

Cleaner Production Manual



ASIE/2006/122-578

**Improving the living and working conditions of people in and around
industrial clusters and zones**

IVAM

2008

PROFITING FROM CLEANER PRODUCTION

**Saving costs and natural resources
by Environmental Efficiency**

MANUAL

CONTENT

1	INTRODUCTION ON CLEANER PRODUCTION	7
1.1	Sustainable development and environmental strategies	7
1.1.1	Passive environmental strategy: pollution and dispersion.....	7
1.1.2	Reactive environmental strategy: end-of-pipe treatment.....	8
1.1.3	Constructive environmental strategy: recycling and recovery	8
1.1.4	Proactive environmental strategy: cleaner production	8
1.2	What is cleaner production?.....	9
1.2.1	Change of input materials	10
1.2.2	Technology change	11
1.2.3	Good operation practises.....	11
1.2.4	Product modification	12
1.2.5	On site re-use and recycling.....	12
1.3	The profits of cleaner production	13
1.4	The barriers for cleaner production	15
1.5	Cleaner production approach.....	15
1.5.1	Planning and organisation	16
1.5.2	Assessment	16
1.5.3	Feasibility analysis.....	17
1.5.4	Implementation	17
2	PLANNING AND ORGANISATION	19
2.1	Obtaining management commitment and participation	19
2.2	Organising a cleaner production project team	20
2.2.1	Selecting the leading team members	20
2.2.2	Selecting the assessment team members.....	21
2.2.3	Selecting a facilitator.....	22
2.3	Identify possible barriers and solutions.....	22
2.4	Setting objectives	23
2.5	Pre-assessment	23
2.5.1	Investigate the present status.....	23
2.5.2	Perform on-site investigation	24
2.5.3	Compile a process flow chart.....	24
2.5.4	Selecting the assessment focus	25
2.5.5	Set cleaner production targets.....	26
2.5.6	Bring obvious options into operation	27
2.5.7	Making an assessment plan	27
3	ASSESSMENT	29
3.1	Making the material and energy balances	29
3.1.1	Unit operation as a basis for the balance	30
3.1.2	The material balance	31
3.1.3	The energy balance	33
3.2	Assessing process in- and outputs	34
3.3	Inputs.....	35
3.3.1	Raw materials and auxiliaries.....	35
3.3.2	Water	35
3.3.3	Energy.....	36
3.4	Outputs.....	37
3.4.1	Products and by-products.....	37
3.4.2	Waste and emissions.....	37
3.4.3	Energy.....	38
3.5	Complete the balance	39
3.6	Presenting and interpreting the data	40
3.7	Conduct a cause assessment.....	41
3.8	Option generation.....	43
3.8.1	Implement the obvious options	43
3.8.2	Structuring the option generation.....	43
3.8.3	Creative thinking techniques.....	43
3.9	Option screening	45
4	FEASIBILITY STUDY.....	50

4.1	Technical evaluation	50
4.2	Environmental evaluation.....	51
4.3	Economic evaluation	52
4.3.1	Pay back period	53
4.3.2	Net present value and return on investment.....	54
4.3.3	Risk considerations.....	54
4.3.4	Market considerations.....	55
4.4	Decision making.....	56
5	IMPLEMENTATION.....	58
5.1	Project preparation	58
5.1.1	Planning	58
5.1.2	Fund raising	59
5.2	Project execution and evaluation	59
5.2.1	Technological evaluation	59
5.2.2	Environmental evaluation	60
5.2.3	Economic evaluation.....	60
5.2.4	Comprehensive evaluation and comparison	60
5.3	Sustaining cleaner production.....	61
5.3.1	Establishing incentive mechanisms for cleaner production	61
5.3.2	Ensuring funding sources for cleaner production	61
5.3.3	Formalising the cleaner production structure	61
5.4	Environmental management system.....	61
5.4.1	Environmental management system according ISO 14001	62
5.4.2	Benefits of an environmental management system.....	63
5.4.3	Synergy between EMS and cleaner production	64
5.5	Planning of sustained cleaner production	64

USER GUIDELINES

Cleaner Production (Cleaner Production) is a method, which enables companies and governments to implement a pro-active environmental strategy. With Cleaner Production industries reduce pollution in their production processes by means of preventive measures. It's a structural business strategy that increases the efficiency and the gross returns (profit).

This manual provides background information and practical guidelines for assessing and implementing Cleaner Production options.

The manual is primarily written as a hands-on implementation guide for *operational managers* involved with Cleaner Production. It provides practical advice, guiding you in the development of a Cleaner Production program, step-by-step from the beginning all the way to evaluation and points beyond. The manual is designed to be user friendly and functional, a tool as much as a teacher. By using the accompanying worksheets the right concepts and questions will be handled as you go along in the process.

Secondly, the manual can be used as background information for *trainers and disseminators*. It is part of and linked to the Cleaner Production training package, which provides a:

- Teacher guide;
- Video;
- Slides (PowerPoint) with notes pages;
- Worksheets;
- Exercise (distillery case).

Finally, the first chapter of the manual provides an introduction on Cleaner Production, which can be useful for *CEO managers* who want a quick overview of Cleaner Production.

To make the manual user-friendly, several icons are used and explained in the next box.

Icon	Item	Explanation
	Summary	At the beginning of each chapter a summary and starting questions are given (also useful for CEO managers).
	Checklists	Practical tools, reminders, fact sheets and do's and don'ts for implementing Cleaner Production.
	Worksheets and Checklists	The number of the worksheets and checklists to be used for exercising the related theory (see next box).
	Examples	Practical case studies, domestic as international, to illustrate the theory and to give an example for each Cleaner Production category.

Worksheet	CP phase	Activity
1A	PLANNING & ORGANISATION	Leading team members (maximum 4 members)
1B		Assessment team members (maximum 5 members)
2		Simple flowchart
3		Setting the CP-assessment focus
4	ASSESSMENT	Input & output tables
5		Assessment of input & outputs
6		Cause analysis of waste & emissions
7		Where – Why – How?
8		Description of option, benefits and results of option screening
9	FEASIBILITY ANALYSIS	Investment and installation costs
10		Running costs before/after investment
11		Pay back time

Checklists	
1	PLANNING & ORGANISATION
2	PREASSESSMENT
3	ASSESSMENT
4	GENERATION & SCREENING OF OPTIONS

Box: list of worksheets and checklists

1 INTRODUCTION ON CLEANER PRODUCTION

 The reasons to start, develop, perform and implement a Cleaner Production program can be country specific but is also general (universally) applicable. Generally the worldwide environmental concerns ask for a more pro-active strategy from the industry. Most governments are developing policy plans within the Sustainable Development framework to stimulate industrial sectors to produce in a cleaner way. Sustainable development meets the needs of the present generations without compromising the ability of future generations to meet their needs (Brundtland 1996). The challenge is to care for people, planet and profit at the same time. Or in other words: there could exist mutual company and governmental benefits to save the environment and improve the living conditions and at the other side to increase the financial performance.

Cleaner Production means the reduction of pollution by means of pollution preventive measures applied to products and production processes.

Cleaner Production generates options for improvement in five categories: Change of input materials; Technology change; Good operation practises; Product modification and on site re-use and recycling. Cleaner Production options can reduce the material-, energy- and water consumption per product, and increase savings made on the costs of these natural resources. The costs for processing waste streams (including solid waste, wastewater, air emissions) will increase in the next future. Minimizing waste streams and a pro-active compliance with laws and regulations can save money. And last but not least, most often with environmental measures, the efficiency of production processes will increase as well, resulting in higher levels of production output, or improvement of the product quality.

Cleaner Production can be approached in four phases: planning and organisation; assessment; feasibility analysis; implementation and sustaining.

In this chapter questions will be answered as:

- Which environmental concerns can be identified and how can they be approached?
- What is sustainable development?
- What is Cleaner Production?
- What are the benefits of Cleaner Production for companies and government?
- What are the barriers and constraints for Cleaner Production?
- How to start with Cleaner Production?

1.1 Sustainable development and environmental strategies

In many countries, industry is a large contributor to water pollution and air pollution. As industry is growing with the same speed of today, its contribution to pollution will also increase, unless action is taken to reduce the monetary cost of industrial pollution to society but also to reduce damage to human health.

The Brundtland commission in 1996 launched a new pattern of development that balances competitiveness, social development and environmental soundness. This so called Sustainable Development meets the needs of the present without compromising the ability of future generations to meet their needs.

This means a pattern of development that balances competitiveness, social development and environmental soundness or concern for:

- People (social development, health and safety, good working climate);
- Planet (conservation of natural resources);
- Profit (economic growth).

The road to Sustainable Development is a long process. Over the past decades, the industrialized nations have responded to pollution and environmental degradation in five characteristic ways:

1.1.1 Passive environmental strategy: pollution and dispersion

In this strategy the problem of environmental pollution is not recognized or ignored by dispersing pollution, so that its effects are less harmful and apparent. This passive attitude leads to containment. A closer look on the evolution in environmental strategies shows a lack of recognition for the problem until mid-20th century. In the sixties, when the first negative signs of pollution became apparent, the government and industry responded with dispersion and dilution, so that its effects are less harmful and apparent.

1.1.2 Reactive environmental strategy: end-of-pipe treatment

This strategy is dominated by seeking control of pollution and wastes. This re-active attitude leads to 'end of pipe' treatment.

Not earlier than in the seventies, when the environmental crisis began to reach its top, the environmental strategy changed towards end-of-pipe treatment. The question 'how to treat the existing waste and emissions' was raised.

Typical for the end-of-pipe treatment approach is that:

- It generally leads to extra costs (expensive solutions);
- Waste and emissions are limited through filters (end of pipe solutions, repair technology, storage of emissions);
- Environmental protection comes in after products and processes have been developed and designed (re-active);
- Environmental problems are solved from a technological point of view (one focus);
- Environmental protection is a matter for competent experts (not shared by the whole company);
- Environmental protection is brought from outside (dependence on technical experts);
- Increased complexity and risks (complicated and artificial high-tech solutions);
- Environmental protection comes down to fulfilling legal prescriptions.

This type of environmental regulation has certainly been needed in order to deal with the severe environmental problems associated with the fast industrial development during the past decades. However the disadvantages of this approach are: high pollution abatement costs, which undermine enterprises' profits and competitiveness; difficulty in eliminating pollutants and risk in pollution transfer; inability to reduce the waste of energy and materials; unaffordable government regulatory costs.

1.1.3 Constructive environmental strategy: recycling and recovery

The constructive strategy focus on the development and improvement of environmental technology that will help close the loops in material flow streams during the production process, and facilitate reuse and recycling. This constructive attitude leads to external and internal recycling (the 1980s). Due to the high abatement costs and the difficulty in eliminating pollutants, the question 'where do waste and emissions come from' was raised and 'how can we recycle them.

Typical for this recycling approach is that:

- It can help reduce costs;
- It leads to waste and emission prevention at the source;
- Environmental protection comes in as an integral product design and process engineering;
- Environmental problems are tackled at more levels and fields in the company;
- Environmental protection is everybody's business and recycling processes are developed within the company;
- Reduced risks and increased transparency;
- Environmental protection becomes a permanent challenge towards Cleaner Production and Sustainable Entrepreneurship.

1.1.4 Proactive environmental strategy: cleaner production

Most recently by implementing Cleaner Production through the prevention of pollution and waste generation at the source. This pro-active attitude leads to reduction at the source.

Since the last decade (the 1990s), Cleaner Production and preventive measures have proved to be a profitable and sustainable strategy to cope with environmental and health and safety problems. Cleaner Production (Cleaner Production) focuses on more efficient use of natural resources (raw materials, energy and water) and reducing wastes and emissions at the source!

Cleaner Production according to the World Business Council is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity.

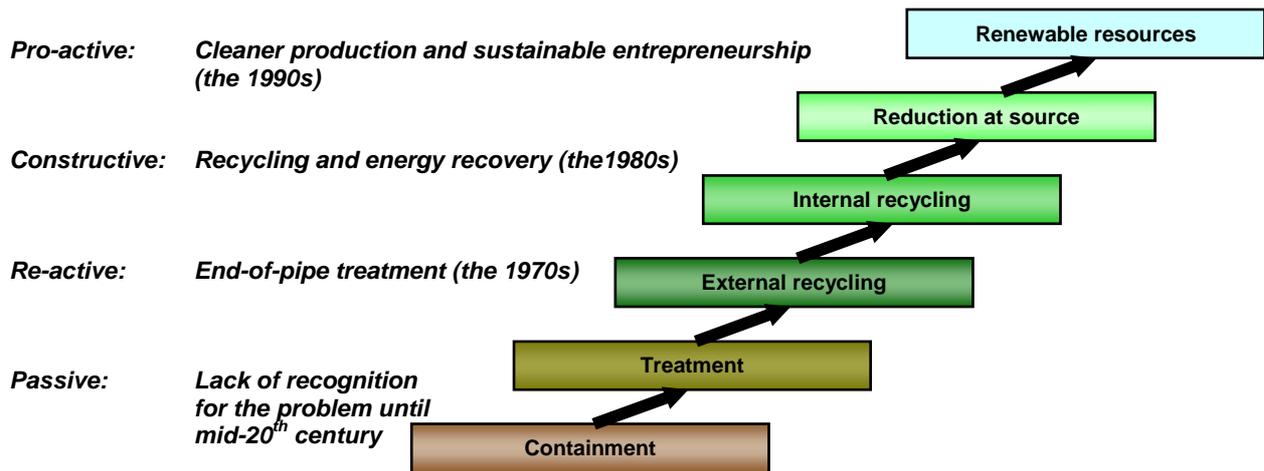


Figure: development in environmental strategies

Generally, a pro-active strategy to environmental concerns is more beneficial than a re-active end-of-pipe approach (see following checklist).

<input checked="" type="checkbox"/> From: end of pipe treatment	<input checked="" type="checkbox"/> To: cleaner production
How can we treat existing waste and emissions?	Where do waste and emissions come from?
Stands for reaction	Stands for action
Generally leads to extra costs	Can help reduce costs
Waste and emissions are limited through filters Repair technology and storage of emissions	Waste and emission prevention at the source Avoids potentially toxic processes and materials
Environmental protection comes in after products and processes have been developed	Environmental protection comes in as an integral product design and process engineering
Environmental problems are solved from a technological point of view	Environmental problems are tackled at all levels and in all fields
Environmental protection is a matter for competent experts	Environmental protection is everybody's business
Environmental protection is brought from outside	Environmental protection is developed within the company
Increased complexity and risks	Reduced risks and increased transparency
Environmental protection is compliance driven	Environmental protection as a permanent challenge

1.2 What is cleaner production?

Cleaner Production is the continuous application of an integrated, *preventive environmental strategy* towards processes, products and services in order to reduce damage & risks for humans and the environment (UNEP).

With Cleaner Production industries reduce pollution in their production processes by means of preventive measures. It's a structural business strategy that increases the efficiency and the gross returns (profit). Related concepts to Cleaner Production are: eco-efficiency; waste minimization; pollution prevention; green productivity; dematerialization.

For production processes, Cleaner Production aims to:

- Reduce at source the quantity and toxicity of all emissions and wastes generated and released;
- Eliminate as far as possible the use of toxic and dangerous materials;
- Reduce the consumption of raw materials and energy used in the production of one unit of product (efficiency improvement).

For products, Cleaner Production aims to reduce the environmental, health and safety impacts of products:

- Over their entire life cycle;
- From raw materials extraction, through manufacturing and use, to the ultimate disposal of the product.

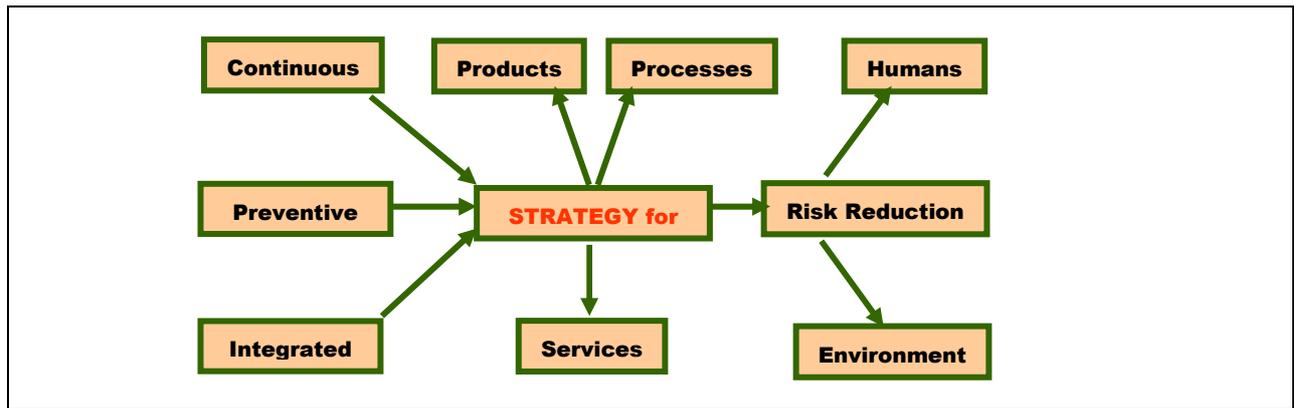


Figure: cleaner production is a continuous, integrated, preventive environmental strategy towards processes, products and services in order to reduce risks for humans and the environment

Cleaner Production measures can be taken in 5 categories:

1. Change of input materials;
2. Technology change;
3. Good operation practices;
4. Product modification;
5. On site re-use and recycling.

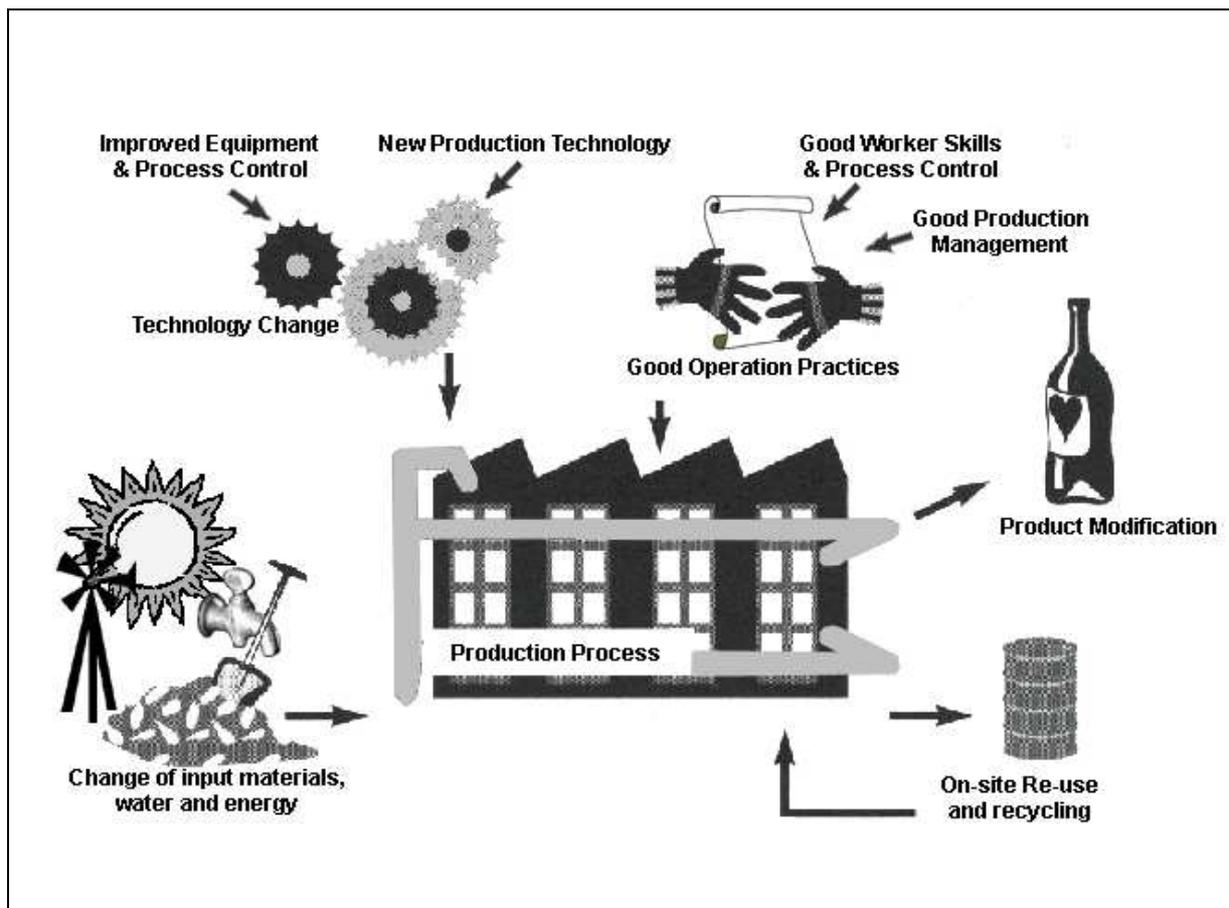


Figure: cleaner production options and measures can be taken in 5 categories

1.2.1 Change of input materials

The first category is changing the input materials by:

- Replacing toxic or harmful materials with less toxic materials;
- Using renewable materials;
- Using adjunct materials which have a longer service life-time in production;
- Material purification.

 **Change from halon as refrigerant to ammonia and CO2 saves 100% on ozone depleting substances**

The Nestlé operations in Beauvais, France, produce a variety of frozen foods and ice cream. The production plant, and the warehouse used to store products prior to shipment, must be maintained at temperatures between -20° and -40°Celsius. A substantial amount of refrigeration is necessary to maintain such temperatures in the 80 000 m³ warehouse. This refrigeration was achieved using halon, an ozone depleting substance. As a result of Nestlé's global phase-out programme, and also of international agreements to stop production and use of these substances, the Company began looking for suitable alternatives. The early solution at many Nestlé factories was to revert to the use of ammonia as a refrigerant. Ammonia systems are technologically proven and operate efficiently in food manufacturing. However, these systems require certain safety precautions, particularly in large installations. The solution found by Nestlé's engineers in Beauvais was to use two substances. Because of its excellent properties as a refrigerant, a very small amount of ammonia was used as the primary refrigerant in an isolated system. This system then cools a secondary material, CO₂, which is used in the extensive network of coolers throughout the warehouse. This type of two-phase refrigeration allows the use of a minimal amount of ammonia and isolates it from the process areas, thus greatly reducing the risk of an accident. Using CO₂ in the production areas is better, as it is non-toxic, non-flammable and has little impact, should a leak occur from the closed system.

 **Change from virgin oil to re-refined oil in 4.500 vehicles saves 18.000 litres and \$1.300/year**

US Postal Service is using re-refined oil-based lubricants in more than 100.000 vehicles (more than half its fleet). USPS also implemented a closed loop-recycling program, whereby its used oil is collected, re-refined, and sold back to the service. After numerous vehicle miles, chemical analyses of re-refined and virgin oil samples taken from USPS vehicles showed that using re-refined oil was no different than using virgin oil-based lubricants. The Santa Ana, California, USPS district uses a closed loop system for re-refining used oil. In its fleet of nearly 4.500 vehicles, the district uses more than 22.000 quarts of motor oil per year and saves more than \$1.300 each year by re-refining its used oil. Some CEOs had the constraint that re-refined lubricating oil is more inferior to new lubricating oil. The fact is that re-refined oil is subject to the same stringent refining, compounding, and performance standards as virgin oil. Extensive laboratory testing and field studies conducted by the National Institute of Standards and Technology (formerly the National Bureau of Standards), the U.S. Army, the U.S. Department of Energy, the U.S. Postal Service (USPS), and EPA concluded re-refined oil is equivalent to virgin oil, passes all prescribed tests, and can even outperform virgin oil. The American Petroleum Institute (API) has licensed qualified re-refined oil products.

1.2.2 Technology change

The second category is technology change, which can be divided in:

- Replacement of the technology: new (chemical) process technology and new equipment technology in order to minimise waste and emission generation during production.
- Equipment modification: modify the existing production equipment and utilities in order to run the processes at higher efficiency and to lower waste and emission generation rates. Improved equipment lay-out and increased automation.
- Better process control: modify operational procedures (pH, T, Flow, Pressure, Dosing etc.); equipment instructions and/or process record keeping in order to run the processes more efficiently and at lower waste and emission generation rates.

 **Measuring equipment and optimization of cleaning saves 23% on cleaning agents and \$30.000/year**

Campina Melkunie is a dairy company that produces milk products. The plant in The Netherlands identified a significant source of product loss from the cleansing of pipes and machines in the 'custard preparation' and 'product filling' units. After installation of measuring equipment the conductivity and the temperature of the rinse water was lowered and the cleansing program was shortened by 20 minutes. Campina Melkunie saved with this process control option 23% on cleansing agents and US\$ 30.000 annually. The investment was ca. \$ 1.000.

1.2.3 Good operation practises

The third category is taking appropriate managerial and operational actions to prevent leaks and spills and to enforce existing operational instructions. This category usually has strong effects without investment. It's known that over 50% of waste can be avoided by simple management measures and minor process changes! And in addition: over 65% of the barriers to Cleaner Production involve human motivation and attitudes!

Good operational practices start with an efficient production planning and a well-planned maintenance programme for all equipment and facilities.

Energy management is an important focus area of good operations. Especially preventing a high peak in energy consumption can save money in terms of tariffs and in terms of high peak load equipment. And of course prevention of unnecessary power consumption through switching off equipment (light/heaters) when not in use will add significant savings.

Finally management should develop proper working instructions and procedures with and for the operational workers and provide a proper training programme with interesting incentives.

The operational workers themselves have to bring into practice the procedures and instructions at the work floor on a day-to-day basis. Especially those on efficient process control; they have to react adequately on any signal given by the process control system.

Proper maintenance and cleaning of the process and manufacturing equipment should be a day-to-day routine, resulting in a clean and tidy workplace.



Recording oil consumption and prolonging periods between oil changes saves \$3.000/year

For the metal company B&S, metal scrap and lubricating oil were set as areas of priority. As feasible option, B&S calculated that the renewal period for lubricating oil in their machines could be extended from 250 to 400 hours without any technical implications. The reduction: 30% and a cost saving of \$3.000/year.



Waste and wastewater minimisation reduces 41% on waste, 8% on waste water and saves \$800.000

Nestlé's Danville, Virginia factory is a medium-sized factory with 480 employees. It produces approximately 25.000 tonnes per year of refrigerated products, including filled pastas, sauces and cookie/brownie dough. In 1996, the factory introduced an environmental management system (EMS). A diverse team of factory and corporate personnel carried out the work. In the first year of EMS implementation, the factory reduced solid waste by over 10%, resulting in savings of \$370.000. Wastewater impact and concentrations were reduced by 8%. Total factory savings now exceed \$800.000 and solid waste has been reduced by 41%. The success at Danville was made possible through the dedication of the factory employees, supported by a strong emphasis on training and awareness.

1.2.4 Product modification

The fourth category is the modification of the product characteristics in order to minimise the environmental impacts of the product during or after its use (disposal) and/or to minimise the environmental impacts of its production. This implies:

- Eco-Design;
- Product Life Extension;
- Environmental friendly packaging.



Redesign with use of potato starch creates a 100% biodegradable ergonomically high tech product

The introduction of potato starch to replace plastic is the result of collaboration between the German firm BIOTEC and Dutch manufacturer De Ster, who sells disposables worldwide. For the first time this unique material has been used in a product which replaces conventional plastic with its cheap 'campsite image' by an ergonomically, high-tech product. Potato starch is a biopolymer with the same properties as conventional plastics. In the manufacturing process the material can be treated like plastics, for instance subjected to normal injection moulding techniques. With these disposables a biodegradable product made from an agricultural raw material is completely reusable as compost. A new generation of biopolymers, which can be recycled into cattle-fodder, are currently being developed. Used in airplanes instead of metal flatware and china tableware, it saves 300kg weight per flight and eliminates dishwashing.



Replacing round yoghurt packing for cubic packing saves 20% energy and 25% tray material

In each phase of the product chain a designer can play an important role. An example is the alternative wrapping design for the yoghurt packing of dairy company Mona. The old wrapping was a round plastic cup and was re-designed to a cup with two flattened sides. This half square cup makes it possible to put 8 cups in a tray instead of 6 round ones. This space saving results an energy saving of 20% on production and transport. In addition 25% of tray material is saved (app. 100.000 kg/year). The supermarkets adopted the new cups with enthusiasm because of space saving and improved presentation in the display. The product itself remained unchanged.

1.2.5 On site re-use and recycling

The last category is reuse of the wasted materials in the same process or for another useful application within the company. In this category also transforming waste into a useful by-product can be considered, for example to be sold as input for companies in another business sector.

The category can be divided in:

- On site recovery and re-use of raw materials in the process; waste water and cooling water; waste heat;
- Transforming waste into an useful by-product;
- Waste segregation and storage.



No industrial growth without water recycling in Shanxi Province China

With additional water, annual industrial output in Shanxi's is projected to increase by 75% between 1993 and 2000. Without additional water, output is likely to stagnate near current level.

Not surprisingly, Shanxi industries have put a lot of efforts in water recycling. In 1980 the average output value per cubic meter of water was 22 yuan. By 1990 this had risen to 48 yuan, and by 1994 it reached 75 yuan.

Soon, Shanxi industries surpassed nation-wide recycling goals for 2000, achieving an 84 percent recycling rate in 1993.

In recent years most investment in Shanxi industries went toward increasing the productivity of water. Still, water remains the main barrier on industry. It is estimated that industrial output in 1993 could have been 6.5 billion yuan greater (22% more) had there been no water shortage. Factories periodically have to shut down when water is not available.

Source: Clear Water, Blue Skies, China's Environment in the Next Century, China 2020 Series, The World Bank, 1997

1.3 The profits of cleaner production

Cleaner Production can create mutual *company and governmental benefits* to save the environment and improve the living conditions and at the other side to increase the financial performance: people, planet profit.

Cleaner Production measures leads to:

- Reduced costs on resources: Cleaner Production options can reduce the material-, energy- and water consumption per product, and increase savings made on the costs of these natural resources.
- Reduced costs for treatment of waste and emissions: the costs for processing waste streams (including solid waste, wastewater, and air emissions) will increase in the next future. Minimizing waste streams and a pro-active compliance with laws and regulations can save money.
- Improved production: Most often, with environmental measures, the efficiency of production processes will increase as well, resulting in higher levels of production output, or improvement of the product quality.



Making money with Cleaner Production without investments

Cleaner Production has proven to be an extremely cost effective approach for China's industry. 29 Cleaner Production assessments were for instance undertaken in food processing, chemical, metal and textile dyeing sectors in a joint project of SEPA, World Bank and UNEP. The assessments resulted in pollution reductions averaging 30-40 % in the audited processes and in some enterprises even reaching a maximum of 95% (!). These reductions required no or little investment (only improved operation and maintenance practices) and were very profitable with annual savings of US \$ 2.9 million.



Making money with Cleaner Production with investments

Technology changes require larger investments. The same 29 plants could save more than US \$ 215 million a year for a once only investment in environmentally sound manufacturing technologies of US \$ 200 million.

China can achieve further savings through further structural shifts toward high value-added and low energy-intensity products and through industrial modernisation. Technological progress can further improve industrial efficiency significantly. It has been estimated that about 20% of current coal consumption could be saved if new technologies were adopted in the power and industry sector. Investing in these technologies would generate high returns from saved energy costs and avoided emission control costs.

Cleaner Production usually:

- Reduces long-term liabilities which companies can face many years after pollution has been generated or disposed at a given site;
- Increases profitability;
- Lowers production costs;
- Enhances productivity;
- Provides a rapid return on any capital or operating investments required;
- Increases product yield;
- Leads to the more efficient use of energy and raw materials;
- Results in improved product quality;

- Increases staff motivation;
- Relies on active worker participation in idea generation and implementation;
- Reduces consumer risks;
- Reduces the risk of environmental accidents;
- Is supported by employees, local communities, customers and the public.

Cleaner Production often:

- Avoids regulatory compliance costs;
- Leads to insurance savings;
- Provides enhanced access to capital from financial institutions and lenders;
- Is fast and easy to implement;
- Requires little capital investment.

<input checked="" type="checkbox"/> Benefits of Cleaner Production	
Financial and economic benefits	<ul style="list-style-type: none"> • Integrated economic benefits due to reduction of waste and emissions and the related fees and treatment costs, reduced material and energy consumption, increased product output and improved product quality. • The economic benefits can be made clear by implementing low/no-cost options. This will enhance the trust and confidence in implementing feasible medium/high cost options.
Production benefits	<ul style="list-style-type: none"> • Increased process and better production reliability due to technological improvements to minimise waste/emissions and energy consumption. • Increased product output and improved product quality also due to technological improvements. • Possibly increased health and safety situation as spin-off of Cleaner Production measures, i.e. by reducing the use of toxic and hazardous components.
Environmental Benefits	<ul style="list-style-type: none"> • It is the international and national-level trend to regulate environmental protection of the industrial sites. The following environmental benefits therefore should be considered on both levels: <ul style="list-style-type: none"> • Decreased water pollution (COD, BOD, TS, SS, N, P): e.g. bio-diversity, but also access to drinkable water and irrigation water, • Decreased air pollution (NOX, SO2): e.g. global warming and climate change, but also health conditions (smog) in the major conglomerations, • Decreased generation of solid and chemical waste, improved living conditions of neighbouring communities and animal species. • Cleaner Production is a systematic method to recognise and solve environmental and financial problems and aims to achieve ongoing improvement of the company's sustainability and the continuous improvement of its technical and managerial processes.
Corporate image improvements	<ul style="list-style-type: none"> • A recent trend in the industry world-wide has been to promote environment-friendly corporate image, as to improve general image of the company and to gain competitive advantage, • Also, the company's management can choose to take its social responsibility towards the neighbouring communities to improve their living environment, • The businesses have responsibility to contribute to solving international social issues, e.g. fair trade, abolishment of child labour, deforestation, climate change, etc. • Improved communications and relationships with authorities will make the enterprises less liable to fines, rigid attitudes, closure and obligatory abatement technology purchase, • It has, obviously, a positive impact on improving the qualification and skills of employees.
Technology Improvement	<ul style="list-style-type: none"> • Implementation of new technologies and equipment, and adoption of sustainable, environmental technologies introduces technical innovation in an enterprise. • The latest worldwide technologies ("state-of-the-art") can be achieved through the Cleaner Production Assessment, using benchmarking and assistance of (inter) national experts.
Management improvements	<ul style="list-style-type: none"> • Management focus on employee's welfare tends to lead to increased employee participation and commitment. • Responsible care of the management includes: <ul style="list-style-type: none"> • Demonstrate interest in improving working conditions, safety and health, • Assure the working place is clean and appropriate, • Maintain clean cloak, shower and bath rooms, • Supply proper tools and protection devices, such as eye, ear and respiratory protection and appropriate clothing (boots, helmets and coveralls), • Stimulate personal and employee's family interest in environmental and health issues.

Summarised Cleaner Production options makes companies more profitable, more environmentally friendly and more efficient. Cleaner Production can be seen as a four-in-one tool:

- A management tool;
- An economic tool;
- An environmental tool;
- A quality improvement tool.

1.4 The barriers for cleaner production

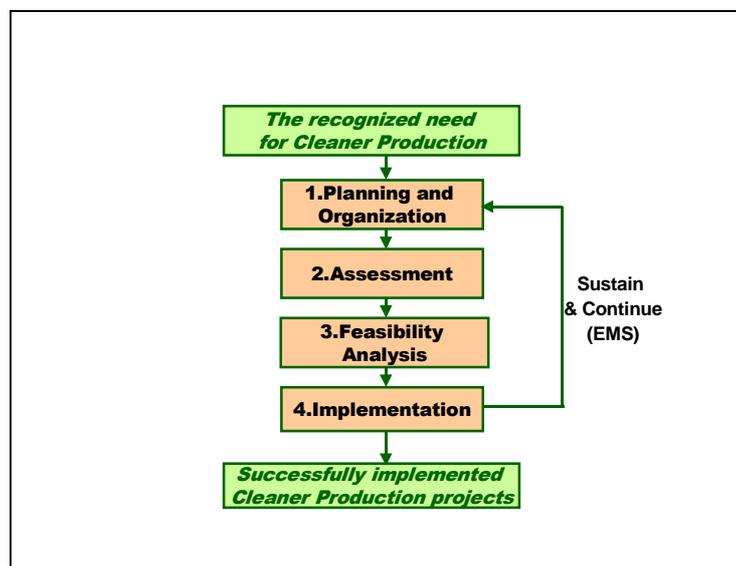
The barriers, which can frustrate the Cleaner Production process, are:

- The business philosophy or environmental attitude of CEOs: that environment will only costs money; that there is a lack of finance, manpower and time; that special experts (and knowledge) are needed to organise and implement Cleaner Production options in the company and; that only technical innovation reduces waste and emissions.
- Initial constraints due to internal organisation and communication: gaining management support (see above); setting up a project group; limited awareness on waste and emissions; limited authority for Cleaner Production; indifference on the working floor etc.
- Limited adequate information, data and expertise on the waste and emissions and the related costs within a company: bookkeeping is financial figures oriented (credit/debit), not material flow oriented; financial figures are not related to environmental costs; material and financial data are purchase and sales oriented, not waste and emission oriented.
- Focus on end-of-pipe solutions: by governmental laws and regulations; by licensing and control authorities; within the compliance framework of ISO14000; by technology suppliers.
- Inadequate cost/benefit accounting of Cleaner Production options against end-of-pipe costs: no calculation of material saving benefits; no full calculation of product value losses in waste streams; no full calculation of waste and emission treatment and management costs, apart from levies and fines; no calculation of externalized costs (burden on society) etc.
- Missing or unreliable process control: lack of information on pH, T, Flow, Pressure, Dosing etc.; no record keeping and monitoring systems; no equipment instructions.
- Lack of information and expertise and low environmental awareness in middle management; lack of communication in firms; labour force obstacles; competing business priorities, in particular, the pressure for a short term profits.
- No management system to formalise improvements and changes made in the production process and no internal policy framework or legal basis for continuation.
- Difficulty in accessing external finance; no availability of investment capital; a negative attitude of financial institutes, funds and banks and other financial obstacles.
- Difficulty in accessing cleaner technologies.

To avoid or to overcome barriers and to guarantee a successful implementation, Cleaner Production calls for an organised approach.

1.5 Cleaner production approach

Cleaner Production should be organized by a systematic approach, informing the necessary stakeholders within the company and bringing together those persons who can develop, evaluate and implement Cleaner Production opportunities. The step-by-step approach, consisting of four phases, is based on the model used by UNEP.



1.5.1 Planning and organisation

After the recognized need for a change towards Cleaner Production, this phase prepares the organisation for the execution of the Cleaner Production assessment and the managerial changes. The steps to be taken are:

- Obtaining (further) management commitment;
- Organising a project team;
- Identifying possible barriers and solutions by a (time limited) pre-assessment;
- Setting strategic objectives;
- Pre-assessing the focus areas for an (in-depth) assessment.

1.5.2 Assessment

The pre-assessment in the first phase will set the focus for the assessment. During the assessment the causes of waste in the selected unit(s) will be researched in detail. As Cleaner Production focuses on the manufacturing processes that inefficiently use raw materials and generate waste, the central element of this approach should be to assess the manufacturing processes and to find the real big opportunities. In manufacturing processes often only 20% of the operations causes more than 80% of the waste. The challenge is to find this 20% by:

- Identifying sources (where): an inventory should be made of the input, throughput and output of material and energy flows, together with the associated costs. This results in a *process flow diagram* (see figure);
- Analysing causes (why): an investigation of the factors that create the volume and composition of the waste and emissions;
- Generation of options (how): to create a vision on how to eliminate or control the identified causes. This results in options and measures for the five categories of Cleaner Production: change of input materials; technology change; good operation practices; product modification; on site re-use and recycling.

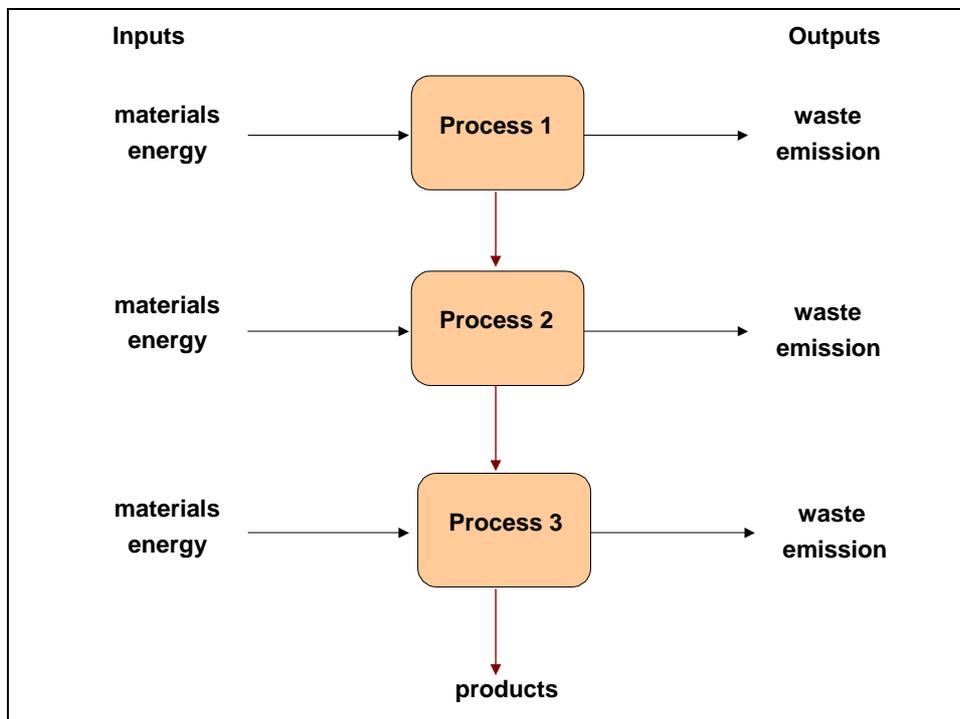


Figure: process flow diagram

1.5.3 Feasibility analysis

When the real opportunities are assessed and options are identified, the next phase is to study the technical, economical and environmental feasibility of the mid and high cost options.

The steps to be taken are:

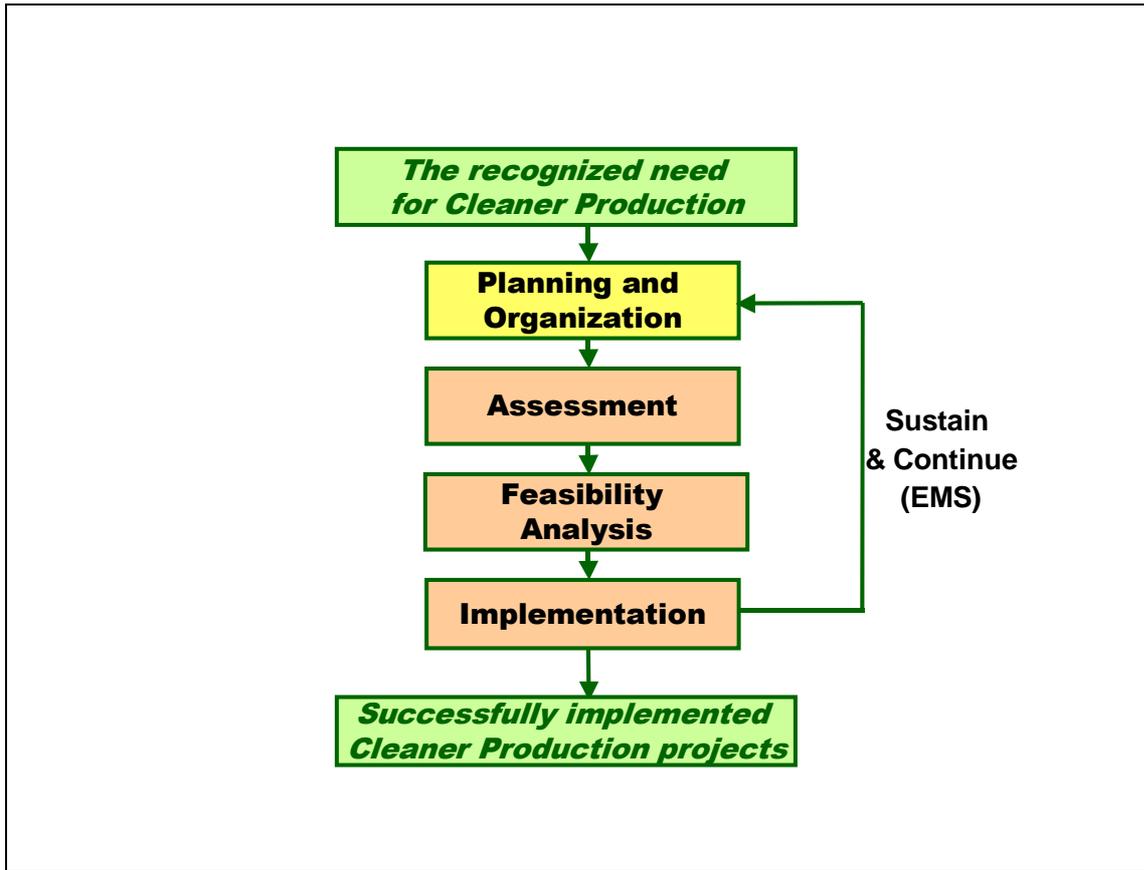
- Screen options technical, economic, environmental;
- Prioritise and select best options.

1.5.4 Implementation

Finally, the feasible options and managerial changes are implemented and integrated into the daily processes. The steps to be taken are:

- Option implementation;
- Monitoring and evaluation;
- Sustain and continue (EMS).

Each phase will be explained step-by-step in the next chapters.



 Planning and organization	
Steps to be taken	Expected results
1. Obtaining management commitment and participation	<ul style="list-style-type: none"> • Commitment and participation of the management
2. Organizing a project team	<ul style="list-style-type: none"> • Leading team and assessment team organized and empowered
3. Identify possible barriers and solutions	<ul style="list-style-type: none"> • Barriers identified and overcome • Employees informed and empowered
4. Setting objectives	<ul style="list-style-type: none"> • Tangible and SMART targets set on strategic level
5. Pre assess	<ul style="list-style-type: none"> • General description of the company • List of unit operations and interrelations between them • Process flow chart and identified waste streams and material, energy and water consumption • Survey of pollution and resource consumption • List of possible focuses • Assessment or area focus selected • Obvious options implemented • Assessment plan made and accepted by CEO

2 PLANNING AND ORGANISATION

■ *Planning and Organization is the first phase in the Cleaner Production approach. It forms the base for a Cleaner Production assessment. It will make the management and selected employees understand: What Cleaner Production is about; Why Cleaner Production is beneficial for the company; How to overcome the barriers resulting from personal attitudes; How to get a general view on the contents, needs and procedures of Cleaner Production and; How to select focus areas for an assessment. The major steps in this phase include: Obtaining management commitment and participation; Selecting team members and organizing an empowered Cleaner Production assessment team; Disseminating the concepts of Cleaner Production in order to overcome barriers within the company's organization; Pre-assessing the present situation; Selecting the focus areas which covers the main sources of pollution and inefficient environmental and energy operation; Drawing up an assessment plan.*

In this chapter questions will be answered as:

- *How to gain commitment and support from the management/CEO?*
- *Who needs to be involved in the Cleaner Production team?*
- *How to communicate Cleaner production to other employees?*
- *How to pre-assess the environmental aspects and impact?*
- *How to select and to prioritize an assessment area?*
- *How to set targets?*
- *How to make an assessment plan?*

2.1 Obtaining management commitment and participation

Without support from the top management a Cleaner Production assessment will fail in an early stage. Gaining top management commitment is a fundamental step in making it work. Top management commitment will be needed:

- To give Cleaner production importance within the organisation;
- To involve all employees and departments needed for a Cleaner Production assessment;
- To provide necessary resources;
- To approve organisational changes needed;
- To encourage a consistent approach of Cleaner Production throughout the organisation.

Both the top management and the line-managers of departments on different levels in the organization, will be interested in the benefits of a Cleaner Production assessment. Possible benefits, other than environmental benefits, include financial and economic benefits, productivity benefits, technological and management improvement. Cleaner Production assessment can contribute in a substantial way to strengthening the company's competitiveness in the market.

In addition, due to the rising influence the stakeholders (banks, NGO's, shareholders, environmental organisations) upon businesses, it is important for a company to adopt Cleaner Production. These benefits should be made clear to the top and the line managers (see box: 'benefits of Cleaner Production' in chapter 1).

The best way to convince the top management of the value of Cleaner Production is to focus on cost reduction. On the long term Cleaner Production will save costs comparing with the more traditional 'end of pipe technology' (see also chapter 1). Initially the costs will be a bit higher due to investments on process control and organisational changes, but the improved efficiency will pay back the investments soon.

A certain amount of inputs will be required to achieve positive results of the Cleaner Production assessment:

- Required working hours for team members;
- Budget for monitoring devices and expenses;
- Expenses due to assessment report;
- If necessary, costs for involving external experts.

However, these inputs are minor comparing with all the benefits that Cleaner Production tends to bring.



 Checklist 1

2.2 Organising a cleaner production project team

A multidisciplinary team, representing all relevant groups within a company, performs the Cleaner Production assessment.

In order to obtain a successful Cleaner Production assessment outcome, the right employees must be selected and the mid- and higher level management should be involved.

We distinguish:

- The leading team;
- The assessment team;
- The facilitator.

2.2.1 Selecting the leading team members

The leading team includes members of the company's management team or other (high level) staff member(s) with a decision-making authority.

The number of members of the leading team depends on the size of the enterprise and the organisation structure but a maximum of three is advised.

The role of the leading team is to:

- Initiate the Cleaner Production assessment;
- Support the Cleaner Production assessment;
- Nominate the Cleaner Production team members;
- Define the role of the facilitator;
- Support and stimulate the Cleaner Production assessment team;
- Set goals for the assessment plan;
- Assign small budgets to the assessment team to cover low cost options and monitoring devices;
- Manage implementation of the feasible Cleaner Production options.

The members of the leading team should jointly have the following characteristics:

- Committed to improve the efficiency, highly motivated.
- A basic knowledge of the principles and technology of waste/emission prevention and energy-efficiency.
- Familiarity with laws and regulations in the area of environmental protection.
- Understanding the assessment process and being familiar with team members.

Leading team	Position in company	Possible roles
Team leader	Director of the company	<ul style="list-style-type: none"> • Organise & facilitate assessment team • Set objectives • Coordinate CP implementation • Review the assessment reports
Vice leader	Chief engineer	<ul style="list-style-type: none"> • Support CP assessment plan • Responsible for CP assessment & implementation
Member	Deputy director	<ul style="list-style-type: none"> • Responsible for CP option generation and implementation

Box: example of leading team members and roles

As the leading team is responsible for the decision-making and the outcome of the Cleaner Production assessment it is important that the tasks of both the leading and the assessment team are well understood.

 Worksheet 1, Checklist 1

2.2.2 Selecting the assessment team members

The number of the team members should depend on the size of the company and should reflect all groups interested in the outcome of a Cleaner Production assessment. Usually, there are three to five full-time staff members in a team.

The team can consist of employees of engineering-, environmental-, sales- and maintenance departments, and an operator or production supervisor.

Temporarily, other employees can be invited to join the team. At least one employee of the financial department (e.g. cost estimator) should also form part of the team. Furthermore, experts from outside the company can be added to the assessment team.

The tasks for assessment team include:

- Establishing Cleaner Production goals;
- Drawing up a working plan;
- Initiating participation and training;
- Identifying assessment focus and goals;
- Performing assessment;
- Selecting suitable options for implementation;
- Monitoring and supervising the implementation of low cost options;
- Writing the assessment report and providing feed back to leading team;
- Making conclusions and providing proposals for continuous Cleaner Production.



The joint qualifications of the team members are:

- A basic knowledge or working experience on Cleaner Production assessment.
- Thorough understanding of the production process, used technologies, management procedures and the new-tech information.
- Familiarity with the issues of waste- and emission generation, treatment and management.
- A basic knowledge of the national and regional legislation, regulations and applicable policies.
- Creativity in order to solve problems using various tactics.
- Highly motivated to overcome barriers and to implement the full range of methods available to assure success of the assessment.

Assess-ment team	Position in companv	Possible roles
Team leader	Chief engineer	<ul style="list-style-type: none"> • Organise team & assessment plan • Coordinate assessment activities • Review/approve assessment report • Report to leading team
Member	Department leader	<ul style="list-style-type: none"> • Collect & analyse information/data • Initiate participation and training • Identify assessment focus & targets • Option generation & implementation
Member	Production unit	<ul style="list-style-type: none"> • Idem
Member	Sales unit	<ul style="list-style-type: none"> • Idem. incl. financial feasibility
CP expert	External	<ul style="list-style-type: none"> • Provide methods and tools

Box: example of assessment team members and roles

 Worksheet 1, Checklist 1

2.2.3 Selecting a facilitator

An external facilitator, i.e. the Cleaner Production-auditor or external consultant, can be included in the team to organise the process of Cleaner Production assessment, to encourage creativity and to provide input for the reports and feedback to the leading team. The advantage is the independent and non-political role of such a facilitator, which leads to more support on all company levels involved. Also, a person from the company itself can act as facilitator, provided that this person has no conflicting interests and remains objective throughout the process of the Cleaner Production assessment.

2.3 Identify possible barriers and solutions

Possible barriers (obstacles) for Cleaner Production success in the company must be identified and overcome, prior to the start of the assessment. In the next box some of them are listed.

<input checked="" type="checkbox"/> Possible barriers	<input checked="" type="checkbox"/> Possible solutions
Prejudicial attitudes of workers and management	Avoid misunderstandings and present Cleaner Production as a challenge and a beneficial activity.
Hierarchical organisation structure	Involve the employees and stimulate two-way communication.
Poor plant equipment, technology and process control	This is generally not a limit to adopt cleaner production. However, it must be possible to measure flows, emissions and analyse toxic concentrations. Stress the importance of good control and improved understanding of the production processes.
Shortage of information	Use purchase and sales data, collect data elsewhere (other companies). Be creative in information gathering.
Poor economic performance of the company	Evaluate the economic aspects of waste management and decrease of discharge and treatment fees.

Most of the time, the identified barriers are based on communication and participation, caused by a lack of information, lack of involvement or wrong attitudes. Therefore, information about Cleaner Production assessments, its objectives, backgrounds and results, need to be disseminated to the relevant managerial levels and employees within the company.

It is of vital importance to obtain support and involvement of top management. However, significant achievements cannot be assured without involvement and participation of personnel on all levels: middle-level cadres, on-site staff, and specialists.

Cleaner Production Assessment can only be carried out successfully and continuously, when the Cleaner Production concepts are self-consciously embedded into the operational practices in all departments throughout the company. Only on this way, Cleaner Production Assessment can bring about substantial economic and environmental benefits, in a structural way.

The contents of Cleaner Production Assessment dissemination and training shall be modified according different stages in Cleaner Production assessment and according to the target group.

In this phase, it is essential to obtain the commitment of the top management, which can be demonstrated through empowering the assessment team, assigning the necessary financial resources, widespread information distribution and two-way communication.

The assessment team and the leading team can use the following dissemination tools:

- Regular corporate meetings at all levels;
- Official documentation on Cleaner Production Assessment;
- TV, video tapes;
- Bulletin board (blackboard);
- In-company seminars, workshops and training courses;
- On-site consulting.

The following topics should be included in the dissemination activities:

- How does management (high/mid/low) and employees affect the generation of waste;
- The concepts of Cleaner Production;
- The advantages and disadvantages of Cleaner Production compared to end-of-pipe treatment;

- The case-studies and practical examples of other (inter)national companies;
- The obstacles in the process of organising and execution of Cleaner Production assessment, and how to overcome them;
- The activities, contents and requirements of Cleaner Production assessment;
- The incentive of promoting Cleaner Production assessment in the enterprise;
- Expected results of Cleaner Production assessment for each department of the company and the specific practices required;
- Cleaner Production options generated and the possible benefits and implications.

 Checklist 1

2.4 Setting objectives

After the assessment team is established and the employees informed, the next step to an assessment plan is the formulation of strategic objectives. Setting the assessment objectives should be done by the leading team and included in the Assessment Plan later on.

Depending on the company's situation, we distinguish:

- Short term (e.g. compliance with regulations, achieving performance of similar enterprises, improved housekeeping, improved maintenance);
- Long term strategic goals (e.g. phase-out of certain toxic components, introduction of new products).

The formulation of an objective is always based on change. For personal behavior the change can be in knowledge, attitude or behavior (KAB). For products and processes the change can be in tons, kwh, m3, quality measures etc.

In addition a good objective must also contain a quantitative element and a deadline to make them accountable. Quantified outcomes can be expressed in various ways: Percentages; Amounts of money; Number of people involved; Number of options to be implemented, etc.

So formulate objectives in a SMART way:

- Specific and supported by the enterprise management (kiss-formula: keep it stupidly simple);
- Measurable; what need to be changed (qualitative) and how much (quantitative);
- Achievable; take small steps;
- Realistic;
- Timed (deadline).

2.5 Pre-assessment

The objective of the pre-assessment is to identify the focus for the real assessment. In this phase a general overview of all production processes is made, following by a strategic choice for further assessment of one or more production units.

2.5.1 Investigate the present status

The pre-assessment starts with collecting data and information that is available in the company, in order to obtain a general overview of the company. The required information and data can be obtained from different sources within the company, like:

- Historical data (annual reports);
- Baseline data (operations manuals, Purchase and sales records);
- Performance indicators (in sector);
- Process flow chart (see further).

The investigation should include all processes and operations within the company, where materials and energy are used and waste materials and emissions are generated.

Finally, a rough estimation of the quantities of raw material, (side) products, energy, waste and emissions consumed and/or produced by each process, facility or unit is made.

- In general, the following questions should be answered:**
 - What are the company's current processes and activities?
 - What is the environmental and economic performance of the company?

2.5.2 Perform on-site investigation

During pre-assessment a general investigation of the entire work floor and the company's site is performed. The assessment team and/or external Cleaner Production consultants will collect practical information about the enterprise and the unit operations.

During the investigation a complete list of unit operations should be made. A unit operation can be defined as a part of the process or a piece of equipment where materials and energy are used, a change occurs and materials (including waste and energy) are produced at the output side. The site investigation should result in a clear understanding off all unit operations and the interrelationships between them.

The site investigation should be scheduled when most unit operations are functioning under the normal operating conditions. In addition to the core operations of the unit, other supporting activities, such as repair, maintenance and cleaning, should be considered.

It is recommendable to start the site investigation at the raw material (storage) and end it at the final product handling and discharge point(s).

During the investigation, it is important to interview the employees on the work floor in a constructive way, in order to collect the necessary information. The employees have often a direct access to (informal sources of) information and can contribute ideas, which can be of great value to the assessment team. For instance, the employees can inform the assessment team about daily practices, uncontrolled spills and washouts, repeating process errors etc.

The site investigation should not only focus on the internal processes, but also on the external impact of the company's activities on their direct environment, such as neighbourhoods, aquatic resources, forests and other aspects like mobility.

At this stage, a simple input-output flow chart, made for entire operations of the company (see next paragraph) could be used as a practical tool. The main input and output data can be documented in the input-output flow chart.

The described investigation is not meant to deliver an in-depth analysis of the process, but to select the assessment focus and to set targets. No detailed data collection is required in this phase.

On site investigation is needed due to the following reasons:

- Processes, equipment and pipelines may have been adjusted, changed or renewed several times and may not be shown in a current form on the schematic drawings.
- Actual operations and process control are usually different from the original design and procedures.
- Important characteristics of the company, concerning maintenance, housekeeping, operational practices, etc, can only be examined by means of a site visit.
- It is also important to identify the material handling operations covering transport and storage of (raw) materials and products.
- The energy supply provided by boilers, etc. should also be identified.

2.5.3 Compile a process flow chart

A simple input-output flow chart can be of help to select the area focus. The list of unit operations can serve as a starting point for the compilation of the process flow chart (see figure).

The process flow chart has to indicate the relevant processes and input and output flows. Also the sequence and influence on other unit operations must be made clear, e.g., recycling streams. The assessment team has to decide on the level of detail that is required to achieve the objectives within the assessment. Oversimplification of the flow chart can result in loss of information and lack of understanding. For complex processes, an overview chart of the main process can be made, with separate charts for the different unit operations.

It should furthermore be helpful to incorporate aspects, which are usually not indicated on flow charts such as electricity consumption for pumps, etc. and measuring points.

Irregular operations with specific waste streams such as cleaning, maintenance, make-up or tank dumping may be distinguished by using different arrows in the process flow chart.

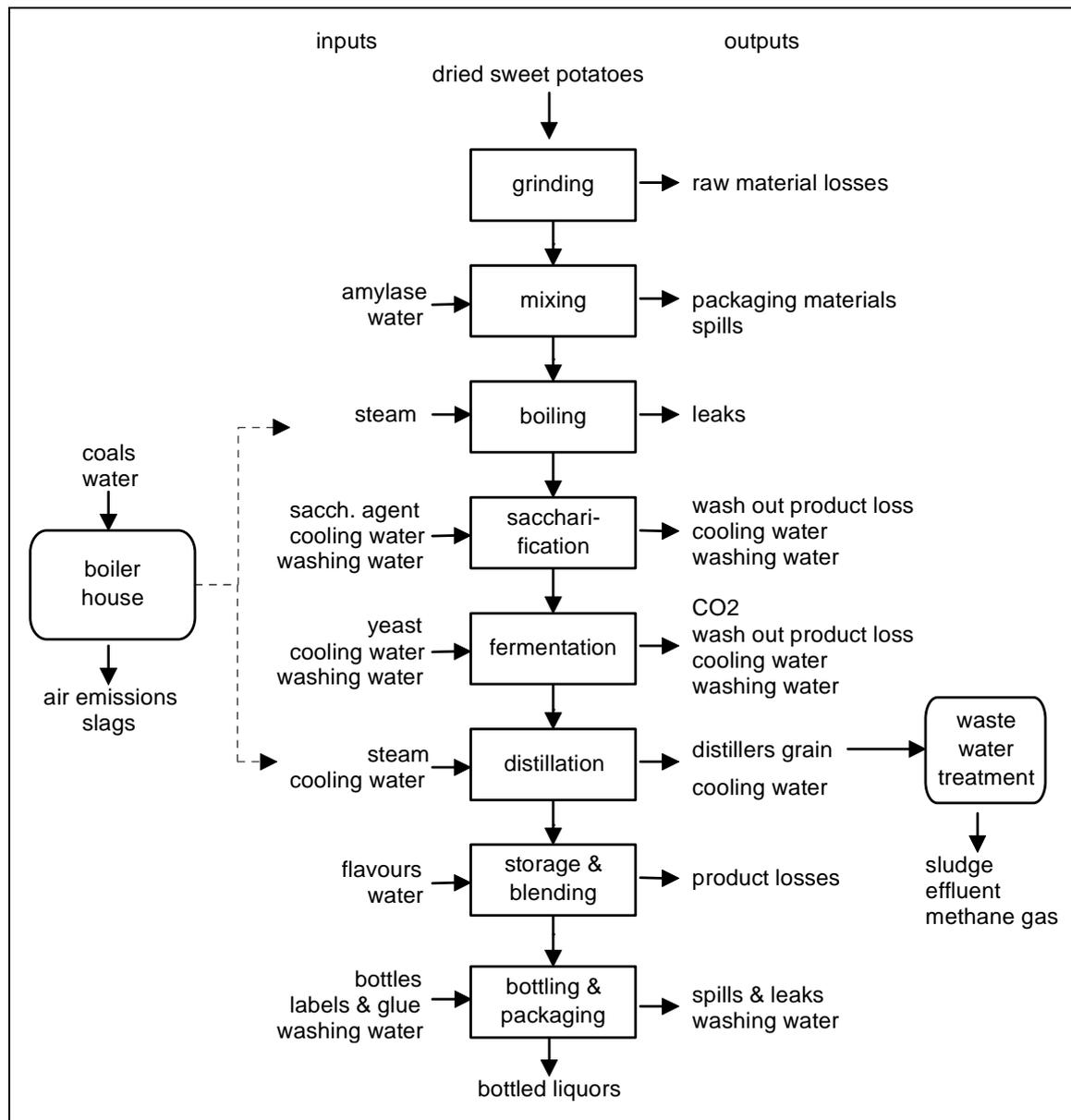


Figure: flowchart derived from an alcohol distillation

 Worksheet 2, Checklist 2

2.5.4 Selecting the assessment focus

Results of the pre-assessment are used to make a list of areas, which may be an assessment focus. An operation unit, department or other physical location can be chosen as a possible focus, as well as for energy or material flows, such as water or dust.

This evaluation is based on common sense, rather than on detailed calculation. By no means should the assessment team try to make a detailed material balance of the process or unit operation. This will be done during the next Assessment phase (phase 2).

Setting an area focus is only relevant in more complex companies. In a very simple and small enterprise, an assessment focus might be not necessary. In this case the complete site will fall within the scope of assessment.

In general, units with a high potential for Cleaner Production are units with high production costs, low efficiency, high waste generation and high material and energy consumption per product.

In case of limited financial and human resources and complex production processes one or two area focuses can be selected for the assessment. The above considerations may help to make justified and conscious selection of the most favourable areas for the assessment.

Choose for processes or unit operations that:

- Are less efficient compared to processes of similar companies (benchmarking);
- Generate high disposal costs for specific waste materials;
- Use extensive and expensive raw material and energy inputs;
- Loose a lot of material and energy at the output side;
- Have high economic and financial losses (including unexpected costs such as break-down, maintenance);
- Bring risks to human health and the environment;
- Have a high amount of (obvious) cleaner production options expected within the area;
- Have a high management commitment for bringing improvements into operation.

 **Worksheet 3, Checklist 2**

2.5.5 Set cleaner production targets

As soon as the focus is chosen, one or more specific targets should be set on which the improvement strategies will be based. The use of quantitative, measurable targets will facilitate implementation of cleaner production options. These tangible targets will also serve as a basis for the final evaluation of the results of the assessment and as a base for strategy to be developed.

In this phase the assessment team should also evaluate, whether the existing monitoring system is adequate. Data on the quantities and composition of inputs and outputs should be recorded periodically. This is important in order to make “ex ante” and “ex post” comparison and to be able to execute the assessment, where detailed data on inputs and outputs will be collected.

 **Target setting**

For example, a water consumption reduction of 10% in the present industry is not a very challenging target, because normally such a reduction can already be achieved by means of few simple measures. In the example of the breweries with water consumption level of 20 m³/m³ of beer, a short-term target can be 12m³ water/m³ beer (40% reduction) and a long-term target be 6m³ water/m³ beer (70% reduction!). Similarly, 1% reduction in consumption of raw material is insignificant, and might be caused by simple variations in production process, precision of measuring equipment, etc.

 **Benchmarking of water use in breweries**

Benchmarking is a tool, which enables us to compare the performance of the company with a similar company in the same sector, being recognised as having a better environmental or energy performance. Benchmarking can be used as a tool to give a proper orientation to the Cleaner Production assessment and to improve the company's performance. Some examples of benchmarks (or performance indicators), which can be used, are material, energy or water consumption rates per unit of final product, employee or time.

As a benchmark for the brewery industry can serve the amount of water consumed per ton beer produced. Breweries, which consume low volumes of water, may have a water consumption of 6 m³/m³ beer. If, in course of pre-assessment, we determine that the water consumption rate amounts to 20 m³/m³ beer, it can be concluded that (too) much water is used. Subsequently, water can be selected as a potential assessment focus.

General selection criteria for setting targets

- Cleaner production targets should be quantitative, operational and challenging. The targets represent absolute requirements related to (reduction of) quantity of inputs consumed and/or output reduction.
- Targets must be measurable and represent significant improvements of the environmental performance, improvements of the energy, material and process efficiency, product quality and/or health and safety situation.
- Time frame for meeting the targets should be clearly defined. Targets are usually set for a short-term or a long-term. Short-term targets can refer to the time period when the first assessment comes to the end and the assessment report is finalised (one year). Long-term targets are usually related to implementation of high-cost options (approx. 5 years).
- Short-term targets reflect the performance in similar companies with better environmental performance and long-term targets are usually based on the performance of advanced international companies in the same sector.
- Targets should be challenging in such a way that an ambitious Cleaner Production program is needed to reach them. Low targets, which are easily met by simple options or which are disappearing in the (annual) variations should be avoided.

2.5.6 Bring obvious options into operation

During the pre-assessment, some problems found in a specific site, section or workplace in the company can be solved rapidly by taking direct action. These obvious options are generally measures that do not need (large) investment, therefore referred to as non/low cost options.

The non/low cost options can be identified during the pre-assessment period, for instance during the site visit, without having to conduct a detailed analysis of the production process. The implementation of the obvious options, evaluation and dissemination of the results obtained tends to motivate the assessment team and raise the management commitment and employee support.

General obvious options are:

- Unnecessary use of lights, machines etc which can be switch off;
- Spills and leaks;
- Unmotivated personnel;
- Inadequate storage conditions;
- Inappropriate tools;
- Non-uniform distribution of materials.

Checklist 2

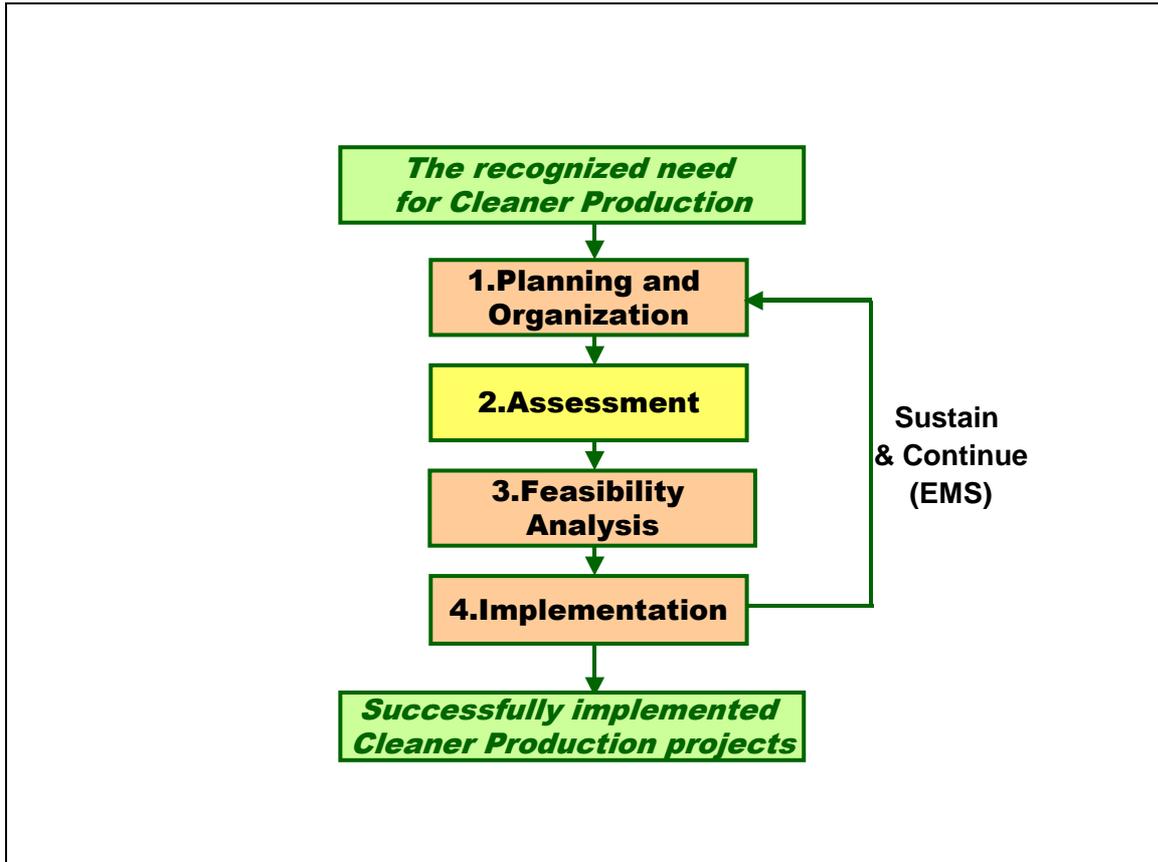
2.5.7 Making an assessment plan

A carefully designed Cleaner Production Assessment plan is needed to perform the Cleaner Production assessment according to the described step-by-step methodology.

The Cleaner Production Assessment plan should be worked out as soon as the assessment focus is set. The plan describes the targets, monitoring, the major activities, the planning, names and positions of persons in charge and the expected outputs in all phases.

Tip box

- Maintain the limited size of the audit team: 3 dedicated persons can do more than 5 equally dedicated persons.
- Don't "flood" employees/management with information but work on a 'need-to-know' and 'need-to-do' basis.
- Take the time needed to set up and execute the project but don't let attention slip away. Avoid 'starting up' your assessment over and over again.
- Keep employees involved, informed and alert.
- It is technically possible to perform an assessment without having the management fully committed; however the results will rarely rank higher than repairing leaks and reducing some maintenance backlog (which was due anyway).
- Cleaner Production cannot be implemented from behind a desk and based on theory only. The situation as perceived by office staff rarely compares to real operating conditions.
- Avoid combining the Cleaner Production assessment with activities aimed to comply with the environmental regulations. In the straggle between voluntary action (Cleaner Production) and obligatory action (compliance) the obligatory action will always prevail in the search for resources, without bringing forward clear economic benefits.
- When you are forced to comply with existent regulations, it means you have been late, and you have to allow external bodies to influence your strategy: you became a follower and not a leader.
- Implement and monitor the most obvious options, as soon as you identified them.
- Eliminate leaks, spills and maintenance backlog before starting the Cleaner Production assessment, as they are likely to influence your results and tend to create an unpleasant working environment for the audit team.
- When binding agreements are made, make sure you either comply or check whether these promises are kept. Make a clear schedule, needed to comply, in order not to be faced with unexpected delays.
- Determine your company into utilities (water, energy) and characterise them by environmental impact, economic impact and commitment to change and nothing more!
- When selecting an audit focus ensures that the commitment of the management to improve the workshop or utility is high because that is what you try to achieve change! Regard this aspect higher than waste quantity, costs, or other.
- Site visit only when the enterprise, equipment and the staff are working.
- When selecting a workshop for an assessment preferably select a workshop at the end of the process line as the loss of intermediate product is much more valuable than the loss of intermediate product at the beginning of the process line. Remember that each process adds value to the intermediate product!
- Only set a pollution reduction target if you are determined to develop a strategy to meet that target.



Assessment	
Steps to be taken	Expected results
1. Identify sources	<ul style="list-style-type: none"> Material and energy balance and wastes and consumption quantified Overview in- and outputs
2. Conduct a cause assessment causes	<ul style="list-style-type: none"> Overview of causes of waste, emissions and energy consumption
3. Generate options	<ul style="list-style-type: none"> List of generated options Benefits established and management informed List of screened options Mid term report

3 ASSESSMENT

 In the previous phase the focus area, environmental impact reduction targets and planning have been set to enable the execution of the assessment. This area focus concerns a specific area of interest, like a unit operation as an important source of pollution, or the object itself, like water reduction, energy-efficiency or reduced amounts of toxic compounds. In this assessment phase the causes of waste and poor environmental, material and energy efficiency will be analyzed in a structured way. In the assessment, the balances are compiled and the important losses of material and/or energy and wastes are determined as well as a cause analysis of the losses or wastes have been made. The following generation of options, within the assessment team, should be a creative thinking process. It is important to start from the examined cause of the specific loss or waste and to find a Cleaner Production option that directly follows from the cause. A loss of material or a waste produced can have several causes and also several prevention practices. To make sure that a complete understanding of the causes is obtained, the five cause categories have been introduced. For each cause, one or more prevention practices can be generated, also belonging to a prevention category that is methodologically linked to the cause category.

In this chapter questions will be answered as:

- How to collect data and information of the selected focus area?
- Where to start with bringing improvements into operation?
- Why is waste originated or what is the cause of the source of waste, process inefficiencies and poor environmental management?
- How to avoid waste or how to improve process efficiencies and environmental management?
- How to find more options and more alternatives?
- How to structure the options?
- How to screen and to prioritize the options?

3.1 Making the material and energy balances

In the previous phase the focus area is selected. For this focus area the *where* question needs to be answered. Where are waste and emissions generated in the focus area? Compiling a detailed process flow chart of the focus area can identify where materials and energy are used and lost! In case of the flowchart derived from the alcohol distillation (chapter 2), the selected focus area with the biggest potential of energy saving is for example the bottling and packaging unit. For this unit a specific process flow chart is made (see next figure).

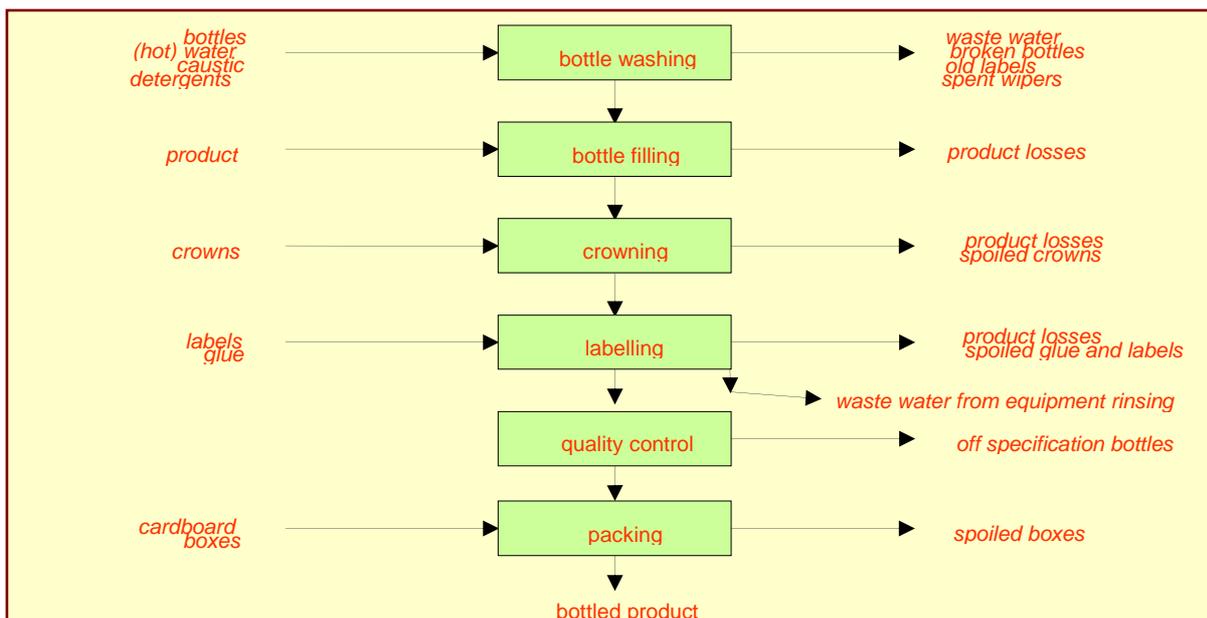


Figure: specific flowchart for the bottling and packaging unit

The process flow chart of the focus area forms the basis for the material and energy balance. During the pre-assessment, some insight in the inputs and outputs has already been gained. However, detailed information or engineering data has not been obtained yet. More data is required to examine why one or more unit operations cause problems regarding poor environmental and energy efficiency. The input and output flows, and efficiencies can also be expressed in costs (and revenues) to show the importance for making improvements. Therefore it is important to provide insight in the loss of material and energy, expressed in money terms, because it can make the management more aware and supportive. Furthermore these costs can illustrate the economical losses and thus the potential savings from the measures that can be generated in the following phase in the procedure (Feasibility analysis).

There are several direct and indirect costs components associated with waste, energy and emissions:

- Costs of raw material in waste and emissions;
- Costs of product in waste and emission;
- Costs of energy in products, waste and emissions;
- Costs of treatment of waste and emissions to comply with regulatory requirements;
- Costs of transport and disposal of waste.

When compiling the balances the material and energy balances are usually separated. This is done to simplify the assessment, however the distinction is not always that clear. For example water is regarded as a material and as such it can be included in the material balance. But when water is used for cooling purposes, it represents a certain amount of energy as well as volume (material). The same can be said for steam that (when inserted as live steam for example in pulp making) represents energy as well as mass.

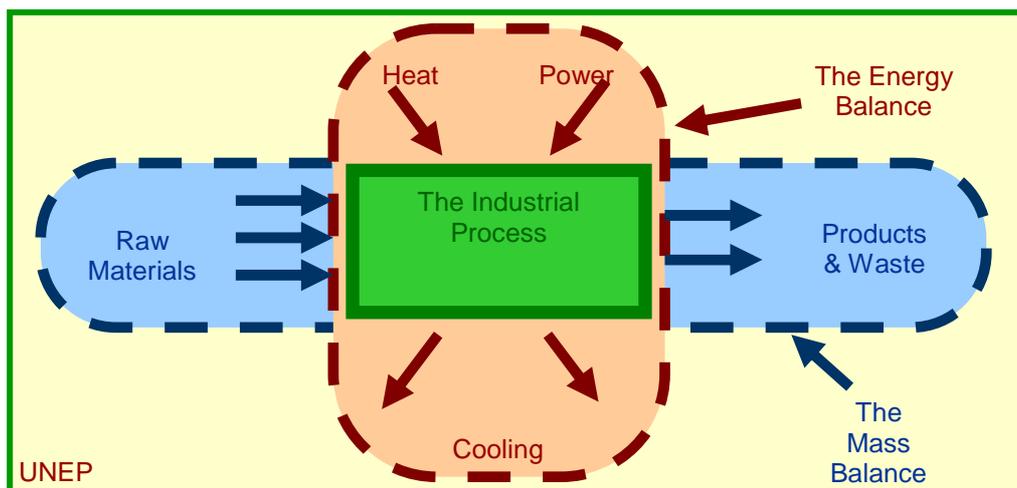


Figure: schematic material and energy balance

3.1.1 Unit operation as a basis for the balance

Before the balances can be derived, the unit operation(s) must be defined carefully. Compilation of balances is easier, more meaningful and more accurate when the balances are made for individual units, operations or production processes. An overall balance for the enterprise can be then be compiled with the balances of the individual unit operations.

As illustrated in the figures below, the unit operations can be considered as boxes and the task is to account for all the material and energy flows into the unit operation and coming from the unit operation during the period set for the calculation of the balances.

The figure below illustrates the different components of the material balance for a unit operation.

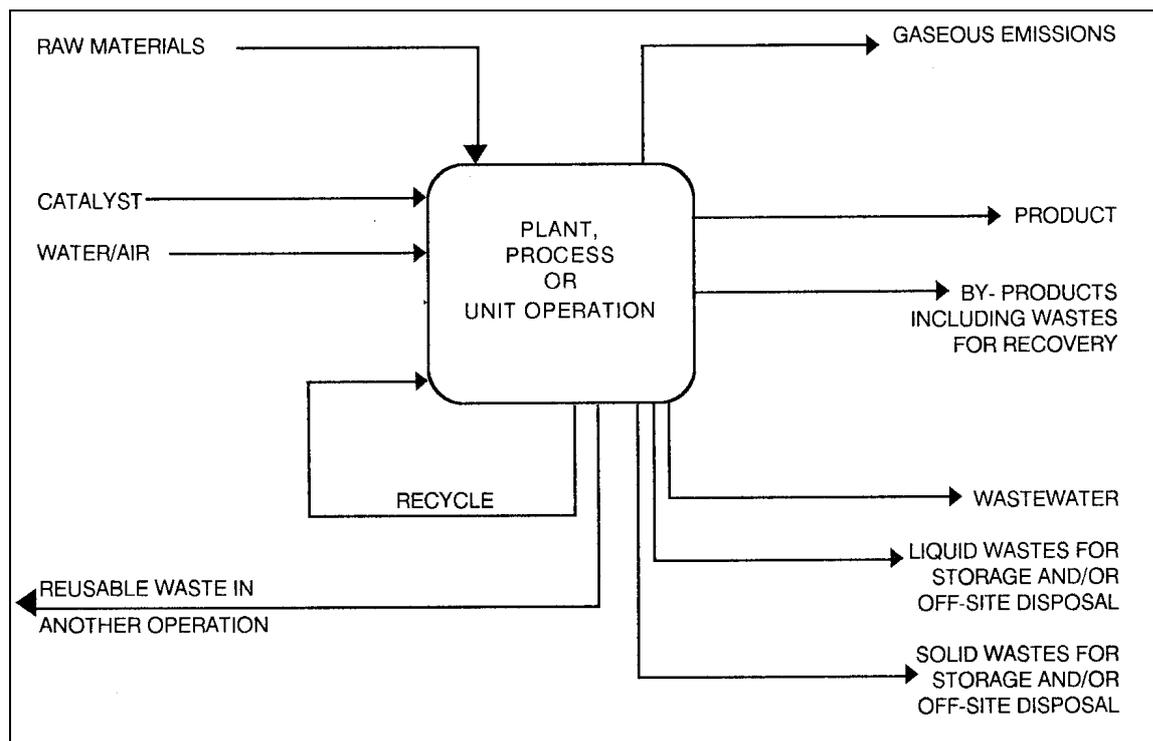


Figure: components of a material balance of a unit operation

The total sum of inputs should always equal the total sum of outputs:

What goes in must come out unless there is accumulation and conversion to another product

Output = input – accumulation – conversion

In case there is no (bio)chemical process in the unit operation, the conversion is zero. Also, for continuous processes, the accumulation can be considered zero (unless there are temporary storage tanks in the vessels). In case of batch processes the accumulation is not negligible.

When the outputs do not equal the inputs minus the accumulation and the conversion than either measurement errors are made and/or there are unaccounted flows or sues to large process variations in case the balance has been established over a time period. In this case measurements and/or the amount of different flows into and from the unit operation should be checked.

While it is not possible to lay down precise and complete guidelines for establishing the material balance boxes, the following guidelines might be useful to you:

- Use the process flow chart and fill in the inputs and outputs;
- Split up the total system and choose the simplest individual subsystem. Generally the individual subsystem is a unit operation, or an element of a unit operation. However, you can also choose a material or energy flow, depending on your assessment focus (e.g. identify where chromium is used as input and where does it end up as output in tanneries);
- Choose unit operation in such a way that the number of streams is the smallest possible.

3.1.2 The material balance

Before establishing a balance it is good to reflect on several aspects first what is the important ingredient, material, auxiliary material, utility etc. and secondly what is the accuracy of the balance and of its individual components. It is advised to always keep in mind what needs to be researched.

In the case chemical conversion occurs which produces the product such as starch converted to alcohol a starch balance can be established. The aim of this balance is then to determine the conversion efficiency, identify locations of starch loss and causes of starch loss.

In the case cooling water is because of scarcity an attention point a cooling water balance should be established.

In case of the bottling and packaging unit of the alcohol distillery, the bottle washing is defined as basis for the balance (see figure).

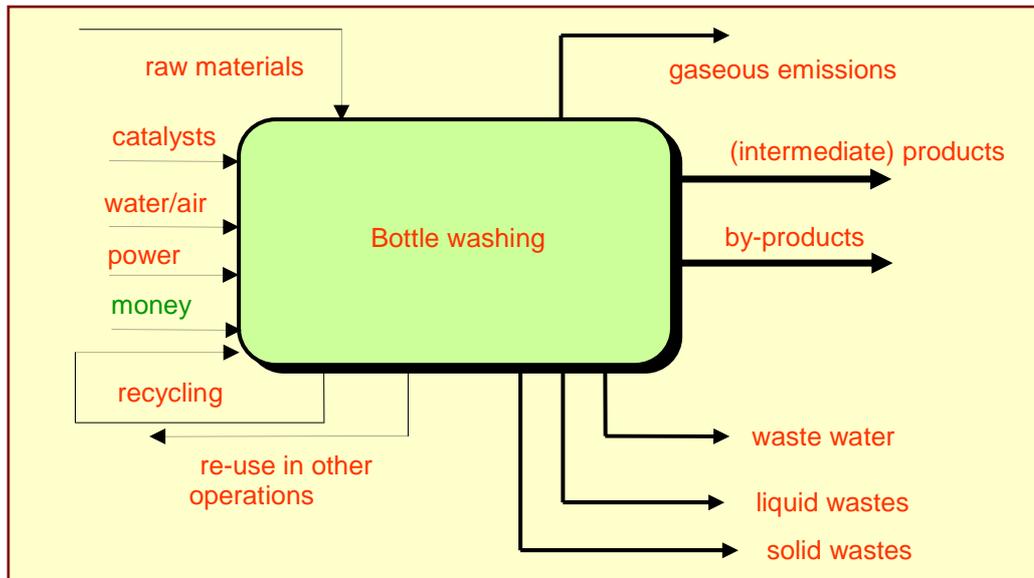


Figure: the unit operation bottle washing

Accuracy of the measuring method is an attention point especially when big volumes are weighed crudely and (expensive) additives are weighed on precision scales. For example when alcohol is produced made with sweet potato measured with the truck balance and enzymes measured with laboratory scales it should be clear that the first weighing method is far less accurate than the second. When the material balance is made then from the calculation of 4000 ± 400 kg sweet potato adding 1.5 ± 0.01 kg amylases it is clear that a variation in the amylase will not show in this balance. In this example large volumes of process water or steam, which are not measured but estimated, will also due to their inaccuracy render the material balance less interesting.

It is in industry not uncommon that low cost material and water flows are not measured or controlled other than by manual intervention. Experiences show that large variations can occur which will then negatively effect the quality of the product and the efficiency of the processes. A thumb of rule is that when the variation of values shows that the standard variation is higher than 10% of the mean value this process is uncontrolled.

The measure unit for in and outputs could vary from case to case but the following guidelines are considered:

- While determining the time factor always choose a time span which includes production quantity: e.g. ton/year or kg/hour;
- Take at least three to five full batches in case of batch production. It is important to include the start up and the cleaning operations;
- Calculate on basis of volume at standard conditions in case of gasses.

In general it can be said that the more data is obtained about a particular flow or process the better the system can be described in terms of variation and trends due to internal and external influences. By recognising and quantifying those influences strategies can be developed to diminish the impact.

 Worksheet 4 and 5, Checklist 3

3.1.3 The energy balance

In the section before a schematic overview of the components of the material balance is given. For energy, a comparable overview can be presented.

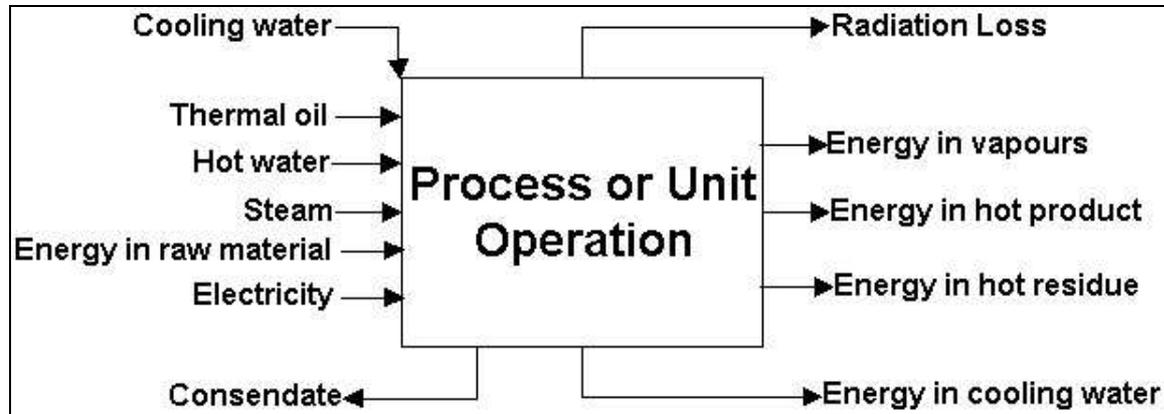


Figure: components for the energy balance

The picture only shows the continuous flows and in some case such as batch process it is worth to consider the energy used to heat or cool the equipment.

In the figure below, the Shankey diagram, the different components relevant for the energy balance are illustrated for a specific case. The thickness of the different arrows is related to the amount of energy/heat. From this Shankey diagram for example it can be concluded that a significant amount of energy (heat) is released or lost from the process with the exhaust air. Only a small amount of energy that has been put into the process can be found in the end product.

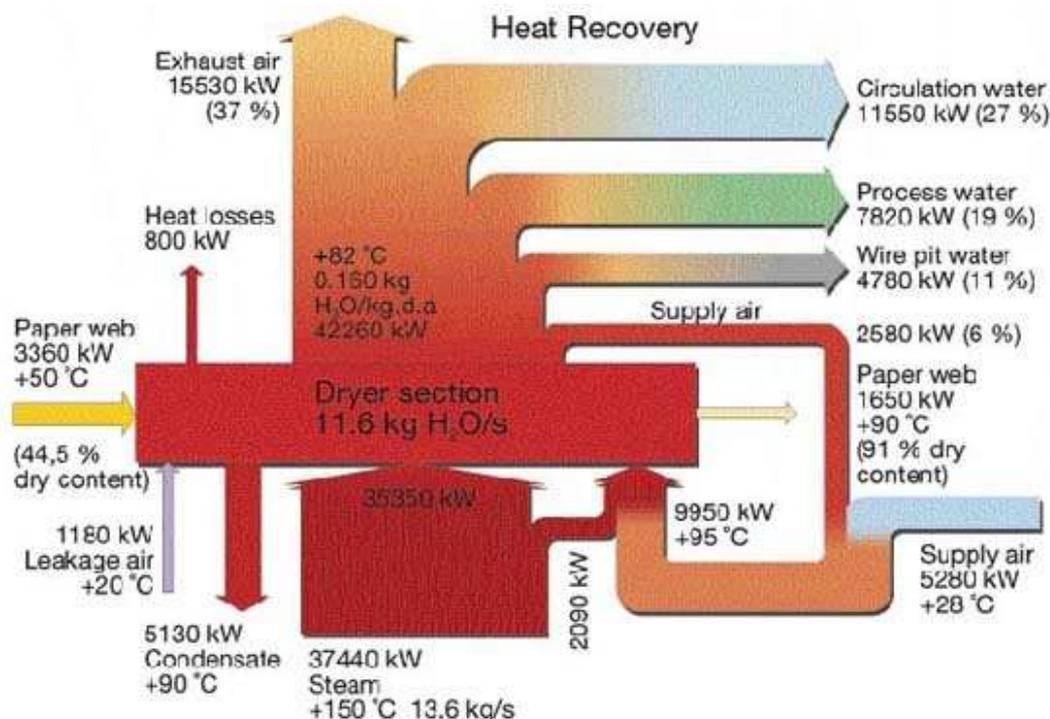


Figure: example Shankey diagram to illustrate the different energy/heat components of a unit operation (dryer)

In the Shankey diagram, the input material (the paper web) is fed into the dryers section. The diagram is used to show the flows and temperatures of various in- and outputs, which carry energy. The paper web

itself contains energy due to a proceeding process. In the drying section steam is used to dry the paper web. From the dryers section, energy is lost via the exhaust air and several output water streams which are fed back to either the wire pit, process, etc. When the potential of heat recovery is examined, all possible heat sources are the exhaust air, the circulation water, the process water etc. should be researched and measured.

 [Worksheet 4 and 5, Checklist 3](#)

3.2 Assessing process in- and outputs

The following breakdown of inputs and outputs can be made:

Inputs	Outputs
Raw materials, auxiliaries, intermediate products	Products and by-products
Water (incl. steam)	Wastes (solid, water) and gaseous emissions
Energy	Energy

Materials and water can be combined in the same material balance. For energy a different balance can be compiled for the purpose of simplicity. However it should always be kept in mind that material and energy balances are related.

While investigating the inputs, talking to staff and observing the unit operations in action, the project team should already be aware about improving the efficiency of unit operations.

As discussed in the pre-assessment, different sources in the enterprise can be used to collect information and data:

General:

- Literature, consultants;
- Interviews with work floor employees to check if operations procedures comply with prescriptions and if not, why they differ.

Records:

- Purchase records;
- Material inventories;
- Batch composition records;
- Product information from suppliers;
- Product specifications;
- Waste discharge fees/costs;
- Waste and emissions form.

Operations:

- Operation logs;
- Standards operating procedures and operating manuals;
- Samples, analysis and measurements;
- Energy bills;
- Emission inventories;
- Equipment cleaning and validation procedures;

Especially in modern enterprises, the use of computers, as part of a process control system (i.e. DCS, SCADA, IPC), for data generation of input and output flows and engineering conditions is widespread. The existence of a DCS or similar system and the installation of instruments in the process units allow following certain measurements over time (trending). Trending and data processing for operations, logistic and marketing purposes is of convenience for the enterprise staff to take appropriate actions but also for the members of the assessment team to assemble information.

3.3 Inputs

3.3.1 Raw materials and auxiliaries

Sometimes quantification of raw materials and auxiliaries is possible by observation and some simple accounting procedures. Also take into consideration that losses of raw material and auxiliaries can be high in storage and transfer activities, which are usually not targeted for determining the material balance. Evaluate these operations in combination with the purchasing records to determine the actual net input to the process.

For solid raw materials and auxiliaries, ask the warehouse operator how many bags are stored at the beginning of the week or prior to a unit operation; then ask him again how many are left at the end of the week or unit operation.

For liquid raw materials and auxiliaries, such as solvents, check storage tank volumes and capacities and ask operators when a tank was last filled. Tank volumes can be estimated from the tank diameter and tank depth. Monitor the tank levels and the number of tankers arriving on site. Also check barrels and containers.

When executing the investigation of inputs, the following questions should be kept in mind to collect the necessary data and information that is necessary in the next step, the analysis of the causes.

<p><input checked="" type="checkbox"/> Generally the following questions should be answered for raw materials and auxiliaries:</p> <ul style="list-style-type: none"> • What raw materials and auxiliaries are used in the process? • What is their function in the production process? • In what quantities are they used? • What are the costs of the raw materials and auxiliaries? • What hazardous characteristics do they have for humans and the environment?
--

<p><input checked="" type="checkbox"/> These questions are already related to simple causes and possible obvious Cleaner Production options:</p> <ul style="list-style-type: none"> • Is the size of the raw material inventory appropriate to ensure that material-handling losses can be minimised? • Transfer distances between storage and process or between unit operations - could these be reduced to minimise potential wastage? • Do the same tanks store different raw materials depending on the batch product? Is there a risk of cross-contamination? • Are sacks of materials fully emptied or is some material wasted? • Are viscous materials used on site - is it possible to reduce residual wastage in drums? • Is the raw material storage area secure? Could a building be locked at night, or could an area be fenced off to restrict access? Is theft of materials considered or relevant? • How could the raw materials be protected from direct sunlight or from heavy downpours? • Is dust from stockpiles a hazard? • Is the equipment used to pump or transfer materials working efficiently? Is it maintained regularly? • Can spillage be avoided? • Is the process adequately manned? • How could the input of raw materials be monitored? • Are there any obvious equipment items in need of repair? - Are pipelines self-draining? • Is vacuum pump water re-circulated?

3.3.2 Water

The use of water, other than for the process, is a factor that should be covered in every Cleaner Production Assessments. The use of water to wash, rinse and cool is very important. It represents an area where reduction in consumption can frequently be achieved simply and cheap. Using less water can be a cost-saving exercise.

<p><input checked="" type="checkbox"/> Generally the following questions should be answered for water:</p> <ul style="list-style-type: none"> • What is water used for in each unit operation (Cooling, gas scrubbing, washing, product rinsing, dampening stockpiles, maintenance, safety quench, etc.)? • Why is the water used in that operation • How often does each action take place? • How much water is used for each action? • What is the cost of water consumption?

- General selection criteria for selecting an assessment focus:**
- Tighter control of water use can reduce the volume of wastewater requiring treatment and result in cost savings - it can sometimes reduce volumes and increase concentrations to the point of providing economic material recovery;
 - Leaking valves, pipelines, pumps etc. result in high losses of water on a yearly basis, even when the loss due to leakage may not look that serious;
 - Attention to good operating practices often reduces water usage and, in turn, the amount of wastewater passing to the drain;
 - The cost of storing wastewater for reuse may be less than for treatment and disposal;
 - Counter-current (rinsing in the opposite direction as the material flow) rinsing and rinse water reuse can reduce water usage;
 - Energy can be saved if only the volume of water is heated that is really needed.

3.3.3 Energy

Energy can form input for a unit process in different shapes such as steam, cooling water, energy in raw material, electricity etc.

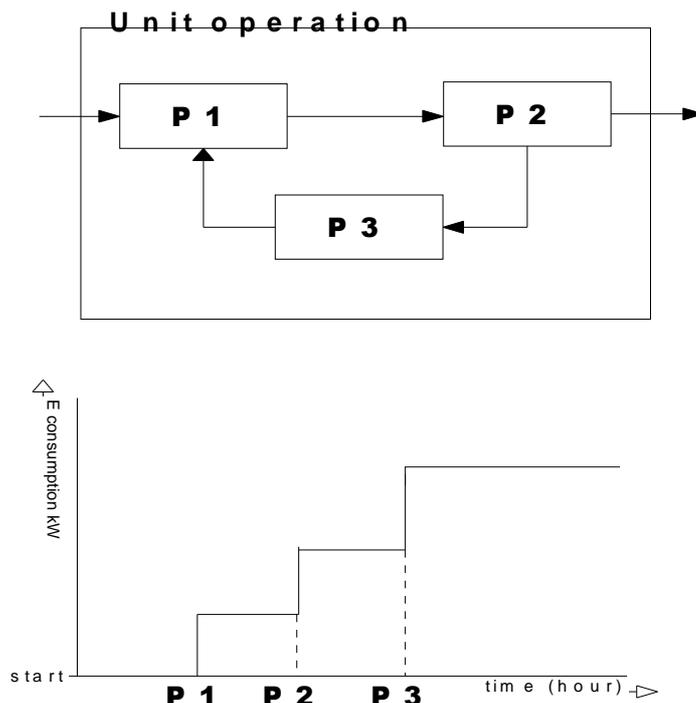
Getting detailed information about energy consumption can be difficult when individual meters for unit operations are not installed. You can get some idea about the energy use by looking at how many Kilowatts equipment uses according to its specifications. However be aware that due to poor maintenance and old age the use of electricity may turn out much higher than indicated.

A method that can be applied to determine the electricity consumption of individual pumps is called the Conditional Demand Analysis. In the next figure for example three pumps are placed in a unit operation. The intermediate vessels and tanks are not indicated. The overall power consumption of the unit is measured by means of a power meter; however the power consumption by the separate pumps cannot be measured.

To determine, indirect, the power consumption by each pump, the following method can be applied. First, all the pumps are off. The power consumption should be zero, unless other electrical machines in the unit operation consume any electricity, however this is no problem. Then pump 1 is started and the power consumption is measured again. The increase in power consumption can be attributed to pump 1. Subsequently the pump 2 is started and again the power consumption is measured. Then the pump 3 is started etc.. In this way the power consumption by each separate pump can be measured. Of course, this method can only be applied if the process allows this.

If the power consumption of pump 3 should be measured, the following can be done: all pumps are running and the central power meter measures the power consumption. Pump 3 is then stopped and again the power consumption is measured. The reduction in power consumption should then (theoretically) equal the power consumption by pump 3.

In stead of a unit operation, a complete process can be taken as well, and P1, P2 and P3 can be unit operations. So this simple method can be applied in many different ways.



Generally the following questions should be answered for energy:

- Where is energy consumed in the process?
- What is the function of the energy in the process?
- In what quantities is energy consumed?
- What are the costs of energy consumption?

Energy is used in production processes in several ways including:

- Transportation of material or people;
- Changing the temperature of materials or spaces;
- Lighting spaces;
- Changing the form of materials; and
- Changing the physical or chemical properties of materials

3.4 Outputs

3.4.1 Products and by-products

To gather information about the amount of inputs converted into a product you need two types of information: information about product composition and information about the quantity of the product that is produced. The first type information can often be found by reviewing job sheets and mix tickets, customer specifications, quality control data, and product data sheets. The second type of information can be found in the sales records of products. Note that the amount of products sold by a enterprise does not always equal the production of products because of loss during product handling, transportation, or theft.

If the product is an intermediate product, which serves as an input to another process or unit operation, then the output may not be so easy to quantify.

Production rates will have to be measured over a period of time.

Similarly, the quantification of any by-products may require measurement. A by-product is a non-product output of a production process. By-products do not necessarily become waste and emissions. It may be reintroduced into a unit operation and reused within the production operations so that it becomes an input again, or sold on the market as raw material or as product.

Generally the following questions should be answered for products and by-products:

- What are the products and by-products?
- In what quantities are they produced?
- Are there hazardous components?
- How high is the product loss and what are the costs associated with this loss?
- Is there a recycling unit for rejected products?

3.4.2 Waste and emissions

Measuring the quantity and composition of waste and emissions must be done periodically. By monitoring waste and emissions, seasonal fluctuations or single large waste and emissions streams can be distinguished from continuous flows. Changes in waste and emissions cannot be measured accurately unless the information is collected both before and after the implementation of a cleaner production option.

Generally the following questions should be answered for waste and emissions:

- What waste and emissions are being generated?
- In what quantities are they generated?
- What is their composition and is this hazardous to humans and environment?
- What are the costs associated with the waste and emissions?

Costs of waste and emissions and energy loss depend on the costs of:

- Loss of raw materials and auxiliaries;
- Product losses;
- Energy losses;
- Internal recycling;
- Disposal and treatment;
- Levies and permits;

- Penalties for exceeding limit;
- Costs of non-productive working hours (e.g. maintenance, cleaning).

The following breakdown of waste and emissions can be made:

Solid wastes and sludge

When measuring the quantity of solid wastes or sludge that do not end up in the wastewater, the assessment team should also consider the following questions:

Some solid wastes lend themselves to direct reuse in production and may be transferred from one unit operation to another. Others require some modification before they are suitable for reuse. The reused waste streams should be quantified.

Qualifying solid waste can be done using the following questions:

- Where does the waste originate?
- Can the manufacturing operations be optimised to produce less waste?
- Can potential raw materials be used which would produce less waste?
- Is there a particular component that renders the whole waste hazardous?
- Can this component be isolated?
- Does the waste contain valuable material?
- Can the waste be recycled?

Wastewater

Often significant quantities of wastewater are discharged into the sewer or to the watercourse. Apart from the environmental implications and cost of treatment, wastewater contains valuable unused raw materials and energy. Measuring the wastewater flow and the concentration of raw materials it carries is therefore crucial for a completion of the material balance.

Below some suggestions are made on how to carry out a survey of wastewater flows:

- Identify the effluent discharge points (be aware of the fact that there may be several discharge points);
- Identify where flows from different unit operations or process areas - contribute to the overall flow;
- Identify wastewater treatment facilities and recycling streams;
- Plan your monitoring program thoroughly and try to take samples over a range of operating conditions such as full production, start up, shut down, and washing out;
- Be aware that discharge does not always relate to the location of the cause.

Gaseous emissions

Gaseous emissions can constitute a considerable loss of inputs, and are therefore important to consider carefully when deriving a material balance. Gaseous emissions are not always obvious and can be difficult to measure.

Qualifying gaseous emissions can be done using the following questions:

- Are odours associated with a unit operation?
- Do gaseous emissions contain aerosols?
- Are there certain times when gaseous emissions are more prominent - are they linked to temperature?
- Is any emission control equipment in place?
- Are gaseous emissions from confined spaces (including fugitive emissions) vented to the outside?
- If gas scrubbing is practised, what is done with the spent scrubber solution? Could it be converted to a useful product?
- Do employees wear protective clothing, such as masks?

3.4.3 Energy

Energy is a significant cost element for most production units and is therefore important to determine the energy balance. Figure 3.4 in this chapter illustrates the energy flow through a unit operation.

Inventorizing the energy users in the enterprise and understanding the production energy linkages is very important in the assessment. At enterprise level, developing overall energy balances at the enterprise helps in characterisation of the energy users, and allows the prioritisation of the energy consumers. Detailed energy balances for unit operation are very valuable as well; however data are often not available.

Besides the process flowcharts, the energy balances, the list of installed power of motors or energy consumers, the steam demand surveys or separate heat balances can be very useful in the energy

analysis. Tracking the energy demand over the day, the month or the year helps to figure out peaks and valleys in demand, i.e. when the energy is used.

Generally the following questions should be answered for energy:

- What energy consumption is there?
- How big are the energy losses?
- What are costs associated with these losses?

In general the following categories for energy inputs and losses can be distinguished:

- Energy in radiation;
- Energy in vapours (incl. steam);
- Energy in hot products;
- Energy in hot residues;
- Energy in cooling water,
- Electricity for pumps, etc

3.5 Complete the balance

Now that the inputs and outputs have been identified the assessment team can complete the material and energy balances for a unit operation. The results of the balances can be summarised on worksheet 4 and 5.

Merging the balances of the individual unit operations can be done to compile a balance for the entire process. This will allow insight in components throughout the processes and subsequently identify ways to improve efficiency, improve waste management practices, prevent waste and emission, and segregate or recycle waste streams.

The material balance should be checked on inconsistencies and inaccuracies. Ideally, the inputs should equal the outputs but in practice this will rarely be the case and some judgement will be required to determine what level of accuracy is acceptable. The acceptability of a discrepancy in the balances depends on the importance of that particular balance, considering toxicity, cost, environmental impact, etc. It should be clear that unacceptable imbalances would imply (or enforce) further investigation. Avoid pitfalls when preparing material balances. Some guidelines for the material balance are:

- Properly determine the location of the measuring points;
- Check whether the instruments are well calibrated;
- Check consistency of units used;
- The more harmful a toxic or more expensive a material or energy flow, the more precise the balance should be;
- The balance can become more meaningful if made for each material separately, however this depends on specific material or energy with regard to cost, volume, and toxicity.

Several factors have to be taken into account when constructing balances, in order to avoid errors that could overstate or understate waste and emissions. The precision of analytical data and flow measurements is important. Especially in production processes with large inputs and outputs, the absolute error in measurement of these quantities may be greater than the actual waste or emissions. In this case, the assessment team cannot obtain a reliable estimation of the waste and emissions by subtracting the materials in the product from those in the raw materials. Instead the assessment team can conduct a direct monitoring and analysis of waste and emissions streams.

The time span for the material balance should be of a representative period. That is, the operations and processes usually associated with the unit operation should all be performed during the period for typical portions of the total time. If not, the entire exercise will not provide an accurate picture of the process in question. Balances constructed over a short time span require more accurate and more frequent stream monitoring. Balances calculated for a complete production run are typical the easiest to construct and are reasonable accurate.

Another recommendation is that the assessment team should make a good effort to compile a reliable balance but should avoid a struggle in making a perfect balance. Even a preliminary balance can already reveal plenty of cleaner production opportunities. There is not a fixed guideline for accuracy of the

balance. In some cases a standard deviation of 10% is acceptable, in other cases on 0.1% is acceptable (depending on for example cost, quantity, process condition). The assessment team has to judge on a case-by-case basis whether it is cost beneficial to improve the balance or whether for example the toxicity of the materials involved in the balance require a more precise material balance.

Measuring instrumentation is in a lot of industries lacking and when a material balance is prepared new locations have to be determined. These locations should yield the information that is sought. For example when measuring the contamination it is not sufficient to measure only on the outlet point of the enterprise because due to the mixing of waste streams inside the factory this does not reveal the location of the contamination generation.

 **Worksheet 4 and 5, Checklist 3**

3.6 Presenting and interpreting the data

The data that is collected to compile the balances can be presented in different ways to enable identification and illustration of trends, recognition of patterns, or inefficiencies etc. Using spreadsheet programs the following diagrams can be derived:

- historical trending, e.g. showing in- and decreases of mass flows of product, or electricity consumption, over time;
- sector diagrams, e.g. showing the distribution over unit operations of water consumption;
- stack diagrams, e.g. demonstrating input/output and efficiency ratios for raw material and energy consumption per kg of product.

In case a modern process control system is present, these diagrams can easily be generated. The interpretation of the diagrams is to be done by the assessment team.

The attached checklist can be used to roughly guide the assessment and to make suggestions to establish the material and energy balance.

According to the Cleaner Production methodology, all wastes, emissions, material and energy consumption should be assessed and for all the losses in the production, causes and prevention practices should be determined. If not all the losses can be examined; some direction can be given to the prioritisation for the losses, to ensure further examination of losses that are relevant and important.

The following questions can therefore be asked:

- Can the toxicity of the wastes and emissions be qualified?
- Are the losses or the material or energy consumption rates very high? (compare with benchmarks or process indicators if available for the unit operation)
- Can the cost of the losses be estimated?
- Does the quantified loss of material or energy exceed the possible inconsistencies and errors in the balances?

Trend analysis of energy consumption, energy costs and other relevant production features help to understand effects of capacity utilisation on energy use efficiency and costs on a wider scale. For example, when the installation/process capacity is normally only partly utilised, the energy efficiency might be low due to this. If the total capacity of the process line is only fully utilised once in a while, the high inefficiency under normal operation might justify a reduction of the total capacity in order to increase the efficiency. This can be called peak shaving (however this can already be called a prevention practise, a subject dealt with in the next chapter).

What can also become clear from energy consumption trending is for example accidental peaks in the consumption, that do not come from a sudden increase in the production output. During these peaks, certain other causes lead to the high-energy consumption. These causes should of course be examined (see the next section).

Benchmarking is a valuable tool to examine whether or not the assessed unit operation is performing efficient or inefficient, compared to advanced or “clean” companies. However, benchmarks are not always available, so this technique should not serve as the only basis of the interpretation of the data.

Benchmarking relates to inter unit comparison across a group of similar units. However, it would be important to ascertain similarities, as, otherwise, findings can be grossly misleading.

- The following comparative factors should be looked into when benchmarking is applied are:
- Scale of operation;
 - Vintage of technology;
 - Raw material specifications and quality;
 - Product specifications and quality.

3.7 Conduct a cause assessment

The cause assessment should be conducted to enable the assessment team to generate options; without a proper cause analysis no appropriate options can be generated or options that are generated do not have the desired effect of reducing the specific waste or energy loss. The following questions should be answered:

- Where do waste, emissions, and energy losses take place? (this should be examined and determined during the assessment),
- Why do they occur? (this will be answered by conducting the cause assessment);
- How can they be solved? (options for improvement).

 [Worksheet 6 and 7, Checklist 3](#)

As explained in chapter 1, the Cleaner Production methodology distinguishes the following categories of causes that lead to waste or emission production or high material and energy consumption and low environmental and economical performance:

1. Change of input materials:
Cleaner production by input substitution is accomplished by reducing or eliminating the hazardous materials that serve as input for the production process. Raw material can be substituted by a less toxic or renewable material or by an adjunct material with a longer service-lifetime; Input substitution also includes material substitution.
2. Technology change; improved equipment and process control and new production technology:
The process technology can be changed by substitution of the existing production technology (and process) by new, cleaner technologies in order to minimize waste and emission generation and/or resource (energy, materials and water) consumption during production. However, also minor changes in the process can concern technology change, such as modification of equipment, changing of piping.
Process optimisation concerns the modification of the (existing) equipment and utilities in order to run the processes at more optimal conditions. Process optimisation can be achieved through addition of measuring and control devices, improved process control, changes of process conditions such as flow rates, temperatures, pressure or increasing the use of the existing production capacity, process automation, modification of the layout etc.
3. Good operation practices; good workers skills and good production management:
The improved operation and maintenance can concern the modification of the working procedures and (process) parameters for equipment operation and maintenance. The operation procedures are of course closely linked to for example the production management. Examples are development of appropriate provisions/procedures to avoid leakage and spills and to assure high quality repair, development of a preventive maintenance plan, etc.
Improvements of the procedural, administrative, institutional and planning measures can be taken by the management to minimise losses, wastes and emissions, such as improved production planning/scheduling to optimise equipment use and minimise losses, inventory practices, cost accounting practices etc.
Employees can be educated and trained on-the-job and reward and punishment schemes can be developed to encourage staff to minimise spills and leaks, to work according to standardised production practices, and to improve their process control skills. Many of these options from the last three categories are low cost options but it takes substantial effort to implement.

4. Product modification:

Product features can be changed in order to minimize the environmental impacts of the product during or after its use or to minimize the environmental impacts of its production.

5. On site re-use and recycling:

Depending on the characteristics of the waste or the loss that is produced, certain re-use and recycling options can be generated. This of course is the last category, because the assessment team should first examine all the possibilities to prevent wastes and losses. For example, wasted materials can be recovered to serve as an input again or wasted materials can be recycled in another process at the same plant. Also, heat can be recovered by using heat exchangers.

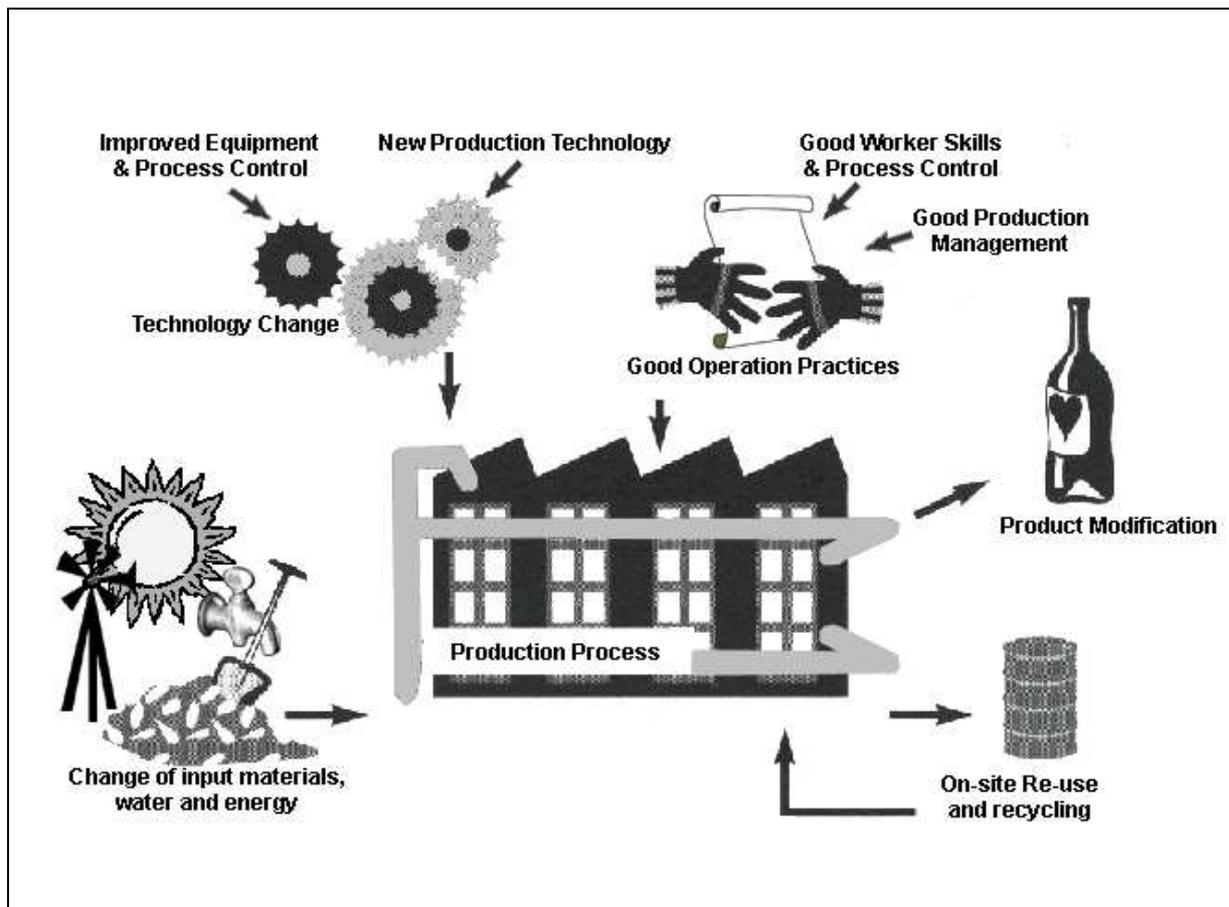


Figure: schematic presentation of the different causes that can be distinguished in the determination of the causes to waste and emissions and energy consumption in the Cleaner Production methodology

For each loss of raw materials, auxiliaries, water and energy and production of waste and emissions all the cause categories should be considered and the assessment team should determine which causes contribute to this loss or waste. A waste stream is usually caused by more than one cause category. For example: when analysing a waste stream (or high material or energy consumption, etc.) one can ask questions like:

- How do the choice and quality of input materials cause the waste stream?
- How does the type of product technology cause the waste stream?
- How does the technical status of the equipment cause the waste stream?
- How does the process efficiency cause the waste stream?
- How does the management and information system cause the waste stream?
- How does the personnel skills and motivation cause the waste stream?
- How do the product specifications cause the waste stream?
- How do the waste characteristics of the waste stream cause the waste stream?

The answer to these questions will then automatically analyse the waste stream into its distinguishable impacts.

3.8 Option generation

3.8.1 Implement the obvious options

As discussed in Chapter 2, it is always important to implement simple, obvious, low cost options during the assessment. Also, the impact of the implementation of these options should be monitored and reported accordingly.

3.8.2 Structuring the option generation

Once a list of causes has been made, the assessment team should generate the possible Cleaner Production options or prevention practices per cause of waste or loss. The Cleaner Production options should represent ways to increase the environmental and energy-efficiency, reduce the waste and emission production and raw material losses and improve the financial situation of the enterprises.

As well as for the cause evaluation as for the generation of options a logical and creative thinking process should be adopted. The thinking process should be logical, because the causes follow from the losses and wastes that are found in the material balances and the other worksheets. And subsequently the prevention practices follow from the examined causes. The steps, as described earlier, are:

Waste or energy loss → source inventory → cause analysis → Cleaner Production option generation

However, to be able to find the logical patterns behind the cause evaluation and option generation, the assessment team (team) should think creative. Do not stick to conventions; try not to be think selective in this part of the procedure.

A method to achieve such a creative thinking process is brainstorming. Brainstorming can be useful when the assessment team or a different group would like to generate a large number of options. Other persons than the assessment team members, who can contribute to the generation of options, are:

- Other employees in the enterprise or from other companies;
- Trade associations;
- Research institutes;
- International experts;
- Consultants;
- Equipment suppliers;
- International organizations such as UNEP, UNIDO, etc.

3.8.3 Creative thinking techniques

Brainstorming stimulates the creative thinking. The results of the brainstorm sessions, potential cleaner production options, must be reported to be able to learn from the sessions with regard to another area focus (another assessment cycle).

Three methods of brainstorming can be distinguished. The facilitator (or team leader) should find out which technique works best and is most appropriate.

With the 'question round' method, the facilitator asks the team members one by one to mention ideas and possible options. The ideas and options will be written down on for example a white board. The advantage is that all group members get equal chances to present their ideas. One member can elaborate on or adjust previously mentioned ideas. A disadvantage is that members have to wait with presenting their ideas until it is their turn and this might lead to commotion and unrest, or might reduce the creativity in the session.

Based on the prevention practices the facilitator or other person can ask the team members the following questions. Of course one question can have various answers:

- How can we modify the product specifications in order to decrease or eliminate the waste stream?
- How can we change the choice and quality of input materials in order to decrease or eliminate the waste stream?
- How can we change the type of product technology in order to decrease or eliminate the waste stream?

- How can we improve the technical status of the equipment in order to decrease or eliminate the waste stream?
- How can we increase the process efficiency in order to decrease or eliminate the waste stream?
- How can we improve the management and information system in order to decrease or eliminate the waste stream?
- How can we improve the personnel skills and motivation in order to decrease or eliminate the waste stream?
- How can we change the waste characteristics of the waste stream in order to recycle and reuse and decrease or eliminate the waste stream?

Another method is the 'free contribution'. With this method, group members can spontaneously put their ideas forward. One group member writes down all the ideas. The advantage is that ideas are presented on the moment that they come up. Also members can easily elaborate on ideas from others. The disadvantage can be that certain members dominate the brainstorm session so that ideas and options from other members are not brought forward. Also, confusion can arise in the group.

With the 'write down' method, the ideas that members of the brainstorm session have are written down. For example each members can be asked to write down a certain number of options on a piece of papers. Than, this paper is given to for example the person sitting at the left and this person elaborates on the options that are written down and ads some more options. This process can go on until everybody in the group has written down his or her comments and options on the different pieces of paper. However, different versions can be found with this method. The pieces of paper can also be collected and not shifted to the neighbour and than the elaboration on the options and ideas can be done group wise. An advantage of this method is that ideas are not directly related to a specific person, something that can be desirable when there is a strong hierarchy in the group, or when there is a 'blaming' aspect in the ideas, or the ideas come from mistakes and wrong decisions that are made by others. A disadvantage of this method is that it might be less creative.

- When brainstorming is used, the following 'tips' should be kept in mind:**
- A facilitator should ensure that everyone is given the opportunity to share his ideas and remain focussed;
 - Every idea is considered to be serious and valuable and should be added to the list. The wildest ideas are sometimes the best ideas;
 - No value judgement should made, related to the person or the content of the idea, no hierarchic constraints should prevent the creative process;
 - The problem definition is important, take time to do it properly;
 - Structure the generation of ideas;
 - Use flipcharts or black/white boards to explain the ideas graphically;
 - Members should build and elaborate on ideas from others.

If a brainstorm session does not result in a satisfactory number of ideas, a different session can be considered at a different time, a different technique or with different group members.

Once the options (ideas) are generated, a clear understanding of what the options comprise should be developed and a complete list should be made of these options.

In the box below, barriers are listed that can be experienced when creative thinking methods are used for option generation. This list has been incorporated here in order to understand the lack of creativity and to enable the assessment team to deal with this lack of creativity within the team or group when options have to generate.



- Barriers to creativity**
- Fear of making mistakes;
 - Fear of being seen as a fool or saying foolish things;
 - Fear of being criticised;
 - Fear of being misinterpreted;
 - Fear of standing alone with your ideas;
 - Fear of losing the acceptance of the group or colleagues;
 - Fear of disturbing traditions and representing changes;
 - Fear of being associated with taboos;

- Fear of losing the security of a habit;
- Fear of being an individual.

Of course a proper preparation and thorough understanding of the causes of wastes, product technology and modern management will overcome many barriers. Sometimes repetitive sessions are more constructive due to the fact that the team members are used and more confident with the technique and with the team (structure). A proper selection of team members who will contribute to the 'creative thinking' sessions should be done. For example a financial manager who has never seen the enterprise from the inside will have little contribution to creative thinking the decreasing of a waste stream he has never seen, doesn't understand about its causes etc. However this person can have a strong contribution to improve the management and information systems.

 **Worksheet 8, Checklist 4**

3.9 Option screening

Once all the options have been listed and shortly described, a preliminary screening can take place in order to get a more useful list of options. The following issues can be considered:

1. Check on duplicate options:
Once the options are clarified and described, similar, overlapping or duplicate options should be combined.
2. Organise the options per unit operation:
The options generated during the brainstorming session refer to different unit operations. Organising the options per unit operations allows for a more structural approach during the screening.
3. Evaluate obvious mutual interference:
The implementation of an option might make another option irrelevant. It is crucial to identify mutually exclusive options to avoid a selection of both options. Mutual interference across unit operations should also be investigated. Options for one unit may exclude an option in another operation. For example the option 'replacing the leaking pump' can exclude the option 'replacing the seal of the leaking pump' or vice versa when the problem is just caused by the seal and not because the pump is old or does not comply with the requirements.
4. Implement obvious options:
Obvious non- or low cost options that are cost effective and easy to implement do not require an extensive feasibility study and can be implemented immediately.

At this stage no options should be disregarded, unless the options are obviously technically unfeasible. However this will follow from the feasibility analysis so in this stage it is not wise to already remove options from the list.

If not all options can be implemented or evaluated on their feasibility, options can be prioritised. The options listed higher can be made subject to the evaluation, described in the next chapter. To be able to prioritise, the options should be further screened.

Five aspects of a quick and qualitative evaluation of options can be distinguished, as listed below (see also worksheet 8). Based on knowledge and experience of employees and information that is available in the enterprise, the options can probably already be qualified according to the indicators below. However there will also be options for which information is lacking. For these options a more detailed feasibility study might be necessary. This can be indicated on worksheet 8.

1. Technical availability:

- Is the required equipment or service for the cleaner production option available on the market?
- Is there a supplier that can provide the equipment/services?
- Can the option be easily implemented or is there an adviser/expert that can support the development of the option if necessary?
- Has the cleaner production option already been implemented, in a different enterprise for example?
- If so, what are the results and experiences?

If these questions are all considered, a qualitative impression can be obtained about the (technical) availability of the option. For example, if the option is available, and the equipment can be provided, and the option has been implemented successfully in other companies already, then the availability can be qualified as high. Other possibilities are a medium and low availability.

2. Consequences (of implementation):

- Does the option (the modification, adjustment, replacement or extension etc.) fit in the enterprise production or management processes?
- Does the implementation of the option require adjustments in other parts of the enterprise?
- Does the implementation of the option require additional training of staff or employees?
- What are the consequences for the enterprise logistics, production time, and production planning, etc. when the option is implemented?
- What are the consequences for the product (quality) when the option is implemented?

If implementation of the option does not have a large impact on the production and if the option can be easily fit in the process line, the consequences of the option can be qualified as low. But the consequences can also be medium or high.

3. Environmental effect:

- What is the anticipated environmental benefit from the option, are the benefits substantial, or marginal or even negative?
- How big are the estimated reductions in the wastes and emissions and the losses of raw material and energy due to the implementation?
- Is there any effect from implementation on the public or workers health?

4. Investment costs:

- What are the anticipated costs from implementing the options?
- Are these costs considered high, medium or low?

5. Profitability:

- What are the estimated savings and or benefits from the implementation of the option?
- Is the profitability considered to be high, medium or low?
- Is there an increase in production rate and product quality?
- Is there an opportunity raise the revenue due to improved quality and production rate?

Once the screening has been done, the different options can be divided in several categories:

- Obvious non and low cost options that can be implemented immediately;
- Options that require small investments which have to be applied for;
- Medium and high cost and/or complex options that require certain further evaluation. A technical, environmental or financial feasibility study will then be done for these options;
- Options that will put on hold for example due to lack of information to do the feasibility study.

After the screening and prioritization of the options, the actual feasibility analysis can take place, as described in the next chapter.

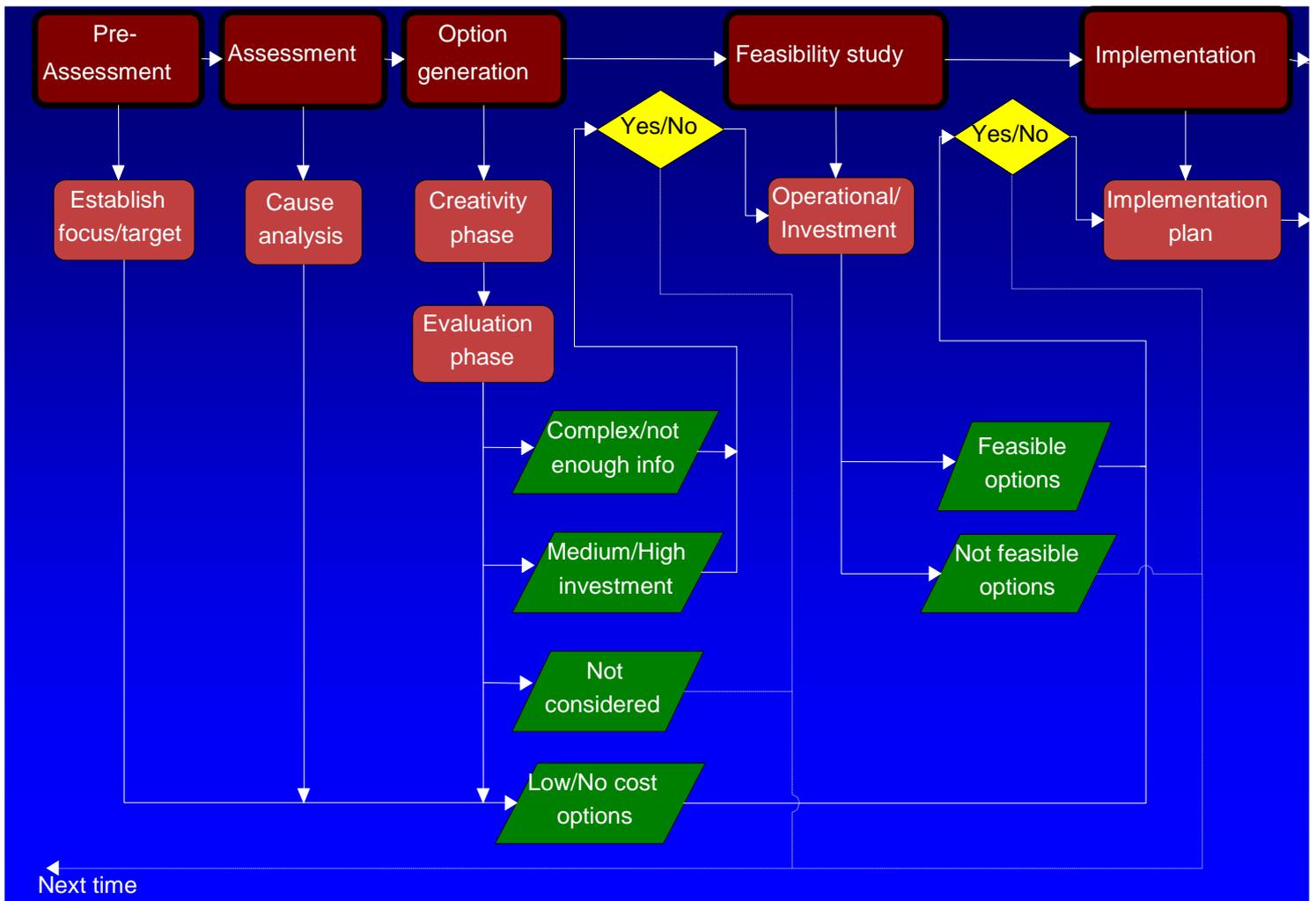


Figure: flow sheet option generation and screening

At the end of this phase, the assessment team should write a mid term report. This report should include all relevant information that is obtained during the first phase of the pre-assessment. In the mid term report the following issues should be addressed. This list of issues can serve as a basis for the chapter division:

- *Foreword*: illustrating the participation and commitment of the corporate leaders;
- *Introduction of the enterprise*: outline of the industrial sector to which the company belongs, the description of the company and its history, market prospects, economic performance, organization diagram, the processes applied in the company, the main raw materials and final products, the environmental impact of the company, compliance with the relevant laws;
- *Planning and organization*, containing an overview of the assessment team members and their role in the team, a review of expected obstacles and ways to overcome them, an outline of the assessment plan;
- *Pre-assessment*, containing the overview and description of the process (steps) and baseline data, the selected assessment focus and targets and a motivation of this selection, and the obvious options that have been/can be implemented;
- *Assessment* this chapter should include the material and energy balances, the direct and indirect costs of the material and energy losses and wastes, the cause evaluation and the obvious options that have been/can be implemented.
- *Generation and screening of options* should contain a list of the selected and prioritized options with the specified needs for the evaluations and the screening criteria.

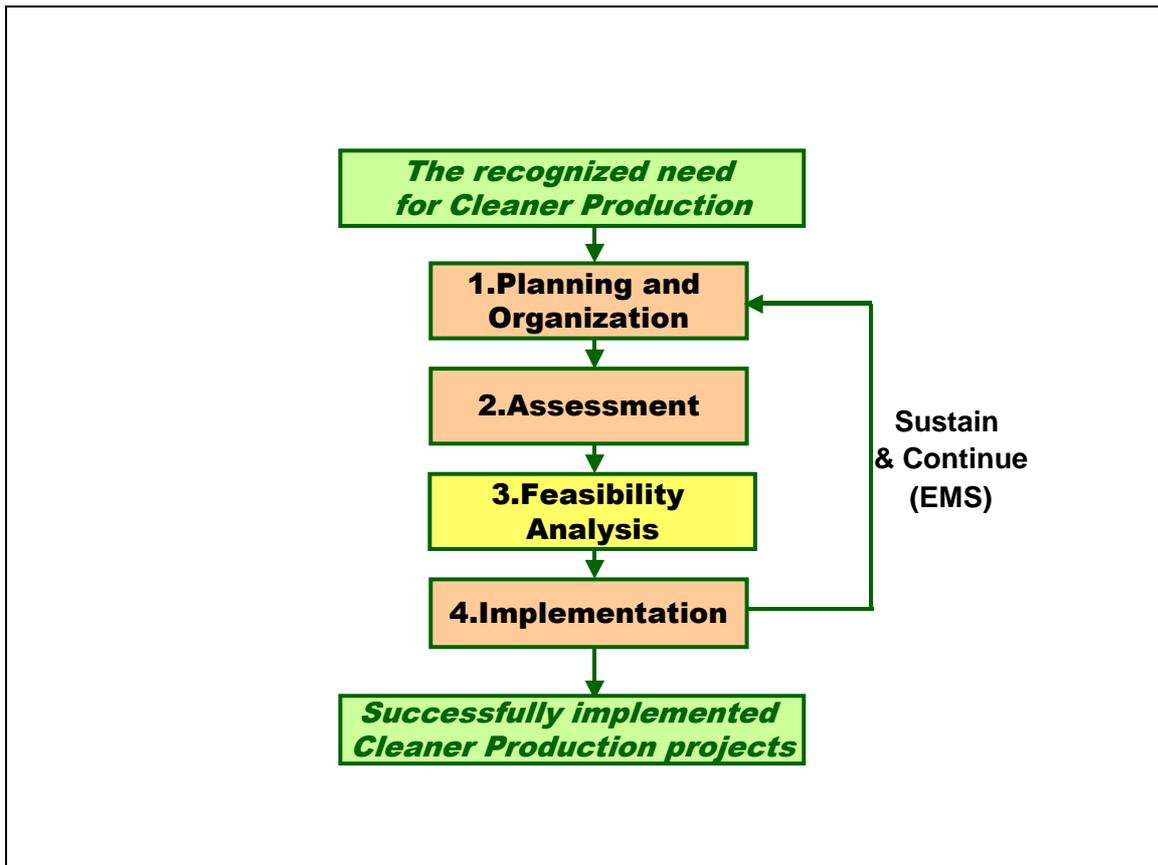
 Worksheet 8, Checklist 4



Tip box

- Measuring is knowing!
- Make sure dimensions are consistent and tell you what you want to know.
- The four aspects which influence the efficiency of a process are procedures, staff, equipment and technology they should all be assessed.
- Know where to measure and what to measure.
- There is no need to measure the pollution load when you mix waste streams this will only tell you something on the emitted load and nothing on the origin and cause of the waste stream.
- Follow process from beginning to end and list all visible waste emissions and extraordinary observations.
- When establishing a material balance does not limit you in measuring. Better too many than too few measurements.
- A process is considered uncontrollable when the relative variation (the standard variation¹ divided by the mean multiplied by 100%) is higher than 10%.
- The lower the level of process control and the higher the variation in the process conditions the more data needs to be measured.
- Be critical on measurements and data: a material balance with 5 times measuring of 200 grams exactly means that these data are most likely not measured and coming from recipes, procedures, handbooks or other source of process information. This may not reflect the actual situation!
- Establish accurate efficiency indicators telling you how you are doing: pollution/product, energy/product, material/product, cost/product, etc. You can do this for the overall plant but also for the individual workshop.
- Make staff aware how they perform and how to improve!
- Literally dissect the individual waste stream (and material and energy consumption) each into the five Cleaner Production categories
- Go back to the waste stream origin and visually check the completeness and feasibility of options.
- Visualise results of the enterprise, for example put the water consumption figures each month on the wall for everybody to see and establish objectives and incentives. This motivates workers to be careful with water.
- Make people aware of what you expect from them by using posters, briefings and assign people on the work floor whose responsibility it is to keep people involved and motivated.
- Rank 'true' prevention before recycling or reusing as this will always involve an extra process step and thereby a degrading of material leading to waste and loss of product or lower product quality plus extra use of equipment, energy and water.
- Adopt responsibility for your work and environment, why is your house clean and your workshop dirty?
- A mid term report is the writing down of the results of executed activities and when started when the audit starts it takes no extra efforts.

¹ Standard variation to be determined with $n > 5$ measurements



 Feasibility analysis	
Steps to be taken	Expected results
1. Technical evaluation	<ul style="list-style-type: none"> • Feasibility analysis for each option documented
2. Environmental evaluation	<ul style="list-style-type: none"> • Expected benefits for each option documented
3. Economic evaluation	<ul style="list-style-type: none"> • Pay back time calculated
4. Decision making	<ul style="list-style-type: none"> • Go/No Go decision to implement feasible options • Final assessment report

4 FEASIBILITY STUDY

 The screening of options in the former chapter has resulted in a short-list of options for further investigation. Also, the screening provided a guideline for analysis; which has been concluded which aspects of the investment need further investigation.

The purpose of this phase is to come to a investment decision that, at one hand has the potential to add maximum value to the enterprise, and at the other hand, has a limited risk of failing to so. The techniques used to assist this decision-making are technical, environmental and economic feasibility analyses. As being said, the techniques described in this chapter can only assist the decision-making.

In this chapter questions will be answered as:

- How to analyze the economic, environmental and technical feasibility of the options?
- How to determine which options are feasible and not feasible?
- How to use the Pay Back Time calculation?
- What to include in the final Cleaner Production assessment report?

4.1 Technical evaluation

The purpose of the technical evaluation is to study whether a plan is realistic given the technical conditions. The main activity in this evaluation is the collection of additional information, which was not gathered in the assessment phase, and the analysis of that information. Therefore it is important to involve the right people at the enterprise. If the assessment team feels that the in-enterprise know-how is not adequate to make a good judgment of the collected information it may be wise to temporarily involve external experts.

The technical evaluation of the cleaner production options should include the following aspects:

- Operation procedures and technical skill requirements;
- Process control requirements;
- Maintenance requirements;
- Space requirements;
- Spare part requirements;
- Need for new utilities or upgrades;
- Safety and health;
- Compatibility with environment (quality of raw materials, ambient temperatures and dust levels);
- Supplier service levels.

In some cases the commissioning and maintenance of equipment is underestimated. It is not unusual that the commissioning costs are two to three times the equipment costs. Especially, if the equipment is sophisticated, costs of commissioning can be high. Training of operators and maintenance staff can be crucial to the success of an investment. Sophisticated equipment can lose all its advantages over the equipment it replaced if it is not well operated and adequately maintained (for example by not checking or replacing -parts of- analyzers). It is therefore of utmost importance to analyze the need for regularly replacement of machine parts and process control equipment, and the costs of this. In this respect the need for supplier services and the availability thereof should be investigated. Also good training of operators cannot be underestimated.

The compatibility of the equipment with the Chinese environment of newly imported equipment (or equipment from parts of China with a different operation environment) is not always certain. Certainly if the equipment is placed in a hot humid and/or dusty environment, operation of the equipment may hamper. In such cases expensive investments in the infrastructure of the equipment should be included.

An interesting aspect of the technical evaluation that is worth mentioning is the production capacity. Replacement of equipment can increase production capacity at a certain point in the production line. Obviously, this does not automatically mean that the overall capacity of the production line increases. It will only do so if the replacement solves a capacity bottleneck (the weakest link of the chain) or if the capacity of other parts of the process is increased as well. Hence, it is advisable to investigate the capacity bottlenecks in the whole process before assuming a *real* capacity increase based on the design capacity of the replacement alone.

Also the product quality can increase, for instance as a result of improved process control.

4.2 Environmental evaluation

Before implementing any investment proposal it is important to estimate the impact of that investment on the environment: knowing the impact of its production process on the environmental and energy-efficiency of a unit operation is a key responsibility of every enterprise.

Yet, there are more reasons to pay attention to the change of waste streams or other Cleaner Production options, resulting from an investment. First, an option can result in sub-optimization of raw material use. For example, if the assessment team manages to save 100 tons of water per week in a certain process unit it does not necessarily result in 100 tons water saving by the enterprise. Sometimes downstream units utilize water coming from upstream units. In such a case the 100 tons saved in an upstream unit will have to be replaced with fresh water to feed the downstream unit. Second, although a cleaner production option reduces the overall environmental impact of an enterprise due to increased material and energy efficiency; it can bring the enterprise in conflict with environmental authorities. Sometimes an investment shifts the waste stream from one medium to another, for example from liquid waste to solid waste or vice versa. Authorities may have certain policies towards one medium resulting in a violation due to the shift. If this is not the case and a quick estimate confirms a reduction in waste load it is not very valuable to start calculating exact figures. Better, the enterprise measures the performance improvement after realization of the investment.

If the objective of the cleaner production assessment is to make the enterprise comply with the environmental regulation then the assessment team has to pay more attention to the environmental evaluation. In most cases compliance is not achieved by implementing cleaner production measures alone and complementary measures in the field of treatment and disposal will be required. Consequently it is important to come to a reliable estimation of the waste situation as a result of the implementation of the cleaner production investment. Based on this result the enterprise can design or redesign its treatment facilities. A too optimistic estimation of the waste reduction will lead to insufficient complementary treatment measures and thus failure to come into compliance. On the other hand too pessimistic estimations will lead to more expensive treatment measures than necessary. If time allows, the enterprise should first take cleaner production measures, monitor the results and based on the results plan for treatment measures (and/or additional cleaner production measures).

A way to estimate the reduction of resource use and waste flows is to prepare an 'after implementation' material balance and subtract this balance from the current material balance. The result is the change in environmental impact. Changes at the input side reflect changes in resource use, and changes at the output side of the material balance reflect changes in waste generation. On the basis of these figures the assessment team can investigate whether problems can be expected or not. Doing so, it is important to include toxicity of waste and the impact on the working environment of the staff (health and safety issues).

In short the following issues need attention:

- Scarcity of resources;
- Volume of waste streams;
- Toxicity of waste streams;
- Shifts of waste from one medium to the other and sub-optimization;
- Health and safety issues;
- Energy consumption.



If the objective of the assessment is compliance, the assessment team will need to calculate what the change in waste flows means for the relevant dimensions in which its environmental performance is evaluated by the environmental authorities.

 **Closed loop system for cooling water saves water and money**

The management of an enterprise producing alcohol has made a material balance (see also previous chapters). Based on a cause analysis, a brainstorm and a first screening of the options the assessment team has come to the conclusion that the implementation of a closed loop system for cooling water would provide a good environmental benefit (less water use) and save the enterprise money. Below the water balance of the existing situation is put next to the expected water balance after implementation of the water closed loop system resulting in reduced water consumption (24,5 kg per kg of alcohol produced) and wastewater generation (22,8 kg per kg of alcohol produced). Because new piping will be installed the assumption is that leaking will be reduced (loss of material).

Values in kg/kg alcohol final product

Inputs 'before'	Quantity
Intermediate product	
Water	15,2
Alcohol	1,05
Solids	0,25
Steam	2
Cooling water	30

Inputs 'after'	Quantity
Intermediate product	
Water	15,2
Alcohol	1,05
Solids	0,25
Steam	2
Cooling water	5,5

Difference
0
0
0
0
-24,5

Outputs 'before'	Quantity
Distillers grain	
Water	16
Alcohol	0,05
Solids	0,25
Alcohol product	1
Cooling water	28

Outputs 'after'	Quantity
Distillers grain	
Water	16
Alcohol	0,05
Solids	0,25
Alcohol product	1
Cooling water	5,2

Difference
0
0
0
0
-22,8

4.3 Economic evaluation

The need for an economic assessment is based on the risk a capital owner wishes to take with his capital as a capital owner has basically two options. First, he can put the money in the bank and earn an interest. He does not need to do anything for this and runs virtually no risk of losing his money. The capital owner can also invest in an enterprise and produce a product that satisfies the need of a market. However, in doing so he takes a risk of losing his money when potential customers do not buy his product, or do not buy it for a lower price. In general, the capital owner want to be rewarded for his efforts and risk taking and will therefore demand that the enterprise in which he has invested makes a profit on that investment. From that profit the enterprise should be able to pay the capital owner for making available the capital. This 'return on investment' should, due to the higher risk, be higher than the bank interest rate. If not, the capital owner better put his money on the bank. Consequently, for an enterprise it is important to determine the economic sustainability of an investment.

An enterprise produces and sells products. Costs are made to produce and sell the products. The revenues are generated at the point of sale. The difference between the two constitutes the profit made by the enterprise. Part of the profit will be deducted as profit tax.

An economic assessment will assist the assessment team to assess the profit of a proposed investment, and in doing so enable the assessment team to advice enterprise management. The economic assessment presented in this chapter is simple but sufficient in most situations. In some cases, however, more sophisticated instruments will be required to provide a more advanced insight in the feasibility of an investment. In these cases the assessment team will have to get extra information from the financial department of the enterprise or from specialized external assistance.

Companies use specific criteria to assess the profitability of an investment. Three of the most common methods are the Pay Back Period, the Net Present Value and the Return on Investment. All three criteria are introduced in this chapter, but only the payback period is explained in detail.

 **Worksheet 9, 10 and 11**
4.3.1 Pay back period

The payback period determines the exact amount of time required by an enterprise to recover its initial investment. The equation is written as follows:

$$\text{Pay back period} = \frac{\text{Cost of Investment}}{\text{Annual extra cash flow}}$$

Annual extra cash flow = changes in incoming cash flows + changes in outgoing cash flows

Changes in outgoing cash flows are the extra costs for production, personnel, logistics and sales due to the changes in the enterprise for which the investments are used. Changes in incoming cash flows are expected extra revenues due to higher sales or other incoming cash flows. Extra cash flow therefore represents the change in cash flows due to an investment.

In the case no extra sales revenues are expected:

Annual extra cash flow = operational costs after investment – operational costs before investment

The cost of the total investment represents a cash flow. However only once, namely at the moment the investment is paid for.² The investment is represented by the cost of the following items:

- Process equipment;
- Materials and location preparation;
- Utility connections;
- Additional facilities (see technical feasibility);
- Construction and installation;
- Engineering and consulting services;
- Start up (including training of operators and maintenance personnel, and production lost);
- Permits;
- Subsidies.

If working capital changes significantly, it may be best to include this in the investment costs too. Working capital is the capital invested in raw materials and spare-parts stock, materials and product in process and product in stock. Working capital may increase if imported raw materials and spare parts replace local raw materials and spare parts due to higher stock level requirements. Two important aspects should be taken into account when importing raw materials and spare parts: delivery time and possible deviations from this delivery time. The importance of the latter is often underestimated. Loss of production due to late arrival of raw material or spare parts may not only result in loss of sales during the period of reduced production but also can cause clients to move to a competitor.

Although the item working capital may decrease instead of increase, most probably subsidies is the only the investment item in the list above that will represent a positive cash flow to the enterprise. Hence, good investigation of possibilities for subsidies can be worthwhile. Sometimes subsidies can provide that extra push necessary to make the investment feasible.

The following items should be taken into consideration with regard to operational costs:

- Change in input material costs;
- Change in utility costs (water, steam, energy);
- Change in auxiliary costs;
- Change in operating and maintenance costs;
- Change in personnel costs;
- Change in treatment and disposal costs;
- Change in permit, levies, insurance and liabilities costs.

². In cases the equipment is leased or hired the investment this is different. In such a case the cost of investment is represented by periodic negative cash flows. In such cases, the pay back period depends on the agreement and the initial costs of commissioning the equipment (e.g. the training of operators, civil works, laid out changes of equipment or initial loss of production due to testing).

- The following items should be taken into consideration with regard to revenues:**
- Change in revenues from by-products;
 - Change in revenues from final products.

 **Calculation of a closed loop system for cooling water**

Together with the engineering department, the assessment team calculated the investment costs and the changes in the operating costs of the closing the cooling water system using a cooling tower in a Chinese distillery.

Pumps, nozzles and one flow meter			RMB	32,000		
Civil works (60m ³ basin) and piping			RMB	88,000		
External support (engineering)			RMB	18,000		
Training of operators and maintenance staff			RMB	5,000		
Subsidies			RMB	-12,000		
Total investment			RMB	113,000		
Before	Quantity	Costs RMB	After	Quantity	Costs RMB	
Water (m ³)	150,000	150,000	Water (m ³)	27,500	27,500	
Electricity (kWh)	129,600	25,900	Electricity (kWh)	21,600	4,320	
Operation (m/y)*	0	0	Operation (m/y)*	1	18,000	
Maintenance*	0	0	Maintenance*	1	24,000	
Total		175,900			73,820	
Annual savings			RMB	102,080		
The payback period of the cooling tower			113,000			
			----- = 1,1 year (or approximately 13 months)			
			102,080			

4.3.2 Net present value and return on investment

Net Present Value (NPV) and Return On Investment (ROI) make use of time-discounted cash flows. This means that cash flows that are generated on different moments during the lifetime of an investment are not valued the same. The further away from the moment of investment a cash flow is generated the less value it has to the enterprise. This has two reasons: cash now can be invested and consequently becomes more over years. Therefore it is better to have a thousand RMB today than in two years. Second, there is a risk the promised revenues are not realised. The further way for the present moment the higher the risk that this is the case. For investments that pay back their money quickly the time value of money will have little effect. However, for investments that have a long pay back time, it becomes important to take into account the time value of money. In such cases the NPV and the ROI are calculated.

The decision when to apply pay back time only and when to also to apply the NPV and the ROI depends on the size of the investment, business environment in which the enterprise operates and the preferences of enterprise management.

4.3.3 Risk considerations

Taking risk is part of doing business. Without risk there would be few profit opportunities. However this does not mean that risk should be taken for granted. It can be rewarding to try to assess the risks taken and to quantify them (in terms of money): it assists in making better judgements.

In the technology assessment the assessment team has already looked at the sensitivity of the technology to, for example, raw materials that fall short to specifications, or to the sensitivity of technology to imported spare parts, good maintenance or incompatible utilities. There are however also other risks at the input side: the risk of unexpected price increases of raw materials, spare parts and qualified labour. Further risks exist at the output side: the risk of quality deterioration of final products or the risk of a production increase that remains unsold. It is difficult to put each of these risks into money figures, but the assessment team may be able to group these risks together and agree on a 'bad situation' scenario. This is a situation in which some of the issues discussed above indeed happen. What would be the pay back period in such a case? Would it still be a profitable investment? Such an exercise is called a sensitivity analysis. In fact, in sensitivity analysis the assessment team normally develops three scenarios:

1. Pessimistic scenario (which is the same as the 'bad situation' scenario described above)
2. Most likely scenario
3. Optimistic scenario

The assessment team will not only need to present the calculations. The team is advised to describe briefly the assumptions behind each scenario. The three scenarios give decision-makers a relative good idea if there are risks and whether these risks are acceptable.

 **Risk scenarios in a Chinese enterprise**

In an enterprise producing small industrial valves an investment in the coating line reduces the need for amount of heavy metals in the effluent stream. Because the coating line constituted a capacity bottleneck in the plant (also because it generated many rejects) production will be increased. Together with the financial department the assessment team calculated the profitability of the investment:

Most likely scenario:

- Expected extra revenues from production increase: RMB 300,000
- Investment costs: 450,000
- Expected extra operation costs: RMB 95,000

$$\text{Pay back period} = \frac{450,000}{300,000 - 95,000} = 2,2 \text{ year}$$

Optimistic scenario:

The enterprise can make use of increased volume of sale and sell at more retail outlets. Extra operational costs are made due to higher production volume.

- Expected extra revenues from production increase: RMB 350,000
- Investment costs: 450,000
- Expected extra operation costs: RMB 110,000

$$\text{Pay back period} = \frac{450,000}{300,000 - 110,000} = 1,9 \text{ year}$$

Pessimistic scenario:

Due to increased competition the enterprise may not increase market share. Extra external support is required for maintenance. Slow spare parts delivery requires higher stock levels.

- Expected extra revenues from production increase: RMB 200,000
- Investment costs: 450,000
- Expected extra operation costs: RMB 110,000

$$\text{Pay back period} = \frac{450,000}{200,000 - 110,000} = 5 \text{ year}$$

The conclusion may be that the highest risk lies in the failure of market share expansion. Even if the operation costs remain within the budget of 95,000 the pay back period will be still well over 4 years. This is too long. As a thumb of rule the enterprise management requires a pay back time of 3 years or less. This would mean a minimum extra sale of around RMB 240,000 (assuming a slight decrease of operation costs due to a lower production). This is 80% of expected revenues. The sales department, which took part in the feasibility study, thinks 240,000 to 300,000 is realistic but would like to have more information before it commits itself to extra sales. Therefore enterprise management is advised to consider a market study.

Often cleaner production investments can be considered ‘normal’ investment opportunities that compete with other profitable ‘normal’ investment opportunities. Sometimes however, the situation is different, such as when an enterprise needs to comply with certain environmental standards and regulations. In such a situation, an assessment team may have the objective to reduce the waste flow of the enterprise at the least cost. At such a moment the profitability of a cleaner production option is not so important, but at what cost the option contributes to a lower waste level. As long as the cost of the option to reduce a certain waste is lower than the marginal costs of treatment, the option is feasible.

End-of-pipe treatment facilities usually have a higher operational cost and no economic benefits except for lower environmental fines and levies. Calculating a payback period is therefore not possible. End-of-pipe treatment usually are installed for strategic reasons for example to avoid closure by the environmental authorities

4.3.4 Market considerations

If the final product of the enterprise undergoes changes in composition, appearance, quality or functionality, or if the production is increased, it is advisable to investigate the appreciation of the market towards these changes. This can be done through a market survey. A market survey provides insight in market preferences and does not only reduce the risk of failure of the investment; it may also identify opportunities for, e.g., new target groups or a price increase.

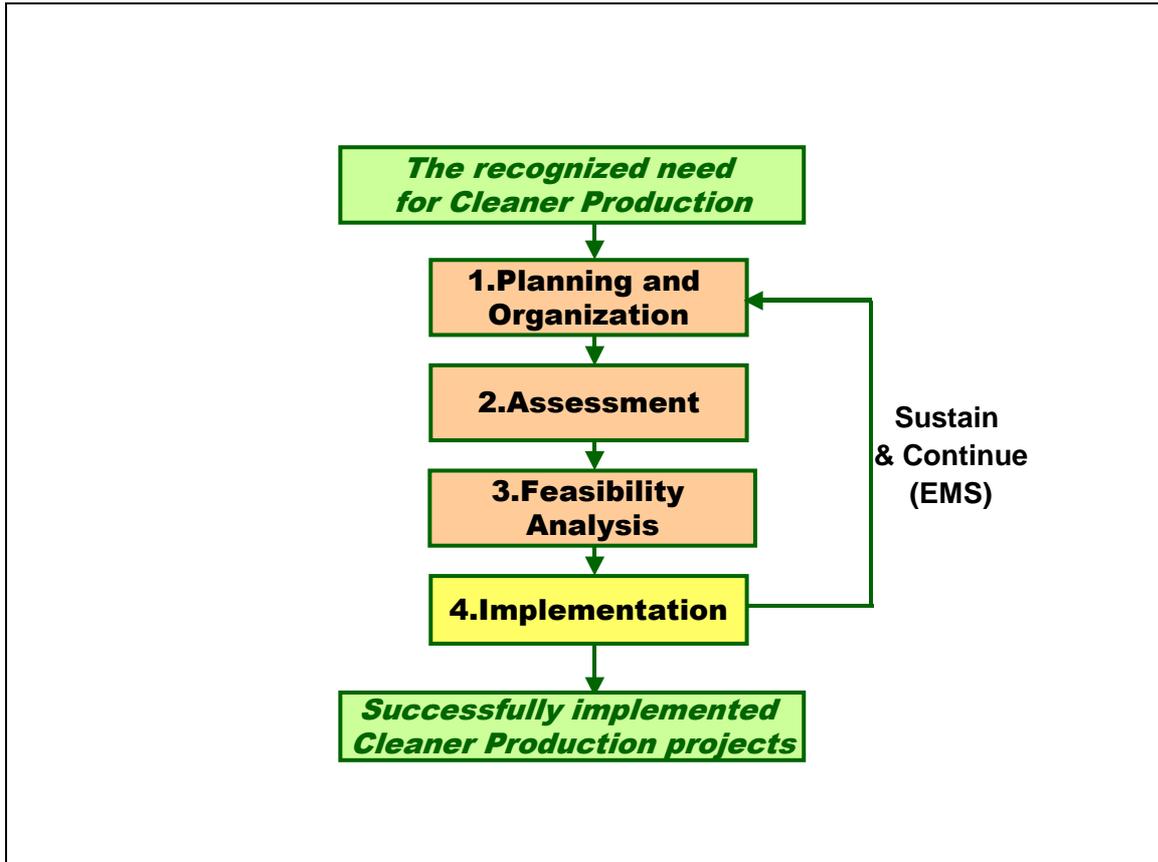
Another consideration to examine market situation is when (new) by-products are generated. Often, by-products are difficult to market because they are low-value products and exchangeable for other by-products or raw materials. This makes them very susceptible to market changes. It may therefore be better to consider internal uses or to avoid producing them: in many cases by-products represent inefficiencies in the production process and thus a lost opportunity to turn raw materials, energy and labour into final products.

The risk of marketing by-products is not only at the side of the supplier; also the customer takes a certain risk: as by-products are often a result of inefficiencies in the process, process changes at the supplier's side may deprive the customers of a valuable input to their production process. Therefore, often suppliers and customers sign contracts to ensure continued supply of by-products. Being the supplier, careful consideration of such a contract is advised as it may hamper future profitable efficiency changes in the process.

4.4 Decision making

In principle the assessment of the area focus has now been finalized. The assessment team compiles the results of the feasibility analysis and adds this to the mid term report. This report will go to enterprise management for decision-making. Based on the decisions made enterprise management will establish one or more project teams that will make a plan for implementing the selected cleaner production options and which will lead the implementation itself.

<p><input checked="" type="checkbox"/> Tip box</p> <ul style="list-style-type: none">• Assess what the risk is your company wants to run: a viable company with a long-term strategy can afford payback times of 10 years, which constitutes a high (economical) risk. For a company in debt on an oversupplied market a payback time of a year can be a too high (economical) risk.• A feasibility study should be used as a confidence builder by you, your management and if necessary by external financing bodies, so be complete.• Take into account service obligations, guarantee, liability, insurance, spare parts and other aspects with which the supplier has to comply (you can and should negotiate this).• Focus on what you want to know not on what you already know.



Implementation	
Steps to be taken	Expected results
1. Project planning	<ul style="list-style-type: none"> Project team and implementation schedule prepared
2. Execution and implementation	<ul style="list-style-type: none"> Construction and installation supervised Necessary equipment, spare parts, chemicals purchased Operators trained in usage and maintenance
3. Evaluation of the effects	<ul style="list-style-type: none"> Changes in waste quantities, resource consumption, profitability and total production output measured Benefits with expected benefits measured and compared Ways to further improve the installations Identified
4. Establishing and improving cleaner production in (environmental) management system (EMS)	<ul style="list-style-type: none"> Incorporation of Cleaner Production results in daily management Integrated Cleaner Production assessment approach as part of EMS
5. Formulating plans for sustained cleaner production	<ul style="list-style-type: none"> Cleaner Production continued

5 IMPLEMENTATION

 Sustaining cleaner production forms the last phase of cleaner production assessment in a company. Its purpose is to achieve sustained and long-term implementation of cleaner production. The aim of this phase is to set up a formal structure for the implementation and management of cleaner production, establish the management system for promoting the implementation of cleaner production, formulate plans for sustaining cleaner production, and write up cleaner production assessment report.

In this chapter questions will be answered as:

- How to establish cleaner Production in Environmental Management System (EMS)?
- How to improve Cleaner Production in a structural way?
- What is EMS in conformance with ISO 14001?
- How to integrate cleaner production in EMS?
- How to formulating plans for sustained cleaner production?
- How to achieve continual improvement of cleaner production?

5.1 Project preparation

In the previous phase, the leading team and/or management have approved feasible cleaner production options, which are going to be implemented. In this phase the feasible option(s) will be implemented. Furthermore, the impact of the changes due to the option implementation on the environmental performance and energy-efficiency of the enterprise will be monitored and evaluated.

Once the management has approved a feasible option, the option will be regarded as a 'normal' project. A dedicated project team will be established to design, engineer, purchase the equipment and execute the project.

The assessment team will hand-over the assessment results (copy of assessment report, material balance, calculations etc.) to the project team. The kick-off of the project will be a meeting with the assessment team members, the Cleaner Production-consultant and key engineers of the project team to discuss the assumptions and results of the assessment ('lessons learned').

Also, suggestions should be made how to monitor the economic and environmental results of the implemented option. If necessary, measuring devices can be installed.

5.1.1 Planning

Depending on the extent of the project for option implementation, one or more steps can be omitted. Moreover, in existing enterprises, the feasible option comprises redesign and reconstruction of a certain unit operation or facility.

The implementation scheme could be as follows:

1. Fund raising;
2. Design and engineering;
3. Land and construction site acquisition and development;
4. Applying for construction license;
5. Construction of factory buildings;
6. Selecting the type of equipment needed, carrying out investigation and research on, such equipment, designing, processing or placing purchase order for them;
7. Setting up counterpart infrastructure facilities;
8. Installation of equipment;
9. Lining up operation, maintenance and management teams;
10. Formulation of various regulations;
11. Conduct personnel training;
12. Purchase and preparation of raw materials;
13. Formulation of contingency plans (in case of accidents or obstacles);
14. Co-ordination between construction and the normal operation of the enterprise;
15. Start-up and commissioning and facility acceptance test;
16. Operation and production.

5.1.2 Fund raising

Especially in the case of bigger projects (medium/high-cost options), fund raising comprises the preparation of a bankable proposal, since the capital investment costs can only be partially financed by the enterprise itself.

In general two sources of financing can be distinguished:

- Internal financing and;
- External financing.

Internal financing is composed of two parts: the first part is funds that are already available; the second part is funds that have been accumulated gradually through implementation of obvious-cost cleaner production options (as preparations for the implementation of medium/high-cost cleaner production options).

External financing include:

- Domestic loans, such as loans from domestic banks
- International loans, such as loans from foreign banks
- Other sources, such as grants for international co-operation projects, refund for environmental purposes, government allocated fund, fund acquired through issuing stocks or securities, etc.

Rational use of the fund: if more than one cleaner production options are to be implemented and require financial input, then careful thoughts must be given to the rational use of the limited fund.

If the options can be implemented respectively without affecting production negatively, one or some of them could be implemented first, so that the profits made out of them could be used as the starting fund for the other options. Another thumb of rule is to prioritize the implementation of option according their payback period, i.e., implement the options with the lowest payback period first.

Combine the investment plan with regular investments and strategic long-term planning.

5.2 Project execution and evaluation

The design, engineering and construction of the project should be implemented according to the relevant national, local or regional regulations.

During design and engineering of the unit or facility, environmental and energy issues should be continuously considered and in this respect more improvements could be made.

After implementation, the evaluation of the effect of the options should be assessed. The achievements of obvious options mainly include two aspects: environmental benefits and economic benefits.

Environmental benefits can be investigated, measured and calculated by comparing the changes of resources consumption indicators (such as material consumption, water consumption and electricity consumption, etc.) and waste generation indicators (such as waste water, exhaust gas, solid waste, etc) before and after the implementation of the options.

Economic benefits can be investigated, measured and calculated by comparing the changes of economic indicators (such as production value, raw materials cost, energy cost, infrastructure cost, water cost, pollution control cost, maintenance cost, taxes, net profits, etc.) before and after the implementation of the options. Based on this, the achievements of obvious options could be assessed.

The achievements of medium/high-cost options will be assessed from technological, environmental, economics and comprehensive perspectives. Compare the measured benefits with expected benefits and use it to further improve the performance.

5.2.1 Technological evaluation

This is mainly to assess whether the performances of various technological indicators have reached the designed levels, i.e. product quality, level of process control energy-efficiency, etc.

5.2.2 Environmental evaluation

This is mainly to study the performance of various environmental indicators before and after the implementation of the medium/high-cost options, and compare them with the designed levels. The purpose is to assess the environmental benefits of the options and the improvement of the enterprise's environmental image.

This could not only assess the environmental benefits of the options, but also help to identify the gap between the designed environmental performance and the practical performance so as to provide basis for future improvement of the options

5.2.3 Economic evaluation

Economic evaluation is an important means of assessing the practical effect of the implementation of medium/high-cost cleaner production options. The economic benefits of the options could be assessed by comparing the various indicators before and after the implementation of the options. The benefits could be:

- Extra production flow;
- Reduced raw materials cost, energy cost, infrastructure cost, water cost, pollution control cost, maintenance cost;
- Reduced taxes, levies, etc.

But there also drawbacks possible:

- More training costs;
- More process control costs;
- More maintenance costs.

Also the extra revenues, directly and indirectly (spin-off) due to the option implementation, should be assessed, such as extra revenues, because of higher product quality and higher added value.

5.2.4 Comprehensive evaluation and comparison

By synthesising the technical, environmental and economic evaluation on every medium/high-cost cleaner production option, a comprehensive conclusion could be drawn on the performance of the option. Other intangible assets should be considered as well, like improved relationship with stakeholders, better image and increased community support.

The environmental improvements and economic achievements of obvious-cost and medium/high-cost cleaner production options should be synthesised into a comprehensive table for several enterprises. Such a table shall include items of implementation time, investment and operation cost, economic benefits and environmental benefits. The table shall then be studied and analysed to improve future feasibility studies.

The achievements of cleaner production could be assessed from the changes of technical performance, process control level, management level of the enterprise, and the capacity of the workers. However, the most persuasive evidence of the benefits of cleaner production is the performance change of various indicators for per unit product before and after assessment.

Through such qualitative and quantitative analysis, the enterprise could compare itself with domestic and international enterprises of the same kind (benchmarking), find out its own shortcomings and the reasons of such shortcomings, so that it could make improvement and better promote cleaner production in the future.

Based on the assessment of the achievements of obvious-cost and medium/high-cost cleaner production options, the results should be widely published within the enterprises, so as to lay a foundation for further promotion and sustainability of cleaner production.

5.3 Sustaining cleaner production

The important thing of the implementation of the Cleaner Production results is not the initial integration or the formalizing but permanent and continuous incorporation of these results into the daily management. Continuation of Cleaner Production principles can only prevail when the top management is committed and requires on a continuous basis the same commitment and awareness from their management and staff. Therefore:

1. Measures proposed by cleaner production assessment to promote management should be documented and systemized;
2. Measures proposed by cleaner production auditing to promote technical operations shall be incorporated into the operation regulations for specific posts, and shall be abided by in a strict way;
3. Measures that are proposed by cleaner production assessment to improve technological process control should be incorporated into the technical regulations of the enterprise;
4. Measures that are proposed and implemented should be evaluated and if necessary improved.

In order for management to be aware of their responsibilities and act accordingly these responsibilities should be laid down and evaluated.

5.3.1 Establishing incentive mechanisms for cleaner production

Incentive mechanisms for Cleaner Production must be established, in order to stimulate the initiative and obtain optimal input and feedback of all employees. Salaries, promotion, job assignment and awards for workers could be linked to their performance in implementing cleaner production.

For management levels, complying with the environmental impact and cost reduction targets set for their departments should also be linked to a bonus program.

5.3.2 Ensuring funding sources for cleaner production

The funding sources for cleaner production can be of various kinds, such as loans or fund-raising. However, a key positive effect of the cleaner production management system is to make sure that, the economic benefits generated by cleaner production practice be reused in all or partially to promote the sustained implementation of cleaner production. It is recommended that the financial department of the enterprise set up a separate account for the investment in and benefits by cleaner production.

5.3.3 Formalising the cleaner production structure

As Cleaner production is a mobile concept because it can be implemented in every activity of the enterprise and a relative concept because the enterprise can always be improved on economic, environmental and technical performance. The implementation of Cleaner Production is therefore a continuous process. In the view of implementing a continuous improvement process, companies need to establish a system or an organizational structure, which will be responsible for the organization and co-ordination of its implementation, with a view to sustained cleaner production. An Environmental Management System (EMS) can provide such an organizational structure.

5.4 Environmental management system

A cleaner production management system includes the incorporation of assessment results into the daily management of the enterprise, establishment of incentive mechanisms, and to provide funding sources. Furthermore the cleaner production assessment can be seen as the basic starting point for an environmental management system (UNEP, 1995).

Environmental Management System (EMS) is the part of the company's overall management system, which includes the organizational structure, planning activities, responsibilities, operating practices, procedures, processes, and resources for design, implementation, accomplishment, evaluation and maintenance of the Environmental Policy.

<input checked="" type="checkbox"/> When establishing an EMS it is good to understand that it concerns all business and management activities:
--

- *Research and development:* environmental criteria for product design,
- *Manufacturing:* pollution control, cleaner production, protection of employees,
- *Finance:* obtaining finance at favorable rates may depend on environmental risk control,
- *Planning and development:* obtaining construction permit for new projects often requires an environmental impact assessment,
- *Marketing:* customers expect certain level of environmental performance from the products they purchase,
- *Management and distribution:* requirements governing packaging and material composition, recovery and recycling impose new demands.

Environmental Policy is defined as company's statement of intentions and basic principles, related to its overall environmental performance, which forms a basic framework for specific action and the environmental objectives and targets.

Environmental Management System offers the company a structured way to accomplish process of continuous improvement, of which the time frame and results will depend on the economic and other company specific factors.

When Environmental Management System is compared to Cleaner Production, substantial synergy can be perceived, as the EMS strives to:

- Recognition that environmental management belongs to top priorities within the company;
- Establishment and maintenance of effective communication with the internal and external stakeholders;
- Identification of the applicable legal requirements and the environmental aspects related to the company's activities, products and services;
- Commitment of top management and the employees to environmental protection, with clear assignation of liabilities and responsibilities;
- Continuous attention to and control of environmental aspects during the entire life cycle of product and /or process;
- Implementation of a process, necessary to meet target levels of environmental performance;
- Sufficient and adequate resources (including training), required to meet target levels of environmental performance;
- Evaluation of the environmental performance of the company against its environmental policy, objectives and targets and, where applicable, obtain improvement;
- A management process for environmental audits and periodical review of the EMS and for identification of opportunities for improvement of the system and the resulting environmental performance;
- Stimulate suppliers and contractors to implement environmental management system.

Environmental Management System has to be seen as an integral part of the overall management system of the company. Implementation of EMS is a continuous and interactive process. The structure, responsibilities, practices, processes, resources required to meet the environmental policy, objectives and targets must, therefore, be coordinated with efforts in other areas (for instance: operations, finance, quality management, health & safety).

5.4.1 Environmental management system according ISO 14001

The ISO 14001 is an international standard for Environmental Management Systems. The Demin circle of 'Plan – Do – Check - Act' forms the basic idea in this system. Compared to other similar documents and standards, ISO 14001 focuses strongly on the results produced by the management system, via its requirement of commitment to continuous improvement and its preventive approach. This implies that the Demin circle, in fact, reaches further than sole operational control necessary to obtain the required environmental licenses and permits. The EMS cycle is as follows:

Plan: Policy formulation and planning phase: identification of environmental aspects and effects, identification of applicable legal requirements, formulation of environmental objectives and targets, detailed action plan.

Do: Implementation phase: designation of responsibilities and authorities, raising employee awareness and training, communication and documentation of EMS, operational control and emergency preparedness

- Check:** Control and review of the system: measurement and monitoring, collecting the evidence, internal audits and management review of EMS.
- Act:** Corrective and preventive action and continuous improvement: detected non-conformities are corrected, causes of (possible) deficiencies are removed, new (higher level) objectives and targets are formulated.

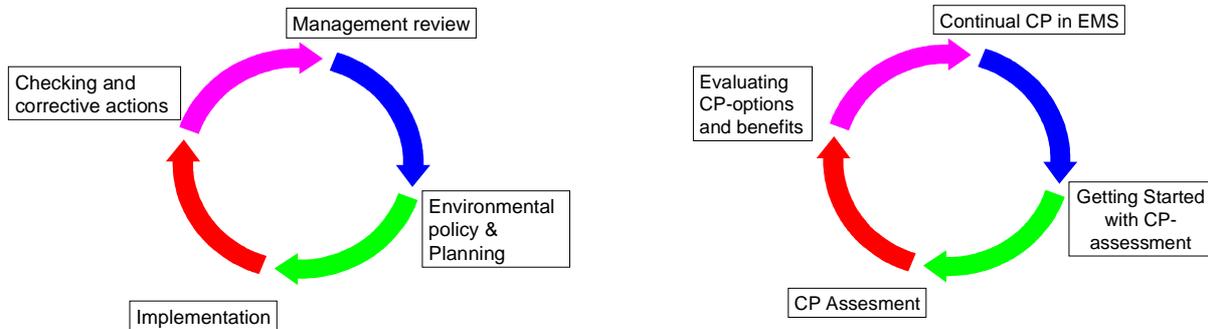


Figure: EMS and CP as a continual process

5.4.2 Benefits of an environmental management system

The benefits of an EMS are similar to those of cleaner production in terms of:

- Minimizing environmental risk liabilities;
- Maximizing efficient use of resources;
- Reducing waste;
- Demonstrating a good corporate image;
- Building awareness of environmental concern among employees;
- Gaining a better understanding of the environmental effects of business activities;
- Increasing profit, while improving environmental performance, through more efficient operations.

An Environmental Management System, when well implemented and effectively functioning, will enable the company to:

- Formulate a suitable environmental policy;
- Identify environmental aspects related to the activities, products and/or services of the company, and the resulting environmental effects;
- Identify applicable legal requirements;
- Identify priorities and formulate environmental objectives and targets, addressing the identified priorities;
- Establish formal organizational structure (responsibilities and tasks) aimed to implement the environmental policy and to meet the objectives and targets;
- Formulate and implement specific environmental improvement action plans (Cleaner Production assessments, investment, implementation and monitoring);
- Initiate planning and control activities, monitoring and corrective/preventive actions, internal audit and management reviews, aimed to assure that the policy is complied with and that the EMS continues functioning effectively;
- Build capacity to efficiently adapt to changing environment.

The intention is that implementation of ISO 14001 Environmental Management System will result in an improved environmental performance. The principal idea, on which the standard is based, is that the company will review its EMS periodically, in order to identify improvement possibilities and the chances for realization thereof.

5.4.3 Synergy between EMS and cleaner production

Cleaner Production and Environmental Management System have many aspects in common. Therefore, it can be expected that the Cleaner Production objectives, assessment and procedures could easily be integrated within an environmental management system, such as ISO 14001, or can be used as a starting point, in the preliminary phase of establishing an EMS.

The implementation of an EMS provides an ideal opportunity for organizations to implement cleaner production, as cleaner production provides instruments by which organizations can improve both their environmental and economic performance. Thus, it is in the identification of environmental aspects and effects (focus areas) and in the attainment of EMS objectives and targets that cleaner production is most often considered.

The cleaner production assessment will give the management answer to the fundamental question 'where are we and where do we go'. The top management can, based on this answer, formulate the environmental policy. Based on this policy an environmental action plan will be developed (analogue to the cleaner production assessment plan) which addresses the objectives, targets, priorities, schedules and milestones, responsibilities and accountabilities, communications (internal and external) and resource allocation.

Cleaner production concepts harmonize with the goals of ISO 14001, as they require a shift from focusing on end of pipe solutions to one in which all phases of processing, service provision and product life cycle are investigated.

Considering the above, we can conclude that cleaner production and environmental management systems are complementary and can produce important synergy effects. When implemented effectively, they will strengthen and support one another.

Cleaner production offers instruments for focusing on the vital areas (pollution sources), while an EMS provides assurance that Cleaner Production activities are implemented continuously and structurally and are sustained effectively over time.

5.5 Planning of sustained cleaner production

In order to play its due role, it is important for the Cleaner Production organization to adopt an appropriate form according to the size, sector, and internal organizational structure of the company.



A company can consider the following organizational changes:

1. A separate Cleaner Production department, which directly reports to the top management of the company;
2. A Cleaner Production department reporting to the Environmental Department;
3. A Cleaner Production department reporting to the Administrative, Technical- or Quality Department.

No matter what form the formal structure of Cleaner Production may take, a senior manager of the company should head it. This is because cleaner production activities are not limited to one single department and require involvement of production, environmental, technical and management departments, among others. Therefore, a basic requirement for the Cleaner Production organization to work effectively is that a senior manager, with sufficient formal authority within the company, provides effective co-ordination among various departments. Furthermore, authority and tools should be assigned to the Cleaner Production department, as discussed in the planning and organization phase.

The responsibilities of the Cleaner Production coordinating team will, in the first instance, include to:

- Organize, co-ordinate and supervise the implementation of Cleaner Production options as proposed by the assessment;
- Recognize the educational and training needs, in relation to cleaner production, and set up an annual training plan for the employees involved;
- Determine the area focus of the next cleaner production assessment, and initiate the next cleaner production assessment activities;
- Be responsible for the daily supervision of cleaner production activities;
- Assign and evaluate the responsibilities of the management (low/mid/high).

In order for the Cleaner Production structure to be truly effective, it is necessary to designate responsibilities for specific Cleaner Production tasks to selected individuals within the company.

The individuals concerned should have the following qualifications:

- Possess sound knowledge of cleaner production assessment (preferably have participated in the first Cleaner Production assessment activities);
- Be familiar with the environmental management of the company;
- Have authority to propose managerial changes;
- Be familiar with the production process and technology of the company;
- Be able to train management and workers and make them aware off their impact on the environmental performance;
- Have good communication skills, as to keep the management and workers informed;
- Have capability to co-ordinate and organize capacity building meeting, cleaner production assessments, etc;
- Possess strong sense of responsibility and commitment.

Depending on the size, environmental impact, financial situation and complexity of the company, the individual(s) concerned and the cleaner production department may operate full time or part time. The Cleaner Production department should be in a position to obtain the necessary support from other departments and specialists.

Cleaner production cannot be completed within short term. Therefore, the enterprise should formulate plans for sustained cleaner production, so that cleaner production could be implemented in an organized and planned way. Such plans shall include the following items:

- The next cycle of cleaner production assessments. The new cycle of cleaner production assessment does not have to be postponed until the current cycle of assessment has been completely finished. So long as most feasible no- or low-cost options have been implemented and have achieved preliminary effect, the new cycle of assessment could begin on the basis of cleaner production experience already acquired;
- Implementation plans for cleaner production options. This refers to medium/high-cost investment options that are proposed by the current cycle of assessment and have passed feasibility analysis;
- Plans for research and development of new cleaner production technologies. This refers to plans for carrying out research and development on new cleaner production technologies according to problems identified by the current cycle of assessment;
- Training plans for workers of the enterprise on cleaner production.

Tip box

- Focus on bottlenecks not on the aspects you are confident with.
- Make sure that the supplier of the technology retains (a part of) responsibility for his products until you are satisfied with its and his performance.
- Although new equipment can significantly improve your environmental situation be aware that even new equipment can be improved because developers and builders do not always take the Cleaner Production principles into account.
- Accept technology only after an agreed trial period resulting in the optimal functioning of the technology according to the agreed conditions (and let the guarantee period start on that date).
- Make payments in 2 to 3 stages: first upon delivery, second after installing third after a successful trial period (usually one month).
- Let your workers know how expensive the materials are that they work with or how much a product costs so that they are more aware and careful with materials/products/energy, etc. and it will stimulate them to suggest improvement options.
- Document environmental responsibilities for top management, middle management, and lower cadres and evaluate their performance annually. It is easier when everybody knows his duty.
- Initiate your organizational change simple: for example by making the chief engineer (or similar function) responsible for all leaks, spills and maintenance backlog. When necessary second your chief engineer with an electrician and a mechanical engineer.
- Oblige your workers to immediately report spills, leaks, improper functioning of equipment, offset conditions or other malfunctioning of the process.
- Acquaint yourself with ISO 9.000 and/or ISO14.000 standards and methods and implement the system or adopt those elements, which you think are beneficial for your company.
- Make somebody responsible for Cleaner Production and let him set up an annual prevention plan.
- Focus not only on improving your environmental performance, pay also attention to other Cleaner Production-related elements, such as i.e., management, social responsibility, communication with authorities, external expertise.
- Investigate new approaches to improve the ratio result/resources, i.e., more result with fewer efforts.
- Form new Cleaner Production assessment teams so your organization will become more Cleaner Production experienced.