European Commission

Sustainability competences

A systematic literature review

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Executive summary

Facing today's climate and environmental emergency, the Commission has committed in its Green Deal for the European Union to take action and to reach zero net emissions of greenhouse gases in 2050, while maintaining its economy competitive, thus making the EU "carbon neutral". The transition to a green economy is, together with the digital transition, the main policy underpinning the Commission's proposal for a European Recovery Plan to tackle the socio-economic consequences of the Covid-19 crisis. The green transition requires investments in updated skill sets to master green technologies and reduce the environmental footprint of activities.

This report aims to support the implementation of the European Green Deal, the European Industry Strategy and the recently adopted European Skills Agenda for Sustainable Competitiveness, Social, Fairness and Resilience in the area of the EU citizens' skills necessary to guarantee a smooth twin digital and green transition.

The present study consisted of an exploratory review of the literature that aimed to look at existing definitions of sustainability; development of sustainability competence frameworks in education; and the identification of green skills and skills for the circular economy. In doing so, we conducted a systematic literature review involving academic and grey documents, with the aim to meaningfully contribute to bring to the fore scientific evidence and current practices to future debates.

The necessity of introducing sustainability themes into education in academic and policy-making arenas occurred as early as in the 1970s. Since then, there has been a general agreement that sustainability competences are needed for society to be able to tackle these sustainability challenges and re-learn to live in tune with the planet on which our economy and our society depend. Yet the lack of a wide-spread and universal competence framework for sustainability has led to the proliferation of many definitions of what knowledge, skills, attitudes, and values for sustainability are, failing to provide a clear and unified direction to educate sustainable citizens.

Noting that there is a great deal of terminological ambiguity, in this study we adopted the concept of "competence" in its wider meaning, i.e. as an organised conceptualisation of competences. In this context, we differentiated between competences in sustainability and key competences in sustainability. We defined

> **Competences in sustainability** as: "the interlinked set of knowledge, skills, attitudes, and values that enable effective, embodied action in the world with respect to real-world sustainability problems, challenges, and opportunities, according to the context" (cf. Wiek et al., 2011; Redman & Wiek, under review; UNESCO, 2007).

In particular, the role of values and context stand out: while the first provide a normative guidance, one's context determines the extent to which an action can be undertaken. Instead,

> **Key competences in sustainability** are "a distinctive and multifunctional competenc[e], which is composed of several sustainability competences that functionally relate to each other. It facilitates achieving successful performance and a positive outcome that progresses sustainability (given what is known, valued, and aspired at a given moment in time), while working on specific sustainability challenges and opportunities in a range of contexts" (Brundiers et al., 2020).

Key competences in sustainability equip individuals with the necessary competences to solve complex problems and exploit opportunities in favour of sustainability. Knowledge in a specific discipline, as well as other basic or interrelated competences, are critical but acquired through specific course in higher education. Key competences in sustainability should be **transversal and intrinsic** in education. Scholars who support this view support the concept of

> **Sustainability education** as encompassing, whereby sustainability is integrated with education in all areas and aims to change the behaviour of individuals to live in tune with their society, environment, and the planet.

Sustainability is a long term goal and differs from sustainable development which is about supporting those processes to achieve a sustainable progress. Equally, sustainability education differs from education for sustainable development which envisions education as a way to educate students to enact a sustainable development (or progress or growth).

There is a high degree of convergence among scholars, and between academic and grey literature, on what key competences in sustainability are. In particular, the recent **works by Brundiers et al. (2020) and Redman and Wiek (under review)** best encapsulate the **most encompassing frameworks** which **identified eight key sustainability competences** in higher education. They showed how key competences interlink with each other to undertake sustainability challenges. Furthermore, the role of values-thinking is especially underlined, in line with previous literature. Additional studies which focused on specific disciplines or aspects of sustainability may add invaluable concepts, such as the importance of lifecycle thinking or the notion of diachronic & differentiated responsibility.

In light of said convergence on **what** key competences in sustainability are, scholars and policy-makers also question:

- **How** can key competences in sustainability be learnt?
- **How** to assess that the eight key competences in sustainability do equip professionals and citizens in general to move towards sustainable behaviours in their daily personal and professional lives?

The OECD Future of Education and Skills 2030 project has precisely embarked in this direction (OECD, 2019). While the first part of the project focused on identifying transformative competences, the second aims to answer how they can be learnt.

While pedagogical approaches and assessment methods were not in the scope of this research, their salience in research is worth noting, in light of future discussions. Furthermore, despite recognizing the importance of **lifelong learning** in education, there is limited research on sustainability education beyond higher education, including early childhood, primary and secondary school, vocational education, adult education, and so forth. Equally, research should address how to convey sustainability competences through online education.

In relation to **work**, there are two main strands of literature that conduct research on competences, or skills, employees should have to contribute to sustainable outcomes in their jobs. The first stream is composed by scholars in education or sustainability or both. For this reason, much of the terminology and ideas converge with what said afore. In particular, these works highlight how competences in sustainability are necessary in sustainability-related jobs.

The second strand of research involves experts from economics, who may not necessarily consider sustainability in its broadest meaning. In fact, starting from the definition of a green economy, the main aim of studies stemming from this field is about identifying the necessary skills – understood as abilities to perform a job – to perform green jobs. First, we noted that despite a general agreement on the definition of skills, there is no convergence on what **green skills** are. This is because quite often green skills are cofounded with green jobs (Vona et al., 2015) and, as such, they vastly depend on how a green job is defined. As we have seen, Consoli et al. (2016) summarized four approaches to define green jobs. Therefore, green skills can vary accordingly to the methodology used. Second, in contrast with the concept of sustainability, green jobs include only environmentally-related jobs. Third, considering only skills may not capture all the necessary components to perform jobs in the circular economy. As jobs become less routinized and more cognitive-intensive, requiring creative and (eco-)innovative solutions, the importance of knowledge, attitudes, and values cannot be denied. UnionCamere (2020) has partially tried to address this point by identifying green skills and attitudes, together with education levels, in their Excelsior Information System, based on the O*NET database and converted into the European and Italian classification systems.

This study underlines the **need to develop a more encompassing system to identify** and update the necessary **sustainability** (instead of green) **competences** critical to perform **sustainability-related jobs** and **other jobs in a sustainable manner**. Taking the evidence stemming from sustainability education, sustainability competences should and could be embedded in any job, while **key** competences should and could be related to sustainability-related jobs.

Furthermore, the green economy has started to lose traction in the second decade of the 2000s, given a lack of operationalisation and progress in achieving a more sustainable economy in line with planetary limits. At the same time, the **circular economy** has now become the key policy priority in Europe. Despite this, research on employment associated with the circular economy either focuses on the net employment generated or adopts the notion of green jobs. While this latter approach can be useful, it does not capture the full dimensions of a circular economy. Scholars

claim that the circular economy requires new and innovative approaches to the way we do business, where all actors are involved in addressing environmental, social, and economic criteria and regenerate resources to be able not to take from the planet more than it generates.

1 Introduction

Unsustainable production and consumption patterns, and natural resources depletion driven by a growing demand have contributed to deteriorating the planet at an increasing rate (UNEP, 2019). According to the latest special report on global warming by the UN Intergovernmental Panel on Climate Change, we only have ten years left to limit a climate change catastrophe by keeping global warming at a maximum of 1.5°C (IPCC, 2018). In order to halt this "silent crisis" of global significance and unprecedented proportions, major changes are needed in our education system (Nussbaum, 2010). Sustainable development cannot only be obtained by means of political agreements, financial benefits or technological innovations; education plays a critical role for the development of competences needed for dealing with sustainable development (Barth et al., 2007; Rieckmann, 2012; Wiek et al., 2011; UNESCO, 2014). New competences are needed for citizens, consumers, professionals, communities, and society at large to be able to tackle these sustainability challenges, and create new paradigms that can lead to global sustainability (Steinfeld & Mino, 2009; UNESCO, 2014). As argued by Sipos and colleagues (2008), we need to rethink and redesign our education curricula in order to foster the kind of critical thinkers and ethical problem solvers who are needed to promote a sustainable society.

The relationship between education and environmental protection can be traced back to the 1970s and is documented through global declarations and the formations of several networks at the international level (Sipos et al., 2008; Michelsen, 2016). Furthermore, the years 2005-2014 were declared as the UN Decade of Education for Sustainable Development (DESD), which aimed to bridge the gap between society's needs and academia, through the promotion of sustainability in higher education in order to positively affect society and the planet. This culminated with the embedding of education for sustainable development in Target 4.7 of the Sustainable Development Goal (SDG) 4, whose objective is to ensure that all learners acquire the knowledge and skills needed to promote sustainable development and is understood as a critical goal to achieve the other 16 SDGs (UNESCO, 2017, 2018). The key message is that modern education needs to provide students with the knowledge, skills, attitudes, and values to become change agents to achieve a social, environmental, and economic sustainable future and a resilient society (Glasser & Hirsch, 2016; Kagawa, 2007; Nejati & Nejati, 2013; Sterling et al., 2017). Education needs "to do more than prepare young people for the world of work; it needs to equip students with the skills they need to become active, responsible and engaged citizens" (OECD, 2018, p. 4).

1.1 Objective of the study

Following from the acknowledgment of the critical role of education for sustainability (Wals et al., 2016; Wiek et al., 2011; Brundiers et al., 2020) and as a catalyst for sustainable development (Quendler & Lamb, 2016; United Nations Division for Sustainable Development, 1992; UNESCO, 2014), various institutions have made efforts to incorporate sustainability concepts into their academic and vocational curricula, as well as in formal, non-formal and informal educational sectors (Aurandt, & Butler, 2011; Dvorak et al., 2011; Hegarty et al., 2011; Copernicus Alliance, 2011; Michelsen, 2016). At the same time, the stream of literature and policies which focus on sustainability in education has started to explore what key competences students and professionals need in order to become change agents (Mochizuki & Fadeeva, 2010). However, the large variety and ambiguity surrounding definitions of the terms 'sustainability' and 'competence' has underlined the urgent need to develop and promote a universal and widely accepted competence framework to provide direction to educators and guidance to students and future professionals (Cebrián, & Junyent, 2015; Cebrián et al., 2019; Redman & Wiek, under review). A European competence framework to meet these requirements will help focus on providing the necessary skills to students, as well as up- and reskill the existing workforce throughout their entire lives and covering the whole value chain to benefit from the ecological transition (EU Green Deal, 2019).

In this respect, the European Green Deal underlined the urgent need to develop a "European competence framework to help develop and assess knowledge, skills and attitudes on climate change and sustainable development" (p.19). This commitment was reiterated in the 2020 Commission communication on achieving the European Education Area and also echoed in the 2020 Commission communication on a European Skills Agenda for sustainable competitiveness, social fairness and resilience, calling for "a European competence framework on education for climate change, environmental issues, clean energy transition and sustainable development, which will spell out the

different levels of green competence" (p.12) ([1]). Such a competence framework will help spell out the necessary knowledge, skills, attitudes, and values needed in order to build a more resilient and sustainable Europe and guarantee a smooth twin digital and green transition.

The aim of this exploratory study is to define the state-of-the-art while providing evidence for devising a European competence framework to develop first, and nurture through lifelong learning then, the necessary knowledge, skills, attitudes, and values for a sustainable society. To fulfil this objective, the present study is an exploratory review of the literature that aims to shed some light on existing definitions of sustainability competences in education and green skills in employment (including skills for the circular economy); as well as past and ongoing projects and initiatives that were directed to promote sustainability competences and green skills globally; and then key elements in the discussions on development of competences and skills with respect to the EU policy context.

This study focuses on collecting existing definitions in the literature for what concerns sustainability competences or green skills in education and employment, in the attempt to operationalise the development of a "sustainability competence" framework. Taking the aforementioned statements of the EU Green Deal and the European Skills Agenda as guidelines, the study operationalises this into broader concepts to fulfil the objective of the research, such as sustainability, sustainable development, circular economy, etc. In this report, the term sustainability competence includes both 'sustainability competences' (in education) and 'green skills' (in employment) and has been used for easiness. At the same time, the present report highlights the need for a coherent and comprehensive terminology in line with existing literature and European policy documents.

1.2 Methodology for the literature review

This report aims to systematically gather and analyse the information and knowledge about different concepts and approaches as documented in the academic and grey literature on sustainability education and employment. To fulfil this goal, a systematic literature review was undertaken ([2]). Research for preparing this report has aimed to cover the most relevant aspects and sources in relation to the status and developments of the sustainability competence in Europe. Not all literature, projects, organizations are covered, nor was this intended. The selection of topics and approaches has been made on the basis of their relevance and visibility in the related research and their potential for European scale implementation. The following tools have been used to prepare the review and analysis presented in this report:

- Literature search from scientific publication databases using the following terms, their different combinations, as well as singular/plural forms and linguistic variations (American and British English):
    - Skills, competence, competency, education, behaviour;
    - Green economy, green, sustainable development, circular economy, climate change, sustainability, green jobs;
    - Student, employees, individual, citizens; citizenship.

The search was conducted on Web of Science and Scopus, focusing on documents published between 2010 and 2020 in English with no restriction on where research was carried out. A snowball technique was used whenever relevant papers were found. For this reason, documents published before 2010 may be included in the review.

- Review of European Commission policies and activities;
- Review of reports and studies from international organizations with known activities (for example, UNESCO, OECD, Cedefop, etc.).

The study aims to build a structured story of the rich, dispersed yet converging landscape of sustainability competences.

(1) In this report, "sustainability competence framework" will be used in lieu of "green competence framework", as suggested by experts in this field.

(2) The protocol for our systematic literature review is available from the author upon request.

1.3 Structure of the report

In the next chapters we endeavour to summarise the key findings on the literature on sustainability education and green employment. This aims to set the basis for the conceptualisation regarding sustainability competences and environmental and sustainability education for lifelong learning in order to equip future graduates and professionals with the appropriate competences to contribute to a circular economy.

This report is structured as follows:

Chapter 2 and 3 focus on sustainability education and key competences in sustainability. Specifically:

- Chapter 2 introduces some insights from the literature and provides an overview of key concepts, such as 'competence' and 'sustainability education';
- Chapter 3 presents the main findings on key competences in sustainability education identified in academic and grey literature.

Chapter 4 and 5 are focused on employment and sustainability competences and "green skills". In particular:

- Chapter 4 describes key concepts such as that of "green skills" in relation to "green jobs" and jobs in the circular economy.
- Chapter 5 shows the main findings on employment in relation to sustainability professionals, green jobs, and circular economy jobs.

Chapter 6 concludes the report.

2 The evolution of sustainability in education

In order to fulfil the objective of this study, namely to review evidence on past and ongoing attempts to define the necessary competences to develop a sustainability competence framework "on education for climate change, environmental issues, clean energy transition and sustainable development" (European Skills Agenda, p.12), and in light of the current findings, a clarification of the terms used seems mandatory before proceeding any further. Section 2.1 focuses on the use and meaning of the terms used in relation to competence frameworks (2.1.1), and sustainability education (2.1.2). Section 2.2 describes the use of 'sustainable development' or 'sustainability' and similar terms in the literature on education that aims to foster competences for a sustainable society.

2.1 A sea of labels

In order to correctly review and analyse definitions, concepts, frameworks and components of a sustainability competence it is necessary to shed light on the different approaches undertaken in the literature and practice so far. The definitions and conceptualisations vary across, and within, academic literature and policy documents. Terms such as "competence", "competency", or "skills" are often employed interchangeably (Lester, 2014; Mitchelmore & Rowley, 2010; Winterton, 2002).

It is therefore worth highlighting the different terminology used as well as their implications for this current study and for future steps towards the development of a European sustainability competence framework.

2.1.1 Competency and competence

First, a definition of the terms competence and competency is given. The term 'competency', originated in the USA, focuses on behaviour, motivations and other personal traits and it is used in reference to superior performance and high motivation (Gagliardi & Komarkova, 2015). This characterisation is attribute-based, as it originates from looking at the personal attributes of the individual (Lester, 2014). The term competence, of British origin, refers to practical skills, knowledge and understanding of the work environment and is tied to job performance (Winterton, 2002). Competence-based education is outcome-focused, as it is centred on enabling individuals to engage effectively in different situations and contexts to contribute to transform their structures (Rieckmann, 2012).

As noted by Gagliardi and Komarkova (2015), it is clear that the definitions of competency and competence are intimately linked by their reliance on knowledge, skills and attitude. While knowledge and skills are common to both definitions, attitudes related to 'competency', is increasingly becoming a cross-cutting issue common to the two domains.

In alignment with previous preliminary studies for developing Key Competence Frameworks (e.g. Ala-Mutka, 2011; Ferrari, 2012; Gagliardi & Komarkova, 2015), the term 'competence framework' is used in its wider meaning, i.e. as an organised conceptualisation of competences. Furthermore, the EU policy debate on competences has tended to lean towards the use of 'competence' which promotes an outcome-based approach. That being said, attitudes are included as one of the main defining constituent. Both the 2006 and 2018 European Recommendation on Key Competences put forward by the European Commission defined competence as a set or combination of knowledge skills, and attitudes. This approach is widely adopted in the European policy debate.

2.1.2 Competences in sustainability education

The literature on competences in sustainability is characterized by a great deal of terminological ambiguity, resulting in a "sea of labels" (cf. Brundiers et al., 2020), whereby the term competences is often associated, or used interchangeably, with competence, skills, abilities, capabilities, capacities, and similar concepts (Baartman et al., 2007; Baethge et al., 2006; Cebrian & Junyent, 2015). While there is a general agreement over the importance of key competences in sustainability, what is lacking is a common understanding of what is meant with the term competence (Barth et al., 2007).

Two of the most cited articles in the literature on sustainability education use both terms to indicate the same concepts, e.g. 'systems thinking competence' (Wiek et al., 2011) and 'systems thinking competency' (Brundiers et al., 2020). According to Rieckmann (2012), "competencies may be characterised as individual dispositions to self-

organisation which include cognitive, affective, volitional (with deliberate intention) and motivational elements; they are an interplay of knowledge, capacities and skills, motives and affective dispositions" (emphasis added). Similarly, Wiek et al., (2011; 2016) use the following definition: "competence as a functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem solving" (emphasis added). Both definitions support the **knowledge-skills-attitudes** (KSA) approach to define competenc(y)e.

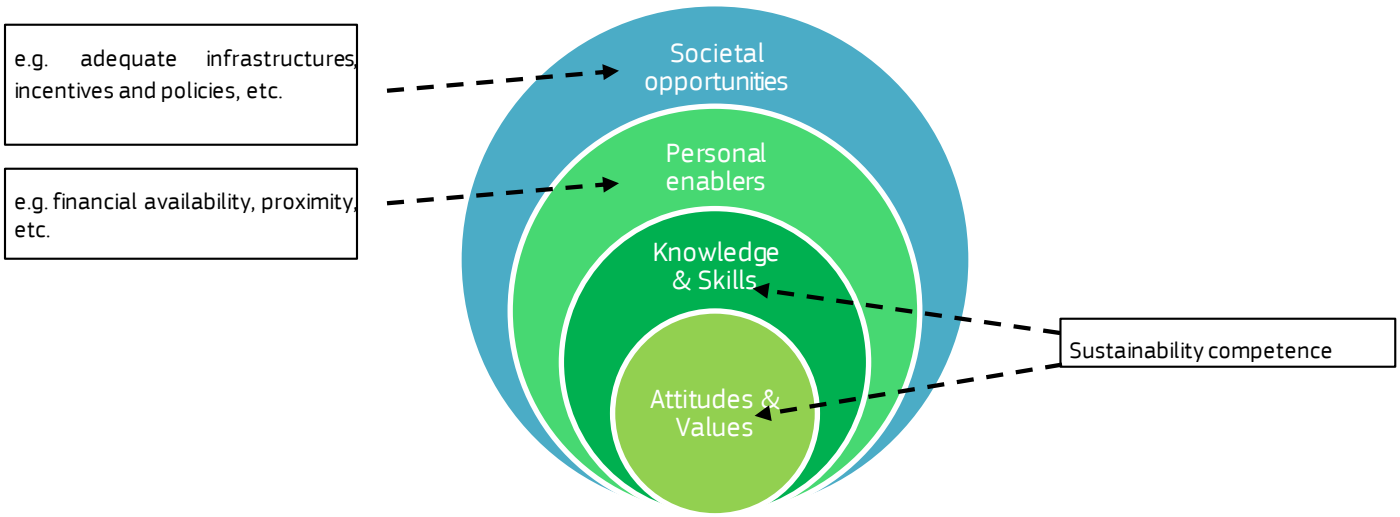
In reviewing the literature, we often found the term competence (singular) and competencies (plural) used in the same document (see Rieckmann, 2012; Wiek et al., 2011). This may be due to the fact that competence is an uncountable name (MacMillan dictionary), and non-native English speakers or authors who are unaware of the conceptual difference between the two terms, may use 'competencies' as a plural form of competence. This could explain the presence of both terms in the same document.

Given these premises and the use of competence/es in EU policy contexts, the use of competence (singular) and competences (plural) is preferred in this document.

In reference to sustainability, we use the following **definition of sustainability competences** as the interlinked set of knowledge, skills, attitudes, and values that enable effective, embodied action in the world with respect to real-world sustainability problems, challenges, and opportunities, according to the context (cf. Wiek et al., 2011; Redman & Wiek, under review; UNESCO, 2007).

The role of **values** in this definition, as opposed to the more traditional KSA approach, is particularly important (Lambrechts et al., 2013). While competences describe whether an individual is catered to contribute to a more sustainable society, certain values and motivational drivers need to be present to enact effective behaviour change for sustainability (Drissner et al., 2010; Molderez & Fonseca, 2018; Murga-Menoyo, 2014; Rieckmann, 2012). Furthermore, it is equally important to acknowledge the role played by **contextual factors**, such as personal enablers, for example financial availability, as well as institutional opportunities, such as availability of infrastructures or societal acceptance. One of the reasons underlying the gap between intention to behave and actual behaviour lies in financial, social, structural and institutional barriers (cf. Eagle et al., 2016). Therefore, effective behaviour change which would contribute to a sustainable transition rests on the development of knowledge, skills, attitudes, and values, i.e. sustainability competence, as well as the presence of instrumental and external factors (Figure 1).

Figure 1. Sustainability competences and context for sustainable behaviour performance.



Source: elaborated from Rieckmann, 2012; Wilhelm et al., 2019.

Some authors argued that competence frameworks for sustainability do not often take into account different cultural and local contexts, despite their relevance for achieving a truly sustainable development (Cebrian & Junyent, 2015; Demssie et al., 2019; Eizaguirre et al., 2019). In light of this, some scholars focused their attention on those competences which are essential for sustainability and irrespective of the context or discipline, namely key competences in sustainability (Brundiers et al., 2020; Wiek et al., 2011, 2016; Glasser & Hirsh, 2016; Pacis & Van Wynsberghe, 2020; Rieckmann, 2012).

Authors defined **key competences in sustainability** as: "a distinctive and multifunctional competenc[e], which is composed of several sustainability competences that functionally relate to each other. It facilitates achieving successful performance and a positive outcome that progresses sustainability (given what is known, valued, and aspired at a given moment in time), while working on specific sustainability challenges and opportunities in a range of contexts" (Brundiers et al., 2020). Key competences are becoming more and more relevant competences vis-à-vis the complex challenges, and opportunities, of modern societies, such as globalization, artificial intelligence, or sustainable development (Lambrechts et al., 2013; Mindt & Rieckmann, 2017).

2.2 Towards sustainability education

An overview of the history of the introduction of environmental and sustainability concepts into education in order to better understand the state-of-the-art on the matter was deemed necessary. A closer look at the evolving nature of the role of education in the context of environmental and sustainability matters can better inform the reader on what changes there have been in discussions around these topics. Not only is this important to inform the terminology to use in future steps, but it also helps comprehend what to include in the development of a sustainability competence framework and what may be out of scope.

While scholars and policy-makers agree on the need to instil sustainability concepts and competences in education, the **vast array of terms used** to indicate this kind of education mirrors the **lack of an agreed and common direction** for a framework on competences for sustainability (Cebrian et al., 2019; Cebrian & Junyent, 2015; Mochizuki & Fadeeva, 2010). This fails to provide guidance to educators and to accelerate progress on achieving the SDGs (Redman and Wiek, under review). In the literature, several terms are to be found across and within documents, such as *environmental education* (e.g., Correia et al., 2010; Dewhurst & Pendergast, 2011; Iyengar & Bajaj, 2011; Michalos et al., 2011;), *education for sustainable development* (e.g., Cebrian & Junyent, 2015; Glasson et al., 2010; Murray et al., 2014; Naeem & Peach, 2011; Rieckmann, 2012, 2018; UNESCO, 2017; Trad, 2019; Yoon et al., 2013), *education for sustainability* (e.g., Garcia et al., 2017; Hegarty et al., 2011; Iyengar & Bajaj, 2011), *sustainability education* (e.g., Armstrong et al., 2016; Brundiers et al., 2020; Croft, 2017; Eagle et al., 2016; Holdsworth & Thomas, 2016; Redman & Wiek, under review; Tarrant & Thiele, 2016; Wiek et al., 2011, 2016;), *ecological education* (e.g., Drissner et al., 2010; Pehoiu, 2013), *education for planetary citizenship* (Haigh, 2008), and so forth.

In this context, we focus on the most recurrent concepts, namely environmental education, education for sustainable development, education for sustainability, and sustainability education. These concepts categorized the evolution of sustainability education since its inception.

Sustainability is a difficult term to grasp, which bears a great deal of ambiguity (Molderez & Ceulemans, 2018), as it holds different meanings for different groups of people (Croft, 2017). Furthermore, sustainability is not a fixed and pre-determined concept which determines one best way to produce and consume that is static in time, but it rather depends on contextual factors, such as location and timeframe to name some (Jickling & Wals, 2012).

Sustainability and sustainable development are often used interchangeably, despite their conceptual difference. In reference to the UNESCO definitions ([3]), **sustainability** is best described **as a long-term goal**, such as attaining a more sustainable world; while **sustainable development**, like the term suggests, refers to the many processes and **pathways to achieve development**, or progress, in sustainable ways, for example through sustainable agriculture and forestry, sustainable production and consumption, appropriate government measures, research and technology transfer, education and training, etc.

([3]) https://en.unesco.org/themes/education-sustainable-development/what-is-esd/sd

Following from this, we can argue that **education for sustainable development** (ESD) underlines the idea that education is a way to equip students with the necessary set of knowledge, skills, attitudes, and values throughout their lives to enact a sustainable development (or progress or growth). **Sustainability education** (SE) is more encompassing whereby sustainability is integrated with education in all areas and aims to change the behaviour of individuals to live in tune with their society, environment, and the planet. The difference between the two concepts, ESD and SE, is subtle but it is worth noting in order to fine-tune future discussions.

Policies on the introduction of sustainability themes into education have been around since the 1970s (Scott, 2009). However, their focus has greatly changed since the beginning. Michelsen (2016) has divided the evolution of education for sustainable development in three key phases: *the orientation and experimental phase*, spanning from the 1970 to 1990, with a focus on environmental issues; *the transition phase*, ranging from 1990 to 2000, with the introduction of development related themes; and *the expansionary phase* up until 2014 (and onwards) where the focus is on sustainability.

The **first phase** was rather characterised by environmental education (EE). Events in the 1960s and early 1970s such as, but not confined to, the publication of Rachel Carson's *Silent Spring* (1962); Kenneth Boulding' *The Economics of the Coming Spaceship Earth* (1966); the birth of the Club of Rome (1968) which spurred the publication of Meadows et al.'s *Limits to Growth* (1972) lead the growing awareness of environmental issues at the international level. This triggered the organization of the conference on environmental education in Tbilisi, known as the UN Conference on Human Environment (1972), which called for involving education to prevent or solve environmental problems. As a result, the Tbilisi Declaration was adopted leading to many countries undertaking both policy initiatives and actions in education to establish environmental education in different educational sectors. At the same time a scientific discussion on environmental education began which culminated in the publication of the Brundtland Report (1987). The report produced the modern concept of sustainable development that has become an important element in international political and societal discourse. The report famously describes sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (ch.2, par. 1).

The **second phase** was marked by the publication of Agenda 21 adopted at the UN Rio Conference in 1992 focusing on the role of education in the context of sustainable development: "*Education is critical for promoting sustainable development and improving the capacity of the people to address environment and development issues*" (United Nations Division for Sustainable Development, 1992, ch. 36.3). In this phase, the role of education gained a new direction (Pehoiu, 2019). The social and development aspects of sustainability were highlighted, promoting education for sustainable development, or ESD as well as the role of schools as social institutions responsible to equip students with the values and attitudes, life-skills and ethical behaviours consistent with sustainable development, and to inform graduates' future professional practice (Iyengar & Bajaj, 2011).

Finally, in **third phase**, the role of education, and lifelong learning, as an integral component in sustainable development "as a key agent for change" (UN, 2002) was strengthened. An important event that marked this phase was played by the World Summit for Sustainable Development in Johannesburg in 2002. It followed the implementation of the World Decade of Education for Sustainable Development running from 2005 to 2014, whose main aim was to embed sustainability in lifelong learning and spur initiatives worldwide. The UN Decade was then followed by the Global Action Programme (2015-2019) whose main aim was to generate and scale-up education for sustainable development and accelerate progress towards sustainable development (UNESCO) ([4]).

Similar to Michelsen, Holdsworth and Thomas (2016) argued that the vast array of definitions on education and sustainability or sustainable development, or similar definitions, has caused some controversy. For this reason, based on Sterling (2001), they differentiate among three main types of education:

- *Education about sustainable development / sustainability*, whose main aim is to raise awareness without challenging the current paradigm (Dewhurst & Pendergast, 2011);
- *Education for sustainable development*, that can be equated to a second-order learning, which envisions education as a means to achieve sustainable development;

([4]) https://en.unesco.org/globalactionprogrammeoneducation

- *Sustainability education / Education as sustainability* sees the aim of learning as change by engaging both the person and the social institution through a holistic approach. This type of third order learning calls for behaviour change through transformative learning.

Sustainability education sees education as intrinsically intertwined with sustainability at all levels (Lozano et al, 2017; Rieckmann, 2018), whereby competences in sustainability are naturally acquired for a sustainable society (McGregor, 2013). This is why Holdsworth and Thomas (2016, p. 1077) also referred to sustainability education as 'education as sustainability'.

3 Sustainability competences in sustainability education

In order to illustrate the key competences highlighted in the literature, this chapter is divided as follows. First, section 3.1 presents a review of the most influential frameworks in sustainability education (SE). It is then followed in 3.2 by an overview of additional findings on competence frameworks in this stream of literature. Third, an overview of the main findings in grey literature in sustainability education is provided in 3.3. Finally, concluding remarks are presented together with the limitations of the studies examined.

3.1 Most influential frameworks in the literature on sustainability education and education for sustainable development

There is some degree of **convergence** in the literature on sustainability education about what competence young graduates and professionals need to possess in order to be change agents and contribute to sustainability problems and opportunities. This may be due to the early paper by Wiek, Withycombe, and Redman (2011) which contributed to set the stage for future works and has been often used by scholars as the foundation for any attempt to describe sustainability competences. The authors had undertaken a literature review and developed a framework on key competences on sustainability. This is often regarded as the most influential and unifying work in the literature on sustainability education (Grosseck et al., 2019).

In 2020, fourteen experts joined their expertise in order to discuss on the convergence and comprehensiveness of the original framework by Wiek and colleagues (2011, 2016) ([5]). While they agreed on the former framework, they added two additional competences.

Finally, Redman and Wiek (under review) conducted a literature review on the research dealing with the 2011 framework on key competences in sustainability by Wiek et al. (2011). They found confluence with Brundiers et al. (2020) and added a set of complementary competences.

The aforementioned frameworks are now summarised in this order:

- Wiek et al., 2011 & 2016
- Brundiers et al., 2020
- Redman and Wiek, under review

3.1.1 Wiek et al., 2011 & 2016

The most influential study on sustainability competences is the literature review conducted by Wiek, Withycombe, and Redman (2011) which focuses on **key competences in sustainability** for academic program development. Besides being the most cited study in the field (Brundiers et al., 2020), it is also often used as the basis of subsequent frameworks, where the authors complement it by adding some competences, or by slightly modifying the original key competences titles.

In their study, the authors focused on key competences in sustainability as opposed to "regular or basic" competences, such as but not confined to "critical thinking, communication, pluralistic thinking, research, data management, etc." (Wiek et al., p.211). This is not because they are not critically important to sustainability, but they can rather be learnt through regular academic education and they are not exclusive to **sustainability education**. In their view, "sustainability education should enable students to analyse and solve sustainability problems, to anticipate and prepare for future sustainability challenges, as well as to create and seize opportunities for sustainability" (Wiek et al., 2011, p. 204). However, their framework is focused on higher education as opposed to the full breath of education levels.

The five key competences that represent their framework are: systems-thinking competence, anticipatory competence, normative competence, strategic competence, and interpersonal competence. As they argue, rather than being a "laundry list" of competences, they are **interlinked and interdependent**, as each contributes its part to sustainability problem-solving processes. Subsequently, Wiek and colleagues (2016) added a sixth key

([5]) In 2016, Wiek and colleagues added a sixth competence, which was only implicitly included in the 2011 framework by Wiek, Withycombe, & Redman.

competence, namely integrated problem-solving competence, which as the authors argued was already implicit in the 2011 study. Table 1 describes the set of key competences in sustainability as in Wiek et al. (2011, 2016).

Table 1. Key competences ([6]) in sustainability

Systems-thinking competency "ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks." (Wiek et al. 2011, p. 207)	*Integrated problem-solving competency* is a meta-competency of meaningfully using and integrating the five key competencies [left] for solving sustainability problems and fostering sustainable development (Wiek et al. 2016, p. 243). It is the ability "to apply different problem-solving frameworks to complex sustainability problems and develop viable solution options" in order to "meaningfully integrate problem analysis, sustainability assessment, visioning and strategy building" (Wiek et al. 2016, p. 251)
Anticipatory/futures-thinking competency "ability to collectively analyze, evaluate, and craft rich "pictures'' of the future related to sustainability issues and sustainability problem-solving frameworks". (Wiek et al. 2011, pp. 208–209)	
Normative/values-thinking competency "ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets". (Wiek et al. 2011, p. 209)	
Strategic-thinking competency "ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability". (Wiek et al. 2011, p. 210)	
Interpersonal/collaborative competency "ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving". (Wiek et al. 2011, p. 211)	

Source: Brundiers et al., 2020.

3.1.2 Brundiers et al., 2020

In 2020, fourteen international experts in sustainability education conducted a Delphi study on the framework of key competences in sustainability by Wiek et al. (2011, 2016) to build expert consensus ([7]) (Brundiers et al., 2020). The experts agreed with the original framework and added two additional competences ([8]) to the framework, namely intrapersonal and implementation competences. Table 2 presents the updated definitions of the framework on key competences in sustainability.

In relation to these eight key competences, the authors pointed to **values-thinking** as a lead-competence, providing a normative orientation for all other competences and clarifying values embedded in the framework. In relation to this, they defend this stance by arguing that, while several frameworks point to systems thinking as being the most important competence (e.g., Demssie et al., 2019; Molderez, & Fonseca, 2018; Redman & Wiek, under review; Rieckmann, 2012), values-thinking permeates all other competences. By providing a normative guidance, it reinforces the framework with a distinctive and applied purpose. In other words, a normative sustainability orientation helps distinguish this set of competences from other frameworks. Figure 2 shows the interrelatedness and integration of all the key competences.

The main purpose of the framework is enabling and empowering students in positively contributing to sustainability problem-solving in their lives, professions, and communities" (Brundiers et al., 2020; Wiek et al., 2011, 2016). It is worth noting that experts could not reach full agreement on the categorisation of intrapersonal and implementation competences. With respect to the implementation competence, they argue that the pragmatic, action-oriented characteristic of this competence may not fit with the cognitive orientation of the framework of key competences in sustainability. Such a competence would indeed require a hands-on approach, which aligns hardly with the mission of higher education institutions, and could be difficult to evaluate. As for the intrapersonal competency, some experts support it noting how this competence was already present in other frameworks (e.g. Giangrande et al., 2019); while others argue that intra-personal or self-efficacy is more a mindset than a competence.

([6]) In Wiek et al., 2011, they use the term competence, e.g. systems thinking competence

([7]) The study was funded by the US National Council for Science and the Environment (NCSE)

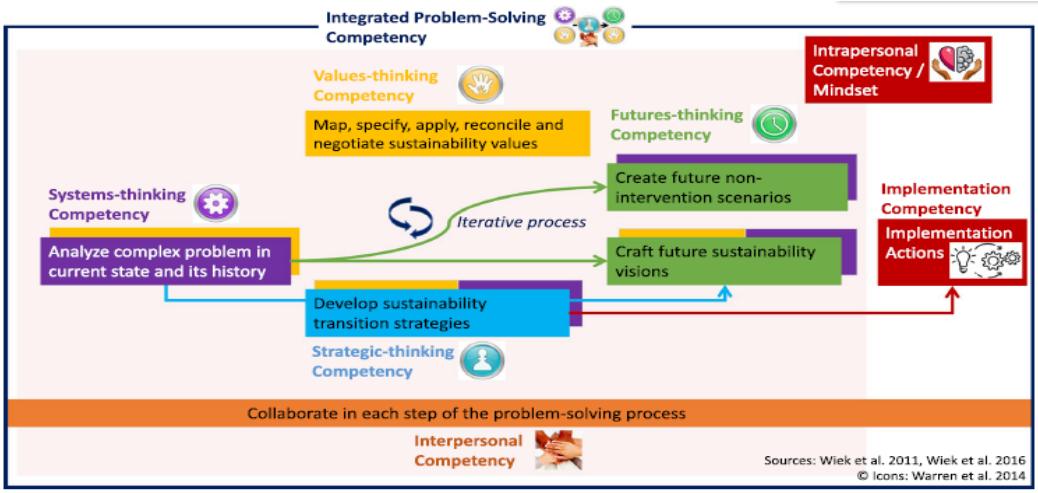
([8]) In Wiek et al. (2011, 2016) the terms competence (s.) and competencies (p.) are used. Brundiers et al. (2020) use competency (s.) and competencies (p.) to refer to the original 2011 study without an explanation.

Table 2. Definitions of key competences in sustainability

Competences	**Definitions**
Systems thinking	As in Wiek et al., 2011, p. 207 (See Table 1)
Futures-thinking	To be able to iterate and continuously refine one's own futures thinking (visions, scenarios, etc.), in productive and explicit tension to the status quo; recognizing the implicitly held (and largely unrecognized) assumptions about how society works and how they influence the status quo and critically reflecting how they might influence futures thinking
Values-thinking	To be able to differentiate between intrinsic and extrinsic values in the social and natural world; to recognize normalized oppressive structures; to identify and clarify one's own values; to explain how values are contextually, culturally, and historically reinforced; to critically evaluate how particular stated values align with agreed-upon sustainability values; and to differentiate between espoused values and practiced values.
Strategic-thinking	To be able to recognize the historical roots and embedded resilience of deliberate and unintended unsustainability and the barriers to change; to creatively plan innovative experiments to test strategies.
Interpersonal	To be able to apply the concepts and methods of each competency not merely as "technical skills," but in ways that truly engage and motivate diverse stakeholders and to empathically work with collaborators' and citizens' different ways of knowing and communication.
Integrated problem-solving	To be able to combine and integrate steps of the sustainability problem solving process or competences, while drawing on pertinent disciplinary, interdisciplinary, transdisciplinary, and other ways of knowing.
Implementation	The collective ability to realize a planned solution toward a sustainability-informed vision, to monitor and evaluate the realization process, and to address emerging challenges (adjustments), recognizing that sustainability problem-solving is a long-term, iterative process between planning, realization, and evaluation
Intra-personal or self-awareness	The ability to be aware of one's own emotions, desires, thoughts, behaviors, and personality, as well as to regulate, motivate, and continually improve oneself drawing on competences related to emotional intelligence and social and emotional learning

Source: adapted from Brundiers et al., 2020.

Figure 2. How key competences in sustainability interlink

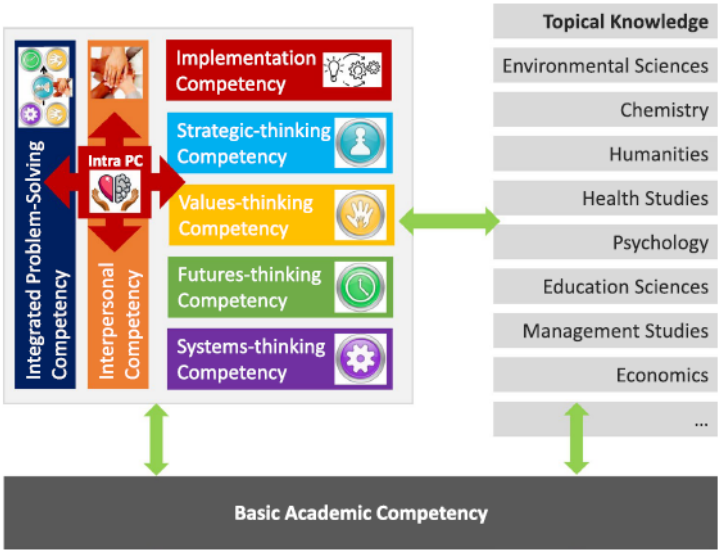


[red boxes: newly added competences; integrated problem-solving is emphasized by the blue line around the other competences; implementation competence results from the process developing the solution (red-shaded background); the classification of intrapersonal as a competence is not final].

Source: Brundiers et al., 2020 (elaborated on Wiek et al., 2011).

Figure 3 shows how the **key competences in sustainability relate to basic competences and topical knowledge**. Key competences in sustainability are interdependent and related to academic competence which can be acquired in any academic setting (as in Wiek et al., 2011). In addition to the original 2011 study, they explicitly address the need for student to possess topical knowledge, for instance on water, energy, international development, etc. However, key competences in sustainability are independent of any specific knowledge, meaning that the framework can be used for sustainability-related courses in any academic program.

Figure 3. Key competences in sustainability framework.

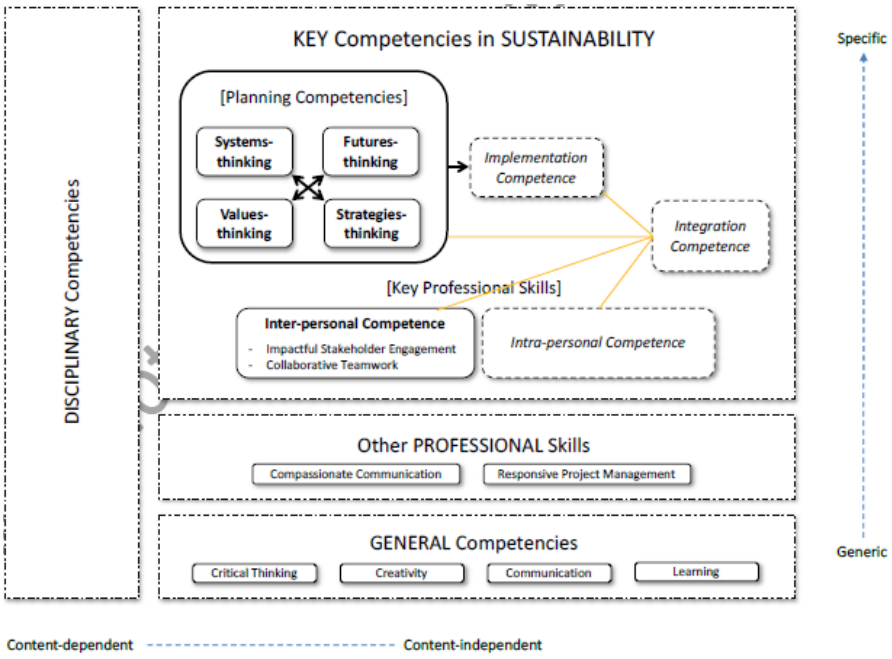


Source: Brundiers et al., 2020.

3.1.3 Redman and Wiek (under review)

Finally, Redman and Wiek (under review), starting from their 2011 study (Wiek et al., 2011), conducted a review of the literature to draw a coherent and comprehensive framework of key competences in sustainability (figure 4). In order to lead to sustainable transformations, key competences must be inherently interlinked and integrated with each other, as opposed to just being "laundry lists" (see also Wiek et al., 2011). Systems thinking, futures thinking, values thinking, and strategies thinking contribute to drafting sustainability action plans. These can lead to positive sustainability outcomes if successfully implemented (implementation competence). Key professional skills in sustainability, such as inter- and intrapersonal competences guarantee collaboration and self-care which are necessary for long-term success. Integration competence enables a coherent combination of sustainable planning and implementation efforts.

Figure 4. Integrated framework of competences for advancing sustainability transformations



[Key competences in sustainability: 5 established (in bold), 3 emergent (in italic); complemented by other professional, disciplinary, and general competences]

Source: Redman & Wiek, under review.

Additional competences that fulfil important functions complementary to the key competences in sustainability are displayed on two axes according to content knowledge specificity and competence specificity. These are generic competences taught in higher education (Brundier et al., 2020; Murga-Menoyo, 2014; Wiek et al., 2011, 2016); discipline competences or topical knowledge (Brundiers et al., 2020; Demssie et al., 2019; Heiskanen et al., 2016; Kerry et al., 2012; Murga-Menoyo, 2014; Roorda, 2013); and other professional skills. General competences for advancing sustainability transformations are critical thinking, creativity, communication, and learning. Other professional skills include (advanced) compassionate communication and responsive project management (Brundiers & Wiek, 2010). Finally, disciplinary competence is crucial to advancing sustainability changes, for example by possessing knowledge on climate, water, energy, food, international development.

The main takeaways from the three analysed frameworks are presented in table 3.

Table 3. Summary of three frameworks

Wiek et 2011, 2016	**Brundiers et al., 2020**	**Redman & Wiek, under review**
Most influential framework	*Deplhi study of 14 experts to review Wiek et al., 2011, 2016*	*Literature review to find convergence over Wiek et al., 2011*
Framework on **Key** Competences in Sustainability for **academic** program development		
Systems-thinking competence Anticipatory competence Normative competence Strategic competence Interpersonal competence Integrated problem-solving competence	Systems-thinking competency Futures thinking competency Values thinking competency* Strategic competency Interpersonal competency Integrated problem-solving competency Implementation competency** Intra-personal competency***	Systems-thinking competence Futures thinking competence Values thinking competence Strategic competence Interpersonal competence Integrated problem-solving competence Implementation competence**** Intra-personal competence****
	* Described as a lead-competency: it provides normative orientation and value clarification for all the competences in the framework **Implementation competence needs further elaboration *** No full agreement on whether intra-personal (or self-efficacy) is a competency or a mindset.	**** In this framework, they are categorized as Professional skills
Complementary to key competences in sustainability: • *Basic competences*: acquired in higher education	Complementary to key competences in sustainability: • Basic competences: acquired in higher education; • Topical knowledge: content knowledge in sustainability and in other disciplines	Complementary to key competences in sustainability: • *General competences* (acquired in higher education): critical thinking, creativity, communication, learning; • *Other professional skills*: compassionate communication; responsible project management; • *Disciplinary competences*: related to specific disciplines
Strengths: - **Convergence** in the literature on these key competences in sustainability; - The **eight key competences in sustainability** are interrelated and can be applied to different settings. This is possible by integrating them with complementary competences acquired through higher education (basic competences, professional skills) and with topical / discipline knowledge; - These works are not a list of separated competences, but a framework of integrated and interrelated competences taken together to solve sustainability problems; - The above papers focus on **key competences** (as opposed to competences) which are strictly related to **sustainability** and on **higher education**. This makes it a **transversal** competence framework.		
Limitations: - Experts mainly from USA and Europe (with minor exception for one of the articles). This constitute a problem for lack of representation and inclusion but also for the potential comprehensiveness of the framework, i.e. no inclusion of indigenous scholars (as noted in Brundiers et al., 2020); - No in-depth definition of components of the aforementioned competences, although this was not in the scope of the studies; - **No in-depth definition of topical knowledge / discipline competences (except for some examples**, e.g., climate, water, energy, food, international development). This may be because each discipline has to tailor sustainability-related content knowledge according to its subject.		

Source: author's own elaboration.

3.2 Additional evidence from sustainability education and education for sustainable development

3.2.1 Additional key sustainability competence frameworks

Alongside the most influential frameworks illustrated in section 3.1, many scholars have tried to contribute to the debate on sustainability education (SE) and education for sustainable development (ESD). Tables 4 and 5 ([9]) show some additional competence frameworks that were published between 2012 and 2020. While a broader list of articles was analysed in preparation of this study, tables 4 and 5 present:

- The most relevant frameworks in the literature, e.g. most cited;
- Those that satisfy our research purpose, i.e. focusing on sustainability competences rather than generic purposes such as 21st century competences etc.;
- Competence frameworks which add conceptual value with respect to those already illustrated, e.g. describe sustainability competence components, such as skills and knowledge, or identify other competences;
- Or frameworks that explore a different setting of SE, e.g. sustainability education in engineering; circular economy education, etc.

As a result, nine additional competence frameworks in sustainability or sustainable development are reported in tables 4 and 5. Key competences already identified in section 3.1 are highlighted in blue. However, other competences such as "critical thinking" or "interdisciplinary work" are not in blue, but are indirectly included in frameworks described in 3.1 (e.g. critical thinking). Rather than merely trying to find commonalities among them, it is also worth highlighting key peculiarities of each framework.

First, Rieckmann (2012) tried to address the lack of diversity among scholars who were engaging in studies on ESD. In particular, the author conducted a Delphi study engaging 70 experts from Latin America and Europe, in order to build consensus on an inclusive set of key competences necessary for sustainable development. Experts were first divided in two geographical groups who ranked a priori identified competences according to the saliency of their local context. Then, both groups convened on a common ground and selected key competences for sustainable development as in table 4. Their framework can be distinguished by the attitudinal description of competences. It is worth noting the importance of **interdisciplinary work** (e.g., Chandu & Kancharla, 2012; Dimante et al., 2019; Lozano et al., 2017) and **heterogeneous collaboration** (e.g., Armstrong et al., 2016); **empathy and change of perspective** (e.g, Garcia et al., 2017; Lozano et al., 2017), as well as **ambiguity and frustration tolerance**. Differing from Wiek et al. (2011, 2016) and Brundiers et al. (2020), experts include **critical thinking** among the core competences for sustainable development.

Glasser and Hirsh (2016) identified five additional core competences in their case study by building on the original framework by Wiek and colleagues (2011). They conducted a workshop with 100 participants and tried to identified the core competences necessary for students, who by being responsible citizens, can influence (and educate) the wider community. In particular, authors added **affinity for life**; a **general knowledge about the state of the planet**; and two performance related competences such as **modelling sustainable behaviour**, and **transformative social change**.

Quendler and Lamb (2016) administered two questionnaires with a broad set of competences (C), knowledge (K), and skills (S) for sustainable development to higher education institutions in life sciences and companies. The main aim was to compare the set of competences, knowledge, and skills taught in higher education and those requested in the labour market. Their framework addresses the need of focusing on three aspects of sustainable development, namely by showing **social responsibility** (C) and **knowing social aspects of SD** (K; Eagan et al, 2012); possessing **economic optimisation skills** (S); and **analysing** (S, K) and **knowing how to reduce** (K) **environmental impacts** (Kerry et al., 2012).

Dimante and colleagues (2016) focused their research aims on the circular economy in business education. Surprisingly, this is one of the few research papers on competences needed in circular economy education. According to our definitions of SE and ESD (section 2.2), the circular economy can be considered as a paradigm on how to

([9]) Split in two for layout purposes

achieve sustainability. In their framework, they highlight those competences that are needed to enact circular economy principles. Among their competences, they include **lifecycle thinking**, recently acknowledged for its fundamental contribution to move efficiently and sustainably towards more responsible consumption and production patterns, in the position paper by the UNEP-SETAC Life Cycle Initiative, that highlights LCA as a tool to attain a sustainable transition towards the circular economy (Life Cycle Initiative, 2020). They also add **understanding of eco-design principles** as well as **social entrepreneurship** and **business ethics** to grow students into being future ethical and circular managers. They also mention **creativity skills** to spur circular innovation (Ellen MacArthur, 2012).

Lozano et al. (2017) developed a conceptual paper where they identified twelve competences and twelve pedagogical approaches for sustainable development. They conducted a literature review which was then analysed with a Delphi study based approach. In their set of competences, they underlined some of the competences already discussed in Rieckmann (2012) as well as the **importance of justice**, **responsivity and ethics** in their thinking and behaviour (Eagan et al., 2012).

Table 4. Competence frameworks in SE and ESD (1/2)

Authors and year	Rieckmann, 2012	Glasser & Hirsh, 2016	Quendler & Lamb, 2016	Dimante, Benders, Atstaja, Tambovceva, 2016	Lozano, Merrill, Sammalisto, Ceulemans, Lozano, 2017
Framework title	Key competencies for SD	Learning for Sustainability Core Competencies	Competences, Knowledge, Skills for ESD (desirable professional profile)	Competences for the Circular Economy in business education	Competences for ESD in Higher Education

Competences	• Systemic thinking and handling of complexity;
	• Anticipatory thinking;
	• Critical thinking;
	• Competency for acting fairly and ecologically;
	• Competency for cooperation in (heterogeneous) groups;
	• Competency for participation;
	• Competency for empathy and change of perspective;
	• Competency for interdisciplinary work;
	• Competency for communication and use of media;
	• Competency for planning and realising innovative projects;
	• Competency for evaluation;
	• Competency for ambiguity and frustration tolerance
		• Systems thinking competency;
		• Interpersonal competency;
		• Normative competency;
		• Anticipatory competency;
		• Strategic competency;
		• Affinity for life;
		• Knowledge about the state of the planet;
		• Wise decision-making;
		• Modelling sustainable behaviour;
		• Transformative social change
			• SD Competences:
			  • Social responsibility;
			  • System orientation;
			  • Future orientation;
			• SD Skills:
			  • Analysing environmental impacts;
			  • Economic optimisation;
			  • Communicating;
			  • Implementing sustainability;
			  • Leadership and teamwork;
			• SD Knowledge:
			  • General SD knowledge;
			  • How to analyse environmental impacts;
			  • How to reduce environmental impacts;
			  • Economics;
			  • Value of nature;
			  • Social aspects of SD.
				• Life cycle thinking (or life cycle assessment understanding);
				• Understanding of eco-design principles;
				• Systems thinking;
				• Multidisciplinary approach to problem solving;
				• Ability to work in interdisciplinary groups;
				• Creativity skills;
				• Negotiation skills;
				• Principles of social entrepreneurship;
				• Business ethics;
				• Long-term thinking
					• Systems thinking;
					• Interdisciplinary work;
					• Anticipatory thinking;
					• Justice, responsibility, and ethics;
					• Critical thinking and analysis;
					• Interpersonal relations and collaboration;
					• Empathy and change of perspective;
					• Communication and use of media;
					• Strategic action;
					• Personal involvement;
					• Assessment and evaluation;
					• Tolerance for ambiguity and uncertainty

Method	70 Experts from Latin America (Chile, Ecuador, Mexico) and Europe (Germany, Great Britain)	Based on Wiek et al., 2011, authors added 5 core competences	Two surveys: one for HEIs and one for companies to define C, K, S needs for ESD	Analysis based on literature review and academic courses at three HEIs in Latvia	Conceptual paper

Source: author's own elaboration.

Table 5. Competence frameworks in SE and ESD (2/2)

Authors and year	Rieckmann, 2018 (Same as in Unesco, 2017)	Trad, 2019	Giangrande, White, East, Jackson, Clarke, Coste, Penha-Lopes, 2019	Pacis & Van Wynsberghe, 2020
Framework title	Key competences for ESD	ESD Collective Competences* for tertiary education (focus on engineering)	Competency Framework for ESD which applies to all learning (F,I,NF)	Key Competencies for Sustainability
Competences	• Systems thinking competency; • Anticipatory competency; • Normative competency; • Strategic competency; • Collaboration competency; • Critical thinking competency; • Self-awareness competency*; • Integrated problem-solving competency *self-awareness or intrapersonal competency	• Change management and envisioning a better future (change management; envision a better future; anticipatory competence); • Value-based thinking, self-awareness & global responsibility (interpersonal competence; values-based thinking; global citizenship; global resource knowledge; self-awareness; capacity for empathy, compassion and solidarity); • Complexity and systems thinking, Triple Bottom Line (systems thinking (applying a TBL); complexity & systems thinking (TBL); transdisciplinary; • Stakeholder engagement and collaboration (collaboration in decision-making; normative competence; sustainability growth and development; conflict resolution); • Life-long learning skills and continuous reflection for sustainability (learning for life; judge consequences; act upon reflection; self-learning; distanced reflection on individual and cultural models); • Lifecycle analysis (strategic competence; lifecycle analysis);Decision-making for sustainability (decision-making for sustainability development when designing; interdisciplinary); *each collective competence includes a subset of sustainability competences (in italic); *critical thinking*: included in each collective competences as a sustainability competence (defined as: objective analysis of a problem by judging results or weighing values to form the most sustainable judgement).	• Interpersonal competence (collaborative skills; mediation; leadership; cooperation; empathy; teamwork); • Strategic planning competence (decision making strategies; awareness of success factors; obstacles to change; knowledge of behavioural change; organisational development skills); • Normative competence (knowledge of the sustainability of current or future states; knowledge of and awareness of justice, fairness, happiness, wellbeing, risk, trade-offs, and ethical questions); • Anticipatory competence (working with scenarios, forecasting and backcasting; intergenerational equity); • System thinking (ability to work with Feedback loops, systems and sub-systems, buffers and multiple variables, nested scales, resilience, and tipping points); • Intrapersonal competence (ability to hold contradictory feelings and thoughts; personal and group stress management; cultivating awareness; finding inner peace, compassion, meaning making, experiencing love and connection)	**Knowledge and understanding:** • Integrating tradition with future thinking; • Applying systems thinking and dynamics; • State of planet literacy and numeracy; **Social skills and agency:** • Implementing transformative change; • Modelling sustainable behaviour; • Wise, compassionate decision-making; • Empathy, mindfulness and social learning; **Values and commitments:** • Commitment to the common good (affinity for all life); • Care and interest for others; • Care for self
Method	Conceptual paper	Literature review and tested in engineering curricula	20 experts from formal & informal ed. and NGOs	Literature Review

Source: author's own elaboration.

Rieckmann (2018) summarised the key competences for sustainable development identified in previous works, which coincides with the UNESCO key competences for sustainable development (2017). As already stated, there is a high degree of convergence in the literature on key competences in SE (and ESD), as well as in academic and grey literature or policy documents (Wiek et al., 2011) as can be seen in tables 4 and 5.

Trad (2019) identified the collective competences for sustainable development needed in engineering education. Within their collective competences, authors integrated the more transversal key sustainability competences by Wiek et al. (2011) with discipline-oriented competences such as **lifecycle analysis** and **triple bottom line**, i.e. contemporaneously considering environmental, social, and economic aspects. Furthermore, their framework underscores the importance of **values-thinking and reflection** in a discipline such as engineering, which is traditionally positivistic. Being able to reflect upon one's own values as well as cultural and political aspects is a fundamental aspect of sustainability. Effective SE should lead students to cogitate their assumptions and beliefs to challenge and transform these, thus leading to changes in values, attitudes and behaviours (cf. 617). In this respect, SE literature highlights how students, and individuals in general, should be able to reflect and understand their and other people's attitudes, beliefs and values, and prioritise those in tune with the environment.

Then, through a qualitative approach, Giangrande et al., (2019) engaged with twenty experts from formal and informal educational settings and representatives from non-governmental organizations (NGOs) to discuss the framework by Wiek et al. (2011), to which they added the intrapersonal competence (see also Brundiers et al, 2020).

Finally, Pacis and colleagues (2020) described knowledge, skills, and values as part of key competences in sustainability. In their literature review, they identified key skills for sustainability in line with the afore discussed article by Glasser and Hirsh (2016). A distinctive feature of their framework is the importance of **considering traditions** when making scenarios or decisions about the future. Tradition can be understood as including past experiences, but also cultural and context dependent factors.

To summarise, we gathered in table 6 some of the key components that emerged from this study. While some of them are already included in the key competences in sustainability (Brundiers et al., 2020; Redman & Wiek, under review), it is worth highlighting them, especially for future discussions.

Table 6. Additional sustainability competence components emerged from the literature.

Sustainability components	Principles	Reference
Empathy and change of perspective	Being truly compassionate for each other and the planet, understanding our actions affect others; transcultural understanding; Willing to change perspective as new information becomes available;	Glasser & Hirsh, 2016; Lozano et al., 2017; Pacis & Van Wynsberghe, 2020; Rieckmann, 2012; Trad, 2019;
Inclusive and interdisciplinary work	Taking into consideration the representation of different voices, including minorities; Valuing local and indigenous knowledge, practices, and contexts and relation with society and the planet; Including cultures and past traditions into own evaluation and thinking; Appreciation, evaluation, contextualisation, and use of knowledge and methods of different disciplines; Ability to work on complex problems in interdisciplinary contexts;	Lambrechts et al., 2013; Lozano et al., 2017; Rieckmann, 2012 ;
Ambiguity and frustration tolerance	Coping with conflicts, competing goals and interests, contradictions, and setbacks; Recognizing the impossibility of finding balance, but learning to navigate paradoxes, e.g. among the three pillars of sustainability development;	Lozano et al., 2017;
Lifecycle thinking and triple bottom line	Analysis of environmental, social, economic impacts of existing alternatives as well as future actions (e.g. when designing a future product; when considering a personal choice such as between taking the train or the bus, etc.);	Dimante et al., 2016; Trad, 2019;
Creative use of existing resources	Questioning own needs for new products or activities, instead of creatively using resources already owned at individual, community, and societal level	Dimante et al., 2016 ;
Continuous learning and question-asking	Desire to continue learning and to reflect on sustainability in a time where knowledge quickly becomes outdated; Ability to retrieve information in a critical manner and understand their relation with the state of the planet	Trad, 2019;
Sustainable entrepreneurial behaviour (not only in the business domain)	Assessing environmental and social aspects when undertaking a new enterprise, intended as a new action, activity, be it economic or otherwise	Dimante et al., 2016; Ellen MacArthur Foundation, 2014 ;
Justice, ethics, and diachronic & differentiated responsibility	Application of concepts of ethics, justice, social and ecological integrity, and equity; Description, negotiation, and reconciliation of principles, values, aims, and goals for sustainability; Ethics and sustainability of personal and professional behaviour Diachronic responsibility in relation to past and future generations; Differentiated responsibility in relation to one's own possibilities, circumstances, and contextual factors	Lozano et al., 2017; Murga-Menoyo, 2014;
Care for the common good (affinity for all life)	Harmonious relation to nature, other human beings, and the planet	Glasser & Hirsh, 2016; Pacis & Van Wynsberghe, 2020;
Knowledge about the state of the planet	Ability to understand and possessing general knowledge about the state of the planet and sustainability	Pacis & Van Wynsberghe, 2020;

Source: author's own elaboration.

3.2.2 Learning sustainability

Although the primary focus of this report was to review past and existing attempts to develop sustainability competence frameworks, a brief overview of pedagogical approaches in SE is also provided. This is because not only scholars have tried to understand **what** key sustainability competences should be learned, but they have also been trying to define **how** and which learning processes trigger significant shifts in people's values, attitudes, and beliefs (Thoresen, 2017).

In particular, the role of values in relation to SE has been highlighted by scholars and institutions (e.g., Brundiers et al., 2020; Molderez & Fonseca, 2018; UNESCO, 2007; Wiek et al., 2011) as "guiding principles in an individual's life" (Schwartz, 1992, p.17). This is because competences in sustainability, such as futures thinking or strategic thinking, can fulfil their true purpose only if intrinsically linked to values attuned with sustainability principles. In referring to systems-thinking, Sleurs (2008) argued that it is only useful when linked to values and ethics, as it could otherwise be used in ways that are non-sustainable.

Because competences are made of interlinked knowledge, skills, attitudes, and values, they cannot be taught adopting traditional pedagogical approaches, but they have to be acquired by learners through reflection, action, and experience (Mindt & Rieckmann, 2017; Molderez & Fonseca, 2018). A new learning culture that embeds and promotes sustainability is required. First it should put learners at its centre and facilitate competence development (Barth et al., 2007; Mindt & Rieckmann, 2017; Sipos et al., 2008). Second, educational institutions should collaborate with other stakeholders, e.g. the local community, to understand mutual needs and exploit learners' potential to make a positive impact in society at the local and global level (Sipos et al., 2008).

Transformative learning (Mezirow, 1978) has been often associated by scholars as an effective pedagogical approach for SE. It argues that learning should not only be about acquiring competences, but also about becoming critically self-aware of tacit experience and assessing its relevance to interpret the world (Mezirow, 2000). As a result, transformative learning aims to profoundly change our perspectives, beliefs, and behaviours through **reflecting** what we know and do not know, and **questioning** the understanding of ourselves, in relation to the interpretation of our surroundings (Simsek, 2012). In practical terms, transformative learning allows learners to understand what they learn by re-conceptualising it and applying it to their daily lives (Thoresen, 2017).

According to some scholars (cf., Cranton, 2006; Holdsworth & Thomas, 2016; Howlett et al., 2016; Michelsen, 2016; Thoresen, 2017; Wiek et al., 2011) SE must be transformative so that it challenges core assumptions that students have accrued through their upbringing and context, but also those imposed by society. The outcomes of transformative learning have been described as the competence to integrate, connect, confront and reconcile multiple ways of looking at the world (Wals & Corcoran, 2006). Given the intrinsically complex nature of sustainability, this represents a necessary condition.

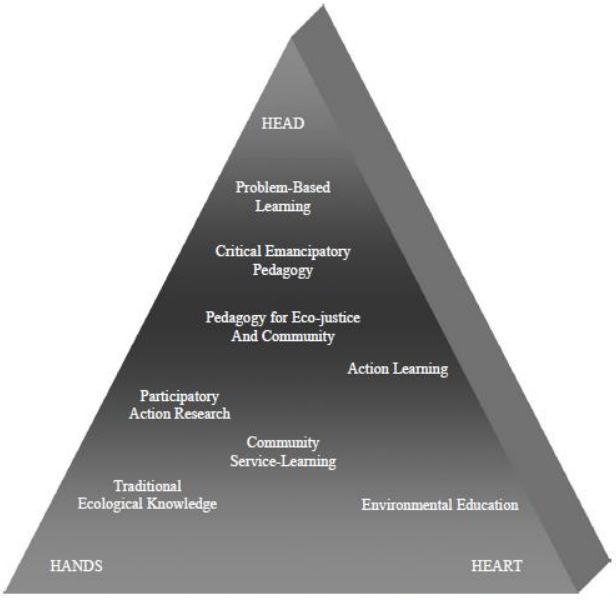
In their seminal paper, Sipos and colleagues (2008) describe the framework of **transformative sustainability learning** (TSL) through the planning principle of head, hands and heart.

TSL claims that profound changes in knowledge, skills and attitudes related to enhancing ecological, social and economic justice can be triggered by engaging cognitive (**heads-on**), psychomotor (**hands-on**) and affective (**hearts-on**) learning domains (Sipos et al., 2008). In particular, they aim to affect the behavioural domain through the following:

- *Cognitive domain* (head, knowledge): integrating learning processes rooted in participants' heads to trigger *engagement*, e.g. through academic study and understanding of sustainability and global citizenship;
- *Psychomotor domain* (hands, skills): *enactment* of theoretical learning through practical skill development and physical labour, e.g. by building, painting, planting;
- *Affective domain* (heart, attitudes and values): to foster an *enablement* of values and attitudes to be translated into behaviour, e.g. by developing a learning community with individual and group responsibilities.

In addition, the authors revised the most cited pedagogical models in SE literature and presented in figure 5 in relation to TSL.

Figure 5. A pedagogical categorization of sustainability and transformative learning models based on head, hands, heart.



Notes: This ternary diagram charts the relatedness amongst these pedagogies to each other and to the foci of Head, Hands and Heart. The pedagogies are not fixed in position; their relative positions will be influenced by their particular practice

Source: Sipos et al., 2008, p. 77

Table 7. An overview of some established pedagogies related to sustainability and transformative learning.

Pedagogical model	Overview of intended learning outcomes
Action learning	A form of experiential learning that enlists peers in helping learners question their assumptions and (optimally) experience a paradigm shift before applying their learning in new situations (McGill and Brockbank, 2004; Revans, 1998)
Community service-learning	An educational approach that integrates service in the community with intentional learning activities. Within effective CSL efforts, members of both educational institutions and community organizations work together toward outcomes that are mutually beneficial (Hayes, 2006, p. 2)
Critical emancipatory pedagogy	An ideology for learning facilitation that arises from an emancipatory tradition, focusing on equity amongst classes, races and genders (Mezirow, 1985; Freire, 1970)
Environmental education	An approach to teaching and learning that provides people with experience and knowledge to care for our environments (Gruenewald, 2004; Orr, 1994)
Participatory action research	A summary of terms in social science that refer to involvement of participants in the research process, commitment to social change, and that include aspects of social learning. There are many ways to define true participation, action and exactly what constitutes true research (Moore, 2005b; Coghlan and Brannick, 2001, Ch. 1; Stringer, 1999)
Pedagogy for eco-justice and community	An ideology for learning facilitation that acknowledges and finds tensions in "industrial mindset," works to replace attitudes with the metaphor of ecology (Bowers, 2001)
Problem-based learning	A framework for learning that is focused, experiential and organized around investigation of real-world problems. Authentic experiences foster active learning, support knowledge construction and integrate school learning and real life (Association for Supervision and Curriculum Development, 2005; Barrows, 1994)
Traditional ecological knowledge	Knowledge bases built by local or traditional resource users, as opposed to "experts"; argues for acknowledgement of more diverse forms of knowledge (as opposed to simply expert western science) (Berkes, 2004; Turner *et al.*, 2000)

Source: Sipos et al., 2008, p. 76

Table 7 is an overview of some of the pedagogical approaches that are often associated with SE. Similarly, Lozano and colleagues (2017) ([10]) selected twelve pedagogical approaches that emerged from their literature review that can contribute to promote transformation. In their review, they divide pedagogical approaches in three main categories:

- *Universal* are those pedagogies that have been used in many disciplines and contexts, such as case studies, interdisciplinary team teaching, lecturing, mind and concept maps, and project and/or problem-based learning;
- *Community and social justice* are pedagogies purposely used to address social justice and community-building, like community service learning, jigsaw/interlinked teams, participatory action research;
- *Environmental Education* describes the set of pedagogies emerging from environmental sciences and education practices, including for example eco-justice and community, place-based environmental education, supply chain/lifecycle analysis, and traditional ecological knowledge.

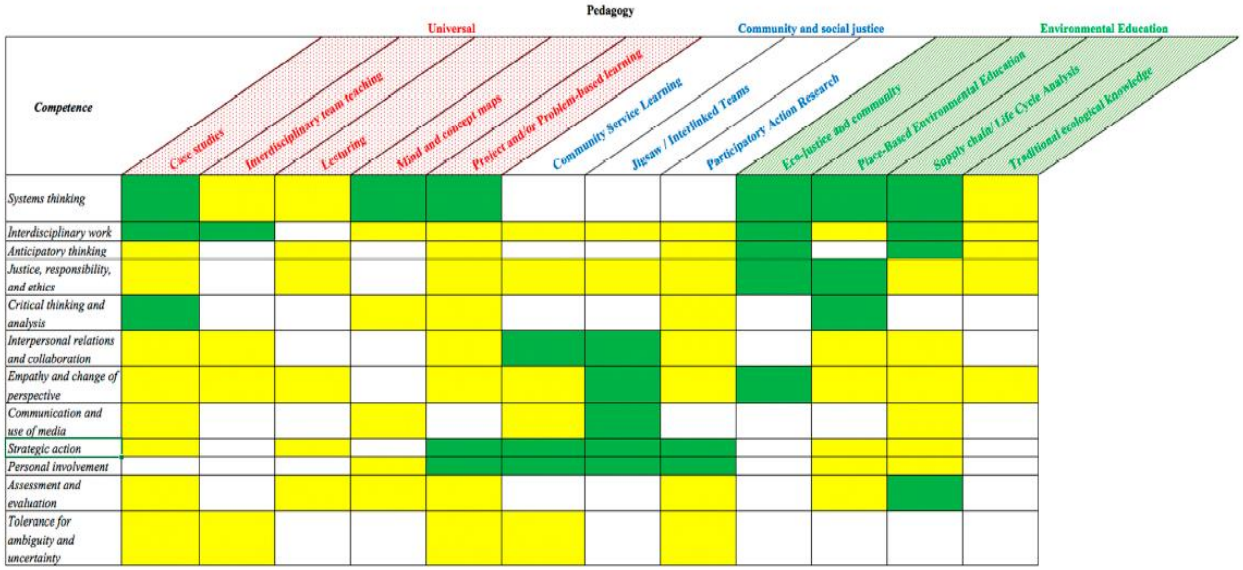
The authors specify that the above methods can be complementary and transversal to any academic programme. For example, lifecycle analysis is generally associated to technical courses or STEM disciplines, a simplified version can teach students how to consider and evaluate environmental, social, and economic aspects of the object at hand (be it products or activities) that relates to their lives (Lozano et al., 2017).

Furthermore, in their study, the authors tried to connect the identified twelve competences for ESD (see table 5) with the twelve pedagogical approaches just discussed. In figure 6, green cells represent pedagogical approaches

([10]) For an in-depth description of each method, please refer to table 2 on page 7, in Lozano et al., 2017

that usually contribute to develop certain competences, while yellow cells represent pedagogical approaches that are likely to contribute to competence development.

Figure 6. Framework connecting sustainable development pedagogical approaches to competences.



Source: Lozano et al., 2017, p.10

Methods within the community and social justice as well as environmental education show a satisfactory coverage of all competences; while approaches in universal-based pedagogies seem to underperform, with the notable exceptions of case studies and project/problem based learning.

In light of our literature review, we can affirm that scholars point to transformative learning as one of the most suitable and recommended methods to learn SE. However, few are the examples that empirically test this notion. Furthermore, much of the literature focuses on higher education, in spite of recognizing the importance of lifelong learning and learning beyond the classroom for sustainability.

3.3 Sustainability competences from grey literature

In conducting this review, we confirm what had already been stated by scholars in highlighting the overlap of grey literature with academic peer-reviewed articles (e.g., Sterling & Thomas, 2006; Wiek et al., 2011).

We left out from our analysis frameworks that concentrated on mapping broader set of competences necessary for a modern society. While such frameworks may incorporate sustainable lifestyles, it is not their only focus. Frameworks that fall in this description include competences on how to respond and take advantage of artificial intelligence, globalisation, and so forth. Despite being interrelated areas, the scope of the present study is mapping studies with a primary focus on key competences in sustainability.

Although the OECD Future of Education and Skills 2030 project focuses on broader themes, i.e. education for 2030, it is worthwhile providing a brief description of it, as it could inform the reader on current trends in education and education for "well-being of individuals, communities and the planet". This project was launched in 2015 with the aim of helping countries prepare their education systems for the future by undertaking the following:

- The first phase (2015-19) focused on "**what**" questions – what kinds of competences (knowledge, skills, attitudes and values) today's students need to thrive in and shape the future for better lives and for individual and societal well-being;

- The second phase (2019 and beyond), on "**how**" questions – how to design learning environments that can nurture such competencies, i.e. how to implement curricula effectively.

In the first phase, the OECD Learning Compass 2030 was developed. It is a work-in-progress learning framework developed in collaboration with a wide range of stakeholders and recognizes the importance of education beyond schools. The compass was chosen as a metaphor for students having to navigate through unfamiliar contexts while finding, or building, their direction in a meaningful and responsible way. It embeds a complex concept: the mobilisation of knowledge, skills, attitudes and values through a process of reflection, anticipation and action, in order to develop the inter-related competencies needed to engage with the world.

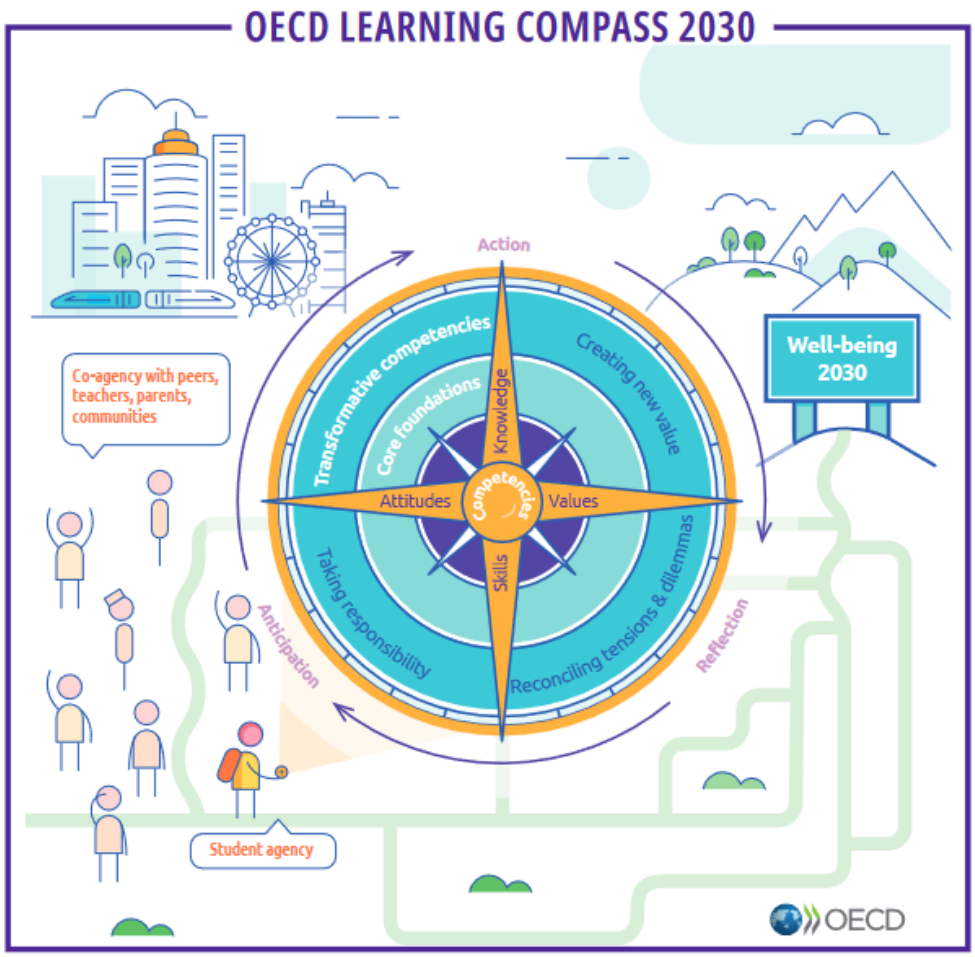
Figure 7 shows the OECD Learning Compass, which is composed by: core foundations, that include fundamental conditions and core knowledge, skills, attitudes and values; transformative competences, such as creating new value, reconciling tensions and dilemmas, and taking responsibility; the iterative AAR cycle, i.e. reflection, anticipation, and action, whereby learners continuously improve their thinking and act intentionally and responsibly; and finally, student agency (thinking and acting to make a positive impact individually and for society) and co-agency with peers, teachers, parents and communities.

Transformative competences, that emerged from the first phase of the project ([11]), are competences students need in order to contribute to and thrive in our world, and shape a better future. Transformative competences can be described as follows:

- *Creating new value* is about thinking outside the box and find innovative solutions and new sources of growth by developing new products, processes, and business models to achieve well-being. The constructs that underpin the competency include adaptability, creativity, curiosity and open-mindedness (OECD, 2018).
- *Reconciling tensions and dilemmas* involves thinking and acting in an integrated way, taking into account the interconnections and inter-relations between contradictory or competing demands, a diverse set of stakeholders, and different temporal perspectives. Systems thinking is at that basis of this competence (OECD, 2019);
- *Taking responsibility* underpins the previous two competences and is connected to the ability to reflect upon and evaluate one's own actions in light of one's experience and education, and by considering personal, ethical and societal goals. Self-regulation is a key component of this competence and involves self-control, self-efficacy, responsibility, problem solving and adaptability (OECD, 2018).

([11]) Competences included in core foundations include financial literacy, media literacy, global competence, etc

Figure 7. OECD Learning Compass 2030.



Source: OECD, 2019.

The second phase of OECD Future of Education and Skills 2030 is currently undergoing and focused on addressing the following question: how education systems should change to meet, and anticipate, future challenges and opportunities.

As highlighted in the conceptual notes of the project, if education institutions were seen as independent entities, or "ivory towers", they are now embedded in a larger ecosystem to which they proactively contribute and by which they are influenced. To explain this fundamental aim, experts draw a critical comparison among different pedagogical purposes used in different time periods as explained below (OECD, 2019).

In the 19th century, the objective of education was to prepare students for jobs. Teaching was standardized and made efficient through mass education. Besides, the environment was seen as something for humans to exploit in the pursuit of economic growth. Teaching was static, linear and standardised.

In the 20th century, broader goals were set for education, like individual fulfilment. In this period of rapid growth, competition among businesses became more intense, and society had started to hold them accountable. It is in this period of ecological destruction that the notion of corporate social responsibility was promoted. Teaching remained largely static and standardized as a proof that all students, regardless of their background, were provided equitable opportunities to learn.

Finally, in the 21st century, education needs to empower every individual to live in tune with the environment and the ultimate goal is the wellbeing of society and the planet. While the aim of education is now also to educate "for

citizenship", there is a need to recognize individual differences and different methods of teaching and learning. In this context, curricula will have to be dynamic and allow for non-linear learning paths.

Table 8 describes some new emerging trends as compared to the more traditional education system.

Table 8. OECD Education and Skills 2030: "The new normal in education".

Features	Traditional education system	An education system embodying the "new normal"
Education system	Education system is **an independent entity**	Education system is **part of a larger eco-system**
Responsibility and stakeholders engagement	**Decisions made based on a selected group of people** and thus they become held accountable and responsible for the decisions made	**Decision-making and responsibilities shared among stakeholders**, including parents, employers, communities, and students
	Division of labour (Principals manage schools, teachers teach, students listen to teachers and learn)	**Shared responsibility** (everyone works together and assumes responsibility for a student's education and students also learn to be responsible for their own learning)
Approach to effectiveness and to quality of school experience	**Outcomes most valued** (student performance, student achievements are valued as indicators to evaluate systems for accountability and for system improvement) **Focus on academic performance**	**Valuing not only "outcomes" but also "process"** (in addition to student performance and student achievements, students' learning experiences are in and of itself recognised as having intrinsic value)
		Focus on not only academic performance but also on holistic student well-being
Approach to curriculum design and learning progression	**Linear and standardized progression** (the curriculum is developed based on a standardised, linear learning-progression model)	**Non-linear progression** (recognising that each student has his/her own learning path and is equipped with different prior knowledge, skills and attitudes when he/she starts school)
Focus of monitoring	**Valuing accountability and compliance**	**System accountability as well as system improvements** (e.g. continuous improvement through frequent feedback at all levels)
Student assessment	**Standardised testing**	**Different types of assessments used for different purposes**
Role of students	Learning by listening to directions of teachers with emerging student autonomy	Active participant with both **student agency and co-agency** in particular with teacher agency

Source: OECD, 2019

3.4 Concluding remarks

To conclude and summarise, in sections 3.1, 3.2, and 3.3 we presented the main findings on existing attempts to identify key competences in sustainability education (SE) and education for sustainability (ESD). We noted that there is a great extent of convergence on what key competences in sustainability are among scholars in academic literature (3.1 & 3.2) and among academic and grey literature (3.3) in general.

For this reason, in this report we focused on presenting the most relevant sources that met our inclusion criteria and can inform the development of a sustainability competence framework.

The frameworks developed by Brundiers et al. (2020) and Redman and Wiek (under review) represent **the most encompassing frameworks** to date. This is mostly because they review and discuss previous findings in order to build expert consensus on key competences in sustainability; and they incorporate the framework by Wiek et al (2011) regarded as one of the most influential one in SE. Section 3.1 describes their frameworks.

In section 3.2 we presented additional findings that may trigger further discussion for a sustainability competence framework. While sections 3.1 and 3.2 were focused on what key competences are to be learned in SE, paragraph 3.2.2 shed some light on further discussions that constitute the SE literature. Notably, how key competences in sustainability can be learned. As seen in 3.3, the second phase of the OECD Education and Skills 2030 project aims precisely to answer this question.

Some of the limitations of the aforementioned studies are identified. First, their main focus is on higher education. While there are some studies focusing on **early education** (e.g., Arlemalm-Hagser & Sandberg, 2011), they are mainly focused on environmental education. Equally, there is a lack of studies focusing on **continuous learning**,

i.e. **adult learning** beyond the classroom. Typically, after higher education, sustainability is analysed in relation to green jobs and skills acquisition. However, since sustainability in entrenched in our day lives, in our vests of responsible citizens, ethical consumers, active participants in the community through for example volunteering or activism, and so forth, an investigation on how adults can learn to live according to sustainability principles is deemed necessary. This is especially true considering the **ageing of our population** that was educated in the previous century, where the main focus was on economic growth. Then, in light of our findings, more research should be conducted on **online learning** in relation to pedagogical methods for sustainability that may require proactive collaboration, action, and (physical) participation to tasks and assignments in local contexts. Finally, more research needs to be performed in relation to two key areas: first, how to best convey and learn sustainability competences, i.e. **teaching and learning approaches for sustainability;** second, additional research should focus on **assessing learning outcomes,** not only for the purpose of **higher education curriculum development,** but also to try and assess key sustainability competences learnt in education, **in the working lives of sustainability professionals** (Barth et al., 2007; Wiek et al., 2011).

4 Towards a circular economy – sustainability in the workforce

Mirroring chapter 2, we now present a brief overview of key concepts used in employment to describe jobs in sustainability or "green jobs". Section 4.1 discusses the notions of skills. Section 4.2 introduces the notions of the green economy (4.2.1) and that of the circular economy as a key European priority for our economy (4.2.2) and the identification of green jobs and green skills (4.2.3).

4.1 Green skills for the green economy and circular economy

While discussions on sustainability education focus on identifying **key competences in sustainability**, the notion of **green skills** is mostly used to identify the needs of the current and future workforce in relation to jobs.

First, sustainability is used in relation to education, while green is often associated to employment. The use of "green" derives from the concept of "green economy", as discussed in section 4.2. Second, there is no widespread consensus on the use of 'competence' or 'competency' (in education), and 'skills' (in employment). As emerged from this study, the most salient concepts used in academic and policy documents are respectively: key competences in sustainability education, and green skills (and green jobs) in employment.

Skills are defined as "the ability to carry out processes and use the existing knowledge to achieve results" (European Commission, 2018) or "capabilities of individuals gained through experience and practice, which help individuals to acquire knowledge" (O*NET) ([12]). As can be noted, skills represent one of the components of competences, in line with the definition used in the field of education.

However, when the term 'skills' is used in policy or scientific documents in relation to employment, it can also acquire an encompassing characteristic. To put it simply, in relation to jobs, **skills is sometimes used in lieu of competence**. Indeed, "**green skills, or skills for sustainability** as they are also called, are defined as the technical skills, knowledge, values and attitudes needed in the workforce to develop and support sustainable social, economic and environmental outcomes in business, industry and the community" (Cedefop, 2019, p. 16). That being said, most of the databases and policy-documents refer to green skills as in the definition given by the European Commission and O*NET.

In light of this, "green skills" is a concept that is vastly used in policy documents, the employment and economics literature, and among practitioners. The salience of skills in relation to jobs may be due to the inherent notion of skills, representing the application of knowledge in a specific context or job. That being said, focusing merely on skills as abovementioned in the definition by the European Commission (2018) or O*NET in relation to jobs may be rather reductive. Especially, when considering the **rapid pace** at which the nature of jobs and the broader industry is shifting towards **less routinized jobs**, where a higher level of education is required. Furthermore, the role of **attitudes and values** in guiding individuals towards sustainable behaviours in uncharted territories cannot be ignored.

As such, in chapter 4, the terms skills and green skills are used as originally found in the studies presented, although reckoning that a mere focus on skills does not capture the full breadth of the competences required to work in the green (and circular) economy. The term competence is also used when found. While this could be confusing for the reader, it is in line with the publications on green employment and employment in the circular economy. Equally, such confusion highlights **the necessity to make definitions uniform** across institutional contexts (policy and academia) and within institutions.

4.2 Towards a circular economy

As discussed in section 2.2, sustainability can be described as a long-term goal, while sustainable development defines those pathways or avenues that help achieve progress in a sustainable manner, such as sustainable agriculture and forests, responsible modes of production and consumption, etc. For what concerns the economy, several concepts have been suggested as sustainable avenues both in literature and policy documents at the

([12]) The US Occupational Information Network (O*NET) is an online database that gathers occupational information. It is developed under the sponsorship of the U.S. Department of Labour/Employment and Training Administration

national and international levels (c.f. D'Amato et al., 2017), such as green economy, green growth, blue economy, circular economy, low carbon economy, sharing economy, doughnut economy, etc.

While it is not the aim of this study to focus on the implications, nor to discuss merits and limitations, behind each concept, it is worthwhile understanding their difference vis-à-vis current policies and strategies, in order to better understand what the most appropriate competences needs are for a given concept. In this study, we focus on the green economy and growth, and the circular economy.

4.2.1 Green economy and green growth

Despite being coined in the late 1980s, the concept of green economy was only rarely addressed in the previous century. This may be due to the onset of Sustainable Development as a concept in the Brundtland report (1987) and its institutionalization within the UN Rio summit in 1992. Both green economy and sustainable development advocate for sustainable progress by addressing environmental conservation and social wellbeing. However, in the late 2000s, sustainable development had started to lose traction in economic policymaking (Jacobs, 2013), while green economy re-emerged as an operational strategy to tackle economic recovery and a more sustainable growth in the future (c.f. Merino-Saum et al., 2020). Indeed, the **green economy** was identified as "one of the important tools available for achieving sustainable development" (UN, 2012, p. 56; emphasis added). As a result, the United Nations Environment Programme (UNEP) launched the Green Economy Initiative in 2008 and the green economy was one of foci of the 2012 UN Conference on Sustainable Development (Rio +20). These events contributed to bringing to the fore the concept, and definition, of green economy at the global level. UNEP defined the **green economy** as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2010, p.5).

Similarly, green growth was coined in the early 1990s, but it was only in concurrence with the 2008 global financial crisis, and the acknowledgment of the limits of the current systems, that the concept of green growth was adopted (Bina, 2013; Merino-Saum et al., 2020). In 2009, the Organisation for Economic Co-operation and Development (OECD) launched the Green Growth Declaration (OECD, 2009) and published the Green Growth Strategy Package in 2011. This included the highly cited Towards Green Growth, where **green growth** is about "fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (OECD, 2011, p.9).

Green economy and **green growth** are often used interchangeably, despite underpinning a conceptual difference (Bina, 2013). A lack of a common and agreed definition of these concepts contributes to continuing this trend. Merino-Saum and colleagues (2020) found that a total of 140 definitions were used to define green economy and green growth in academic literature (117 definitions) and policy documents (23) between 2008 and 2018. Furthermore, definitions vary according to the geographic location and institutional context (academia or policy). It is however important to highlight that **green growth** is primarily **focused on economic growth**, while **green economy** conceives it **as a way to achieve development**; green economy also involves a more balanced treatment of social issues and environmental limits (Merino-Saum et al., 2020).

4.2.2 Circular economy

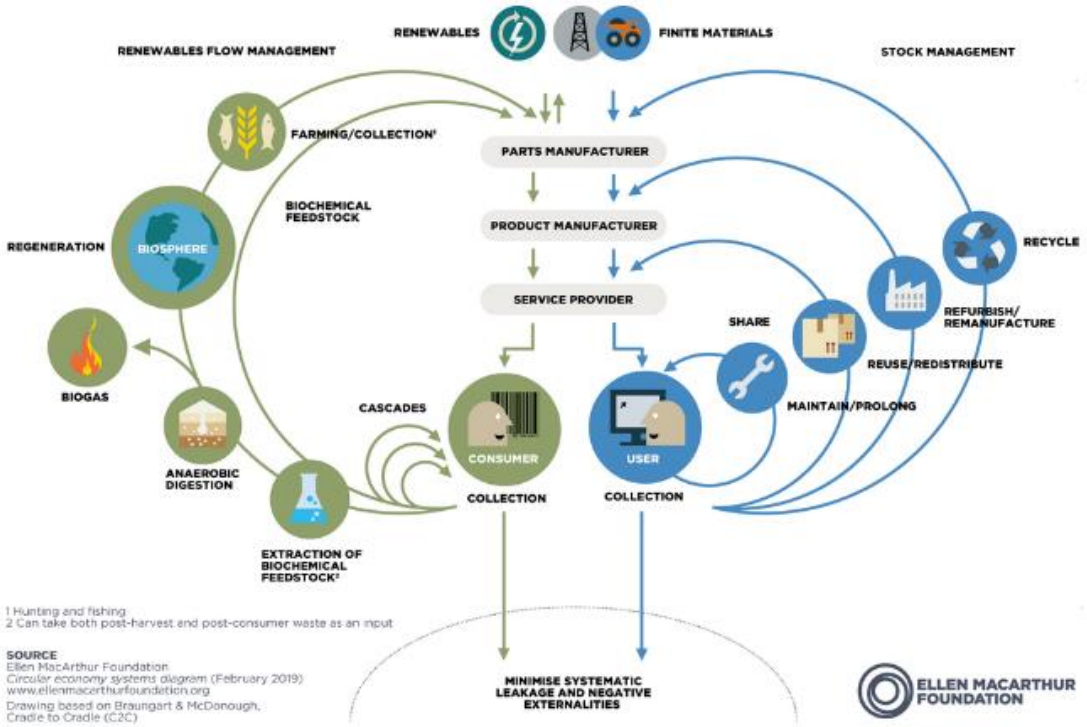
The concept of a circular economy can be traced back to the notion of industrial ecology emerged in the 1970s in parallel with expert concern of the limits of planetary resources (eg., Boulding, 1966; Pearce et al., 1989). The idea of a circular economy started to gain an increased interest in the 1990s in opposition to the linear model of take-make-dispose. One of the defining objectives of the circular economy is to exert zero, or little, effects on the environment by recovering resources already in the system through reuse, repair, and recycling (Burger et al., 2019; D'Amato et al., 2017). Despite the vast amounts of definitions in use, the one by the Ellen MacArthur Foundation is the most used (Kirchherr et al., 2017) and describes the **circular economy** as "an industrial economy that is restorative or regenerative by intention and design" (2013, p. 14). It is based on three interlinked concepts such as: the elimination of waste and pollution through superior design; the substitution of the 'end-of-life' concept in favour of restoration, by keeping resources and products in use; the avoidance of toxic materials which neglect reuse and affect the health of all living systems (Ellen MacArthur Foundation, 2012).

In its early conception, the circular economy had been associated to waste management, due to its focus on eliminating waste. However, the circular economy concept is **more encompassing** as it understands regeneration not only of resources, but also as an improvement of a society that would live in tune with the environment in which it is embedded (D'Amato et al., 2017; Ghisellini et al., 2016).

Figure 8, also known as the **butterfly diagram**, depicts the circular economy systems. The diagram is split into two interlinked and interacting halves. The green part denotes biological materials that can re-enter the environment and regenerate through biological processes through cascades, i.e. using a product, or its parts, for another application, e.g. in another value chain. During cascading, quality is reduced and energy is consumed (Ellen MacArthur Foundation, 2013). Instead, the blue part represents materials that cannot re-enter the environment (e.g. plastics, metals, etc.), and their value remains in the systems through continuous cycles involving: (i) maintenance and repairing; (ii) reusing or redistributing; (iii) remanufacturing or refurbishing; and (iv) recycling ([13]).

The shift to a circular economy thus requires key competences in order to maximize the use of existing assets, the shift to renewable resources as opposed to finite ones, and the extension of product and process lifecycles so that materials can remain in the loop. The emphasis is on **superior design**, while recognising at the same time that **all actors along the product lifecycle and across the value chain** must work in synergy.

Figure 8. Circular Economy systems diagram.



Source: Ellen MacArthur Foundation, 2019

Finally, following from above, seven key strategies pertaining to the circular economy were identified, which can be divided into four core and three enabling strategies (Burger et al., 2019; Circle Economy & EHERO, 2018). The **four core strategies** of the circular economy are described as follows:

- *Preserving and extending what is already made* that entails reusing, repairing, remanufacturing and similar actions aimed at maximizing the value of what is produced;

([13]) A full explanation can be found here: https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf

- *Prioritising regenerative resources* by avoiding the use of toxic materials and prioritizing the use of renewable resources;
- *Using waste as a resource* by keeping materials in the loop;
- *Rethinking the business model* which involves envisioning new ways of doing business and devising incentives on business models that build on the interaction between goods and services.

Instead, three **enabling strategies** are those that support and enable the functioning of core strategies and are the following:

- *Designing for the future* means adopting a systems perspective in the design phase so that regenerative materials are used and products have an extended lifetime;
- *Incorporating digital technology* allows to become more efficient at connecting demand and supply for resources already in use and connecting stakeholders through digital platforms that provide insights;
- *Collaborating to create joint value* includes working together along a product lifecycle and across the value chain with different actors to increase transparency and joint value.

4.2.3 Green jobs and circular economy jobs

The green and circular economy concepts, while differing in their assumptions, have often been used as synonyms, due to their common objective of achieving contemporaneously economic, environmental, and social goals (D'Amato et al., 2017). Furthermore, the green economy was previously understood as an umbrella term, thus incorporating the circular economy as a way to achieve a green economy (European Environment Agency, 2014). However, while the green economy is an end per se, i.e. achieving an economy that is sustainable; the circular economy is both a means and an end. This is because it provides an operational approach on how to abandon the linear economy (means), while aiming for a regenerative and healthy planet (end).

Given these premises, the circular economy requires new competences in several areas, such as the understanding of raw material cycles; the ability to design out waste; the recognition of the roles and responsibility of different actors in the system, including designers, producers, consumers, policy-makers, etc. (European Environment Agency, 2019). Identifying such competences is important to educate citizens and to skill the future workforce, as well as re- and upskill the current one.

However, despite the widespread focus on the circular economy both in the literature and in policy documents, the concept of circular jobs – or **circular economy jobs** – is only nascent. Little is known about the type of workforce that the circular economy requires (Burger et al., 2019; Cambridge Econometrics et al., 2018b). Currently, jobs in the circular economy tend to be **labelled as green jobs** (Horbach, 2015). However, such definition may exclude some jobs that enable and sustain the circular economy (c.f., Burger et al, 2019). For example, designing products to last longer which are made in modular parts helps avoid waste and favour recycling. While this may not be captured by certain definitions of green jobs, it is part of a circular economy.

There are many definitions of what a green job is (Consoli et al., 2016) and its understanding varies across countries (Cedefop, 2019). That being said, the definition of **green jobs** by the International Labour Organization (ILO) is often used in the literature and policy documents. The ILO defines green jobs as "decent jobs that contribute to preserve or restore the environment, be they in traditional sectors such as manufacturing and construction, or in new, emerging green sectors such as renewable energy and energy efficiency" (ILO, 2016). According to the ILO, green jobs helps to:

- Improve energy and raw materials efficiency;
- Limit greenhouse gas emissions;
- Minimize waste and pollution;
- Protect and restore ecosystems;
- Support adaptation to the effects of climate change.

The ILO identifies green jobs according to two main criteria: the production of goods or services that benefit the environment, e.g. green buildings or electric mobility; and/or jobs that contribute to more environmentally friendly

processes (e.g., water consumption or improve recycling systems). The dashed area in figure 9 shows green jobs as interpreted by the ILO (2016).

Figure 9. Green jobs as defined by the International Labour Organization

Source: International Labour Organization

Following from this, Consoli and colleagues (2016) identified **four main approaches on how green jobs can be identified** (see also Peters et al., 2011). Table 9 describes the four approaches in use, by providing examples, drawbacks, and information on how each approach is computed. Both the ILO and the US Department of Commerce (2010) take into account **products** and **process** to identify green jobs, while Eurostat uses an **industry** approach (Eurostat & ICEED, 2009). O*NET instead adopts an **occupation**-based classification and sees green jobs as any occupation affected by greening, whether via increased demand, changes in work or worker requirements, or the creation of unique worker requirements.

Table 9. Four approaches to identify green jobs.

Approach	Example	Drawbacks	Calculation method
Focus on process Selecting jobs involved in industrial green processes	Jobs related to waste management, waste treatment, energy use monitoring, etc.	This approach relies on information that is often firm-specific	**Indirect** Green jobs are defined indirectly by assimilating the environmental properties of industry to those who carry out the work activities. this logic may not be appropriate as it enforces an isomorphism between the structure and organisation of knowledge at the industry and occupation levels.
Focus on product Selecting jobs involved in the production of goods and services that are known to contribute to environmental and conservation objectives	Jobs related to products and services as described by procurement programmes. It may however encompass 'suspects' such as hybrid or electric automobiles, insulation products or energy monitoring systems.	This approach relies on ad-hoc definitions that may yield many false negatives, for example by overlooking green activities that are not directly associated with the production of a particular product or service like energy conservation within a firm.	
Focus on industry Selecting industries that have a high fraction of firms actively engaging environmental and conservation objectives	Manufacturing of energy-efficient appliances, filters or wind turbines, etc.	This approach relies on industrial classification schemes. As such, the number of green jobs may be over described, because the industrial classification schemes are not detailed enough to distinguish green goods and services from similar non-green goods and services. This in practice means that the green jobs count may easily include false positives (Peters et al., 2011).	
Focus on occupation Selecting an occupational-based lens for probing the distinctive characteristics of employment associated with environmental sustainability	For example, the 'Green Economy' programme within O*NET focuses on activities "related to reducing the use of fossil fuels, decreasing pollution and greenhouse gas emissions, increasing the efficiency of energy usage, recycling materials, and developing and adopting renewable sources of energy" (Dierdorff et al., 2009, p. 3).	Consoli et al. (2016) regard it as the best available method. It is not free of criticism, as some argue it does not acknowledge jobs that support indirectly green production activities (e.g., Peters et al., 2011).	**Mixed** Literature reviews and data-driven approach (e.g., review and evaluation of job titles)

Source: Consoli et al., 2016

Defining jobs in the circular economy, or circular jobs, may be even more complicated. Circular economy activities incorporate more than one sector and involve new kinds of activities that are not yet captured by traditional classifications of economic sectors (Cambridge Econometrics et al., 2018b). For example, design for re-use and recyclability, repair, reuse or waste management can involve a variety of economic sectors and actors that generate additional obstacles for analyses of labour impacts.

Circular jobs have been defined as those jobs that contribute to one of the 7 key strategies of the circular economy. Because they contribute to the enactment of the circular economy, circular jobs have been categorised according to the main circular strategy they pursue, i.e. **core, enabling, and indirect jobs** (Circle Economy, 2018):

- *Core circular jobs* ensure that raw material cycles are closed and thus form the core of the circular economy. Examples of core jobs include jobs in renewable energy, repair and waste and resource management sectors.

- *Enabling circular jobs* enable the acceleration and upscaling of core circular activities and thus support the development of the circular economy. Examples of enabling jobs include jobs in leasing, engineering and digital technology - albeit only those that actually contribute to circularity.
- *Indirectly circular jobs* are all other sectors that provide services to primary circular activities and that create supporting circular activities.

Distinguishing green (linear) jobs from circular jobs could help highlight those skills and education needs necessary to shift to a circular economy (Burger et al., 2019; Cambridge Econometrics et al., 2018a).

5 Insights on employment

This chapter is focused on competences in sustainability or green skills ([14]). In section 5.1, the main findings from academic literature on competences in sustainability are presented. Section 5.2 focuses on key findings concerning green skills from the economics strand of literature. Section 5.3 concentrates on green skills for the circular economy. Finally, section 5.4 draws some conclusions.

5.1 Evidence on sustainability competences from academic literature

In contrast to sustainability competences in education, research on sustainability competences in relation to other fields, such as employment, is scant (MacDonald et al., 2020; Salgado et al., 2018). Few are the studies that have tried to identify what key competences in sustainability professionals need to have. Below, we summarize some of the findings that emerged from our exploratory study. Before proceeding, it is worth noting that these studies use the term competences as in the education literature (section 2.1.2). Therefore, competence is used in this section.

Table 10 shows the identified sustainability competences in relation to sustainability professions. As in tables 4 and 5, competences that were already discussed in section 3.1 are highlighted in blue. Equally, we highlighted only those key competences explicitly cited in the frameworks by Wiek et al. (2011), Brundiers et al. (2020), and Redman and Wiek (under review). However, we acknowledge that other competences were also included in these latter frameworks, either as part of a broader competence or indirectly as a complementary competence. For example, "disciplinary knowledge" was not identified as a key competence, but as a necessary complementary component of sustainability competence frameworks described in 3.1.

Pruneau et al. (2013) conducted a qualitative study to assess what kind of competences are needed vis-à-vis adaptation to climate change. In this context, adaptation refers to the potential of a community to adapt to climate change, mitigate potential damages, take advantage of opportunities, or cope with consequences (IPCC, 2007). This study was based in Canada, in a community where sea level rise due to climate change can have profound impacts. Therefore, the authors involved in their research a diverse set of municipal employees working with climate change adaptation measures. As such, adaptive competences are: "a group of abilities and resources that allow a community group to detect and define local impacts of climate change, to choose a top priority issue, to predict the numerous links between the elements of this issue and finally, to propose, choose, and implement thought out actions adjusted to the local culture and to the sociopolitical and economic contexts" (Pruneau et al., 2013, p.228). While some competences were already highlighted in other general contexts, of particular interests to climate change adaptations were: local knowledge of the region paired with hindsight of past climate-related events.

([14]) See section 2.1.3 for a definition of the term "skills" and how it is used in relation to employment

Table 10. Sustainability competences among professionals working in sustainability-related professions.

Pruneau et al., 2013	Heiskanen, Thidell, Rodhe, 2016	Demssie, Wesselink, Biemans, Mulder, 2019	Krasna et al., 2020	MacDonald, Clarke, Ordonez-Ponce, Chai, Andreasen, 2020
Competences for adaptation to climate change among municipal employees	Competencies of sustainability professionals	Sustainability competencies relevant to the Bottom of the Pyramid context	Competences for public health professional trained in climate change	Sustainability management competencies
• Problem-solving; • Futures thinking; • Risk prediction; • Local knowledge; • Hindsight;* • Critical thinking; • Mathematics competences;*** • Linking thinking;** *to recall details of past climate events **to create links between elements of the problem ***lower evidence for this competence	• Acting decisively under uncertainty, improvising and "making do"; • Interdisciplinary and inclusive communication within and outside the workplace • Systems-thinking; • Interpersonal competence/ emotional intelligence; • Anticipatory competence; • Strategic competences; • Normative competence/ responsibility; • Action skills; • Subject-specific competences: life cycle assessment, carbon footprint, environmental management systems, economics and environmental law;	• Systems thinking; • Disciplinary competence;* • Interpersonal competence; • Action competence; • Anticipatory competence; • Strategic competence; • Normative competence; • Transdisciplinary competence; • Flexibility and continuous learning competence; • Communication and information acquiring competence; • Stakeholder and policy coordination competence; • Resource utilization competence; • Social justice and inclusion competence; • Competence to balance sustainable development dimensions; • Competence to utilize indigenous resources for sustainability; *knowledge about sustainability in relation to one's own discipline	• Knowledge of climate mitigation/adaptation; • Climate-health justice; • Direct/indirect and downstream effects of climate on health; • Health impact assessment; • Risk assessment; • Pollution-health consequences and causes; • Geographic Information System mapping; • Communication/writing, • Economic evaluation; • Policy analysis; • Systems thinking; • Interdisciplinary understanding;	• Communication; • Change management; • Multi-disciplinary collaboration for intervention formulation and implementation; • Interpersonal competence; • Sustainability knowledge; • Strategic thinking; • Information seeking; • Project management; • Future-oriented thinking; • Sustainability values; • Systems thinking
Municipal employees in Canada involved in a problem-solving exercise to find a solution to local sea level rise. Participants also attended four educative workshops on sea level adaptation.	Survey and interviews with sustainability professionals, previously enrolled in a sustainability real-life solution-oriented consultancy project (alumni) at a Swedish University	Delphi study involving experts from academia and industry from the Ethiopian context	Job postings (2003-2019) for public health professionals and survey to employers based in the US	Interview analysis of 26 sustainability professionals employed by Canadian municipalities

Source: author's own elaboration.

Heiskanen et al. (2016) assessed the impact of learning sustainability competences at university among alumni now working in sustainability-related professions. Alumni took part in a sustainability real-life solution-oriented consultancy project. Teams were made of four students from different disciplines who prepared the case in class, while data gathering and presentations were done on site, typically overseas. Some examples of cases included sustainable urban planning, introduction of renewable energy solutions, sustainability projects for local industries, and so on. Their findings converged with other sustainability competences highlighted in the literature.

Demssie et al. (2019) reported the findings of a Delphi study involving thirty-three experts from academia and industry in Ethiopia. Given the prevalence of studies conducted in Europe or North America, the authors wanted to assess whether competences in sustainability were different in a "bottom of the pyramid" context. They found that there was a common agreement on key competences, the majority already identified in the literature. For this reason, they reckoned that the nature of sustainability competences is universal, irrespective of their context. What may vary is the salience, or ranking, of sustainability competences, in accordance with the local environment.

In their study, Krasna and colleagues (2020) gathered evidence on the competences needed for public health professionals trained in climate change from two main sources: they examined job postings for public health professionals with some expertise in climate change for a period of 16 years; then they administered a survey to employers based on a literature review of competences requested in such jobs. In table 10 the most important competences emerging from both data sources are reported. In line with other findings, it can be seen that, some of the identified competences are not exclusive to climate change related professions, such as economic analysis. Limitations of this study include: job posting data is historic data, as such it may not represent current or future competence needs, especially when considering that the effects of climate change in 2003 were not as salient nor pervasive as they are in recent years. Second, there is no evidence that these competences are actually felt as critical by those performing the job.

Finally, MacDonald et al. (2020) interviewed twenty-six municipal sustainability manager working in different Canadian municipalities. Communication, change management, multi-disciplinary collaboration, and interpersonal competencies were the most cited competences that emerged from their interviews. Some of the identified competences are not exclusive to sustainability tasks, but they may be so in relation to other competences. For example, change management is interlinked with communication and interpersonal competence, so that sustainability managers listen and respond to stakeholder needs, by being empathic and open to change perspective. In particular, it can be noted that some of the competences in their study converge with previous literature in SE (Brundiers et al., 2020; Redman & Wiek, under review; Wiek et al., 2011). In relation to this, the authors, argue that such similarities point to the need of building on existing work and validating "a generic sustainability competenc[e] model comprised of behavioural indicators that predict job performance across many different jobs in the sustainability profession (cf., MacDonalds et al., 2020, p. 23).

A few remarks are necessary in light of our findings. First, **fewer studies** investigated sustainability competences among professionals as compared with those focusing on students. In particular, more research should be done to assess the benefits of having learned sustainability when entering the working life (Wiek et al., 2014). Second, in the afore studies **some convergence** was found between their identified sustainability competences and those presented in the SE literature. However, in contrast to SE, studies focusing on sustainability professionals had a narrower focus, e.g. working towards climate change adaptation measures, or working in the public sector, or both. This is not surprising considering that jobs vary according to specific roles, sectors, local contexts, etc. For example, in relation to professionals working on climate change adaptation, geographic competences, local knowledge and knowledge of past events, that can inform risk prediction and analysis are considered critical competences. Consequently, our findings do not aim to be representative of all professional working in sustainability, but to shed some light on sustainability competences for sustainability professionals as emerged from the literature. Third, it is important to highlight, that these studies concentrate on sustainability competences, sustainability professionals, or sustainability-related jobs, as they embrace the full dimension of sustainability, i.e. environmental, social, and economic. Furthermore, the qualitative data they present can encapsulate the different components of a sustainability competence. Finally, sustainability competences are not only necessary for professionals working in sustainability-related professions, but should be pervasive to all workforce if the overarching aim is to reduce our footprint on the planet and live sustainability. However, to our knowledge studies that assess sustainability competences among professionals in standards (i.e. non-sustainability-centred) positions are scarce.

Before concluding, it is worth mentioning that sustainability experts are now trying to engage with stakeholders from industry and academia to develop tailored solutions to instil sustainability concepts in organisations. For example, the Sustainability Learning Centre (2011) has developed the Green Core Competencies® and training courses aimed at embedding sustainability not only in the workforce but also at the core of a business in their strategies and operations (see figure 10).

Figure 10. Green Core Competencies(R)

Source: Sustainability Learning Centre, 2011

5.2 Evidence on green skills

Recent literature on green employment has focused on green occupations in order to identify green skills. **Green occupations** are described as occupations that emerge in response to specific needs of the green economy or that are expected to undergo significant changes in terms of task content due to the creation of a green economy (Consoli et al., 2016; Vona et al., 2015). In this section, **green skills** are intended as per the O*NET definition, i.e. those "capabilities of individuals gained through experience and practice, which help individuals to acquire knowledge". We now present the main findings and at the end present some reflection on them.

Such studies used the **O*NET** database for insights on the nature of green occupations. O*NET, developed by the US Department of Labour, is a cross-sectional database that contains detailed occupation-level information such as work tasks, skills involved, education and experience requirements, and a list of green tasks unique to green jobs. Three main categories of green occupations ([15]) are identified according to the effect that greening will have on the tasks, skills, and knowledge required for the job:

([15]) The full list of occupations that use green skills is available in Annex 1. Jobs are divided according to three categories id entified by O*NET. Data was downloaded from O*NET database 25 release [accessed 22 September 2020]

- *Green Increased Demand* (GID) are existing occupations that are expected to experience significant employment growth due to the greening of the economy, but do not require significant changes in tasks, skills, or knowledge. They support green economic activity, but do not involve any green tasks (Bowen et al., 2018);
- *Green Enhanced Skills* (GES) are existing occupations that are expected to undergo significant changes in tasks, skills, and knowledge as a result of the greening of the economy;
- *Green New and Emerging* (GNE) are new, unique occupations (as defined by worker requirements) created to meet the new needs of the green economy.

Starting in order, Vona et al. (2015) focused on GES and GNE and developed a measure of green occupations based on a two-step procedure. In the first step, they constructed a measure of "greenness", i.e. the number of green-specific tasks over non-green specific tasks within a given occupation. Green-specific tasks ranged from conducting sustainability- or environment-related risk assessments and analysing green product marketing trends to operate balers to compress recyclable materials into bundles or bales (Burger et al., 2019). As such, the researchers were able to estimate the greenness of a certain occupation and the time spent on green activities within that occupation. An example is provided in table 11. In the second step, the researchers identified skills that complemented the green skills in occupations by examining the combination of green skills with other skills.

Table 11. Example of green occupations by level of greenness.

	Greenness=1	Greenness btw 0.5 and 0.3	Greenness<0.3
Green Enhanced Occupations	Environmental Engineers, Environ Science Technicians, Hazardous Material Removers	Aerospace Engineers Atmospheric and Space Scientists, Automotive Speciality Technicians, Roofers	Construction Workers, Maintenance & Repair Workers, Inspectors, Marketing Managers
New and Emerging Green Occupations	Wind Energy Engineers, Fuel Cell Technicians, Recycling Coordinators	Electrical Engineering Technologists, Biochemical Engineers, Supply Chain Managers, Precision Agriculture Technicians	Traditional Engineering Occupations, Transportation Planners, Compliance Managers

Source: Vona et al., 2015 ([16])

Vona et al. (2015) empirically found that green skills are to be found among managers and engineers, where the most demanded green skills are Engineering and Science; and hard technical occupations that require Monitoring and Operation Management skills. A breakdown of these skills is given in table 12. Furthermore, they claimed that it is environmental regulation that triggers technological and organizational changes that demand green skills, that they defined as high-level analytical and technical know-how related to the design, production, management and monitoring of technology.

([16]) A full list can be accessed in Vona et al., 2015, p. 49

Table 12. Green skills measures from O*NET.

	Engineering & Technical
2C3b	Engineering and Technology
2C3c	Design
2C3d	Building and Construction
2C3e	Mechanical
4A3b2	Drafting, Laying Out, and Specifying Technical Devices, Parts, and Equipment
	Science
2C4b	Physics
2C4d	Biology
	Operation Management
2B4g	Systems Analysis
2B4h	Systems Evaluation
4A2b3	Updating and Using Relevant Knowledge
4A4b6	Provide Consultation and Advice to Others
	Monitoring
2C8b	Law and Government
4A2a3	Evaluating Information to Determine Compliance with Standards

Source: Vona et al., 2015

Consoli et al. (2016), in a similar fashion, found that when compared with non-green occupations, green occupations use on average more high-level cognitive and interpersonal skills and require higher levels of education, work experience and on-the-job training.

Similarly to the two afore mentioned studies, Bowen et al. (2018) used the O*NET database definition of green occupations, and found that approximately 19.4% of the US workforce could be considered in the green economy, despite a big proportion of green employment being indirectly green. Furthermore, in line with Vona et al. (2015) and Consoli et al. (2016) suggested that green jobs should be rather thought as a continuum rather than a binary classification, e.g. either being green or brown.

In the report "Skills for Green Jobs – A Global View" (Cedefop, 2019), experts argued that what constitutes green skills may well be green skills specifics to the green economy, such as resource or waste skills, together with transversal skills that are to be found across industry sectors. However, in their country studies, Cedefop (2010b, 2019) noted that training programmes have rarely a focus on green skills development.

One of the inherent shortcomings of these studies is that they focus mostly on skills and education levels, without considering attitudes and values of environmental sustainability. The Excelsior Information System for Employment and Training ([17]) partially tried to address this point by including a measure of **green attitude**. This also why they refer to **green competences** for the green economy, rather than green skills. The Excelsior Information System has identified "green competences" by combing the O*NET classification based on green skills associated with green skills and a measure of green attitude. They defined as green an attitude towards energy-saving measures and reducing the environmental impacts of business activities (UnionCamere, 2020, p.13). This is because, while professionals may be equipped with green skills in line with the characterization of green jobs, they may not necessarily use them. In this case, a green attitude for green jobs is seen as a sort of "activator" of green skills.

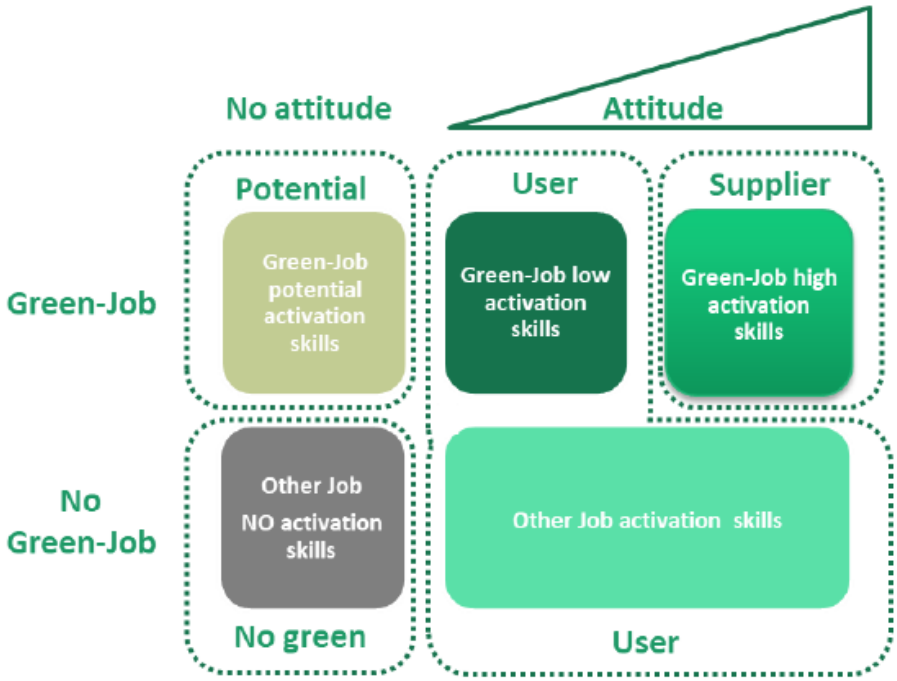
As a result, they identified the following types of job in relation to the green economy (Figure 10):

- *Green-job high activation skills*: these are green jobs where a high degree of green attitude is required, that in turn triggers green skills to support the green economy. These green jobs are further considered as suppliers to the green economy (e.g. technicians and mechanical engineers; construction and environmental engineers);
- *Green-job low activation skills*: these are green jobs where a lower degree of green attitude is required, so that it does not fully trigger green skills. As a result, these jobs act more as a user than as a supplier;
- *Other job activation skills*: they are not classified as green jobs and therefore they do not include green skills. They do not act as direct suppliers to the green economy, but they use tools, rules and practices useful to support a green approach within companies;

([17]) The Excelsior Information System is an initiative supervised by the Italian Union of Chambers of Commerce, Industry, Crafts and Agriculture (UnionCamere), in collaboration with the Ministry of Labor, the National Agency for Active Labor Policies (ANPAL), and the European Union.

- *Green-job potential activation skills*: these are green jobs for which a green attitude is not requested, however they have some potential to make them potential users or suppliers in the contexts in which they operate;
- *Other job NO activation skills*: they are not classified as green jobs and therefore do not possess green skills nor a green attitude (e.g. buildings maintenance personnel).

Figure 11. Identification of green jobs in relation to the green economy.



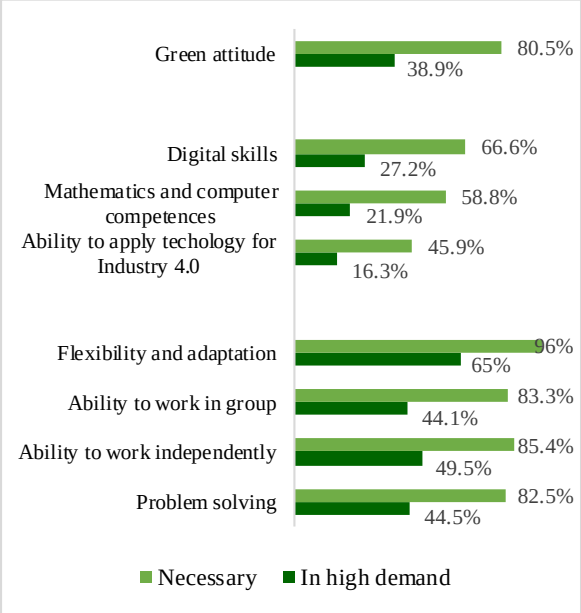
Source: UnionCamere, 2020, p.16

In addition, the Excelsior system identifies what competences are necessary (light green, figure 12) or in high demand (dark green, figure 12) for green jobs; and also compares high demand skills in green jobs with other jobs in figure 13.

For what concerns green jobs, a green attitude is rated as a necessary requirement for hiring in 80.5% cases and in high demand by 38.9%. A similar rating is registered for non-green jobs, where green attitude scores 78.5% as necessary and 37.9% in high demand. As stated by UnionCamere (2020), these findings testify the importance of (environmental) sustainability to all professional figures. Equally, this may also point to the inadequacy to such a method for defining green jobs, or even the concept of green job per se, as sustainability should be at the basis of any endeavour.

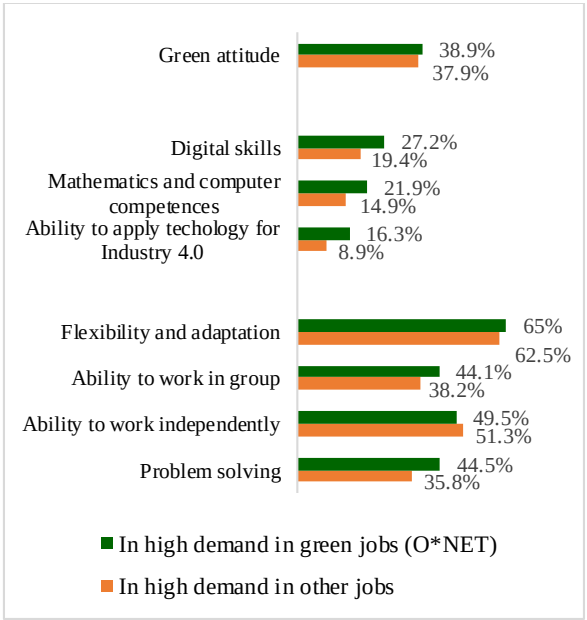
Other skills that were deemed necessary for green jobs are flexibility and adaptation, the ability to work in group but also independently, and problem solving. However, there is no marked difference between green and other jobs.

Figure 12. Skills necessary (light green) or in high demand (dark green) in O*NET green Jobs



Source: UnionCamere, 2020

Figure 13. Skills in high demand in O*NET green jobs (green) or other jobs (orange)



Source: UnionCamere, 2020

Some difference arises with respect to digital skills. In particular, they are considered as in high demand for 27.2% for green jobs against 19.4% for other jobs. Similarly, some difference is also found with respect to: the ability to use mathematical and computer languages and methods to organize and evaluate qualitative and quantitative information (21.9% against 14.9%) and the ability to manage innovative solutions by applying digital technologies to business processes, also in line with Italy's Industry 4.0 Package (16.3% against 8.9%; UnionCamere, 2020). This is in line with previous studies (e.g. Vona et al., 2015) highlighting that green jobs include high-level cognitive skills and/or technical know-how.

To summarise and conclude, table 13 presents the main foci of the above discussed studies on green skills. Limitations were identified bearing in mind that our goal is to describe sustainability competences rather than a narrower subsection merely focused on environmentally-related skills.

Table 13. Summary concerning studies on green skills.

Key focal points of studies on green skills	• Research on green skills for the green economy; • **Green technology** adoption & implementation as the main driver for the greening of the economy, for which green skills are needed; • Focus **strictly on skills**, where skills are intended as capabilities of individuals gained through experience and practice, which help individuals to acquire knowledge" (O*NET, 2012); • **Economics literature** – main aim is to assess and predict future industry trends and needs to inform policy-making.
Limitations of studies on green skills	• Only focus on environmental side of sustainability: **no inclusion of** the **social aspect** of sustainability; • **Win-win approach** (or business case) for environmental sustainability: firms commit to environmentally-related practices and investments only if economically convenient. Therefore, economic aspect is predominant and prioritised; • **No** consideration of **attitudes nor values** of individuals, important component of sustainability; • **Assumption** that only those employees working in environmentally-related firms or sectors (e.g. waste management) need sustainability competences, instead of recognizing sustainability as a transversal competence; • May not be capturing skills or some jobs related to the **circular economy**.

Source: author's own elaboration.

Studies that focus on green skills and green jobs or occupations can be ascribed to a win-win approach, or the "business case" for sustainability. In other words, environmental initiatives are undertaken at the firm level only if it is economically convenient. In fact, such studies focus on green technology as the main driver for investing in the green economy. Equally, under such approach, firms publicly engage in corporate social responsibility practices to obtain a license to operate from their stakeholders. For such firms, adopting green technologies is undertaken if mandated by law (i.e. through environmental regulation) or if they economically benefit from doing so, or both. Furthermore, literature that falls in this stream of reasoning does not generally focus as much on the social aspect of sustainability when describing (green) jobs (Cedefop, 2010a). For example, in the case of Benefit Corporations (or B corps) ([18]) and social enterprises, such an approach could underestimate the necessary competences that are required.

In addition, these studies pertain to the economics literature, where the main goal is to assess (green) skills needs in order to assess and predict future industry trends and skills needs to inform policy-making. To put it simply, green skills, such as Science and Engineering identified by Vona et al. (2015), can indeed be used to predict and inform society on which type of graduates will be most sought after for the greening of the economy. While this approach can be useful for making estimates and general assumptions, it does not inform us on other qualities necessary to shift to a sustainable economy and society. It follows that in these studies, employees are not seen as change agents for sustainability, but as passive recipients of regulatory or organizational policies. However, merely identifying what skills are the most used in green jobs, with the aim of informing industry on the re-training programmes needed is not sufficient if the goal of society is to give equal importance to environmental, social, and economic aspects.

At the heart of the concept of green skills is technology to achieve green growth. Indeed, in order to study a green transition of the economy (mostly based on the adoption of green technology), economists refer to other types of transitions (e.g., globalisation, ICT, etc.). Understood it this way, sustainability becomes a means to achieve green growth, and not a long-term goal as it is intended. As experts and society have realized that the current paradigm is not sustainable, a more value-centred paradigm in line with our planet on which we depend is urgently needed. One of the concepts that should be put in place is envisioning education not only as a stepping stone for the world of work, but as a continuous gymnasium to re-learn to live in tune with our planet and stay within planetary boundaries.

([18]) Certified B Corporations are businesses that meet the highest standards of verified social and environmental performance, public transparency, and legal accountability to balance profit and purpose. B Corps are accelerating a global culture shift to redefine success in business and build a more inclusive and sustainable economy (https://bcorporation.eu/about-b-corps)

Finally, the identification of green occupations and skills as discussed above may not fully reflect the needs and potential of the circular economy. In light of the fundamental importance of the circular economy for Europe, as seen in the EU Green Deal (2019), these shortcomings need to be addressed.

5.3 Circular economy skills

Scholars have only recently tried to investigate what skills are necessary for the circular economy. This is because most of the times, studies focusing on circular economy employment tended to use the lens of green jobs (Horbach et al., 2015) or jobs mainly related to waste management. While more research is needed, we present a few studies that try to identify the necessary skills for the circular economy.

First, one study (Burger et al., 2019; Circle Economy, 2018) tried to address the need of linking skills to circular economy employment. Following the classification of circular economy jobs, they differentiate among core, enabling, and indirect jobs (not included in the analysis). Table 14 provides some examples of jobs according to this classification.

Table 14. Examples of circular jobs.

Directly Circular Jobs	
Core jobs	Enabling jobs
Prioritise regenerative resources - Solar Panel Installer The solar panel installer works within the energy sector to promote the use of solar as a renewable energy source. The job contributes to the CE by 'prioritizing regenerative resources', the first strategy of the CE.	Collaborate to create joint value - Director of a Trade Association The director of a trade association manages a membership organization composed of multiple companies within a specific industry. The director can support the CE by encouraging greater collaboration, knowledge sharing, and networking between companies. As such, the director can employ the 'collaborate to create joint value' strategy in order to contribute to the CE.
Preserve and extend what's already made - Appliance Technician The appliance technician contributes to the CE by extending the lifetime of products. By embodying one of the strategies of the CE, 'to preserve and extend what's already made', all repair and maintenance jobs are considered circular.	Design for the future - Architect An architect is responsible for designing buildings and, by extension, for the materials used during a building's construction, its energy efficiency during the use phase and the potential for material recovery when it is demolished. An architect can thus contribute to the CE by 'designing for the future'.
Use waste as a resource - Recycling Operative The recycling operative's job consists of sorting through recyclable waste and separating materials to be recovered. This sorting and separating constitutes an essential element in the recycling process, which involves the 'use waste as a resource' strategy and thus presents itself as a circular job. Day-to-day activities of the recycling operative include physical labour and machine handling such as forklift driving.	Incorporate digital technology - Data Analyst The data analyst makes sense of large amounts of information by means varying from simple data aggregation to complex data mining. The data analyst's occupation involves the 'incorporate digital technology' strategy and thus allows for smart systems and technology integration in the CE. This job often requires tertiary education in relatively new fields of data science and computer engineering.
Rethink the business model - Leasing Process Manager The leasing process manager is responsible for the coordination of the external service partners distributed across market segments. By contributing to the workings of a product as a service model, the leasing process manager contributes to the CE through the 'rethinking the business model' strategy	
Indirectly Circular Jobs	
The courier The courier's job does not directly contribute to the CE; however, they can play a role in enabling reverse logistics schemes for circular businesses. When the number of circular activities increases, the demand for logistics services will grow. At the same time, the more circular the operation of these logistic services, by, for example, using renewable resources, the more circular their jobs will be.	
The teacher The teacher does not directly contribute to the CE; however, they can play a role in educating the future work force about the CE. CE education ranges from vocational training to tertiary education and therefore pertains to both core and enabling circular jobs. During a transition to the CE, education and training needs will evolve, and so will the jobs catering to those needs.	

Source: Van Oort et al., 2018, in Burger et al., 2019

Instead, they adopted the categorization of skills done by O*NET in 35 main skills grouped as shown below in six categories:

- *Basic skills*: facilitate learning or the more rapid acquisition of knowledge (e.g. critical thinking, active listening, etc.);
- *Complex problem solving skills*: used to solve novel, ill-defined problems in complex, real-world settings;
- *Resource management skills*: used to allocate resources efficiently;
- *Social skills*: used with people to achieve goals (e.g., negotiation, coordination, etc.);
- *Systems skills*: used to understand, monitor, and improve socio-technical systems (systems analysis and evaluation);
- *Technical skills*: used to design, set up, operate, and correct malfunctions involving applications of machines or technological systems (e.g., equipment maintenance) ([19]).

Accordingly, they found that on average **jobs in core sectors** require **lower education levels** and are also generally less skill-intensive than those in enabling circular economy sectors, except for a notably **higher need for technical skills. Jobs in enabling sectors** require **higher levels of education** than the rest of the economy and display a **higher demand across the whole range of skills** (Burger et al., 2019). In aggregate terms, circular economy jobs require higher levels of skills (with the exception of basic and social skills) than the rest of the economy. However, neither core nor enabling circular economy sectors are entirely cohesive in terms of skill requirements (Burger et al., 2019).

Another recent study focused on the circular economy is "Impacts of circular economy policies on the labour market" report (Cambridge Econometrics et al., 2018a), where experts identified four main sectors as those where the circular economy will have a substantial impact in terms of jobs and skills needs, such as: the waste and recycling sector; the motor vehicles sector; the electronics sector, and the food sector. Without providing examples of what new or existing skills will be needed the most in a new circular scenario, the authors further added that the impact of the circular economy should be viewed in relation to other market trend changes such automation, innovation, etc., as they feed the potential of the circular economy, e.g. through the digitalization or servitization of some activities.

In line with previous finding on green jobs, the report highlights that circular economy jobs are primarily higher-skilled, including design- and technology-related jobs, potentially across a range of circular economy sectors. However, the circular economy also requires low-skilled jobs, often found in tandem. As argued in Cambridge Econometrics et al. (2018b), by adopting a circular economy lens for jobs that focuses on "creating shared value", in contrast to green jobs that address the needs of a green but linear economy, it is possible to better understand how these different types of new jobs co-exist. The experts argued that, for example, remanufacturing creates new skilled jobs, including roles related to refurbishment, disassembly, maintenance, and redistribution that are a mix of high and low skilled jobs. However, conversely, in the consumer goods sector, the circular economy is expected to primarily create entry level and semi-skilled jobs, and higher-skilled jobs in product and process design. This finding reflects the fact that jobs are created across the "lifecycle of circular economy 'products'"; this helps to explain the complex skills mix associated with the circular economy (Cambridge Econometrics et al., 2018b, p.27).

5.4 Concluding remarks on competences and skills in relation to work

Starting from the question of "what are the competences in sustainability that professionals need to possess, so that they contribute to a more sustainable society?", this study tried to identify existing research and projects to answer this question. This chapter presented an overview of what has been done by academics and policy-makers.

There are two main strand of literature: education (5.1) and economics (5.2 & 5.3). Because, they attend to different objectives, their investigation lens and, therefore terminology used, can vary substantially.

First, section 5.1 is focused on sustainability competences that sustainability professionals need to have in their daily working lives. Scholars involved in this stream of research come from the SE literature. For instance, one of the papers reviewed interviewed alumni previously enrolled in a sustainability-related course and now working in sustainability (Heiskanen et al., 2016). Moreover, the majority of the findings in this literature converge on many competences identified in chapter 3, either directly (highlighted in blue in table 10; e.g. systems thinking) or indirectly (e.g., disciplinary knowledge). Some differences do arise - between studies in chapter 3 and those in 5.1- according to which type of professionals, or what sustainability-related problem these studies focus on.

([19]) The full lists of skills under the six categories here reported can be found at p. 259 in Appendix B in Burger et al., 2019

Second, in section 5.2 and 5.3 studies and projects from the economics literature and policy-making are presented. Similarly, to SE there is a great extent of terminological confusion. Two main points deserve our attention. First, experts from this field are economists and they are informed, and inform in return, policy-making in relation to employment. As such, they do not necessarily know what sustainability entails. This may be why we encounter here the notion of "green skills", which is often confounded with "green jobs" (Vona et al, 2015), and both derive from "green economy". Green skills focus on environmental aspects and serve to undertake green, or partially green, jobs, and they do not consider the social aspects or impacts of jobs. This stands in contrast with the notion of sustainability as envisioned in SE, i.e. every individual, and therefore every worker, should be equipped with sustainability competences to live in tune with society and the environment. This is because the identification of green skills serves to statistically assess and predict future industry needs. Second, such studies focus on skills for analytical purposes, rather than competences. However, leaving out attitudes and values-thinking can be a shortcoming in reference to sustainability. In other words, green skills serve to identify the capabilities and abilities needs of employees working in jobs, or performing job tasks, with a heavy impact on the environment (e.g., waste management). Accordingly, only some sectors are considered. Furthermore, employees are passive recipients of green requirements. In other words, there is no room for "sustainable intrapreneurship", i.e. workers who proactively take actions and decisions in favour of sustainability when performing their jobs. As argued in Heiskanen et al. (2016, p. 218), sustainability problems require "active professionals who want to change the world, who are willing to break conventions, start new initiatives, and take responsibility for solving environmental, social and economic problems in a sustainable way".

This critical assessment is necessary when analysing such approaches **from a sustainability standpoint**. In this sense, more dialogue, and "interdisciplinary work" should be encouraged among experts from the two fields abovementioned in order to arrive at a meaningful classification of sustainability competences needed to perform jobs.

Furthermore, future approaches should focus their efforts on the circular economy and what it entails for employment. The circular economy can bring about new types of jobs in diverse but interrelated sectors, where traditional definitions and classifications may not be fit.

6 Conclusions

In light of our findings, this exploratory study will inform future discussions on the development of sustainability as a transversal key competence to develop and nurture through lifelong learning, the necessary knowledge, skills, attitudes, and values for a sustainable society. In light of this, the present study consisted of an exploratory review of the literature that aimed to look at existing definitions of sustainability; development of sustainability competence frameworks in education; and the identification of skills related to sustainable jobs.

The necessity of introducing sustainability themes into education in academic and policy-making arenas occurred as early as in the 1970s. Since then, there has been a general agreement that sustainability competences are needed for society to be able to tackle these sustainability challenges and re-learn to live in tune with the planet on which our economy and our society depend. That being said, the vast array of terms used and ambiguity surrounding definitions of the concepts 'sustainability' and 'competence' has mirrored the lack of an agreed and common direction, failing to provide guidance and accelerate the progress on achieving the SDGs. More so, it generated an urgent need to develop and promote a universal and widely accepted competence framework to provide the kind of sustainability learning that students, citizens, consumers, professionals, communities, and society need to live in a more meaningful way.

Our research has tried to review past and existing research and practice on sustainability in order to present our insights such as:

- Sustainability and sustainable development and the evolution of education vis-à-vis sustainability;
- The notions of green skills stemming from the green economy, and the implications of the emergence of the circular economy as a European key policy priority;
- Sustainability key competences in sustainability in education, what they are and how to learn them;
- Green skills for green and circular jobs.

Noting that there is a great deal of terminological ambiguity, in this study we adopted the concept of "competence" in its wider meaning, i.e. as an organised conceptualisation of competences. In this context, we **differentiated** between competences in sustainability and key competences in sustainability. In particular, the role of values and context stand out: while the first provide a normative guidance, one's context determines the extent to which an action can be undertaken. Instead, **key competences in sustainability** equip individuals with the necessary competences to solve complex problems and exploit opportunities in favour of sustainability. Knowledge in a specific discipline, as well as other basic or interrelated competences, are critical but acquired through specific course in higher education. Key competences in sustainability should be **transversal and intrinsic** in education. Scholars who support this view support the concept of **sustainability education** as encompassing, whereby sustainability is integrated with education in all areas and aims to change the behaviour of individuals to live in tune with their society, environment, and the planet.

Sustainability is a long term goal and differs from sustainable development which is about supporting those processes to achieve a sustainable progress. Equally, sustainability education differs from education for sustainable development which envisions education as a way to educate students to enact a sustainable development (or progress or growth).

There is a high degree of convergence among scholars, and between academic and grey literature, on what key competences in sustainability are. In particular, the recent **works by Brundiers et al. (2020) and Redman and Wiek (under review)** best encapsulate the **most encompassing frameworks** which identified **eight key sustainability competences** (figure 5 and 6) in higher education. They showed how key competences interlink with each other to undertake sustainability challenges. Furthermore, the role of values-thinking is especially underlined, in line with previous literature. Additional studies which focused on specific disciplines or aspects of sustainability may add invaluable concepts, such as the importance of lifecycle thinking or the notion of diachronic & differentiated responsibility (see table 6).

In light of said convergence on **what** key competences in sustainability are, scholars and policy-makers now question:

- **How** can key competences in sustainability be learnt?
- **How** to assess that the eight key competences in sustainability do equip professionals and citizens in general to move towards sustainable behaviours in their daily personal and professional lives?

The OECD Future of Education and Skills 2030 project has precisely embarked in this direction (OECD, 2019). While the first part of the project focused on identifying transformative competences, the second aims to answer how they can be learnt.

While pedagogical approaches and assessment methods were not in the scope of this research, their salience in research is worth noting, in light of future discussions. Furthermore, despite recognizing the importance of **lifelong learning** in education, there is limited research on sustainability education beyond higher education, including early childhood, primary and secondary school, vocational education, adult education, and so forth. Equally, more research should be conducted on online learning and how to convey sustainability competences.

In relation to **work**, there are two main strands of literature that conduct research on competences, or skills, employees should have to contribute to sustainable outcomes in their jobs. The first stream is composed by scholars in education or sustainability or both. For this reason, much of the terminology and ideas converge with what said afore. In particular, these works highlight how key competences in sustainability (as per for example Brundiers et al., 2020) are necessary in sustainability-related jobs.

The second strand of research involves experts from economics, who may not necessarily consider what sustainability, in its most encompassing concept, entails. In fact, starting from the definition of a green economy, the main aim of studies stemming from this field is about identifying the necessary skills – understood as abilities to perform a job – to perform green jobs. First, it must be noted that despite a general agreement on the definition of skills, there is no convergence on what **green skills** are. This is because quite often green skills are cofounded with green jobs (Vona et al., 2015) and, as such, they vastly depend on how a green job is defined. As we have seen, Consoli et al. (2016) summarized four approaches to define green jobs. Therefore, green skills can vary accordingly to the methodology used. Second, in contrast with the concept of sustainability, green jobs include only environmentally-related jobs. Social aspects are not considered nor jobs or tasks with a high social impact. Third, considering only skills may be an outdated and reductive approach to define jobs in relation to sustainability. As jobs become less routinized and more cognitive-intensive, requiring creative and (eco-)innovative solutions, the importance of knowledge, attitudes, and values cannot be denied. UnionCamere (2020) has partially tried to address this point by identifying green skills and attitudes, together with education levels, in their Excelsior Information System, based on the O*NET database and converted into the European and Italian classification systems.

We recognize the **need to develop a more encompassing system to identify** and update the necessary **sustainability** (instead of green) **competences** critical to perform **sustainability-related jobs** and **other jobs in a sustainable manner**. Taking the evidence stemming from sustainability education, sustainability competences should and could be embedded in any job, while **key** competences should and could be related to sustainability-related jobs.

Furthermore, the green economy has started to lose traction in the second decade of the 2000s, given a lack of operationalisation and progress in achieving a more sustainable economy in line with planetary limits. At the same time, the circular economy has now become the key policy priority in Europe. Despite this, research on employment associated with the circular economy either focuses on the net employment generated or adopts the notion of green jobs. While this latter approach can be useful, it does not capture the full dimensions of a circular economy. For this reasons, future endeavours to identify sustainability competences in employment should put the circular economy at their centre. The circular economy requires new and innovative approaches to the way we do business, where all actors are involved in addressing environmental, social, and economic criteria and regenerate resources to be able not to take from the planet more than it generates.

To conclude, in order to tackle complex sustainability problems, we need to foster sustainability into education inside and outside the classroom in order to educate learners to be catalysts of change, who are willing to start initiatives in favour of society and take responsibilities towards the planet. This requires the development of a common framework to integrate key sustainability competences into our education.

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Annex 1

List of jobs using green skills (elaborated from O*NET 25 database release)

Category	Code	Occupation	Sectors
Green Increased Demand	13-1021.00	Buyers and Purchasing Agents, Farm Products	Agriculture and Forestry
Green Increased Demand	45-1011.07	First-Line Supervisors of Agricultural Crop and Horticultural Workers	Agriculture and Forestry
Green Enhanced Skills	19-4011.01	Agricultural Technicians	Agriculture and Forestry
Green Enhanced Skills	11-9013.02	Farm and Ranch Managers	Agriculture and Forestry
Green Enhanced Skills	11-1021.00	General and Operations Managers	Agriculture and Forestry; Energy Efficiency
Green Enhanced Skills	17-1012.00	Landscape Architects	Agriculture and Forestry; Environment Protection; Green Construction
Green Increased Demand	45-2011.00	Agricultural Inspectors	Agriculture and Forestry; Governmental and Regulatory Administration
Green New & Emerging	19-4099.02	Precision Agriculture Technicians	Agriculture and Forestry; Research, Design, and Consulting Services
Green Increased Demand	49-9051.00	Electrical Power-Line Installers and Repairers	Energy Efficiency
Green Increased Demand	51-8021.00	Stationary Engineers and Boiler Operators	Energy Efficiency
Green New & Emerging	47-4099.03	Weatherization Installers and Technicians	Energy Efficiency
Green Enhanced Skills	51-8013.00	Power Plant Operators	Energy and Carbon Capture and Storage; Green Construction; Renewable Energy Generation
Green Enhanced Skills	49-9071.00	Maintenance and Repair Workers, General	Energy Efficiency; Environment Protection; Green Construction; Manufacturing; Renewable Energy Generation
Green Enhanced Skills	13-2051.00	Financial Analysts	Energy Efficiency; Governmental and Regulatory Administration; Green Construction; Research, Design, and Consulting Services
Green Enhanced Skills	53-6051.07	Transportation Vehicle, Equipment and Systems Inspectors, Except Aviation	Energy Efficiency; Governmental and Regulatory Administration; Transportation
Green New & Emerging	13-1199.01	Energy Auditors	Energy Efficiency; Governmental and Regulatory Administration
Green Increased Demand	47-2011.00	Boilermakers	Energy Efficiency; Green Construction
Green Increased Demand	47-2131.00	Insulation Workers, Floor, Ceiling, and Wall	Energy Efficiency; Green Construction
Green Increased Demand	49-9021.02	Refrigeration Mechanics and Installers	Energy Efficiency; Green Construction
Green Enhanced Skills	49-9021.01	Heating and Air Conditioning Mechanics and Installers	Energy Efficiency; Green Construction
Green Enhanced Skills	17-2071.00	Electrical Engineers	Energy Efficiency; Green Construction; Renewable Energy Generation; Research, Design, and Consulting Services
Green Enhanced Skills	17-2141.00	Mechanical Engineers	Energy Efficiency; Green Construction; Renewable Energy Generation; Research, Design, and Consulting Services; Transportation
Green Enhanced Skills	13-1151.00	Training and Development Specialists	Energy Efficiency; Green Construction; Research, Design, and Consulting Services

Green New & Emerging	17-2199.03	Energy Engineers	Energy Efficiency; Green Construction; Research, Design, and Consulting Services
Green New & Emerging	41-3099.01	Energy Brokers	Energy Trading
Green New & Emerging	13-2099.03	Investment Underwriters	Energy Trading; Research, Design, and Consulting Services
Green New & Emerging	41-3031.03	Securities and Commodities Traders	Energy Trading; Research, Design, and Consulting Services
Green Increased Demand	19-2041.00	Environmental Scientists and Specialists, Including Health	Environment Protection
Green Increased Demand	25-9021.00	Farm and Home Management Advisors	Environment Protection
Green Increased Demand	45-1011.05	First-Line Supervisors of Logging Workers	Environment Protection
Green Increased Demand	33-3031.00	Fish and Game Wardens	Environment Protection
Green Increased Demand	19-4093.00	Forest and Conservation Technicians	Environment Protection
Green Increased Demand	45-4011.00	Forest and Conservation Workers	Environment Protection
Green Increased Demand	11-9121.00	Natural Sciences Managers	Environment Protection
Green Increased Demand	19-1023.00	Zoologists and Wildlife Biologists	Environment Protection
Green Enhanced Skills	17-3025.00	Environmental Engineering Technicians	Environment Protection
Green Enhanced Skills	19-4091.00	Environmental Science and Protection Technicians, Including Health	Environment Protection
Green Enhanced Skills	19-1013.00	Soil and Plant Scientists	Environment Protection
Green New & Emerging	11-9199.11	Brownfield Redevelopment Specialists and Site Managers	Environment Protection
Green New & Emerging	19-2041.01	Climate Change Analysts	Environment Protection
Green New & Emerging	19-3011.01	Environmental Economists	Environment Protection
Green New & Emerging	19-2041.02	Environmental Restoration Planners	Environment Protection
Green New & Emerging	19-2041.03	Industrial Ecologists	Environment Protection
Green New & Emerging	11-9121.02	Water Resource Specialists	Environment Protection
Green New & Emerging	17-2081.01	Water/Wastewater Engineers	Environment Protection
Green Enhanced Skills	17-2081.00	Environmental Engineers	Environment Protection; Governmental and Regulatory Administration
Green Enhanced Skills	19-1031.01	Soil and Water Conservationists	Environment Protection; Governmental and Regulatory Administration
Green Enhanced Skills	11-9021.00	Construction Managers	Environment Protection; Green Construction
Green Enhanced Skills	47-4041.00	Hazardous Materials Removal Workers	Environment Protection; Green Construction; Recycling and Waste Reduction
Green Increased Demand	19-2043.00	Hydrologists	Environment Protection; Research, Design, and Consulting Services
Green Enhanced Skills	11-9041.00	Architectural and Engineering Managers	Environment Protection; Research, Design, and Consulting Services
Green Enhanced Skills	19-2021.00	Atmospheric and Space Scientists	Environment Protection; Research, Design, and Consulting Services
Green Enhanced Skills	19-2042.00	Geoscientists, Except Hydrologists and Geographers	Environment Protection; Research, Design, and Consulting Services
Green Enhanced Skills	27-3031.00	Public Relations Specialists	Environment Protection; Research, Design, and Consulting Services
Green Enhanced Skills	27-3022.00	Reporters and Correspondents	Environment Protection; Research, Design, and Consulting Services

Green New & Emerging	11-1011.03	Chief Sustainability Officers	Governmental and Regulatory Administration
Green New & Emerging	11-9199.02	Compliance Managers	Governmental and Regulatory Administration
Green New & Emerging	11-9199.01	Regulatory Affairs Managers	Governmental and Regulatory Administration
Green New & Emerging	13-1041.07	Regulatory Affairs Specialists	Governmental and Regulatory Administration
Green New & Emerging	13-1199.05	Sustainability Specialists	Governmental and Regulatory Administration
Green Enhanced Skills	47-4011.00	Construction and Building Inspectors	Governmental and Regulatory Administration; Green Construction
Green Enhanced Skills	19-3051.00	Urban and Regional Planners	Governmental and Regulatory Administration; Green Construction; Research, Design, and Consulting Services
Green Enhanced Skills	51-9061.00	Inspectors, Testers, Sorters, Samplers, and Weighers	Governmental and Regulatory Administration; Manufacturing
Green Enhanced Skills	23-1022.00	Arbitrators, Mediators, and Conciliators	Governmental and Regulatory Administration; Research, Design, and Consulting Services
Green Enhanced Skills	17-2161.00	Nuclear Engineers	Governmental and Regulatory Administration; Research, Design, and Consulting Services
Green New & Emerging	19-3099.01	Transportation Planners	Governmental and Regulatory Administration; Research, Design, and Consulting Services; Transportation
Green Increased Demand	17-3011.01	Architectural Drafters	Green Construction
Green Increased Demand	47-2051.00	Cement Masons and Concrete Finishers	Green Construction
Green Increased Demand	47-2031.01	Construction Carpenters	Green Construction
Green Increased Demand	47-2111.00	Electricians	Green Construction
Green Increased Demand	47-3012.00	Helpers—Carpenters	Green Construction
Green Increased Demand	49-9098.00	Helpers—Installation, Maintenance, and Repair Workers	Green Construction
Green Increased Demand	47-2073.00	Operating Engineers and Other Construction Equipment Operators	Green Construction
Green Increased Demand	47-2031.02	Rough Carpenters	Green Construction
Green Enhanced Skills	47-2061.00	Construction Laborers	Green Construction
Green Enhanced Skills	47-2152.01	Pipe Fitters and Steamfitters	Green Construction
Green Enhanced Skills	47-2152.02	Plumbers	Green Construction
Green Enhanced Skills	47-2181.00	Roofers	Green Construction
Green Increased Demand	53-7062.00	Laborers and Freight, Stock, and Material Movers, Hand	Green Construction; Manufacturing
Green Increased Demand	51-4121.07	Solderers and Brazers	Green Construction; Manufacturing
Green Increased Demand	47-2221.00	Structural Iron and Steel Workers	Green Construction; Manufacturing
Green Increased Demand	51-2041.00	Structural Metal Fabricators and Fitters	Green Construction; Manufacturing
Green Increased Demand	51-4121.06	Welders, Cutters, and Welder Fitters	Green Construction; Manufacturing
Green Enhanced Skills	47-2211.00	Sheet Metal Workers	Green Construction; Manufacturing; Renewable Energy Generation
Green Enhanced Skills	17-2051.00	Civil Engineers	Green Construction; Renewable Energy Generation; Research, Design, and Consulting Services

Green Enhanced Skills	17-1011.00	Architects, Except Landscape and Naval	Green Construction; Research, Design, and Consulting Services
Green Increased Demand	53-7051.00	Industrial Truck and Tractor Operators	Green Construction; Transportation
Green Increased Demand	51-9011.00	Chemical Equipment Operators and Tenders	Manufacturing
Green Increased Demand	51-8091.00	Chemical Plant and System Operators	Manufacturing
Green Increased Demand	19-4031.00	Chemical Technicians	Manufacturing
Green Increased Demand	51-4011.00	Computer-Controlled Machine Tool Operators, Metal and Plastic	Manufacturing
Green Increased Demand	51-4031.00	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	Manufacturing
Green Increased Demand	51-4032.00	Drilling and Boring Machine Tool Setters, Operators, and Tenders, Metal and Plastic	Manufacturing
Green Increased Demand	51-2022.00	Electrical and Electronic Equipment Assemblers	Manufacturing
Green Increased Demand	17-3023.01	Electronics Engineering Technicians	Manufacturing
Green Increased Demand	51-2031.00	Engine and Other Machine Assemblers	Manufacturing
Green Increased Demand	49-1011.00	First-Line Supervisors of Mechanics, Installers, and Repairers	Manufacturing
Green Increased Demand	51-1011.00	First-Line Supervisors of Production and Operating Workers	Manufacturing
Green Increased Demand	49-9041.00	Industrial Machinery Mechanics	Manufacturing
Green Increased Demand	11-3051.00	Industrial Production Managers	Manufacturing
Green Increased Demand	49-9044.00	Millwrights	Manufacturing
Green Increased Demand	51-9023.00	Mixing and Blending Machine Setters, Operators, and Tenders	Manufacturing
Green Increased Demand	43-5061.00	Production, Planning, and Expediting Clerks	Manufacturing
Green Increased Demand	51-2092.00	Team Assemblers	Manufacturing
Green Enhanced Skills	51-2011.00	Aircraft Structure, Surfaces, Rigging, and Systems Assemblers	Manufacturing
Green Enhanced Skills	17-3023.03	Electrical Engineering Technicians	Manufacturing
Green Enhanced Skills	17-3024.00	Electro-Mechanical Technicians	Manufacturing
Green Enhanced Skills	17-3026.00	Industrial Engineering Technicians	Manufacturing
Green Enhanced Skills	29-9012.00	Occupational Health and Safety Technicians	Manufacturing
Green New & Emerging	17-3029.12	Nanotechnology Engineering Technicians	Manufacturing
Green Enhanced Skills	51-4041.00	Machinists	Manufacturing; Renewable Energy Generation
Green Enhanced Skills	51-9012.00	Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders	Manufacturing; Renewable Energy Generation
Green Increased Demand	19-2031.00	Chemists	Manufacturing; Research, Design, and Consulting Services
Green Increased Demand	27-1021.00	Commercial and Industrial Designers	Manufacturing; Research, Design, and Consulting Services
Green Increased Demand	49-2094.00	Electrical and Electronics Repairers, Commercial and Industrial Equipment	Manufacturing; Research, Design, and Consulting Services
Green Increased Demand	17-2111.01	Industrial Safety and Health Engineers	Manufacturing; Research, Design, and Consulting Services

Green Increased Demand	19-2032.00	Materials Scientists	Manufacturing; Research, Design, and Consulting Services
Green Increased Demand	29-9011.00	Occupational Health and Safety Specialists	Manufacturing; Research, Design, and Consulting Services
Green Enhanced Skills	41-4011.00	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.01	Biochemical Engineers	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.02	Electrical Engineering Technologists	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.03	Electromechanical Engineering Technologists	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.04	Electronics Engineering Technologists	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.05	Industrial Engineering Technologists	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.06	Manufacturing Engineering Technologists	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.04	Manufacturing Engineers	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.09	Manufacturing Production Technicians	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.07	Mechanical Engineering Technologists	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.05	Mechatronics Engineers	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.06	Microsystems Engineers	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.09	Nanosystems Engineers	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.11	Nanotechnology Engineering Technologists	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.07	Photonics Engineers	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3029.08	Photonics Technicians	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.08	Robotics Engineers	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-3024.01	Robotics Technicians	Manufacturing; Research, Design, and Consulting Services
Green New & Emerging	17-2199.02	Validation Engineers	Manufacturing; Research, Design, and Consulting Services
Green Enhanced Skills	43-5071.00	Shipping, Receiving, and Traffic Clerks	Manufacturing; Research, Design, and Consulting Services; Transportation
Green New & Emerging	13-1081.02	Logistics Analysts	Manufacturing; Research, Design, and Consulting Services; Transportation
Green New & Emerging	13-1081.01	Logistics Engineers	Manufacturing; Research, Design, and Consulting Services; Transportation
Green New & Emerging	11-3071.03	Logistics Managers	Manufacturing; Research, Design, and Consulting Services; Transportation
Green New & Emerging	11-9199.04	Supply Chain Managers	Manufacturing; Research, Design, and Consulting Services; Transportation
Green Enhanced Skills	53-7081.00	Refuse and Recyclable Material Collectors	Recycling and Waste Reduction

Green New & Emerging	51-9199.01	Recycling and Reclamation Workers	Recycling and Waste Reduction
Green New & Emerging	53-1021.01	Recycling Coordinators	Recycling and Waste Reduction
Green Increased Demand	51-8012.00	Power Distributors and Dispatchers	Renewable Energy Generation
Green Enhanced Skills	47-5041.00	Continuous Mining Machine Operators	Renewable Energy Generation
Green Enhanced Skills	19-4051.01	Nuclear Equipment Operation Technicians	Renewable Energy Generation
Green Enhanced Skills	51-8011.00	Nuclear Power Reactor Operators	Renewable Energy Generation
Green Enhanced Skills	47-5013.00	Service Unit Operators, Oil, Gas, and Mining	Renewable Energy Generation
Green Enhanced Skills	11-3071.02	Storage and Distribution Managers	Renewable Energy Generation
Green New & Emerging	51-8099.01	Biofuels Processing Technicians	Renewable Energy Generation
Green New & Emerging	11-3051.03	Biofuels Production Managers	Renewable Energy Generation
Green New & Emerging	11-9041.01	Biofuels/Biodiesel Technology and Product Development Managers	Renewable Energy Generation
Green New & Emerging	51-8099.03	Biomass Plant Technicians	Renewable Energy Generation
Green New & Emerging	11-3051.04	Biomass Power Plant Managers	Renewable Energy Generation
Green New & Emerging	11-3051.02	Geothermal Production Managers	Renewable Energy Generation
Green New & Emerging	49-9099.01	Geothermal Technicians	Renewable Energy Generation
Green New & Emerging	51-8099.04	Hydroelectric Plant Technicians	Renewable Energy Generation
Green New & Emerging	11-3051.06	Hydroelectric Production Managers	Renewable Energy Generation
Green New & Emerging	11-3051.05	Methane/Landfill Gas Collection System Operators	Renewable Energy Generation
Green New & Emerging	51-8099.02	Methane/Landfill Gas Generation System Technicians	Renewable Energy Generation
Green New & Emerging	47-1011.03	Solar Energy Installation Managers	Renewable Energy Generation
Green New & Emerging	17-2199.11	Solar Energy Systems Engineers	Renewable Energy Generation
Green New & Emerging	47-2231.00	Solar Photovoltaic Installers	Renewable Energy Generation
Green New & Emerging	41-4011.07	Solar Sales Representatives and Assessors	Renewable Energy Generation
Green New & Emerging	47-4099.02	Solar Thermal Installers and Technicians	Renewable Energy Generation
Green New & Emerging	17-2199.10	Wind Energy Engineers	Renewable Energy Generation
Green New & Emerging	11-9199.09	Wind Energy Operations Managers	Renewable Energy Generation
Green New & Emerging	11-9199.10	Wind Energy Project Managers	Renewable Energy Generation
Green New & Emerging	49-9081.00	Wind Turbine Service Technicians	Renewable Energy Generation
Green Increased Demand	17-2041.00	Chemical Engineers	Research, Design, and Consulting Services
Green Increased Demand	43-4051.00	Customer Service Representatives	Research, Design, and Consulting Services
Green Increased Demand	17-2112.00	Industrial Engineers	Research, Design, and Consulting Services
Green Increased Demand	15-1133.00	Software Developers, Systems Software	Research, Design, and Consulting Services
Green Enhanced Skills	19-4041.02	Geological Sample Test Technicians	Renewable Energy Generation; Research, Design, and Consulting Services
Green Enhanced Skills	19-4041.01	Geophysical Data Technicians	Research, Design, and Consulting Services
Green Enhanced Skills	11-2021.00	Marketing Managers	Research, Design, and Consulting Services
Green Enhanced Skills	13-2052.00	Personal Financial Advisors	Research, Design, and Consulting Services

Green Enhanced Skills	13-1022.00	Wholesale and Retail Buyers, Except Farm Products	Research, Design, and Consulting Services
Green New & Emerging	13-2099.01	Financial Quantitative Analysts	Research, Design, and Consulting Services
Green New & Emerging	15-1199.05	Geographic Information Systems Technicians	Research, Design, and Consulting Services
Green New & Emerging	15-1199.04	Geospatial Information Scientists and Technologists	Research, Design, and Consulting Services
Green New & Emerging	11-2011.01	Green Marketers	Research, Design, and Consulting Services
Green New & Emerging	19-2099.01	Remote Sensing Scientists and Technologists	Research, Design, and Consulting Services
Green New & Emerging	19-4099.03	Remote Sensing Technicians	Research, Design, and Consulting Services
Green New & Emerging	13-2099.02	Risk Management Specialists	Research, Design, and Consulting Services
Green Enhanced Skills	17-2011.00	Aerospace Engineers	Research, Design, and Consulting Services; Transportation
Green Enhanced Skills	17-2072.00	Electronics Engineers, Except Computer	Research, Design, and Consulting Services; Transportation
Green New & Emerging	17-2141.02	Automotive Engineers	Research, Design, and Consulting Services; Transportation
Green New & Emerging	17-2141.01	Fuel Cell Engineers	Research, Design, and Consulting Services; Transportation
Green New & Emerging	17-2051.01	Transportation Engineers	Research, Design, and Consulting Services; Transportation
Green Increased Demand	53-3021.00	Bus Drivers, Transit and Intercity	Transportation
Green Increased Demand	43-5032.00	Dispatchers, Except Police, Fire, and Ambulance	Transportation
Green Increased Demand	53-4011.00	Locomotive Engineers	Transportation
Green Increased Demand	47-4061.00	Rail-Track Laying and Maintenance Equipment Operators	Transportation
Green Increased Demand	53-4031.00	Railroad Conductors and Yardmasters	Transportation
Green Enhanced Skills	49-3023.02	Automotive Specialty Technicians	Transportation
Green Enhanced Skills	49-3031.00	Bus and Truck Mechanics and Diesel Engine Specialists	Transportation
Green Enhanced Skills	53-3032.00	Heavy and Tractor-Trailer Truck Drivers	Transportation
Green Enhanced Skills	11-3071.01	Transportation Managers	Transportation
Green New & Emerging	17-3027.01	Automotive Engineering Technicians	Transportation
Green New & Emerging	43-5011.01	Freight Forwarders	Transportation
Green New & Emerging	17-3029.10	Fuel Cell Technicians	Transportation

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