Green Chemistry, Circular Economy and Sustainable Development: An Operational Perspective to Scale Research Results in SMEs Practices

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Abstract. Green Chemistry, Circular Economy and Sustainability are issues at the center of the modern scientific debate and three major trends in the global market. These three subjects are interconnected and interdependent and represent an affordable set of principles bringing innovations in the management of complex processes connected with anthropic use of resources.

Today's world population requires more natural resources be consumed than in previous decades, thus contributing to making primary resources increasingly scarce and with limited access.

Furthermore, an issue that persisted over time to become unsustainable is the waste emergency. It is also linked to the low capacity of operators to recover and re-use scraps of the production processes losing production values and generating environmental pressure.

Companies, whose growth is crucial for the economic system, generate waste in all stages of the production processes; although there is an increasing attention and awareness on the issue of waste, we are still in the early stages of the process that will lead SMEs to zero waste production. If we recognize such attribute as a competitive factor, we can identify in advance a critical innovation demand generated by SMEs operating in low competitive areas which has to be supported with technological transfer inn order to result "green" and effective in the short/medium term.

This paper presents data and defines there critical innovations domain in order to deliver an effective and scalable innovation transfer concerning circular economy thorough the application of green chemistry principles exploiting territorial factors in order to deliver sustainable local production chains.

Keywords: Green chemistry · Circular economy · Sustainable development

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1 Introduction and Research Position

Green Chemistry, Circular Economy and Sustainability are issues at the center of the modern scientific debate and three major trends in the global market. These three subjects are interconnected and interdependent and represent an affordable set of principles bringing innovations in the management of complex processes connected with anthropic use of resources. The Green Economy discourses is representative of the effort in applying Green Chemistry, Circular Economy and Sustainability thinking on systems innovations defining an attractive framework to deliver more resource efficient, lower carbon, less environmentally damaging, more socially inclusive societies [1].

Global sustainability challenges are closely interconnected yet often separately studied and managed. Systems integration-holistic approaches to integrating various components of coupled human and natural systems is critical to understand socioeconomic and environmental interconnections and to create sustainability solutions [2].



Fig. 1. Sustainability triangle

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Companies, whose growth is crucial for the economic system, generate waste in all stages of the production processes; although there is an increasing attention and awareness on the issue of waste, we are still in the early stages of the process that will lead SMEs to zero waste production. If we recognize such attribute as a competitive factor, we can identify in advance a critical innovation demand generated by SMEs operating in low competitive areas which has to be supported with technological transfer inn order to result "green" and effective in the short/medium term.

This paper presents a critical proposal oriented to defines three innovations domain in order to deliver an effective and scalable innovation transfer concerning circular economy in peripheral production and manufacturing systems thorough the application of green chemistry principles, exploiting territorial factors in order to deliver sustainable local production chains.

2 "Green" and "Circular": For a Systemic Integration

Green Chemistry (or sustainable chemistry) is a concept orienting the approach of the research and the chemical industry on paths of sustainability. Sustainable development today asks the chemical sciences to play a primary role in the conversion of old technologies into new clean processes and in the design of new products and new eco-compatible processes. Green Chemistry is therefore an area of chemistry and chemical engineering focused on the design of products and processes that minimize the use and generation of dangerous substances and the consequent environmental impact.

"Green chemical" was coined in 1991 by Paul Anastas and refers to a new order of priority in scientific and technological innovation based on general principles aimed at eliminating the use of procedures and substances dangerous [3, 4]. Paul Anastas and John C. Warner published a set of principles to guide the practice of green chemistry [5]. The principles concern these concepts:

- the design of processes to maximize the quantity of matter converted into product and therefore the optimization of the global mass balance so as to minimize waste;
- the use of raw materials and renewable energy sources and therefore the minimization of energy costs, for example by designing processes at room temperature and pressure;
- the use of harmless and safe substances for humans and the environment, therefore the replacement of obsolete compounds with others that maintain their functional efficacy while reducing toxicity towards man and the environment.
- the design of energy efficient processes through, for example, the use, at industrial level, of micro-organisms in enzymatic reactions at ambient temperature and pressure.
- the reduction, through the use of biomimetic processes, of the reaction by-products, present (in different percentages) in all reactions of traditional organic chemistry.

Such principles are scalable and realize a driving framework in order to deliver innovative production approach based on innovation transfer from research to industry. This is the core issue in order to achieve sustainability horizontal principles globally.

It is possible to identify large development share of the green innovation with consequent positive effects in all sectors of primary production and manufacturing, in particular in terms of product technological innovation and eco-innovation processes. Especially if we focus on the contribution of green chemistry as a fundamental link between circular economy and sustainability to guide scientific research and industrial production towards achievable change for a sustainable world.

A transversal market that looks to the development of more sustainable processes/products, from both an environmental and economic point of view, is the goal proposed as a long-term goal by the Green Economy. The growing attention towards sustainable production is also strengthened by legislation, according to what emerged from the latest European measures, increasingly stringent towards criteria of major sustainability [6]. The concept of a green economy has become the new buzz word in sustainability debate translating the effort of decision makers to set their hopes on greening the economy. Particularly after the United Nations Conference on Sustainable Development (or Rio + 20) the "greening" effort applied at political, economical, industrial and cultural domains represents a part of the solutions the last economic crisis [7]. Furthermore, three key issues are highlighted in the global (/local) process of innovation toward sustainability [8]: i) the direction in which innovation and development proceed; ii) the distribution of the costs, benefits, and risks associated with such changes; iii) the diversity of approaches and forms of innovation that contribute to global transitions to sustainability. All this aspects are coupled with the critical issues related to waste management and disposal: hence the great interest in the enhancement of processing by-products.

Especially for those economic systems characterized by a structural peripheric degree, it is difficult to implement effective processes to apply such sustainable production innovations in local SMEs. We directly consider the situation of Basilicata Region (Italy) characterized by a scattered productions in primary sector, weak economic structures, scarce attitude in cooperation among SMEs, low competitivity of local production and a delay in green innovation and sustainable development [9–11].

3 Main Domains for Knowledge and Innovation Transfer

The link between the research activities and small scale production represents the main barrier in order to promote green an circular innovation in practice. It depends on the starting threshold that enterprises perceive in the dialogue with research academics. The threshold could be measured in terms of mutual competences and its integration potential and the need of funds in order to start collaboration and knowledge transfer. Such aspects, combined with small companies structural weaknesses in strategic innovation thinking shape a non-collaboration area between SMEs (the huge microcosmos of productions units) and research and innovations centers.

If we consider the assumption that such barriers doesn't exists a number of applications domain for green chemistry application and sustainable development immediately open: agro-food sector, nutraceutical, primary productions etc.

In all those domains, basic and effective green-chemistry innovations may bring a significant product' and process' improvements with consequent enhancement of competitivity for operators.

Three main innovation demand areas could be identified in order to deliver a systemic green and circular approach for SMEs operating in remote areas:

1. Green Chemistry & Circular Economy
2. Product-territory and local supply chains.
3. Scientific dissemination and training

The first area directly refers to the Green Chemistry & Circular Economy and is based on the provisioning of innovative consulting and experimental research services for qualified companies interested in expanding their market through eco-efficient solutions and products. Using a "green-chemistry" approach, also based on the rediscovery and updating of traditional methods, it implements the recovery of waste products and by-products useful for the production of: bio-materials (textile fibers, insulators and materials for bio-building, bio-plastics), dyes, essences and natural extracts, products for bio-cosmetics.

The second area is oriented to design sustainable and circular "local supply chains" based on "synergies" between companies that, in a specific territory/place, share production processes in terms of raw and second materials supply, waste management, reuse of by-products also for energy purposes. Such agglomeration may offer the opportunity to local operators to raise the required stock in order to access effective technologies and economies reinforcing competitivity.

The third area represents the efforts to be done in the field of scientific dissemination and training. The users/consumers awareness concerning green and circular economy is an huge challenge in order to achieve a shared background knowledge orienting individual and collective behaviors.

4 Final Considerations

According to MIT report [12], companies that engage in a green-innovation process identify the following advantages of choosing the green economy and the principles of sustainability:

1. improvement of the image on the market
2. competitive advantage
3. openings to new markets
4. higher market shares and higher profits
5. reduction of energy costs
6. innovation of the business model and production processes
7. innovation of the products and services offered
8. reduction of costs for raw materials and waste
9. increase in labor productivity
10. less risk

Such benefits are at the basis of the SMEs competitivity and covers structural gaps of organizations operating in peripheral economic system like Basilicata Region one.

Therefore the envisaged schema of innovation transfer connecting research centers and SMEs ecosystem becomes a strategic vision for sustainable development in lagging regions.

The contribution of applied green chemistry is based on the transfer of basic improvement from main stream researches [12–31] to production processes in primary sector.

The analysis proposed by MCKINSEY [32] in the report "Towards the circular economy" is based on the identification of three drivers/factors fundamental for the transition to a circular economy: "Many factors are leading to a change in the consumer and producer habits, making the circular economy increasingly attractive. The growing scarcity of resources together with technological advancement and the development of cities generate a growing awareness that the time is ripe for change:

- scarcity of resources with stringent environmental standards
- advanced technologies generate new opportunities for the transition to a circular model
- growing urbanization is leading to the centralization of flows of consumer goods.

These conditions are also found in peripheral contexts such as that of Basilicata where the growth model of the industry connected with the circular economy exceeds 2% - per year as evidenced by the "Priority Sector Report: Circular Economy, European Commission" (2017).

Most European countries appear to be uniformly growing (e.g. France, United Kingdom, Sweden), falling uniformly (Spain, Portugal, Western Balkan states), or steady (Germany, Poland). Only Belgium, Italy, the Netherlands, Norway and Switzerland show varying situations within the country. In Italy Basilicata has a singular behavior which expresses a favorable tendency for the application of innovation transfer efforts according to the proposed intervention areas. Further researches are needed in order to asses specific case study concerning production sectors and/or selected operators in order to assess to efficiency of applied circular approach in small medium case company located in peripheral areas. Such evaluation could provide reference inn order to assess the propensity for the transition to a circular model by the production system in lagging territories.

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