Ten years working together for a sustainable world, dedicated to the 6th IWACP: Introductory article

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ARTICLE INFO

ABSTRACT

This special volume of the JCLP is mainly built upon articles presented at the 6th International Workshop Advances in Cleaner Production held in São Paulo, Brazil, in 2017. The event had provided a progressive interdisciplinary meeting for knowledge advance and information trade. Papers in this issue cover a broad range of perspectives of cleaner production strategies and practices, and a special focus was placed upon the type of contribution — practical, conceptual/practical, conceptual - and the scale of their coverage — local, regional and global. The papers provide understanding on the research intended to systematically include cleaner production in the path sustainability, and identifies the extent to which cleaner production practitioners directly and indirectly provide local, regional and global solutions. Key results of this introductory article include research on: efficient and responsive use of energy and resources; the search for reduced emissions, the role of managerial support and environmental assessments, and the implementation/analysis of closed-loop systems of materials.

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1. Introduction

Throughout the last decades, Cleaner Production (CP) evolved in scope, contents and was widely used by a growing number of different sectors. During this evolution, the targets also moved from just avoiding pollution and waste during the production, to new targets such as eco-design, green supply chains, environmental assessments, smart cities/regions, sustainable consumption and life-quality. In this context, CP also advanced as an approach for achieving not only local issues, but also contributing to regional, and global sustainability. Academic and non-academic communities embraced the idea since its beginning (Engelhardt et al., 1994), and CP-related initiatives are spread all over the world, also evolving to new targets such as the African Roundtable on Sustainable Consumption and Production (ARSCP, 2016), the Asia

Pacific Roundtable for Sustainable Consumption and Production (APRSCP, 2014) and the European Commission, Review of Cleaner Production (2017). Hens et al. (2018) provided a detailed description on CP evolution in this special volume, followed by a reflection on benefits and difficulties on the implementation of CP (Matos et al., 2018), the recognition of CP as a precursor for circular economy (Souza-Zomer et al., 2018), and as a key element for the framework for actions to achieve strong sustainability (Oliveira Neto et al., 2018). Examining the roles of CP for the achievement of sustainability in an expert forum was the main task for the participants at the 6th IWACP, and deep and broad discussion took place in order to encourage reflection on the real outcomes of the application of CP strategies along time. In this context, Merli et al. (2018) discussed the Italian situation in which why many organizations have dropped out of the eco-management and audit scheme identifying facilitating measures, which would encourage organizations to renew certification. Mata et al. (2018a,b) reviewed environmental reports published between 2006 and 2015, and concluded that most studies are based on longitudinal approaches and lack information on stakeholders' expectancies and on aspects

that could affect their decisions.

The Advances in Cleaner Production Network (ACPN) was driven by the perception that CP is a potent tool for accelerating the shift to a sustainable future. Under this perspective, the ACPN organized five special volumes of the JCLP including submissions from a wider scientific community (Table 1). This sixth special volume combines and strengthens the efforts of authors and ACPN members to keep and follow CP evolution.

A multi-base search performed for the last 20 years (Scopus; ScienceDirect Journals; Science Citation Index Expanded - Web of Science; OneFile - GALE; Materials Science & Engineering Database; Technology Research Database; Engineering Research; Materials Research Database; Mechanical & Transportation Engineering Abstracts; Pollution Abstracts; Springer Link; Environmental Engineering Abstracts; Engineered Materials Abstracts and AGRIS -United Nations, Food and Agriculture Organization) revealed that 34,963 peer reviewed articles were published with the term "Cleaner Production" in the title/abstract/keywords, being the oldest for this period one article published in JCLP describing the experiences from cleaner production training programme in Roslavl, Russia (Mont et al., 1999). Since then, authors dealt with the several aspects covered by CP apparently in a random way, such as the articles published in 2018 dealing from specific practical solutions (Prem et al., 2018), passing through more sophisticated methods such as process efficiency optimization (Fan et al., 2018), and discussing the use of big data to assist the transition to a sustainable production system (Ren et al., 2019).

This introductory article identifies and discusses the current research on CP, mainly developed by the members of ACPN, aiming the evolution and reinforcement of CP principles and practices. The six areas covered by the authors since the first SI are (1) energy efficiency, (2) resource saving, (3) green chemistry and green engineering, (4) CP case studies, (5) Education and (6) managerial support and environmental assessment — in many cases clarified by the use of case studies. This review categorizes the types of contribution (conceptual, conceptual & practical or practical) and the scale intended to be impacted by the authors (local, regional or global) to encourage readers to focus in pending research efforts for the reinforcement of CP concepts and practices.

2. Method

The research method is based on a three-step procedure, comprising (i) literature search and narrative review, (ii) a grouping and (iii) an assessment about the scale covered by the CP research and the identification of gaps (step 3). The narrative review approach used for examining and organizing the papers that compose this special volume (Hammersley, 2001 is not as rigorous as systematic reviews, but it is useful for relating studies on different topics, not only with the purpose of understanding but also indicating interconnections (Hagen-Zanker et al., 2012).

3. Narrative literature review

This special volume includes CP concepts and practices that cover not only the industrial sector, but also different subject areas: education, energy efficiency, resources savings, corporate social responsibility and citizen participation, which are especially relevant for the context developing countries. For example, Bustos and Moors (2018) have promoted the reduction of post-harvest food losses through innovative collaboration in Colombia and Mexico. Exploring ineffectiveness (corporate, cognitive and affective, and tangible) leading to postharvest losses, this research identified effective partnerships as the pillar of innovation. The response to natural disasters of the Brazilian cashew nut supply chain was explored by Silva et al. (2018a,b) in regard to the requirements for companies to restructure their tactics towards social responsibility and sustainability. Exports of commodities were also addressed through the life cycle assessment of perennial agricultural products. Coltro and Karaski (2019) calculated environmental indicators for two varieties of banana to help producers to improve crop management and lower the environmental impact of the products directed to local and overseas consumers.

3.1. Education

Education programs environmentally oriented, at each level, are essential for an all-inclusive approach to sustainable development. Brunstein and King (2018) posed that individual dilemmas are those reinforced in higher education. These authors analyzed the organizing reflection process of universities, teaching and student engagement on collective dilemma, and concluded that there is a need to involve students and faculty in a permanent and institutionalized transformative learning activity. Vieira et al. (2018) identified barriers and motivations influencing the implementation of sustainable practices in institutions of higher education. These authors studied the increase of staff awareness and involvement and suggested that the combination of participatory and top-down approaches is vital for sustaining environmental management practices in education institutions; and that in chasing sustainability a broader and deeper research on the role of bureaucracy is mandatory. Perkins et al. (2018) argue that education is strategic to the sustainable development, and that education on climate change is especially complex since various factors play

Table 1
Themes and main topics of the previous ACPN special issues.

Theme	Topics	Reference
The roles of cleaner production in the sustainable development of modern societies	Papers covered the complementarity of informal and formal knowledge to assess environmental impact; radical and incremental innovation benefits of eco-design; and tool and methods for environmental assessment.	Bonilla et al. (2010)
Key elements, stages and tools for a sustainable world	Key elements to achieve SD were explored: as the role of regulation and instruments to improve environmental performance; innovation through the information shared by academy and industry; alternative proposals for waste use, raw materials replacement; carbon emissions reduction in production and transport.	Bonilla et al. (2013)
Cleaner Production initiatives and challenges for a sustainable world	Different and complimentary initiatives and challenges that systematically addressed raw material changes, technological modifications, product and policy changes.	Almeida et al. (2013)
Integrating cleaner production into sustainability strategies	Articles underscore the need for shifting from production and societal patterns providing new methods to help industries, governments and society to speed up the transition to sustainable patterns.	Almeida et al. (2015)
Cleaner Production towards a sustainable transition	Efforts on new uses of raw materials and energy, technological advances, product and policy changes are discussed to improve corporate management, empower consumers to foster innovation in companies, industries, productive chains and countries creating circumstances to assist a "leapfrogged" path toward SD.	Almeida et al., 2017

important roles. Survey and interview data collected in several countries provided meticulous analyses of the climate change social context and different perspectives of the education for sustainability. The results showed that the scholar's concepts of an education for sustainability orbited around teaching of scientific knowledge on its all forms; ample and practical knowledge of climate change - including principles, debates; critical analysis, integration, and commitment with international and transdisciplinary standpoints; transformative pedagogies encompassing a sustainability and climate change curricula; and students realistic participation.

3.2. Energy

For each subject area, such as the search for **energy efficiency**, new ideas and applied methods covered a varied array from technical solutions to reduce carbon emissions (Wei et al., 2018) to a discussion on the potential redesign of the bioenergy sector in EU (Zabaniotou, 2018). The documents make available many real-world examples on how to implement CP concepts and practices to make possible a shift to a more sustainable society. The articles cover solutions not only for specific problems, but also to assessments of regional conditions offering foundation for elaborating public policies. Joppert et al. (2019) proposed a time saving approach to precisely and readily estimate biomethane potentials to fulfill a specific biomethane standard. The model based on mass balance was applied to a case study of upgrading biogas from vinasse from ethanol production, and in choosing the upgrading technology for biogas focusing on biomethane injection in the natural gas pipeline and in replacing diesel oil in trucks and heavy-duty machinery in the ethanol plant. In the technical grounds, a method for controlling the consumption of electricity in lead-acid battery plants helped to improve efficiency local standards by detecting inadequacies and isolating their sources (Sagastume et al., 2018), and in the same scale, Zanlorenzi et al. (2018) present a prototype for improving the efficiency of hybrid photovoltaic modules. The authors introduced an automatic water cooling system that absorbs solar irradiation and converts it into electrical and thermal energies with efficiency improvement of 33% in average.

At regional level, Zucaro et al. (2018) performed a "cradle-to-wheel" life cycle analysis to explore the production of bioethanol from wheat straw and its usage as transport fuel in Campania Region, Italy. Their results showed that the differences between the bio-based systems were higher depending on the type of the feedstock supply and the conversion steps. Coss et al. (2018) explored the design of small to medium scale district heating networks with increased biomass portion and proposed an energy service model for energy supply optimization. The model was examined using a case study that included the demand side, providing evidence that demand does not always contribute to higher performance of such systems. The carbon balance of the medieval historic centre of Siena, Italy, was presented, and the results provided ideas for investigating environmental policies based energy efficiency and on the potential shift towards renewable energy (Marchi et al., 2018). The potential alternatives, such as the use of photovoltaic panels, indicated a decrease in GHG emissions in approximately 10 years and foreseen carbon neutral condition in about 30 years. An effective framework to assess the general condition at city-scale was proposed by Huang et al. (2018a,b). The authors examined the Jing-Jin-Ji region to discuss the uncertainties and limitations for the use of emergy analysis. Their study contributed to solve the problem of data scarcity and inconsistency, establishing a method that helps dealing with missing physical data at small scale.

In a larger scale, Franco and Steiner (2018) assessed the social,

economic and environmental advantages of the revitalization of unproductive areas by implementing solar power plants. To delimit the best locations, these authors used a new hybrid fuzzy c-means algorithm that indicated places with potential for installing solar energy facilities. Changing the traditional distribution grid structure by using microgrids was presented as a promising option by Huamani et al. (2018) for the Brazilian power sector. The authors described the main barriers to the admittance of microgrids and identified limitations on supporting their implementation. Cucchiella et al. (2018a,b) discussed the role of the efficient use of energy and CO_2 emissions control for the development of a sustainable economy. Using Data Envelopment Analysis, these authors classified the competitiveness of European Union member states in terms of sustainable growth, and proposed an efficiency-based indicator that combines the countries' economic-social-environmental performance. Since bioenergy was presented as key preference for energy supply due to its inherent renewability and GHG emissions counterbalancing, Ko et al. (2018) reviewed the transport and the logistics in the biomass supply chain. Their review examined the present-day challenges, tendencies, and ideas for biomass transport and logistics investigation. Their findings identified great variability of fixed and variable transportation costs and the ideal delivery distance based on logistics conditions. These authors also claim that it is essential to explore the effects of feedstock conversion and upgrading options to biomass transportation logistics and to mitigate supply variations. Zabaniotou (2018) performed a comprehensive review including studies on several layers (legal, technical, economic and environmental) of the bioenergy sector. Environmental indicators related to bioenergy systems were discussed based on the environmental, economic, and social dimensions. Conclusions in the context of circular bio-economy indicated that sustainable paths would be selected based on high efficiency, closed loops and integrated bio refineries supported by social acceptance. Energy savings was also explored under the perspective of the provision of ecosystem's services. He et al. (2019) introduced a 3-D urban canopy parameters dataset into the integrated Weather Research and Forecasting urban modelling as an efficient approach to improve the modelling know-how in urban areas and support urban developers to deal with the impacts of urban surfaces on land surface energy budget.

3.3. Resources

Beyond the focus on energy efficiency, practitioners agree that CP approaches are effective in regard to **resource savings**, and this is a recurrent theme within CP research, whether these savings are focused directly toward natural resources or those materials already processed by industrial systems in order to keep materials circulating as long as possible and avoiding disposal. Local and practical solutions were explored in regard to maintain or increase water quality. The effect of diverse covering systems was evaluated in constructed wetlands concerning nitrogen removal (Ding et al., 2018). This study identified the structure of surface flow built wetlands to the nitrogen elimination providing a speculative basis for adjusting the structure of small-scale wetlands to control dispersed pollution sources. Water savings were studied within cities (Dias et al., 2018), industries (Gonçalves Filho et al., 2018) and regions (Zepeda Quintana et al., 2018). The causes of water consumption in buildings were identified not only due to the per capita consumption but also to constructive aspects such as the type of the control system and alternative supply structure in Southern Brazil (Dias et al., 2018). Gonçalves Filho et al. (2018) considered the CP prospects and barriers to decrease water consumption in sugar-energy plants in Brazil, which consumes more than 750 million cubic meters of water per year. These authors identified

alternatives as the use of dry cleaning systems, the categorization and analysis of effluents, and the concentration of vinasse.

Closest to the interface between the human activities and the environment, Zepeda Quintana et al. (2018) studied the sustainability strategies for coastal aquifers that supply both urban centers and industries. These authors provided a plan for coastal aquifers management using the Hermosillo Coast Aquifer (Mexico) as a case study. The plan takes into consideration the environmental costs to funding decision-making and suggests sustainability strategies for recovering, conserving, and sustainably exploiting water resources. Hanckok (2018) and Gastauer et al. (2018) explored mining management and tools for rehabilitating ecosystems and support sustainable mining. Using Bolivia's lithium as example, Hanckok et al. (2018) discussed a model for developing isolated mineral reserves using cleaner technologies with focus on the transition to a low carbon economy. Their research provided a framework and preliminary criteria for evaluating how public private partnerships interface can interact to deal with an escalating lithium demand with smallest environmental and social impacts. Gastauer et al. (2018) outlined the potential of phylogenetic and practical methods to overcome the challenges concerning after-mining land repair. Their review discussed the principles and limits of species selection for restoration purposes, barriers and options for controlling biological invasions, and the principles of monitoring recuperation activities. Yang et al. (2018), who established a framework on chronological evaluation and future prognosis of ecological security, also examined the interface between anthropogenic activities and the environment. Their results indicated that most of the Chinese western provinces are secure, but there is an ecological deficit in developed provinces highly dependent on fossil fuels. The authors provided policy recommendations to increase the country's ecological security.

Concerning processed materials, Marques et al. (2018) described the outcomes of the addition of polyethylene terephthalate residues on the fabrication of a fire-resistant thermal-acoustic insulation material. Composites with different percentages of this residue maintained the thermal isolation capacity and increased the acoustic insulation ability, being suitable for construction material formulations. Xue et al. (2018) investigated the recycling options of aluminum. An emergy-based life cycle inventory showed that aluminum waste could bring wealth for China by controlling bauxite mining. Their results also showed that increased recycling also improves energy and material efficiencies all over the production chain. Recycling was also examined through the consumer (Huang et al., 2018a,b) and the manufacturer (Satyro et al., 2018) perspectives. From the consumer side, results showed that funding programs with human interaction to spread information about recycling might not be satisfactory for waste managers, due to cost implications of training. Satyro et al. (2018) pointed out that in spite of all the research to improve environmental conditions applying CP concepts, little care was taken to short lifetime products. Combining field research, secondary data and a literature review, these authors discussed the need of moving from the planned obsolescence architype to the long-lasting products one.

There are also proposals to reduce the use of materials through the benefits of eco-design. Pinheiro et al. (2018) proposed a theoretical framework integrating eco design with portfolio management. A pilot test was performed in two firms that develop products originated in biodiversity in Brazil, and the results allowed establishing a set of practices such as the implementation of a project management department and the use of social media. The association between sustainable development and the product development process of small and medium-sized companies was investigated by de Medeiros et al. (2018) through a field research

including 18 industries of different segments. Their results indicated that small and medium firms understand the need of environmentally friendly products and processes, and can adopt suitable practices, adapted to regulatory and market demands. Two articles explored the concept of life cycle thinking. Luz et al. (2018) proposed the inclusion of LCA in the product development process in three phases named pre-integration, integration and post-integration. A softener package illustrated the use of the proposed method. Della Volpi and Paulino (2018) adopted a theoretical framework combining the nature of services and the life cycle thinking concept to address the sources of service materiality. Their results portrayed the material support for the provision of services, and highlighted the trade-offs between services and the environment through the life cycle stages.

3.4. Green chemistry and green engineering

CP practices such as **green chemistry** and **green engineering** have recognized benefits that include maximizing material and energy efficiency, producing value from waste, or applying philosophies to move from nonrenewable to renewable resources. Engineering tools and methods inspired by CP concepts have prospered in recent years. In this context, Akinsemolu (2018) reviewed and discussed the role of microorganisms to alleviating climate change. This author found that in spite the promising experimental results, the cost for scale-up to industrial level persists as a major difficulty. Akinsemolu (2018) also discussed the latest developments in several and distinct areas with focus on new practical engineering solutions to achieve sustainable production using renewable materials. Ali et al. (2018) and Ahmed and Hameed (2018) studied the use of straw as adsorbent. Both articles embrace the idea of converting renewable waste to high-value products. Wheat straw ash was used as a precursor for the synthesis of zeolites for consequent adsorption of antibiotic pollutants (Ali et al., 2018), and barley straws were employed to prepare biochar as adsorbent to remove salicylic acid from wastewater (Ahmed and Hameed, 2018). The elimination of heavy metals from synthetic wastewater using biomass derived from Cinnamomum camphora was achieved by Wang and Wang (2018), offering a sustainable technique to exploit agroforestry wastes and increasing the biomass value.

Silva et al. (2018a,b) simulated and assessed the use of indirect heating on the distillation process of an ethanol distillery, estimating the environmental and economic impacts related to vinasse fertirrigation. The results showed a decrease of about 15% on the vinasse amount providing a new configuration to diminish environmental damages and increase incomes. The use of carbon dioxide captured from the fermentation process in ethanol production distilleries was modeled and optimized, and the results indicated that even with the high-energy consumption for hydrogen generation by electrolysis the integration of methanol and ethanol plants results decreasing CO_2 emissions (Bonfim-Rocha et al., 2018). As a characteristic of green engineering evaluation, economic assessments are performed intending to promote a link between the environment and the economy, and to show the additional benefits of CP actions and practices. Cucchiella et al. (2018a,b) evaluated the economic performance of small plants for biomethane injection into the gas grid, and found economic feasibility for four scenarios that included municipal solid waste, and manure residues. The economic potential of lessening the acidity of animal fats by enzymatic esterification was evaluated by Mata et al. (2018a,b). Applied at industrial scale in a Portuguese company, the enzymatic esterification resulted in acidity reduction, but was not economically feasible, since the sale price of fish oil, for example, would have to increase about 4%.

3.5. Managerial support and assessment tools

Due to the philosophical and trans-disciplinary and long-term perspectives of the 6th IWACP, an innovative set of perspectives and operational tools and applicable practices were proposed and examined. The desirable changes from unsustainable to sustainable industrial systems motivated authors to evaluate the role of **managerial** support **& assessments**, to develop models to guide practices and to evaluate the companies' performance and their influence on societal patterns (and vice-versa). Public and private administration must be prepared to deal with multifaceted operations nets and closed-loop supply chains for handling the fluxes of information, materials and energy. From the management support and assessment tools perspective, new strategies and processes for organizations and institutions were presented.

A procedure for evaluating the implementation of sustainable practices in higher education technological institutions services was examined by Drahein et al. (2019). The procedure consists of more than a hundred criteria covering governance and policies, people, food, energy and water, and waste and environment. The seven higher education institutions showed isolated initiatives mainly related to solid waste management. The results obtained indicated that these institutions do not address properly sustainability issues with incipient selective waste collection in six of them. The proposed procedure was found convenient for developing policies for sustainable development, especially in service operations. Rodrigues et al., (2018) addressed the solid waste management in small cities, and developed a performance measurement using a tailor-made model that allowed to set a sustainability index, and to identify opportunities for improving governance and operational competence.

In a larger scale, Braz et al. (2018) argued that bullwhip effect affects the environmental performance of supply chain's by increasing emissions, waste and the usage of natural resources comparing the origins and alleviating factors of this effect in forward and closed-loop supply chains. Their study indicated that mitigating factors are associated to the increase of the product return rate, and that closing supply chains can reduce the bullwhip effect leading to a better environmental performance. Macke and Genari (2019) assessed the literature regarding human resources management and identified four research categories: studies on sustainable leadership, research on the correlation among resources management, environmental sustainability and organizational performance, studies on pressures and contradictions between management practices and sustainability, and studies on the link between management actions and the social dimension of sustainability.

The microfoundations of corporate citizenship inside companies were investigated by Pacheco et al. (2018) who depicted four distinct profiles below the firm level: (i) those who act coherently with the firm strategy; (ii) those who see room for improvement; (iii) critics that identify faults; and (iv) skeptics. These authors developed a framework for managing corporate citizenship inside firms and increase employee engagement. The connection between environmental consciousness and sustainable consumption was analyzed under the concepts of CP, social responsibility and eco-innovation. Based on the perception of more than one thousand participants from South Brazil, Severo et al. (2018) found a link between CP, social responsibility and eco-innovation, which inspires environmental awareness and consequently, Sustainable and recommend companies to disclose their CP practices to stimulate sustainable consumption. Morais and Silvestre (2018) presented some lessons on the advances of social sustainability in supply chain management. These authors discussed the strategy of six focal companies that had implemented 34 supply chain social

initiatives, and developed a typology that expands understanding on the interfaces between the supply chains management and social sustainability performance. Pacheco et al. (2019) described the difficulties for the shift towards sustainable product-service systems and identified the need for well-structured methods to create innovations and resolving conflicts during the servitization process. These authors explore the potential of the theory of inventive problem to systematically solve contradictions and generate innovations in synergy with the CP strategies.

To undertake the required changes for sustainability achievement, integration of academic results and practical applications, Cazeri et al. (2018) focused on Latin America companies to assess the integration between practices of corporate social responsibility and management systems. Their results exposed opportunities in all social practices improvement, especially those related to planning activities. Magon et al. (2018) provided a systematic literature review on sustainability relations with companies performance, including social and environmental dimensions. The review identified the main variables on causal models and discussed the effect and the mechanisms through which sustainability influences operational performance. Nicoletti et al. (2018) proposed an assessment model for sustainability based on a correlation matrix between the triple bottom line idea and the management model of the balanced scorecard (learning and growth, process, market and financial). Supported by a literature review, these authors suggested performance indicators for each correlation, and the model was applied to a Brazilian company of food and beverage. The guides published earlier than CP to lead companies toward a sustainable competitive advantage were analyzed on 1774 small companies using structural equation modelling (de Guimarães et al., 2018), characterizing the drivers that can increase the effectiveness of CP initiatives. Knowledge Management Orientation was found the main influencer over CP actions, and the authors recommended enterprises to develop strict structures for the advancement of knowledge produced in the organization.

Reficco et al. (2018) investigated the influence of deep-rooted business models as barriers for sustainable innovation. These authors examined the mechanisms that support sustainable innovation and discussed the integration of social and environmental collaboration mechanisms, their connections, and some facilitating conditions within focal firms that expedite cooperation. Co-creation was proposed as a key element to attract stakeholders' engagement (Kruger et al., 2018). A conceptual model of co-creation was proposed and the authors recommended managers to foster actions that stimulate dialogue to encourage stakeholders' participation. In spite of stakeholders' collaboration being considered by some authors as a positive element, Silvestre et al. (2018) raised a discussion on the case when stakeholder collaboration contributes to corruption. These authors explored and discussed the backgrounds, underlying forces, and consequences of corruption in the beef supply chain in Brazil and suggested that stakeholder collaboration might not be always positive in providing awareness for policy makers and regulators.

The inclusion of papers in this special issue was not restricted to procedural approach or focused activity, consequently, **case studies** allied (or not) to **theoretical contributions** are included to offer an inclusive variety of possible ways to make improvements by applying CP approaches. Examples go from improving unit operations to management practices. Lopes Silva et al. (2018) carried out a life cycle assessment of automotive components. CP options were developed to alleviate environmental burdens and to increase manufacturing eco-efficiency. Modest changes allowed minimizing environmental burdens, particularly in terms of impacts for resources depletion. Studying a cluster of ceramic tile industries, Vieira et al. (2018) identified how eco innovation practices were

implemented and consolidated in South Brazil, and concluded that most of the eco-innovation in Brazilian ceramic clusters were driven by specific legislation and market requirements. Using a machine-learning algorithm to pinpoint companies' commitment to CP actions, Benites-Lazaro et al. (2018) showed how sugarcane ethanol companies use social and environmental indicators to integrate sustainability with their priorities. Selitto (2018) studied three companies: beverages, packaging, and construction chemicals with the purpose of identifying favorable conditions to recover value from waste. This author established that the combination of processes with superior potential for recovering value are reuse in fabrication and distribution, remanufacturing in maintenance, and recycling in post-consumption. Also with the intention of creating value in industrial systems, Leme et al. (2018) developed a Lean-Green model based on eco-efficiency indicators to assess the performance of a metalworking industry. The model can be implemented in other firms to create value with lower environmental load. Caldera et al. (2018) explored small manufacturers in Australia concerning their engagement to 'sustainable business practice'. Environmental stewardship, process excellence, and sustainability oriented-culture were the themes chosen for helping small business to address the responsible consumption and production sustainable development goal. Claiming that CP has still limited application in small and medium-sized enterprises, Nunes et al. (2019) attributed this reduced use to barriers such as the lack of capital and leadership in owners' hands. These authors proposed a CP-based management methodology for small companies involving a meta phase and a five-step cyclic phase. Continuous improvement was achieved through promoting and monitoring activities, prioritizing preventive opportunities and employee participation.

4. Matching the efforts of CP research to scale of action/effects

The complexity of the activities for making the required changes to SD often seem scattered or, sometimes, impeding academics from attaining solutions beyond local solutions (Fig. 1). Fig. 2 shows the overall distribution of the articles in this special volume (left), and the accountancy of all special volumes dedicated to the International Workshop on Advances in Cleaner Production since its beginning, ten years ago. There is a clear preference for research that seeks for practical and local solutions. Consequently, a slow
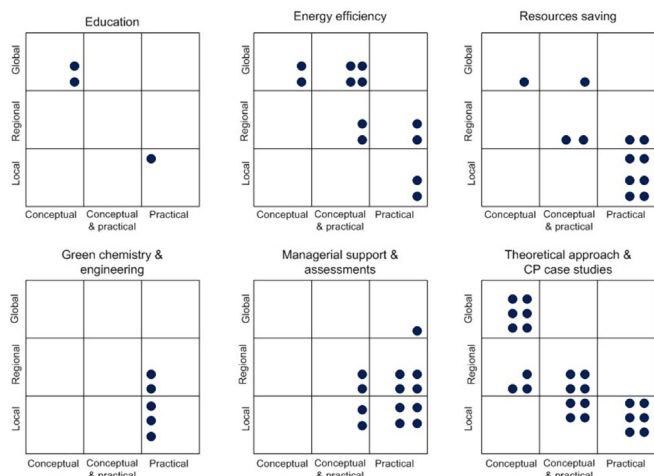

Fig. 2. Distribution of articles in this Special Issue (left) and of the articles published in the five previous special volumes (right) - according to the type of contribution: conceptual, conceptual and practical, practical and the scale of coverage: global, regional and local.

progress may be expected in combining the social, environmental and economic dimensions, underscoring the urgency to increasingly develop and implement multi-disciplinary schemes to progress toward sustainable societies. Practical and local solutions in general diffuse slowly, notwithstanding the benefits that have been documented (Dovì et al., 2009) and CP programs are alone no warranty of environmental improvement unless allied to management systems to secure continuous and systematic progress (Zwetsloot, 1995). In this way, the increase in research seeking for regional solutions and theoretical contributions that can be applied globally may supply some needs of decision makers for developing and implementing integrated procedures and strategies for assisting society to manage energy and resources in a more sustainable manner.

In spite of the increase of articles dealing with large scale problems and conceptual research that could be applied at global level, the challenge is not trivial because all dimensions and scales to be dealt with have their own peculiarities that will have to be understood from an all-inclusive standpoint to integrate the parts and to accomplish constructive and enduring results. Nevertheless, each contribution and each scale must be exhaustively researched and the results must be systematically verified. That being said, it is worthy to mention that the social dimensions of human conduct are not entirely within the scientific territory, consequently, stakeholders' participation and enablement are vital in pursuing compromise on the alternative paths toward a rightful and sustainable future.

The creation and sharing of new perspectives require the strengthening of positive connections among potential partners, disciplines and institutions. Challenges emerged in this special volume in regard to the necessity for value-added collaboration among different research groups (Giannetti et al., 2018), but progress in both theoretical and practical CP approaches seems very promising.

Fig. 1. Distribution of articles in this Special Issue according to the type of contribution (conceptual, conceptual and practical, practical) and the scale of coverage (global, regional, local).
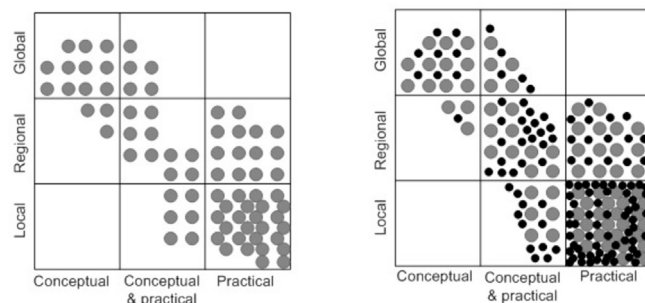
5. Concluding remarks

The articles published in this special volume make clear that the transition to a sustainable future is closely tied to some significant aspects: i. more efficient and responsive use of resources; ii. more efficient and responsive use of energy non-renewable and renewable sources with the development of energy (bio)technologies; iii. decreased emissions; and iv. increased application of closed-loop arrangements of materials, both in companies and supply chains.

The implementation of environmentally all-encompassing technical solutions based upon systematic studies and public examination is another relevant matter that should be addressed.

Auspiciously, the role of the social component is being progressively examined by many scientists through the development of socially responsible management programs, models and frameworks; potentiating the benefits of simultaneously achieve environmental, social and economic advance.

Cleaner Production changes as we do. After ten years, a slight but not imperceptible shift of interest on global and conceptual research could be noticed, although there is still hard work invested in local and practical solutions. Whatever the possibilities, it has become clear that the impetus towards the transition for sustainable development will be translated by a convergence of solutions integrated in closed loops with potential to reach regional or global issues. It is also clear that this shift is due to the perception that incremental change will not work in an economy that is resource-driven. Along these ten years, CP community has been carefully inserting pieces in a complex puzzle, but is reaching the point in which the puzzle must be seen and evaluated as a system.

Acknowledgments

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