



# **AI-Driven Process for Analyzing Business Actors and their Capabilities in CE Ecosystem**

Master of Engineering  
Transformative Leadership and Smart Services  
Spring 2024  
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Tietojohtaminen ja älykkäät palvelut

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Työn nimi Tekoälyavusteinen prosessi kiertotalousekosysteemin toimijoiden ja heidän kyvykkyyksiensä analysointiin

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Tiivistelmä

Vuosi 2024

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Tämän opinnäytetyön tarkoituksena oli tunnistaa yritystoimijoita ja arvioida heidän kyvykkyyksiään toimia kiertotalousekosysteemeissä Etelä-Pohjanmaan alueella. Työ pyrki tukemaan kiertotalousekosysteemin orkestraattoreita alueellisen kiertotalousekosysteemin käynnistämässä luomalla systemaattisen tavan tunnistaa toimijoita sekä arvioida heidän kiertotalouskyvykkyyksiään. Työn tarkoituksensa oli tukea Seinäjoen ammattikorkeakoulun RIIHI-hanketta, jonka päämääränä on kiertotalousekosysteemien vahvistaminen ja kiertotalousliiketoiminnan edistäminen alueella.

Opinnäytetyössä kehitettiin ja testattiin CEULA - Circular Economy Uptake Level Assessment -nimistä prosessimallia. Mallin avulla pyrittiin systemaattisesti tunnistamaan alueelliset toimijat toimialoittain avointa julkishallinnon tarjoamaa dataa rikastamalla, ja tämän jälkeen arvioimaan toimijoiden kiertotalouskyvykkyyksiä käyttämällä apuna generatiivista tekoälyä ja luonnollisen kielen prosessointia. CEULA-työkalut rakennettiin ChatGPT4:n GPT Builderia hyödyntäen.

CEULA-mallin arviointikehikko perustuu Ellen MacArthur Foundationin kehittämään ReSOLVE-viitekehikseen ja kiertotalouden maturiteettimalleihin. Systemaattinen prosessi sisältää kaksi vaihetta: ensimmäisessä vaiheessa tapahtuu toimijoiden tunnistaminen ja toisessa vaiheessa toimijoiden kiertotalous- ja ekosysteemikyvykkyyksien arviointi. Kehitetty prosessimalli tarjoaa kiertotalous-ekosysteemien orkestraattoreille systemaattisen työkalun, jonka avulla voidaan analysoida toimijoiden rooleja ja kyvykkyyksiä CE-ekosysteemin muodostamisen alkuvaiheessa.

Opinnäytetyön tulokset indikoivat, että CEULA-prosessimalli tukee potentiaalisten ekosysteemin toimijoiden tunnistamista ja kiertotalouskyvykkyyksien arviointia, edistäen näin kiertotalousekosysteemien rakentumista ja syventäen ymmärrystä alueen kiertotalouspotentiaalista. Tämä on erityisen tärkeää Etelä-Pohjanmaan alueelle, jossa on havaittu selkeä tarve kehittää kiertotalousekosysteemejä systemaattisemmin, mutta mallin toistettavuus mahdollistaa sen, että mallista on hyötyä myös laajemmin.

Työ tarjoaa uutta tietoa ja konkreettisia välineitä alueellisten kiertotalousekosysteemien kehittämiseen. CEULA-mallin avulla voidaan laajentaa ymmärrystä kiertotalouden toteuttamisesta ja toimijoiden roolista niin alueellisesti kuin kansallisestikin. Työssä kehitetyllä CEULA-mallilla voidaan nähdä sekä käytännöllistä ja tieteellistä arvoa, sillä se tarjoaa lisää ymmärrystä sekä akateemiseen kiertotaloustutkimukseen että käytännössä tapahtuvaan kiertotalouden liiketoimintamallien kehittämiseen.

Avainsanat kiertotalous, kiertotalousekosysteemi, kiertotalouskyvykkyys, generatiivinen tekoäly

Sivut 94 sivua

Transformative Leadership ja Smart Services

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Subject AI-Driven Process for Analyzing Business Actors  
and their Capabilities in CE Ecosystem

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Abstract

Year 2024

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This thesis focuses on the development of Circular Economy (CE) ecosystems, identifying and assessing the roles, capabilities, and business models of actors within the South Ostrobothnia region. Aimed at enhancing the adoption of CE principles and their practical application in the region's industry, the research supports the formation of a regional CE ecosystem and strengthens the competitiveness of local businesses from a circular perspective. The study was conducted to support the RIIHI project at Seinäjoki University of Applied Sciences, with the primary goal of strengthening CE ecosystems and promoting CE business in the area.

A process model named CEULA - Circular Economy Uptake Level Assessment was developed and tested to systematically identify and evaluate actors' CE capabilities using open government data and generative artificial intelligence (AI) with natural language processing (NLP). The model, leveraging the ReSOLVE framework by Ellen Mac Arthur Foundation for business model transformation, consists of two phases: actor identification and capability assessment. It provides a tool for ecosystem orchestrators to systematically analyze actor roles and capabilities during the early stages of forming a CE ecosystem. The CEULA tools were built by ChatGPT's GPT Builder.

The results demonstrate that the CEULA process model can facilitate the identification of potential ecosystem actors and assess their capabilities in CE, promoting ecosystem formation and deepening understanding of regional CE opportunities. This is particularly significant for the South Ostrobothnia region, which has recognized the need for a more systematic approach to developing CE ecosystems but can benefit a larger audience as well.

The work provides new insights and tools for the development of regional CE ecosystems, expected to advance the wider adoption and application of CE principles both regionally and nationally. Thesis highlights the practical and scientific significance of the CEULA model, contributing to the academic CE research and practical development of circular business models.

Keywords circular business models, CE ecosystems, circular capabilities, generative AI  
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# 1 Introduction

The shift towards a circular economy is becoming a widely accepted pathway for sustainable production and consumption, as the circular economy (CE) is recognized as a pivotal strategy for mitigating the global planetary triple crisis of climate change, pollution, and biodiversity loss. (Geissdoerfer et al., 2017, p. 757; Kirchherr et al., 2023, p. 8; Korhonen et al., 2018, p. 37) The Ellen MacArthur Foundation (2021, p. 7) proposes that transitioning to circular business models (CBMs) holds significant economic potential and provides opportunities for novel business growth. Other central building blocks for the advancement of CE are CE ecosystems. CE ecosystems can be found, for example, in local industrial symbioses between companies, or within international intra-industrial ecosystems (Järvenpää, 2022, p. 14; Pietrulla, 2022, p. 5). Additionally, digitalization and data utilization hold crucial roles in the CE transition (Kortus & Gutmann, 2023, p. 7). These elements require new ways of learning and operating in a fast-changing business environment.

Adopting and embracing the new practices that are reshaping the current economic model is essential to the CE transition. The transition demands a wide range of new skills and knowledge, or capabilities, from various economic actors. Business actors within CE ecosystems play a crucial role in the transition towards CE, as they possess a significant amount of industry-specific knowledge and understanding of local circumstances. (Chembessi, 2023, p. 1; Eisenreich & Füller, 2023, p.1) By gaining a comprehensive understanding of these manifold aspects affecting circular transition, policymakers, regional developers, educators etc. may provide solutions to further enhance circular transition and

## 1.1 Background

The transition towards a CE represents a macro-societal transformation, that requires a reconfiguration of production and consumption patterns to meet sustainability objectives. From this macro-societal viewpoint, the shift towards CE is heavily reliant on learning and the exchange of knowledge across various sectors and among different economic stakeholders (Chembessi et al., 2023, p. 1). As highlighted by Kauppila et al. (2022, p.10) the establishment of a fully functional circular economy in Europe requires the acquisition of new knowledge about the dynamics of raw material cycles and the roles of various actors like producers, manufacturers, and recycling firms. This is particularly needed in the development and implementation of new CE business models (Brendzel-Skowera, 2021, p. 16).

Research on CE often prioritizes technological aspects, such as platforms and materials, and frequently overlooks the roles and capabilities of actors, including businesses and individuals in organizations. Despite the fact that previous studies have proven the lack of skilled personnel and knowledge to be the key hinderance to CE transition, research has overlooked the effect of both organizational and personal capabilities. This oversight can lead to deficiencies in CE transformation processes, as critical elements are neglected. (Trevisan et al., 2022, p. 297) Put differently, to be effectively implemented, CE requires substantial amounts of new knowledge and action derived from it. However, a significant number of firms aiming towards CE continue to struggle with identifying and implementing circular business models (Brendzel-Skowera, 2021a, p. 17).

Additionally, to enable a circular transition, it is imperative to acknowledge the regional economic and industrial structural variances. These distinct characteristics must be recognized in the development of regional circular ecosystems (Haila et al., 2023, p. 74). Viewed through the lens of CE, South Ostrobothnia stands out as an example of a region with defying characteristics. The region holds long distances and a low-density population, yet it is home to over 15,000 companies, many of which are integral parts of specialized international manufacturing industry value chains (Regional Council of South Ostrobothnia, 2022, p. 20). This unique combination of factors makes South Ostrobothnia an intriguing case study in the context of CE ecosystems.

South Ostrobothnia has several vital ecosystems, alongside others presenting opportunities for further development. However, these ecosystems are typically personified and, therefore, exclusive, with divergent stakeholder interests in ecosystem engagement. (Regional Council of South Ostrobothnia, 2022, pp. 31-32) Various ecosystems exist in the South Ostrobothnia region, and the need to make these existing ecosystems and their inherent interests more transparent is evident. Additionally, their potential for circular economy-based action has not been researched or identified and there is a lack of comprehensive understanding of actors and their capabilities in ecosystems.

The recent assessment of Finland's Strategic Circular Economy Program indicated a shortfall in meeting transition and implementation goals, positioning Finland below the European average in circular economy endeavors. Inertia in CE ecosystem activities in Finland is partly implicated in this underachievement (Haila et al., 2023, pp. 45,112). For example, CE-based ecosystems are virtually non-existent in South Ostrobothnia, barring a few industrial symbioses between two entities. The region's circular economy-based turnover ranks fourth lowest nationally. (Orko et al., 2020, p. 127). Additionally, spontaneous identification of



proactive business actors with the capabilities and willingness to spearhead CE ecosystem activities in South Ostrobothnia remains elusive. (CircEPos Project Business Interviews, 2022).

Both nationally and in the South Ostrobothnia region, there is an identified imperative for a more systematic initiation and orchestration of CE ecosystems. The need for a coordinating body and established processes to facilitate CE cooperation, support networking, aid in discovering synergies and collaborative opportunities, and offer guidance on development projects and investments is evident. Furthermore, efforts are necessary to encourage the formation of industrial symbioses and to develop business practices aimed at leveraging these symbioses. (Regional Council of South Ostrobothnia, 2022, p. 32).

To support these regional needs, this thesis contributes to the research and development (RDI) project RIIHI at Seinäjoki University of Applied Sciences, thus furthering regional vitality and the progression of the CE transition in South Ostrobothnia. The main goal of the project is to strengthen CE ecosystems and grow CE business in the region. The project enhances the CE practices and cooperation of companies, developer organizations and public actors, which promotes an overall CE transition in the region. The thesis provides theoretical background to activities pursued in the project and records the development work done as part of the project activities regarding CE ecosystems and ecosystem actors.

## **1.2 Research Objectives and Research Gap**

The thesis examines a selection of key industrial sectors in the South Ostrobothnia region, with a particular focus on their potential integration into the regional CE ecosystem. The thesis proposes a process model with a set of tools to systematically identify ecosystem actors in the initiation phase of the CE ecosystem and to evaluate actors' circular capabilities. These selected sectors, including timber products, furniture manufacturing, fixed furniture, and home textiles, demonstrate unique opportunities for advancing CE principles and have been nationally identified as possessing substantial potential for the circular economy. These sectors present considerable opportunities for mutually advantageous business collaboration at the regional level, transcending the traditional limits of their individual industry domains (Regional Council of South Ostrobothnia, 2022, p. 30).

The primary goal of this thesis is to first identify and then characterize the actors within these selected sectors. The thesis seeks to understand their potential role and impact in fostering a robust CE ecosystem in the region. Identification is achieved through systematically

processing, enriching, and visualizing open government data. This identification phase is then complemented by a CE capability assessment based on the ReSOLVE framework (EMF, 2015) and conducted using generative AI and natural language processing (NLP) techniques.

The developed process model is tested and validated with selected test cases, and the results are reported in the thesis. The process model is designed to be adaptable for subsequent research endeavors across various sectors and industries within the South Ostrobothnia region and initially the proposed process model will be applied to the development activities of the RIIHI project at Seinäjoki University of Applied Sciences. However, the developed process model also holds potential to benefit a wider range of Finnish CE ecosystem orchestrators, particularly by supporting the initiation phase of ecosystems. Additionally, it addresses key research areas in the field of CE academia by providing empirical insight from the point of view of CE practitioners and making circular practices and capabilities more visible.

The concept of a circular economy has gained significant academic interest over the years, evolving from a niche idea into a mainstream research area. Recent CE studies have seen a growing effort to identify the challenges and solutions to the successful adoption of CE practices. However, much of this research focuses on external and technical factors influencing CE, such as customer behavior patterns, technological advancements, material characteristics and legislation (Bertassini et al., 2021, p. 3160; De Los Rios & Charnley, 2017, p. 116; Ranta et al., 2021, p. 3), thus often overlooking the capabilities of organizations. Key areas like organizational learning and knowledge acquisition are relatively less explored (Nujen et al., 2023, p. 8619). As Chembessi (2023, p. 3) suggests, one of the central research avenues in CE is to examine required capabilities in the transition to CE, in particular the forms of learning, knowledge and actors involved.

Circular business models are widely regarded as crucial drivers for the CE transition (Geissdoerfer et al., 2020; Bocken et al., 2019). However, much of the research tends to concentrate on single firms, which narrows its ability to illustrate CE principles' systemic nature, typically involving multiple entities beyond just individual firms (Kanda et al., 2021, p. 2815). As a result, there is an increasing consensus among scholars about the importance of collaborative networks, the engagement of various stakeholders, effective ecosystems to align different agents (Tukker, 2015; Geissdoerfer et al., 2017 ; Aarikka-Stenroos et al., 2021), and adopting a more comprehensive approach to CE (Kirchherr et al., 2023). These factors are essential for transitioning from a linear to a circular economy and should be

further researched (Geissdoerfer et al., 2020, p. 14). This thesis aims to address this research gap.

The use of the ecosystem concept, which highlights the increasing interdependencies among various actors, has become prominent in CE research (Aarikka-Stenroos et al., 2021; p. 260). This idea is frequently discussed in management studies, as evidenced by authors like Adner (2017) and Thomas & Autio (2020). Nevertheless, its examination in the context of the CE has not been as thorough and is relatively underexplored (Aarikka-Stenroos et al., 2021, p. 262). This thesis seeks to provide actionable insights for practitioners looking to initiate, support, facilitate, or engage in CE ecosystems, while also enriching the understanding of these concepts for academic researchers.

To facilitate the transition towards CE, it's crucial to comprehend and modify how resources and information circulate within ecosystems and sub-systems. This shift towards CE is increasingly powered by digitalization, making the use of digital tools and data essential capabilities for enabling CE (Parida et al., 2019, p. 715). There's considerable research highlighting the critical role of digital technologies in fostering innovation within circular business models. However, the dynamic capabilities necessary for the digital-enabled transition from linear to circular models have not received adequate attention. (Van Eechoud & Ganzaroli, 2023, p. 2) This thesis provides new insight on how digital technology, and more precisely AI, can enhance circularity from a capability perspective.

As Nujen et al. (2023, p.1) point out, most of the CE research has not concentrated on the 'soft' aspects of the CE, such as internal organizational dynamics or capabilities required during the transition to CE. Similarly, a review by Sarja et al., (2021, p.19) indicated learning and knowledge are the keys to CE transitions in organizations, yet topics related to such organizational factors in CE transitions were underrepresented in the field of research. The knowledge utilization and understanding necessary capabilities to support CE transitions are not adequately explored (Chembessi, 2023, p. 3). Additionally, there is a scarcity of studies that explore the interaction between knowledge management and the circular economy, such as the development of circular business models or the transition towards CE. (De Los Rios, & Charnley, 2017; EMF, 2015; Geissdoerfer et al., 2017)

The thesis addresses these presented research gaps by exploring organizational capabilities essential for the transition to CE. Additionally, this thesis extends the current understanding of CE ecosystems by investigating interaction capabilities of CE ecosystem actors. The thesis aims to bridge the existing research gaps by providing a comprehensive analysis of

the capabilities influencing the adoption of CE principles in specific industries. It also aims to offer actionable insights for practitioners and contribute empirical knowledge to academic researchers in the field of CE. Kortus & Gutman (2023, p.13) proposed that to broaden the research scope and identify synergies with the dynamic capabilities' framework, future studies could integrate other existing frameworks, like SDG's (Sustainable Development Goals) into capability research. This thesis integrates dynamic capabilities perspective with the ReSOLVE framework (EMF, 2015).

The novelty and impact of the work are further enhanced by deliberately selecting free and publicly accessible open government data and commonly used easy-access programs and applications for data processing. Over the past six months, generative AI has rapidly integrated into the means of data gathering and analysis. Therefore, generative AI was incorporated into the process, and data acquisition, processing, and refinement were conducted by generative AI (ChatGPT4). The utilization of ChatGPT4 in the development work is conducive to mainstreaming the process model as it lowers the barriers to utilizing (open government) data and simultaneously mainstreams the adoption of related technologies and techniques in data utilization in the CE transition.

Additionally, by conducting the capability assessment via generative AI assisted Natural Language Processing (NLP), the thesis contributes to the understanding of how novel research methods can be used to bridge theoretical research and business development. This enables researchers, individual companies, and ecosystem orchestrators to adopt these methods with ease, thereby benefiting from the creation of more detailed value networks and ecosystem modeling.

### **1.3 Research Questions and Scope**

The primary objective of the thesis is to address the following research questions:

*RQ1: How can CE ecosystem actors within a region be systematically identified and characterized?*

To support RQ1, following research questions are presented:

*RQ2: How can open government data be utilized in the CE ecosystem actor identification process and in the initiation phase of a CE ecosystem?*

*RQ3: Can proposed CE capability assessment tool help CE ecosystem orchestrators to systematically analyze actors' capabilities?*

By answering these research questions, the thesis aims to evaluate if systematic process model and capability assessment tool can help CE ecosystem orchestrators efficiently form an overview of prospective ecosystem actors and provide a clear and concise analysis of the actor roles and capabilities in the initiated CE ecosystem.

The underlying hypothesis of the thesis is that systematic identification and characterization of actors will facilitate a comprehensive mapping of inter-actor relationships within the ecosystem, serving as a knowledge management tool in the initiation phase of CE ecosystems. Systematically and analytically processed open government data, enriched with diversely sourced information, can incorporate data pertinent to initiating CE business opportunities, such as material flow dynamics or knowledge requirements. Furthermore, this thesis assumes that comprehensive mapping of actors could enable the discovery and understanding of CBM's beyond material flow utilization, offering potential greater business benefits to CE ecosystem participants.

Another foundational premise of the thesis posits that the way corporations articulate their operations externally, such as through narratives presented on their websites, enables the identification of distinct capabilities organizations posit regarding CE ecosystems. For example, CE principles can be embedded in an organization in a variety of ways, from a narrow way i.e. considering CE as a synonym for recycling, to a wide and deep way, i.e., adoption of the systemic perspective. The thesis assumes that these identified capabilities and their maturity levels serve as predictive indicators of a corporation's potential to successfully engage in business models underpinned by circular economy principles or to effectively function within CE ecosystems.

It should be acknowledged that external communications, such as websites, do not encompass the entirety of a company's operations and capabilities. However, they provide a rigorous source to study how organizations describe their operations and business and whether they posit understanding in CE at a level they can communicate about it. Websites provide an interesting source of information for CE ecosystem orchestrators to discern the unique attributes of companies. This is particularly vital when tasked with synthesizing a comprehensive overview of a broad spectrum of companies.

## 1.4 Structure of the Thesis and Key Concepts

The thesis proceeds as follows. The thesis begins with a background overview, setting the stage for the thesis by identifying the research objectives and the existing gap in CE literature. It then formulates specific research questions and outlines the scope of the thesis, followed by an overview of the structure and key concepts. The main body of the thesis delves into the circular economy as a new business paradigm. It explores the transition towards CE, discussing its benefits and barriers, and examines circular business models, including the ReSOLVE framework for business model transformation. The role of data and AI as enablers of the CE transition is also highlighted. Further, the thesis investigates circular ecosystems, analyzing the roles of various actors within these ecosystems and their circular capabilities.

The methodology section outlines the research strategy and approach, detailing the processes of data collection and analysis and addressing ethical considerations. The application-oriented part of the thesis focuses on regional CE ecosystem modeling. It discusses the utilization of open government data for ecosystem modeling, the identification and classification of ecosystem actors, and the assessment of CE capabilities using Natural Language Processing (NLP) methods. This includes building an assessment tool based on the ReSOLVE framework and leveraging ChatGPT4 for data gathering and analysis. The concluding chapter summarizes the thesis's practical and scientific significance, proposes directions for further research, and discusses the validity and reliability of the thesis work. The thesis culminates by highlighting the comprehensive investigation into circular economy, blending theoretical insights with practical applications.

Key concepts discussed in the thesis are presented below:

**Circular Economy (CE)** “is a technical and economic model that aims at eliminating waste and pollution, reducing the consumption of materials and energy, keeping products and materials in use, and regenerating natural systems in a way that is environmentally, socially, economically, and energetically sustainable (Kauppila et al., 2022, p.12).” A new paradigm to replace the current linear economy and the take-make-waste approach to consumption (Geissdoerfer et al., 2017).

**Circular Economy Ecosystem (CE Ecosystem)** refers to a collaborative network comprising various stakeholders (such as businesses, governments, and consumers) that operates under the principles of the circular economy to reduce waste, increase the reuse

and recycling of resources, and foster sustainable economic growth (Aarikka-Stenroos et al., 2021). The CE ecosystem aims to design out waste, keep products and materials in use, and regenerate natural systems (Pietrulla et al., 2022).

**Circular Business Models (CBM's)** business strategies that companies adopt to create value through the recovery and regeneration of products and materials. CBMs are designed to maximize resource efficiency, extend product lifecycle, and minimize environmental impact, aligning with the principles of the circular economy. Examples include product-as-a-service, refurbishment, and recycling models (Lüdeke-Freund et al., 2019).

**CE Capability** refers to the ability of an organization or system to effectively implement principles of the circular economy. It encompasses the knowledge, skills, resources, and processes required to design out waste, keep products and materials in use, and regenerate natural systems (Saari et al., 2024). Developing CE capability is essential for transitioning to more sustainable and circular business models (Bocken et al., 2019).

**Open government data (OGD)** involves the release of government datasets to the public in a way that is accessible, usable, and free to use. It promotes transparency, accountability, and innovation by enabling citizens, researchers, and businesses to analyze and utilize public data for various purposes, including developing new applications, enhancing public services, and informing policy decisions. (Ministry of finance, 2024)

**Generative AI** refers to artificial intelligence technologies that can generate new content, ideas, or data patterns that did not previously exist. This includes creating realistic images, videos, text, and sounds. Generative AI learns from existing data to produce novel creations, often used in applications like art generation, content creation, and design innovation. (IBM, 2023)

**Natural Language Processing (NLP)** is a branch of artificial intelligence that focuses on enabling computers to understand, interpret, and generate human language. This technology allows machines to process and analyze large amounts of natural language data, facilitating tasks such as translation, sentiment analysis, and conversational agents. NLP applications aim to improve human-computer interaction and automate text-based tasks. (Lipenkova, 2022)

## 2 Circular Economy as New Business Paradigm

The traditional linear production model, in which resources are extracted, transformed into products, used, and discarded has resulted in increasing pressure on resources and the accumulation of waste (Lewandowski, 2016, p. 1). The unsustainable practices of production and consumption have caused critical global issues collectively termed as the triple planetary crisis, encompassing climate change, biodiversity loss, and pollution. Thus, the increasing appeal of the CE concept stems from the worsening state of the environment and the resulting need to explore production and consumption methods that rely less on diminishing natural resources and minimize their negative impact on the environment. (Kirchherr et al., 2023, pp. 9-15; Geissdoerfer, 2017, p.757)

The CE has become the most powerful and comprehensive paradigm for incorporating firms' value creation activities with sustainability as CE's central aim is to develop economic and industrial models that decouple economic growth from the consumption of finite natural resources and the production of waste, thus overcoming the destructive value creation model in the linear economy. (EMF, 2015 p.14; Ghisellini et al., 2016, p. 3) Moving towards a CE offers not just environmental advantages but also substantial social and economic gains (Lewandowski, 2016, p.1).

### 2.1 Circular Principles to Overcome Linear Economy

The concept of the CE has been gaining momentum since the late 1970s and has its origins in industrial ecology. The term CE was introduced in the 1990's and the modern interpretation of CE, along with its implementation in economic systems and industrial procedures, has developed around the notion of closed-loop systems. (Geissdoerfer, 2017, p. 764) The concept of the CE encompasses a range of established frameworks and concepts, including cleaner production, ecological efficiency, and zero emissions. It also integrates more specific concepts such as 'cradle to cradle' (C2C) regenerative design, biomimicry, the blue economy, as well as life cycle assessment (LCA) and industrial symbiosis (Brendzel-Skowera, 2021, p. 3).

To reflect the systemic nature of the circular economy, CE was originally defined and conceptualized by the Ellen MacArthur Foundation as “an industrial system that is restorative or regenerative by intention and design” (EMF, 2013, p. 7). The rising popularity of the circular economy brings with it varied interpretations and applications by many stakeholders,



potentially leading to a blurred and disjointed understanding of the concept. This was evidenced by comprehensive studies by Kirchherr et al., (2017; 2023), which identified 95 distinct definitions of the circular economy and its multifaceted and evolving nature. Thus, it is important to acknowledge CE in more multidimensional approach than just managing waste.

At the very core of the CE transition is the improvement of systemic resource efficiency and sustainability which can be considered through the principles of “3R”: reduce, reuse, and recycle (Ghisellini et al., 2016, p. 12). Reducing implies delivering the same amount of value and comfort while utilizing fewer resources, such as goods and materials. This can be achieved through means like digitization, sharing platforms, or the development of lighter and more efficient products. Reusing involves bringing products that have reached the end of their life cycle back into use. This is commonly achieved through second-hand markets, refurbishing items, or establishing systems for taking back used products for remanufacturing. Recycling refers to the process of converting materials back into a usable form, effectively allowing them to be utilized again. This is done through the specific processes of material recycling. (Ranta et al. 2018; p. 5.; Geissdoerfer, 2017, p. 6; Nußholz, 2017, p. 764)

Alternatively, these CE principles can be described as narrowing, slowing, and closing resource loops (Bocken et al. 2016, p. 309). Konietzko et al. (2020, p. 4) have completed the list of CE principles with two new principles: regenerating and informing. Regenerating encompasses the maintenance and support of natural ecosystem functions, along with the adoption of renewable, harmless substances and energy forms. Informing is seen as leveraging digital technology to enhance the circular economy's efficiency. Kauppila et al. (2022, p. 50) argue that it's advantageous to categorize the principles of circular design across three distinct tiers: those that apply to products, those that shape business models, and those that govern ecosystem level principles.

The shift towards CE is increasingly recognized as a necessary response to the pressing challenges of the triple planetary crisis, moving away from the traditional linear economy's take-make-waste approach. This transition has attracted widespread interest around the world, from government officials to leading businesses. (Ghisellini, 2016, p.11; Lewandowski, 2016, p. 1, Kirchherr et al., 2017, p. 221) The objective of maximizing resource efficiency across the full spectrum of production and consumption processes seeks to achieve environmental and economic gains by reutilizing products, components, and materials at their highest value across successive cycles. This approach leads to a decrease in waste

generation, environmental degradation, and reliance on limited natural resources (Kirchherr et al., 2017, p. 227).

## **2.2 Transition Towards Circular Economy – Business Model Perspective**

As Aarikka-Stenroos et al. (2021, p. 262) note, the transition towards circular principles has become imperative for value chains, industries, and business ecosystems. The circular economy aligns with the principles of the waste hierarchy and is facilitated through the innovation of product designs and the establishment of closed-loop systems for products, components, and materials. (Kirchherr et al., 2017, p. 227; EMF, 2015, p. 25.)

For a successful transition to the CE, these actions need to take place at the individual and firm (micro) level, regional or network (meso) level, and national or governmental (macro) level. (Ghisellini et al., 2016, p.14; Kirchherr et al., 2017, p. 227) Arising from these distinct levels of action in the circular economy, research recognizes both top-down and bottom-up approaches as applicable methodologies. The top-down perspective highlights the importance of political and societal initiatives as driving forces in the execution of CE strategies. Conversely, the bottom-up approach places greater emphasis on actions initiated at the business level, suggesting that these are more critical in the CE transition. (Kortus & Gutmann, 2023, p. 9) The intrinsic nature of change in transition processes is strongly present in CE experiments (Chembessi et al., 2023, p. 3).

The transition towards CE encompasses significant advantages for businesses. However, transitioning existing industrial ecosystems to circular business models requires changing the roles and the ways ecosystem actors interact with each other. This includes new and expanded roles, improved communication, and a shift in understanding the value of circulated resources. (EMF, 2021, p. 8; Harala et al., 2023, p.7) These changes lead to benefits at different levels: companies see gains in business, competence, and employee satisfaction; the industry benefits from environmental sustainability and competitiveness; and society gains from an improved environment and job creation. Previous research has shown that businesses embracing circular business models are likely to be more profitable compared to those operating in a traditional linear way. The World Economic Forum has highlighted that by adopting circular economy approaches, companies stand to gain an extra \$4.5 trillion in profits by 2030. (Brendzel-Skowera, 2021, p.1)

Brendzel-Skowera (2021, p.12) highlights that the adoption of circular business models remains limited in practice, and the primary obstacle to circular transition is the absence of sufficient knowledge and skilled personnel. The global paradigm shift from one economic model to another presents manifold challenges and concerns, particularly for smaller and mid-size enterprises, which face numerous barriers in adapting to the new CE framework. Small companies face significant challenges in adapting to these trends, as it demands a disproportionately higher investment of effort and resources in both financial and organizational aspects. The findings of Brendzel-Skowera's research are consistent with the other research findings in the field, such as Parida et al. (2019) and Nußholz (2017).

The shift towards CE is inherently disruptive: adopting new circular principles challenges existing norms and alters the dynamics of collaboration and competition among technological, innovative, business, and governmental entities (Aarikka-Stenroos et al., 2021, p. 260). Significant obstacle to moving away from a linear system and towards a circular economy are not technological but rather inadequate patterns in systemic elements such as consumer behavior, a lack of functioning ecosystems, and financing schemes that create barriers to the CE transition (Kauppila et al., 2022, p. 12). These barriers are all related to a lack of comprehensive understanding and implementation of circular practices. This competence gap hinders the initiation, implementation, and particularly the development of new business models within the CE framework.

Developing a thorough understanding of circular business models is crucial for fostering and facilitating their uptake in enterprises, promoting the shift towards a circular economy (Lewandowski, 2021, p. 2). Aarikka-Stenroos et al. (2021, p. 262) emphasize that embracing the circular economy demands a fresh approach to innovation, technological advancement, and the creation of knowledge, with companies adopting CBMs frequently needing to pioneer and implement new ideas in their operations. The design and application of circular business models play a pivotal role in accelerating the transition to a circular economy (Lewandowski, 2016, p.1). Circular business models will be further discussed in the following section.

### **2.2.1 Circular Business Models as Enablers of Transition**

Shifting to circular business models is recognized as a fundamental approach to realize a circular economy and sustainability. Traditional business model frameworks are applicable to the circular economy but there are specific frameworks developed for circular business models, catering to both linear and circular aspects (Ghisellini et al., 2016, p. 3). CBMs incorporate the fundamental principles of a traditional business model, while also integrating

circular principles and strategies to narrow, slow, and close the loops in resource and energy usage. This added dimension of circularity is a distinguishing feature that sets CBMs apart from conventional business models as indicated by multiple studies. (Bocken et al., 2016; Aarikka-Stenroos et al., 2021; Konietzko et al., 2020)

Van Renswoude et al. (2015, p. 3) state that 100 % circular business models do not yet exist because the total elimination of waste is a challenging goal due to physical and practical limitations. However, Lewandowski (2016, p. 10) notes that to some degree, every business model incorporates elements of both linearity and circularity. This is attributed to the fact that companies continuously optimize their processes, transition towards virtualizing products or processes and utilize resources from material loops, thereby integrating aspects of the circular economy, sometimes unintentionally.

De Los Rios & Charnley (2016, p.1011) highlight that the primary incentive for businesses to adopt CE is that CBMs minimize reliance on critical resources. Decreasing this dependency can offer a strategic edge to companies and bolster their resilience against shortages and fluctuations in material prices. For promoting and advancing the implementation of the circular economy, developing more ambitious and contextual CBMs is crucial (Lewandowski, 2016, p. 2). Hansen et al., (2020, p. 8), observe that strategies such as repair, maintenance, upgrade, reuse, redistribution, refurbishment, remanufacturing, and recycling are fundamental approaches centered on value creation from a company's standpoint.

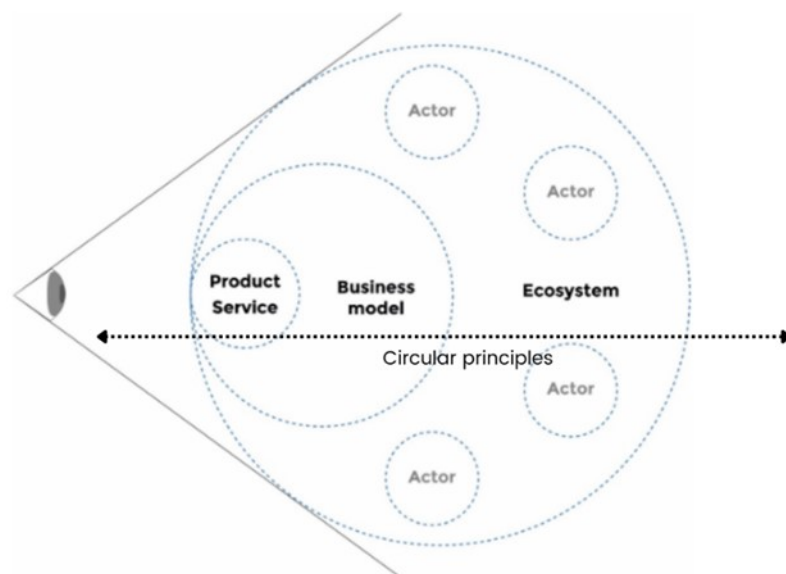
Even when the advantages are broadly acknowledged, business actors' limited knowledge regarding the effective implementation of CBMs creates a significant barrier to the circular transition (Lüdeke-Freund et al, 2019, p. 38). This is due to the fact that although there is a wide range of business model classifications available, many are not specifically tailored to the CE and remain on an abstract level. The effects of circular business models are hard to predict because designing products for many life cycles is uncertain and involves complex interconnected relationships with stakeholders. (Eisenreich & Füller, 2023, p.1) Research has shown that this leaves stakeholders with only a basic understanding of how to effectively implement and spread CBMs. (Bocken et al., 2014, Hansen et al, 2020)

Adopting CBMs requires detailed planning and careful execution, like any significant business transformation. This is particularly crucial because of the complex interdependencies inherent in circular business models. Business leaders must carefully evaluate the potential advantages of adopting these models and consider them against the associated costs. (Nußholz, 2017, pp. 6-8). Choosing the right circular business model,

determining the right time to adopt it, and figuring out how to implement it can be a complicated and lengthy process. There is no one perfect solution, so it's essential for business leaders to plan strategically, test different approaches, and keep a range of options open (Kauppila et al., 2022, p. 69).

Numerous models presented in both scholarly and practical literature suggest ways for businesses to rethink their value generation methods in line with CE principles (Hansen et al., 2020; Lüdeke-Freund et al., 2019; Bocken et al., 2016). Central to these CBMs, as Lüdeke-Freund et al. (2019, p. 42) point out, is the implementation of circular strategies to narrow, slow, and close resource loops. The concepts of value creation, capture, and delivery serve as frameworks for how entities can integrate circularity principles into their operational practices (Nußholz, 2017, p. 5). Circular principles are advocated to be integrated across all aspects of business operations, ranging from the level of products and services to the broader ecosystem (Konietzko et al., 2020, p. 4). The following figure presents how circular principles are crosscutting product/service, business model and ecosystem levels.

Figure 1 Crosscutting circular principles (adapted from Konietzko, 2020)



The key elements of circular business models are the business model strategies, or patterns, of the circular economy. Value generation in CBMs is realized by engaging in concrete circular patterns in everyday business operations. (Levandowski, 2016, p. 5). Patterns for narrowing loops, or reducing material usage, are dematerialization and design for longevity and efficiency. The CBM patterns for slowing resource loops, or reuse, are repair,

maintenance, redistribution, refurbishment, and remanufacturing, which are instrumental in the preservation of product value. On the other hand, patterns like cascading, and organic feedstock aim to preserve material value by closing resource loops or recycling. (Bocken et al, 2016, pp. 2-4)

Research on CBM's has primarily focused on the Business Model Canvas to classify characteristics of product-service systems in CE and emphasized managing circular supply chains (CSC). CSCs deal with organizing and synchronizing the supply chains to achieve objectives like closing, narrowing, slowing, intensifying, and dematerializing resource loops, as described by Geissdoerfer et al. (2017, p. 767) One of the most famous key frameworks is the Ellen MacArthur Foundation's Butterfly Diagram which presents flows of materials as two loops: the technical cycle, focusing on retaining the value of non-biodegradable materials; and the biological cycle, managing biodegradable materials to safely reintegrate them into the environment (EMF, 2013).

Another well-known framework for circular business models is the Cradle-to-Cradle design philosophy. All the presented frameworks aim to close material flows. From a business model perspective, one of the most viable frameworks is the ReSOLVE framework (2015), originally presented by the Ellen MacArthur Foundation. (Hansen et al., 2020, pp. 5,45) The ReSOLVE framework is further discussed in the following chapter.

### **2.2.2 ReSOLVE Framework for Business Model Transformation**

The ReSOLVE framework can be seen as a strategic approach that integrates circular actions, sustainability, and social responsibility into business decisions. While the circular economy broadly reconsiders the interplay between economic activities and environmental health, ReSOLVE specifically tailors it to business decision-making. It serves as a practical tool that integrates financial, environmental, and social metrics, offering a focused approach to implementing circular principles within business contexts (Sell et al., 2023, p. 2).

The ReSOLVE framework identifies six key actions for applying circular economy principles, each offering significant business opportunities. These actions encapsulate the core strategies for businesses to transition towards circularity and capitalize on its benefits. These actions are identified as *Regenerate*, *Share*, *Optimise*, *Loop*, *Virtualize*, and *Exchange*. The identified actions emphasize harnessing renewable resources, maximizing product utilization through sharing, enhancing efficiency and waste reduction, maintaining products and materials in closed loops, delivering utility virtually, and adopting new technologies or

products. (EMF, 2015) Following sections provide definitions for each action as presented by the Ellen MacArthur Foundation (2015).

*Regenerate* is focused on returning recovered biological resources to the biosphere and shifting to renewable energy and materials, thus aiming to reclaim, retain, and regenerate the health of nature's ecosystems. Businesses in various sectors are finding innovative ways to use renewable energy and materials. For instance, construction companies are not only using sustainable materials but also participating in projects aimed at restoring natural habitats. Similarly, solid wood producers are turning to regenerative practices to improve biodiversity, which in turn ensures the long-term productivity of the forests. (EMF, 2015, p. 25; Sell et al., 2023. p. 2)

*Share* actions aims to keep products in use as long as possible and technically acceptable. This means maximizing the utilization of products by sharing them among users and prolonging product life through maintenance, repair, and design-enhancing durability. The sharing economy is transforming business models across industries. Office space providers are offering co-working spaces, significantly reducing the environmental footprint by maximizing the use of physical resources. The technology sector is embracing the concept by offering refurbished devices, thereby extending the lifecycle of electronic products, and reducing e-waste. (EMF, 2015, p. 25; Lewandowski, 2016, p. 6)

*Optimize* actions focus on improving the performance/efficiency of a product and removing waste in the production process and in the supply chain. This could be done by leveraging big data, automation, remote sensing, and other technological improvements, but does not necessarily require changing the product or the technology, only ways of doing or thinking. Efficiency is key to sustainable business operations. Manufacturing businesses are investing in energy-efficient machinery to reduce their carbon footprint. Software companies are leveraging cloud computing to minimize the need for physical infrastructure, thus saving energy and resources. (EMF, 2015, p. 25; Renswoude et al., 2015, pp. 4-6)

*Loop* actions prioritize keeping components and materials in closed loops. Electronics firms are implementing take-back programs to recycle and refurbish old devices. Fashion retailers are creating new lines from recycled materials, thus keeping resources in use for as long as possible and reducing the demand for virgin materials. Additionally, this activity could entail utilizing side streams or waste materials in production. (EMF, 2015, p. 25.)

*Virtualize* actions assume to deliver utility virtually instead of materially. The virtualization of services and products is an effective way to dematerialize business operations. Maintenance firms are increasingly offering their services virtually, which cuts down on travel and associated labor costs. Retailers are expanding online storefronts, thereby reducing the need for physical retail space and the associated environmental impact. Furthermore, this activity could include using more sophisticated technological solutions, such as artificial intelligence or augmented reality as part of service production. (EMF, 2015, p. 26; Sell et. al., 2023, p. 2)

*Exchange* actions are focused on replacing old materials with advanced non-renewable materials and/or on applying new technologies, or new products and services. The exchange activity encourages the adoption of new, more sustainable technologies and materials. For example, packaging companies are moving towards biodegradable materials, and the automotive industry is integrating recycled materials into their processes and investing in the development of electric vehicles to reduce greenhouse gas emissions. (EMF, 2015, p. 26)

The transition to practices encompassed by the ReSOLVE framework—Regenerate, Share, Optimise, Loop, Virtualise, and Exchange—requires a deliberate shift in how businesses view and manage their resources, from procurement to product lifecycle management. ReSOLVE integrates sustainability into business decisions, helping companies develop circular strategies and address contemporary challenges. It's a strategic tool combining financial, environmental, and social metrics, offering a pathway for businesses and society to transition towards a more sustainable and resilient economy. Utilizing the ReSOLVE framework, companies can develop circular strategies and initiatives for growth and use the framework as a tool to identify investments and actions needed in transitioning to CE. (EMF 2015, Sell et al., 2023)

Incorporating the ReSOLVE framework into business strategy is a strategic choice that can propel companies toward a competitive edge, foster innovation, and support sustainable growth over the long term. By adopting circular economy principles, companies do not just follow a trend—they set a precedent for responsible business practices that can make a substantial impact on both the market and the environment. (Brendzel-Skowera, 2021, p. 7.) Table 1 combines the discussed ReSOLVE framework activities and their short description.



Table 1 ReSOLVE framework (EMF, 2015)

Activity	Key Elements	Potential Impact	Description
<b>Regenerate</b>	Replenishing and restoring natural capital, Regenerating ecosystems, Return recovered biological resources to the biosphere.	Low	Use renewable energy and materials, Reclaim, retain and regenerate health of ecosystems. Return recovered biological resources to the biosphere
<b>Share</b>	Maximising asset utilisation. Prolong the use of assets.	High	Enhancing product utility by sharing the use, access or ownership. Extending product life through reuse, maintenance (e.g., repair, refurbish) or design for durability
<b>Optimise</b>	Optimising system performance. Optimising assets' life.	Medium	Optimisation of resource use through increasing performance or outsourcing activities. Remove waste in production and supply chain. Leverage data and automation.
<b>Loop</b>	Keeping resources in cycles. Remanufacturing. Recycling materials.	High	Close material loops by remanufacturing, repurposing, recycling or recovering. Keep products and materials in cycles. Remanufacturing and refurbishing products and components.
<b>Virtualise</b>	Replacing resource use with virtual use. Delivering services remotely	Medium	Dematerialize products or services through digital appliances. Replacing resource use with virtual ones, Delivering services remotely.
<b>Exchange</b>	Replace resources and technology with better options.	Medium	Employ new technologies, materials or processes. Selecting resources and technology wisely. Using virtual technology.

It's highlighted that the shift towards a CE is reshaping the framework of business models. This shift necessitates that companies integrate loops for resource recovery into their supply chains, prioritize the use of renewable resources, and incorporate an increased number of service components into their current business strategies (Ranta et al., 2018, p. 5). CE strategies, like those presented in the ReSOLVE framework, redefine the value creation logic for businesses, impacting not just individual products and companies but also the broader value chains and ecosystems. This calls for the recognition of a wider and more varied group of actors and stakeholders. (Harala et al., 2023, p. 1; Ranta et al. 2018, p. 3; Eisenreich & Füller, 2023, p. 2)

The transition towards a CE and transforming traditional business models more circular requires a wide array of stakeholders across economic and other sectors, spanning from individual businesses to entire industries, all operating within a multifaceted framework of

interactions (Geissdoerfer et al., 2020, p. 8). Companies are required to acquire knowledge and skills pertinent to the specific conditions of varied markets (e.g. raw materials, energy, logistics), forge trustful connections with external parties, and handle a range of interactions that could be markedly more complex and thus harder to manage compared to those in a standard business framework (Kanda et al., 2021, p. 2816).

CBMs evidently depend on collaborations with other companies, customers, and civil society organizations. However, there is often a lack of detail about the specific roles and significance of these partners. Evans et al. (2017, p. 604) summarize that the role of a business model as an intermediary among different participants in a real-world value network business model innovation requires CE accurately to represent human behavior and decision-making processes. This brings CBM's and ecosystems together.

Reim et al. (2021, p. 2754) highlight in their study that companies require specific capabilities to develop and organize new CBMs that generate value for customers. Due to the diversity among companies, the adoption of CBMs significantly hinges on their readiness and eagerness to implement CBMs effectively (Lewandowski, 2016, p. 8). This calls for a socio-technical transition that touches on actors across the micro-, meso-, and macro levels. Leveraging circular economy solutions strongly depends on an interlinked network of actors (Eisenreich & Füller, 2023, p. 1). The shift towards CE is driven by the participation of all societal stakeholders and their ability to establish and foster appropriate patterns of collaboration and exchange (Ghisellini et al., 2016, p. 11). CE ecosystems are discussed in the following chapter.

### **2.2.3 CE Ecosystems as Business Model Transformation Enablers**

In navigating the complex transition from linear to circular paradigms, the notion of an "ecosystem" has become crucial for understanding how to effectively make this shift. The transition towards ecosystem-oriented thinking becomes even more central for circular business models, as these models often rely heavily on the intricate interplay among various stakeholders within complex value networks (Geissdoerfer et al., 2020, p. 8).

Given that the entities within an ecosystem can be viable businesses on their own, the ecosystem approach's value primarily stems from the dynamics among the actors. Companies that integrate ecosystem thinking into their business strategies must extend their focus beyond immediate partners to explore wider ecosystem linkages across different industries and value chains. This broader perspective is essential for achieving sustainability

and advancing the principles of the circular economy. Embracing an ecosystem perspective that considers the interactions between different actors allows a business to go beyond just economic value creation. This approach includes the integration of social and environmental values, thereby offering a competitive advantage (Kanda et al. 2021, p. 2826). In simpler terms, companies cannot achieve circularity in isolation; they require the support of a robust circular ecosystem to facilitate their business model transformation (Parida et al., 2019, p. 715).

As Trevisan et al. (2022, p. 293) state, the CE ecosystem represents more than the junction between the business ecosystem and the circular economy: it is a unique phenomenon. According to Konietzko et al. (2020, p. 21), "an ecosystem perspective on a circular economy is both needed and useful for firms to capture circularity as a systemic property." Research on CE ecosystems reflects the evolution of the wider ecosystem literature into specialized subcategories, like innovation, entrepreneurial, and knowledge ecosystems (Aarikka-Stenroos, 2021, p. 272).

The research area is still in its infancy, as highlighted by Pietrulla (2022, p. 8). This nascent stage of development means that the terminology within the field is not yet well-defined, leading to varied references by different authors to concepts such as "circular ecosystems," "circular economy ecosystems," or "circular business ecosystems." In this thesis, these concepts are uniformly referred to as "circular economy ecosystems," or CE ecosystems. According to Aarikka-Stenroos et al. (2021, p. 271), a "circular economy (CE) ecosystem is a multi-actor entity in which interdependent actors play complementary roles. The actors can include companies, industry actors, public and government actors (such as cities and municipalities), ministries, universities, non-profit organizations, and citizen-consumers. A CE ecosystem emerges or is created around a common, system-level goal related to resource circularity, circular economy knowledge, or circular economy business and business models."

Antikainen and Valkokari (2016) were the first to pioneer the integration of the business ecosystems' perspective into a framework for innovating circular business models, presenting the circular ecosystem as a distinct entity that transcends merely combining business ecosystems with the circular economy. In the business context, ecosystems have been defined as "the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize." This framework, together with interconnected notions such as business models, platforms, coopetition, multi-sided markets, networks, technological systems, supply chains, and value networks, has been instrumental

in honing the focus on and promoting innovation within the processes of value creation and capture. (Adner, 2017, pp. 39-40)

Konietzko et al. (2021, p. 4) emphasize the importance and utility of adopting an ecosystem viewpoint on the circular economy, arguing it is essential for companies to understand and leverage circularity as an inherent system-wide attribute. Kanda et al. (2021) conducted an extensive study on how circular business models are transformed into circular ecosystems and stated that by engaging in ecosystems businesses “can move beyond economic value creation to include social and environmental value and use it as a competitive advantage.” Aarikka-Stenroos et al. (2021, p. 272) offer a framework designed to clearly distinguish a circular business ecosystem from other types of ecosystems. The following Table 2 distinguishes the differences.

Table 2 Circular economy ecosystem definitions (Aarikka-Stenroos et al., 2021)

<b>Term/Category</b>	<b>Definition</b>
<b>CE Industrial Ecosystem</b>	A regional community of a hierarchically independent, yet interdependent, heterogeneous set of actors that sustainably produce industrial goods and services in symbiotic collaboration and resource use
<b>CE Urban Ecosystem</b>	An urban community of a hierarchically independent, yet interdependent, heterogeneous set of actors that collectively produce sustainable urban amenities
<b>CE Entrepreneurial Ecosystem</b>	A regional community of a hierarchically independent, yet interdependent, heterogeneous set of actors that facilitate the start-up and scale-up of entrepreneurial new ventures that are focused on sustainable business opportunities
<b>CE Knowledge Ecosystem</b>	A regional community of a hierarchically independent, yet interdependent, heterogeneous set of actors that advance the translation of advances in CE research knowledge into sustainable products and services
<b>CE Innovation/ Business Ecosystem</b>	A community of a hierarchically independent, yet interdependent, heterogeneous set of actors that collectively deliver a sustainable value offering that is typified by resource recycling, reuse, and/or reduction

A circular economy ecosystem is a business ecosystem where the actors are linked through economic interdependencies (Aarikka-Stenroos et al., 2021. p. 268). Previous research has shown that the business ecosystems of companies and their refreshed propositions for circular value have emerged because of enhanced circularity and reuse practices within the business ecosystem. Harala et al. (2023, p. 14) suggest the coexistence of circular industrial, innovation, and business ecosystems, all representing different forms of circular ecosystems.

Therefore, CE ecosystems are suitable as a comprehensive overarching concept (Aarikka-Stenroos et al., 2021, p. 271) for the ecosystems under examination.

The ecosystem approach aids in addressing the complexity and coordination challenges inherent in circular business models, highlighting the interdependence within the ecosystem, and thereby influencing company business models. However, this perspective demands enhanced capabilities from companies to manage these interconnected ecosystem components. (Kanda et al, 2021, p. 2862) This leads to the exploration of both circular economy capabilities and ecosystem capabilities that are crucial for business' as ecosystem actors.

Pietrulla et al. (2022, p. 5) build upon Aarikka-Stenroos' typology and provide an interesting division of locally operating ecosystems into cross-industrial and intra-industrial circular ecosystems. These are characterized by their geographical constraints and cross-sectoral circular dynamics, such as eco-industrial parks and circular cities. These local ecosystems are defined by their spatial limitations and involve participants from various sectors. Firms within the same sector located in these areas are referred to as local specialists. Such businesses often come together to form regional business ecosystem, exchanging services, resources, and knowledge to enhance efficiency. Although not every one of these collaborative networks can fully achieve a closed-loop material cycle, their contributions toward sustainable development and their efforts to at partly close the loop of material flow render them significant steps toward the realization of a circular economy (Pietrulla et al., 2022, p. 6).

The ecosystem perspective facilitates an understanding of intricate arrangements of actors, technologies, and institutions, that are interconnected through flexible interdependencies and patterns of co-evolution, as discussed in works by Aarikka-Stenroos, (2021), and Aarikka-Stenroos & Ritala (2017). The interconnectedness among ecosystem participants is often rooted in shared institutional principles, aligned aims or missions, joint value creation strategies, partnerships, or a technological infrastructure that supports their mutual connections. This concept has been investigated by Adner (2017), as well as Thomas & Autio (2020), and further elaborated by Pietrulla et al. (2022). These relationships underscore the complex web of collaboration and shared vision that underpins the dynamics within ecosystems, highlighting how these elements work to facilitate synergistic interactions among actors.

## **2.3 Gaining Circular Maturity Through Capability Development**

For companies aiming to implement circular business models, it is essential to gain expertise and competencies to develop and implement sustainable practices (Trevisan et al. 2022, p. 287). Capabilities and intellectual property associated with e.g. product design, recycling methods, and sustainable technologies give organizations a distinct advantage as they progress towards embracing CE (Tukker, 2015, p.76). The level of such expertise and capabilities can be evaluated through a maturity assessment. The concept of maturity provides a framework for understanding CE transformation elements and their connection to organizational change. (Uhrenholt et al., 2022, p. 15)

Maturity models outline expected evolution paths in a straightforward manner, suggesting that achieving mature performance follows a predictable and desirable trajectory marked by a series of ordered, discrete levels that form a hierarchical system (Kreutzer et al., 2023, p. 666). The purpose of a maturity model is to chart a structured progression of capabilities through various stages, each enabling the next. Through maturity models, organizations can pinpoint their current developmental stage to determine their next target stage, which is crucial for maintaining competitive advantage (Uhrenholt et al., 2022, pp. 13-14). As De Los Rios & Charnley (2017, p.3) note, the essential skills for transitioning to CE span from the implicit understanding of materials' composition to an in-depth comprehension of social behavior dynamics. These multifaceted aspects of circular maturity, and their levels particularly in the CE ecosystem context, are further studied in the following sections.

### **2.3.1 Actor's CE and Ecosystem Capabilities**

In the adoption of CBMs, it is crucial for companies to evolve in their comprehension of the circular steps required—from increasing awareness to systematically advancing capabilities in solution configuration, orchestration, and digitalization. Many companies lack these necessary capabilities, and progressing from lower to higher levels of sustainability and circularity requires specific implications that companies must understand and value. (Reim et al. 2021, p. 2753) Developing the required capabilities ensures that companies may possess advanced competencies in CE implementation, allowing them to actualize their CE strategies and visions (Saari et al., 2024, p. 2). These capabilities act as a precursor to CBM implementation efforts and act within CE ecosystems, yet they are hard to distinguish (Brenzel-Skowera, 2021, p.17).

Capability development in organizations is traditionally studied from two different perspectives: a resource-based view and a capability-based view. Concept of dynamic capabilities builds on both perspectives. The dynamic capabilities framework can be seen as a tool to evaluate strategic changes and transformations in organizations from sensing, seizing, and transforming perspectives (Teece et al., 1997). Teece (2020) extended the original proposed framework from 1997 by splitting the original dynamic capability 'seizing' into 'organizing' and 'capturing value'. After the split, dynamic capabilities can be divided into four major clusters: (1) scanning the environment, also known as sensing, (2) integrating and reconfiguring resources to address opportunities, known as organizing (3) capturing value, and (4) transforming to execute and sustain innovation at scale.

Dynamic capabilities in a company are defined as "the ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al., 1997, p. 516). The dynamic capabilities point of view posits that the foundation of sustainable competitive advantage lies in the unique aggregation of organizational resources (Van Eechound & Ganzaroli, 2023, p. 1). Furthermore, dynamic capabilities represent combinations of routines that offer a systematic method for addressing new challenges and facilitating organizational transformation. Dynamic capabilities offer novel perspectives on the ways companies can navigate and adapt to rapidly changing external conditions, such as CE ecosystems. (Linde et al., 2021, pp. 2-3)

Research has illustrated that developing and mobilizing dynamic capabilities around CE enables firms to bring new sustainable offerings to market. Consequently, for a company concentrating on a CBM implementation, the development of such capabilities is a critical prerequisite for achieving the desired transformation and innovation. (Reim et al. 2021, pp. 2745, 2758) The dynamic capability view emphasizes the importance of an organization's capacity to innovate, expand, and adapt its valuable resources and capabilities over time, ensuring long-term competitiveness and success (Linde, 2021, p. 3). These capabilities and intermediary actions are key to the success of CE initiatives, with systems understanding and innovative thinking being crucial for developing sustainable CBMs (Brenzel-Skowera, 2021, p. 4)

Recently there has been increasing interest in building comprehensive frameworks to understand the development of dynamic capabilities required in CE transition (Parida et al., 2019; Brenzel-Skowera, 2021; Uhrenholt et al., 2022, Saari et al., 2024). Additionally, Kreutzer et al. (2023) conducted a systematic literature review on CE maturity models, thus providing a synthesis of the current stage of academic research in the field. Maturity models

are useful tools for offering a framework of development stages for various objects, showing a path from early stage emerging awareness to full maturity (Kreutzer et al., 2023, p. 667).

Uhrenholt et al. (2022) introduced in their research a capability assessment model called the circular economy maturity reference model to evaluate the level of circular capabilities in a company. The CE maturity reference model offers prescriptive characteristics designed to assist organizations in navigating through a circular transformation. Levels in the model range from none – basic, explorative, systematic, integrative – to highest level of regenerative. Evaluated aspects are value creation, governance, people and skills, supply chain and partnerships, operations, and technology, and finally product and material. At the highest level of maturity, the organization achieves a full separation between value creation and resource usage by adopting an all-encompassing approach to systems.

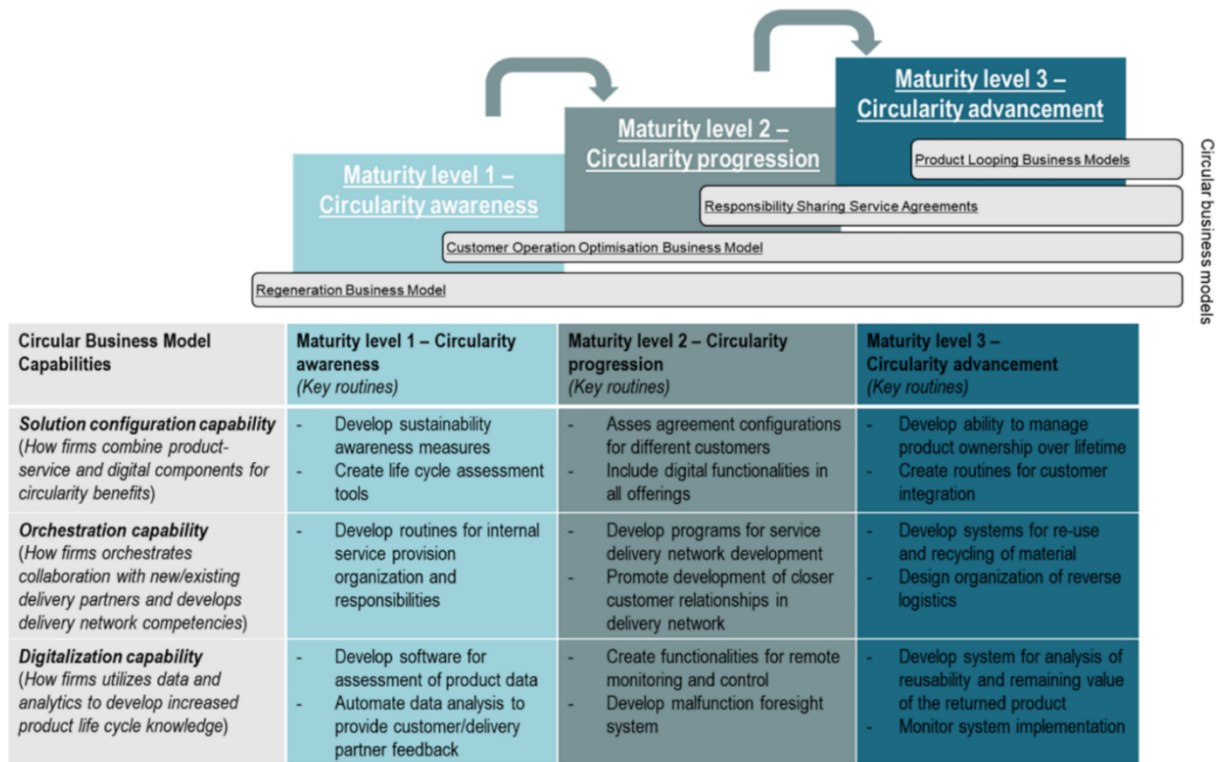
Brenzel-Skowera (2021) proposed that circular capabilities can be evaluated through the implementation of the most favorable circular strategies (R-strategies), as these are hierarchically connected. The classification of organizational maturity levels ranges from initial to managed, defined, quantitatively managed, and finally, optimizing. At the initial level, there is very little environmental awareness, and an understanding of circular strategies is lacking. At the highest level, circular business models are implemented, and a formal environmental management system is established.

Reim et al. (2021) introduced a circular business model capability roadmap, outlining various maturity stages from circularity awareness, through circularity progression, to circularity advancement. This model assesses circular capabilities focusing on solution configuration capability, orchestration capability, and digitalization capabilities.

Maturity level 1 focuses on circularity awareness, achieved as companies transition from regeneration business models to customer operation optimization models. This shift, from concentrating on internal production circularity efforts to optimizing customer operations, necessitates significant capability development. On maturity level 2 businesses move from customer operation optimization models to responsibility-sharing service agreements. Maturity level 3 is characterized by circularity advancement, achieved when companies evolve from responsibility-sharing service agreements to product-looping business models. Advancing to higher CBM levels is highly beneficial but requires comprehensive capability development to be feasible. Figure 3 summarizes the model.



Figure 2 Circular business model capability roadmap (Reim et al., 2021)



Additionally, Parida et al. (2019) proposed a framework for assessing circular economy ecosystems and their actors, highlighting the importance of so-called readiness assessment in transitioning towards CE. This assessment can be used to identify shortcomings in adopting circular practices, allowing managers to acknowledge external information, identify new business opportunities in the circular economy, and evaluate their ability to capitalize on these opportunities. The assessment involves analyzing the existing business model with a focus on value creation, capture, and delivery, and identifying the steps required to embrace transformative circular business models.

Uhrenholt et al. (2022) suggest that the development of businesses' maturity in the circular economy capabilities can be understood through two key principles: expertise and a systems-oriented approach. The principle of expertise involves the establishment of a degree of using strategies and frameworks that streamline organizational efforts in adopting CE practices. When an organization reaches a more advanced stage of maturity, the principles of CE are more extensively embraced. (Uhrenholt, 2022, p. 12) This suggestion would bring together Parida's ecosystem perspective and Brenzel-Skowera's perspective on circular strategies. One example of such circular strategies is the ReSOLVE framework, previously covered in the thesis. A systems-oriented approach is further studied in the following section.

The CBM's rely on new technologies and necessitate changes across all business operations, including product design, resource acquisition, supply chain management, usage, and end-of-life strategies. Thus, companies must adopt a more dynamic approach due to the swift advancements in technology, digitalization, and the principles of the circular economy, which are driving greater industry convergence and extensive industrial change. (Van Eechound & Ganzaroli, 2023, p. 1). Consequently, companies from different industries are investigating novel forms of synergies, alliances, and collaborative approaches that will secure their future competitiveness and sustainable profitability within the context of an ecosystem framework, as identified by Parida et al. (2019). Additionally, the importance of developing capabilities that facilitate and support the achievement of CE objectives is emphasized (Saari et al. 2024, p .1). For example, willingness to experiment and provide novel solutions is crucial to a sustainable CE transition (Evans et al., 2017, p. 603). This brings the recognition of ecosystem capabilities into the focus of the maturity assessment.

In the development CE requirements and creating new products/services for CE, organizations must be open to trying new things and finding innovative solutions, a trait Saari et al. (2024, p. 2) call a general innovation capability. When companies have general innovation capability, they can experiment with new business models (Bertassini et al., 2021, p. 3160). General innovation capability is crucial for enhancing organizational performance and can influence different factors that precede performance, such as an organization's ability to learn. It encompasses both product innovation and process innovation. (Saari et al. 2024, p. 2)

CBMs rely on the network of actors and capabilities for efficient management and knowledge exchange with partners in the network. This networking capability is crucial for harnessing the varied and frequently dispersed knowledge required to develop and market innovative product-service combinations (Teece, 1997, p. 517). Orchestrating capabilities concern the identification of essential assets and potential deficiencies in a company's framework, encompassing the allocation of investments, the coordination of routines, and the deployment of additional resources necessary to capitalize on opportunities. This process also involves aligning co-specialized assets to effectively generate value (Teece et al., 2020, p. 234).

Businesses aiming for CE solutions should establish a sustainability vision and focus on product innovations that provide substantial sustainability benefits (Geissdoerfer, 2017, p. 757). Sustainability should be a core motivator across the organization and integral to the company's value proposition, positioning a sustainability capability as a key dynamic

capability for those targeting CE goals (Bertassini, 2021, p. 3161). Crafting a comprehensive sustainability vision that directs all innovation efforts and effectively communicates sustainability achievements enables companies to showcase their leadership and reduce market and demand uncertainties. Additionally, publicly sharing specific sustainability goals and ambitions enhances awareness and creates a heightened sense of urgency to achieve these objectives. (Linde et al., 2021, p. 3) A company needs to be able to recognize its role as a responsible actor and identify the sustainability impacts of its operations. Recognizing the sustainability expectations of its stakeholders and communicating its activities transparently demonstrates sustainability capability.

Uhrenholt et al. (2022) suggest that enhancements in capabilities for CE transformation can occur simultaneously across various areas, as these improvements mutually reinforce each other. The model adopts a cumulative capability perspective for discussing CE transformation, positing that achieving sustainability goals should not compromise other performance aspects like cost and quality. They propose that transitioning from linear to circular principles is seen as a "brownfield" initiative, one that involves augmenting and building upon the existing capabilities rather than starting from scratch. Circular maturity and systems-oriented maturity are gained simultaneously. This is because the process of systematization and integration of CE principles necessitates the harmonization of operations both within the organization and with external collaborators. (Uhrenholt et al., 2022, pp. 1-4.)

Similarly, Saari et al. (2024, p. 2) state that both CE capabilities and general innovation capabilities are needed. CE capabilities are described as efforts that merge overarching CE objectives, principles, CBMs, and recovery approaches with actionable technical and market-oriented innovations. These capabilities of organizations play a crucial role in facilitating the CE implementation. General innovation capabilities would support the implementation of CE capabilities. Additionally, examining dynamic capabilities within a CE ecosystem can reveal the effective routines and activities that drive innovation success, as noted by Parida et al. (2019, p. 716).

### **2.3.2 Synthesis: CE Ecosystem Capability Maturity Assessment**

This thesis introduces the CE ecosystem capabilities assessment model, a tool designed for evaluating the circular economy and ecosystem capabilities of companies. The proposed model is a synthesis of insights from the breadth of academic research on the circular economy, as outlined earlier in this chapter. It integrates circular economy strategies according to the ReSOLVE framework—a framework that encompasses Regenerate, Share,

Optimize, Loop, Virtualize, and Exchange strategies—and incorporates elements from existing circular economy maturity models. This integration results in a two-part framework aimed at assessing a company's capabilities within the circular economy and its broader ecosystem. The first part of the assessment evaluates a company's capabilities in alignment with the strategies of the ReSOLVE framework, providing a structured approach to operationalizing circular economy principles. The second part focuses on assessing the general ecosystem capabilities essential for thriving within a circular economy, emphasizing the interconnectedness of businesses and the importance of collaborative efforts.

The maturity model proposed follows a 5-tiered scale that categorizes companies' maturity levels as None, Basic, Explorative, Systematic, Integrative, and Regenerative. At the initial level (0 - 'None'), companies exhibit no circular activities. At level 1 ('Basic'), there is a nascent emergence of circular activities. Level 2 ('Explorative') sees organizations beginning to experiment with circular initiatives, aiming to build knowledge and expertise. By level 3 ('Systematic'), these experimental initiatives mature into systematic efforts, integrating circular activities into daily operations with clear responsibilities and structured resource allocation. Level 4 ('Integrative') emphasizes collaboration both within and beyond organizational boundaries, aiming for more efficient and effective circular operations. Beyond this, level 5 ('Regenerative') represents the pinnacle of circular economy engagement, where organizations achieve a transformative role, driving widespread adoption of circular principles.

For each maturity level, drawing on the CE research literature, an expert panel has provided examples of specific tactics or capabilities identifiable at the stages of maturity. These examples are detailed in Table 3 and Table 4 on the following pages.

Table 3 CE capabilities based on the ReSOLVE framework

ReSOLVE	LEVEL 0 NONE	LEVEL 1 BASIC	LEVEL 2 EXPLORATIVE	LEVEL 3 SYSTEMATIC	LEVEL 4 INTEGRATIVE	LEVEL 5 REGENERATIVE
	No awareness, no reaction, no capabilities, ignorance	Emerging awareness, reaction, initiate, must do -attitude	Active, progression, managing, obligation, standard	Established, continuous improvement, smart to do, consistent practices	Intagrated, inspiring, leadership, long-term viability, collaboration	Proactive, advanced, govern, create value, transformative
<b>Virtualize</b>	No action.	Digital services, eg. online shop instead of physical	3D planning or scanning, special applications	IoT, machine learning	Augmented reality, virtual reality	Sharing platforms, artificial intelligence
<b>Optimize</b>	No action.	Monitoring use of raw materials, efficiency improvements, savings in materials and energy	Warranty and maintenance contracts, lean practices in production	Energy efficiency improvements, led lightning, timely production practices	Modular productus, process automation, optimized usage of materials and energy	Forecasting, predictive maintenance, remote sensing
<b>Share</b>	No action.	Spare parts, maintenance, inspection	Refurbishing, upgrade, utilization rate.	Renting, leasing	Re-use, repurpose, add-ons and updates	Take-back, remanufacturing, reverse logistics
<b>Exchange</b>	No action.	Recyclable, less harmful substances	Life cycle thinking	New innovative materials	Wasteless production, harmless substances	3D printing, additive manufacturing
<b>Regenerate</b>	No action.	Waste or sidestreams used in energy production	Biofuels: wood, wood chips, wood pellets	Hydropower, wind power, geothermal heat, solar energy, renewable energy.	Heat recovery	Hydrogen or biogas in energy production
<b>Loop</b>	No action.	Recycling, sorting, waste reduction	Minimization of waste, minimization of loss, reuse of materials	Design for longevity, minimal material usage	Utilization of side streams or waste materials	Return to loop, reprocessing, refilling

Table 4 Ecosystem capabilities

ECOSYSTEM CAPABILITIES	LEVEL 0 NONE	LEVEL 1 BASIC	LEVEL 2 EXPLORATIVE	LEVEL 3 SYSTEMATIC	LEVEL 4 INTEGRATIVE	LEVEL 5 REGENERATIVE
	No awareness, no reaction, no capabilities, ignorance	Emerging awareness, reaction, initiate, must do -attitude	Active, progression, managing, obligation, standard	Established, continuous improvement, smart to do, consistent practices	Integrated, inspiring, leadership, long-term viability, collaboration	Proactive, advanced, govern, create value, transformative
<b>Smart solution capability</b> <b>Perception on company's role a solution provider</b>	The company does not disclose anything which could be interpreted as problem-solving ability. Only products or services are presented.	The company defines itself as a professional supplier or manufacturer. Emphasis is on reliable delivery and modern machinery.	The company defines itself through high quality and emphasizes customer-specific solutions.	The company defines itself as active solution provider. The principle of continuous improvement is mentioned. Skills are emphasized. May use Lean or 5S.	The company defines itself as a pioneer within the industry and mentions innovations or best practices as part of its operations. Transparency is emphasized.	The company defines itself through active agency and clearly describes the challenges it aims to solve with its business. The solution is described broadly.
<b>Network capability</b> <b>Perception on company's role in relation to other actors</b>	The company does not disclose anything from which conclusions could be drawn about its networking ability.	The company describes itself as a reliable actor. Company is described solely based on the company's own activities.	The company describes its operations in relation to a few key customers.	The company introduces its customers and suppliers and describes itself in relation to those.	The company describes its customer and supplier relationships as partnerships and describes its operations in relation to the industry.	The company describes itself in relation to networks or ecosystems.
<b>Sustainability capability</b> <b>Perception on company's role in enabling sustainability</b>	The company does not provide any information which could be interpreted as sustainability capability. Alternatively, it presents incorrect sustainability claims.	The company mentions the environment, natural materials, or the value of nature but does not provide concrete examples of how it considers these aspects in its operations. Mentions compliance with laws.	The company describes using renewable energy. The company mentions monitoring the use of raw materials.	The company describes its operations through optimization, and savings. It highlights domestic production.	The company discusses its sustainability. It mentions EMS or certifications. It mentions emissions or carbon footprint and describes the systematic development of sustainability.	The company clearly states environmental certifications or environmental systems it adheres to. It presents a sustainability report or commitment. EPD's are available.

### 2.3.3 Generative AI and NLP to Assess CE Ecosystem Capabilities

Digitalization plays a crucial role in enhancing CE implementation and solving complex issues with greater forms of control, optimization, and collaboration (Pathan et al. 2023, p. 3). Technologies like artificial intelligence (AI), the Internet of Things (IoT), and Big Data enable more efficient and precise resource management, supply chain transparency, and the development of new business models. (Chauhan et al., 2022, p. 1) Researchers propose that digital technologies, including AI, are capable of executing tasks with greater speed, accuracy and efficiency, offering businesses the essential assistance to adopt CE concepts (Wilts et al., 2021, p. 8) For example, scholars and policymakers interested in observing CE initiatives and resource consumption, along with understanding the effects of these activities, believe AI has the potential to provide valuable insights (Circle Economy, 2024). Chauhan et al., (2022, p. 1) propose that AI holds the greatest potential to influence on the development of CE.

AI covers the creation of computer technologies capable of executing functions traditionally requiring human cognitive processes, such as reasoning or learning (Pathan et al. 2023, p. 9). As Chauhan et al. (2022) summarize in their research, AI tasks may include speech recognition, natural language understanding, decision-making, and visual perception among other possible usages. One of the key advantages of AI is its ability to process and analyze large datasets, identifying patterns and insights that can inform decision-making processes. Thus, AI plays a pivotal role in facilitating the circular economy, greatly assisting with its adoption and practical implementation in real-world scenarios (Pathan et al., 2023, p. 1).

Generative AI is a subset of AI focused on content generation. This form of AI can produce a range of outputs, from text to images, and even music. Generative AI uses sophisticated algorithms designed to produce text that is coherent, contextually appropriate, and frequently comparable to content authored by humans. (IBM, 2023) The applications of generative AI in CE are vast, from generating reports on resource usage to creating educational material that promotes sustainable practices (Circle Economy, 2024). One particularly interesting model in terms of CE and generative AI are large language models (LLMs). LLMs represent a distinct utilization of generative AI, marking a sophisticated advancement in the domain of natural language processing (NLP) which resides at the confluence of computer science, artificial intelligence, and linguistics (Alawida, 2023, pp. 3,18).

NLP occupies a unique position at the crossroads between fundamental science and practical technological applications (Newman-Griffis et al., 2021, p. 4125). Literature on the nexus between CE and NLP is relatively recent, although NLP has already been used in several ways for analyzing large amounts of textual data related to CE, for sustainability reports, regulatory documents, social media discussions, and more, extracting insights that could inform CE strategies and practices, as Borms et al. (2024, pp. 44-45) summarize in their research.

NLP encompasses a range of techniques and tools designed to solve language-related tasks through computing. These tasks include speech recognition, natural language understanding, natural language generation, and machine translation, among others. (Crowston et al., 2012, p. 7) Large language models (LLMs) are one of the most sophisticated outcomes of NLP research and development. LLMs use deep learning algorithms trained on massive datasets to recognize, translate, predict, or generate text.

LLMs have revolutionized the way to process human language data, enabling more accurate translations, summarizations, and content generation (Techopedia, 2024) For example, AI-based tools, leveraging NLP, can automatically classify a company's activities as more or less circular based on their descriptions, thereby providing a dynamic and scalable approach to assessing CE across the economy. This can lead to a more profound insight into the challenges and opportunities businesses face in their transition to more circular practices. (Borms et. al, 2024, p. 52; Circle Economy, 2024)

LLMs are trained on using NLP techniques with vast amounts of text data, and they are designed to handle large datasets of text and a wide array of language tasks, often with a single model (Lipenkova, 2022). This training involves understanding the context within the text, discerning the relationships between words and phrases, and learning from the structure and nuances of language. (Techopedia, 2024) At the heart of LLMs is the transformer model, which uses a mechanism of attention, allowing the model to focus on different parts of the input sequence when producing an output. These models are often referred to as neural networks due to their structure, which is inspired by the human brain's network of neurons. (Alawida et al., 2023, pp. 4-5)

Once trained, LLMs can perform a variety of NLP tasks with a high degree of proficiency. LLMs have pushed the boundaries of what's possible in NLP by demonstrating that a single model can perform a multitude of language tasks without task-specific training. This versatility has led to significant advancements in NLP applications, making it possible to



create more human-like interactions with computers and providing the ability to analyze and understand large amounts of unstructured text data efficiently. (Lipenkova, 2022) LLMs represent a significant leap in AI's ability to handle and generate language data, which is increasingly relevant to the communication and implementation strategies of CE (Circle Economy, 2024).

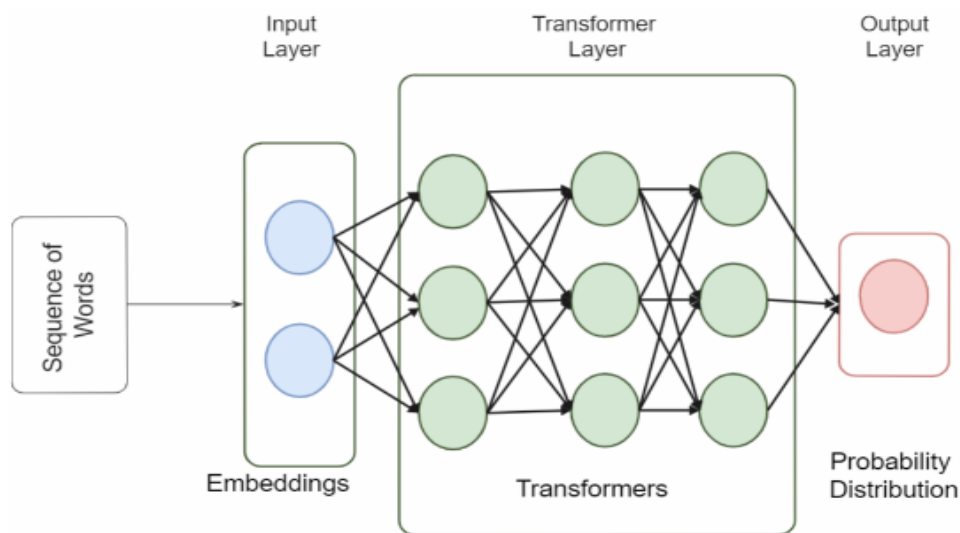
The Generative Pretrained Transformer (GPT) is categorized under Large Language Models (LLMs) and employs deep learning methodologies to generate text closely resembling human output. These models are grounded in the transformer architecture introduced by Google in 2017, as noted by IBM (2023). The term "transformer" in its name derives from this architecture, a type of neural network that utilizes self-attention mechanisms for making predictions. This architecture allows the model to weigh the importance of different words within a sentence or paragraph, leading to more coherent and contextually appropriate text generation. Transformers, particularly via their sophisticated feature known as multi-head self-attention, have showcased the capacity to identify and manage various linguistic elements. This skill stems from their exposure to extensive datasets of human language. (Alawida et al., 2023, p. 5)

The "generative" aspect refers to these models' ability to create content. After being trained on large datasets, they can compose text that closely mimics human-written material. They are "pretrained" because before being fine-tuned for specific tasks, they undergo a general training process on a diverse set of text data. This pre-training enables them to develop a broad understanding of language patterns and contexts. (Alawida et al., 2023, p. 1) ChatGPT is an iteration of the GPT language model technology, fine-tuned to engage in conversational exchanges (OpenAI, 2023). The fine-tuning process with conversational text helps it recognize and replicate the nuances of conversational language. This allows ChatGPT to maintain a coherent flow of dialogue, which is crucial for applications such as chatbots. (Alawida et al., 2023, p. 1)

ChatGPT refines its model through reinforcement learning, where data for comparison is amassed, featuring a variety of model outputs prioritized by their quality. This data originates from dialogues between AI trainers and the chatbot. (IBM, 2023) The initial layer receives a word sequence, transforming it into numerical forms known as embeddings. The embeddings are subsequently passed to the transformer layers, incorporating multi-head self-attention mechanisms and feed-forward neural networks, as detailed by Alawida et al. (2023, pp. 2-3). These self-attention mechanisms allow the model to focus on specific parts of the input when generating responses, while the feed-forward neural networks are instrumental in learning

and extracting features from the input. These transformer layers, arranged sequentially and linked via residual connections, empower the model to discern and abstract features at varying levels. (OpenAI, 2023) Figure 3 shows the basic model used to train ChatGPT.

Figure 3 ChatGPT neural network model (IBM, 2023)



ChatGPT models have been further refined to better understand and generate human-like responses in a chat format. These improvements have included understanding more nuanced queries, maintaining context over a series of interactions, and being more responsive to the conversational cues that typically occur in human dialogue. (Alawida et al., 2023, pp. 2-3) In practical terms, ChatGPT can be used for a variety of applications, including, but not limited to customer service bots, virtual assistants, and tools for aiding writers and researchers. The model's ability to understand and generate natural language text makes it a versatile tool for any task that involves language, from summarizing manifold documents to creating entire articles. (OpenAI, 2024) Following Table 5 summarizes the different tasks ChatGPT can be used for.

Table 5 Applications of ChatGPT (Alawida, 2023)

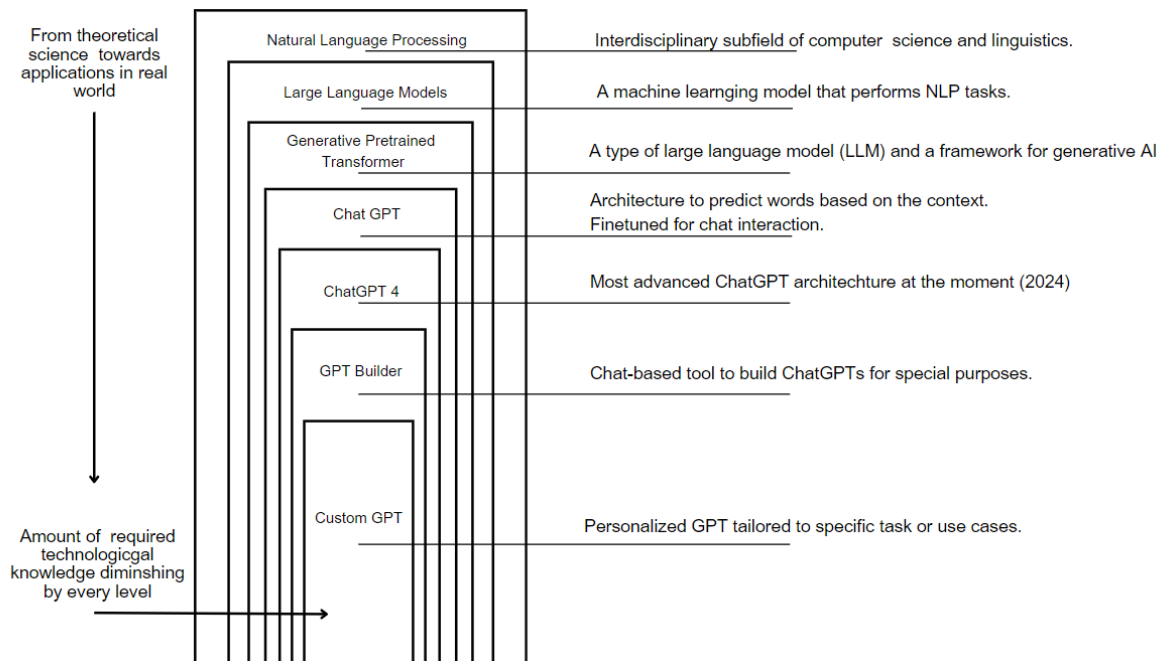
<b>Task</b>	<b>Description</b>
<b>Text Generation</b>	ChatGPT can be used to generate a wide range of text, such as articles, essays, stories, and poetry. It can also be used to generate responses to user input in natural human language.
<b>Question Answering</b>	It can be used to answer questions, such as providing definitions, performing calculations, and providing information on a wide range of topics.
<b>Content Creation</b>	It can be used to generate content for websites, social media, and other platforms. It can also be used to generate product descriptions, reviews, and other types of content.
<b>Language Translation</b>	ChatGPT can be fine-tuned to perform language translation, translating text from one language to another.
<b>Dialog Generation</b>	ChatGPT can be used to generate responses in a conversational context, making it suitable for building chatbots, virtual assistants, and other conversational systems.
<b>Text Summarization</b>	ChatGPT can be fine-tuned to perform text summarization, condensing long text into shorter, more concise versions.
<b>Sentiment Analysis</b>	ChatGPT can be fine-tuned to perform sentiment analysis, analyzing text to determine the expressed sentiment (positive, negative, or neutral).
<b>Text Completion</b>	ChatGPT can be used to complete text. Given a partial text, it can predict the next word, sentence, or even a whole paragraph.
<b>Text Correction</b>	ChatGPT can be fine-tuned to perform text correction, rectifying grammar, spelling, and punctuation errors in the text.

The development of ChatGPT has been rapid. In November 2022, the domain of GPTs was enriched by the introduction of ChatGPT version GPT-3.5 by OpenAI. Subsequently, in early 2023, Microsoft's integration of ChatGPT into Bing search functions signified a pivotal point for mainstream platform adoption. By February, these capabilities were manifest in Bing, underscoring the utility of AI in consumer technology. The advent of GPT-4 in March 2023 marked another milestone, offering ChatGPT Plus subscribers a robust model capable of managing more nuanced tasks and supporting a more extensive conversational context. In July 2023, the beta launch of custom instructions afforded users granular control over the AI's interactive responses. This feature was complemented by a code interpreter, enhancing ChatGPT's operational versatility. (Alawida et al., 2023, OpenAI, 2024; IBM, 2023)

The stride toward technological democratization was further exemplified in late 2023, with the introduction of the GPT Builder—enabling user-generated custom ChatGPT models—and the GPT Store, which fostered a marketplace for these innovations. This timeline reflects ChatGPT's rapid evolution, its significant impact on technology and society, and OpenAI's commitment to enhancing its capabilities (OpenAI, 2023). The platform's development has not only advanced the state of AI but has also spurred discussions on ethics, copyright, and the regulatory environment surrounding generative AI technologies. Moreover, the broader implications of ChatGPT's development have led to widespread adoption across industries, reshaped public perceptions of AI, and prompted multiple organizations to accelerate their AI initiatives. As ChatGPT continues to evolve, it's poised to further transform the landscape of

digital interaction. As ChatGPT's functionalities continue to expand, the anticipation for more autonomous integrations and applications grows, signifying a transformative phase in AI's role within the technological paradigm. (Alawida et al., 2023, pp. 11-12) This makes it a particularly interesting tool to utilize in the thesis as well. The following Figure 4 summarizes how these different concepts are related to each other. Moving from theoretical science towards real world applications, the amount of required technological knowledge diminishes, thus allowing larger audiences to utilize these technological advancements.

Figure 4 Custom GPTs are evolving from computer science and linguistics



Integrating AI and NLP into the circular economy presents transformative opportunities but also significant challenges. Data privacy emerges as a critical issue, with the need for extensive data collection raising concerns over sensitive information security and regulatory compliance. The success of these technologies largely depends on access to comprehensive datasets reflecting complex supply chains and sustainability practices, a task complicated by the data's often proprietary nature and fragmentation. Additionally, the potential for training data biases poses a risk of skewed decision-making, potentially disadvantaging certain materials, suppliers, or practices, thus threatening fair CE development. (Alawida et al., 2023, p. 18; Pathan 2023, pp. 13-14).

Mitigating these biases requires meticulous data management and the creation of transparent, explainable models. Their development has led to remarkable improvements in

the accuracy and efficiency of NLP applications, impacting a wide range of industries and fields, including the circular economy. The literature at the intersection of CE and NLP is growing, reflecting the increasing application of NLP techniques in this field. Research on this subject is in its infancy, but practitioners have explored how NLP can support the identification and classification of circular activities across different sectors, analyze the communication strategies of companies engaging in CE, and even assess the impact of such strategies on economic performance.

In conclusion, AI and LLMs are two cornerstones of modern computational technology with profound implications for various sectors, including the circular economy. Custom GPTs represent the pinnacle of machine learning and natural language processing capabilities, designed to interpret, predict, and generate human language with a degree of sophistication that is continually advancing. Custom GPTs represent a giant step forward in the quest to enable computers to understand and generate human language. Thus, advances in these subfields of computer science are significantly aiding CE by improving the understanding of how businesses implement circular activities.

### **3 Methodology**

This section of the thesis outlines the methodological framework employed in the development and implementation of the CEULA - Circular Economy Uptake Assessment Tool. CEULA is designed to be a solution to enhance the systematic assessment of circular economy and ecosystem capabilities within CE ecosystems. Recognizing the complexities of evaluating circular economy readiness and the absence of suitable tools in the field, the thesis aims to solve the problem stemming from the real-world context.

The thesis adopts a Design and Development Research (DDR) approach, underpinned by Reeves' Design-Based Research Model (2006). This methodology was chosen for its practical applicability and its emphasis on creating tangible, innovative solutions to real-world problems. In the following sections research strategy, realized research process and data collection are discussed in more detail.

#### **3.1 Research Approach and Strategy**

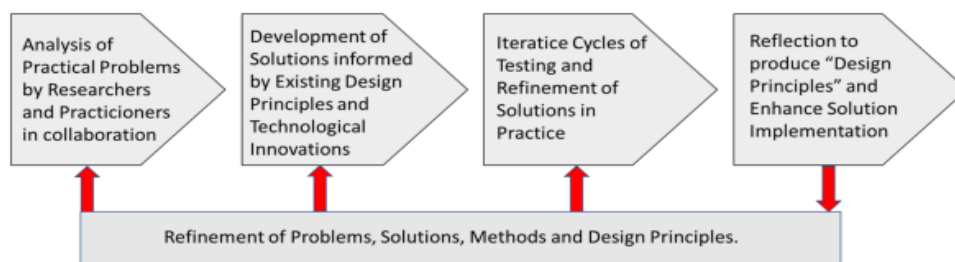
The thesis is grounded in applied research discipline. Applied research prioritizes practical results, leveraging insights from fundamental research to create innovative solutions or tools

for specific issues (National University, 2023). This approach is particularly common in Research and Development (R&D) departments within universities of applied sciences, where the goal is to transform academic findings into real-world applications, thereby acting as a catalyst for innovation, economic growth, and societal improvement. The alignment of this thesis with the objectives of the Seinäjoki University of Applied Sciences Riihi RDI project underscores the relevance of its research discipline.

Applied research has its own variety of methodologies to choose from. This thesis uses Design and Development Research (DDR) as a methodological framework. DDR is used in applied research in various fields, including education, information science, and technology development, aimed at producing new knowledge, processes, solutions, or products through iterative design and evaluation. It focuses on addressing practical problems by designing and implementing innovative interventions and evaluating their impact. This approach is particularly relevant in disciplines where the goal is to create artifacts or systems that can be directly applied to solve real-world problems. (National University, 2023) The CEULA assessment tool provides an example of such an artifact.

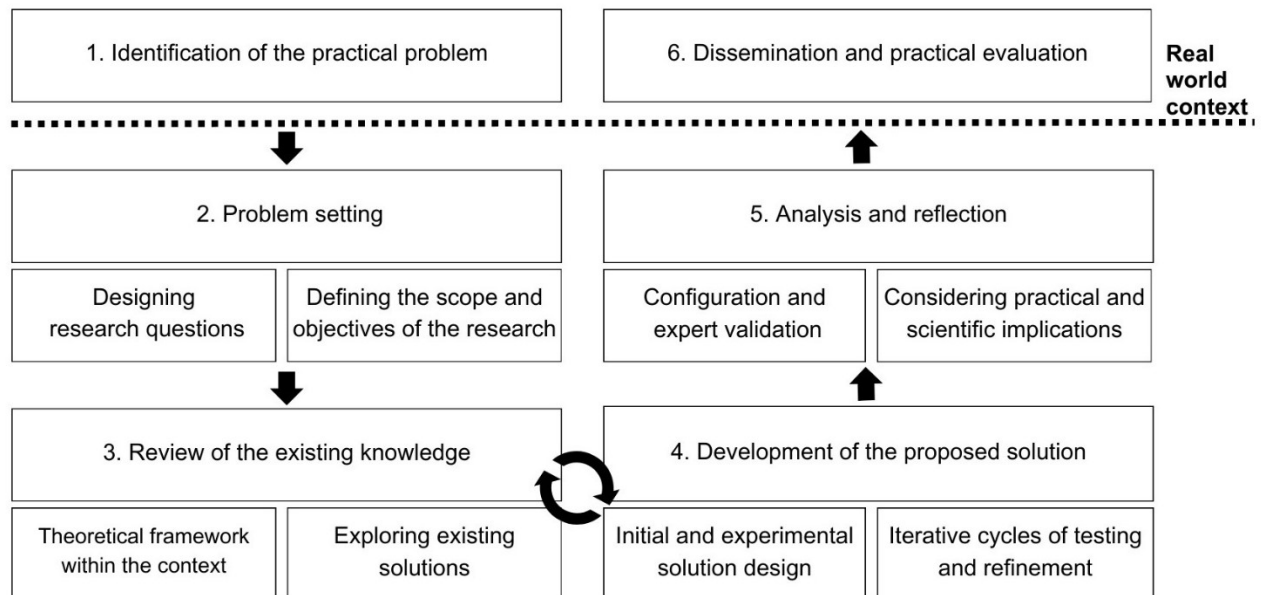
DDR is characterized by its iterative, cyclical nature, involving phases of analysis, design, development, implementation, and evaluation. Design and Development Research is described as a “systematic study of design, development, and evaluation process with the aim of establishing an empirical basis for the creation of instructional and non-instructional products and tools and new or enhanced models that govern their development.” (Richey & Klein, 2014, p. 22). One example of design and development research model is Reeves (orig. 2000, revised 2006) Design-Based Research Model (DBRM), which initially provided a four-stage model for educational technology development but has since gained significant interest in other fields with similar real-life problem-based solution development needs. The stages were 1. Analysis, 2. Development of solutions, 3. Iterative cycles of testing and refinement, 4. Reflection. Figure 7 below shows the original Reeves’ process model.

Figure 5 Design-Based Research Model (Reeves, 2006).



The research strategy of this thesis is built upon the DDR methodology and Reeves' Design-Based Research model. The systematic research process includes the following phases: 1. Identification of the practical problem; 2. Problem setting; 3. Review of the existing Knowledge; 4. Development of proposed solution; 5. Analysis and Reflection and 6. Dissemination and practical evaluation. The process model describes a structured approach to conducting research, particularly within an applied science context and emphasizes the connection between theoretical research and practical application. The following Figure 6 presents the cyclical nature of the research process in the thesis work and its relation to real world context, typical of DDR methodology. Additionally, research strategy breaks Reeves' process model into more detailed phases, which benefits the transparency of the development process and thesis work.

Figure 6 Research strategy based on Reeve's (2006) development research model



Research begins with the first phase, where the real-world issue that requires a solution or further investigation is identified. Once the problem is identified, corresponding research questions are designed. By finding answers to the designed research questions, the original identified problem could be solved. The research scope and objectives for the thesis are then matched to the research questions. By defining the scope and objectives of the thesis, what it will cover and what it aims to achieve, it is ensured that the research stays within the planned focus area and timeframe.

Once the original practical problem is clearly mapped, research questions formulated and scope decided, review of the existing knowledge is conducted in the third phase of the research process. This step is critical for grounding the research in existing literature and involves academic research of circular economy, capabilities, and circular economy ecosystems. Based on academic literature, mainly peer-reviewed articles and policy publications, a theoretical framework within the context is created. Additionally, there is a need to explore existing solutions to understand what has been tried before, what gaps or opportunities exist, and what novel tools could benefit research work.

After reviewing the existing theoretical and practical knowledge, the development of the proposed solution begins. Initial solution design is considered, and iterative cycles of testing and refinement are continued until satisfactory results are achieved. Then, in the Analysis and Reflection phase, proposed solution is validated by expert panel from Riihi RDI project personnel, and practical and scientific implications are discussed in detail to further understand the applicability of the proposed solution. Finally, the process ends to real world context, where the solution is disseminated, and practical evaluation starts. By following this research strategy, thesis aims to create a viable solution to the acknowledged real-world problem. Documenting the entire research and development process ensures the transparency and repeatability of the proposed solution.

### **3.2 Realized Research Process**

Research followed the planned research strategy. At first, the real-world problem was identified. Targeting the practical challenge of the scarcity of tools for efficiently assessing the visible circular economy and ecosystem capabilities of companies, the primary objective of the thesis was to design and conduct a case study focused on the development process of tools to systematically identify and analyze business actors and their CE and ecosystem capabilities. To propose a solution to this identified problem, research questions were formed, and the scope of the research was defined. The research questions and scope are presented in detail in section 1.3. Research Questions and Scope.

By emphasizing applied research, the thesis then connected theoretical insights from the circular economy with real-world applications of generative AI. As mapped in the research strategy, academic peer-reviewed articles from well-known academic journals and policy publications were used as a main source of the literature review. These were accompanied by selected research handbook articles and conference papers to form a comprehensive

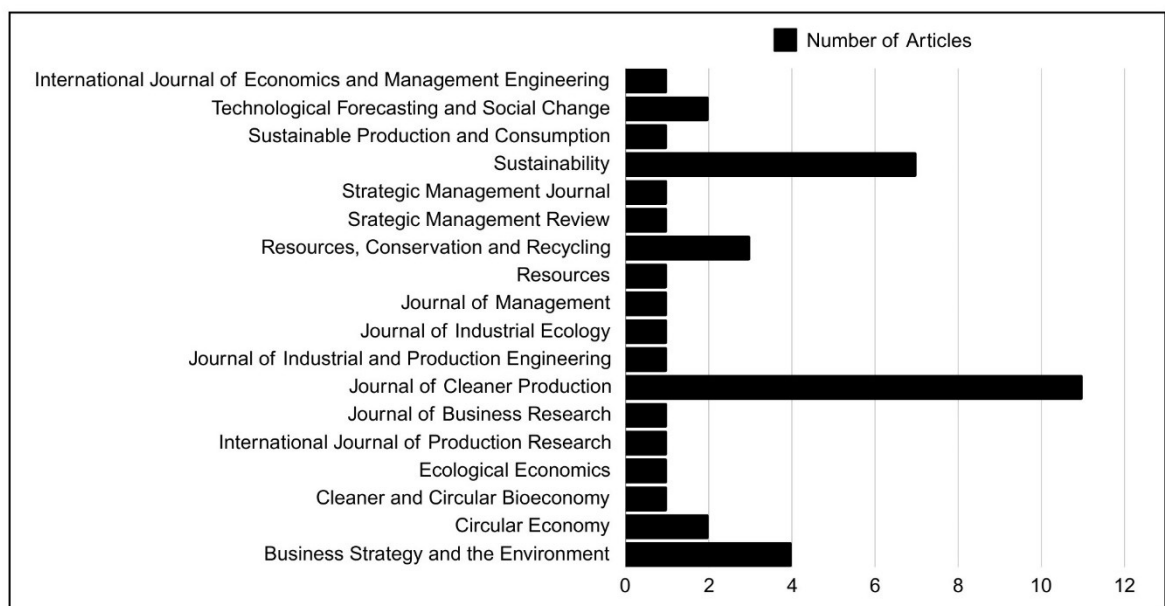


theoretical understanding of capabilities and strategies related to circular economy and acting in ecosystems.

To establish a comprehensive knowledge base on CE capability framework, overall, 48 academic articles in the field of circular economy, particularly in themes of CE ecosystems, circular business models and circular capabilities were screened. Three policy publications by the Ellen McArthur Foundation and one conference paper were used to gather. It should be noted that Sustainability has been considered possibly predatory journal since year 2023 by Finnish Publication Forum, as issues of peer-reviewing process transparency have been reported.

After thorough assessment, seven academic articles from Sustainability were used as source material. Most of the articles, eg. articles by Levandowski (2016), Bocken (2019), and Nußholz (2017) are widely cross-referenced in academic literature of CE and thus can be considered as reliable sources. Additionally, the more currently published articles, e.g. articles by Brenzel-Skowera (2021) and Konieczko et al. (2020), were considered as reliable sources, as they were authored or co-authored by established academic researchers and the articles have been cited in high-quality journals. Figure 7 describes how different academic journals are presented in the source material.

Figure 7 Academic journals presented in the source material



The initial research strategy did not incorporate the use of generative AI. However, in 2023, the emergence of ChatGPT by OpenAI gained significant attention, bringing AI tools to a wider audience. This prompted exploration of ChatGPT's potential as an AI-assisted assessment tool. Despite being relatively new, ChatGPT stood out for its widespread adoption and affordability, making it a feasible solution for experimental purposes. Nevertheless, leveraging ChatGPT required significant research effort due to the evolving nature of the field.

The understanding of generative AI applications and their relevance to the circular economy context was largely drawn from practitioner sites and developer documentation, as academic research on this subject is still emerging. For example, academic literature on ChatGPT is limited and struggles to keep up to date, requiring reliance on practitioner insights to grasp its utility. This phase primarily focused on grasping the technical evolution and best practices for creating assessment tools utilizing generative AI, which in turn necessitated an understanding of natural language processing (NLP). Thus, both academic and practitioner literature were screened. This foundational knowledge formed the theoretical framework for the CEULA tool development project. The framework is presented in section 2.3 in the thesis.

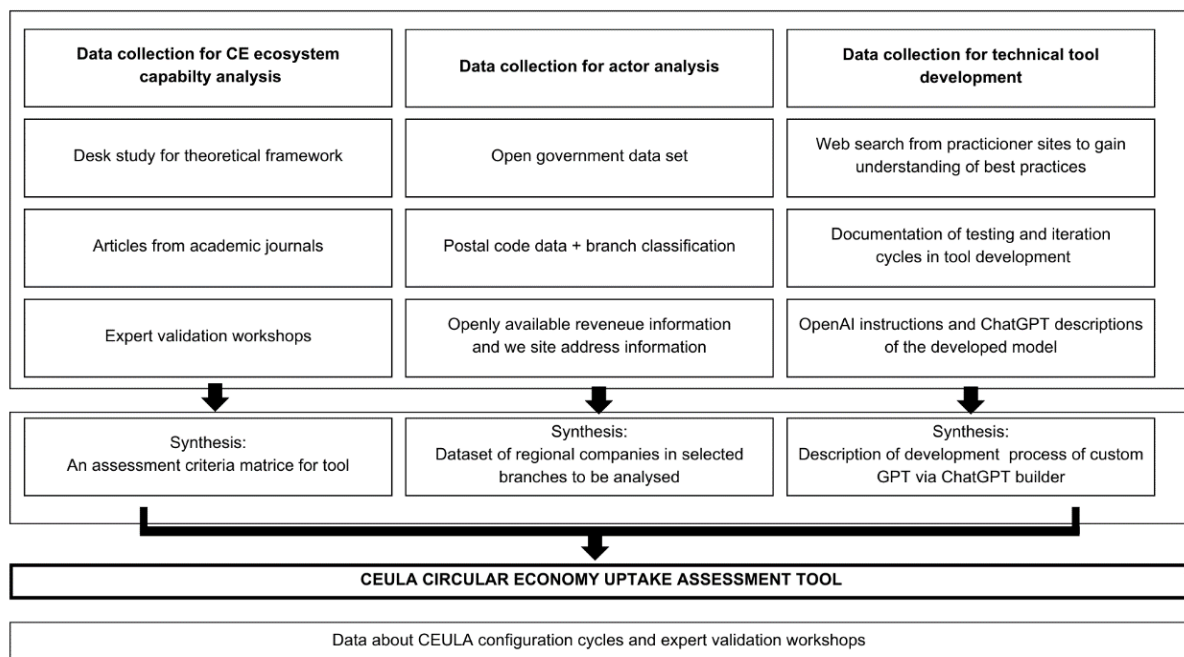
Following a comprehensive literature review, the CEULA concept was presented to a 3-person panel of circular economy experts of Riihi project, sparking in-depth discussions on synthesized findings. Subsequently, the proposed solution underwent further design and testing in phase four. This involved improving solution design and multiple experimental cycles to ensure ChatGPT's responsiveness and operational capabilities. Results were systematically compared with the knowledge base, and iterative testing and refinement cycles were conducted based on feedback and process outcomes. This phase will be further discussed in the following section covering data collection and data analysis process.

The process continued with configuration and adjustments to fine-tune CEULA's parameters for optimal performance, addressing any identified issues during initial testing. Subsequently, rigorous validation cycles were conducted by RDI team members associated with the project. This validation involved generating CEULA assessments for selected case companies, replicating assessments for each company to ensure consistency, and comparing them with manually performed assessments. Once CEULA passed testing and consistently produced systematic results, the project transitioned to a phase focused on comprehensive analysis and reflective evaluation of the process model. This stage included targeted configuration adjustments and in-depth validation by project experts to ensure the solution's viability.

### 3.3 Data Collection and Analysis

For applied research in general, data collection methods often span from secondary research, which entails reviewing existing information like statistical databases, records, research articles, and books, to primary research techniques such as observing specific populations or processes, conducting surveys and interviews, and occasionally organizing focus groups (Richey & Klein, 2014, pp. 56–58). In this thesis there are three distinct streams of data collection, each contributing to a different aspect of CEULA tool development. In the first phase of data collection from research articles, practitioner materials and expert opinions were collected to shape a set of criteria for assessing circular economy practices effectively. This stream of data collection was discussed in the previous section, and in this section the data collection for actor analysis is explained in detail. Figure 8 below shows three streams of data collection.

Figure 8 Three streams of data collection for the development work.



Most of the data sources have been established for non-circular purposes, yet many of those data sources that are created, collected, and processed in Finland can also be exploited from the perspective of the circular economy (Kauppila et al, 2022, p. 32). Information regarding prosperous CE business actors in the South Ostrobothnia region was collected using publicly

available government data. The main source utilized for this detailed analysis was data from the business register provided by the Finnish Patent and Registration Office (PRH).

As stated in the web page <https://avoindata.prh.fi/>: *“Open data interface provides data from the Finnish Business Information System (BIS) maintained by the PRH and the Finnish Tax Administration. Data is available about the following company or business types: limited liability companies, public limited companies, housing companies, co-operatives, insurance companies, or public insurance companies. In addition to basic details of businesses or companies registered at the Finnish Trade Register, the service also provides information on other registers they have been added to the Prepayment Register, the Employer Register, the VAT Register, the register of bodies liable for tax on insurance premiums, and the Client Register of the Tax Administration.”* Government research institutes and administrations gather data from diverse sources or utilize their own resources to collect data for specific purposes. While a significant volume of open data is automatically collected through measuring instruments, stakeholders also manually input data into registries (Kauppila et al. 2022).

The process of collecting the required business data was rather uncomplicated as the data was provided in .csv file format instead of an interface. This experimental format of open governmental data sharing was freely loadable on the [avoindata.fi](https://avoindata.fi) website. Details on how this data was further processed are discussed in the development work section, underscoring its critical role in the development of the tool. The following Figure 9 presents a snippet from the site information.

Figure 9 Open government data source information

Collection	Open Data
Maintainer	<a href="#">Patentti- ja rekisterihallitus</a>
Maintainer email	<a href="mailto:avoindata@dvv.fi">avoindata@dvv.fi</a>
Maintainer website	<a href="http://www.avoindata.fi">www.avoindata.fi</a>
Links to additional information	<a href="http://avoindata.prh.fi">http://avoindata.prh.fi</a>
Geographical coverage	<a href="#">suomi</a>
Update frequency	
Valid from	18.08.2017
Last modified	25.04.2023 <a href="#">Show change log</a>
Created on	18.08.2017

The data, captured in April 2021, excludes the most recent company information, and is confined to limited liability companies. This data limitation was deemed acceptable considering that the limited liability company is the most prevalent business structure, and the most significant businesses in terms of resources and capabilities have typically been operational for more than two years. An expert assessment confirmed that the selected dataset offers a thorough perspective on companies within the South Ostrobothnia region.

The final master data contained information about 9846 limited companies in total, representing 56 % of the total 17 538 companies in all forms, including open companies, sole traders, limited partners, and cooperatives. There is no available data on the of number of companies in each different company form in the South Ostrobothnia region, but the percentage would indicate that that limited liability companies located in the region are comprehensively presented in the data. The following snippet presented in Figure 10 shows different datasets in .csv format available on the site. Documentation of how this open government data set was processed and utilized is discussed in more detail in the section.

Figure 10 Open government data files available for download



	<a href="#">2021-02-15_full_prh_data.csv</a> Popular	<a href="#">DOWNLOAD</a>
	<a href="#">2021-03-14_full_prh_data.csv</a> Popular	<a href="#">DOWNLOAD</a>
	<a href="#">2021-04-13_full_prh_data.csv</a> Popular	<a href="#">DOWNLOAD</a>

Additionally, the documentation of experimenting with ChatGPT forms a crucial component of this thesis's data collection. The exploration of ChatGPT's methodologies and the rationale for its design primarily relied on information obtained from various online practitioner sources, reflecting the novelty of the subject and the absence of contemporary academic literature on its most recent enhancements and capabilities. Testing was documented and this forms a stream of data for the thesis. The pace of development for ChatGPT was so swift that information compiled within a week could become obsolete, given its evolution towards greater user accessibility and reduced coding requirements. This rapid rate of change suggests that certain sections of the thesis may be outdated by the time of its release, serving as a testament to the dynamic nature of this field.

In essence, the entire data collection process was designed to collect a mix of theoretical knowledge, expert insights, and illustrative real-life data from various sources. This

comprehensive approach ensures the assessment tool is robust, relevant, and capable of assessing the adoption of circular economy practices with accuracy. The CEULA tool is anchored in a theoretical framework derived from prior academic work on circular economy and ecosystem capabilities and aims to bridge the gap between academic research and practical application in the business world.

### **3.4 Ethical considerations**

The research utilizes ChatGPT's ability to search for information and data directly from a webpage. This can be compared to web scraping, which involves many ethical questions. When scraping websites, it's crucial to consider the privacy of individuals whose data might be collected. This includes adhering to data protection regulations such as the General Data Protection Regulation (GDPR) in Europe. This research conducted data gathering in a way that no personal information was gathered and thus no data under GDPR regulation was gathered to ensure no privacy violations were done. Additionally, no complete web page data was collected, but the analysis was conducted based on the web page texts.

Open government data provides a vast amount of company data in structured format. By scraping publicly available information about the website address or revenue information, no privacy is violated. However, it's important to highlight that some data providers monetize this information, such as revenue figures, by intentionally placing it on "business directory pages." This strategy aims to prevent easy mass access, allowing them to offer this information as a separately purchasable service. By engaging in web scraping of these directory pages, there's a slight chance that the original business opportunities intended by these data providers could be compromised. Nonetheless, data providers have chosen to make this information freely available on the internet without imposing usage restrictions.

The advancement of AI and natural language processing (NLP) technologies offers transformative potential for analyzing data to identify actors and their CE ecosystem capabilities. However, this potential comes with substantial ethical responsibilities to ensure the privacy, fairness, and transparency of the thesis' approach to analyzing and visualizing CE capabilities. As the application of AI and NLP technologies in research broadens, the imperative to navigate these technologies responsibly, ensuring equitable outcomes and the protection of privacy, becomes paramount. This section integrates an analysis of bias, privacy concerns, misinformation risks, and the necessity for user consent and transparency within NLP research frameworks.

A key characteristic of large language models (LLMs) is their lack of understanding regarding the truthfulness of information; rather, they gauge what is statistically probable to be mentioned. This attribute can result in the generation of sentences or code completions that are not necessarily the best or most accurate. When LLMs are used to find information, they often give just one answer. This can be problematic because it makes it seem like they have the final say or definitive knowledge on the subject, which isn't always the case.

It's recognized that models can inherit or even amplify biases present in their training data, which can compromise the fairness and neutrality of their outcomes. Ensuring that models do not perpetuate or exacerbate existing societal biases was a fundamental ethical priority. The quality and representativeness of the data also played a critical role. The performance and reliability of the model are significantly influenced by the diversity and quality of the training data used. A lack of representativeness in the data can lead to irrelevant or unpredictable outputs, underscoring the need for careful data selection and preprocessing.

Given the inherent complexity and ambiguity of natural language, ensuring consistent understanding and generation of language by the model presented a substantial challenge. This complexity makes it difficult for models to always interpret or generate language accurately, highlighting the importance of sophisticated modeling techniques to better handle linguistic nuances. The model's ability to generalize from the training data to unseen examples was another crucial consideration. Limited generalization capabilities can affect the model's predictability and usefulness in real-world applications, emphasizing the importance of robust model design and validation methods.

As language changes over time, maintaining the model's relevancy and effectiveness requires ongoing updates and adaptations. Finally, the susceptibility of models to adversarial attacks, where small, deliberate changes to input data can lead to incorrect outputs, was a significant concern. Ensuring the robustness of the model against such attacks is crucial for maintaining its predictability and reliability. Addressing the challenges posed by language complexity and ambiguity requires ongoing research and development efforts to improve model robustness and understanding. The following Table 6 provides a summary of key ethical considerations in the thesis.

Table 6 Main ethical issues of the thesis

Ethical Issue	Description	Consideration
<b>Predictability and Generalization of the Assessment</b>	The performance and predictability of model are influenced by the quality and diversity of the training data. Lack of representativeness can lead to irrelevant or unpredictable outputs. Model can inherit or amplify biases from its training data, affecting the fairness and neutrality of outcomes.	To assure predictability and fairness, several validation cycles were conducted when testing the tool, and the results were checked by expert panel. However, this would require larger amount of test cases to ensure the predictability on more rigorous actor pool.
<b>Transparency of Provided Assessment</b>	There should be transparency about the limitations and capabilities of ChatGPT in assessing websites. The tool may not perfectly interpret nuanced expressions, which could affect fairness in assessment. The "black box" nature of the LLM model makes it difficult to understand why specific predictions are made, complicating the predictability of outputs.	This ethical concern cannot be completely resolved; instead, it must be clearly communicated that the provided tool is not exhaustive and does not assess the real-life capabilities of various actors. It serves primarily to grasp the broad differences among multiple actors at a basic level. Furthermore, it's essential to emphasize that the analysis represents merely the result of an algorithm, not an absolute truth.
<b>Privacy and Data Protection of Actors</b>	When scraping websites, it's crucial to consider the privacy of actors whose data might be collected. This includes adhering to data protection regulations such as the General Data Protection Regulation (GDPR) in Europe.	No personal data was gathered. All data is business related. Revenue information and web page address is freely available. No complete web pages or parts of the sites were gathered, only used as a direct source for the semantic analysis.
<b>Language Complexity and Ambiguity</b>	Natural language's inherent complexity and ambiguity make it challenging for models to consistently understand and generate language predictably.	Continuous monitoring and updating of the model based on real-world usage and feedback is done to ensure that tool operates as planned.

Throughout the thesis work, these ethical considerations were addressed through careful design, rigorous testing, and ongoing evaluation to develop an NLP model that is not only effective but also fair, transparent, and resilient. Addressing the ethical challenges posed by AI and NLP technologies requires a comprehensive approach, incorporating ethical frameworks, regulatory oversight, and the development of technological safeguards. Transparency in the use of AI, along with education and awareness-raising among the public, is essential in mitigating the risks associated with these technologies.

#### 4 Development work: CEULA – AI-driven CE Ecosystem Analysis

The aim of the thesis was to present a process model and set of tools to identify circular economy ecosystem actors and assess the visible ecosystem capabilities of those identified actors. To meet this aim, the CEULA (Circular Economy Uptake Level Assessment) process model and set of tools were designed. The CEULA process model and tools were particularly



created to assist CE ecosystem orchestrators in identifying companies that exhibit a strong potential for circular economy practices in the South Ostrobothnia region and to assess the capacity of identified actors to serve as foundational members of the circular economy ecosystem. The systematic process model is two phased. At the first phase actors are systematically identified and in the second phase these identified actors are assessed based on the CEULA assessment model. The subsequent sections offer a comprehensive examination of the CEULA process model's development and implementation.

## **4.1 Phase 1: Actor Identification**

Phase one can be divided into seven process steps, resulting in listings of systematically identified actors in selected business lines. The development process started by selecting open government data from the Finnish Trade Register (Finnish business register) as the main data source to systematically identify business actors within the region. The terms and conditions of use and licenses of open data guarantee the data producer the right to be mentioned as source and the user to be sure of the origin of the data. There are no other conditions restricting use. (Digital and Population Data Services Agency, 2021)

Because of multiple considerable benefits, such as easy accessibility and comprehension of a dataset, Finnish business register data was selected as main source of data. The role of open data was further discussed in the data collection section of the thesis, and this section describes in detail, how the data preparation process was done, as one aim of the development work was to provide a concrete example how open government data could be utilized in a business setting. The dataset was downloaded as a .csv file and then converted to an Excel format by using the text-to-columns feature in Excel. The following sections explain in detail how the data processing was done.

### **4.1.1 Regional Actor Master File Data Preparation**

The original Finnish Trade Register dataset contains the following information: Business Identity Codes (Business IDs), company names, company forms, business line codes, business line names, date of registrations, places of registered office (home municipalities), or municipalities where the companies are managed, postal codes, postal addresses and/or street addresses and liquidation information. Initially, the dataset included companies from all over Finland. The dataset originally contained more than 330 000 rows of company information which made the file very heavy to use in further analysis. As there was a need to

analyze only companies located in the South Ostrobothnia region, these companies were isolated from the original dataset. This extraction was done using the ChatGPT data analysis feature.

The original full\_PRH\_data 2021 file was too large for ChatGPT to be analyzed at once. The original Excel file was manually divided into three approximately equal-sized chunks of data, each containing about 110 000 rows of data. These files were then attached to ChatGPT one by one. The simplest way to identify actors located within a certain region was to search for them based on the postal code. This information was provided in the original dataset and thus could be used to extract regional actors from the data mass. A comprehensive listing of postal codes used in the South Ostrobothnia region (or any region in Finland) is freely available on the internet and this listing was used as a tool to extract all regional actors from the original dataset. A listing of regional postal codes was provided in the ChatGPT chat window. The prompting was as follows:

*“From the provided source file, extract rows containing the given postal codes. Look for column postal\_post\_code to find a match. Postal\_post\_code contains this kind of information: 66300, 60100, 62100, 61800, 63610. Here is the list of postal codes to be searched: 62900 62730 63540 62940 62740 62710 63500 63510 62920 62830 63530....”*

To keep the prompt as simple as possible, the prompt tells ChatGPT to extract rows. This provides ChatGPT with the idea that entire information set of each row should be extracted, but there is no need to use resources to analyze data in different columns further. To help ChatGPT find the correct column to match data with, the name of the column is provided in the prompt. However, at the first trials, ChatGPT struggled to identify postal numbers even when the column name was provided in the prompt. This problem was solved by giving an example of data in the column. Then the entire list of 183 different postal codes was pasted into the chat window. This was done to each of three files and ChatGPT provided a new Excel file with extracted rows. The following Figure 11 provides an example of how ChatGPT provided the new file to be downloaded.

Figure 11 ChatGPT's download the file message



**ChatGPT**

I've isolated the rows containing the specified postal codes and saved them into a new file. You can download it using the link below:

[Download the filtered file \[->\]](#)

The following Figure 12 shows that the file ChatGPT provided follows the original data format yet contains only companies from the South Ostrobothnia region. As part of the development process the results of the extraction were manually verified to ensure the robustness of the extraction. Results showed that ChatGPT conducted extraction flawlessly.

Figure 12 ChatGPT data extraction example

company_name	business_id	postal_address	apu	postal_post_code	postal_city	street_address	street_post_code	street_city
NYQS Oy	2011502-4	Rengastie 44	Seinäjoki	60120	SEINÄJOKI	Rengastie 44	60120	SEINÄJOKI
Pakko jaksaa O.N	2036393-3	Litsellintie 2	Lapua	62100	LAPUA	Litsellintie 2	62100	LAPUA
iTive Oy	2075308-5	Teknologiapuisto	Kauhajoki	61800	KAUHAJOKI	Piililänkuja 21 as.	61800	KAUHAJOKI
Prinkkilä Oy	2023742-7	Salonkyläntie 592	Alavus	63610	TUURI	Salonkyläntie 592	63610	TUURI
Seiverkot Oy	2083762-5	Varastotie 5	Seinäjoki	60100	SEINÄJOKI	Varastotie 5	60100	SEINÄJOKI
PME-Control Oy	2061463-2	Luhtatie 4 A 3	Kurikka	66300	JURVA	Viitaharjuntie 4	66300	JURVA
Esteko Oy	2065653-3	Ylisentie 1 C 8	Seinäjoki	60100	SEINÄJOKI	Ylisentie 1 C 8	60100	SEINÄJOKI
Pekmet Oy	2030251-6	Karhukorventie 2	Vimpeli	62860	SAHI	Karhukorventie 2	62860	SAHI
KNA Corporation	2069850-6	Keskuspuistikko 2	Kurikka	61300	KURIKKA	Keskuspuistikko 2	61300	KURIKKA
Finnlanka Oy	2075154-9	Mäenpääntie 190	Kauhava	62200	KAUHAVA			
Jurvan Kalusteput	2019277-5	Larvatie 60	Kurikka	66300	JURVA			
Raikos Oy	2076947-4	Kannaksenkatu 1	Seinäjoki	60120	SEINÄJOKI	Kannaksenkatu 1	60120	SEINÄJOKI
Kuntosali Taku Oy	2084010-3	Ostolantie 15	Ähtäri	63700	ÄHTÄRI	Ostolantie 15	63700	ÄHTÄRI
MP-Viihde Oy	2074905-1	Asemankatu 3	Lapua	62100	LAPUA	Asemankatu 3	62100	LAPUA
Mäkelä Forest Oy	2061277-6	Havukaskentie 21	Lappajärvi	62630	KARVALA			
Saranperä Oy	2048088-1	Soinintie 77	Seinäjoki	60550	NURMO	Soinintie 77	60550	NURMO
Rioxx Finland Oy	2040977-8	Puuttomankoski	Seinäjoki	60200	SEINÄJOKI	Kalevankatu 14	60100	SEINÄJOKI
Juustoportti Oy	2065563-7	Meijeritie 3	Kurikka	61600	JALASJÄRVI			
Aortae Holding O	2030580-5	Toritaival 14 A 3	Seinäjoki	60200	SEINÄJOKI	Ludviginkatu 3-5-	130	HELSINKI
JL Metals Oy	2047885-3	Leppäläntie 566	Kuortane	63120	LEPPÄLÄNKYLÄ	Leppäläntie 566	63120	LEPPÄLÄNKYLÄ
Milnet Oy	2081130-2	Yrittäjätie 16	Ähtäri	63700	ÄHTÄRI	Yrittäjätie 16	63700	ÄHTÄRI
Myllly Papat Oy	2030288-2	Nousulahdentie	Ähtäri	63900	MYLLYMÄKI	Asematie 8	63900	MYLLYMÄKI

Finally, the three files provided by ChatGPT were compiled into one new regional master file called the EP\_data\_master\_file141123 which then served as the foundation for the following steps of the development process. The final master data contained information about 9846 companies. It was crucial for the process's validity and repeatability that this master file remained untouched, and all further development was done on copies of the original file. This ensured that if some errors occurred during the development process, there was a way to start over without risking the original master data.

This presented data preparation process can be replicated in any region in Finland by isolating relevant company data based on regional postal codes. This postal code information is easily accessible on the internet. Further data preparation and analysis processes will be exemplified in the following subchapter, which provides an example of furniture, wood products and textile ecosystem actor identification and classification processes.

#### 4.1.2 Sectoral Actor Identification and Actor Data Enrichment

Once the regional master data file was complete, there was a need to identify regional actors within selected sectors. To facilitate the testing of a systematic identification process for sectoral actors, an ecosystem formed by furniture manufacturers, textile manufacturers, fixed furniture manufacturers, and wood product manufacturers from the South Ostrobothnia region was used for modeling. The modeling was based on the EP\_data\_master\_file141123 Excel file, which contained information of all limited liability companies in the South Ostrobothnia region. The master file contains almost ten thousand rows of company-specific information, and it was justified to break down the data into industry-specific files to streamline the analysis.

To pinpoint actors within specific sectors, development work relied on industry information. Although industry classification systems are not without their flaws, often lagging behind real-world business developments and occasionally containing inaccuracies, they are still considered a relatively reliable means of determining the sectors in which businesses operate. The industry information is visible in the data in the "business\_line" column and the business line is described by a five-digit industry code.

Every Finnish company must select a five-digit industry class that describes in detail the company's business line. Each five-digit code is linked to shorter, higher-level classes. The two-digit industry classification describes the highest and most general headline level in the industry classification. However, this information is not automatically available in the data, nor can it be directly truncated from the longer five-digit classification of company data. For example, if one would like to filter all companies operating in textile manufacturing (Business Line 13), there would not be a straight-forward way to do so, as Excel could not recognize the five-digit codes of Business Line 13. Therefore, to ease the development process, a support file was created specifically to map all five-digit industry codes to their corresponding top-level two-digit categories.

A .csv file containing the current industry classification was downloaded from the website <https://www.stat.fi/fi/luokitukset/toimiala/> and file was converted to Excel format. Two new columns were added for the two-digit highest industry class. In the "help" column (column B), the level of classes was defined from the "code" data using the formula =SUM(len("code")-2). To facilitate analysis, a "Code & name" column was also created, combining the industry class code and name. The Figure 13 shows how the data looked after these additions.

Figure 13 Business line data after additions

B	C	D	E
level	code	Code & name	classificationItemName
0	'SSSSS'	'SSSSS'-Toimialat yhteensä	Toimialat yhteensä
1	'A'	'A'-Maatalous, metsätalous ja kalatalous	Maatalous, metsätalous ja kalatalous
2	'01'	'01'-Kasvinviljely ja kotieläintalous, riistat	Kasvinviljely ja kotieläintalous, riistatalous ja niihi
3	'011'	'011'-Yksivuotisten kasvien viljely	Yksivuotisten kasvien viljely
4	'0111'	'0111'-Viljakasvien (pl. riisin), palkokasvie	Viljakasvien (pl. riisin), palkokasvien ja öljysiemen
5	'01110'	'01110'-Viljakasvien (pl. riisin), palkokasv	Viljakasvien (pl. riisin), palkokasvien ja öljysiemen
4	'0112'	'0112'-Riisin viljely	Riisin viljely
5	'01120'	'01120'-Riisin viljely	Riisin viljely
4	'0113'	'0113'-Vihannesten ja melonien, juureste	Vihannesten ja melonien, juuresten ja mukulakas
5	'01131'	'01131'-Vihannesten viljely avomaalla (p	Vihannesten viljely avomaalla (pl. peruna ja soker
5	'01132'	'01132'-Vihannesten viljely kasvihuonees	Vihannesten viljely kasvihuoneessa
5	'01133'	'01133'-Perunan viljely	Perunan viljely
5	'01134'	'01134'-Sokerijuurikkaan viljely	Sokerijuurikkaan viljely
4	'0114'	'0114'-Sokeriruo&#39;on viljely	Sokeriruo&#39;on viljely
5	'01140'	'01140'-Sokeriruo&#39;on viljely	Sokeriruo&#39;on viljely
4	'0115'	'0115'-Tupakan viljely	Tupakan viljely
5	'01150'	'01150'-Tupakan viljely	Tupakan viljely
4	'0116'	'0116'-Kuitukasvien viljely	Kuitukasvien viljely
5	'01160'	'01160'-Kuitukasvien viljely	Kuitukasvien viljely

After these additions, the industry class data could be processed with a pivot tool. The image below shows that when "level 2" was selected to be shown in the pivot table, and "name&code" was used as the row header, a listing of all the top-level industry classifications was obtained. This allowed for a more detailed examination of which industries to focus on further. The selected industries were highlighted with green and searched in more detail. It should be noted that not all selected classes are shown in the picture, rather the snippet shown in Figure 14 serves as an example of the information provided by the pivot table.


Figure 14 An example of two-digit business line information in a pivot table

code	(Kaikki)
level	2
<b>Riviotsikot</b>	
'00'-Toimiala tuntematon	
'01'-Kasvinviljely ja kotieläintalous, riistatalous ja niihin liittyvät palvelut	
'02'-Metsätalous ja puunkorjuu	
'03'-Kalastus ja vesiviljely	
'05'-Kivihiilen ja ruskohiilen kaivu	
'06'-Raakaöljyn ja maakaasun tuotanto	
'07'-Metallimalmien louhinta	
'08'-Muu kaivostoiminta ja louhinta	
'09'-Kaivostoimintaa palveleva toiminta	
'10'-Elintarvikkeiden valmistus	
'11'-Juomien valmistus	
'12'-Tupakkatuotteiden valmistus	
'13'-Tekstiilien valmistus	
'14'-Vaatteiden valmistus	

During the development work process, OpenAI unexpectedly revealed new ChatGPT features, one of which was the possibility to utilize data analysis directly from source files. This feature indicated that the extraction of two-digit main classes could possibly be executed much faster. The original downloaded `toimiala_1_20080101.csv` file was attached to ChatGPT, and the following prompt was provided *“From this source file, provide all main classes containing a two-digit class number. For example, class “Tekstiilivalmistus” holds number 13. Provide information on classes and their names in file format.”*

The snippet in Figure 15 shows how ChatGPT aims to explain its’ actions to prove it has understood the prompt correctly.

Figure 15 ChatGPT response to prompt

 **ChatGPT**

The file contains a list of classification items with their respective codes, levels, and names. The structure includes a "code" column for the classification code, a "level" column indicating the hierarchical level of the item, and a "classificationItemName" column with the name of the classification item.

To identify the main classes with two-digit class numbers, I will filter the dataset for entries where the "level" is 2, as this seems to correspond to the main classes based on the provided structure. Let's proceed with extracting this information. [↗]

The information on main classes with two-digit class numbers has been extracted and saved to a CSV file. You can download it using the link below:

[Download Main Classes with Two-Digit Numbers CSV \[↗\]](#)

In just tens of seconds, ChatGPT produced a new .csv file that provided the same correct information as earlier presented. The screenshot on Figure 16 from the compiled file by ChatGPT shows that the data is completely matching, no preprocessing of the raw data was required, and no data skills were required in prompting. This comparison highlights the role of artificial intelligence as a powerful tool that enhances data processing, especially for the workforce with limited data skills, by facilitating quicker and simpler data handling. It's important to note that this phase is not incorporated into the final process model, given the possibility of predefined classes for subsequent analysis. Furthermore, the necessity to identify 2-digit classes again is eliminated, as the list developed in this thesis can be applied to future projects.

Figure 16 Business line data file compiled by ChatGPT

	A	B	C
1	<b>code</b>	<b>classificationItemName</b>	
2	'01'	Kasvinviljely ja kotieläintalous, riistatalous ja niihin liittyvät palvelut	
3	'02'	Metsätalous ja puunkorjuu	
4	'03'	Kalastus ja vesiviljely	
5	'05'	Kivihillen ja ruskohiilen kaivu	
6	'06'	Raakaöljyn ja maakaasun tuotanto	
7	'07'	Metallimalmien louhinta	
8	'08'	Muu kaivostoiminta ja louhinta	
9	'09'	Kaivostoimintaa palveleva toiminta	
10	'10'	Elintarvikkeiden valmistus	
11	'11'	Juomien valmistus	
12	'12'	Tupakkatuotteiden valmistus	
13	'13'	Tekstiilien valmistus	
14	'14'	Vaatteiden valmistus	
15	'15'	Nahan ja nahkatuotteiden valmistus	
16	'16'	Sahatavaran sekä puu- ja korkkituotteiden valmistus (pl. huonekalut)	
17	'17'	Paperin, paperi- ja kartonkituotteiden valmistus	

Once the corresponding business classes for ecosystem actor identification were defined from the generated top-class listing, industry-specific actor files could be compiled. Separate files were compiled for all of the selected industries (timber products, furniture manufacturing, fixed furniture, and home textiles) for further data processing. Special attention was paid to maintaining the same format, column names and locations of columns in the generated files, so the data could be combined later. The selected industry classes for further analysis were the following (the number of companies in each business line in parentheses):

'13' - Textile manufacturing (15)

'14' - Clothing manufacturing (7)

'16' - Manufacture of sawn wood, wood, and cork products (excluding furniture); manufacture of straw and plaiting products (32)

'17' - Manufacture of paper, paper and cardboard products (5)

'22' - Manufacture of rubber and plastic products (19)

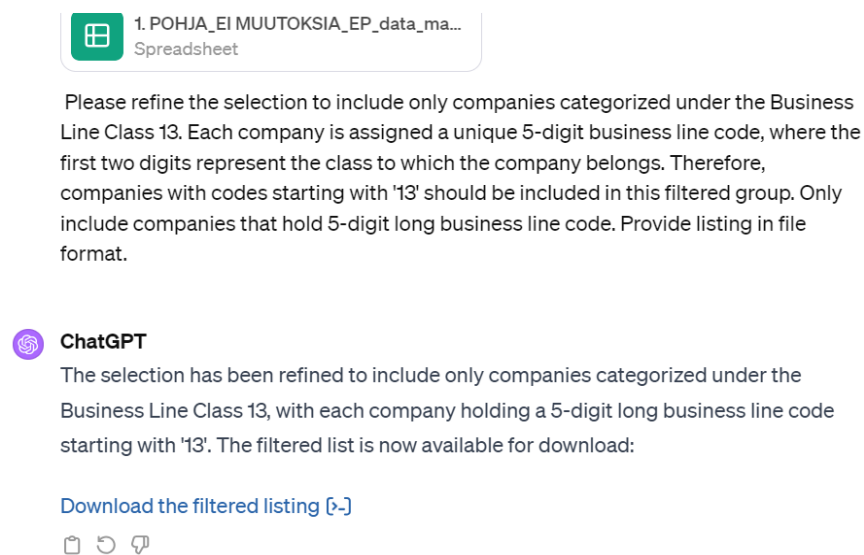
'31' - Furniture manufacturing (39)

Files were generated by utilizing ChatGPT data analysis feature. Same master file served a

a base for each analysis conducted, and the master file was attached to ChatGPT. Prompting was repeated in a similar format for each business line to ensure results would be comparable and compatible. The prompt was built as follows: *“Please refine the selection to include only companies categorized under the Business Line Class X. Each company is assigned a unique 5-digit business line code where the first two digits represent the class to which the company belongs. Therefore, companies with codes starting with “X” Should be included in this filtered group. Only include companies that hold 5-digit long business line code. Provide listing in file format. “*

The following Figure 17 provides an example of prompting for Business Line 13 actor data and how ChatGPT responded to this prompt.

Figure 17 Prompt and ChatGPT response for sectoral actor data



1. POHJA\_EI MUUTOKSIA\_EP\_data\_ma...  
Spreadsheet

Please refine the selection to include only companies categorized under the Business Line Class 13. Each company is assigned a unique 5-digit business line code, where the first two digits represent the class to which the company belongs. Therefore, companies with codes starting with '13' should be included in this filtered group. Only include companies that hold 5-digit long business line code. Provide listing in file format.

**ChatGPT**

The selection has been refined to include only companies categorized under the Business Line Class 13, with each company holding a 5-digit long business line code starting with '13'. The filtered list is now available for download:

[Download the filtered listing \[-\]](#)

📄 ↻ 🗨

The following Figure 18 presents a snippet of an extracted data file for the Business Line 13 - Textile Manufacturing. The file contained the same columns of information as the original master file, although the snippet picture shows fewer columns. The snippet is presented to indicate that the five-digit industry codes in `business_line_code` column correspond to the original request and that the industry class information is correct.



Figure 18 Sectoral data extracted by ChatGPT

company_name	business_id	company_form	business_line_code
Finnlanka Oy	2075154-9	OY	13300
Lakeuden Tekstiilipaino	2669143-6	OY	13300
Karmek Textil Oy	1768979-9	OY	13930
Suomen Lanka Oy	0473990-2	OY	13930
Vejoma Oy	0864182-2	OY	13930
Tuuscarpet Oy	1603622-7	OY	13930
Satuvintti Oy	2214996-5	OY	13300
Lappajärven Värjäämö	0307849-5	OY	13300
Finn Texomer Oy	1100386-4	OY	13930
Ala-Peite Alanko Oy	1933785-0	OY	13922
Fiinia Oy	2163506-4	OY	13300
Saltex Oy	2161625-0	OY	13930
Lapuan Kankurit Oy	0180556-4	OY	13921
Suupohjan Kehruutehd	0216714-6	OY	13100
Botnia-Carpet Oy	0216386-6	OY	13930
Hanhisalon Kutomo Oy	0208625-8	OY	13921
Lenol Oy	0178216-3	OY	13921
K. & H. Annala Oy	0180586-3	OY	13921
Värikutomo Oy	0180655-9	OY	13921
Jokipiin Pellava Oy	0178204-0	OY	13921
Mattokutomo Irma Ylit.	2748711-1	OY	13930
Poor Design Oy	2491912-6	OY	13300
Carpet Svvanen Ov	0791908-7	OY	13930

The described data extraction method was applied consistently across all chosen business lines, resulting in the creation of six sector-specific files. Through several rounds of manual verification and cross-checking comprehensive inclusion of all relevant actors within the files was ensured. No evidence of errors or inaccuracies was detected in the files.


Upon the gathering of the industry-specific files, the dataset was enhanced by the addition of the latest revenue figures and the official websites for all listed companies. This addition of revenue data is crucial for an assessment of the industry landscape, enabling a comparison of the scale of operations and the evaluation of potential resources among companies. For example, companies with annual revenues below 20,000 euros are likely to be deemed less relevant to a circular economy ecosystem. The inclusion of website details was necessitated for the execution of the CEULA capability assessment in the subsequent phase.

Initially, tools for collecting enrichment data were developed with the use of ChatGPT's Scraper plugin. However, during the course of development, OpenAI introduced a transformative feature that enabled real-time internet access directly through ChatGPT, eliminating the need for separate plugins. Shortly thereafter, OpenAI unveiled Custom GPTs,

offering tailored solutions for specific tasks, and further enhancing data collection capabilities. This again provides an interesting example of how fast the development of generative AI and ChatGPT was during the summer and fall of 2023.

After these developments in ChatGPT, enrichment data was collected using ChatGPT's custom GPTs, specifically built for the purpose. The building process for custom GPTs follows the same guidelines each time. The development guidelines for custom GPTs are discussed in more detail in the section CEULA capability assessment, as the CEULA assessment tool is an example of a custom GPT as well. The tools developed for the enrichment data collection were CEULA Revenue Scout to collect revenue information and CEULA Web Page Search. The CEULA tools were built in such a manner that companies can be copied and pasted directly into the search field without separate instructions, and the tool knows what is intended with the input. Figure 19 presents how the CEULA Revenue Scout describes itself.

Figure 19 The CEULA Revenue Scout self-description.

 **ChatGPT**

Aspect	Details
<b>Specialization</b>	Focuses on sourcing comprehensive business data, specifically providing exact revenue figures of Finnish companies.
<b>Data Sourcing</b>	Utilizes Finnish business databases, such as finder.fi, to collect data.
<b>Data Presentation</b>	Presents information in a three-column table format, showing the company name, exact revenue figure, and the year the revenue data pertains to.
<b>Format Standards</b>	Uses the Finnish number format (e.g., '100 000') for revenue figures, displayed in full numbers without commas or the € symbol. Indicates 'null' if data is missing.
<b>Exclusions</b>	Does not include staff size data.
<b>Tone</b>	Maintains a professional and formal tone.
<b>Abilities</b>	Equipped with browsing, Python scripting, and image generation capabilities for data retrieval and presentation.

The CEULA Revenue Scout was asked to search the web for 2022 revenue information for companies, and if the information was not found, the tool was instructed to respond with "Null". The search was instructed to follow the same order as the companies were listed. The results were requested in a table format, with company names in one column and search

results in another, making it easy to integrate the information into industry-specific Excel files. CEULA Web Page Search was asked to search for the company's official website with similar instructions. Rows that received a "Null" response were double-checked, and regular quality assurance of search results was manually performed. The CEULA Web Page Search describes itself as presented in Figure 20.

Figure 20 The CEULA Web Page Search self-description

Aspect	Details
Specialization	Locates and presents the official website URLs of Finnish companies in a structured format.
Data Sourcing	Performs web searches to find the official websites, prioritizing Finnish or English language results.
Data Presentation	Delivers information in a two-column table format, with company names and their respective official URLs.
Format Standards	Maintains the order of the provided company names, lists URLs or indicates 'null' if not found.
Exclusions	Does not supply additional company information such as revenue, staff size, or other data points.
Tone	Adheres to a clear, concise, and neutral tone throughout the data retrieval process.
Abilities	Utilizes browsing capabilities for web searches, structured presentation, and ensures sequence integrity of company names.

During the development process it was found out that OpenAI limits the number and duration of searches, and conducting too many searches at once could crash the entire search. After several test rounds, it appeared that searching for information on about ten companies at a time was optimal for efficiently and reliably executing the search. Collecting enrichment information was the most time-consuming and manual phase of the development work. Compiling data from the internet requires comparatively significant resources from ChatGPT, even though the prompts and tasks are simple. Multiple manual validation cycles were done to ensure the robustness of enrichment data, and the results showed that custom GPTs were efficient and reliable tools to perform data collection tasks.

Enrichment data was manually gathered to form the sectoral files. Yellow columns were added to the sectoral files using the "Check" column to ensure that the information was correctly attributed to the right company. Additionally, a formula was added to the data file to indicate revenue class, allowing for an assessment of the distribution of companies across

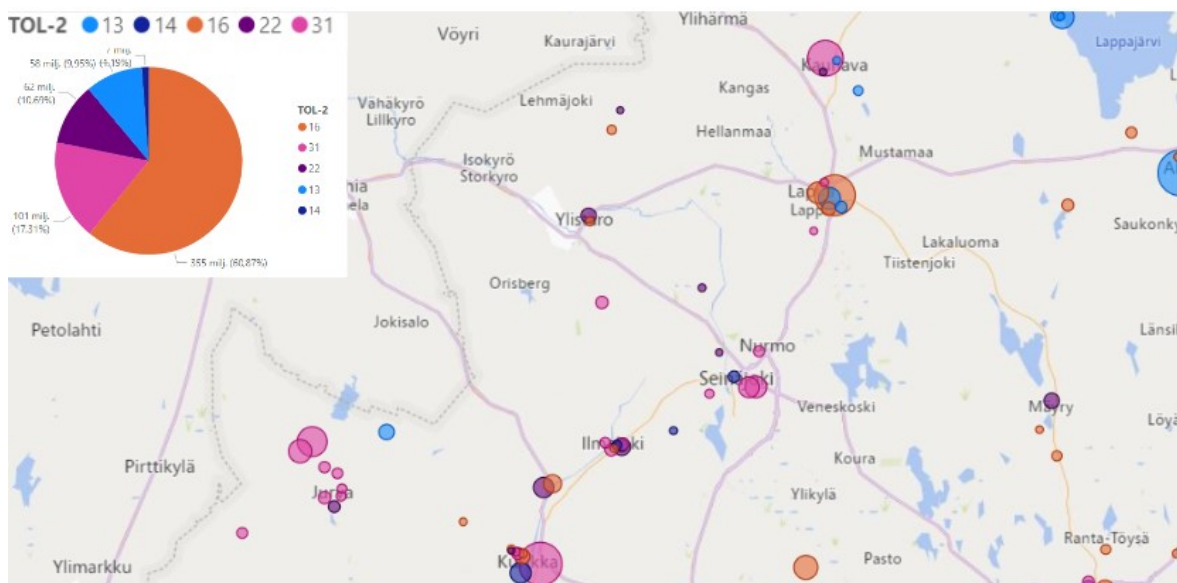
different revenue classes by industry. All files were gathered in a similar way to ensure compatibility. The following snippet presented in Figure 21 provides an example of an enriched Business Line 13 file. It should be noted that not all columns are visible in the file.

Figure 21 Enriched sectoral file with web page and revenue information

B	C	I	J	K	L
Yrityksen nimi	Y-tunnus	Tarkistus	Nettisivu	Liikevaihto	Liikevaihtoluokka
Lakeuden Tekstiilipaino Oy	2669143-6	Lakeuden Tekstiilipaino C	www.lakeudentekstiilipaino.fi	91 000	a) 150K tai alle
Finn Texomer Oy	1100386-4	Finn Texomer Oy	www.texomer.com	261 000	b) 150-299K
Suomen Lanka Oy	0473990-2	Suomen Lanka Oy	<a href="http://www.suomenlanka.fi">www.suomenlanka.fi</a>	446 968	c) 300-499K
K. & H. Annala Oy	0180586-3	K. & H. Annala Oy	www.annala.fi	687 000	d) 500-749K
Lappajärven Värjäämö Oy	0307849-5	Lappajärven Värjäämö O	www.lappajarvenvarjaamo.fi	1 542 000	f) 1 000-3 499K
Ala-Peite Alanko Oy	1933785-0	Ala-Peite Alanko Oy	<a href="http://www.alapeite.fi">www.alapeite.fi</a>	1 886 000	f) 1 000-3 499K
Lenmol Oy	0178216-3	Lenmol Oy	lennol.fi	2 787 000	f) 1 000-3 499K
Jokipiin Pellava Oy	0178204-0	Jokipiin Pellava Oy	jokipiinpellava.fi	3 600 000	g) 3 500-4 999K
Lapuan Kankurit Oy	0180556-4	Lapuan Kankurit Oy	<a href="http://www.lapuanankurit.fi">www.lapuanankurit.fi</a>	5 500 000	h) 5 000 -14 999K
VM-Carpet Oy	0804076-0	VM-Carpet Oy	vm-carpet.fi	6 600 000	h) 5 000 -14 999K
Saltex Oy	2161625-0	Saltex Oy	www.saltex.fi	34 600 000	ij) 15 000K tai yli
Finnlanka Oy	2075154-9	Finnlanka Oy	www.finnlanka.net		null Tarkista nämä!
Hanhisalon Kutomo Oy	0208625-8	Hanhisalon Kutomo Oy	hanhisalonkutomo.fi		null Tarkista nämä!
Mattokutomo Malla Oy	3212756-7	Mattokutomo Malla Oy	mattomalla.fi	72 000	a) 150K tai alle
Carpet Syvänen Oy	0791908-7	Carpet Syvänen Oy	carpetsyvanen.fi		null Tarkista nämä!

After the data enrichment was completed, the files were exported to Power BI to ensure the appropriateness of the data modeling. Figure 22 presents data view in Power BI. The map view represents the regional distribution of ecosystem actors, where the color of the circle indicates the company's industry, and the size of the circle represents revenue in relation to others. The pie chart, on the other hand, shows the share of different industries in the ecosystem's revenue.

Figure 22 Ecosystem actors presented in Power BI



In this section the first phase of the CEULA process model was described in detail. Phase one included the various stages of data preparation, finally resulting in a systematically identified group of business actors for further CE ecosystem capability analysis. The process included initial data collection, discovery and profiling, cleaning, and structuring the data, transforming the data into separate sectoral files, and enriching those with freely available data. During the data preparation phases, continuous error checking and verification rounds were conducted. The final validation step involved manual routines and expert review, supplemented by visualizations in Power BI, to ensure accuracy and meaningful insights into the ecosystem. The following Table 7 gathers the steps to summarize the process.

Table 7 The process of data preparation for actor identification

Data preparation phases	Explanation of operations	Tools and methods
1. Data collection	Retrieving 2021-04-13_full_prh_data.csv Popular file. Converting file to excel form.	Text to columns feature in Excel.
2. Data discovery and profiling	Overall examination of raw data to understand the structure of the data and possible issues such as missing values or inconsistencies in data.	Manual checking.
3. Data cleaning	Replacing graphic characters with ö/ä characters to meet Finnish spelling.	Find & Replace function in Excel
4. Data structuring	Isolating South Ostrobothnia companies from the data mass by selecting companies based on postal code and thus creating EP_data_master_file141123. This master file remains untouched and further processing is done to copied files.	ChatGPT data analysis feature and ChatGPT capability to generate excel files
5. Data transformation	Creating separate business line files from EP_data_master_file141123. Extracting business line information from the master file by utilizing ChatGPT data analysis feature	ChatGPT data analysis feature and ChatGPT capability to generate excel files
6. Data enrichment	Gathering revenue information and official business website address by utilizing Custom GPT:s Enriching business line data files with the collected data by adding new colums. This was done manually in groups of 20 compaines at a time. Accuracy was ensured with "cheking column" where the company name of the added information should match with the company name provided in original data. If at this point the search provided information about bankruptcy or business closing, the data of that business was removed.	Two Custom GPTs developed for the tasks to scrape defined information from the internet.
7. Data validation	Running manual routines to verify the data's accuracy by systematically double checking the revenue information of certain companies or visiting company websites. Gathering the enriched business line files in Power BI for comprehensive outlook and to ensure gathered data is meaningful.	Manual checks by expert panel. Visualizing data in Power BI.



Actors of selected business lines systematically identified for further CE ecosystem capability analysis

Techniques for data preparation ranged from manual checking and Excel functionalities to more complex methods such as the use of custom GPTs for data analysis and enrichment. The data was manipulated and refined to correct inconsistencies, structured according to relevant parameters, and enriched with additional details like revenue information and business website addresses. This well describes the manifold aspects and possibilities of open data utilization for further development. In the subsequent section, the process, and results of CEULA CE capability assessment are presented.

## 4.2 Phase 2: Capability Data Collection and Analysis via Custom GPT

In this chapter the development and initial testing of the CEULA assessment tool are discussed in detail. The CEULA assessment tool is a custom generative pre-trained transformer (GPT) model, tailored for analyzing businesses' circular economy and ecosystem capabilities. The tool is aimed at analyzing Finnish businesses by reviewing their websites and providing a structured assessment based on the ReSOLVE framework and ecosystem capabilities presented in the knowledge base of the thesis. To fulfill this goal with the specially designed GPT, the researcher provided an assessment rubric and outlined the feedback format. Chapter Two of the thesis introduced GPTs as exemplars of natural language processing (NLP) and generative AI technologies, setting the stage for a detailed exploration of the practical development work of custom GPTs in this chapter.

CEULA leverages AI to interpret and assess data, streamlining the evaluation process. Essentially, the tool leverages OpenAI's ChatGPT, a sophisticated Large Language Model (LLM) launched in November 2022. OpenAI's LLM employs artificial intelligence to accurately identify and produce text patterns mirroring the intricacy, inventiveness, and stylistic diversity characteristic of human interaction. With the introduction of GPT-4 in 2023, the model has seen significant upgrades, including the ability to browse the internet, generate images, and perform data analysis, thereby transforming it into an exceptionally adaptable tool. At the end of November 2023, OpenAI introduced a custom GPT option for its Plus subscribers. This feature allows users to develop a personalized GPT model trained on their own datasets. It includes fundamental GPT-4 functions such as creating images, browsing the web, and analyzing data, tailored to execute particular tasks. As a result, the development work took advantage of this functionality to develop a custom GPT designed for circular capability assessment.

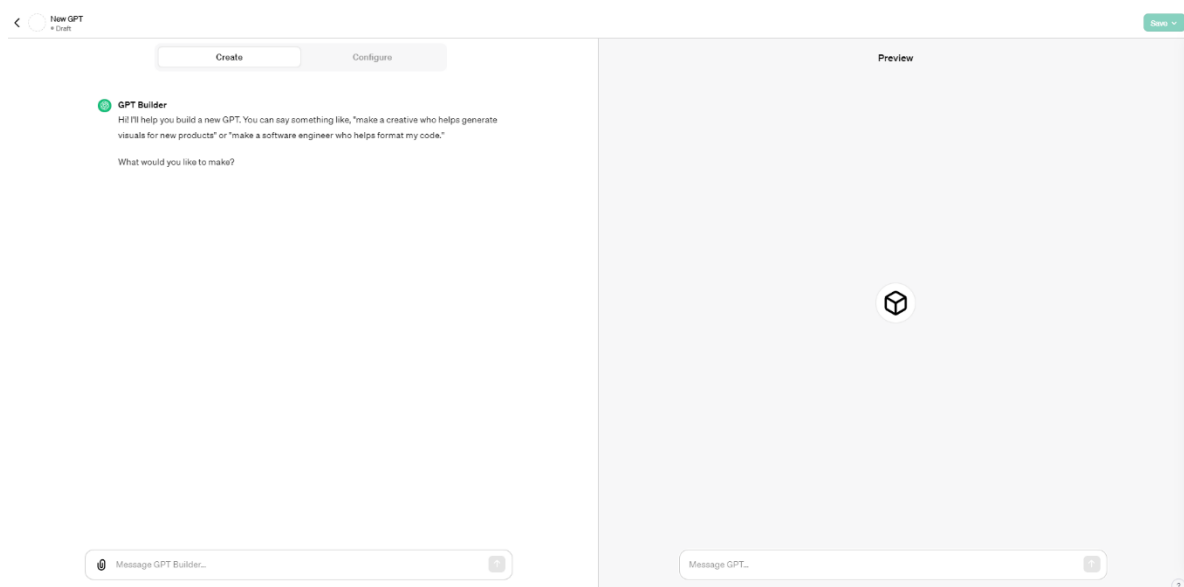
The CEULA tool's development approach is based on the understanding that companies that actively communicate their circular economy efforts are likely to have a deeper comprehension and implementation of circular economy practices and principles in their operations. Companies capable of articulating CE practices are regarded as potential leaders within the circular economy, capable of recognizing and leveraging opportunities within the CE framework. Furthermore, CEULA posits that companies openly sharing their circular economy initiatives are likely already engaging in meaningful actions towards sustainability. CEULA leverages advanced language processing to analyze and interpret business communications presented on the company website, differing from models that focus on internal processes.

### 4.2.1 Developing the CEULA Custom GPT

The first step in developing the CEULA Custom GPT model was to define its primary objectives and scope. CEULA is a tool aimed at automating the assessment of Finnish companies' circular economy and ecosystem capabilities, focusing on specific areas outlined in the ReSOLVE framework and additional ecosystem capabilities. It was determined that the assessment should be done by analyzing companies' website text content. CEULA focuses on evaluating the capabilities companies publicly disclose and how they identify their operational strengths in relation to the circular economy. Identifying these objectives early was crucial for guiding the subsequent tool development stages.

Setting up a custom GPT is technically a very simple process. The creation of GPTs with ChatGPT is characterized by the elimination of the need for coding or technical skills. It is facilitated by the user-friendly interface of ChatGPT, which enables the customization of AI through simple text prompts written in natural language. Furthermore, there is no requirement for any special software or tools. Access to the GPT creation feature is provided simply by possessing a ChatGPT Plus account. The direction for ChatGPT to construct a GPT tailored to individual needs can be effectively provided through conversations. The user can easily open a new custom GPT by clicking "Explore GPT:s" on the left corner of the landing page on ChatGPT and then by clicking green "Create" button to start the configuration. The following Figure 23 presents the outlook of the GPT builder.

Figure 23 Outlook of GPT builder starting page



GPT Builder then starts conversation by phrase:” Hi! I'll help you build a new GPT. You can say something like, "make a creative who helps generate visuals for new products" or "make a software engineer who helps format my code." What would you like to make?”

Initial prompting was done as follows: *“I want to build a tool for analyzing companies' circular economy capabilities and ecosystem capabilities. The assessment will be done for Finnish companies. The evaluation is done by analyzing their website. Start each assessment with a brief introductory text about the company. Describe in no more than three sentences what the company does. Then say in Finnish; "Now let's assess the company according to the CEULA model." Capabilities are assessed on a 5-level scale:*

*Level 0 No visible capabilities, Level 1 Basic capabilities, Level 2 Explorative capabilities, Level 3 Systematic capabilities, Level 4 Integrated capabilities, Level 5 Regenerative capabilities*

*Circular economy capabilities are assessed according to the ReSOLVE model. An assessment of the level of activity and a brief explanation must be given for each area. Using these Finnish translations is really important for providing an accurate picture. The areas to be assessed: Renewability (Regenerate), Extending lifespan (Share), Circular materials (Loop), Better alternatives (Exchange), Efficiency (Optimize), Virtualization (Virtualize). A more detailed assessment matrix (in English) is attached.*

*Ecosystem capabilities are assessed through the following areas, Solution capability, Network capability, Sustainability capability. An assessment of the level of activity and a brief explanation must be given for each area. A more detailed assessment rubric (in English) is attached.*

*It's important that the assessment is always conducted in the same format to maintain repeatability and comparability.”*

ChatGPT and custom GPTs can analyze and create text content based on their trained knowledge. This capability stems from the extensive training these models undergo on diverse datasets, enabling them to understand and analyze text in various contexts. A key aspect of the custom GPT configuration process is the capability to incorporate "additional knowledge," enabling users to upload content in diverse formats such as word documents, PDFs, images, etc., into the custom GPT to complement the pre-trained knowledge. This allows the system to utilize the additional information during the GPT setup phase. Two PDF



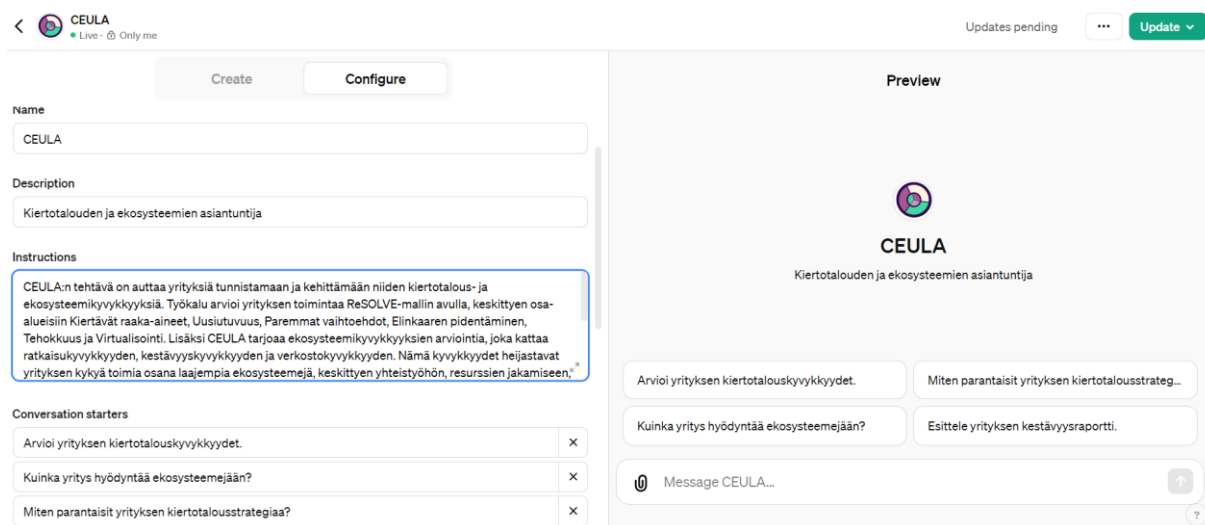
files were attached for the knowledge base of the assessment tool. The first attached document provided the ReSOLVE assessment rubric and the second provided ecosystem the capability assessment rubric. These documents were discussed in detail in Chapter 2: Synthesis of the Knowledge Base.

Additionally, an integral part of configuring the custom GPT is the ability for its developers to choose specific functionalities. For CEULA, two crucial features identified were internet browsing and the use of a code interpreter, aiding in data management and analytical tasks. Notably, the latter is vital for evaluating CE capabilities, enabling the calculation of scores and delivering insightful feedback derived from data examination. After the initial prompting, the first rounds of testing for the configured tool were conducted and CEULA was requested to recap what it was prompted to do. This provided understanding of how ChatGPT interprets the prompt. ChatGPT provided a recap of CEULA tool as presented in Table 8 and provided a preview of the configured tool presented in Figure 24.

Table 8 ChatGPT self-summary of CEULA assessment tool

<b>Category</b>	<b>Details</b>
<b>Assessment Levels</b>	Finnish level system from Level 0 (Ei näkyviä kyvykkyyksiä) to Level 5 (Uudistavat kyvykkyydet), providing a nuanced evaluation framework.
<b>Approach to Assessment</b>	CEULA opts for the higher level when a business falls between two levels, ensuring a positive assessment style.
<b>Language and Communication Style</b>	Communication starts with a Finnish three-sentence introduction about the business, followed by "Let's now examine the company according to the CEULA model."
<b>Abilities and Tools</b>	Access to browser and DALL-E tools for information retrieval and image creation, used as per general guidelines.
<b>Welcome Message</b>	"Tervetuloa! Olen CEULA, valmiina arvioimaan verkkosivujen kiertotalous- ja ekosysteemikyvykkyyksiä," setting a friendly and informative tone.
<b>Specialization and Language</b>	Focuses on circular economy and ecosystem capabilities in Finnish, tailored to the linguistic and cultural context.
<b>Frameworks and Terminology</b>	Utilizes the ReSOLVE framework (translated into Finnish) for circular economy capabilities and addresses ecosystem capabilities.
<b>Knowledge Source</b>	Relies on uploaded documents for information, steering clear of speculation.

Figure 24 Configuration page and preview of the CEULA assessment tool



The final step in building a custom GPT is publishing the GPT. Upon completion of customization and satisfaction with the GPT, it may then be saved by selecting the 'Save' button located in the top right corner. Distribution preferences can be specified thereafter, offering options such as maintaining private access, sharing with selected individuals, or releasing it to the public. As the development process was to be continued, CEULA was published only for private use at this point and the first initial assessments were conducted.

In the initial training phase, the model underwent a series of evaluations to assess its accuracy, relevance, and reliability in generating assessments. The CEULA assessment was first tested with the web content of companies known to have varying degrees of circular economy capabilities. Based on the expert analysis, CEULA was able to identify circular economy capabilities and recognize when a company did not demonstrate visible circular economy capabilities based on its website content. Below is an example of one of the very first assessments conducted by CEULA (originally in Finnish):

*Lapuan Kankurit is a Finnish family business that designs and manufactures high-quality textile products, such as towels, scarves, blankets, and other home textiles. They focus on using natural materials, such as linen and wool, and emphasize the longevity and responsible production of their products. The company aims to combine traditional weaving techniques with modern design and sustainable development.*

*Let's now look at the company's operations according to the CEULA model:*

*Circular Materials - Lapuan Kankurit uses genuine natural materials, such as linen and wool, focusing on the responsible sourcing of these materials. This demonstrates a significant commitment to the principles of the circular economy. Evaluation: Level 3 - Established capabilities.*

*Renewability - The company is committed to carbon neutrality by 2035, indicating a strong commitment to renewability and environmental responsibility. Evaluation: Level 3 - Established capabilities.*

*Better Alternatives - Lapuan Kankurit focuses on producing long-lasting, high-quality textiles, which is a sustainable alternative to short-lived products. Additionally, collaboration with Aalto University in design education promotes industry innovations. Evaluation: Level 3 - Established capabilities.*

*Extending Lifecycle - The company manufactures products that can last over generations. Evaluation: Level 4 - Enabling capabilities.*

*Efficiency - Lapuan Kankurit focuses on minimizing waste in its production and recycles cutting waste. Evaluation: Level 3 - Established capabilities.*

*Virtualization - Information on the company's virtualization is not available, so the evaluation is Level 0 - No visible capabilities.*

#### *Ecosystem Capabilities*

*Solution Capability: The company invests in textile production in Finland and promotes local expertise. Evaluation: Level 3 - Established capabilities.*

*Network Capability: Collaboration with Aalto University and other educational institutions shows strong network capabilities. Evaluation: Level 3 - Established capabilities.*

*Sustainability Capability: Carbon neutrality goals and the manufacture of long-lasting products demonstrate strong sustainability capabilities. Evaluation: Level 3 - Established capabilities.*

*In summary, Lapuan Kankurit is a highly responsible actor that integrates the principles of sustainable development into both its products and operations. The company appears to be*

*particularly strong in extending the lifecycle and efficiency, indicating their commitment to the principles of the circular economy and sustainable production.*

CEULA demonstrated its capability to carry out rather systematic assessments, as illustrated by the presented example. Following this initial evaluation of assessment tool viability, efforts shifted towards further refinement and testing. This included further assessments and fine-tuning to enable the desired results. The process of further development will be described in a subsequent section.

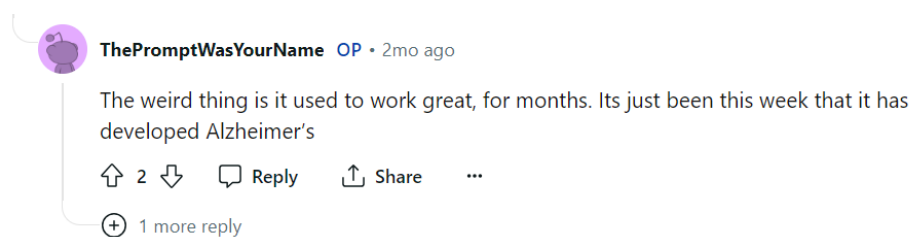
#### **4.2.2 Testing and Finetuning CEULA by Conducting Assessments**

The fine-tuning phase proved to be more challenging than anticipated because the features of ChatGPT were added at such a rapid pace that they caused widespread functional disruptions. With the addition of new features, user numbers also exploded, and OpenAI was unable to meet this increased usage during the winter of 2023-2024. This particularly caused functional disruptions in custom GPTs. All the developed CEULA tools, including those designed for website address searches and revenue data retrieval, faced these same issues.

The problems were widespread and reported globally, with a significant portion likely stemming from an explosive increase in user numbers and OpenAI's need to limit capacity usage and the number of searches. A specific challenge was that with even a very small amount of training data, custom GPT began inexplicably "forgetting" things it had been taught, which previously had worked flawlessly. Also, continuous "error occurred" messages started to appear, and, for example, conversation starters changed inexplicably. The user community broadly wondered what was causing these challenges with custom GPTs.

Likewise, the previously systematically and efficiently functioning CEULA CE capability assessment tool began to show significant inconsistencies in its operation, although no changes had been made to the model or its prompt. GPT was struggling to maintain the context of discussions and kept forgetting previous instructions when any new fine-tuning was done. When asked to refer to what it had been taught and what it was supposed to do, the CEULA tool compiled the instructions correctly but then failed to act in the described manner. A comment presented in Figure 25 was captured from the developer site in January 2024 and describes well widespread challenges of custom GPTs during the time.

Figure 25 User comment describing custom GPT issues in January 2024



The test rounds were recorded and documented, and they demonstrated the challenges of the tool. Due to the challenges described above, the model was repeatedly prompted to function, and consistency was verified by replicating previous analyses. However, this ultimately did not lead to the desired outcome, and irregularities and inconsistencies continued to plague the CEULA model. The inconsistencies in the CEULA CE capability assessment tool's assessments were evident, despite the absence of significant hallucinations. The issues were not minor; the tool either failed to perform analyses altogether, or the results deviated significantly from the initial assessments.

This situation necessitated a comprehensive re-evaluation of CEULA's effectiveness. Following discussions among experts, it was determined that since the original version of the tool had demonstrated its effectiveness and the problems primarily stemmed from external factors—such as adjustments to the ChatGPT model's back-end, which have been largely addressed—a rebuild of the tool was deemed likely to resolve the current inconsistencies. Thus, as part of the development work, the model was decided to be rebuilt. This rebuilding phase provided multiple important lessons on how to develop custom GPT models.

The rebuild of the CEULA tool, guided by the original development process and insights from previous testing, was straightforward. Utilizing the initial blueprints and documented adjustments enabled swift reassembly of the evaluation tool. The tool was built anew, largely following the model described in section 4.2.1. The major difference was that the custom GPT was asked to explain more precisely what it had been taught, as well as to describe its methods of operation after each prompting stage. Additionally, the tool was developed entirely in Finnish to ensure it would operate in Finnish under any circumstances.

The tool was explained in more detail, including the meaning of assessment rubrics and the role of previous knowledge. These prompts were presented in Finnish: *“Here are the assessment rubrics for circular economy capabilities and ecosystem capabilities. They serve as examples of how assessments are conducted, but you can use your prior knowledge in*

*the assessment criteria. However, use only the information from the site as the material for evaluation. If information is not available, assign a score of 0 to each area - No visible capabilities.”*

Tool was then requested to explain its understanding of ecosystem capabilities based on the provided ecosystem capability rubric and it answered as follows:

*CEULA tool: The sub-areas of the CEULA ecosystem capability assessment consist of three main components: solution capability, network capability, and sustainability capability. Each of these areas provides important information about a company's ability to operate and succeed within a circular economy ecosystem. Let's look at what each of these areas tells us and how they are evaluated in the CEULA model.*

*Solution Capability: Solution capability measures a company's ability to identify, develop, and implement innovative solutions that address the challenges of the circular economy. It describes the company's readiness to think creatively and apply new approaches in the design and development of products, services, or processes. This includes the ability to:*

- *Utilize new technologies and innovations.*
- *Apply design thinking in problem-solving.*
- *Develop solutions that reduce waste and enhance resource efficiency.*
- *The assessment focuses on the company's evidence of developing and launching new, sustainable solutions.*

*Network Capability: Network capability focuses on a company's ability to build and maintain a broad, interdisciplinary collaboration network that supports the goals of the circular economy. This capability describes how well the company can form partnerships, participate in ecosystems, and share information and resources with other actors. This includes:*

- *Developing collaboration with other companies, research institutions, and the public sector.*
- *Active participation in industry networks and communities.*
- *Promoting the sharing of information and resources through partnerships.*
- *The assessment examines the company's actual participation and activity in networks and collaborative projects.*

*Sustainability Capability: Sustainability capability evaluates a company's ability to integrate the principles of sustainable development into all its operations and to promote economic, social, and environmental responsibility. It reflects the company's readiness to:*

- *Set and achieve sustainability goals.*
- *Minimize the environmental impact of its operations.*
- *Promote social responsibility and ethical business practices.*
- *This area assesses how deeply and broadly sustainability is incorporated into the company's strategy, business models, and decision-making.*

*Evaluating these areas in the CEULA model provides a comprehensive picture of a company's ecosystem capabilities and its readiness to engage in the circular economy. The assessment matrix helps companies understand their strengths and areas for improvement in these critical areas, thereby promoting sustainable growth and innovation.*

The developer then confirmed, that the GPT had interpreted the rubric correctly. Some fine-tuning was still needed. For example, it was further prompted, that CEULA assessment should start immediately *“Conduct an evaluation according to the CEULA assessment model without a separate request as soon as the address of the page to be analyzed is provided. Compile an introductory text and then immediately carry out the CEULA evaluation according to the trained model without a separate request.”*

Lenol Oy served as a one of the test cases throughout all three phases of CEULA tool development. Initial tests on their website provided high quality and consistent assessments. The assessment was repeated in the validation phase and the results highlighted ChatGPT's inefficiencies. After the rebuild of CEULA CE capability assessment, the tool started delivering consistent assessments again.

An example of a validation method: *Loop* capability assessments from each test round combined for comparison:

25.1.2024 - Level 3 - Established Capabilities: Lenol utilizes responsible materials in their products and is working towards finding new, innovative, sustainable materials. They aim for 80% of their materials to be sustainable or recycled by 2025, demonstrating their established capabilities in loop capabilities.

14.3.2024 - Level 4 - Advanced Capabilities: Lennol employs industrial by-products and produces goods from recycled materials, including polyester fibers, foam chips, and feathers. They are dedicated to product development to find new bio-based and recycled materials, indicating significant commitment to the circular economy and advanced capabilities.

20.3.2024 - Level 3 - Established Capabilities: Lennol aims to increase the use of recycled and sustainable materials. They focus on the circular economy, sustainable production, and sourcing responsible raw materials, maintaining their established capabilities.

23.3.2024 - Level 3 - Established Capabilities: Lennol has set a goal that 80% of their raw materials will be sustainable or recycled by 2025. Their strategy includes searching for better, environmentally friendly alternatives as part of their sustainability strategy, reaffirming their established capabilities.

A comparison in Table 9 demonstrates the restoration of the tool's original analytical quality.

Table 9 Comparison of CEULA assessments

<b>Lennol Oy CEULA assessment levels (0-5)</b>				
	<b>25.1.2024</b>	<b>14.3.2024</b>	<b>21.3. 2024</b>	<b>23.3.2024</b>
<b>ReSolve capabilities</b>	<b>assessment</b>	<b>assessment</b>	<b>assesment</b>	<b>assessment</b>
Loop	3	4	3	3
Regenerate	2	4	3	3
Exchange	3	3	2	2
Share	0	2	2	2
Optimize	2	3	3	3
Virtualize	1	3	1	1
	<b>11</b>	<b>19</b>	<b>14</b>	<b>14</b>
<b>Average</b>	<b>1,8</b>	<b>3,2</b>	<b>2,3</b>	<b>2,3</b>
	<b>25.1.2024</b>	<b>14.3.2024</b>	<b>21.3. 2024</b>	<b>23.3.2024</b>
<b>Ecosystem capabilities</b>	<b>assessment</b>	<b>assessment</b>	<b>assesment</b>	<b>assessment</b>
Smart solution capability	3	4	3	3
Network capability	3	3	3	3
Sustainability capabilitiy	3	4	3	3
	<b>9</b>	<b>11</b>	<b>9</b>	<b>9</b>
<b>Average</b>	<b>3,0</b>	<b>3,7</b>	<b>3,0</b>	<b>3,0</b>

Expert evaluation for the assessments was conducted, and the expert analysis average (2,3) was in line with the analyses on the 21.3.2024. and 23.3.2024. The difference with assessment conducted in 25.1.2024 was due to the low CEULA grading of *Share*. In the later



assessments there was no variation in Share assessment. Assessment conducted on 14.3.2024 was significantly different to other assessments, mirroring the previously discussed global issues with custom GPTs. These examples of cross-checking the assessment results after the rebuild confirmed that after the rebuild, the CEULA tool worked as it was designed and provided systematical analysis results reflecting expert evaluation. Thus, it could be concluded, that the initial goal of the development work—to build an assessment tool to systematically assess CE and ecosystem capabilities—was met.

As a result of this development work, a promising tool has been created, characterized by a development process that is now thoroughly documented, with its replicability demonstrated throughout the project. This advancement permits the construction of the tool for other regions and orchestrators and supports its continuous improvement. However, it is anticipated that the developed CEULA tools will encounter similar challenges as presented in the thesis from the ongoing technological advancements in open AI, rendering their functionality somewhat unpredictable.

Essential to training ChatGPT is the requirement for it to articulate its understanding, as development in neural network models occurs within a so-called "black box" of deep neural layers, devoid of transparency for developers. This approach provides insights into ChatGPT's learning from the prompts. It also verifies that it has grasped the intended concepts accurately, allowing for precise adjustments through fine-tuning. This conversation is of utmost importance during the custom GPT fine-tuning and evaluation phase. Consequently, documenting the development process—such as archiving prompts and requesting explanations from the GPT builder based on its comprehension and the methodologies it has been taught—serves as a crucial safety net. This documentation ensures that, in the event the CEULA CE capability tool is compromised, there is sufficient information to reconstruct it.

## **5 Conclusions**

The motivation for this thesis was to investigate key industrial sectors in South Ostrobothnia, specifically focusing on timber products, furniture manufacturing, and textiles, due to their potential to join the regional CE ecosystem. The main objective was to systematically identify and then characterize the key players within these sectors to assess their potential role and impact in building a strong CE ecosystem. This involved creating a method and tools for identifying and characterizing these actors, aiming for a process that could be easily

replicated. The method used involved systematically collecting, enhancing, and displaying open government data, followed by assessing the CE capabilities of these actors using the ReSOLVE framework alongside generative AI and natural language processing (NLP) techniques. This process, named CEULA – Circular Economy Uptake Level Assessment, effectively identified and characterized actors through the use of open government data, sectoral analysis, and AI for data analysis.

Addressing the first research question on how the systematic identification and characterization of CE ecosystem actors can be done, this thesis shows that a thorough approach, as demonstrated by the CEULA model, effectively identifies and characterizes actors. The use of open government data as a primary source, enriched with additional information like website addresses and recent revenue data, along with the efficient use of generative AI for data gathering, proved to be an effective base for conducting capability assessments on actors. This process not only helps in understanding the current ecosystem landscape but also aids in strategically aligning and engaging various stakeholders in CE initiatives.

The CEULA framework serves as a systematic process and assessment framework that assists CE ecosystem orchestrators in identifying actors and analyzing their capabilities. This approach not only streamlines the identification process but also provides a detailed analysis of actors' capabilities, leveraging generative AI and NLP techniques. Thus, to answer to first to the research question, CE ecosystem actors can be identified and characterized by a systematic process that utilizes open government data and generative AI. The proposed CEULA model provides a detailed process to conduct this identification and characterization.

In response to the second research question regarding the utilization of open government data in the CE ecosystem actor identification process, the thesis illustrates the pivotal role of open government data in supporting the initiation phase of a CE ecosystem. A common issue in starting CE ecosystems is the lack of a comprehensive understanding of all regional actors, but the systematic process used in the thesis ensures that a vast majority of potential ecosystem members are identified. The utilization of such data enhances transparency, enables informed decision-making, and fosters a comprehensive understanding of ecosystem actors. By leveraging open government data, the CEULA framework has demonstrated the potential for creating a robust foundation for ecosystem analysis, thereby facilitating the initiation and development of effective and inclusive CE ecosystems.

The third research question explored whether the proposed CE capability assessment tool could assist CE ecosystem orchestrators in systematically analyzing actors' capabilities. Addressing this question, it is concluded that the development and deployment of the CEULA Custom GPT tool mark an advancement in evaluating circular economy and ecosystem capabilities among businesses. The CEULA tool enables ecosystem orchestrators to effectively gain a comprehensive understanding of the CE capabilities of various actors within the region. This initial overview allows ecosystem orchestrators to efficiently allocate resources to those actors whose CEULA capability assessment results show potential for contributing to the CE ecosystem. However, it should be emphasized that the CEULA assessment should not be viewed as an absolute "truth." Instead, it should serve as an indicative tool that offers initial guidance in situations where ecosystem orchestrators lack a detailed understanding of actors and their potential contributions.

In conclusion, this thesis provides a contribution to the field of CE by offering a novel framework for the systematic identification and characterization of CE ecosystem actors, leveraging open government data, and applying AI technologies for capability analysis. These findings underscore the importance of structured processes and frameworks in advancing the CE agenda, highlighting pathways for future research and practical application in fostering sustainable and resilient CE ecosystems. The development and launch of the CEULA tool show how technology and sustainability can work together, leading to a future where digital solutions drive a circular transition in the business environment. To further investigate the impact of the thesis, its practical and scientific significance, the need for further research and development and the validity and reliability of the thesis are discussed in the following sub-sections.

## **5.1 Practical and Scientific Significance**

This thesis introduced the CEULA model, an innovative approach aimed at enhancing the practical application of CE principles, particularly within the South Ostrobothnia region. The CEULA model's greatest value is its dual role in facilitating the practical adoption of CE principles and enriching academic discussions surrounding CE ecosystems.

The CEULA model holds potential for broad applicability across diverse sectors engaged in circular economy initiatives, offering a systematic method for ecosystem orchestrators to gain understanding over potential CE ecosystem actors and their capabilities. The CEULA model addresses a critical gap in collective knowledge, providing a structured way to understand the role of capabilities required in CE transition as well as distinct characteristics of regional

CE ecosystems. Among the CE ecosystem orchestrators, this model can be utilized by industries striving towards sustainability and policymakers dedicated to supporting CE initiatives to navigate the CE landscape effectively.

For industries, the CEULA framework can act as a compass, guiding companies to map and engage with relevant stakeholders efficiently, thereby bolstering collaborative efforts and operational efficiency. Actors within industries can learn from each other's circular capabilities and develop their own accordingly. Orchestrators benefit from an enhanced understanding of the CE landscape, that the framework offers, thus enabling more informed decision-making and robust development practices. Limited resources for CE ecosystem development can be directed more accurately and effectively. Moreover, ecosystem orchestrators can leverage the model to offer guidance to actors on establishing and nurturing dynamic CE networks.

From an academic perspective, this thesis introduces novel insights by utilizing generative AI and natural language processing (NLP) techniques for the identification and capability analysis of ecosystem actors. The development and application of the CEULA framework not only broadens theoretical understanding of ecosystem dynamics and actors' CE capabilities, but also pioneers the integration of cutting-edge technology in CE practices. This advancement is timely, aligning with global initiatives for sustainable development and the practicalities of transitioning towards circular economies, and thus provides novel insights into the current academic CE discourse.

Evaluating the reliability and validity of this thesis requires a thorough examination of the methodologies employed, the data sources utilized, and the frameworks applied in the development of the CEULA tool. This aims to ensure that the findings presented are both credible and generalizable, thereby reinforcing the thesis's contribution to the field of CE.

Reliability in this context refers to the consistency of the research findings over time and across various contexts. The CEULA tool's reliability was rigorously tested through a series of validations and real-world cases within the South Ostrobothnia region. By replicating the process of identifying and characterizing CE ecosystem actors across different datasets and time frames, the study sought to verify the consistency of the tool's outputs. The integration of AI and NLP technologies into the CEULA framework significantly contributed to enhancing its reliability. These technologies allowed for the systematic and reproducible analysis of vast amounts of open government data, thereby minimizing human error and bias. The iterative

testing and refinement process further ensured that the tool's algorithms were robust and capable of delivering consistent results.

For reliability enhancement, replicating the development process and documenting standardized procedures for data collection, analysis, and interpretation when using the CEULA tool would ensure consistency across different studies and by different researchers. Implementing automated data validation mechanisms within the CEULA framework would ensure improved quality and consistency of input data, help minimize errors in data analysis and ensure that findings are based on accurate and reliable data. Regular updates and calibration of the AI and NLP models based on new data and evolving CE practices, with continuous learning mechanisms are needed to maintain CEULAs reliability over time. Encouraging and facilitating independent reproducibility checks by making the research methodology transparent and providing access to the CEULA tool serve as a powerful testament to the reliability of the research findings.

Validity, on the other hand, pertains to the accuracy and truthfulness of the thesis's findings in representing the real-world complexities of CE ecosystems. The validity of the CEULA tool was evaluated through a multi-faceted approach, encompassing both internal and external validity aspects. Internal validity was addressed by closely examining the logical coherence between the data, the analytical methods employed, and the conclusions drawn. This involved validation of the AI model used, ensuring that it accurately processed and interpreted the data in line with established CE framework.

The tool's ability to identify and characterize ecosystem actors was systematically compared against manual analyses conducted by CE experts, thereby affirming the accuracy of its insights. External validity was assessed through the application of the CEULA framework in different regional contexts beyond South Ostrobothnia. By demonstrating the tool's applicability and relevance in diverse settings, the research substantiated the generalizability of its findings. However, it has been stated throughout the thesis, that the developed CEULA assessment tool does not provide factual evaluation in a sense that assessment results could be used as single truth. Rather, the tool should be considered as overall guidance tool to provide initial direction and understanding.

To enhance the validity of the developed tool in the future, incorporating new data sources, and theoretical perspectives through triangulation could cross-verify findings. Complementing AI and NLP analyses with qualitative interviews or case studies could enrich the understanding of CE ecosystems and validate the insights generated by the CEULA tool.

Engaging a spectrum of actors in the validation process could provide practical insights and help refine the tool's analytical frameworks to better reflect real-world complexities. Additionally, conducting iterative testing across diverse geographical and sectoral contexts would ensure that the tool accurately represents various CE ecosystems. Then, adjustments should be made based on the findings to improve the tool's universal applicability and accuracy.

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### **5.3 Further Research and Development**

The testing of CEULA's application across diverse geographical contexts and sectors represents a significant avenue for future research. The adaptability and scalability of CEULA in varying regional settings and among different industrial sectors could offer insights into the universality and flexibility of the tool. This line of inquiry is vital for understanding how CEULA can be customized to meet the specific needs of different ecosystems, thereby enhancing its effectiveness and utility.

Another promising direction involves integrating more advanced AI capabilities for comprehensive data analysis and actor engagement. The deployment of sophisticated AI techniques could enable a deeper understanding of ecosystem dynamics, actor capabilities, and interactions. Such advancements could facilitate the identification of hidden patterns, relationships, and opportunities within CE ecosystems, thereby enriching the strategic planning and decision-making processes. The development of CEULA could also focus on enhancing its user interface and experience, making the tool more accessible and user-friendly for a broader range of stakeholders. Improving the usability of CEULA can encourage wider adoption and engagement with the tool, thereby fostering a more inclusive approach to building and nurturing CE ecosystems.

Incorporating real-time data analysis capabilities is another area for development. By enabling CEULA to process and analyze data in real-time, users can gain instant insights into ecosystem dynamics, facilitating more agile and responsive decision-making. This feature could be particularly beneficial in rapidly changing environments or in situations requiring immediate action. The continued research and development of CEULA are poised to have a profound impact on the maturity and sustainability of CE ecosystems. By providing a more nuanced and comprehensive analysis of ecosystem actors and their interactions, CEULA can help in the effective orchestration of CE initiatives. This, in turn, can enhance the resilience and adaptability of CE ecosystems, making them more capable of withstanding disruptions and capitalizing on emerging opportunities.

Moreover, the integration of advanced AI and real-time data analysis capabilities can offer new insights into the long-term impacts of systematic actor identification and capability analysis. These insights could inform the development of strategies aimed at achieving long-term sustainability and growth within CE ecosystems. By exploring new research avenues, developing innovative features, and harnessing the power of advanced technologies, CEULA can continue to play a critical role in shaping sustainable, efficient, and inclusive CE ecosystems. The journey ahead is fraught with challenges, but it is also filled with enormous potential to make a lasting impact on the way we understand and engage with CE ecosystems and how actors' CE capabilities shape the business environment.



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