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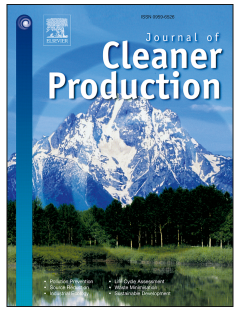

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A Framework of Actions for Strong Sustainability

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A Framework of Actions for Strong Sustainability

Abstract

Strong sustainability (SS) aims for the maintenance of economic, environmental, and social capital through an efficient use of resources and by replacing non-renewable natural resources with renewable ones. Despite this, there is still a grey area the academic literature and managerial practice regarding the existence of specific actions to promote SS. Therefore, the objective of this study is to advance the development of a framework of specific actions and recommendations to assist the adoption of SS by companies. A content analysis of articles included in the Special Volumes of the Journal of Cleaner Production (SVJCP) derived from the International Workshop Advances in Cleaner Production (IWACP), and interviews conducted with experts. The study revealed that only 5% of the articles sampled are related to SS. In this context, the proposed framework of specific actions for SS contributes to the theory by proposing actions that ensure the functioning of ecological systems while promoting sustainable development. The actions identified can also be used in multi-criteria analysis and for the development of sustainability indicators. The practical contributions of this study come from suggesting the application of the actions by organizations to promote the following: (i) increasing the efficiency of resource consumption; (ii) harvesting renewable resources limited by their regeneration rates; (iii) reducing greenhouse gas emissions; (iv) reusing wastes as input in other processes; (v) replacing toxic inputs with organic ones ; (vi) replacing energy from non-renewable sources with that from renewable ones; (vii) increasing affordability; and (viii) increasing sustainable manufacturing.

Keywords: Strong Sustainability, Triple Bottom Line, Framework, Sustainability Actions, Specialists Analysis

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Table 1. Acronyms

Acronyms	Meaning
SS	Strong Sustainability
IS	Intermediate Sustainability
WS	Weak Sustainability
SVJCP	Special Volumes of the Journal of Cleaner Production
IWACP	International Workshop Advances in Cleaner Production
SI	Sustainability Index

1 Introduction

Sustainability and sustainable development are concepts that became popular from the end of the 1980s onwards, through the Brundtland Report, and which remain a challenge for policy makers and the scientific community (Ramcilovic-Suominen and Pülzl, 2018). In the early 1990s, Herman Daly defined the principles of sustainability, implying that some metrics for material and energy balance should be adopted to overtake the limits of gross domestic product (GDP) (Giannetti et al., 2015).

Moreover, Daly (1991) proposed a classification system that distinguished three types of sustainability: weak, intermediate, and strong. In Weak Sustainability (WS), economic, natural, and social capital are considered substitutes. In Intermediate Sustainability (IS), natural capital can be partially substituted for by economic capital. In Strong Sustainability (SS), economic activity preserves natural resources and promotes social wellbeing.

These definitions were enhanced by Neumayer (2010), who proposed indicators for WS and SS: genuine savings, indexes of sustainable economic welfare, ecological footprints, and material flows. Furthermore, Elkington (1997) advanced the concept of the 'triple bottom line', which aimed for an equilibrium among economic, environmental, and social factors in corporate decision-making.

SS is the great target for human life and a challenge for organizational practice that involves changing societal habits. However, SS is a topic that is largely unaddressed in the scientific literature. Some articles analyse the market and stakeholders (Heikkurinen and

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Bonnedahl, 2013), the circular economy (Geissdoerfer et al., 2017), the green economy and bioeconomy (D'Amato et al., 2017), design and innovation (Gaziulusoy, 2015), and educational practice (Evans et al., 2017) through theoretical lenses. Such research has created new opportunities for future work, notably for the development of SS frameworks. Other research has analysed sustainability using multi-criteria decision tools (Cinelli et al., 2014). Suhariyanto et al. (2017) used a Multi-Life Cycle Assessment to remanufacture and recycle post-consumption products in a closed loop cycle. However, most existing research has reviewed the use of indicators with the purpose of offering additional indicators to recommend as complements or substitutes for resources extracted from the environment (Giannetti et al., 2015), which is evidence of a lack of work addressing sustainability assessments based on energy indicators (Romero and Linares, 2014), the Global Reporting Initiative (Grabs et al., 2016), and sustainability indexes (Gan et al. 2017; Mori and Christodoulou, 2017).

In this context, the literature review conducted for this study indicates that a framework of actions to promote SS, particularly as related to the principles and types of sustainability proposed and defined by Daly (1991) and enhanced by Neumayer (2010), and Elkington's (1997) triple bottom line has not yet been developed. This demonstrates the gap addressed by this study: what are the specific actions and recommendations to promote SS in companies? To meet the 'Call for Papers for the Special Volumes of the Journal of Cleaner Production: Ten Years Working Together for a Sustainable World, dedicated to the 6th International Workshop on Advances in Cleaner Production (IWACP)', this study presents the results of a systematic literature review based on 163 articles published in the five SVJCPs resulting from the publications and presentations from the five previous meetings of the IWACP, with the objective of proposing a framework of specific actions, validated by experts, for promoting SS practice in companies.

The development of the proposed framework was stimulated by the calls for future research, and aims to contribute to the promotion of corporate responsibility (Heikkurinen and

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Bonnedahl, 2013) and to take the opportunity of including the principles of the Triple Bottom Line in the proposed model, thereby respecting the functionality of the ecological system oriented toward the sustainable development (Giannetti et al., 2015; Mori and Christodoulou, 2017) and building on the premises of sustainability (Gan et al., 2017; Gaziulusoy, 2015).

The objective of this study was to propose a framework to support managers with actions and recommendations for promoting strong sustainability in companies. To meet this goal, the work addressed five specific questions: (i) was there an evolution in the number of articles addressing the three sustainability dimensions proposed by Elkington (1997) and published in the five SVJCPs from the IWACPs?; (ii) how was the content of such research related to the types of sustainability (weak, intermediate, strong) defined by Daly (1991) and Neumayer (2010)?; (iii) what specific actions and recommendations for SS can be identified in the literature, in accordance with the sustainability principles from Daly (1991)?; (iv) how has the topic and its deployment in research related SS evolved?; and (v) what is the perspective of experts concerning the dissemination of SS actions in organizational practice and future research?

This work was structured as follows: the introduction is followed by a literature review that addresses research that mentions the adoption of SS in companies, an overview of the research methodology, a presentation and discussion of the results, and conclusions and suggestions for future research.

2. Review of articles mentioning Strong Sustainability

Previous literature reviews have highlighted the lack of research on SS in companies. Heikkurinen and Bonnedahl (2013) concluded that the theories oriented towards the market and the stakeholders are based on WS suppositions because the focus is placed on economic gains, while environmental and social aspects are neglected. D'Amato et al. (2017) noted that research on the circular economy, green economy, and bioeconomy related to WS and SS were strictly focused on economic growth. Geissdoerfer et al. (2017) also found that the adoption of a circular economy contributes to SS by minimising resource consumption by reuse and recycling in a closed loop. Gaziulusoy (2015) concluded that it is important to include legislation with social and environmental initiatives in the process of design and innovation aimed at SS. Evans et al. (2017) concluded that there is a lack of teaching and learning models that promote SS.

Other researches concluded that the adoption of some tools can be useful to analyse SS. Cinelli et al. (2014) observed that both multi-attribute utility theory and analytical hierarchy processes are used to evaluate WS, whereas the use of elimination and choice expressing the reality, preference ranking organization method for enrichment of evaluations e dominance-based rough set are approaches more adequate for the SS analysis. Suhariyanto et al. (2017) proposed the use of Multi-Life Cycle Assessments to remanufacture and recycle products in closed loop systems to promote SS.

There is also a lack of analysis of both WS and SS in works that address energy, such as the Sustainability Index (SI) (Romero and Linares, 2014) and the global reporting index (Grabs et al., 2016). Therefore, it would be important to consider the functioning of the ecological system in the SI (Giannetti et al., 2015), to ensure sustainable social development by analysing its environmental, economic, and social aspects (Mori and Christodoulou, 2017), particularly by taking the participation of experts into account (Gan et al., 2017).

3. Research Methodology

This study builds on systematic literature review published in five SVJCPs from IWACPs: volume 18 (2010), volumes 46 and 47 (2013), volume 96 (2015), and volume 142 (2017). Each of these had the objective of identifying specific actions towards SS. The IWACP promotes discussions on eco-efficiency tools, especially cleaner production, and directions to stimulate the adoption of sustainability in companies (Neto and Shibao, 2014; Neto, Godinho Filho and Shibao, 2016., Giannetti et al. 2018). The first step involved the download of 163 articles from SVJCPs. The systematic literature review was developed to address the content of this material by codifying the data from the content analysis using a two-step approach. The selected articles were first analysed and classified according to the premises of the Triple Bottom Line, which prioritises economic prosperity, environmental quality, and social justice (Elkington, 1997). This led to the selection of 35 studies that mentioned economic, environmental, and social factors simultaneously. Those 35 studies were then classified according to sustainability types proposed by Neumayer (2010) and Daly (1991), i.e. WS, IS, and SS – according to, from which it was possible to select 8 articles that used the SS perspective (Figure 1).

Bardin (1986) mentions that the content analysis conducted in such a study is documental, and infers knowledge by the codification and categorization of data to inform the selection of adequate publications with which to develop the conceptual model. The content analysis of the 163 articles lasted 12 months, allowing codification of the data and categorization of existing research. The analysis was conducted independently by two researchers to reduce error and bias, as indicated by Hayes and Krippendorff (2007).

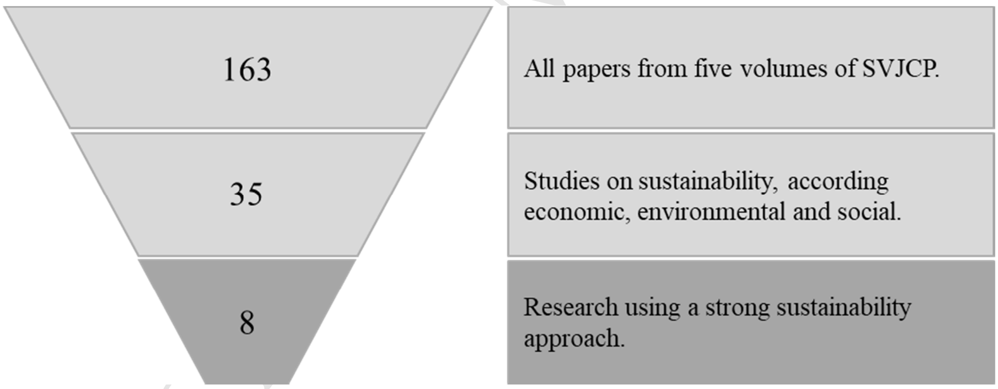

Figure 1. The methodology for the selection of articles addressing strong sustainability.

A social network analysis was then conducted on the eight SS articles; the software UCINET was used to create graphs (Borgatti, 2002) of the relationships between the three principles of sustainability (Daly, 1991), the six concepts of the triple bottom line (Elkington, 1997), the actions identified to promote SS, the authors and methodologies used, and the sector being researched. This allowed for an analysis of centrality with which to assess the number of links that each element had with other elements in the network (Wasserman and Faust, 1994).

When an element had a superior number of connections, it was said to be more central (Scott, 2000). The development of the graphs and the content analysis enabled the identification of actions to promote SS in companies.

The citations for the eight articles were also analysed to identify the evolution of actions to promote SS. Sharplin and Mabry (1985) and Culnan (1986) state that the analysis of citations is based on the premise that authors cite articles they consider important, and that the most cited authors exert a stronger influence in their respective research field. To support this, a network representation was developed (Borgatti, 2002), relating the eight selected articles to the works that cited them, allowing an analysis of the degree centrality of the actors, as recommended by Wasserman and Faust (1994).

The research also involved collecting information from experts. To this end, semi-structured questionnaires were sent to seven authors and co-authors of research on SS, keeping in mind their qualifications and familiarity with the research topic (Otto-Banaszak et al., 2011). Four experts, who consented to have their names disclosed (Table 2) returned the questionnaires, representing five of the articles related to SS. The expert analysis was conducted in two stages. In the first stage, the questions formulated aimed at learning about (i) the perspective of such actions exerting influence on new research addressing SS and (ii) the perspective of adopting SS actions in organizational practice, as described in appendix 1. Any doubts that the experts had concerning the questions were addressed using semi-structured interviews. According to Bogner et al. (2009), semi-structured interviews aim to collect exclusive and specialised knowledge to compare and bring together data on the research topic.

Table 2. Descriptions of the expert sampled to validate the results of the review of research on strong sustainability

Name	Title/affiliation	Function	Expertise
Abigail Metchtenberg	PhD / University of Notre Dame	Professor / researcher	Energy & Sustainable Development
Carmen Cabanillas	PhD / Universidad Nacional de Cordoba	Professor / researcher	Sustainable agriculture
Feni Agostinho	PhD / Universidade Paulista	Professor / researcher	Sustainability
Yan Zhang	PhD / Beijing Normal University	Professor / researcher	Sustainable development

The questionnaires were sent to the experts by e-mail in August 2017. The average response time was about three weeks. The semi-structured interviews had an average duration of 30 minutes each. This process allowed the development of a framework of actions for SS.

The development of the framework preceded the second stage in the data analysis, in which the experts validated the set of actions to promote SS in companies, as described in appendix 2. The average feedback time was about one month. In November 2017, the framework developed and a table describing the content of the eight articles under analysis was sent to the experts to support their contribution.

4. Results and discussion

4.1 Evaluation of the articles published in the Special Volumes of the Journal of Cleaner Production that addressed dimensions of sustainability

There were a total of 163 articles in the five editions of the SVJCPs, of which 35 addressed all three sustainability dimensions proposed by Elkington (1997): the economic, natural, and social. The remaining 128 articles failed to mention at least one dimension, addressing only (i) environmental and economic; (ii) environmental; and (iii) environmental and social approaches, as illustrated in Figure 2.

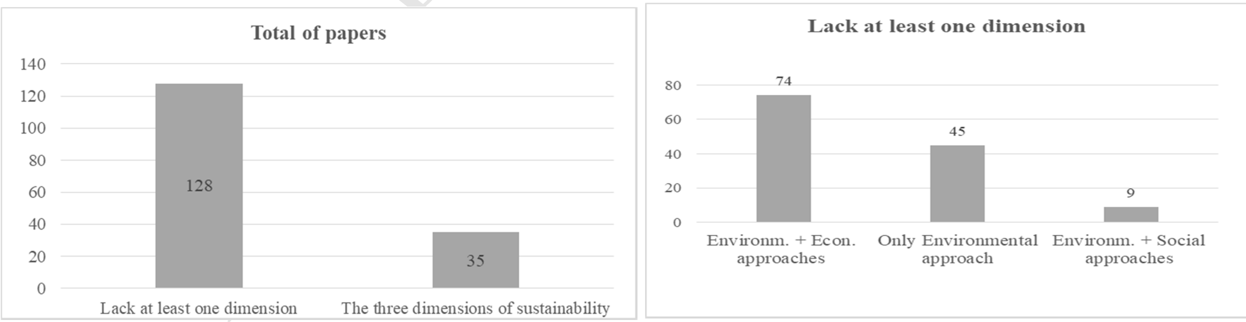

Figure 2. Papers published in the Special Volumes of the Journal of Cleaner Production and groups that do not mention at least one sustainability dimension.

Appendix 3 presents information on the 128 papers that were not included in the analysis because they did not mention all three sustainability dimensions. The findings from these articles suggest that environmental and economic analysis were the most frequent (74 papers). Overall, the economic analyses were based on cost reduction and return on investment calculations. Most studies that focused on environmental aspects analysed only one component of the ecosystem (e.g. air, water, materials, residuals, or energy). Therefore, the adoption of environmental practices creates economic gains that represent trade-offs for decision-making.

Another 45 papers dealt exclusively with the environmental dimension, referring to ecological footprints, environmental management systems, and environmental labelling. Nevertheless, analyses of the environmental dimension alone are not enough to promote sustainable development.

Another nine papers were identified as dealing with environmental and social aspects, indicating that health and social wellbeing are related to the environmental preservation. None of the studies identified social gains, therefore pointing towards future research.

4.2 Linking research content to weak, intermediate, and strong sustainability (WS, IS, and SS)

The results of the content analysis showed that the three dimensions of sustainability were addressed in 35 SVJCP papers (see appendix 4) that were classified according to the scientific evidence on the type of sustainability presented in each of them – WS, IS, and SS – (Table 3), following the recommendations of Daly (1991) and Neumayer (2010).

Table 3. Number of papers in the Special Volumes of the Journal of Cleaner Production that address three dimensions of sustainability – environmental, economic, social

IWACP	SJCP	Weak	Interm.	Strong
2007	2010	1	1	0
2009	2013(1)	0	1	0
2011	2013(2)	5	3	2
2013	2015	2	5	4
2015	2017	7	2	2
	Total	15	12	8

The WS approach was identified in 15 studies that showed that the economic is the main factor on the decision-making and can provide mechanisms to substitute environmental services and human welfare to keep the exploitation of natural resources. It was concluded that some of

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the research noted that reducing environmental impact was not possible due to the high cost of the production of biomass (Hornsby et al., 2017; Jamali-Zghal et al., 2013) and to the lack of fiscal and financial incentives to promote the recycling of solid urban waste (Echegaray and Hansstein, 2017). It was also observed that there was a trade-off between the preservation of human health and economic gain. The companies researched chose alternatives with higher economic advantages rather than opting for gains in social aspects. Rong et al. (2017) noted the existence of risks to landfill workers. Almeida et al. (2013) reported that the substitution of lead in welding processes was beneficial for human health although it was more expensive. Pereira and Ortega (2010) observed that growing sugar cane to obtain financial gain through the production of ethanol reduces the area of land available for food production. Such studies were not classified as dealing with SS because the economic aspects were dominant in the decision-making processes, indicating an imbalance in the dimensions of the triple bottom line and thus not favouring a legitimate sustainability approach.

Some research also pointed out the need to invest in environmental legislation to promote environmental education and the implementation of control practices in companies to reduce environmental and social impacts. Ribeiro and Kruglianskas (2015) suggest that environmental regulations in developing countries should be improved. Seckin et al. (2013) refer to the need to create laws regulating the carbon emissions in transportation services. In this context, it would be important to increase the participation of governments in the development of environmental regulations to reduce CO_2 in industrial activities, notably in transportation. Such actions could improve the eco-efficiency of companies and the social wellbeing.

Another important finding is related to the need for companies to develop sustainability indicators, as Senechal (2017), Santos et al. (2017), Hens et al. (2017), and Khalili and Duecker (2013) mention. The adoption of sustainability indicators represents a preliminary step towards the promotion of SS, because monitoring alone is not enough to improve the sustainable performance of companies. It would be important to define requirements and targets for

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education and the global development of sustainability indicators. This finding is relevant because the research only analyses the relationship between environmental and financial performance, and does not consider social performance (Lucato et al. 2017).

Another relevant finding is related to the implementation of environmental control by companies that explore non-renewable resources, with an aim to mitigate the damage to the environment and minimize the social impacts. Silvestre (2015) and Silvestre et al. (2017) reported the need for monitoring the processes of oil exploration, given the highly polluting nature of the oil. Freitas and Magrini (2013) noted that the implementation of systems to control the process of handling pulp waste contributed to reduce the environmental impact. In this vein, environmental impacts are controlled through the development of renewable products to act as substitutes for the exploration of non-renewable resources and for the control of the processes required to extract minerals. Mining and Oil & Gas companies exist because of extractive activities. However, natural resources are limited and their conservation is essential for human life and long-term business. Therefore, they should invest in the development of new products to reduce the exploitation of natural resources. For instance, companies could invest in producing fuels from renewable resources such as ethanol and bio-fuels. Furthermore, the mining industry could implement controls for extraction processes, focusing on maintaining dams to avoiding damage to forests and people.

Among the selected studies, 12 were classified as dealing with IS, due to evidence that they were concerned with actions to preserve some natural resources; this indicates that environmental and social dimensions have significant impact on decision-making. The findings also suggest that it is necessary to substitute non-renewable products with sustainable renewable resources, for example by using giant bamboo instead of native wood resources (Bonilla et al., 2010); substituting 1.6 kg of steel for 0.43 kg of aluminium in every item produced (Aguado et al., 2013); installing small-scale hydroelectrical units to substitute for diesel generators (Costa Junior et al., 2013); using solar power and biomass to reduce the consumption of coal and wood in the production of energy (Mohammed et al., 2015); using synthetic rubber (Lopes et al., 2017); and purchasing "green products" (Medeiros and Ribeiro, 2017). It is therefore important for small firms and large enterprises to invest in renewable resources as a business strategy that can improve their corporate image and reach new customers that demand cleaner processes and products.

Two studies mentioned ways to reduce the consumption of natural resources. Yılmaz (2013) compared the efficiency of cutting processes, illustrating the advantages of the sandwich-core blade: lower energy consumption and waste generation, and benefits for the worker health. With tools used to analyse the of value of cleaner production, Henriques et al. (2015) found an average reduction of 19% in energy, 35% in water, 7,6% in raw materials, while the generation of effluents, solid waste, and gas emissions were reduced by 40%, 30%, and 14,7%, respectively. This way companies could develop processes that are eco-efficient for the reduction in the consumption of natural resources.

Two other studies implemented indicators that improved the efficiency of processes, which reduced resource consumption and CO_2 emissions (Govindan et al., 2013; Luz et al., 2015). Sánchez (2015) observed that improvements in the efficiency of water and energy consumption is a business strategy and is demanded by stakeholders. Therefore, companies could implement performance indicators to monitor the sustainability of their processes, along with the indicators suggested in the sustainability reports from the Global Reporting Initiative, to improve the operational efficiency, particularly in terms of resource consumption and the emission of pollutants.

4.3 Specific actions and recommendations for SS in the literature

Research with a SS approach indicated a concern with the maintenance of the natural capital through the substitution of non-renewable resources with renewable ones, the substitution of toxic inputs by organic inputs, the reuse of waste in different production processes, and the

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elimination of greenhouse gas (GHG) emissions. These findings are in line with the three sustainability principles in Daly (1991) and the sustainability indicators in Elkington (1997).

The analysis considered 42 articles that cited the 8 papers identified as having a SS approach, as illustrated in Figure 3.

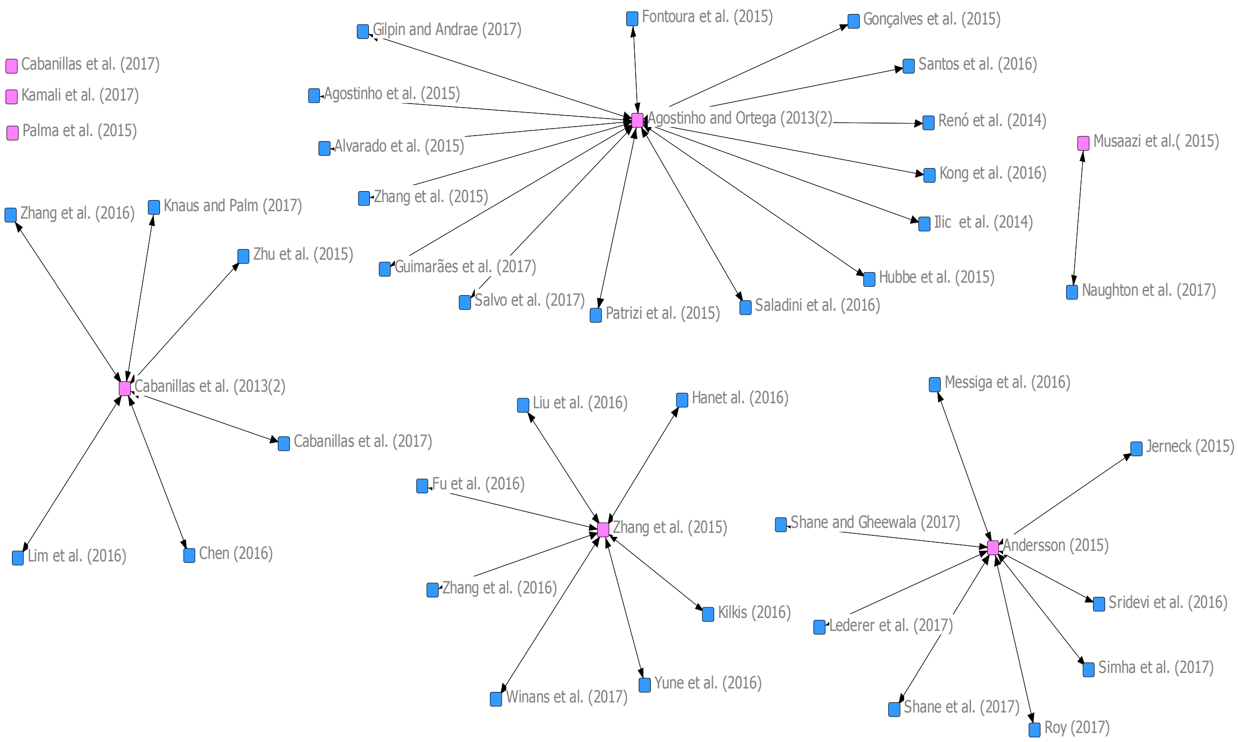

Figure 3. Network of citations for papers discussing strong sustainability approaches

In accordance with the first sustainability principle, Agostinho and Ortega (2013) observed that ethanol produced with biomass had a higher energy efficiency than that produced at a biorefinery and conventional ethanol systems, therefore indicating more efficient resource consumption, better performance, and energy safety. Other studies citing these results focused on the efficient use of resources that enabled energy efficiency by using bio-fuels (Renó et al., 2014), the production of ethanol and biogas (Ilic et al., 2014; Patrizi et al., 2015), the production of fuel with elephant grass (Fontoura et al., 2015), and integrating systems for the growth of grains and bio-fuel production (Saladini et al., 2016). Other works demonstrated the efficiency of using cleaner production in the use of production resources (Zhang et al., 2015), the substitution of raw materials with an aim to reduce electricity consumption (Hubbe et al., 2015), public

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policies to encourage companies to be energy efficient (Kong et al., 2016), project management (Guimarães et al., 2017), and centralizing data centres to achieve reductions in electricity consumption (Salvo et al., 2017). Thus, increasing the efficient use of resources is a smart way to save costs associated with environmental conservation. Therefore, companies should consider the continuous development of mechanisms to reduce the consumption of energy, water, and materials. For instance, they could provide rewards for ideas related to these problems and create multidisciplinary teams to work continuously on looking for sustainability solutions.

Andersson (2015) stated that the substitution of inorganic fertilizers with urine reduces soil contamination, and is an efficient and low-cost practice that offers low risks to human health. The results of this study contributed to others that considered the use of human urine as an input in the agricultural sector, leading to productivity gains (Sridevi et al., 2016; Lederer et al., 2017; Simha et al., 2017). Other research approaches studied seafood sediments and the recovery of phosphorus (Messiga et al., 2016; Roy, 2017) and the efficiency of burning of bio-fuels for soil fertility (Shane and Gheewala, 2017; Shane et al., 2017). The finding that some organic wastes have positive results when properly applied on soil suggests the possibility for new studies on the kinds of organic waste that can be used as fertilizer. This will reduce both the waste needing disposal and the use of chemicals in the agricultural sector, providing economic gains as well as environmental and social benefits.

Zhang et al. (2015), analysed the transformation and the distribution of sulphur in Lubei and observed that industrial symbiosis has increased the reuse of resources by 95.6% and the use of clean energy by 85.9%. Other studies focused on energy efficiency by comparing countries (Kilkis, 2016), in the analysis of resource flows among urban regions (Zhang et al., 2016; Fu and Zhang, 2017) and industrial regions (Yune et al., 2016), in the application of green chemistry and green engineering (Winans et al., 2017), and in the efficiency of copper and sulphur use (Han et al., 2016). Thus, industrial symbiosis offers opportunities for the exchange resources among companies, as waste from one process is input for another. In this aspect, firms in the same industrial park take advantage of avoiding high expenditures on logistics. Therefore, we suggest new studies comparing sustainability performances at industrial parks based on industrial symbiosis.

Cabanillas et al. (2013), found that manure from rabbit and cows can be alternatives to urea in the out of season production of basil; making it efficient to use renewable resources at a low cost and in a way that is not aggressive to the ecosystem. Some researchers have taken these results forward, looking that the efficient use of resources in agriculture by using larvae to reduce the moist in manure (Zhu et al., 2015), reducing consumption of O_2 with grass (Knaus and Palm, 2017), and improving the productivity of soils associated with the use of fertilizers (Zhang et al., 2016; Chen, 2016). Symbiotic systems also have advantage for the agricultural sector; therefore, agricultural cooperatives could use events and other communication channels to disseminate good practices and results encouraging farms to seek environment-friendly alternatives to increase overall efficiency.

Musaazi et al. (2015), developed organic absorbents with renewable and biodegradable materials, renewable energy, and rainwater. Naughton et al. (2017) implemented process efficiency improvements in wood furnaces to improve energy efficiency. Although rainwater is free, issues like space availability and investment for building storage tanks are barriers for towards use. However, lower availability of drinking water has increased pressure to raise its price, and this has significant weight on operational costs. So, companies should conduct comprehensive analyses on the feasibility of rainwater capture.

Palma et al. (2015), identified changes in conventional agriculture towards agroecology, resulting in the efficient use of organic inputs. Pashaei-Kamali et al. (2017) observed that an organic soy production system had was highly efficient in terms of energy consumption. Cabanillas et al. (2017) observed that reusing waste with biocontrollers is an efficient way to add value to production as it prevents the entrance of plagues.

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There was a concern with the efficient use of production resources in the literature. In many cases, these inputs were originated in other processes through recycling or reused material with low cost and high availability. Therefore, it was possible to verify that th e focus of organizational practices directed towards the optimization of resources. This suggests that the first action aligned with the promotion of SS is **increasing the efficiency of resource consumption**.

Four other actions were identified as being aligned with the promotion of SS according to the second sustainability principle. Agostinho and Ortega (2013) verified that the renewability of an integrated system that creates and generates energy (55%) is larger than that for a conventional factory (26%) or a biorefinery (20%). This study was cited frequently, highlighting the regeneration of the renewable resources in the planting of sugar cane (Renó et al., 2014; Gonçalves et al., 2015; Santos et al., 2016) and elephant grass (Fontoura et al., 2015) and in the collection of residual geothermal energy (Patrizi et al., 2015) and cattle manure (Saladini et al., 2016). Regeneration rate is a constraint in planning the production of ethanol from sugar cane. Companies must find ecologically friendly ways to reduce the regeneration cycle for increasing output without environmental damages. Thus, De Oliveira Neto and Lucato (2016) suggest the adoption of production planning and control to reduce environmental impacts.

Andersson (2015) verified that human urine is a resource with high level of availability and of easy absorption by nature, supported by Simha et al. (2017) and Sridevi et al. (2016); it was also found to be useful for soil fertilization, in the use of seafood sediments (Messiga et al., 2016) and urban waste (Lederer et al., 2017), and in the production of bio-fuel from crop waste (Shane and Gheewala, 2017). Furthermore, Palma et al. (2015) observed that 60% of green areas use diversified systems, in which biological consumption increased renewability and reduced the dependency on external inputs.

However, the consumption of some renewable resources needs to be controlled; otherwise these will limit the industrial activity, inhibit economic development, and compromise social dimensions such as employment and family income. As such it is also suggested that the second specific action to promote SS should **limit the consumption of renewable resources to the level of their regeneration rate**.

Furthermore, it was observed that there are concerns about the reduction of GHG emissions by using integrated systems for growing and co-generating energy (Agostinho and Ortega, 2013), as mentioned in work on carbon emissions from biomass burning being balanced with planting (Renó et al., 2014), growing ethanol crops (Agostinho et al., 2015), mineral mining (Zhang et al., 2015), producing enzymes (wood cellulase) (Gilpin and Andrae, 2017), industrial waste (Alvarado et al., 2015; Guimarães et al., 2017), and the reduction of 15,000 tons of CO_2 in Siena (Patrizi et al., 2015).

Moreover, the implantation of an 1800-kW turbine as a new technology, reduced the emissions of CO_2 (Zhang et al., 2015); this was cited in other studies that highlighted reductions in GHG emissions (Fu and Zhang, 2017; Han et al., 2016; Liu et al., 2016), and carbon sequestration (Kilkis, 2016). Furthermore, Musaazi et al. (2015) observed that the not polluting gasses were emitted in the production of absorbents; this was cited by Naughton et al. (2017), who identified a 78% reduction in GHG when the production process for butter was improved. Also, Pashaei-Kamali et al. (2017) verified that an organic system for growing soy offered a lower potential for global warming than the traditional system.

These findings suggested that the emission of GHGs can cause damage to the ecosystem and, consequently to the human health. Therefore, this concern must be embedded in decision-making because people facing bad health conditions also consume fewer products and services, which generates a reverse cycle that is not beneficial to companies. This suggests that the third action directed towards the promotion of SS is the **reduction in the emissions of greenhouse gases**.

Furthermore, this can be related to the second principle of sustainability as it was possible to identify the reuse of residuals by means of the use of human urine as fertilizer (Andersson, 2015;, Simha et al. 2017; Messiga et al. 2016), seafood sediments (Sridevi et al., 2016), and urban waste (Lederer et al., 2017; Shane and Gheewala, 2017; Shane et al., 2017). Landfill areas have a limited capacity to absorb urban waste. Thus, material recycling cooperatives should be incentivised to extend their coverage as well as campaign for enhance people awareness to separate household waste, organic and recyclable.

Zhang et al. (2015) observed evidence of industrial symbiosis in Lubei; this was cited such by Zhang et al. (2016), Fu and Zhang (2017), and Winans et al. (2017), and for design and construction companies (Yune et al., 2016), in the reuse of 83% of the residuals from casting (Han et al., 2016), and as a criteria to promote sustainable development (Kilkis, 2016).

Other researchers addressed the reuse of waste to fertilize the soil. Cabanilla et al. (2013) used vermicomposts from rabbit manure and bovine ruminal contents to grow basil. This practice was followed in the reuse of food waste (Chen 2016; Lim et al. 2016) and in the reuse of animal manure (Zhu et al. 2015). In this way, non-sustainable cattle farms could use cow manure as fertilizer or for energy generation; these are sustainable solutions for this residual material.

Musaazi et al. (2015) mentioned the reuse of recycled paper to produce absorbents. Palma et al. (2015) and Cabanilla et al. (2017) refer to the use of organic inputs. These works, and the synergy between companies able to reuse waste as inputs in other production processes, can contribute to the achievement reductions in natural resource consumption, operational costs, and reductions in the needs for landfills. This suggests that the fourth action to promote SS is to **reuse waste as inputs in other production processes**.

The studies examined also identified the concern with the use of toxic inputs for the damage they cause the environment and human health by substituting inorganic fertilizers with human urine (Andersson, 2015; Simha et al. (2017); and by research that suggests the substitution of chemical fertilizers with organic ones (Shane and Gheewala, 2017; Lederer et al., 2017), urban solid waste (Shane et al., 2017), and seafood sediments (Messiga et al., 2016). This is also related to the second principle of sustainability.

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Cabanilla et al. (2013) observed that exchanging urea (a chemical fertiliser) with an organic composite, and were cited by Chen (2016); Lim et al. (2016) and Zhu et al. (2015). Musaazi et al. (2015) observed the absence of toxic inputs in the production of absorbents, as cited by Naughton et al. (2017) in work on the reduction of 83% in human toxicity by means of improvements in butter production. Palma et al. (2015) identified the substitution of chemical pollutants with organic inputs. Pashaei-Kamali et al. (2017) demonstrated that an organic system for growing soy can replace the conventional system using genetically modified seeds. Cabanilla et al. (2017) also observed that the use of agrochemicals is not allowed in the region of Córdoba.

As such it was observed that companies need to reduce the use of toxic inputs, given that there are limits in capacity of the ecosystem to absorb them. The damage caused by inorganic products have been stimulating stakeholder demand for green products, and this has stimulated the search for organic alternatives by companies, consequently triggering economic development. This leads to suggest that the fifth action to promote SS is to **substitute toxic inputs with organic materials.**

The use of renewable energy sources, such as biomass (Agostinho et al., 2013) was cited in articles that addressed the generation of energy from ethanol (Renó et al., 2014; Patrizi et al., 2015), elephant grass (Fontoura et al., 2015) and biomass (Saladini et al., 2016). This is to the third sustainability principle.

However, there are other means to avoid the use of non-renewable sources of energy, such as the introduction of the 1800-kW turbine as a new, energy-saving technology (Zhang et al., 2015). This study was supported by the findings of Han et al. (2016). Musaazi et al. (2015) also mentioned the use of solar energy as a source. Following this, alternatives to substitute or reduce the consumption of non-renewable resources should be extended to companies in sectors such as construction, for instance; it involves the use of a large amount of non-renewable resources like energy, sand, steel, and stones that could be replaced with renewable materials.

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Therefore, the utilization of renewable sources is important for sustainable development; otherwise the scarcity of non-renewable materials will be a limiting factor in economic development, such as how a lack of petrol can impact industrial activity. On the other hand, the existence of renewable resources to use as substitutes for oil will guarantee continued industrial activity, economic development, and job creation. This suggests that the sixth action to promote SS is the **substitution of non-renewable energy sources with renewable alternatives.**

The six actions directed towards the promotion of SS were identified before the development of the graph that related them to Daly's principles of sustainability, Elkington's principles of the triple bottom line, and the authors, methodologies, and sectors of research illustrated in Figure 4. An interesting finding is that Daly's second principle of sustainability, which establishes that rates of extraction must not exceed the rates of regeneration and that the generation of residuals must not exceed the absorption capacity, led to the following four actions directly linked to SS: limiting the use of renewable resources to their regeneration rate; reducing GHG emissions; reusing waste as inputs in other production processes; and substituting toxic inputs with organic materials. Furthermore, the agricultural sector, which had a degree of centrality of 5, was where most of the research was conducted.

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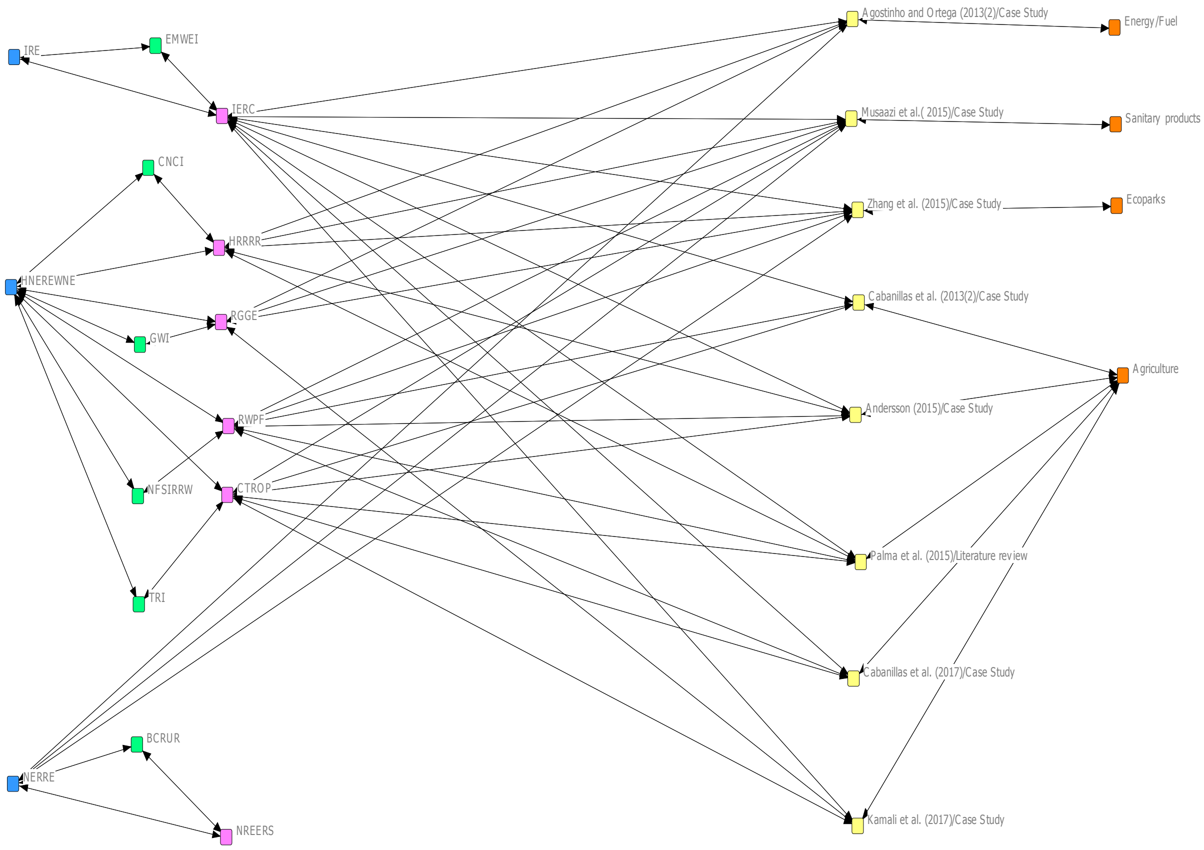

Legend: ■ Sustainability principles (Daly, 1991): (i) Increasing of resource efficiency (IRE); (ii) Harvesting rates should not exceed regeneration rates and waste emissions should not exceed the renewable assimilative capacity of the environment (HNEREWNE); (iii) Non-renewable resources should be exploited, but at a rate equal to the creation of renewable substitutes (NREERS).

■ The triple bottom line (Elkington, 1997): (i) Energy, materials and water usage efficiency indicator (EMWEI); (ii) Consumption of critical natural capital indicator (CNCI); (iii) Global warming indicator (GWI); (iv) Switch to the evolution of new forms of symbiosis, increasing the levels of reuse and revalorization of wastes (NFSIRRW); (v) Toxic releases indicator (TRI); (vi) Boost the conservation of resources and the use of renewable (BCRUR).

■ Actions: (i) Increasing efficiency of resources consumption (IERC); (ii) Harvesting of renewable resources limited by their regeneration rates (HRRRR); (iii) Reduction of greenhouse gases emission (RGGE); (iv) Recycling wastes as input in other process/firms (RWPF); (v) Chemicals and/or toxic inputs replaced by organic products (CTROP); (vi) Non-renewable energy resources replaced by renewable energy (NERRE).

Figure 4. The relationship between the principles of sustainability; the triple bottom line; and specific actions for strong sustainability, authors, methods, and sectors addressed in this study.

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Table 4 –Specific actions for the promotion of strong sustainability

Principles of sustainability (Daly, 1991)	Actions toward the strong sustainability	Agostinho et al., 2013	Evolution and deployment through citation.	Cabanillas et al., 2013	Evolution and deployment through citation.	Zhang et al., 2015	Evolution and deployment through citation.	Palma et al., 2015	Musaazi et al., 2015	Evolution and deployment through citation.	Andersson, 2015	Evolution and deployment through citation.	Pashaei Kamali et al., 2017	Cabanillas et al., 2017
1. Increasing of resource consumption efficiency.	Increasing efficiency of resources consumption.	IFEES* has net energy efficiency 3 times higher than biorefinery and CEP**.	Guimarães et al. (2017); Salvo et al. (2017); Kong et al. (2016); Saladini et al. (2016); Fontoura et al. (2015); Hubbe et al. (2015); Patrizi et al. (2015); Zhang et al. (2015); Ilic et al. (2014); Renó et al. (2014);	The output is greater for plants treated with vermicompost compared to the one treated with urea.	Cabanillas et al. (2017); Knaus and Palm (2017); Chen (2016); Zhang et al. (2016); Zhu et al. (2015).	The turbine allowed the sulfuric acid plant to decrease its energy use.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	Subsystems became increasingly specialized and efficient per unit of energy and nutrient consumption.	Water is collected from roofs. All rainwater is harvest into huge underground water tanks.	Naughton et al. (2017)	Urine application has a positive impact on crop yields.	Lederer et al. (2017); Roy (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).	Organic systems have lower potential environmental impact than the conventional system related to energy consumption.	The application of native biocontrollers is an efficiency way to add value to production.
2. Harvesting rates should not exceed regeneration rates and waste emissions should not exceed the renewable assimilative capacity of the environment.	Harvesting of renewable resources limited by their regeneration rates.	IFEES* has a renewability of 55% against ontra 20% for biorefinery and 26% for CEP**.	Saladini et al. (2016); Santos et al. (2016); Fontoura et al. (2015); Gonçalves et al. (2015); Patrizi et al. (2015); Renó et al. (2014).	-	-	This project allowed the utilization of the phosphoric acid resources, without imposing additional environmental impacts.	Fu and Zhang (2017); Han et al. (2016); Kilkis (2016); Liu et al. (2016);	Close to 60% of Cuba's arable land is in the hands of peasant families or cooperatives which use diversified systems, biological inputs.	Papirus grows again eithin a short period (6-8 months cycle).	-	Human urine is available with low-cost.	Lederer et al. (2017); Shane and Gheewala (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016); Jerneck (2015).	-	-
	Reduction of greenhouse gases emission.	IFEES* has a potential about 9 times lower than the other two systems for global warming.	Gilpin and Andrae, (2017); Guimarães et al. (2017); Salvo et al. (2017); Agostinho et al. (2015); Alvarado et al. (2015); Patrizi et al. (2015); Zhang et al. (2015); Renó et al. (2014).	-	-	The turbine allowed the sulfuric acid plant to reduce its emission of CO2.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	-	No GHG emission.	Naughton et al. (2017)	-	-	Organic systems have lower potential environmental impact than the conventional system related to global warming.	-
	Reuse of wastes as input in other processes/firms.	-	-	The reuse of agricultural and agro-industrial solid refuse (vermicompost) can be applied in the organic production	Cabanillas et al. (2017); Chen (2016); Lim et al. (2016); Zhu et al. (2015).	Industrial symbiosys results 95,6% of resources utilization efficiency.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	Agroecology and use of locally produced organic inputs.	The recycled paper used is paper waste from offices, banks and others offered free as a social corporate responsibility.	-	Use of human waste.	Lederer et al. (2017); Roy (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).		The use of reused waste revalues its production and processing within the system itself.
	Chemicals and/or toxic inputs replaced with organic products.	-	-	Use of vermicompost replacing chemicals input in the production of basil.	Cabanillas et al. (2017); Chen (2016); Lim et al. (2016); Zhu et al. (2015).			Replace toxic inputs with organic matter.	There are no toxic emissions.	Naughton et al. (2017)	Replacing chemical fertilizers with human urine.	Lederer et al. (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).	Organic system does not use genetically modified soybeans.	The use of agrochemicals is not permitted.
3. Non-renewable resources should be exploited, but at a rate equal to the creation of renewable substitutes.	Non-renewable energy resources replaced by renewable energy.	Energy generation from biomass replacing fossil fuel.	Saladini et al. (2016); Fontoura et al. (2015); Patrizi et al. (2015); Renó et al. (2014).			The introduction of the 1800-kW turbine as a new technology to save energy.	Fu and Zhang (2017); Han et al. (2016); Zhang et al. (2016).		Electricity is provided from solar photovoltaic panels.	Naughton et al. (2017)				

Notes: *IFEES - integrated food, energy and environmental services production;
**CEP - conventional ethanol plant.

4.4. First Expert Analysis – Actions and Perspectives

The following section presents insights from analyses conducted by four experts, with the purpose of identifying avenues for further research, concerning the specific actions for the promotion of SS in organizations,.

4.4.1 Actions to promote Strong Sustainability

To increase the efficiency in resource consumption, the respondents indicated that it would be important to establish the means to increase the overall efficiency in consumption. Cabanillas mentioned that *'The output (Gross income-Input cost) is greater for plants treated with vermicompost compared to the one treated with urea.'* Mechtenberg noted that *'The inputs into the manufacturing phase of a new Sustainable product continues to be limited by the status-quo networks that exist. There needs to be a network capability that researchers can present potential increases in efficiency once new up-stream innovations come on-line that would then affect their product. This could be introduced as an uncertainty calculation.'* Zhang stated, *'we think controlling the resource and energy at the beginning, which is related to the first action, is significantly important, more specifically, energy held by the steam can be captured again by other firms to raise the resource efficiency.'*

Therefore, improvements in the production processes and increases in efficiency must start by implementing controls in the use of production resources, with the purpose of eliminating waste. Therefore, companies should adopt indicators focused on consumption as part of their corporate targets and disclosures, and cooperate with all stakeholders to achieve them.

In terms of **limiting the consumption of renewable resources and their renewal rate**, the experts suggested that the former should be controlled by the creation of mechanisms to collect and store the available resources. In this vein, Agostinho stated that, *'Not producing in accordance with the demands from society, but rather by aligning with the available capacity at local/regional levels. The production must respect the limits that are imposed by the environment, who is the resource provider"*. Mechtenberg felt that *"New research should look at regeneration*

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rates of all renewable resources, but should include rainfall values and the uncertainties due to this. For example, as rain patterns are changing in Uganda, this is changing the rate of regeneration of papyrus.'

The analysis of the product life cycle must include the renewal period for the relevant renewable resources and be analysed in accordance with potential demand. Similar initiatives have been attempted by the thermoelectrics industry; it uses reforested wood, which has a renewal rate in of five years, as a raw material. Furthermore, it also uses an ethanol production plant based on sugar cane, which regenerates within 12 months.

Regarding GHG **emissions**, Mechtenberg stated that *'There is no GHG emission. ELCA [environmental life cycle assessment] air emissions results from transportation and production of plastic imported from China as well as incineration during disposal phase.'* Therefore, cleaner technologies could be employed by companies to reduce GHGs. Controlling carbon emissions is a widespread practice around the world, particularly after the signing of the Kyoto Protocol intended to encourage GHG emissions reduction projects for the leading economies that ratified it.

Regarding the **reuse of residuals as inputs to other production processes**, Cabanillas stated that *"Solid rural refuse such as rabbit manure and agro-industrial wastes as bovine ruminal content, are sometimes discarded. This refuse increases total waste volume, polluting soil, air and water. It is feasible to reduce the volume of rural and agro-industrial solid refuse by reusing it in the form of compost or vermicompost"*. Mechtenberg noted that "*Yes, in Manufacturing phase: we use recycling paper. The recycled paper used is paper waste from offices, banks and others offered free as a social corporate responsibility*". Zhang highlighted the fact that *"since there are large numbers of in-use stocks reach the end of there lifetimes, we should pay more attention on wastes recycling as well"*. The synergy between production processes would then have to be promoted by industrial and rural enterprises. The residuals would add value to other processes, and their reuse has shown to be advantageous at the economic, environmental, and social levels. In addition, tax incentives could be offered to industries such as construction to help overcome barriers such as logistics costs.

In terms of **substituting toxic inputs with organic materials**, Cabanillas highlighted the fact that *'Trichoderma spp. along with other native microorganisms can be investigated as a biocontrol of soil fungi and for their ability as biofertilizers in ancestral, aromatic and horticultural crops. Social communication, open channels for sharing knowledge, products and projects, are thereby constructed with geographical areas for direct relations between producers and consumers, which, with access to fresh, local produce free of pollutants, consolidate agro-ecological and sustainable forms of production.'* Mechtenberg noted that *'There are no toxic emissions at the Ugandan manufacturing plant. ELCA toxicity results from transportation and production of plastic imported from China.'* Thus, the preservation of soils, water, and human health depends on the substitution of chemical inputs with organic ones. In this vein, further research must look for alternative inputs that are less aggressive particularly those composed of biodegradable materials. Furthermore, people have expressed an increasing interest in organic fruits and vegetables that can indicate a tendency for a competitive differential in the medium term.

T**o substitute non-renewable energy resources for renewable alternatives**, Agostinho stated that *'High expectations for biomass energy and production distributed in small scale rather than in large scale.'* Cabanillas highlighted the fact that *'avoiding the use of urea contributes to the conservation of non-renewable resources such as gas, a necessary input for its production.'* For Mechtenberg, *"most of the energy is renewable, specifically electricity from solar photovoltaic panels, except for transportation (shipping plastic and delivery trucks),'* and Zhang indicated that *'corporations should focus on resource and energy utilizations.'* Therefore, managerial decision-making should consider the use of renewable energy sources such as solar, wind, and biomass. Farms that do not have access to electricity grid, in particular, could develop

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or buy equipment to generate cleaner energy instead of using generators that need non-renewable fuels such as diesel and coal.

Thus, the expert analysis of actions to promote SS support the findings of the content analysis of the literature. The sustainability assumption assumes that all actions result in reductions in cost. However, actions such as increasing the efficiency of consumption and reusing residuals as input for other production process have a clear and positive impact on overall costs that make it easy for management to implement them. They are standard in firms that adopt cleaner production and design programmes for environment. Environmental design promotes economic and environmental gains, contributing towards sustainability (De Paoli et al. 2013). In addition, actions such as substituting toxic inputs seem to be more common in agriculture, and controlling GHG emissions common in the industrial and transport sectors due to regulation. Finally, limiting the consumption of renewable resources at their renewal rates, and substituting non-renewable energy resources for renewable alternatives, must be recommended as needful for business survival in the long term, since the scarcity of natural resources can limit economic development.

4.4.2. Prospects for promoting strong sustainability in companies and future academic research

Agostinho indicated that the prospects for promoting SS in companies is *'very superficial and scarce. Stronger public polices are necessary in this sense. ISO 14000, ESI from IBFBovespa, GRI, and other standards, indicators and labels can be seen as positive actions, but represent just a first step towards strong suatainability.'* Therefore, address changes in public policies and its influence in companies, further research on this is recommended, particularly in terms of its environmental and social aspects.

Cabanillas highlighted the fact that *'The agro-ecological fairs contribute to the social, environmental and productive processes of transition farming, by connecting small family*

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producers devoted to different production areas." Thus, studies to evaluate the productive processes of small farms are recommended in terms of economic, environmental, and social aspects.

In Mechtenberg's analysis, *"The inputs into the manufacturing phase of a new Sustainable product continues to be limited by the status-quo networks that exist. There needs to be a network capability that researchers can present potential increases in efficiency once new up-stream innovations come on-line that would then affect their product. New research should look at regeneration rates of all renewable resources, but should include rainfall values and the uncertainties due to this. About non-renewable energy, the level of uncertainty in the transportation phase seems huge still. For example, ultracapacitor vehicles versus battery vehicles charged from the uncertainty in storage options and solar panels and/or wind turbines energy sources. GHG emission and waste recycling are strong in the research literature."* This illustrates the existence of opportunities in researching how to increase in the efficiency and regeneration rates of renewable resources and on the use of non-renewable energy sources.

For Zhang, *"these actions are all quite meaningful in the future corporate practice"*. As such, further research could explore the importance of sustainability for decision-making in companies.

After the first analysis of the contributions from the experts, it was possible to develop the framework for specific actions for SS presented in Figure 5.

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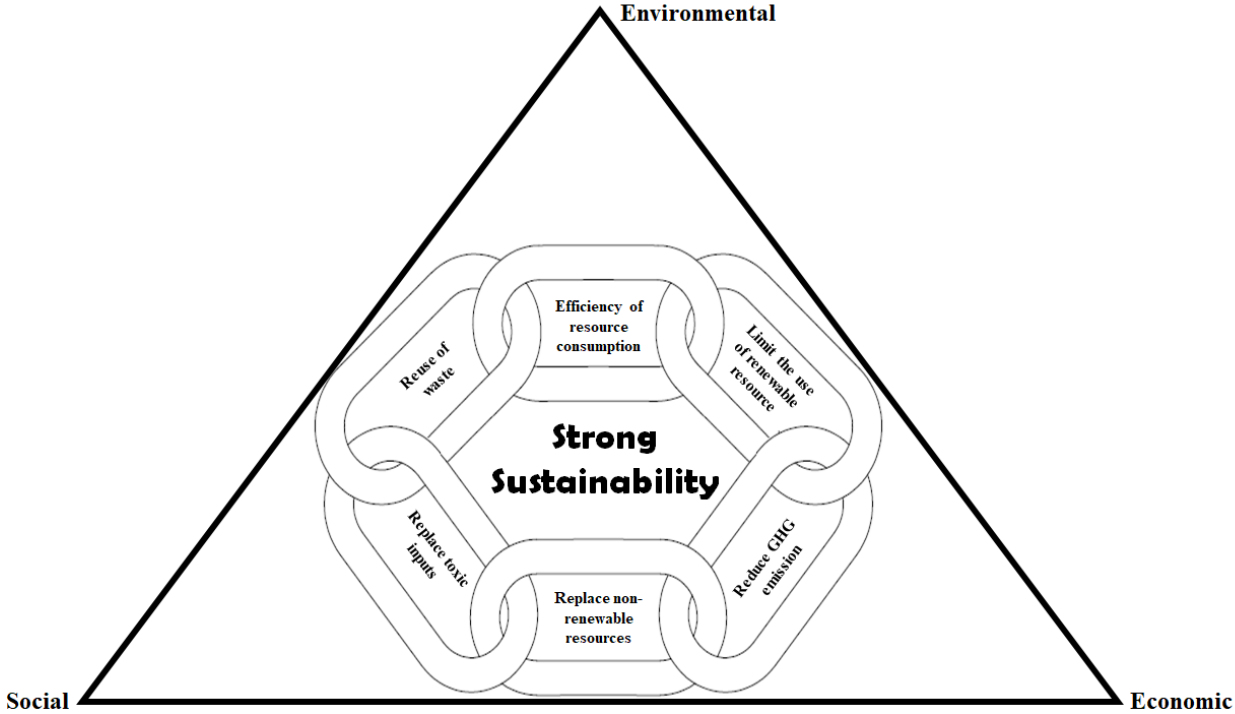

Figure 5. Framework of six specific actions to promote strong sustainability

4.5 Second analysis by experts: framework validation

After the content analysis and framework development were finished, the experts were consulted again to confirm if the six actions grouped in the framework were enough to promote the adoption of SS by companies.

Agostinho stated that *'I understand that actions provided in framework are correct to achieve strong sustainability, because in that phase, fossil energy will not be available at low cost (monetary and net energy) and the biocapacity of world will be drastically reduced; i.e. lower capacity to provide resources and depurate waste.'* Zhang confirmed that *'Yes, I agree that your proposal of those 6 actions can encourage the strong sustainability.'* Cabanillas highlighted the fact that *'in the agro-ecological production, the use of wind and sun energy, biodigester effluent is favored. Socio-economically, multipurpose crops provide alternative sources of income for family farms. Family farming is a strategic framework for promoting conservation and the sustainable use of resources. These actions further strong sustainability, covering environmental, social and economic aspects."* Mechtenberg approved of the six actions included in the framework and suggested that actions focused on social dimension be included: *'In social life cycle assessment, we are very concerned with the ability to include actions that are quantifiable social metrics as reduce poverty by decreasing costs (increasing affordability) and increasing wages (increasing sustainable manufacturability).'*

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All the experts agreed that the six actions were aligned with the promotion of SS adoption by companies. The integration of different economic, environmental, and social factors is believed to be relevant for promoting sustainability, specifically for developing actions to (i) increase resource consumption efficiency; (ii) harvest renewable resources limited by their regeneration rates; (iii) reduce GHG emissions; (iv) reuse wastes as inputs in other processes/companies; (v) replace chemicals and/or toxic inputs with organic materials; and (vi) replace energy from non-renewable sources with renewable energy.

Nevertheless, the inclusion of the following actions that focus on social aspects were suggested to reduce poverty levels: (i) increasing affordability and (ii) increasing sustainable manufacturability. These two actions support the human development indicators and sustainable economic welfare proposed by Elkington (1997), and can be used to evaluate the contributions of companies towards social development.

Increasing affordability means facilitating access to products and services through competitive prices by reducing costs and profit margins. Companies increase their revenue by increasing sales volume. Increasing the affordability of basic needs such as food, medicines, and personal care products is important to improve quality of life and reduce the occurrence of diseases.

Sustainable manufacturability conforms to the concept of SS since it aims to increase economic growth and global competitiveness through the creation of new jobs, while ensuring community and product safety and environmental conservation. The case of the production of sanitary products in Uganda (Musaazi et al. 2015) demonstrate the feasibility of stimulating the local design and manufacture of sustainable products. These findings must be disseminated to encourage other countries to undertake similar actions.

The latter two actions suggested by experts, increasing affordability and sustainable manufacturability, highlight the importance of addressing other social issues to reduce poverty and enhance equity, in addition to ensuring human health and employment, which were the focus of the first six actions.

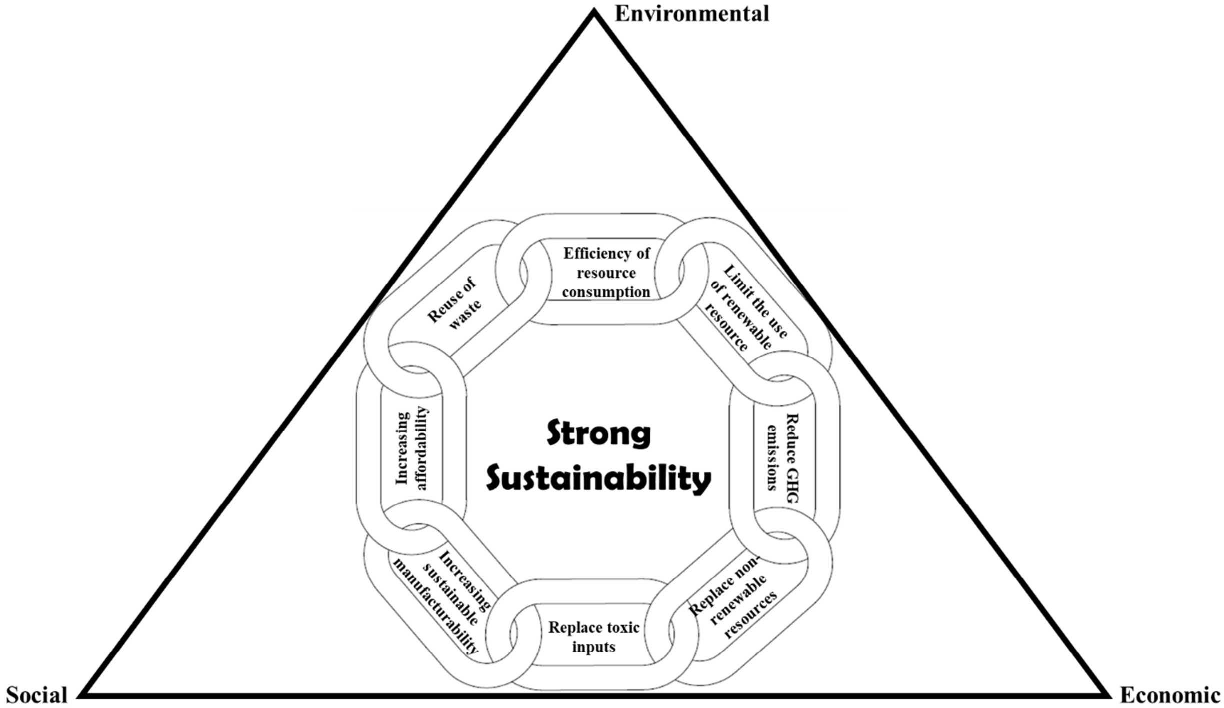

Figure 6. Final framework with eight specific actions to promote SS.

Unlike in previous studies (Heikkurinen and Bonnedahl, 2013; D'Amato et al., 2017; Geissdoerfer et al., 2017), the proposed framework considers the balance between economic, environmental, and social factors, and does not merely focus on economic factors. The substitution of toxic inputs by organic inputs, in addition to the use of a green label to promote change in mindsets (Evans et al., 2017), can be carried out in the design and innovation stages to promote adoption of the SS concept as discussed by Gaziulusoy (2015).

Our proposed framework suggests eight specific actions for the promotion of the SS concept. This framework could form a basis for establishing criteria and indicators for the application of multi-criteria analysis, contributing to the research area of Cinelli et al. (2014). Such criteria could also be used indexes, such as energy index (Romero and Linares, 2014), global reporting index (Grabs et al., 2016), sustainability indexes (Mori and Christodoulou, 2017), in the existing organizational performance indicators because they have been approved by experts and agree with the findings of Gan et al. (2017).

Furthermore, in accordance with Giannetti et al. (2015), the proposed framework can contribute towards ensuring the sustainability of ecosystem functions because it aims to promote the efficiency of resource consumption, reuse of waste, production of cleaner energy and organic products, minimization of carbon emissions, and access to basic products while generating employment with fair payment.

5. Conclusions and directions for future research

Existing studies on sustainability showed lack of relevant aspects. Studies with WS focused primarily on economic factor. Furthermore, existing studies are limited to the observance of legislation, which is characteristic of end-of-pipeline control and does not provide preventive measures to deal with environmental and social damages. Studies on IS have reported some advances, such as initiatives for the partial preservation of natural resources and social wellbeing.

The SS concept was discussed in only 5% of the existing studies using exploratory approaches, which indicates that this concept is still largely unexplored. Advances in the SS concept will require the direct involvement of companies that hold economic power, and a decision-making process that aims to respond to stakeholder demands. Therefore, changing societal habits to promote the demand for sustainable products and processes can stimulate the adoption of SS by companies.

The theoretical contribution for the science relies on the adoption of a framework that involves specific actions to promote SS aimed at improving the functions of the ecological system, while ensuring sustainable development, by maintaining an equilibrium between economic, environmental, and social factors. This suggests opportunities for future studies into the design and development of green products, efficiency of the resource consumption, reuse of waste, production of clean energy, reduction in carbon emissions, strategies for developing low value-added products to promote access for all individuals, and creation of jobs with fair compensation.

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The contribution of this study towards organizational practices that promote SS is related to the simultaneous application of the following eight actions:

(i) **increasing the efficiency of resource consumption** to preserve natural resources for future generations through energy calculations;

(ii) **limiting the consumption of renewable resources according to their regeneration rates** so that they do not become a limiting factor for economic development;

(iii) **reducing greenhouse gas** emissions to prevent atmospheric pollution and changes in living conditions;

(iv) **reusing waste as inputs in other processes** to minimize environmental and social impacts;

(v) **substituting toxic inputs with organic materials** to protect human health and mitigate environmental impacts (e.g. impacts on soil and water quality);

(vi) **substituting non-renewable energy resources with renewable alternatives** to avoid depletion of finite resources;

(vii) **increasing affordability** of basic items to improve health and living conditions for low-income individuals; and

(viii) **increasing sustainable manufacturability** with fair compensation to increase purchasing power and stimulate local economies.

This study reports the observations made through an analysis of 163 articles published in the five SVJCPs, from the IWACPs, to contribute to the 'Call for Papers for SVJCP: Ten Years Working Together for a Sustainable World, dedicated to the 6th IWACP', and discusses the gaps in the existing literature. Multiple case studies, surveys, and actionable research that addresses the implementation of specific actions that promote the SS concept by companies should be carried out to contribute towards the dissemination of knowledge on this topic.

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Acronyms	Meaning
SS	Strong Sustainability
IS	Intermediate Sustainability
WS	Weak Sustainability
SVJCP	Special Volumes of the Journal of Cleaner Production
IWACP	International Workshop Advances in Cleaner Production
SI	Sustainability Index

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Name	Title/affiliation	Function	Expertise
Abigail Metchtenberg	PhD / University of Notre Dame	Professor / researcher	Energy & Sustainable Development
Carmen Cabanillas	PhD / Universidad Nacional de Cordoba	Professor / researcher	Sustainable agriculture
Feni Agostinho	PhD / Universidade Paulista	Professor / researcher	Sustainability
Yan Zhang	PhD / Beijing Normal University	Professor / researcher	Sustainable development

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IWACP	SJCP	Weak	Interm.	Strong
2007	2010	1	1	0
2009	2013(1)	0	1	0
2011	2013(2)	5	3	2
2013	2015	2	5	4
2015	2017	7	2	2
	Total	15	12	8

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Principles of sustainability (Daly, 1991)	Actions toward the strong sustainability	Agostinho et al., 2013	Evolution and deployment through citation.	Cabanillas et al., 2013	Evolution and deployment through citation.	Zhang et al., 2015	Evolution and deployment through citation.	Palma et al., 2015	Musaazi et al., 2015	Evolution and deployment through citation.	Andersson, 2015	Evolution and deployment through citation.	Pashaei Kamali et al., 2017	Cabanillas et al., 2017
1. Increasing of resource consumption efficiency.	Increasing efficiency of resources consumption.	IFEES (Integrated food, energy and environmental services production) has net energy efficiency 3 times higher than biorefinery and CEP (conventional ethanol plant).	Guimarães et al. (2017); Salvo et al. (2017); Kong et al. (2016); Saladini et al. (2016); Fontoura et al. (2015); Hubbe et al. (2015); Patrizi et al. (2015); Zhang et al. (2015); Ilic et al. (2014); Renó et al. (2014);	The output is greater for plants treated with vermicompost compared to the one treated with urea.	Cabanillas et al. (2017); Knaus and Palm (2017); Chen (2016); Zhang et al. (2016); Zhu et al. (2015).	The turbine allowed the sulfuric acid plant to decrease its energy use.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	Subsystems became increasingly specialized and efficient per unit of energy and nutrient consumption.	Water is collected from roofs. All rainwater is harvest into huge underground water tanks.	Naughton et al. (2017)	Urine application has a positive impact on crop yields.	Lederer et al. (2017); Roy (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).	Organic systems have lower potential environmental impact than the conventional system related to energy consumption.	The application of native biocontrollers is an efficiency way to add value to production.
2. Harvesting rates should not exceed regeneration rates and waste emissions should not exceed the renewable assimilative capacity of the environment.	Harvesting of renewable resources limited by their regeneration rates.	IFEES has a renewability of 55% against ontra 20% for biorefinery and 26% for CEP.	Saladini et al. (2016); Santos et al. (2016); Fontoura et al. (2015); Gonçalves et al. (2015); Patrizi et al. (2015); Renó et al. (2014).	-	-	This project allowed the utilization of the phosphoric acid resources, without imposing additional environmental impacts.	Fu and Zhang (2017); Han et al. (2016); Kilkis (2016); Liu et al. (2016);	Close to 60% of Cuba's arable land is in the hands of peasant families or cooperatives which use diversified systems, biological inputs.	Papirus grows again eithin a short period (6-8 months cycle).	-	Human urine is available with low-cost.	Lederer et al. (2017); Shane and Gheewala (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016); Jerneck (2015).	-	-
	Reduction of greenhouse gases emission.	IFEES has a potential about 9 times lower than the other two systems for global warming.	Gilpin and Andrae, (2017); Guimarães et al. (2017); Salvo et al. (2017); Agostinho et al. (2015); Alvarado et al. (2015); Patrizi et al. (2015); Zhang et al. (2015); Renó et al. (2014).	-	-	The turbine allowed the sulfuric acid plant to reduce its emission of CO2.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	-	No GHG emission.	Naughton et al. (2017)	-	-	Organic systems have lower potential environmental impact than the conventional system related to global warming.	-
	Reuse of wastes as input in other processes/firms.	-	-	The reuse of agricultural and agro-industrial solid refuse (vermicompost) can be applied in the organic production	Cabanillas et al. (2017); Chen (2016); Lim et al. (2016); Zhu et al. (2015).	Industrial symbiosys results 95,6% of resources utilization efficiency.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	Agroecology and use of locally produced organic inputs.	The recycled paper used is paper waste from offices, banks and others offered free as a social corporate responsibility.	-	Use of human waste.	Lederer et al. (2017); Roy (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).		The use of reused waste revalues its production and processing within the system itself.
	Chemicals and/or toxic inputs replaced with organic products.	-	-	Use of vermicompost replacing chemicals input in the production of basil.	Cabanillas et al. (2017); Chen (2016); Lim et al. (2016); Zhu et al. (2015).			Replace toxic inputs with organic matter.	There are no toxic emissions.	Naughton et al. (2017)	Replacing chemical fertilizers with human urine.	Lederer et al. (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).	Organic system does not use genetically modified soybeans.	The use of agrochemicals is not permitted.
3. Non-renewable resources should be exploited, but at a rate equal to the creation of renewable substitutes.	Non-renewable energy resources replaced by renewable energy.	Energy generation from biomass replacing fossil fuel.	Saladini et al. (2016); Fontoura et al. (2015); Patrizi et al. (2015); Renó et al. (2014).			The introduction of the 1800-kW turbine as a new technology to save energy.	Fu and Zhang (2017); Han et al. (2016); Zhang et al. (2016).		Electricity is provided from solar photovoltaic panels.	Naughton et al. (2017)				

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Principles of sustainability (Daly, 1991)	Actions toward the strong sustainability	Agostinho et al., 2013	Evolution and deployment through citation.	Cabanillas et al., 2013	Evolution and deployment through citation.	Zhang et al., 2015	Evolution and deployment through citation.	Palma et al., 2015	Musaazi et al., 2015	Evolution and deployment through citation.	Andersson, 2015	Evolution and deployment through citation.	Pashaei Kamali et al., 2017	Cabanillas et al., 2017
1. Increasing of resource consumption efficiency.	Increasing efficiency of resources consumption.	IFEES* has net energy efficiency 3 times higher than biorefinery and CEP**.	Guimarães et al. (2017); Salvo et al. (2017); Kong et al. (2016); Saladini et al. (2016); Fontoura et al. (2015); Hubbe et al. (2015); Patrizi et al. (2015); Zhang et al. (2015); Ilic et al. (2014); Renó et al. (2014);	The output is greater for plants treated with vermicompost compared to the one treated with urea.	Cabanillas et al. (2017); Knaus and Palm (2017); Chen (2016); Zhang et al. (2016); Zhu et al. (2015).	The turbine allowed the sulfuric acid plant to decrease its energy use.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	Subsystems became increasingly specialized and efficient per unit of energy and nutrient consumption.	Water is collected from roofs. All rainwater is harvest into huge underground water tanks.	Naughton et al. (2017)	Urine application has a positive impact on crop yields.	Lederer et al. (2017); Roy (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).	Organic systems have lower potential environmental impact than the conventional system related to energy consumption.	The application of native biocontrollers is an efficiency way to add value to production.
2. Harvesting rates should not exceed regeneration rates and waste emissions should not exceed the renewable assimilative capacity of the environment.	Harvesting of renewable resources limited by their regeneration rates.	IFEES* has a renewability of 55% against ontra 20% for biorefinery and 26% for CEP**.	Saladini et al. (2016); Santos et al. (2016); Fontoura et al. (2015); Gonçalves et al. (2015); Patrizi et al. (2015); Renó et al. (2014).	-	-	This project allowed the utilization of the phosphoric acid resources, without imposing additional environmental impacts.	Fu and Zhang (2017); Han et al. (2016); Kilkis (2016); Liu et al. (2016);	Close to 60% of Cuba's arable land is in the hands of peasant families or cooperatives which use diversified systems, biological inputs.	Papirus grows again eithin a short period (6-8 months cycle).	-	Human urine is available with low-cost.	Lederer et al. (2017); Shane and Gheewala (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016); Jerneck (2015).	-	-
	Reduction of greenhouse gases emission.	IFEES* has a potential about 9 times lower than the other two systems for global warming.	Gilpin and Andrae, (2017); Guimarães et al. (2017); Salvo et al. (2017); Agostinho et al. (2015); Alvarado et al. (2015); Patrizi et al. (2015); Zhang et al. (2015); Renó et al. (2014).	-	-	The turbine allowed the sulfuric acid plant to reduce its emission of CO2.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	-	No GHG emission.	Naughton et al. (2017)	-	-	Organic systems have lower potential environmental impact than the conventional system related to global warming.	-
	Reuse of wastes as input in other processes/firms.	-	-	The reuse of agricultural and agro-industrial solid refuse (vermicompost) can be applied in the organic production	Cabanillas et al. (2017); Chen (2016); Lim et al. (2016); Zhu et al. (2015).	Industrial symbiosys results 95,6% of resources utilization efficiency.	Fu and Zhang (2017); Winans et al. (2017); Han et al. (2016); Kilkis (2016); Zhang et al. (2016); Yune et al. (2016).	Agroecology and use of locally produced organic inputs.	The recycled paper used is paper waste from offices, banks and others offered free as a social corporate responsibility.	-	Use of human waste.	Lederer et al. (2017); Roy (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).		The use of reused waste revalues its production and processing within the system itself.
	Chemicals and/or toxic inputs replaced with organic products.	-	-	Use of vermicompost replacing chemicals input in the production of basil.	Cabanillas et al. (2017); Chen (2016); Lim et al. (2016); Zhu et al. (2015).			Replace toxic inputs with organic matter.	There are no toxic emissions.	Naughton et al. (2017)	Replacing chemical fertilizers with human urine.	Lederer et al. (2017); Shane and Gheewala (2017); Shane et al. (2017); Simha et al. (2017); Messiga et al. (2016); Sridevi et al. (2016).	Organic system does not use genetically modified soybeans.	The use of agrochemicals is not permitted.
3. Non-renewable resources should be exploited, but at a rate equal to the creation of renewable substitutes.	Non-renewable energy resources replaced by renewable energy.	Energy generation from biomass replacing fossil fuel.	Saladini et al. (2016); Fontoura et al. (2015); Patrizi et al. (2015); Renó et al. (2014).			The introduction of the 1800-kW turbine as a new technology to save energy.	Fu and Zhang (2017); Han et al. (2016); Zhang et al. (2016).		Electricity is provided from solar photovoltaic panels.	Naughton et al. (2017)				

ACCEPTED MANUSCRIPT