9% respectively (Wang, 2014).

The food processing industry utilizes huge amounts of energy and water (Compton *et al.,* 2018; Nikmaram & Rosentrater, 2019). Water is a very important resource for the food processing industries due to the fact that it is not only an ingredient but also a major processing constituent. The fruits and vegetable processing sector is among the main water-intensive sub-sector of the food sector (Fusi *et al.,* 2016; Nikmaram & Rosentrater, 2019). Hence sustainable utilization of water is a huge environmental as well as economical problem for the fruits and vegetables processing industries (Ölmez, 2017).

Heating and cooling processes consumes the largest amounts of energy in the food processing industry. The food processing industry utilizes immense quantities of energy and water thus making it one of the top most sub industry for addressing anthropogenic impact on the environment (Compton *et al.,* 2018). Fuels such as petroleum oil, natural coal and electricity are the two main types of energy consumed in a food processing plant (Wang, 2014). The food industry globally utilizes approximately 200 exajoules of energy annually (EIA, 2017; FAO, 2017). With production predicted to increase by 25% between present day and 2030, sustainable energy sourcing is increasingly becoming a huge concern (IME, 2015).

Presently approximately 3.8 trillion m^3 of water is utilised by human beings annually; about 70% of this is utilised by the agricultural sector worldwide (IME, 2015) while a further 20% is utilised in the production and processing industries leaving just 10% for domestic usage (IChemE, 2014) and the level of usage will keep on rising in the decades to come. It's further projected that the demand for water to be used in food production could reach 10 to 13 trillion m^3 yearly by mid of the century. This translates to 2.5 to 3.5 times higher than the total human beings usage of fresh water presently (IME, 2015).

Large quantities of water are utilised in processing fresh vegetables, removal of soil from unpeeled vegetables, for cleaning, rinsing and cooling of processed vegetables as well as for cleaning the various environmental surfaces in the processing plants. The washing in addition to the sanitation activities are a significant concern in reduction of total water consumption within the fresh cut processing sector (Lehto *et al.,* 2014). Reduction of the water footprint of the cleaning operation poses a setback to the fresh-cut fruits and vegetables industries as well as to food scientists (Manzocco *et al.,* 2015).

An MSME is defined as enterprises that employs less than 250 persons and has an annual turnover of not more than Euro 50 million and/or an annual balance sheet that doesn't surpass Euro 43 million. An MSME with 1 – 9 employees is categorised as a micro enterprise, 10 – 49 employees is a small enterprise and 50 – 250 is medium enterprise (European Union, 2015).

Theoretical Framework

The study was grounded on the Triple Bottom Line (TBL) Theory which was advanced by John Elkington in 1994. Sustainability is becoming more and more an essential prerequisite for anthropogenic activities thus making sustainable development a key objective in human development. At the centre of sustainable development is the opinion that environmental, economic and social concerns ought to be dealt with concurrently and holistically in the development process. Making manufacturing sustainable demands an equilibrium and integration of economic as well as environmental, societal objectives, supportive practice and policies (Rosen & Kishawy, 2012).

The concept of sustainable development can be traced back to 'Our common Future' which was published in 1987 following the World Commission on Environment and Development and the UN Conference on Environment and Development (UNCED) which was held in Rio de Janeiro in 1992 whereby sustainability was defined as "*development that meets the needs of the current generation without compromising the needs of the future generation to meets its own needs*". This concept entails integration of environmental thinking into all aspects of economic, political and social activities and has turned out into a focal point of the environmental debate (WCED, 1987).

TBL is an accounting framework that includes three measures of performance that is social, environmental and financial hence is different from the conventional methods of reporting since it incorporates ecological or environmental and social measures which may be hard to allot suitable ways of quantification. The TBL dimensions are often referred to as people, planet and profits i.e. 3Ps. The triple bottom line (TBL) went past the habitual determination of profits, return on investment and shareholder value and went on to include environmental as well as social dimensions. (Francisco & Moura, 2017; Slaper & Hall, 2011).

A TBL company tries to profit the natural setting to the maximum while ensuring no or minimal damage so as to decrease the environmental effect. A TBL approach will reduce its ecological footprint by efficient use of energy and non-renewable resources, reducing production of waste as well as converting waste into less toxic form before its disposal in safe and regulated way (Francisco & Moura, 2017; Sitnikov, 2013).

The TBL concept is presented in the figure that follows:

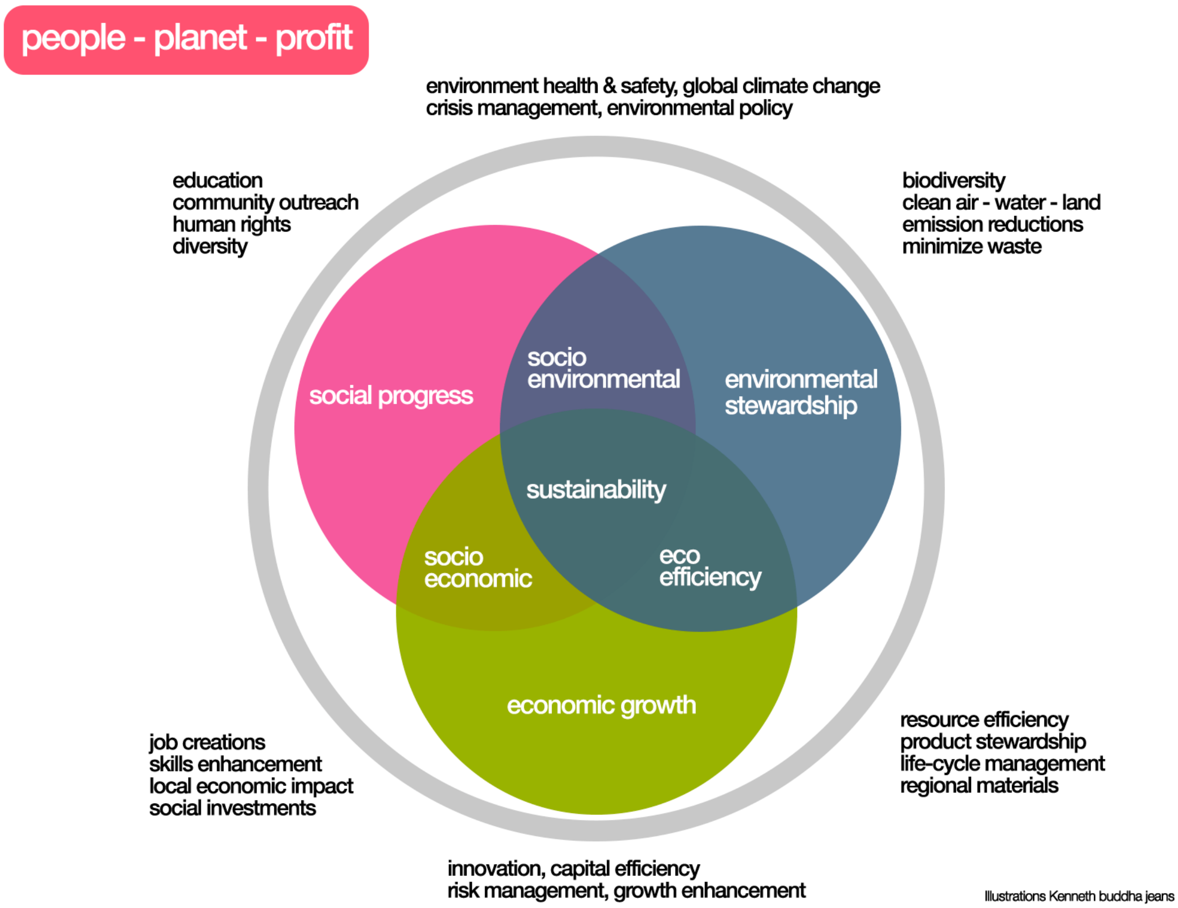

Figure 1. Triple Bottom Line Sustainability Accounting Model (Adapted from Lyngaas, 2013)

Materials and Methods

This paper is a systematic review of published scholarly work on energy and water use by MSMEs for processing. A comprehensive synthesis of academic literature on energy and water use for horticultural processing was conducted based on Tranfield, Denyer and Smart's (2003) systematic review approach. This study was quite broad and there was need to gather evidence on the energy and water use for horticultural processing to establish sustainability trends in this sector. According to (Tranfield *et al*., 2003), the movement to anchor practice on the best available evidence has shifted from medicine to other disciplines as well. The initial step was a literature search using identified key words relevant to the research topic. Articles were searched for in Science Direct, Google Scholar, Scopus and Web of Science Science Direct databases. The selected articles went through a search, screening and extraction stages to identify the articles relevant to the research in question. The initial search yielded a result of 486 articles. These articles were subjected to further screening to identify the relevant articles. It is after this process that 18 articles were selected and included in this review.

Searching

A search was done to identify relevant peer reviewed journals for inclusion in the study. The study considered only peer reviewed journal articles written in English and published between 2010 to 2020 in Science Direct, Google Scholar, Scopus and Web of Science databases. Key words were identified that were used in performing the search: energy and water use for horticultural processing, energy and water use for processing fruits and vegetables, energy use for horticultural processing by MSMEs, water use for horticultural processing by MSMEs, energy and water use for processing, energy and water use by agro-industry, water and energy efficiency in food processing industry. Alternative key words such as water use efficiency, processing of fruits and vegetables, sustainable food processing, energy use efficiency were also used. This led to the identification of 486 articles.

Screening

Screening was done based on the inclusion and exclusion criteria to determine the articles to be included in the study for detailed review. Abstracts of the selected articles were read through to determine their suitability to the research in question. Out of the 486 articles identified, 18 articles were selected for inclusion in the systematic review.

Extraction and synthesis

After identification of the 18 articles, these articles were analysed by reading through the abstract, objectives, results and discussions. The analysed articles were grouped in to three categories: energy use for food processing, water use for food processing and legal and regulatory framework on energy and water use for processing

Table 1. Inclusion and Exclusion criterion

Criterion	Inclusion	Exclusion
Type of Study	Conceptual or theoretical studies, peer reviewed articles, conference articles, book chapters and PhD thesis were included if relevant and of high quality	Articles in low quality journals were excluded
Date	Relevant articles published between 2010 to 2020	Articles published before 2010 were left out
Sector	Articles focusing on MSMEs water and energy use for processing were included	Articles on energy and water use in other sectors for example households, hotels, institutions were excluded
Relevance	Sustainability in terms of energy and water use of MSMEs.	General sustainability of MSMEs e.g. financial or environmental sustainability.
	Addresses legal and regulatory framework with respect to energy and water use for processing.	Legal and regulatory framework on operations of MSMEs.
	Energy and water use efficiency measures.	Measures for MSMEs to cut down costs and become more efficient
Language	Only articles written in English were included	Articles written in other languages were excluded

Results

A total of 18 articles were included in the evidence synthesis. Out of this, two articles were on Italy, five on UK, two on European Union, two on USA, one on Germany, Finland, Canada, Turkey, Australia, Egypt and one had no study area defined but drew examples from Sweden. This review identified a research gap in similar in Africa. This finding is in line with Fawcett (2017) that energy use by MSMEs is poorly understood, evidence on the amount of energy, why and where energy is used is incomplete. Further 13 articles focused on energy while only 5 articles were on water. Further on the methodology 56% of the articles reviewed were qualitative research, 22% cross sectional research while 22% was quantitative research.

Table 2. Descriptive analysis of articles reviewed

Author/publication year	**Country**	**Objective of study**	**Methodology**	**Main results and conclusions**
Cagno, E. *et al.* (2010)	Italy	To introduce the Quick E scan methodology that will help SMEs achieve operational energy efficiency	Cross sectional	MSMEs lack technical know-how and resources to help them in achieving energy efficiency. The study proposes a methodology that SMEs can use in scanning themselves to identify critical areas of energy use and define the energy saving opportunities
Chowdhury, J. I. *et al.* (2018)	UK	To provide an overview of the energy consumption and emission reduction potential offered by the food and drink industry	Qualitative	Energy efficiency opportunities from References UK industry have been identified by many previous studies, yet most of the opportunities remain unimplemented due to technical, economic
EuroChambers (2010)	European Union (EU)	To investigate the factors that influence the uptake of energy efficiency measures or renewable energy sources either positively or negatively thus providing insights to policy makers	Cross sectional	There are many obstacles that prevent MSMEs from achieving energy efficiency
Fawcett, (2017)	UK and France	To investigate where the major difficulties arise in designing effective, economic	Qualitative	Even though MSMEs in totality are notable consumers of energy, there is inadequate

		an equitable policy for SMEs, and suggests how this might be improved.		information on their energy usage and the potential for energy savings. The study also explored new ways of focusing policy designs so as to include MSMEs
Fleiter, T., Schleich, J. and Ravivanpong, P. (2012)	Germany	To investigate factors driving the adoption of energy efficiency measures by SMEs	Cross sectional	An empirical analysis was done based on the energy audit from Germany to determine the most suitable energy efficiency measures that can be adopted by MSMEs
Ladha-Sabur, A. *et al.* (2019)	UK	To gain a better understanding of the energy usage during manufacturing and distribution of foods globally and in UK	Empirical	Energy consumption is highest in MSMEs that do processing compared to in MSMEs that do minimal processing and packaging
Lehto, M. *et al.* (2014)	Finland	To monitor water consumption in a vegetable processing plant	Empirical	Water consumption is highest in agroindustry where processing is involved; waste water produced also high. Study recommends reusing and recycling of water to achieve water efficiency
Manzocco, L. *et al.* (2015)	Italy	This review paper examines the current status of the water resource management in the fresh-cut industry	Qualitative	Th article critically describes a comprehensive approach to the improvement of the water use efficiency by implementing strategies of water recirculation, reuse and recycling.
Nikmaram, N. and Rosentrater, K. A. (2019)	Canada	To review various environmental aspects of food processing operations and to	Qualitative	Improving water and energy efficiency in food processing industries through using efficient

		discuss several strategies in use by companies to reduce the negative impacts and to improve water and energy efficiency		technologies such as non thermal processing, recycling and reconditioning treatment
Ölmez, H. (2017)	Turkey	To minimise water, use in the fruits and vegetables sector	Qualitative	Water use consumption can be minimised in the FFV industry through adoption of appropriate technology, reuse and recycling of water
Sims, R. *et al*. (2016)	USA	To obtain more information on the amount and types of energy required at specific stages of the agrifood chain, to establish the forms of energy and technologies currently in use and practical alternatives for replacing fossil fuel for heating, cooling and electricity generation with renewable energy systems	Qualitative	There are various opportunities that exist for MSMEs to become energy smart. Findings also indicate the current dependence on fossil fuels results in 7 to 8% of GHG emissions
Smith, M. H. *et al.* (2010)	Australia	To provide an overview in which food processors can minimize the amount of water consumed in food processing and auxiliary amenities	Cross sectional	The study identified water saving opportunities in process operations which is the largest consumer of water in a processing plant
Thollander *et al.* (2019)	Selected EU member states, Norway and Japan	The aim of the paper was to provide a global overview of existing energy efficiency policies with a focus on energy management practices	Qualitative	Subsidies encourage MSMEs to adopt energy efficiency measures
Thollander, P. and Palm, J. (2013)	Study area not defined	To examine energy efficiency in SMEs	Qualitative	Improvement of energy efficiency in

				food processing industry
Wang, L. (2014)	USA	Energy consumption and reduction strategies in food processing	Qualitative	Energy conservation technologies can reduce the total energy consumption of a food process thereby reducing production costs
Wu, H. *et al.* (2012	UK	Modelling of energy flows in potato crisp frying processes',	Quantitative	Frying of potatoes is energy intensive due to the initial water content in potatoes
Wu, H. *et al.* (2013)	UK	To provide an overview of analysis and simulation of continuous food frying processes	Quantitative	The results indicate that the model can represent the behaviour of the overall frying system and behaviour of an industrial frying system. Better combustion of the flow rate of fuel in response to final product parameters such as moisture and oil content can produce energy savings of between 5% and 10% content
Zohir, A. E. (2010)	Egypt	To explore simple housekeeping measures for energy conservation	Qualitative	Simple housekeeping measures that can be adopted by MSMEs to achieve energy efficiency at no or little cost

Energy Use for Processing of Fruits and Vegetables

The food processing sub sector will be compelled to increase food production by 70% so as to feed the growing global population which is estimated to have reached 9.5 billion by 2050; this implies that energy and water use needs to increase as well by close to 50% and 40% respectively based on the current consumption rate (FAO, 2017).

Processing of food consumes considerable amount of energy, labor as well as machinery to transform comestible raw materials into food products that are of higher value (Wang, 2014).

The food industry globally utilises 200 exajoules (EJ) of energy annually. This energy intensity is linked to large levels of greenhouse gas emissions and declining resources (FAO, 2017). Hence sustainable consumption and production is important in the agro-industry.

According to (Wu *et al.,* 2013), the foods and drinks sector is a major consumer of resources for instance energy, water as well as packaging materials thus faces immense pressure from national governments as well as global organizations to improve on usage of resources. It is estimated that close to 68% of energy is consumed by fuel fired boilers as well as direct heating systems for processing and heating of spaces. A further 16% of electrical energy is utilised by electric motors, 8% taken up through electric heating, 6% consumed by refrigerators and 2% by air compressors (Wu *et al.,* 2013).

Fresh fruits and vegetables (FFV) need to be stored in cold conditions ranging from 0 to 5°C and temperatures should be controlled during the preliminary stages of processing so as to avoid spoilage. Temperature should be maintained at around 0°C (Bansal *et al.,* 2015). Energy which is a prerequisite in the food processing industry is used for running machines, heating, cooling and lighting. The whole demand for energy for food processing is about thrice the direct energy utilised behind the farm gate. Additionally, energy is entrenched in the packaging which can be comparatively energy-intensive due to the usage of plastics and aluminum (FAO, 2011).

According to Nikmaram & Rosentrater (2019) an immense amount of energy is normally consumed in converting raw materials into higher value food products and this is dependent on the type of product being produced. For instance, to evaporate 1kg of water from products, an average of 6 MJ of heat will be required all through the drying process; on the other hand, to reduce the temperature of products below –20°C, 1 MJ or 0.3 kWh of electricity will be needed all through the freezing processes. Thus heating processes are the most energy intensive unit operations utilised in the food industry and include dehydration, pasteurisation , evaporation and sterilization (Nikmaram & Rosentrater, 2019).

Temperature has an important function in determining the shelf-life of processed fruits and vegetables due to the fact that it determines not only the postharvest quality of the produce but also has a direct influence of growth of spoilage microorganisms (James & Zikankuba, 2017). Both low and high temperatures are used in the processing of fruits and vegetables. Heat treatment includes dipping in hot water, hot water rinse with brushing, saturated water vapor and hot dry air blanching. Heat treatment can either last for a brief time for instance an hour long or can be lengthy taking one to four days at 37 – 55°C or below a minute in sweltering water of about 63°C. Chilling temperatures lie between 1–4°C, whereas frozen temperatures scope is 18 − 35°C (James & Zikankuba, 2017).

Processed potato products utilize a lot of energy (Ladha-Sabur *et al.,* 2019). Drying , for instance, utilizes huge amounts of energy because of the high initial water content in the raw material (Wu *et al.,* 2013). Potatoes crisp are dried till a water content of 2% is achieved and since the final water content of potato flakes is lower than that of French fries, their production is thus much more energy intensive (Ladha-Sabur *et al.,* 2019). Figure 2 summarizes the amount of energy utilized to process fruits and vegetables with potato-based products consuming the highest quantities of energy due to the initial high-water content of the raw materials. Ketchups, jams and marmalades consume relatively lower amounts of energy compared to potato products.

Most of the energy usage transpires during transporting of raw materials and other products, powering various processes, heating of buildings (where applicable), sterilization and in other unit operations. In order to achieve higher energy efficiency in the food processing industries, adoption of two essential operations can play important functions i.e. non thermal processing such as high pressure processing and membrane processes (Nikmaram & Rosentrater, 2019).

Energy Efficiency Measures (EEMs)

Globally there's raising concern over energy due to two major factors that is the need for the reduction of greenhouse gases emissions or reduction of the environmental impact of production as well as usage of energy; and the need for better usage of the scarce energy resources. The most promising viable solution entails deploying renewable energy resources and energy efficiency that is in some way the best available renewable energy source (Cagno *et al.,* 2010). Improving energy efficiency is deemed as an essential approach for reducing greenhouse gas emissions particularly in the short and medium term (Fleiter *et al.,* 2012). MSMEs view investment in energy efficiency as low priority projects, allocate less resources to energy management and exhibit lower adoption rates for energy efficiency measures (EEMs) (Cagno *et al.,* 2010).

Approximately 30% of the energy demanded by MSMEs may possibly be reduced by cost effective EEMs for instance energy management software and this would result in energy savings. Energy efficiency can be of immense assistance to MSMEs in monumental ways such as cutting costs thus freeing up resources to invest in more productive activities as well as becoming increasingly resilient, innovative and competitive. If MSMEs were to implement EEMs to their full potential, it would result in savings of over 20% of their energy bills; this is a measure that MSMEs in Europe and beyond cannot afford not to do (DEXMA, 2016).

Governments as well as policy makers have been strongly committed to reach a common environmental and energetic policy. In order to be fully effective, Governments should take measures while taking into consideration that MSMEs are usually less efficient than large enterprises, they account for 99% of the total number of industries in most countries globally and consume approximately 40% of the total energy for the industrial sector Cagno *et al.,* (2010).

Attention towards MSMEs is needed for several reasons: MSMEs don't have an internal structure capable of focusing on energy consumption and doesn't have a chance to (Cagno *et al.,* 2010). In SMEs, the entrepreneur has to play a number of roles such as operations, sales, marketing, safety, planning, administration and he or she may also be employed within the factory. Thus energy is just one of the issues and there is no specified focus on it (Cagno *et al.,* 2010; DEXMA, 2016). Another reason is that the time allocated for energy efficiency activities is usually quite limited. SMES also lack the knowhow of energy management and practices. Financial barriers especially pay back times of more than two to three years are regarded as limiting to SMEs whereas large enterprises are able to afford investments for even more than eight years (Cagno *et al.,* 2010).

According to Sims, Flammini, Puri, & Bracco (2016), the energy demand of a system can be minimised through the usage of more efficient technologies such as membrane processing and non-thermal processing (Nikmaram & Rosentrater, 2019), changes to behaviour as well as development of generally energy management systems. Such EEMs not only minimise the costs but can also minimise greenhouse gas emissions where combustion of fossil fuel is reduced. Combining improved energy efficiency with renewable energy can help in keeping the energy costs low. Solar heat can also be used for drying fruit or grain either naturally in the open air or in solar heated facilities. Heat recovery can be one of the most cost effective efficient EEMs in food processing plant. It entails usage of waste heat from one process for another useful purpose (Sims *et al.,* 2015).

Due to equipment or process inefficiency, a significant amount of waste heat is released and lost by the sector annually. The UK industry produced approximately 11.4TWh/year of recoverable waste heat of which 2.8 TWh is from the food and drink manufacturing process (Chowdhury *et al.,* 2018). Utilization of this waste heat can reduce CO_2 emissions by 541.08 ktCO2e and save 89 million USD every year. Unlike the heat source from the iron and steel industry, the waste heat from food and drink processing is majorly low-grade energy whose energy is typically below 260^{o}C. In the food and drink manufacturing industry, approximately 64% of the energy is used for low temperature processes (Chowdhury *et al.,* 2018).

Sims et al. (2016) further states that prior to investment in heat recovery systems, it's advisable to look into if the waste heat can be minimised in the first place through improved energy efficiency. A majority of the processing operations produce considerable amounts of waste heat while at the same time another section of the plant or process requires heat. The energy intensity of various food processing factories may be more than 50% higher than necessary because of low energy efficiency systems when bench marked against the best available technologies. The low energy efficiency of small sized food processing plants in a majority of developing countries allow for the use of enhanced technologies and processes to bring about significant environmental and economic benefits even though energy bills accounted for only 5% to 15% of the total factory costs (Sims *et al.*, 2015).

Good housekeeping refers to various realistic methods that a company can adopt right away on their own to advance productivity, realise cost-savings, and lessen the environmental impacts of their operations; advance organizational procedures and safety at the work place (DEC, 2015; Zohir, 2010). Therefore, it's a tool for the management of the environment, cost and change in the organization. When these areas are sufficiently taken into consideration, a triple win i.e. economy, environment and organization can be achieved as well as a thriving method for the establishment of continual advancement in the organization. The gains of good housekeeping can be regarded as a triangle with synergistic effect that enables companies to tap into the triple win options which can lead to a process of continual improvements (Zohir, 2010).

Simple housekeeping or general maintenance measures on older, less efficient processing equipment can often yield energy savings of 10% to 20% for little or no capital investment (EuroChambers, 2010; Sims *et al.*, 2015). Medium cost investment measures for instance optimising combustion efficiency, recovering the heat from exhaust gases and selecting optimum size of high efficiency motors can result in energy savings of 20% - 30% for minimal or no capital investment. Higher savings are possible but usually demand greater capital investment in new equipment (Sims *et al.*, 2015).

Energy efficiency can be attained in various ways for instance improvement of efficiency of equipment plus unit processes, recovery of heat and assimilation of processes (Wu *et al.*, 2012). The focus of management in food processing is inclined towards quality of the product instead of usage of energy. This can be changed into an advantage if management is urged to re-examine critically the technical processes and control systems used as well involvement of staff in this activity (Sims *et al.*, 2015).

Water Use for Processing of Fruits and Vegetables

The International Fresh-Cut Produce Association (IFPA) defines fresh-cut fruit and vegetable products (FFVP) as fruits or vegetables that have been trimmed, peeled or cut into a 100% usable product that has been packaged to offer consumers high nutrition and flavour whilst maintaining its freshness (Jideani *et al.*, 2017). Control of water use is a significant constituent of sustainable fresh cut vegetable production due to inadequate water resources as well as controlling the waste water reused for vegetable processing or for irrigation of cultivated land (Lehto *et al.*, 2014).

Nikmaram & Rosentrater (2019) state that all through food processing operations, water is utilised in various unit operations and functions as well as, an ingredient, a preliminary and intermediary cleaning source or as an efficient transportation mechanism for some raw materials and is an essential resource used for sanitization of plant equipment and areas. Water utilization will probably carry on being an essential part of the food industry but it has become a target for efficiency and reduction endeavours (Nikmaram & Rosentrater, 2019).

According to a study by (Lehto *et al.*, 2014), it was established that utilization of water was highest in the plants in which vegetables were processed and lowest in the plants where vegetables were washed and packed. In the plants studied the total water consumption varied from 1.5 to 5.0 m^3 t^{-1} of finished product as shown in table 3.

Table 3. Total water consumption in Different Kinds of Processing Plants

Plant	Operation of the Plant Examined	Total amount of raw material treated	Range of volume m^3t^{-1} (finished product)
A	Washing of root vegetables	6000 t of carrots, 3000 t of potatoes	1.5 – 3.0
B	Washing and processing of carrots	5000 t washed and packaged, 5000 t washed and processed	2.0 – 5.0
C	Processing of vegetables	6500 t of carrots and other root vegetables washed and peeled	3.5 – 5.0
D	Production of vegetable salads	500 t of lettuce and small amounts of other vegetables washed and cut	2.2 – 3.2

Source: (Lehto et al., 2014)

It is estimated that the water consumption and wastewater volumes lie in the scope of 2.4 – 11m^3 and 11 – 23m^3 respectively per tonne of produce for the FFV processing sub-sector. Thus sustainable water usage is a huge environmental as well as economic problem for the FFV processing sub-sector (Manzocco *et al.*, 2015; Ölmez, 2017). This signifies huge wastage of water plus energy due to the reason that these wastewaters are cooled at refrigeration temperatures to meet fresh-cut processing requirements. The water used for processing is discharged to surface water hence exacerbating the global water scarcity challenge (Manzocco *et al.*, 2015).

The fruit and vegetable processing industry consist of manufactures of bottled as well as canned produce, sauces, concentrates, dried vegetables and fruit products (Smith *et al.*, 2010). Categorization of the water use in a conventional fruits and vegetable processing plant is as displayed in figure 3. Processing operations consume the largest amount of water that is 78% of the water supplied to the processing plant with auxiliary usage accounting for the least amount of the water consumed in a fruit and vegetable processing plant.

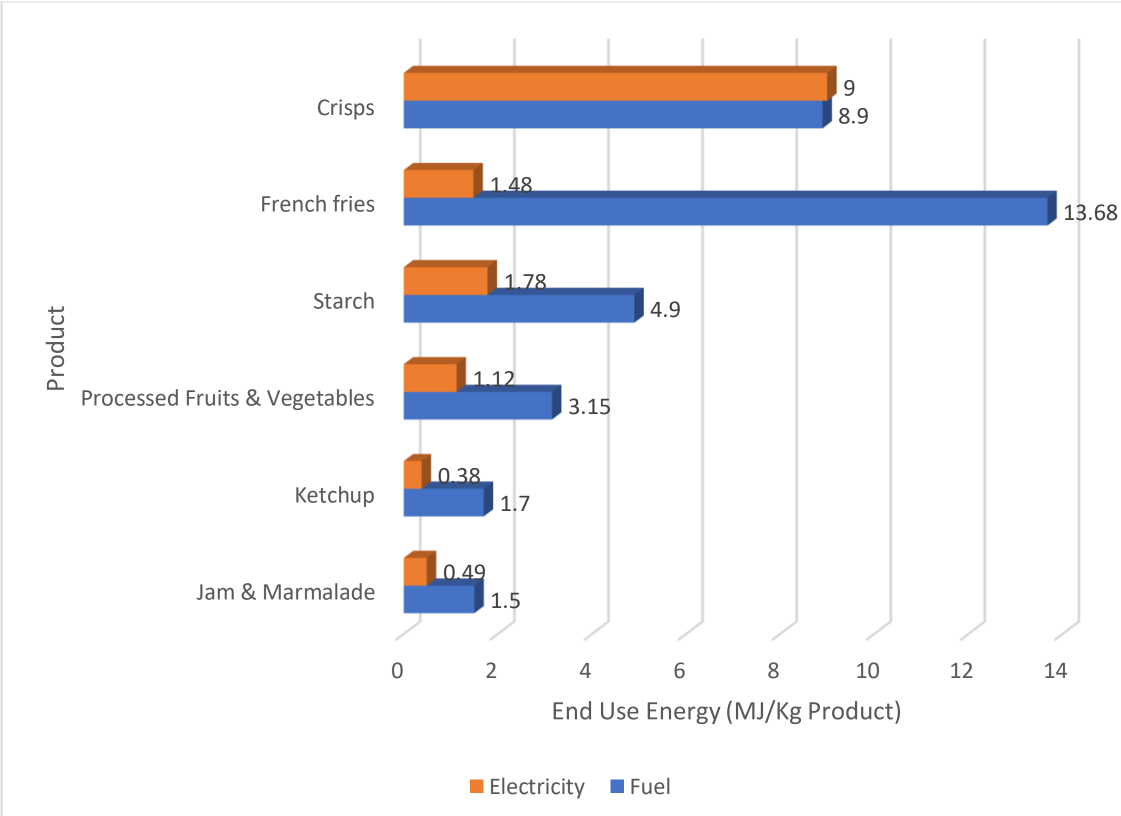

Figure 2. Energy consumed to process fruits and vegetables

Source: Ladha-Sabur et al., 2019

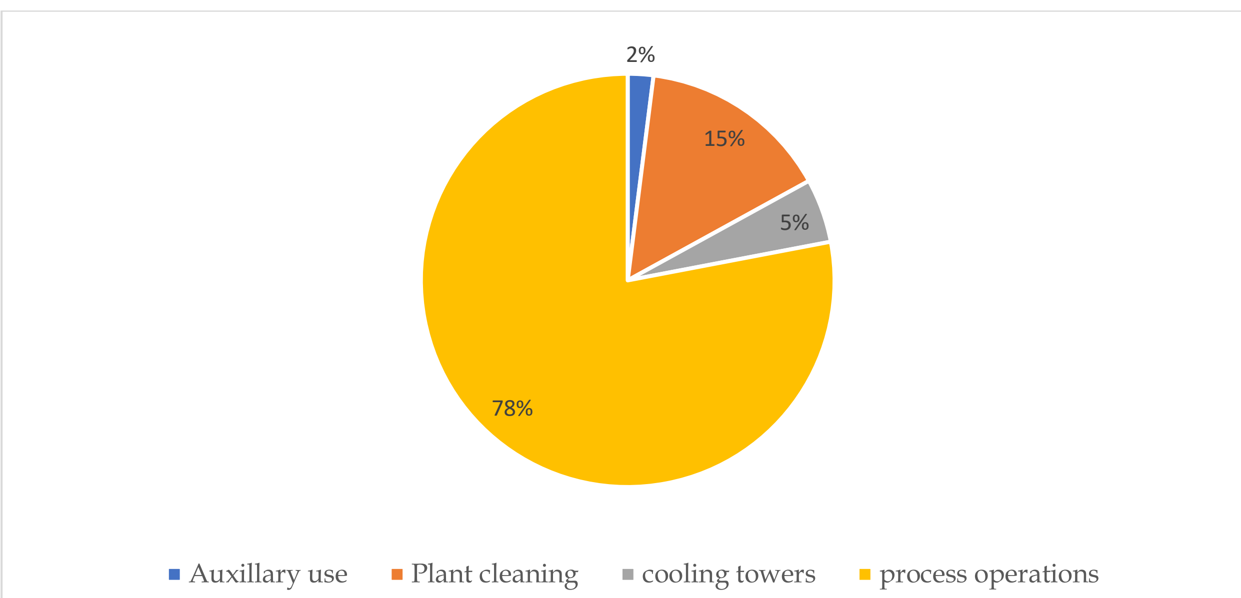

Figure 3. Categorization of water use in a conventional fruit and vegetable processing plant

Source: Smith et al., 2010

Legal and Regulatory Framework

Energy Efficiency Policies for Micro, Small and Medium Enterprises globally

In a number of countries, small and medium sized enterprises (SMEs) account for over 99% of the number of companies and 60% of employment (DEXMA, 2016; Thollander *et al.,* 2019). Therefore, this sector consumes energy, is a significant player in the economy with respect to GDP, exports, innovations as well as innovation. Even though SMEs are significant in the economy, they haven't gotten a great deal of consideration in the energy policy activities of most countries (Thollander *et al.,* 2019).

MSMEs are widely acknowledged as difficult for energy policy and this is because of their diverse nature; they operate virtually in all sectors, in every property type and vary from one-person operations without a business premise to manufacturers with up to 250 employees. Furthermore, their energy usage isn't understood well; evidence on why, how much and where it's used is insufficient (Fawcett, 2017). A recent study by International Energy Agency (IEA, 2015) estimated that SMEs collectively use over 13% of the energy globally and that significant opportunities exist for implementing energy efficiency measures (EEMs) with a potential saving of up to 30%. However, in many priority areas such as energy efficiency and low carbon heat, SMEs are poorly addressed by existing policies (Committee on Climate Change, 2016).

In Japan, subsidies for energy efficient investments have been implemented since the late 1990s and the total budget for energy efficiency investment subsidies is roughly USD 2 billion in recent years (Kimura, 2017). Amongst them, the largest program for industrial and commercial sectors is named 'Support program for enhancing energy efficiency investments' which was started way back in 1998 and its budget recently is approximately between 400 and 500 USD million. The program subsidizes energy efficiency projects which install new or improves existing industrial equipment and systems for instance boilers, furnaces, cogeneration systems as well as energy management systems. Projects that qualify are subsidized by one third up to one half of their investments while they are required to achieve energy savings of more than 1% of the firm's energy consumption or more than 10.8 GWH, that is 1,000 kiloliters on crude oil equivalent compared to the baseline.

Selected countries in the European Union (EU) member states, that is Germany, Italy, Ireland and Sweden that were studied by (Thollander *et al.,* 2019) apply some form of investment subsidy to promote uptake of industrial EEMs that form a backbone of industrial energy policy. Italy which is among the countries studies also relies on a 'white certificate scheme' whereas Japan relies on both the energy Conservation Law and the VAP Keidran. All the studied countries apply separate energy audit policy schemes for industrial SMEs and two countries, Sweden and Germany, also apply energy efficiency implementation networks as key policy programs for the sector (Thollander *et al.,* 2019). Notably energy efficiency networks as a form of energy management support for industrial SMEs seem to only be present in two countries, that is Germany and Sweden (Durand *et al.,* 2018; Carlén *et al.,* 2016).

If results of the energy efficient networks of energy efficiency policy program initiatives are as good as the current research states, i.e., about twice as high a degree of improved energy efficiency compared with a stand-alone energy audit program, such a policy initiative is suggested to also be used as an argument for undertaking pilot studies in other parts of the world as well.

Legal and regulatory framework in Kenya

There are a number of policies that have been formulated and documented and these give a framework and guidance to the agro-food chain in Kenya. It's noteworthy that some of these policies have not been gazetted yet even though they are largely used as reference in the horticultural sector. This research reviews only policies which are most relevant to energy and water use practices by horticultural processing MSMEs.

Water Act 2016

Water Act, 2016 came into law in October 2016 after the 2014 Water Bill was assented into law thereby repealing the Water Act, 2002. The Act states that its essential function is to regulate, manage as well as develop water resources, water supply and sewerage services and related purposes.

This Act gives direction on regulation, managing and improvement of water resources in line with the Constitution. The Act establishes the Water Resources Authority (WRA), the National Water Harvesting and Storage Authority (NWHSA), the Water Services Regulatory Boards (WSRB), the Water Sector Trust Fund (WSTF) and the Water Tribunal. WRA is a regulatory authority with the mandate of issuing permits among other functions. The Act further states that all water resources are bestowed on the national government and held in trust for its citizens.

The WRA which was established in Section 11(1) of the Water Act 2016 is mandated to serve as an agent of the national government, regulate the management and usage of water resources. The function of WRA include formulation and enforcement of standards, procedures and regulations for the management and use of water resources; enforcement of regulations enacted under this act, receiving water permit applications for water abstraction, water use and recharge; determine, issue vary water permits and enforce conditions of those permits; collection of water permit fees as well as water use charges, determine and set permit and water use fees among others.

Energy Act, 2019

The Energy Act, 2019 came into effect on March 28, 2019 thereby repealing the Energy Act, 2006 (the repealed Energy Act), the Geothermal Resources Act, 1982 and the Kenya Nuclear Electricity Board Order No. 131 of 2012. This act consolidated all the laws related to energy in Kenya. The new act contains several amendments to the repealed Energy Act that are meant to consolidate all the laws related to energy in Kenya, to effectively define functions of the national and devolved levels of government with respect to energy, to provide for the utilization of renewable energy sources, supply as well as use of electricity plus other forms of electricity, regulation of midstream and downstream petroleum and coal activities.

The new act is cognisant of the changing environment of energy regulation in Kenya by acknowledging the different sources of renewable energy as well as creating the corresponding licensing and regulatory agencies in addition to a dispute resolution tribunal. The new entities created are Energy and Petroleum Regulatory Authority (EPRA), the Energy and Petrol Tribunal (EPT), the Rural Electrification and Renewable Energy Corporation (REREC) and the Nuclear Power and Energy Agency (NPEA).

Discussion

The food processing industry is one of the most energy and water intensive industries. Thus, for the continual growth and sustainability in this sector, energy and water conservation is vital (Compton *et al.*, 2018) . It's estimated that the food industry globally utilises 200 exajoules of energy annually. This consumption causes decreasing resources and large levels of greenhouse gas emissions. Energy conservation opportunities lie in use of renewable energy. Energy conservation measures will only be adopted by MSMEs if they are cost effective (Wang, 2014). SMEs are estimated to represent 57 % of electricity and 50 % of gas demand (DEC, 2015).

According to Compton *et al.,* (2018), 46% of potential energy savings can be attributed to a number of energy management programs. These programs are categorised into three groupings and there's gradual increment in their complexity. Plant energy management measures include basic conservation measures for instance preventive maintenance, system operator training and using utility incentives. Energy project management is a bit advanced and includes identification and prioritization of capital projects, usage of system optimization tools and practices of important operations as well as assigning an energy engineer. The third grouping is integrated plant energy management programs that comprise of autonomous authentication of energy savings together with execution of an energy management plan that consists of policies, accountability plus system/department level target goals (Compton *et al.*, 2018).

Even though MSMEs in totality are very important consumers of energy, there is an inadequate understanding of their energy use and the potential for energy savings. In addition, there is lack of agreement on MSMEs decision making process on energy, and consequently how policy can be best designed to encourage their choices. Considering their heterogeneousness in business sectors, types of buildings occupied, equipment used, forms of organisation, and so on, using empirical evidence on MSMEs to improve understanding and policy design is fundamentally hard (Fawcett, 2017).

Proper management of water in the fruits and vegetable industry is mostly reliant on pecuniary motivations as governed by regulation. The dispersed nature of the MSMEs in the food industry depicts diminished capability for setting up their own waste water treatment system thus heightening the significance of effective water management given that water is a scarce resource (Sánchez *et al*., 2011). Case in point is Botswana whereby the government has executed policies such as Botswana National Water Policy (BNWP) that aims at promoting sustainability, equity and efficient usage of water as a crucial resource (BNWP 2012). Water recycling and raising water conservation awareness are examples of some other measures that have been put in place to decrease water scarcity (Farrington 2015).

MSMEs viewed in totality have a significant environmental as well as social impact (Revell *et al.,* 2011) and therefore these enterprises should begin to adopt more sustainable behaviours and a long term vision to design environmentally and organizationally sustainable processes (Shankar *et al.,* 2017). Utilization of the best available technologies as well as application of a structured water management strategy could bring about a decrease of about ninety percent in the demand of fresh water due to the reuse of water used for processing (Ölmez, 2017)

Conclusion

This systematic review's objective was to explore literature on energy and water use for horticultural processing by MSMEs. Through the literature reviewed, three thematic areas were identified: energy use for horticultural processing by MSMEs, water use for horticultural processing by MSMEs and influence of policies and regulation on energy and water use for processing. Findings indicated that processing of fruits and vegetables by MSMEs is indeed energy and water intensive; there is need for MSMEs to check on their usage of energy and water for processing if sustainable consumption and production is to be achieved in the long run. Further it emerged that there is inadequate information on the energy and water usage by horticultural processing MSMEs, what and why these resources are used for. Further studies need to be carried out in Africa to establish the sustainability trends of horticultural processing MSMEs. Lessons can be learnt from countries that have given economic incentives to agro industries. Efficient management of energy and water resources are largely dependent on the economic incentives as provided for by law. Kenya should consider adopting economic incentives in managing water and energy resources that is consumed by MSMEs.

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