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Improving Energy Efficiency in Industrial Solutions – Walk the Talk

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Abstract

This paper describes the outline of the energy efficiency and environmental care policy and management at Siemens Industry Solutions Division. This environmental policy coherently embraces strategic planning, eco-design of energy-efficient industrial processes and solutions, design evaluation and finally communication of both environmental and economic performance of solutions to customers. One of the main tools supporting eco-design and evaluation & controlling of derived design solutions is the so called “Eco-Care-Matrix” (ECM).

The ECM simply visualizes the eco-efficiency of solutions compared to a given baseline. In order to prevent from “green washing” criticism and to ensure “walk the talk” attitude the ECM should be scientifically well-founded using appropriate and consistent methodology. The vertical axis of an ECM illustrates the environmental performance and the horizontal axis describes the economical customer benefit of one or more green solutions compared to a defined reference solution. Different scientific approaches for quantifying the environmental performance based on life cycle assessment methodology are discussed especially considering the ISO standards 14040/14044:2006.

Appropriate ECM application is illustrated using the example of the Siemens MEROS® technology (Maximized Emission Reduction of Sintering) for the steel industry. MEROS® is currently the most modern and powerful system for cleaning off-gas in sinter plants. As an environmental technology MEROS® is binding and removing sulfur dioxide and other acidic gas components present in the off-gas stream by using dry absorbents and additional electrical power. Advantage in the impact category of acidification potential (by desulfurization) is a trade-off to disadvantages in global warming and resource depletion potential caused by use of electricity. Representing different impacts, indicator results for impact categories with different tendencies have to be compared category by category and therefore should not be aggregated to a single-score result. Results communicated in the form of a self-declared environmental claim (type II environmental labeling, ISO 14021) for MEROS® are presented.

1 Introduction

The Eco Care Strategy at Siemens Industry Solutions Division serves to generate and expand its Environmental Portfolio in line with company corporate requirements and regulations. The elements listed in this Environmental Portfolio are designated "Green Solutions" at Siemens Industry Solutions Division. A "Green Solution" is defined in the Eco-Care-Matrix (ECM, see fig. 1 below) and is thereby characterized by a positive environmental impact (y axis), linked to an increased customer benefit (x axis), as shown in the "A" square of figure 1 (ref. to [1]). Products in the "B" and/or "C" areas are, from the product portfolio point of view, acceptable elements for niche markets, but do not constitute a "Green Solution".

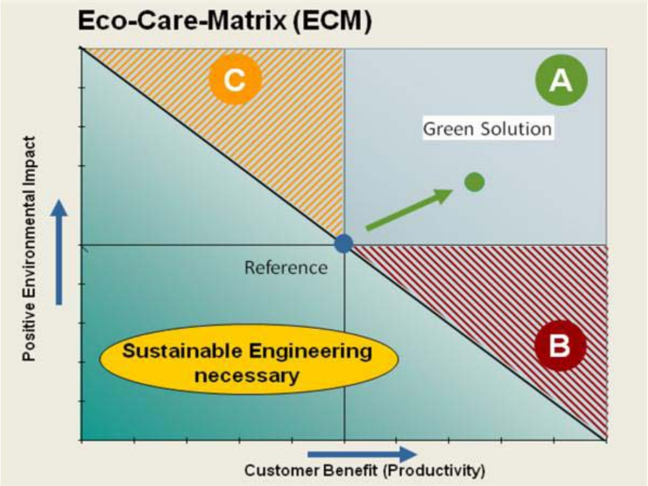

Figure 1: Eco-Care-Matrix (ECM)

The Eco-Care-Matrix has to be applied in the early stages of the product lifecycle especially in product portfolio management process (PPM) as well as in research & development process (R&D) - but only to parts in the Environmental Portfolio. As shown in figure 2 the ECM is used within PPM to support product portfolio decisions (ECM@PPM) and in the R&D process to help with product design selection (ECM@R&D).

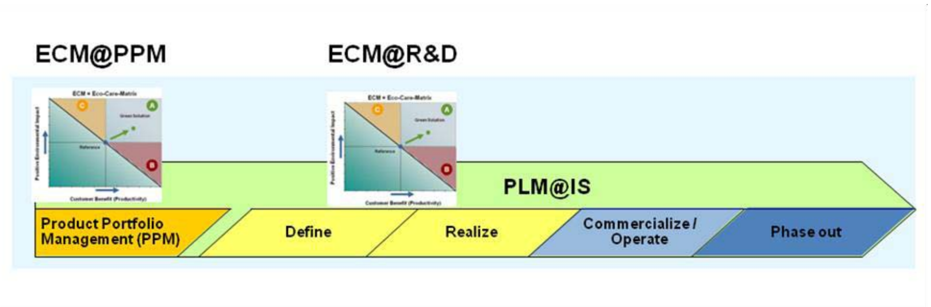

Figure 2: Application of the Eco-Care-Matrix as part of product lifecycle management (PLM)

The maximized emission reduction of sintering (MEROS$^{®}$) is an innovative environmental process characterized by a series of treatment steps in which dust, acidic gases and harmful metallic and organic components still present in the sinter off-gas after the electrostatic precipitator are further reduced.

Figure 3 shows the process flow sheets of two different MEROS$^{®}$ applications:

- Figure 3a: MEROS$^{®}$ plant with $Ca(OH)_2$ and lignite as additive
- Figure 3b: MEROS$^{®}$ plant with $NaHCO_3$ and lignite as additive

In the first step, special C-based adsorbents and desulphurization agents (hydrated lime see figure 3a or sodium bicarbonate refer to figure 3b) are injected into the sinter off-gas stream in the countercurrent direction to bind heavy metals and organic compounds. In the second step, the gas stream passes to a conditioning reactor where the gas is moisturized and cooled. This accelerates the chemical reactions required for binding and removing SO_2 and other acidic gas components.

In the third step, the off-gas stream which exits the conditioning reactor passes through a bag filter equipped with special high-performance fabrics where the dust with the trapped pollutants is removed. In order to enhance the gas cleaning efficiency and to significantly reduce additive costs, a portion of this dust is recycled to the off-gas stream after the conditioning reactor. This also accelerates the formation of a filter cake on the surface of the bag filter which enhances the removal of fine dust in the off-gas stream. The dust removed from the system is conveyed to intermediate storage silos for subsequent disposal or for use in other applications.

Sinter-gas-cleaning efficiency with MEROS® process results in emission reduction level previously unachieved applying conventional gas-cleaning technologies. Dust emissions are lowered by more than 99% to less than five milligrams per Nm^3. Emissions of mercury and lead are reduced by 97% and 99% respectively. Organic compounds such as dioxins and furans (PCDD/F) are eliminated by about 97% and total condensable volatile organic compounds (VOCs) by more than 99%. SO_2 emissions were also considerably reduced.

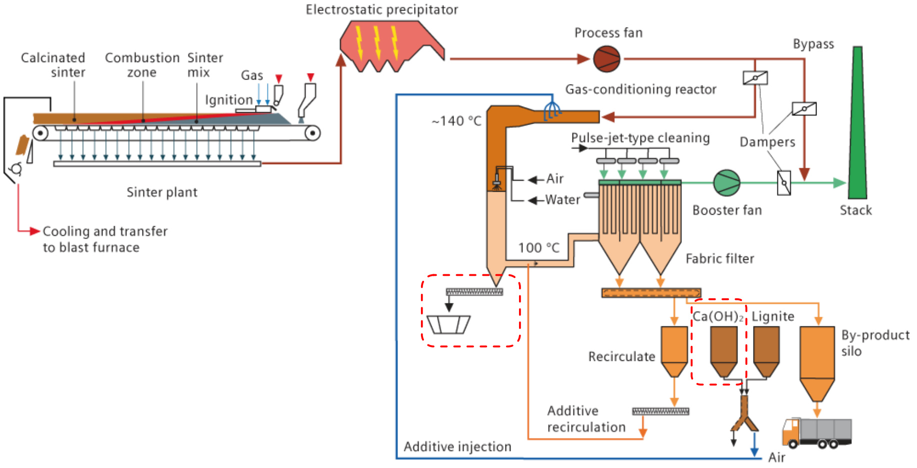

Figure 3a: Process flow sheet of the MEROS® plant with $Ca(OH)_2$ and lignite as additive

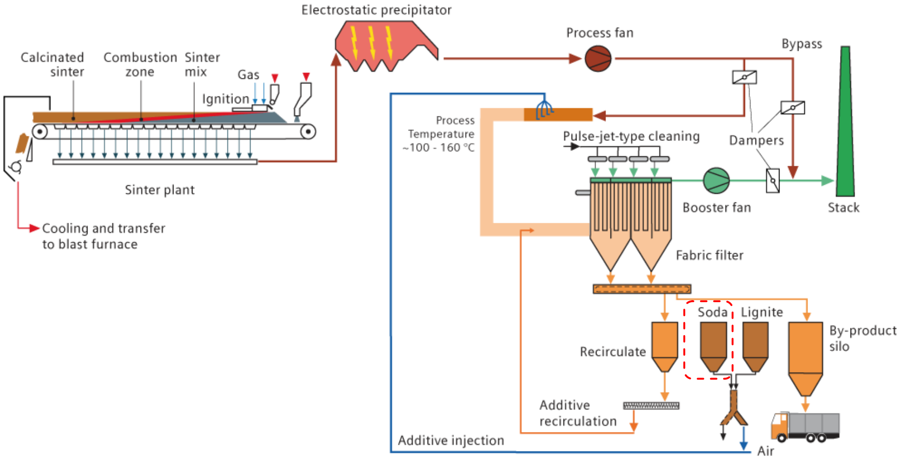

Figure 3b: Process flow sheet of the MEROS® plant with $NaHCO_3$ and lignite as additive

The reference process as the baseline for the comparison to MEROS® is chosen to be AIRFINE®. The AIRFINE® process is a wet-type sinter plant off-gas treatment (refer to figure 4). The heart of this process is the fine scrubber system, where dual flow nozzles eject water and compressed air as high pressurized mist jets into the cooled waste gas stream.

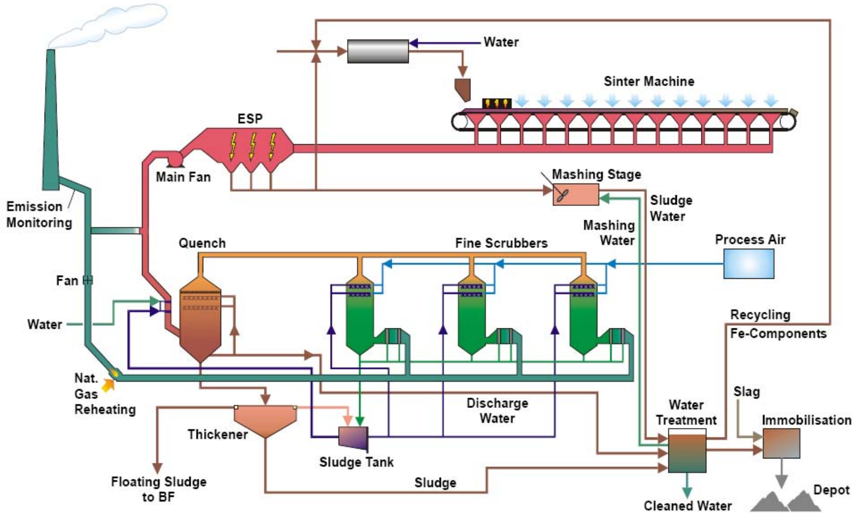

Figure 4: Principle flow sheet of the AIRFINE® process at voestalpine Stahl Linz, Austria

The AIRFINE® scrubber allows simultaneous removal of the finest dust particles (including alkali and heavy-metal chlorides) and noxious waste gas components. The latter (PCDD/F, heavy metals, polycyclic aromatic hydrocarbons (PAH)) are mainly associated with the fine dust. Compared with dry abatement systems this system can also remove water soluble compounds, such as alkali chlorides and heavy metal chlorides. In case of addition of alkalines to the scrubbing water also acidic components like HF, HCl and SO_2 can be removed significantly. The aqueous solution from the scrubber containing alkali and heavy metal salts is consequently treated by precipitation/ flocculation. The solids are deactivated with slag followed by disposal to secure landfill. The overflow is neutralized and passed through several gravel beds before discharge to the municipal sewage system.

2 Methods

The methods employed for the environmental part of the matrix are based on Life Cycle Assessment (LCA) (ref. to [2]) which is standardized in ISO 14040/44 (ISO, 2006). LCA is a tool that considers the environmental impacts of a service or a product throughout its life time, from the extraction of raw materials to the final disposal after end of useful life. LCA encompasses a range of environmental impacts (e.g. global warming, acidification, eutrophication etc.). Since the object of an LCA study is a product or a service, it is a comparative tool useful for comparing the environmental impacts of different solution or products. It can for example be used to identify design guidelines for environmental improvements of the products, solutions or services. It is evidently important to define the goal or purpose of the study including the “product” (used interchangeably with solution, project, system, or technology) that is subject to study. It should be clear what the study is intended to support and how the results are going to be used in the end. In the scoping of the study it is more clearly defined what is to be studied and how. The scope of the study should be defined according to at least the following parameters:

- The functional unit i.e. what is the delivered service of the product is the reference quantity for the study
- System boundaries. How much is included? How to define the system boundaries: Is it necessary to include the whole life cycle? Is it possible to do some simplified LCA? Which technologies are considered and in which geographical area? Etc.

Following the goal and scope definition environmental input and output data for each process within the system boundaries are collected in the inventory.

Life Cycle Impact Assessment (LCIA) transfers the data generated in the inventory into information with environmental relevance. The following section summarizes some key requirements of the international standards with regard to LCIA. According to ISO 14040/44 the LCIA phase shall include the following mandatory elements:

- Selection of impact categories, category indicators and characterization models;
- Assignment of LCI results to the selected impact categories (classification);
- Calculation of category indicator results (characterization).

The selection of impact categories, category indicators and characterization models shall be both justified and consistent with the goal and scope of the LCA. In addition to the mandatory elements of LCIA, there could be optional elements and information as listed below which can be used depending on the goal and scope of the LCA:

- Normalization: calculating the magnitude of category indicator results relative to reference information;
- Grouping: sorting and possibly ranking of the impact categories;
- Weighting: converting and possibly aggregating indicator results across impact categories

Normalization transforms an indicator result by dividing it by a selected reference value. Furthermore normalized indicator results can be weighted to reflect different preferences based on value-choices of involved stakeholders. Finally normalized and weighted indicator results may be aggregated across selected impact categories providing a single score which might be desirable for the sake of simplicity and to deliver results at a glance. However, especially weighting steps are based on value-choices and are not scientifically based. Different individuals, organizations and societies may have different preferences; therefore it is possible that different parties will reach different weighting results based on the same indicator results or normalized indicator results. In an LCA it may be desirable to use several different weighting factors and weighting methods, and to conduct sensitivity analysis to assess the consequences on the LCIA results of different value-choices and weighting methods.

Because of the subjective nature of weighting and the possible consequences on third parties, the standard says that weighting shall not be applied in LCA studies used for comparative assertions intended to be disclosed to the public. It should be recognized that there is no scientific basis for reducing LCA results to a single overall score or number. The standard explicitly states that such LCIAs shall employ a sufficiently comprehensive set of category indicators and the comparison shall be conducted category indicator by category indicator. Nonetheless, in order to illustrate results in the ECM in this case they have been implicitly weighted by the factor of 1, i.e. every impact is weighted equally.

In the Eco-Care-Matrix new technological solutions are compared to a given baseline. The environmental baseline or reference serves as a benchmark for the potential environmental improvements. Comparability is thus the main criterion for choosing the appropriate reference system or technology to perform the comparison of environmental impacts between green solution and baseline. The reference system should deliver nearly the same function or service to the customer as the considered green solution. Only if both product systems under examination have the same function using of course different process technologies and product designs, their environmental impacts can be related to the same functional unit.

The reference must be a realistic alternative to the green solution so it is obvious that the most recent antecedent product is a reasonable reference system for the new next generation product having the same function but different performance and design. Though competitive products might also be an applicable baseline, inventory data and process information needed are seldom publicly available. Another option for appropriate definition of reference systems is to use description of “best available techniques” (BAT) reported in sector-specific and cross-sector reference documents (e.g. BREFs issued by European IPPC Bureau; http://eippcb.jrc.es/reference/).

If a retrofit green solution is to be assessed modernizing an existing solution one could perform a “before - after” comparison considering impacts of the former process technology as baseline. Especially in the case of an assessment of environmental technologies like flue gas treatment the baseline consideration should be based on the actual former situation taking into account legal obligations. For example it would not be realistic and therefore not allowed to compare retrofit flue gas treatment with the former “virtual” situation of flue gas emissions without any treatment. An important aspect of the establishment of an environmental baseline is the consideration of important stakeholder‘s interpretation of environmental care. If stakeholders do not agree it is risky to claim environmental care.

Reference technology for the flue gas treatment of sinter off-gas has carefully been chosen to be the Airfine® process. Figure 5 illustrates the reason for justifying Airfine® as an appropriate reference process because both process technologies are having the same function to treat sinter off-gas by removing dust particles and other waste gas components. The Airfine® process also complies with regulations for off-gas. The product of the sinter plant provides the functional unit (1 ton sintered ore).

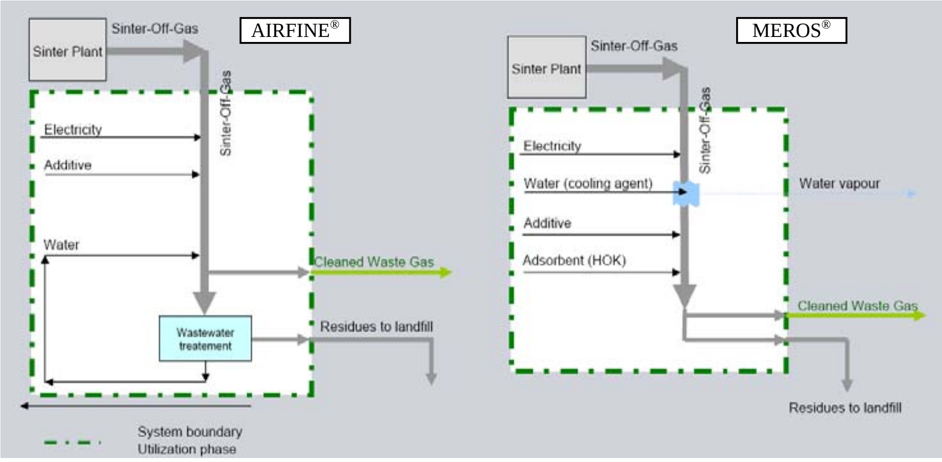

Figure 5: AIRFINE® system and MEROS® system with system boundaries

3 Results

The life cycle impact assessment of the different dedusting product systems reveals environmental impacts in five selected impact categories. The following impact categories have been selected:

- Abiotic resource depletion potential (ADP)
- Eutrophication potential (EP)
- Photo-chemical ozone depletion potential (POCP)
- Global warming potential (GWP)
- Acidification potential (AP)

The selection of the impact categories reflects goal and scope of the comparison of product systems dedicated to dedusting and desulfurization of sinter off-gas by applying additives (water, lime and sodium bicarbonate) and electrical power. Figure 6 shows the impact indicator results in each of the selected impact categories. Compared to the baseline process AIRFINE® the MEROS® process with additive hydrated lime shows the lowest environmental impact with respect to global warming (GWP), resource depletion (ADP) and eutrophication (EP). MEROS® with sodium bicarbonate ($NaHCO_3$) as additive leads to higher environmental impacts in these impact categories due to fact that it bears increased upstream environmental burdens compared to lime though it consumes less electrical energy per functional unit (4.83 kWh/ t sinter for additive hydrated lime – 3.63 kWh/ t sinter for additive sodium bicarbonate). Looking at the impact categories of photochemical ozone creation and acidification MEROS® with hydrated lime as additive reveals an increased desulfurization potential due to higher separation process efficiency compared to AIRFINE®. If sodium bicarbonate substitutes hydrated lime as additive the degree of SO_2 separation can further be increased from 55% up to 90% removal. This takes additional resources of about 63% more $NaHCO_3$ per functional unit compared to the conventional SO_2 separation degree of 55%.

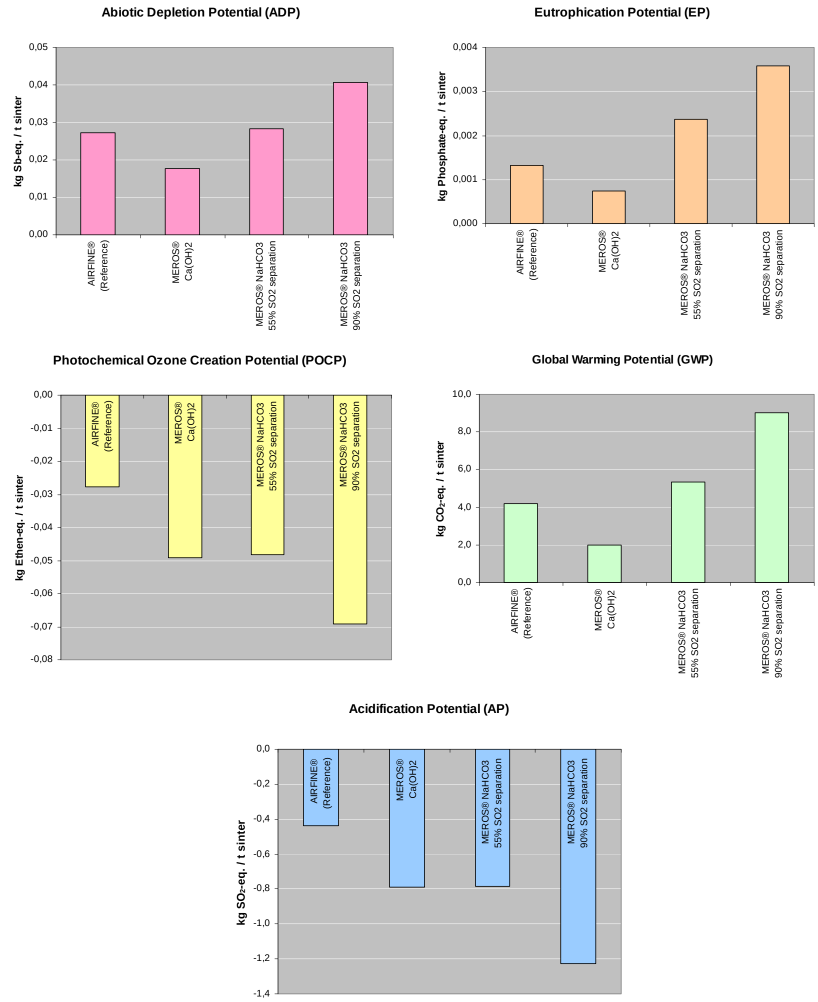

Figure 6: Category indicator results for selected impact categories derived from life cycle impact assessment for the different product systems (characterized acc. to CML 2001, Dec. 2007)

To derive an aggregated value across all selected environmental impact categories the impact indicator results have been normalized using the CML normalization values in the GaBi software tool (GaBi: “Ganzheitliche Bilanzierung”). As mentioned previously it should be kept in mind that weighting and aggregation of indicator results may cover effects of trade-offs between impact categories. Figure 7 illustrates the comparison of normalized indicator results for the test case of dedusting product systems.

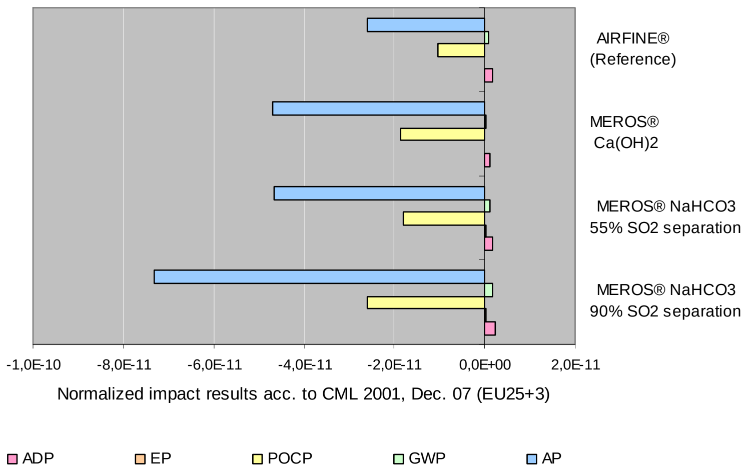

Figure 7: Profile of normalized indicator results for selected impact categories according to CML 2001, Dec. 2007 (spatial normalization to European area (EU25+3))

For presentation and illustrative purposes the normalized indicator results are aggregated across the five selected impact categories by equally weighting in order to derive a single environmental score. In figure 8 the result for such an aggregation is used to place the different product systems on the y-axis. Additionally to the environmental benefit information customer benefits of the product system is reflected by the total cost of ownership on the x-axis.

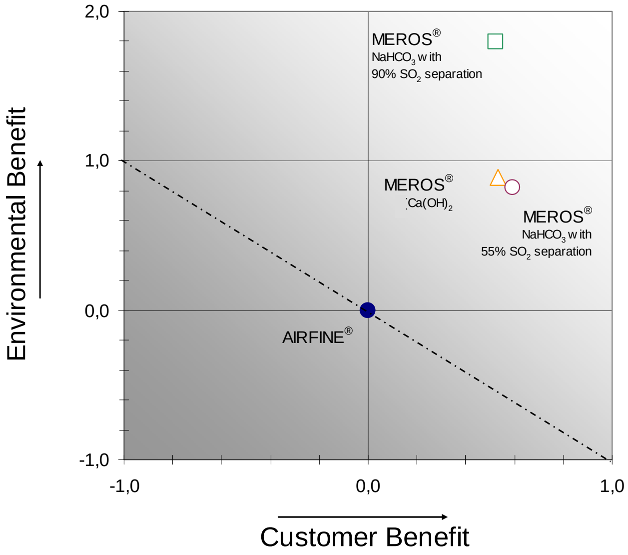

Figure 8: Eco-Care-Matrix representation of aggregated single scores based on five different selected environmental impact categories (aggregated with similar weighting of normalized indicator results)

The Eco-Care-Matrix in figure 8 delivers decision supporting information about the different dedusting product systems at a glance but it may hide the full extent and ramifications of the underlying life cycle impact assessment results because of the aggregation of several impact categories. Trade-off effects between the impact category indicator results as illustrated in figure 6 are not visible anymore in this aggregated view. This could cause incorrect decision-making and also “green washing” criticism by stakeholders. In order to provide the appropriate extent of information it is recommended according to ISO standard 14044:2006 to make data and indicator results or normalized indicator results reached prior to weighting available.

Figure 9 delivers an appropriate ECM representation of multiple environmental indicator results avoiding aggregation to a single score. For each single impact category the relative changes compared to the reference is illustrated. The enlarged detail of the Eco-Care-Matrix comprehensively provides information about the environmental profile of each of the product systems under consideration. For example the MEROS® with hydrated lime additive provides environmental benefits in all considered impact categories compared to the baseline AIRFINE®. The length of the interval between the lowest and highest indicator result for given product system (indicated with a white arrow in figure 9) represents the potential range of environmental trade-off or shifting effects between different impact categories and thus provides the reader with the entire extent of information needed for decision-making.

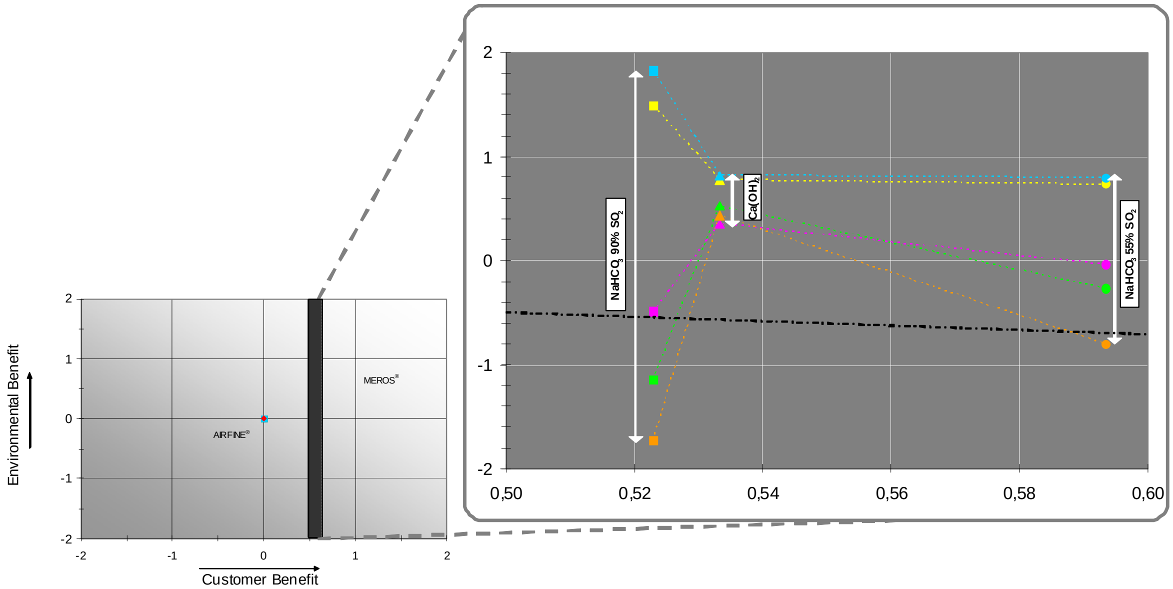

Figure 9: Multiple indicator representation in Eco-Care-Matrix for selected impact categories comparing different MEROS® product systems to baseline AIRFINE®

ADP = '●'; EP = '●'; POCP = '●'; GWP = '●'; AP = '●'

Used additives $Ca(OH)_2$ = '△'; $NaHCO_3$ with 55 % SO_2 separation = '○'; $NaHCO_3$ with 90% SO_2 separation = '□'

It is clear that the aggregated single score for the environmental impacts presented in figure 8 provides an easy overview of the systems, whereas it may be more difficult to interpret the variation of results between impact categories obtained by the more detailed presentation in figure 9. But it is also clear that the aggregated single score to some extent is misleading in their presentation of the sodium bicarbonate environmental impacts since it does not illustrate the potential problem shifting or trade-off between EP (eutrophication potential) and POCP (photochemical ozone creation potential) for the benefit of global warming (GWP) and acidification (AP). This is much better observed in the multiple impact category presentation in figure 9. Presentation of this type of trade-offs is important in many cases to be aware that the avoided environmental problem is not overshadowed by environmental impacts induced. For example is it generally seen that environmental technologies (cleaning and abatement) helps remediate one environmental problem through the consumption of energy or that providing a higher energy efficiency in the use phase may cause higher environmental impacts during production (e.g. depletion of scarce resources). In order to raise awareness of the consequences of decisions taken it is therefore advocated that presentation of results cannot be solely done by the single score indicator.

4 Conclusion & Discussion

The Eco-Care-Matrix (ECM) simply visualizes the eco-efficiency of solutions compared to a given baseline. In order to prevent from “green washing” criticism and to ensure “walk the talk” attitude the ECM should be scientifically well-founded using appropriate and consistent methodology. The vertical axis of an ECM illustrates the environmental performance and the horizontal axis describes the economical customer benefit of one or more green solutions compared to a defined reference solution. Different scientific approaches for quantifying the environmental performance based on life cycle assessment methodology have been discussed especially considering the ISO standards 14040/14044:2006.

Since the assessment of different alternatives only makes sense in a comparative setting it is chosen to let the ECM present results relative to a reference technology. The proper choice of a reference technology is therefore a necessary prerequisite to be able to use the ECM. If the ECM should really represent the potential improvement of the new technologies the reference technology must represent a realistic alternative technology performing the same function, e.g. the current generation of technology being produced by Siemens. The choice of Airfine® in the study complies with all requirements to a reference technology.

As illustrated with the single score vs. multiple score presentation there is a strong need for using multiple rather than single scores in order to improve decision making since the single score may hide relevant potential environmental impacts. The use of aggregated single score result may cause intransparency of shifting and trade-off effects between different impact categories and lifecycle phases.

5 References

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