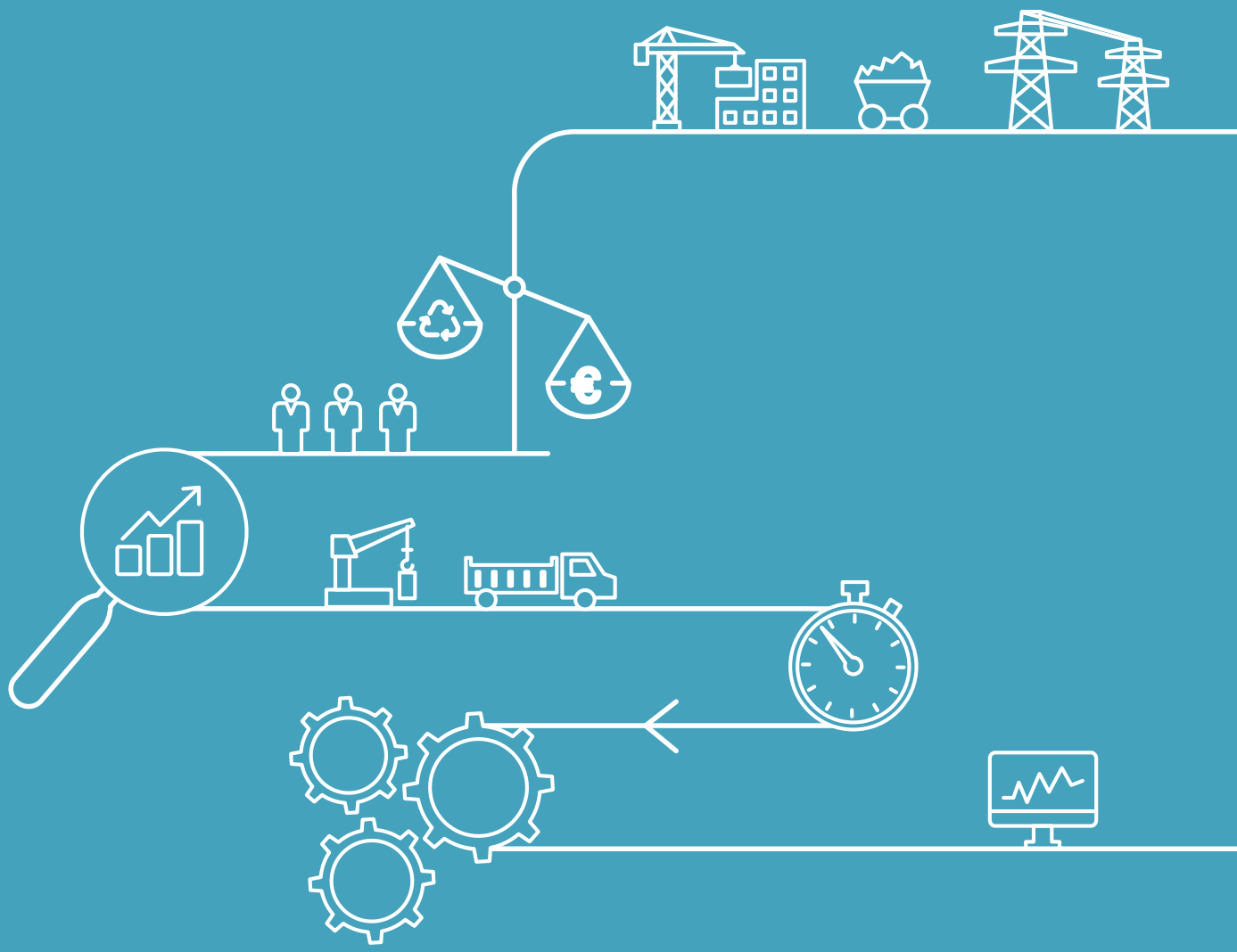
MATERIAL FLOW COST ACCOUNTING (MFCA)

A GUIDELINE FOR SMEs



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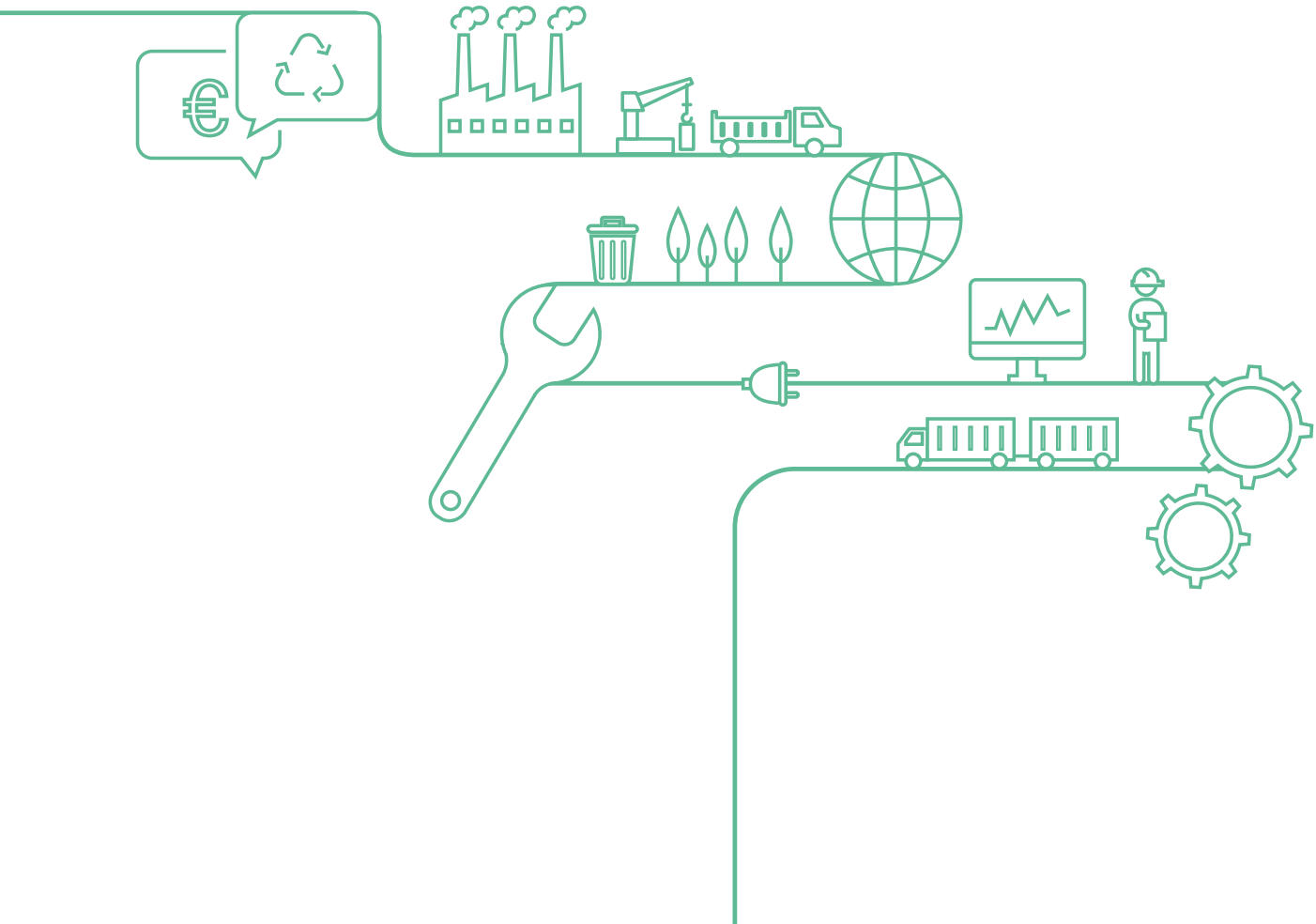


INTRODUCTION

Preventive industrial environmental management is a well-known concept for aligning two seemingly competing goals: economic growth and environmental protection. At the core of preventive strategies there are win-win solutions for a better management of resources like material and energy.

Several proven tools can be used for assisting companies to integrate environmental management into their business operations, such as Resource Efficient and Cleaner Production Assessment (RECPA), Environmental Management Systems (EMS) and Energy Management Systems (EnMS), Life Cycle Assessment and Eco-design, Corporate Social Responsibility (CSR), Environmental and Material Flow Cost Accounting (EMA and MFCA), etc. However, stand-alone implementation of individual tools, although effective in identifying particular improvements, can easily lead to sub-optimal solutions and as a result the company may have difficulties in maintaining the desired complex changes in their strategies or systems as well as their alignment to the desired outputs of sustainable production. Effective integration of some of these tools into one package can significantly accelerate organizational changes in the direction of sustainability, taking advantage of the complementarity and the synergies that the combined use of specific tools can provide.

In 2000, UNIDO developed just such an integrated approach named "Transfer of Environmentally Sound Technology" (TEST), which consist of a set of preventive environmental tools (mainly RECPA, EMS and MFCA), whose elements are applied in a customized way based on an enterprise's needs. The implementation of TEST is done at the different levels of a company:

1. At the process level: the approach gives priority to the preventive approach of Resource Efficient and Cleaner Production (RECP) based on the adoption of pollution prevention techniques in the production process. It considers the transfer of additional technologies for pollution control (end-of-pipe) only after the feasible RECP solutions have been explored. This leads to the transfer of procedures, techniques and technologies that are focused on simultaneously optimizing both environmental and financial performances.
2. At the management system level: the TEST approach establishes information systems on relevant material, energy and related financial flows necessary for linking together the strategic and operational levels within an enterprise. This is done by applying the basic elements of an EMS and directly linking MFCA to the company's existing financial information systems.
3. At the strategic level: by leading a company towards the adoption of sustainable enterprise strategies the TEST approach embeds environmental management within the broader strategy of corporate social responsibility (CSR).

This document illustrates the concept and methodology of MFCA, which is one of the tools used in TEST. It is used to support and sustain the implementation of the other tools used in TEST, e.g. RECPA and EMS. MFCA reveals the hidden costs of production inefficiencies and losses, by putting in place an information system to track and monitor the non-product output (NPO) costs as well as other environmental costs. Thus, companies can identify the focus areas to be addressed, including essential material/energy flows, and determine what improvements and saving opportunities exist in those areas. The MFCA's information system enables an effective monitoring of the improved environmental and economic performance arising from implementation of RECP programmes, which is essential to demonstrate their impact on medium to long-term decisions, thus promoting their continuous application.

This document proposes a simplified step-by-step approach for SMEs to introduce MFCA into their operations. The approach proposed is based on ISO 14051 for Material Flow Cost Accounting. The environmental cost categories used in the MFCA tool are consistent with the definitions used by statistical agencies, UN DSD and IFAC.

This document includes several case studies from the MED TEST UNIDO project1 as well as the results from a ficticious pulp and paper company in a country in transition. A separate MFCA excel file for data assessment and recording is also part of the training material.

Target group of this manual are beside external providers of technical assistance both financial staff and the technical staff members of the company who should be working together. MFCA enables them to find common language to explore company RECP opportunities.

This manual is based on MFCA principles but does not seek to guide a company to full implementation of the MFCA standard, as this would not be feasible for most SMEs.

[1] The MED TEST programme is an initiative of UNIDO for promoting sustainable production in the southern Mediterranean Region. The MED TEST programme was first launched in 2009 with a pilot phase supported by the Global Environment Facility (GEF) and the Italian Government in Egypt, Tunisia and Morocco. In 2014 the MED TEST programme was extended to other countries (Algeria, Israel, Jordan, Lebanon and Palestine) and incorporated within the Switch-Med initiative funded by the European Union (www.switchmed.eu).

1. GETTING STARTED

1.1 WHAT IS MFCA AND WHAT IS IT GOOD FOR?

The ISO standard on Material Flow Cost Accounting, ISO 14051, 2011, defines MFCA as "a tool for quantifying the flow and stock of materials in processes or production lines in both physical and monetary units". It is used as a tool to improve material productivity by reducing the relative consumption of materials, energy and water. As such, MFCA is regarded as an effective means by which companies can simultaneously seek both environmental as well as financial benefits. In MFCA, the flow of materials used in a company as well as the amounts in inventory (stock) are measured in physical units of weight (kg or tonnes) and subsequently evaluated in monetary units, which are based on the manufacturing costs incurred.

ENVIRONMENTAL MANAGEMENT ACCOUNTING

MFCA evolved from Environmental Management Accounting (EMA). EMA is defined as the identification, collection, analysis and use of two types of information for internal decision-making:

- physical information on the use, flows and destinies of energy, water and materials (including wastes) and
- monetary information on environment-related costs, earnings and savings

As such, both tools are based on the assessment of a material flow balance, also known as mass balance or input output balance in volumes terms. The development of these balances is an important part of the TEST approach.

Where the two tools differ is the system boundaries which they may use. The boundary for an EMA is generally the system boundary of the company. The boundary for an MFCA, on the other hand, is generally within the organization's boundary; it could be a process, a department, a unit. Since analysis at this level is more useful for the generation of RECP options, TEST projects rely primarily on MFCA. However, the starting point is normally an EMA: at the beginning of TEST projects most data is available in companies only for this system boundary. This is especially true for small and medium-sized enterprises (SMEs), which normally do not have a cost accounting system established and may only annually assess the losses of materials and products in stock management. Therefore, in this manual and TEST, both approaches are combined by first doing the input/output balance in physical terms on the system boundary of the company, then calculating the costs for non product output and consequently distributing these costs to the main production steps or cost centres.

To assess costs correctly, a company should collect both monetary and non-monetary data on materials use, personnel hours and other cost drivers. MFCA used in the context of TEST places particular emphasis on materials and related costs because of the environmental impacts of the use of energy, water, materials, waste generation and related emissions. These factors, together with the material purchase costs, are the prominent cost drivers in many companies, especially in countries with low enforcement of legal compliance and relatively low labour costs.

The underlying assumption of the MFCA approach and especially the physical mass balance is that all purchased materials must leave the company either as product or waste and emissions. Waste, discharges, and emissions are thus a sign of inefficient production because they have been purchased and paid for, they have often been processed to some degree in the company's operations, but they have not been turned into a marketable product. Instead, they have become **non-product outputs (NPOs)**, often requiring specialized management to minimize their environmental impacts. Thus, in addition to being responsible for a certain portion of the company's overall purchase and production costs, NPOs add an extra cost for their correct treatment and disposal.

A prerequisite for a proper implementation of MFCA is that a company has internal information systems (accounting and management systems) which clearly define and systematically record material flows, which then would allow it to calculate and demonstrate all these costs. However, many companies do not have such information systems in place and use their accounting system only for external reporting to tax authorities and not for internal process and production monitoring. Some of the biggest challenges are a number of current accounting practices in use such as:

- **Inadequate links** between accounting and production departments;
- Unintentional **hiding** of environment-related cost information in overhead accounts;
- Inadequate tracking of information on **materials use, flows, fates, resource efficiency** and **costs**; and
- **Lack of some environment-related information** in the accounting records.

This lack of proper information often leads companies to make distorted **investment decisions**. Specifically, companies often do not realize that the actual costs to them of the waste and pollution they generate – the full NPO costs - include not only disposal fees, treatment and equipment costs, but also those related to the inefficient use of materials purchased and used in processes that end up as waste and emissions, instead of products. This "hidden" portion of NPO costs can be on average one order of magnitude higher than the costs for disposal and emissions treatment. Several case studies have shown that the costs of waste disposal and emission treatment are typically 1-20% of total NPO costs, while the purchase costs of the wasted materials represent 40-90% of total NPO costs, depending on the business sector examined. The result of this is that companies do not recognize, and by far, the full value to them of environmental protection projects aimed at preventing or reducing emissions and wastes at source by more efficient use of materials and aimed at shifting to the use of less harmful materials, and therefore they fail to implement such projects.

Although actual NPO costs are rarely tracked by companies' accounting systems, they can be calculated or well enough estimated with the assistance and cooperation of accounting and production managers, as will be illustrated in this manual. The results of the MFCA assessment can be used to guide a company towards the choice of an optimal menu of RECP options which not only prevent, or at least minimize, the production of wastes and emissions, but also maximize the financial benefits by reducing, and in some cases totally eliminating, the related purchase costs, operational costs (energy, labour, and equipment), and disposal or treatment costs.

MFCA is especially useful in countries where the costs for environmental protection are negligible, which is often the case in developing and transitional economies, either because there is a lack of environmental legislation and regulation or because these are not properly enforced. But the other portion of the NPO costs – the costs of inefficient use of materials and energy – are still very significant in these countries.

In summary, MFCA is good for:

- Making **all** environment-related costs and benefits visible.
- Helping to raise environmental awareness in the "core" of a company's business, by providing data to formulate targets and programs for integrated environmental prevention, and by giving line managers and project managers an additional point of view – the environmental impacts, costs and benefits of their decisions – in their decision-making.
- Providing data and information for the annual report (e.g. non-financial information in the Director's report); MFCA tells the "environmental story" of costs.
- Giving the possibility to communicate the progressive shift: from emissions control to integrated prevention processes to integrated prevention products.
- Providing arguments as to why RECP pays; MFCA provides the information needed to convince the financial department to invest in RECP technologies and in the human resources for environmental management.
- Possibly helping management to identify environmental risks and to adopt measures to reduce them and the associated costs (e.g., insurance).

SOME DEFINITIONS:

Environmental costs are all internal and external costs related to environmental protection and to the use of natural resources. MFCA only deals with a company's internal costs, not the external costs to society.

MFCA is a tool for quantifying the flows and stocks of materials in processes or production lines in both physical and monetary units (ISO 14051). Like EMA, it involves the identification, collection, analysis and use of two types of information for internal decision making:

- physical information on the use, flows and destinies of energy, water and materials (including wastes) and
- monetary information on environment-related costs, earnings and savings [UN DSD, 2001].

Non Product Outputs (NPOs) are all physical material outputs generated for a defined system boundary, except those embedded in intended products. In other words, NPOs include all inputs (materials, water and energy) that have not been transfered into a product output. When calculating NPO costs, not only disposal fees are calculated, but in addition the wasted material purchased value and the production costs of waste and emissions are included. NPOs include inputs that end up as air emissions, wastewater and solid waste, even if these material outputs can be reworked, recycled or reused internally, or have market value. By-products can be considered as either NPO or products, at the discretion of the company. Typically, when sold, they are considered a product. When they have to be disposed off at costs or zero costs, they are considered waste. (Similar to "material loss" as defined in ISO 14051).

1.2 INTRODUCTION TO FINANCIAL AND COST ACCOUNTING TERMINOLOGY

The MFCA tool is very much based on standard accounting practices and requires the involvement of staff from the company's accounting department, therefore this section gives an overview of accounting practices and explanations of key terms for non-accountant readers.

Conventional corporate monetary accounting is comprised of:

- Financial accounting (bookkeeping, balancing, consolidation, auditing of the financial statement and reporting)
- Cost accounting (also called management accounting)
- Corporate statistics and indicators (past oriented)
- Budgeting (future oriented)
- Investment appraisal (future oriented)

Financial accounting is mainly designed to satisfy the information needs of external shareholders and financial authorities. Both groups have a strong economic interest in standardized comparable data and in receiving true and fair information about the actual financial performance of the company. Therefore, financial accounting and reporting are covered in national laws and international accounting standards. They regulate how specific items should be treated, specifying, e.g., whether investments should be capitalized or expensed, under which circumstances provisions may be made for future treatment liabilities, or when contingent liabilities should be disclosed. Imputed (calculatory) approaches as used in cost accounting are not permissible.

Financial accounting deals with **revenues and expenditures** as shown in the profit and loss account and with assets and liabilities as listed in the balance sheet. More detailed information is available from the list of balances.

Bookkeeping, financial and cost accounting provide the data base for the other accounting information systems.

Cost or management accounting constitutes the central tool for internal management decisions such as product pricing and investment appraisal and is not regulated by law. This internal information system deals with the following questions: What are the production costs for different products and what should be the selling price of these products? For determining the inventories of finished goods and work-in-progress for the balance sheet, cost accounting also needs to be done for financial reporting. The main stakeholders in cost accounting are members of different management levels (e.g. executive, site, product, and production managers). The costs related to environmental management (mostly hidden in general overhead costs) may be traced and allocated to products and cost centers.

Cost accounting is based on data obtained from financial accounting and from production planning systems. Sometimes the values from financial accounting are adjusted for cost accounting purposes, following the system of **transition from expenditure to costs**. However, most SMEs use the same figures with only minor adjustments, if they have a cost accounting system at all.

Typically, SMEs do not have a separate cost accounting system. Instead, they make their internal decisions based on calculations which are made with financial accounting data from bookkeeping. For all companies, annual data must be available for the system boundary of the whole company ("company system boundary") based on financial accounting requirements.

Therefore, the starting point for an MFCA assessment is the **list of accounts** of the trial balance of the previous business year. As all companies have to pay taxes, the list of accounts is the only mandatory information system, and is therefore available in companies of all sizes throughout the world. Another reason for starting with the system boundary of the company is that much information is only collected for this system boundary. In addition, this information is often only collected annually. For instance, the changes in stock may only be recorded annually. Also, waste volumes and other environmental performance indicators, almost always recorded at the company system boundary, are often not monitored monthly, but only annually in some companies.

In cost accounting, the terms **costs and earnings** are related to the terms revenues and expenditures in financial accounting. There is no equivalent to financial accounting's balance sheet.

The various expenditure items in financial accounting correspond to the categories of costs used in cost accounting. Costs are allocated to the relevant cost centers (in-house production processes) and cost carriers/objects (products). Because the system boundary differs, the level of cost details is different between financial accounting and cost accounting. For financial accounting, the system boundary is the legal entity (the whole company) and therefore expenditures mostly deal with the company as a black box, sometimes aggregating over several production sites. Cost accounting, on the other hand, drills down inside the company and traces the costs to the specific production steps (related to cost centers) and to the products which generated those costs.

FINANCIAL ACCOUNTING	COST ACCOUNTING
Balance sheet	No equivalent
Assets	No equivalent
Liabilities	No equivalent
Profit and loss account	Cost statement
Expenditures	Costs
Expenditure items	**Cost categories**
Revenues	Earnings
No equivalent	Cost calculation
No equivalent	**Cost centers**
Calculation of production expenditure	Cost carriers/objects (products)

Table 1: Relation between Financial Accounting and Cost Accounting

The MFCA assessment should be based on expenditures from the profit and loss account and/or on cost accounting and stock management information, depending on the structure of internal information systems. It is the task of the company's controller or financial manager to define the most appropriate database for the mass balance of the organization.

SOME IMPORTANT TERMS TO DISTINGUISH:

Costs Centers are those parts of the company that are organized as independent clearinghouses; they should be connected to production processes. Maximum consistency between cost centers and process-oriented material flow analyses is the prerequisite for good data. Cost centers generate costs, are responsible for costs, or are attributed costs, e.g. for production and administration.

Overhead Costs are costs that cannot be directly attributed to cost centers and cost carriers (true overhead) or costs that are not directly attributed for reasons of economic efficiency (untrue overhead), e.g. administrative costs, insurance, advertising costs. Many environmental costs are considered overhead costs, and for the most part fall into the category of untrue overhead. There are a number of methods to allocate overhead to cost centers and cost carriers.

Cost Carriers or Objects are products and services produced either for the market or for internal needs. By attributing types of costs to cost centers and cost carriers, production costs and sales price floors are calculated.

Cost-Category Accounting is the first phase of cost accounting and aims to define which costs have been incurred in which amounts during the accounting period. In cost-category accounting, data from financial accounting is being transferred into costs. These costs are recorded in accordance with a cost category plan and divided into direct costs and overhead.

Cost Center Accounting follows cost-category accounting and identifies where and in which amounts have costs been incurred during the accounting period. Also, it is is also responsible for internal cost assignments and determines cost estimate rates or billing rates (or surcharge rates) should they be required for cost carrier accounting based on the company's operational situation. For this accounting procedure, an overhead allocation sheet is used.

Cost Carrier Accounting is the final phase of cost accounting and determines the production costs for each product (or service). It provides the basis for price calculation and determines: which types of costs have been incurred at what amount to produce a certain product or to deliver a certain service.

The process by which costs are allocated to cost centers and then cost carriers is shown diagrammatically in Table 2.

COST CATEGORY ACCOUNTING		COST CENTER ACCOUNTING		COST CARRIER ACCOUNTING (PRODUCT)
Which costs have been incurred in which amounts? Cost distribution to direct costs and overhead Cost roll-over from financial accounting	⇨	Where and in which amounts have which costs been incurred during the accounting period? Internal cost attribution and cost estimates or billing rates	⇨	Which types of costs have been incurred in what amount for a certain product or service?
e.g. Labor Raw Materials Operating materials Energy External Services Calculated Write-Off Calculated Interest Calculated Risk Other Costs		e.g. I Manufacturing Process Ia Process Ib Process Ic II Warehouse III Distribution IV Administration		Product A Product B Product C

Table 2: Relationship between Cost Category, Cost Center and Cost Carrier Accounting

Cost attribution is done in two steps: first from joint cost centers like waste management and emissions treatment, to the responsible cost centers in the production process, and secondly from the production cost centers to the respective cost carriers/objects (e.g., products A and B).

A key to proper attribution of costs is how the company attributes its overhead costs. A simple example in Tables 3 and 4 shows how overhead cost-attribution can significantly change the production costs of products.

COST CATEGORIES		TOTAL COSTS	PRODUCT A	PRODUCT B
Materials by recipe/ formula and stock issuing	Direct costs	140	70	70
Working hours by time records	Direct costs	60	30	30
Depreciation	Overhead	50		
Rent		10		
Energy		5		
Communication		10		
Administration		25		
Top management's salary		10		
Waste & Emissions Treatment		10		
Total Overheads	**Distribution by % product turnover**	**120**	**60**	**60**
Total Product Costs			**160**	**160**

Table 3: Environmental Costs hidden in Overhead Accounts

COST CATEGORIES		TOTAL COSTS	PRODUCT A	PRODUCT B
Materials by recipe/ formula and stock issuing	Direct costs	**140**	70	70
Working hours by time records	Direct costs	**60**	30	30
Energy	**Cost attribution to cost centers and products by actual process flows**	5	2	3
Waste and Emissions treatment		10	4	6
Depreciation		50	20	30
Rent	Overhead	10		
Communication		10		
Administration		25		
Top management's salary		10		
Total Overheads	**Distribution by % product turnover**	**55**	**27,50**	**27,50**
Total Product Costs			**153,50**	**166,50**

Table 4: Environmental Costs attributed to Cost Centers and Products

What this simplified example shows is that an untrue overhead like waste and emissions treatment can be attributed more realistically to the company's two cost carriers, product A and product B, based on the actual flows of waste and emissions generated by the processes manufacturing the two products and their associated costs. As a result of this more realistic attribution of costs, Product A has significantly lower costs (13% lower) than Product B. The conclusion is that whenever possible, costs should be allocated to the respective cost centers and cost carriers/objects (products) based on actually measured data.

2. STEP BY STEP ASSESSMENT APPROACH

2.1 GENERAL OUTLINE OF THE MFCA ASSESSMENT

The MFCA assessment is done using a step-wise approach:

1. Assessment of **materials inputs and outputs** in physical terms for the previous business year, and consequently calculation of total **annual NPOs** in volumes and value on the system boundary of the company (this is undertaken in TEST Step 1.4: Identifying total costs of NPOs and priority flows). The data gathering for the input output mass balance in kg or tonnes as well as calculation of percentage losses is described in Chapter 2.3. Chapter 2.4 deals with the NPO cost calculation.
2. Distribution of the annual costs to **cost centers** or more specific processes (this is undertaken in TEST Step 1.5. Setting up focus areas). In TEST, the NPO costs can be distributed to the process flow chart of a company (Chapters 2.6 and 2.7.). To satisfy reporting requirements in some countries, companies may also need to distribute the NPO costs to the environmental media affected (Appendix A)
3. Selection of specific processes or material flows for in depth investigation (TEST Step 1.5)

Steps 1 and 2 also generate **improvement options** for the accounting information system, in order to allow for better future data management. Typical recommendations for the improvement of the data information system are described in Chapter 2.9.

The assessment also provides the baseline for appraisal of **investment options** as described in TEST Step 1.8. (e.g. comparing the performance of different RECP technologies and/or end-of-pipe solutions to each other or to existing technologies). The application of MFCA for investment appraisal is dealt with in Chapter 2.10.

The starting point for the assessment of NPO costs is putting the right team members together. Experience shows that the production and environmental managers have hardly any access to the accounting documents of the company and are only aware of a tiny fraction of the company's environmental costs. On the other hand, the financial accountant/controller has access to most of the information but is unable to separate out the environmental part, to calculate a physical mass balance without further guidance, and is limited to thinking within the framework of existing accounts. Also, there are severe communication issues between the production and environmental departments, on the one hand, and the financial department, on the other.

Therefore, having a TEST Team which combines the competencies for monetary accounting, process engineering, and environmental management, as well as ensuring that the Team gains support from all sides is vital for the success of any MFCA project.

It is also recommended to focus the assessments on what is easily available from existing records. It is NOT the goal of an MFCA assessment to come up with "complete data" for the past, thus forcing the TEST Team to spend a lot of time tracing old invoices. Rather, its goal is to open the eyes of management to areas of improvement and to develop an overview on the most significant material and energy flows and their related costs. It also aims to determine where existing information systems need improvement so that it provides better data and faster in any future assessment. For this, the TEST Team should note possible areas of improvement in the information system and submit these as recommendations to management.

The main source of information for an MFCA assessment, especially in SMEs, is the list of accounts of the previous fiscal year, as in most companies only this information is consistently available. Thus, the assessment starts with the list of accounts of the trial balance for the previous business year.

For the first assessment of a material flow balance, only a rough estimation may be performed. In many companies, the result of the first assessment is not a complete mass balance, but a list of recommendations for improvements of data management, a preliminary understanding of the consistency or inconsistency of material flows and a baseline for the NPO costs of the previous year, as data in terms of money is typically more available than in volumes.

Any further splitting down to processes or cost centers or product groups should only be done once the information has been gathered at the system boundary of the company or legal entity (resulting in the definition of **priority flows - step 1.4 of TEST**) and then distributing the total NPO costs to cost centres or production steps (resulting in the definition of **focus areas - step 1.5 of TEST**). For these, the technical analysis for process optimization is then performed.

The first MFCA assessment should not take longer than a 1 to 2 days workshop with the accountant and process engineer.

NOTE:

The mass balance for the previous business year can be completed well enough in a one-day workshop together with some additional time for data refinement. The goal is not to be perfect, but to check the consistency of inputs to outputs, to record significant data inconsistencies, and to note improvement options for the existing information systems. The MFCA excel tool can still be used even if the TEST Team only has estimates available to it. It provides a structured approach that allows gradual refinement over time.

The only necessity is that someone with in-depth knowledge about, and preferably with direct access to the company's financial accounting and stock management systems, is working together with someone from the production department (and environmental department, if it exists). Whenever data is not available, the Team makes an estimate, it draws up a record on how the estimate was calculated, and it formulates a recommendation to improve the data/information system. All this can be made directly in the MFCA excel tool.

Do not be shy about using estimates! It is better to have an estimate than no figure. Production staff often can provide very good estimates for loss percentages, which are much more accurate than the figures used by the accounting department. At a later stage, these estimates can be improved by more detailed measurements. But always record the calculation procedure and the information source for the estimate.

The goal of the first assessment is to:

- Present to top management as entire a picture as possible of material inputs and outputs as well as total NPO costs of the previous fiscal year, perhaps even a first distribution of these cost to main production steps;
- Formulate recommendations on how to improve the information system; and
- Gain management's support to improve the information system as well as the technical processes.

In summary, the first assessment can open the eyes of management in three broad areas:

1. What assessments always make visible, mostly for the first time, are the true size of the costs of inefficient production and the related wastage of materials and energy use. Even if technical solutions to reduce these inefficiencies will not be apparent at the end of the first assessment, the priority flows and focus areas for deeper investigation will be defined and the total range of NPO costs will be visible as a benchmark against the zero-waste option.
2. New technical improvement options may become obvious, even at this early stage.
3. What assessments will also always make apparent are measures necessary to improve the quality and consistency of data and information flows in the company. This is the starting point of most projects and the focus of most follow-up projects.

2.2 GUIDANCE IN THE USE OF THE MFCA EXCEL TOOL

The TEST Team, which should include the company accountant, should use the **MFCA Assessment Template** to assess the total annual material and energy flows and related NPO costs. The tool also provides the option of distributing the NPO costs to different cost centers. Since these are often equivalent to production processes, the tool therefore also provides good quality data for investment appraisal of specific processes. In a second step, the system boundary for the material flows in the MFCA can focus on more detailed processes within a cost centre.

Once the data has been assessed at the company level for the previous business year, the TEST Team can define the **priority flows** as described in Step 1.4 of TEST. Next, the data can be distributed to cost centers, reflecting production processes, thereby allowing the TEST Team to decide on **focus areas** for the later in-depth technical assessments (Step 1.5. of TEST). In the end, this may become the basis for the appraisal of investment proposals.

The MFCA Assessment Template is part of the TEST training kit and has been developed to assist practitioners in the detailed analysis of material and energy flows in a company.
The tool can be used for:

i. Input/output analysis in volumes (kg or tonnes) at the company system boundary;

ii. Identification of NPO volumes and costs at the company system boundary and at specific cost centre level;

iii. Selection of priority flows and focus areas associated with highest production losses, NPO costs or environmental impact;

iv. Distribution of total NPO costs and volumes by environmental media affected or by production steps;

v. The distribution by cost centers or production steps provides a good basis for defining focus areas for further technical assessment;

vi. Recording of recommendations for addressing gaps in the existing company information system for monitoring important flows.

The MFCA Assessment Template consists of a Microsoft Excel file made up of 4 worksheets that are interconnected. **It is recommended to open the excel file while reading this text.**

The Worksheet 1 ("I-O Balance") allows the TEST Team to build up the **Input/Output mass balance** at the company system boundary in physical terms, kg or tonnes. The Team records both physical and cost information on the company's inputs, physical data on outputs, as well as the sources of the information as this should be consistently taken from the list of accounts. Later, the portion of each input which becomes non product output (NPO %) in volume terms are determined, along with the related NPO costs. The Worksheet 1 records the physical and monetary values of material inputs in one work step, as these amounts should be consistent with the financial accounting data. The Worksheet 1 contains two columns for the source of information for both values. The financial accounting system, especially the accounts for materials used for production, as well as stock management and environmental management, should provide this information in a consistent and detailed manner. The two columns in the Worksheet 1 entitled "source of information" are intended to ensure that the same cost centres and accounts are used in future years without having to spend a lot of time finding them again. It is also practical to document the calculations or estimates made to arrive at a certain figure. It is possible to add lines into the sheet, just ensure that the automatic excel calculations are maintained.

The assessment can be done in any currency, which should be noted in the heading where EURO stands in the tool.

At the bottom of Worksheet 1 the relation of input volumes to output volumes should be calculated. This can be done once for all inputs and outputs (including operating materials and waste volumes) and another time for the relation of raw and auxiliary materials and product packaging to production volume only. This depends on the data availability and production necessities.

The table at the bottom of Worksheet 1 also relates the total costs of inputs to the total expenditure from the list of accounts. In manufacturing companies the costs for materials, water and energy inputs are about 50-90% of total expenditures. Any improvement of resource efficiency will thus also significantly improve economic performance.

Note that wherever the sign "#DIV/0!" appears in the table, the calculation is done automatically.

See Chapter 2.3 for further information on the physical mass balance.

As a result of completing the Worksheet 1, the priority flows for further investigation should be defined (at the end of STEP 1.4 of TEST).

The Worksheet 2 ("process flow chart") contains a simple structure to record the main production steps and supporting cost centers, and should follow the **process flow chart** of the company (Chapter 2.6). The cost centers defined here should next be linked to the production steps of third worksheet ("NPOs cost breakdown").

The Worksheet 3 is used for accounting for the **total NPO costs** and is explained further in Chapter 2.4. The actual cost assessment is performed in this worksheet only. Note that the I-O mass balance in worksheet 1 is calculated in tonnes or kg and contains no data on costs for disposal, depreciation etc. Not all costs are calculated on the Worksheet 1 for the I-O balance. This occurs in the Worksheet 3. The NPO costs of material and energy inputs are directly transferred from the Worksheet 1, and in addition, in cases where the company has a very well developed cost accounting system, Worksheet 3 records the costs for waste management/end-of-pipe costs as well as MFCA system costs. The most common costs recorded in addition to the NPO costs of material and energy inputs are related to waste disposal and waste handling, as well as depreciation of a wastewater treatment plant or other end-of-pipe equipment.

All the cost categories are already set and should not be changed, otherwise the aggregation to Worksheet 4 will not work. However, the TEST Team should list the different cost items related to each cost category under that cost category and should indicate the reference (the cost accounts or cost centre reports from which they are taken). With respect to costs that are incurred by a defined piece of environmental equipment it is recommended to simultaneously collect the data on external services, personnel, and operating materials, especially if this information is available from the same cost centre reports. Care needs to be taken to avoid double counting if data is taken from the list of accounts as well as from cost center reports, e.g. the same operating materials will show up on different cost centre reports and on the list of accounts.

Once the total annual costs have been recorded in column B of Worksheet 3 (Chapter 2.4), they can be distributed to the main production steps (Chapters 2.6 and 2.7). The last work step in Worksheet 3 provides a **breakdown of NPO costs by cost centres** or major production process. In most SMEs this break down will have to be estimated by the production manager during the first workshop, as most likely no detailed records are available. During the TEST project a refinement of this first estimate will gradually reveal the real distribution of NPO cost to main production steps. This may require installing a metering system at critical production steps, most likely defined as focus areas for further investigation.

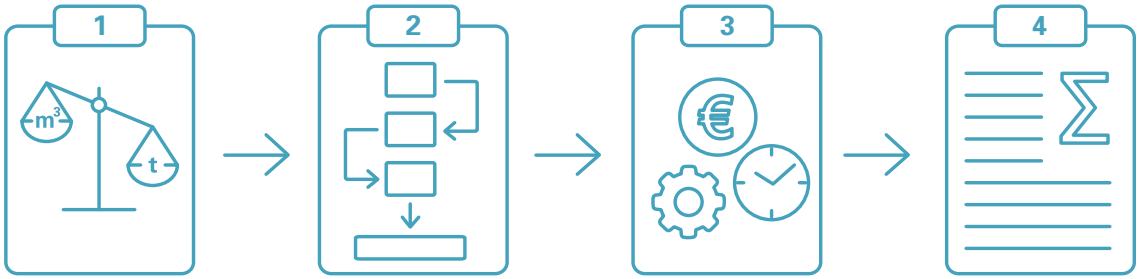
The excel tool automatically aggregates the costs of each category, but when adding lines to fill in more details a last cross check is recommended to make sure all aggregations are complete. There is a control function in Worksheet 3, to cross check that the value in the column "Total Euros" is identical to the sum of costs assigned to the cost centers. If this is not so, an error will show. The values are only identical if all costs in the "Total Euros" column are assigned to a cost center.

As a result of completing the Worksheets 2 and 3, the focus areas can be defined based on the production steps with the highest NPO costs (at the end of STEP 1.5).

The sum of the costs of all categories in Worksheet 3 is automatically transferred to the Worksheet 4, "NPOs Cost Summary" (Chapter 2.4.5). This worksheet provides an overview and a better presentation layout, showing the aggregated totals by cost category and calculates the costs into percentages to show the most relevant costs. This figure should also be compared to the total expenditures from the list of accounts.

Please note: If columns or rows are added or deleted, then the same needs to be done for the other worksheets, if the information is linked.

Working with the worksheets and the different cost categories are explained further in the next chapters.



2.3 INPUT-OUTPUT ANALYSIS OF MATERIAL FLOWS IN PHYSICAL TERMS

2.3.1. THE PHYSICAL MASS BALANCE

The mass balance is based on the assumption that whatever materials enter a company must (at some point) also leave it. The mass balance includes all material inputs, as well as the resulting amounts of products and waste and emissions in physical volumes (kilograms or tonnes). The volumes of purchased inputs (or better yet, the volumes of materials actually used for production, if the company has a good stock management system) are compared to the production volume or the sales statistics, as well as to the records of waste and emissions.

The first step in implementing an MFCA assessment is the development of a mass balance or input output balance in volumes of the materials flowing through (inwards and outwards), and stored within, the system boundary of the company for the complete previous fiscal year. As noted earlier, in most companies data is available only for this system boundary. This is especially true for SMEs, which normally do not have a cost accounting system established and might only annually assess the losses of materials and products through stock management. Thus, the assessment starts with the list of accounts of the trial balance for the previous business year and data from the stock inventories.

Table 5 below shows the overall structure of the mass balance, which is reflected in the structure of Worksheet 1. The input-output types are in line with the standard practice of mass balancing and the general structure of ISO 14031 for environmental performance indicators for operational systems.

MATERIALS INPUTS	PRODUCT OUTPUTS
Raw and Auxiliary Materials, Packaging	Products (including their packaging) and sold by-products
Operating Materials	NON-PRODUCT OUTPUTS (Waste and Emissions)
Water	Waste
Energy	Wastewater
	Air Emissions

Table 5: Input and Output Types

First, on the input side, raw, auxiliary, and operating materials consumed in the previous business year according to the accounting records are entered in detail, with their monetary values, volumes and account number. The quantities (e.g. tonnes) and monetary values (e.g., in €) of each input are entered. Similarly, on the output side, the products and by-products are entered in detail, along with their quantities and monetary values. The volumes of waste and emissions are also entered, but not the costs of their management; this is entered in the Worksheet 3. It is most important to make sure that all this volume data is consistently recorded (this may require recalculations) in the same mass units (kilograms or tonnes), not in pieces, m2, bottles, or other units that do not allow for aggregation. Water and energy should be recorded in the Worksheet 3 (and throughout the Excel file) in their respective units (liters, kWh, etc.) but not aggregated.

The following is guidance as to the categorization of possible input and output materials present in a company.

Raw materials
Raw materials constitute the main components of the company's products.

Auxiliary materials
Auxiliary materials become part of the product, but are not its main components (e.g. glue in furniture or shoes, baking powder and salt in cakes).

Packaging
A distinction needs to be made between packaging entering the company as part of the input materials and packaging leaving the company as part of the product(s).

Packaging of input materials should be recorded under output (as waste) if becomes solid waste (e.g. paper, plastic, glass). If instead it is returned to the supplier, it should not be recorded at all. Its input is typically not recorded separately, as it is part of the weight of the input materials. If packaging is kept in a reuse system, e.g. pallets, then the amount repurchased annually is recorded as input and as output as equivalent to broken packaging.

With regard to packaging of the companies products, several countries require a detailed recording as taxes are levied on packaging put on the market. So typically there are good records available.

Operating materials
By definition, operating materials are not included in the product(s). Some of these materials may be incorporated into the buildings of the company, but the major part are used to service the technologies or the raw and auxiliary materials along the process lines. Examples include cleaning chemicals, solvents, detergents, oils, etc.

Energy
In general, energy is an input. Apart from companies in the utility sector, companies do not normally sell energy as a product, although some of the companies which produce their own electricity are selling any excess to the grid.

When energy is an input, in almost all cases it can be considered equivalent to an operating material. Like operating materials, the energy which a company brings into its premises is not a visible part of the final product, but it is necessary for production.

Energy can enter the company as a material input in the form of energy carriers like coal, oil, natural gas, and biomass (and, very rarely, in the form of stored energy, in batteries). It can also enter the company in the form of electricity, purchased from external suppliers. Increasingly, companies are also generating their own electricity, mostly from renewable energy sources.

Where coal, oil, natural gas, and biomass are burned on-site to generate energy these inputs emit CO2 and other air pollutants, requiring efforts by the company to control these emissions. Where data on volumes is available, these would be recorded under air emissions.

Energy is recorded as an input in non mass units (e.g. Kwh) and it is not balanced. Emissions from energy consumption are also recorded. The costs related to energy use are recorded in Worksheets 1 and 3.

Water
Water consists of all the fresh water which the company takes from public grids, from private wells, and from surface waters (in some cases, it can also include rainwater; in rare case, sea water). It is recorded in cubic meters in order to able to relate it to the mass balance in tonnes. It may however be tricky to calculate the mass balance if water is part of the product. Depending on production and specific products, It may also be decided to calculate the mass balance without the water balance.

Products

For product output it is possible to record only the volumes and not the turnover, if the company does not wish to share this information with external members of the TEST project team.

By-products

By-products are all those outputs which the company sells in addition to the main product(s); this includes waste sold for recycling.

If a company produces electricity on-site using diesel generators or renewable energy technology, the percentage of electricity that is sold to the grid is considered a by-product.

Out-of-specification products might be recorded as waste or as by-products depending on whether they are sold or not. If they are internally re-processed, their record is only kept for the identification of efficiency improvements and will not show up in the mass balance, as they do not leave the system boundary of the company.

Waste, Wastewater, Air Emissions

In the Worksheet 1, waste, wastewater and air emissions are recorded only with their respective volumes for the mass balance. It may be necessary to work with estimates for the first assessment. The costs for disposal and emissions treatment are recorded in the Worksheet 3 in the cost category “waste management/end-of-pipe costs”, sub-category “fees, taxes, and permits”.

Other NPO costs are also recorded in the Worksheet 3 and not in the Worksheet 1 for the mass balance.

2.3.2. GUIDANCE ON THE MASS BALANCE

Companies may find it useful to separately calculate the material, the energy and the water balances and we can recommend this approach based on experience from TEST. While the material balance cannot be calculated without inputs from accounting and stock management, the energy and water balances will need the help of process technicians.

Once as much as possible of the input and output data are entered, the sum of the volumes of output products and waste is checked for consistency with the sum of the input materials (column 3). In theory, these should be equal. However, in most companies the Input/Output analysis does not necessarily balance very well in the first years of data assessment. In fact, a mass balance simply may not be possible if, as is often the case, no data on the volumes of operating materials and waste is available: what is often most easily available is data on raw and auxiliary materials because of their strong connection to the products made. Table 6 shows a typical although fictitious result of a first assessment for a company in the pulp and paper sector in a developing country.

Other issues can make reaching a balance tricky. For example, there is the issue of purchase versus actual consumption. The materials purchased include all inputs to the warehouse (stock) by delivery notice. However, the material actually used for production may be significantly different due to changes in inventory and losses on stock. Depending on the company, these materials are assessed by separate recordings of the materials withdrawn from stock for production, by measurements at the processes, or by simply recording inventory losses. Ideally, the mass balance should be based on the materials used for production. The same issue holds on the output side. Perhaps only sales volumes exist for products rather than production volumes, which might not be the same if there is a stock of products taking place.

In addition to this, there can be difficulties where several processes involve water and there are significant evaporation losses, or there can be chemical reactions, where materials “disappear” but only to “reappear” as different chemical species.

In many companies, only rough estimations may initially be possible for some input data, so the first mass balance is often incomplete. This will lead to a list of recommendations for improvements of the company’s data management, a preliminary understanding of the level of coherence of the material and energy flows and a baseline for the Non-Product Output (NPO) costs of the previous year, as data in terms of money is typically more available than in volumes. These results are used to define **priority flows - step 1.4** of TEST. After this, the total NPO costs can be split up and allocated down to the level of processes or cost centers or product groups. This allocation can be limited to the priority flows only. This results in the definition of **focus areas - step 1.5** of TEST. For these, the technical analysis for process optimization is then performed.

In the first assessment, the Input-Output-Balance hardly ever balances off to zero. But the goal is not to be perfect in the initial assessment, but rather to gain an understanding of the dimensions of material flows and of the quality of the information systems that record them. With increased quality of information systems, the differences between inputs and outputs can be reduced, sometimes by simple good housekeeping measures.

Experience from implementation of TEST in SMEs shows that for the sake of RECP can be sufficient to try to complete specific mass balances for priority flows only. To focus specific mass balance(s) on matching only specific important inputs with related product and non-product output(s) can be more effective for exploration of RECP potential as it enables to utilizes limited capacities for going deeper for selected priority flows and focus areas.

MATERIAL & ENERGY FLOWS BALANCE: INPUT / OUTPUT (year 2014)	USD*	TONNES*	SOURCE OF INFORMATION for USD	SOURCE OF INFORMATION FOR TONNES	NPO percentage [% volume]	RECOMMENDATIONS FOR INFORMATION SYSTEM
1. Materials Inputs			Account number			
1.1. Raw and Auxiliary Materials						
Raw Materials	1.700.000	8.000	50500	Weighted at the incoming warehouse	25%	It is recommended to monitor the actual loss of raw materials
Subtotal	1.700.000	8.000				
1.2. Packaging Materials						
Strings and steel traps	5.000	not available	Included in account #89000	Not monitored	2%	It is recommended to assign packaging materials costs on a separate account
Subtotal	5.000	-				
1.3. Merchandise						
not to be recorded, only if they run through the production process						
Subtotal	-	-				
1.4. Operating Materials					100%	
Repair & Maintenance Materials	12.000	not available	70000 & 70100	Not monitored		Separate materials and services on this account. Gradually include these materials in stock management and record also volumes.
Operating materials	50.000	not available	50600	Not monitored		Record the total volume of chemical s bought by material groups, as well as the total input into production.
Aluminium sulfate		0,5		Estimated by production manager		
Caustic Soda		0,15				
Bleaching chemicals		70				
Subtotal	62.000	71				
1.5. Water						
Water from the river		not available		Not monitored		establish a metering system
Water consumption from public supply (hl)	100	not available	78010	Not monitored		should be available from the invoice
Subtotal	100	-				
1.6. Energy						
Electricity in Kwh	300.000	1.500.000	78030	Calculated as 0.2usd per Kwh		record information from the invoice
Diesel	20.000	not available	65620			
Wood in m^3	150.000	6.500	65630	invoices		measure delivery into incoming store and the amounts actually used to production
Petrol	5.000	not available	65600			
Gasoline	300	not available	65610			
Subtotal	475.300					
TOTAL INPUTS	2.242.400,00					

MATERIAL & ENERGY FLOWS BALANCE: INPUT / OUTPUT (year 2014)	USD*	TONNES*	SOURCE OF INFORMATION for USD	SOURCE OF INFORMATION FOR TONNES	NPO percentage [% volume]	RECOMMENDATIONS FOR INFORMATION SYSTEM
2. Product Output			Account number			
2.1. Products						
Sales Finish Goods		6.600	40000	The production volume of each day is physically measured.		It is recommended to keep a record of the monthly production volume.
Subtotal	-	6.600				
2.2. Byproducts						
Subtotal	-	-				
TOTAL TURNOVER / PRODUCT OUTPUT	-	6.600				

MATERIAL & ENERGY FLOWS BALANCE: INPUT / OUTPUT (year 2014)	USD*	TONNES*	SOURCE OF INFORMATION for USD	SOURCE OF INFORMATION FOR TONNES	NPO percentage [% volume]	RECOMMENDATIONS FOR INFORMATION SYSTEM
3. Waste and Emissions						
3.1. Solid Waste						
Total non hazardous waste		not available				It is recommended to record the amount of waste regularly (weekly, daily, per shift).
Plastic waste		40		Estimated as 115kg per day as waste in the trash paper; sorted out during the pulping process		Record the amount of plastic waste if not available form the disposal invoice
Waste for Recycling						
Subtotal		40				
3.2. Hazardous Waste						
Hazardous Waste		5		estimated		Record the amounts of hazardous waste
Waste oil		1		estimated		Record the amounts of waste oil and ensure correct disposal
Subtotal		6				
3.3. Waste Water						
Quantity of waste water in m^3		not available				Establish metering system
COD		not available				
cellulose material in waste water		1.500		Calculated as total solid input minus output at the bottom		
Subtotal		-				
3.4. Air Emissions						
CO_2 emissions heating plant				to be calculated based on boiler fuel CO_2 emission factor		
CO_2 emissions vehicle fleet				to be calculated based on car fuel CO_2 emission factor		
Subtotal		-				
TOTAL Waste and Emissions						

		in %
Total solid input paper and chemicals in volumes	8.071	
Total output in volumes	6.606	
Difference	1.465	18
Total input trash paper in volumes	8.000	
Total output paper in volumes	6.606	
Difference	1.395	17

*unless otherwise indicated

Table 6: Pulp and Paper Company – Example of Mass Balance and Worksheet 1

2.3.3. GUIDANCE ON DATA GATHERING

Table 7 below shows where it is normally possible to find data for completing the input/output mass balance on the system boundary of the company using different information systems. If consistent and well kept, these allow a monthly data controlling system.

INPUTS		OUTPUTS	
Sources of information	Materials	Products	Sources of information
List of accounts, stock management, recipe	Raw materials	Main products	Production statistics, production planning system, recipe
List of accounts, stock management, recipe	Auxiliary materials	By-products	Production statistics, production planning system, recipe
List of accounts, stock management, recipe	Packaging	Waste and emissions	
List of accounts, stock management, cost centre reports	Operating materials	Hazardous waste	Invoices, separate monitoring
	Water	Solid waste	Invoices, separate monitoring
Invoices, separate monitoring, cost centre reports	Different sources	Air emissions	Measurement, calculations
	Energy	Wastewater	Invoices, separate monitoring
Invoices, separate monitoring, cost centre reports	Different energy carriers		

Table 7: Data Sources for the Mass Balance

As a starting point, it is best to start with the accounts in the list of balances (also called list of accounts) of conventional bookkeeping from the previous business year. Only this information source is available in all companies and should be quite complete. It certainly provides a complete overview in monetary terms of purchased and used raw materials, auxiliary and operating materials in a given month or year as well as the cost of disposal, repair, insurance, transportation etc. Each account of the profit and loss statement should be examined to determine whether any material flows are recorded there. Personnel costs are not considered in the physical material flow balance but in later steps as part of the MFCA cost assessment in the third excel sheet.

Operating materials are usually not (well) recorded in the warehouse stock management system, but are assigned to expenditure at the time of purchase. In most companies, their consumption is not recorded on the production cost centers, making it practically impossible to trace who has used how much of them. In cost calculation, often only estimates are used for the calculation of product prices, but hardly ever does anyone check if these estimates conform to real consumption.

The material purchase cost of wasted materials is often the most important NPO cost category, although this will depend on the value of raw materials relative to the labour intensity of the sector. In companies with stock management, it is not the value for materials **purchased** which is used, but the value of materials which is **consumed for production**.

In some enterprises the entire material purchase is booked on one account and only by evaluating manually the extensive cost centre accounts or stocktaking lists is it possible to expose the actual material use into the material groups. As an aid, the recordings of the production manager can be multiplied with the assigned quantities with average prices, in order to at least be able to indicate orders of magnitude. Unfortunately, it is obvious that such a system cannot strengthen cost consciousness in handling raw, auxiliary and operating materials.

The frequent lack of proper balancing at the system boundary of the company is the first step in identifying gaps in the company's information systems. For this reason, it is important for the TEST Team to develop recommendations on how to gradually improve the company's information systems. Their implementation during the TEST cycle ensures that better data can be generated for the next year, leading to a better closure on the mass balance. The goal should be that after a certain number of TEST cycles the balancing is equal within an acceptable margin of error.

Data inconsistencies in the information systems are not the only barrier to arriving at good mass balances. The lack of data on materials and energy flows within the company boundary also represent a major barrier. These barriers can be overcome by improving the cooperation between the production and accounting departments.

The only information system available in all companies is the accounting system where all invoices are recorded. These normally contain information not only on costs, but also on volumes purchased. The goal is for both sets of information to be captured from invoices at the moment they are recorded in the accounting system and to gradually improve the regular data monitoring systems. However, volumes need to be consistently recorded in mass units (e.g., kilograms or tonnes), not pieces or units, in order to be able to aggregate the volume figures. Often, investing in a weighing scale at the incoming warehouse in order to be able to recalculate pieces, boxes, bottles, m2 and other units consistently into kg or tonnes is the first improvement measure implemented.

Other common recommendations are the opening of new accounts for the different material inputs, and the clear definition of which material numbers are to be posted to which account to make aggregation possible.

All material inputs should be recorded in the Worksheet 1 of the excel file with the amount of material used for production. The materials lost on stock should be recorded separately, as the measures needed to address these losses are different from the material used during the technical processes (material deterioration, spoilage and sometimes theft instead of leakages and scrap). Often, only the amounts purchased may be available for several material categories, but not the actual amounts consumed in a given period, and perhaps only sales volume for the output side and not production statistics for a given period. The problem of purchase/sale numbers versus actual consumption and production numbers has been alluded to. So, one immediate improvement option would be in the stock management and recording of all materials actually used for production.

Clear definitions as to which elements of the Input/Output analysis are recorded on what accounts, which material numbers are assigned to which accounts and which materials are also recorded in stock management are essential and should be noted in an internal accounting manual. The objective is to obtain as complete a listing as possible of all material inputs by main categories. This will help avoid having to break down accounts at a later date to show quantities used.

Once the total material input has been recorded in physical and monetary terms to the degree available, the Worksheet 1 is used to answer the question: how much of the listed inputs actually leave the company as product and how much is wasted as NPO? An estimate is made of the product output and non-product output percentages for all input volumes. The results are recorded in the column "NPO %" of Worksheet 1. The losses for each listed material input need to be traced or estimated. In companies with good information systems, NPOs are monitored, not estimated.

The inputs with a high NPO share which is associated with high financial losses and where there is potential for improvement will be identified as priority material, water or energy flows and become subject for further investigation in TEST Step 1.5 and 1.6.

2.3.4. WHAT MIGHT CONSTITUTE NPOs?

The Table 8 summarizes the concept of MFCA: all inputs by definition either become a product or a non-product output. The balance, however, can only be calculated if all inputs and outputs are recorded consistently in volumes (for example tonnes and hectolitres).

MATERIALS INPUTS	PRODUCT OUTPUTS
Raw and Auxiliary Materials, Packaging	Products (including their packaging) and sold By-products
Operating Materials	NON-PRODUCT OUTPUTS (Waste and Emissions)
Water	X % NPO of Raw, Auxiliary and Packaging
Energy	X % NPO of Water
	100 % NPO of Operating Materials, Energy

Table 8: Materials Inputs, Product Outputs and Non Product Outputs

Advice on the estimation or calculation of loss percentages is provided as follows:

Raw materials
Non-product solid raw material output will mostly be disposed of as solid waste. Examples are metal scrap from metal cutting operations, metal turnings from metal drilling operations. They can also end up as the pollutant load in wastewater (e.g., in the form of high BOD in fish processing) or as an air pollutant (e.g., as dust from grinding). If the raw materials are gaseous (e.g., industrial gases, perfume) they will most often be emitted to the atmosphere. If the raw materials are liquid (e.g. milk), the non-product raw material output is generally disposed of as part of mixed wastewater streams.

For a first estimate, the company's internal calculation percentages for scrap of final product can be used to estimate the NPO of raw materials. The employees at the related production lines often can provide very good estimates, which are not known to the environmental or financial departments.

Eventually, with more detailed material flow balances, scrap percentages may need adjustment. Product returns, obliteration, repackaging for other countries or specified customer requests, quality control, production losses, spoilage, wastage, decay in storage, shrinkage, etc. are some of the causes of waste generation that call for measures to increase production efficiency, which may be profitable both from an economic and environmental point of view.

Auxiliary materials
In general, non-product outputs of auxiliary materials come from the same sources as raw materials and suffer the same fates. However, sometimes the loss percentages are lower.

Packaging

The packaging for products which is purchased will mostly leave the company with the product, but a certain (normally small) percentage of internal losses, e.g. due to repackaging for specific destinations or poor housekeeping, can occur and should be estimated.

The packaging materials delivered together with input materials are not recorded under inputs and thus no NPO needs to be calculated. Packaging material not returned to suppliers of input material ends up as solid waste and should be recorded there. As there isn't a recording on the input side of this kind of packaging, the mass balance will be off, however, the goal of this analysis is not to achieve an overall balance matching to zero but to identify priority flows and focus areas and to make detailed balances only for those.

Operating materials

Since operating materials are by definition not included in the product, all goes to non-product output (some of these materials may be incorporated into the buildings of the company, but will eventually also become NPO). They can contain dangerous substances that need to be disposed of under special regimes.

Administrative operating materials (like paper and other office supply) may be disregarded in the first assessment.

Energy

As mentioned earlier, in the TEST approach, as in accounting, energy is considered to function like an operating material, with 100% of it becoming NPO. Since energy is expensive in many countries, the recording of energy as NPO is also necessary to ensure its distribution to cost centers in the third worksheet, which in turn leads to define the focus areas for the TEST project. In companies with substantial flows of raw materials and products, energy consumption is often defined as priority flow.

The form that energy-related NPOs will take can vary. Where energy carriers such as coal, oil, natural gas, and biomass are material inputs to the company and are burned on-site to generate energy (most often in the form of steam) these inputs emit CO2 and other air pollutants. These will be the material NPOs from energy inputs recorded in Worksheet 1 under emissions. There are also other forms of NPOs from all types of energy inputs, the most common being heat and noise, but these are not considered in the MFCA Excel Tool except where equipment is purchased to mitigate their effects.

Water

In many sectors, water is used mostly or entirely as an operating material (e.g., cleaning water, cooling water, steam) and therefore 100% of the input becomes non-product output. For some sectors, especially in the food industry, water also acts as an auxiliary material, with some of the water inputs going into the product.

Products

Even after their manufacture, products can become non-products outputs. Product returns, obliteration, repackaging for other countries or specified customer requests, quality control samples, production losses, spoilage in storage, shrinkage, etc. are some of the causes of products becoming non-product outputs.

Care needs to be taken with certain flows. For instance, returns of final product and losses of product during production may be considered as a waste output or, if sold, as a byproduct. Double counting of raw material and product losses must be avoided. The lost sales volume may also be considered on Worksheet 3 as cost with a separate line under raw materials.

INPUT	HINTS FOR ESTIMATION OF NON-PRODUCT OUTPUT (NPO) IN PERCENTAGES
Raw materials	For the first assessment, it may be reasonable to estimate the NPO percentage for all raw materials as a total if no data is available for each separate material input, e.g. 5-20 %. For example in the pulp and paper sector, an overall NPO of up to 25% seems reasonable. Over time it is best to gradually improve the information system, especially the measuring and quality management for the main inputs and processes
Auxiliary materials	For auxiliary materials the loss percentage may be lower than for raw materials.
Product Packaging	Experience shows 1–10% to be a reasonable range. In case no better data are available, start the calculation with 5 %.
Operating materials	Defined as 100 % non-product output
Energy	Defined as 100 % non-product output (unless company sells electricity produced on site to the grid)
Water	Depending on product and processes. 100% for the pulp and paper sector as the sold product is dry.

Table 9: Estimating NPO percentages

2.4 PROCESS FLOW CHARTS

For TEST, or any RECP project, it is important to distribute the total company-wide annual NPO costs to production steps or cost centres. Therefore, once the material flow balance and NPO cost assessment on a company level have been completed, and once top management has given its agreement as to which flows should be considered priority, , the next step is to allocate the data from the system boundary of the company fence to its internal processes. It is a prerequisite in order to proceed from Step 1.4 of TEST to step 1.5. To do this, the structure for the process flow chart must first be set up, using Worksheet 2.

In accordance with cost accounting principles, internal processes are differentiated between the main production processes, where the raw materials are converted into products, and additional supporting processes, which are not directly linked with the flow of raw materials and products.

Cost centres are defined departments, units or even machines in a company to which costs are allocated. Different managers are often responsible for different cost centres. Sometimes there is also a differentiation between profit and cost centres or production and supportive cost centres. Production cost centres (also called profit centres) are directly linked to the value-added process of the company (the production process) while (supportive) cost centres are not directly linked to production process (e.g. advertising, human resources, maintenance, steam production, wastewater treatment).

The structure of existing cost centres is often not related to the company's production steps. So, a process flow chart can be drawn and amended by supportive business areas like stock management or quality control.

Figure 1 provides a schematic process flowchart that can be viewed from different perspectives: engineers go from the system boundary of the company down to specific processes via process flow diagrams, Sankey charts etc., while accountants apply cost accounting, stock management and production planning systems in addition to the profit and loss accounts. The secret to efficiency lies in defining interfaces at which all these information systems are linked to each other and provide consistent information on a regular basis, opening the door to management and resource efficiency improvements.

Process flow charts, which trace the input and output volumes of material flows (solid, liquid and gaseous) on an engineering process level, give insights into company-specific processes and allow the determination of losses, leakages and waste streams at the originating source. This requires a detailed examination of individual steps in production - again in the form of an input-output analysis, but sometimes linked to technical Sankey diagrams.

The process flow charts may be used to combine technical information with cost accounting data. This can be done on a yearly basis, for cost centers or even more specific production units like a single piece of equipment. In total, the data should aggregate to the yearly amount at the company level.

This level of material flow analysis will be the responsibility of technicians, but the data gathered should be crosschecked to ensure consistency with the cost accounting system. Usually, a harmonization of technical data with data from financial bookkeeping is not undertaken due to lack of inter-departmental communication. Experience has shown that such a consistency check provides great optimization potentials, and has thus become a major tool in environmental accounting. Consistent data and information systems for process engineering and financial accounting are vital for efficient production management.

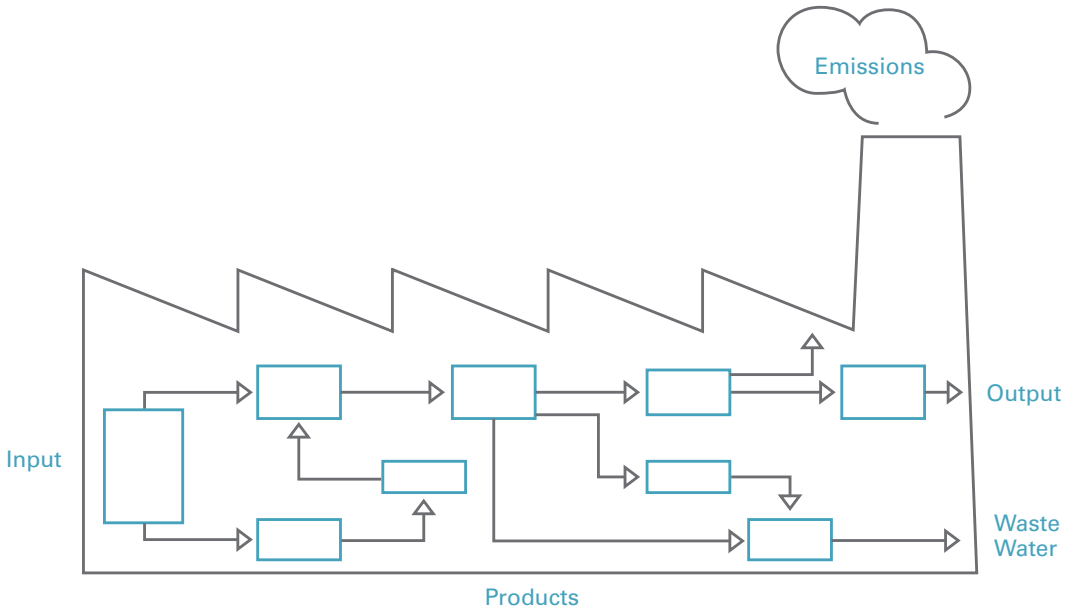


Figure 1: Process Flow Charts: Opening of the Black Box

Splitting up the corporate flows into cost centers, or even down to specific production equipment allows for more detailed investigation of technical improvement options, but also for tracing the sources of costs. Most companies have their very specific process flow charts at hand. Linking them with the existing cost centre structure may be a challenge and opportunity for improvement. For SMEs with no cost accounting, this project step often means that this is the first time when costs are distributed to production steps.

It is recommended to draw the process flow chart developed at maximum for the 20 most significant process steps related with significant shares of NPO. The total NPO costs, and if available also the volumes, will then be distributed down to these process steps in order to define the focus areas for further investigation of improvement options.

Table 10 shows an example for a bakery, which is also available in the training tool kit. Table 11 provides an example of how to complete this step in a pulp and paper company. Worksheet 2 of the MFCA excel file is used for the process flow chart, which should later be linked to columns C onwards of Worksheet 3.

INPUT	MAIN PRODUCTION PROCESSES	ADDITIONAL PROCESSES	OUTPUT
Materials purchased		Incoming Store	Materials used for production
Electricity		Refrigeration	Air emissions
Cooling agent			
Materials used for production	Preparation of materials and tools		Packaging waste of input materials
Egg white Electricity	Beating the egg white		Beaten egg white Dirty bowl
Egg yolks, flour, sugar, etc. Electricity	Mixing		Cake dough Dirty bowl Organic waste
Oil for the baking pan	Baking pan filling station		Cake ready for oven Dirty bowls
Gas	Baking		Baked cake Dirty pan Waste heat CO_2, NO_x emissions
	etc.		
Test cake Chemicals		Quality assessment	Organic waste chemicals waste (hazardous waste) Waste water
Dirty bowls and pans Cleaning agents Hot water		Cleaning room	Clean bowls and pans Waste water cleaning agents in waste water
Packaging materials Electricity		Packaging room	Packaged cake Solid waste
Electricity Marketing and back office materials		Sales room	Solid waste
Wood pellets Gas		Energy conversion with combined block and steam production as well as the compressed air system for cooling	Fossil and perhaps biogenic CO_2
Maintenance materials and tools		Maintenance	Solid and hazardous waste
Untreated waste water from production		Waste water treatment	Pretreated water to municipality
Solid waste from the different production steps/ cost centres		Waste collection centre	Waste to licensed supplier
Office materials		Administration	Waste
		Etc.	

Table 10: MFCA Worksheet 2: Process Flow Chart for a Bakery

INPUT	DETAILED PRODUCTION STEPS	MAIN PRODUCTION PROCESSES	ADDITIONAL PROCESSES	OUTPUT
Waste cardboard, waste paper Auxiliary and operating materials including their packaging			Incoming storage	Losses on stock, Waste
Waste cardboard, waste paper	1st separation of solid waste	Pulp preparation		Waste Waste (rubbish), plastic waste
Water, electricity	Pumping water from the river			
Water, electricity	Soaking the paper			
Electricity	2nd separation of waste			
Auxiliary and operating materials, chemicals, electricity	Mixing	Mixing		Waste, wastewater
Auxiliary and operating materials, electricity	Paper forming and compressing	Paper machine		Waste, wastewater, unqualified product
Wood			Steam production	Steam
Electricity, steam	Drying	Drying		Unqualified product, waste heat
Electricity	Sizing	Finishing & packaging		Waste
Electricity	Rolling			Waste
Electricity	Packaging			Waste
Final products			Product storage	Losses on stock
Operating materials			Maintenance	Waste
Diesel, petrol, gasoline			Logistics	Air emissions
Operating materials			Administration	Waste
Total cost centres		5	6	

Table 11: Pulp and Paper Company – Process Flow Chart Worksheet 2. Due to complexity of production process, the detailed production steps are added to the main production processes.

2.5 ANNUAL NPO COSTS AT THE COMPANY LEVEL

After completion of the mass balance to the degree possible, the next step is to record in Worksheet 3, column B those annual NPO costs which have not been automatically exported from Worksheet 1. The purpose of this is to add to the latter the universe of costs that the environmental manager deals with and that can possibly be reduced by integrated pollution prevention and material and energy efficiency projects. These costs include not only the typical end of pipe and waste management costs (Category 2), but also MFCA system costs (Category 3), which are the NPO share of the costs of the cost centers with NPO losses. The goal is not to show that environmental protection is expensive, but rather to highlight the scope for savings potentials.

Overall, Worksheet 3 is used to estimate the **Total NPO Costs**, where these are made up of the following items:

Environmental protection expenditure
(waste disposal, emissions treatment, control and waste prevention costs)

+ **Material Costs of Non Product Output**
(Costs of unproductive material at purchase prices or production costs (including e.g. capital
and personnel costs)

+ **MFCA System Costs**
(NPO share of the costs of the cost centers with NPO losses)

= **Total NPO costs**

Figure 2: Total NPO Costs

Environmental and material flow costs at the company level are just a subset of the bigger cost universe that management need to consider for good decision-making. Environmental costs are just part of an integrated system of materials, energy and money flows through a company, and not a separate type of cost. Doing MFCA is simply doing better, more comprehensive Management Accounting, where the eyes of management are opened to hidden costs. Therefore, the focus of MFCA is not so much on assessing total environmental costs, but on arriving at a revised calculation of production costs on the basis of material flows (including energy and water).

For the assessment of total annual NPO costs, the broad cost categories in Figure 2 are further divided into cost categories that conform to standard accounts. These are shown in Table 12 which shows the typical loss percentages and relate to column B in Worksheet 3. The total costs are also automatically aggregated to Worksheet 4.

NPO COST CATEGORIES	% SHARE OF NPO
1. NPO COSTS OF MATERIAL AND ENERGY INPUTS	
• Raw and Auxiliary Materials	e.g. 2- 20 %
• Packaging Materials	e.g. 2- 10 %
• Operating Materials	100 %
• Water	1-100 %
• Energy	100 %
2. WASTE MANAGEMENT/END OF PIPE COSTS	
• Equipment Depreciation of EoP Equipment	
• Internal Personnel	
• External Services	
• Fees, Taxes and Permits	
• Fines, Remediation and Compensation	
3. MFCA SYSTEM COSTS	
• Equipment Depreciation	
• Internal Personnel	
• External Services	
• Other Costs	
• TOTAL COSTS	
4. ENVIRONMENT RELATED EARNINGS	
• Other Earnings	
• Subsidies for RECP/EMS Projects	
TOTAL NPO COSTS (minus TOTAL ENVIRONMENT-RELATED EARNINGS)	

Table 12: NPO Cost Categories. This table is not a separate worksheet but shows how the columns of Worksheet 1 and Worksheet 3 should be automatically linked to each other regarding the NPO costs.

2.5.1. MATERIALS AND ENERGY COSTS OF NON-PRODUCT OUTPUT

The total set of entries in column A of Worksheet 3 in the category NPO Costs of Material and Energy Inputs should be identical and linked to column A of the mass balance in Worksheet 1. The different inputs of material, water and energy should therefore be copied and pasted from (or linked from) Worksheet 1 to Worksheet 3. Take care to insert enough lines before inserting in order to maintain the automated summary and control functions.

Column B of Worksheet 3 should next be directly linked to Column G of Worksheet 1, where the NPO costs have already been recorded. If the cells are not directly linked it is likely to lose changes during the data assessment.

2.5.2. WASTE MANAGEMENT/END OF PIPE COSTS

This cost category comprises **conventional waste disposal and emission treatment costs** including related equipment, internal personnel and external services. It comprises all treatment, disposal and clean-up costs of existing waste and emissions and can often be directly traced from the list of accounts or from cost centers like wastewater treatment or waste management. The related costs should be recorded in column B of Worksheet 3.

There can be questions as to what assets constitute end-of-pipe solutions. In general, it may be stated that assets are allotted 100% to Category 2 when they offer no integrated solution to an emission, but rather constitute a technology that does not solve the emissions problem at its source, but rather shifts it from one environmental medium to another (e.g., from the air to the soil and then into the water). These approaches are often expensive and inefficient, but seem to provide a quick answer to a legal emission requirement.

Another issue is the apportioning of costs as environmental from projects which have a broader scope, where these are related to the control of material and energy flows. Some projects not only have effects of environmental protection (protecting nature), but also have effects on neighbours (noise, odours) or employees (health and safety). In addition, projects can be aimed at reducing risks in cases of accidents and other occasional production events for employees, nature or neighbours. It is often difficult to determine precisely the environmental portion of these costs. Here, it should be kept in mind that it is not the most important task to spend a lot of time defining exactly which costs are environmental and which are not, or what percentage of something is environmental or not, or if Energy belongs to NPO and to what degree. The most important task is to make sure that ALL relevant and significant costs are considered when making business decisions.

Depreciation for related equipment

This cost category contains the depreciation costs for End-of-Pipe equipment, like waste compacting equipment, wastewater treatment plants, dust, air and noise filters. Depreciation spreads the investment costs over the expected lifetime for the equipment. Depreciation can be based on financial or cost accounting procedures, or simply be estimated as 10 % of investment costs, depending on the accounting data of the company.

Related Personnel

Labour time related to equipment linked to control and management of the existing waste and emission flows is recorded here, along with the costs of personnel for waste collection and disposal, legal compliance, e.g., reporting to authorities and the staff of a wastewater treatment plant.

Taxes, Fees, Charges, Permits

Disposal fees, wastewater fees, packaging-license charges, energy taxes, emission permits and other eco-taxes are recorded here.

Fines and Penalties, Clean-up costs, remediation, etc.

The fines for exceeding pollution restrictions are to be recorded here. In some sectors, costs for clean-up, remediation and landscaping may be required, especially in the mining and oil industry, for gas stations, power plants, etc.

2.5.3. MFCA SYSTEM COSTS

This cost category deals with additional MFCA System Costs according to the MFCA ISO 14051 standard. ISO 14051:2011 defines system costs as cost incurred in the course of in-house handling of the material flows, except for material cost, energy cost and waste management cost, and provides as

examples the cost of labour; cost of depreciation and maintenance; cost of transport. For cost centers with highly inefficient production processes this actually implies recording nearly all costs of this cost center as NPO costs. As a baseline for further investment options this actually makes sense.

These costs need to be taken from cost centre reports. If the cost centers or production steps, defined in Chapter 2.6., are identical to an existing well developed cost accounting system, then the remaining costs of these cost centres, not already captured in the cost categories Materials Costs of NPO and Waste Management/End of Pipe Costs, could be included here with the loss percentage share of the main raw material or final product. The total MFCA system costs need then to be manually counted from the related cost centre distribution, as this information is not available from the list of accounts.

This cannot be done in the first one-day workshop, but may be a follow-up project for companies with well advanced information systems.

2.5.4. ENVIRONMENT RELATED EARNINGS

Revenues from selling materials for recycling and other by-products, as well as funding for environment projects and the receipt of monetary environmental awards are recorded here. It is recommended not to offset sales of materials for recycling in the input category, but to separately account for it as an output.

2.5.5. TOTAL ANNUAL NPO COSTS

The MFCA Worksheet 4 automatically calculates the total NPO costs, showing the percentage distribution by cost categories.

Table 13 provides an example for a pulp and paper company. It is worth highlighting that the data of this case study refers to an SME located in a transitional economy with no EMS and no wastewater treatment plant in place. This explains the negligible NPO costs associated with end-of-pipe and integrated prevention (readers can compare this situation to that described in Table 21 in Appendix A, which is a pulp and paper plant in Austria). Under these circumstances, energy costs accounts for 49% of all NPO costs and the losses of raw materials for 44 % of total NPO costs. Improving efficiency for those two inputs will thus also significantly reduce costs.

	USD	PERCENTAGE [%]
1. NON-PRODUCT OUTPUTS (NPO)	965.000	99,8%
1.1. Raw and Auxiliary Materials	427.500	44,2%
1.2. Packaging Materials	100	0,0%
1.4. Operating Materials	62.000	6,4%
1.5. Water	100	0,0%
1.6. Energy	475.300	49,2%
2. END-OF-PIPE	2.000	0,2%
2.1. Equipment Depreciation	0	0,0%
2.2. Operating Materials	0	0,0%
2.3. Water and Energy	0	0,0%
2.4. Internal Personnel	0	0,0%
2.5. External Services	2.000	0,2%
2.6. Fees, Taxes and Permits	0	0,0%
2.7. Fines, Remediation and Compensation	0	0,0%
3. INTEGRATED PREVENTION	0	0,0%
3.1. Equipment Depreciation	0	0,0%
3.2. Operating Materials, Water, Energy	0	0,0%
3.3. Internal Personnel	0	0,0%
3.4. External Services	0	0,0%
3.5. Other	0	0,0%
TOTAL ENVIRONMENT-RELATED COSTS (1. + 2. + 3.)	967.000	100,0%
4. ENVIRONMENT-RELATED EARNINGS		
4.1. Other Earnings	0	0,0%
4.2. Subsidies	0	0,0%
TOTAL ENVIRONMENT-RELATED EARNINGS	0	0,0%
TOTAL ENVIRONMENT-RELATED COSTS & EARNINGS	967.000	100,0%

Table 13: Pulp and Paper Company - Total NPO Costs in Worksheet 4

2.5.6. PRESENTATION TO TOP MANAGEMENT

Once the TEST Team has these results, it is recommended that the table created on the Worksheet 4 be presented to Top Management, as the basis for a discussion and agreement about which material or energy flows the company will choose as priority flows for the TEST project (see the case studies in Chapter 3).

2.6 MFCA - DISTRIBUTION OF COMPANY-WIDE NPO COSTS TO COST CENTERS OR PRODUCTION STEPS

The process level is the main focus for pollution prevention and RECP projects. Data on the process level is also necessary for further analysis by products. It is crucial that the system boundaries for financial calculation by cost centers and for technical monitoring can be related to each other.

According to ISO 14051, a full MFCA across all cost centers or process levels requires full mass balances for each process step. In the TEST approach, this is not generally recommended. The aim in TEST is to use the MFCA approach to focus efforts on a few priority flows, which should then be the subjects of full mass balances. However, a full MFCA may be recommended, if:

- The portion of material costs of the entire operational expenditures is least 50%.
- There are production procedures where a broad product range can go through alternatively various production steps.
- Cost Accounting is well established in the organization; and
- Product prices are actually being calculated on the basis of the cost center accounts (many SMEs do not apply cost accounting at this level of detail).

In business sectors where basically one product is produced with a set procedure (breweries, paper industry, energy utilities), an extensive allocation of material flows and related system costs to different cost centers and production processes may not be necessary. In these sectors it may be sufficient to perform MFCA on an annual basis for the system boundary of the company and only break down the total annual NPO costs including waste management costs to the main process steps as performed on Worksheet 2 and 3.

This section describes how to complete compilation of the MFCA excel worksheet 3, by filling columns C onwards during step 1.5 of the TEST guidelines. This step is useful for the identification of priority areas, highlighting processes that are associated with high economic losses related to NPO. At this step the total NPO costs in column B of Worksheet 3 are apportioned to cost centres or production steps as defined in Worksheet 2. Columns C-O (or more or less as defined in Worksheet 2) should be directly linked to the cost centers/process steps defined in Worksheet 2.

Assign the total NPO costs in Column B to each cost centre/main process where they originated. The annual costs are distributed to cost centres based on measured or estimated data. Use measured data to the degree possible and record recommendations for improved data availability. In order to facilitate the distribution of the figures in column B to column C-O, line 15 for raw and auxiliary materials allows you to estimate the percentage distribution of the total NPO costs across the cost centres, which can then be used, together with the subtotal of NPO costs to fill out line 14. Experience shows that production managers are better able to estimate the percentage distribution than the cost allocation. Certainly, 100 % of all costs for each cost category need to be distributed to the defined cost centers/process steps. In order to ensure consistency, column P contains a function that automatically cross checks the full distribution of all costs recorded in column B. A similar system exists for all the subcategories.

Next, all costs for waste management and end-of-pipe should be distributed to the relevant cost centers/process steps to the degree possible. This is facilitated by cost accounting reports and requires expert judgements from the assessment team. The cost center HSEQ (Health Safety Environment Quality) may also be used as a collection option.

The MFCA system costs should only be reported if a detailed cost accounting system allows drawing them directly with their respective NPO share from cost center reports.

The outcome is a distribution of total annual NPO costs by costs centre or production step - line 180 of Worksheet 3. These costs should then be transferred into a percentage distribution (line 181) and the cost centers/process steps with the highest share of NPO costs are candidates for being chosen as focus areas (these costs also become the baseline for any RECP project established for chosen focus areas). Other criteria, like the technical possibility to reduce NPO in a defined process step, should also be taken into consideration and recorded.

An example of worksheet 3 for the pulp and paper company, for the first cost category only, is provided in Table 14.

ENVIRONMENTAL COST CATEGORIES	TOTAL USD	COST CENTERS (PRODUCTION PROCESSES, DEPARTMENTS, ETC.)									
		Storage	Pulp Preparation	Mixing	Paper Machine	Drying	Finishing & Packaging	Energy Management	Maintenance	Logistic	Administration
1. Non-Product Outputs (Npo)	965.000										
1.1. Raw and Auxiliary Materials											
Raw Material 25 % loss druing production	425.000	38.250	148.750	21.250	4.250	127.500	85.000				
Loss in Stock	2.500	2.500									
Subtotal	427.500										
1.2. Packaging Materials											
Strings and steel traps 2 % loss	100						100				
Subtotal	100										
1.4. Operating Materials											
Repair & Maintenance, +-M/C	12.000		600	1.200	600	6.600	600	1.200			1.200
Operating materials	50.000	2.500		42.500		5.000					
Subtotal	62.000										
1.5. Water											
Water from the river											
Water consumption from public supply	100			5				80			15
Subtotal	100										
1.6. Energy											
Electricity	300.000	6.000	75.000	15.000	15.000	135.000	15.000	9.000	9.000		21.000
Diesel	20.000									20.000	
Wood	150.000							150.000			
Petrol	5.000									5.000	
Gasoline	300									300	
Subtotal	475.300										
Total Category 1	965.000	49.250	224.350	79.955	19.850	274.100	100.700	160.280	9.000	25.300	22.215

Table 14: Pulp and Paper Company - Breakdown of NPO Costs by Cost Centers in Worksheet 3

2.7 RECOMMENDATIONS FOR IMPROVING INFORMATION SYSTEMS

In general, the data quality depends on the quality and availability of traditional accounting systems like financial accounting, stock management, and for larger companies cost accounting and production planning. Some recommendations for the improvement of data collection and information systems have resulted from several case studies with SMEs in transitional countries and are discussed below.

Data recording of material purchase by material groups in financial accounting

In many companies the entire material purchase is booked to one account only, material purchase, and not to several accounts according to the different materials (e.g. flour, sugar, eggs for a bakery). Even if materials are also assigned numbers it is difficult to expose the actual material use within larger material groups (actual amount of flour used for production). As an aid, the recordings of the production manager can perhaps be multiplied with average prices, in order to be at least able to indicate orders of magnitude. The fact that such a system cannot strengthen cost consciousness in handling raw, auxiliary and operating materials is obvious. It is recommended that goal be that the purchase for each material group is eventually recorded on a separate account and that inventory differences are recorded separately.

Separate accounts for material groups

A clear distinction between the accounts for raw, auxiliary and operating materials is necessary, especially when non-product output (NPO) costs are intended to be assessed. Raw and auxiliary materials are part of the product, thus loss percentages need to be calculated or estimated. Operating materials are by definition not part of the product and thus must become part of waste and emissions. The amounts and values used are often not consistently recorded.

• Separate materials from services

Accounts for materials and utilities should be clearly distinguished from accounts for services. If only materials are collected on an account then the volumes used may be estimated dividing with average prices. Materials and supplies for maintenance need to be separated from maintenance services, thus allowing total materials input to be calculated.

Posting of inventory losses

The posting of inventory changes should be carried out separately for the different materials accounts (e.g. flour, sugar, eggs) and include a separate recording of the price and volume difference. This way, accurate data on materials inputs and outputs in volume and price can be obtained for each material group and the total amounts and values of materials used are available for further controlling measures. Posting of the total difference of inventory change to one separate account leads to lack of knowledge regarding actual materials used.

Recording of material numbers in production planning systems

It should be clearly defined which material numbers belong to which material group and account. The material groups should be traceable, e.g. by separate accounts. This recommendation calls for a consistent hierarchy between accounts, material groups and material numbers on stock.
Volumes should be added gradually to the recordings of material numbers in stock management. This way, consumption would be aggregated automatically into volumes. Consistent use of volumes (kg or tonnes), not units (pieces) in the information system ensures that the total sum automatically aggregated does not have to be manually corrected.

Estimation and recalculation of scrap percentages

The loss percentages for raw materials, packing material, auxiliary materials and the final product are often based on outdated estimated values and only are recalculated for a few material groups. The employees on-site usually have more precise estimated values than the accountants. A correct recalculation often leads to frightening results.

Strive for consistency of system boundaries for MFCA in technical and financial information systems and define which accounts, cost centers and cost categories must be consistent by amount and value.

The input-output material balance is hardly ever consistent with the system boundaries of the accounts and cost center reports. For example, for the recording of the costs and amounts of waste in one company project three different values and records were provided for one site (record of the environmental manager without the costs for weighing, transporting and renting the disposal bins; the financial account with some wrong postings; and the accounts of the several suppliers with additional services).

New Accounts

Separate accounts for the utilities (energy, water) should be established, defined as direct costs of production.

Earnings from sales of scrap metal, steam condensate etc. should not be offset directly against the materials purchase account. Instead, separate accounts for other earnings from by-products should be established.

Mass, water and energy balances for defined process steps

During the first MFCA assessment, the mass balance is split up into the main production steps or cost centres. Establish data monitoring points to regularly repeat this exercise and check consistency with existing information systems.

New Cost Centers

Rework the structure of cost centres and make it consistent with technical data monitoring interfaces, so that regular performance measurement is possible. The creation of self-standing, independent cost centers is recommended for:

- Waste landfills (only in the case where the company has its own existing landfill or or is planning one)
- Wastewater treatment plants (especially if these have their own personnel, significant maintenance and chemicals consumption)
- Environmental, health and safety management (This is very useful if a joint responsibility is defined as well and the related invoices for monitoring, equipment, prevention and disposal become easily available from the information system.)
- Energy management (recommended if energy, e.g. steam, is produced on site)

COMMON RECOMMENDATIONS FOR IMPROVEMENT OF INFORMATION SYSTEMS

This box gives a list of the most common recommendations from the case studies and can also be used to benchmark companies.

FINANCIAL ACCOUNTING

The financial accounting system with the list of accounts of the trial balance should be used as the starting point for the NPO assessment. Thus, the data is consistent and can be benchmarked.
The accounts for raw materials, packaging and operating materials, as well as energy and water consumption should be clearly separated and not mixed into other accounts. It may be recommended to separate accounts (e.g. for packaging and auxiliary materials) or create additional accounts to clearly reflect the consumption of the different input categories of the mass balance.
There should be a defined hierarchy between main accounts e.g. for main raw materials, more detailed accounts for e.g. several raw materials of one type by different suppliers and the system of material numbers in stock management. Thus, the material numbers in stock management can be aggregated by value and volume and are directly related with one specific account in financial accounting.
Posting of inventory losses should be done separately for each main accounting group and not only in one line. The actual consumption is thus available for each material group or category.
The accounts for material inputs in physical volumes should be separate from accounts for services, e.g. also for maintenance, water and energy management, disposal fees.
Earnings from sales of scrap metal, steam condensate etc. should not be offset directly against the materials purchase account. Instead separate accounts for other earnings from by-products and waste for recycling should be established.

COST ACCOUNTING

If the company is large and complex enough, a cost accounting system with assessment of costs by defined cost centers should be installed.
The structure of the cost centers should be consistent with the process flow chart. It is recommended to use the diagram of main processes to define cost centers.
For large companies with an existing cost center system it is recommended to establish a cost center for environmental management and perhaps for the wastewater treatment plant in order to be able to trace the related costs more easily.
If energy or steam is produced on-site a separate cost centre for energy management may be advisable.
The total annual NPO **costs** should be distributed to the main cost centers/production centers.
The NPO **volumes** of lost materials and used operating materials and energy should be distributed to the main cost centers/production centers.
This distribution should be based on regular measurements (per shift, dialy, monthly) for the important consumption/waste streams.

STOCK MANAGEMENT

A stock management system with recording of materials used for production should be established at least for raw materials.
It should also include packaging materials.
It should also include operating materials. (Starting point should be all chemicals and cleaning materials).
The materials should be consistently recorded by volumes, not by units. Units can not be aggregated.
There should be a defined written procedure, which materials should be posted on which accounts. The consumption of different material groups should available in money and volume. (not only one account for materials purchased and another for changes in stock of many materials together, but one account for each material group, e.g. wheat, milk, butter). It is recommended to

post the inventory differences specifically to the different material groups so that actual consumption and expenditure is available not only on the highest aggregated level but by material type.
There should be a scale in the incoming store. All purchase can thus be weighted. This is also necessary for monitoring of maximum shelf weight.
It is recommended to monitor total production volume before packaging. In some companies only sales volume was available.
The production loss and returns from customers should be weighted and monitored in a monthly statistic.
Loss of raw materials and loss of final product should be separately monitored and measured.
The scale should also be used to weight the waste volumes. A monthly statistic should be kept on the waste volumes produced.
Waste should be stored at appropriate stores (separate stores with readable labeling for main waste types, safety containment for hazardous waste) and disposed regularly.
Raw materials are often purchased in small bags and in huge quantities, require a lot of handling and packaging materials. It is recommended to investigate with suppliers if shipping and storage in large bags, bulks or even lorries are possible.
Loss of packaging materials for own products should be monitored.
It is required to separate the stores for chemicals, fuels and other liquids from stores for solid materials.
It is required to install retention safety containment for all chemical stores.
It is recommended to improve labelling in all stores.
It is recommended to monitor maximum shelf weight in the stores.
It is recommended to switch to electrical forklifts in all stores. The gasoline is polluting the raw materials.
It is recommended to assess the amounts actually used for production and separately monitor losses on stock and during production.

ENVIRONMENTAL MANAGEMENT

A waste separation and management scheme that allows for waste separation for recycling and monitoring of volumes and costs per type of waste should be installed.
Keep monthly statistics on all types of waste in an excel file.
It's recommended to monitor hazardous waste and its correct disposal.
It is recommended to monitor the amounts of waste oil from maintenance and to dispose of it correctly, in addition, there may be soil contaminated with oil which also should be disposed as hazardous waste and treated properly.
It's recommended to collect organic waste separately and compost it.
It is recommended to establish a regular monitoring system for water consumption in production and other processes.

SAFETY MANAGEMENT

It is recommended to install a safety management system and establish a person responsible for safety management.
It is recommended to store liquids separate from solid goods. It is recommended to investigate if safety containments are required for chemicals in order to prevent spills.
Make sure that the floors are not slippery or wet as there is a risk of accidents and a waste of water.
Provide safety paintings on the floor to differentiate between path ways and production areas.
Make sure that no materials are stored in undefined areas.
Control of steam pressure in order to prevent risks.

2.8 APPLICATION FOR INVESTMENT APPRAISAL OF RECP TECHNOLOGIES

Environmental managers face a common dilemma when it comes to investment decisions related to environmental protection. First, they often have an engineering background and are not so familiar with accounting tools. Second, they often have no direct access to the financial information system. Third, the data that would be needed to show the costs of existing inefficient equipment are not visible in the existing accounting information systems. Thus, the benefits of integrated pollution prevention are often underestimated.
Investment appraisal is used to determine the cost savings of an investment option compared to the current situation or for comparing two competing investment choices. It is thus essential that the current status of operating cost of equipment and related physical material flows be known.

The economic variables for assessment in static financial analysis include:

- Initial investment costs
- Operating costs and earnings,
- Profit,
- Return on Investment, and
- Pay-back period.

All methods of investment appraisal assume that all future inputs and outputs of an investment decision are quantifiable and financial values can be attached to them.

In dynamic financial analysis, the expected future monetary inflows and outflows are discounted to the time of the investment and calculated into an internal discount rate or annuity. The opportunity costs of capital (the lower value of cash flows which do not occur today but only in the future) are considered by discounting them with the interest rate of the financial markets. The sum of all discounted future cash flows determines the net present value of a project or investment, which is compared to the value of the old equipment and to the interest rate of the financial markets. A planned investment has to be more profitable than receiving interest on a bank deposit.

Payback methods for capital budgeting do not consider cash flows beyond the payback period. Some companies adopt internal rules that only projects with a payback period of two or three years will be accepted, regardless of possible long-term benefits. Discounted cash flow methods in principle consider all relevant future cash flows until the project ends, but as many companies apply excessively high interest rates, which result in a negligible present value for medium- and long-term costs and savings, only the first three years count in effect for the investment decision.

The approach and shortcomings of methods such as the payback period, internal rate of return, or internal interest rate (IIR) are discussed in any textbook on corporate finance.

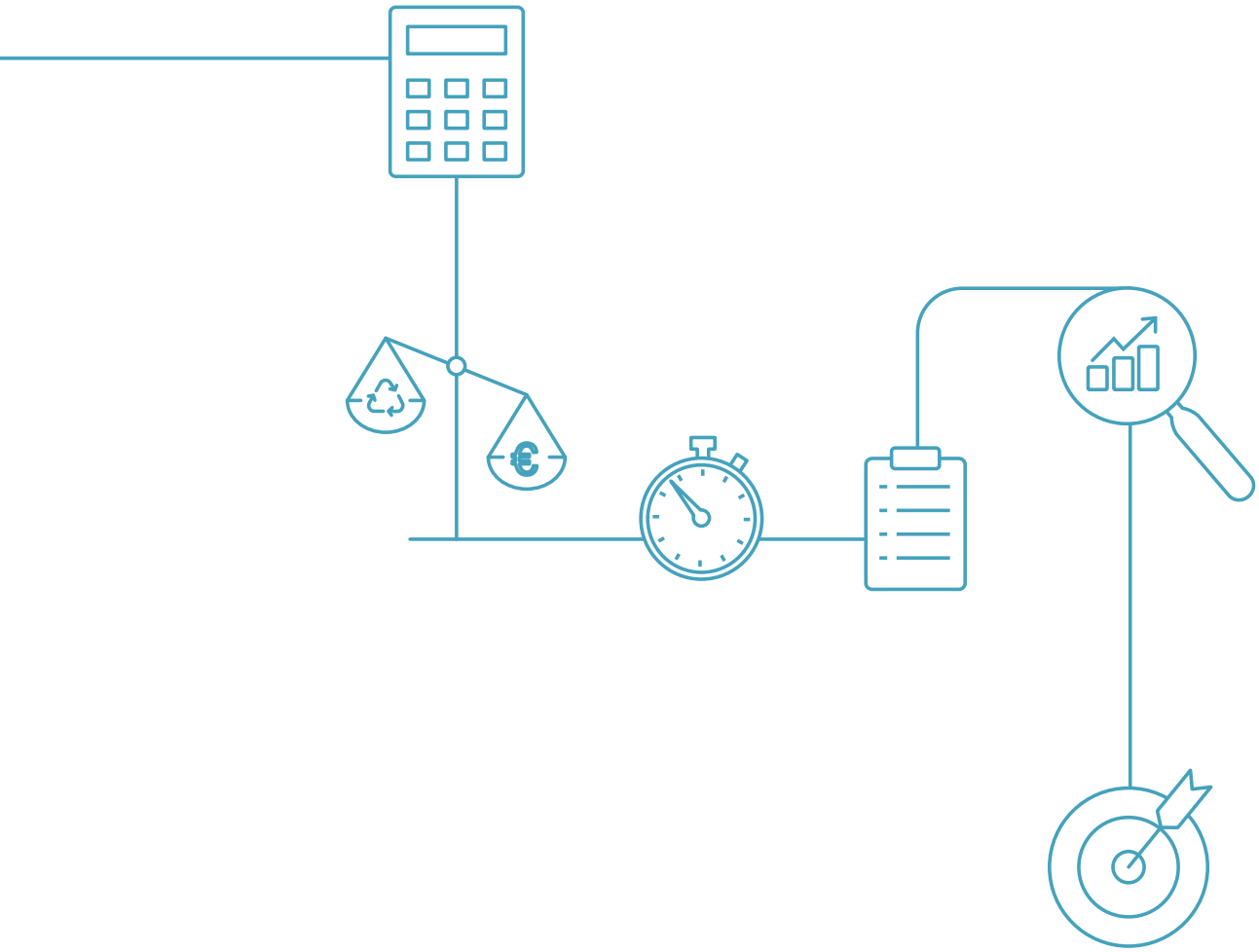
For RECP and environmental protection, the task is not so much to change the basic concept of discounting future monetary flows, but to ensure the inclusion of all relevant earnings and expenses. RECP measures help to reduce not only disposal and emissions treatment costs but also increase the efficiency with which purchased materials and energy are used. Costs of lost input materials are usually much higher than pollution treatment costs. However, when calculating investments, the former costs reduced costs for materials and emission treatment are often not completely calculated. This results in distorted investment decisions.

The calculation sheet for Total NPO cost in Table 12 and Worksheet 3 and 4 may also be used to calculate several investment alternatives and comparing them, or to directly estimate the resulting cost savings. An annual assessment of total environmental expenditures should have been performed

beforehand, in order to provide a sound data basis. Depending on the project or investment, only some cost categories may be relevant, but the likelihood of forgetting significant cost factors is decreased.

Once the total costs of two alternatives have been assessed for one year, they can be extended into time series for capital budgeting. Estimates of monetary inputs and outputs for the first three years should be more detailed. For years 4 to 10 rough annual estimates would be sufficient.

Once the data is available in good quality, the actual calculation can then be made by applying the related functions in Microsoft Excel or by using other software like the UNIDO COMFAR III EMA tool. The latter is an advanced version of financial appraisal software that is being used to asses RECP Technology Options.



3. CASE STUDIES

3.1 AIGUEBELLE, MOROCCO

The company Aiguebelle is active in the food industry. It has one production site with 146 employees. It works 3 shifts, 6 days a week. The main products are confectionery and chocolates. The main market is the local market (90%), with the remaining 10% being exported to Africa and the Middle East. The company was founded in 1868 and still works on the same site, but now has too little space. It is planning to move to a new factory outside Casablanca in a couple of years. Chocolate production is quite labour intensive. There is no separation into specific production lines in the cost accounting. The company does not have an environmental management system according to ISO 14001, but is planning for ISO 22001 certification.

At the beginning of the TEST project, Aiguebelle was not aware of its total environmental costs, nor did it have knowledge of the concept of NPOs. After the MFCA assessment, which was done based on preliminary estimates using data from production, accounting and the monitoring system for internal production waste, the company realized that 5.18% of the total sales in monetary terms was lost (not converted into final product). The total NPOs were estimated at 950,000 Euros and represented 9 % of total costs.

The company also initially wanted to focus only on energy, as they considered this their main priority. Yet after the MFCA assessment they realized that raw material losses were also a significant loss in monetary value, corresponding to 36.2 % of total NPOs. The company had some environmental costs in the form of payments to external service providers for waste management, but it also had some environmental revenues since it was able to sell some of its waste for recycling. This is shown in lines 2.3 and 4.1 of the Table 15. These costs are the only ones related with environmental management which are visible in the accounting system. The breakdown of NPO is presented in Table 15 (the monetary value is not disclosed due to confidentiality reasons).

NON-PRODUCT OUTPUTS (NPO)	PERCENTAGE DISTRIBUTION %
1. Costs of Material and Energy Inputs	98.1%
1.1. Raw and Auxiliary Materials	36.2%
1.2. Packaging Materials	3.6%
1.3. Operating Materials	6.9%
1.4. Water	2.7%
1.5. Energy	48.7%
2. Waste Management/End of Pipe Costs	2.5%
2.1. Equipment Depreciation of End of Pipe Equipment	0,0%
2.2. Internal Personnel	0,0%
2.3. External Services	2.5%
2.4. Fees, Taxes and Permits	0,0%
2.5. Fines, Remediation and Compensation	0,0%
3. MFCA SYSTEM COSTS	0,0%
3.1. Equipment Depreciation	0,0%
3.3. Internal Personnel	0,0%
3.4. External Services	0,0%
3.5. Other costs	0,0%
TOTAL COSTS (1. + 2. + 3.)	100.6%
4. ENVIRONMENT-RELATED EARNINGS	
4.1. Other Earnings	-0.6%
4.2. Subsidies	0,0%
TOTAL ENVIRONMENT-RELATED EARNINGS	**-0.6%**
TOTAL NPO costs	**100.0%**

Table 15: Aiguebelle NPO break down

KPIs and related baselines were identified for all flows with significant NPO costs. Benchmarking and estimation of potential for savings showed there could be reasonable potential for improvement. Based on high NPO costs and potentials for savings and improvements, energy consumption and raw materials were defined as priority flows selected for detailed analysis. The company implemented a monitoring system consisting of several weighing scales in the packaging line. Finally, the following focus areas were selected considering the breakdown of NPOs to cost centers and potential for improvement as shown in Table 16.

COST CENTERS	% OF TOTAL NPO	% OF TOTAL NPO EXCL. ENERGY AND WATER
Store house	4.96%	8.58%
Mixing of ingredients	19.49%	5.53%
Conching	20.13%	18.23%
Temperature control of dough	6.12%	10.00%
Molding or extrusion of products	13.66%	25.00%
Recooling	20.57%	14.08%
Quality control	4.65%	9.11%
Cleaning of equipment	3.80%	0.89%
Administration	1.99%	0%
Logistics	4.65%	8.58%

Table 16: Aiguebelle focus areas highlighted in green

In order to have better information, the company established a monitoring system for the loss of materials, and particularly its chocolate. Some of the chocolate can be recycled, but some is burned during the process.

2015	TO RECYCLE	TO BURNING	TOTAL
January	15,674.80	10,110.70	25,785.50
February	16,603.00	6,058.21	22,661.21
March	16,587.00	5,434.00	22,021.00
April	13,491.20	4,793.40	18,284.60
May	12,447.50	7,378.00	19,825.50
June	10,509.00	5,768.40	16,277.40
July	3,922.00	8,963.00	12,885.00
August	13,790.50	3,301.00	17,091.50
September	17,611.00	5,197.46	22,808.46
October	16,561.00	5,897.74	22,458.74
November	10,001.80	7,169.82	17,171.62
December	12,687.40	5,906.48	18,593.88
TOTAL	159,886.20	75,978.21	235,864.41
%	68%	32%	100%

Table 17: Aiguebelle monthly data monitoring

It was thus noticed that losses by burning represented only 32% of total rejects, with 68% being recycled as shown in Table 17.
The losses of chocolate were further broken down by production steps as presented in Figure 3.

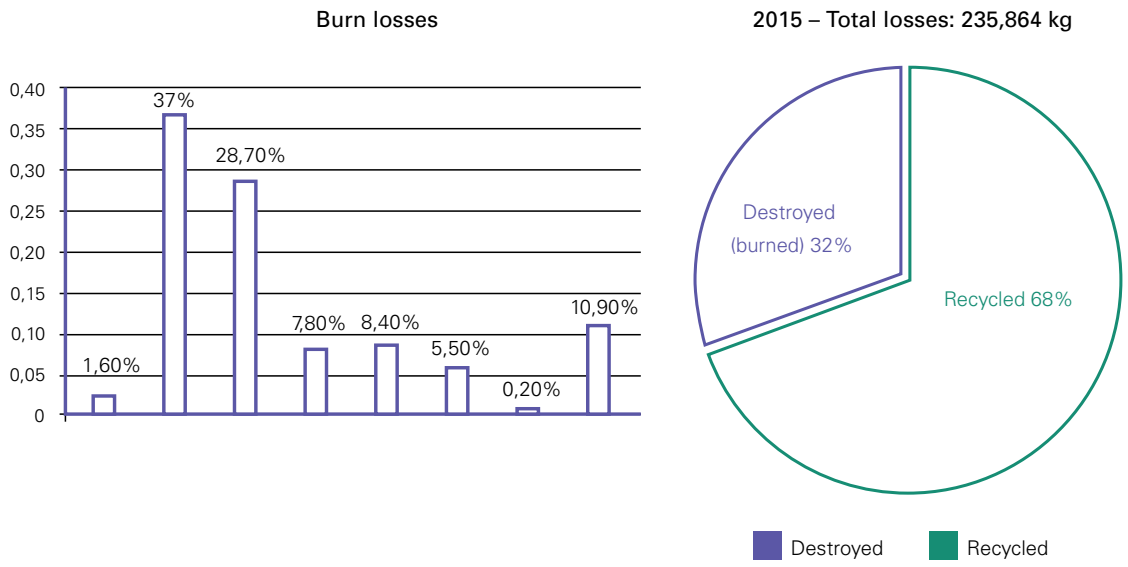


Figure 2: Aiguebelle loss statistics

It turned out that one specific line in the molding flow process was responsible for 28.7 % of burn losses and was thus chosen as first priority for detailed analysis (TEST Step 1.6) and for the generation of improvement options. The preparation phase was not chosen as a priority area as it had recently been investigated and improvements were in the planning stage already. OPIs were identified and monitoring was also installed at the level of focus areas. After having enough data on performance of specific OPIs the baselines were established.

Improvement options were generated. The suggested investments, estimated to be 795,236 Euros, will save around 1,161,226 Euros per year, with a payback period equal to 0.68 years. This will reduce the consumption of water by 12,154 m^3/year, of energy by 2,067 MWh/year and of raw materials by 96 tons/year. The emissions of CO_2, BOD_5 and COD will be reduced by 1,023 tons/year.

3.2 AL-HAY HAMOUD HABIBA & SONS, JORDAN

Al-Haj Mahmoud Habibah & Sons Co. is a medium-sized enterprise that was established in 1951 for producing different types of oriental sweets and pastries (hot and cold) for the local market. The company participated in the MED TEST II project in order to reduce production losses and costs through a more efficient use of resources and to reduce operational costs by reducing energy consumption.

At the beginning of the project, the company was not aware of its total environmental costs, nor was it familiar with the concept of NPO. They estimated the total environment related costs to about 2,500 Euros annually for waste disposal. After the MFCA assessment, which was done based on preliminary estimates using data from production and accounting for the fiscal year 2015, the company realized that from a financial point of view 63% of the total NPOs was due to energy consumption, 32% was due to losses in raw and auxiliary materials (including losses of products) and that 5% of NPOs was related to packaging materials and water.

The mass balance of raw materials input to products output showed a loss of about 6% of raw materials. It was recommended to actually monitor the loss of raw materials and final products. It was also recommended to record the actual amounts of raw and auxiliary materials consumed in stock management on separate financial accounts, and to consider purchase in larger bulks and big bags, as there is a lot of handling and waste related with packaging of raw materials.

KPIs and related baselines were identified for all flows with significant NPO costs. Estimation of potential for savings and regular monitoring of the relevant focus processes showed that there could be a reasonable potential for improvement.

Based on high NPO costs and potential for savings, energy as well as raw and auxiliary materials flows (the latter including losses of products in the production processes) were selected as priority flows for detailed analysis.

The company decided to put in place a regular inspection and monitoring system of the generated solid waste from each focus area in the process. The measurements of solid waste generated showed significant improvements due to the implementation of saving measures: through these, 64% of the solid waste could be reduced. Most of the implemented measures can be considered good housekeeping measures such as changing the way of cutting the products and controlling staff practices in the cutting process. Additionally, they include investments to replace the dough cutting machine by a more efficient machine to consistently portion dough and to install an on site laboratory that can measure specific characteristics of the used frying Ghee to check its suitability and to determine when to dispose of it.

The project's energy efficiency experts investigated the plant's energy system and conducted energy measurements to identify the main energy users, inefficiencies and their root causes. Accordingly, 10 saving measures were proposed to reduce the consumption of energy (electricity and fuel) by heat conservation and recovery, and improve the lighting and cooling systems. Implementation of these measures will reduce the company's energy consumption by approximately 28% and CO_2 emissions by 21%. Additionally, the company decided to replace its chiller, which will also result in further energy savings.

3.3 PATES WARDA, TUNISIA

Pates Warda operates in the agri-food sector, employs 400 persons, and produces couscous, pasta and special pasta. 65% of the production of the company is sold in the local market and 35% is exported to the international markets. This company is a leader in the local market, holding 36% of market share. It is certified ISO 9001, ISO 14001, ISO 22000.

At the outset of the project, it was found that the company did not have an exact idea of its total environmental costs. The environmental costs recorded in its accounting system were limited to the costs of solid waste collection and transport to landfill and the wastewater fee for discharge into the public sewerage system.

The company had no precise knowledge of, or tracking system for, its losses of raw materials during production operations, losses of packaging, losses related to customer returns and operating materials. The use of the MFCA tool by the company was intended to improve this situation by establishing a reliable information system useful for setting objectives for reducing losses.

Setting up the MFCA tool already led to the identification of several shortcomings of the existing information system:

- Difficulties in data collection related to quantities of consumed materials such as packaging and the rate of waste generated;
- Conflicting data between the accounting system and the ERP operating system;
- Global accounts that record expenditures of different kinds and natures;
- Absence of weighing scales at the reception of raw materials;
- Need to estimate the NPO percentages, mainly for raw materials and packaging, as no monitoring data was available;
- Difficulties to gather data for product returns from customers for couscous and pasta.

The implementation of the MFCA concept provided the opportunity for testing the relevance and coherence of the information system in place. Interesting, and for the plant personnel exciting, discussions between the production, accounting and quality departments took place throughout the MFCA exercise. These highlighted the need to work together and to communicate regularly. Discussions on the estimates of the rate of loss of raw materials oscillated between 5% and 3%, to be consensually determined at 3.1%. Also, in the beginning there was no estimate of the packaging loss rate. Testing and evaluations of packaging consumption over a certain period of production made it possible to estimate the NPOs of the main packaging materials at 1.86%.

Of paramount importance was the fact that the implementation of MFCA demonstrated that 1,160,000 Euros of sales are lost as NPO (not converted into final products), which corresponds to a total NPO estimated at 5% for raw materials.

At the beginning of the project, the company wanted to focus only on energy as its priority flow, but the MFCA assessment revealed that material losses were also very important as they accounted for 28.7% of total NPO costs. Another priority flow that was not well monitored was operating materials, which represented 17% of the total NPO costs.

The graph in Figure 4 shows the distribution of NPO costs:

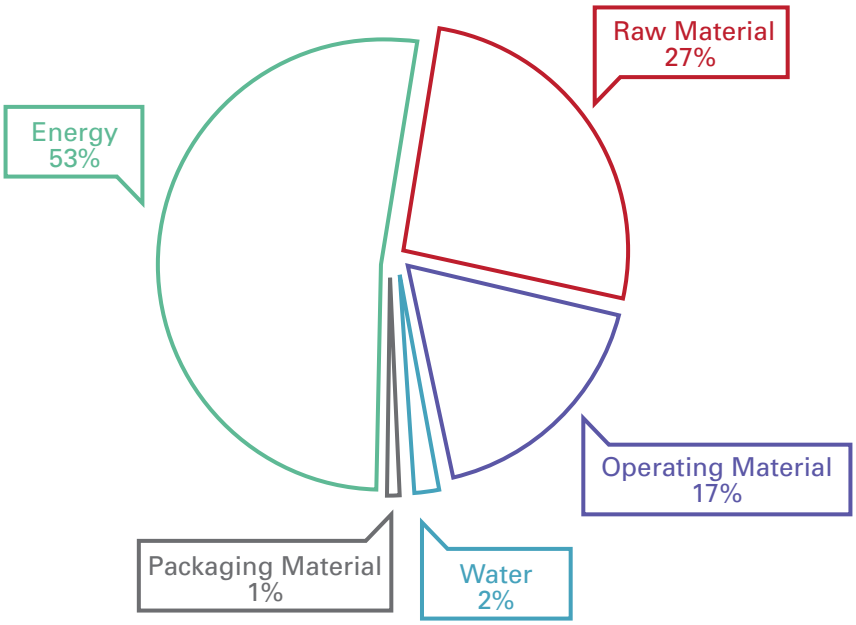


Figure 4: Pates Warda, NPO costs break down

Key Performance Indicators (KPIs) were established for all priority flows. Comparison with international benchmarks was used for setting targets for improvement. Based on criteria related to the high costs of NPOs and consideration of the potential for improvement, priority flows and priority areas were selected for further analysis and identification of RECP solutions.

Aware of the importance of NPO costs, the company decided to implement the following actions:

- Installation of a weighing system for raw materials at reception (incoming store)
- Installation of a hook scale for weighing packaging waste and recording it
- Installation of a flow meter and ultrasonic air leak detector for monitoring the consumption of compressed air
- An energy data acquisition system connected to a computer processing station
- A system for monitoring maintenance and repair expenditures, with particular attention to preventive actions in order to manage the consumption of operating materials.
- Implementation of good housekeeping measures such as improvement of the brushing system in order to reduce losses in the couscous line.
- A facility for collecting and recycling product waste from the lines of short and long pasta.
- A system for recovering steam emitted into the air, resulting from the couscous cooking operation, in order to reuse it for preheating of the drying air and the water upstream of the boiler.

The first cycle of implementation of MFCA during the first year in the company allows to draw the following lessons learnt:

- The company initially wanted to focus only on energy flows but the MFCA assessment revealed that material losses were too high, corresponding to 28.7% of NPO costs. Also, the company was surprised by the NPO value of the operating materials which represents 17% of the total NPO costs; The MFCA exercise revealed that total environmental costs are underestimated by the company as the accounting system records only waste management costs estimated at 38.400 Euros or and no attention is paid to losses of raw material et packaging that account for an NPO value of 1,240.000 Euros;

- Gaps in the information system led to providing conflicting data between the accounting system and the ERP operating system and resorting to the use of estimates in the absence of weighing scales;
- Lack of communication between accounting and production departments resulting from inconsistencies in the data, concerning losses (e.g. variation in estimates between 5% and 3% for raw materials loss)
- The MFCA exercise allowed to provide a realistic estimate of the NPO rate at 5% (3.1% NPO related to raw materials and 1.9% NPO related to finished products returned from customers), thus making the lost value of sales at about 1,160.000 Euros;

Other unexpected revelations were:

- The MFCA exercise triggered the awareness of the company about the importance of NPO and convinced it to set a target for the reduction of NPO by 25% per year.
- A series of actions were taken to improve company's information system for flow costs, in particular, a system for weighing raw materials at the reception stage as well as the generated waste from production. Also, the company will invest in an energy data acquisition system connected to a computer processing station. This will be included in TEST action plan adopted by the company.
- After the MFCA first cycle evaluation, the company intends to integrate the MFCA tool within its accounting management system.

3.4 AL-GHRAWI, LEBANON

The Al-Ghrawi business began manufacturing a number of Dried Fruit, Malban and Nougat products in 1891. At that time, production was done solely by hand. Today, the company offers about 500 different sweets produced in two factories. The main processes are:

- Chocolate Dipping
- Chocolate Filling
- Delights

At the beginning of the TEST project, the company was estimating the total costs for energy consumption, but was recording no other environmental costs, so there were no costs recorded for water input, wastewater treatment, and waste disposal.

The MFCA assessment was done based on the list of accounts for 2015 and preliminary estimates for the loss percentages based on production data. For the year 2015 the costs for water input and wastewater treatment could be neglected. But, in light of upcoming legal requirements, the total NPO costs were first calculated as they show up in the list of accounts 2015 and then with additional costs for water input calculated at an average price of 0.0084 Euro/litre of water input. This average price was calculated based on the actual costs of purchasing water from external suppliers and several studies done on water shortage in Lebanon.

The company initially wanted to focus the improvement options on energy, as it considered this its main priority. But the MFCA assessment showed that the NPO costs of raw and auxiliary materials are significantly higher as shown in Table 18.

	% WITHOUT WATER COSTS	% INCLUDING WATER COSTS
	100.0%	100,0%
1.1. Raw and Auxiliary Materials	52.3%	47%
1.2. Packaging Materials	1.6%	1%
1.4. Operating Materials	9.9%	9%
1.5. Water	0.7%	11%
1.6. Energy	35.6%	32%

Table 18: Al-Grahwi, NPO breakdown without and including shadow water prices

The MFCA assessment showed that the costs for materials and energy input account for about 53% of total expenditures. Using an estimate for loss of raw materials of 4% in line with international benchmarks, the NPOs of raw materials account for 52.3% without water costs, and 47% including water costs, of total NPO costs. The total NPO costs including water costs account for 5% of total production costs.

After conducting the mass balance based on measured data, the previously estimated NPO for raw materials was accurately calculated based on a flow chart process. The resulting recalculations decreased the NPOs of raw materials from 52.3% to 32.3% without water cost and from 47% to 28.3% with water cost. These losses cannot be avoided due to current process constraints. Also, the records for packing materials, which previously were estimated as only recorded in units, were converted into volumes and the mass balance was gradually refined.

Al-Ghrawi next installed meters for energy and electricity as well as for water consumption. Since November 2016, readings have been taken from installed meters. Data analysis for installed meters and expert observations showed a high potential for energy savings and a good potential for water savings.

Based on high NPO costs and savings potentials the Table 19 shows which processes were selected for further investigation:

Steam system	30% of energy consumption
Air Conditioning system (AC)	23% of energy consumption
Chocolate Production without AC	10% of energy consumption
Delight Production without AC	11% of energy consumption
Hot water for delights	3.5% of water consumption
Hot water for other non products	44% of water consumption

Table 19: Al-Ghrawi, processes with high NPO share

According to the TEST methodology, the following priority flows and focus areas were selected for further monitoring and improvement options as presented in Table 20.

PRIORITY FLOW/	FOCUS AREA
Energy	Air Conditioning Units
Energy	Steam Boiler
Water	Hot water for Delight Vats Cleaning
Water	Hot water for other non-production uses
Raw and auxiliary materials	Solid Waste Generation
Heat loss t	Generators Heat Loss
Heat loss	Hot Water Tank

Table 20: Al-Ghrawi, priority flows and focus areas

It was recommended to repeat the MFCA assessment for the upcoming financial years. Thus, the improvements of the information system and of inputs and outputs in costs and volumes will become visible.

APPENDIX A EMA - DISTRIBUTION OF NPO COSTS TO ENVIRONMENTAL MEDIA

Statistical agencies in several countries require reporting of environmental protection expenditures by environmental media from certain large companies in specific business sectors, especially energy utilities and companies who also fall under the CO2 Emission Trading Schemes. In this case, the companies will perform an EMA, since there is no need for more detailed analysis of NPO cost distribution within the company. In cases where this reporting is mandatory, this may be the main reason for a company to establish an EMA system. Note that the NPO costs of materials input are typically not reported to national agencies.

To assist any users of this manual who are subject to such reporting requirements, a number of case studies described in the public literature are given here. Table 21 provides published information on an EMA assessment of the pulp and paper company SCA Laakirchen in Austria, which indicates the average distribution of the total environmental costs to the different environmental media, by environmental cost categories. This Table is highly valuable to show a real case example with a real cost distribution. Please note that the terminology is slightly different to the MFCA standards terminology, which was developed significantly later.

EMA FOR ESTIMATION AND DISTRIBUTION OF TOTAL ENVIRONMENT-RELATED COSTS – AUSTRIA

SCA Graphic Laakirchen AG, one of SCA's pulp and paper production sites, has been tracking its physical and monetary information under EMA since 1999 and has a well-established, consistent system for capturing and assessing material flows and environment-related costs. The information collected is used for decisions related to both environmental management and general production. SCA Laakirchen annually calculates total environment-related costs and discloses their percentage distribution by environmental domain in its environmental statement, as illustrated in Table 21.

The data in Table 21 illustrate the fact that the "materials purchase and processing costs of NPOs" (cost category 1 in Worksheet 3) in many companies are often significantly higher than more familiar environment-related "waste and emissions control costs" (cost category 2 in Worksheet 3) – approximately four times higher in the case of SCA Laakirchen. Fig. 21 also illustrates the fact that "prevention and other environmental management costs" at SCA Laakirchen are quite low, despite the fact that the company has implemented a number of preventive projects in past years that have achieved significant savings in "materials cost of NPO" as well "waste and emission control."

The data allow SCA Laakirchen to compare its environment-related costs from year to year. For example, although manufacturing output rose almost 23% between 2002 and 2003, the use of a new paper machine kept the total environment-related cost increase to just 14.7% over the same period. This illustrates the overall positive financial impact of the company's environmental management initiatives. A more detailed look at the cost changes between 2002 and 2003 also revealed some interesting points. For example, the overall cost of operating the wastewater treatment plant did not change even though it was enlarged to handle the increased wastewater resulting from expanded production. This was because the operational efficiency and maintenance of the wastewater treatment plant were improved in several ways as it was expanded.

Costs in other categories did increase. For example, the purchase costs of auxiliary materials increased not only because of expanded production, but also because of international price changes. SCA Laakirchen also observed that the distribution of total costs and earnings across the different environmental domains remained more or less constant over the years: 22% air/climate; 54% wastewater; 23% waste; 1% other.

The physical results of SCA Laakirchen's environmental management efforts were also presented in the company's annual environmental statement. For example, despite a production increase of about 23%, the procurement of water increased by only 11% and wastewater volume by only 13%. In absolute terms these represent increases, but they are improvements per unit of production. Use of physical inputs, such as fillers, recovered paper and energy, also increased in absolute terms but reflected eco-efficiency improvements.
Source: SCA Laakirchen Website, IFAC EMA Guidance document, 2005

Note: the data in the Table 21 below are presented as a percentage of the total environment-related costs and earnings for the company

ENVIRONMENTAL DOMAIN ENVIRONMENT-RELATED COST CATEGORIES	AIR + CLIMATE	WASTE-WATER	WASTE	SOIL + GROUND WATER	OTHERS	SUM
Material Consumption Cost of NPOs						
Raw materials			15.2%			15.2%
Packaging			0.1%			0.1%
Auxiliary materials			2.7%			2.7%
Operating materials	0.1%	42.2%	0.5%			42.8%
Energy	19.8%					19.8%
Water		0.0%				0.0%
Material Processing Cost of NPOs		0.2%	1.0%			1.2%
Subtotal	19.9%	42.4%	19.5%			81.8%
Waste & Emission Control Costs						
Equipment depreciation	0.1%	2.8%	0.4%			3.3%
Operating materials and services	0.2%	5.5%		0.1%		5.8%
Internal personnel	0.7%	1.0%	0.1%			1.8%
Fees, taxes and fines	0.9%	2.7%	6.0%			9.6%
Subtotal	1.9%	12.0%	6.5%	0.1%		20.5%
Prevention and other Environmental Management Costs						
External services for env. management					0.4%	0.4%
Internal personnel for env. protection	0.1%				0.3%	0.4%
Subtotal	0.1%				0.7%	0.8%
I - VI Environment-related Cost Total	21.9%	54.4%	26.0%	0.1%	0.7%	103.1%
Environment-related Earnings Total			-3.1%			-3.1%
Total Environment-related Costs & Earnings	21.9%	54.4%	22.9%	0.1%	0.7%	100.0%

Table 21: Environment related Costs by environmental Media at SCA Laakirchen

APPENDIX B: REFERENCES

Bouma J.J., Wolters J. Management Accounting and Environmental Management: A survey among 84 European companies, Erasmus Center for Environmental Studies, Rotterdam, 1998

Fischer, H., Wucherer, Chr., Wagner, B., Burschel, C. Umweltkostenmanagement. Kosten senken durch praxiserprobtes Umweltcontrolling, München, Wien, 1997.

IFAC, Environmental Management Accounting International Guidance Document on environmental management accounting (EMA), International Federation of Accountants, IFAC, New York 2005, www.ifac.org

International Organization for Standardization (ISO) ISO 14031, Environmental Performance Evaluation - Guideline and general principles, Geneva, 1999.

International Organization for Standardization (ISO) ISO 14051, Material Flow Cost Accounting, Geneva, 2011

Jasch Ch., Danse M., Environmental Management Accounting pilot projects in Costa Rica, in Bennet M., Rikhardson P., Schaltegger S. (Eds.) Implementing Environmental Management Accounting: Status and Challenges, Kluwer Academic Publ. , Dordrecht, NL, 2005

Jasch Chr. Environmental Management Accounting: Procedures and Principles, UN Divisions for Sustainable Development, 2001.

Jasch Ch., Schnitzer H., Umweltrechnungswesen – Wir, zeigen, wie sich Umweltschutz rechnet, Beispielsammlung zur Umweltkostenrechnung und Investitionsrechnung, Im Auftrag von Bundesministerium für Verkehr, Innovation und Technik sowie Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasser, Wien, erschienen als Schriftenreihe 29/02 des IÖW Wien, Oktober 2002 und in den Berichten aus Energie- und Umweltforschung des BM VIT 4/2003

Jasch Ch., Institut für Ökologische Wirtschaftsforschung, Vienna, Austria, Environmental and Material Flow Cost Accounting - Principles and Procedures, (Eco-Efficiency in Industry and Science, Vol. 25), Springer, Heidelberg, New York, 2009

Jasch Ch., Governmental Initiatives: The UNIDO Test approach, Journal of Cleaner Production, 108 (2015), 1375 - 1377

UNEP. 2001. Promoting financing of Cleaner Production Investments – UNEP Experience. Ari Huhtala. UNEP: Paris, 2001. www.financingCP.org

UNIDO COMFAR III Expert, COMFAR III EMA Module, Vienna, 2009