

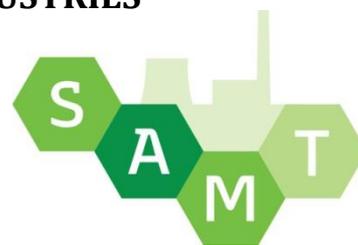
# SAMT

## SUSTAINABILITY ASSESSMENT METHODS AND TOOLS TO SUPPORT DECISION-MAKING IN THE PROCESS INDUSTRIES



COORDINATION & SUPPORT ACTION

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## Deliverable 3.1

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### Sustainability assessment methods and tools for cross-sectorial assessment

#### Responsible authors & organisations:

Hanna Pihkola, Tiina Pajula (eds.)  
VTT Technical Research Centre of Finland  
Carlos Tapia  
Tecnalia Research and Innovation  
Michael Ritthoff, Mathieu Saurat  
Wuppertal Institute for climate, environment and energy

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**Abstract / Executive summary:**

The aim of the SAMT project (2015-2016) is to review and make recommendations about the most potential methods for evaluating sustainability and therein the energy and resource efficiency in the process industry. SAMT will collect, evaluate and communicate the experiences of leading industrial actors from cement, oil, metal, water, waste and chemical industry and review the latest scientific developments within the field of sustainability assessment. SAMT is a coordination and support action that will promote the cross-sectorial uptake of the most promising methods and tools by conducting case studies, organizing workshops and producing recommendations for further implementation of the best practices in sustainability assessment.

This report is the first of the three final reports that together summarise the main findings and conclusions of the SAMT project. The aim of the report is to discuss identified development needs and bottlenecks for sectorial and cross-sectorial assessment. The focus of the report is on practical challenges especially related to implementing the methods in an industrial context and in communicating and comparing the results of the assessments. The conclusions are based on a review and evaluation of existing methods and tools, interviews and group discussions with industrial sustainability experts and sustainability experts, case studies and workshops.

A number of cross-cutting implementation challenges turned out to be common to almost all of the tested methods. These can be considered as bottlenecks that currently hinder sustainability assessments across different sectors and as part of daily decision-making. They can be summarised to three main categories: data availability and management issues; diversity of tools and data formats; and variety of methodological approaches and assumptions.

There is a demand for both developing existing methods to cover and integrate different aspects of sustainability (environmental, economic and social), and to develop simplified assessments with harmonised guidelines, in which the assessment process could be integrated to the daily decision-making by automating part of the work flow. Adding more dimensions to the assessment adds challenges also for communication. Communication is an area in which need of further harmonisation was recognized.

Cross-sectorial sustainability assessment, focusing on evaluating impacts at sectorial level using hybrid methods, is considered interesting at macro level, for the purposes of research projects, policy planning and evaluation. However, these methods could also be useful for evaluating the impacts of circular use of resources and recycling or, for example, in a case of industrial symbiosis platforms. These methods require further development and harmonisation to allow their implementation in practice.

The other two of the final reports are SAMT deliverable D3.2 'Future research needs and input for standardisation' and SAMT deliverable D3.3 'Sustainability assessment in the process industry – Future actions and development needs'.

**KEY WORDS:**

Sustainability assessment, life cycle assessment, decision-making, process industry, cross-sectorial, research and development

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# 1 Introduction

## 1.1 Background

Sustainability assessment methods are needed for various industrial sectors to support sustainable technology development, decision-making and to evaluate the impacts of existing solutions, products and technologies. Ideally, sustainability assessment methods should address the environmental, economic and social aspects of technologies and cover the whole life cycle of the solutions. The assessment methods should provide robust knowledge to support decision-making, and allow comparability of the results. However, addressing all those aspects within one tool or assessment method is challenging, or even impossible. While there are aspects and indicators that are common to all process industries, sector specific methods, tools, or indicators are often required to address the specific features of each industrial sector in a fair and transparent way.

The SPIRE Public –Private Partnership (PPP)<sup>1</sup> brings together several sectors of process industry: cement, ceramics, chemicals, engineering, minerals and ores, non-ferrous metals, and water. All SPIRE sectors can be considered as resource and energy intensive and thus improving resource and energy efficiency are urgent issues for improving the sustainability and competitiveness of the sectors. Within the Horizon 2020 work programme, the specific and common goals listed for the SPIRE sectors are:

- A reduction in fossil energy intensity of up to 30% from current levels by 2030.
- A reduction of up to 20% in non-renewable, primary raw material intensity compared to current levels by 2030.
- A reduction of greenhouse gas emissions by 20% below 1999 levels by 2020, with further reductions up to 40% by 2030.

For the SPIRE sectors, sustainability assessment methods are crucial for evaluating the current state and the achievement of the goals related to resource and energy efficiency. For evaluating the overall resource and energy efficiency of the SPIRE sectors as a whole, tools and indicators that are applicable for cross-sectorial assessment are required.

At the moment, several tools, assessment methods and indicators exist, but they differ in their goal and scope and are intended for different kind of use within companies, by consumers or by authorities to support policy planning and evaluation. Additionally, different methods and tools are focused for different levels of assessment: product, company, industry or society. Thus the problem is not so much the existence of proper methods and tools but rather the lack of understanding and knowledge on how they should be applied and in which context. Thorough understanding of the underlying mechanisms and calculation principles incorporated in the tool in question is often required to make a trustworthy assessment. Furthermore, it should be recognised which of the existing methods and tools are suitable for analysing

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<sup>1</sup> SPIRE stands for Sustainable Process Industry through Resource and Energy Efficiency. For more information see: [www.spire2030.eu](http://www.spire2030.eu)

resource and energy efficiency within the process industries and across the different sectors of the industry.

The SAMT project will respond to the need for cross-sectorial sustainability assessment methods by bringing together representatives of several process industry sectors, namely cement, metal, oil, water, waste and chemical industry, and collecting and evaluating the current best practices from each industrial sector, together with the latest research know-how related to sustainability assessment methods and recent activities in standardisation within the field.

SAMT is funded by the Horizon 2020 work program SPIRE.2014-4: Methodologies, tools and indicators for cross-sectorial sustainability assessment of energy and resource efficient solutions in the process industry.

## 1.2 Some definitions

In this report we use consequently the terms ‘method’, ‘tool’, and ‘indicator’. The definitions applied here were first defined in the context of the first SAMT deliverable D1.1, and slightly updated for the second SAMT deliverable D1.2. The definitions are as follows:

- **Method:** set of instructions describing how to calculate a set of indicators and how to assess them. Methods include official standards.
- **Tool:** working and calculation platform that assists with the implementation of a method. A tool is usually software but it could also be, for example, a paper-based check-list.
- **Indicator:** a quantitative or qualitative proxy that informs on performance, result, impact, etc. without actually directly measuring it. For example, a low carbon footprint indicates a low environmental impact for the category climate change, but it does not measure the impact, it refers to greenhouse gas emissions, i.e. the environmental pressure.

Those definitions are by no means “official” but the ones we use in this project to avoid confusion. These terms are indeed used differently by many stakeholders in the scientific community, in policy, in the industry etc. For more information, please see SAMT D1.1.

## 1.3 Aim of this report

This report is the first outcome of WP3 that aims to provide recommendations for cross-sectorial assessment, future actions and standardization related to sustainability assessment. The aim of the report is to discuss both sectorial and cross-sectorial applicability of the evaluated life cycle based assessment methods. In addition, identified development needs from the point of view of industry and policy making are considered. The focus of this report is on practical challenges especially related to implementing the methods and in communicating and comparing the results of the assessments.

The report summarizes and synthesizes the findings from the first two work packages of the SAMT project (WP1 and WP2). The findings of this report are based on further analysis of the results related to:

- review of existing methods, tools and standards for sustainability assessment (SAMT D1.1)
- interviews with industrial sustainability experts (SAMT D1.2)
- evaluation of selected sustainability assessment methods (SAMT D2.1)
- testing of selected methods using a case study approaches (SAMT D2.2 & annexes 1, 2, 3).
- group work and discussions held during the three open workshops and internal project meetings.

The report at hand is the first of the three final reports that together summarise the main findings and conclusions of the SAMT project. Identified future research needs related to sustainability assessment methods, tools and data, and proposed actions related to future standardisation are presented in the SAMT deliverable D3.2 'Future research needs and input for standardisation'. The third report, D3.3 'Sustainability assessment in the process industry – Future actions and development needs' presents a roadmap and vision for developing consistent sustainability assessment methods in the process industry by 2030. In addition to the roadmap, the report includes an implementation plan in which concrete steps for moving towards the vision are proposed.

## 2 Available methods and tools

The first task of the SAMT project was to review existing sustainability assessment methods and tools, to have an understanding of the characteristics of existing methods and tools and their applicability for different decision-making contexts.

The web based search conducted at the beginning of SAMT project found over 100 methods and tools for sustainability assessment. Out of this number, 51 methods and 38 tools were included in the review. Of the 51 methods, 9 were sector-specific (6 specific to chemical industry, 2 to agriculture and food sectors and 1 for forestry sector). Of the 38 tools, 15 were sector specific, and majority of them (11) related to chemical industry, while 2 were related waste sector and 2 to energy sector. (See table 1)

**Table 1 Clusters of reviewed methods and tools**

<b>Methods</b>	<b>Total nr. 51</b>
Life cycle based methods	10
Hybrid methods	5
Integrated methods	10
Methods focusing on costs	6
Methods specific to the chemical industry	6
Methods specific to the agricultural, forestry and food sectors	3
Other methods	11
<b>Tools</b>	<b>Total nr. 38</b>
Full LCA tools	10
Simplified LCA tools	6

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Tools specific to chemical industry	11
Tools focusing on energy	2
Tools focusing on waste	2
Other tools	7

Out of the reviewed 51 methods and 38 tools, the ones not specified to any sector were selected for a more detailed review, from which the results are presented in SAMT D1.1. The findings of the review pointed out that large number of tools seem to implement a rather small amount of methods. Method most frequently implemented was life cycle assessment (LCA). LCA method appeared in 19 tools and in 9 methods.<sup>2</sup>

After interviews with industrial sustainability experts that represented seven companies from six process industry sectors the list of 51 methods and 38 tools was complemented with additional 9 methods and 17 tools that are applied by the industries themselves<sup>3</sup>. These included both qualitative and quantitative methods, and both in-house and publicly available methods and tools. Publicly available, sector specific methods and tools were found also from the construction and oil and gas sectors. Altogether the number of available methods and tools based on the review and interviews rose to 60 methods and 55 tools.

One of the interesting findings from the interviews was that in addition to using available methods and tools, all of the interviewed companies had developed their own tools for sustainability assessment. Development of own tools was mostly due to practical needs: adapting the assessments and data handling to match with own needs. In addition, some of the companies have developed their own methods, many of which include extensions of existing methods (such as the LCA based integrated Eco-efficiency assessment and SEEBALANCE methods developed by BASF). (SAMT D1.2).

In the second stage of the project, a smaller group of methods was selected for further evaluation. When narrowing down the list of methods to be evaluated, the focus of the assessment was on methods that include a life cycle perspective, are applicable in different sectors, cover different dimensions of sustainability (environmental, economic and social), are capable of assessing impacts at different levels (product, company, industry or society, upstream and downstream) and that would have tools available for implementing them in practice. This cross-check analysis led to selection of 14 methods that were considered potential from the point of view of the SAMT project goals and partner interest. These methods are presented in table 2.

**Table 2 Methods selected for further evaluation using the adapted RACER method**

Short name	Method	Description
<b>LCA</b>	Life Cycle Assessment	Life cycle method
<b>MIPS</b>	Material Input Per Service	Life cycle method, focus on resources
<b>CED</b>	Cumulative Energy Demand	Life cycle method, focus on energy

<sup>2</sup> For detailed results from the review, see SAMT D1.1 (Saurat et al. 2015a)

<sup>3</sup> Results from the interviews, together with the list of additional methods and tools are presented in SAMT D1.2 (Saurat et al. 2015b).

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<b>E-LCA</b>	Exergetic Life Cycle Assessment, Exergy analysis	Life cycle method
<b>CF</b>	Carbon Footprint	Life cycle method, focus on GHG emissions
<b>WF</b>	Water Footprint	Life cycle method, focus on water
<b>LCA/PEM</b>	Hybrid LCA + partial equilibrium model	Hybrid method
<b>LCAA</b>	Life Cycle Activity Analysis	Life cycle method
<b>EEA</b>	Eco-Efficiency Analysis	Integrated method
<b>SEEBALANCE®</b>	Socio-Eco-Efficiency Analysis	Integrated method
<b>PROSA</b>	Product Sustainability Assessment	Life cycle method
<b>LIInX</b>	Life cycle iNdeX	Integrated method
<b>SustV</b>	Sustainable Value	Integrated method
<b>EcoD</b>	Ecodesign, Design for Environment	Life cycle method

The findings from the method evaluation point out that in principle, most of the methods (13 out of 14) are applicable in different sectors, and also at different levels of assessment (12 out of 14). However, only four of the methods are capable of handling with all the three dimensions of sustainability (environmental, economic and social). These methods were titled as integrated methods.

A further analysis of the ability of these methods to support decision-making and evaluate sustainability was conducted using an adapted version of the RACER-method. The RACER-method was originally developed for assessing value of scientific tools in supporting policy making. RACER includes criteria for five key components that stand for:

- Relevant = i.e. closely linked to the objectives reached
- Accepted = i.e. by staff and stakeholders
- Credible for non-experts = unambiguous and easy to interpret
- Easy to monitor = e.g. data collection should be possible at low cost.
- Robust = e.g. against manipulation. (EC 2009)

The criteria applied in the RACER evaluation were defined taking into account industrial development needs that were identified during the interviews with industrial sustainability experts and discussions held during the first project workshop at Wuppertal in June 2015. The RACER method was adapted to the goals of the SAMT project by including criteria that covered the following aspects:

- *Cross-sectoral applicability:* Comparability among sectors cannot be fully achieved unless similar methods are applied to assess sustainability of the products and processes specific to each sector. Although each sector has its own specificities that should be tackled by means of tailor-made tools, a simultaneous application of cross sectorial methods to assess different products and processes across sectors is needed for supporting e.g. cross-sectoral policy development.
- *Focus on the whole life cycle of products:* The results of a given sustainability assessment of a product or a process could vary substantially depending on the scope of the assessment. For instance, a product with a low environmental impact in its production phase could be difficult to reuse or recycle. This would not be reflected in the assessment if the end of use phase is neglected.

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- *Consideration of economic, environment and social issues:* Methods that cover the three dimensions of sustainability are needed in order to fully characterise the long-term sustainability of a given product or a process. However, it is difficult to find methods that consider all of them without losing relevance in any of the sustainability aspects.
- *Inclusion of resource and energy efficiency criteria:* Energy and resource efficiency are two of the main priorities of European policies, and specific targets have been set for both dimensions in the main strategic documents of the EU. The process industries hold a great level of responsibility for these efficiency targets to be achieved.
- *Relevance for decision making in the process industry:* Ultimately, enabling or improving decision-making is the main determinant for any sustainability assessment method to be accepted by the process industries.<sup>4</sup>

One of the challenges faced during the evaluation of the methods was that since sustainability assessment methods are applied for many different purposes, it is difficult to define criteria that would cover all needs. Additionally, the evaluation of the methods itself poses some challenges, since the methods have been developed for different purposes, and thus judging them according to certain pre-defined criteria might create misleading results on the value or applicability of the methods. On the other hand, even though this type of generalised assessment is challenging, there seems to be a growing need for that type of information. Despite the availability of a vast number of methods and tools, only a small number of them are frequently applied by the industry. (SAMT D2.1)

Another challenge pointed out by the industrial experts was that it is difficult to find enough information about available methods and tools. Thus there would be a need for easily accessible and up-to-date information on methods and tools available and suitable for different purposes, and also about the requirements for implementing them in practice (e.g. data needs and available tools). In big companies, implementing a new method or a tool is a time consuming process, and requires a lot of effort and data collection. Thus, extensions or updates to existing methods and tools might be easier and practical to implement, compared to totally new approaches. However, despite the challenges, there is a continuous interest towards potential new methods as well. (SAMT D1.2)

A graphical summary of the results from the cross-check analysis and RACER evaluation are presented in table 3.

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<sup>4</sup> Detailed description of the evaluation criteria and results can be found from SAMT D2.1 (Lopez et al. 2015).

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Table 3 Table 9: Overview of the results given by RACER. SC: Sectors covered; AA: Addressed aspects; LA: Level of assessment; Tools: Tool availability

	General criteria (cross-check)				RACER evaluation						
	SC	AA	LA	Tools	Relevant	Accepted	Credible	Easy	Robust	Total	Score
LCA	✓	~	✓	✓	✓	✓	~	~	✓	✓	25
CF	✓	✗	✓	✓	~	✓	~	~	~	~	24
EcoD	✓	~	✓	✓	~	✓	~	~	~	~	22
EEA	✓	~	✓	✓	✓	~	✗	~	~	~	21
CED	✓	~	✓	✓	✓	✗	✗	~	~	~	20
WF	✓	✗	✓	✓	~	~	~	~	~	~	19
MIPS	✓	~	✓	✓	~	~	~	~	~	~	19
E-LCA	✓	~	✓	✗	✓	✗	✗	✗	~	~	19
SEEBALANCE®	✓	✓	✓	✓	✓	~	~	~	~	~	18
IInX	✓	✓	~	~	~	✗	✓	✗	~	~	18
LCAA	✓	~	✓	✗	~	✗	✗	~	✗	~	17
LCA/PEM	✓	~	~	✗	~	✗	✗	✗	✗	✗	15
PROSA	✓	✓	✓	~	✓	✗	✗	✗	✗	✗	14
SustV	~	✓	✓	~	✗	✗	~	✗	~	✗	14

The findings from the RACER evaluation showed that for the moment, there was no single method that would achieve high scores in all the evaluated criteria<sup>5</sup>. While the scoring of the methods was not straightforward and included a level of subjectivity, the following general conclusions could be made based on the results regarding applicability of the methods for different purposes:

- When considering the possibility to evaluate and integrate different aspects of sustainability, four of the evaluated methods (out of 14), namely SEEBALANCE, PROSA, LInX and SustV, integrate all the three aspects (environmental, economic and social). However, according to the evaluation it seems that these methods have some deficiencies in practical tool availability, and they are not yet well-known or applied by the industry.
- When considering the possibility to evaluate resource and energy efficiency, all of the evaluated methods include aspects that provide relevant information, but for a comprehensive assessment of resource or energy efficiency, a combination of methods is likely needed.
- A few of the methods focus specifically on energy related aspects (such as carbon footprint and cumulative energy demand) and a few on resource aspects (Water footprint and MIPS). Exergetic-LCA (E-LCA) is a method that has been developed to assess the qualitative degradation of resources, and can be considered as a very relevant method from this perspective. However, in order to become more adaptable from industrial point of view, the E-LCA approach seems to face some development needs that include dealing with complexity of the inventory phase (due to need for transforming all inputs and outputs into exergy units) and need for further standardisation and practical guidelines for the assessment, to improve robustness of the method.
- From the point of view of industrial users, credibility, robustness and easiness related to implementation are aspects that would require further development in general, when all the evaluated methods are considered.

A conclusion that can be drawn based on the RACER-evaluation is that for the moment, a combination of different assessment methods seems to be the most informative solution, especially when resource and energy efficiency assessments are considered. In an ideal situation, especially when entering to new areas of study, triangulation of methods (or indicators calculated using different methods) would be recommended. However, since all of the evaluated methods have potential in supporting decision-making, and in practice there is often a need to operate with limited resources, starting from implementation of one life cycle based method may be relevant solution. Although it might not provide a comprehensive understanding of all relevant issues, it usually increases understanding of potentially relevant questions, and of the data needs and other requirements for successful implementation. This understanding can be deepened by adding further indicators or methods upon needs and available resources. In any case, in addition to the data availability, an important criterion for selecting a method would be the goal and purpose of the assessment. (SAMT D2.1)

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<sup>5</sup> Detailed results from the RACER evaluation of the methods can be found from SAMT D2.1 (Lopez et al. 2015)

### **3 Identified development needs vs. available methods and tools**

One of the overall aims of the SAMT project was to describe current best practices related to sustainability assessment as applied in different sectors of the process industry, and to identify future development needs. In practice, this was mainly done by conducting interviews with industrial sustainability experts representing leading industrial actors from cement, metal, oil, water, waste, chemical and forest industries. Altogether twelve interviews with seventeen people from seven companies were made. The remaining tasks of the project, including the classification and evaluating the methods, the case studies and the review of existing standards, also contributed to this identification of future development needs. In addition, the interim results from the project have been presented and discussed in three open project workshops and several meetings between project partners.

In this section, the findings from the review, evaluation and testing of different sustainability assessment methods are discussed in relation to the point of view of industrial development needs identified during the project. These aspects are discussed in chapter 3.1. Another important point of view and area of interest related to sustainability assessment method development relates to needs for policy making and evaluation, which is further discussed in chapter 3.2.

#### **3.1 Needs for industrial use**

In addition to identifying best practices in different industrial sectors, an important aim for the interviews was to find out which of the available methods and tools are currently applied in industrial decision-making and why. In addition, the aim was to identify development needs in the area of sustainability assessment, and how could the methods and tools be further developed in order to support decision-making in different contexts.

According to the interviews, carbon footprint and life cycle assessment are methods that are most commonly applied by the industry. Typically, carbon footprint is a method that is applied frequently, and gathering carbon footprint information might be integrated for example as part of project management and evaluation tools or performance tracking. LCA method is well-known, but in practice applied more seldom. This is due to resource and cost demands: LCA is a comprehensive method for environmental assessment, and when several environmental impact categories covering the life cycle of a product or service are included, it requires a lot of data and some time for the implementation. However, there are differences between different industrial sectors, since in some sectors customers frequently ask for sustainability information, and on some sectors it is required by law (e.g. the water sector and biofuel sector). In other sectors, LCA is applied more seldom, mainly in the context of bigger research projects or via joint projects led by the industry associations. (SAMT D1.2)

In addition to carbon footprint and LCA, water footprint was a method that was most often mentioned. There is a growing interest towards the water footprint and by the time of the interviews (May-June 2015), most of the interviewed companies had done preliminary studies and testing of the different water footprint methods, tools and databases. In addition to these and other life cycle based assessment methods, different kinds of standards, checklists and qualitative or semi-qualitative evaluation methods and reporting frameworks are applied both for internal and external purposes. Different methods and

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approaches are currently also applied for combining results from different environmental evaluations, economic and social assessments. (SAMT D1.2)

In general, interviewed persons expressed an interest towards integrated methods that would allow assessing different dimensions of sustainability at the same time. This was considered important to support decision-making. There was interest for different kind of methods, for ones integrating environmental and social aspects, for ones integrating environmental and economic aspects, and for ones integrating all three dimensions. However, with the exception of the SEEBALANCE method and eco-efficiency assessment, so far there was little practical experience from using the integrated life cycle based methods in practice. A possible reason is that a number of methodological limitations of the integrated methods still remain. (SAMT D1.2; 2.1;2.2)

Within the literature related to sustainability and sustainability assessment, different kind of definitions for integrated assessment methods can be found. In this context, integrated methods refer to methods that aim to provide consistently prepared information on the three pillars of sustainability. The integrated methods included in our evaluation (EEA, SEEBALANCE, LiNX, SustV) include normalisation, weighting and aggregation of the environmental, economic and social indicators into indices or new indicators. (SAMT D1.1)

The findings of the case studies highlighted that the already known challenges of normalization, weighting and communication are still present. Even in the case of eco-efficiency, a challenge is that despite the existence of one standardised approach there are many alternative ways for combining the different dimensions in a single analysis, leading to many different kinds of interpretations of the same phenomena. E.g. in the case of economic and environmental spheres one could focus on eco-productivity instead of eco-efficiency. Two of the approaches that combine economic and environmental dimensions were tested within the integrated case study conducted as part of the SAMT project, highlighting these differences in practice. However, the findings from the method testing also pointed out that despite some challenges related to the implementation phase, these integrated methods are capable of providing added value and interesting viewpoints to decision-making, but certain level of expertise is required both for the implementation and interpretation phases. (SAMT D2.2)

Interviewed experts pointed out that sustainability is often one of the criteria in decision-making, but usually it is not the only one, and thus there is a need to combine information describing different aspects of sustainability, and to have a better overall view of potential impacts. On the other hand, this also adds further demands for the methods, which was commonly acknowledged. In addition to technical properties of the methods, communicating the results in a meaningful way towards both internal and external stakeholders was one of the challenges regularly faced by the sustainability experts. Adding more dimensions to the assessment typically adds challenges for communication as well. If the final results are presented in an integrated manner, integration should be done in a transparent way, making it possible to trace back important underlying assumptions and their impacts for the final results. Potential trade-offs between different dimensions and domains should be adequately communicated, enabling conscious management decisions to be taken. (SAMT D1.2)

To enhance the use of these methods in practice, implementation of the methods within either existing LCA-based tools, or commonly applied easy-to-use tools (such as MS Excel) would be important. According to the review results, it is possible to insert both economic and social data in the commonly applied LCA softwares, but it seems that this possibility has not yet been systematically applied in practice, and the challenge related to integration of the results remains. Implementing the integrated methods in to existing tools is an area that also according to the results of the RACER evaluation would require further research and development, together with weighting and normalisation steps and communication of results. (SAMT D1.1; 1.2; 2.1)

In addition to integrated methods, there is a growing need for simplified or streamlined methods that could be used regularly, and in different kinds of decision-making situations. Additionally, interviewed sustainability experts would be in favour of standardising or at least creating harmonized approaches for the simplified assessments. Although specific guidelines for simplified assessments are missing, these are regularly conducted and communicated using different kind of approaches. This poses challenges for evaluating the results and again increases the challenges related to comparability of the results. Another important point would relate to handling uncertainty in the context of these simplified assessments, especially when they are applied as the first step of the assessment, in guiding decision-making and development activities to a certain direction. Creating joint principles for conducting and communicating about the streamlined assessments could help in harmonizing the terminology (e.g. what is meant with a streamlined assessment in different contexts), but also interpreting the results of these assessments.

Increasing the use of Product Category Rules (PCR) is one attempt towards more harmonized and partly streamlined approach. PCRs determine the life cycle stages to be included, the parameters to be covered, and the way in which the parameters shall be collated and documented. This enables comparability especially within product categories, but by enhancing the credibility and transparency, improves also cross sectoral consistency. In future, if more PCR's are developed, they include more default values to be used, possibly decreasing the amount of work needed for the data collection.

Currently available simple tools mainly use pre-calculated data blocks, and are intended for the use of non-experts. These tools might be useful in some situations, when no primary data is needed, and only some very general level information is sought for. However, our interviewed industrial experts regularly pointed out that using site-specific or primary data for own processes, and preferably also for the upstream processes as much as possible is considered as a best practice, and one of the most important things for ensuring the quality of the assessment. In addition, there is typically a need to make adjustments and assumptions related to own processes, products or services (e.g. by inserting specific data such as energy profiles and modifying process information), which might not be possible in case the tool uses a so called black box-model (and doesn't allow modifications).

### **3.2 Needs for policy making and evaluation**

Each research and innovation action, or innovation action funded from the Horizon 2020 via the SPIRE program, should conduct a sustainability evaluation, to be able to evaluate the contribution of the project in achieving the overall goals, or achieving the targets specified within the expected impacts of the specific

call text. Typically, these assessments are conducted using life cycle assessment, often focusing on few selected indicators or impact categories.

The specific environmental goals of the SPIRE PPP include

- a reduction in fossil energy intensity of up to 30% from current levels by 2030,
- a reduction of up to 20% in non-renewable, primary raw material intensity compared to current levels by 2030, and
- a reduction of greenhouse gas emissions by 20% below 1999 levels by 2020, with further reductions up to 40% by 2030.

A challenge for evaluating the overall impact from the SPIRE sectors based on outcomes of the individual research projects is that the results conducted at the project level are typically done on a micro-level (technology or product specific assessment). Since the results can seldom be published on a very detailed level due to confidentiality reasons, comparing the results of individual assessments done in different projects is practically impossible. Even if full transparency regarding the results could be achieved, the studies would differ in their goal and scope, using different functional units and system boundaries. Thus the findings of different studies cannot be summarized, in order to have an overall view of the total impact of the projects across different SPIRE sectors.

To achieve an understanding of a potential contribution of an individual project, product or technology on the assessed sector, or on the SPIRE sectors as a whole, some form of economic modelling, or hybrid methods combining LCA with economic models and/or environmentally extended input-output tables would be required in the context of environmental and economic impact assessments. Hybrid methods are methods in which sub-methods can be computed together in one consistent model (“hybridised”). While some of the methods are intended for micro-level (eg. product or company) level assessments, the aim of the hybrid methods is typically to extend the scope of LCA towards macro-level assessment (sectorial or territorial/economy level), while enabling calculation of basic LCA indicators at product level. These methods are typically not available in existing tools, but require programming skills and some computational power to implement. In addition, sector or economy wide environmentally extended input-output tables are required. (See e.g. SAMT D1.1)

The interviews and discussions held during the project indicate that hybrid models at the moment seem not like realistic or implementable methods for the industry. However, for purposes of more general level sectorial or cross-sectorial assessment required for example for policy evaluation, hybrid models would be useful and provide important information. Based on our evaluation, their implementation requires a lot of resources and might be realistic only in the context of large-scale research projects, when there is a chance for both, extensive data gathering and tool building. These hybrid approaches are considered promising also from the point of view assessing the circular economy objectives and resource use or recycling in a larger scale.

However, especially in the context of early technology readiness level (TRL) or a new innovative solution, there seldom is enough data for very detailed assessments, even for the micro-level approaches. On the other hand, as there is a need to develop these hybrid methods further in order to increase their

applicability in practice, including some level of method testing and development in the context of SPIRE and other EU-funded projects would be welcome. In addition to hybrid methods, this applies also for the previously discussed needs to further develop the methods for simplified assessments and integrated assessments, and on the ways to handle uncertainty in data, modelling and interpretation.

In future, harmonization of applied assessments and communication of the results among different projects is required, in order to have a better understanding of the impact of developed solutions and of the impact of the research funding in general. For example, the hybrid methods included in our evaluation, or the approaches used within these methods are currently not standardised in any way, and similarly to other assessed methods, full comparability of results would require almost full transparency concerning both data and models used.

While harmonization of the approaches and applied methods is needed, it is also important that new methods would be applied and tested in the context of the EU-funded projects. As these projects are an excellent possibility for testing and further developing the sustainability assessment methods in cooperation with industrial and academic experts, and for achieving practical user experience of relevant new methods not yet regularly applied by the industry.

#### **4 Bottlenecks for sectorial and cross-sectorial assessments**

SAMT project was originally developed as a response to a call topic titled “Methodologies, tools and indicators for cross-sectorial sustainability assessment of energy and resource efficient solutions in the process industry” (SPIRE 2014-4). The specific challenge as set out in the work programme highlighted the need to increase European knowledge base related to applied sustainability assessment methods, tools and indicators and to overcome bottlenecks for cross-sectorial take-up and further development in the process industry. This section discusses the findings of the project and considers potential bottlenecks for cross-sectorial application of the methods evaluated and tested during the project.

Based on the findings of the review and evaluations discussed in the previous sections, it can be stated that in principle, most of the assessed and tested, currently existing methods are applicable in different sectors, including those represented in the SPIRE initiative. In addition to sector specific tools, there are tools that are applicable on any sector. However, some of the potentially interesting methods for sustainability assessment or resource and energy efficiency assessment still lack practical tool implementations, especially when integrated methods and hybrid methods are considered. On the other hand, a number of what we called ‘integrated tools’ exist, but these tools implement their own combinations of methods, and not the ones considered in the context of integrated methods in our review.

From industrial point of view, the situation overall seems a bit confusing, and in practice only a few of the existing methods and tools have been implemented by the industry for regular use. To integrate the methods in daily activities, many industrial actors have developed their own tools or even methods. In addition, many industrialists are facing questions from their stakeholders (including customers, authorities and investors), that use their own approaches and questionnaires which typically have their own features to deal with. (SAMT D1.2)

The applicability of the methods for sectorial or cross-sectorial assessment also varies depending on what is actually meant by sectorial or cross-sectorial assessment. Based on our current understanding, this could be defined either as:

1. an assessment that is focusing on impacts on a sectoral level, or economy level (including different sectors), or
2. an assessment or method that is applied within a sector or across different sectors.

In the first case, methods best applicable for assessments at sectoral level seem to be the so called hybrid methods, and approaches developed for consequential LCA, (such as LCAA, LCA + EE-IOA, LCA + equilibrium models). At the moment, these methods are mainly applied by research organisations, in the context of large research projects.

In the second case, our review and evaluations show that there are several methods that can be applied within and across different sectors, but one of the practical challenges is that results of these assessments are not comparable. Comparability would be important for applying the results for benchmarking purposes, and for guiding customers and end-users in making sustainable choices. Benchmarking was also among the joint needs expressed by the industrial actors during the interviews.

In addition to challenges related to comparability, implementation of the evaluated life cycle methods in different sectors seems to be challenged by the lack of relevant data or characterization factors, or lack of practical tool implementations. Even though many of the methods have existing standards (LCA, CF, WF, Eco-efficiency), some of the less implemented methods could benefit from additional guidance or agreed principles. These challenges were confronted during the practical case studies conducted as part of the SAMT project, but many of the aspects were discussed in the context of the interviews, which signals that these are also aspects that are faced in practice when applying these methods.

Within the case studies, several LCA methods were implemented in practice in a joint, collaborative working environment, in which the methods were applied by different organisations. This allowed us to test an approach in which different value chain actors would work together, each applying their own tools and databases. Additionally, the implementation of a few of the methods was simulated considering the actual needs for application of the methods in practice and using a dedicated set of questionnaires for this purpose. The methods and tools applied within the case studies are presented in tables 4, 5 and 6.<sup>6</sup>

**Table 4 Methods, tools and impact categories applied within the integrated case study (SAMT D2.2 Annex 1)**

Used tool	Type of indicators	Impact category	Characterisation model
<b>Standard LCA (comparison of two productions systems located in Germany and Spain)</b>			
SimaPro	Environmental	Abiotic depletion	CML 2001
		Acidification	
		Eutrophication	
		Global Warming 100a	
		Ozone layer depletion 40a	
		Photochemical oxidation	

<sup>6</sup> Detailed descriptions of the method selection, case study framework and the specific results from the case studies are presented in SAMT D2.2 (Tapia et al. 2016 and related annexes 1-3).

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MIPS			
OpenLCA	Resource Use	Abiotic raw materials	Saurat & Ritthoff 2013
		Biotic raw materials	
		Earth movement in agriculture and silviculture	
		Water	
		Air	
LCC			
Excel	Economic	Development costs	Sell et al., 2014
		Use costs	
		Disposal costs	
EEA			
BASF EEA tool	Environmental	Resource depletion (mineral & fossil)	EU PEF 2014
		Acidification	EU PEF 2014
		Climate change	EU PEF 2014
		Eutrophication (freshwater & marine)	EU PEF 2014
		Human toxicity	BASF 2002
		Photochemical ozone formation	EU PEF 2014
	Economic	Development costs	Total Cost of Ownership (TCO)
		Use costs	
		Disposal costs	
GP			
Excel	Environmental	Abiotic depletion	CML 2001
		Acidification	
		Eutrophication	
		Global Warming 100a	
		Ozone layer depletion 40a	
		Photochemical oxidation	
	Economic	Development costs	Sell et al., 2014
		Use costs	
		Disposal costs	
S-LCA			
Handbook for Product Social Assessment	Social	Basic rights and needs	Roundtable for Product Social Metrics <sup>7</sup>
		Employment	
		Health and safety	
		Skills and knowledge	

Table 5 Methods, tools and impact categories applied within the water footprint case study (SAMT D2.2 Annex 2)

WATER FOOTPRINT			
Used tool	Type of indicators	Impact category (Midpoint)	Characterisation model
Waterlily	Consumptive water use	Water scarcity	Water scarcity index from Pfister et al. (2009)
	Water degradation	Freshwater eutrophication	ReCiPe (Goedkoop et al. 2009)
		Marine eutrophication	ReCiPe (Goedkoop et al. 2009)
		Freshwater acidification	IMPACT 2002+ (Jolliet et al. 2003)

<sup>7</sup> Applied on the “mandatory” social topics within the WBCSD method.

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		Freshwater ecotoxicity	USEtox (Rosenbaum et al. 2008)
		Toxicity to human	USEtox (Rosenbaum et al. 2008)
SULCA	Consumptive water use	Water scarcity	WULCA / AWaRe, 2016
	Water degradation	Aquatic eutrophication	WorldImpact+, 2012
		Aquatic ecotoxicity, long-term	
		Aquatic ecotoxicity, short-term	
		Terrestrial acidification	
		Carcinogens, long-term	
		Carcinogens, short-term	
		Non-carcinogens, long-term	
Non-carcinogens, short-term			
<b>MIPS</b>			
OpenLCA	Resource use	Abiotic raw materials	Saurat & Ritthoff 2013
		Biotic raw materials	
		Earth movement in agriculture and silviculture	
		Water	
		Air	

**Table 6 Methods tested at a simulation level (SAMT D2.2 Annex 3)**

Simulation methods	Type	Main motivation
Carbon Footprint	LCA-based	It is a widely used method. CF is the basis for many energy efficiency assessments.
Exergetic-LCA	Exergy-based method. LCA-based	High relevance according to the RACER evaluation
LCAA	Hybrid method	Promising method

The findings from the case studies point out that there is a number of cross-cutting implementation challenges that were common to almost all of the methods tested within our case studies. These are topics that can be considered as bottlenecks that currently hinder sustainability assessments across different sectors and as part of daily decision-making. In short, identified bottlenecks (implementation challenges) can be summarised to three main categories that include Data availability and management issues; Diversity of tools and data formats and Variety of methodological approaches and assumptions. These challenges have been discussed to some extent throughout the SAMT deliverables, and many of them were faced in practice in the context of the case studies.

- Data availability and management issues:

The critical phase of all these assessments, environmental, economic, social, integrated and hybrid alike is data availability. All the methods applied in our case studies rely on the collection of a large amount of value chain data whose absence greatly compromises the overall quality of results. Many of the challenges relate to accessing data related to processes outside organisations own activities (both upstream and downstream of the life cycle), and an access to a life cycle database is usually required. When primary data is collected, it often entails a lot of manual work, which is time consuming and altered for mistakes. Furthermore, whereas environmental and economic data can be obtained from well-established commercial and public databases, the social assessments are still challenged by the lack of generalised database data. Averaged and/or aggregated data can be used to go around the challenges related to

confidentiality, but in these cases it is often difficult to trace back data sources and evaluate the content or origin of the data. Similar issues are typically faced with the commonly applied LCI-databases.

- Diversity of tools (software) and data formats:

In those situations where the assessment covers the whole life cycle, it usually includes process data from different actors that have their own software solutions and databases in use. Sharing inventory or impact data across different software platforms and database versions might become tricky, since according to the experience from the case studies, software tools are not entirely compatible with the exchange formats available for sharing LCA datasets – particularly with the ILCD standard. Some of the tools available for data exchange and transformation did not seem to work properly. This created some degree of uncertainty on the extent to which the analysis done by each contributor was based on the exact same data. The same holds for the impact methods chosen. For instance, certain impact assessment methods are not comprehensively documented in certain tools, and therefore might not be easily implemented to other tools. This can also be motivated by the differences between the specific versions of the databases and impact assessment methods. Differences between different generations of datasets and impact methods may have significant impacts on the final results, but finding out the exact reason for these discrepancies might be challenging if the methods are not documented thoroughly and transparently. In some cases sustainability expertise is not enough, as some of the challenges might also require expertise in programming and database management.

- Variety of methodological approaches and assumptions (“Interpretation challenge”):

Conducting a sustainability assessment requires making many assumptions and choices that relate for example to applied methods, system boundaries, data sources and allocation. When conducting an LCA, there is a variety of impact assessment methods for different environmental impact categories to choose from. Although there are some guidelines for selecting options in different situations (e.g. the ELDC handbook provides recommendations on impact assessment methods and the ISO14040 provides guidelines for selecting the correct allocation methods), this selection is not always straightforward. Sometimes applying different methodological approaches may lead to radically different conclusions. In addition, interpreting the results of an assessment requires a vast amount of information of the underlying assumptions and methodological choices made. Unless a full LCA report is available, interpreting the results is difficult. Besides being important for better interpretation of the results, transparency would also be required in order to create benchmarks against which companies could evaluate their own products and performance. Availability of benchmarks was one of the needs identified by our industrial experts during the interviews. Needs related to benchmarking were highlighted regularly also during workshop discussions.

All the above mentioned bottlenecks related to data, tools and methods might have a huge impact in terms of the resources required for the assessments. All of the evaluated methods can be considered as data intensive. Their implementation in practice requires expertise and some level of investment to create meaningful results. Although the need to provide high quality results using as much primary data as possible was highlighted by the industry representatives, there is a constant need to automatize and to lighten the assessment process. While it was acknowledged that some level of uncertainty should be accepted, further developments would be required for handling and communicating uncertainty. In general, new solutions would be needed especially for visualising and communicating the results to non-expert audiences. This would be important for both internal and external communication purposes. There is a need to persuade stakeholders about the additional value these assessments can create for decision-making. The more the assessments require resources, more clearly should the benefit and additional value of the assessment for decision-making be expressed.

## 5 Conclusions and discussion

The aim of the report was to discuss sectorial and cross-sectorial applicability of the evaluated life cycle based assessment methods based on different studies conducted during the SAMT project. In addition, identified development needs from the point of view of industry and policy making were considered. The focus of this report was on practical challenges especially related to implementing the methods in an industrial context. By summarising the challenges and development needs related to implementation and applicability of the methods in practice, this report highlights some of the bottlenecks that would need to be overcome in order to increase the uptake of life cycle based sustainability assessment methods in different sectors of the process industry.

Overall, based on the findings of the project it can be concluded that there are several methods and tools that can be applied for the purposes of life cycle sustainability assessment. Out of the methods and tools evaluated in the SAMT project, the vast majority are applicable in different sectors. However, there are practical bottlenecks that would need to be solved in order to increase the use of the methods within industries. These include several aspects ranging from incompatibility of existing software tools and data formats, to variety of methodological choices and assumptions, and data scarcity. Expert knowledge is needed to navigate through all these methodological and operational choices. One specific aspect that was underlined by all interviewed actors is that despite life cycle based assessment approaches are necessary in order to understand potential impacts along the whole product chain; such methods are data and resource intensive to apply in practice. Combined, all these factors may lead to increased –sometimes unaffordable – implementation costs.

As the development of the LCA based methods is moving from environmental assessments towards multidimensional assessments that would include economic and social aspects and extend from product level to sector level, requirements related to successful implementation and interpretation of the results increase. From industrial point of view, there is an interest to increase harmonisation of applied methods and assessment approaches, and thus to increase the use of similar methods across different sectors.

Harmonised use of the methods and communication of the results is expected to clarify current situation, in which results of different studies are not comparable. An important, practical benefit from harmonised approaches could be increasing transparency of the reporting, which would allow better use of the results from different studies for benchmarking purposes. Lack of benchmarks is one of the challenges, since there is a constant need to evaluate and communicate about the performance of different products and achieved improvements and resource and energy savings.

From the evaluated life cycle based methods, all are capable of providing useful information to decision-making, but only few of the methods are currently applied by the companies who participated in the study. To ease the implementation of methods in practice and to match with the specific needs of own products, companies have developed their own tools and even methods. In addition, several qualitative and semi-qualitative assessment methods and tools are used for assessment, reporting and communication purposes.

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To enable more efficient implementation of the evaluated life cycle-based assessment methods for industrial purposes, all of the assessed methods would benefit for further development related to credibility, robustness and easiness to use. From an industrial point of view, there is an interest for both developing existing methods to cover and integrate different aspects of sustainability, and to develop harmonised guidelines for simplified assessments, in which part of the work flow could be automated and the assessment process could be better integrated as part of daily decision-making.

Cross-sectorial sustainability assessment, focusing on evaluating impacts at sectorial or even economic level using hybrid methods (LCA) is currently not among the main interests of the industrial actors, but is in general considered interesting and useful for examples for the purposes for evaluating the impacts of circular use of resources and recycling. A challenge for implementation in practice is also that available hybrid methods currently lack concrete tool implementation. Thus it seems that, with the possible exception of specific business implementations where sustainability improvements stem from the creation of ecosystems of industries operating physically closed to each other, like e.g. industrial symbiosis platforms, the hybrid methods designed for sector level assessments could be more useful for the purposes research projects, and policy planning and evaluation.

The final conclusions and recommendations from the SAMT project are discussed in three separate project deliverables. While this report summarised the main findings related to sectorial and cross-sectorial applicability of the evaluated methods, the second report (SAMT D3.2) presents identified future research needs in a summarised way, and includes proposals related to future standardisation that could support future harmonisation activities related to sustainability assessment. Finally, recommendations for accelerating further uptake of sustainability assessment methods in the process industries, and for developing consistent sustainability assessment methods within the process industries are discussed in SAMT D3.3, in which a vision, a roadmap and an implementation strategy describing concrete actions for short, medium and long term are presented.

## 6 References

### SAMT project deliverables

- SAMT D1.1 Overview of existing sustainability assessment methods and tools, and of relevant standards (2015). Responsible authors and organisations: Mathieu Saurat & Michael Ritthoff, Wuppertal Institute for climate, environment and energy; Luz Smith, AENOR.
- SAMT D1.2 Description of current industry practice and definition of the evaluation criteria (2015). Responsible authors and organisations: Mathieu Saurat & Michael Ritthoff, Wuppertal Institute for climate, environment and energy; Hanna Pihkola, VTT Technical Research Centre of Finland; Aritz Alonso & Arantza Lopez, Tecnalia.
- SAMT D2.1 Best practice solutions: Methods for sustainability assessment within the process industries (2015). Responsible authors and organisations: Arantza López, Lara Mabe, Beatriz Sanchez, Carlos Tapia and Aritz Alonso, Tecnalia.
- SAMT D2.2 Case Study Report: Analysis of best practice solutions in comparison with currently used techniques (2016). Responsible authors and organisations: Carlos Tapia, Aritz Alonso, Ales Padró, Raul Hugarte, Marco Bianchi, Arantza López (Tecnalia); Hanna Pihkola, Elina Saarivuori (VTT); Michael Ritthoff (Wuppertal Institute); Peter Saling (BASF); Kianga Schmuck (Bayer); Ywann Penru, Pascal Dauthuille (SUEZ); Alexander Martin Roeder, Martin Jenke (CEMEX); Jostein Søreide (Hydro); Annamari Enström, Sari Kuusisto (Neste).
  - o Annex 1 Integrated case study
  - o Annex 2 Water footprint case study
  - o Annex 3 Simulation case study

All deliverables are available at [www.spire2030.eu/samt](http://www.spire2030.eu/samt)