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ASSESSING ENVIRONMENTAL SUSTAINABILITY OF PROJECTS WITH DIFFERENT TOOLS. A LIFE CYCLE PERSPECTIVE

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ABSTRACT

In recent years, industrial and civil projects and policies usually include improvement of sustainability performance. Many instruments, tools, and targets exist to assess environmental performance and sustainability. Life cycle assessment is one of the most used and robust tools. The aim of this analysis is to evaluate if different approaches can result in different environmental sustainability assessment results. Some case studies based on previous research are listed. Results of selected tools – carbon footprint, design for disassembly criteria, environmental product declaration targets, national targets of the Italian recovery plan, sustainable development goals, green chemistry principles, waste hierarchy objectives, material circular indicators – are compared to the outcomes of the life cycle thinking approach. The assessment of environmental sustainability performance of projects appears to depend on the tool used. Thus, the role of selected instruments, subjective choices, fair communication of results, and sustainability definition are investigated. Finally, future areas of study are indicated.

1. INTRODUCTION

In the last decades, international, national, regional, and local projects and policies have been more and more interested in improving sustainability. Environmental sustainability concept is historically derived from the awareness of resource scarcity in a world with finite planetary boundaries (Randall, 2021). Therefore, a critical and scientific approach to mitigate environmental impacts of humans' activities in Anthropocene and to preserve the planet is needed and not postponable to guarantee the conditions for a decent survival for future generations (Ekins, 2011). The governance of this epoch-making process includes an institutional approach (Genus, 2014) and policies that support technological changes (Rogge & Reichardt, 2016). In this context, the so-called "green policies" proposed by governments, industries, or citizens need to be scientifically analysed to evaluate their real effects and to assess their factual pros and cons for the planet. In fact, benefits of green policies and related green projects need to be confirmed by independent analyses of their environmental consequences. The ethical superiority of a strategy cannot be defined by preconceptions, but must be investigated, even in widespread and worldwide accepted environmental policies (Lavagnolo, 2020).

Therefore, the fair evaluation of environmental performance is a key issue open in the international debate. Different environmental projects can be evaluated with dedicated tools, instruments, targets, or indicators. Some tools refer to specific impacts; the carbon footprint methodology (ISO, 2018), for instance, computes global warming impacts of products, services, and processes, with a streamlined methodology (Bala et al., 2010) or a more complex analysis (Cherubini et al., 2016). Other tools are used to assess general product policies, from cradle to grave, as integrated product policies targets (IPP), environmental product declaration labels (EPD) (Rehfeld et al., 2007), disassembly strategies (Vanegas et al., 2018), green chemistry principles (Anastas & Kirchhoff, 2002), etc. Specific targets are used in territorial waste management: local circular economy vision usually refers to circularity indexes (Rufí-Salís et al., 2021) as well as local waste reduction and prevention strategies are strictly linked to waste hierarchy criteria (Nessi et al., 2013). Widespread sustainable development goals (SDG) support humans 'progress worldwide (Cernev & Fenner, 2020). National (Maranzano et al., 2021) and European (Crescenzi et al., 2021) targets measure actions of international strategies of member States. Many others assessment tools, indicators, and instruments exist worldwide to analyse products, processes, projects, or policies and to assess their environmental performance.

Among existing tools for environmental assessment of sustainability, life cycle assessment (LCA) (ISO, 2017)

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is one of the leading ones (Toniolo et al., 2020). The life cycle thinking (LCT) approach is promoted by the European Union. An investment is considered environmentally sustainable in Europe (EU, 2020) if it contributes substantially to one or more of the environmental objectives (climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, protection and restoration of biodiversity and ecosystems) but does not significantly harm any of the same environmental objectives (Article 17) and is carried out in compliance with the minimum safeguards (Article 18) and complies with established technical screening criteria and life cycle considerations (Article 16). The core aim is to guarantee that the decrease of an environmental impact in a step of the life cycle does not lead to rebound effects of increasing another environmental impact in another step of the life cycle. LCA studies cover the whole life cycle of product, services, and organization and therefore give comprehensive results. Many environmental aspects are assessed simultaneously, in a broader context. This might be useful to limit rebound effects from an environmental compartment to another (or among supply chain processes, design strategies, stakeholders, territories). LCA is often used for comparative studies. Therefore, it can be useful to compare different – real or planned – projects, policies, and scenarios. In recent years different environmental strategies have been analysed in a LCT perspective. Studies comprise many goals and scopes, including for instance product policies of packaging (Brock & Williams, 2020), recycling strategies and circular economy of construction and demolition waste (Iodice et al., 2021), local waste management and energy recovery (Burnley, 2019), integrated territorial management systems (Sisani et al., 2019) and international and normative strategies (Sala & Castellani, 2019).

All existing environmental assessment tools are based on similar pillars, but they focus on different aspects (Sassanelli et al., 2019; Visentin et al., 2020). Results of various assessment tools are not always overlapping. In fact, the instruments give specific results, depending on their principles, their limits, and the question they answer. Moreover, they may be considered individually or together because they might interact or overlap. Some studies on possible integration or combination between tools and LCA approach have been conducted in recent years. Sustainable Development Goals on responsible consumption and production have been analysed by an LCT perspective (Sala & Castellani, 2019), as well as green chemistry principles (T. L. Chen et al., 2020) and design for disassembly strategies (Joensuu et al., 2022). Integration among tools is studied also for circular economy (Q. Chen et al., 2022) and sustainable chemistry (Pleissner, 2018). However, at the state of the art, a consensus and integration on tools, indicators, and environmental performance is not yet reached.

This article proposes a method to investigate the possible use of life cycle thinking to assess the sustainability of projects in comparison with other environmental sustainability tools. Results of this method can be used both by decision makers and by academic stakeholders to investigate if the preferability of a policy depends on the indicator chosen, or not. Comments are provided based on existing literature research and case studies performed and published in the last two years. The overall aim of the study is to verify whether and how the results of different assessment tools for the same project are similar or not, and why. Moreover, some suggestions, advantages, and disadvantages of environmental evaluation in this perspective are proposed.

2. RESEARCH QUESTION AND METHODOLOGY

The core question of the research is how the environmental gains achievable with “Sustainable Development policies” can be assessed.

This study investigates if LCT and other environmental assessment tools can be usefully combined to assess the environmental sustainability of policies. This is in line with the EU taxonomy (EU, 2020) that promotes a broader approach - LCT based - for the assessment of projects. Therefore, for each policy and for each related case study, an environmental assessment tool (EA tool) and a LCT tool are chosen. Environmental performance and impacts are calculated, in each case study, both by the EA tool and by the LCT tool; results obtained are then compared to highlight similarities and discrepancies.

In detail, for this purpose, eight widespread sustainability policies at different levels are selected: global warming potential (GWP) reduction, integrated product policies (IPP) and Design for Disassembly (DfD), end-of-waste (EoW) strategies, national territorial policies for recovery and resilience (PNRR), international sustainable development goals (SDGs), general principles of greener production and green chemistry (GC), local waste reduction criteria, and circular economy (CE) objectives. These policies cover industrial and institutional sectors from small to large scale.

For the first three policies (GWP reduction, IPP, EoW), three product case studies are performed (see Figure 1).

The objective is to verify if improvement suggested by the policies through their EA tool (i.e., respectively, GWP reduction, DfD optimization, and EPD labelling) for the selected products really guarantee a decrease of environmental impacts in a life cycle perspective. Therefore, environmental indicators are calculated for the products with the quantitative methods defined by the international standards for GWP, DfD and EPD. Results of these indicators - in the three case studies - are then compared with complete LCA results for the same products (Figure 1), to verify if they are similar, different, combinable, or not.

For the other five policies, some key characteristics of policies themselves are selected, and five qualitative case studies are performed (see Figure 2).

The objective is to verify if improvement suggested by the policies through their EA tools (i.e., respectively, fulfilment of PNRR targets, achievement of SDG, use of GC principles, compliance with waste hierarchy criteria, improvement of circularity indicators) really guarantee a decrease of environmental impacts in a life cycle perspective. The aim is also to examine environmental advantages and dis-

Environmental policy	Product case study	Assessment of environmental sustainability priorities with two different quantitative methods	
		Environmental Assessment tool (EA)	Life Cycle Assessment (LCA)
Global warming potential (GWP) reduction	Comparison between a standard plastic-package with an eco-package (Camana et al., 2021a)	Calculation of the carbon footprint (CF) of the two products and comparison of results (ISO, 2018)	Complete LCA study for the two products and comparison of results (ISO, 2017)
Integrated product policies (IPP)	Study of environmental impacts of an exhibition stand and comparison with an older stand (Toniolo et al., 2021)	Use of design for disassembly (DfD) criteria to evaluate environmental performance of the stand (ISO, 2020)	Complete LCA study and carbon footprint analysis (ISO, 2017; ISO, 2018)
End of waste policies (EoW)	Study of environmental impacts of a concrete from recycled waste (Camana et al, 2022a)	Calculation of concrete environmental product declaration (EPD) (ISO, 2006; EN, 2012)	Complete LCA study including all life cycle steps for the concrete (ISO, 2017)
Interpretation of results	→	Comparison of obtained results with the two methods	
		Are environmental gains achieved by the policy both according to EA tool and to LCA tool? Are EA results and LCA results for each "product case study" similar, different, combinable?	

FIGURE 1: List of product-policy case studies.

Environmental policy and details of the policy case study	Assessment of environmental sustainability priorities with two different qualitative methods	
	Environmental indicators	Life Cycle Thinking approach (LCT)
Territorial policies Critical analysis of the Italian recovery and resilience plan (PNRR) (Camana et al. 2021b)	PNRR Italian targets (IT, 2021)	Each Italian target is analysed to assess environmental aspects and life cycle steps included in it. The PNRR investments are assigned: (i) to different matrices (energy, air, water, waste, soil-biodiversity) according to the most significant environmental impact involved; (ii) to different phases of the life cycle (design, production-use, end of life, integrated) according to the predominant supply chain step. This classification allows to view which matrices and which stages of the life cycle are most closely monitored by the legislator and which are neglected.
Responsible production and consumption Analysis of SDG12 with a LCT approach (Camana et al., 2020)	Sustainable Development Goals (SDG) (UN, 2015)	SDG12 is analysed to assess environmental aspects and life cycle steps integrable with the goal. A systematic review of 89 Italian papers is performed: (i) to assess if LCA is useful to define and to measure performances of SDG 12 at local level; (ii) to indicate LCT possible uses. Economic, social, and institutional aspects assessed by LCA studies are shown and many other environmental tools that overlap (as CE, CF, etc.) are presented. Pros and cons of LCA methodology are studied.
Greener production Analysis of green chemistry studies with a LCT perspective (Camana et al., 2022b)	Green chemistry (GC) principles (Anastas et. al, 2002)	Each GC principle is analysed to assess environmental aspects and life cycle steps integrable with it, and vice-versa A literature review is performed, to investigate: (i) contributions that LCT may give to green chemistry, and vice-versa; (ii) possible points of integration between green chemistry and environmental policies.
Waste reduction Analysis of existing research in Italy on waste management (Camana et al., 2021c)	Waste hierarchy criteria (Khandelwal, 2019)	LCT theory: advantages and disadvantages of waste hierarchy use in a life cycle perspective are investigated. A systematic analysis of 381 papers on Life Cycle Thinking tools used for local waste management in Italy is conducted: (i) to investigate how these instruments are applied for assessing territorial waste policies; (ii) to show methodological characteristics and future progresses.
Circular economy Analysis of existing research in Italy on circular economy (Camana et al., 2021d)	Circular economy indicators (CE) (Ellen McAr., 2015)	LCT theory: advantages and disadvantages of circular economy improvement in a life cycle perspective are investigated. A systematic analysis of 609 papers is conducted: (i) to explore the main tools, topics, and sustainability issues of waste studies in Italy; (ii) to propose a critical approach LCT based on.
Interpretation of results →	Critical analysis of obtained results with the two methods	
	Does compliance with environmental indicators of the policy permit the reduction of many other environmental aspects in a LCT approach, or not? Are indicators results similar, different, combinable with LCT results, or not?	

FIGURE 2: List of case studies on policies targets.

advantages of "green" policies with a LCT approach. Does fulfilment of PNRR targets guarantee a decrease of environmental impacts? Are SDGs and GC principles appliable in many life cycle stages to promote better environmental performance? Does compliance with waste hierarchy criteria and with circularity priorities permit the reduction of many other environmental aspects, or not? Therefore, in each case study, environmental aspects usually included (or excluded) in the policy and life cycle steps included (or excluded) in the policy are listed (see Figure 2 for details of methodology). This qualitative analysis permits to highlight rebound effects in different environmental impacts or life cycle stages. In fact, if some environmental aspects or supply chain steps are neglected in the policy, the connected environmental impacts are also neglected in the policy itself; this might lead to neglect relevant environmental impacts for the policy, in a LCT perspective.

More details on data collection, calculations, methodology, and limitations of each case study can be directly found on previous published research (as reported in the 1st column of the Figure 1 and Figure 2).

In this paper, results obtained are analysed and discussed in four steps. Firstly, the different case studies conducted are briefly summarised and commented. Secondly, based on obtained results, different outcomes and communication strategies for stakeholders are outlined and discussed. Thirdly, a special focus on overall sustainability is proposed. Limitations of methodology and future steps are finally suggested.

3. RESULTS AND DISCUSSION

3.1 Comparison between environmental instruments in selected case studies

In the first step of this analysis, a summary of the results of the conducted studies with different tools is provided: carbon footprint (Camana et al., 2021a), design for disassembly (Toniolo et al., 2021), environmental product declaration (Camana et al, 2022a), Italian targets (Camana et al. 2021b), sustainable development goals (Camana et al., 2020), green chemistry principles (Camana et al., 2022b), waste hierarchy criteria (Camana et al., 2021c), circular economy indicators (Camana et al., 2021d). Results both from environmental assessment tool – or target or indicator – and LCT tool are briefly shown in Figure 3. More quantitative details are available in original publications.

In the eight case studies, according to the environmental assessment tool typically used to evaluate the policy, environmental gains are always achieved (as it is evident in the third column of the Figure 3). This result is obvious. In fact, projects are built by producers, stakeholders, or politicians to comply with the EA tool, with the purpose of claiming their project as “sustainable”.

The broader approach used in this research indicate, on the other side, that environmental gains are dubious or not achieved in six case studies, when an LCT tool is used (as it is shown in the fourth column of the Figure 3). In fact, the analysis of the selected case studies shows that, even if a particular tool (as DfD or CF or CE) evaluates a project as environmentally advantageous, not all impacts are reduced for the same project in a life cycle thinking perspective. Therefore, results of different environmental assessment indicators are rarely overlapping. This is mainly because each tool refers to a particular environmental impact (for example carbon emissions) or life cycle stage (for example recycling process or disassembly strategies). If all environmental impacts and the whole life cycle are considered, rebound effects and trade off often occur.

Consequently, different tools can result in different evaluation of the environmental performance of projects in a LCT perspective. Therefore, instruments might be coupled and combined to provide a more comprehensive perspective of environmental impacts of products, services, organisations, and territories. In fact, for same impacts, different tools provide similar outcomes while in the overall assessment, different tools provide different results. Interconnections among tools permit to use the best characteristics of each method to improve the reliability of the other method and finally, to afford environmental, industrial, and engineering problems with a more comprehensive approach. This allows to use results, knowledge, and expertise of different frameworks together and to apply them to different projects.

3.2 Subjective choices and communication strategies

The choice of an environmental assessment tool to assess the environmental sustainability of a process/system/project is therefore not neutral. In fact, as shown, different indicators and assessment instruments give diverse environmental assessment. The choice of an environmental assessment tool, de facto, gives importance to a particular environmental aspect or to a particular stage of the life cycle of the project analysed, as shown in Figure 4.

A decision maker can select the environmental assessment indicator that investigates the environmental aspect that he prefers, disregarding other impacts. Paradoxically, a decision maker could choose the indicator that gives best results, avoiding indicators that outline negative environmental consequences. These choices can be aware or unconscious and can lead to greenwashing.

LCA, that is a comprehensive approach, can help to have a more complete picture of environmental aspects in different compartments (air emissions, resource use, land consumption, waste management, etc.) from the cradle to the grave of the project. Therefore, LCA is confirmed as a good tool for environmental assessment of projects.

However, LCA methodology has also many hypotheses in its development (burdens, impact categories, grouping and weighting, etc.) and therefore the subjectivity of choices is anyway unavoidable. Limits of the LCA methodology are the strong dependency to data availability and the presence of many assumptions such data quality, selection of the software, allocation choices, trade-off, methodology chosen, etc. Consequently, good sensitivity analysis and uncertainty analysis are crucial to give consistency to declarations. One important limit of LCA is that if some aspects are neglected, the risk is the burden shifting of impacts in time or space and the inconsistency of overall results for improving better conditions for all people and for resource decoupling (Camana et al. 2021d).

A simplified or streamlined LCT approach can be also used to analyse projects. Limitations and advantages of a full LCA or a simplified LCT approach are given in Table 1.

A simplified LCT approach is used in the European strategy for national recovery and resilience plans with the Do No Significant Harm principle (DNSH) that states that the actions may not cause any significant harm to the environment. The purpose is that each project accessible to EU funds must protect and improve one environmental goal, without get worse any of the environmental goals,

Legenda According to the tool used:
- Environmental gains are **achieved**
- Environmental gains are **dobious**
- Environmental gains are **not achieved**

	Case study	Overall comments	EA Tool Results	LCT results
Quantitative Studies	Plastic-package and eco-package	Results of CF must be combined with LCA results to include all others environmental impacts (not only GWP)	CO_2 emissions and carbon footprint are minor for the eco-pack than for the standard pack	A single aspect does not cover the complexity of many environmental impacts (for example, ozone depletion impact is minor for the standard pack than for the eco-pack)
	Exhibition stand	The use of LCA permits to analyse not only the positive effects of reuse and recycling (supported by DfD) but also the negative ones	The new designed exhibition stand has better Design for Disassambly (DfD) characteristics than the old one	The better DfD characteristics of the new stand do not improve all environmental impacts of the stand (for example reuse should be improved to diminish carbon footprint and recycling impacts must be included and computed)
	Concrete from recycled waste	Results of EPD must be integrated with LCA results for other life cycle stages not included in the EPD	An EPD is well achieved by the producer and directly usable in the market	Results of complete LCA studies are different to EPD results since they consider all impacts and all phases (regarding for example transports, end of life, trade off)
Methodological Studies	Italian recovery and resilience plan (PNRR)	Targets of PNRR do not guarantee improvement of environmental sustainability in a LCT perspective	Italian targets of PNRR are met in accordance to EU guidelines	LCA can provide suggestions to analyse weaknesses of policies (for example, environmental payback time in building sector that influence environmental sustainability of civil investments)
	SDG12 - food production and consumption	An LCT approach can support SDGs improvement since it permits to quantify advantages in environmental matrices	Sustainable Development Goals and targets can be achieved modifying policies	LCA is useful to define and to measure performance of SDGs and reduction of impacts, providing quantitative analysis
	Green chemistry studies	An LCT approach can support GC policies by including all life cycle steps and environmental aspects in GC principles	Green chemistry design and 12 GC principles improve performance of products/processes	LCT and GC might be positively integrated in theoretical and practical case studies
	Research in Italy on waste management	LCT theory is helpful to analyse weaknesses and strengths of waste hierarchy strategies	Waste hierarchy can be addressed by territories and municipalities	The waste hierarchy does not always guarantee the best environmental performance (for example impacts of separate waste collection and of the transport to the recycling plants can be environmentally relevant and can nullify advantages of waste recycling)
	Research in Italy on CE	LCT theory is helpful to analyse weaknesses and strengths of CE strategies	Circular economy (CE) can be positively addressed by territories	The CE projects do not always guarantee the best environmental performance (for example if prevention policies are neglected and social trade off nullify possible environmental advantages since consumerism attitude does not change)

FIGURE 3: Summary of results of studies.

based on an existing Annex of Taxonomy (EU, 2020). This is a clear regulatory commitment to life cycle thinking approach. However, solution proposed by governors to evaluate sustainability of projects seems weak. In fact, neither full LCA studies nor existing LCA research are suggested by EU policies, but only a simplified, streamlined, and integrated approach. Without quantitative results of LCA studies, the risk of bias, subjectivity of choices and greenwashing is very high (Table 1) for policies that claim to be greener than others.

For all these reasons, there is a need of minimum requirements also for LCT studies, deriving from this research. Some suggestions include: (i) clear definition of hypotheses; (ii) sensitivity analyses on hypotheses; (iii) comments on impacts and life cycle stages; (iv) use of existing quantitative studies ad similar case studies; (v) independent third-part review.

3.3 Sustainability of projects

Sustainability does not comprehend only environmental issues, but also economic and social concerns (Camana et al., 2021e). In addition, the importance given to

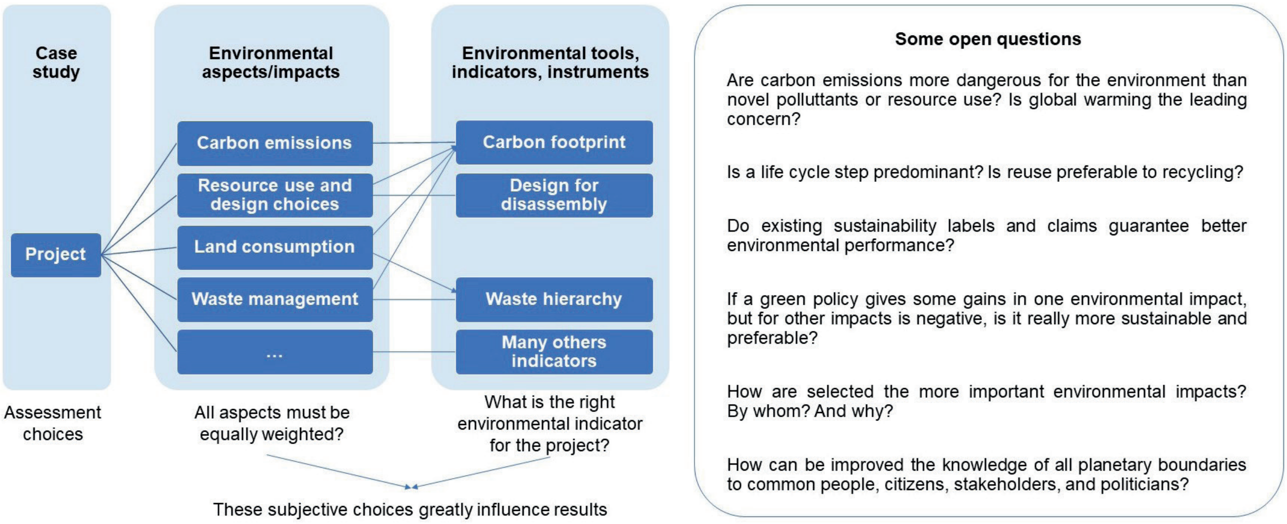

FIGURE 4: Environmental sustainability assessment of projects: subjectivity of choices.

each aspect can be subjective. Therefore, the sustainability definition depends on priorities given by the analyser or by the policy maker. Consequently, sustainability is not only a scientific and mathematic approach, but also includes ethical choices that greatly influence results. The definition of "sustainability" or "sustainable development" is not unequivocal (Somogyi Zoltan, 2016). Commonly, the three-pillar method is used, including environment, society, and economy. Many other pillars might be added – see for example SDGs - and each pillar can be differently weighted. When comparison between projects is undertaken, areas investigated, tools used, strategies implemented, should be explicated. An example of sustainability assessment using life cycle sustainability is shown in Figure 5.

As seen, value choices are present in the whole assessment process. Many instruments have been tested and numerous guidelines have been provided in the years to promote the sharing of data on sustainability among different non-expert stakeholders, including governors, entrepreneurs, and citizens (Camana et al., 2021e).

The concept of sustainability is widespread and abused in communication, including in the institutional statements. For example, a product is said to be sustainable if it has a lower carbon footprint than another, or a policy is said to be sustainable if it is simply circular. However, results of this research highlight that the environmental assessment indicator usually proposed for the policy is sectorial (as GWP, CE, DfD, EPD etc.) and does not analyse all environmental impacts and life cycle steps. The choice of the environmental indicator greatly influences preferability results. The same applies to the other aspects of sustainability (economy, society, health, etc.) that are also more qualitative and debatable and where are present subjective choices and values. This concept needs to be honestly communicated to citizens to avoid institutional misunderstanding, people manipulation, and policies of greenwashing at every level.

TABLE 1: Advantages and disadvantages of a streamlined LCT approach, based on existing case studies.

	Full LCA	Simplified LCT approach
Advantages	Integrated approach Internationally standardised method	Integrated approach Easy to perform
Disadvantages	Time and resource consuming Need of expertise, skills, and software Strong dependency of results on assumptions	Risk of bias Subjectivity of choices Risk of greenwashing

The key role of fair communication strategies to stakeholders – and of the clear definition of limitations and assumptions for each indicators chosen - is crucial to avoid misinterpreting, greenwashing, and untruthful green policies. Without this transparency the debate at local, regional, national, or global levels risk to be distorted and open to manipulation.

Probably, to avoid misunderstanding and greenwashing, in the scientific approach it might be preferable to limit the use of the word "sustainability". Results of this research show that it is preferable and more reliable to refer - for each case study - to the diminution of many environmental aspects in a life cycle perspective instead of claiming environmental sustainability of policies referring only to their environmental indicator (as PNRR targets or EPD achievement).

In the sustainability assessment process other qualitative aspects deserve attention, for instance, the debate on sustainable degrowth of environmental impacts and economic paths (Jaeger-erben & Hofmann, 2019; Lorek & Fuchs, 2013; Lorek & Spangenberg, 2014), the crucial role of prevention activities to diminish humans' footprint (Shaw & Williams, 2018), the social aspects (Charis et al., 2018) as well as Universities and academic participation (Qu et al., 2021) and solidarity principles (Gutberlet et al., 2020).

3.4 Limitations of methodology and future steps

This study explores a list of policies and case studies. Of course, this list is not exhaustive and other environmental territorial strategies can be investigated in future analyses. Moreover, other environmental assessment tools, indicators, or criteria may be examined for the same policies or for other selected strategies. However, both the quantitative approach (Figure 1) and the qualitative approach (Figure 2) proposed are flexible and can be used for different tools, case studies, and LCT research in other case studies in the future.

Thus, some general suggestions for future analyses, based on the methodology proposed in this paper, are highlighted: (i) to promote studies of other projects, targets, and policies; (ii) to investigate relationship among other different environmental assessment tools; (iii) to define minimum requirements of quality of studies and of ease of reporting of the studies to private and public stakeholders; (iv) to improve communication strategy for sharing complex data, including ethical priorities in sustainable development; (v) to include social aspects that are crucial to achieve sustainability improvements; (vi) to verify if improvements are marginal or significant for their scope of preserving planet for future generation; (vii) to encourage independent review process – that include also the critical analysis of the tool used - for all project evaluation that are relevant for policies.

4. CONCLUSIONS

In this research eight environmental policies are selected and the environmental performance of each case study, using life cycle assessment in comparison with other environmental assessment tools, is analysed and commented (based on previous publications) in a wider perspective. Results reveal that different assessment instruments give different preferability outcomes. Firstly, some environmental assessment tools investigate only selected aspects (as global warming potential for carbon footprint), and other instruments are focused only on selected life cycle steps (as environmental product declaration that does not include end-of-life impacts). With a comprehensive life cycle approach all impacts and steps are involved, and outcomes of case studies reveal that, even if LCT indicators are combinable with sectorial indicators, they permit a more complete analysis and may show different preferability options in the other aspects included. Secondly, life cycle approach allows also to investigate pros and cons of different policies: this has been tested for circular economy, waste management strategies, targets of the Italian recovery and resilience plan, and design for disassembly strategies. Thirdly, the possibility of a quantitative assessment for sustainable development goals and green chemistry criteria by using the life cycle approach, is highlighted. For each tool investigated, it emerges that fair communication of choices, burdens, and limitations are essential to provide transparent data to stakeholders. If subjective choices are unavoidable – both in environmental indicators and in economic and social aspects – they should be clearly explained and motivated to give consistency to results. In particular, the critical analysis of the environmental tool chosen for the assessment of projects that are relevant for public policies should be fully transparent, motivated, and detailed, to avoid greenwashing. The comparative methodology proposed is flexible and usable to assess sustainability of other projects, tools, and policies. Results obtained can be used both for future theorical research and for practical choices by different stakeholders.

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