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Responsible Research and Innovation (RRI) is a currently important proposal for doing science and innovation with and for society. Sustainability has for the last 30 years had a similar function in providing limits and direction for societal activities, including science and innovation. In this discussion paper, we ask what RRI can learn from sustainability and how RRI and sustainability can strengthen each other, focusing especially on social sustainability. We suggest that the social life cycle approach of the United Nations Environmental Programme and the Society of Environmental Toxicology and Chemistry may address the product aspect of RRI, provide resources for governance in the face of the problem of anticipation, facilitate a useful value-chain approach and offer several other benefits in an RRI perspective. Conversely, we show that RRI can complement sustainability models by more specifically addressing the responsibilities of the different actors involved in the research, innovation and marketing process.

Keywords: social sustainability; social life cycle assessment; responsible research and innovation; life cycle assessment

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Introduction: RRI and sustainable development

The concept of Responsible Research and Innovation (RRI) has become increasingly important in science and innovation policy. It represents an attempt at redefining what is termed the Social Contract for Science in what Owen, Macnaghten, and Stilgoe (2012) describe as a move away from 'Science in Society' towards 'Science for Society'. The European Commission (EC) has embraced the concept, expressing the relationship as 'Science with and for Society'.[1] The EC highlights the importance of RRI as a ''cross-cutting issue' in Horizon 2020, which will be promoted throughout Horizon 2020 objectives'[2]. RRI is also embraced by national research funders e.g. in the Netherlands (NWO), the UK (the EPSRC) and in Norway (the Research Council of Norway). RRI is rapidly gaining traction as a general policy goal in European research and innovation policy.

RRI builds on established traditions such as research ethics, studies of Ethical, Legal and Social Aspects of new technologies (ELSA), technology assessment (TA) and Science

[1] http://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society
[2] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation

and Technology Studies (STS), but the new conceptualization has spurred a large amount of new research and development work (von Schomberg 2012, 2013; Stilgoe, Owen, and Macnaghten 2013; Grunwald 2011). RRI is a general approach to science and innovation, but the discussions have largely revolved around how to make responsible technology development and governance decisions when new technologies generate novel consequences where we have limited means for scientific knowledge for risk assessment. How to tackle the inherent uncertainties generated by new technologies is therefore a main motivation for developing RRI approaches, but also a main challenge for RRI approaches in practice.

An important issue for RRI is the notion of a 'responsibility gap'. This refers to a situation inherent in innovation where there is no single agent who considers herself or himself singularly blameworthy for negative impacts or damages to others because '[i]nnovation is not a simple, linear model with clear lines of sight from invention to impact, and where accountability for such impacts can be traced. It is an undulating path, sometimes with dead ends, involving many, often loosely-connected actors' (Owen et al. 2013, 33).

Another foundation for RRI is a forward-looking notion of responsibility. Henry Richardson (1999) and Luigi Pellizzoni (2004) have developed such notions from different grounds. Richardson's notion of prospective responsibility suggests that responsibility transcends rules and demands that a responsible agent responds to novel situations. Pellizzoni proposes four categories of responsibility, developed in the context of policies for environmental protection, of which two have an anticipatory nature. The two retrospective responsibility dimensions are liability and accountability and the two anticipatory dimensions are conceptualized as care and responsiveness. Pellizzoni argues that the radical uncertainties we are facing today render liability and accountability as weak instruments for ensuring environmental protection. Moreover, he claims that the belief in a state that truly cares for the environment started to shatter in the 1950s-1960s, leaving responsiveness as the most potent responsibility strategy for environmental protection in the light of uncertainty. Central RRI scholars such as Owen and Stilgoe have emphasized the importance of care and responsiveness in their accounts of RRI.

Much discussion about RRI has so far focused on overarching principles of responsibility; e.g. what does it mean to act in a responsive and reflexive way and how should this be accomplished. Von Schomberg shows that responsibility in the context of science and innovation has a process and product side (von Schomberg 2013). Examples of the process side are Owen et al.'s four main dimensions of RRI; that the innovation process needs to include anticipation, reflection, deliberation and responsiveness (2013, 38). Examples of the product side are that products should be 'ethically acceptable, sustainable and socially desirable' (von Schomberg 2013, 64). The requirement of being socially desirable also relates to the notion of 'right impacts of research' (von Schomberg 2013, 56). Von Schomberg suggests that products should be evaluated and designed with a view to normative anchor points 'with a high level of protection to the environment and human health, sustainability, and societal desirability' (2013, 65).

The process and product sides of RRI are not clearly separated, but refer to different perspectives or emphases. The process side (i.e. how to do anticipation, stakeholder involvement, etc.) is much explored. Such topics are central in the TA and STS fields, which are important foundations for RRI. The product side, with its focus on the specifics of particular outcomes of innovation, has been more explored in economy and environmental sciences, and remains less discussed in the RRI field. This makes it interesting to allocate more attention to it in RRI.

In order to address the product side an RRI informed integrated risk-benefit assessment could be developed, though this could clearly not be a traditional risk-cost-benefit analysis (Owen et al. 2013, 29). The right impacts approach stresses that such benefit assessment cannot simply be a matter of economic benefits to the company or contribution to GNP; generating right impacts involve responding to societal needs (von Schomberg, 2013, 56). Such societal needs must be identified by society and/or stakeholders without prior framing from one disciplinary perspective (such as economics). Current RRI approaches do not include specific procedures for the assessment of benefits versus risks. However, the sustainability tradition may offer tools for this.

Sustainable development has been an important political goal since the United Nation's (UN) World Commission on Environment and Development. In their report *Our Common Future,* published in 1987, it is defined as meeting 'the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development 1987, 43). It is commonly held that economic development, social development and environmental protection are interdependent and mutually reinforcing components of sustainable development (UN 1997, 23).

There is a 30 year long discussion about sustainability assessment and numerous models for calculating *economic* sustainability (economic impact assessments) and *environmental* sustainability (most importantly life cycle analysis) are developed (Stern 2007; Finnveden et al. 2009; EPA 2012; Morgan 2012). Social life cycle assessment approaches have also been developed, addressing the *social* dimension of sustainability. These practical approaches to sustainability assessments appear prima facie relevant for assessing benefits and risks in an RRI perspective since the social sustainability dimension explicitly address societal values, goods and risks.

To date, it is mainly the environmental LCAs that have been considered for assessment of emerging science and technologies. Here, a range of new ways of applying data and new assessment processes have been promoted (Wender et al. 2012; Wender et al.

2014b). The resources of social sustainability have not been sufficiently explored as a way to facilitate responsible development and governance of new technologies.

Social sustainability has mostly been connected to issues concerning developing countries (Littig and Greissler 2005; Dillard, Dujon, and King 2009). However, our starting point in this article is that S-LCA may currently have more resources for RRI than currently acknowledged. As we have seen above, sustainability already has a place in an RRI framework, but it has so far not been much developed. We will therefore here explore resources for addressing the product side of RRI, and we will do this by combining RRI (emphasizing the responsible agent) with the notion of sustainable development (more specifically in the form of social life cycle assessment (S-LCA)). In the paper we will discuss how S-LCA and RRI may strengthen each other with regard to developing the RRI perspectives on assessments of specific product developments or innovation projects.

In the following we will first present some important approaches to social sustainability assessment, centering in on S-LCA, and present some key challenges to this approach. Then we will discuss whether S-LCA is at all applicable in an RRI perspective, and in particular in the context of new technologies. We will proceed to discuss the value in the RRI context of taking the value chain perspective that S-LCA allows, followed by a discussion of other potential benefits. In the conclusion we summarize how we have made the case for the value of S-LCA for RRI.

Social sustainability assessments as an integrated product assessment approach

As with the concept of sustainability generally the concept and content of social sustainability is not unequivocal or easily operationalized. Several approaches to social sustainability and its assessment exist, and different scholars and institutions emphasize different fundamental concepts of social sustainability. Magis and Shinn (2009) highlight human well-being, equality, democratic government and democratic society as central aspects of social sustainability. Littig and Dreisler (2005) focus on basic needs, quality of life, social justice and social coherence, and suggest that (paid) work and the inclusion of women in work should be the preferred strategy to fulfill such goals. McKenzie (2004, 12–13) underlines equity (of key services and between generations), cultural values, participation, socialization systems, and a sense of community as social mechanisms to identity and fulfill needs and to facilitate participation. Colantonio (2009) documents a change from 'hard indicators' as Gini, employment and GNP to 'soft indicators' as happiness and sense of place in the debates on the content and meaning of social sustainability. Murphy (2012) finds that the different discourses on social sustainability can be grouped together under the four categories 'equity', awareness for sustainability', 'participation', and 'social cohesion'.

On the policy side the World Economic Forum (WEF) defines social sustainability as 'the institutions, policies, and factors that enable all members of society to experience the best possible health, participation, and security; and that maximize their potential to contribute to and benefit from the economic prosperity of the country in which they live' (Bilbao-Osorio et al. 2013, 59). In this article we do not find it useful to present a specific unequivocal definition of social sustainability, but take a pragmatic approach by referring to approaches that are presented as social sustainability approaches.

WEF further proposes to measure social sustainability by three main categories, each with three sets of indicators. The first category is 'Access to basic necessities', understood as 'Access to sanitation, access to improved drinking water, and access to healthcare services'. The second category is 'Vulnerability to shocks', understood as 'Vulnerable employment as a percentage of total employment, the extent of informal economy, and social safety net protection'. The last category in WEF's understanding of social sustainability is 'Social cohesion', measured by the income Gini index (income inequality), social mobility, and youth unemployment (Bilbao-Osorio et al. 2013, 58–63). However, in these accounts it is not clear how the social sustainability approach may assist in specific evaluations of products. But more resources exist. Catherine Benoît and Gina Vickery-Niederman take a broader stance in a review of social sustainability tools and identifies six main types of references and instruments as relevant to social sustainability assessment: ‘International Policy Frameworks, Codes of Conduct and Principles, Sustainability Reporting Frameworks, SR Implementation Guidelines, Auditing and Monitoring Frameworks and Financial Indices’ (2010, 7). In addition, the Life cycle initiative of the United Nations Environmental Programme (UNEP), in collaboration with the Society of Environmental Toxicology and Chemistry (SETAC), set up a working group that developed a more product-oriented approach to social sustainability assessment (Benoît Norris & Revéret 2015). This approach, developed in 2009, is particularly relevant as it has been developed in a comprehensive process involving experts and stakeholders, and is consequently not only the suggestion of an individual social sustainability research group. The approach uses established models for Corporate Social Responsibility (CSR) as a starting point for social sustainability assessments.

Describing this approach, Benoît and Vickery-Niederman explain:

> We can look at CSR in a horizontal manner, where the focus is on the impacts of ‘one’ organization, often the end producer or brand. We can also look at CSR in a vertical manner, where the spotlight is on the impacts associated with a product life cycle. The term ‘product’ refers to both goods and services. By definition, a product’s life cycle includes ‘all stages of a product system, from raw material acquisition or natural resource production to the disposal of the product at the end of its life, including extracting and processing of raw materials, manufacturing, distribution, use, re-use, maintenance, recycling and final disposal (i.e., cradle-to-grave)’ (2010, 4).

They explain that the horizontal view has been dominant in CSR, for instance in ISO 26 000[3] and Global Compact,[4;5] and suggest that 'adopt[ing] a product life cycle view for the assessment of social responsibility, looking at impacts one product at a time, may be new in several business contexts.' (2010, 5). The main benefit of a social sustainability assessment is, in Benoît and Vickery-Niederman's view, that '[s]ocial Life Cycle Assessment provides added value to the evaluation of Social Responsibility because it provides a comprehensive and targeted analysis of a product's social footprint. When enterprises adopt a product life cycle perspective, they prevent the shifting of negative impacts from one life cycle stage to another, or from one social issue to another.' (2010, 5). It should be noted that social life cycle analysis is only one alternative approach to social sustainability assessment,[6] but that it is held to be particularly useful as it is easily combinable with environmental LCA, making the tool truly integrative (UNEP-SETAC 2009; Franze & Ciroth 2011). S-LCA follows the ISO 14040 and ISO 14044 frameworks on Life Cycle Analysis in Environmental Management.[7]

The UNEP-SETAC S-LCA approach is structured by stakeholder groups and social impact categories. There are two types of impact categories. Type 1 impacts are those actually studies in the S-LCA and 'represent social issues of interest that will be expressed regarding

[3] ISO, 26000 Social responsibility, http://www.iso.org/iso/home/standards/iso26000.htm
[4] Global Compact. Geneva: UN. http://www.unglobalcompact.org/AboutTheGC/TheTenPrinciples/index.html.
[5] We would suggest that the horizontal view also is dominant in RRI, where 'one organization' may be, for instance, a research team.
[6] Others include combinatory approaches between environmental and social analysis as the social and environmental life cycle assessment (SELCA) (O'Brien, Doig, and Clift 1996) and the SEEbalance (Schmidt et al. 2004); the development of Social Impact Indicators (Brent and Labuschagne 2007); focus on social acceptability (Assefa & Frostell 2007), on business and human rights (Ruggie 2008); on urban development (Cuthill 2010); and on subjective and objective wellbeing (Stiglitz, Sen, and Fitoussi 2009). For a review of different types and developments of social life cycle assessments, see Fan et al. (2015).
[7] ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework, http://www.iso.org/catalouge_detail?csnumber=37456; ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines, http://www.iso.org/catalouge_detail?csnumber=38498;

the stakeholders affected and may cover health and safety, human rights, working conditions, socio-economic repercussions, cultural heritage and governance' (UNEP/SETAC 2009, 71), while type 2 impacts are connected to human capital, cultural heritage and human well-being. The main literature on and tests of S-LCA looks at type 1 impact (Wu, Yang and Chen 2014; Garrido et al. 2016), so the current study will limit itself to type 1 and refer to these as 'social impacts'. Social impacts are defined as 'consequences of positive or negative pressures on social endpoints (i.e. well-being of stakeholders).' (UNEP-SETAC 2009, 44). Subcategories of impacts are the basis of an S-LCA assessment and each particular assessment project needs to explicitly consider these. The subcategories are socially significant themes or attributes that are classified according to stakeholder and impact categories and are assessed by the use of inventory indicators, measured by unit of measurement (or variable). Several inventory indicators and units of measurement/reporting types may be used to assess each of the subcategories. Inventory indicators and units of measurement may vary depending of the context of the study (UNEP/SETAC 2009, 44).

Wender et al. (2014a) criticize traditional LCA for lacking an emphasis on stakeholder engagement. In contrast to such traditional LCA approaches the UNEP-SETAC S-LCA approach opens up for stakeholder engagement for identification and ranking of impacts (see figure 1). In the UNEP-SETAC S-LCA approach the impact categories have a central place that serves to ensure the inclusion of stakeholders. It is stated that 'the impact categories should reflect internationally recognized categorizations/standards […] and/or result from a multi-stakeholder process.' (UNEP/SETAC 2009, 44). That social/socio-economic subcategories are related to the general stakeholder categories facilitates operationalization and ensures the comprehensiveness of the framework (see figure 1).

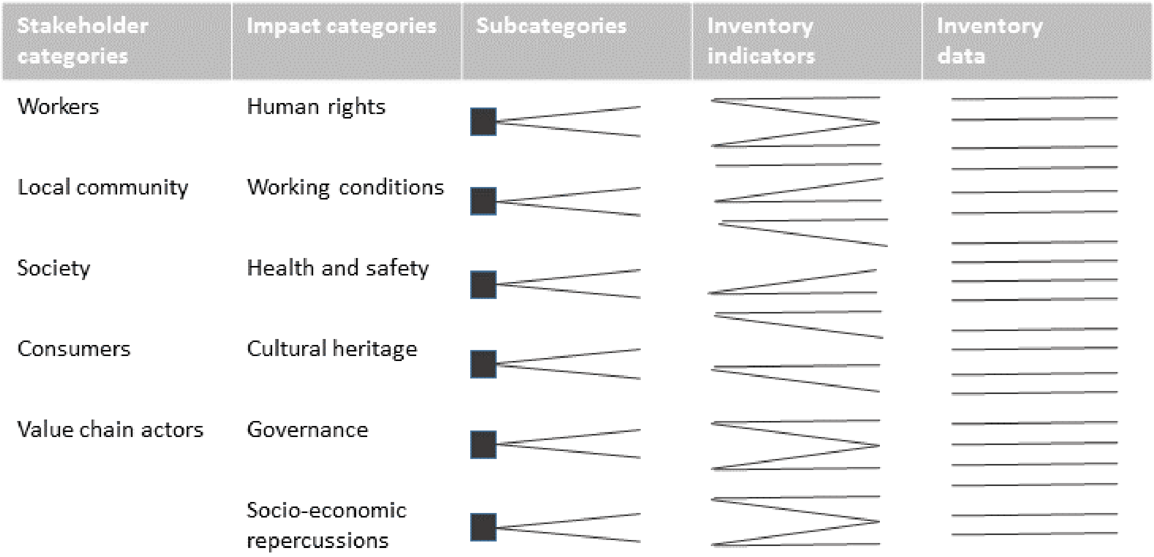

Figure 1. Assessment system from categories to unit of measurement from UNEP-SETAC (2009, 45).

Examples of specifications of the stakeholder ‘local community’ are access to material resources, access to immaterial resources, delocalization and migration, cultural heritage, safe and healthy living conditions, respect of indigenous rights, community engagement, local employment and secure living conditions. Similar examples are given for the other stakeholders (Benoît Norris et al., 2013). The strength of such a list is that it does not only include process recommendations (such as community engagement), but also specific impact requirements (such as secure living conditions).

Many details need to be established when carrying out such an assessment. In the case of mass products certain use scenarios must be established. Where information on more specific use scenarios is lacking or for the purpose of learning in order to avoid potential negative impacts or create positive impacts, as in the case of technologies of an emerging character, there is also an option to conduct so-called ‘hotspots assessments’, which are on a more generic level. Similar to the environmental LCA, the hotspot assessment start out with generic data in order to uncover the need for more specific data in the assessment process (Benoît Norris, Norris & Aulisio 2014).

A hotspots assessment mostly provides information about where controversies and problems are most likely to be found. This may also help to identify the greatest improvement potentials. A Social Hotspots Database (SHD) has been developed providing data for S-LCA assessments (http://socialhotspot.org/). This database can allow users to screen for social risks and opportunities in order to focus the data collection strategies. UNEP/SETAC (2009, 60) suggest that uncertainty levels for social hotspots assessment should be assessed in the future in order to indicate validity and reliability of hotspot assessments. Revéret, Couture and Parent (2015, 47) see the hotspot assessment as suitable for upstream analysis of value chains.

Pelletier et al. (2016) use the hotspot assessment method on the macro-scale in order to investigate social risks connected to traded commodities to the 27 EU countries and conclude that 'the life cycle-based approach provides insight as to the distribution of risk along supply chains, which may be low in the sector of a given country exporting products to Europe, but high overall for those products due to the social risks associated with the supply chain activities that support production in that sector' (Pelletier et al. 2016, 7). This suggest that the S-LCA has usefulness in discovering distributed risks that might shed light on future production.

An obvious strength of the S-LCA approach is its proximity with Environmental LCA. The S-LCA is in principle possible to combine with Environmental Life Cycle Analysis (E-LCA) and Life Cycle Costing (UNEP/SETAC 2009, 16; 76–77). This renders possible integration between the different dimensions of sustainability (Ciroth & Franze 2011). In the European EST-Frame project, the current authors found that although sustainability figures as an overarching value in most assessment reports in the field of emerging technologies, it was seldom operationalized and the social dimension was particularly hard to integrate (Thorstensen et al. 2013).

The S-LCA is a decision support resource. Its primary use is for ‘collecting, analyzing and communicating information about the social conditions and impacts associated with production and (in some applications) consumption’ (Benoît Norris, Norris & Aulisio 2014, 6974). The outcomes of an S-LCA application can be used in policymaking, for company-internal development and improvement, for measuring distributive justice, and for assessing and comparing the ‘social footprint’ of companies and products (Benoît Norris, Norris & Aulisio 2014). Jørgensen, Dreyer and Wangel (2012) show that the use S-LCA can impact for example workers through two mechanisms. The first is that outcomes from an S-LCA can influence how a given company produces, and the second mechanism is then how a given company conducts itself towards its employees and the local community. Consequently Jørgensen, Dreyer and Wangel differentiate between three different types of S-LCA: a consequential S-LCA that ‘presumably creates its effect through *influencing the production levels in companies*’ (2012, 829); a lead firm S-LCA that seeks to create impacts through influencing the behaviour of a given company; and an educative S-LCA that uses both mechanisms. The S-LCA can cause changes through both mechanisms and through their combination. However, as Jørgensen, Dreyer and Wangel point out, all these three specifications of S-LCA create new challenges for the S-LCA method.

Problematic points and current discussions in S-LCA

There are many discussions about still problematic points in S-LCA and we will here address some of the most important.

Andrea Colantonio (2009) points out that the notion of ‘social sustainability’ is itself in change and since it is approached by different disciplines for different purposes a common definition is difficult to achieve (see also our overview of different approaches above).

The institutional logic of a Life Cycle Assessments is also discussed. Heiskanen (2002) claims that in the case of LCA, we see the world through the eyes of a social planner. Similarly, according to Hobson and Lynch (2015), S-LCA carries with it an epistemology based on ecological modernization; ‘the convergence of environmental interests and state imperatives’ (Dryzek et al. 2003, 165). In contrast to this, however, is the claim that the reconfiguration of the LCA method in the social domain is a social innovation (Benoît Norris & Revéret 2015). Arie Rip states: ‘[a]s with technological innovation, a social innovation is new and uncertain, and distributed. Because of the many and varied inputs, the eventual shape of the innovation will be a *de facto* pattern, with dedicated inputs. To get taken up, institutional changes and sub-cultural changes (where different actors have to change their practices) are necessary’ (2014, 8). Thus, an S-LCA approach does not need to imply a linear, rigid view on development and does not necessarily conflict with more ecologically based approaches (Deblonde 2015). Rather, the S-LCA has a potential to ‘realise […] a locally feasible and globally justifiable humane and sustainable response to a context-specific sustainability challenge’ (Deblonde 2015, 28) within the social domain.

The challenge of stakeholder involvement in practice has been addressed by several scholars, including Benoît Norris and Revéret (2015) and Mathe (2014). Mathe (2014) points out that the normative impact categories presented in the UNEP-SETAC guidelines might not be intelligible for stakeholders at a local level, and that the role and identification of stakeholders varies between different projects. Mathe states: ‘Stakeholders may be considered in four ways: (1) as LCA method users, (2) as LCA result users, (3) as victims or beneficiaries of impacts, or (4) as actors in the definition of either the types of relevant impact or more generally LCA methodology’ (2014, 1508). Arcese, Di Pietro and Guglielmetti Mugion (2015) suggest that in order to develop a practical implementation of stakeholder inclusion in S-LCA, it is necessary to identify the service or the product that is to be produced. Wender et al. (2014a) also point out a need for additional methods for identifying and engaging with stakeholders in S-LCA.

Mathe (2014) develops a five-step method for selecting stakeholders for S-LCA. As a first step, she follows Gene Rowe and Lynn Frewer (2000) in using the criteria impact, legitimacy, and completeness for identifying and selecting stakeholders. The second step is a literature and data review that will serve to 'reveal the social principles and impacts which are the most significant for stakeholders' (Mathe 2014, 1511). The input from step one and two are then investigated by a S-LCA team that creates a list of social principles and impacts, which in the fourth step is discussed with the stakeholders identified in the first step. The fifth and last step is first a literature and database review of the outcomes from the fourth step followed by a choice of impact indicators by the researchers for the case in question. This approach responds to a call in this journal for '[e]xchanges between local problem-solving initiatives and rather globally oriented professional knowledge and know-how' (Deblonde 2015, 29).

Another issue for debate has been the normative foundation for the assessment of impacts. The UNEP-SETAC S-LCA provides such a normative foundation for its assessment of impacts. However, Arvidsson et al. (2015) point out that some of these normative foundations are ambiguous and should be better grounded in the scientific literature, just as environmental LCA is based on natural science. They show that there are assumptions on the effects of working hours, child labour, and property rights in the UNEP-SETAC S-LCA that lack refinements and are – in their present description – not sufficiently fine-grained to account for combining the potential positive and negative aspects of country variations in working hours, child labour, and property rights. They suggest that S-LCA should be amended to account for both ambiguous social topics and unambiguous ones. Whereas Arvidsson et al. might be right in their theoretical point, it seems that the S-LCA will lose relevance if the demands for theoretically informed viewpoints should take up too much place in the actual performance of an S-LCA.

Similarly, Pizzirani, McLaren and Seadon (2014) address the importance of including cultural specificities and values at an early stage in LCAs in general, and for S-LCA in particular. They recognize that S-LCA to some extent have tools to address aspects of culture, but agree with Hutchins and Sutherland who claim that S-LCA ‘have tended to focus on social measures that are closely linked to environmental issues (e.g., human health) as opposed to the impacts on the culture and institutions of a society’ (2008, 1689). Susanne Freidberg suggests overcoming the difficulty in including cultural values through recognition among LCA-practitioners that they themselves are the agents conducting an assessment instead of presuming a ‘view from nowhere’ (2015, 3). The issue of culture and cultural values can to a certain extent be solved by the reflexive method suggest by Mathe (2014) for stakeholder inclusion. The advantage of Mathe’s stakeholder approach over LCA-practitioners engaging in cultural anthropology, is that one avoids a reified view on culture, and places cultural conditions as a possibility for development and sustainability (Sen 2004 & 2007).

Fan et al. formulate the following main challenges for S-LCA: ‘(1) the definition of human well-being; (2) the selection of social indicators for SLCA; (3) the preference of site-specific data or generic data; and (4) the method for quantifying the social impacts’ (2015, 4). With regard to the topic of site-specific vs. generic data, this is connected to the ambition in S-LCA to be able to conduct comparisons. Access to specific data might be most relevant to study specific cases, but the process of obtaining these is cumbersome and might also jeopardize the quality of the comparative ambitions (Jørgensen et al. 2009).

With regard to the other challenges identified by Fan et al., this is acknowledged also by UNEP-SETAC. It is clear that many methodological aspects are still debated and will continue to be debated, both in principle and also in practice in specific assessment projects. For instance, the following decisions must be taken, all of which can be easily contested:

- Step 1. Describe the product by its properties including the product's social utility.
- Step 2. Determine the relevant market segment
- Step 3. Determine the relevant product alternatives.
- Step 4. Define and quantify the functional unit, in terms of the obligatory product properties required by the relevant market segment.
- Step 5. Determine the reference flow for each of the product systems. (Weidema et al. 2004 in UNEP/SETAC 2009, 53)

Thus, though S-LCA appears to have many benefits Benoît and Vickery-Niederman (2010, 13) acknowledge that 'standalone social LCA methods have advanced to the point where it is left with many of the same issues as Environmental LCA', namely:

(1) The challenges of tracking down site specific data
(2) The challenges of integrating location sensitive information
(3) The challenges of integrating information collected at different scale (from general sectors to specific unit processes)
(4) Developing characterization method (Benoît and Vickery-Niederman 2010, 13).

Such uncertainties would have to be faced no matter the tool, but a more fine-grained approach (such as the one presented here) may be better positioned to more clearly specify the relevant uncertainties and therefore suggest more specific research or knowledge generation needs.

Is S-LCA at all applicable for RRI related to emerging technologies?

The methodological challenges within the social sustainability field should not discourage us from considering how we could take advantage of its resources in the RRI field. The above accounts of social sustainability indicate that the dimension of social sustainability correspond with RRI's focus on creating right impacts and right products. Moreover, an advantage of the social sustainability dimensions as opposed to the environmental and economic varieties is that substantive values such as autonomy, well-being, freedom and fairness are inherently integrated into this dimension (Reitinger et al. 2011). S-LCA approaches and methodologies are continuously evolving and we will therefore here not focus on reviewing the validity or viability of details of the UNEP-SETAC model. For our concern here it is the principled viability of S-LCA approaches in RRI that is the issue.

The most interesting set of criticism against S-LCA for our purposes is the claim that LCA in general is not useful for studying emerging technologies. These sets of criticisms are generally raised in the environmental LCA context.

There are several varieties of this objection. Braden R. Allenby (2013) observes that technology systems do not have life cycles. With reference to Freeman and Louçã (2001), Allenby explains that technology systems refer to the combination of science, technology, economics, politics and culture, and suggest that since LCAs do not aim at such a complex level this is an important limitation in the approach. However, these would be arguments against assessing an emerging technology system as such, but not against assessing specific applications of emerging technologies.

Berube (2013) voices skepticism towards the use of LCA in nanotechnologies since so much is unknown about nanotechnologies, because of incompleteness of data and because there is no real place for societal concerns in LCA. Berube's concerns can be met with by references to other studies. Gavankar, Suh, and Keller (2012) find 14 LCAs of manufactured nanomaterials, but none of them meet the ISO 14040 standard for LCA since many are limited to material and energy flow, lack focus on the use and end phases, and/or avoid issues as nano-specific fate, transport, and toxicity. However, in contrast to Berube, Gavankar, Suh, and Keller call for an integration of Life Cycle Inventories with data on nanomaterials and show that even if there currently are no complete LCAs on nanomaterials such a task is possible.

Ness et al. (2007) propose to analyze sustainability assessments according to a temporal dimension in order to tackle the problem of uncertain future consequences. In their analytic framework, indicators are based on retrospective analysis while integrated assessments are anticipatory. In between these two dimensions lie the product-related assessments. With reference to Ness et al. (2007), Hischier and Walser write: ‘For engineered nanomaterials, product-related assessment tools make the most sense, as this category consists of tools that focus on production and consumption of physical goods and services’ (2012, 272). Hetherington et al. (2013) point to similar concerns as Gavankar et al., but continue to propose an overview of an LCA process for emerging technologies based on case studies of nanotechnologies, biofuels, and novel foods. Hetherington et al. recommend using an early stage LCA in order to discover environmental hot spots.

Wender et al. (2014b) make a similar point about the possibility of doing LCA of emerging technologies that are experiencing rapid rates of innovation even as they mature: ‘critical data are unknown or highly uncertain, including: technology-specific commercial-scale manufacturing inventories, use-phase product performance, end-of-life disposal pathways, life cycle material releases, and risk-relevant properties’ (Wender et al. 2014b, 10532). Focusing on environmental LCA they claim that no amount of increased effort in inventory data collection will yield representative data sets. In their opinion a more process-based approach, such as their anticipatory LCA, is useful in such a situation. Wender et al.’s framework does not directly address social issues, but is concerned with how to achieve transparency and increase validity in making anticipatory environmental LCA under uncertainty. This is an approach to environmental sustainability that

> is not predicative, but rather systematically and iteratively explores uncertainties across the life cycle of an emerging technology to prioritize research with the greatest potential for environmental improvement and contributions to responsible innovation by redirecting a technology's development pathway (Wender et al 2014b, 10536).

In our opinion, this is approach is more process- than product-focused and is not a competitive, but a complementary approach to the UNEP-SETAC approach. While Wender et al. focus on environmental responsibility, the UNEP-SETAC approach focuses on societal goals. Moreover, their proposal confirms that useful approaches to tackle uncertain consequences of emerging technology can be developed.

The viability of using *social* LCA in the context of emerging technologies is less discussed. While advocating further study into S-LCA, Cummings, Frith and Berube (2013) state that LCA has a highly deterministic view of technology and its social use, but that in reality the use phase and the end-of-life phase of products are often different from what has been anticipated. Further, they stress the products' influence of the whole of the social lives of citizens and consumers. Such end-of-life uncertainty would need to be accounted for within the S-LCA, and S-LCA should be carried out in an iterative way, with stakeholders broadening the range of end-points considered, as exemplified in Mathe's (2014) stakeholder approach and/or Wender et al.'s (2014b) anticipatory governance LCA. In this way S-LCA should be considered a process, even if it is oriented towards products.

Finally, in an RRI perspective, any prospective LCA in general should be able to address the difficult issue of abstaining from producing specific goods. The 'no-development option' is an integrated part in Social Impact Assessment (SIA) (Vanclay 2003). Although the

SIA provided input to the social indicators to S-LCA (Benoît Norris et al. 2011), the later developments of the S-LCA methodology do not seem to consider the 'no development option'. However, this can be included in further developments of the method.

In sum, it does not appear that any of the objections raised towards LCA are sufficient to disregard S-LCA's potential significance as an RRI tool. Methodological development is ongoing and RRI scholars should provide input to this discussion in order to contribute to refining S-LCA as a tool for RRI. S-LCA is not about preparing for a future that is just like today or radically different because of technological or societal changes, but rather a well-informed estimation of well-known processes in the present that are projected into current and future production chains. S-LCA is rather about increasing the epistemic quality of the information available for making considered judgements in the face of uncertainty, which is a crucial concern in RRI (see e.g. Gunnarsdottir and van Dijk 2015). The combination of a specified process, a clear purpose, inclusion of stakeholders, available data and a transparent framework are all factors that can improve the assessment of a given product.

The usefulness of a value-chain approach in RRI

In the above discussion, we have suggested that S-LCA is a relevant approach for considering the product aspect of RRI. After having considered the objections to applying S-LCA for emerging technologies we would in this and the following section like to highlight the strengths. Here we will in particular highlight the fact that emerging technologies often enter into society in the form of more complex products (for instance nanoparticles as part of paint) that contain diverse components; many of which are from conventional technologies. With reference to the issues 'responsibility gap' of 'organized irresponsibility', 'division of moral labour', and 'forward-looking responsibility' (Richardson 1999; Beck 2002; Pellizzoni 2004; Shelley-Egan 2010; Owen et al. 2013), we will present how S-LCA can be used to map and discover how and where different social impacts of technologies might occur. Here we will therefore present the benefits of S-LCA for considering RRI for emerging technologies in a value-chain approach.

The LCA and S-LCA concept allows for addressing not only (for instance) the nano part of the product, but also all aspects of the product, which allows for a more authentic assessment of the product that is enabled by the emerging technology. S-LCA analysis may potentially reveal a great complexity of impacts, where in many cases (at least in the nanotechnology context) only some can be attributed to the nanoparticle used in the product. A case study of a laptop computer provides a good example on how this can be done in practice (Ekener-Petersen and Finnveden, 2013). Ekener-Petersen and Finnveden apply the UNEP-SETAC S-LCA on the total social impacts of a 'generic' laptop computer through a hotspots assessment of the countries involved in the production. Using a Bill of Materials, a service providing information on the materials and assemblies of a given product which is available by different providers,[8] Ekener-Petersen and Finnveden identified the resources used in a laptop, and the material categories were divided into specific materials according to data from the Global e-sustainability initiatives.[9] The main supplying countries of these materials were identified through existing datasets on supply chains and resource extractions.[10] The countries were divided into their activities in the different phases. The authors then highlighted the countries in the worst and second worst quartile and in addition marked the countries with no available data. The authors summarized the findings according

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[8] See EuP Ecodesign Preparatory Study - Computers and Monitors http://www.ecocomputer.org/ or Intertek's Bill of MaterialAssessment Services http://www.intertek.com/green/bom/

[9] See for example the Global e-sustainbility initative's project reports http://gesi.org/ICT_sustainability_studies_and_reports

[10] RESOLVE 2010, GreenhouseGasMeasurement.com 2008, Ecoinvent (www.ecoinvent.org), U.S. Energy Information Administration 2013

to the activity (low>high) and the number of identified hotspots and divided them into countries with both high activity and severe impacts.[11]

We can here see that related to value chains, the S-LCA approach would allow scrutiny of what role new technologies play in concrete product developments. Are they used in products with clear societal benefits, or do they contribute to products that are controversial or lack societal benefits? This may help make responsible decisions in the face of uncertainties of the long-term environmental impacts of the emerging technologies themselves.[12]

The laptop case demonstrates that S-LCA can be used to address the 'responsibility gap' that might accompany complex products. Firstly, the responsibility of the researchers that have contributed with the element of interest, for instance the nanoparticle, is highlighted. Secondly, it becomes apparent how the effects of the nanoparticle will be modulated by other aspects of the product. There needs therefore to be a certain distribution of responsibility of the final product over the manifold of actors involved. So including social sustainability in RRI may help establishing 'responsibility teams' in value chains. We believe it is necessary to discuss further the notions of value chains in discussions of RRI.

When doing this it might be found that the different notions of responsibility as set out by Richardson (1999) and Pellizzoni (2004) are mobilized. For some impacts (such as occupational health) and some agents, there will be accountability and liability requirements. For other impacts, such a cultural heritage, the notions of care and responsiveness, may be more appropriate.

[11] A similar example is provided by France and Ciroth (2011). In their investigation of a laptop, they address the production of lithium-ion batteries.

[12] Please note that to add a value chain approach to RRI does not imply excluding system approaches to grand challenges. In the case of biofuels as a mitigation effort to climate change, a pure LCA approach will not be able to address all the indirect effects, such as indirect land-use change or rural development, that might occur (McKone et al. 2011; Boucher, Smith & Millar. 2014). In cases where there are a range of diverse impacts, these should be considered and assessed as complex systems with internal interactions, and this is beyond the scope for an S-LCA.

Other benefits of using S-LCA in RRI

In the above section, we saw that S-LCA could be helpful for articulating responsibilities in the value chain. It can provide instruments for assessing the product side of RRI, whether or not the product itself is an application of an emerging technology (e.g. a genetically modified crop) or it is part of a more complex product (paint with nano particles). Here we will mention several other potential benefits of applying S-LCA in the context of RRI.

(1) S-LCA could contribute to partially solving the problem of uncertainties of harms and benefits of emerging technologies. We can here distinguish between uncertainties about current and future harms and benefits. With regard to current uncertainties, some of the impact categories allow addressing social structure issues that may be immediately affected by the introduction of new technologies (a new genetically modified plant, a new nano-enhanced packaging material, a new nano-remediation project), in particular: human rights, working conditions, cultural heritage, governance and socio-economic repercussions. In other words, even if we do not have information about long-term health and environmental effects we can still possess significant information about what current social effects a technology/product may cause. For instance, will they cause worry in the affected societies/cultures? Will they contribute to making people more autonomous or making societies more democratic? Will they increase economic differences, for instance by reinforcing power in supply chains? Clarifying such issues may show a pattern of impacts that is clear enough to make governance decisions even if longer-term scientific uncertainties reign in several areas.[13] Admittedly, there may be problems with gaining this kind of social data, but stakeholder processes may give sufficient insight for the assessment purpose. The

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[13] Though we do not suggest that it an S-LCA will provide solutions in all cases.

UNEP-SETAC report provides guidance on a number of such methodological points. Moreover, gaining information on the existence of relevant democratic and knowledge generating institutions (universities, research facilities, schools) will also provide a basis for considering the acceptability of future risks. When local societies have such capacities they will be better able to monitor, and potentially handle, future risks, while societies without this infrastructure will be much more vulnerable.

(2) Another apparent benefit of S-LCA is to allow for more refined assessments of potential impacts of science and innovation. It may for instance turn out that it is responsible to produce and market an innovation in one country, but not in another. This will depend upon the social benefits (work and income for local communities, enhanced technological infrastructure, etc.) and the social risks (the lack of appropriate governance infrastructure, the breach with cultural heritage, etc.). Such information may reduce the risk of the actor (an innovator, a state department, etc.) universalizing one's own cultural heritage and making assumptions about the conditions in the receiving end. For instance, marketing GM plants is opposed by the majority in Norway, but experience tells us that other countries find GM variants ethically acceptable and not in conflict with their cultural heritage.

(3) S-LCA can also contribute in showing potentials for values-sensitive design (van den Hoven 2013). When looking at a generic product it will become clear what the hot issues will be and measures can be taken at the design phase to counteract negative side effects. For instance, if the availability of ground water is a problem in the intended producing countries, measures can be taken to reduce water expenditure in the production process. Or, if patent protection of the innovation will seriously reduce the benefits to local societies, the responsible innovator can agree to licensing deals or patent pooling systems that ensure such benefits. Similarly, S-LCA can be used as an

instrument in midstream modulation (Fisher, Mahajan, and Mitcham 2006; Fisher and Rip 2013) or Real Time Technology Assessment (Guston and Sarewitz 2002). As a mechanism for upstream assessment, the hotspot variant may be the most appropriate version (see Revéret, Couture & Parent 2015).

(4) In the report of the Expert Group on the State of Art in Europe on Responsible Research and Innovation (Jacob et al. 2013) an approach based on standards, like the S-LCA, is endorsed as one possible and recommended way forward since it could be effective and transparent while minimizing risks for interference on issues like non-tariff and/or technological barriers to trade – and as such could constitute an instance of 'trading-up', i.e. that stronger local/regional/national environmental regulations lead to an environmentally qualitatively improved global exchange of goods and services (Vogel 2003).

(5) We would also like to suggest that a benefit of taking a product/project oriented perspective is that public deliberations may become more fruitful. Thorstensen (2014) shows that public deliberation on too generic technology narratives is problematic because it appears to reinforce stereotypes that are not related to specific technology applications, and are therefore not very informative when it comes to governance questions related to emerging technologies. The ethics of emerging technologies may remain abstract for lay people until they can see the impacts of specific products/projects. Doing an S-LCA assessment with stakeholders and/or lay people may provide a substantive framework for discussion.

(6) S-LCA provides one way to operationalize ethical concerns in RRI. Ethical concerns are frequently voiced with regard to emerging technologies and such concerns have been interpreted by a number of researchers (Allhoff et al. 2007; Lein Kjølberg and Wickson 2010; Gordjin and Cutter 2013). RRI is meant to involve taking

responsibility for such ethical issues and S-LCA can assist here. Ethical concerns related to emerging technologies can very crudely be split into three categories; inherent concerns about the acceptability of manipulating (and not showing respect for) human beings, animals or the environment; concerns about equality, equity or justice; and concerns about human and environmental safety and security and how to have responsible governance in the face of uncertainties and ambiguities (Forsberg 2007). We will argue that all three kinds of concerns can be informed by S-LCA and the same concerns can be used to further develop the S-LCA as an ethical resource. First; intrinsic concerns may be argued to form a part of different societies' cultural heritage. Perceiving genetic modification of plants as tampering with creation is a cultural expression. Acknowledging this does not diminish the force of such arguments, but it does mean that they can be placed under 'cultural heritage' in the UNEP-SETAC framework. Second; concerns about justice may be addressed under 'socio-economic repercussions' and by studying the balance between the impacts of products on different stakeholder groups (the innovating company and different stakeholders). Third; uncertainties about risks and benefits are considered in the determination of impacts; including social, environmental and economic impacts.

(7) Finally, S-LCA might also be able to assist in anticipation. RRI has an inherent temporal dimension. Anticipation of potential futures, as Guston (2014) suggests, is not to be confused with prediction, and prediction is not the strength of any LCA – including the S-LCA approach (Wender et al. 2014a). If RRI is interpreted as being essentially about societal deliberation on future scenarios of technologies not yet developed, the S-LCA framework is not likely to be useful. However, for instance the European Commission Directorate General for Research and Innovation sees RRI as a broader framework to be applied in ongoing applied research and innovation projects.

Since users hold RRI to be applicable in current research and innovation, RRI should then not be limited to varieties of forecasting. S-LCA seems to be applicable both in the context of current technology applications and in longer-term applications. On the S-LCA side the UNEP-SETAC report states that the framework can be used for generic products, using hotspots and other heuristics tools, besides for specific applications. This means that the framework can be used before the final product system is determined (i.e. the end-product with all its component parts). The level of specificity of the framework can therefore be adapted to the stage in the technology development. We would like to suggest that such a generic framework would enhance reflection on potential future impacts in potential future use scenarios. The S-LCA assessment scheme does not in itself address future generations, but such an anticipatory dimension may easily be integrated by including future generations as a stakeholder in the assessment tool.

Concluding reflections

We have above indicated several ways in which S-LCA can strengthen RRI. RRI, on its side, can strengthen social sustainability as it addresses explicitly the responsibilities of agents in the innovation system. This is important for mobilizing actions on different levels, by different actors and at different times. However, will such detailed assessment frameworks as S-LCA turn off potential subscribers to RRI? RRI is not supposed to be a purely academic exercise, but supposed to be acceptable also to individual researchers, innovators and other stakeholders. Will such complex assessment mechanisms turn off private companies? Will mapping out such a complexity of impacts put people off RRI instead of motivating them? Further research should be carried out on the reception of different RRI approaches among stakeholders.

The methodological uncertainties of the S-LCA may be another reason for not using this in RRI product assessments. However, it is not necessarily better to refrain from systematically gathering information just in order to avoid the uncertainties related to the results. Abstract discussion, decoupled from real world information, may yield interesting arguments, but may still be less informative for the making of decisions, - which will be made whether we believe we have sufficient information or not. Other alternatives to social assessments are also available and some have been considered in this article (e.g. Wender et al. 2012 and Deblonde 2015). These should be considered as complementary tools in a toolbox rather than competitors to S-LCA. However, an advantage of S-LCA (in the UNEP-SETAC version) is that it is more established in broad institutions than the many other approaches.

We have here argued that sustainability, and in particular social sustainability, can provide resources for the current RRI discussion. Methods from the social sustainability field may inform both the process and the product side of RRI, but relatively established approaches are already in place for the process side (Owen et al. 2012). Thus, the benefits of S-LCA apply especially when considering the product-side of innovation. As sustainability focuses on the state of development and not on the particular responsible (or irresponsible) agent, sustainability and RRI seem to complement each other. Here we showed one example of a promising S-LCA approach. Further research should be conducted systematically evaluating the strengths and weaknesses of different approaches in an RRI context, but perhaps more important would be to establish forums for learning between social sustainability scholar and RRI scholars. Both working towards a better future from slightly different angles, it seems there are many synergies to harvest from joining the two discourses.

In conclusion, we believe that when RRI is becoming central in European research policy and funding it is necessary not to forget the important domain of sustainability. A focus on responsibility cannot come at the cost of a focus on sustainability. Rather the two must be seen together. This article has been an attempt to do this.

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