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## Emerging digital technologies to support circular manufacturing systems implementation: a literature review

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### 1 Introduction

Faced with the repeated warnings issued by the IPCC (Intergovernmental Panel on Climate Change) about the emergency of the climate situation, Circular Economy is one of the solutions enlightened by diverse economic, political, and academic actors. In opposition to the linear economy (take-make-use-dispose), Circular Economy could be defined as “an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes.” [1].

To initiate the implementation of these circular economy strategies, it is necessary for new production systems to take place to allow the return of products, their disassembly, refurbishment or improvement. Numerous scholars predict that emerging technologies will be a key element to unlock the potential of a circular economy [2]–[6]. Through the study of the case of SMEs, Prieto Sandoval [7] particularly indicates that the modernization of manufacturing systems is one of the major levers to achieving circularity in this type of company.

Considering the three pillars of sustainable development (economic, social and environmental), emerging technologies have important potential positive effects, but many risks must be anticipated from the adoption of these technologies to ensure social and environmental sustainability in particular [13]. The impacts of these technologies, when not implemented with a systemic and sustainable vision, could have important negative effects on several pillars. The consequences in terms of sustainability of Industry 4.0 also should not be taken for granted because it depends on the environment and conditions in which firms operate [14].

Nevertheless, the majority of works on the connection between CE and Industry 4.0 have primarily been conceptual or exploratory [8], and only few studies provide technical demonstrations of the observed contributions of these emerging technologies in the context of circularity [9]. Indeed, the main published studies are surveys on the feelings of industrialists about the expected or obtained benefits of these future technologies [10], [11]. Kirchherr and van Santen [12] particularly emphasize the need for industrialists to benefit from concrete, large-scale work to support the transition to these circular production systems.

## **2 Objectives of the communication**

In this context, the cross-disciplinary CIRCULAR project aims to support the transition of industrial systems towards more circularity, through the transformation of end-of-life objects into high-value-added products. Bringing together 12 research teams and 3 technological platforms in Grenoble, this project aims to participate in the deployment of methods of the industry of the future and emerging technologies to support companies in their transition to the production of objects that meet the needs of consumers, while reducing the use of resources necessary for their production.

This communication will present the results of a literature review whose objective is to determine whether the technologies of the industry of the future will be adequate resources for the conduct of workshops in the context of circular economy, by adopting a multidisciplinary approach mixing engineering and human sciences. In this paper, we will present an analysis of circular economy practices, levers and barriers in the first part, before making a similar study on emerging technologies (notably with a focus on Industry 4.0 and related concepts). We will briefly point out the negative effects that could occur if the focus of a project is not based on a systemic and sustainable vision. Then, our objective will be to show the synergies and divergences between the two studied concepts, by comparing them with the one already highlighted in the literature. In particular, we will criticize the research methods adopted for the combination of circularity and emerging technologies, and show the obvious lack of empirical evidence on this topic. We will conclude by proposing a roadmap of topics to be studied around digital industrialization in the context of the circular economy.

This literature review is part of a larger study, which aims to explore the concrete contributions of some of these emerging technologies (connected objects, autonomous logistics vehicles, information and communication technologies, collaborative robots, ...) through technical or experimental evidence to facilitate the implementation of the circular economy of the industry. In other words, we will aim to determine a methodology to study several technologies to draw up their benefits and potential risks associated in the context of their implementation of the circular economy, within a systemic analysis. Consideration of different perspectives including notably ethical and sustainable aspects will also be part of the study [11], [15].

### 3 Conclusion and perspectives

In a particularly difficult environmental and geopolitical context, the circular economy is perceived as a solution by many actors. To remove the many obstacles linked to circularity in a manufacturing context, the adoption of new technologies is seen as a real lever in this transition by academics.

This communication will present a preliminary literature review with a multidisciplinary perspective, which will carefully focus on the environmental, social and economic pillars of sustainability, as well as on ethics. This exploratory research has raised a number of issues that require more study. Following objectives of this research project will be to promulgate empirical evidence, both technical and experimental, to determine the impact of emerging technologies in circular production systems.

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