

# Towards Sustainability: A Quintuple Helix Approach in the Circular Economy Framework

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**Abstract.** The combination of innovative technological solutions with the natural ecological frameworks of our planet offers a crucial path towards sustainable development goals (SDGs) delineated in The 2030 Agenda for Sustainable Development, as well as the transition to a circular economy (CE) with the adoption of the principle of circularity and natural-based business models. As we navigate the challenges of sustainable advancement, it must be pointed out that innovation's crucial role in accomplishing the SDGs. The Quintuple Helix Model and the SMART Quintuple Helix System offer an innovative framework for encouraging innovation that need to be closely interwoven with sustainable development activities. These models underscore the necessity of a collaborative approach involving academia, industry, government, civil society, and environmental considerations to address the complex challenges of today necessary transition to the CE.

**Keywords.** Quintuple Helix Innovation Model, SMART Quintuple Helix Innovation System, Sustainable Development Goals, circular economy *1 Introduction*

## 1 Introduction

Earth is the only planet we know that can sustain life, thanks to its unique combination of natural conditions that support a diverse range of life. The intricate balance between the atmospheric, geophysical, and hydrological systems, which together produce a favorable habitat for a variety of living forms, gives the planet its unique characteristics. Fundamental to Earth's ability to sustain life is the dynamic interaction between these systems, which operate within an intricate net of interdependencies.

Acknowledging the importance of sustainable development (SD), it becomes even more important to put in place a strategy that carefully balances human ambitions with the planet's intricate natural processes. To effectively address the issues raised by the SDGs, human civilization's further development needs to reflect a thorough understanding of these thin interdependent connections with the aim of safeguarding Earth's unique ability to nurture life for future generations through the application of scientific knowledge and responsible sustainable practices. The overwhelming scientific consensus underscores the urgent need to confront sustainability challenges, lending significant weight to our collective pursuit of innovative and collaborative solutions.

The CE as a model is on the way to meeting the environmental protection, sustainability practices, and SDGs, having in mind that “the application and transition to a CE reduces the depletion of natural resources, reduces the amount of waste generated, reduces the amount of waste in landfills and thus the consequent pollution of water, air, and land, global warming, land destruction, as well as improved energy efficiency and raise of use of renewable energy sources” (Petrović et al., 2023, p. 6). In this approach, CE as well as the sharing economy (SE) maintain natural resources for the benefit of people and the Earth, rather than substituting resources with human capital (Henry et al., 2021).

The assumption of the European Commission and numerous national administrations that innovations among current businesses and entrepreneurs are an important driver in switching from a linear economy to a CE (Hofmann, 2019), is putting in line with CE the concepts of the Quintuple Helix Innovation Model,

and Smart Quintuple Helix Innovation System. They represent an advanced frameworks for fostering innovation (Carayannis & Campbell, 2018) that is deeply integrated with SD, especially in the context of achieving SDGs (König et al., 2021).

In the paper, the authors conducted a review of existing literature with the aim of highlighting the importance of the Quintuple Helix Approach in the context of CE, with the necessary connection to the achievement of SDGs, but also to indicate future development of models and systems in this area.

## 2 A Quintuple Helix Approach, Sustainability and CE

Sustainability has been operationalized through the United Nations' (UN) 17 Sustainable Development Goals (George et al., 2016). At a historic UN summit held on September 25, 2015, 193 UN member countries adopted a set of 17 goals as part of the new Sustainable Development Agenda (Transforming our world: the 2030 Agenda for Sustainable Development). These goals, along with their 169 specific targets, are set to be achieved by the year 2030, and all in pursuit of establishing a just and sustainable society that benefits all individuals. It must be noted that “the transformation into a sustainable society requires new challenge-driven innovations and new collaborations between more actors than earlier from different spheres in society with a variety of knowledge and practices, including civil society” (Grundel & Dahlström, 2016).

According to König and others (2020), the Helix Models of Innovation are pivotal for understanding the integration of SDGs within the framework of industry, innovation, and infrastructure. This understanding is built upon foundational work by Leydesdorff and Etzkowitz (1996), Carayannis and Campbell (2009, 2010), and Carayannis et al. (2012), who explored the dynamics of knowledge production and innovation ecosystems. König et al. (2016) reference initiatives by UNESCO/IFAP & UNU-EGOV that underscore the importance of socio-environmental transitions for SD within these models.

Furthermore, in the academic and professional realms, the term “SMART” is commonly adopted as an acronym to delineate the attributes of effectively structured objectives. As outlined by the authors Carayannis and others (2022) in their discussion on *Smart Environments and Techno-centric and Human-Centric Innovations*, the acronym stands for goals that are: *Specific* (focused on a particular area for enhancement), *Measurable* (providing a way to gauge progress, whether through quantifiable metrics or indicative markers), *Achievable* (realistic in terms of what outcomes can be attained), *Relevant* (aligned with overarching strategies and goals), and *Time-bound* (clearly defining a timeline for achieving the results).

This framework, rooted in earlier analyses by Frey and Osterloh (2002) and Dezi et al. (2018), emphasizes the importance of precise, assessable, feasible, pertinent, and timely objectives in driving meaningful advancements within Industry and Society 5.0, underpinning the move “towards smart, sustainable, and inclusive solutions” (Mabrouki, 2023). This model builds upon the Quintuple Helix innovation model by incorporating “smart” technologies and practices, emphasizing a systemic approach to innovation that involves “collaboration among five key stakeholders: academia, industry, government, civil society, and the environment” (Carayannis & Campbell, 2018).

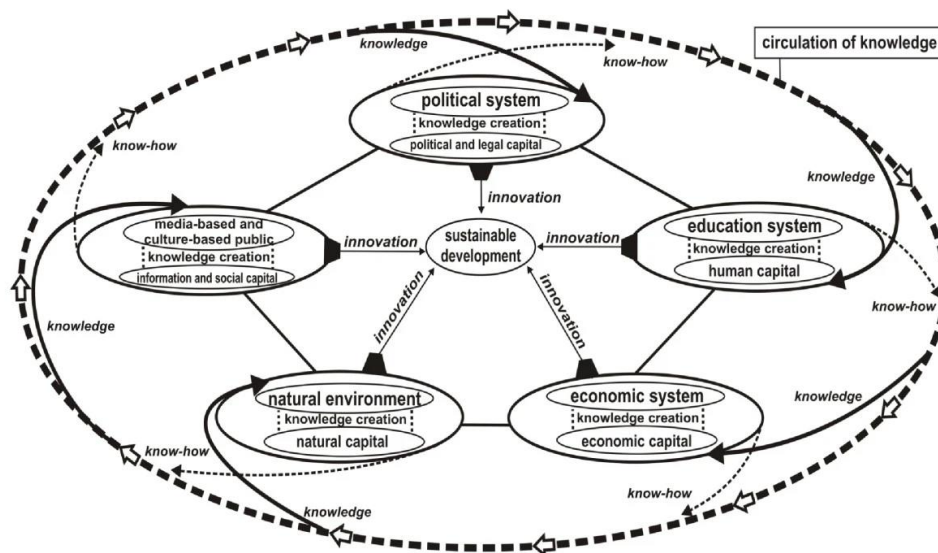
Based on the research of the authors Barcellos-Paula et al. (2021), Table 1 shows the evolution of the theoretical Quintuple Helix Innovation Model and the Smart Quintuple Helix Innovation System.

**Table 1.** Evolution of the theoretical Quintuple Helix Innovation Model and the Smart Quintuple Helix Innovation System (Source: Barcellos-Paula et al., 2021)

Typologies	First Definition	Scope and Approaches of the Proposals
Quintuple Helix Innovation Model	In addition to describing five knowledge subsystems (helices), this model places significant emphasis on the environment as a determinant in the decision-making process. Knowledge is of utmost importance in	The objective of this model is to encourage innovation endeavors that aim to create socio-ecological interactions through the dissemination of knowledge from the subsystems (helices). The core principle of this model

	<p>this model as it facilitates the generation and modification of innovations that stimulate the exchange of information between subsystems.</p>	<p>centers on the ecological consequences and aims to foster consciousness regarding the accountability of societies with respect to this matter.</p>
<p>Smart Quintuple Helix Innovation System</p>	<p>Innovation and the interactions of five subsystems that exchange knowledge to generate and promote SD form the foundation of this theoretical model. Political capital, educational capital, economic capital, environmental capital, and social capital comprise the subsystems.</p>	<p>This conceptual framework represents an extension of the triple helix, wherein pertinent actors are represented as knowledge subsystems. It commences with the formulation of innovative initiatives and proceeds with the ideation of a quest for developing countries. Every capital has a distinct function for which the surrounding environment is vital. Similarly, media channels, social capital, and social networks all play crucial roles in the formation of opinion matrices through which society can “audit” the decisions of other actors.</p>

The authors Carayannis et al. (2012), as well as Barcellos-Paula et al. (2021), proposed that SD must be in the center of the of the Quintuple Helix Innovation Model (Figure 1).



**Figure 1.** The Quintuple Helix Innovation Model (Source: Barcellos-Paula et al., 2021; Carayannis et al., 2012)

The problem-oriented quintuple helix innovation system seeks to serve as a means of achieving socioecological transformation, or the conversion of society to a bioeconomy or a CE and hence towards sustainability (Carayannis et al., 2012). When it comes to CE, the authors Durán-Romero et al. (2020) proposed that CE and eco innovations must be in the middle of the Quintuple Helix Innovation Model (Figure 2) because they claimed that “CE arises in the middle of the innovation system and plays a key role in achieving decarbonization objectives” (Durán-Romero et al., 2020).

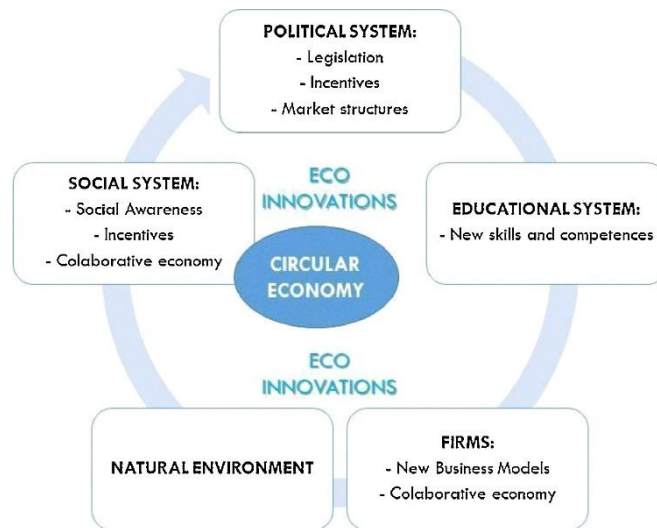


Figure 2. Relating the Quintuple Helix Innovation Model with the CE and eco-innovations (Source: Durán-Romero et al., 2020)

## 4 Discussion and Conclusion

Although many studies have indicated that helix models provide substantial advantages, particularly in the realms of entrepreneurship, innovation, and connections with nature – many research gaps still remain: (Malik et al., 2021):

“There is no clear understanding of how helices interact with each other.

There is little evidence of how a temporal interaction between these helices influence the dynamics of innovation at a firm level.”

The solution and path for future study may lie inside the Smart Quintuple Helix Innovation System, which plays a crucial role in facilitating transparent, sustainable, and circular progress, because when it comes to “smart” technologies, such as IoT (Internet of Things) devices, AI (Artificial Intelligence), and blockchain, it must be noted that they can optimize resource use and minimize waste, and enable smarter energy management systems that mimic the natural balance of ecosystems. These technologies facilitate real-time data collection and analysis, informing policy and business practices to align with SDGs and goals and principles of CE. It must be noted that “digital SE platforms relate to CE” (Henry et al., 2021). “Smart” practices involve collaborative efforts across all helices, fostering a culture of co-creation and shared responsibility that reflects the mutual dependencies found in nature (Abiri et al., 2023; Bibri et al., 2024; Chen et al., 2023; Dhanaraju et al., 2022).

This comprehensive approach not only mirrors Earth's complex ecological systems but also serves as a foundational blueprint for navigating the multifaceted challenges posed by the SDGs, illustrating a systemic approach where innovation and environmental stewardship converge to secure a sustainable future for all.

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