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Intersection, interrelation or interdependence? The relationship between circular economy and nexus approach

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ABSTRACT

Circular Economy (CE) and nexus thinking are increasingly considered as promising solutions for resource sustainability. While CE aims to design out waste through reducing, reusing, recycling and recovery of materials, the Nexus approach is interested to minimise waste and inefficiencies by focusing on the interlinkages between resources. Both concepts have been evolving separately with limited academic work to analyse their relationship. The aim of this systematic review, based on academic publications from 2004 to 2020, is to scrutinise the relationship between the circular economy and the nexus approach by adopting a mixed methods research design including bibliometric analysis and thematic synthesis. Our quantitative bibliometric analysis shows that, out of 7956 circular economy and 5795 nexus papers, academic documents explicitly mentioning both concepts account for less than 1% of each literature. Nonetheless, there is considerable overlap in most frequent words (50%–71%) as well as the most relevant sources (54%–56%) between both literatures. A detailed qualitative analysis of the documents relevant to both concepts also supports the existence of a close relationship between the two. From these analyses, we develop a new integrative conceptualization of the relationship between circular economy and the nexus approach. We conclude that there is good evidence for a three-tiered hierarchical relationship: 'intersection', 'interrelation' and 'interdependence', which we discuss in detail. Finally, emphasising the importance of an integrated approach, we propose a novel conceptual framework which combines circular economy and nexus approaches, which helps to operationalise nexus thinking on the one hand, and to converge the circular economy towards environmental sustainability on the other hand. As such, the framework addresses two known challenges of the concepts. However, whilst our integrated framework contributes to the conceptual development of both circular economy and the nexus approach, further research is required to highlight and facilitate their interrelation and interdependence in practice.

1. Introduction

Circular economy (CE) and 'nexus approach' (hereinafter Nexus, including nexus thinking, resource nexus, etc.) are novel concepts in the realm of sustainability discourse. With significant annual publication growth, both concepts have had garnered increasing attention in recent years (Geissdoerfer et al., 2017); (Kirchherr et al., 2017); (Kalmykova et al., 2018); (Albrecht et al., 2018). CE is "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes […] with the aim to accomplish sustainable development" (Kirchherr et al., 2017). On the other hand, Nexus is defined as either "the interlinkage between different resources" or "an analysis approach to quantify the links between the nexus nodes (i.e., water, energy and food)" (Zhang et al., 2018). As the definitions demonstrate CE is concentrated on resource circularity, whilst the focus of Nexus is on understanding and analysing of interlinkages between resources. Despite this distinction, both concepts share common aims of resource sustainability and waste minimisation.

Distinguishing between academic and practice-oriented perceptions, the CE concept has its theoretical roots mainly in the academic field of environmental economics, which gradually emerged in 1960s in response to the raising concerns about inconsistencies between economic growth and environment sustainability (Wiesmeth, 2021). Particularly, the idea of CE draws on relevant concepts such as 'spaceman economy', 'limits to growth', 'cradle-to-cradle', 'industrial

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ecology', 'steady-state economy' and 'performance economy' in the last half century (Kalmykova et al., 2018). However, the more technical-practical perception of CE, which is deeply grounded in industrial ecology and its engineering, science and technology approach (Wiesmeth, 2021), only started to flourish after being adopted by China in 2002 and later EU as a new development strategy (Kalmykova et al., 2018).

Similarly, the notion of integrating research and policy analysis across regions and sectors –as the main idea of Nexus– also was part of the early environmental economics discussions (Wichelns, 2017). Emphasising on the role of Integrated Natural Resources Management (INRM) and Integrated Water Resources Management (IWRM) in development of Nexus approach, some recent studies doubt the actual novelty or innovativeness of the Nexus (e.g. (Wichelns, 2017)). However, this interpretation has been contested by others, highlighting key differences between Nexus and IWRM. Among others, integration of water, energy and food in most nexus studies from a multi-centric point of view is an important aspect which distinguishes it from IWRM water-centric perspective (Benson et al., 2015). Regardless of the historic roots, the Nexus concept has rapidly gained traction in scholarly literature and policy settings after World Economic Forum's 2011 report on water, food, energy and climate nexus (World Economic Forum, 2011) and Hoff's background paper for the Bonn 2011 Conference on water, energy and food security nexus (Hoff, 2011). This marks not only the emergence of Nexus as a new approach to resource sustainability, but also the dominance of food, energy and water as the main pillars of Nexus studies.

In line with its flourishing technological perception, CE is widely recognised as an operationalization tool (Kirchherr et al., 2017) or 'strategy' for sustainable development (Heshmati, 2017). Conversely, Nexus is being promoted as a 'conceptual tool' for the discourse (Biggs et al., 2015). In principle, integration of both concepts can have a synergistic output towards optimisation of resources and minimisation of waste. This potential highlights the importance of defining the CE-Nexus relationship and their integration.

Both CE and Nexus have, individually, received a lot of academic attention and their respective literatures have been extensively reviewed, e.g. (Geissdoerfer et al., 2017; Kalmykova et al., 2018; Schöggl et al., 2020; Zhang et al., 2018; Friant et al., 2020; Kirchherr et al., 2017) for CE and (Albrecht et al., 2018; Zhang et al., 2018, 2019; Jabbour et al., 2019; Endo et al., 2020; Ghodsvali et al., 2019) for the Nexus approach. However, their interrelationship has received far less attention. Although this relationship has been discussed in a handful research articles (e.g. Del Borghi et al., 2020; Lehmann, 2018; Brandoni and Bosnjakovic, 2018) and scientific events (e.g. Dresden Nexus Conference, 2020), an in-depth systematic analysis of the relationship is still missing. This systematic review aims to fill the gap by presenting the first detailed overview on the state-of-the-art of CE-Nexus relationship studies. Using a mixed-method approach, we first conduct a bibliometric analysis to find out if there is a meaningful relationship between CE and Nexus concepts, and then qualitatively analyse the relationship through a thematic synthesis. Finally, we provide a new conceptual framework that integrates both concepts.

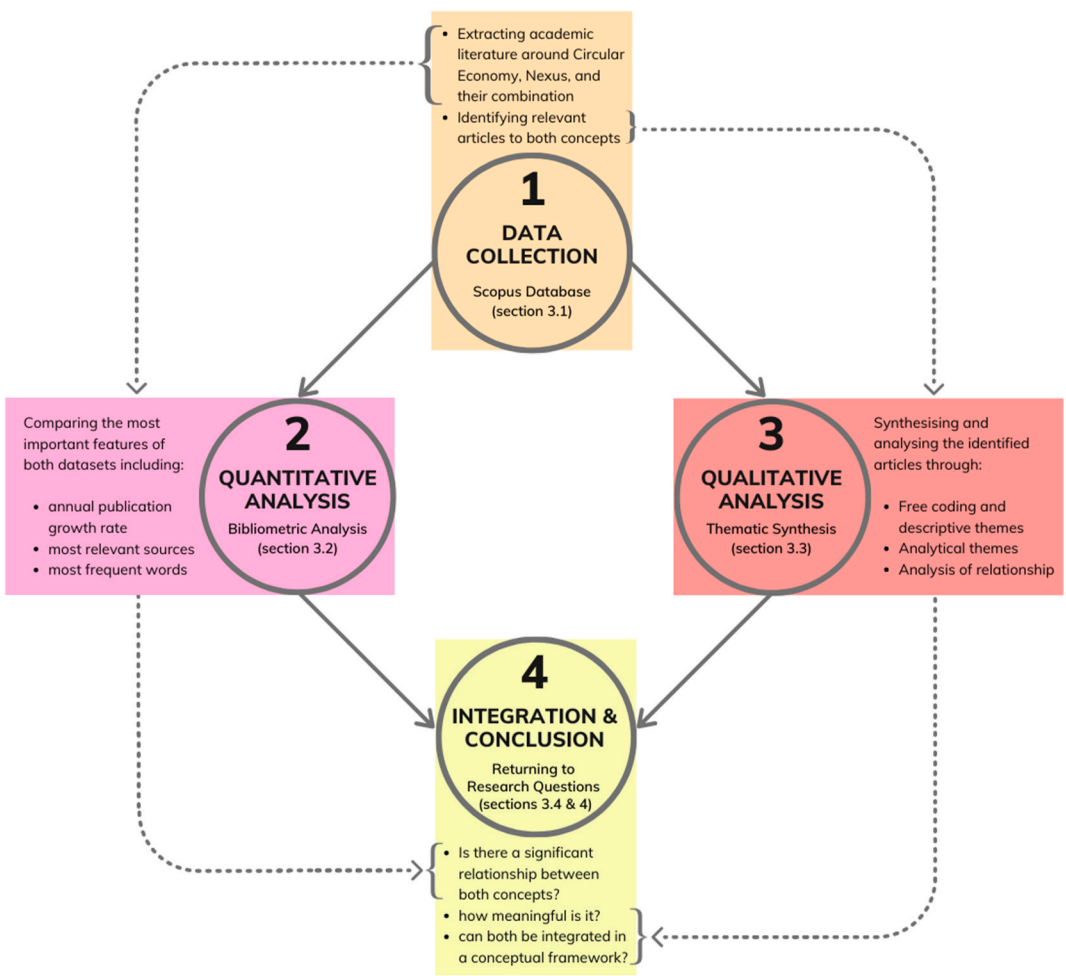


Fig. 1. The main steps of this literature review (section references denote sections where corresponding results are presented).

2. Methodology

This systematic review adopts mixed quantitative and qualitative methods to study the relationship between CE and Nexus (Fig. 1). First, to identify the most relevant academic literature, we search for CE and Nexus key phrases, both separately and in combination, in the Scopus database (Step 1). The extracted datasets are then used to analyse the state-of-the-art in CE-Nexus literature, both quantitatively and qualitatively. For the quantitative analysis, important aspects of the data (including annual scientific production, most relevant journals and most frequent words in each dataset) are compared through a bibliometric analysis method (Step 2). Here, the objective is to identify overarching similarities and commonalities between CE and Nexus literature. Next, a thematic synthesis as a qualitative method for analysis of the most relevant papers is used to shed light on the nature of relationship between both concepts by (Step 3). Finally, the results from steps 2 and 3 are integrated to elucidate the relationship between CE and Nexus (Step 4). The methods for the first three steps are detailed below; the fourth step is implicit in our discussion of the results.

2.1. Scopus search (step 1)

The Scopus database is used as the main data source for this review. The search for CE and Nexus scientific literature includes all types of documents (e.g. article, review, book chapter, etc.) in English which used the key phrases in their title, abstract and/or keywords. As both emerging concepts have been mostly reflected in the literature in the last decade, and the first identified CE document was from 2004, the results are filtered for the period 2004–2020.

To include most relevant documents on the one hand and exclude irrelevant search results on the other hand, various alternative combinations of key phrases are tested. The test searches suggest that although 'circular economy' has a more established uniform usage in the literature, the term 'Nexus' is used broadly in different forms and for different purposes, for example, as 'saving and investment nexus' in the field of finance and economics (Narayan, 2005), or 'language-culture nexus' in an anthropology context (Silverstein, 2004). To limit the Nexus search results to the natural resources context, the phrase (*Nexus AND Food OR Energy OR Water) OR "Nexus Approach" OR "Nexus Thinking"* is finally chosen as the search phrase for Nexus documents. While this phrase helps to exclude the unwanted results (such as above examples), it enables to include the very relevant documents which discuss at least one of the three most popular pillars of Nexus, such as 'waste-to-energy nexus' (Sharma et al., 2020), or those which use merely 'Nexus thinking' (Ruiz-Salmón et al., 2020) or 'nexus approach' (Schneider et al., 2019). The term 'Nexus' represents the above search phrase throughout this review.

The Scopus search process is conducted in two rounds. First, CE and Nexus key phrases are searched separately and databases including title, keywords, abstract and other bibliometric details are created for each search. Next, to identify the documents which have mentioned both CE and Nexus concepts, both key phrases are combined as *"circular economy" AND (Nexus AND Food OR Energy OR Water) OR "Nexus Approach" OR "Nexus Thinking"*. The results of the latter round are then studied and sorted for qualitative analysis in the thematic synthesis section (3.3).

To assess their relevance, the second-round documents are categorised as 'not relevant', 'slightly relevant' and 'relevant' based on their content and context. The 'not relevant' category includes the documents in which one or both concepts (CE and Nexus) are used in a context different than natural resources. The 'slightly relevant' are the documents in which CE and Nexus are both used in the natural resources context, but there are none or few references to either or both concepts in the main text with no further detail on their relationship. Finally, the 'relevant' category includes all the documents which have discussed both concepts in the natural resources context with detailed information about both. The qualitative analysis of this review (Section 3.3) is based on the last category.

2.2. Bibliometric analysis (step 2)

Bibliometric analysis is a reliable quantitative method to produce a systematic, transparent and reproducible literature review (Aria and Cuccurullo, 2017), which helps to discover interesting, useful and novel patterns, relationships and trends within the CE and Nexus literature. This method is adopted herein to visualise, compare and analyse the state of the art in CE and Nexus literature.

Based on the Scopus data (Step 1), annual scientific production rate from 2004 to 2020 is the first comparable characteristic. Next, the most relevant journals to CE and Nexus are compared. The total quantity of the journals relevant to each concept, the top 20 most relevant journals and the diversity in each literature will be analysed.

Using Bibliometrix, an open-source quantitative tool for performing comprehensive science mapping analysis (available from www.bibliometrix.org), the most frequent words (MFWs) in abstracts of each dataset are also extracted for comparison. The aim of this exercise is to identify the common words in both MFWs lists and to assess the significance of this overlap. Assuming that the rate of common words may vary depending on the sample size of the MFWs, the comparison is conducted for top 1000, 500, 200, 100, 50 and 20 MFWs of each list.

Moreover, to understand the significance of the results, we estimate the highest and lowest possible values for overlap between two hypothetical literatures. The highest possible overlap is assumed between two sets covering the same subject. To calculate this, the CE dataset is randomly divided into two roughly equal-size subsets and the percentage of commonality between MFWs of the subsets is marked as the highest possible overlap. The lowest possible overlap is assumed between two searches that have no obvious commonality. To estimate this, we conduct a separate search for 'Blended Learning' and after extracting the list of MFWs from the new dataset, we compare its MFWs with CE's. The key phrase 'Blended Learning' is randomly chosen for this comparison because: 1) it comes from a very different conceptual and disciplinary background (i.e. pedagogy), which means there will be a very low commonality between both datasets; and 2) as a new and emerging concept, it has similar chronological and bibliometric features to CE (e.g. conceptual emergence, literature size and growth rate). The results of these two comparisons, which establish upper and lower bounds for possible overlap values, can help to make sense of the overlap between CE and Nexus MFWs.

2.3. Thematic synthesis (step 3)

As a foundation method in qualitative research, thematic analysis is 'a method for identifying, analysing and reporting patterns (themes) within data' (Braun and Clarke, 2006). While other similar pattern-seeking analytic methods are usually theoretically bounded, the flexibility of thematic analysis provides theoretical freedom and enhances its usability to get a 'rich and detailed' account of data (Braun and Clarke, 2006). Considering this advantage, we adopt this method to identify, analyse and report the patterns in the CE-Nexus relationship. Since 'thematic analysis' is generally used for analysing primary data, 'thematic synthesis' has been proposed as an alternative term for thematic analysis of primary researches in a systemic review (Thomas and Harden, 2008). In this context, 'synthesis' implies the idea of 'going beyond' summarising the findings of primary studies (Thomas and Harden, 2008).

Regarding the flexibility of the method, different frameworks have been proposed for thematic analysis/synthesis (Braun and Clarke, 2006; Saldana, 2011). Integrating these frameworks and techniques, Thomas and Harden (2008) three overlapping stages of thematic synthesis are adopted in this review. These stages are: 'free line-by-line coding', 'construction of descriptive themes' and 'development of analytical themes'.

In qualitative research, 'coding is a heuristic —a method of discovery— to the meanings of individual sections of data … [and] codes function as a way of patterning, classifying, and later reorganizing each datum into emergent categories for further analysis' (Saldana, 2011). In thematic synthesis, the line-by-line coding enables to translate the concepts from one study to another (Thomas and Harden, 2008). Hence, at the first stage, we read through all relevant papers and identify the sentences pertaining to CE, Nexus and their relationship. After summarising each relevant sentence or passage, a new code is created unless the section can be assigned to an existing code. The label of each code is meant to reflect the content and meaning of the sentence. For more organisation, the bank of codes is divided into three generic groups: 'CE', 'Nexus', and 'CE-Nexus relationship'. After the first round of coding, the codes are reviewed to make sure no further adjustment or redefinition is required. NVivo, a qualitative data analysis software produced by QSR International, was used to facilitate this process.

For constructing descriptive themes, we look for emerging patterns in the codes based on their similarities and differences. The themes can be developed either in a bottom-up (inductive) or in a top-down (deductive or theoretical) way (Braun and Clarke, 2006). Herein the descriptive themes are created inductively with the least possible subjective intervention. Hence, the overall goal behind creating the descriptive themes is to synthesise the relevant papers while keeping a very close proximity to the original contents.

Contrary to the descriptive themes, 'analytical themes' are developed deductively. At this stage, the objective is to 'go beyond' the findings of the primary studies and answer the review questions which were 'temporarily put to one side' during development of the descriptive themes (Thomas and Harden, 2008). In other words, the expectation is to provide a deep analysis of some aspects of data in contrast to a broad descriptive overview of the whole data (Braun and Clarke, 2006). Regarding these, the goal behind generating analytical themes at this review is to develop a conceptual framework which can present a novel understanding of the relationship between CE and Nexus.

3. Results

3.1. Scopus search

The Scopus searches on January 03, 2021 resulted in 7956

Table 1
An overview of Circular Economy-Nexus relationship in the 19 relevant papers.

Typology	Citation	Circular Economy-Nexus Relationship
Papers aiming to conceptualise the relationship between CE and Nexus	Del Borghi et al. (2020)	A Nexus approach in CE is essential because closing loops as the main goal in a CE setting can lead to shifting burdens from one sector to another. At the meantime, CE principles helps to operationalise the FEW Nexus approach.
	Lehmann (2018)	Resource nexus and circular economy 'are not exactly the same', even though there are 'clear overlaps' between them and both have 'resource efficiency of urban systems' at their core.
	Brandoni and Bosnjakovic (2018)	Lack of awareness on interlinkages between energy, food and water resources is a critical challenge to develop Nexus thinking in the EU, and a CE framework can help to address it.
Papers utilising CE and Nexus to conceptualise either Circular City or FEW Nexus concepts	Paiho et al. (2020)	In a circular city, a nexus approach can help to identify the synergies and trade-offs among diverse urbanisation challenges by providing a broader and more holistic analysis.
	Williams (2019)	By elaborating that CE literature is mostly focused on actions within resource sectors, the article identifies five common challenges to implementing Nexus solutions, namely competing political priorities, lack of institutional capacity, lack of data availability, lack of joined-up supportive framework, and lack of common standards.
	D'Odorico et al. (2018)	Analysis of the inherent linkages of the FEW Nexus in a CE paradigm is critical for enhancing the resilience of global water, energy and food security.
Methodological papers that introduce new tools to assess Nexus in a CE	Xue et al. (2018)	This tool enables visualization of different CE pathways, and development of different CE scenarios associated to FEW Nexus management
	Slorach et al. (2020)	According to CE waste hierarchy, in-vessel composting is favoured over incineration and landfilling while the results of this Nexus based methodology contradicts it and raises the conclusion that circularity does not necessarily overlap with environmental sustainability.
Papers on various topics which do not focus on conceptualising the CE-Nexus relationship	Brears (2015)	Despite distinct discussions, the study does not provide a clear description of the relationship between both concepts.
	Laso et al. (2018)	Circularity without a Nexus thinking does not necessarily propose the best possible options for environment and natural resources management; thus, application of CE needs a deeper analysis from Nexus approach.
	Greer et al. (2020)	Study of circular services from a FEW Nexus perspective enables to address the inherent interconnections of the water, energy and food sectors, and avoid ignoring or overlooking the cross-over impacts in the circular system.
	Maaß and Grundmann (2016)	Interdependency between water, energy and biomass is an inherent characteristic of a natural-resources-based CE such as agriculture. This highlights the need for the FEW Nexus as an analytical and conceptual approach to better understand and manage the interrelated natural resources across different scales and sectors.
	Chen et al. (2020)	Transition towards CE in chemical industry is achievable through 5R practices (i.e. redesign, reduction, recovery, recycle, and reuse), establishment of FEW Nexus approach and development of green smart chemical industry.
	Ruiz-Salmón et al. (2020)	Nexus thinking is 'the most appropriate way' in transitioning to a CE in the seafood sector.
	Udugama et al. (2020)	FEW Nexus can help to analyse the environmental and societal impacts of resource recovery technologies which is crucial for transition to a CE.
	(Kılkış and Kılkış, 2017)	Towards integrating the CE concept in a higher education course, a Nexus approach enables to model multiple aspects and interlinkages within the energy, food, water and education system, and develop potential solution areas.
	Loh et al. (2019)	'Waste (POME)-to-Wealth (compost)' is a good example of FEW Nexus optimisation which benefits all three resources and lead to a CE.
	Sharma et al. (2020)	Shifting towards CE requires generating green energy and managing waste which can be attained through Waste-to-Energy Nexus.
	Schneider et al. (2019)	Nexus approaches complement 3R principles (i.e. reduce, reuse and recycle); the principles which have a central role in CE practice and policies.

documents for CE, 5795 documents for Nexus and 57 documents for their combination. Despite the remarkable body of literature around each concept, this shows that only less than 1% of each literature has mentioned both concepts in their title, abstract or keywords. From the 57 combination documents, one third (19 documents) are 'not relevant' (e.g. nexus as 'interconnection of circular economy and energy transition' (Chen and Kim, 2019)), another third (19 documents) are 'slightly relevant' (e.g. using 'nexus' without any detailed discussion in the context of 'global nexus of soil-water-air-energy' (Rhodes, 2017)), whilst the remainder (last 19 documents) are 'relevant' to the objectives of this review (Table 1).

Of these 19 relevant documents, only three are explicitly dedicated to scrutinising the relationship between CE and Nexus (Table 1). While the next three documents are interested in conceptualising either Circular City or FEW Nexus, they take advantage of the other concept to enrich their analysis. Among the list, there are two methodological articles that introduce new tools for assessing the Nexus impacts in a CE. As can be expected, these papers do not provide a deep conceptual discussion of the concepts. Finally, the remaining 11 papers predominantly comprise case studies on various topics (Table 1). Hence, despite multiple references to the CE and Nexus concepts, these papers do not focus on defining or conceptualising the CE-Nexus relationship. These 19 papers are the basis for the thematic synthesis (Section 3.3).

3.2. Bibliometric analysis

3.2.1. Annual scientific production

CE and Nexus are both young and emerging concepts in the scientific literature (Fig. 2). With average annual growth rates of 54% and 32% respectively, both CE and Nexus literature exhibit remarkable exponential growth over the last decade. However, particularly in the last 5 years, the CE seems to have the bigger impact. In addition to the similar growth rates, the following graph also exposes simultaneous emergence for both literatures.

3.2.2. Most relevant sources

CE's 7956 documents are published in 1824 sources, whilst the 5795 Nexus documents are published in 2077 sources. This implies a remarkable diversity in the literature. Of these, 432 sources have published at least one article on each of the two concepts. Overall, these 432 sources published over half of the literature around both concepts (i.e. 54% of Nexus and 56% of CE documents). Listing the most relevant sources, by sorting the journals based on their publication quantity, shows that a third of the total literature is published by only 20 sources (Fig. 3). The 'Journal of Cleaner Production', with 684 CE and 176 Nexus papers, is the frontrunner in both lists by a significant margin. Overall, the source diversity of Nexus literature is higher than CE's. The top four CE journals have jointly published 20% of the publications in the respective literature, whilst the top four Nexus journals have only published 10% of the overall articles.

3.2.3. Comparison of most frequent words

The result of comparison between MFWs in CE and Nexus datasets shows that the overlap between both lists varies from 71% for top 1000 words to 50% for top 20 words (Fig. 4). This means that at least half of the most commonly used words in the CE and Nexus literatures are shared between both. A comparison of MFWs between CE and 'blended learning' MFWs shows a lower overlap, from 54% (for top 1000 words) to 20% (for top 20 words). While this marks the lowest possible overlap, comparing the MFWs of two CE subsets indicates that the highest possible overlap can be between 80% (for top 1000 words) and 75% (for top 20 words) (Fig. 4).

Moving down from the top of the MFWs lists indicates that more generic words would appear. This explains the 54% overlap between top 1000 MFWs of CE and 'blended learning' literature. However, when the comparison sample size is narrowed down to the top 20 MFWs, there are only 2 words (i.e. 'study' and 'model') repeated in both lists. On the contrary, the overlap between MFWs of the two CE subsets varies slightly between 75% and 80% for different sample sizes. Although the linear graph of CE-Nexus overlap sits between the lower and higher guiding lines, the chart shows a remarkable $\geq$50% overlap between CE and Nexus MFWs, even for the top 20 MFWs. This indicates that the literature around the two concepts is significantly homogeneous and intertwined (unlike CE and 'blended learning').

The software-generated MFW lists included various research generic terms (e.g. 'review', 'case', etc.), geographical areas (e.g. China, EU, etc.), abbreviations (e.g. CE, FEW, etc.) and different forms of the same words (e.g. 'resource' and 'resources', 'economy' and 'economic', etc.). We filtered the first three groups out and combined the last (i.e. words with the same roots) to extract more exclusive lists of meaningful MFWs. Since there is still 50% (10 out of 20 words) overlap between both lists, this adjustment does not contradict the above findings, yet it helps towards a more insightful overview of the data. The following clustered bubble chart (Fig. 5) depicts the top 20 MFWs in CE and Nexus datasets where the area of the bubbles represents the occurrences of meaningful words in the CE and Nexus literature.

As it can be seen, the 'nexus' and 'circular' keywords have been abundantly used in their respective list. However, neither of them has a significant role in conceptualization of the opposite literature (i.e. they do not appear in the top 20 MFWs for the opposing literature). In fact, 'nexus' and 'circular' are used only 70 and 75 times in the MFWs list of the opposite literature, respectively ranking 1637th and 1392nd. This suggests that, although at least half of the MFWs in both lists are repeated, there has been notably less academic work towards conceptualising both concepts in an integrated framework.

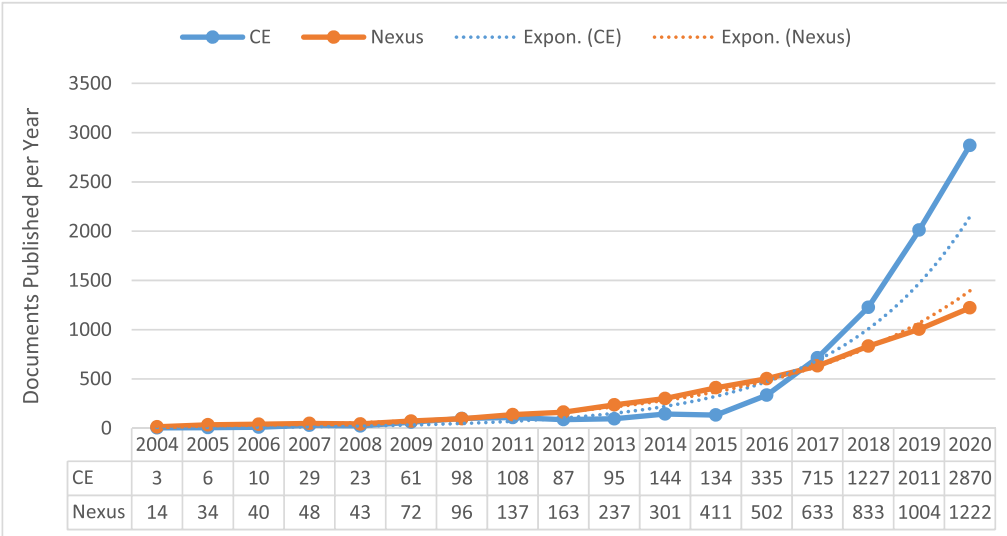
The MFW data suggests that 'water', 'energy' and to a lesser extent 'food' are the most important keywords in the Nexus literature. This is not surprising as we focussed our Nexus search on the FEW Nexus specifically. However, it does indicate that the three-pillar FEW Nexus is a dominant Nexus approach. In the CE dataset, after 'circular' and 'economy', the most repeated keyword is 'waste', which affirms the importance of the concept in the literature as many believe that 'designing out the waste' and 'waste minimisation' is the main aim of CE (e.g. EMF, 2017; Kirchherr et al., 2017).

Fig. 5 also reveals that the meaningful MFWs in both literatures are broadly relevant to resource management and sustainability. 'Sustainable', 'development', 'management' 'production', 'resources', 'environment', etc. are among the top MFWs in both lists which reflects the deep interconnection of both concepts with the sustainability discourse.

Moreover, while 'water', 'energy' and 'economy' are among the top 20 meaningful MFWs in both literatures, the uneven dominance of first two in Nexus, and the last in CE datasets can meaningfully describe the divergence between both concepts. In fact, they are not only the most common words, but also the core nodes of the MFWs network. In the list of Nexus top 20 MFWs, for instance, 'agriculture', 'electricity', 'power', 'consumption', etc. are the keywords quite relevant to 'water' and 'energy' core concepts. This confirms arguments about the 'water-centric' nature of the Nexus literature, whereas the 'food' pillar is relatively understudied (see Albrecht et al., 2018; Endo et al., 2017). The same pattern can be seen in the CE dataset as well. 'Materials', 'efficiency', 'products', 'industry', 'design', etc. are the examples of CE's MFWs which surrounded the 'economy' keyword and together widened the gap between CE and Nexus concepts.

3.2.4. CE-Nexus Relationship from the quantitative data

Referring to the shared academic documents between both literatures, the less than one percent commonality does not imply a noticeable relationship between both concepts (Fig. 6). The comparison of the most relevant sources (Section 3.2.2) and most frequent words (Section 3.2.3), however, contradicts the prior speculation. As illustrated, the 432 shared sources have published more than half of the literature around each concept. On the other hand, at least half of the most



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CE	3	6	10	29	23	61	98	108	87	95	144	134	335	715	1227	2011	2870
Nexus	14	34	40	48	43	72	96	137	163	237	301	411	502	633	833	1004	1222

Fig. 2. Annual exponential growth rate and trendline of Circular Economy and Nexus literature.

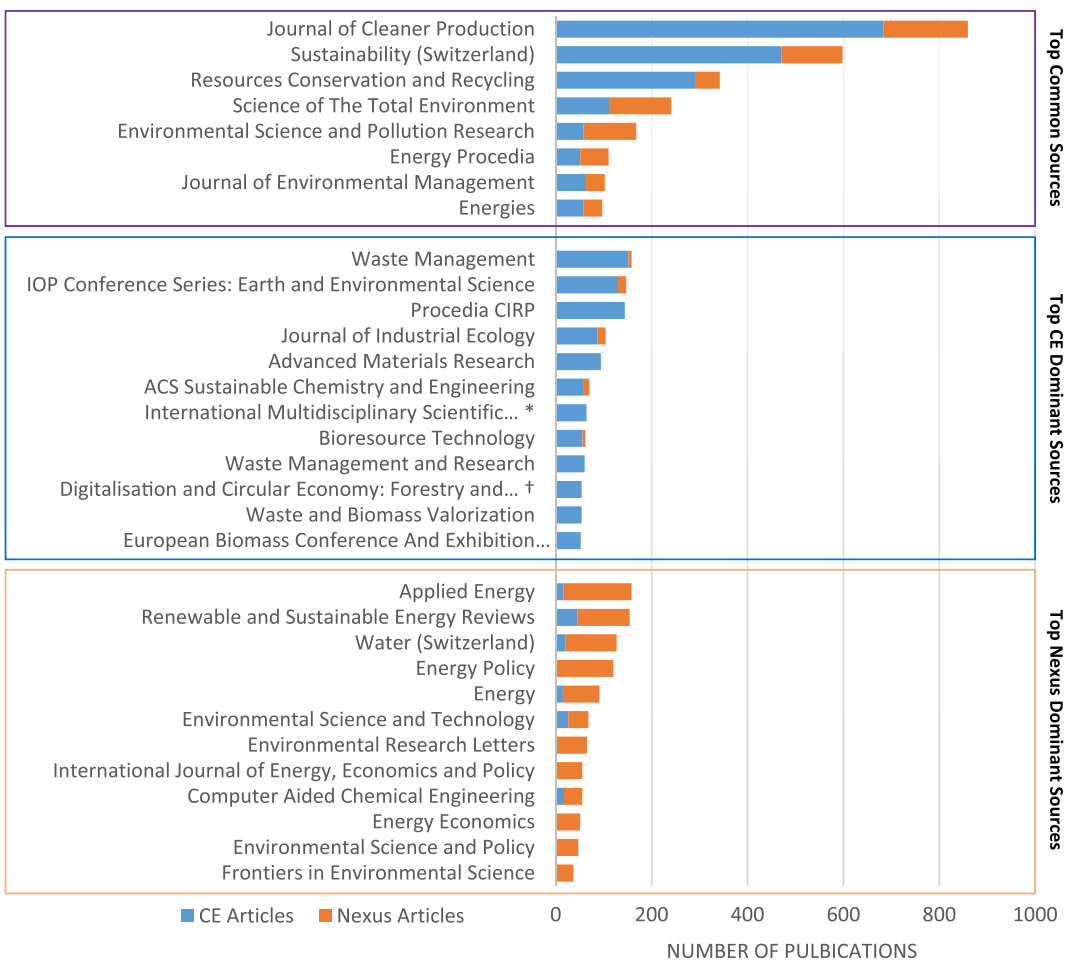


Fig. 3. Most relevant sources to circular economy and nexus literature (* International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management SGEM; † Digitalisation and Circular Economy: Forestry and Forestry Based Industry Implications - Proceedings of Scientific Papers).

frequent words in CE and Nexus literatures are common. Such quantitative findings suggest that while there is a remarkable intersection between both concepts, the analysis of their relationship in the academic literature is widely underrepresented (Fig. 6).

3.3. *Thematic synthesis*

3.3.1. *Free coding and descriptive themes*

Free line-by-line coding of all the texts about CE, nexus, and their relationship in the 19 relevant papers (Table 1) resulted in creating 34

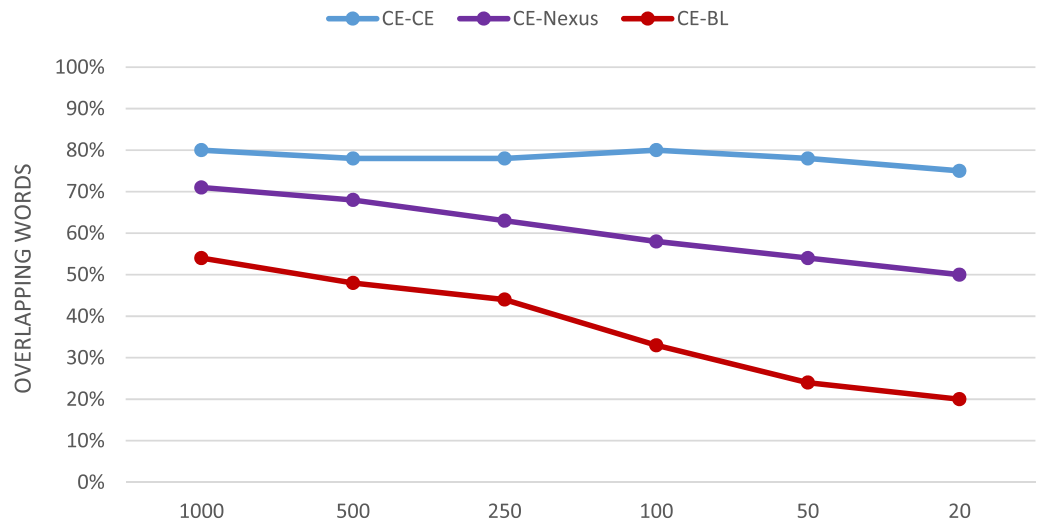


Fig. 4. Overlap between Circular Economy and Nexus (CE-Nexus) most frequent words lists in comparison with the overlap between Circular Economy and Blended Learning (CE-BL), and two sub-lists of Circular Economy (CE-CE).

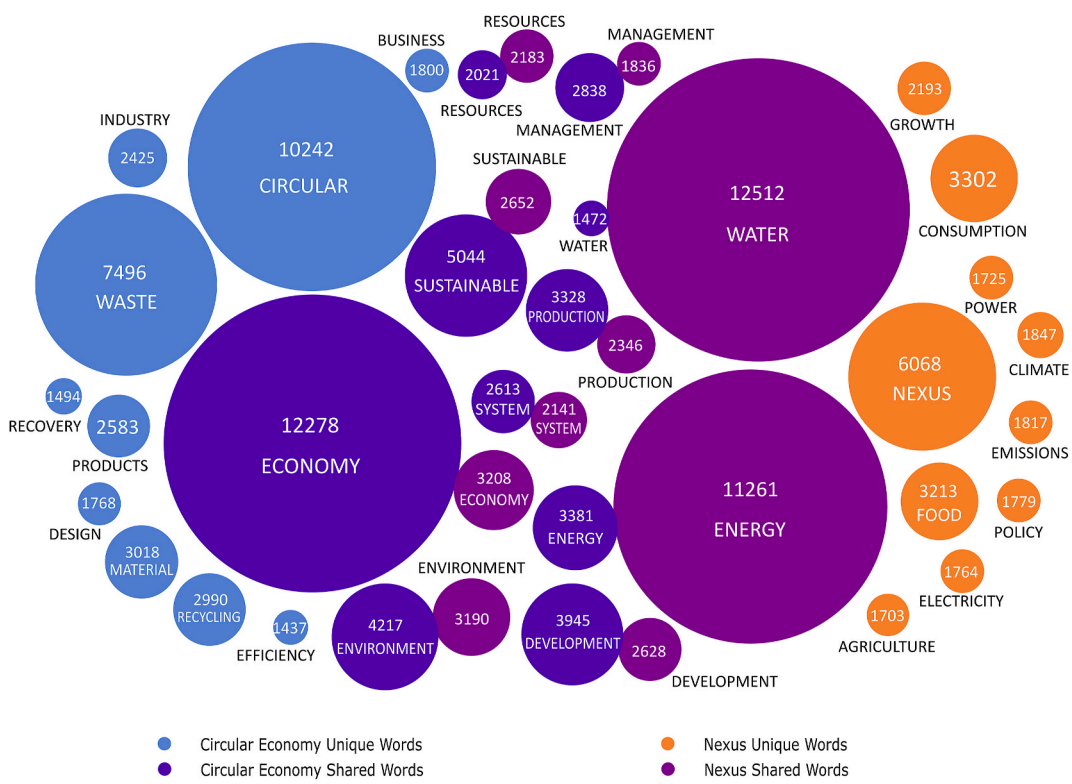


Fig. 5. Clustered Bubble chart of Circular Economy and Nexus top 20 most frequent meaningful words and their overlap (the numbers on the bubbles and their areas represents the number of its occurrence in the dataset).

unique codes. These include 16 'CE', 11 'Nexus' and six 'CE-Nexus relationship' codes (Appendix 1; Fig. 7). For ease of access in descriptive and analytical themes, an ID is assigned to each code. Some codes are referenced multiple times, while others are unique, i.e. occurring only once within the 19 papers (Appendix 1). However, the quantity of documents and references for a qualitative analysis code does not indicate anything about its importance (Thomas and Harden, 2008).

A comparative approach to identify emerging patterns within the initial codes enabled to create five descriptive themes, namely: 'CE and Nexus as Emerging Paradigms', 'Resource and Waste Minimisation as Common Aim', 'CE and Nexus Links to Sustainability', 'CE and Nexus in Policy, Practice and Research', and 'In Pursuit of Defining CE-Nexus Relationship'. While an objective bottom-up approach at this stage was a major criterion, these five themes are developed with minimum subjective intervention. This means that finding a logical relationship between the themes and further classification of them is neither possible nor desirable. Hence, there is no intended order of the themes, and the assigned numbers does not imply any hierarchical or other sort of relationship between the themes. To get a better grasp of the themes, the equivalent code of CE (on the left) and Nexus (on the right) are placed in the same row, and where there is no equivalent code to a code in the opposite literature, a blank space is inserted (Fig. 7).

a) CE and Nexus as Emerging Paradigms

CE and nexus are both widely addressed as emerging paradigms (Brandoni and Bosnjakovic, 2018; Voulvoulis, 2018; Smajgl et al., 2016) or discourses (Friant et al., 2020; Keskinen et al., 2016; Lehmann, 2018). Decoupling economic growth and resource consumption (Schneider et al., 2019; (Lehmann, 2018); 'slowing, narrowing and closing the resource loops' (Paiho et al., 2020); and ultimately 'transition of the linear production and consumption model' (Maaß and Grundmann, 2016) stand at the heart of the CE paradigm. On the other hand, the core argument of the proponents of Nexus as a new paradigm/discourse is that 'interdependencies resulting from linkages among subsystems, such as water, food and energy, jointly affect the sustainability of the broader social–ecological system … [and] are generally overlooked when independently analysing sub-systems' (Maaß and Grundmann, 2016).

There are at least two major critiques on 'closing the loop', as the core argument of the CE paradigm (Fig. 7). The first addresses fragile theoretical foundation of the CE concept by arguing how indefinite and complete recycle of resources are 'unrealistic' and 'unattainable' according to the entropy and laws of thermodynamics (Friant et al., 2020; D'Odorico et al., 2018). Second, even regardless of this inherent limitation, closing loops does not necessarily guarantee the environmental sustainability because recycling and reusing of materials may only shift the burden, for instance by increasing energy and water consumption or GHG emission (e.g. Laso et al., 2018; Del Borghi et al., 2020). This has been echoed widely in the Nexus literature as a 'silo mind-set' that fails to account the complex interconnections and potential synergies and trade-offs between the sub-systems (Lehmann, 2018).

b) Resource and Waste Minimisation as Common Aim

Sustainability of resources and minimisation of waste are the common goal of both CE and Nexus. The aim of Nexus is to "integrate resource management processes that increase the efficiency of natural resource use and infrastructural systems, transform planning practice and reduce CO2 emissions and waste generation" (Lehmann, 2018). Similarly, CE aims at "keeping the added value in products, materials and resources for as long as possible and minimising waste generation". CE's goal can be consolidated as three principles: 'designing out waste and pollution', 'keeping products and materials in use', and 'regenerating natural systems' (EMF, 2017), where it is emphasised that designing out waste takes place 'throughout the value chain, rather than relying on solutions at the end of a product's life' (Brears, 2015).

Towards this aim, CE has established its foundation on looping actions including reduce, reuse, recycle and recover (Williams, 2019). These are also referred to as the 'core principles' (Maaß and Grundmann, 2016) or 'core aspects' of CE (Paiho et al., 2020; Geissdoerfer et al., 2017), '5Rpractices' (i.e. plus reclamation) (Pan et al., 2015), 9Rs framework (i.e. plus refuse, rethink, repair, refurbish, remanufacture, repurpose) (Kirchherr et al., 2017) or similar concepts. In spite of the variety in looping actions, an overarching critique on the current state of CE research and practice refers to the disproportionate focus on manufacturing rather than services industries (Kirchherr and van Santen, 2019; Greer et al., 2020), and similarly on recycling rather than reusing (Ghisellini et al., 2015; Paiho et al., 2020).

c) CE and Nexus Links to Sustainability

CE and Nexus have been both defined as key elements of the sustainability discourse. While CE is being promoted as a practical tool (Chen et al., 2020), Nexus is considered more as a 'conceptual tool' to achieve sustainable development' (Biggs et al., 2015; Lehmann, 2018). In this sense, Nexus is important 'to ensure the sustainability of the environment' (FAO, 2014; Laso et al., 2018) and 'essential for urban sustainable development' (Xue et al., 2018). CE, on the other hand, is generally defined as a 'strategic approach' or 'pathway' (Clark et al., 2016) 'to accomplish sustainable development' (Greer et al., 2020; Chen et al., 2020). However, CE's link to sustainability is also challenged, as several authors illustrated that there are conflicting targets and trade-offs between circularity and sustainability (Paiho et al., 2020), and that 'circular' does not necessarily mean 'environmentally sustainable' (Slorach et al., 2020).

Regarding the three pillars of sustainability (i.e. environmental quality, economic prosperity and social equity), CE has been focused more on the economic and environmental benefits, whereby CE can facilitate economic growth through 'creating new businesses and job opportunities, saving material cost, dampening price volatility, and improving security of supply', while reducing the environmental costs (Del Borghi et al., 2020). The United Nations Environment Programme (UNEP, 2013) even defines CE as "an economy which balances economic development with environmental and resources protection" (Lehmann, 2018). On the contrary, Nexus is more considered as 'one notion that can be used to put the social and environmental aspects into perspective' (Endo et al., 2017; Udugama et al., 2020).

d) CE and Nexus in Policy, Practice and Research

Unlike Nexus, the topic of CE is "high on the political agenda and in particular in Europe" (Del Borghi et al., 2020). In 2015, the EU launched a CE package which contains "an action plan, a deadline for the actions to be completed and four legislative proposals mainly on waste management", and ambitious targets on 'waste recycling, landfilling and hazardous waste' were set in 2018 (Brandoni and Bosnjakovic, 2018). However, the current policies such as EU biofuel support policies have

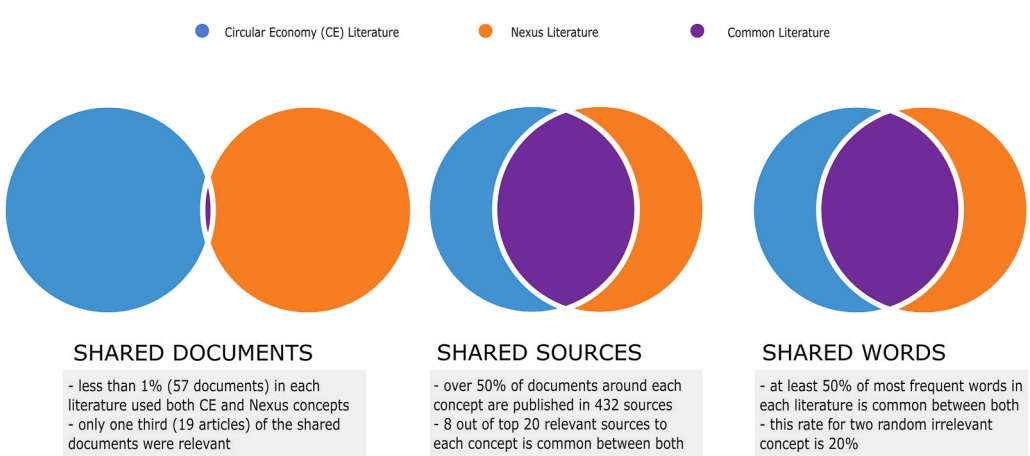


Fig. 6. Conceptualized summary of bibliometric data on commonalities between circular economy and nexus approach.

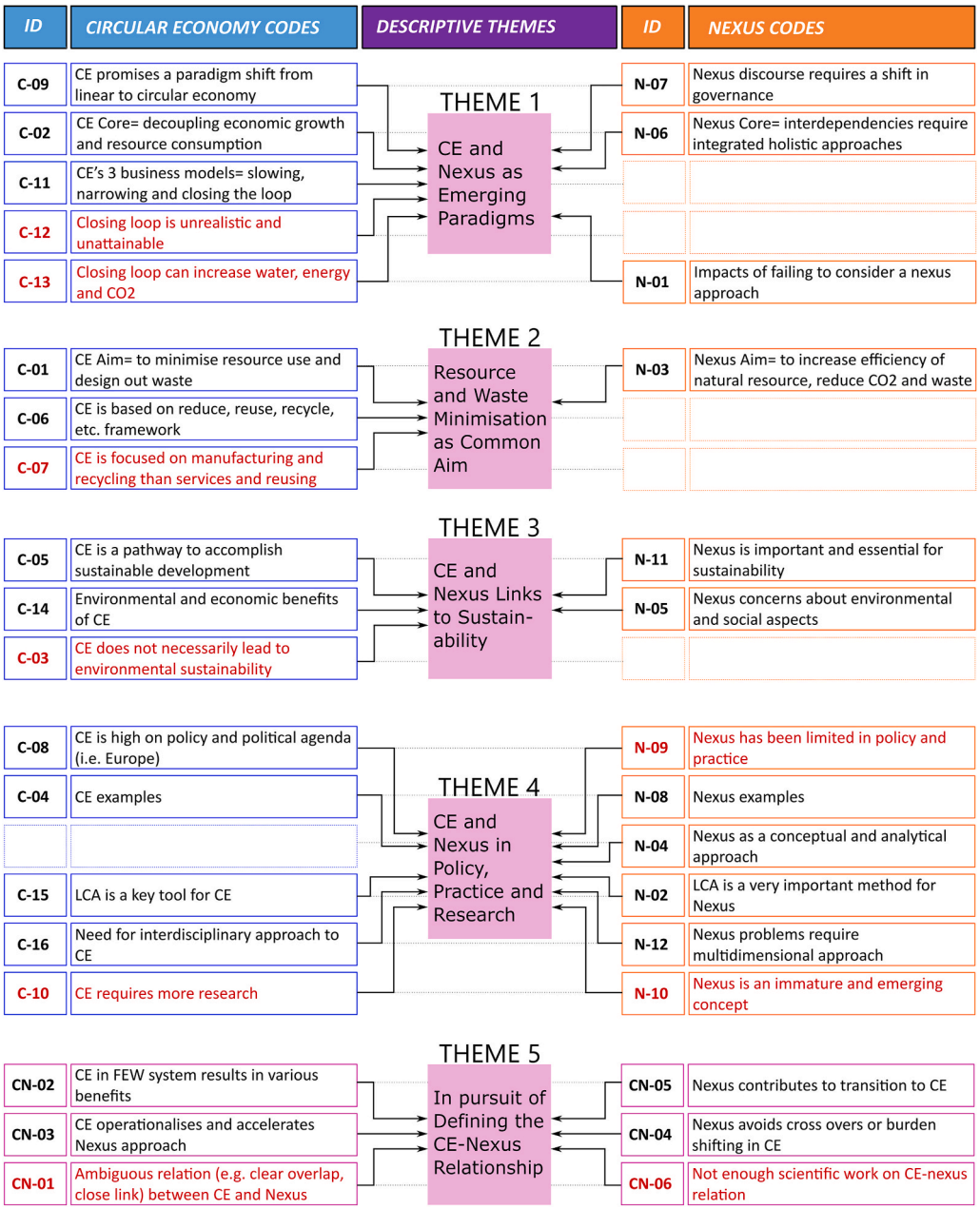


Fig. 7. Visualization of distribution of Circular Economy and Nexus codes into five descriptive themes with no hierarchical order (Blue boxes represent CE codes, while orange boxes represent Nexus codes. Pink boxes in Theme 5 represent the codes which discuss both concepts. Red font represents limitations and critiques. Dotted connecting lines between left and right boxes represent their comparability. Blank boxes mean that the code has no equivalent in the opposite literature).

been developed in silos which overlook the impact of such policies on other sectors and on the sustainability (Brandoni and Bosnjakovic, 2018). Hence, despite the outstanding progress in scientific aspect, moving from a theoretical framework to an integrated policy approach is still a matter of concern in Nexus literature (Del Borghi et al., 2020). This highlights the responsibility of the governments in addressing the Nexus legislative barriers (Brandoni and Bosnjakovic, 2018).

While limited in policy and practice, Nexus has been mainly promoted as a 'conceptual and analytical approach' to better quantify, analyse and understand the interrelations between natural resources and human activities (Maaß and Grundmann, 2016). This can then support 'policy integration and governance enhancement' (Loh et al., 2019). The scientific literature on Nexus has been primarily focused on 'quantifying nexus relations', as well as 'highlighting the institutional, political, and cultural dimensions of nexus policy making' (Del Borghi et al., 2020). Although 'there is no universally recognised methodology for Nexus analysis', Life Cycle Analysis (LCA) is being known as an important and appropriate tool for quantifying the environmental impacts on different resources within the Nexus (Ruiz-Salmón et al., 2020; Laso et al., 2018). Similarly, LCA is recognised as the 'key tool' in CE which enables to measure the environmental sustainability of products and technologies, and potential for their productivity enhancement (Del Borghi et al., 2020).

As an analytical framework, Nexus requires 'a multidimensional approach' in which technological, political and legal aspects are considered (Lehmann, 2018). The need for an inter/transdisciplinary approach has been broadly echoed in the literature (e.g. Albrecht et al., 2018; Keskinen et al., 2016). This can be also witnessed in CE literature where the combination of engineering and economic points of view are undoubtedly required to address the challenges (Brandoni and

Bosnjakovic, 2018). The call for inter/transdisciplinarity raises when many authors evaluate the both CE and Nexus as immature and emerging concepts which require more research (Lehmann, 2018; Laso et al., 2018; Paiho et al., 2020).

e) In Pursuit of Defining the CE-Nexus Relationship

Despite ever-increasing amount of papers for each concept, a lack of academic literature around their relationship has been recognised as a gap in a couple of recent papers. The literature pertaining the relationship between CE and Nexus is 'limited in number and uneven' (Del Borghi et al., 2020). Moreover, the analytical studies of interrelations between Nexus resources with a circular city context 'seems to be missing' (Paiho et al., 2020). Among the few papers interested in CE-Nexus relationship, ambiguous descriptions such as 'not exactly the same', 'closely linked' and 'clear overlaps' can be frequently noticed (e.g. Del Borghi et al., 2020; Lehmann, 2018). Despite these, the literature suggests that CE and Nexus approach each have at least two critical impact on the other.

In the most discussed relationship, Nexus thinking has been illustrated as 'the most appropriate way to go ahead' for transitioning to CE (Ruiz-Salmón et al., 2020). Distinguishing between 'integrated resource management strategies' and 'inter-sectoral [or Nexus] resource management strategies', the latter provides critical advantages for CE policies (Schneider et al., 2019). A Nexus approach can be also combined with a LCA to create 'an excellent opportunity to facilitate the transition to a circular economy' (Ruiz-Salmón et al., 2020). Avoiding 'burden shifting', 'cross-over effects' and indirect impacts of one resource on other resources is an even more critical advantage of Nexus approach for CE (Greer et al., 2020; Del Borghi et al., 2020). In an urban context, this means that lack of a Nexus approach can obscure the understanding of circularity solutions effects on other parts of the city (Paiho et al., 2020). In these narratives, Nexus is usually considered as a useful or even necessary approach/tool which lead towards CE as an overall appealing goal.

In return, a Nexus approach in which by-products of one resource are used as resources for other products, can be made operational by applying the principles of CE (Del Borghi et al., 2020; Brandoni and Bosnjakovic, 2018). Regarding the limitation of Nexus in policy and practice level, the use of a CE framework not only operationalises, but also accelerates the adoption of Nexus thinking (Brandoni and Bosnjakovic, 2018). For instance, the transition to CE can facilitate the employment of labour and investments in technological innovations that are required for FEW Nexus practices (e.g. waste-to-energy) (D'Odorico et al., 2018), and eventually help to reduce the Nexus pressures (Brears, 2015).

3.3.2. Analytical themes

Analytical themes go beyond the content of the primary studies and address the main question of this review. The aim here is to transform the aforementioned descriptive themes into new analytical themes to provide a deeper analysis of the relationship between CE and Nexus. This process resulted in the development of three analytical themes: intersection, interrelation and interdependence, each of which represents a distinct level of relationship between both concepts (Fig. 8).

a) Intersection

Pointing to the 'clear overlaps' between CE and Nexus literatures (Lehmann, 2018), this is the most recognised relationship which can be inferred from all of the descriptive themes. Despite the undeniable differences, the synthesis of the codes explicitly shows that both concepts have remarkable similarities and commonalities in between. According to the descriptive themes, CE and Nexus are both emerging sustainability-oriented paradigms which aim to reduce resource consumption and waste generation through inter/transdisciplinary approaches. Admitting to the intersection between CE and Nexus concepts, in this interpretation, is marked as the elementary level of relationship.

b) Interrelation

This is a higher level of relationship in which CE and Nexus are not only overlapping concepts, but also complementary – where a combination of both concepts enhances their individual qualities. Here, the underlying assumption is that while each concept can thrive individually in isolation, their integration will functionally contribute towards enrichment of each individual concept. Evidences for this level of relationship are abundant among the descriptive themes (Section 3.3.1). For instance, it was discussed that "the use of CE framework can accelerate the adoption of a nexus thinking" (Brandoni and Bosnjakovic, 2018), or from a CE point of view, it was emphasised that the Nexus thinking provides 'an excellent opportunity' for transition to CE (Ruiz-Salmón et al., 2020). Thus, translating the relationship between CE and Nexus as 'interrelation' implies that each concept has a constructive role in development of the other.

c) Interdependence

Adopting the term to define the highest level of relationship between CE and Nexus, interdependency relies on a mutual dependency between both concepts. The underlying assumption, at this level, is that the concepts in isolation provide an incomplete and flawed picture of the broader sustainability discourse. Hence, the concepts must be synthesised together to be able to address their fundamental critiques and to fill the current gap in the literature. The footprint of such an interpretation can be traced in the descriptive themes (Section 3.3.1) for instance in arguments about 'crossover effect' (Greer et al., 2020) and 'burden shifting' (Del Borghi et al., 2020) in CE when a nexus approach is missing, or where it was argued that "[Nexus] can be made operational by applying the principle of circular economy" (Brandoni and Bosnjakovic, 2018).

3.3.3. Intersection, interrelation, or interdependence?

The results of both quantitative and qualitative analyses (Sections 3.2 and 3.3) suggest that there is a meaningful relationship between CE and Nexus concepts. While the findings of bibliometric analysis (Section 3.2.4) discovered a remarkable intersection between both literatures through numbers, the thematic synthesis codes and descriptive themes (Section 3.3.1) provided affluent evidence for such similarities and commonalities. Moreover, a review of descriptive themes developed from the common literature between both concepts revealed that there is a consensus on mutual benefits of collaboration between both concepts. This higher level of relationship, in this review, is recognised as 'interrelation'.

In addition to the two obvious levels of relationship, there are some indications of 'interdependence' between both concepts. While not explicitly addressed, the necessity for recognition of a bilateral interdependency between CE and Nexus can be inferred from the broader literature. It has been already discussed that a lack of Nexus thinking in CE paradigm can cause undesirable and unsustainable consequences. For instance, the trade-off between local CO2 emissions and energy from waste incineration highlights conflicting targets between CE and sustainability, the resolution of which requires a Nexus approach (Paiho et al., 2020).

This interdependence can particularly be concluded from at least two case studies. The first is a comparative analysis of three scenarios for reducing food loss from the Spain anchovy canning biogas recovery (Laso et al., 2018). The findings of this study suggest incineration as the best scenario since the valorisation alternative is more water-intensive and not sufficiently nutritional energy productive. The second is a

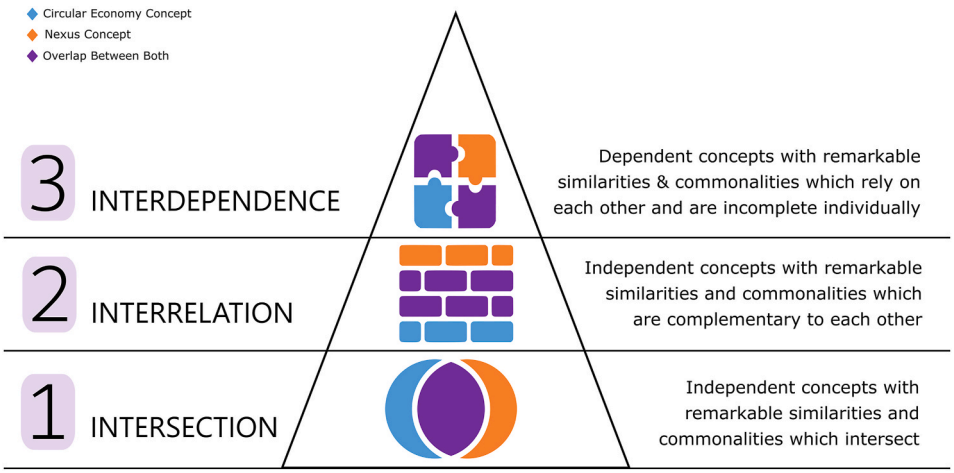


Fig. 8. Levels of relationship between CE and Nexus.

similar comparison of four different technologies for resource recovery from household food waste which finds 'in-vessel composting' the worst option "despite being favoured over incineration and landfilling in circular-economy waste hierarchies" (Slorach et al., 2020). According to CE's waste hierarchy framework, reusing and recycling is always more favourable than energy recovery (i.e. incineration). The findings of these Nexus-oriented case studies, however, contradict this hierarchical assumption which is repeated in "30 percent of [CE] definitions" (Kirchherr et al., 2017). While the CE literature is mainly concentrated on material loops, this means that lack of a nexus approach can shift the environmental pressure to other sectors by increasing other resources' consumption (e.g. water and energy) or GHG emissions. Given that, a Nexus approach is necessary for CE to avoid this pitfall.

Meanwhile, even though not rigorously analysed, the concept of the FEW Nexus relies vastly on the idea of circularity. In fact, a nexus approach which is primarily based on the feedback loops between resources is not compatible with the 'take, make, use, dispose' model of linear economy. Moreover, CE not only provides the ontological and epistemological foundations of the nexus approach, but also facilitates its operationalization. Despite the accelerating research in the last decade, limited work has been done on transition from 'nexus thinking' to 'nexus doing' (Simpson and Jewitt, 2019; McGrane et al., 2019). CE principles including 'design out waste and pollution', 'keep products, components, and materials at their highest value and in use', and 'regenerate the natural system' (EMF, 2017) can be specifically utilised as underlying principles for FEW Nexus policies and practical measures.

3.4. *An integrated CE-Nexus framework*

Admitting to interdependency, or even only interrelation, between CE and Nexus concepts spotlights the need for an integrated conceptual framework. Such an integrated framework can provide a better understanding of the concepts as well as addressing various theoretical and practical challenges surrounding both literatures. Practically speaking, adopting a nexus approach in CE context can ensure that the CE paradigm does not fall short of the sustainability expectations, and does not lead to shifting the burden to other sectors. Similarly, the integration facilitates the utilisation of the nexus approach in policy and practice settings and enables to pursue the transition from nexus thinking to 'nexus action'.

Aiming to demonstrate how an integrated CE-Nexus approach can develop a more comprehensive picture of both concepts, the following schematic depicts the output of integration in four steps (Fig. 9). The first part of the quadruplet presents a common understanding of the CE concept (Fig. 9a), which is then integrated with the Nexus to provide a comprehensive and novel conceptual framework (Fig. 9b). Similarly, a prevalent illustration of the FEW Nexus is provided (Fig. 9c). After integrating the CE, the new framework is optimised to outline a more detailed and practical integrated understanding of the FEW Nexus (Fig. 9d).

A common realistic approach to CE always indicates that a minimum of raw materials and resources is required along with maximum recycling to meet the demands (Fig. 9a). Adopting a lifecycle approach, 'design and pre-production' is a critical step towards circularity, followed by 'production and processing', 'distribution and supply' and 'use and reuse' steps. Using different technologies, the generated waste after 'use and reuse' can be either recycled or incinerated for energy recovery. However, there is always a portion of 'undeniable waste and pollution' throughout the process (Fig. 9a).

Integrating the CE with Nexus thinking adds another layer to this established understanding of CE (Fig. 9b). This helps to see the bilateral importance of Nexus resources in a CE which has been neglected. While CE is excessively focused on material circularity, it is hardly acknowledged that any step in CE requires some sort of scarce Nexus resources (e.g. energy and water). Not only CE uses such resources, but also any looping action has accumulative impacts on sustainability of these resources. Hence, as illustrated (Fig. 9b), a CE-Nexus integrated approach shows a more accurate picture of the CE and avoids 'cross-over effects' and 'burden-shifting' which was identified as one of the main challenges in the CE literature.

Contrary to CE, Nexus is highly concentrated on interlinkages between resources, and the impacts from/on other resources. A commonly accepted illustration of the three-pillar FEW Nexus, which can be adjusted for other multi-pillar Nexus frameworks, is depicted in Fig. 9c. Each Nexus resource is affected from other resources while simultaneously having impacts on them. This, however, provides a very generic and simplistic sense of the complex interlinkages between FEW resources. Integrating a lifecycle-based CE with this generic framework of FEW Nexus enables to see a more detailed picture of the impacts from/on other resources throughout their lifecycle (Fig. 9d). Hence, this integrated framework can be useful for a more accurate understanding and analysis of the Nexus complexities. This, consequently, can lead to move from 'Nexus thinking' to 'Nexus action' (Simpson and Jewitt, 2019) which is considered as an essential challenge in the Nexus literature.

4. Conclusion

Promising resources sustainability and waste minimisation, CE and FEW Nexus are both thriving and fast-growing concepts which emerged predominantly in the last decade. Despite the significant amount of scientific literature on each concept, less work has been done to define the relationship between them. The overall aim of this systematic review

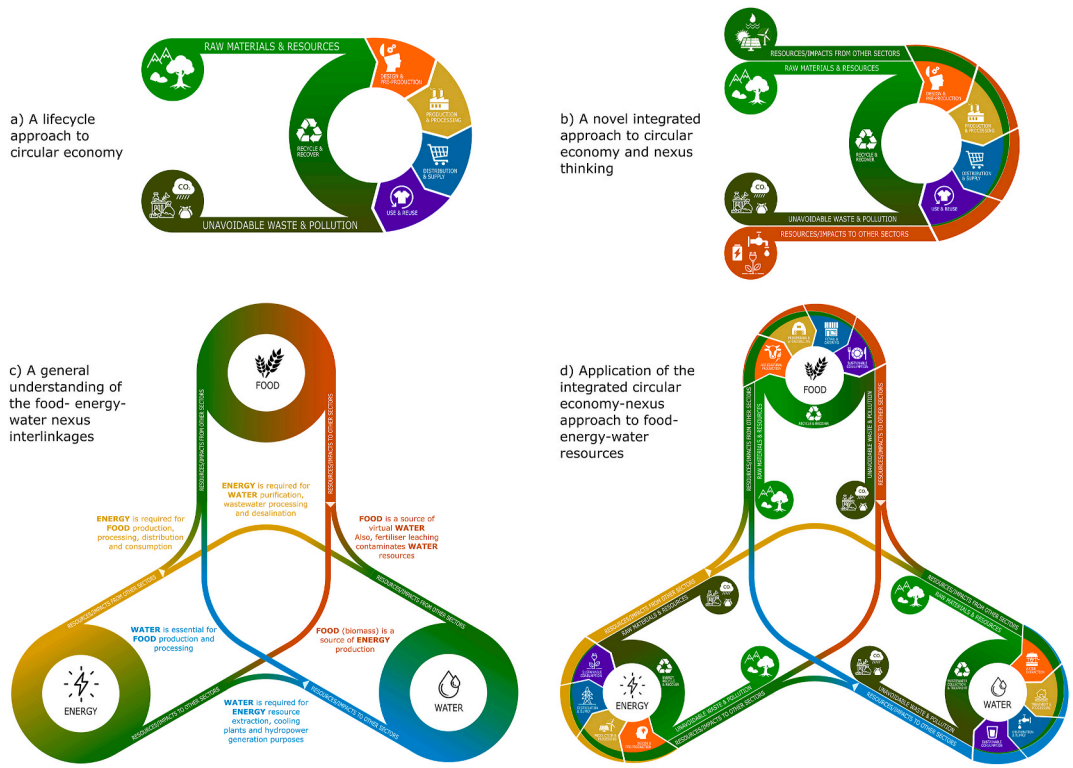


Fig. 9. CE-Nexus integrated framework illustrating how an integrated approach can lead to a better understanding of Circular Economy and Nexus concepts.

was to fill this gap by adopting a mixed quantitative and qualitative methodology. This process involved three steps including a systematic search in Scopus database, bibliometric analysis and thematic synthesis. The findings of this review suggest that there is a meaningful relationship between CE and Nexus, even though this is not adequately conceptualized. Particularly, three levels of relationship including 'intersection', 'interrelation' and 'interdependence' have been identified between both concepts. While there is abundant quantitative and qualitative data to conclude an 'intersection', the thematic synthesis at this review identified many examples to approve an 'interrelationship' between CE and Nexus. Nevertheless, there are indications for existence of 'interdependency' between both concepts as the highest level of relationship. This raises the fact that more primary research is required to examine the interdependency between CE and Nexus concepts. Finally, a new conceptualization of an integrated CE-Nexus framework is presented to facilitate a more comprehensive understanding of both CE and Nexus thinking in general, and in the context of food, energy and water sectors specifically.

Author contribution statement

AP, MVDW and US conceived the original idea, discussed the results and contributed to the final manuscript. AP developed the theory, conducted the analyses and wrote the manuscript. MVDW and US supervised the project and provided advice and feedback throughout.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. list of Circular Economy (ID starts with 'C'), Nexus (ID starts with 'N'), and Circular Economy-Nexus relationship (ID starts with 'CN') codes

ID	Codes	References
C-01	CE Aim = to minimise resource use and design out waste	(Lehmann, 2018) (Paiho et al., 2020) (Maaß and Grundmann, 2016) (Del Borghi et al., 2020) (Laso et al., 2018) (Brandoni and Bosnjakovic, 2018) (Schneider et al., 2019) (Chen et al., 2020) () (Greer et al., 2020) (Sharma et al., 2020) (Brears, 2015)
C-02	CE Core = decoupling economic growth and resource consumption	(Maaß and Grundmann, 2016) (Lehmann, 2018) (Schneider et al., 2019) (D'Odorico et al., 2018)
C-03		(Paiho et al., 2020) (Slorach et al., 2020)

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(*continued*)

ID	Codes	References
	CE does not necessarily lead to environmental sustainability	
C-04	CE examples	(Laso et al., 2018) (Brandoni and Bosnjakovic, 2018) (Schneider et al., 2019) (Brears, 2015)
C-05	CE is a pathway to accomplish sustainable development	(Chen et al., 2020) (Greer et al., 2020)
C-06	CE is based on reduce, reuse, recycle, etc. framework	(Brandoni and Bosnjakovic, 2018) (Maaß and Grundmann, 2016) (Williams, 2019) (Chen et al., 2020) (Greer et al., 2020) (Paiho et al., 2020)
C-07	CE is focused on manufacturing and recycling than services and reusing	(Paiho et al., 2020) (Greer et al., 2020)
C-08	CE is high on policy and political agenda (i.e. Europe)	(Del Borghi et al., 2020) (Brandoni and Bosnjakovic, 2018) (Schneider et al., 2019) (Paiho et al., 2020) (Brears, 2015)
C-09	CE promises a paradigm shift from linear to circular economy	(Brandoni and Bosnjakovic, 2018) (Chen et al., 2020) (Greer et al., 2020) (Paiho et al., 2020)
C-10	CE requires more research	(Laso et al., 2018) (Lehmann, 2018) (Paiho et al., 2020)
C-11	CE's 3 business models = slowing, narrowing and closing the loop	Paiho et al. (2020)
C-12	Closing loop is unrealistic and unattainable	D'Odorico et al. (2018)
C-13	Closing loop can increase water, energy and CO2	(Del Borghi et al., 2020) (Paiho et al., 2020)
C-14	Environmental and economic benefits of CE	(Maaß and Grundmann, 2016) (Ruiz-Salmón et al., 2020) (Paiho et al., 2020) (Williams, 2019) (Del Borghi et al., 2020) (Chen et al., 2020) (Lehmann, 2018)
C-15	LCA is a key tool for CE	(Ruiz-Salmón et al., 2020) (Del Borghi et al., 2020)
C-16	Need for interdisciplinary approach to CE	Brandoni and Bosnjakovic (2018)
N-01	Impacts of failing to consider a nexus approach	(Lehmann, 2018) (Brandoni and Bosnjakovic, 2018) (Udugama et al., 2020)
N-02	LCA is a very important method for Nexus	(Ruiz-Salmón et al., 2020) (Laso et al., 2018)
N-03	Nexus Aim = to increase efficiency of natural resource, reduce CO2 and waste	Lehmann (2018)
N-04	Nexus as a conceptual and analytical approach	(Maaß and Grundmann, 2016) (Del Borghi et al., 2020) (D'Odorico et al., 2018) (Loh et al., 2019)
N-05	Nexus concerns about environmental and social aspects	(Udugama et al., 2020) (Laso et al., 2018)
N-06	Nexus Core = interdependencies require integrated holistic approaches	(Loh et al., 2019) (Maaß and Grundmann, 2016) (Del Borghi et al., 2020) (Laso et al., 2018) (Brandoni and Bosnjakovic, 2018) (Chen et al., 2020) (Lehmann, 2018) (Udugama et al., 2020) (D'Odorico et al., 2018)
N-07	Nexus discourse requires a shift in governance	Lehmann (2018)
N-08	Nexus examples	(Maaß and Grundmann, 2016) (Paiho et al., 2020)
N-09	Nexus has been limited in policy and practice	(Williams, 2019) (Del Borghi et al., 2020) (Xue et al., 2018) (Brandoni and Bosnjakovic, 2018) (Lehmann, 2018)
N-10	Nexus is an immature and emerging concept	Lehmann (2018)
N-11	Nexus is important and essential for sustainability	(Lehmann, 2018) (Laso et al., 2018) (Xue et al., 2018) (Chen et al., 2020) (Loh et al., 2019)
N-12	Nexus problems require multidimensional approach	(Lehmann, 2018) (D'Odorico et al., 2018)
CN-01	Ambiguous relation (e.g. clear overlap, close link) between CE and Nexus	(Lehmann, 2018) (Del Borghi et al., 2020)
CN-02	CE in FEW system results in various benefits	(D'Odorico et al., 2018) (Brears, 2015)
CN-03	CE operationalises and accelerates Nexus approach	(Del Borghi et al., 2020) (Brandoni and Bosnjakovic, 2018)
CN-04	Nexus avoids cross overs or burden shifting in CE	(Paiho et al., 2020) (Del Borghi et al., 2020) (Greer et al., 2020)
CN-05	Nexus contributes to transition to CE	(Chen et al., 2020) (Loh et al., 2019) (Maaß and Grundmann, 2016) (Ruiz-Salmón et al., 2020) (Udugama et al., 2020) (Schneider et al., 2019) (Sharma et al., 2020)
CN-06	Not enough scientific work on CE-nexus relation	(Del Borghi et al., 2020) (Paiho et al., 2020)

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