Journal of Industrial Engineering and Halal Industries (JIEHIS) P-ISSN 2722-8150
Vol. 3 No. 2 December 2022 E-ISSN 2722-8142

Achieving Sustainability in Manufacturing Micro, Small and Medium Enterprises (MSMEs') in Tanzania Through Adoption of Solar Energy

Felichesmi Selestini Lyakurwa
Department of Engineering Management Studies, Faculty of Science and Technology, Mzumbe University
Po Box 87, Mzumbe, Tanzania
Email: felichesmi.lyakurwa@mu.ac.tz/ felichesmi@gmail.com

Abstract

Globally, energy demand has increased significantly whereby consumption of nonrenewable energy is dominant. The reliance on nonrenewable energy sources, not only threatens the efforts to achieve the stated Sustainable Development Goals but also affects community's participation in the economic activities. The increased concern over resource depletion, and environmental impacts, has suggested future reliance on renewable energy. Tanzania has high levels of solar energy, whose exploitation could contribute significantly to energy access. Despite the benefits of renewable energy use, studies to establish factors for energy choice by manufacturing Micro Small and Medium Enterprises (MSME's) in Tanzania are inadequate. Hence, this study intended to establish the dominant factors for the choice of solar energy by manufacturing industries, and workers perceptions about sustainable manufacturing practices. A cross sectional survey research design was employed whereas questionnaires were used to collect data (n = 236) from employees working in the manufacturing MSMEs' in the selected districts in Morogoro region. A descriptive, Confirmatory Factor Analysis (CFA) and a multinomial probit (MNP) model were employed to establish the dominant factors for the solar energy use. The MNP results (tested at : 95% confidence level) indicated that not expensive energy source (Pvalue = 0.01) and other factors, including availability of solar appliances (Pvalue = 0.02) have significant influence on industry's choice of solar energy, while choice of hydro-electricity was significantly influenced by not expensive (Pvalue = 0.01) and advised to use energy source (Pvalue = 0.001). Easy access (Pvalue = 006), and not expensive energy source (Pvalue = 0.001) were found to have significant influence on the use of fossil fuels. Also, the CFA results indicated that all factors i.e., environmental, social, and economic have significant influence on the workers perception about sustainable manufacturing practices. The results therefore, provides critical information to policy making institutions in Tanzania to make informed decisions on the formulation of national strategies that attracts use of renewable energy for manufacturing sustainability.

Keywords: Solar energy choice, sustainable manufacturing, Multinomial Probit Model

INTRODUCTION

Energy is not only a basic necessity but also an important parameter for the satisfaction of all human needs whereas the magnitude of energy use is critical for the country's social-economic development (Urbano et al., 2021). Usually energy sources are categorized into conventional and renewable. The former is the energy generated from nonrenewable sources including fossil fuels (i.e., coal, oil and natural gas) that have many challenges particularly global warming, the situation which has made majority countries of the world to introduce policies that encourage adoption of renewable energy technologies. The latter constitutes energy generated from various renewable energy sources such as sunlight, biogas, wind, hydropower, tides, waves and geothermal heat. To date, renewable energy sources have been widely used for different domestic and industrial applications such as electricity generation, space heating, and off-grid mainly for rural energy services e.g., lighting, charging mobile phones and powering machines (Lyakurwa and Mkuna, 2019; Kumar and Majid, 2020). The world's energy use statistics revealed that industrial sector uses more delivered energy compared to other end-use sectors which consumes more than 54% of the world's total energy (IEO 2016). The manufacturing industries mainly cement, iron and steel are categorized as the energy intensive industries.

Apart from the energy intensity of manufacturing sector, population growth and the country's implementation of industrialization agenda especially in developing countries has triggered the increase in the global energy demand. The International Energy Outlook report (IEO 2021) indicates the global energy demand to have increased from 470 in 2010 to 610 British thermal units (Btu) in 2020, and projected to approximately 820 Btu in 2050 such that consumption of nonrenewable energy is dominant. The reliance on nonrenewable energy sources for domestic and industrial use, not only threatens the efforts to achieve the Sustainable Development Goals (SDGs: 7) which emphasizes on access to reliable, clean and affordable energy; and SDGs: 13 about climate action, but also affects community's participation in the economic activities especially in rural areas which are not connected to the national electricity grid. Stern, (2006) documented that despite the fossil fuels to have significant contribution to the world's socio-economic growth, yet they release Green House Gasses (GHGs) mainly carbon dioxide (CO_2) and Chlorofluorocarbons (CFCs into the atmosphere that are main drivers of the global warming and climate change. EPA (2021) revealed that the global CO2 emissions resulted from burning fossil fuels has increased significantly from 500 to 10,000 million metric tons in 1900 and 2010 respectively, which was the main reasons for the integration of alternative energy sources into the national energy mix.

The increased concern over resource depletion (i.e., fossil fuels), environmental impacts, and increased energy price has suggested future reliance on renewable energy sources for different applications (Worrell et al., 2009; Höök and Tang, 2013; URT, 2021). Though the world is blessed with various renewable energy sources, yet only 16% of the total energy consumption comes from renewables whereby the traditional biogas is dominant contributing about 10%, 3.2% hydroelectric power, and other renewables contributing 2.8% (UNEP, 2011). Globally, the total energy supply by sources comes more from fossil fuels including oil (34.6%), coal (28.4%), and natural gas (22.1%) than renewable energy contributing only 12.9% (IPCC, 2012). Considering the health impacts of fossil fuels, and lack of access to reliable, clean and affordable energy sources, majority countries of the world have invested heavily on renewable energy sources. For example, the developing countries outpace developed countries in terms of renewable energy investment whereas in 2019, a total of $152.2 billion was invested compared to $130 billion energy investment in developed countries (UNEP 2020). While there is significant increase in renewable energy investment in the developing and middle-income countries in which largest finance was on solar energy, yet China and India have lowered their investment. Moreover, the majority countries of Africa have attained the highest level of investment in renewable energy sources excluding South Africa such that the total investment raised from $750 million to $3.6 billion because of strong performance that was realized by some countries including Egypt (UNEP, 2011).

In efforts to increase access to clean energy, and compliance to the SDGs, the government of Tanzania has invested a total of $112.4 million for the off-grid generation of energy for the past twelve years i.e., 2007 - 2019 (IRENA and CPI, 2020). Despite the significant investments in renewable energy technologies, yet its adoption is inadequate. Hence, Worrell et al., (2009), Urbano et al., (2021) suggests a paradigm shift by industries including manufacturing Micro, Small and Medium Enterprises (MSME's) from fossil fuels to use of renewable energy. This situation was caused by increased fossil fuel prices, environmental impacts and lack of connection to the national electricity grid or powering the machines during power rationing. This was also identified by OECD (2018), whereby small and medium enterprises mainly those in the manufacturing sector have high environmental footprints in which they contribute about 60 - 70% of the total industrial pollution in Europe whereas switching from fossil fuels to renewable energy was critical. Presently Tanzania is blessed with many renewable and non-renewable energy resources whereas the country produces natural gas and coal for electricity generation. Bonjour et al. (2013) documented that more than 85% of the population in Tanzania uses traditional fuels for various domestic uses. According to Bishoge et al. (2018) about 32.8% of communities in Tanzania have access to electricity such that more communities in urban areas have more access i.e., 65.3% than communities residing in the rural areas of the country i.e., 34.7%.

The study added that, out of the total electrified households about 75% are electrified with the national energy grid, 24.7% with the solar energy and 0.3% are electrified with individual electricity generated from other sources like small generators. These findings revealed the potential of solar PV in increasing energy access particularly to the communities leaving in the rural areas of Tanzania. The Africa Energy Outlook Report of 2019, indicates that Africa has the richest solar resources in the world, yet the continent has installed only 5 gigawatts (GW) of solar PV which is less than 1% of the global installed capacity (AEO 2019). In Tanzania, solar home systems, and small-scale commercial systems amount to about 75% of the total PV installed capacity whereas it contributes significantly to the country's solar market (Ondraczek, 2013). For example, in the year 2008, only 40,000 solar home systems were installed whose annual sales ranged between 4,000 and 8,000 units (IRENA, 2017). Similarly, Tanzania has high levels of solar energy, ranging between 2,800 to 3,500 hours of sunshine per year, and a global radiation of between 4 to 7 kWh per square meter per day whose exploitation can contribute significantly to the energy access (Sarakikya 2015, TIB 2021). This was also found by Aslam et al., (2021) study which documented that majority African governments like Tanzania can increase number of population/households with access to reliable, clean and affordable energy through utilization of renewable energy sources particularly solar PV which is readily available. Bishoge et al., (2018) added that renewable energy will increase direct and indirect employment opportunities in Tanzania from 10.3 million in 2017 to about 24 million in 2030.

Despite the opportunities available in exploitation of renewable energy sources including solar PV, studies to establish solar energy choice decisions by manufacturing industries are inadequate. The conceptual framework presented by Figure 1 explains the link between manufacturing enterprises use of solar energy for various production activities and sustainable manufacturing practices. Whereas Chiarini (2014) defines sustainable manufacturing as the creation of goods via environmental and economically-sound processes with conservation of energy and natural resources.

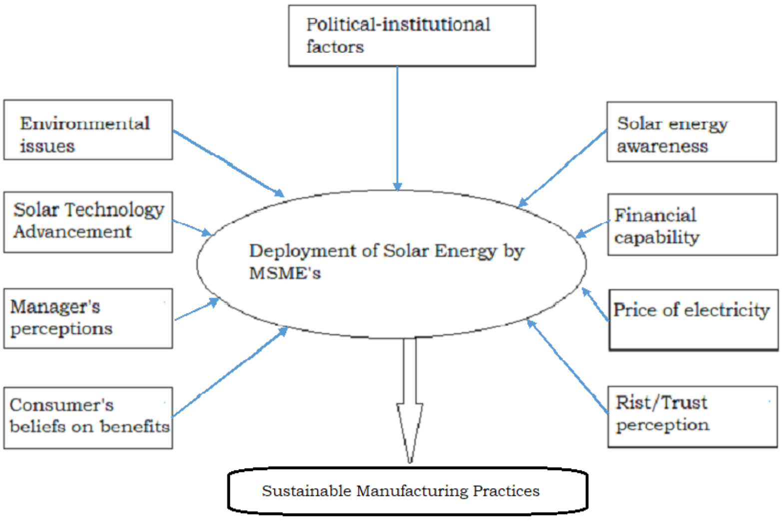

Figure 1: Conceptual Framework: **Source** (Author's construction, 2022)

Theoretical Framework

This study was guided by the Innovation Decision Process theory which is among the four theories of diffusion as discussed by Rogers (1995) like innovation decision process, individual innovativeness, rate of adoption and perceived attributes. ISO (2020) innovation refers to the "new or changed entity realizing or redistributing value". The innovation decision process theory explains diffusion as a process which occurs over time in five different stages such as knowledge, persuasion, decision, implementation and confirmation (IBID). Also, Rogers (2003) describes diffusion as the process through which the innovation is communicated via certain channels over time amongst members of a social system such that the theoretical foundation of diffusion theory is based on the four distinct elements including innovation, communication channels, time and social systems i.e., the potential chasm between the early and the adopting majority. The theory contends that all potential adopters of an innovation must learn about the innovation, be persuaded as to the advantages of the innovation, decide to adopt, implement, and confirm i.e., reaffirm or reject the choice to innovation. Usually many population groups and individuals perceive the same innovation differently due to certain characteristics such as relative advantage whereas the most obvious attribute which adopters seek in a new technology is the degree to which an innovation is perceived better than the previous idea (Eder et al. 2015).

According to Greenhalgh et al., (2004) all potential users will not consider the innovation if they do not see its relative advantage which are measured in economic returns and social factors mainly user's satisfaction and prestige which control individual's perceptions. Hence, diffusion of innovation is relatively complex particularly in the developing countries whereby understanding the perceptions of adopters' i.e., early adopters, early majority, later majority and laggards is necessary. Also, the study to investigate min-grid electricity diffusion in the rural settings of China; revealed that diffusion from end user's perceptions' is determined by various social traits such as satisfaction, supply behaviors, positive and negative experiences (Shyu, 2013). Moreover, this study concluded that adopters were not satisfied with the electricity generated by the min-grids since it was insufficient and unreliable. Different results were obtained by a qualitative study conducted by Mallett, (2007) whereas social acceptance was neglected in adoption of renewable technologies i.e., solar water heaters. Therefore, based on the existing dilemma about the diffusion theory of innovation, the proposed study intended to establish the determinants of solar energy choice by manufacturing MSME's in Tanzania.

DATA AND METHODS

Study Area

The proposed study was conducted in the Morogoro Municipal council, Mvomero district, Kilombero and Kilosa district councils forming the seven (7) districts of Morogoro region in Tanzania. The region is located at latitudes 6.8278°South of equator and longitudes 37.6591° East of Greenwich Meridian. Morogoro region covers an area of 70,624 Sq. Kms and a population of 2,218,492 with the household size of 4.4 (URT 2013). This study was conducted in the selected districts of Morogoro region because many households are livestock keepers and farmers whereby their produce requires value addition by manufacturing MSME's. According to URT, (2012) enterprises are classified into four (4) main groups based on the total number of employees, total investment, and sales turnover (Table 1).

Table 1: Categories of Micro, Small, Medium and Large Enterprises

Category	Employees	Capital investment in Machinery (TZS)
Micro enterprise	1 – 4	Up to 5 million
Small enterprise	5 – 49	Above 5 million to 200 million
Medium enterprise	50 – 99	Above 200 million to 800 million
Large enterprise	100+	Above 800 million

Source: URT, (2012)

Also, the region has adequate number of renewable energy sources such as solar PV, biomass, biogas, wind and hydro power, to mention few. Despite the fact, the selected districts as other districts in Morogoro region experiences inadequate access to reliable, clean and affordable energy sources the situation which force them to depend on non-renewable energy for different domestic and industrial applications. The dependency on non-renewable energy sources can be a sign of the regions' failure in realizing the Tanzania National Five-Year Development Plan 2021/22 - 2025/26, National Strategy for Growth and Reduction of Poverty (NSGRP), the SGDs, and the Tanzania Development Vision 2025 (URT, 1999; URT, 2005; URT, 2021). Thus, establishing the dominant factors for the manufacturing MSME's use of solar energy is critical towards achievement of the NSGRP, SDGs, Tanzania vision 2025 and the National Five-Year Development Plan 2021/22 - 2025/26.

Research Design

This study has employed a cross sectional survey research design to establish solar energy choice decisions by the manufacturing MSMEs in Tanzania. According to Krishnaswami and Ranganathan (2005), Ndunguru (2007), this design enabled one to collect large amount of data at one location in time, and in the most economical way. This method was also supported by Yin (2003) by indicating that, a cross sectional survey design is mostly appropriate when the study intends to answer the questions of who, what type, where, how many and how much questions as revealed in the study.

Sources of Data and Data Collection Process

The targeted population was manufacturing MSME's in Morogoro Municipal council, Mvomero, Kilombero and Kilosa district councils. A well-structured questionnaire, interviews and focus group discussion was used to collect primary data from the manufacturing MSME's located in the selected districts in Morogoro region (a sample size (n) of 236 enterprises). The multistage sampling technique was also applied in the selection of representative manufacturing MSME's in the selected districts whereas descriptive and inferential statistical methods were used in the data analysis.

METHODS FOR DATA ANALYSIS

Modeling Drivers for the Solar Energy use by Manufacturing MSME's

The multinomial probit (MNP) models have been widely used in modeling discrete choices including choice of a particular voter in a multiparty election (Michael and Nagler 1998), choice of graduation year by high school students (Jepsen 2008), the household choice of fuelwood source (Jumbe and Angelsen 2011), and household's choice of energy for cooking, heating, lighting and powering machines (Lyakurwa and Mkuna 2019), due to the feasibility of predicted probabilities that are obtained from the multiple choices. This study therefore, has employed a MNP in favor of other probabilistic choice models like multinomial logit model (MNL) based on the assumptions related to the residual values. The MNL models usually assume residuals to be identical and independently distributed while MNP models consider residual values as independent and normally distributed (Maddala 1983). The solar energy choice model will be presented as: -

$$\text{Energy Choices } (Y_{ir}) = \beta_0 + \beta_1 X_{1ir} + \beta_2 X_{2ir} + \ldots + \varepsilon_{ir} \quad \ldots\ldots\ldots (1)$$

where by the Yir is a categorical value for energy choices, X_i represents social-economic factors including financial capability, policy incentive, and solar technology advancement, among others. The energy choices considered in the selected districts are such as solar PV, hydro electric-power and fossil fuels e.g., diesel and coal whereas the proposed study assumes that, manufacturing MSME's will use energy sources that have the highest utility.

Worker's Perceptions about Sustainable Manufacturing Practices

The Structural Equation Modeling (SEM) through Confirmatory Factor Analysis (CFA) technique was employed to establish factors influencing worker's perceptions about sustainable manufacturing practices. Haroon et al., (2021) sustainable manufacturing practices are influenced by various factors such as environmental (e.g., reduced use of resources like water and energy; reduction of waste generation and pollution emission), social factors (e.g., the welfare of local community and employees, legal and ethical behavior of staff and employers as well as obedience to government laws and regulations), and economic (e.g., reduced cost of solar items, increased productivity, cost of waste disposal and increased use of appropriate technology). Also, the ANOVA test was used to test the hypothesis that, "Workers perceptions have significant influence on implementation of the sustainable manufacturing practices by manufacturing MSME's". Lastly, a MNP model was developed to establish how workers' perceptions about sustainable manufacturing practices can influence choice of sustainable manufacturing practices by a manufacturing MSME's in Tanzania.

RESULTS AND DISCUSSION

Descriptive Results for the Energy Choice Decision by Manufacturing MSMEs'

The descriptive results for the gender, age, reason for the energy choice, and the working experience of the working staff in the selected manufacturing MSME's in the four districts in Morogoro region of Tanzania are presented by frequencies (N) and percentages (%). The results (Table 2) revealed that out of 232 respondents, 168(72%) were male and 64 (28%) were female workers. This implied that the majority working staff in the surveyed manufacturing MSMEs' were male and could be caused by nature of jobs performed which are masculine and requires energetic person. In regard to age of the workers, out of 236 respondents, 38 (16%) aged between 18-24, 83(35%) aged between 26-31, 80(34%) aged between 32-38 while 35(15%) were found to age 39 years and above. This implies that majority working staff ages ranges between 26 and 38 years old, the generation which is energetic and matured enough to work in working environment that need masculine people. Also, about 91(41.7%) the majority workers have a working experience of 1-5 years while 78(35.8%) were found to have a working experience of between 6 and 10 years.

In terms of the manufacturing MSMEs' reason for the choice of the energy source, the results (Table 2) revealed that energy efficiency is the main driving factor guiding industries choice of natural gas 138(63%), hydro-electric energy146(63.2%), solar PV 115(62.2%) and fossil fuels 140(65.7%) for different industrial applications such as lighting, heating and powering the machines. This implies that energy efficiency is the main controlling factor for the choice decision for energy source by manufacturing MSMEs' in Tanzania followed by the easy to access the energy source. Besides, the results indicated that easy to access the energy source ranked 2 after energy efficiency such that the scores in each energy source was as follows: 54(25%) for the natural gas, 57(24.7%) for hydro-electric power, 43(23.2%) solar PV and 50(23.5%) for the fossil fuels accordingly.

Table 2: Descriptive results for the energy choice decision by manufacturing MSMEs'

S/No.	**Variable measure /Reason for choice**	**N**	**%**	**Rank**
Gender	Male	168	72	
	Female	64	28	
Total		232	100	
Age	18-24	38	16	
	25-31	83	35	
	32-38	80	34	
	>39	35	15	
Total		236	100	
Working	1-5	91	41.7	
experience	6-10	78	35.8	
	11-15	19	8.7	
	16-20	19	8.7	
	>20	11	5.0	
Total		218	100	
Natural gas	Energy efficiency	138	63	1
	Easy to access	54	25	2
	Not expensive	16	7	3
	Advised to use	7	3	4
	Others	3	1	5
Total		218	100	

S/No.	Variable measure /Reason for choice	N	%	Rank
Hydro-electric	Energy efficiency	146	63.2	1
power	Easy to access	57	24.7	2
	Not expensive	17	7.4	3
	Advised to use	7	3.0	4
	Others	4	1.7	5
Total		231	100	
Solar PV	Energy efficiency	115	62.2	1
	Easy to access	43	23.2	2
	Not expensive	16	8.6	3
	Advised to use	6	3.2	4
	Others	5	2.7	5
Total		185	100	
Fossil fuel	Energy efficiency	140	65.7	1
	Easy to access	50	23.5	2
	Not expensive	17	8.0	3
	Advised to use	3	1.4	4
	Others	3	1.4	5
Total		213	100	

*N = frequency, Percent = %

MNP Model Results for the Choice of Natural Gas by Manufacturing MSMEs'

The MNP results for manufacturing MSME's choice of a natural gas is presented (Table 3). The MNP results revealed that the majority manufacturing industries use natural gas because of the energy efficiency ($P_{value} < 0.05$), advised to use ($P_{value} = 0.001$) and other factors ($P_{value} < 0.005$) than what appears on the model (Table 3). The results imply that users prefer energy source with the highest efficiency and also, they have prior information about energy source before going to purchase, and use the source in the industrial operations. Also, other factors than easy to access, not expansive, energy efficiency, and advised to use have significant contribution to industry's use of natural gas for different manufacturing process. The results are in-line with the study by Mathur et al., (2022) which revealed that natural gas has many benefits to industrial applications including lower capital and operating costs, high energy efficiency and lower GHG emissions compared to other fossil fuels.

Table 3: MNP model results for the choice of natural gas

```
. mprobit Reason_choice ng, iterate(3)

Iteration 0:   log likelihood = -100.87823  (not concave)
Iteration 1:   log likelihood = -100.65293  (not concave)
Iteration 2:   log likelihood = -100.64994  (not concave)
Iteration 3:   log likelihood = -100.62923  (not concave)
convergence not achieved

Multinomial probit regression                   Number of obs     =         87
                                                Wald chi2(3)      =          .
Log likelihood = -100.62923                     Prob > chi2       =          .

------------------------------------------------------------------------------
    Reason_choice |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
------------------+-----------------------------------------------------------
Easy_to_access    |
               ng |   .2365168   .5019534     0.47   0.638    -.7472937    1.220327
            _cons |  -.4720682   .4509266    -1.05   0.295    -1.355868    .4117316
------------------+-----------------------------------------------------------
Not_expensive     |
               ng |   .8141831   .7194324     1.13   0.258    -.5958784    2.224245
            _cons |  -1.669314   .6720165    -2.48   0.013    -2.986443   -.3521863
------------------+-----------------------------------------------------------
Energy_efficiency |  (base outcome)
------------------+-----------------------------------------------------------
Advised_to_use    |
               ng |   12.50921   .3201976    39.07   0.000     11.88163    13.13678
            _cons |  -13.93022          .        .       .            .           .
------------------+-----------------------------------------------------------
Others            |
               ng |  -13.33243          .        .       .            .           .
            _cons |  -1.138354   .5414319    -2.10   0.036    -2.199541   -.0771666
------------------------------------------------------------------------------
```

MNP model results for the choice of solar PV by manufacturing MSMEs'

The MNP results for manufacturing MSME's choice of a solar PV is presented. Table 4 presents the MNP model results for the manufacturing MSMEs' choice of solar PV for different industrial activities. The MNP results revealed that the reason not expensive (P_{value} = 0.085), energy efficiency (P_{value} < 0.05) and other factors than what appears on the model (P_{value} < 0.05) were found to have significant influence on the manufacturing MSMEs' choice of solar PV for different industrial applications. This implies that the cost of solar PV appliances, energy efficiency and other factors like utility, availability and reliability of solar appliances are the main drivers for the industries to choose solar PV for different applications. The results are similar to United States future energy (2021) report that documented that apart from greening the environment, use of solar PV by manufacturing industries can create more jobs, savings on electricity bills, increase access to clean - reliable energy and enhanced energy resilience. However, the report added that there is need for awareness creation to employees, industry owners and other relevant stakeholders about the benefit and cost of solar energy deployment for industrial production.

Table 4: MNP model results for the choice of solar PV

```
. mprobit Reason_choice spv, iterate(3)

Iteration 0:   log likelihood = -218.01067  (not concave)
Iteration 1:   log likelihood = -216.21284  (not concave)
Iteration 2:   log likelihood = -216.10496  (not concave)
Iteration 3:   log likelihood = -215.99589  (not concave)
convergence not achieved

Multinomial probit regression                   Number of obs     =        219
                                                Wald chi2(4)      =    1528.64
Log likelihood = -215.99589                     Prob > chi2       =     0.0000
```

Reason_choice	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Easy_to_access						
spv	-.2464913	.2989511	-0.82	0.410	-.8324247	.3394422
_cons	-.5967027	.2592228	-2.30	0.021	-1.10477	-.0886354
Not_expensive						
spv	1.093297	.6357201	1.72	0.085	-.1526911	2.339286
_cons	-2.581834	.6081937	-4.25	0.000	-3.773872	-1.389796
Energy_efficiency	(base outcome)					
Advised_to_use						
spv	.5155174	.6206015	0.83	0.406	-.7008391	1.731874
_cons	-2.484386	.5747192	-4.32	0.000	-3.610815	-1.357957
Others						
spv	10.37764	.2677336	38.76	0.000	9.852891	10.90239
_cons	-12.56917	.	.	.	.	.

MNP Results for Choice of Hydro-electric Power by Manufacturing MSMEs'

The MNP model results (Table 5) indicated that the reason not expensive, energy efficiency and other reasons than what appears on the model have a P_{value} < 0.05, advise to use by experts or friends has P_{value} = 0.020. This implies that such factors have significant influence on the industry's choice of hydro-electric power for the various operations. While easy access to hydro-electric power does not have significant influence (P_{value} = 0.193) on the industry's choice of this energy source. The results are in-line with Nasir (2014) study which documented that the hydro-electric energy is preferred for industrial application because it is clean, affordable, reliable and has high energy efficiency, however, it requires high initial investment cost the reason why even majority households are not connected to the national electricity grid. Given its benefits, other study by Lyakurwa and Mkuna (2019) have suggested governments to endorse taxi subsidy on electricity bills and connection charges mainly to those located in the rural areas.

Table 5: MNP model results for the choice of Hydro-electric power

```
. mprobit Reason_choice hep, iterate(3)

Iteration 0:   log likelihood = -208.34454  (not concave)
Iteration 1:   log likelihood = -205.64041  (not concave)
Iteration 2:   log likelihood = -205.52824  (not concave)
Iteration 3:   log likelihood = -205.47117  (not concave)
convergence not achieved

Multinomial probit regression                   Number of obs     =        216
                                                Wald chi2(4)      =    3175.96
Log likelihood = -205.47117                     Prob > chi2       =     0.0000
```

Reason_choice	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Easy_to_access						
hep	-1.278428	.9829751	-1.30	0.193	-3.205024	.6481678
_cons	.5192977	.9743412	0.53	0.594	-1.390376	2.428971
Not_expensive						
hep	8.894492	.1766884	50.34	0.000	8.548189	9.240795
_cons	-10.5476	.	.	.	.	.
Energy_efficiency	(base outcome)					
Advised_to_use						
hep	9.099746	.2819448	32.27	0.000	8.547145	9.652348
_cons	-11.54342	.	.	.	.	.
Others						
hep	-2.483413	1.06738	-2.33	0.020	-4.57544	-.3913865
_cons	.1729703	1.036089	0.17	0.867	-1.857727	2.203667

MNP results for Choice of Fossil fuel by Manufacturing MSMEs'

The MNP model results for the manufacturing MSMEs' choice of fossil fuels for different industrial applications is presented (Table 6). The results revealed that all factors in the model have significant influence on the manufacturing industry's' choice of fossil fuels i.e., usage of generators to power machines, and for lighting. The reasons easy to access has a $P_{\text{value}} = 0.006$, while not expensive, energy efficiency, advised to use and other factors than what appears on the model were found to have a $P_{\text{value}} < 0.05$. The results have a lot of meaning looking at usage of diesel generators in the majority manufacturing industries in Tanzania, and thus they provide an important information to the energy policy making and planning institutions in Tanzania especially in formulation of strategies towards deployment of renewable energy sources for manufacturing sustainability. The results are similar to the study by Branca, (2021) which documented that process industries in Europe due to its energy intensity and Efficiency. The same was found from the interview conducted to some workers in the manufacturing MSMEs who responded that: *we usually use diesel generators to power machines in the production line during hydro-power rationing and outbreak because it is reliable, and it has high energy efficiency compared to other energy sources".*

Worker's Perceptions about Sustainable Manufacturing Practices by MSME's

The CFA model for the workers perceptions about sustainable manufacturing practices by manufacturing MSMEs' is explained by three constructs i.e., environmental (e.g., reduced use of resources e.g., water, energy, raw materials, reduced amount of wastes generated and pollution (e.g., emissions of CO2), reduced climate change impacts, and improved ecosystems' supply of goods and services); social factors such as improved welfare of local community and staff, improved legal and ethical behavior of staff and employers, builds staff/employees obedience to the Government laws and regulations and improved livelihood of the staff and entire community; and lastly the economic factors i.e., reduced production cost, increased productivity, reduced cost of wastes disposal, increased usage of appropriate technology as well as increased products quality (Figure 2).

Table 6: MNP model results for the choice of fossil fuel

```
. mprobit Reason_choice ff, iterate(3)

Iteration 0:   log likelihood = -121.66198  (not concave)
Iteration 1:   log likelihood = -121.62856  (not concave)
Iteration 2:   log likelihood = -121.56995  (not concave)
Iteration 3:   log likelihood = -121.56643  (not concave)
convergence not achieved

Multinomial probit regression                   Number of obs     =        139
                                                Wald chi2(2)      =          .
Log likelihood = -121.56643                     Prob > chi2       =          .
```

Reason_choice	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Easy_to_access						
ff	-1.219283	.4410034	-2.76	0.006	-2.083634	-.3549319
_cons	.17044	.4004095	0.43	0.670	-.6143483	.9552282
Not_expensive						
ff	11.39974	.2144145	53.17	0.000	10.9795	11.81999
_cons	-12.89054	.	.	.	.	.
Energy_efficiency	(base outcome)					
Advised_to_use						
ff	-13.64261	.	.	.	.	.
_cons	-.4301746	.4508163	-0.95	0.340	-1.313758	.4534092
Others						
ff	-13.63683	.	.	.	.	.
_cons	-.8752244	.5179762	-1.69	0.091	-1.890439	.1399903

The CFA model fitting results are presented by Table 7. The measurement components i.e., environmental concern, social, and economic factors were employed to measure the endogenous latent variable i.e., perceptions about sustainable manufacturing practices by manufacturing MSMEs' in Tanzania. All factors i.e., environmental, social, and economic ($P_{value} < 0.05$) were found to have significant influence of the workers perception about sustainable manufacturing practices. Also, the model vs. saturated chi-squared test indicates the model is fit whereas no modification indices to report because all modification indices value are less than 3.841. The results are in-line with Aldewachi and Aya˘g (2022) study which revealed that sustainable manufacturing practices are controlled by three main pillars of sustainability i.e., social, economic and environmental factors whereas consideration of these factors by manufacturing industries is critical.

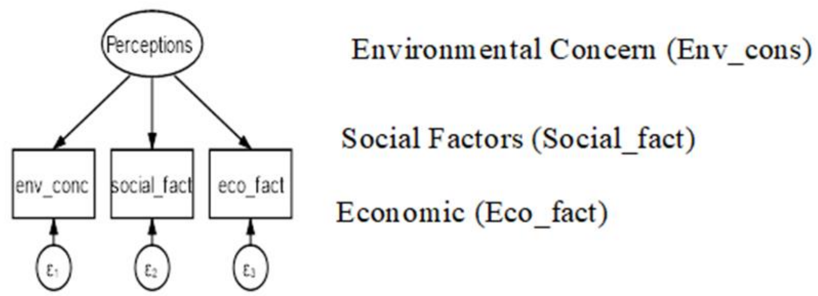

Figure 2: CFA Model for the workers perceptions about sustainable manufacturing

Table 7: CFA model fitting results

```
note: The following latent variable name is also present in the data: Perceptions.
(10 observations with missing values excluded)

Endogenous variables

Measurement:  env_conc social_fact eco_fact

Exogenous variables

Latent:       Perceptions

Structural equation model                    Number of obs     =        232
Estimation method  = ml
Log likelihood     = -494.12628

 ( 1)  [env_conc]Perceptions = 1
```

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Measurement						
env_conc						
Perceptions	1	(constrained)				
_cons	2.060345	.0344922	59.73	0.000	1.992741	2.127948
social_fact						
Perceptions	1.117706	.1617057	6.91	0.000	.8007683	1.434643
_cons	2.497845	.0378535	65.99	0.000	2.423653	2.572036
eco_fact						
Perceptions	.8191076	.1203936	6.80	0.000	.5831405	1.055075
_cons	1.756897	.0354312	49.59	0.000	1.687453	1.82634
var(e.env_conc)	.1278107	.0225511			.0904441	.1806153
var(e.social_fact)	.1472858	.0275846			.1020334	.2126078
var(e.eco_fact)	.1918106	.0219705			.1532406	.2400886
var(Perceptions)	.148203	.0297264			.1000285	.2195786

```
LR test of model vs. saturated: chi2(0)   =      0.00, Prob > chi2 =      .
```

The estimation of all equation's parameters (Table 8) revealed seemingly unrelated regression estimate parameters of all equations simultaneously such that the parameters of each single equation also take the information provided by other equations into account.

Table 8: Equations parameters estimation

```
. sureg (Perceptions env_conc-eco_fact)

Seemingly unrelated regression
```

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
Perceptions	232	3	.0603326	0.9833	13688.33	0.0000

Perceptions	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Perceptions						
env_conc	.3791146	.009305	40.74	0.000	.360877	.3973521
social_fact	.308544	.0085145	36.24	0.000	.291856	.325232
eco_fact	.3694582	.0084274	43.84	0.000	.3529407	.3859757
_cons	-.1384018	.0195611	-7.08	0.000	-.1767409	-.1000626

ANOVA test

The ANOVA test results revealed that the test hypothesis on "a worker's perceptions have a significant influence on implementation of the sustainable manufacturing practices by manufacturing MSMEs' in Tanzania". The test results are presented in Table 9.

Table 9: ANOVA test results

```
. oneway Perceptions Operations_sustainable, tabulate
```

Operations_ sustainable	Summary of Perceptions Mean	Std. Dev.	Freq.
No	1.9705705	.50966896	73
Yes	2.0474808	.52365573	106
Total	2.0161152	.51794328	179

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	.255708201	1	.255708201	0.95	0.3303
Within groups	47.4955053	177	.268336188		
Total	47.7512135	178	.268265244		

Bartlett's test for equal variances: chi2(1) = 0.0620 Prob>chi2 = 0.803

The ANOVA test results indicated a *F*-statistic of 0.95, and a corresponding P_{value} of 0.3303 such that since the P_{value} is > than alpha = 0.05, hence, we cannot reject the null hypothesis that "a worker's perceptions have a significant influence on implementation of sustainable manufacturing practices by manufacturing MSMEs' in Tanzania. This implying that, there is no statistically significant difference in the mean change in worker's perceptions between at least two of the sustainable operations groups.

CONCLUSION

The determinants for the manufacturing MSME's choice of solar energy for different industrial applications have been established. As the first study to model dominant factors for the manufacturing industries choice of solar energy in the selected districts in Morogoro region, the key decision factors have been identified based on the multinomial probit model (MNP) analysis. The energy efficiency, and not expensive (i.e., cost of solar PV appliances) were found to be the main dominant factor for the choice of energy source to power the machines. Also, the CFA results revealed that all factors i.e., environmental, social, and economic have significant influence on the workers perception about sustainable manufacturing practices. Therefore, the CFA and MNP model results can be used by energy policy making instruments in Tanzania to make informed decisions about renewable energy investment needs for sustainable manufacturing practices by manufacturing MSME's.

ACKNOWLEDGEMENTS:

This study was supported by VLIR-UOS Project 3, Mzumbe University, Tanzania.

REFERENCES

Aldewachi, B., & Aya˘g, Z. (2022). Achieving sustainability in solar energy Firms in Turkey through adopting lean principles. Sustainability 14, 108.

Aslam, Z., Li, H., Hammerton, J., Andrews, G., Ross, A., & Lovett, J.C. (2021). Increasing access to electricity: An assessment of the energy and power generation potential from biomass waste residues in Tanzania. Energies 14(1793), 1-22.

Bishoge, O. K., Zhang, L., & Mushi, W. G. (2018). The potential renewable energy for sustainable development in Tanzania: A Review. Clean Technology 1, 70-88.

Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N.G., Mehta, S., & Prüss-Ustün, A. (2013). Solid fuel use for household cooking: Country and regional estimates for 1980-2010. Environmental. Health Perspectives 121, 784-790.

Branca, T. A., Fornai, B., Colla, V., Pistelli, M. P., Faraci, E. L., Cirilli, F., & Schröder, A. J. (2021). Industrial symbiosis and energy efficiency in European process industries: A Review. Sustainability13, 9159.

Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. Journal of Cleaner Production, 85, 226-233.

Eder, J. M., Mutsaerts, C. F., & Sriwannawit, P. (2015). Mini-grids and renewable energy in rural Africa: How diffusion theory explains adoption of electricity in Uganda. Energy Research & Social Science 5, 45-54.

EPA (2021). Global Greenhouse Gas Emissions Data: The contribution of working group III to the fifth assessment report of the Intergovernmental Panel on climate change, United States Environment Protection Agency (US EPA): Accessed on: October 2021 at https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of innovations in service organizations: systematic review and recommendations Milbank, 82(4), 581-629.

Haroon, S., Wasif, M., Khalid, R., & Khalidi, S. (2021). Supply chain practitioners' perception on sustainability: An empirical study. Sustainability 13(9872), 1-16.

Höök, M., & Tang, X. (2013). Depletion of fossil fuels and anthropogenic climate change: A review. Energy Policy 52, 797-809.

IEO (2016). U.S. energy information administration, International Energy Outlook (IEO) 2016.

IEO (2021). International Energy Outlook 2021. https://www.eia.gov/outlooks/ieo/pdf/IEO2021_ReleasePresentation.pdf . Accessed on 19th October 2021.

IPCC. (2012). Renewable energy sources and climate change mitigation special report of the intergovernmental panel on climate change. Cambridge University Press.

IRENA & CPI (2020). Global landscape of renewable energy finance, 2020: International Renewable Energy Agency, Abu Dhabi. GLOBAL LANDSCAPE OF RENEWABLE ENERGY FINANCE 2020. International Renewable Energy Agency (IRENA), ISBN 978-92-9260-237-6 (Accessed on: 15th October 2021).

Jepsen, C. (2008). Multinomial probit estimates of college completion at 2-year and 4-year schools. 333 Economic Letters 98 (2): 155-160.

Jumbe, C. B. L., & Angelsen, A. (2011). Modeling choice of fuelwood source among rural households in Malawi: A multinomial probit analysis. Energy Economics 33, 732-738.

Krishnaswam, O, R., & Ranganathan, M. (2005). Methodology of research in social sciences. Meena Pandey for Himalaya Publishing House, Mumbai.

Kumar. J., & Majid, M. A. (2020). Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. Energy, Sustainability and Society 10(2), 1-36.

Lyakurwa, F. S., & Mkuna, E. (2019). Dominant factors for energy choice decisions by households in Tanzania: A case study of selected villages in Mvomero District, African Journal of Science, Technology, Innovation and Development, DOI: 10.1080/20421338.2018.1550929.

Maddala, G.S. (1983). Limited dependent and qualitative variables in econometrics. Cambridge University Press, NY. USA.

Mallett, A. (2007). Social acceptance of renewable energy innovations: the role of technology cooperation in urban Mexico. Energy Policy 35(5), 2790-2798.

Mathur, S., Gosnell, G., Sovacool, B. K., Furszyfer Del Rio, D. D., Bazilian, G. S. M., & Kim, J. (2022). Industrial decarbonization via natural gas: A critical and systematic review of developments, socio-technical systems and policy options. Energy Research & Social Science, 90, p.102638, ISSN 2214-6296.

Michael, A. R., & Nagler, J. (1998). When politics and models collide: estimating models of multiparty elections. American Journal of Political Science 42, 55-96.

Nasir, B. A. (2014). Design considerations of micro-hydro-electric power plant. The international conference on technologies and materials for renewable energy, Environment and Sustainability, TMREES14. Energy Procedia 00, 000-000.

Ndunguru, P. C. (2007). Lectures on research methods for social sciences. Research Information and Publications Department, Mzumbe University.

OECD (2018). Environmental Policy Toolkit for SME Greening in EU Eastern Partnership Countries. OECD Green; OECD Publishing: Paris, France.

Ondraczek, J. (2013). The sun rises in the east (of Africa): a comparison of the development and status of solar energy markets in Kenya and Tanzania", Energy Policy, 56, 407-417, http://doi.org/10.1016/j.enpol.2013.01.007.

Rogers, E. M. (1995). Diffusion of innovations (4th ed.). New York: The Free Press.

Rogers, E. M. (2003). Diffusion of innovations. 5th ed. New York: Free Press.

Sarakikya, H. (2015). Renewable energy policies and practice in Tanzania: Their contribution to Tanzania economy and poverty alleviation. Environmental Health Perspectives 4, 333.

Shyu, C. W. (2013). End-users' experiences with electricity supply from stand-alone mini-grid solar PV power stations in rural areas of western China. Energy for Sustainable Development 17(4), 391-400.

Stern, N. (2006). Stern review on the economics of climate change. UK Treasury.

TIB (2021). Investment Brief for the Electricity Sector in Tanzania: Tanzania Investment Brief (TIB). Accessed on: October 2021).

UNEP (2020). Global trends in renewable energy investment 2020. FS-United Nations Environment Program (UNEP) Collaborating Center, Frankfurt School of Finance & Management gGmbH 2020 (Accessed on: 24th October 2021).

UNEP. (2011). Global trends in renewable energy' analysis of trends and issues in the Financing Renewable Energy, Investment Report 2011. Nairobi: UNEP.

P-ISSN 2722-8150
E-ISSN 2722-8142

Urbano, E. M., Martinez-Viol, V., Kampouropoulos, K., & Romeral, L. (2021). Energy-investment decision-making for industry: Quantitative and qualitative risks integrated analysis. Sustainability 13(6977), 1-30.

URT (2012). National Baseline Survey Report for Micro, Small, and Medium Enterprises in Tanzania.

URT (2013). 2012 population distribution and housing census: Population distribution by administrative areas. National Bureau of Statistics, Ministry of Finance Dar es Salaam.

URT (2021). National Five-year Development Plan 2021/22 - 2025/26: "Realizing Competitiveness and Industrialization for Human Development". United Republic of Tanzania (URT), Ministry of Finance and Planning.

US (2021). Solar futures study. US Department of Energy. Office of Energy Efficiency and Renewable Energy. U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf

Worrell, E., Bernstein, L., Roy, J., Price, L., & Harnisch, J. (2009). Industrial energy efficiency and climate change mitigation. Energy Efficiency, Lawrence Berkeley National Laboratory, University of California DOI:10.1007/s12053-008-9032-8.

Yin, R. K. (2003). Case study research: Design and methods. Sage. Thousand Oaks, California.