Social Life Cycle Assessment of Solar Dryer House for Postharvest Loss Management Technology in Tanzania

Francis Mwaijande[1]

[1]mwaijandef@gmail.com

[1]Mzumbe University, Department of Social Sciences and Humanities, Dar Es Salaam Campus College, Tanzania

………..…

ABSTRACT

Agricultural products are dried to improve their life-span, enable storage stability, and reduce postharvest losses. Open-sun crop drying is the most popular method in Sub-Saharan Africa because it has a lower energy cost. However, this method is more often unsuitable due to climatic conditions in some areas, resulting in poor-quality drying and spoiled food products. Solar dryer house technology is designed to address challenges related to cleaner energy costs for efficient post-harvest loss management. Life Cycle Sustainability Assessment (LCSA) is a methodology used to integrate a compatible analysis of three pillars of sustainability: economy, environment, and society. Social Life Cycle Assessment (S-LCA), on the other hand, is a methodology used to cover the social aspects of sustainability. This article examines the S-LCA of solar dryer house technology for post-harvest loss management. It found that S-LCA is a useful framework for sustainability assessment and social impact estimation for analyzing the effects of products or services on stakeholders at local, national, and global levels beyond environmental and economic impact. The article contributes to knowledge and understanding of UNEP and SETAC guidelines in Africa.

Keywords: Africa, Food Security, Management, Post-Harvest Loss, S-LCA, Solar Dryer, Sustainability

………..…

I. INTRODUCTION

Climate change brings challenges to post-harvest drying crops to the maximum required moisture content. Solar dryer house is one of the emerging cleaner energy technologies for reducing post-harvest loss responding to climate change challenges. The solar dryer technology provides sustainable solutions to the world's food and energy crises as it is used to produce higher temperatures and lower crop product moisture content to the required moisture content. This technology is considered to be cost-effective (Burade et al., 2017) and sustainable in Africa where sun-shine is abundant and underutilized. The concept of sustainable energy technology evolved at the United Nations Conference on Environment and Development (UNCED) in Río de Janeiro (Gunnarsdottir et al., 2021; Heijungs et al., 2010; Zafar et al., 2024) where it defined sustainability as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Hajian & Kashani, 2021). Sustainability has become an important scientific methodological tool for assessment of energy technologies for post-harvest loss management that incorporate Life Cycle Sustainability Assessment (LCSA) and Social Life Cycle Assessment (S-LCA) (Corona et al., 2017). This approach align sustainability of products services or technologies on three impact pillars, namely; economic, social, and environmental impacts (Valdivia et al., 2021). These pillars of sustainability are used for products' assessment as well as on systems and services in the sense of understanding impact to "People, Planet, Profit" , where People refers the social pillar, Planet refers the environmental pillar, and profit refers the economic pillar (Heijungs et al., 2010).

1.1 Statement of the Problem

Post-harvest losses (PHL) constitute a development challenge in Africa where population growth is projected to increase from 1.1 billion to 2.4 billion by 2050, but food production is unproportionally available partly due to post-harvest losses. Food situation shows that one third of the food insecure in the world are found in Africa (Obayelu, 2014), while post-harvest loss accounts 46 percent happens at the processing, distribution and consumption stages (Obayelu, 2014). With the increasing population and the looming food crisis, finding appropriate technologies for managing postharvest food loss becomes a going policy concern by adopting environmentally sustainable post-harvest loss technologies (Fernandez et al., 2021; Osabohien et al., 2021). Since post-harvest food loss poses a threat to the actualization of the United Nations (UN) Sustainable Development Goals (SDGs) of no poverty (SDG1) and food security (SGD2) adoption of Life cycle Assessment (LCA) informs the appropriate technologies to sustainably overcome post-harvest loss. Among these, and of particular significance, is the Social Life Cycle Assessment (S-LCA) (Arcese et al., 2013) as a tool to inform policy decision making on stakeholders' welfare dimensions.

1.2 Objective

The main objective of the study was to assess the social life cycle of solar dryer technology adoption for post-harvest loss management in Africa, whereas the specific objectives are to identify the social impact of Solar Dryer House technology for postharvest loss management.

1.3 Research Questions

1. What are the social impacts of Solar Dryer House technology?
2. What sustainability pillars attract policy interventions in Solar Dryer House technology?
3. What UNEP/SETAC Guidelines address S-LCA in Solar Dryer House technology?

1.4 Description of Solar Dryer House

The manufacturing of solar dryer house use a selection of variety of raw materials including iron, aluminum, wood, plastics, glass, cement in a combination of various types of energy such as electricity generated from hydropower or gas. The raw materials that are depleted over years generate emissions thus risking sustainability. The construction of solar dryer consumes raw materials such as wood (Lobsiger-Kägi et al., 2018), steel pipes, iron sheets, aluminum, sand, cement, etc which has adverse effects to environment. The construction of SDH in Tanzania takes aluminum, steel pipes, electricity, sand and cement.

Table 1

Materials for Construction of Solar Dryer House

Materials/fuels	Measurement	Quantity	Comment
Aluminum alloy, AlLi {GLO}| market for | APOS, U	7.6	kg	Undefined
Flat glass, coated {GLO}| market for | APOS, U	0.8	kg	Undefined
Agricultural machinery, tillage {GLO}| market for | Conseq, U	0.0006	kg	Undefined
Electricity/heat			
Electricity, medium voltage {TZ}| market for | APOS, U	1	kWh	Undefined
Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | APOS, U	0.7	MJ	Undefined
Waste to treatment			
Waste aluminum {RoW}| treatment of, sanitary landfill | APOS, U	0.6	kg	Undefined
Inert waste, for final disposal {RoW}| treatment of inert waste, inert material landfill | APOS, U	0.1	kg	Undefined

A case study of SDH describes the Social-Life Cycle Assessment of SDH in Tanzania is used in the contexts of sustainable development. Social Life Cycle Assessment (S-LCA) is a methodology to assess the social impacts of products and services across their life cycle (UNEP, 2009). It has becomes a useful framework for sustainability assessment of products and services (Kalvani et al., 2021). S-LCA include the social dimension to examine the subcategories related to impact on labor conditions, local community conditions, consumers' well-being (Manik et al., 2013; UNEP, 2009). Social life cycle assessment therefore guides social impact evaluation on stakeholders throughout the life cycle of production and consumption.

Solar dryer house temperature ranges between 20 – 59.5°C, 21.5 - 68°C, and 25-78°C with average relative humidity of 71.64%, 60.21%, 49.77% capable to dry cereals, chilli pepper, yam, fish, vegetables and spices in a period of 5 days (Ade et al., 2018). The socio-economic value of solar dryer enables farmers to dry food products without degrading contents, enables seasonal products to be sold at any time of the year at a cost that is higher than cost of the original fresh product without any fear of climate change (Bishwash et al., 2017).

Figure 1
Solar Dryer House

II. LITERATURE REVIEW

Many studies focus on sustainability of products and interventions whereby the concept of sustainability is known as the development management as the ability of products and interventions to meet today's needs of environment, social justice and economic prosperity without compromising the ability of future generations to meet their needs (Finkbeiner et al., 2010; Jørgensen et al., 2010). The contemporary sustainability research considers the environment, economic and social impact of technologies such as the SDH for the reduction of post-harvest loss. (Toboso-Chavero et al., 2021) argue that the social dimension of sustainability captures the impact of organizations, products or process on society that can be estimated by analyzing the effects of the organization on stakeholders at local, national and global levels (Cadena et al., 2019; Peruzzini et al., 2017).

In the same vein, scholars have examined the Life Cycle Assessment (LCA) of Solar Dryer House and the environmental (Bishwash et al., 2017; Burade et al., 2017; Fudholi et al., 2018; Malik et al., 2019) only a few scholars (Dreyer et al., 2006; El-mesery et al., 2022; Finkbeiner et al., 2010; Kalvani et al., 2021) have studied the solar dryer technology but not on the Social Life Cycle Assessment (S-LCA) of SDH . Thus, there is inadequate evidence on the Social Life Cycle Assessment of Solar Dryer House Solar Drier House used for postharvest losses management. One of the reasons is a lack of a methodological framework for the analysis of social dimensions in the value chains for estimating the social impacts of technical innovations.

S-LCA divides impact on stakeholders to include; impact on workers, local communities, consumers, society, value chain actors, human rights, health and safety, working environment, and governance (Kalvani et al., 2021; UNEP, 2009). The purpose of S-LCA is to evaluate the social aspects associated with the life cycle of goods and services in manufacturing or production systems (Corona et al., 2017; Zafar et al., 2024).

III. METHODOLOGY

The United Nations Environment Program/Society for Environmental Toxicology and Chemistry (UNEP-SETAC) Life Cycle Initiative (UNEP-SETAC Life Cycle Initiative 2009) are the protagonist and developer of S-LCA procedures. The S-LCA methodology described in the UNEP-SETAC Guidelines methodology ISO 14040 and 14044 consists of four interconnected phases: goal and scope; inventory analysis; impact assessment; and interpretation (Corona et al., 2017). This study use UNEP-SETAC guidelines (UNEP, 2009) for Social life cycle assessment (S-LCA) in the context of sustainable development which follows key steps of defining the goal and scope, developing and weighting the criteria and assessing the criteria. We adopt ISO 14040 framework for the elaboration of S-LCA thus we consider four phases: Goal and Scope, Life Cycle Inventory, Life Cycle Impact Assessment and Interpretation (UNEP, 2009) (Fig. 2).

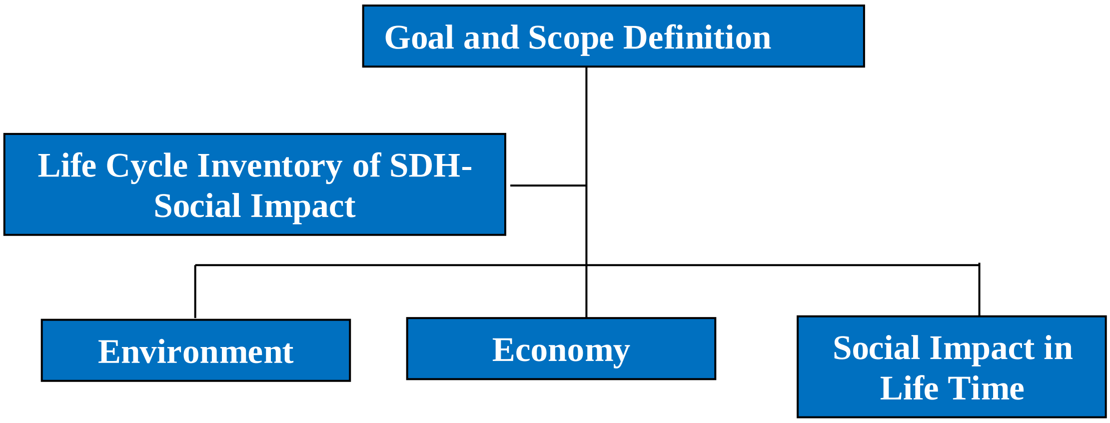

Figure 2
S-LCA Basic Steps

A Boolean search query technique was used that key words "S-LCA" + "Solar" + "Dryer"+ "House" + "postharvest" + "Loss management" conducted in Environmental science database. The search string comprised social life cycle assessment, "Solar"+ "Dryer" AND "posthavest loss"+ "technology*"

The S-LCA methodology requires an examination of social impact assessment of products and services adopting the Life Cycle Assessment (LCA. A conceptual formula for sustainability assessment that account for a life cycle sustainability assessment (LCSA), a life cycle assessment (LCA), life cycle costing (LCC) and a social life cycle analysis (SLCA) is represented as: LCSA= LCA + LCC + S-LCA (Kloepffer, 2008).

Since a United Nations Environment Programme / Society of Environmental Toxicology and Chemistry (UNEP/SETAC) Life Cycle Initiative guidelines provide a framework to assess social impacts across product life cycles (Benoit-norris et al., 2012; Benoît-Norris et al., 2011; UNEP, 2009), we apply UNEP / SETAC to examine the social life cycle assessment of SDH manufacturing technology on categories including producers, workers, distributors, consumers. Different subcategories and social indicators were developed with the scoring system to describe the potential positive and/or negative social impacts on related stakeholders within life cycle stages. Also the framework for the Social Life Cycle Assessment of product value chains follows the research stages to identify the main social issues and indicators for a Life Cycle Assessment (Reinales et al., 2020).

The developed subcategories became the base for S-LCA of SDH because they are the items on which justification of inclusion or exclusion needs to be provided and they are assessed by the use of inventory indicators. The relationship among stakeholder group and impact categories is defined by the United Nations Environment Programme classification (UNEP, 2009), whereby stakeholder categories impact subcategories that comprise socially significant attributes. These subcategories are assessed by the use of impact indicators whose inventory indicators link directly with the inventory of the product life cycle (UNEP, 2009; Wu et al., 2014). Studies of (Martucci et al., 2019) developed a similar methodological framework for the Italian wine sector by defining the social impacts and indicators applying the Social Life Cycle Assessment methodology for identification of the social impact in the wine production sector.

IV. FINDINGS & DISCUSSIONS

4.1 Response Rate

Stakeholder analysis involved identification and mapping of stakeholders in SDH as a cleaner energy technology for reduction of post-harvest loss and enhancing food and nutrition insecurity. It uses power- influence matrix (Fig.3) for mapping out stakeholders in the post-harvest loss management.

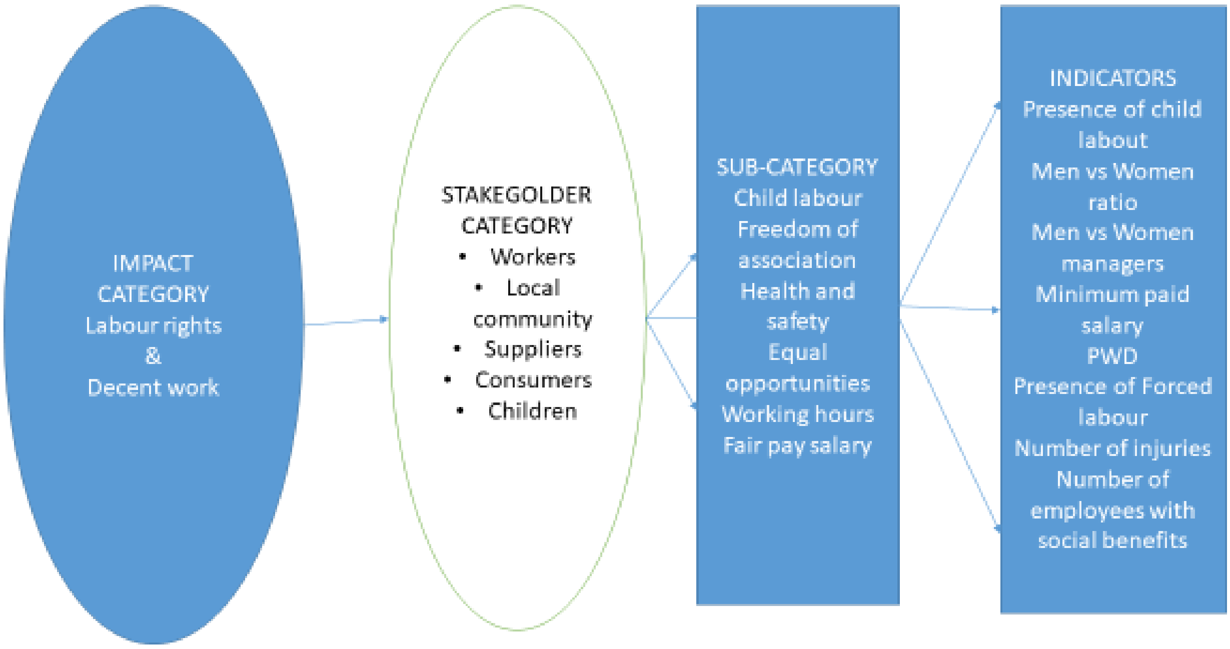

Figure 3
S-LCA of SDH Technology

Sustainability assessment of post-harvest management technology in Tanzania takes into consideration on its environmental, economic and social impact on stakeholders, who include SMEs owners- investors, traders, farmers, workers, Government (Ministry of health, agriculture), labor (unions, medical associations), private sector for-profit and non-governmental organizations (NGOs). UNEP guidelines for Social Life Cycle Assessment of products provide the generic methods for conducting S-LCA. Although the guidelines do not sufficiently address the sustainability social context in Africa, the S-LCA of post-harvest technologies is described below.

Step I: Identification and elaboration of stakeholders

The identification and elaboration of a stakeholders disaggregated by gender in the SDH industry was done and it found major categories including workers, community, as well as consumers and suppliers of technology.

Step II: Definition and scope

Definition and scope of social impact categories/subcategories and social indicators for the SDH was done covering (i) geographical relevance, (ii) data availability and (iii) bibliography validation. Tanzania labour law and the Sustainable Development Goal (SDG) guided the framework for decent jobs and equal opportunities, child labour protection, and gender inclusion. The social indicators subcategories selection considered social protection and benefits policy related actions. Specific factors for health and safety issues at work place were examined in the SDH technology and manufacturing in accordance to Tanzania labour law.

Step III: End –of-Life Assessment

An end –of-life assessment or the end-of-life performance is a means of improving recyclability and recycling of SDH products. This is an important step for ensuring sustainability of products and technologies.

Step IV: Goal setting

Goal of the Social Life Cycle Assessment was to assess the social aspects of SDH based on the scoring system on a five-point scale between -2 and +2, where 0 represents the baseline conditions, positive values represent an improvement and negative values represent a deterioration in comparison with the baseline conditions. The adoption of UNEP methodology gives us the stakeholder categories with significant social significance results as indicated in Table 2.

Table 2
Social Life Cycle Assessment of Solar Drier House

Stakeholder's category	**Impact category**	**Subcategories**	**Inventory data source**
Local community	Engagement	Local employment	Company website
		Local supplies	
Society	Human rights	Freedom of association	National policy Company regulations
		Right to organize and collective bargaining	
		Abolition of child labour	
		Abolition of forced labour	National policy Company regulations
Workers	Health and safety	Health Insurance	
		Protective gears	
	Equal opportunities	Gender inclusion, diversity	National policy Company regulations
	Decent job		National policy
Consumers	Cultural aspects	Perception on end product quality on performance	National policy Company regulations
		Convenience	
Value chain actors	Governance		National policy Company regulations
Technology adoption	SMEs		
	Farmers (consumers)		National policy Company regulations
	Certified environmental impact assessment	Ecolabelling	National policy Company regulations
	Investment on SDH technology		
End-of-Life Responsibility	Waste management		National policy Company regulations
	Information on product end-of-life		National policy Company regulations

4.2 Discussion

There has been technological development to address postharvest loss including the Solar Dryer House. These technologies are developed in the context of sustainable development whose goal is to achieve and sustain human well-being, while considering the needs of current and future generations (UNEP, 2009). Scientists and scholars have developed methodologies for sustainability assessment for products and services to support policy making and decision making for three pillars of sustainability (i.e. environmental, economic and social). Social Life Cycle Assessment is one of the adopted methodologies that facilitates organizations to be socially responsible when conducting their business and operations by providing information about the potential social impacts on people caused by the activities in the life cycle of their products or services(Dreyer et al., 2006). Considering SUGECO as an organization producing Solar Dryer House (Product), their business operations have potential social impact to workers, communities, consumers and all other actors in the value chain as S-LCA adds indicators of human wellbeing that are influenced by processes or companies in supply chains, such as worker's rights, community development, consumer protections, and societal benefits (Benoit-norris et al., 2012). This study found potential social impact of SDH to workers who must be protected by ILO conventions and the National Employment Policy.

ILO has set minimum standards of basic labour rights in countries including the human rights in a labour market stipulated as Freedom of Association and Protection of the Right to Organize Convention (No. 87) Right to Organize and Collective Bargaining Convention (No. 98) (ILO -International Labour Office, 2015; URT, 2008). ILO convention on Forced Labour Convention (No. 29) and Abolition of Forced Labour Convention (No. 105) restricts employment of children (ILO -International Labour Office, 2015).

Tanzania National Employment Policy 2008 (3.22) guides institutions and employers on elimination of child labour (URT, 2008). Our assessment at SUGECO found that workers on SDH are graduates of Sokoine University of Agriculture who enters after completing their university programmes at the age of 23 years. S-LCA contributes to informed policy decision making on selecting policy options and decisions that brings optimal value on sustainable development (Kalvani et al., 2021).

The UNEP/SETAC provides methodological sheets for subcategories of S-LCA of products like SDH (UNEP/SETAC 2009) that aim to describe the impact on basis of S-LCA. The subcategories are socially significant as they contribute to stakeholder analysis and impact categories noted on health and safety of workers, employment rights, as well as the environmental impact on the surrounding community.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

Solar drying technology is one of the emerging cleaner energies with potential solutions to climate change and post-harvest loss solutions. This paper examined the social aspects in the adoption and use of SDH, thus it contributes to the understanding and application of the S-LCA methodology in Africa where post-harvest loss technologies are highly needed. The methodology relies on the UNEP guidelines that take into consideration of sustainability assessment of products and services. While the environmental and economic impacts of Solar Drier House are well covered in literature, the social dimensions are barely considered. It is recommended that the social impact dimensions of SDH are well established including the effect on employment, health and safety of workers, workers' rights as stipulated in the UNEP guidelines.

5.2 Recommendations

The S-LCA of postharvest technologies should be encouraged to promote the attainment of Sustainable Development Goal 5 whereby SDH technology observes gender equality in the value chain; it responds to Sustainable Development Goal 8 seeking for decent work and economic growth in the SDH value chain; and Sustainable Development Goal 12 of having responsive consumption and production. The S-LCA methodology and practice in SDH manufacturing confirms an adherence to the Universal Declaration of Human Rights, ILO Prevention of Major Industrial Accidents Convention as well as the Tanzania Employment and Labour Relations Act 2004 on prohibition of child labour, employee's right to freedom of association, prohibition of discrimination in the workplace, working hours and occupational safety and health.

REFERENCES

Ade, A. R., Olayemi, F. F., Adebiyi, A. O., Zubair, O. M., Adeiza, O. A., & Achime, K. C. (2018). Recent Advances in Solar Drying of Agricultural Produce in Nigeria: Nspri Experience. *Food Sufficiency AZOJETE*, *14*, 86–94. www.azojete.com.ng

Arcese, G., Lucchetti, M. C., & Merli, R. (2013). Social life cycle assessment as a management tool: Methodology for application in tourism. *Sustainability (Switzerland)*, *5*(8), 3275–3287. https://doi.org/10.3390/su5083275

Benoit-norris, C., Cavan, D. A., & Norris, G. (2012). *Identifying Social Impacts in Product Supply Chains: Overview and Application of the Social Hotspot Database*. 1946–1965. https://doi.org/10.3390/su4091946

Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., & Mazijn, B. (2011). Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. *International Journal of Life Cycle Assessment*, *16*(7), 682–690. https://doi.org/10.1007/s11367-011-0301-y

Bishwash, H., Bobadi, S., & Nikam, M. (2017). *Design and Material Optimisation of a Solar Dryer - Tray Section*. *137*, 27–34. https://doi.org/10.2991/iccasp-16.2017.5

Burade, P. N., Dongre, R. M., Thomas, S., Tamgadge, S., & Mandavgade, N. K. (2017). Application of Solar In Food Dryer-A Literature Review. *International Journal of Innovations in Engineering and Science*, *441*(11), 2456–3463. www.ijies.net

Cadena, E., Rocca, F., Gutierrez, J. A., & Carvalho, A. (2019). Social life cycle assessment methodology for evaluating production process design : Biore fi nery case study. *Journal of Cleaner Production*, *238*, 117718. https://doi.org/10.1016/j.jclepro.2019.117718

Corona, B., Bozhilova-Kisheva, K. P., Olsen, S. I., & San Miguel, G. (2017). Social Life Cycle Assessment of a Concentrated Solar Power Plant in Spain: A Methodological Proposal. *Journal of Industrial Ecology*, *21*(6), 1566–1577. https://doi.org/10.1111/jiec.12541

Dreyer, L. C., Hauschild, M. Z., & Schierbeck, J. (2006). A framework for social life cycle impact assessment. *International Journal of Life Cycle Assessment*, *11*(2), 88–97. https://doi.org/10.1065/lca2005.08.223

El-mesery, H. S., El-seesy, A. I., Hu, Z., & Li, Y. (2022). Recent developments in solar drying technology of food and agricultural products : A review. *Renewable and Sustainable Energy Reviews*, *157*(August 2021), 112070. https://doi.org/10.1016/j.rser.2021.112070

Fernandez, C. M., Alves, J., Gaspar, P. D., & Lima, T. M. (2021). Fostering awareness on environmentally sustainable technological solutions for the post-harvest food supply chain. *Processes*, *9*(9). https://doi.org/10.3390/pr9091611

Finkbeiner, M., Schau, E. M., Lehmann, A., & Traverso, M. (2010). *Towards Life Cycle Sustainability Assessment*. 3309–3322. https://doi.org/10.3390/su2103309

Fudholi, A., Ridwan, A., Yendra, R., Desvina, A. P., Bin, M. K., & Fudholi, A. (2018). *Solar Drying Technology in Indonesia : an Overview*. *9*(4), 1804–1813. https://doi.org/10.11591/ijpeds.v9.i4.pp1804-1813

Gunnarsdottir, I., Davidsdottir, B., Worrell, E., & Sigurgeirsdottir, S. (2021). Sustainable energy development : History of the concept and emerging themes. *Renewable and Sustainable Energy Reviews*, *141*(August 2020), 110770. https://doi.org/10.1016/j.rser.2021.110770

Hajian, M., & Kashani, S. J. (2021). Evolution of the concept of sustainability. From Brundtland Report to sustainable development goals. In *Sustainable Resource Management: Modern Approaches and Contexts* (pp. 1–24). Elsevier Inc. https://doi.org/10.1016/B978-0-12-824342-8.00018-3

Heijungs, R., Huppes, G., & Guinée, J. B. (2010). Life cycle assessment and sustainability analysis of products, materials and technologies. Toward a scientific framework for sustainability life cycle analysis. *Polymer Degradation and Stability*, *95*(3), 422–428. https://doi.org/10.1016/j.polymdegradstab.2009.11.010

ILO -International Labour Office. (2015). *Compendium of international labour conventions and recommendations Compilation of international labour Conventions and Recommendations*. http://www.ilo.org/wcmsp5/groups/public/---ed_norm/---normes/documents/publication/wcms_413175.pdf

Jørgensen, A., Finkbeiner, M., Jørgensen, M. S., & Hauschild, M. Z. (2010). Defining the baseline in social life cycle assessment. *International Journal of Life Cycle Assessment*, *15*(4), 376–384. https://doi.org/10.1007/s11367-010-0176-3

Kalvani, S. R., Sharaai, A. H., & Abdullahi, I. K. (2021). Social consideration in product life cycle for product social sustainability. *Sustainability (Switzerland)*, *13*(20). https://doi.org/10.3390/su132011292

Kloepffer, W. (2008). Life cycle sustainability assessment of products (with Comments by Helias A. Udo de Haes, p. 95). *International Journal of Life Cycle Assessment*, *13*(2), 89–95. https://doi.org/10.1065/lca2008.02.376

Lobsiger-Kägi, E., López, L., Kuehn, T., Roth, R., Carabias, V., & Zipper, C. (2018). Social life cycle assessment: Specific approach and case study for Switzerland. *Sustainability (Switzerland)*, *10*(12). https://doi.org/10.3390/su10124382

Malik, A. U., Ali, S., Munir, A., & Amjad, W. (2019). *Modern drying techniques in fruits and vegetables to overcome postharvest losses: A review*. Journal of Food Processing and Preservation, 43(2), 1-15. https://doi.org/10.1111/jfpp.14280

Manik, Y., Leahy, J., & Halog, A. (2013). Social life cycle assessment of palm oil biodiesel: A case study in Jambi Province of Indonesia. *International Journal of Life Cycle Assessment*, *18*(7), 1386–1392. https://doi.org/10.1007/s11367-013-0581-5

Martucci, O., Arcese, G., Montauti, C., & Acampora, A. (2019). Social aspects in the wine sector: Comparison between social life cycle assessment and VIVA Sustainable wine project indicators. *Resources*, *8*(2). https://doi.org/10.3390/resources8020069

Obayelu, A. E. (2014). Post-harvest Losses and Food Waste: The Key Contributing Factors to African Food Insecurity and Environmental Challenges. *African Journal of Food, Agriculture, Nutrition and Development*, *14*(2), 1–8.

Osabohien, R., Olurinola, I. O., Matthew, O. A., & Igharo, A. E. (2021). Enabling environment and agriculture in ecowas: Implications for food security. *WSEAS Transactions on Environment and Development*, *17*, 38–46. https://doi.org/10.37394/232015.2021.17.4

Peruzzini, M., Gregori, F., Luzi, A., Mengarelli, M., & Germani, M. (2017). Journal of Industrial Information Integration A social life cycle assessment methodology for smart manufacturing : The case of study of a kitchen sink. *Journal of Industrial Information Integration*, *7*, 24–32. https://doi.org/10.1016/j.jii.2017.04.001

Reinales, D., Zambrana-Vasquez, D., & Saez-De-Guinoa, A. (2020). Social life cycle assessment of product value chains under a circular economy approach: A case study in the plastic packaging sector. *Sustainability (Switzerland)*, *12*(16), 6671. https://doi.org/10.3390/su12166671

Toboso-Chavero, S., Madrid-López, C., Villalba, G., Gabarrell Durany, X., Hückstädt, A. B., Finkbeiner, M., & Lehmann, A. (2021). Environmental and social life cycle assessment of growing media for urban rooftop farming. *International Journal of Life Cycle Assessment*, *26*(10), 2085–2102. https://doi.org/10.1007/s11367-021-01971-5

UNEP. (2009). Guidelines for Social Life Cycle Assessment of Products. *Management*, *15*(2), 104. http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf

URT. (2008). *National Employment Policy*. Government Printers.

Valdivia, S., Backes, J. G., Traverso, M., Sonnemann, G., Cucurachi, S., Guinée, J. B., Schaubroeck, T., Finkbeiner, M., Leroy-Parmentier, N., Ugaya, C., Peña, C., Zamagni, A., Inaba, A., Amaral, M., Berger, M., Dvarioniene, J., Vakhitova, T., Benoit-Norris, C., Prox, M., Foolmaun, R., & Goedkoop, M. (2021). Principles for the application of life cycle sustainability assessment. *International Journal of Life Cycle Assessment*, *26*(9), 1900–1905. https://doi.org/10.1007/s11367-021-01958-2

Wu, R., Yang, D., & Chen, J. (2014). Social life cycle assessment revisited. *Sustainability (Switzerland)*, *6*(7), 4200–4226. https://doi.org/10.3390/su6074200

Zafar, I., Stojceska, V., & Tassou, S. (2024). Social sustainability assessments of industrial level solar energy : A systematic review. *Renewable and Sustainable Energy Reviews*, *189*(PA), 113962. https://doi.org/10.1016/j.rser.2023.113962