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Cleaner Production towards a sustainable transition

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ABSTRACT

This special volume of the Journal of Cleaner Production was built principally upon articles submitted for the 5th International Workshop Advances in Cleaner Production held in São Paulo, Brazil, in 2015. The **43** articles emphasize the imperative need for shifting from unsustainable production and societal patterns to sustainable ones. They provide many new technological and/or management related approaches to help industries, governments, and society to speed up the transition to sustainable patterns. Efforts on defining and solving problems with the special accent upon a sustainable solution for the use of raw materials and energy, technological advances, product and policy changes are presented and deeply discussed. Improved corporate management for sustainable societal transitions is discussed, highlighting consumer empowerment in sponsoring implementation of innovative cleaner technologies within companies, industrial sectors, supply chains and countries. Multiple examples are provided relating the successful combination of cleaner production in policy structures, illustrating on how the focused work in production sectors is delivering multiplier benefits and creating conditions to facilitate a "leapfrogged" path toward SD.

1. Introduction

Since 2007, during the International Workshops on Advances in Cleaner Production, academics have studied, assessed and deliberated about production systems transformation—the circumstances that stimulate it, the connections and barriers that arise, the principles stated and suppressed, and the potential intended and unintended consequences. Two books (Giannetti et al., 2011, 2016) and four Special Volumes (SV) of Journal of Cleaner Production (Almeida et al., 2013, 2015; Bonilla et al., 2010, 2013) were published, and the Advances in Cleaner Production Network (ACPN, 2015) was founded in 2015 for the exchange of information to assist the desired transition to a sustainable society. Recognizing the complex multi-disciplinary array of human creativity, this 5th SV focuses on the prospect to expand our thinking about production systems transformations by incorporating new research and practice centered on the idea of transitions to sustainability.

The Latin root of the term transition, *transire*, means "to go across". Transitions are usually defined as a route from one form, state or place to another signaling orderliness movement that may be traceable, but not immediately noticeable. As a movement from one state to another, transitions apply to several the human and social sciences, and transversely these different fields, transitions point toward a slow, persistent shift from the present condition to something changed. The transition is not radical in its manifestation, though it may be revolutionary and undoubtedly consequential in its outcome.

The central purpose of this SV is to highlight the importance of the academic research in the transition to sustainability, especially by detailing how the combination of cleaner production (CP) initiatives with sustainable development (SD) concepts can assist to assess possible paths of action. A stimulating array of original research examples, most of them presented during the 5th International Workshop Advances in Cleaner Production held in São Paulo, Brazil, in 2015, aim to speed up the transition from the present unsustainable patterns and answering questions that include: When and why do producers develop and use more sustainable production practices? What explains the rising power of large greener supply chains? What draws some consumers to green products offerings, while others remain with the same purchasing habits? Do institutions and technologies encourage environmental improvement and economic fairness in production systems? Do other institutions and technologies menace these goals, and how do society respond?

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2. How accelerate transition to SD: ideas presented in this SV

Results of research are presented and ordered according to their main theme. Motivations and results may appear discrete, but a deep scrutiny through the articles shows that they are all linked through an unfolding process where researchers deal with multiple influences. Any expectations about the order, linearity, directionality or final solutions of transitions will be simplistic. Some articles propose actions with respect to the promotion of specific improvements within different individual companies and management practices systems (Fig. 1). Others propose multi actions and measurements to be applied to various specific systems, with consequences in larger systems. The inclusion of stakeholders and consumers is also taken into account and the several approaches are shown in this SV, that seem to be unrelated at a first sight, are interconnected and provide solutions at various levels and scales, thereby, contributing to achieving broader goals. The main focus seems to be how to accelerate the transition by changing the current production model, but it is clear that issues concerning energy and materials usage and societal and political posture and actions dispersed within and around the central concern. These elements are crucial for influencing, encouraging, strengthening and forcing the desired changes.

Production management and operation (Fig. 1) appear as a main concern not only in individual firms and organizations but also along the whole value chain that includes consumers and waste management. Research on different backgrounds worldwide provide context, counterpoint and sometimes the empirical subjects for a developing sustainability transitions research field.

2.1. Production operation and management

Evaluations to determine the best production model for a given product with the concern in the greenhouse/climate change gases emissions or the resources depletion inspire authors to apply assessment methods that can assist in public policy development and decision making within the production systems by providing information on the environmental cost of each decision.

With concern on the resource use of large scale industrial sectors, Almeida et al. (2016) evaluated the selection of the most feasible packaging options for the soft drink industry. Downscaling packaging waste was considered a key approach towards reducing resources depletion, and material selection was examined under all product life stages using the environmental accounting based on emergy. The results obtained for the Brazilian case make it possible to select the best option (refillable glass) according to the resources available in the country; establishing the best production model and determining when and if a recycling stage should be implemented. In an industrial sector of smaller scale, Lo Giudice et al. (2016) assessed the Sicilian traditional ceramics sector using and LCA that showed that the efforts for improving environmental performance should concentrate on reduction of energy consumption or on the use of renewable energy.

Figueiredo et al. (2016) assessed how integrated systems may be used as an efficient land-management strategy for restoring degraded areas. The greenhouse gas balance and the carbon footprint of the beef cattle fattening cycle were investigated in three contrasting systems: degraded pasture, managed pasture and integrated crop-livestock-forest. The results showed that the conversion of the degraded pasture to a well-managed pasture and the introduction of crop-livestock-forest integrated system can reduce greenhouse gases (GHG) emissions, increasing the production of meat, grains and timber. Also in the agricultural sector, Kamali et al. (2016) evaluated global warming, land occupation, primary energy use, profitability, and employment for two soybean farming systems. The conventional system, which produces genetically modified or non-genetically modified soybeans, and the organic system. Monte Carlo simulation was used to account for the variation in input parameters, and the results exposed that organic systems have a lower global warming potential, energy use, profitability, and employment, but higher land occupation than the conventional systems.

As characteristic of transitions, there is also a recent concern in combining technical assessments with the consumer perception and behavior. This tendency is reflected in the studies of Cabanillas (2016) that evaluated the producer's efforts to meet the demand for products more environmentally friendly; Hanssen (2016) that evaluates the impact of consumer choices on emissions and Lombardi et al. (2016) who seeks to understand how to communicate with consumers to encourage them to consume products

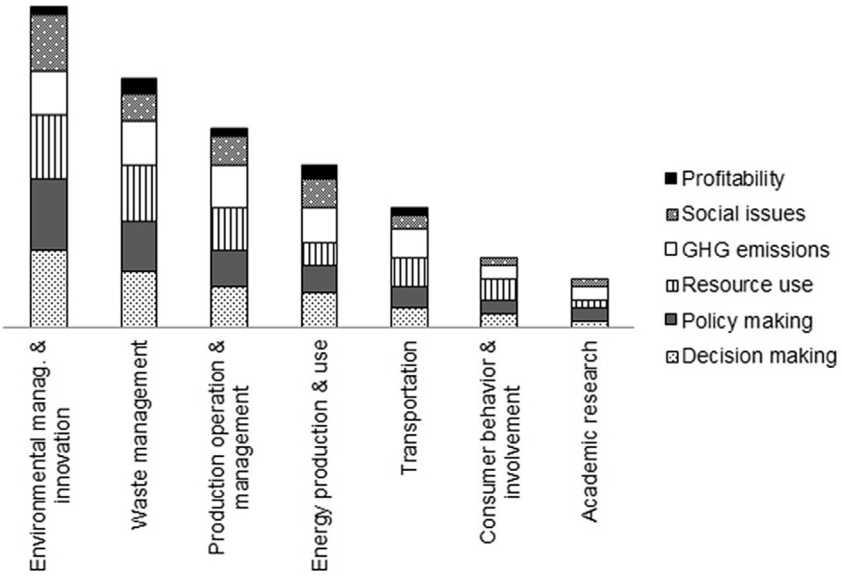

Fig. 1. Distribution of the sub-topics covered in each article of this SV. Each color is associated to one of the articles.

produced by climate neutral techniques. Cabanillas (2016) proposed and evaluated sustainable management strategies focused on native bio-inputs to crops producers that are currently in an agroecological transition process. The estimated environmental-economic output showed that native bio-inputs and ancestral culture can provide affordable and sustainable strategies for farmers in agroecological transition. A consumer study carried out as part of the packaging optimization program in Norway (Hanssen, 2016) evaluated the waste generation, energy use and GHG emissions from the product value chain of meals prepared from fresh ingredients at home, based on semi-prepared ingredients and ready to eat meals based on Life Cycle Assessment and Material Flow Analyses. The results showed that energy consumption and GHG emissions decrease from meals ready to eat, prepared from fresh ingredients and semi-prepared ingredients. Production of ingredients, especially meat, was the key element for all products, but preventing food waste from retail and use stages would contribute to 13% reduction in GHG emissions. Consumers regarded packaging solutions from ready to eat meals to be too big and with materials that are difficult to recycle.

2.2. Environmental management and innovation

The endurance of production systems involves the integration of environmental, economic and social aspects within private companies and supply chains, and CP practices may not result in a transformation in the short run without the integration of environmental, economic and social dimensions to innovations in the companies' managerial systems. In this context, Severo et al. (2016) examined the contribution of CP methods and environmental management practices to sustainable product innovation. A survey in 762 companies of different sizes of the metal-mechanic sector highlighted that both CP and environmental management influenced positively the achievement of product innovation, and the financial performance of the companies. Santos et al. (2016) identified hotel companies with a predisposition for environmental and external social responsibility and structured a holistic criterion, integrated into the internal/external hotel organizational background to enable this kind of organization to protect the environment considering sociocultural, political and economic aspects. A similar approach was used by Blass et al. (2016) in measuring the environmental performance of hospitals aiming to the reduction of their operations. A framework defining relevant and meaningful indicators for monitoring and assessing environmental healthcare systems was proposed on the basis of a literature review, current legislation and feedback from field research. Six case studies were conducted to exam the applicability of the approach and to contribute to a wider theoretical discussion on strategically focused public policy concerning the improvement of healthcare environmental performance. A similar approach was used to evaluate 14 wastewater treatment plants by considering their running as an industrial process (Henriques and Catarino, 2016). The results of energy audits showed that every wastewater treatment plant independently of its dimension presented opportunities for energy savings. Other improvement opportunities were detected in what concerns the inputs related to population training and information, namely those related to water savings, internal housing water reclamation and chemicals use. These authors propose the Sustainable Value performance indicator for wastewater treatment plants to follow up and monitor the evolution of energy efficiency in processes.

Improved sustainability performance in increasingly complex business environments is a challenging task for organizations operating in many different industries. Corporate sustainability, which has become essential to most companies in the last decades, stipulates that environmental requirements should be incorporated into diverse business processes. To effectively integrate environmental aspects into product innovation processes, companies might have to significantly change some of the practices and habits of all the stakeholders involved and of the organization. Exploring a case of a Brazilian family-owned company of rubber products, Machado et al. (2016) analyses the experience in adopting the strategic organizational sustainability using knowledge management and open innovation, and propose a simple model relating organizational sustainability, knowledge management, open innovation, and sustainable innovations through the lenses of absorptive capacity theory and eco-innovation.

The environmental impacts at the organizational level were examined by Neppach et al. (2016) using the Organizational Environmental Footprint Guide developed by the European Commission. Using a case study within a German organization, the feasibility of the application of the guide in construction companies was reviewed and possible adjustments were proposed. Using the Greenhouse Gas Protocol, decision supports were set to generate emissions data. The results were generalized to construction companies aiming to support such organizations to achieve a sustainable transition to a CP. A descriptive case study of the offshore oil and gas industry was presented by Silvestre et al. (2016) employing document analysis and an analysis of the Health, Safety and Environment Management System of Petrobras. The authors explored the design of regulatory frameworks in preventing the risk of major accidents. By employing multiple primary and secondary data collection strategies, including a number of formal expert interviews, Silvestre et al. (2016) mapped and compared major recommended practices and identified a series of gaps in policy and practice, offering a number of recommendations for practice, policy, and research.

Authors also discuss managerial, market and technical barriers, which may inhibit CP diffusion of CP technologies that are under within companies and organizations. Liboni et al. (2016) conducted a systematic literature review of the dynamic organizational capabilities for sustainability. Systematizing the available knowledge, a lack of research for integrating sustainability and organizational capabilities was identified. Providing recommendations to guide future research, the authors suggest that studies should consider mixed methodologies and comparative perspectives to discuss managerial innovations. In the same context, Oliveira Neto et al. (2016) proposed a framework to surpass obstacles to implementing CP by small and medium-sized companies. Multiple case studies enabled the development of a framework with four simple and friendly steps to be used by managers and employees. Considering that among the activities managed by an organization, the maintenance of the resources it uses considerably affects sustainable performance, Sénéchal (2016) proposed that maintenance processes should be on the core principles of decision systems. Brones et al. (2016) explored the use of a multiple step literature review associated with a longitudinal action research in a large cosmetics company concerning the product's ecodesign. As a result, an “ecodesign transition framework” was built, combining both top-down planning and bottom-up innovation with dynamic cycles of action and learning. The framework may help companies evolve toward a more effective sustainable product innovation process, through evolving business management practices that require progressive change and more human-based strategies.

Application of CP to the whole product chain was another important route explored by researchers, under the viewpoint that integrated supply chain management can help each chain member to reduce their individual wastage of materials and energy. Tramarico et al. (2016) carried out a multi-criteria training assessment through the four top-level processes of Supply Chain

Operations Reference Model (Plan, Source, Make and Deliver) in a chemical industry. The analysis revealed that training essentially resulted in organizational and individual benefits. A comprehensive review of the publications in the field of reverse logistics and closed-loop supply chain was undertaken aiming to categorize and to provide a systemic view of the past and an appropriate vision of the future (Hamed and Govindan, 2016). The results clarify the main trends in reverse logistics and closed-loop supply chain subjects and the evaluations reveals some suggested opportunities of research as new directions of research.

2.3. Energy production and use

Assessment to determine the critical parameters for CP application in regard to energy production and use can be useful for energy planners to select future green scenarios based upon increasing use of renewable energy. The Italian electricity market, strongly dependent on hydrocarbons, was evaluated through the Portfolio Theory aiming the selection of the right mix of renewable energy sources (Cucchiella et al., 2016). An economic analysis evaluated the profitability of investments in renewable technologies. Each renewable source presented its own profitability dependent on a number of factors and subject to market fluctuations, cost and frequent changes in the incentive policies. Applying Portfolio Theory made possible to select the right mix of renewable energy sources and simulate its evolution.

Mayer et al. (2016) investigated the possibilities to consider risks and uncertainties in early stage investment planning for emission abatement technologies in large combustion plants. Using as example the nitrogen oxide emission reduction, the application of a specifically developed risk portfolio to identify the most critical risks. Results may be applied not only by investors but also for policies, especially if data is scarce or uncertainties exist regarding specific plant parameters or cost and price components. Focusing on group meetings and stakeholder interactions, Narula and Bhattacharyya (2016) undertook a survey in a cluster of five remote off-grid villages in India to verify the requirements of electricity access in rural areas and potential for improvement in the value chain. The results showed that value-added services can be developed through an off-grid electrification intervention, supporting productive activities, thereby offering an opportunity for improved income generation and a better quality of life-based on cleaner energy sources. The article provides a value chain framework for linking off-grid projects with local livelihoods that may be replicable across multiple geographies. In Brazil, González et al. (2016) evaluated how the communities may be affected positively and/or negatively by wind farms projects and other energy renewable sources. A set of guidelines and best practices for public managers and wind farms owners was proposed and the results show the political dimension of sustainability as the primary cause of communities under-development.

The commitments to reduce energy use and GHG emissions inspired articles dealing with energy conservation and improvements in energy use efficiency. Analyzing the statement that district heating networks are environmentally friendly solutions for providing heating services for the built environment, Andric et al. (2016) examined the frequently overlooked impacts associated with both construction and operation phases of heating services to the urban environment. A sensibility study accounting for different district system configurations was conducted, and results showed how the network construction phase may become the dominant impact on the environmental performance of the system. The authors considered the use various renewable energy sources for heat production and technical limitations of each heat production source and fuel used and concluded that the district heating networks are the most suitable solution for providing sustainable urban environments with heating services. In this context, Coss et al. (2016) developed a method to optimizing energy services based on sustainable criteria. Their approach, merging carbon footprint and emergy analysis, includes both the requirements and effects of policy targets for defining systems configuration.

2.4. Transportation

The possible effects of transportation on CO_2 emission reduction and fuel use was investigated to gain an understanding and providing subsidies for decision making and policy design. The performance of urban passenger transport was assessed through a structured method that links eco-efficiency with sustainability (Guimarães and Leal Junior, 2016). The conclusions indicated that neither the most used transportation alternative nor the one with the highest capacity attained the best eco-efficient performance, being both highly dependent on the occupancy rates. The authors propose actions that can be implemented to improve urban passenger transport. Li et al. (2016) studied the effectiveness of a personal gasoline permit trading scheme to limit the total gasoline consumption. A general utility optimization model was used to analyze the response of permit demand to price changes with the Slutsky decomposition of price effects. The results, defined in economic terms, indicate that the permit demand of consumers in higher and medium income groups are negatively related to permitting price.

In the search for an efficient mean to mitigate carbon dioxide emissions in the transport sector, Ensslen et al. (2016) measured electricity consumption of electric vehicles during driving and charging in a French-German customer scenario. The electric vehicles electricity consumption was matched to disaggregated electricity generation data with national electricity generation matrixes and carbon dioxide emissions. The findings of this study underline the postulation that hypothetical energy consumptions of the standardized driving cycles should be validated by long-term real-world consumption analysis. Romejko and Nakano (2016) investigated the increasing interest in alternative fuel vehicles (electric vehicles, fuel cell vehicles and compressed natural gas vehicles) as a promising option for mitigating global warming and reducing energy consumption. Their research included energy security aspects and scenario analysis to predict an optimal alternative to sustain energy security under gas and petroleum restrictions until 2030. Both Ensslen et al. (2016) and Romejko and Nakano (2016) offer recommendations to help automakers and policymakers to improve services provision and recognize investment possibilities.

2.5. Consumer behavior and involvement

Assuming that an information transition gap still exists between cleaner production and sustainable consumption, authors call the Governments and organizations to take responsibility for making adequate product-level sustainability information available for consumers. Shao et al. (2016) proposed a set of product-level sustainability attributes that captures influencing factors to facilitate sustainable consumption behavior. Their results indicated that consumers are increasingly concerned about the social impact of a product in its production phase and require more related information. They proposed that similar studies would serve for developing related public or industrial policies providing information for a transition to sustainable consumption.

Consumers decision process regarding environmentally sustainable products was investigated by Medeiros and Ribeiro (2016) to identify the green expected attributes for product and process in

automobile and furniture purchases. The results indicated as important green attributes for automobiles items such as “economy”, “engine” and “new technologies”. Regarding furniture, green attributes were “design”, “origin label” and “origin of the raw material”. The study allowed improving the theoretical comprehension regarding green products and decision-making. Lombardi et al. (2016) analyzed how information and communications could impact or affect the consumer's attitude toward climate neutral fresh milk. The research focused on a sample of supermarket customers, showed that communication could play a role in changing consumer attitude toward carbon-free products. The determinants of consumer intentions and behavior towards e-waste recycling were discussed by Echegaray and Hansstein (2016). Modeling measures obtained from a general population survey sample after the Theory of Planned Behavior, the authors found that the majority of respondents hold a positive intention towards recycling electronic appliances. In contrast, only a minority of respondents actually adopts adequate recycling practices connected to e-waste.

2.6. Academic research supporting CP activities

Universities are key stakeholders in teaching, researching and supporting the implementation of CP activities. Hens et al. (2016) discussed the experience of establishing and operating a CP Center at the University of Cienfuegos, in Cuba. The authors describe a Cuban-Belgian inter-university collaboration that allowed to establish a master program on CP, which acts as a bridge between the university and the industrial and service sectors. Research aiming to improve the environmental performance of the companies and organizations resulted in a measurable improvement of the air and surface water quality in Cienfuegos city. Authors provide information about the strengths and the weaknesses of this type interuniversity collaboration and offer framework data on increasing the effectivity of cooperation projects on CP. Ashton et al. (2016) introduce the “Pathways to CP in the Americas”, a multinational effort aimed at facilitating the transition to sustainability in the America Latina and Caribe. The project incorporates multidisciplinary education in business, engineering, and the environment enhancing sustainability awareness, technical competence, and innovative skills of industry professionals from micro, small and medium enterprises. In this article, the authors share the most valuable lessons from this project, which can be more widely adopted to facilitate industry-academic engagement in the transition to sustainability.

2.7. Waste management

The concern with different waste disposal methods and different types of wastes are evidenced by the number of articles submitted to this SV. The articles aim to support the appropriate decision, improve legislative requirements, and prevent conflicts at the local level. Technical feasibility, socio-economic benefits, and environmental impacts are addressed to provide decisions that may lead to the appropriate waste management process. Moreover, assessment tools are evaluated and applied in order to really solve the problem of meeting law requirements and the acceptance of the stakeholders.

The outcomes of using the Clean Development Mechanism (CDM) in landfills were verified by Cruz et al. (2016) using indicators organized into social and environmental dimensions, and subdivided into five themes: participation of associations and cooperatives surrounding landfills; the interface between agents involved; benefits to waste pickers' cooperatives and technology transfer; environmental quality monitoring; and efficiency of the biogas capture system. The results highlighted the importance of using indicators developed based on interdisciplinary and multiagent approaches. Marchi et al. (2016) presented the GHG inventory of an integrated waste management system aiming to orient emission reduction strategies and decrease the environmental impact of the waste sector. The authors recommend that calibration of the waste management system may be done according to the results obtained by GHG inventories, which can be verified and validated according to international standards and systematically facilitate the link between GHG computation and political action. Another example of solid waste management used to test and validate a broader strategy, including the need for appropriate participatory and scientifically decision-making processes is presented as a Roadmap by Hornsby et al. (2016). An innovative waste management technology and the decision-making roadmap were applied to the city of Naples, characterized by conflicts around waste management policies. Authors claim that although the focus on technical aspects is useful it can never be used as a stand-alone criterion for decision making, and cannot guarantee lasting success whether measured along with a good participatory consultation of all stakeholders. For the same city, Ripa et al. (2016) used site-specific data to compare different waste management routes. An extensive collection of primary data is carried out to describe the main input/output flows associated with the treatment and recovery of each single waste fraction. LCA results allowed the identification of the weak points along the waste management chain and the assessment of potential improvements by means of a scenario analysis. The use of site-specific data of full-scale waste treatment facilities and the definition of alternative waste management hierarchies may help decision-making by local public administrators and stakeholders, providing a transparent picture and deep understanding of costs and benefits for waste

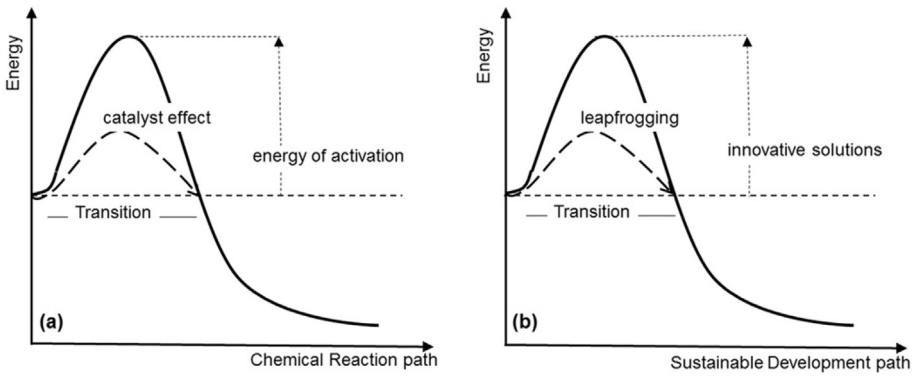

Fig. 2. Illustration of (a) energy activated chemical reaction and (b) the transition to SD activated by innovative solutions and research.

management at local scale. Arıkan et al. (2016) evaluated 10 disposal alternatives of solid waste using 18 criteria determined by Istanbul Environmental Management Industry and experts to select the best disposal technology. Using three different multi-criteria decision-making methods, authors recommended ordered storing and burning systems for the Istanbul case.

Still dealing with waste management, but from another perspective, some authors seek ways to use waste, whether those already disposed of in landfills, such as those that can be used before the final disposal, avoiding forwarding it to the landfill. Rong et al. (2016) assessed the recycling potential of municipal solid waste from a closed irregular landfill in Beijing. The assessment comprised an analysis protocol, including waste composition, chemical characteristics, and environmental bioassays. These authors concluded that, in view of the experimental activities conducted, recycling waste soil is potentially safe and suitable for remediation activities.

By focusing their efforts on closing materials cycles and on valorization or elimination of waste flows, the use of industrial wastes as raw materials was also explored. Wiemes et al. (2016) examined alternatives for bricks manufacturing using different types of waste as raw material. Automotive industry waste sludge, glass waste from a galvanic plant, and wood ash from ceramic burning furnace were mixed with clay in an attempt to establish cycles of material exchange among different production systems. Chrispim and Nolasco (2016) evaluated the greywater collection and treatment system for the non-potable reuse. A pilot system using a moving bed biofilm reactor implemented at the University of Sao Paulo allowed evaluating the greywater production and treatment as satisfactory according to Brazilian standard. The treatment was considered stable and reliable ensuring the potential for a safe reuse.

3. Concluding remarks

The transition to SD clearly passes through a disorderly fashion that involves changes in the current production models, with and without the help of academic research; improvements in the efficiency of energy use, transportation, and waste management; coupled with a gradual change in consumer behavior and involvement. The next steps in this transition also include an increase in the use of renewable energies to replace ultimately the use of fossil fuels which are the main source of present environmental problems.

The authors in this SV focused on the role that new ideas could play in promoting SD. All these ideas may help raise support for “leapfrogging” to improve the production systems’ conditions in more environmentally sound ways. The “leapfrog strategy” (Goldemberg and Lucon, 2007) establishes that a developing country can incorporate the available most efficient and modern technologies, but also introduce innovative ones, leapfrogging over some of the historic steps toward industrialization. As shown in Fig. 2, as human activities come to a point where they can be changed, the current way of thinking must be twisted or bent in an unstable state called transition state. The transition state is a high energy state, and a certain amount of energy – analogous to the thermodynamic energy of activation (Fig. 2a) - must be added to achieve a transformation. As the transition state is unstable, the current state is not there for long but quickly advances to the next stage. The transition to the next stage may be accelerated by a catalyzer.

Clearly, this transition to SD is already taking place and the potential for leapfrogging (with a similar effect to a catalyst) is inherent in all human activities, since synergy among two or more ideas may occur and facilitate a “leapfrogged” path toward SD (Fig. 2b). The idea of leapfrogging finds a new application in sustainability challenges, and the research covering innovative solutions for the human activities in a variety of fields may lead a smooth and fast transition.

This SV presents contributions that advance knowledge on shifting society-production-environment interactions to a world in which human beings and other life flourish in diverse social and environmental contexts. Transitions to sustainability entail change in people's activities at local to global scales. In spite of the apparent insufficient knowledge of changes that can effectively promote sustainability transitions, and of the causal mechanisms involved, contributions that develop innovative approaches to concepts, theory, methods or analysis have, or will have in a near future, a deep and broad implication to accelerate transitions to sustainability. Making use of all these innovative contributions, we just need to think and get involved during this transition.

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