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

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Deliverable 2.1

Best practice solutions: Methods for sustainability assessment within the process industries

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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 industries 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 by conducting case studies, organising workshops and producing recommendations for further implementation of the best practices in sustainability assessment.

D2.1 Best practice solutions: Methods for sustainability assessment within the process industries

The aim of this report is to provide a comparison of some of the methodological and procedural alternatives available to conduct sustainability assessments within the process industry. This comparison has been carried out by providing a well-structured evaluation of a total of 14 sustainability assessment methods selected from the extensive list of methods and tools characterised within SAMT deliverables 1.1 - Overview of existing sustainability assessment methods and tools, and of relevant standards and 1.2. - Description of current industry practice and definition of the evaluation criteria.

This report is thus the third outcome of the SAMT project. It builds on the evidence collected by a number of related activities covering several aspects of sustainability assessment within the process industry. In particular, the 14 methods have been selected basing on a cross-check analysis that took account of a number of criteria that were jointly identified by all partners as the most relevant dimensions to be accounted for within the SAMT project. These included aspects such as cross-sectoriality, multi-dimensionality, lifecycle orientation and availability of supporting tools. The 14 methods that passed the evaluation are listed below:

1. LCA: Life Cycle Assessment
2. MIPS: Material Input Per Service
3. CED: Cumulative Energy Demand
4. E-LCA: Exergetic Life Cycle Assessment, Exergy analysis
5. CF: Carbon Footprint
6. WF: Water Footprint
7. LCA/PEM: Hybrid LCA + Partial Equilibrium Model
8. LCAA: Life Cycle Activity Analysis
9. EEA: Eco-Efficiency Analysis
10. SEEBALANCE®: Socio-Eco-Efficiency Analysis
11. PROSA: Product Sustainability Assessment
12. LInX: Life cycle iNdeX
13. SustV: Sustainable Value
14. EcoD: Ecodesign, Design for Environment

These methods were subsequently evaluated basing on a modified RACER methodology, which is an evaluation framework designed by the European Commission to assess the value of scientific tools for decision-making. The SAMT-RACER evaluation was applied as a semi-quantitative assessment performed over a total of 16 dimensions under the following components: **R**elevant, **A**ccepted, **C**redible, **E**asy to monitor and **R**obust. An overview of the different criteria included in the evaluation framework was provided for each method. The evaluation also allowed ranking all methods within each of the dimensions considered in the assessment.

The evaluation was designed as an iterative process involving all partners of the SAMT project. The preliminary evaluation of methods was conducted by a team of sustainability experts at Tecnalia R&I. These outcomes of this initial review were presented to the remaining project members, leading to a number of modifications on the original evaluation results and scores. The evaluation approach was in

itself one of the main contributions of this work, as the method proved to be rather stable and could be adapted to the objectives of the SAMT project with relative ease.

The main outcomes of the SAMT-RACER evaluation are presented below:

- **SEEBALANCE®** was the only method that fulfilled all the general criteria considered in the cross-check analysis, namely cross-sectoral applicability, multi-dimensional nature, level of assessment and availability of tools.
- The **E-LCA** ranked on top of the list within the ***Relevant*** criterion among the methods evaluated using the SAMT-RACER evaluation approach. It was also one of the methods ranking above average in the ***Robust*** dimension. The E-LCA was also the method showing the highest potentials to combine the resource and energy efficiency perspectives. Furthermore, it also delivers material and energy efficiency results in a unified measure for all types of resources.
- The **LinX** framework ranked highest over the ***Credible*** dimension as its results could be easily interpreted and its data collection process could be traced back with ease.
- The **EEA**, **WF**, **CED**, **E-LCA**, **LInX** and **SustV**, alongside **LCA** and **CF**, ranked above average within the ***Robust*** criterion.

It is important to note that the list of evaluated methods was not exhaustive, and it might be that due to very large amount of existing methods, some interesting or potential methods have been missed already in the earlier stages of assessment within the project. Additionally, it should be noted that this kind of assessment always includes some level of subjectivity, although this can be reduced using an iterative process.

The main conclusion that drawn from the SAMT-RACER implementation is that there is not a one-size-fits-all solution in terms of sustainability assessment methods within the process industry. Gains in versatility and multidimensionality generally imply less acceptance, credibility and, particularly, simplicity and user-friendliness of methods. A combination of methods seems to be the only alternative, which entails finding appropriate methods to complement each other within specific industries and sectors.

The SAMT case studies will be of much help in identifying which of the methods could realistically be applied across sectors and effectively cover more than one sustainability dimensions, in particular capturing the energy and resource efficiency perspectives. In this respect, the sustainability assessment methods listed in the bullet points above could be proposed as good alternatives for the case study testing that will take place during the subsequent implementation phase of the SAMT project. However, this proposal has to be confronted with other practical issues related to the interests and operational needs shown by the industrial partners.

KEY WORDS:

RACER, methods, tools, sustainability assessment, evaluation

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Contents

List of abbreviations

CED	Cumulative Energy Demand
CF	Carbon Footprint
EcoD	Ecodesign, Design for Environment, Life Cycle Design, Sustainable Process Design
EEA	Eco-Efficiency Analysis
E-LCA	Exergetic Life Cycle Assessment, Exergy analysis
GWP	Global Warming Potential
LCA	Life Cycle Assessment

LCA/PEM	Hybrid LCA + partial equilibrium model
LCAA	Life Cycle Activity Analysis
LCI	Life cycle inventory
LInX	Life cycle iNdeX
MIPS	Material Input Per Service
PROSA	Product Sustainability Assessment
SEEBALANCE®	Socio-Eco-Efficiency Analysis
SustV	Sustainable Value
WF	Water Footprint

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)[1] 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 SPRIRE 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 resource and energy efficiency within the process industries and across the different sectors of the industry.

[1] See: www.spire2030.eu

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 asses 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.[2]
- **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 (Saurat & Ritthoff 2015).

1.3 Aim of the report

The aim of the SAMT project is to review, make recommendations and develop an implementation strategy about the most promising methods for evaluating sustainability and therein the energy efficiency and resource efficiency in the process industry. The goals of the second work package in the project (WP2) are:

- to classify and select the best practices to carry out sustainability assessment throughout evaluation matrixes and performing case studies;
- to evaluate the applicability of selected tools for evaluating resource and energy efficiency using case studies, and;

[2] Please note that minor specifications to the definitions of method and tool were made compared to the definitions presented in SAMT D1.1.

- to evaluate the suitability and to classify the selected sustainability assessment methods according to their ability to support management and decision-making in different contexts and at different levels of action.

This report addresses specifically the first and second bullet points above. The ultimate aim of this work is to evaluate the different sustainability assessment methods described within D1.1 against a set of criteria jointly defined within the SAMT project, with a particular focus on the industry practice described within D1.2. Its specific goals have been to:

- Pre-select a restricted number of sustainability assessment methods among those considered within D1.1, according to a number of critical characteristics defined by the SAMT project, including the feedback received from the industrial partners within D1.2.
- Evaluate the selected methods against a stable and coherent methodology and elevate a number of policy recommendations based on such

1.4 Method

The analytical work performed in this work was based on a two-stage evaluation of the sustainability assessment methods considered in the SAMT project that included:

1. a pre-selection of methods based on a cross-check analysis implemented on the 51 sustainability assessment methods considered by the SAMT project;
2. an evaluation of methods based on the application of a adapted RACER method, which is an evaluation framework designed by the European Commission to assess the value of scientific tools in policy-making.

The following sections provide a detailed overview of the methods underpinning these two analytical steps:

1.4.1 Pre-selection of methods for evaluation: a cross-check analysis

For operational reasons, only a subset of the 51 quantitative sustainability assessments methods relevant for the process industry among those characterised within the previous SAMT tasks could be evaluated within this report. Such 51 sustainability assessment methods are described in more detail within SAMT Deliverables 1.1 and 1.2. In particular, D 1.1 provides an overview of all of these quantitative assessment methods and clusters them in the seven method-categories shown in Figure 1 (Saurat et al. 2015a). D1.2 builds on this characterisation of methods, providing evidence about how these methods are applied in practice by engaging in a dialogue with sustainably assessment practitioners within the process industry. This dialogue illustrated how companies also apply a number of qualitative research methods for sustainability assessment (Saurat et al. 2015b), which have not been included in this assessment, which was focused mainly on quantitative assessment methods. Additionally, many companies use their own methods and tools for sustainability assessment. There are also many industry specific methods and tools that were not included in the assessment. A list of these additional methods and tools can be found as an appendix to SAMT D1.2.

Figure 1: Sustainability assessment methods and tools considered in SAMT Deliverable 1.1.

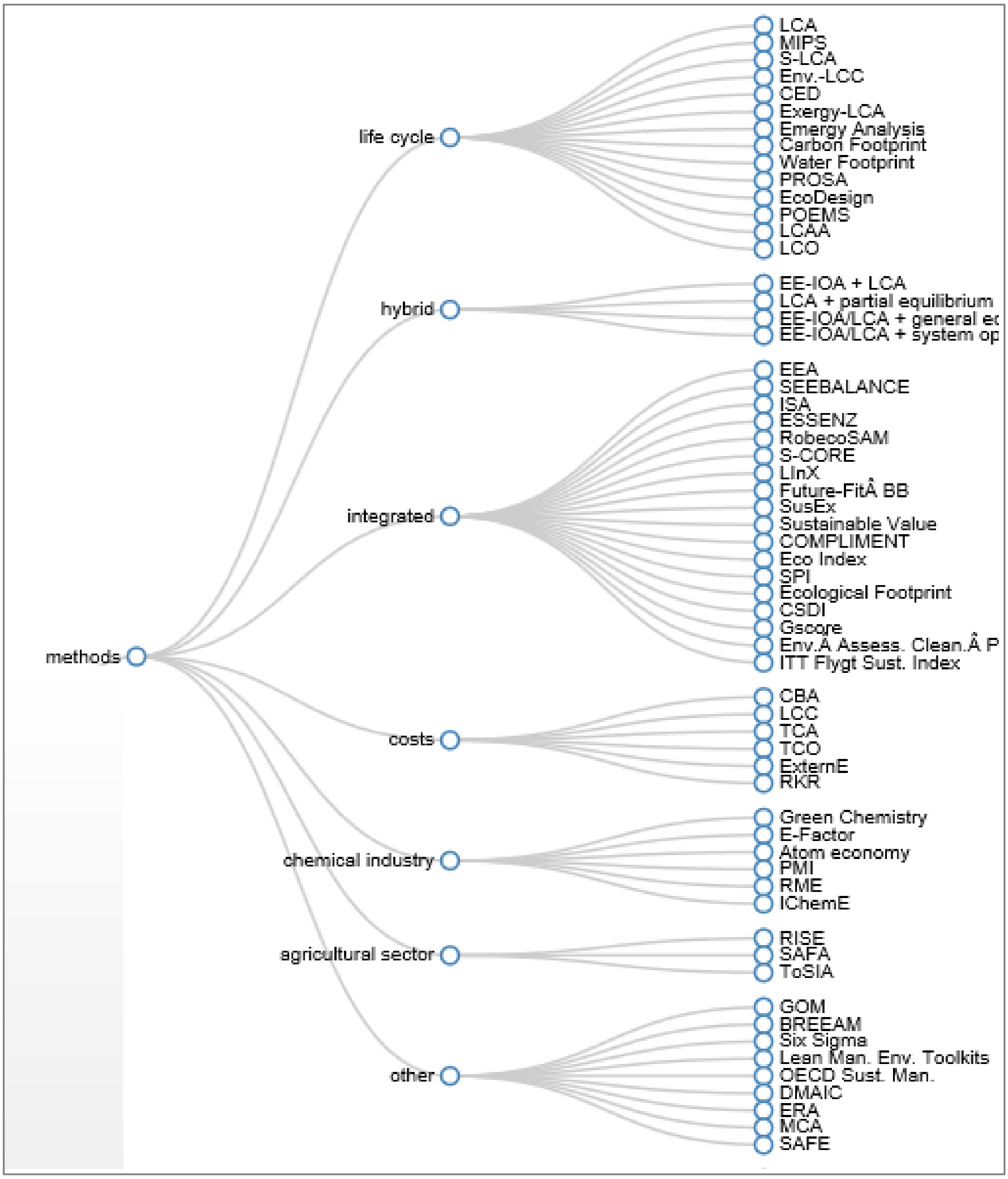


Table 1 below provides an overview of the method and tool clusters defined within SAMT D1.1.

Table 1: Clusters with potential for cross-sectorial applications, according to SAMT D 1.1.

Method and tool clusters	Description
Life cycle methods	LCA, subsets or derivatives of LCA, and life cycle methods beyond environmental assessment
Hybrid methods	Fusion of existing methods (the limit between methods becomes blurred) in order to increase the scope of each individual method.
Integrated methods	Juxtaposition of well-delimited methods ("Russian dolls" construct) to support decision making. Usually includes a weighting scheme to aggregate sub-indicators into one or a small number of indicators.
Full LCA tools	Implementation of ISO-conform LCA and possibly other life cycle methods
Simplified LCA tools	Implementation of streamlined LCA and possibly other life cycle methods
Integrated tools	Interestingly, available integrated tools do not implement the integrated methods described above but provide their own combinations of methods

In order to select a restricted number of methods for in-depth evaluation, a cross-check analysis has been applied on all the 51 quantitative sustainability assessment methods. The cross-check analysis was based on the following criteria:

- **Sectors covered**: Cross-sectorial, multi-sectorial, sector specific
- **Sustainability dimensions addressed**: environmental, social and/or economic, including specific aspects within each dimension.
- **Level of assessment / lifecycle approach**: product, company, industry or society, upstream and downstream
- **Availability of tools and implementation complexity**: availability of good-quality tools, data, manuals, etc., facilitating the application of the different methods.

These criteria were jointly defined among all the SAMT project partners, including the industrial partners and the Research and Technology Organisations involved in the consortium. The initial feedback was collected during the first SAMT project workshop that was held in June 2015 in Germany. Subsequently, an iterative reviewing process was held until consensus among all partners was achieved.

The cross-check analysis was subsequently performed by a team of sustainable assessment specialists at Tecnalia R&I. In the end, a total of 14 methods – presented in Table 2 – were selected for in-depth evaluation.

Table 2: Methods pre-selected for the complete RACER evaluation

		Sectors Covered	Addressed aspects	Level of Assessment	Availability of tools
LCA	Life Cycle Assessment	✓	~	✓	✓
MIPS	Material Input Per Service	✓	~	✓	✓
CED	Cumulative Energy Demand	✓	~	✓	✓
E-LCA	Exergetic Life Cycle Assessment, Exergy analysis	✓	~	✓	✗
CF	Carbon Footprint	✓	✗	✓	✓
WF	Water Footprint	✓	✗	✓	✓
LCA/PEM	Hybrid LCA + partial equilibrium model	✓	~	~	✗
LCAA	Life Cycle Activity Analysis	✓	~	✓	✗
EEA	Eco-Efficiency Analysis	✓	~	✓	✓
SEEBALANCE®	Socio-Eco-Efficiency Analysis	✓	✓	✓	✓
PROSA	Product Sustainability Assessment	✓	✓	✓	~
LInX	Life cycle iNdeX	✓	✓	~	~
SustV	Sustainable Value	~	✓	✓	~
EcoD	Ecodesign, Design for Environment	✓	~	✓	✓

As shown in Table 2, the focus has been placed on those methods that can be applied across different sectors. From the SAMT perspective, this implies that we have just evaluated those methods that could be applied to any of the process industry sectors considered in the SAMT project, namely cement, oil, metal, water, waste and chemical, taking also into account the feedback collected within D 1.2. These methods were identified with a tick in Table 2. However, this criterion does not assume that the methods yielded results allowing direct comparisons across sectors. This quality has been included as a criterion to assess robustness of methods but not as a pre-requisite for evaluating them. The only method that did not directly comply with this criterion was the Sustainable Value method, considering that evaluations performed with this method are based on the comparison of the units being analysed with a set of pre-defined benchmarks. So far, benchmarks are only available for a restricted number of sectors. Still the method was included in the evaluation as it was considered that additional benchmarks could be easily provided to cover additional sectors as well. Accordingly, this sector was identified with a tilde within the Table 2.

Similarly, only those methods that at least cover one environmental aspect of sustainability have been selected for evaluation. In this respect, in tables, a cross means that the method only covers one specific environmental dimension – e.g. CO_2 emissions by CF, water by WF –. A tilde sign indicates that methods cover more than one environmental aspect, but do not consider the social and economic dimensions of sustainability –e.g. Life Cycle Assessment –. A tick means that method covers at least two dimensions of sustainability – i.e. environment, economical and/or social –.

Most of the methods considered cover all levels of the life cycle assessment –identified with a tick in the table –, except LCA/PEM and Life Cycle index, which focus in the production and design phases of products, respectively. These are identified with a tilde in table 2.

With respect to the availability of support tools simplifying the application of methods within industries, several methods still present weaknesses in this respect. Some methods, namely the hybrid LCA/economic models and the Exergy analysis –identified with a cross in the Table–, still lack of tools supporting the application of methods. Other methods have support tools but these are still in an early phase of development, are difficult to obtain or require considerable expertise to make appropriate use of them. These methods are identified with a tilde in Table 2. Finally, another group of methods –identified with a tick in Table 2– can already rely on a number of well-functioning tools specifically designed for the application of the methods with much lower implementation costs.

1.4.2 The SAMT-RACER in-depth evaluation method

This section describes the method that has been developed to evaluate the methods for assessing sustainability in the process industries. Our approach is based on the RACER method, an evaluation framework designed by the European Commission to assess the value of scientific tools for use in policy making (European Commission, 2005 and 2009).

In 2005 the European Commission published the first version of the Impact Assessment Guidelines (European Commission, 2005). In this document the European Commission defined six steps to follow when performing an impact assessment, namely:

1) Identify the problem
   - Delineate the extent of the problem
   - Identify the key players/affected populations
   - Establish the causes

   Define of the objectives
   - Set accurate objectives following “SMART” considerations (see below)
2) Assess the policy options
3) Identify the type of impacts
4) Compare the options
5) Identify key indicators

In the second step, after identifying the problem, the definition of the objectives is targeted. For this purpose, the guideline establishes that the objectives should be directly related to the problem and its root causes and that they should also be set in hierarchical order and become increasingly detailed or “SMART”, embracing the following criteria:

- ✓ **Specific:** objectives should be precise and concrete enough not to be open to varying interpretations. They must be understood similarly by all.
- ✓ **Measurable:** objectives should define a desired future state in measurable terms, so that it is possible to verify whether the objective has been achieved or not. Such objectives are either quantified or based on a combination of description and scoring scales.
- ✓ **Achievable**: if objectives and target levels are to influence behavior, those who are responsible for them must be able to achieve them.
- ✓ **Realistic:** objectives and target levels should be ambitious – setting an objective that only reflects the current level of achievement is not useful – but they should also be realistic so that those responsible see them as meaningful.
- ✓ **Time-dependent:** objectives and target levels remain vague if they are not related to a fixed date or time period.

In the second version of the Impact Assessment Guidelines of the European Commission (2009) a description of how to define SMART objectives is also included. Moreover, it is stressed that SMART objectives are essential to define good monitoring indicators.

Against this framework, the RACER method was defined in order to design sound measuring frameworks to track progress towards predefined policy goals (European Commission, 2009). RACER is an evaluation framework applied to assess the value of scientific tools for use in policy making. RACER stands for Relevant, Accepted, Credible, Easy and Robust (1 and 2).

RACER means:

- ✓ **Relevant** – i.e. closely linked to the objectives to be reached
- ✓ **Accepted** – e.g. 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

Section 1.5 below provides a thorough description on how the RACER method has been adapted to fulfil the specific objectives of the SAMT project.

1.5 The SAMT-RACER evaluation criteria

1.5.1 An overview of the evaluation criteria

The generic RACER approach has been adapted in order to fit to the purpose of the study. In practice, the RACER method has been modified to consider the following dimensions characterising the different sustainability methods included in this assessment:

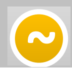
- **Cross-sectoral applicability**: Comparability among sectors cannot be fully achieved unless similar methods are applied to assess sustainability of the products and processes specific to each sector. Although each sector has its own specificities that should be tackled by means of tailor-made tools, 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.
- **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.

These dimensions have been considered as the main criteria to appraise the sustainability assessment methods. Sections 1.5.2 to 1.5.6 below provide a detailed description of these criteria.

In operational terms, the RACER assessment relied on the elaboration of a number of "evaluation matrices". Each of those matrices focused on one component of the RACER method, namely **R**elevance, **A**cceptance, **C**redibility, **E**asy to monitor and **R**obustness. During the assessment procedure each criterion included in the evaluation matrices was classified as "fully achieved", "partly achieved" or "not achieved" (see Sections 1.5.2 to 1.5.6 for details).

Numerical scores have been assigned to each method according to the degree to which it complied with the predefined set of criteria. The scoring system is as follows: fully achieved criterion – 2 points, partly achieved criterion – 1 point, not achieved criterion – 0 points. The overall score resulting for each RACER component and sustainability assessment method was derived from a simple aggregation of the partial scores for each evaluation criterion and RACER component, respectively. A symbol code has also been defined for each score range, rendering a visual representation of results. The scoring and symbol coding system is shown in the following Table 3.

Table 3: Scoring system for the SAMT-RACER evaluation method

RACER components	Maximum score	Symbol codes and thresholds		
				
Relevant	8 points	8-7	6-4	3-0
Accepted	6 points	6-5	4	3-0
Credible	6 points	6-5	4	3-0
Easy to use	6 points	6-5	4	3-0
Robust	6 points	6-5	4	3-0
Total score	32 points	32-25	24-17	16-0

Each method was assessed by a team of experts from Tecnalia R&D. This team was composed by specialists with different professional backgrounds, including environmental engineers, chemists, biologists and social scientists. All of them hold a strong research record in sustainability assessments within various technology fields. The evaluation was subsequently validated by all the industrial and RTO partners involved in the SAMT project. This led to minor changes in the scoring of two of the methods considered here.

1.5.2 Characterisation of the "Relevant" component

The following criteria have been considered to assess the relevance of sustainability assessment methods within the process industry:

- **Life cycle oriented method**: the evaluation of this criterion is based on the number of life cycle stages considered by each method.
    - Methods covering the full life cycle of a product or a process are those for which this criterion is considered to be fully achieved.
    - Methods having a lifecycle approach but that only focus on the most relevant life cycle stage(s) partly achieves this criterion.
    - Methods that do not achieve this criterion are those focused in a limited part of the life cycle or methods that are not life cycle oriented.
- **Sectors covered**: the possibility to apply this method to more than one sector determines the evaluation of this method.
    - Whenever a method is applicable across sectors and allows assessing and contrasting results between sectors, it is labelled as fully achieved.
    - Methods that can be applied to the most relevant sectors – i.e. those sectors related to the process industry –, albeit not being genuinely cross-sectoral, or being particularly relevant

for one specific group of sectors –e.g. WF for the water-intense sectors–, will be considered partly achieving this criterion.
  - If a method can only be applied to one sector, it is considered that this criterion is not achieved.
- **Potential to assess resource efficiency**: this criterion judges if a method is useful to assess resource efficiency.
  - A method that could provide a resource efficiency assessment of a product or a process is considered as fully achieving this criterion.
  - A method that provides relevant information for assessing resource efficiency but does not directly assess this dimension would partly achieve this criterion.
  - If a method neither assesses resource efficiency nor provides relevant information for this purpose, this criterion is not achieved.
- **Potential to assess energy efficiency**: this criterion judges if a method is useful to assess energy efficiency.
  - A method that could provide an assessment of the energy efficiency of a product or a process is valued as fully achieving this criterion.
  - A method that provides relevant information for assessing energy efficiency but does not directly assess this dimension would partly achieve this criterion.
  - If a method neither assesses energy efficiency nor provides relevant information for this purpose, this criterion is not achieved.

In the following table a condensed definition of "Relevant criteria" is given.

Table 4: Evaluation matrix for the RELEVANT category

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Fully achieved	The method covers the full life cycle of the product/process	The method is applicable across-sectors	The method allows assessing resource efficiency	The method allows assessing energy efficiency
Partly achieved	The method covers several or at least the most relevant life cycle stages	The method covers several sectors, but it has been designed specifically and/or is particularly relevant for one sector	The method provides relevant information for assessing resource efficiency	The method provides relevant information for assessing energy efficiency
Not achieved	The method is focused on limited parts of the life cycle or it is not life cycle oriented	The method is sector-specific	The method cannot be used for assessing resource efficiency	The method cannot be used for assessing energy efficiency

Complementary to the above criteria, two additional informative components have been considered:

- **Geographical context**: Some methods have a broad geographical focus and do not differentiate between the specific characteristics of the local context where products and services are generated. The results provided by these methods do not allow local production parameters and factors – like e.g. different energy mixes – to arise. Although this spatial dimension has not been considered as one of the key issues to monitor within the SAMT project, some insights on this point have nonetheless been provided when performing the evaluation of specific methods.
- **Adaptability**: The possibility of adapting a method to one specific sector is one example of what adaptability means in this context. Considering that the adaptability of a method to different purposes could be a relevant advantage in comparison to other methods, this criterion has been considered in an informative/qualitative way within this evaluation.

1.5.3 Characterisation of the "Accepted" component

Within the **accepted** criterion both the points of view of the industry – as the main implementer and user of the methods – as well as the policy-makers – as the potential prescriptor or promoter of methods – have been considered.

More specifically, the acceptance criteria have been defined following the assessment categories hereafter described:

- **Industry status**: defined by extent of the use of methods among the industry or other businesses. The results provided by the interviews with the industrial partners have been a primary source of information in this respect – see SAMT Deliverable 1.2 for further details (Saurat et al. 2015b) –.
    - This criterion is considered as "fully achieved" if the use of methods is widespread in the industry with satisfactory results (according to the description of current industry practice gathered within SAMT Deliverable 1.2).
    - Some methods are frequently used in industry but only in very specific sectors. Other methods are promising but lack maturity to be widespread within the industry. In this case we consider that the method partly achieves the criterion.
    - It is considered a method does not achieve this criterion if it is not used in the industry due to its novelty, interpretation barriers or limited recognition.
- **Acceptance by the industry**: defined by the usefulness for decision-making within the industry.
    - A method fully achieves this criterion if the industry frequently uses this method within a decision making process.
    - If the method is gaining momentum as a decision making tool or it is considered by the evaluators as a method with significant potentials in this respect, it is considered that it partly achieves this criterion.
    - If the method is not used for decision making and does not seem to hold any particular potential in this respect, it is considered that the method does not achieve this criterion.
- **Public administration status**: this criterion is defined by the acceptance or recognition by the policy-makers and other members of the public administration. The recognition of the methods by

these agents can promote – or sometimes prescribe – their development and consequently increase interest of the industry on them.

- Methods that are approved and recommended by policy-makers fully achieve this criterion.
- Methods that partly achieve this criterion are those that are positively considered by policy-makers but are not explicitly promoted or prescribed by them.
- If the methods are not recognised by the public administration, this criterion is not achieved.

In the following table a condensed definition of “Accepted criteria” is given

Table 5: Evaluation matrix for the ACCEPTED category

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by policy-makers
Fully achieved	The method is widespread in the industry with positive results	The method is frequently used in the industry for decision-making	Approved and recommended by policy-makers/public administration agents
Partly achieved	Several industries use the method frequently	The industry is starting to use the method and/or it is very useful for decision making	Positively considered by policy-makers/public administration agents
Not achieved	The method is not widespread in industry	The method is not used for decision making, or it is difficult to be used for this purpose	Not recognised by policy-makers/public administration agents

1.5.4 Characterisation of the “Credible” component

The following category considered in our evaluation is “**credibility**”. This category refers to the ability of the methods according to their degree of ambiguity and simplicity of interpretation. This dimension was assessed against the following criteria:

- **Unambiguous**: this criterion relates to the interpretation of the results. It is based on the extent to which the results derived from the application of each sustainability assessment method are clearly understood and are not open to alternative interpretations, so that different practitioners can draw similar conclusions based on similar outcomes.
    - This criterion is fully achieved when the meaning of the results given by the method is clearly defined and the interpretation of its results does not require extensive explanations.
    - If the interpretation of the results is not as clear and explanations are needed for a correct interpretation of the outcomes, the criterion is considered as partly achieved.

  - Uncomprehensive results due to lack of clarity and/or potentially open interpretation of results mark this criterion as not achieved.
- **Transparency**: this criterion focuses on the clarity and transparency of the data collection process. Ideally, results could be traced-back in detail.
  - This criterion is fully achieved if data collection and pre-processing are clearly defined and traceability is possible. For confidential data, a review process is implemented where reviewers can have a detailed look into the data sets.
  - In case data collection and treatment processes are defined but lack accuracy so that traceability is hardly achievable or not completely possible, it is considered that this criterion is only partly achieved. For confidential data, no clear process of data reviewing is defined.
  - If the data collection and treatment processes are not specified in the definition of the method, this criterion is not achieved.
- **Consensus**: in order to define the consensus criterion, the existence of a standardisation scheme and/or commonly used practices has been considered as the main assessment criteria.
  - A standardised method fully achieves this criterion.
  - A method in process of standardisation or for which guidelines or international working groups exist, partly achieves this criterion.
  - The remaining methods do not achieve this criterion.

Table 6 summarises the "Credible" category criteria:

Table 6: Evaluation matrix for the CREDIBLE category

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Fully achieved	Method results are well-defined and are self-explanatory	Data collection and treatment are clearly defined and it is possible trace both processes back	The method is standardised
Partly achieved	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is in process of standardisation
Not achieved	Method results are not clearly defined and/or subject to open interpretation	Data collection and treatment processes are not detailed. Traceability is not possible	The method is not standardised nor a standardisation process has started

1.5.5 Characterisation of the "Easy to monitor" component

In the definition of the **easy to monitor** category, the availability of tools and data, as well as the level of automation that support the application have been considered:

- **Availability of tools**: in order to simplify the application of methods, the availability of tools supporting the implementation of methods has been considered as a relevant criterion. The tools can support the data management process, enable the assessment and help communicating results. At the same time, tools can also be of help to reduce mechanical errors.
    - If high quality and accepted tools for the implementation of a method are available, this criterion is fully achieved.
    - If tools are not generally accepted or have a low quality, this criterion is considered as partly achieved.
    - If no tools are available at all, this criterion is not achieved.
- **Data availability**: the availability of high quality data is determinant for obtaining reliable results. Sometimes the data collection process requires strong efforts, making the application of the method very complicated.
    - This criterion is fully achieved if a good quality data is directly available.
    - If the data needs to be pre-compiled prior to its exploitation and/or it cannot be collected in a reasonable timeframe, this criterion is considered as partly achieved.
    - If strong efforts are needed to collect good quality data, this criterion is not achieved.

- **Automatization**: another element supporting the application of a method is the degree to which the process is automated. In general, novel methods tend to be less automated than older ones.
    - In case that the data and results are automatically compiled and scenarios can easily be derived based on a scientific interpretation, this criterion is fully achieved.
    - This criterion is considered as partly achieved in case that several parts of the application of the method are automated and delivering scenarios can be done by investing additional resources.
    - If automation has not been enabled for any parts of the implementation process, this criterion is not achieved.

The following table summarises the "easy to monitor" criteria:

Table 7: Evaluation matrix for the EASY TO MONITOR category

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automatization
Fully achieved	The method relies on good quality tools that simplify its application	Good quality data are directly accessible without any additional processing	Data and results are automatically compiled, displayed and reported
Partly achieved	Tools are available but show quality or consistency issues	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Not achieved	Tools for the application of the method are not available	Strong efforts are needed to collect good quality data	Automatization is not possible or has not been implemented

1.5.6 Characterisation of the "Robustness" component

The **Robust** category is also defined by 3 assessment categories:

- **Responsiveness**: this criterion refers to the ability of a method to respond to changes in its input variables and render different results accordingly.
    - If the method allows detecting minor changes, including a significance assessment, it is considered that it fully achieves this criterion.
    - If several changes are reflected in the results (but not all of them), the method partly achieves this criterion.
    - In case only big changes are reflected and significance criteria do not exist, it is considered that the method does not achieve this criterion.
- **Comparability**: Usefulness for making comparisons
    - If results can be compared through ordinary normalisation procedures, this method will fully achieve this criterion.
    - In case normalisation requires efforts and is not easy to apply, but comparisons are possible, the method will partly achieve this criterion.
    - If comparisons are not possible, this criterion is not achieved.
- **Reliability**: this criterion refers to the precision of the results and the possibilities of making a consistency check.
    - If the results obtained by the application of the method are of good precision with little error and both consistency and significance checks are possible, the method fully achieves this criterion.
    - This criterion is partly achieved if the results are of good precision but a consistency and/or significance checks are not possible.
    - The criterion is considered as not achieved whenever the precision of results cannot be assessed or validated.

The following table summarises the “robust” criteria:

Table 8: Evaluation matrix for the ROBUST category

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Fully achieved	Final results change following to the introduction of minor changes in the input data	Results obtained for one application of the method can be compared to other applications within different industries/sectors with little normalisation effort	Results are of good precision with little error and a consistency check is possible
Partly achieved	Several changes (but not all of them) on the input data are reflected in the results	Several normalisation changes are needed in order to make the results comparable	Results are of good precision with little error, but consistency checks are not possible
Not achieved	Only big changes on the input data are reflected in the results	Cross-sectoral / cross-industry comparisons are not possible	The precision of results cannot be assessed/validated

2 Evaluation of methods for sustainability assessment

This section provides an overview of the evaluation for each one of the 14 methods included in our analysis. The information organised as follows:

1. Short description of the method
2. Useful information about the method (the fourth criteria previously commented about sectors covered, addressed aspects, level of assessment and costs)
3. Summary of results from RACER assessment
4. Some conclusions

The complete evaluation results of the application of the RACER method are presented in Appendixes 1 to 14. Table 3 above shows the scoring system and the meaning of the different symbols used to represent results under the different dimensions being evaluated.

2.1 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a structured, comprehensive and internationally standardised method. Considering the long history and the wide diffusion that the LCA method has, it is no surprise that a number of alternative approaches exist for its application. This evaluation focus specifically on the ISO 14040 standard, which provides a narrow definition of this method, in opposition to other methods mentioned in this report that to a large extent can be considered variants or derivatives of the traditional LCA – and are often subsumed as LCA in a wider sense.

The LCA quantifies all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with any goods or services (“products”). LCA takes into account a product´s full life cycle: from the extraction of resources, through production, use, and recycling, up to the disposal of remaining waste (European Union, 2010).

Critically, LCA studies thereby help to avoid resolving one environmental problem while creating others: This unwanted “shifting of burdens" is where you reduce the environmental impact at one point in the life cycle, only to increase it at another point. Therefore, LCA helps to avoid, for example, causing waste-related issues while improving production technologies, increasing land use or acid rain while reducing greenhouse gases, or increasing emissions in one country while reducing them in another. Life Cycle Assessment is therefore a vital and powerful decision support tool, complementing other methods, which are equally necessary to help effectively and efficiently make consumption and production more sustainable.

Additionally, LCA can be extended to include costs (Life Cycling Costing) and the social dimension (Social-LCA). The Life Cycle Sustainability Assessment, not included in the SAMT review of methods, can integrate all the three dimensions in one comprehensive sustainability assessment with a lifecycle orientation.

Useful information about LCA to take into account before the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	Environmental
- Level of assessment:	Most of levels are covered
- Tool availability:	There are tools for its application available for free

Summary of the results from RACER assessment:

RACER	25	/ 32 points
- Relevant category	6	/ 8 points
- Accepted category	6	/ 6 points
-Credible category	4	/ 6 points
- Easy to use category	4	/ 6 points
- Robust category	5	/ 6 points

LCA is a useful method to comprehensively evaluate the environmental impact(s) of products, processes or organisations. LCA relies on a standardised method (ISO 14040-44) to model the environmental indicators or impact assessments of a product. It is the only method providing such an a holistic approach (multiphase and multi-criteria) allowing to identify the main sources of impact along the product's life stages, and to avoid – or at least to identify – potential trade-offs between different environmental impacts when setting eco-design requirements.

Thanks to the current state of maturity of LCA tools, this method is widely used in the industry. Among other objectives, the LCA is frequently applied: (1) to compare alternative product designs – as a key method for eco-design –; (2) to calculate specific environmental indicators for communicating the environmental performance of a given product or process to the end users / consumers; (3) to identify the major sources of negative environmental impacts connected to a given product or production process in order to improve its environmental performance as far as possible; (4) to benchmark different technologies, and; (5) to plan investment portfolios. However, based on the feedback received from the industry (see SAMT D1.2 for details), it seems that some of the companies that used traditional LCA for decision making in the past are currently moving towards simplified environmental assessment methods and tools –e.g. simplified LCA, CF, etc.– due to resource constraints within companies.

Moreover, the LCA method presents some limitations, in particular its intensive data requirements. Whenever real data gathered from the actual plant or industry where the LCA is carried out are not available –which would be the best practice, as documented by SAMT D1.2 –, generic data – i.e. data from similar processes– can be used to make the calculations. These data are available from commercial –e.g. Ecoinvent, GaBi – and free – like e.g. ELCD – databases with various orientations – including the social aspects, like e.g. and the Social Hotspots Database. Thus, although the LCA method can been implemented using a number of tools that make the implementation easier, the impact calculation associated with generic data ultimately relies on the information provided by the reference databases implemented by the LCA tool. A certification scheme to validate the consistency of the data provided by these providers is not available. So, there is no way of ensuring the accuracy of the data. Ultimately, this may undermine the reliability and comparability of LCA results.

Furthermore, there is also a lack of consensual and relevant indictors to evaluate each case. In practice, the indicators to be used within each sector are still subject to exploratory studies, considering that there is no consensus on the indicators to be used among LCA experts. Except for the construction sector, the indicator selection process is not yet harmonised between sectors or application type.

The results of LCA still present high uncertainty and are quite complex. This makes them difficult to communicate to the end users. This is due to the fact that LCA results vary greatly depending on how the LCA is implemented and the accuracy of the modelling. The development of more specific rules and standards for each category of product would be necessary. This would help ensuring that the product environmental characteristics calculations are compiled on an objective, transparent and consistent basis.

In conclusion, several efforts are still needed in order to make comparable the results from the LCA applied on different products or processes. The dependency of the method on external data or generic data providers undermines its accuracy. Besides, considering that the LCA is strictly focused on the environmental aspect, it needs to be coupled together with other methods covering the economic and social pillars of sustainability. However, despite the weaknesses identified in this report, the LCA results can still considered of high quality simply because there is not a better alternative to account for the impact of products along their lifecycle. The information provided by LCA is useful for several purposes both within and outside the industries, and it can also be used to build simple what-if scenarios for eco-design purposes.

See appendix 5.1 for the complete RACER evaluation results for LCA.

2.2 Material Input per Service (MIPs)

The MIPS method was developed in the early 1990s by the Wuppertal Institute (Ritthoff, M., Rohn, H. & Liedtke, C., 2002). The MIPS can be considered as a sub-method of the broader LCA method.

In order to estimate the input orientated impact on the environment caused by the manufacture or service of a product, MIPS indicates the quantity of resources – (known as “material” in the MIPS terminology – used for this product or service. Once the reciprocal has been computed, a statement can be made about resource productivity, i.e. it can be calculated how much use can be obtained from a certain amount of “nature”. (Ritthoff, M., Rohn, H. & Liedtke, C., 2002)

A MIPS value is expressed as the sum (in mass unit) of all resources ("material" in the MIPS concept) extracted from nature along the lifecycle of one service-unit of the studied product (Saurat, M. & Ritthoff, M., 2013).

In the MIPS concept, the material inputs are divided into five different input categories; abiotic raw materials, biotic raw materials, earth movements in agriculture and silviculture (mechanical earth movement or erosion) water and air.

Useful information about MIPS to consider before performing the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	Environmental: biotic raw material, abiotic raw material, water, air, and earth movement
- Level of assessment:	Most of levels are covered: applicable to products, services, and processes
- Tool availability:	There are tools for its application available for free

Summary of the results from the assessment:

RACER	19	/ 32 points
- Relevant category	6	/ 8 points
- Accepted category	3	/ 6 points
-Credible category	3	/ 6 points
- Easy to monitor	4	/ 6 points
- Robust category	3	/ 6 points

The MIPS indicates the quantity of resources used for one product or service with a lifecycle perspective. As such, it is a cross-sectoral method. All inputs from nature at each step of the process chain of the modelled product are inventoried and summed up.

The main advantage of MIPS is that in principle it is simple and does not require complex or costly software tools. The official handbook applicable to products, services, and processes describes a MS Excel-based sequential approach for calculating MIPS (Saurat, M. & Ritthoff, M., 2013). Today's computing power and access to software and databases supporting LCA make calculating MIPS using matrix inversion a feasible task for most industries. The Wuppertal Institute developed such an impact method for calculating MIPS on top of the Ecoinvent database.

However, the Ecoinvent database or the built-in GaBi database provides no unused extraction flows. Such flows must be entered by hand along the modelled process chain, wherever they might occur. Thus, the associated cost could sometimes be a limitation of this method. A closer integration of the MIPS concept in LCA databases such as Ecoinvent will benefit both the ISO LCA and MIPS analysts.

Similarly to LCA, LCI spreadsheet should also be used in a MIPS framework, in order to guarantee consistency of data flows.

When carrying out a MIPS, the aim of the analysis and evaluation must be clearly defined, as well as the objects under scrutiny. Generally a differentiation must be made between a comparison of one or more objects, of a single object analysis, or of optimising production or of the use of the objects. In most cases, but particularly for product comparison, a unit of measurement must be initially set. This unit of measurement will thus be the standard to which all data can then be related.

MIPS allows comparing different products with each other in terms of material use. This indicator offers the advantage to be adaptable for macro-economic and micro-economic assessment levels. One of the disadvantages is that this indicator cannot discriminate in terms of quality and that the method to calculate this indicator does not differentiate between types of masses. However, the aggregation could also mean an opportunity because it makes the indicator more intuitive, simplifying its communication.

See appendix 5.2 for the complete RACER evaluation results for MIPS.

2.3 Cumulative Energy Demand (CED)

Cumulative Energy Demand (CED) can be considered as a sub-method of the broader LCA method. CED is used as indicator of energy requirements. An LCI is needed for its calculation.

A potentially suitable option to simplify LCA is to apply the concept of CED as a screening impact indicator (M. A. J. Huijbreghts et al, 2006). Compared to complete LCA studies, the calculation of CEDs requires less information in the inventory analysis, i.e. no emission estimates and impact assessment factors are required.

The CED represents the energy demand, valued as primary energy during the complete life-cycle of a product, including direct and indirect uses of energy. It can be divided in non-renewable and renewable impact categories (M. A. J. Huijbreghts et al, 2006).

Useful information about CED to take into account before the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	Environmental: It only covers the fossil and renewable energy consumption.
- Level of assessment:	Most of levels are covered
- Tool availability:	There are data available to transform LCI in CED

Summary of the results from RACER assessment applied to CED:

RACER	20	/ 32 points
- Relevant category	7	/ 8 points
- Accepted category	2	/ 6 points
-Credible category	3	/ 6 points
- Easy to monitor	4	/ 6 points
- Robust category	4	/ 6 points

Energy consumption is very important in the industrial sector, particularly as it is directly related to production costs. However, only energy consumed during the production phase is considered within the CED.

The use of fossil fuels is an important driver of several environmental impacts and thereby indicative for many environmental problems. Fossil CED correlates well with most impact categories, such as global warming, acidification, or human toxicity.

In contrast to the emission-related impact categories, land use and fossil CED show a relatively low explained variance. Land use plays an important role in relation to the production of renewable energy carriers and less for fossil fuel extraction. Therefore, CED can be complemented by selected LCA indicators such as land use to represent impact categories not closely correlated.

CED results should present separately Primary Energy from non-renewable resources (fossil CED) and Primary Energy from renewable resources (renewable CED) in order to evaluate sustainability of products and processes. Still, there is currently no consensus about how to define the equivalent primary energy of renewable and nuclear sources.

CED guidelines have been developed - VDI 4600: 2012, but characterisation factors should be standardised. Different concepts for determining the primary energy requirement exist. For CED calculations one may chose the lower or the upper heating value of primary energy resources where the latter includes the evaporation energy of the water present in the flue gas.

To summarise, the strengths of the method mainly stem from the fact that it only focus on one or two dimensions. It is thus easy to convey to non-experts, it relies on relatively good quality data – there are a number of precise and reliable sources for energy data –, and it is tightly correlated with many environmental impact indicators, as well as with the economic dimension of processes along the value chain. Its weaknesses mainly relate to the fact that it is a highly aggregated indicator, with a consequential loss of detailed information. Besides, it relies on a subjective definition of the primary energy content of processes. Finally, it has to be considered that the energy component as such – partially renewable energy – is not an environmental impact per se, but just a proxy for the actual impacts.

See appendix 5.3 for the complete RACER evaluation results for CED.

2.4 Exergetic Life Cycle Assessment (E-LCA)

An exergy analysis, based on the first and second law of thermodynamics, shows the thermodynamic imperfection of a process, including all quality losses of materials and energy (Cornelissen, R. 1997).

Useful information about E-LCA to take into account before the assessment:

- Sectors covered:	Multi sectorial	✓
- Addressed aspects:	Environment: resources and energy efficiency	~
- Level of assessment:	Most of levels are covered: applicable to most situations/problems/case studies and at all levels	✓
- Tool availability:	There are no tools available without cost	✗

Summary of the results from RACER assessment applied to E-LCA:

RACER	19	/ 32 points	~
- Relevant category	8	/ 8 points	✓
- Accepted category	3	/ 6 points	✗
-Credible category	2	/ 6 points	✗
- Easy to monitor	2	/ 6 points	✗
- Robust category	4	/ 6 points	~

Exergetic Life Cycle Analysis[3] is a flexible method at all levels (micro, meso, macro) and allows for a wide range of applications, from identifying opportunities to save costs to assess societal sustainability.

The most important limitation of most sustainability assessment methods is the inability to measure the quality degradation of the resources. Tackling this issue is the main goal of the E-LCA method indicators, since exergy not only measures the quantity but also the quality of the resources.

However, it is important to stress that currently a robust alternative to measure the qualitative degradation of resources does not exist. The cost accounting method proposed by the E-LCA method implies transforming inputs and outputs of a system into exergy units, for which a detailed knowledge of every single operation unit is required. Accordingly, the inventory analysis of the E-LCA is much more complex than the traditional LCI. Furthermore, waste streams and inefficiencies of a system must also be calculated using the exergy cost accounting method.

If the scope of the study is well-documented, Energetic Analysis results are easily comparable (energy units) and due to this transparency reliability can quite easily be assessed. Exergetic analysis is a very robust method when the study is well-defined and documented. However, lack of documentation, guidelines and standards raise the question of the validity and reliability of its results.

See appendix 5.4 for the complete RACER evaluation results for E-LCA.

2.5 Carbon Footprint (CF)

Carbon footprint (CF) represents net emissions of CO_2 and other greenhouse gases over the full life cycle of a product, process, service or organisation. Normally, it is expressed as a CO_2 equivalent (usually in kilograms or tonnes per functional unit) and as such is equivalent to the usual LCA impact category Global Warming Potential (GWP). The life cycle concept of the carbon footprint means all direct (on-site, internal) and indirect emissions (off-site, external, embodied, upstream and downstream) need to be taken into account.

Useful information about CF to take into account before the assessment:

- Sectors covered:	Cross sectorial	
- Addressed aspects:	Environmental: It only covers the greenhouse gas emissions	
- Level of assessment:	Most of levels are covered	
- Tool availability:	There are tools for its application available for free	

[3] http://toprefproject.eu/?p=13979

Summary of the results from the assessment:

RACER	24	/ 32 points
- Relevant category	6	/ 8 points
- Accepted category	6	/ 6 points
-Credible category	4	/ 6 points
- Easy to use category	4	/ 6 points
- Robust category	4	/ 6 points

CF provides a standard approach (ISO 14064-2012) to calculate the net emissions of CO_2 and other greenhouse gases over the full life cycle of a product, process, service or organisation. It is one of most popular and widespread method in the industry.

The CF can be calculated using the LCA standard (ISO 14044) as well as other standards largely in compliance with it, such as the GHG Protocol. The LCA approach ensures that the emissions from the whole supply chain are accounted for. But whereas the full LCA method accounts for a range of potential impacts on the environment, the CF focuses on the climate change impact category. For this reason, its data requirements are only limited to the potential sources of GHG emissions. Data processing is also easier in comparison to a full LCA. Besides, as the CF focuses on GHG emissions, it is easier to understand and communicate to the stakeholders – impacts are quantified as CO_2 equivalents. Another strength of CF compared to other methods is that results are typically of much higher precision, particularly if fossil fuel combustion or similar chemical processes –e.g. dissociation of limestone– dominate the results.

This largely explains why, as illustrated by SAMT D1.2, currently the CF seems to be the method that is most widely applied across industries. Moreover, many companies have developed their own tools for calculating the CF and for handling the data required, as there has been a need for tools that are well adapted with company specific demands, as argued below. However, it should be stressed here that in order to provide an overview of the environmental impact of a product or a process, more impact categories should be taken into account.

The CF calculation process is standardised, but still work is needed in order to standardise the data collection and harmonization process. Depending on the assessment tool selected, it is not possible to trace the origin of the data. Currently there is a lack of consistency in methods for calculation and reporting, which means it can be difficult to compare published footprints. Furthermore, it seems also challenging benchmarking different industries, if these have not the same function or serve the same purpose and have not identical system boundaries.

Even among the conceptually very simple and similar tools to estimate the carbon footprint the typical trade-off between user friendliness and rigor can be observed. In particular, the online calculators to estimate an individual's carbon footprint lack consistency. In addition, most calculators lack information about their methods and estimates, which impedes validation.

In conclusion, the CF method can be a useful method for decision making within the industries but not to compare with other similar products from other industries if they are not evaluated with the same conditions (the same product system value, identical system boundaries). It may be worth reminding, that, the issue of biogenic CO_2 flows is not included in ISO standards[4]. This method takes only one indicator into account, excluding other relevant indicators from decision-making. We believe CF should be considered together with other methods as it is only focused on selected environmental aspects.

See appendix 5.5 for the complete RACER evaluation results for CF.

2.6 Water Footprint (WF)

The water footprint (WF) is one of the environmental footprints which help understanding how production and consumption choices are affecting natural resources[5]. According to the standard ISO14046[6] definition, the WF include the metrics that quantify the potential environmental impacts related to water, and a water footprint assessment is thus the compilation and evaluation of the inputs, outputs and the potential environmental impacts related to water of a product, process or organisation.

Useful information about WF to take into account before the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	Environmental: it covers only water related issues
- Level of assessment:	Water footprints can be calculated for an individual person, a process, a product's entire value chain or for a business, a river basin or a nation.
- Tool availability:	There are tools available for free

[4] Biogenic CO_2 emissions are defined as CO_2 emissions related to the natural carbon cycle, as well as those resulting from the combustion, harvest, combustion, digestion, fermentation, decomposition, or processing of biologically based materials (Source: http://www3.epa.gov/climatechange/ghgemissions/biogenic-emissions.html)

[5] Although the concept was first introduced in 2002 by Hoekstra and the Water Footrint Network (http://waterfootprint.org/en/water-footprint/), the approach now used in the ISO14046 is very different from the initial one. The ISO standard defines several kinds of assessments, and a full water footprint (according to ISO) would require including all those assessments or aspects. However, it is possible to define it only partly (e.g. water scarcity).

[6] ISO 14006:2014. Environmental management – Water footprint – Principles, requirements and guidelines

Summary of the results from the assessment:

RACER	21	/ 32 points	~
- Relevant category	5	/ 8 points	~
- Accepted category	4	/ 6 points	~
-Credible category	4	/ 6 points	~
- Easy to use category	4	/ 6 points	~
- Robust category	4	/ 6 points	~

A water footprint assessment is in itself insufficient to describe the overall potential environmental impact(s) of products, processes or organisations (Source: ISO 14046). The focus of WF on water resources alone undermines its relevance, according to the evaluation criteria designed within the SAMT project. However the evaluation also takes into account (1) that its calculation is based on a life cycle approach; (2) that water impacts cannot be thoroughly assessed by the traditional LCA methods, and; (3) that water itself is a critical resource for human wellbeing and environmental sustainability.

Besides, the relatively high degree of acceptance and recognition of WF among the policy makers has increased the momentum of WF as a decision-oriented method. However, it is important to emphasise that the use of this method as an input decision making within the policy arena is usually linked to its application at the regional level – i.e. territorial level – rather than at the industry or sector level. In terms of acceptance among firms, according to D1.2 most of the industrial actors interviewed were very interested in WF and many of them have tested it already, but most of them declared that some challenges related to its application still remained due to its novelty.

Being a Life Cycle-based method, data collection and pre-processing method is well structured. For this same reason, WF also shares with the LCA some of the shortcomings that affect the latter. The standardisation of the method alongside the easy interpretation of its outputs makes this method potentially credible, but it will take some time and a larger number of practical implementations before this can be fully confirmed.

The availability of free databases and tools for the application of WF and the automation of several parts of the assessment simplifies the application of this method. However, it is still necessary to combine several of those tools to be able to have a comprehensive understanding or WF. At the same time, although some pre-calculated data are available these have to be processed in a specific way in order to apply the method. Similarly, some efforts are also needed in order to make the results from different products or processes comparable. Using already available databases reduces the accuracy of results.

Overall, it can be stated that the information provided by WF is useful for several purposes within a variety of decision making steps within companies, in particular for those sectors with water intensive processes. However, it has to be considered together with other methods because it is only focused on one environmental aspect. At the same time, more efforts are still needed to make it more accepted by the industry and to make it more robust. See appendix 5.6 for the complete RACER evaluation results for WF.

2.7 Hybrid Life Cycle Assessment and Partial Equilibrium Model (LCA/PEM)

A consequential prospective LCA framework is used to assess the environmental impacts tied to large changes and their consequences on the economy modelled through a partial market equilibrium model (PME) (Earles, M. Et al, 2013).

PME models are typically used to analyse the possible effects of a policy on a market or set of markets. PEM produce information on substitutable and complementary goods and how these relate to price variations. PEMs can be relatively small and simplified, or large models that include hundreds of goods across multiple sectors and/or multiple regions. In combination with LCA, for a given policy scenario, LCA/PEM provides information about the expected environmental impacts directly resulting from the production of a good and indirectly resulting from its economic relationship with other goods. A typical research goal of a LCA/PEM is to compare the results from a given policy scenario with the results of the business as usual scenario.

Useful information about the LCA/PEM before the assessment:

- Sectors covered:	Cross sectorial	✔
- Addressed aspects:	Environmental impacts indirectly resulting from the good's economic relationship with other goods	~
- Level of assessment:	production of a good	~
- Tool availability:	There are no tools available	✖

Summary of the results from the assessment:

RACER	14	/ 32 points	✖
- Relevant category	5	/ 8 points	~
- Accepted category	2	/ 6 points	✖
-Credible category	3	/ 6 points	✖
- Easy to use category	1	/ 6 points	✖
- Robust category	3	/ 6 points	✖

Depending on the aim of the assessment, LCA/PEM studies could be very relevant for the process industries. LCA/PEM allow to assess direct and indirect environmental impacts under a given policy scenario. The expected environmental impacts directly resulting from the production of a good are calculated using an approach similar to attributional LCA. Environmental impacts indirectly resulting from the good´s economic relationship with other goods are modelled using a partial equilibrium framework.

This means that LCA/PEM models allow assessing the most relevant phases of the life cycle of a product and can provide useful information to the industry. Sometimes, the information on the potential environmental impacts of a product or a process calculated using a LCA/PEM can provide information that justifies the adoption of a technology that might have not been accepted if the focus was on a single value chain. Additionally, the LCA/PEM are cross-sectorial and provide relevant information for assessing resource and energy efficiency at various levels.

Since it is an LCA-based method, the credibility and robustness of LCA/PEM is similar to LCA. However, its acceptance and usability within the process industry seems to be rather poor. The LCA/PEMs are mainly useful for conducting prospective studies at the sectoral and/or territorial levels under specific policy scenarios. Their attractiveness for specific industries is limited, in particular for the smaller companies. In conclusion, it could be said that the LCA/PEM method is a promising method for policy making at the sectoral and territorial level, but its usefulness for the industry is still limited, in particular for the smaller companies.

See appendix 5.7 for the complete RACER evaluation results for LCA/PEM.

2.8 Life Cycle Activity Analysis (LCAA)

LCAA is based on the classical formulation of Activity Analysis and on the LCA framework (Freire et al., 2001). LCAA is a hybrid modelling framework based on an input-output approach. The LCAA was developed by Thore and Freire (1999) basing on the Activity Analysis (AA) concept, a well-known procedure in economics solving for optimal levels of production and for the optimal allocation of resources. As such, the AA is based on general equilibrium analysis (Freire, Thore, & Ferrao, 2001). The list of goods is partitioned into four classes (primary, intermediate, final and environmental goods). Once the AA is defined, the matrix is turned to the full accounting of physical flows between processes and between the processes and the environment. Thus, the LCAA provides a computable approach to economic and environmental optimisation of the supply chain of products, processes or services.

Useful information about LCAA to take into account before the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	Based on economic activity and relations - Activity Analysis - and transformed into environmental impacts. The assessment is limited to the chosen impact assessment method.
- Level of assessment:	Most of levels are covered
- Tool availability:	Some modelling tools exist (basically, the GAMS software), but the formulation of a fit-to-purpose model has to be defined for each implementation.

Summary of the results from the assessment:

RACER	17	/ 32 points
- Relevant category	6	/ 8 points
- Accepted category	2	/ 6 points
-Credible category	2	/ 6 points
- Easy to monitor	4	/ 6 points
- Robust category	3	/ 6 points

LCAA is imbedded in a model of relevant industrial activities, accounting for the presence of alternative technologies and determining the optimal level of operation of each activity. LCAA explicitly recognises the possibility of alternative ways of production, alternative distribution channels, and alternative reuse or recovery processes (the programming model determines the optimal choices).

Furthermore, LCAA is a concrete step to the inclusion of economic aspects to LCA. It has the potential to be used for the study of trade-offs between alternatives e.g. various environmental goals. It also has the possibility, by its mathematical structure, to include some social aspects, such as jobs created or lost.

LCAA is a numerical technique, facilitated by the use of mathematical programming software (i.e. GAMS with a price > 3500 euros). The equilibrium software is needed to create and solve LCAA equations. The mathematical formulation allows the representation of life cycles of products based on individual activities through the identification of inflows and outflows associated with each activity and its links with other activities.

LCAA requires a high knowledge in the evaluated process, in general equilibrium models and in LCA. Additionally, LCAA requires the co-operation of many different specialists. The industrial engineer's approach operating on process or plant level and focused on logistics and cost accounting will be one ingredient in this joint effort. The economist's approach operating on regional or macro-economic level will be another. The environmental scientist/engineer evaluating environmental impacts needs certainly to be integrated.

LCAA in its current format is designed to be compatible with ISO-LCA but it has not yet been standardised. Still, LCAA is based on the classical formulation of activity analysis and on the life cycle assessment framework (Freire, Thore, & Ferrao, 2001). Thus, LCAA can be considered a robust tool to work internally within a company, as a decision making tool easy to validate (i.e. through a mass/energy/economic balance) and easy to monitor. Also a responsiveness analysis is easy to perform due to the methods computable format. However, it cannot be used to compare products and processes.

See appendix 5.8 for the complete RACER evaluation results for LCAA.

2.9 Eco-Efficiency Analysis (EEA)

Although the concept of Eco-efficiency (EE) was first introduced by Schaltegger and Sturm (1990), it only became popular after its adoption by the World Business Council for Sustainable Development (WBCSD) [7] in 1992. According to the WBCSD, the Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity. In short, it is concerned with creating more value with less impact. EE analysis has slowly emerged from then on dealing with measuring EE through e.g. indicator(s).

Useful information about EEA to take into account before the assessment:

- Sectors covered:	Cross sectorial	✓
- Addressed aspects:	Environmental and economic	~
- Level of assessment:	Most of levels are covered	✓
- Tool availability:	There are free tools for its application	✓

[7] http://www.wbcsd.org/pages/EDocument/EDocumentDetails.aspx?ID=13593

Summary of the results from the assessment:

RACER	22	/ 32 points
- Relevant category	7	/ 8 points
- Accepted category	4	/ 6 points
-Credible category	3	/ 6 points
- Easy to use category	4	/ 6 points
- Robust category	4	/ 6 points

The most obvious strength of EE analysis is of course the combined analysis of economic and ecological aspects of goods and service systems, without the use of monetisation or any another harmonisation technique. Most EE methods developed produce one or more indicators, generally expressing the ratio between an environmental and an economic/financial variable. EE and its indicator(s) can be applied for comparing companies, products, countries. The framework can be used for monitoring and benchmarking purposes, including cross-temporal comparisons.

The main weakness of the EEA approach stems from the variety of methodological approaches followed to assesses the range of environmental impacts considered (with or without weighting) by the LCA method, which in turn creates a number of potential scenarios for the combination of these LCA-based impacts with the indicators assessing the economic performance of products and processes (costs, profits, etc.).

One option in the EEA method is to set the environmental impacts in relation to costs or other non-environmental parameters, defined in terms of the product/service value, to compute eco-efficiency indicators. Different approaches for weighting and normalisation can be applied, but these are not yet harmonised. In case of considering more than one environmental indicator and product/service value, the environmental impacts and product/service values must be aggregated by weighting in order to calculate the eco-efficiency indicator. This aggregation depends on the stakeholders and it is not explicitly explained – but not excluded – within the standard (ISO 14045).

Further, the EEA only considers two out of three pillars of sustainability, being necessary the combination with other methodologies to include the social aspect.

The EEA provides results in eco-efficiency indicator in a transparent and sound way, but the interpretation is rather complicated when comparing eco-efficency results out of different studies between similar products. This is due to the variety of alternatives and scopes when it comes to the impacts considered within the environmental assessments.

In conclusion, the EEA method can be a useful method for evaluating products within the industry but not for comparing products from other industries if these are not evaluated with the same conditions (the same product system value, identical system boundaries and environmental indicators). If it is set up as a comparative study, it is possible as well as with LCA, if the ISO standards are applied. Similarly to e.g. LCA, some efforts are needed to do several normalisation changes in order to aggregate the results in a comparable way and to make a consistency check possible.

See appendix 5.9 for the complete RACER evaluation results for EEA.

2.10 Socio-Eco-Efficiency Analysis (SEEBALANCE®)

SEEBALANCE® is an innovative sustainability assessment method developed by BASF that allows the assessment not only of environmental impact and costs but also of the societal impacts of products and processes. The aim is to quantify performance of all three pillars of sustainability with one integrated tool in order to direct - and measure - sustainable development in companies[8].

SEEBALANCE®has been the result of a cooperation (2002-2005) between BASF SE and various academic research institutions including the Institute for Geography and Geoecology of Karlsruhe University, Ökoinstitut e.V. and Jena University. The framework was partially developed in a project funded by the German Federal Research and Education department (BMBF).

Useful information about SEEBALANCE® to take into account before the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	economy, environment and society
- Level of assessment:	Most of levels are covered
- Tool availability:	There are free tools for its application

8 https://www.basf.com/us/en/company/sustainability/management-and-instruments/quantifying-sustainability/SEEBALANCE®.html

Summary of the results from the assessment:

RACER	18	/ 32 points	~
- Relevant category	7	/ 8 points	✓
- Accepted category	3	/ 6 points	✗
-Credible category	2	/ 6 points	✗
- Easy to use category	3	/ 6 points	✗
- Robust category	3	/ 6 points	✗

SEEBALANCE® analysis considers the three dimensions of sustainability: economy, environment and society.

The societal responsibility and social impacts within this analysis are grouped into five stakeholder categories: employees, international community, future generations, consumers, and local & national community. For each of these stakeholder categories measurable indicators are considered, for example number of employees, occupational accidents occurring during production but also risks involved in the use of the product used by the end consumer. However, the SEEBALANCE® analysis needs setting some environmental impacts to calculate the eco-efficiency indicator, define the meaning of the "product service value" to be included in the economic aspect. If more than one environmental indicators are considered, the environmental impacts and product service values must be aggregated and weighted in order to evaluate these aspects. This aggregation depends on the stakeholders and is yet not a standardised but was worked out by professional institutes.

SEEBALANCE® provides results in a clear way, but the interpretation is complicated because of the three dimensional direction of the integrated results. A structured process from single results to fully integrated final results can be shown and enables the interpretation and practical use of the results in decision-making.

In conclusion, the SEEBALANCE® analysis can be a useful method for evaluating products within a given sector or industry. However, it might not be indicated for comparing similar products from different industries if they are not evaluated under the same conditions (i.e. using the same social indicators, which can be difficult to be collect and/or might have different relevance for different industries). Under these circumstances, several normalisation efforts would be needed in order to make the results more comparable and enable consistency checks.

See appendix 5.10 for the complete RACER evaluation results for SEEBALANCE®.

2.11 Product Sustainability Assessment (PROSA)

PROSA is a method for the strategic analysis and evaluation of product portfolios, products and services. The goal of PROSA is to identify system innovations and options for action towards sustainable development. PROSA structures the decision-making processes that this requires, reducing complexity to key elements[9].

Important fields of application include:

- Strategic planning and product portfolio analysis in companies
- Product policy and dialogue processes
- Sustainable consumption and product evaluation
- As well as product development and marketing

Thanks to its open structure, PROSA can also be used to analyse sustainability at other levels, such as technologies, large infrastructural projects or geographical units.

PROSA spans complete product life cycles and value chains; it assesses and evaluates the environmental, economic and social opportunities and risks of future development trajectories. PROSA is a process-driven and iterative method which gives due regard to time and cost restrictions. It refers to existing, well-established individual tools (Megatrend Analysis, Life-Cycle Assessment, Life Cycle Costing, etc.)

Useful information about PROSA before the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	integrated analysis of the environmental, economic and social dimensions, giving equal standing to each dimension.
- Level of assessment:	product portfolios, products and services.
- Tool availability:	Description of the method publicly available. No tool publicly available

[9] PROSA guideline, 2007.

Summary of the results from RACER assessment:

RACER	14	/ 32 points	✗
- Relevant category	7	/ 8 points	✓
- Accepted category	1	/ 6 points	✗
-Credible category	2	/ 6 points	✗
- Easy to use category	1	/ 6 points	✗
- Robust category	3	/ 6 points	✗

The main characteristic of PROSA is its relevance. As it is an integrated method that includes several methods PROSA is very complete and relevant considering the purposes of SAMT. The inclusion of complete product life cycles and value chains, the integrated analysis of environmental, economic and social dimensions with equal importance to each dimension, are the most relevant characteristics of PROSA.

Special process tool, called the Pathfinder, exists for the application of PROSA. The Pathfinder specifies the way PROSA is carried out and provides aids such as indicator lists, time and cost management structures, graphics routines and interpretation frameworks.

A set of core tools is used to support work in the individual phases. Most of the tools are mature in common use, and are already deployed in most large companies and in public product policy. These include megatrend analysis, consumer research and Life Cycle Assessment. On the other hand, three new core tools were specially developed for PROSA implementation, namely SocioGrade (implementing a Social LCA), BeneGrade (implementing a Benefit Analysis based on consumer research) and the ProfitS (Products Fit to Sustainability, which is the overall interpretation framework).

Despite PROSA's support in mitigating trade-offs in decision making in corporate product development or in product policy and dialogue processes, further developments are still needed to make it more accepted. Further, PROSA has significant flaws in terms of credibility and feasibility to use, motivated in particular by its high data intensity, the unavailability of free and open tools for its application, as well as by a rather difficult interpretation of its results.

See appendix 5.11 for the complete RACER evaluation results for PROSA.

2.12 Life Cycle Index (LInX)

LInX is an indexing system that incorporates the life cycle attributes of process and products in decision-making (Khan, et al., B., 2004). Its purpose is to aid the selection and design of processes and products. LInX is comprised of environment, cost, technology, and socio-political factors. Further, each attribute contains a number of basic parameters (e.g: health and safety consists of 11 parameters).

Useful information about LinX before the assessment:

- Sectors covered:	Cross sectorial	✓
- Addressed aspects:	includes: environment, health and safety (EHS), cost, technical feasibility, and socio-political factors	✓
- Level of assessment:	process and product design	~
- Tool availability:	There are no tools available without cost	~

Summary of the results from RACER assessment:

RACER	18	/ 32 points	~
- Relevant category	5	/ 8 points	~
- Accepted category	1	/ 6 points	✗
-Credible category	5	/ 6 points	✓
- Easy to use category	3	/ 6 points	✗
- Robust category	4	/ 6 points	~

It is important to note that in terms of relevancy, LInx is one of the methods that scored less. This is because it provides relevant information for assessing resource and energy efficiency, but does not permit to calculate it directly. On the other hand, there are life cycle phases of the product that LInX does not cover and, because of that, it is less relevant when considering SAMT aims.

Other interesting conclusion from RACER assessment of LInx is that it is very credible. A clear definition of data collection and treatment processes and a clear definition of the results given make this method credible for the purposes of SAMT.

Although LInX involves some subjective quantifications and decisions, the robustness of the method is also high considering SAMT aims. This is mainly because of its usefulness to make comparisons.

“Accepted criteria” reflects that strong efforts are needed in order to make it more interesting and useful for the industry. The availability of tools and the automation of the process could help to make the assessment easier.

See appendix 5.12 for the complete RACER evaluation results for LInX.

2.13 Sustainable Value (SustV)

Sustainable value approach allows sustainable performance to be measured in monetary terms (Figge, F. & Hahn, T., 2004). SustV results are expressed as the excess return on resources a company has achieved with its set of resources compared to a pre-defined benchmark (Figge, F., & Barkemeyer, R. 2006). Thus, SustV measures the value that a company has been able to create or destroy through its production processes in comparison to other companies operating in the same sector or territory. SustV can evaluate environmental, social and economic aspects.

Useful information about SustV to take into account before the assessment:

- Sectors covered:	Affiliated sectors: Automobile, chemicals, engineering & machinery, forestry & paper, oil & gas, pharmaceuticals, and utilities.
- Addressed aspects:	Sustainable Value integrates the economic, environmental and social dimension of sustainability.
- Level of assessment:	Products, companies
- Costs:	The method is available without costs, tools do not exist

Summary of the results from the assessment:

RACER	14	/ 32 points
- Relevant category	5	/ 8 points
- Accepted category	1	/ 6 points
-Credible category	3	/ 6 points
- Easy to monitor	1	/ 6 points
- Robust category	4	/ 6 points

Corporate managers can use SustV and the assessment results to monitor and communicate their sustainable performance. The results of SustV can be used also by policy makers. Results can be used to identify those sectors and companies that are most critical for implementing economic, environmental and social policies. However, SustV can be only applied to evaluate the sustainability performance of a company within a sector, whenever predefined benchmarks are available.

SustV only evaluates the production phase within a company. It considers the most commonly reported environmental aspects, but it can also consider social aspects i.e. number of employees, number of work accidents, etc. Furthermore, SustV considers the productivity of the company. SustV can cover and integrate all three dimensions of the sustainability concept.

This method is very useful for decision making and it allows making comparisons in terms of resource efficiency. Furthermore, SustV translates the efficiency with which a company uses its economic, environmental and social resources into monetary terms. Working with only one indicator makes the comparison between companies easier. Still several efforts are needed in order to make it more accepted and easy to use.

The quality of the SustV results will strongly depend on the quality of the assessment itself; the data collection, the evaluated processes as well as the choice of the benchmark. Benchmarks are pre-defined by the developers of this method basing on average values recorded within a given economy or sector, but they might not tell anything on the overall sustainability of the processes carried out within companies. Thus, the method only allows performing comparisons in terms of relative efficiency of companies in relation to a pre-defined average.

See appendix 5.13 for the complete RACER evaluation results for SustV.

2.14 Ecodesign, Design for Environment, Life Cycle Design, Sustainable Process Design (EcoD)

Ecodesign (EcoD), also referred to as Design for Environment, Green Design, Environmental conscious/friendly Design, Life Cycle Design, is a systematic way of incorporating environmental attributes into the design of a product. It can be defined as “design which addresses all environmental impacts of a product throughout the complete life cycle of the product, without unduly compromising other criteria like function, quality, cost and appearance”[10]. An ecodesign procedure starts considering the potential environmental impacts of a product throughout its life-cycle and leads to improvement steps, paths of product eco-innovation and new creative management approaches.

Useful information about EcoD to take into account before the assessment:

- Sectors covered:	Cross sectorial
- Addressed aspects:	Environmental
- Level of assessment:	Most of levels are covered
- Tool availability:	There are tools for its application available for free

[10] ECO2-IRN (Ecologically and Economically Sound Design and Manufacture— Interdisciplinary Research Network). Defining ecodesign, workshop: economically and ecologically sound design and manufacture. Third Forum, Manchester Metropolitan University, UK; 1995.

Summary of the results from the assessment:

RACER	22	/ 32 points	~
- Relevant category	6	/ 8 points	~
- Accepted category	5	/ 6 points	✓
-Credible category	4	/ 6 points	~
- Easy to use category	4	/ 6 points	~
- Robust category	3	/ 6 points	✗

The aim of EcoD is the integration of environmental aspects into product design and development, with the aim of reducing adverse environmental impacts throughout a product's life cycle.

EcoD is a systematic method that incorporates environmental considerations into the design process of products. Its main purpose is to develop environmentally friendly goods and services. This is achieved by reducing products' environmental burdens throughout the whole life cycle and taking into account the other product and customer requirements such as functionality, quality, safety, cost, manufacturability, ergonomics and aesthetics. Ecodesign is not an assessment method or a model, but a procedural framework which includes iterative steps of assessment and design and requires the use of analytical tools as checklists, LCA, guidelines, databases, etc. and design tools/procedures. ISO/TR 14062 supplies a method to implement an ecodesign process at enterprises.

EcoD allows preventing environmental damages in the design phase of a product rather than intervening to reduce them after production; it is flexible with respect to different situations that require interventions of product/system modification; it offers a variety of methods and techniques to integrate a wide range of design requirements (performance, costs, environmental impact) in product development from conception to disposal. In the frame of an ecodesign process the potential of a life cycle analysis to enhance the environmental performance of a product is maximised. At the same time, the integrated analysis of different criteria (functionality, quality, safety, cost etc.) allows reducing costs throughout product's life cycle phases, improving technical characteristics of the product and increasing competitiveness. However, a weak point of ecodesign, as it is presently, is that it can be applied to the product's development without taking into account meso and macro-economics, social, cultural and political relations established outside the enterprises' horizon. As a consequence, the risk occurs that the process of product's development leads to select options internally optimised but unsuitable if evaluated from a wider point of view. Different designs of the same product are comparative but more information is needed in order to make comparisons between different products.

In conclusion, the EcoD has been largely used in the industry since long time in different ways, due to the potential economic benefits that can be obtained. However, the interaction between the product and the overall economy is particularly critical. If this interaction is at such a level that the studied life cycle does not cause significant changes to other life cycles, the introduction of market mechanisms (and potentially of most of the social ones) in the assessment could be neglected. Otherwise including these aspects will be necessary, causing consequent increase of the assessment complexity.

Although in some sectors, economic and social aspects are included in eco-design, for example the EcoD for energy-related products, the ISO 14062 only covers environmental issues. So, the EcoD method should be considered together with other methods to include the economic and social pillars of sustainability.

See appendix 5.14 for the complete RACER evaluation results for EcoD.

2.15 Overview of the results resulting from the SAMT-RACER evaluation

The following table summarises the results provided by the application of the SAMT-RACER method on the 14 sustainability assessment methods considered here. Thresholds for the different categories are included in Table 3 in Chapter 1.

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

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

3 Conclusions and recommendations

3.1 Main conclusions

The evaluation process based on the application of the adapted RACER method involved the ranking of the 14 pre-selected methods by a team of sustainability specialists and the subsequent revision of the results by the RTOs and industries participating in the project. Albeit the evaluation was characterised by a certain degree of subjectivity, its outcomes proved to be rather stable across the entire evaluation process.

Thus, the adapted RACER method could itself be considered one of the main contributions of this project. Despite this method was not conceived for this type of application, it could be successfully adapted for this purpose with relative ease. This makes us believe that it could equally be adapted within specific sectors, such as e.g. the process industries, in order to take decisions on which sustainability methods to apply for more specific goals besides the ones pursued within the SAMT project.

The evaluation process was not easy in any case. The main reason for this is that all the methods that have been evaluated were designed for specific purposes within the process industry or other sectors. In many occasions these goals were not aligned with those of the SAMT project. This made comparisons rather complicated and implicitly involved contrasting not only the methods themselves but to some extent also the underlying objectives for which they were conceived.

In particular, it was difficult to find a cross sectorial method that allows assessing the three pillars of sustainability at different levels and without incurring in too high implementation costs. In terms of environmental subdomains, the biodiversity dimension is neglected by virtually all the methods evaluated in this report. Lack of methods for assessing potential impacts to biodiversity was one of the challenges raised by the industry representatives during the first open SAMT workshop.

Among the assessed methods, the SEEBALANCE® method developed by BASF seems to be the one having higheest ambition to cover the three dimensions of sustainability. However, according to the SAMT-RACER classification efforts are still needed in order to make it more accepted, credible, easy-to-implement and to some extent also more robust. In turn, the traditional LCA, which is the method with the highest overall capacity to assess sustainability in the process industry according to the SAMT-RACER evaluation, does not provide economic and social information[11]. Furthermore, the difficulties related to data collection and processing, as well as with the interpretation of results somehow jeopardise the credibility and simplicity of this method. On the other hand, similar challenges relate to some extent to nearly all methods with a life cycle perspective, as covering each process along the whole life cycle of a product requires a lot of input and output data.

[11] However, a multi-dimensional alternative to traditional LCA called ” Life Cycle Sustainability Assessment”, which was not included among the methods considered by the SAMT project, is being currently developed by the United Nations Environmental Programme (UNEP, 2011).

Along these lines, it should be emphasised that the SAMT-RACER evaluation was somehow biased towards the most accepted and used methods. Alongside the traditional LCA method, other well-established methods such as CF and EcoD ranked high in the classification, whereas more novel and sophisticated approaches, such as E-LCA, are still lagging behind despite showing higher ambition. Similarly, other methods such as the E-LCA, PROSA, LCA/PEM and LCAA show clear trade-offs between the relevance component and the remaining ones. Figure 2 shows a spider diagram illustrating the scores received by each method under the different SAMT-RACER dimensions.

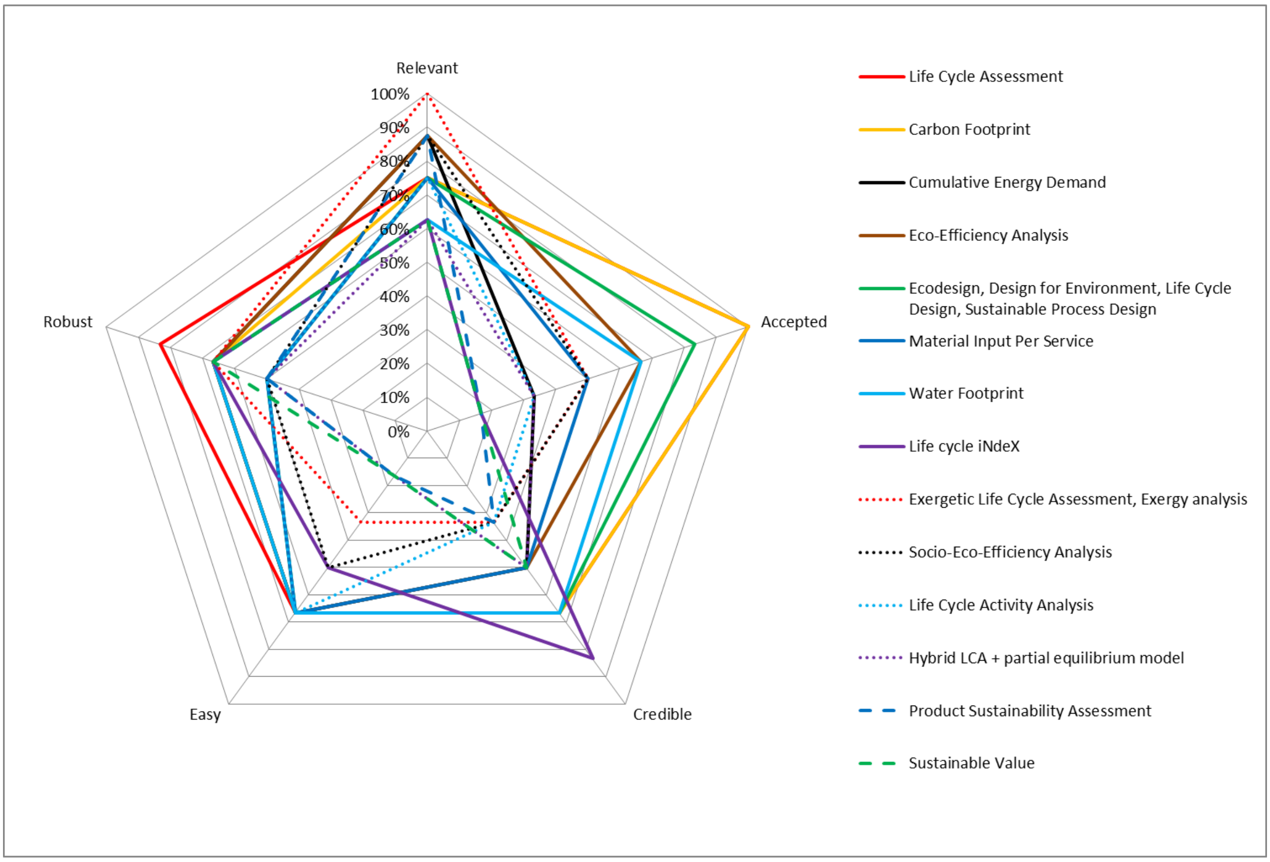


Figure 2: Scores obtained by the different methods under each RACER component

Taking into account all the criteria considered within the SAMT-RACER evaluation, it could be said that methods that seem to be relevant such as E-LCA, SEEBALANCE®, PROSA, CED, and to a lower extent EEA, need to concentrate efforts to become more credible, robust and thus become widely accepted. Similarly, methods such as LCA/PEM, PROSA, SustV and E-LCA still seem to have a long way to go in terms of simplifying their implementation.

As the methods were pre-selected in terms of their alignment with the general goals of the SAMT project, most of the methods assessed fulfil the **Relevance** criterion, which takes account of the comprehensiveness of the methods to consider different dimensions of environmental sustainability across multiple sectors under a lifecycle orientation.

This was not the case for the **Acceptance** criterion, which focuses on the current and past record of application of methods within industries and on their degree of acceptance by private and public actors. In this case, strong differences among methods persist. These differences stem from the rather uneven diffusion that the methods have among industries and the public sector, regardless of their intrinsic quality. However, in this context it is important to note that evaluating the actual use of different methods within industries is a challenging task since internal use of methods for decision-making purposes is not necessarily reported anywhere. And thus the assessment is mainly based on the experiences of the SAMT partner organizations (like reported in D1.2 and discussed within the first workshop) and to the feedback received from the SPIRE community.

Probably, the reluctance to introduce new promising methods within industries is connected to the fact that the interpretation of results is not always straightforward. Additionally, almost all methods suffer from ill-defined data collection and management processes and/or lack of approved standards. Within the RACER evaluation, the methods showing higher **Credibility** in this respect are LInX, LCA, EcoD, WF and CF, mostly because results are easily understood and the underlying information used to compute them can be traced-back with relative ease.

Still, the implementation of sustainability assessment methods still is not an **Easy** task for neither in-house nor external experts. Although considerable efforts have already been placed within companies to develop ad-hoc tools to implement some of these methods, the automatization of specific sub-tasks is not possible or has not yet been addressed for all applications. Similarly, a successful implementation of most methods considered here ultimately depends on the availability of a significant amount of good quality data that is not always ‘ready for delivery’ within companies. Actually, most of the companies interviewed within the SAMT project had developed their own approaches and tools for data collection, which is a time consuming but important phase of the assessment (Saurat et al. 2015b).

In some cases access to data is eased by existing databases, which not only simplifies the implementation of methods, but also enhances the comparability of results across cases – to the detriment of accuracy –. Although relying on in-house data should be the preferred option and can be considered a good practice (Saurat et al. 2015b), a better coverage and increased consistency of the existing databases would benefit the usability and usefulness of the methods.

In terms of the ability of the assessed methods to account for small changes in the input variables and to consistently report comparable and accurate values, no method could be considered as entirely **Robust**. From this perspective, the traditional LCA method performed slightly better than CF, EEA, WF, CED, LinX, E-LCA and SustV methods, but none of them fulfilled all the criteria considered in our evaluation. In this respect, the dimension in which the methods seem to have more room for improvement is the possibility to include consistency-checks to validate results.

Against this background, the main conclusion that can be drawn from the SAMT-RACER implementation is that there might not be a one-size-fits-all solution in terms of sustainability assessment methods within the process industry. This conclusion supports the previous findings of the SAMT deliverables D1.1 and D1.2, and the discussions held during the first workshop. Provided that accuracy and scientific soundness of all methods is granted by a good design and a correct implementation, gains in versatility and multidimensionality generally imply less acceptance, credibility and, particularly, simplicity and user-friendliness of methods. A logical conclusion could be that a combination of methods could be the 'best' solution, but finding the 'best' methods to complement each other is in any case a challenge.

In this respect, the SAMT case studies will be of much help in identifying which of the methods could realistically be applied across sectors and effectively cover more than one sustainability dimensions. In addition, special focus will be given to methods considering different aspects of resource and energy efficiency, these aspects being among the key targets of the SPIRE Public-Private Partnership in reducing the environmental impacts of the process industries. Similarly the case studies will also allow to test to what extent such overarching methods should be coupled by complementary methods within specific industries. The practical experience with method implementation matured within the companies could provide important information in this respect, allowing the identification of 'incremental pathways' for the implementation of sustainability methods, and help to fill the gaps within the methods now evaluated.

3.2 Recommendations for the case studies

Considering all the evidence collected so far in the SAMT project, and in particular the results of the two-stage evaluation presented in this report, the methods to be tested within case studies could include:

- SEEBALANCE®, because is the only method that fulfils all the general criteria considered in the cross-check analysis, namely cross-sectoral applicability, multi-dimensional nature, level of assessment and availability of tools.
- E-LCA, because albeit its acceptance is jeopardised by its limited diffusion, it ranked at the top of the relevance classification – it is also well positioned in terms of robustness –. In particular, E-LCA was the only method among those evaluated in this report deemed to simultaneously assess resource and energy efficiency within industries.
- LinX, because it is the method that ranks on top in terms of credibility, considering that its results can be easily interpreted and its data collection process can be traced back with ease.
- EEA, CED, WF or SustV, because these are among the most robust methods in our evaluation. Although also performing rather well in terms of robustness, the LCA and CF methods have not been considered due to the fact that they have already been extensively applied within the companies.

The outcomes from the evaluation will be applied and discussed within the project group to find a good combination of methods to be tested within the case study framework. Alongside the SAMT-RACER evaluation, the final decision on the methods to implement within the case studies will also take into account the interest shown by the industrial partners to apply the different methods in terms of, inter alia, (1) the relevance of the different methods for their own decision making, (2) data availability within companies and (3) the existence of tailor-made tools within companies. All these issues will be discussed in the up-coming SAMT meeting, which will be almost entirely focused on the SAMT case study design. The experiences and learnings from the case studies are further discussed and presented during the second SAMT open workshop that will be held in Bilbao, Spain, in February 2016. The workshop is open to all interested stakeholders and experts or organizations applying sustainability assessment methods for different purposes.

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5 Appendices

5.1 RACER criteria applied to LCA

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	Covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It provides relevant information to assess energy efficiency
Explanations	It is a method oriented to evaluate the whole life cycle (from cradle to grave)	It is a multi-sectoral method	It provides information that can be used to assess resource efficiency	It provides information that can be used to assess energy efficiency
Level of achievement:	2	2	1	1

Total for Relevant: 6/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is widespread in the industry with positive results	Frequently used in the industry for decision-making	Approved and recommended by policy-makers/public administration agents
Explanations	It has been used increasingly by industry to help reduce the overall environmental burdens across the whole life cycle of goods and services. It is also used to improve the competitiveness of the company's products and in communication with governmental bodies.	It is a decision making tool commonly used by the industry, scientific world and the policy makers.	In its Communication on Integrated Product Policy (COM (2003)302), the European Commission concluded that Life Cycle Assessments provide the best framework for assessing the potential environmental impacts of products currently available.
Level of achievement:	2	2	2

Total for Accepted: 6/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is standardised
Explanations	Provides results in terms of different categories of environmental impact and use of resources. The results are clear to each indicator. Interpretation is complicated when there is no similar product with which to compare.	The process is standardised, but in some case, exist lack of primary data and the use of generic data is necessary. So, in some case it is not possible to trace the origin of the data used.	It is currently being standardised within the ISO framework (ISO 14040-14044).

Level of achievement:	1	1	2	Total for Credible: 4/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	There are tools available for free and subject for a fee. Depending of the tool, the trace of the data can be very complicated or ineffective.	The method requires the collection and treatment of data	The generation of graphics and the collect of the results directly from the software is available in some tools.

Level of achievement:	2	1	1	Total for easy to monitor: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Final results change following to the introduction of minor changes in the input data	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error and a consistency check is possible.
Explanations	Minor changes are reflected in the results. Within the interpretation phase, the quality of the assessment is done by carrying out a completeness check, a responsiveness check, and a consistency check.	Two industries are comparable by LCA method if they fulfil the same function or serve the same purpose and have identical system boundaries.	The results obtained are of good precision and a consistency check is possible
Level of achievement:	2	1	2

Total for Robust: 5/6

5.2 RACER criteria applied to MIPS

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	It covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It provides relevant information to assess energy efficiency
Explanations	It is a life cycle oriented method		The MIPS method is focused on resources, but it is mainly a pressure indicator	The MIPS method provides MI values for power generation, considering various energy carriers and generation systems. MI values are provided for the following five material input categories (biotic raw material, abiotic raw material, water, air, and earth movement). This information can be used to infer energy efficiency of production processes basing on alternative energy mixes.
Level of achievement:	2	2	1	1

Total for Relevant: 6/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Several industries use it frequently	The industry is starting to take it into account and/or is very useful for decision making	Positively considered by policy-makers/public administration agents
Explanations	The method and tool are available without costs	The concept was developed at the Wuppertal Institute and is not focused on specific applications like "industrial products" and therefore not driven by interest of certain industries	

Level of achievement:	1	1	1	Total for Accepted: 3/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is in process of standardisation

Explanations	A MIPS value is the sum (in mass unit) of all resources (“material” in the MIPS concept) extracted from nature along the life cycle of one service-unit of the studied product. Material inputs are classified in biotic raw material, abiotic raw material, water, air, and earth movement in agriculture and silviculture.	MIPS handbook available for free	MIPS can be calculated with information from ISO LCA VDI guideline on Cumulative Resource Use in development in Germany

Level of achievement: 1 | 1 | 1 | Total for Credible: 3/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	MS Excel-based sequential approach for calculating MIPS	Compared to other life-cycle approaches, MIPS is relatively easy to calculate, it needs less information and allows working with more or simpler estimations without weakening the results.	Thanks to the Excel based tool

Level of achievement: 2 | 1 | 1 | Total for easy to monitor: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
	Several changes (but not all of them) on the input data are reflected in the results	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error but a consistency check is not possible.
Explanations	The preparation of MIT factors, is cost intensive and keeping them up-to-date has proven too big a challenge for the traditional MIPS calculation method.		WI prepared so-called material intensity (MIT) factors for many materials, energy and transport services and made them publicly available through its website

Level of achievement:	1	1	1	Total for Robust: 3/6

5.3 RACER criteria applied to CED

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	Covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It allows assessing energy efficiency
Explanations	It is a life cycle oriented method		It does provide indirect information to assess resource consumption	It does provide direct and indirect information to assess energy consumption
Level of achievement:	2	2	1	2
				Total for Relevant: 7/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Several industries use it frequently	The industry is starting to take it into account and/or is very useful for decision making	Not recognised by policy-makers/public administration agents
Explanations	Energy consumption is very important in the Industrial Sector, but only energy consumed during the production phase.	Energy is related to cost reduction. Only considering energy consumed during the production process.	Public administrations should consider Energy consumption with Life Cycle Perspective. Public administrations use Carbon Footprint as an indicator rather than CED
Level of achievement:	1	1	0
			Total for Accepted: 2/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is in process of standardisation
Explanations	Direct energy consumed during the process is easy to be understood, but embodied energy need for an explanation. Also make a difference between non-renewable and renewable energy demand.	Based on LCI. The process is standardised, but still several work is needed in order to standardise the data collection and treatment process. Depending on which tool supports the assessment, it is not possible to trace the origin of the data	Guideline developed - VDI 4600: 2012. But characterisation factors should be standardised
Level of achievement:	1	1	1
			Total for Credible: 3/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized

Explanations	there are tools that are available for free (with the problem of being a black box) and others that are not free but that allow a complete trace of the data	The method requires the collection and treatment of data	For instance, the generation of graphics in some tools in which this method is available. Initiatives to collect the data directly from the management software exist

Level of achievement:	2	1	1	Total for easy to monitor: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
	Several changes (but not all of them) on the input data are reflected in the results	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error and a consistency check is possible.
Explanations	Different concepts for determining the primary energy requirement exist. For CED calculations one may chose the lower or the upper heating value of primary energy resources	If calculations have been made with the same environmental database and calculation methods, results should be comparable.	When working with the LCI consistency check is possible.

Level of achievement:	1	1	2	Total for Robust: 4/6

5.4 RACER criteria applied to E-LCA

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	It covers all the sectors (cross sectorial)	It allows assessing resource efficiency	It allows assessing energy efficiency
Explanations	An extension to the E-LCA, the Zero-E-LCA, is developed to include environmental effects associated with emissions and it can in particular cases replace the LCA.		This method provides efficiency information in a direct and unified way both for energy and resource consumption	This method provides efficiency information in a direct and unified way both for energy and resource consumption
Level of achievement:	2	2	2	2

Total for Relevant: 8/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is not widespread in industry	The industry is starting to take it into account and/or is very useful for decision making	Approved and recommended by policy-makers/public administration agents

Explanations	It is not very known in the industry	The industry does not take it into account but it is very useful for decision making	It is necessary to assess how it is possible to maintain our current needs and habits at the same quality as we have come to expect, and what extra efforts are required to ensure that. This may turn out to be the appropriate question in the context of sustainable use of resources, and exergy may well provide a key to this (Source: http://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-LCIA-Framework-Requirements-ONLINE-March-2010-ISBN-fin-v1.0-EN.pdf

Level of achievement:	0	1	2	Total for Accepted: 3/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are not detailed. Traceability is not possible	The method is in process of standardisation
Explanations	advantage of working with one unit only (energy unit)	Lack of documentation guidelines	LCA part is standardised

Level of achievement:	1	0	1	Total for Credible: 2/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	Tools are available but show quality or consistency issues	Strong efforts are needed to collect good quality data	Several phases of the application of the method are automatized
Explanations	Available but rarely used	The inventory analysis of the E-LCA is more elaborate than LCI. A complete flowsheet of the mass and energy streams of the different production steps are needed.	

Level of achievement: 1 | 0 | 1 | Total for easy to monitor: 2/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
	Final results change following to the introduction of minor changes in the input data	Obtained results can be compared to other industries/sectors with little normalisation effort	The precision of the results is not validated
Explanations		when the study is well-defined and documented	Lack of documentation guidelines raise the question of validity and reliability of results Not robust due to lack of definition and common rules

Level of achievement: 2 | 2 | 0 | Total for Robust: 4/6

5.5 RACER criteria applied to CF

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	It covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It provides relevant information to assess energy efficiency
Explanations	It is a life cycle oriented method		It provides information that can be used to assess resource efficiency	It provides information that can be used to assess energy efficiency

Level of achievement: 2 | 2 | 1 | 1 | Total for Relevant: 6/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is widespread in the industry with positive results	Frequently used in the industry for decision-making	Approved and recommended by policy-makers/public administration agents
Explanations	We consider that in comparison with other methods is one of the most widespread in the industry	As it was one of the firsts methods implemented in the industry, the use of it for decision making is frequent	

Level of achievement: 2 | 2 | 2 | Total for Accepted: 6/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is standardised
Explanations	Provided results are in terms of CO equivalents. This unit is understood (climate change contribution potential), the problem is at the interpretation what is difficult if there is no something which compare with	The process is standardised, but still several work is needed in order to standardise the data collection and treatment process. Depending on which tool supports the assessment, it is not possible to trace the origin of the data	ISO14064:2012
Level of achievement:	1	1	2

Total for Credible: 4/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	There are tools that are available for free (with the problem of being a black box) and others that are not free but that allow a complete trace of the data	The method requires the collection and treatment of data	For instance, the generation of graphics in some tools in which this method is available. Initiatives to collect the data directly from the management softwares exist
Level of achievement:	2	1	1

Total for easy to monitor: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Final results change following to the introduction of minor changes in the input data	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error and a consistency check is possible.
Explanations	As it is a very detailed method, minor changes are reflected in the results	Comparisons between different industries is still a lack of this method (based in the definition of a functional unit)	
Level of achievement:	2	0	2

Total for Robust: 4/6

5.6 RACER criteria applied to WF

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	the covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	The method cannot be used for assessing energy efficiency
Explanations	According to the international Standard, a water footprint assessment considers all stages of the life cycle of a product, as appropriate, from raw material acquisition to final disposal.		The Water Footprint method provides information that can only be used to assess the efficiency with respect to the water resource.	The method is focused on water use. It does not provide any specific information to assess energy efficiency within industry.
Level of achievement:	2	2	1	0

Total for Relevant: 5/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Several industries use it frequently	The industry is starting to take it into account and/or is very useful for decision making	Approved and recommended by policy-makers/public administration agents
Explanations	There is a growing demand for assessing water footprint and reporting water footprint results	WF is interesting for informing decision-makers in industry, government or non-governmental organisations of their potential impacts related to water (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign, decisions about investment of resources);	It is starting to be considered in policy making.

Level of achievement:	1	1	2	Total for Accepted: 4/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is standardised
Explanations	A water footprint considers all environmentally relevant attributes or aspects of natural environment, human health and resources related to water (including water availability and water degradation).	Sufficient and appropriate information is disclosed in order to allow users of the water footprint assessment to make decisions with reasonable confidence.	ISO 14064:2014

Level of achievement: 1 | 1 | 2 | Total for Credible: 4/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	LCA tools are useful for its application WF network provides specific tool for its calculation	i,.e: quantities of water used, types of water resources used, data describing water quality, etc.	Some data needed for the assessment is included in databases

Level of achievement: 2 | 1 | 1 | Total for easy to monitor: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Several changes (but not all of them) on the input data are reflected in the results	Several normalisation changes are needed in order to make the results comparatives	Obtained results are of good precision with little error and a consistency check is possible.
Explanations	It will depend on the scope of the assessment. Responsiveness analysis are needed in several steps of the application of the method (LCI, allocation,…)	The comparison of the results between products from different sectors does not provide useful information, but only which of the sector is more water demanding	Assumptions, methods and data are applied in the same way throughout the water footprint assessment to arrive at conclusions in accordance with the goal and scope definition.

Level of achievement: 1 | 1 | 2 | Total for Robust: 4/6

5.7 RACER criteria applied to LCA/PEM

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers several or at least the most relevant life cycle stage	It covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It provides relevant information to assess energy efficiency
Explanations	Focused in production		Same results as LCA	Same results as LCA
Level of achievement:	1	2	1	1

Total for Relevant: 5/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is not widespread in industry	The industry is starting to take it into account and/or is very useful for decision making	Positively considered by policy-makers/public administration agents
Explanations	Still, relatively few PME-LCA models exist.	Prospective method: Aims to increase LCA´s relevance for decision making	e.g. models have been used in policy-making for indirect land use change impacts associated with biofuel production by the US Environmental Protection Agency (US EPA 2010).
Level of achievement:	0	1	1

Total for Accepted: 2/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is in process of standardisation
Explanations	It provides LCA results. However, it is a consequential LCA		Partly standardised by ISO 14040. Specific standardisation for it does not exist
Level of achievement:	1	1	1

Total for Credible: 3/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	Tools for the application of the method are not available	Strong efforts are needed to collect good quality data	Several phases of the application of the method are automatized
Explanations	There is no readily available "hybrid" tool	Process-based LCI databases; economic databases; literature for econometric estimates of relationships between goods, prices, etc.	LCA part of the method
Level of achievement:	0	0	1

Total for easy to monitor: 1/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Several changes (but not all of them) on the input data are reflected in the results	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error but a consistency check is not possible.

Explanations	Not known: Uncertainty analysis of PME-LCA models, beyond simple responsiveness manipulations, has yet to be developed and could improve confidence assessment of PME-LCA models.	Comparison between PME-LCA model results and those from integrated computable general equilibrium and LCA models could be conducted	Retrospective PME-LCA models could be performed for validation purposes.

Level of achievement:	1	1	1	Total for Robust: 3/6

5.8 RACER criteria applied to LCAA

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	Covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It provides relevant information to assess energy efficiency
Explanations	It is a life cycle oriented method		It does not provide direct information to assess resource efficiency, but it provides results that are useful for its estimation	It does not provide direct information to assess energy efficiency, but it provides results that are useful for its estimation

Level of achievement:	2	2	1	1	Total for Relevant: 6/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is not widespread in industry	The industry is starting to take it into account and/or is very useful for decision making	Positively considered by policy-makers/public administration agents
Explanations		Decision making tool. Method related to industrial activity but economic and equilibrium models are need. Too much complex.	LCAA offers opportunities in local policy analysis (economic-environmental trade-off analysis) but has a limited scope - Micro-level.

Level of achievement: 0 | 1 | 1 | Total for Accepted: 2/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is not standardised nor a standardisation process has started
Explanations	Due to its limited scope, some relevant aspects may be over looped if directly applied to complex systems.	The list of goods is partitioned into four classes (primary, intermediate, final and environmental goods)	

Level of achievement: 1 | 1 | 0 | Total for Credible: 2/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	Mathematical Programming System for General Equilibrium Analysis	Related to Activity Analysis	AA transformation into environmental impacts is needed.
	Level of achievement: 2	1	1

Total for easy to monitor: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
	Several changes (but not all of them) on the input data are reflected in the results	Comparisons are not allowed	Obtained results are of good precision with little error and a consistency check is possible.
Explanations	One main objective is to evaluate economic implications of change in environmental goals	Decision making tool within a micro-level scope.	All results are quantified and can be traced to the sources
	Level of achievement: 1	0	2

Total for Robust: 3/6

5.9 RACER criteria applied to EEA

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	the covers all the sectors (cross sectorial)	It allows assessing resource and/or energy efficiency	It provides relevant information to assess energy efficiency
Explanations	Considers the entire life cycle (from cradle to grave)	It is a multi-sectoral method	It allows to get information to assess resource efficiency directly	It does not provide direct information to assess energy efficiency, but it provides results that are useful for its estimation
Level of achievement:	2	2	2	1
Total for Relevant: 7/8				

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Several industries use it frequently	Frequently used in the industry for decision-making	Positively considered by policy-makers/public administration agents
Explanations	It is used by industry to help improve the competitiveness of the company's products.	It is a decision making tool commonly used by the industry to identify ways to make improvements in terms environmental and economic.	
Level of achievement:	1	2	1
Total for Accepted: 4/6			

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are not detailed. Traceability is not possible	The method is standardised
Explanations	Provides results in eco-efficiency indicator. The results are clear but the interpretation is complicated when comparing eco-efficiency results between similar product, due to variety of methods existent and the different scopes in terms of impact considered within environmental study.	The methodology is standardised, but is necessary define and normalised the methods to do the weighting of impact score and set the environmental impacts and the meaning of product value.	ISO 14064:2014

Level of achievement:	1	0	2	Total for Credible: 3/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	There are available some payment tools	To evaluate the product system value it is necessary to do a weighting to impact score.	

Level of achievement:	2	1	1	Total for easy to monitor: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Final results change following to the introduction of minor changes in the input data	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error but a consistency check is not possible.
Explanations	Minor changes are reflected in the results. Within the method, the sensitivity analysis is done by carrying out a completeness and consistency check.	Two products are comparable by EEA method, if they evaluated with the same conditions (the same product system value, have identical system boundaries and environmental indicators).	The result depends on the different factors selected by the stakeholders, so are not consistency.

Level of achievement: 2 | 1 | 1 | Total for Robust: 4/6

5.10 RACER criteria applied to SEEBALANCE®

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	It covers all the sectors (cross sectorial)	It allows assessing resource efficiency	It provides relevant information to assess energy efficiency
Explanations	Considers the entire life cycle (from cradle to grave)	It is a multi-sectoral method	It allows to get information to assess resource efficiency directly	It does not provide direct information to assess energy efficiency, but it provides results that are useful for its estimation

Level of achievement: 2 | 2 | 2 | 1 | Total for Relevant: 7/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Several industries use it frequently	The industry is starting to take it into account and/or is very useful for decision making	Positively considered by policy-makers/public administration agents
Explanations	It is used by industry to help improve the competitiveness of the company's products.	It is a decision making tool commonly used by the industry to identify ways to make improvements in terms environmental and economic including the social part.	

Level of achievement:	1	1	1	Total for Accepted: 3/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are not detailed. Traceability is not possible	The method is in process of standardisation
Explanations	Provides results in eco-efficiency indicator and societal impacts. The results are clear but the interpretation is complicated when comparing eco-efficiency results between similar product, due to variety of methods existent and the different scopes in terms of impact considered within environmental study.	The method is standardised to economic and environmental aspects, but is necessary define and normalised the methods to do the weighting of impact score and set the environmental impacts and the meaning of product value.	Part of the assessment is standardised

Level of achievement:	1	0	1	Total for Credible: 2/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	Tools are available but show quality or consistency issues	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	There are available some payment tools	To evaluate the product system value it is necessary to do a weighting to impact score.	

Level of achievement:	1	1	1	Total for Easy to monitor: 3/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Several changes (but not all of them) on the input data are reflected in the results	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error but a consistency check is not possible.
Explanations		Two products are comparable by this method, if they evaluated with the same conditions (the same product system value, have identical system boundaries and environmental indicators).	The result depends of the different factors selected by the stakeholders, so there is no consistency.

Level of achievement:	1	1	1	Total for Robust: 3/6

5.11 RACER criteria applied to PROSA

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	It covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It allows assessing energy efficiency
Explanations	Integrated method of other methods: Megatrend Analysis, Life-Cycle Assessment, Life-Cycle Costing, etc.		LCA method is part of PROSA	LCA method is part of PROSA
Level of achievement:	2	2	1	2

Total for Relevant: 7/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is not widespread in industry	The industry is starting to take it into account and/or is very useful for decision making	Not recognised by policy-makers/public administration agents
Explanations		Useful for decision making	
Level of achievement:	0	1	0

Total for Accepted: 1/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is not standardised nor a standardisation process has started

Explanations	Results are understood without a particular knowledge but trained personnel is needed for the assessment	This depends on the methods that it is based on	Standardisation does not exist

Level of achievement: 1 | 1 | 0 | Total for Credible: 2/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	Tools are available but show quality or consistency issues	Strong efforts are needed to collect good quality data	Automation does not exist
Explanations		Megatrend Analysis, Life-Cycle Assessment, Life-Cycle Costing, etc. data is needed	Medium to high complex in the implementation

Level of achievement: 1 | 0 | 0 | Total for easy to monitor: 1/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Several changes (but not all of them) on the input data are reflected in the results	Obtained results can be compared to other industries/sectors with little normalisation effort	The precision of the results is not validated
Explanations	Complex method that provides lots of information but the integration of methods makes the responsiveness be less	Due to normalisation efforts of the method	Weighting processes are needed. Dependent of updates

Level of achievement: 1 | 2 | 0 | Total for Robust: 3/6

5.12 RACER criteria applied to SustV

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers several or at least the most relevant life cycle stage	It covers several relevant sectors and/or is very meaningful for one of them	It allows assessing resource efficiency	It provides relevant information to assess energy efficiency
Explanations	Focused on production phase	Applied to several sectors for which benchmarking exists. Affiliated sectors: Automobile, chemicals, engineering & machinery, forestry & paper, oil & gas, pharmaceuticals, and utilities.	To create value, a company must use resources more efficiently than other companies.	CO_2 emissions are calculated

Level of achievement:	1	1	2	1	Total for Relevant: 5/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is not widespread in industry	The industry is starting to take it into account and/or is very useful for decision making	Not recognised by policy-makers/public administration agents
Explanations		Useful for decision making as it provides a benchmark. Information not available for all the sectors	

Level of achievement: 0 | 1 | 0 | Total for Accepted: 1/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined and are self-explanatory	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is not standardised nor a standardisation process has started
Explanations	Language in line with managers and investors thinking		

Level of achievement: 2 | 1 | 0 | Total for Credible: 3/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	Tools for the application of the method are not available	The data needed for the application of the method have to be collected manually	Automation does not exist
Explanations		The data that has to be collected has to be checked (to date there are no reliable and binding standards in corporate environmental and sustainability reporting.	
Level of achievement:	0	1	0

Total for easy to monitor: 1/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
	Several changes (but not all of them) on the input data are reflected in the results	Obtained results can be compared to other industries/sectors with little normalisation effort	Obtained results are of good precision with little error but a consistency check is not possible.
Explanations	It considers the most commonly reported environmental aspects.	It is one of the main strengths of the method. It allows comparing	

	The changes in them will be reflected in the results: CO_2, CH_4, CO_2 eq, energy consumption, ozone depleting substances, Sox, Nox, waste generation, water use, VOC	companies of different sizes and expresses sustainability efficiency as a benefit-to-cost-ratio.	

Level of achievement:	1	2	1	Total for Robust: 4/6

5.13 RACER criteria applied to LinX

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers several or at least the most relevant life cycle stage	It covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It provides relevant information to assess energy efficiency
Explanations	Presently, LInX analysis is focused only on the outer (overall) boundary of the analysis, and does not address sub boundary analysis, such as process, upstream process, transport, etc.(Source: Khan, et al., B., 2004) On the other hand, The EHS and cost indices are based on the complete life cycle of a process/product.		It considers resource depletion index	The resource depletion index is divided in 3 classes. The first class includes the energy sources (e.g. nuclear and hydro-carbon resources)

Level of achievement:	1	2	1	1	Total for Relevant: 5/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is not widespread in industry	The industry is starting to take it into account and/or is very useful for decision making	Not recognised by policy-makers/public administration agents
Explanations	It is available but not widespread in the industry	Made for being useful for decision making	

Level of achievement:	0	1	0	Total for Accepted: 1/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined and are self-explanatory	Data collection and treatment processes are clearly defined and is possible trace them	The method is in process of standardisation
Explanations	Aim at generating an outcome that can be understood even without particular knowledge e.g. the impact of greenhouse gases is assessed in terms of CO_2 equivalent per unit production. The value is further scaled based on the Montreal protocol (on a scale of 1 to 10).	Trained personal for conducting the assessment	The LCA phase is standardised. Other phases of the assessment are not standardised (and nor are in process of standardisation)

Level of achievement:	2	2	1	Total for Credible: 5/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	Tools are available but show quality or consistency issues	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	LCA tools are useful for it but not enough		Some parts of the assessment are LCA based
Level of achievement:	1	1	1

Total for easy to monitor: 3/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Several changes (but not all of them) on the input data are reflected in the results	Obtained results can be compared to other industries/sectors with little normalisation effort	Obtained results are of good precision with little error but a consistency check is not possible.
Explanations	The LInX involves some subjective quantifications and decisions. In order to evaluate the responsiveness of this subjectivity, a responsiveness analysis was conducted. It was found that parameters involving subjective quantifications did not have pronounced impact on the indices and corresponding rankings.	The results are scaled	The LInX involves some subjective quantifications and decisions.
Level of achievement:	1	2	1

Total for Robust: 4/6

5.14 RACER criteria applied to EcoD

RELEVANT				
Assessment category	Life cycle oriented	Sectors covered	Potential to assess efficiency	Potential to assess efficiency
Criteria	Life cycle stages covered	Sectors for which could be applied	Usefulness to assess resource efficiency	Usefulness to assess energy efficiency
Eligible criteria	It covers the full life cycle of the product/process	It covers all the sectors (cross sectorial)	It provides relevant information to assess resource efficiency	It provides relevant information to assess energy efficiency
Explanations	Life Cycle based method	As same as LCA	The objective of the method is not assessing the efficiency, but it provides relevant information to assess it	The objective of the method is not assessing the efficiency, but it provides relevant information to assess it
Level of achievement:	2	2	1	1

Total for Relevant: 6/8

ACCEPTED			
Assessment category	Industry Status	Acceptance by the industry	Public administration status
Criteria	Use in the industry	Decision making	Acceptance by the policy-makers
Eligible criteria	Its use is widespread in the industry with positive results	The industry is starting to take it into account and/or it is very useful for decision making	Approved and recommended by policy-makers/public administration agents
Explanations	In many different ways, but EcoDesign has been largely used in the industry since long time ago.	In terms of energy and/or material savings, ecodesign it was positively considered at industry. Potential economical savings are a motivation	Policy-makers promote it
Level of achievement:	2	1	2

Total for Relevant: 5/6

CREDIBLE			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Data collection and treatment	Standardisation
Eligible criteria	Method results are well-defined but explanations are needed to interpret them correctly	Data collection and treatment processes are defined, but traceability is only partially achieved	The method is standardised
Explanations	The results should be understood by designers and environmental scientist. Both points of view are useful	Several methods exist for its application.	ISO 14006. Note that this standard is referred to the implementation of Ecodesign processes at company level.

Level of achievement: 1 | 1 | 2 | Total for Relevant: 4/6

EASY TO MONITOR			
Assessment category	Support for its application		
Criteria	Tools availability	Data availability	Automation
Eligible criteria	The method relies on good quality tools that simplify its application	The data needed for the application of the method have to be collected manually	Several phases of the application of the method are automatized
Explanations	For instance, methods supported by LCA	Dependent from who applies the assessment (designers, environmental scientist, …)	For instance, in methods supported by LCA

Level of achievement: 2 | 1 | 1 | Total for Relevant: 4/6

ROBUST			
Assessment category	Responsiveness	Comparability	Reliability
Criteria	Detection of changes	Usefulness to making comparisons	Consistency
Eligible criteria	Final results change following to the introduction of minor changes in the input data	Several normalisation changes are needed in order to make the results comparable	Obtained results are of good precision with little error but a consistency check is not possible.
Explanations	It will depend on the scope of the assessment	Different designs of same product are comparatives. More information is needed in order to make comparisons between different products	In terms of environmental loads avoided

Level of achievement:	2	0	1	Total for Relevant: 3/6