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Sustainablility Impulses from Wuppertal

The Circular Economy Information Ecosystem: Key Success Factor and Innovation Driver for a Digital Circular Economy

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Summary

Transitioning to a sustainable circular economy is one of the major social and political challenges of our time. Only by conserving natural resources can we achieve global climate protection goals and reduce environmental damage. In light of growing geopolitical tensions and conflicts, the circular economy makes a significant contribution to risk management and the resilience of an economy interconnected through global supply chains. Leveraging the digital transformation is a prerequisite for success in this regard. The foundation for this is being laid by the Circular Economy Information Ecosystem (CEIS).

The CEIS describes the interplay of all digital technologies, infrastructures, processes, institutions and individual stakeholders to enable a data-driven digital circular economy – including the necessary standards, rules and coordination mechanisms. It thus creates the conditions for linking physical material and product flows with the associated data flows, thereby supporting the implementation, expansion and regulation of the circular economy. Over the coming years, the CEIS must therefore be systematically established and continuously developed. The particular challenge lies in the strategic coordination of overarching policy frameworks, priorities and standards in conjunction with concrete practical initiatives for developing, piloting and scaling innovative solutions. This In Brief outlines five starting points for the necessary collaboration between government and business, with the involvement of academia and civil society.

1. The digital transformation is key to the success of the circular economy

Digital technologies can help to close material loops and conserve resources in many areas of the economy. The broad portfolio of Industry 4.0 solutions, data protocols, the Internet of Things (IoT) and the growing number of tools based on artificial intelligence (AI) are constantly creating new opportunities to optimise industrial processes at all stages of production. They therefore facilitate the practical implementation of circular business models, such as in the remanufacturing of machinery or the refurbishment of electrical appliances. The same applies to waste management, collection logistics or sorting and recycling facilities. At the same time, the digitisation of the circular economy serves as a catalyst for innovation for businesses and is thus increasingly becoming a competitive factor for Germany as an industrial economy. **Digitisation is key to the success of the circular economy. New opportunities have emerged in recent years – and they must be seized.**

When building a digital circular economy, it is important to recognise that decisions made at every stage of the economic value chain affect the options available to other stakeholders. For example, material manufacturers' specifications influence manufacturing processes in production facilities and subsequent recycling options. Product design and the availability of replacement parts determine products' use, longevity, repairability and refurbishment potential, while quality assurance and documentation in recycling processes are prerequisites for the marketability of the recovered recyclates. This changes the relationships between companies and both upstream suppliers and partners as well as downstream customers and recycling companies. The actions of some and the data and information provided by others are therefore required at every stage. Without this data, a circular economy cannot be implemented. Therefore, all stakeholders along the supply chain must become part of new information relationships and build the capabilities for data exchange and data utilisation. The foundations for this must now be laid with the **Circular Economy Information Ecosystem (CEIS).**

2. The Circular Economy Information Ecosystem (CEIS) as the foundation for a digital circular economy

The CEIS concept describes the interplay of all digital technologies, infrastructures, processes, institutions and individual participants to enable a data-driven digital circular economy (technology & infrastructure layer), including the necessary standards, rules and coordination mechanisms (coordination & governance layer). On this common basis for providing data and information, specific digital solutions can be implemented across a wide range of practical applications within the circular economy, enhanced by innovative technologies and steadily refined over time (data-based solution layer). The CEIS therefore creates the conditions for linking physical material and product flows (material & product layer) with the associated data flows (CE data layer), thereby supporting the implementation, expansion, operation, administration and regulation of the circular economy. Figure 1 illustrates these relationships.

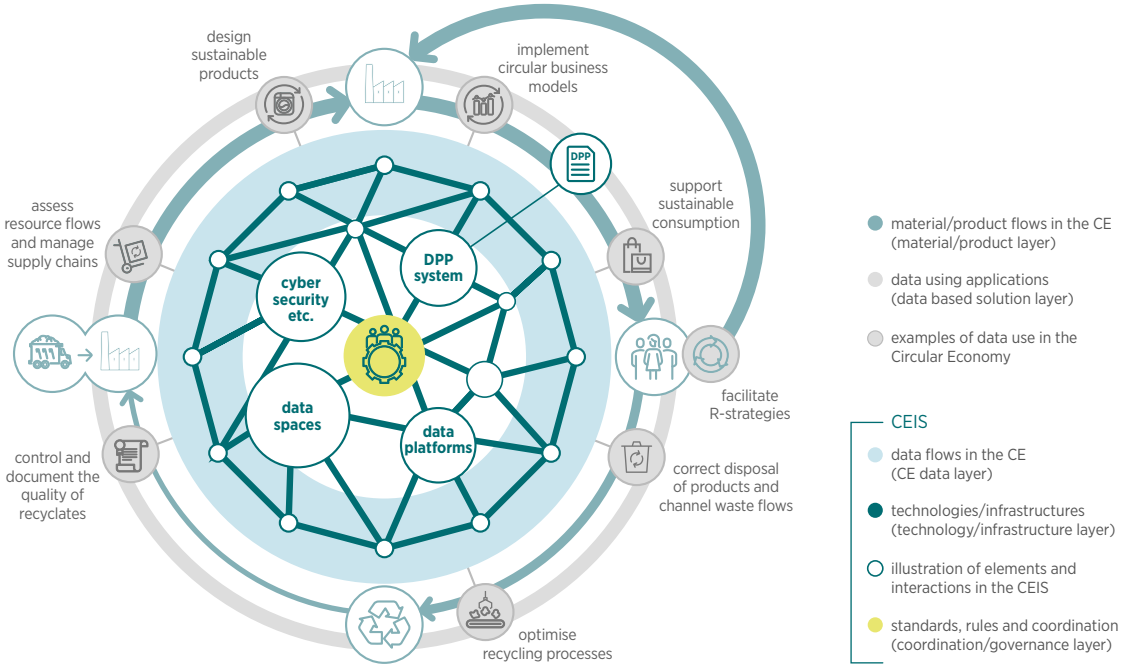

Fig. 1: *The Circular Economy Information Ecosystem (CEIS) forms the foundation of the digital circular economy. The diagram shows the CEIS at its centre, illustrating the interconnections between the various decentralised components for data exchange and data provision within the circular economy.*
Source: *Wuppertal Institute*

In the sense of an "Internet of the Circular Economy", the CEIS thus creates the fundamental data-related conditions that enable various stakeholders in the circular economy to use a wide range of digital technologies and applications – similar to internet-based "apps" – in order to implement, expand and manage the circular economy. These stakeholders include industrial companies with their circular business models, consumers, repair service providers and the waste and recycling industry, all the way up to circular economy policy, as well as administrative bodies and institutions responsible for regulation enforcement, such as market surveillance authorities.

The Digital Product Passport (DPP) as a central element of the CEIS

The introduction of the Digital Product Passport (DPP) will make a significant contribution to the development of a CEIS. The DPP was defined by the European Union under the Ecodesign for Sustainable Products Regulation (ESPR) and other regulations – such as the Battery Regulation – as a data set for environmentally relevant information. In the future, the DPP's role as a universal data carrier for all regulatory information requirements is set to be expanded even further. This will strengthen its significance and make it a central element of the CEIS.

The underlying logic and the expected applications of the DPP are based on the creation of a universal, quality-assured, multifunctional and virtually infinitely expandable information relationship between the economic actors responsible for the product – namely manufacturers, distributors and importers – as well as relevant stakeholders such as customers, service providers and authorities. The DPP is thus more than just a regulatory formality. The Circular Economy Information Ecosystem (CEIS) emerges from the interplay between internal data management within companies and data exchange within the external data ecosystems of circular value networks. Companies issuing DPPs

will need to align their internal data management to the requirement to efficiently – i.e. as automatically as possible – populate the various data fields and categories of the DPP. To do this, internal data sources and stand-alone IT systems, which are often still scattered throughout the company, must be identified and consolidated, for example, via internal data hubs. This alone already strengthens a company's own data competence and offers opportunities for entirely new data-based business solutions. The DPP thus provides important impetus for building end-to-end data ecosystems and is closely intertwined with the scaling of key digital technologies in industry. From a technical perspective, the DPP can become the "single point of trust and truth" for product-related information and thus the direct link between the physical world and the digital space.

The vision of a Circular Economy Information Ecosystems (CEIS)

The CEIS is a vision for the digital circular economy – it is therefore not a static artifact, but rather the result of transformation and innovation processes that are constantly evolving and developing.

The key characteristics of the CEIS as a socio-technical system are:

- By definition, the CEIS is **decentralised and interlinked**. As a **"system of systems,"** it connects the many different stakeholders in the digital circular economy, each of whom contributes their own data systems and individual applications. These building blocks and subsystems remain independent but can interact with one another. There is thus no central, overarching authority on which the participants depend, nor is there a monolithic, all-encompassing IT operating system that would be mandatory for all uses and into which all applications would have to fit. This ensures that participants in the CEIS remain **sovereign and self-determined**. They have a say in the nature, scope and operational details of data relationships and data usage.
- Within the CEIS, participants interact based on **clearly defined roles and permissions** and share data according to the "need-to-know" principle. Participants may include, for example, industrial companies, IT service providers and private end-users, as well as government agencies and policymakers. Furthermore, only data that corresponds to the access rights of a specific organisation or individual are made available.
- The building blocks, subsystems and data relationships within the CEIS are designed to be **interoperable**, meaning they can work together and exchange information seamlessly. Interoperability is the key criterion for the feasibility and successful scaling of the digital circular economy within the CEIS. From a technical and infrastructural perspective, common standards for efficient and secure data transfer help ensure precisely this. The harmonisation of data models and semantics is also crucial. This means that the stakeholders networked within the CEIS agree to speak a "common language" or to apply rules for translation between individual topical domain areas and specific usage contexts. This enables alternative approaches to connecting heterogeneous systems via intelligent interfaces.
- The CEIS can thus be developed in a **technology-agnostic and vendor-neutral** manner. Within the framework of the general requirements for the interoperability of solutions, there are no dependencies on specific technologies or exclusive vendors – anyone can participate, use the technologies of their choice or contribute new solutions. This aspect is

further strengthened by the provision of fundamental technical building blocks as freely accessible open-source software.

- The CEIS thus remains **dynamic and adaptable**; new stakeholders can expand its range of applications, address previous weaknesses through competing innovation and exploit previously untapped potential benefits.

3. Opportunities for a data-based circular economy policy and the digital modernisation of administration and regulation enforcement

The CEIS provides the digital foundation for linking physical material flows and economic value chains with the associated data streams. This primarily benefits all participating economic actors and end users in the practical implementation of their circular economy strategies. In addition, however, new opportunities are also opening up for shaping circular economy policy and increasing efficiency in its practical implementation within administration and regulation enforcement – for example, market surveillance authorities.

The data generated in the course of introducing DPP and data ecosystems within the CEIS can, on the one hand, make an important contribution to **strengthening the capacity to act in circular economy policy**. Increased transparency can help close a significant gap, as insights regarding the state of the circular economy beyond recycling currently rely often on anecdotal evidence. For example, it is often still unclear to what extent, for which products or for which target groups circular strategies such as repair or remanufacturing are being applied. Through the systematic collection and analysis of new data sources such as the DPP, it is possible to gain more up-to-date and broader insights into the circular economy, its development processes and, not least, the impact of policy measures.

On the other hand, new opportunities for **improving administrative efficiency are emerging in more digitised public authorities**, along with the **strengthening of law enforcement through digitally enabled regulatory bodies**. A significant contribution to reducing bureaucratic burdens can already be made today through the systematic digitisation of so-far analogue compliance documentation requirements. The Digital Product Passport is ideally suited to take over from paper-based forms of declarations of conformity, operating instructions and similar documents, or to replace redundant or ineffective database systems used in product regulation. Looking ahead, the CEIS data ecosystem underlying the DPP should also be capable of meeting other requirements, such as automating or supporting companies' regulatory reporting obligations. The particular potential of the DPP within the CEIS thus lies precisely in this multifunctional scalability, which, in the spirit of "once-only" and "single gateway" strategies, enables the consolidation, content harmonisation and operational simplification of information obligations. At the same time, the automated processing of digital product information is a prerequisite for large-scale screening manufacturers and effectively monitoring environmental and safety product standards in the European market – a task that is becoming increasingly important given the flood of millions of packages arriving daily via online commerce in Europe.

As DPP and CEIS scale up to establish the digital circular economy, the potential for a more data-driven circular economy policy and the digital modernisation of administration and enforcement also grows – in a mutually reinforcing process. This potential must be

systematically and continuously explored and consistently harnessed. This is both an investment and an innovation task for the public sector.

4. Areas of focus government and industry

Despite promising prospects, the Circular Economy Information Ecosystem (CEIS) will not emerge “overnight”; rather, it must be built up systematically by policymakers and the business community in collaboration with academia and civil society – deliberate action is needed here. In the coming years, it will be crucial to maintain the current momentum of innovation and to further drive it forward through additional activities aimed at the targeted development and piloting of solution components for the digital circular economy. At the same time, for broad market introduction and scaling, these solutions must converge into an integrated CEIS system. Individual stakeholders and their technological approaches must collaborate across value chains and sectors. This requires strategic coordination of individual initiatives and joint efforts to ensure interoperability through the harmonisation and standardisation of technologies, interfaces and data models.

All parties must therefore organise the interaction between politics and business at various levels in the context of rapidly evolving digital technologies. It is essential to link the strategic coordination and alignment of overarching policy frameworks, priorities and common standards with concrete initiatives for the development, piloting and commercial scaling of industrial solutions (see Fig. 2).

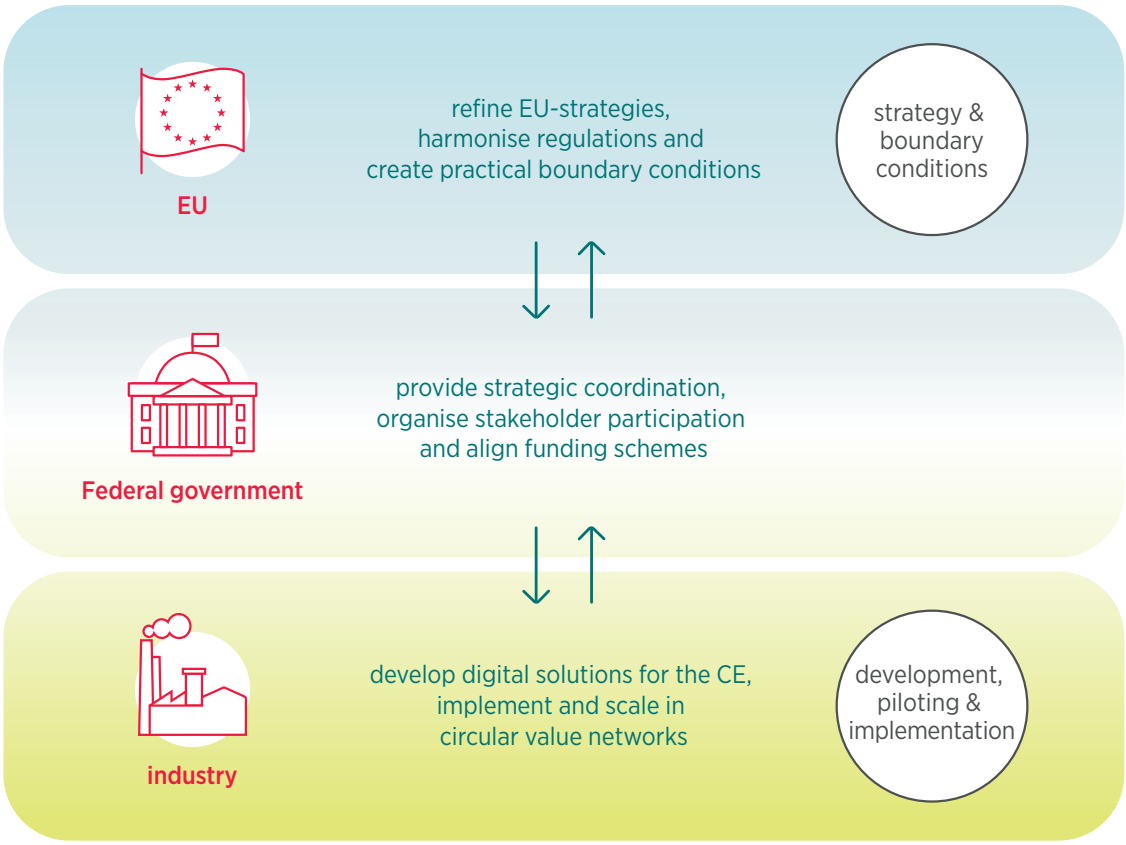

Fig. 2: *The successful implementation of the digital circular economy and the establishment of the CEIS require collaboration between the public and private sectors at all levels of decision-making. The federal government plays a key role in coordinating European framework conditions with national innovation support schemes and practical implementation through industry initiatives.*
Source: *Wuppertal Institute*

This gives rise to distinct tasks and responsibilities for both the political and business sectors. The **German federal government** must seize the opportunity to systematically further develop Germany's existing technological foundation for a digital circular economy and to strengthen the commitment of industry and academia – not least to play a proactive role as an innovation leader in shaping upcoming EU initiatives. Key approaches include the continuation and expansion of industrial data ecosystems, incorporating government infrastructures, processes and applications. To better enable policymaking and regulation enforcement, the governmental bodies must be digitally integrated at all federal levels at an early stage.

The piloting of various DPP applications in conjunction with the implementation of the National Circular Economy Strategy (NCES) and its planned implementation platform should be resolutely pushed forward. Specifically, this means both strategically coordinating the multitude of diverse sectoral approaches and, at the same time, organising the necessary stakeholder participation and providing strategically aligned funding structures.

The actual implementation will then be the responsibility of **industry stakeholders** – companies, associations and standard-setting bodies. It is up to them to work with academia and civil society stakeholders across all areas of the NCES to develop innovative digital solutions and business models for the circular economy, implement them in day-to-day operations and scale them across their industries, supply chains and regional economic networks.

To shape the CEIS, the following five starting points should be at the centre of collaboration between government and industry, in cooperation with academia and civil society:

- Research and development, pilot projects and scaling initiatives focused on practical and efficient **applications for the concrete use of data from the CEIS** should be funded across the entire value chain – from design and engineering through production and innovative circular business models, promotion of the R-Economy (including repair, refurbishment, remanufacturing and reuse), to waste collection, sorting and recycling.
- **Support for pilot projects and collaborative initiatives aimed at establishing and expanding industry-specific data ecosystems** for the circular economy should be continued, for example within the framework of the Manufacturing-X initiative. Cross-industry interoperability should be ensured in this context. In addition, alternative concepts and innovations related to data ecosystems should be continuously explored through dedicated formats.
- A **coordination function should be established for the CEIS and for the scaling of DPP**, with the aim of ensuring cross-project alignment of CEIS-related funding initiatives, guaranteeing the conceptual and substantive consistency of funding programmes, and creating transparency regarding the landscape of current DPP and data ecosystem projects to provide orientation to practitioners. To this end, **service functions and formats should be developed and provided to support the mobilisation and scaling** of digital solutions and address implementation barriers, particularly in small and medium-sized enterprises.
- **Industry initiatives and international standardisation processes aimed at the internationalisation of solution approaches** should be supported and continued. This also includes the cross-sectoral content harmonisation of data models in conjunction with a commitment to internationally aligned policy frameworks for the digital circular economy – for example, through (funding) participation in the UNEP initiative D4CE on the "Global Framework for Digital Product Information Systems."

- The public sector should begin **systematically building the expertise and capacity needed to make use of the data in the CEIS within administrative and regulatory functions**. In doing so, synergies should be leveraged, such as by incorporating this effort as a contribution to ongoing initiatives for digital administrative modernisation and by examining interfaces with the emerging Deutschland Stack. This applies in particular to internal government data ecosystems for the exchange, consolidation and (repeated) use of circular economy and DPP data to enable more evidence-based policymaking and the modernisation and simplification of administrative tasks.

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Further reading

Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN): The National Circular Economy Strategy (NCES), Berlin, December 2024

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