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Everyday Industry—Pragmatic approaches for integrating sustainability into industry decision making

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A B S T R A C T

Many sustainability evaluation tools exist, but few are used on a day-to-day basis within the process industries to help project teams make better decisions regarding process and product improvements. This article presents collated experiences and views from the EU process sectors on the ‘state-of-the-art’ of sustainability evaluation tools, highlighting the differences between the practical use of such tools in an industrial setting versus simplified ideal-world case studies. The review was performed as part of an EU cross-sector project, ‘STYLE’, through formation of an international consortium, reviewing current practice, testing of sustainability evaluation tools in industry case studies, academic validation of tools’ functions and features, and stakeholder consultations. Consequently, a proposal is made regarding the high-level features and functions of a toolkit to address gaps and shortfalls in currently available tools and identification of useful features that could be implemented more widely. The proposed toolkit framework consists of a three-stage process:materiality setup, qualitative screening and semi-quantitative assessment. Recommendations are also made regarding further research and tool development needs, requiring collaboration between sustainability expertise and ‘soft’ sciences to address barriers to tools being used regularly and broadly across industry.

Keywords: Industry; Sustainability assessment; Tools; Decision making

1. Introduction

In an ideal world, sustainability would be at the forefront of everyone’s mind, influencing everyday decisions from your choice of beverage, to your mode of transport for your daily commute. In industry, all employees would consider the ‘big picture’ of sustainability in their decision-making. The process industries, which are responsible for making

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ubiquitous materials such as steel, cement, and chemicals, but also for over 50% of global industrial CO_2 emissions (Worrell et al., 2016), would start implementing best practices autonomously, with sustainability indicators embedded into process modelling software. Meaningful sustainability indicator data would be plentiful, sustainability assessment tools easy to use, and methods consistent across business units, supply chains and process sectors.

However, in real-life industry settings, sustainability evaluations compete with a myriad of other business demands and face significant challenges for meeting the right balance of being easy enough to perform and still producing meaningful, useful output data. The European STYLE Project ("Sustainability Toolkit for easy Lifecycle Evaluation") was developed to address the challenge.

STYLE brought together views from across the EU process sectors to establish what sustainability evaluation tools currently exist and to make recommendations for future developments required to increase the uptake of tools in day-to-day industrial operations.

Today, a wide range of tools are available for tackling different types of questions in sustainability assessments. A sustainability assessment tool is defined here as an artefact that assists with the implementation of a method, whereas a method is a procedure to measure and compare the sustainability performance of a technology. Tools include spreadsheets for single indicator optimisations (e.g. carbon footprinting), software for comprehensive Life Cycle Analyses and simple questionnaires to help designers select different materials.

STYLE considered the use of sustainability assessment tools by process industry project teams developing new technological improvements to their products and processes. These project teams are focused around scientists and engineers from research, development and manufacturing areas, facilitated by a project manager with input from other business areas and broader stakeholders. These are crucial groups and individuals to engage as they are in a position to influence sustainability with their development decisions. However, sustainability is often not their top priority, with issues such as short-term manufacturing troubleshooting taking precedence. If an organisation has sustainability specialists, they are rarely present in every project team, and many smaller organisations will have no-one dedicated to sustainability at all. Consequently, STYLE focused on the following specific scenario:

'A project team is evaluating options for a resource or energy improvement for their process or product and they need a pragmatic tool to check the broader sustainability implications of each technological solution.'

For this scenario, the goal is to find tools that can help teams manage projects, with sustainability embedded, rather than specialist sustainability assessment tools. In practice, a single tool is unlikely to meet all the requirements of the project teams, hence STYLE sought to identify a toolkit containing the most appropriate type of assessment tool for each stage in the project timescale.

In this context, this paper aims to present collated experiences and views from the EU process sectors on the 'state-of-the-art' of sustainability evaluation tools as gained in the STYLE project. Differences between the practical use of such tools in an industrial setting versus simplified ideal-world case studies are highlighted, and recommendations and research needs for building a toolkit meeting the STYLE scenario are presented. This paper thereby contributes to the further development and industrial uptake of sustainability assessment tools.

Methodological details are described in Section 2 of this paper. Further sections discuss the project's results, covering the identified challenges facing industry (Section 3), insights for using sustainability to aid day-to-day industry decision making (Section 4), recommendations for the STYLE toolkit (Section 5) and further research needs to meet this pragmatic STYLE scenario (Section 6).

2. STYLE methodology

STYLE was a two-year project funded under a 2014 Horizon2020 SPIRE call, coordinated by Britest (www.britest.co.uk). The STYLE consortium brought together industry and research partners from across the process sectors represented by SPIRE (www.spire2030.eu)—Solvay (Chemicals), Tata Steel (Steel), LafargeHolcim (Cement), ArcelorMittal (Steel), Carmeuse (Minerals), Veolia (Water), Britest (Chemicals), IVL, RDC Environment and Utrecht University. This cross-sector approach was deemed extremely valuable by enabling both the identification of common ground for a single solution, as well as areas that require certain subsectors or scenarios to be evaluated differently, e.g. where a product is sold for its function, rather than on a volume or weight basis.

The STYLE consortium also worked in collaboration with other stakeholders and SPIRE projects, and built on outputs from previous European research (FP7 and FP6) projects and industry initiatives, e.g. FP7-SYNFLOW (including the development of using 'Sustainability Drivers' to guide project management Lapkin et al., 2016) and SOVAMAT (www.sovamat.org). To help address wider challenges for sustainability evaluations, STYLE synchronised stakeholder activities with other SPIRE projects, namely the MEASURE Project (www.spire2030.eu/measure –focused on comprehensive LCA studies) and the SAMT Project (www.spire2030.eu/samt –focused on industrial best practices).

To establish the STYLE recommendations for a Toolkit, the following approach was taken:

2.1. Tools survey

An online survey of >120 stakeholders (from industry, academia, governmental and non-governmental organizations) across the STYLE, SAMT and MEASURE projects produced an initial inventory of >50 sustainability tools and methodologies that were in use or known to respondents (SAMT, 2017).

Analysis of the survey and additional desk research, led by IVL, indicated that there were no 'off-the-shelf' publicly available tools that met all the needs of the STYLE scenario. Tools were categorised and shortlisted for most closely meeting the needs of the STYLE scenario, or for having specific features of interest. In-house tools, developed and used by some of the STYLE partners (Solvay, Tata, Veolia and LafargeHolcim) were also added to the inventory, to allow analysis of features that could be incorporated into a generic open access Toolkit.

Table 1 – STYLE industry tested tools.

Tool	Testing rationale
Solvay (in-house)	Qualitative screening tool—closely aligned with STYLE scenario usage. Developed for chemicals sector, primarily for process improvements. Testing cross-sector applicability/issues.
Tata Steel New Product Development Tool (in-house)	Qualitative screening tool—closely aligned with STYLE scenario usage. Developed for steel sector, considers products' positive impacts, not just their burden. Testing cross-sector applicability/issues.
LafargeHolcim Integrated Value Assessment Tool (in-house)	Quantitative assessment tool for project portfolio analysis in cement sector. Includes monetisation of financial, socio-economic and environmental impacts and benefits. Testing cross-sector applicability/issues, approach to incorporating social factors and transparency on methodologies used.
Veolia Water Impact WiiX Tool (publicly available)	Quantitative online assessment tool for water footprinting. Testing online interface and potential for specialist modules for hot-spot analysis.
InEDIC eco-design checklist	Qualitative questionnaire designed for the ceramics sector. Testing simple screening approach for hot-sport identification and cross-sector applicability/issues.
CCaLC v2	Simplified quantitative LCA tool, primarily focused on carbon footprints. Testing whether simplified approach is accessible for day-to-day usage by non-specialists and in early project phases.
Ecolizer Ecodesign Tool	Simplified LCA tool for designers. Testing visual interface, simplification of results and how value-chain end-users make decisions using sustainability data.
EPS Externality Cost Model	Excel spreadsheet for converting environmental impacts into externality costs. Testing potential to convert indicators into common unit (i.e. money) to aid decision making.
Social Hotspot Database	Online tool for assessing social impacts of supply chains. Testing methods for incorporating more social factors into sustainability assessments.
PSILCA Product Social Impact LCA	Social impacts database, which can be integrated into LCA tools. Testing methods for incorporating more social factors into sustainability assessments.
IPIECA Community Grievance Toolbox	A resource to help develop procedures to manage complaints and grievances from communities surrounding manufacturing sites. Highlights methods for capturing how local community will be impacted by a change in a process or product (in manufacture or use).
Product Social Impact Assessment Screening Tool	Qualitative and semi-quantitative tool for assessing social impacts associated with manufacturing products and the wider benefits of product use. Testing methods for incorporating more social factors into sustainability assessments.

2.2. *Stakeholder workshops*

Three stakeholder workshops were held to allow broader discussions with >100 stakeholders into the issues raised in the questionnaire survey. The workshops helped characterise the likely users of the Toolkit, discuss issues with currently available tools and establish key features and functions of the ideal toolkit. Stakeholders identified lists of categories for critiquing and specifying tools and proposed examples where tools have demonstrated good approaches, even if for applications away from sustainability evaluation (e.g. Google Analytics approach to results/ data visualisation). Challenges of using existing tools in industry, as raised by stakeholders, are presented in Section 3 of this article.

2.3. *Industry testing*

Industry partners, led by Tata Steel, tested 12 short-listed tools on real-life case studies, specific to their own organisations and sectors. Table 1 lists the tools tested in this phase of the project and the rationale for their selection. Industry partners and stakeholders flagged the lack of tools that successfully incorporate social factors in sustainability assessments; hence, several tools were selected to observe different approaches to evaluating social factors. In some cases, in-house tools developed in one sector were tested on different process sectors to see where commonalities exist, and where issues would limit broader uptake by industry. Beyond specific features of interest, testing covered whether the tools were sector-specific, their scope, at what technology development stage they could be applied, transparency and methodological performance, and use within the STYLE scenario.

2.4. *Academic evaluation*

Research partners, led by Utrecht University, prepared an evaluation protocol and applied it to the short-listed tools. The protocol is a procedure to first systematically gather information on how a tool converts user inputs into results, and then evaluate it using pedigree analysis (i.e. transparent expert judgment) on predetermined criteria. The criteria include both methodological aspects (e.g. theoretical understanding, transparency) and practical aspects (e.g. coverage of sustainability impacts, user-friendliness), in line with the STYLE scenario.

2.5. *Recommendations and roadmap development*

Bringing together the recommendations from Industry Testing and Academic Validation, a roadmap was developed by STYLE partners (STYLE, 2017a) and reviewed with stakeholders, to bridge the gap between current usage of available tools and a vision that: *"by 2030, project teams in the EU process industries will routinely use sustainability evaluation tools to make better decisions when assessing process or product improvements"*.

3. Challenges facing industry

STYLE identified several common issues cited by industry when considering the broader uptake of sustainability evaluation tools by project teams:

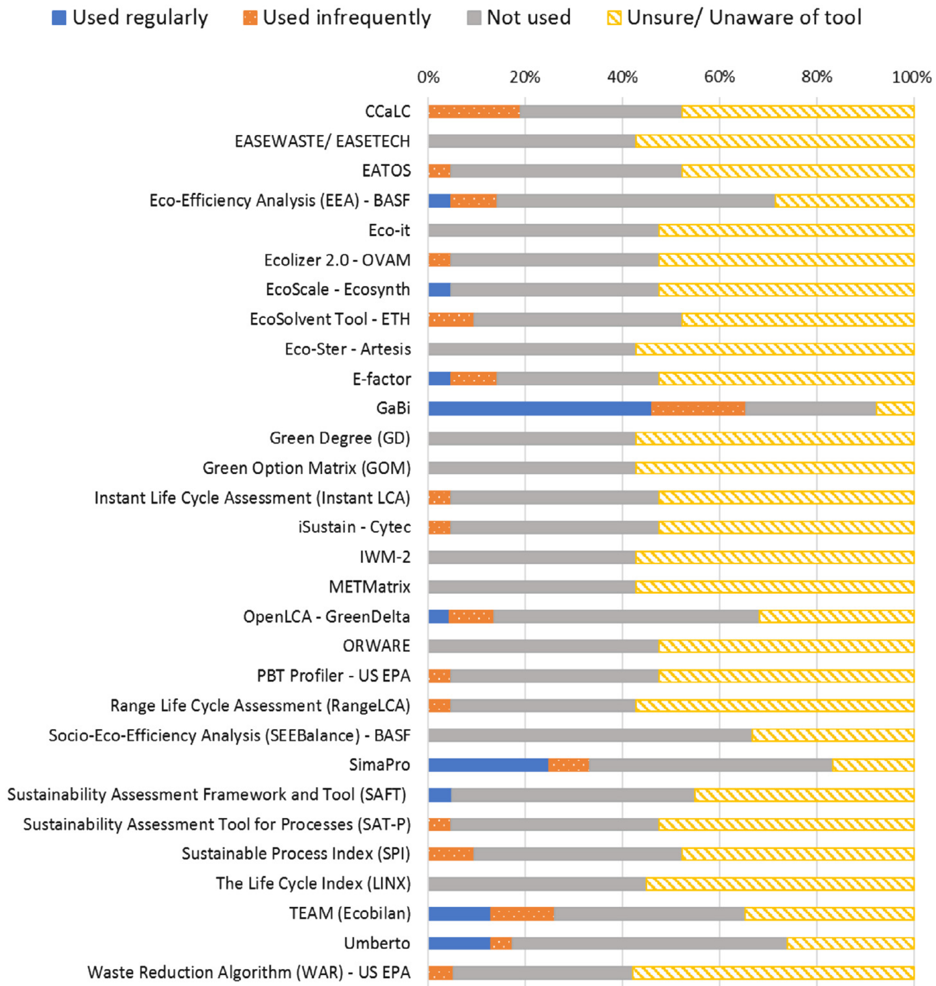


Fig. 1 – Tools usage from industry respondents to stakeholder survey.

- Some sustainability tools use terminology and concepts which are difficult for non-specialists to interpret. For example, more consistent responses would be expected from asking "Will this project reduce emissions of organic material to water?", rather than asking about "the impact on freshwater eutrophication potential".
- Sustainability evaluation tools can be very time consuming to use, so they are seen as an unnecessary extra burden on a project team, particularly in early-stage project evaluations, rather than bringing extra value.
- Industry users (particularly non-sustainability specialists) reported a low tolerance to tools that contained bugs or were not sufficiently straightforward to use. Training can be used to address ease-of-use, but an approximate time limit of half-a-day was proposed as being acceptable for tools training in the STYLE scenario.
- Project teams need to be able to identify where further improvements in the process can be made, but some sustainability evaluation tools lack transparency in how outputs are calculated, limiting the potential to pinpoint key influencing factors.
- Tools may require detailed process data (e.g. toxicity and quantities of all potential input and output materials, including by-products) which are not yet available in early-stage technology development. Being able to input a range of values, access generic databases and/or flag uncertainty in the data input helped mitigate this issue.
- Different tools and data-sets are used for a wide-range of calculations in industry, beyond sustainability evaluations. Although previous attempts have been made to have common formats for data import/export (e.g. ISO 14048—SPINE), industry representatives reported that these do not currently work sufficiently well to be able to transfer data faultlessly.
- Although many sustainability assessment tools exist, when asked about their usage, even those with sustainability expertise in industry had limited awareness of more than a few tools. From the 52 industry respondents to the stakeholder survey, only 26 reported usage of any sustainability tools, with GaBi and SimaPro being the most widely used tools. Fig. 1 shows the pattern of tools usage amongst industry respondents. Industry stakeholders in the STYLE workshops held the view that many of the commercial tools were only suitable for usage by those with sustainability expertise. Some industrial practitioners had developed either simplified spreadsheet interfaces to the more complex tools, with locked-down options, or standalone bespoke spreadsheet tools to allow broader usage in their organisations.
- The scope of projects requiring sustainability evaluations can vary greatly between process sectors, and even within individual organisations. Tools that have

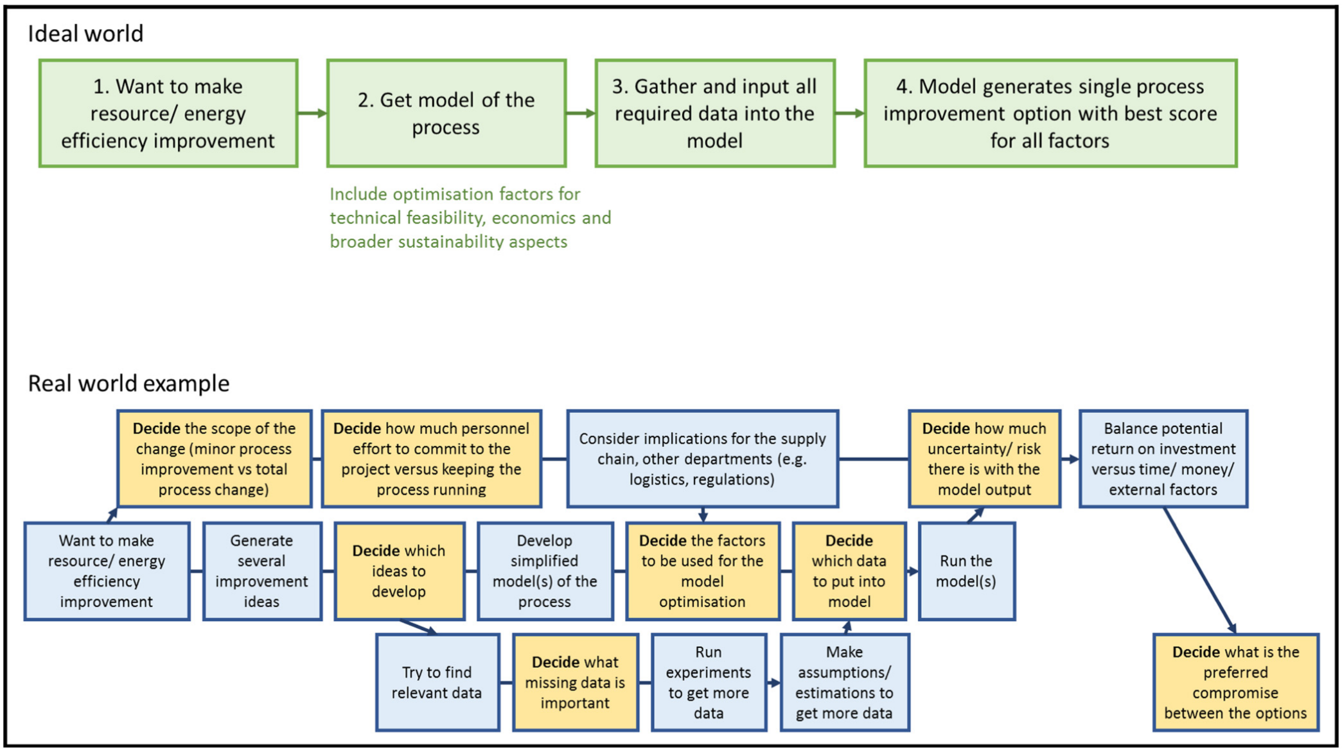


Fig. 2 – Decision making for industry process improvements.

tried to incorporate options for all eventualities can leave users overwhelmed by the quantity of data input fields or questions that are irrelevant to their project. Tools that over-simplify the scope (e.g. having no option for geographical differences between operating sites), can stop users from being able to fully explore options available to them. A compromise can be achieved by having modularised toolkits and/or toolkit setup stages to customise the tool to the problem, prior to data input.

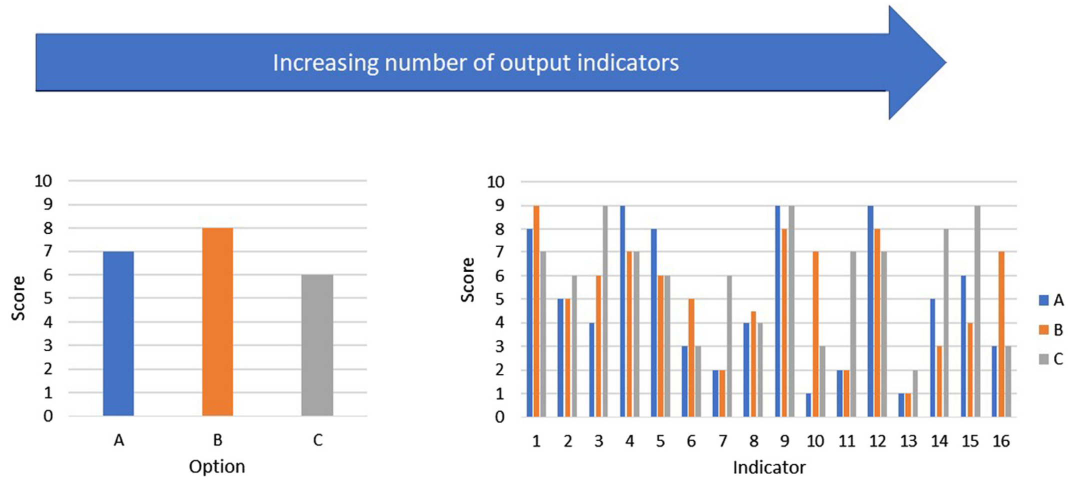
An overarching common theme with the challenges cited by industry was that human factors need to be taken more into consideration with tool design, rather than just technical content. When trying to attract those who are not sustainability specialists, and whose time is limited, to using a tool, an emphasis needs to be placed on how the user will interact with the tool: for example, what happens when they do not know what to put in a data input field; what are the implications of different people interpreting input questions differently; how can the user be reassured that they have made a reasonable interpretation of the outputs? In this respect, more collaboration is encouraged between sustainability specialists, tools designers and those in 'softer' sciences.

4. Sustainability and decision making

Decision making is at the heart of successful industry project management. In an ideal world, a computer model of a process would be able to select the perfect improvement option. In real-life process plants, there are no 'perfect' optimisations; teams must decide between options that have been developed using assumptions and under a variety of constraints, such as the availability of personnel and the regulatory implications of changes to the process (illustrated in Fig. 2).

Decisions also need to be revisited as a project moves through Technology Readiness Levels (TRLs) (European Commission, 2017). STYLE focused on TRL 4 (technology validated in lab) to 7 (system prototype demonstration in operational environment). Consequently, some data would be available at the start of the scenario project, which would increase as the project progresses, but falling short of having large amounts of data from a process that had reached full commercial operation. Decisions, therefore, must be based on a mixture of high-quality quantitative data and more speculative qualitative data, and decision points in the project management process (i.e. 'gates' in the stage-gate process, or interim reviews in funded projects) can be used to prompt the generation or acquisition of more quantitative data, if it is deemed to be significant.

STYLE stakeholders from industry and other EU funded projects indicated that sustainability evaluations can sometimes be perceived as an after-thought; something that is done once process improvement plans are well developed. Most projects will have technical feasibility and economic indicators at their core, with some additional input from areas such as safety, regulatory and legal expertise. Full sustainability (i.e. considering environmental, social and economic impacts) is often left as being a 'check' at the end, if required. During the development of a new product, process or technology, many decisions need to be made, which increasingly limit design freedom (Ruiz-Mercado et al., 2012). It is therefore more effective to start considering sustainability early on, when changes can still be made (Tufvesson et al., 2013). A number of process sector organisations are now understanding the value in integrating sustainability into their project 'stage-gate' systems. At this early stage, qualitative assessments employing in-house tools, such as those in use by Tata Steel (Tata Steel, 2017) and Solvay (Solvay, 2017), allow project teams to consider more radical process and product options. In later stages, organisations such as



(a) Over-simplified: difficult to assess available compromises.

(b) Over-complicated: difficult to see the most important factors.

Fig. 3 – Optimising the number of indicators to enable good decision making.

LafargeHolcim (2017) have monetised the outputs of their sustainability assessments to allow sustainability to be integrated into financial decision at the top of the company.

An important compromise needs to be made when incorporating sustainability into decision making systems (as illustrated in Fig. 3):

- Too much data from many different sustainability indicators can hinder good decision making—it becomes hard to see what the most important factors are.
- Tools that over-simplify sustainability evaluations into a single 'best option' score stop decision makers from being able to see the compromises available and the influencing factors. For example, summing greenhouse gases, eco-toxicity and other environmental factors into one score or summing environmental, economic and social aspects into one score.

There is a risk that embedding sustainability assessments into all decision making can increase the number of indicators to unmanageable levels (as per Fig. 3b) and cloud the ability of the team to make good decisions. Instead, sustainability should be used to frame the success criteria for the industry project—namely: "*Which factors are driving us to do this improvement project?*" and "*What evidence do we need to generate to demonstrate that this project is worth investing in?*" (Lapkin et al., 2016). Tools to aid the decision making, therefore, need to be able to keep the project team focused on their success criteria, the most important indicators and factors, whilst prompting for more evidence and data generation to help understand areas of risks and likely hotspots. The MEASURE project evaluated the use of Multi-Criteria Decision Analysis (MCDA) in sustainability evaluation tools (MEASURE, 2017) to provide a formal, structured and transparent decision making methodology and identified several published studies where MCDA tools have already been incorporated into sustainability assessments (Azapagic and Perdan, 2005a, b; Benetto and Dujet, 2003; Cinelli et al., 2014).

5. Recommendation: the STYLE Toolkit framework

The STYLE project set out with a remit to look for a collection of tools to meet the needs of the STYLE scenario. Although promising features were found in existing open access tools, many of the most suitable tools found were developed in-house by industry and lacked availability and transferability to be used across the EU process industries. Consequently, STYLE worked with project partners and stakeholders to develop a high-level framework for a toolkit, taking useful features from existing tools and feedback from tool users. The STYLE Toolkit is designed to prompt further research and development, with the long-term aim of having an open access version available, but also offering the potential for commercial and industry tool developers to make improvements to their own tools. The structure of this STYLE Toolkit framework is illustrated in Fig. 4.

Through all stages and across all sustainability pillars, a Life Cycle Thinking approach should be taken, and the toolkit should be able to highlight sustainability beneficial aspects, not just negative impacts. As users progress through the stages, the modules should provide a record of the accumulation of data and analysis, acknowledging that modules may be revisited to address alternative improvement options and to incorporate new data and knowledge. Changes and decisions should be traceable and documented to ensure that this valuable corporate knowledge is retained and able to be revisited when similar projects are encountered, or variables change that could alter the decision. This has proven to be effective for supporting decisions relating to whole process design (Hodgett, 2013) where the optimisation of the entire product development process is considered, from raw materials to end-product, rather than focusing on each individual unit operation.

5.1. *Materiality setup*

Materiality assessments are designed to identify the sustainability issues that have the greatest significance to a business or project and tailor the subsequent stages in the Toolkit toward these most material sustainability aspects. This tailoring could mean that preliminary modules and questionnaires are selected and options filtered based on sector, geography, product versus process change, study boundary and corporate priorities. The Materiality Setup serves to

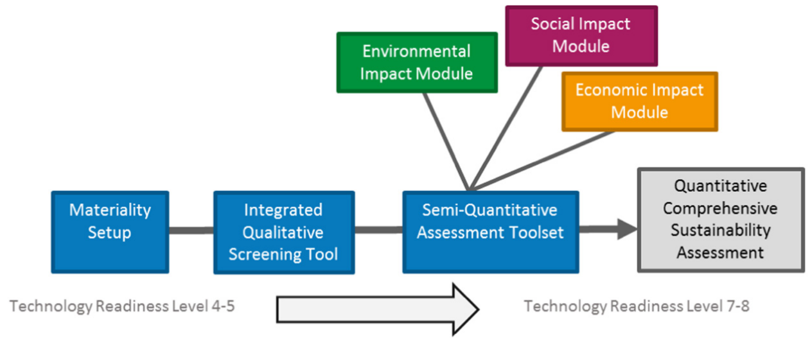


Fig. 4 – Overview of the STYLE Toolkit framework.

Questions	-2 (major improvement)	-1	0	1	2 (major deterioration)	notes/ comment
Consumption of fossil energy	X					
Quantity of pollutants in aqueous effluents		X				
Use of water in regions with high water stress		X				

Fig. 5 – Example format for Qualitative Screening Tool inputs.

(1) Set clear targets
(2) Ensure that subsequent assessments are efficient and relevant.

The setup compels the project team to consider the specific goals that they want to achieve, in terms of a magnitude of improvements (e.g. −30% greenhouse gas emissions) and/or by listing the specific sustainability impact categories that should be used to measure the performance of the technology. This provides focus to the subsequent stages, making it more efficient. For example, it is not worthwhile spending a lot of resources during early-stage development on quantifying a specific sustainability impact if it can be reasonably expected to have a very minor impact based on previous research for (very) similar products. Configuring the rest of the Toolkit in the Materiality Setup can therefore be carried out with assistance from an in-house or sector level sustainability expert.

5.2. *Integrated qualitative screening tool*

This stage is designed to provide insight for data-lean assessments at early TRLs. It takes a project team through a series of qualitative questions, getting them to score the technological solution relative to a defined benchmark (e.g. −2 to +2). The questions cover a range of issues and opportunities across environmental, economic and social pillars. Given that questions are subjective, it is important that they are individually specific to the sector, as comprehensive as possible, and with space to allow justification and comments to be captured alongside the answers, so that the reasoning behind a score can be understood and followed up. Aggregated and/or proxy indicators are necessary to keep the amount of questions at a relevant and manageable level, although transparency on the aggregation and weighting options should be provided to aid acceptance of the tool and to enable potential process improvements to be identified. In addition, documentation will help to ensure that concepts are clearly defined, usable by non-experts of sustainability assessment, and applied consistently across assessments. Questionnaire based tools can be used in project team meetings to bring together those from different disciplines, and can help shape collective ‘success criteria’ for the project. For example, input from purchasing staff may highlight the need to avoid use of a scarce resource. An example format for a Qualitative Screening Tool is shown in Fig. 5.

The output of the screening tool should be simple and visual, to summarise whether technological options are likely to be better or worse in different sustainability areas, as illustrated in Fig. 6.

5.3. *Semi-quantitative assessment toolset*

The goal of this stage is to start generating stronger evidence for the technology options having a positive or negative impact on different sustainability factors. Once the project reaches pilot scale, more data allow semi-quantitative assessments to be carried out, with modules selected based on screening tool areas of interest or concern. Some of the data input will be in the form of a mass balance, which then requires links to generic (e.g. GaBi, ecoinvent) and in-house databases. Given that data uncertainty will still be high, the toolset should allow users to include absolute values, order-of-magnitude comparisons or data ranges. Outputs from such tools should clearly show where likely hotspots are in the process and allow easy export of data. If the project warrants progression to a fully quantitative comprehensive assessment, data input would then not have to start from the beginning again.

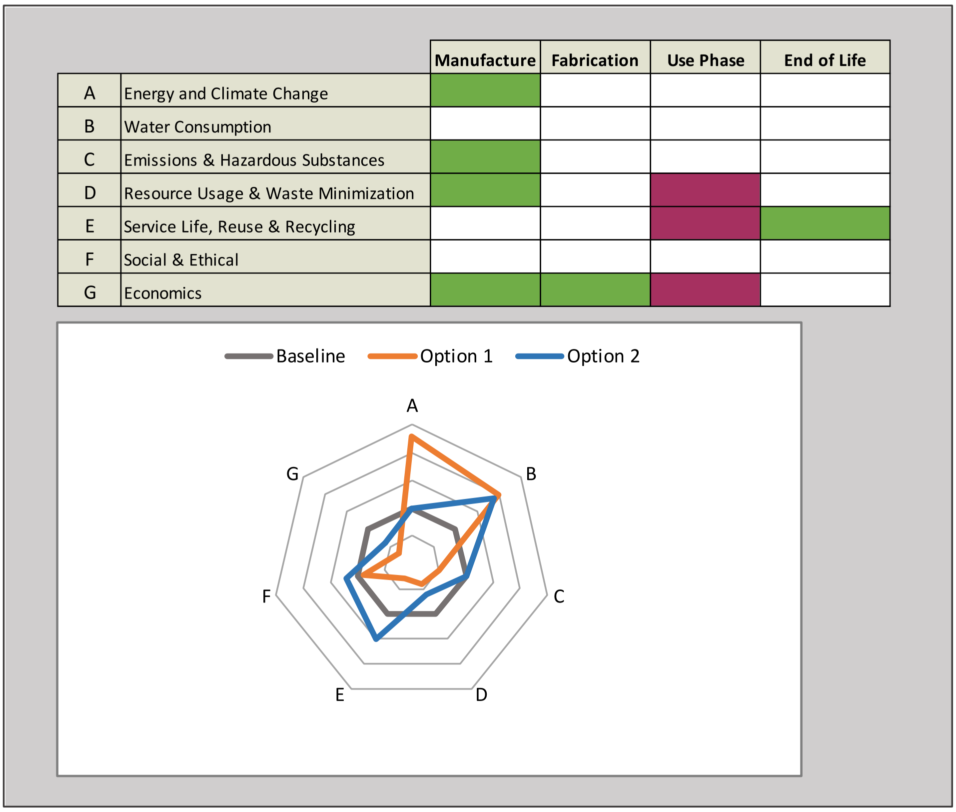


Fig. 6 – Example output formats for Qualitative Screening Tools.

5.4. *Quantitative comprehensive sustainability assessment*

Given that comprehensive studies can be very time-consuming and typically require a sustainability expert to be involved, STYLE recommended that these are only carried out for projects that require robust data for external public use, supply chain demands or promotion, or if the risks to the business were deemed large enough to need the extra assurance. Some organisations have also gained benefit from performing comprehensive assessments on a selection of their projects and products, so that assumptions about hot-spots and business success factors can be tested.

6. Conclusions and further research needs

To bring sustainability assessments into industry on a day-to-day basis, tools need to be designed to help project managers and their teams make informed decisions about their projects. Tools designed for such teams bring disciplines together, challenge assumptions, drive the generation of key data and help justify decisions to senior management. The staged approach of building up from qualitative to quantitative assessment, as proposed in the STYLE Toolkit framework, should minimise effort wasted on costly comprehensive studies, which should only be conducted if it is necessary to meet the needs of downstream customers or more complex decisions.

Beyond the high-level framework for the STYLE Toolkit, the project delivered a *Recommendations Roadmap* (STYLE, 2017a) to plot the route to achieve the vision that: *by 2030, project teams in the EU process industries will routinely use sustainability evaluation tools to make better decisions when assessing process or product improvements*.

Recommendations in the Roadmap are grouped as follows:

- **Toolkit**—features to be incorporated into the Toolkit *software*, some of which require further research and development
- **Methodological**—the methods for how various indicators are measured or outputs calculated (e.g. Developing approaches to uncertainty and sensitivity analysis for data-lean evaluations)
- **Data**—the numbers or information that is input into a tool (e.g. Develop improved standards for harmonised data formats, including social and economic data)
- **Uptake**—getting improved toolkits actually used regularly in industry (e.g. Support for development of an Open Access version of the Toolkit; Coaching of organisations new to sustainability evaluations in the use of the Toolkit).

In the short-term, there is scope for industry and software providers to make improvements to their own in-house and commercial tools, in line with the STYLE Toolkit framework (STYLE, 2017b). In the longer term, public funding is called for to develop open access tools to allow more Small and Medium Enterprises (SMEs) to utilise the approach to embed sustainability into their process and product improvements.

Pragmatic, 'simple' tools for industry are, however, not inherently simple to design, and some of the challenges are not unique to the STYLE scenario. Consequently, further research is recommended for methods to handle data uncertainty, sensitivity analysis, aggregation, multi-criteria decision making and the structuring of qualitative questionnaires that support the development of simple screening tools. Crucially, the involvement of 'softer sciences', bringing in human factors and interface design, is encouraged to bridge the gap between the ideal world and the reality of everyday industry.

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