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► To cite this version:

Eléonore Loiseau, L. Saikku, R. Antikainen, N. Droste, B. Hansjürgens, et al.. Green economy and related concepts: an overview. *Journal of Cleaner Production*, 2016, 139, pp.361-371. 10.1016/j.jclepro.2016.08.024 . hal-02604567

HAL Id: hal-02604567

<https://hal.inrae.fr/hal-02604567v1>

Submitted on 16 May 2020

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Green Economy and related concepts: an overview

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Abstract:

For the last ten years, the notion of a green economy has become increasingly attractive to policy makers. However, green economy covers a lot of diverse concepts and its links with sustainability are not always clear. In this article, we focus on definitions of green economy and related concepts and an evaluation of these concepts against the criterion of strong and weak sustainability. The article serves three purposes: Firstly, we identify and describe diverse theories, concepts, approaches and tools related to a “green economy”. Among these are the theories of environmental economics and ecological economics, the concepts and approaches of cleaner production, waste hierarchy, bio-economy, industrial ecology, circular economy, nature-based solutions, and dematerialization through product-servicizing, and tools like life cycle assessment, and cost-benefit analysis. Secondly, we develop a framework that shows the capacity of the green economy concepts, approaches and tools to support the transition towards sustainability. Such a framework can serve as a heuristic to embed diverse concepts and approaches into a green economy framework. Thirdly, we briefly discuss green economy concepts with respect to their impact on strong and weak sustainability. Depending on the different concepts, approaches and tools identified in the green economy framework, different degrees of substitutability and trade-offs between environmental and economic benefits are allowed, and more or less structural changes of our modes of living are required. By discussing the notion of green economy and related concepts, approaches and tools we seek to make a contribution to their definitions and relationships as a prerequisite for operationalizing green economy.

Keywords: Green economy (GE), Environmental economics, Ecological economics, Sustainability, Substitutability, Trade-offs

Highlights:

- Green economy (GE) is an umbrella concept that lacks operationalization
- Different concepts related to GE are identified through bibliometric analysis
- These concepts are integrated in an heuristic framework for a GE
- Links between GE and sustainability are discussed

47 **1 Introduction**

48 The United Nations (UN) conference on the environment and development held in Rio de
49 Janeiro in 1992 formally adopted the concept of sustainable development defined by the
50 Brundtland report as a “development that meets the needs of the present without
51 compromising the ability of future generations to meet their own needs” (World Commission
52 on Environment and Development, 1987). Twenty years later, the Rio+20 conference coined
53 the concept “green economy” (Barbier, 2012). This popular concept is perceived as a pathway
54 to sustainability by international organizations such as The World Bank (2012) and the United
55 Nations Environment Programme (UNEP, 2011a). Moreover, green economy has been widely
56 used to address the financial and climate change crisis (UNEP, 2011a), and is an essential
57 element in achieving the climate mitigation targets refined in the Paris meeting. However, the
58 connections between green economy and climate mitigation still need to be further explored.
59 On a national scale, several countries are developing green economy strategies, policies and
60 programs. In Asia, South Korea is among the forerunners. In 2009, the country announced a
61 five-year plan to annually invest approximately 2 percent of its Gross Domestic Product
62 (GDP) in the field of green growth¹. China has also implemented a five-year plan (2011-2015)
63 that devotes a large portion of its investments to green key sectors; e.g., renewable energy and
64 technologies² (Mathews, 2012). In the European Union (EU), a range of measures related to
65 the green economy concept are integrated into strategic documents such as the Europe 2020
66 and the Resource Efficiency Roadmap (Mazza & ten Brink, 2012).

67 Compared with the application of green economy in policies, the concept itself has a longer
68 history in the academic world. Green economy was first introduced by Pearce et al. in 1989 in
69 response to the undervaluation of environmental and social costs in the current price system
70 (Le Blanc, 2011). Since then, the concept has been broadened. Green economy has been
71 defined by UNEP (2011a) as one that results in improved “well-being and social equity, while
72 significantly reducing environmental risks and ecological scarcities”. Green economy can be
73 simply defined as being low-carbon, resource efficient and socially inclusive (UNEP, 2011a).
74 UNEP emphasizes the preservation of natural capital, which includes ecosystems and natural
75 resources. In addition to or sometimes interchangeably with green economy, the term green
76 growth is often used (EEA, 2014). For a long time, “green growth” only applied to the growth
77 of the eco-industry. However, the term is currently used for the growth of the entire economy
78 (Jänicke, 2012). Green growth “is about fostering economic growth and development while
79 ensuring that the natural assets continue to provide the resources and the environmental
80 services on which our well-being relies. To achieve this it must catalyze investment and
81 innovation which will underpin sustained growth and give rise to new economic
82 opportunities” (OECD, 2011). Green growth is qualitative growth that is efficient in its use of
83 natural resources, clean in that it minimizes pollution and environmental damages and
84 resilient in that it explains natural hazards (World Bank, 2012). All these definitions show that
85 green economy is an “umbrella” concept that encompasses different implications with regard
86 to growth and well-being, or efficiency and risk reduction in the use of natural resources.
87 These potentially contradictory implications require clarification regarding the capability of a
88 green economy implementation to support a transition towards sustainability.

¹ The Republic of Korea’s Five-Year Plan for Green Growth (For more information, see
http://www.unep.org/PDF/PressReleases/201004_unep_national_strategy.pdf)

² China’s 12th Five-Year Plan (2011-2015) (For more information, see
<http://www.kpmg.com/cn/en/issuesandinsights/articlespublications/publicationseries/5-years-plan/pages/default.aspx>)

89 Despite the popularity of the concept of green economy among international and national
90 policy programs and institutions, its usefulness and appropriateness as a pathway to
91 sustainability can be questioned (Le Blanc, 2011). Operationality of the green economy
92 concept to achieve a transition towards sustainability, and a framework for its implementation
93 and monitoring are still currently lacking.

94 The objective of this paper is to identify and describe the main theories and concepts related
95 to a green economy and to illustrate their links to sustainability. Different concepts of a green
96 economy are embedded in a heuristic framework that can be used to assess current green
97 economy practices, cases and experiments. In particular, we elaborate on the underlying
98 assumptions in terms of substitutability of productive inputs and implications regarding
99 notions of weak and strong sustainability. The framework was tested in various European
100 cases and experiments with a wide cross-sectoral approach of different geographical and
101 temporal scales in two follow-up studies: considering the critical factors of success by
102 Pitkänen et al. (2016) and assessing institutional conditions that facilitate their transition
103 towards a green economy by Droste et al. (2016).

104 The paper is composed of six main sections. Following the introduction, in section 2 a
105 bibliometric analysis is conducted to identify and categorize the main theories, concepts,
106 practical approaches and tools used in the literature as green economy strategies. In section 3,
107 these different elements are described and briefly characterized with respect to sustainability.
108 Based on the relations between these theories, concepts, approaches, and tools in the context
109 of a green economy, in section 4 we provide a conceptual mapping heuristic to highlight the
110 scope of a green economy. In section 5, this generic framework is used to discuss the
111 implications of different theoretical and applied stances for the capabilities of the green
112 economy concept to support transition towards sustainability. We conclude with some
113 summarizing remarks (section 6).

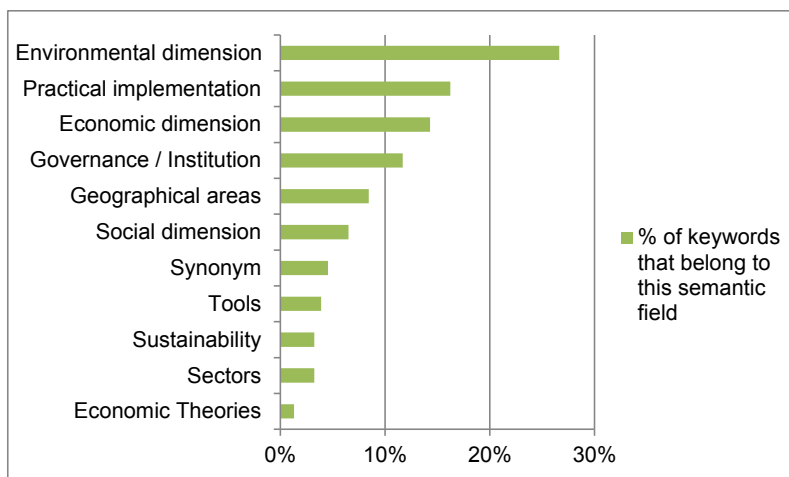
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115 **2 Identifying dimensions and characteristics of a green economy: a bibliometric** 116 **analysis**

117 **2.1 Keywords related to green economy**

118 We conducted a bibliometric analysis in order to identify the main keywords related to the
119 term “green economy” in the scientific literature since 1990. To this end, we used the
120 bibliographic database Scopus as it is likely currently the best tool available for electronic
121 literature search, particularly for articles published after 1995 due to – compared to other
122 databases - its wider subject and journal range (Falagas et al., 2008). In addition, it allows the
123 research of keywords. The literature research found 877 documents where the term “green
124 economy” is mentioned in the title, the abstract or the keywords, occurring jointly with
125 altogether 157 different keywords, respectively. These different keywords can be classified
126 into several semantic fields (Figure 1).

127



128

129 **Figure 1 Semantic fields of the keywords related to “green economy” found in the literature research on the**
130 **bibliographic database Scopus**

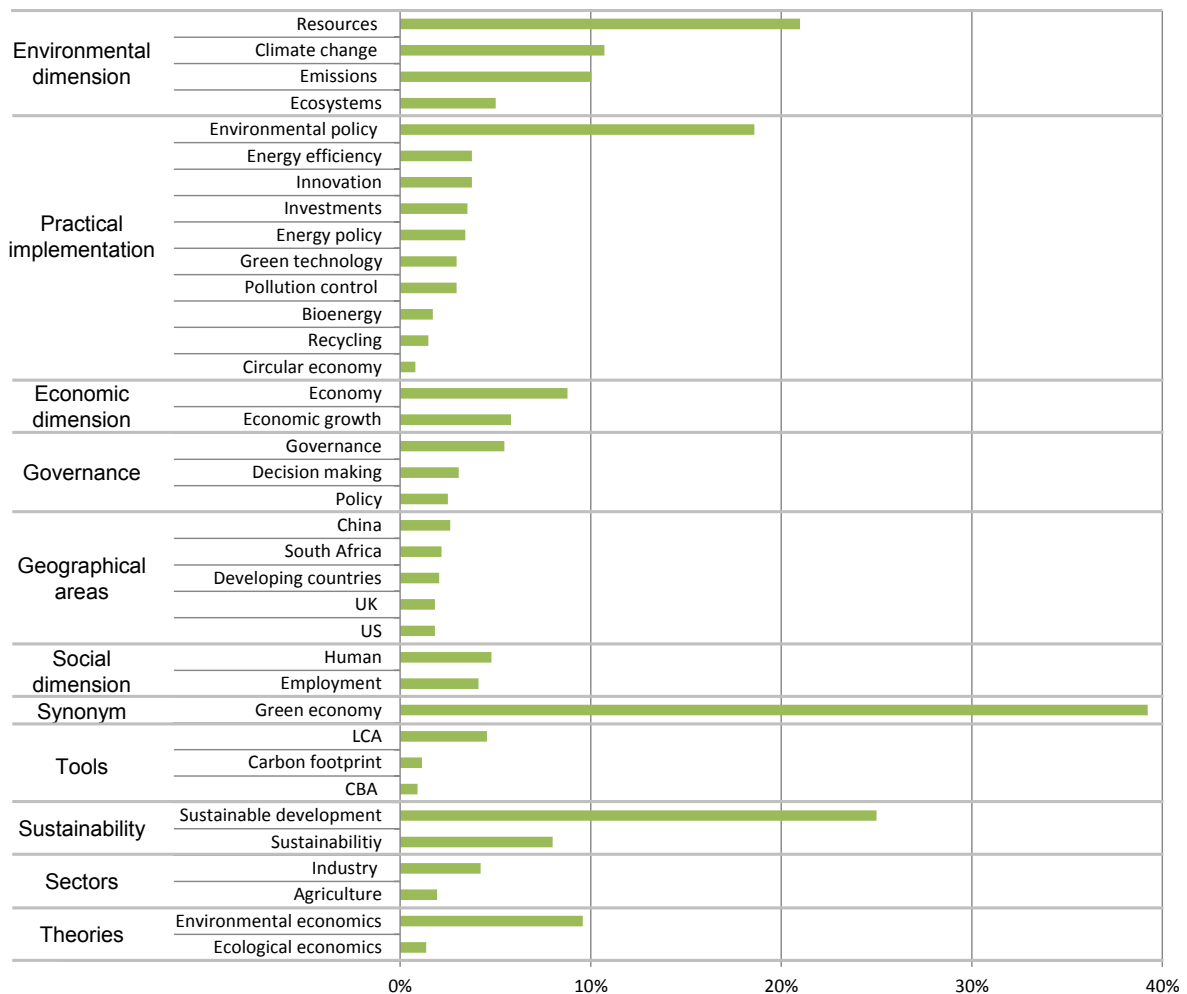
131 The results show that over half of the keywords related to “green economy” belong to the
132 semantic fields of environmental and economic dimensions. The environmental dimension
133 covers different environmental issues (e.g., climate change, renewable resources, energy,
134 natural capital), whereas the economic dimension encompasses different economic aspects
135 such as development, growth, cost, or competitiveness. The social dimension is less
136 represented. The emphasis on these three aspects of sustainability proves the strong links
137 between green economy and sustainability. In addition, several keywords are used for the
138 implementation of green economy in practice showing the interest of the research community
139 in providing operational concepts. The semantic field of governance is also important and
140 emphasizes the needs to define and analyze governance approaches that can support the
141 concept of green economy. Moreover, a lot of keywords refer to “geographical areas” in order
142 to highlight that various national and regional policies towards green economy have already
143 been implemented. Finally, a semantic field on “tools” has also been identified. It points at
144 connections with tools that can be used to assess and monitor the implementation of green
145 economy in practice.

146 **2.2 Keyword occurrence in the scientific literature**

147 Figure 2 provides more details on the main keywords related to the different semantic fields.
148 These keywords correspond to those that have the highest occurrence ratios. These ratios are
149 quantified by dividing the number of times the studied term is associated with “green
150 economy” by the number of times the term “green economy” appears alone. The results show
151 that in more than 35% of cases, the term “green economy” is associated with the particular
152 keywords of “sustainable development” or “sustainability”. This relationship point outs that
153 green economy can often be perceived as a pathway to sustainability. Second, figure 2 brings
154 information on the important terms related to the three dimensions of sustainability
155 (environmental, economic and social). One interpretation of the results is that “green
156 economy” can often be seen as a way to decrease pressure on resources, climate change and
157 emissions, while at the same time ensuring economic growth and employments. In addition,
158 there are more connections between “green economy” and the “environmental economics”
159 theory than between “green economy” and the “ecological economics” theory.

160 Practical implementation of green economy is also important in the keywords. A green
161 economy can be supported by environmental or energy policies and requires innovations and
162 investments as suggested by figure 2. Six main concepts and approaches are identified in
163 figure 2, i.e., energy efficiency, green technology, pollution control, bioenergy, recycling and

164 circular economy. In order to assess the environmental impacts of implementing green
 165 economy in practice, Life Cycle Assessment (LCA) is the most used tool, followed by carbon
 166 footprint and Cost-Benefit Analysis (CBA), according to the occurrence ratio values.
 167



168
 169 **Figure 2 Occurrence ratios of keywords classified according to their semantic fields**

170 In addition to the scientific literature, international institutions also refer to the different
 171 practical concepts and approaches of green economy. For instance, UNEP (2011a) provided
 172 an exhaustive list of concepts and approaches that includes resource efficiency, cleaner
 173 production, the waste hierarchy (reduce, reuse, recycle, and repair), circular economy, LCA
 174 and CBA. These institutions also introduce emerging concepts such as green infrastructure
 175 (UNEP, 2011a), bioeconomy (EC, 2012) or product-service system (PSS) (UNEP, 2015).
 176 Even if these concepts do not appear in the keyword research above, it seems important to
 177 consider them when studying green economy.

178 All these theories, concepts, approaches and tools are briefly described in the following
 179 section. The goal is to illustrate their links with green economy and provide background
 180 information to discuss the relationships between “green economy” and sustainability.

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185 **3 Theories, concepts, approaches and tools for a green economy**

186 **3.1 Underlying theories: environmental economics and ecological economics**

187 *3.1.1 Environmental economics*

188 According to neoclassical economists, environmental issues are due to the inefficient use of
189 natural resources and the undervaluation of natural capital (Borel-Saladin and Turok, 2013).
190 The underlying assumption is that man-made and natural capitals are substitutable (Bina and
191 La Camera, 2011). One of the main assumptions of this perspective is that economic growth
192 and sustainable use of resources can be achieved simultaneously. This so-called Porter
193 hypothesis deserves special attention because it assumes that there can be win-win solutions
194 for both the economy and the environment (Porter and Van der Linde, 1995). It proposes that
195 environmental regulation may spur entrepreneurial innovation, improve business
196 performance, and thus benefits not just the environmental but also the economic dimension
197 (Ambec et al., 2013). This perspective is optimistic regarding the aptitude of humankind to
198 solve any problems that may arise with resource depletion (Williams and Millington, 2004).

199 The starting point of environmental economics is the concept of external effects (Pigou,
200 1920). Thus, the strategy pursued by environmental economics is to set prices right
201 (“internalization”) by providing an accurate valuation of this capital. To evaluate natural
202 capital, the external effects are estimated using different methods and suggestions are made to
203 internalize these effects (Rennings and Wiggering, 1997). External environmental costs can
204 have a variety of forms ranging from local (e.g., noise of an airport) to global (e.g.,
205 greenhouse gas emissions and long-range transboundary air pollution). External benefits can
206 be related to the use of “commons” such as regional spill over benefits from watershed
207 protection areas. If private behavioral incentives do not reflect costs or benefits to third parties
208 or society as a whole, the decisions taken will not lead to a social optimum and may lead to
209 decreased social welfare. The costs and/or benefits that a particular activity incurs to a third
210 party should be addressed by economic instruments in such a way that the respective actor
211 incorporates these values into decision making. A broad set of potential instruments can be
212 used for internalization, i.e., command and control, taxes, subsidies, tradable permits, liability
213 law, or payments for ecosystem services.

214 The underlying assumption of these approaches is that, as soon as society as a whole gets the
215 prices right (reflecting external costs), the non-sustainable use of natural resources will come
216 to a halt (see Williamson 1994, on the development of institutional economics). This
217 assumption implies the notion of weak sustainability where constant welfare over time can (i)
218 be obtained by substituting natural capital by man-made and human capital and (ii) natural
219 capital is not characterized by critical thresholds so that environmental degradation is
220 reversible (Pelenc and Ballet, 2015). These assumptions are often formalized in terms of a
221 welfare functions with different capital goods as inputs and particularly mathematical
222 expressions about the degree of substitutability, for example in terms of input elasticities.

223

224 *3.1.2 Ecological economics*

225 In ecological economics, the economy is defined as a subsystem of the natural which sets
226 limits on the physical growth of the economy. Economic systems are ultimately constrained
227 by the Earth’s biophysical limits, and society must adapt their economic system accordingly
228 to operate within a safe operating space (Bina and La Camera, 2011; Kennet and Heinemann,
229 2006).

230 Ecological economics concepts emerged at the end of the 1980s inspired by previous
231 multidisciplinary research based on natural and social sciences. This ecological economics
232 school attempts to model socio-ecological systems by analyzing cause-effect-relationships
233 and dynamic processes with the environment. These integrated and biophysical perspectives
234 of environment-economy interactions aim at contributing to solutions for environmental
235 problems (Ekins et al., 2003; van den Bergh, 2001). Among these solutions, great emphasis is
236 placed on structural changes within economy and society such as creating a more small-scale
237 decentralized way of life based upon greater self-reliance in order to create social and
238 economic systems that are less destructive towards nature (Williams and Millington, 2004).
239 For this purpose, physical or ecological indicators (e.g., material input per service unit, the
240 ecological footprint, and the critical natural capital) based on the concept of dematerialization
241 and the conservation of non-substitutable natural capital are developed (Ekins et al., 2003;
242 Farley, 2008; van den Bergh, 2001). Accordingly, the concept is rather based on physical
243 measurement and ecological knowledge to assess critical thresholds but it also includes the
244 study of institutions, property regimes and environmental governance mechanisms (Vatn,
245 2007).

246 The dematerialization of economies refers to reducing material or energy use per unit of
247 service output. Dematerialization refers to lowering the volume and toxicity of flows in
248 human linear systems and implies closing cycles of materials or energy (de Bruyn, 2002).
249 Dematerialization reduces emissions, as according to the law of conservation of mass every
250 material input sooner or later turns up as emissions or waste to be an output from the system.
251 However, striving for dematerialization does not always lead to a relative decrease in the use
252 of resources due to rebound effects; i.e., efficiency gains may lower the prices which may
253 increase consumption (Herring 2006), or they may lead to a regional shift of polluting
254 activities. Consequently, technological improvements are necessary but not sufficient to
255 achieve dematerialization, and structural changes and sufficiency policy initiatives must
256 additionally be conducted to ensure sustainable management of resources (Lorek and
257 Spangenberg, 2014). Such a perspective is built upon the assumption that there are ultimate
258 limits to the substitutability of natural capital and man-made capital and that at least certain
259 (critical) stocks of natural capital must be maintained in order to obtain sustainability, which
260 is a strong sustainability notion.

261 In the following we analyze different concepts and their relationships with the notion of green
262 economy. We make the distinction between “well-established” concepts and tools which have
263 been discussed for a longer period, and “emerging” concepts that came up recently.

264 **3.2 Well-established concepts, approaches and tools**

265 *3.2.1 Cleaner production and resource efficiency*

266 The term cleaner production was defined by UNEP in 1990 as “the continuous application of
267 an integrated environmental strategy to processes, products and services to increase efficiency
268 and reduce risks to humans and the environment”. This approach was a paradigm shift
269 because it stated that it was more appropriate to attempt to prevent pollution rather than treat
270 pollution with end-of-pipe techniques (El Kholy, 2002). UNEP recently broadened the
271 definition of cleaner production to include resource efficiency, which is a key element of the
272 transition towards a green economy (UNEP, 2016). Consequently, an emphasis was placed on
273 developing cleaner technologies that generate less pollution and waste and that make more
274 efficient use of materials and resources. Initially, efforts were exerted to develop “green
275 products” that generally focused on one single environmental issue. More systematic
276 approaches to designing for the environment emerged in the 1990s; this was known as eco-

277 design (Roy, 2000), or as design related to environment or green design. It refers to an
278 approach of product designed for zero waste production, take-back and reuse, in which the
279 life-cyclic environmental impacts of a product are considered (section 4). The role of design
280 phase in reducing environmental impacts in the production process, in packaging and
281 logistics, during the use phase and in disposal is crucial, because it is the main phase affecting
282 factors such as the product's material and substance content, durability and possibilities to
283 disassembly. In addition to decreased environmental impacts, the promotion of cleaner
284 production among firms can lead to net job creation. However, these results hold only for
285 highly skilled labor and specific policy programs that differentiate between the types of eco-
286 innovations that should be designed (Pfeiffer and Rennings, 2001).

287 Resource efficiency and eco-design aim mainly at improving the use of natural resources in
288 the value-chain of production focusing on firms and their behavior by focusing on reducing
289 environmental emissions and waste by technological innovations. This is consistent with the
290 environmental economic's assumption that the transition towards sustainability can be
291 supported by constant improvements in the rate of substitution of natural capital into man-
292 made or human capital.

293 3.2.2 *Waste hierarchy: reuse, repairing, recovery and recycling*

294 The waste hierarchy approach along with the waste prevention (EC, 2008) are important
295 elements of green economy by improving resource efficiency, reducing need for raw materials
296 and aiming at closing the material flows. The stages of waste hierarchy are first prevention,
297 then reuse, recycle, recovery, and finally disposal. Moving towards the bottom of the
298 hierarchy, the quantity of auxiliary energy and resources needed for waste management and
299 the losses of materials and energy increase. By waste prevention, these negative impacts can
300 be avoided. Waste prevention starts in the designing and processing of products. The reuse of
301 goods is means to use of a product again for the same purpose in its original form or with
302 minimal upgrading. Material recycling describes the process of recovering materials of a
303 product for the original purpose or for other purposes. A process of converting materials into
304 new materials of higher quality and increased functionality is up-cycling, whereas a process
305 of converting materials into new materials of lesser quality and reduced functionality is called
306 down-cycling. The recovery of materials includes the processing and conversion of the
307 original materials into new products. Energy recovery turns materials into heat, electricity or
308 fuel. Safe disposal, preferably via return to the extraction and production site, is the final
309 option to manage waste as a resource in a green economy. Despite of the environmental
310 benefits of implementing the waste hierarchy, waste generates economic activities, and
311 sophisticated incentives are required to decouple economic growth from waste generation
312 (Bartl, 2014).

313 The waste hierarchy approach is mainly focused on reducing throughput and thereby the
314 environmental pollution of production processes. As such it aims at increasing the resource
315 efficiency similar to the cleaner production approach; it differs from the latter for the stronger
316 emphasis on waste reduction and control of harmful substances. In this respect waste
317 hierarchy comes closer to safeguarding the planetary boundaries according to a strong
318 sustainability perspective.

319 3.2.3 *Industrial ecology and circular economy*

320 Industrial ecology is a research field³ interested in integrating notions of sustainability into the
321 environmental and economic systems. The use of energy and materials is optimized, and the

³ Industrial ecology has been defined as a field, discipline, area of study, and a discourse (Allenby 2006).

322 generation of waste is minimized to move from linear throughput to closed-loop materials and
323 energy use (Ehrenfeld and Gertler, 1997). The core elements of industrial ecology are the use
324 of biological analogy, the use of a systems perspective, the role of technological change and
325 dematerialization from a forward-looking perspective (Lifset and Graedel, 2002).

326 When implementing industrial ecology in practice, industrial symbiosis (IS) aims at engaging
327 traditionally separate activities in physical exchanges of materials and energy flows. These
328 physical exchanges can occur within a facility, firm, or organization; among firms collocated
329 in a defined eco-industrial park; and among firms organized “virtually” across a broader
330 region (Chertow, 2000). Although industrial symbiosis implementations are usually
331 concentrated on the level of industrial parks, larger regional areas may be more suitable for
332 closing material loops and creating sustainable industrial ecosystems (Sterr and Ott, 2004).
333 Furthermore, IS has been recently defined as a path to green growth because it engages
334 organizations in a network to foster eco-innovation and encourages them to make new
335 investments and change business practices, and it also stimulates research and development,
336 new businesses, and joint ventures (Lombardi and Laybourn, 2012).

337 Following in the footsteps of industrial ecology (Mathews and Tan, 2011), the concept of
338 circular economy is becoming increasingly popular in civil society with the works conducted
339 by The Ellen MacArthur Foundation (2012). The Foundation defined circular economy as “an
340 industrial economy that is restorative by design, and which mirrors nature in actively
341 enhancing and optimizing the systems through which it operates”. “Circular economy builds
342 on the concepts of waste prevention and resource efficiency by showing where the greatest
343 benefits are to be realized, and by emphasizing the need to consider the sustainability of the
344 sources of raw materials, as well as their fate. It adds to the development of EU waste and
345 resources policy” (Hill, 2015). As such, synergies exist between the two concepts in
346 supporting an upward transition in the waste hierarchy, e.g., by transforming the by-products
347 of one industry into valuable resources for one or several other industries.

348 Both the industrial ecology and circular economy approaches move beyond the firm level
349 foundations of the resource efficiency and waste hierarchy approaches. By broadening the
350 focus to inter-firm co-operations and designing economy-wide circular resource flows at
351 regional and global level, these approaches take a macro-economic perspective (Lifset &
352 Graedel 2002). By focusing not just on reducing the resource-efficiency and material
353 throughput but by closing the loop of material flows from a linear to a circular flow they take
354 a stance more congruent with the strong sustainability perspective of ecological economics.

355 *3.2.4 Life cycle and material flow based tools and methods*

356 There are several life cycle and material flow-based tools of industrial ecology and economics
357 to assess the sustainability of a green economy. Material Flow Analysis (MFA) refers
358 generally to the analysis of the throughput of process chains comprising extraction or harvest,
359 chemical transformation, manufacturing, consumption, recycling and disposal of materials
360 (Bringezu and Moriguchi, 2002). MFA is based on accounts in physical units and quantifies
361 the inputs and outputs of those processes, MFA can be practiced on the levels of substances
362 (substance flow analysis, SFA), materials (MFA) or products within firms, sectors or regions.
363 The product level MFA normally denotes the life cycle inventory phase of LCA. This level is
364 a widely used tool for assessing the environmental impacts of a product or service from
365 “cradle to grave” (Finnveden et al., 2009). In environmental LCA, impacts such as climate
366 change, acidification and toxic emissions are considered. Environmentally Extended Input-
367 Output (EEIO) model is an elaborated version of the classical input-output (IO) model
368 describing the interdependencies between different sectors of the economy (Leontief (1936).

369 In EEIO, also environmental impacts are included (e.g., Kitzes, 2013; Koskela et al., 2011).
370 EEIO can be viewed as a LCA tool; however, instead of production process-based analyses, it
371 operates at the sector-level of the economy.

372 Tools to assess economic dimension of the green economy include Life Cycle Costing (LCC),
373 which measures the total cost of an asset over its life cycle including capital costs,
374 maintenance costs, operating costs and the asset's residual value at the end of its life (Sesana
375 and Salvalai, 2013). Social Life Cycle Assessment (S-LCA) is developed to evaluate the
376 social dimension using indicators such as employment, workplace health and equity (Benoit
377 Norris, 2012; Macombe et al., 2013). Compared to environmental LCA, S-LCA has been
378 applied to a limited number of real-life case studies; however, the topic is under active
379 development (e.g., Benoit Norris, 2012; Macombe et al., 2013). It is also possible to integrate
380 environmental, economic and social aspects with the concept of Life Cycle Sustainability
381 assessment (LCSA) (Guinée et al., 2011; Heijungs, 2010; Hoogmartens et al., 2014) to have
382 an overall picture of the impacts.

383 *3.2.5 Cost benefit analysis*

384 Cost-benefit analysis (CBA) is a decision support tool used to assess the welfare effects of a
385 project or an investment and has its roots in the welfare measures of producer and consumer
386 surplus (Hanley and Barbier, 2009; Hanley and Spash, 1993; Hansjürgens, 2004; Sen, 2000).
387 A comprehensive CBA can be used to compare the environmental, economic and social
388 dimensions of different green economy strategies (UNEP, 2011a). As such, CBA requires that
389 all project-related disadvantages (costs) and advantages (benefits) are identified and
390 monetized at their margin (the price of an additional unit). Future streams of costs and
391 benefits are integrated with their net present value (the discounted total value of future
392 streams).

393 A prerequisite for a complete welfare assessment is that all project related costs and benefits
394 are assessed. Thus, the concept of Total Economic Value (TEV) is often used to include both
395 use values and non-use values (Pearce and Moran, 1994; TEEB, 2010). Costs and benefits of
396 goods and services that are not traded in markets (such as many ecosystem services) do not
397 have a market price. Stated preference methods can be used to assess a willingness to pay as a
398 proxy for the marginal change in the utility obtained, or preferences for willingness to pay can
399 be obtained from individuals' behavior on markets (revealed preferences).

400 **3.3 Emerging concepts and approaches**

401 *3.3.1 Green infrastructure and nature-based solutions*

402 One of the newly emerging concepts in environmental policy is the concept of nature-based
403 solutions. Implementing nature-based solutions requires designing multifunctional landscapes
404 that contribute to sustainable resource management systems that foster the development of a
405 green economy. Nature-based solutions can simultaneously provide multiple benefits such as
406 flood control, carbon storage, raw materials, human health and biodiversity if its ecosystems
407 are healthy (Mazza et al., 2011). Green Infrastructure (GI) is one example of a nature-based
408 solution. In the EU, GI is a strategically planned network of natural and semi-natural areas,
409 which are viewed as a cost-effective alternative or complement to grey, man-made
410 infrastructure to satisfy human needs (European Commission, 2013a). The concept of GI has
411 been developed to upgrade urban and peri-urban green spaces in terms of both quality and
412 quantity and to emphasize the importance of their multifunctionality as well as their role in
413 the interconnection between habitats (Tzoulas et al., 2007). The European Commission's

414 strategy on GI plans to invest in nature-based solutions to conserve and enhance natural
415 capital such as protected watersheds for clean drinking water, natural floodplains to provide
416 protection, or urban greenspaces to improve climate resilience. GI are designed and managed
417 to provide a wide range of environmental services. GI often yield high economic returns on
418 investment through e.g., tourism and recreation, climate or air quality regulation and
419 provisioning services such as biomass production (European Commission, 2013b; Nellemann
420 et al., 2010). A particular strategy to increase biodiversity in abandoned farmlands is
421 rewilding (Navarro and Pereira, 2012).

422 As such the concept of nature-based solutions is focused on investments into natural capital
423 that enhance the supply of multi-benefit ecosystems. It aims not just at environmental
424 protection through the reduction of pollution but also incrementing the stock of natural
425 capital. Therefore, nature-based solution is the only approach that complies with strong
426 sustainability. But it also entails a micro perspective since it aims at public and private
427 investors to facilitate nature-based solutions in urban and rural landscapes.

428 3.3.2 Bioeconomy

429 Bioeconomy has been defined by the OECD (2009) to include all economic activities that are
430 linked to the development and the use of biological products and processes. However, the
431 definition is not univocal. Georgescu-Roegen's (1975, p. 369) bioeconomic theory refers to
432 the mankind's survival depending on "the three low-entropy sources – free energy received
433 from the sun, and the free energy and the ordered material structures stored in the bowels of
434 the earth", and represents a radical criticism of neo-classical theory (Bonaiuti 2011).
435 Following OECD approach, bioeconomy, bio-based economy or knowledge based bio-
436 economy can be viewed as synonymous (McCormick and Kautto, 2013). Bioeconomy relies
437 on the development of biotechnologies that "apply science and technology to living
438 organisms, as well as parts, products and models thereof, to alter living and non-living
439 materials for the production of knowledge, goods and services" (OECD, 2009).
440 Biotechnology provides wide perspectives for progress in primary production (e.g., plant and
441 animal breeding), health (e.g., pharmacogenetics) and industries (e.g., bioremediation,
442 biosensors) while decreasing the dependence on non-renewable resources and ensuring food,
443 environmental, social and economic security through job creation and competitive position.
444 The European Commission (2012) defined bioeconomy as "an economy using biological
445 resources from the land and sea as well as waste, including food wastes, as inputs to industry
446 and energy production. It also covers the use of bio-based processes to green industries". This
447 definition remains under debate because it can be argued that the EU policy framework is
448 dominated by an agro-industry perspective and that more emphasis should be placed on a
449 public-good oriented concept of the bioeconomy with the inclusion of agro-ecology concepts
450 and local knowledge (Schmid et al., 2012). Nonetheless, the concept is popular among
451 European institutions with the establishment of a bioeconomy observatory⁴, and funding
452 mechanisms are intended to be boosted such as the Horizon 2020, which defines the EU
453 framework for research and innovation for 2014–2020. Establishing a bioeconomy in Europe
454 can maintain and create economic growth and jobs in rural, coastal and industrial areas, while
455 reducing fossil fuel dependence and improving economic and environmental sustainability.
456 Many member States have launched bioeconomy initiatives including France, Germany, The
457 Netherlands, Sweden and Finland. Non-European countries such as the US and China are also
458 investing heavily into bioeconomy (McCormick and Kautto, 2013). The bioeconomy concept
459 and the biotechnology approach taken are rather weak sustainability stances since they are

⁴ Bioeconomy data and information website, managed by the European Commission's Joint Research Centre (JRC);
Available at: <https://biobs.jrc.ec.europa.eu/>

460 focused on using natural resource inputs to production processes. Weak sustainability, in
461 environmental economics, states that 'human capital' and 'natural capital' are substitutable and
462 that a complete change of our economic system is not required (see more in section 5.1), but
463 rather a shifting from fossil to renewable inputs. However, (critical) limits in the supply of
464 these inputs are not at the center of the approach. Furthermore, it is mainly a firm based micro
465 approach since it aims at changing firm's behavior.

466 3.3.3 *Product-service system*

467 A third, relatively new, concept is the product-service system (PSS), defined in Europe in the
468 1990s as “a mix of tangible products and intangible services designed and combined so that
469 they jointly are capable of fulfilling final customer needs” (Tukker and Tischner, 2006, p.
470 1552). Products are owned by companies along their entire lifecycles, and the use of service
471 of the product is what the consumer pays for (Hinton, 2008). Therefore, companies have a
472 strong economic interest to extend the lifespan of their products, to ensure that they are
473 intensively used, to make them as cost and material efficient as possible and to re-use parts as
474 much as possible. However, implementing a product-service system does not mean that it will
475 by definition be more resource-efficient or circular than classical product systems. Tukker
476 (2013) identified different categories of Product-Service System (PSS), including use-oriented
477 PSS in which the product continues to play a central role (e.g., product renting, sharing or
478 polling) and result-oriented PSS in which there is no predetermined product (e.g., pay per
479 service unit). Use-oriented PSS potentially increases the use-stage of products, reducing the
480 need for materials; however, as a possible disadvantage, it can lead to less careful behavior by
481 the user, likely reducing the lifespan of products. The result-oriented PSS have the greatest
482 potential to increase eco-design and resource efficiency. However, many radical changes must
483 be made to develop this approach because firms need to change their business model and their
484 infrastructure and to develop new skills (e.g., relation management skills) (Tukker, 2013). The
485 concept of PSS is closely related to servicizing, or functional economy. Functional economy
486 was proposed by Stahel in 1989 as a means to achieve sustainability (Stahel, 1989). The
487 economic objective of functional economy is “to create the highest possible use of value for
488 the longest time while consuming a few material resources and energy as possible” (Stahel,
489 1997). All these concepts can be perceived as a possible answer to dematerialize the economy
490 (Mont, 2002) and to contribute to a resource-efficient and circular economy (Tukker, 2013).

491 The concept of PSS is close to dematerializing since its central idea is no longer product-
492 based but focused on product life and functionality from which services arise: by sharing and
493 renting the per capita resource consumption is likely to be reduced. However, even though
494 more sustainable business models such as PSS bring green economy benefits, they remain
495 mainly on incremental and micro level and do not aim at systematic changes in overall
496 resource consumption patterns. We therefore locate the concept at an intermediate position
497 between weak and strong sustainability.

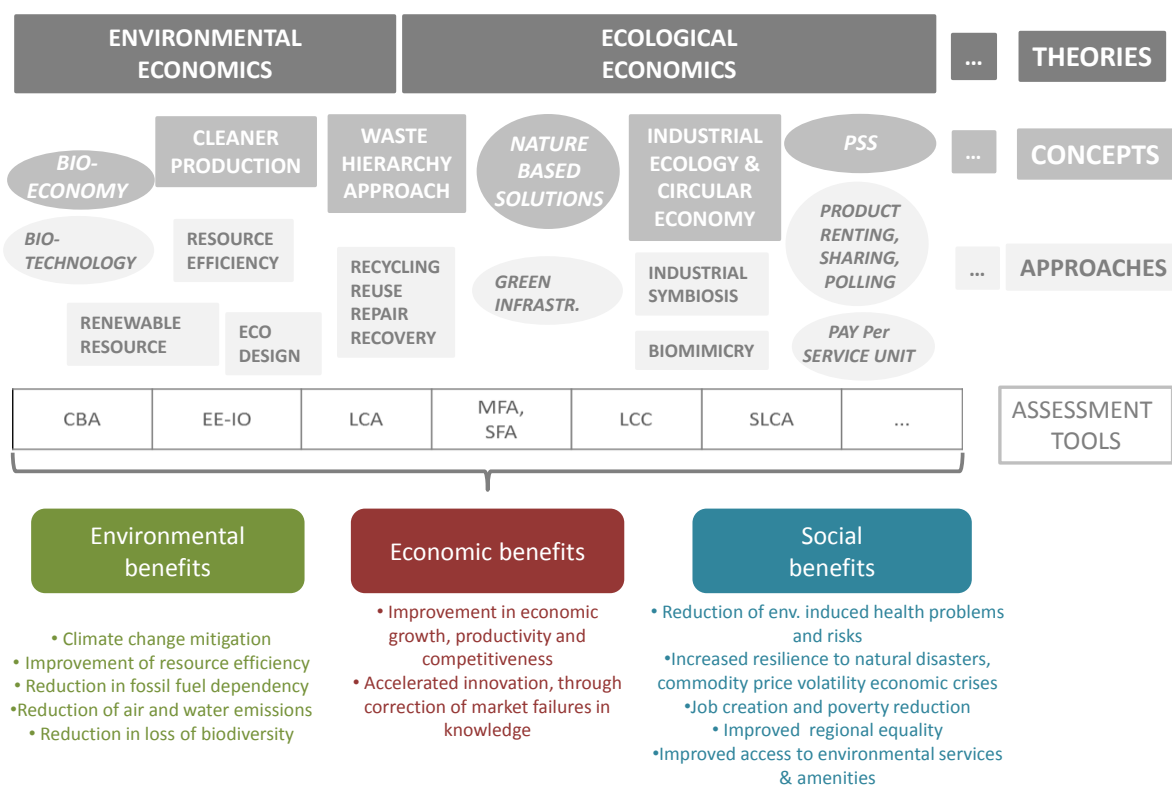
498 **4 Mapping theories, concepts, approaches and tools: a green economy heuristic** 499 **framework**

500 The concept of a green economy is related to several different economic theories, concepts,
501 practical approaches and assessment tools. To clarify these links, all the most evident
502 respective elements were integrated in a multi-layered framework (Figure 3). The purpose is
503 to make explicit these concepts and their relationships, so that the framework can serve as a
504 “green economy heuristic”.

505 First, a green economy can be linked to both theories of environmental economics and
 506 ecological economics. The implementation of these two theories in practice results in different
 507 concepts and approaches. Environmental economics is closely related to cleaner production
 508 and resource efficiency, whereas ecological economics relies on advanced concepts such as
 509 industrial ecology or circular economy. Waste hierarchy can be both related to environmental
 510 economics and ecological economics, depending on the extent to which its different
 511 approaches are implemented (down-cycling versus up-cycling). All these concepts are based
 512 on practical approaches or solutions to achieve the green economy objectives that are listed on
 513 the bottom of Figure 3, i.e., environmental, economic and social benefits.

514 Practical solutions for a green economy encompass a broad range of approaches that can be
 515 implemented such as reuse, repair, recover or recycling, applying eco-design rules or
 516 developing industrial symbiosis. In order to measure the effects of these solutions on green
 517 economy goals, different assessment tools can be used such as LCA, LCC, S-LCA, MFA,
 518 EEIO and CBA.

519 In addition, several potential emerging concepts and their related approaches have been
 520 identified as promising instruments to implement green economy strategies. These approaches
 521 include bioeconomy, which can be related to environmental economics, and nature-based
 522 solutions and PSS, which can be linked to ecological economics.



523
 524 **Figure 3 Generic framework showing the different layers of the green economy concept (for the concepts,**
 525 **current concepts are marked with boxes, emerging concepts are in circles and in italics).**

526 5 Discussion: Sustainability issues and policy implications

527 There are several implications of our generic framework from which we choose two focal
 528 perspectives. Firstly, we consider the relationships of the theories presented, concepts,
 529 approaches and tools discussed to either weak or strong sustainability (section 5.1). Secondly,
 530 we discuss what this implies for the implementation of a green economy in the political and

531 economic realm (section 5.2). When implementing the green economy in practice, there are
532 several critical factors related to economic viability, public funding, technological
533 development, impact assessments, public policies and regulation, social capital, leadership
534 and coordination as well as public acceptability and image, and transition to green economies
535 requires negotiation between potential trade-offs among multiple goals, and interests of
536 various stakeholders (Pitkänen et al. 2016). Furthermore, limiting the action space of the
537 “brown” economy at the least socially and environmentally friendly end is required as well
538 and government interventions, such as regulation, public procurement; and investment, setting
539 incentive and raising revenues, network and capacity building, and monitoring processes can
540 help in this (Droste et al. 2016).

541

542 **5.1 Links with weak and strong sustainability**

543 The generic framework of a green economy shows that different concepts and approaches are
544 available and can be used to support the transition towards sustainability. However, doubts
545 have been expressed regarding the ability of a green economy to support the transition
546 towards sustainability (Bina and La Camera, 2011; Lorek and Spangenberg, 2014). This doubt
547 can be partly explained by the two different visions of sustainability that can be found in the
548 two economics theories related to green economy, i.e., weak sustainability and strong
549 sustainability (Dietz and Neumayer, 2007; Neumayer, 2003; Pearce and Atkinson, 1993).

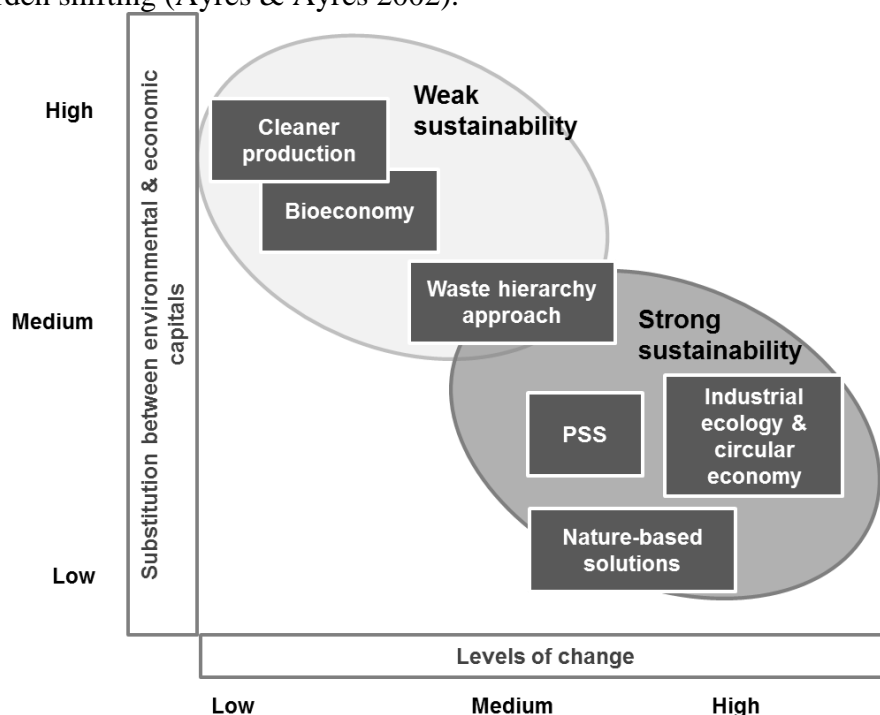
550 Weak sustainability, in environmental economics, states that 'human capital' and 'natural
551 capital' are substitutable and that no complete change of our economic system is required.
552 Therefore, certain elements of concepts and approaches related to environmental economics,
553 i.e., cleaner production, bioeconomy or waste hierarchy assume that natural capital can be
554 substituted by human-made capital. For instance, the use of biotechnology or the quest for
555 efficiency rely on the hypothesis that new technologies will always be developed to meet
556 increasing human needs in a world where natural resources are limited. Similarly, the
557 assessment tools developed in environmental economics such as CBA assume a complete
558 substitutability between natural and human-made capital. For weak sustainability approaches,
559 this assumption could be operationalized by an elasticity of substitution greater than one,
560 meaning that a loss in one dimension can be offset by gains in the other (Neumayer, 2003).
561 Nonetheless, recent developments such as the fostering of upcycling in waste hierarchy tend
562 to consider the vulnerability of the environment and the need to preserve it.

563 Strong sustainability, often found in ecological economics, assumes that human-made capital
564 and natural capital are complementary, but not limitlessly interchangeable. According to this
565 view, concepts and approaches attempt to find solutions to maintain humanity within a safe
566 operating space by closing the loop of material throughput (circular economy and industrial
567 ecology) and respecting critical thresholds of natural capital stocks, and even by facilitating
568 investments into the natural capital stock (nature-based solutions). In economic terms,
569 elasticity of substitution between human-made capital and natural capital would be less than
570 unity, meaning the loss natural capital cannot be offset by gains in the human made capital
571 and their inputs are complements (Neumayer, 2003). As such these more ecological
572 perspectives reveal primarily a macro perspective entailing the utmost system boundaries of
573 our productive systems. These respective solutions require more structural changes in human
574 society because they involve long-term and substantial modifications in our mode of living.

575 Figure 4 classifies the different concepts related to green economy according to these two
576 features of sustainability, i.e., the level of substitution between environmental and economic
577 benefits, and the required level of change. This figure shows that depending on which of the

578 particular concepts green economy relies on, its link to sustainability will differ. The use of
579 concepts such as cleaner production or bioeconomy requires less adaptations of human's
580 mode of living and it assumes substitution between environmental and economic capitals. On
581 the contrary, concepts such as PSS, industrial ecology, or nature-based solutions assume that
582 structural changes are required in our societies to meet the challenges of sustainability. As the
583 bibliographic analysis revealed, green economy is currently more related to concepts linked to
584 weak sustainability (i.e., energy efficiency or pollution control) than concepts that require
585 deep societal transformations (i.e., circular economy). This observation is supported by the
586 fact that in the scientific literature "green economy" is more often associated to
587 "environmental economics".

588 Regarding the issue of substitutability, recent works have attempted to determine biophysical
589 limits or planetary boundaries that define the boundaries within which humanity is expected
590 to operate safely (Rockström et al., 2009; Steffen et al., 2015). Crossing certain biophysical
591 thresholds could have disastrous and irreversible consequences for humanity. In addition, no
592 trade-offs between environmental dimensions are allowed because risks cannot be overcome
593 by substituting deterioration in one biophysical boundary by improvements in others. System
594 and product level tools such as LCA are designed to measure impacts and identify potential
595 burden shifting (Ayres & Ayres 2002).



596
597 **Figure 4 Classification of the different concepts related to green economy according to two sustainability visions**

598 **5.2 Green economy as a concept for policy-making**

599 The concept of a green economy is very attractive to governments and businesses as it aims to
600 provide a simultaneous solution to both unemployment and environmental issues with new
601 green industries and tools for mitigating environmental damage (Borel-Saladin and Turok,
602 2013).

603 The UNEP Green Economy synthesis for policy makers claims that – in the long run - “the
604 so-called ‘trade-off’ between economic progress and environmental sustainability is a myth”
605 (UNEP, 2011a). This point deserves special attention because it assumes that there can be
606 win-win solutions for both the economy and the environment (Porter and Van der Linde,

607 1995). This so called “Porter hypothesis” has been widely debated and is at the core of our
608 conceptualization of the relation of different theoretical assumptions about a feasible degree
609 of substitutability. Considering these elements, most of the green economy debate regards the
610 extent of changes and how to achieve these modifications (Pearce, 1992).

611 However, an empirical question remains about regarding how far economic activity can be
612 decoupled from the consumption and depletion of natural resources remains unanswered.
613 Decoupling environmental harm from economic production has two important dimensions,
614 namely first, the relative decoupling, where both indicators continue growing, the nominator at
615 a slower rate, and second, the absolute decoupling, which means that the nominator is reduced
616 over time in absolute terms (Wernick et al., 1996). For example, UNEP (2011b) has shown
617 how relative resource decoupling is taking place, but on absolute terms, no actual reductions
618 occur, while substantial reductions in the resource requirements of economic activities will be
619 necessary. As fast as the coefficient between growth and environment is lowered, the problem
620 of scale may dominate. This effect is induced by globalization and expanding market access
621 increasing economic activity and hence, the total quantity of pollution produced. This is
622 crucial for practical implications of a green economy, since the contradiction between the
623 feasible degree of substitutability and the ultimate feasibility of absolute decoupling stems
624 from mere theoretical concerns.

625 To clarify the different notions of a green economy we produced a heuristic framework of
626 different theories, concepts and approaches and we discussed their relation to weak and strong
627 sustainability visions. The framework produced in our study provides a support tool for policy
628 makers to identify the levels of change in transition to the green economy, and thus it can be
629 used to assess potential effectiveness of both practical cases and policy instruments.

630 The approaches that can be classified as weak sustainability concepts aim at cleaner
631 production patterns and at reducing pollution and waste, which evidently is positive in terms
632 of sustainability and green economy. Through well-designed and coherent legal frameworks,
633 environmentally friendly and equitable behavior, private sector actors can be encouraged and
634 incentivized to implement green economy concepts and approaches (Lee et al., 2014a, 2014b,
635 2014c). Regulation, charges, levies, taxes, and other market-based instruments such as
636 tradable permit schemes can help to scale-up such investments and internalize the costs of
637 environmental externalities (Pizzol et al., 2014) and implement the weak sustainability portion
638 of the green economy.

639 The green economy concepts targeting at strong sustainability apply dematerialization,
640 servicing, and investments into natural capital. These approaches have not yet gained a foot-
641 hold in broad-scale applications, especially since they require more systemic and substantial
642 changes in the way the economies and societies works. Although the main investment for
643 such a shift will need to originate from the private sector (i.e., from finance, banks and
644 insurance companies), governments will have to play a vital role in steering those investments
645 towards greening the economy (UNEP 2011). Furthermore, governments as such will need to
646 incorporate environmental values into their own decision making, expenditure planning, and
647 accounting in a manner that does not deplete environmental assets (Barbier, 2011; ten Brink et
648 al., 2012). Ultimately, any reduction of environmental impact per unit of production moves
649 the economic system towards a more sustainable development. How strong a movement is
650 required to safe-guard planetary boundaries is a question of socio-ecological knowledge and
651 the potential for innovation. It may, however, require the political imposition of some
652 boundaries for resource consumption in order to unlock the full innovative potential of a
653 green economy. When aiming at making the win-win economy-environment developments a
654 reality, the green economy decision makers should thus focus on the implementation of

655 ecological economics approaches such as industrial ecology, circular economy and nature-
656 based solutions of green infrastructure.

657 **6 Final remarks**

658 The concept of a “green economy” is well established in the political sphere, and it appears in
659 many policy agendas of international institutions. However, the possible misinterpretations of
660 the concept and the lack of proper science-based decision-support tools can hamper its use in
661 politics. The current policies often support vested interests producing vague documents and
662 theoretical projects delaying effective change in the distant future.

663 To clarify the different notions of a green economy we provided a generic framework of
664 different theories, concepts and approaches and discussed their relation to weak and strong
665 sustainability. Depending on the solution chosen, required changes to implement green
666 economy strategies can be more or less incremental. Certain solutions are more compliant
667 with mainstream economy and require few changes, e.g., cleaner production defined as
668 adapted for efficiently green production, whereas other solutions are based on deep
669 transformations of our patterns of production and consumption like industrial ecology or
670 nature-based solutions that require large-scale investments into green infrastructure.
671 Regarding the feasibility of an actual implementation of the Porter hypothesis, we conclude
672 that the green economy decision makers might want to consider a more ecological economics
673 or strong sustainability stance if the win-win, green economy ideas of a thriving human well-
674 being within planetary boundaries are to come true. At this point major knowledge gaps exist
675 on how this shift will be implemented in practice. Different economic sectors also may
676 require different measures. This can be documented and guidance provided if specifically
677 addressed in future studies on greening economy.

678 **Acknowledgements**

679 The authors appreciate the funding of the “Green Economy Initiative” by the PEER institutes
680 “Partnership for European Environmental Research”.

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