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PRE-SME – Promoting Resource Efficiency in Small & Medium Sized Enterprises

Industrial training handbook

Resource Kit

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PRE-SME – Promoting Resource Efficiency in Small & Medium Sized Enterprises

Industrial training handbook

Acknowledgements

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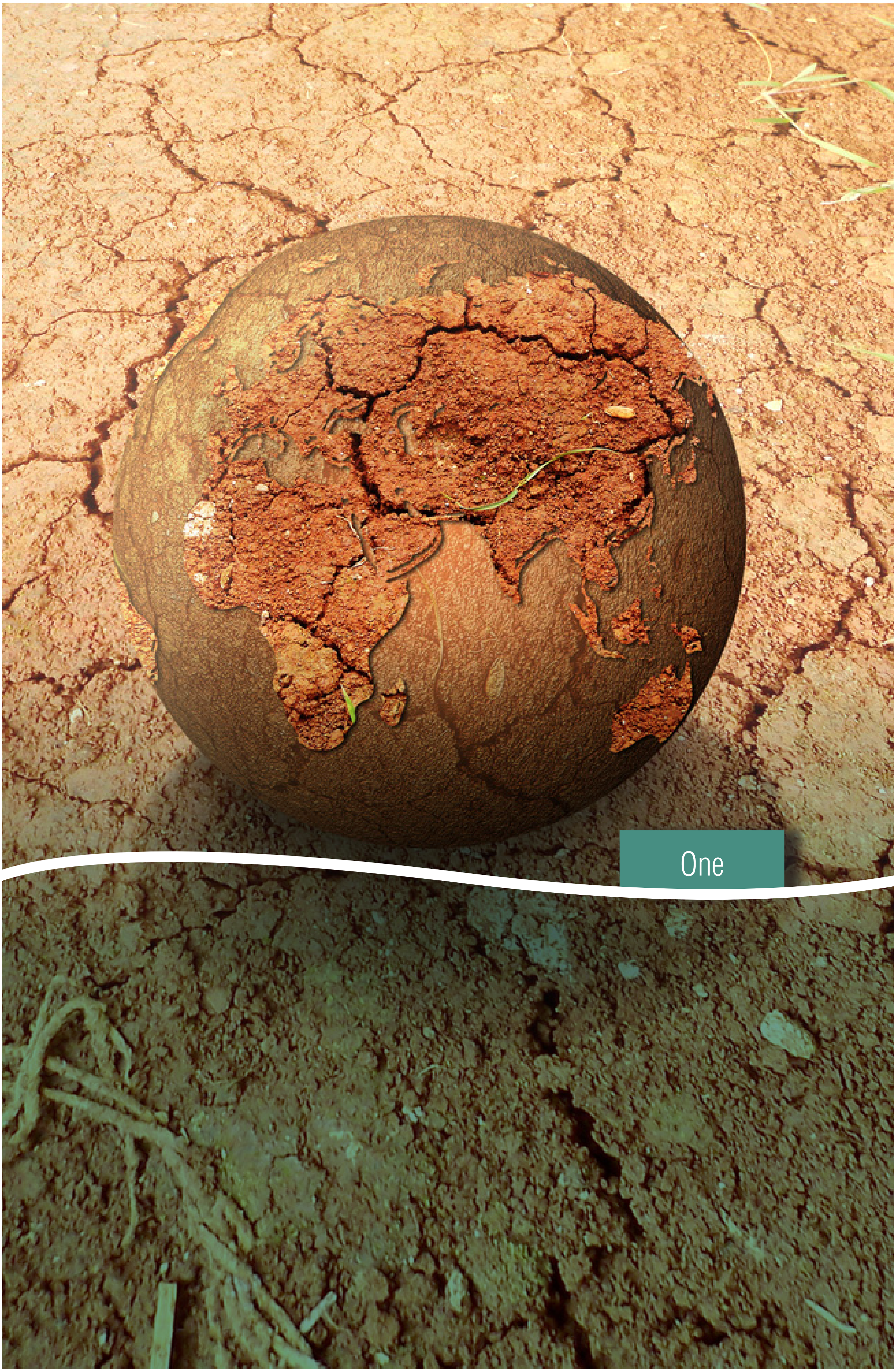
List of Acronyms

BAT	Best Available Techniques
BEE	Bureau of Energy Efficiency
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOD	Biochemical Oxygen Demand
BREF	Best Available Techniques Reference Document
CAS	Chemical Abstracts Service
CDM EB	CDM Executive Board
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFC	Chlorofluorocarbon
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power System
CNS	Central Nervous System
COP/MOP	Conference of the Parties
CP	Cleaner Production
ECHA	European Chemicals Agency
EMS	Environmental Management System
EU	European Union
GHG	Green House Gases
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbons
HDPE	High-density Polyethylene
HET	High-Efficiency Toilets
HFC	Hydro-Fluoro-Carbons
HID	High Intensity Discharge
HVAC	Heating/Ventilation/Air Conditioning
IEQ	Indoor Environment Quality
IGEN	Indo-German Energy Programme
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
IPTS	Institute for Prospective Technological Studies
ISO	International Organization for Standardization
JRC	Joint Research Centre
LCA	Life Cycle Assessment
MA	Millennium Ecosystem Assessment
MIPS	Million Instructions per Second
MSDS	Material Safety Data Sheet
MTBE	Methyl Tert-butyl Ether
NCPC	National Cleaner Production Centre
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substances
OECD	Organisation for Economic Co-operation and Development
ÖGUT	Österreichische Gesellschaft für Umwelt und Technik
OH&S	Occupational Health and Safety
OHSAS	Occupational Health and Safety Assessment System
OSHA	Occupational Safety and Health Administration
PBB	Polybrominated biphenyls
PBDE	Polybrominated Diphenyl Ether
PDCA	Plan-Do-Check-Act
PEL	Permissible Exposure Limit
PER	Perchloroethylene
PET	Polyethylene Terephthalate
PPE	Personal protective equipment
PPIC	Pollution Prevention Information Clearinghouse
PRE-SME	Promoting Resource Efficiency in SMEs
RE	Resource Efficiency
RECP	Resource Efficient and Cleaner Production
RoHS	Restriction of Hazardous Substances Directive
RTU	Roof Top Units
SME	Small and Medium Sized Enterprises
SP	Safer Production
TCE	Trichlorethylene
TEWI	Total Equivalent Warming Index
UNCED	United Nations Conference on Environmental and Development
UNEP	United Nations Environment Program
UNFCCC/FCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
USEPA	United States Environmental Protection Agency
USGS	U.S. Geological Survey
UVCE	Unconfined Vapour Cloud Explosion
VFD	Variable Frequency Drives
VOC	Volatile Organic Compounds
WEEE	Waste Electrical and Electronic Equipment
WWF	World Wide Fund for Nature



One

The PRE-SME Project

In many developing countries, small and medium enterprises (SMEs) are the backbone of economic and industrial activity, contributing to approximately 75% of the industrial output. With increasing resource prices, it is becoming difficult for SMEs to sustain the high costs of energy, water, and material resources for production while remaining competitive in the market.

In numerous developing countries, SMEs are often high polluters due to obsolete technology in their small-scale operations and/or the lack of efficient end-of-pipe pollution control systems. Furthermore, most countries lack the necessary institutional structures and capacity to provide the required technical support services to industries. When limited institutional capacities exist, SMEs often suffer the most.

These factors drive the urgent need to improve the Resource Efficiency (RE) of industrial production in many of the world's regions. This, combined with the increasing awareness of environmental pollution caused by these industries, provides the basis for promoting cleaner, safer and resource efficient production programmes.

For such intervention to lead to concrete and visible economic and environmental benefits, SMEs need to be supported with practical and hands-on tools that will assist them to identify points of inefficiencies and take the necessary action.

UNEP and UNIDO have developed a strategic joint programme to promote Resource Efficient and Cleaner Production in Developing Countries and Economies in Transition (RECP); building upon the lessons and experiences acquired since 1994 through the National Cleaner Production Centres (NCPC) programme.

The International Programme of NCPCs was launched in 1994 as a follow-up to the Rio Conference. Since then, over 40 National Cleaner Production Centres and Programmes have been established worldwide. A number of technical tools and training manuals were produced and thousands of national and industrial experts trained in regional roundtables on sustainable consumption and production. NCPC networks have been established and promoted in Africa, Asia and Latin America.

Resource Efficient and Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment.

It specifically works to advance:

- Production efficiency through improved productive use of natural resources by enterprises
- Environmental conservation through minimization of the impact on nature by enterprises
- Human development through reduction of risks to people and communities from enterprises and supporting their development

"Promoting Resource Efficiency in SMEs" project (PRE-SME) is an effort to upscale the results of the NCPC programme. The overarching goal of the PRE-SME project is to enhance the capacities of developing countries to assist SMEs develop and implement cleaner, safer and resource efficient production programmes that will result in reduced manufacturing costs, lower pollution and improved health and safety performance.

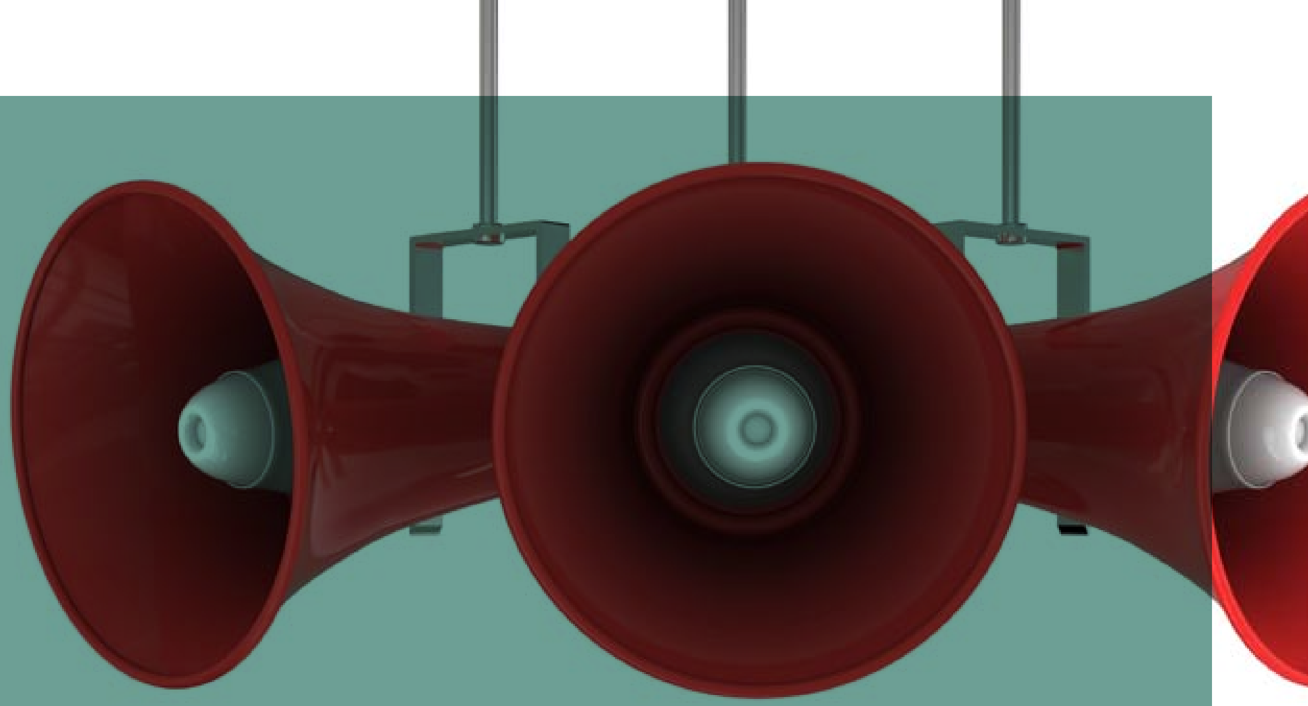
The PRE-SME electronic toolkit and accompanying industrial training handbook have been developed as part of the UNEP project, which was funded by the Norwegian Government and implemented in close consultation with UNIDO. A consortium of Austrian-based and Philippines-based not-for-profit technical institutions was contracted to produce this toolkit.

The PRE-SME toolkit builds upon existing knowledge and tools but focuses on making the content aligned with the specific needs and organisational capabilities of SMEs in developing countries and economies in transition. It was first piloted in Ethiopia and Vietnam and adapted versions can also be found on their respective NCPCs and UNEP websites.

This manual addresses the following topics:

- Explanation of basic concepts including: Resource Efficiency, life cycle thinking, dematerialisation, decarbonisation, the 'Plan-Do-Check-Act' (PDCA) cycle, benchmarking, cleaner production, safer production and integrated management systems
- The PDCA cycle as a basis for continuous improvement
- Five thematic modules for detailed assessment (water, energy, materials, waste, chemicals)
- Benchmarking and benchmarks for different sectors and units
- Relevant international laws, restrictions, standards
- Guidance for planning a Resource Efficiency programme
- Appendices including: slides for trainers, exercises for workshops, worksheets samples for practical work with companies and Internet resources

Two



Basic concepts

2.1 Resource Efficiency

UNEP works to promote Resource Efficiency and sustainable consumption and production in both developed and developing countries. The focus is on achieving increased understanding and implementation by public and private decision makers of policies and actions for Resource Efficiency and sustainable consumption and production.

Resource Efficiency means:

- The careful selection of raw materials and energy resources
- Minimization of waste, emissions, hazards and risks
- Responsible management of material and energy flows during the production process
- Attention to the use, recycling and disposal phases of the product life cycle

International scientific assessments, such as the Millennium Ecosystem Assessment, the Global Environmental Outlook and the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), make it increasingly evident the world cannot achieve sustainable economic growth without significant innovation in both the supply (production) and demand (consumption) sides of the market.

Figure 1 shows the world's landmasses distorted proportionate to population. The majority of the world's population lives in Asia (India, China, South East Asia and the Philippines). However the biggest share of carbon dioxide emissions resulting from the use of fossil fuels (for industry, heating and transport) is used in the United States and Europe, followed by Japan, China and India (Figure 2). Figure 3 shows the 'ecological footprint' of nations. An ecological footprint is a measurement of the land and sea area needed to generate the resources a nation's population consumes and to absorb the corresponding waste.

The Millennium Ecosystem Assessment (MA) was called for by the former United Nations Secretary-General Kofi Annan in 2000. Initiated in 2001, the objective of the MA was to assess the consequences of ecosystem change for human well being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being.

The MA has involved the work of more than 1,360 experts worldwide. Their findings provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (e.g.: clean water, food, forest products, flood control and natural resources) and the potential to restore, conserve or enhance the sustainable use of ecosystems.

Over the past 50 years, humans have transformed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for fuel, food and fresh water. This has resulted in a substantial and largely irreversible loss in the biodiversity of life on Earth.

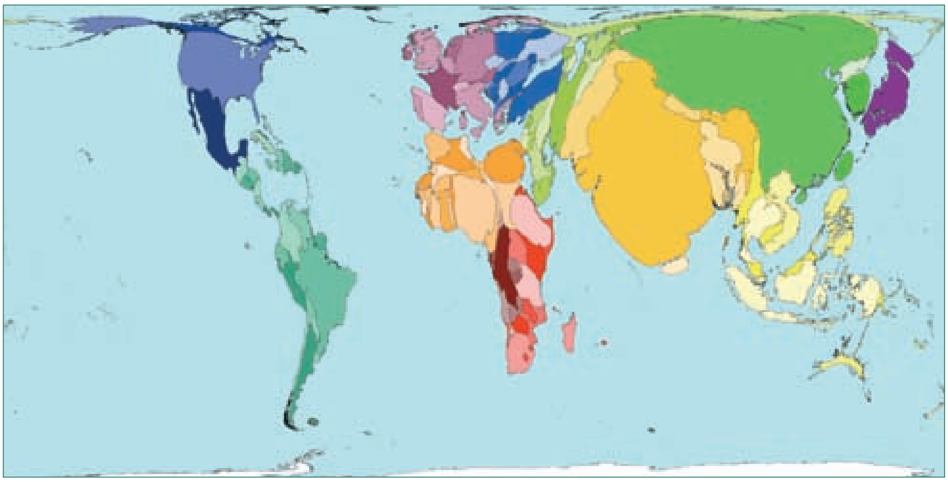


Figure 1: *World map according to population* [1]

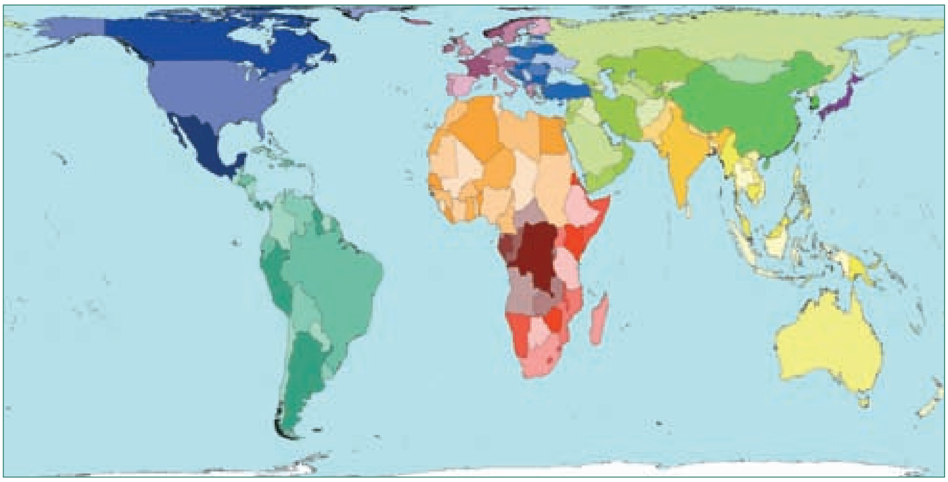


Figure 2: *World map according to carbon dioxide emissions* [2]

The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services (services mankind benefits from such as: clean drinking water, waste decomposition, energy, but also mineral resources and renewable resources like fish), and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish ecosystem services available to future generations.

The Funnel Metaphor from The Natural Step International (www.naturalstep.org) demonstrates the conflict (Figure 5). Until now, the Earth's natural resources have been more than ample to support human needs; however, the Earth cannot keep up with the demand our economy is placing on its ecological assets.

Simply put, there are two major trends that describe the sustainability crisis in our world today: declining resources and ecosystem services are on a collision course with increased demand for resources and ecosystem services. We are living in the moment just before these trends cross.

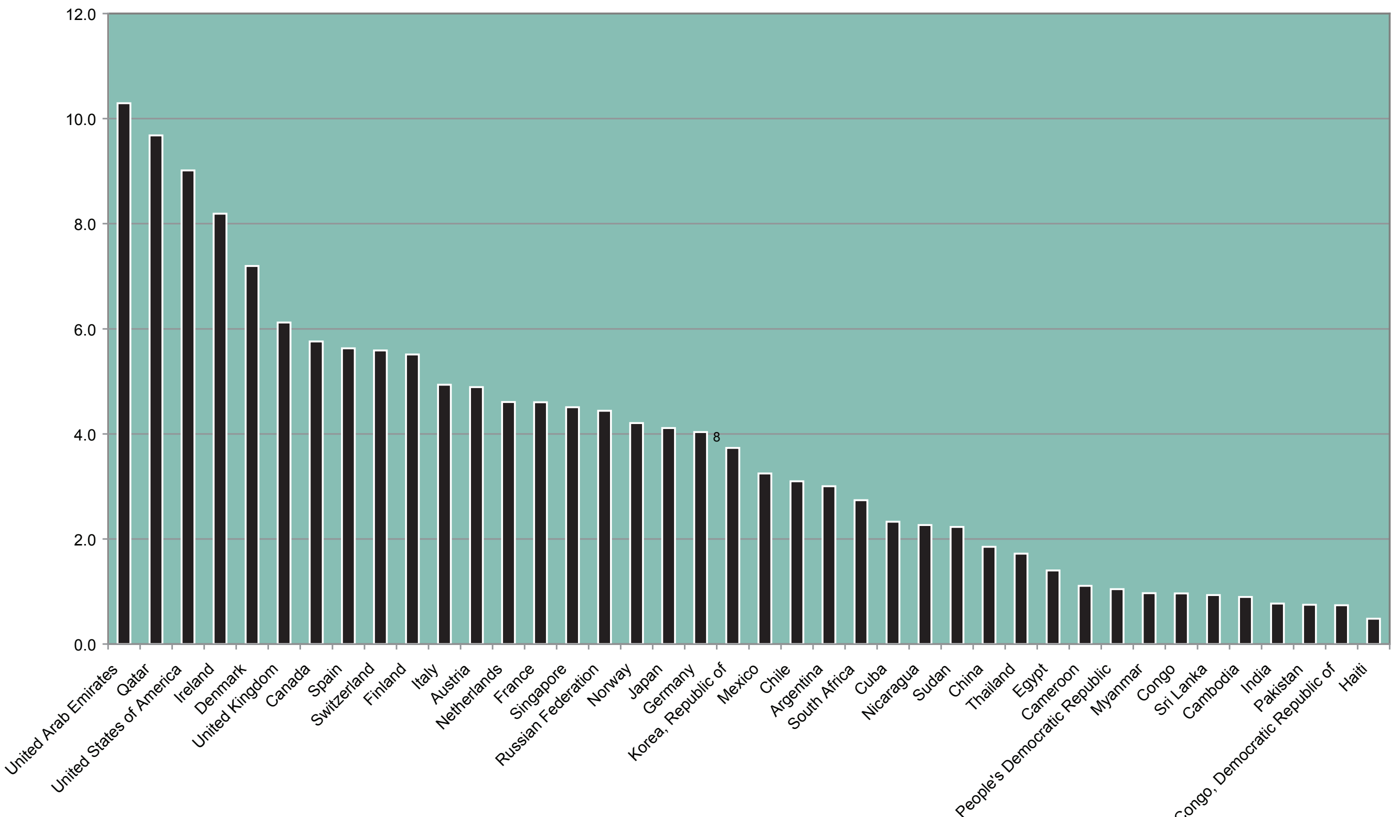


Figure 3: *Ecological footprint of nations 2009 [hectares per capita]* [3]

1) Weizsäcker, Bren School Seminar, Winter 2008

2) Weizsäcker, Bren School Seminar, Winter 2008

3) Global Footprint Network, Advancing the Science of Sustainability, 2009

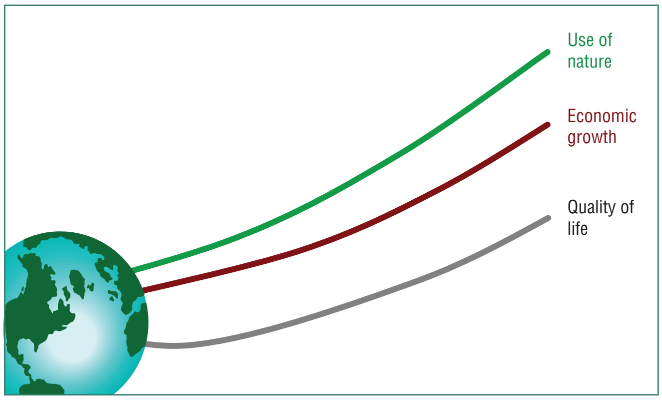


Figure 4: *Increase in quality of life has come at the expense of nature [4]*

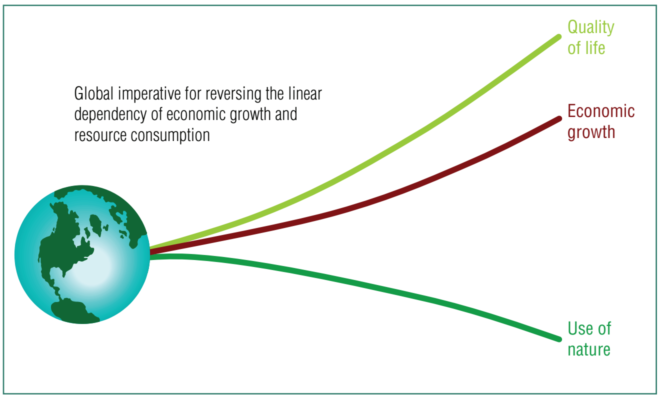


Figure 7: *The answer is decoupling the increase in quality of life from the use of nature*

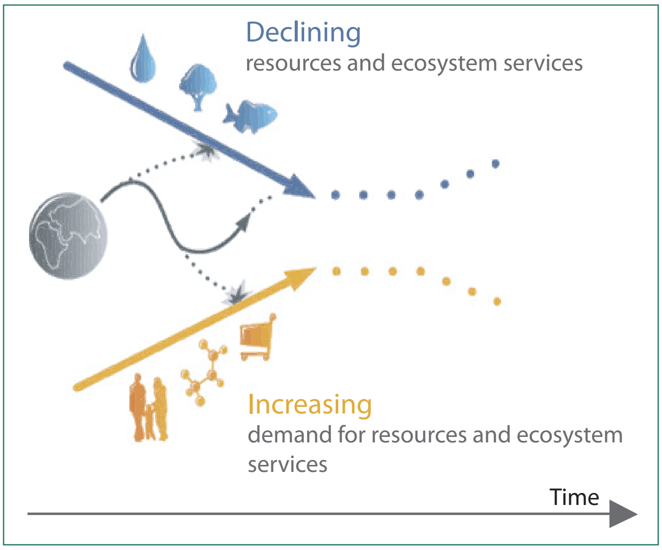


Figure 5: *The Funnel Metaphor*

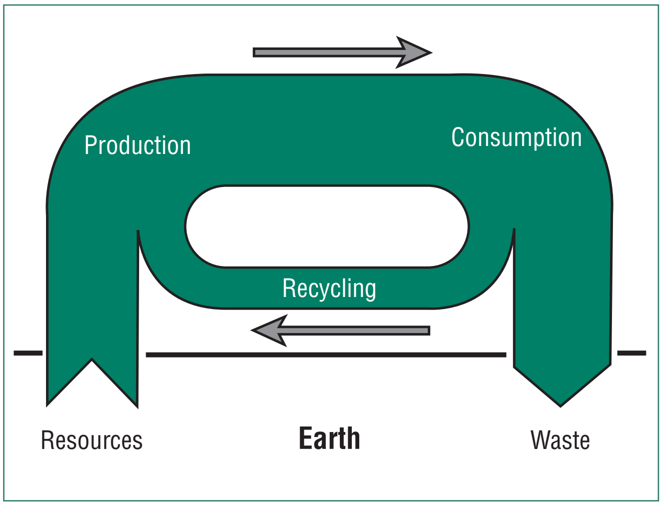


Figure 8: *Resource Efficiency managing materials and energy flows to minimize waste and emissions from production, use and disposal of resources*

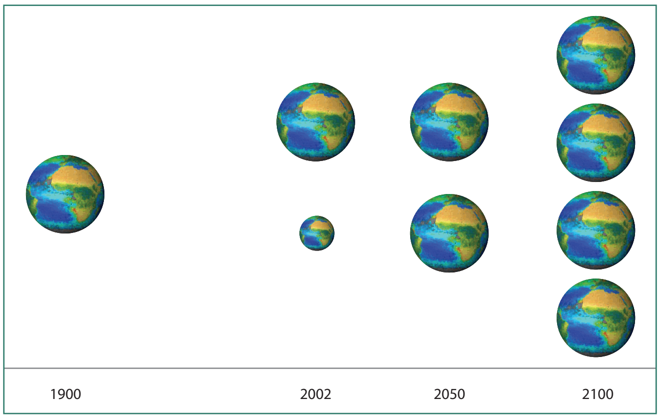


Figure 6: *Mankind is overusing the carrying capacity of our planet. By 2050 a 100% overuse is predicted.*

WWF concluded that we are now living in severe ecological overshoot: global society is consuming 25% more than the regenerative capacity of the planet. Global society lives on "ecological credit", but the longer we over-use this service, the greater the likelihood that the regenerative capacity of the planet's ecosystem will be irreversibly degraded.

Strategic actions like Resource Efficiency in SMEs can open up the funnel and lead to a sustainable future.

Decoupling economic growth from resource use and environmental impacts (Figure 7) means reducing the energy, land, water and materials needed for our growing economies, in a way that reduces the risk to climate change, loss of biodiversity and impacts on human health[5]. For business it will involve changes to desgin, production and marketing activities that will improve profits in the long run, while reducing the resources used and emissions produced.

Decoupling is seen as a strategy to increase Reource Efficiency, and therefore increase productivity and reduce the impacts on the environment.

Resource Efficiency is mainly about managing raw materials, energy and water along the value chain in order to minimize waste and detrimental impacts on the ecosystems throughout the entire lifecycle of production. Being resource efficient will reduce the cost of production (Figure 8).

4) WWF One Planet Business – Creating Value within Planetary Limits. 2007 First Edition

5) The International Panel for Sustainable Resource Management, 2010

When done properly, Resource Efficiency can be a relatively cheap and fast way to reduce waste as well as the cost of any subsequent treatment process and disposal costs. Reusing resources can also save companies money, because if they can efficiently use the resources they already have, they will need to buy less new resources. Regulations and diminishing natural resources will increase the incentive to use and reuse the latter even more efficiently in the future.

Benefits of Resource Efficiency for companies include:

- Reduction in cost for materials, chemicals and energy
- Reduction in cost for disposal of waste and treatment of emissions
- Reduced cost for compliance with laws governing waste, emissions and the use of chemicals
- Over the long term, Resource Efficiency applied at large secures the supply of resources to all businesses
- Resource Efficiency meets the growing customer demand for sustainable business practice

2.2 Serious threats: Global warming, deforestation, water and resource scarcity

2.2.1 Global warming

Global warming refers to the steady increase of the average temperature of the Earth's surface since the mid-20th century. Global surface temperature has increased by 0.74 ± 0.18 °C during the last century (Figure 9). The Intergovernmental Panel on Climate Change (IPCC) concludes that increasing greenhouse gas concentrations resulting from human activity are to blame for most of the observed temperature increases. The IPCC also concludes from simulation calculations that variations in natural phenomena, such as solar radiation and emissions from volcanoes, had a small cooling effect after the 1950s. The IPCC report has been endorsed by more than 45 scientific societies and academies of science.

The main physical result of global warming is the 'greenhouse effect', the atmospheric reflection of heat energy that would otherwise be lost to space. When sunlight reaches Earth's surface, some is absorbed to warm the land but most is radiated back up to the atmosphere at a longer wavelength than the sunlight that entered. Greenhouse gases like carbon dioxide effectively absorb this radiation.

An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere and, therefore, to an effective radiation into space from a higher altitude at a lower temperature. This causes radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect.[7]

Global warming is closely linked to the enhanced greenhouse effect, which is an increase in the concentration of greenhouse gases in the atmosphere leading to an increase in the amount of infrared or thermal radiation near the surface. Most scientists agree that the enhanced greenhouse effect is leading to rising temperatures, referred to as global warming, and other changes in the atmospheric environment, known as climate change.[8]

Carbon dioxide (CO_2) is the most significant anthropogenic (man-made) greenhouse gas. The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 387 ppm in 2009. The atmospheric concentration of carbon dioxide at present exceeds by far the natural range over the last 650,000 years as determined from ice cores (180 to 300 ppm).

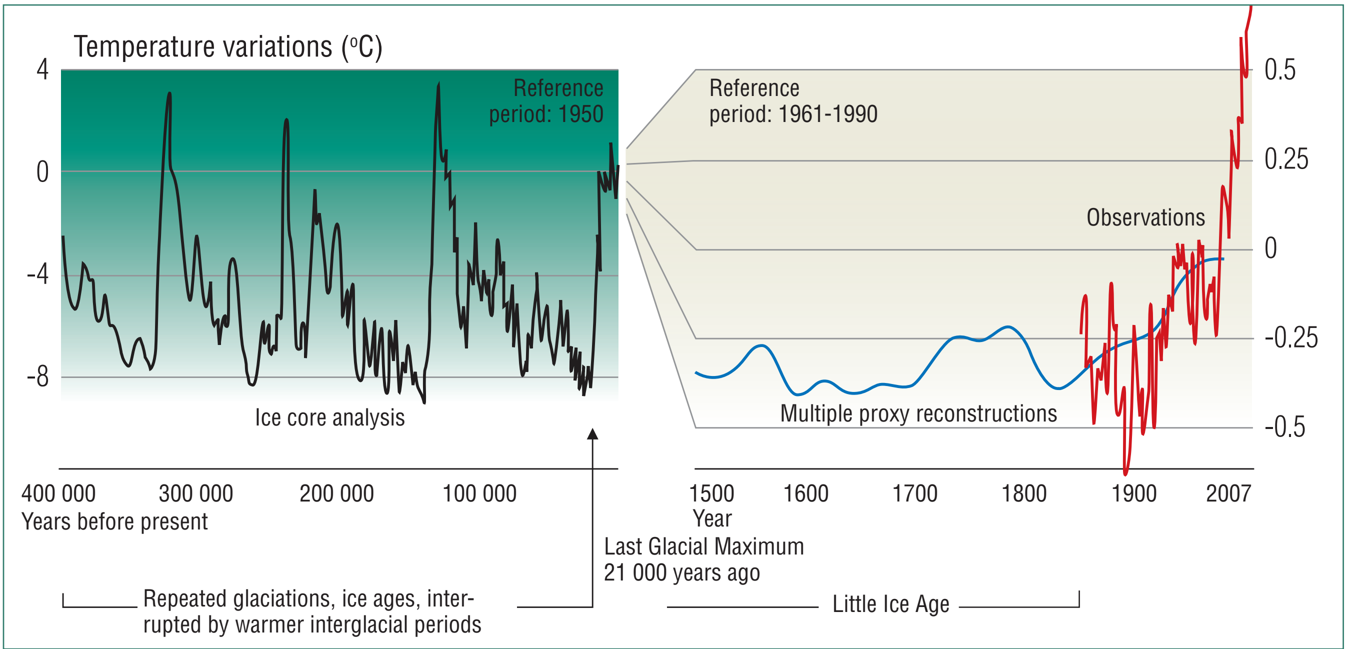


Figure 9: *Increase in carbon emissions has caused global warming* [6]

6) UNEP, GRID Arendal, Interactive map collection, 2008

7) IPCC, A.P.M. Baede, Glossary of Terms used in the IPCC Forth Assessment Report, 2007, S. 943-946.6

8) Global-Greenhouse-Warming.com

2.2.2 Deforestation

Deforestation is caused by farmers that cut down trees to get farmland and fuel and by industrial loggers to get raw material for paper production, for cattle grazing and for the production of crops like palm oil, rubber, spices, fruits, tobacco. When the soil of the rainforest is left without the canopy, it quickly dries out and erodes. In this way it loses the capacity to absorb water, resulting in droughts during the dry season and floods during the wet season.

2.2.3 Water security

As population increases and economies develop, increased use of fresh water for domestic use, for agriculture and for industrial sectors, puts pressure on water resources. This leads to conflicts among users. Furthermore, growing pollution worldwide threatens freshwater resources. Figure 11 shows regions of water scarcity in a world map[10]

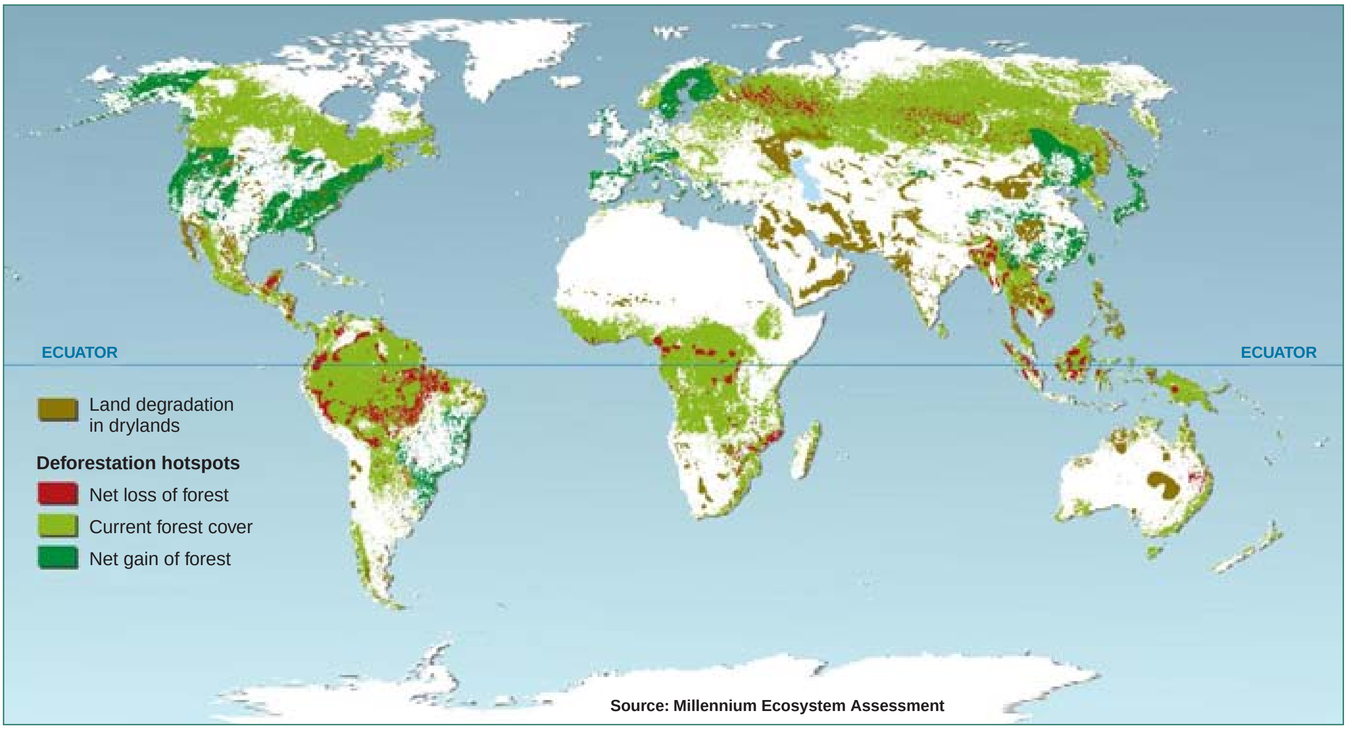


Figure 10: *Deforestation rates globally* [9]

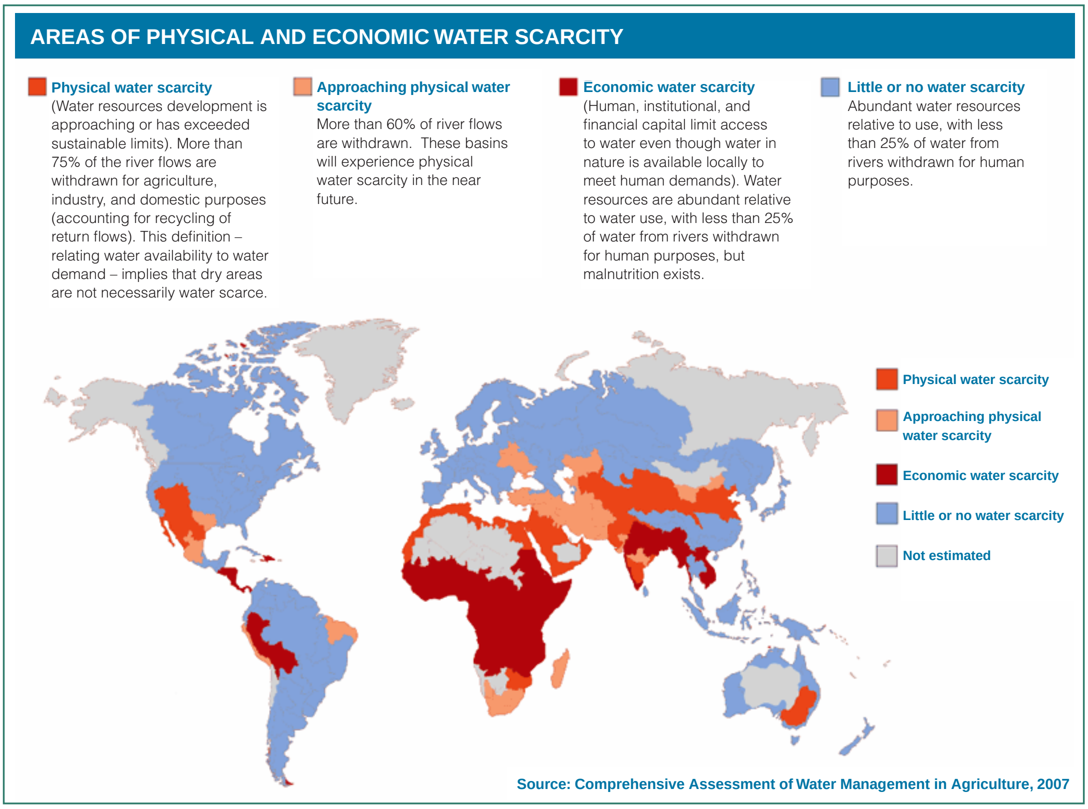


Figure 11: *Regions with physical and economic water scarcity*

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9) FAO, Forest and Griculture assessment, 1995

10) FAO, Comprehensive Assessment of Water Management, 2007

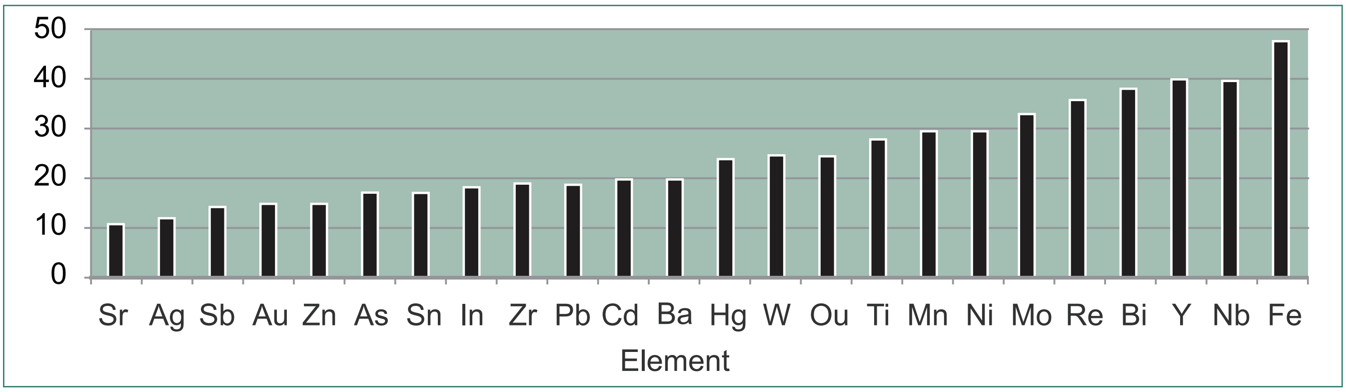


Figure 12: *Years left of reserves for a range of metals*

2.2.4 Resource scarcity

Industrial production presently depends on fossil fuels. Further utilisation of hydro-power is limited and controversial, and the dangers and costs of nuclear power were strongly underestimated in the past. The availability of fossil fuels has been a subject of controversy for a long time. The accessible reserves in fossil fuels have been depleted.[11] The worldwide extraction rate has reached a plateau and will soon begin to decline.[12] The result is a widening supply gap because global economic growth requires a sustained supply in energy.

A number of metals are already in short supply (e.g. indium) and the present extraction rates for many important metal minerals in the next few decades are not sustainable. Amongst them are all precious metals (gold, silver and platinum-group metals), zinc, tin, indium, zirconium, cadmium, tungsten, copper, manganese, nickel and molybdenum.[13]

The research scientist André Diederen concludes that without timely implementation of mitigation strategies, the world will soon run out of all kinds of affordable mass products and services including cheap, mass-produced consumer electronics such as mobile phones, flat screen TVs and personal computers because of the lack of various scarce metals (amongst others indium and tantalum). Most mass-produced products will suffer from much lower production speeds (or much increased tooling wear) during manufacturing owing to a lack of the desired metal elements (e.g. tungsten and molybdenum) for tool steels or ceramics (tungsten carbide). Among the affected mass-produced machined products are various household appliances and all types of motorised means of transportation (cars, trains, ships and aeroplanes). The lack of various metal elements (e.g. nickel, cobalt, copper) for high-performance steels and electromagnetic applications will affect all sectors that use high-performance rotating equipment. Figure 12 shows the years left of reserves globally at a sustained annual primary production growth rate of 2% for a range of metals.

Country	Raw material	Period of conflict
Columbia	Oil, gold, coca	Since 1984
Peru	Coca	1980-1995
Angola	Diamonds, oil	1975-2002
Angola (Cabinda)	Oil	Since 1975
Sierra Leone	Diamonds	1991-2000
Liberia	Diamonds, wood, palm oil, iron, cacao, coffee, marihuana, rubber	1986-1996
Democratic Republic of the Congo	Coltan, diamonds, gold, cobalt, copper	1996-1997; since 1998
Republic of the Congo	Oil	1997
Sudan	Oil	Since 1983
Afghanistan	Opium, jewelry	1978-2001
Burma	Wood, jewelry, opium, tin	Since 1949
Cambodia	Wood, jewelry	1978-1997
Indonesia (Aceh)	Gas, wood	Since 1975
Indonesia (West-Papua)	Copper, gold	Since 1969
Papua New Guinea – Bougainvillea	Copper, gold	1988-2001
Morocco	Phosphate, oil	Since 1975

Table 1: *Wars connected with raw materials 1990-2002*

2.2.5 Scarcity of raw materials and war

An example of the link between the demand for raw materials and war is coltan, which is a mineral concentrate with high contents of tantalum and niobium. It is used, for example, for notebook computers and mobile phones. In the last decade, there was a very high demand for coltan that producing countries such as Australia and Brazil could not meet, causing a supply shortage. This supply shortage occurrred at the same time as the civil war in the Democratic Republic of the Congo started; a war about the future mineral and property rights of coltan. This civil war ended in 2003 and nearly 4 million people died in the conflict. The coltan conflict in the Democratic Republic of the Congo is not the only example of the connection between raw materials and war. A survey of the World Bank shows 16 conflicts where raw materials are the cause of conflicts. Table 3 shows the links between the demand for raw materials and conflicts between 1990-2002.

In the last few years a number of international initiatives have been taken to find solutions to this problem. They offer ethical guidelines for the handling of raw materials in critical regions for nations and companies – for example: the OECD guideline for multinational companies; the Global Reporting Initiative of the United Nations; and the Kimberley-Process especially for diamonds and the Extractive Industries Transparency Initiative for sustainability of mining.[14]

11) Robert U. Ayres, Resources, Scarcity, Growth, and the Environment, 2001
12) Association for the Study of Peak Oil and gas (ASPO), Newsletter No. 97, 2009
13) Diederen A.M, Metal minerals scarcity: A call for managed austerity and the elements of hope, 2009
14) Reuscher G., Innovationen gegen Rohstoffknappheit, 2008, Zukünftige Technologien Consulting, Düsseldorf

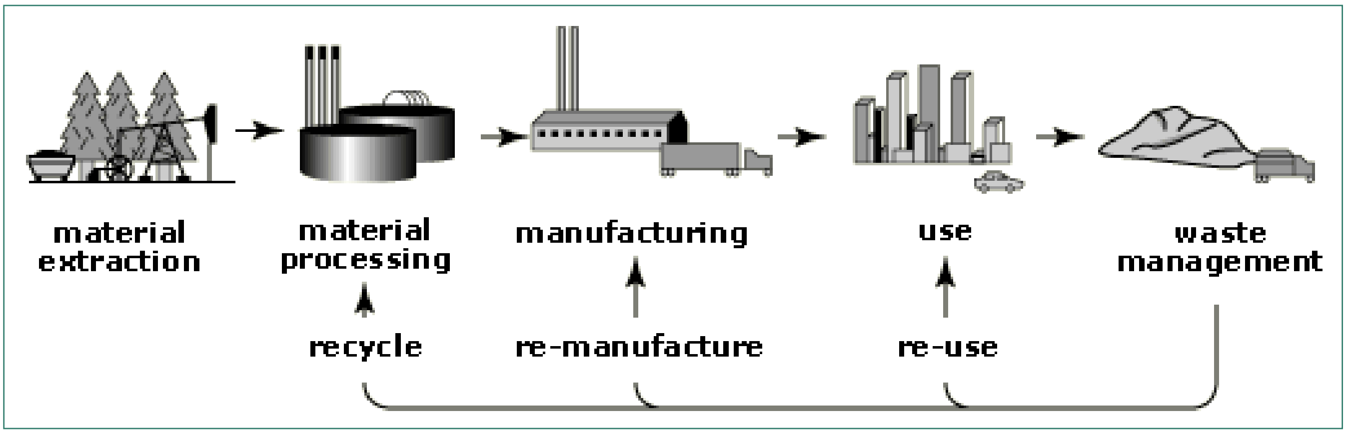


Figure 13: *Life cycle analysis of a product shows material and energy flows of material extraction, processing, manufacturing, use and disposal as a basis to develop Resource Efficiency strategies.*[15]

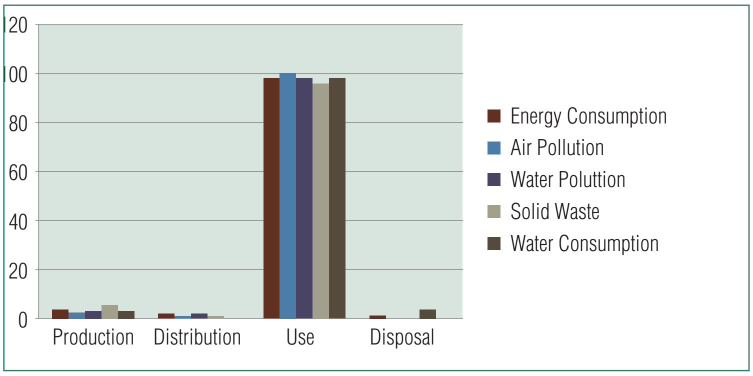


Figure 14: *LCA of a washing machine*[16]

2.3 Life cycle analysis

Resource Efficiency involves the consideration of all the stages of the life cycle of a product including extraction of resources, production, the use of the product and disposal or recycling.

Fabrication of a product with minimal use of resources involves: reducing up-take of raw material, reusing materials from other processes, recycling products into new products and repairing products instead of replacing them with new ones. To be effective, such considerations must be built into industrial processes and the life cycle planning of a product.

The product life cycle in Figure 13 is shown in five distinct phases, all of which interact with the environment. Figure 13 also shows, as feedback loops, the potential for recycling, remanufacturing and reuse. Reuse is the strategy that potentially has the lowest environmental impact, based on the fact that this involves fewer processes; each stage absorbs energy and has an environmental impact.

Depending on the type of product, major environmental and social impacts might originate from different stages. With some materials such as copper or aluminium, the extraction phase has the biggest impact because of the energy intensity of this step. With battery-powered products the phase of use might have the biggest impact because of the use of consumable batteries, which are generally classified as hazardous waste. A car, for example, has equal energy consumption in production and use. The environmental impact of different phases for each product should be understood to identify the priority areas, to reduce the environmental impact and to increase Resource Efficiency.

Figure 14 shows a Life Cycle Assessment (LCA) of a washing machine in terms of the energy and water used, of the contribution to air and water pollution, and of solid waste. As you might expect, most of the environmental impact is during use. You might have predicted that most of the solid waste impact would be the two stages of delivery (when the packaging is removed and disposed of) and eventual end-of-life disposal. Whilst the solid waste levels are indeed significantly higher than other contributors at these stages, in fact they total less than 15% of the solid waste produced by the washing machine. Just think of the many packets of washing powder and other consumables that are thrown out during the machine's life. This illustrates that every aspect of use must be considered carefully and that the 'system boundary' must be drawn broadly enough to cover all relevant externalities.

2.4 Indicators for Resource Efficiency

2.4.1 Dematerialisation: Material intensity per unit of service

As outlined in Agenda 21 of the United Nations Conference on Environmental and Development (UNCED) in Rio de Janeiro in 1992, there is a need for sustainability indicators to provide a solid basis for decision-making and to measure progress.

In 1992, Prof. Schmidt Bleek proposed the Material (including energy) Intensity Per unit of Service (utility or function) - the MIPS - as a measure for "estimating the ecological stress potential of goods and services from cradle to grave". MIPS is computed in material input per total unit of services delivered by the product over its entire useful life span (Resource extraction, manufacturing, transport, packaging, operating, reuse, recycling and remanufacturing are accounted for, and so is the final waste disposal). From the material inputs of resource extraction, manufacturing, transport, etc., the 'ecological rucksack' of a product or service is calculated. Ecological rucksack means the consumption of resources and energy during the extraction of the resources in the ground and its processing.[17]

15) Source: Martin Tarr

16) Source: Andrew Sweatman

17) Schmidt-Bleek F., The Factor 10/MIPS-Concept, Bridging Ecological, Economic, and Social Dimensions with Sustainability Indicators', F., 2000

It is evident that MIPS could be used as the entry point (or 'base set') for a step-system approach in the process of eco-balancing products and services.

Either lowering the Material Intensity (MI) for a given Unit of Service (S) or increasing S with a fixed quantity of resources can improve resource productivity. Both changes can be achieved through technological as well as nontechnical changes. For example, by increasing the longevity of goods, by leasing rather than selling a product, or by sharing buildings, infrastructures, vehicles or machines the total number of service units can be improved dramatically, without a corresponding increase in the total input of natural raw material.

By following the request of hotel owners to utilise towels more than once ("to be nice to the environment"), guests can increase the resource productivity of providing towels without loss of convenience or hygiene by factors 2 or 3, and save money for the hotel owner in the process.[18]

'Factor Ten' (a 90% reduction in energy and materials intensity) and 'Factor Four' (a 75% reduction) have entered the vocabulary of government officials, academics and businesspeople throughout the world.

Country	Lifetime[20] (years)
Methane	12
Nitrous oxide	114
HFC-23 (hydrofluorocarbon)	270
HFC-134a (hydrofluorocarbon)	14
Sulphur hexafluoride	3,200

Table 2: *Global warming potential (GWP) of different substances*

Energy content of various fuel types		
Fuel type	**LCV GJ/t**	**LCV kWh/kg**
Coal	28.1	7.8
Light fuel oil	42.6	11.8
Heavy fuel oil (furnace oil)	41.2	11.4
Natural gas	50.6	14.1
Gasoline	42.5	11.8
Diesel	42.8	11.9
Energy content of various fuel types		
Fuel type	**t CO_2 per TJ**	**t CO_2 per t**
Coal	94.0	2.6
Light fuel oil	73.7	3.1
Heavy fuel oil (furnace oil)	77.0	3.2
Natural gas	55.0	2.6
Gasoline	73.9	3.1

Table 3: *Combustion values and carbon emissions of different fuels*

LCV = lower calorific value

The governments of Austria (National environmental plan 1994, 2002 and again 2009), the Netherlands (1989, 2006), Sweden (2002) and Norway (2008) have publicly committed to pursuing Factor Four efficiencies. The same approach has been endorsed by the European Union (2006) as the new paradigm for sustainable development.

The concept is not only common parlance for most environmental ministers in the world, but leading corporations such as Dow Europe and Mitsubishi Electric see it as a powerful strategy to gain a competitive advantage.

2.4.2 Decarbonisation: Carbon footprint

The various greenhouse gases (GHG) have a different contribution to the greenhouse effect.[19] The strength of the greenhouse effect is expressed by the Global Warming Potential (GWP). GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale that compares the gas in question to that of the same mass of carbon dioxide, whose GWP is by definition: 1. A GWP is calculated over a specific time interval.

To combat global warming, the Kyoto Protocol was drafted and adopted by global governments in 1997. It limits the emissions of the most significant greenhouse gases. For more information on the Kyoto Protocol see Chapter 10.4.

Greenhouse gases have widely varying GWP. The GWP of the most common GHG are indicated in Table 2. Carbon dioxide is the baseline unit to which all other greenhouse gases are compared.

CO_2 is the waste product from the combustion of fossil fuels, which contain - depending on the type of fossil fuel - a variable amount of carbon (C). The specific CO_2 emissions therefore vary depending on the composition of the respective fuel.

Switching from furnace oil to natural gas for example reduces the CO_2 emissions per GJ from 77 to 55 metric tonnes. In other words, the production of ± the same amount of heat in a boiler leads to a reduction of CO_2 emissions by roughly 30%.

The **carbon footprint** relates to the amount of greenhouse gases produced in our consumption of energy for production, heating and transportation. Nearly everything we do emits carbon. For example, a car's engine burns fuel that creates a certain amount of CO_2 depending on its fuel consumption and the driving distance. Heating a house with oil or gas also generates CO_2. of electrical power at a power plant will emit a certain amount of CO_2, unless this is a hydroelectric power plant. Also in agriculture, pesticides and herbicides are responsible for a certain amount of CO_2 from the energy use during production. Transport of food also causes emissions, which are taken into consideration when calculating the carbon footprint of a person, organization or product. A carbon footprint is defined as:

> *The total amount of greenhouse gases produced directly and indirectly supporting human activities, usually expressed in equivalent tons of carbon dioxide (t CO_2e).*

18) Shmidt-Bleek F., The Factor 10/MIPS-Concept, Bridging Ecological, Economic and Social Dimensions with Sustainability Indicators, F., 2000
19) Time for Change, Cause and effect of global warming, undated.
20) Atmospheric lifetime describes how long it takes to restore the system to equilibrium following an increase in the concentration of a greenhouse gas in the atmosphere.

Each of the following activities adds 1 kg of CO_2 to the carbon footprint of a British person (calculated using the current UK mix of electricity and public transport):

- Travel by public transportation (train or bus) a distance of 10 to 12 km (6.5 to 7 miles)
- Travel by car a distance of 6 km or 3.75 miles (assuming 7.3 litres petrol per 100 km or 39 mpg)
- Fly on an aeroplane a distance of 2.2 km or 1.375 miles.
- Operate your computer for 32 hours (60 Watt consumption assumed)
- Production of 5 plastic bags
- Production of 2 plastic bottles
- Production of 1/3 of a cheeseburger

2.5 Cleaner Production

The term 'Cleaner Production' was first coined in September 1990 by UNEP and is defined as "the continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment."[21]

Cleaner Production can be applied to the processes used in any industry, to products themselves and to various services provided in society.

For production processes, Cleaner Production is the result of one or a combination of the following: conserving raw materials, water and energy, eliminating toxic and dangerous raw materials, and reducing all emissions and wastes at the source.

For products, Cleaner Production strategy focuses on reducing the environmental, health and safety impacts of the product over its entire life cycle from raw materials extraction to the ultimate disposal of the product.

For services, Cleaner Production reduces the environmental impacts of the service provided over its entire life cycle: from designing the system, its use, to the entire uptake of resources required to deliver the specific service.

Thus, Cleaner Production is an approach to environmental management that aims to improve environmental performance by focusing on the cause of environmental problems rather than the results. In this way, it is different from traditional 'pollution treatment and control' approaches. Cleaner Production is a pro-active, 'anticipate and prevent' philosophy. Cleaner Production is a 'win-win' strategy; it protects the environment, the consumer and the worker while improving industrial efficiency, profitability and competitiveness.

Cleaner Production can therefore not only be applied to production processes, but it can also be applied throughout the life cycle of a product, from the initial design phase, through to the consumption and disposal phase. It aims to ensure conservation of resources, the elimination of toxic raw materials, and the reduction of wastes and emissions.

Five common generic techniques for implementing Cleaner Production include:

- Improved housekeeping practices
- Process optimisation
- Raw material substitution
- New technology
- New product design

Cleaner Production is an all-embracing strategy, which is directed towards reducing environmental impacts and risks by considering minimisation of pollution at source by a diverse range of activities. Besides preserving environmental value, an important feature of Cleaner Production is that by preventing inefficient use of resources and avoiding unnecessary generation of waste, companies benefit from reduced operating costs, reduced waste treatment and disposal costs and reduced liability. Investing in Cleaner Production to prevent pollution and reduce resource consumption is usually more cost-effective than continuing to rely on increasingly expensive 'end-of-pipe' solutions.

There are a number of analogous terms for Cleaner Production, such as eco-efficiency, green productivity and pollution prevention, among others, with slightly different focuses.

For several sectors, strategies to approach the vision of zero waste appear feasible: in metal manufacturing, steel or aluminium scrap can be collected and reprocessed, oils can be collected and reprocessed or used as fuel to generate energy. In the paper industry, black liquor is recycled generating energy, waste paper is collected and the fibres can be reused for hygienic paper or kraft paper. In the food industry, waste can be collected and used as animal food; wastewater can be treated anaerobically to give methane, which then is used to generate electricity and heat.

2.6 Safer Production for Hazardous Materials

In the industrial environment a variety of hazardous substances, dangerous goods, and combustible liquids are used. Depending on their properties, hazardous materials can cause adverse health effects such as severe poisoning, skin rashes, allergic reactions, cancer, as well as physical effects such as fire, explosion, release of hazardous gases and corrosion. When hazardous materials are not stored or handled correctly, they can cause harm to workers, neighbours and the environment due to their physical, chemical and biological properties.[22]

Examples of some hazardous materials include:

- solvents
- degreasers
- cleaning chemicals
- paints
- drugs
- cosmetics
- detergents
- acids and caustics
- refrigerant gases
- metals such as lead, cadmium, chromium
- gas cylinders
- pesticides
- herbicides
- diesel fuel
- petrol
- liquefied petroleum gas

21) UNEP, Sustainable Consumption & Production Branch, Cleaner Production, undated

22) The State of Queensland (Department of Justice and Attorney-General) 2009, available from www.deir.qld.gov.au/workplace

Hazardous substances and dangerous goods are chemicals for which a manufacturer or importer must provide a Material Safety Data Sheet (MSDS). A MSDS includes a characterisation of the materials, and guidelines for handling, storage and safe disposal.

Unsafe storage and handling of chemicals off-site by both dealers and end-users have documented environmental and health consequences[23] because they frequently do not have the proper training or knowledge regarding the risks posed by products and used containers. Additionally, accidents with hazardous substances can also occur during transport e.g. on roads, railways or inland waterways. Transport accidents involving hazardous substances can have severe consequences for the affected communities.

Safer production aims at using less hazardous materials, understanding the risks involved and controlling their use. Thus it minimises the occurrence and harmful effects of technological accidents and environmental emergencies. The strategy is to identify and create awareness of risks in an industrialised community, to initiate measures for risk reduction and mitigation, and to develop coordinated preparedness between the industry, the local authorities and the local population.

Value of management integration	Explanation
Reduction of duplication	Integrated management systems use a generic management model that encompasses environment, quality and risk management in one tool. Therefore redundancies in defining responsibilities will be avoided and the duplication of documentation is minimized, reducing the cost of maintaining the management systems.
Reduction of risks	A management system assesses risk to a company from different perspectives such as: environmental, quality management, and health and safety. This way, potential problems are more likely to be identified. Regulations and hazards are identified and measures taken to avoid them thus minimizing unknown risks, and reducing costs for potential liabilities and for insurance.
Balance of conflicting objectives	An integrated management system looks at the productive activities of a business and highlights conflicting procedures and objectives. The systems can then help to resolve these conflicts.
Elimination of conflicting responsibilities	Clear structure makes conflicts of responsibility visible and helps resolve them through streamlined organisation.
Focusing on business goals	Harmonizing and coordinating different goals through a system makes it easier to move towards the company's vision while not forgetting the company's environmental and societal responsibilities.
Formalisation of information in systems	Integrated management system uses one centralised information system with clear-cut indicators and reporting system that minimises information loss, inconsistencies and mistakes because of missing information.
Harmonization and optimisation of practices	Annual auditing and reviewing procedure optimise and streamline management practices and procedures systematically. Documentation of the audit is useful to measure progress towards company goals and information gathered can improve communication and be used to facilitate staff training and development.

Table 4: *Value of management integration*

2.7 Integrated Management Systems

An integrated management system is a management system that integrates responsibilities and procedures with regards to different aspects, such as quality, health and safety, environment and risk management, into one complete framework, enabling an organization to work as a single organism with clear and harmonized objectives.

Instead of creating responsibilities for the different departments separately, an integrated management system provides one organised framework, by which each process is controlled with consideration to quality, health and safety, environment and risk management.

An integrated management system allows a management team to create one system with a consistent set of process indicators, objectives and measures. An integrated system provides a clear and holistic picture of all aspects of an organization, how they interact and their associated risks. An integrated management system avoids duplication of documentation, training and auditing, and renders the maintenance of the system easier.

An example of an integrated management system might be a combination of the following standards:

- ISO 9001 (Quality Management)
- ISO 14001 (Environmental Management)
- OHSAS 18001 (Occupational Health & Safety)
- ISO/IEC 27001 (Information Security)
- ISO 22000 (Food Safety)
- ISO/IEC 20000IT (Service Management)
- ISO 31000 (Risk Management)

2.8 Benchmarking

Benchmarking is the process of comparing one business to another one, by using key performance indicators. In classical benchmarking profit related indicators, production cost, or productivity are used as indicators. Applying benchmarking to resource efficiency, the relevant indicators relate to material and energy consumption, to waste generation and emissions.

"Best practice benchmarking" or "process benchmarking" is a process in which organizations evaluate various aspects of their processes in relation to industry standards. This then allows organizations to develop plans on how to make improvements or adapt specific best practices.

When benchmarking, companies need to be comparable in terms of products, processes, legal requirements, applicable prices, productivity, cost materials and energy use. Benchmarking works best on a unit operations level, meaning defined units that can be compared in different companies and sometimes even across sectors, for example, boilers, refrigeration equipment, air compressors, washing operations.

"Internal benchmarking" is a process that tracks the company's consumption patterns over time, and analyses it for variation; from this process, problems can be identified as well as good practices.

Benchmarking may be a one-off event, e.g. at the start of a resource efficiency project to analyse the status quo and the potential for improvement, but it is often treated as a continuous process in which organizations continually seek to improve their practices.

23) UNEP, Safer Production, undated

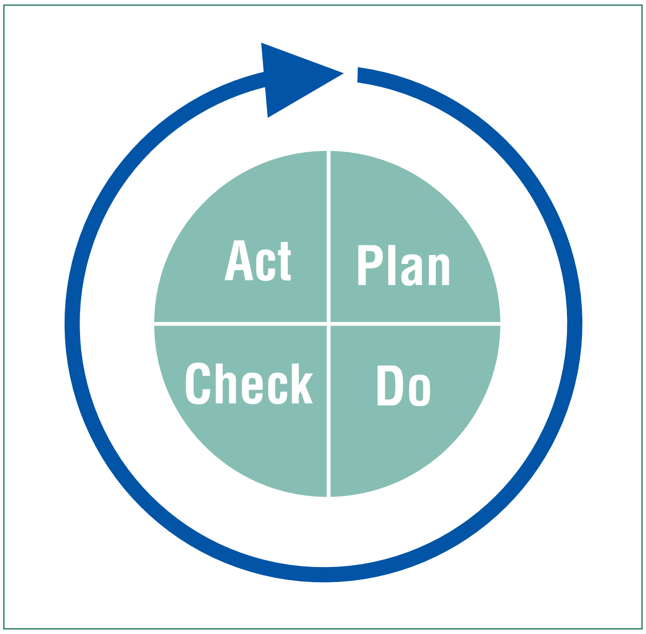


Figure 15: *The Deming Cycle – Plan-Do-Check-Act (PDCA)*

2.9 The Deming Cycle – Plan-Do-Check-Act (PDCA)

Dr W. Edwards Deming is credited with the creation of the Plan-Do-Check-Act (PDCA) and is considered by many to be the father of modern quality control.

The concept of PDCA is based on the scientific method developed from the work of Francis Bacon (1620). Modelling his cycle specifically on the scientific method, Deming's original cycle was "Plan, Do, *Study*, Act" but according to Deming, this was changed in the 1950s during a lecture series in Japan when participants shortened the steps to what we know today: "Plan, Do, Check, Act". Deming stated his preference for "study" over "check".

A fundamental principle of the scientific method and PDCA is iteration - once a hypothesis is confirmed (or negated), executing the cycle again will extend the knowledge further. Repeating the PDCA cycle can bring us closer to the goal, usually perfect operation and output.

The PDCA cycle should be implemented in repeated spirals. Each cycle should converge closer to the objectives than the previous. This approach is based on the theorem that our knowledge of a system always will be limited, but will be improved through learning. It is better to start a process even with limited knowledge, start from an initial analysis and improve it stepwise by developing a hypothesis, test it and proceed according to the results of the testing.

Scientific Method	Explanation
Hypothesise	Plan
Experiment	Do
Evaluate	Check

Table 5: *Scientific Method*

PLAN	Establish the objectives and processes necessary to deliver results in accordance with the goal or ideal state.
DO	Implement the new processes; start small if possible.
CHECK	Measure the new processes and compare the actual results against the expected results to ascertain any differences.
ACT	Analyse the differences to determine their cause. Each will be part of either one or more of the P-D-C-A steps. Determine where to apply changes that will include improvement. When a pass through these four steps does not result in the need to improve, refine the scope to which PDCA is applied until there is a plan that involves improvement.

Table 6: *Explanation PDCA*

The power of Deming's concept lies in its simplicity. The PDCA steps will be explained in detail in the following chapter.

Three

A management approach to PRE-SME

3.1 A systematic approach to PRE-SME

Preparing a SME for resource efficient product design and production is a complex task involving a wide range of departments from product design to purchasing, production, sales and maintenance. Therefore, the process needs a synchronized approach harmonized with the company's management system .

The underlying methodology for the PRE-SME toolkit is defined on the basis of the PDCA cycle. The descriptions of the relevant activities are largely in line with UNIDO's Cleaner Production Toolkit.[24]

3.2 Plan

During the "plan" phase, the following activities are performed:

- Management commitment
- Team formation
- Project planning

Management commitment
The first step in the change process is *getting management commitment*. This means introducing the idea of implementing a Resource Efficiency programme to top management of an SME. Reasons for Resource Efficiency can be found in the introduction to this manual and in the 'What' and 'Why' sections of the thematic modules of the electronic toolkit (or Chapters 4 to 8 of the manual). In the end, the prospect to save money from decreasing waste, energy consumption, chemical consumption, improve compliance without investing in wastewater treatment and reducing risk will motivate management to commit to a resource efficient programme.

Team formation
If the size and structure of the company is suitable an environment team can be set up. In some enterprises, the existing organizational and informational structure may be suitable to integrate tasks of the environment team into existing quality committees or health and safety teams. In small companies with less than 50 employees, it might be possible to involve staff during production meetings.

A 'project champion' is necessary to coordinate the project. Ask for a volunteer. His or her tasks include the coordination of the project, the provision of information and the representation of the project in front of management. A good mix of committed staff from the different departments of the company is the best choice for project champions.

24) Sage J., Fresner J., Engelhardt G., UNIDO Cleaner Production Toolkit, 2005 and 2008

Personnel from across the company can be included in the process, for example:

• Production	• Personnel department
• Engineering	• Legal department
• Maintenance	• Management
• Materials	• Consultant
• Administration	• Works committee
• Purchasing	• Planning
• Acceptance	• Development
• Sales	• Environment
• Buildings	• Safety
• Quality	• Energy
• Assurance	• Company doctor
• Accounting	

Not all of these areas and people need to be involved permanently. After all, if the team is too big, it can become inefficient. However, you should consult the organisational chart of your company to check whether all relevant positions are duly represented and be open to volunteer participation from willing parties in departments that were not considered relevant.

A Resource Efficiency policy should be formulated; it should describe the company's long-term and strategic Resource Efficiency goals and targets. This policy is the foundation which supports everything else. Begin by setting goals and then develop a 'Resource Efficiency action plan' to reach those goals. In this way, the strategic orientation with respect to action can be reliably followed.

Project design

The design phase involves the following steps:

- Initial walkthrough to collect first ideas
- Pre-assessment to set priorities:
  - Develop a process flowchart and identify inputs and outputs
  - Identify baseline: quantify inputs and outputs
  - Set priorities according to volumes, cost of waste and emissions, and risks
  - Develop initial programme
- Detailed assessment and option generation in relevant areas
- Evaluation and programme
- Implementation
- Reports and meetings

Good project design is necessary to manage resources and time, and to have milestones to check project progress against. The project design will dictate who does what and when.

A flowchart is a graphic representation of a process: process steps are represented by boxes; material, water and energy flows by arrows. A flowchart helps to trace waste and emissions back to their respective sources and thus show starting points for potential improvement. See Figure 16.

According to the principles of maintaining mass and energy, every material entering a certain balance area has to leave this area again afterwards. The only exception is if the material is stored or converted. This means that all output (waste) was once an input (purchases or resources).

In a manufacturing enterprise, all materials and energies are tabulated at three stages:

1. When they enter the balance area; i.e. when being purchased
2. When they are used according to specification; i.e. at the machine, plant
3. When they leave the balance area; i.e. as product, emission, waste or thermal discharge

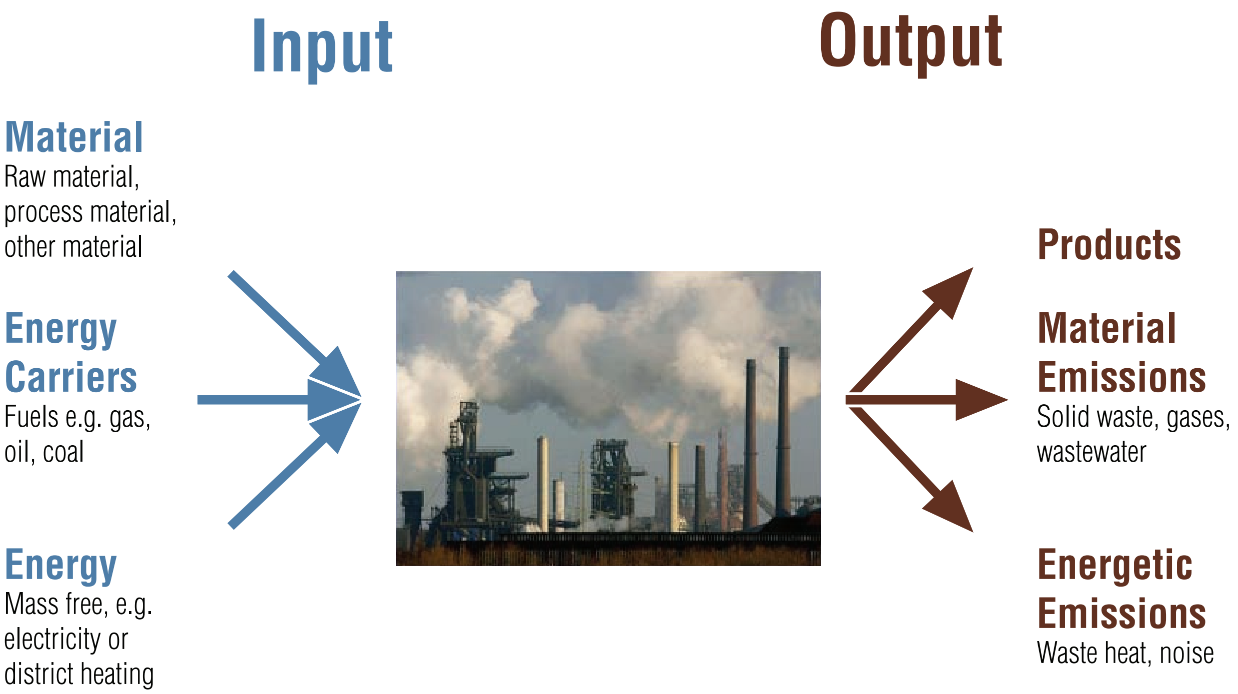


Figure 16: *Input/Output Flowchart*

Because of the previously mentioned principles of conservation, the quantities have to be the same at all three stages. If they do not match, this might indicate losses of optimisation potential.

In order to work out a systematic avoidance of waste and emissions, you should be familiar with the most important mass flows of your company. 'Important' can have the following meanings in this respect:

	Input				Output		
	kg	$	Source		kg	$	Source
Copper	100,000	3 m.	fin. acc.	Cables	110,000	120 m	Sales
PE	30,000	300,000	fin. acc.	Cable waste	15,000	120,000	Revenue, financial accounting
PVC	10,000	100,000	fin. acc.	Plastic waste	15,000	30,000	Financial accounting
Marking ink	3,000	300,000	ware-house	Waste oil	500	1,000	Disposal company
Diluting agent	1,000	180,000	ware- house	Diluting agent	600	1,000	Disposal company
Lubricating oils	500	30,000	ware-house				
Current		1 m.	fin. acc.	Waste heat	?		
Heating oil		500,000	fin. acc.				
Cooling water		?	own well	Waste water	?		Direct discharge

Table 7: *Example of an input/output analysis for a wire manufacturing company*

Numbers for these categories can be extracted from various sources such as:

Entry:
- Documents for bookkeeping and cost accounting
- Shipping documents
- Information of suppliers concerning formulae
- In-house data identification concerning packaging

Use:
- Cost centre accounting
- Measurements at plants and machines
- Information from staff concerning operating hours and change intervals
- Receipts of materials purchased
- Formulae
- Apparatus specifications

Exit:
- Product lists and formulae
- Records of waste and emissions, waybills
- Settlement of accounts with disposal companies
- Information about quantity and quality of wastewater (e.g. from measurements by the authorities or from the water association)

Data from the input/output analysis help to answer the following questions:

- How much raw and processed materials and energy is used?
- How big are waste and emission flows?
- From which process steps do waste and emission flows originate?
- Which waste is hazardous/requires monitoring, and why is it hazardous?
- Which part of raw or process material becomes waste?
- Which part of raw or process material is lost as volatile emissions?
- Which costs are created by the disposal of waste and the loss of purchased raw materials?

Raw materials can be categorised according to the type of waste they become or emissions they emit through processing. Depending on the category of waste and emissions, different strategies of avoidance and reduction can be developed and applied.

- Important because of legal provisions
- Important because of large amounts
- Important because of high costs
- Important because of specific properties of materials that endanger humans or the environment during production or use

In this phase, first indicators are calculated. These are:

- Waste per unit of product
- Material consumption per unit of production
- Water consumption per unit of product
- Energy consumption per unit of product

These indicators can help in an initial benchmarking exercise with data from other enterprises or sector specific data.

This preliminary assessment will generate the first ideas for improvement goals.

The first steps towards these goals should be started as soon as possible. At this stage, simple measures (e.g. training, formulation of identification of appropriate process parameters, introduction of measurement devices, clear regulation for operators) can be identified and acted upon.

3.3 Do

The 'Do' phase comprises of:

- Detailed water, energy, waste, chemicals audits according to the goals set during the pre-assessment
- Identification of improvement options
- Evaluation of feasibility
- Implement improvement measures

The water, energy, waste and chemical audits will be explained in detail in the following chapters. These audits use flowcharts to visualize the flows of water, energy, materials/mass and energy balances.

Figure 17 and Figure 18 show the application of mass balancing at a paint shop. In Figure 17 a comprehensive description of the material flows in a car repair paint shop is depicted. The green arrow is the

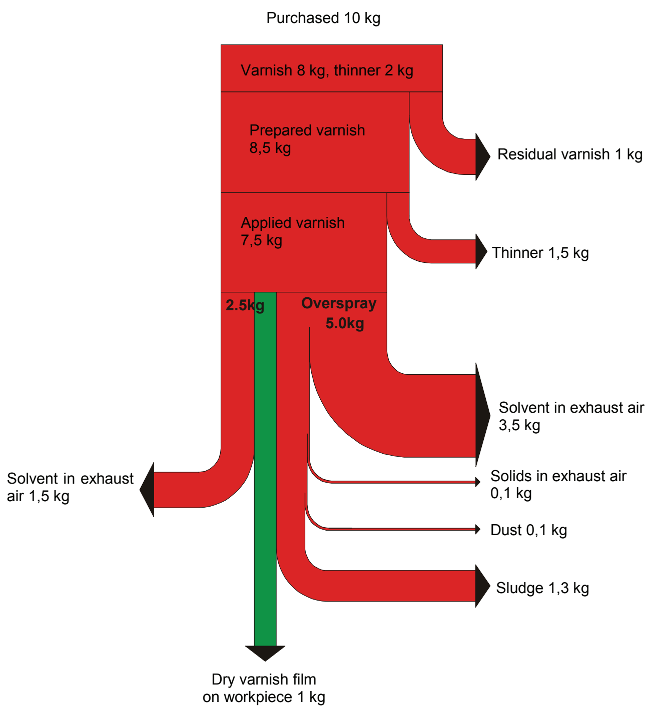


Figure 17: *Material flow analysis for painting a car in an auto repair shop (the green arrow is the product (dry paint on the part), the red arrows indicate wastes and emissions)*

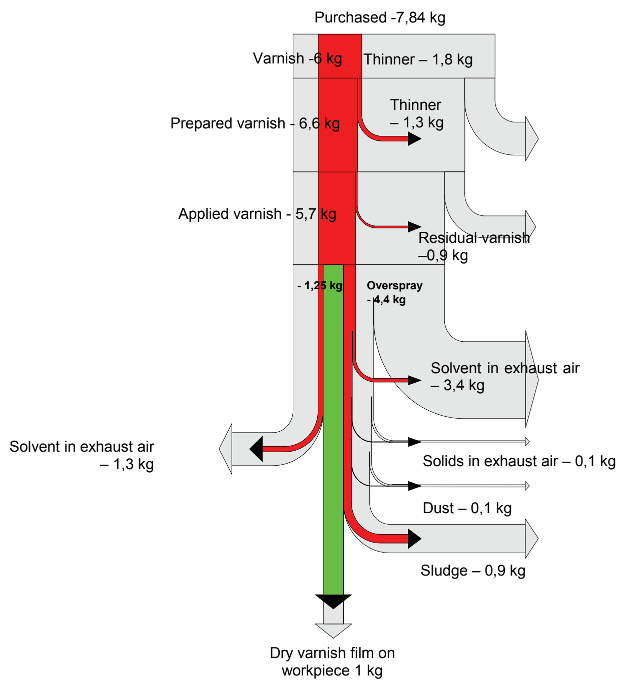


Figure 18: *Optimal material flow analysis for painting a car in an auto repair shop (the green arrow is the processed product, the red arrows indicate wastes and emissions)*

processed product (usually car body parts that have to be coated), the red arrows indicate wastes and emissions such as the thinner which is used for cleaning the tools, extra paint which is prepared but not used, solvent in the exhaust air resulting from the evaporation of the solvent of the paint and sludge generated from overspray.

Figure 18 shows a best practice situation using the latest technology – e.g. automatic equipment to clean the guns, high volume, low pressure guns.

The generation of Cleaner Production Options is at the heart of the activities of a Resource Efficiency project. There are different strategies to identify options:

- Use of manuals and checklists
- Ask equipment suppliers
- Use the creativity of the Resource Efficiency team

Resource Efficiency options can also be derived from information from suppliers who will be glad to give you information on the specific performance data for material and energy consumption of their equipment.

While identifing options for your company it is common to encounter some difficulties raised by personnel; typical concerns include:

- We have always worked like this.
- We are too big/too small for this.
- Do not forget we have to earn money.
- This does not affect my department.
- Nobody told me what to do.
- It is not my business.
- I am very busy.
- Let someone else do this.
- I did not understand.
- It is too early for this or it is too late now.

To overcome these barriers there are a number of methods to help break up these limits to our perception.

It is valuable to divide the process of creative problem solving into four stages as shown in Figure 19: i) Problem analysis, ii) Idea finding, iii) Evaluation and iv) Realisation.

i) Problem analysis: The point of this phase is to arrive at a clear description of the problem. It is here that the focus should be drawn to the actual problem; for example, what is the source of our waste and emissions? Document the boundary conditions of the problem and document the history of the problem; for example, what has been done in the past to solve the problem, what has worked, what has not worked?

ii) Idea finding: The point of this phase is to take a step back from the problem and look at it from a bird's-eye view. Idea finding is done on an abstract level and should build on all available information. In this phase there is absolutely no criticism. The goal is to end up with as many creative ideas as possible. Idea finding is also known as brainstorming.

iii) Evaluation: In the evaluation phase, ideas from the previous phase are evaluated one-by-one on the merits of their technical feasibility, their economic payback time and their ecological impact. After a strict evaluation, the most promising options are selected.

iv) Realisation: In this phase, ideas selected from the process are implemented. For each activity, a team member will be assigned to follow up the process of implementation. Implementation can be straightforward, if the identified activity is, for example: to change set points or recipes, it can involve the definition of working procedures and training; it can involve the design of revamps or the selection of suppliers, a bidding procedure or the supervision of the supply.

There are a number of factors that influence the efficiency of the creative process. Individual factors involve the personalities of the people involved in the process, their age, their experience, intellectual versatility, and also their motivation and disposition. Organisation factors include

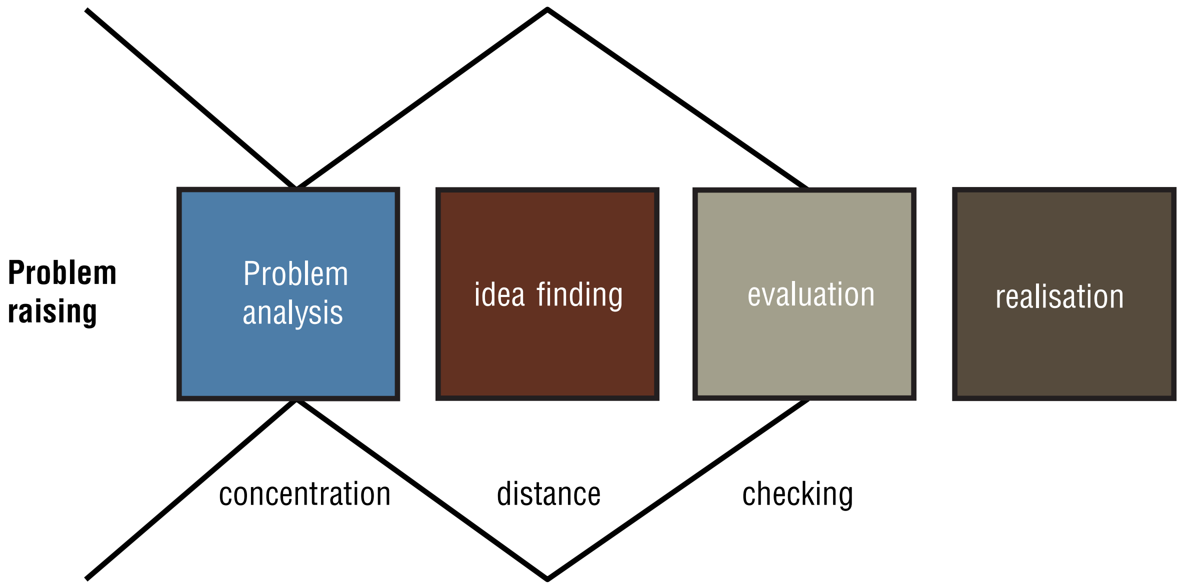


Figure 19: *A problem solving process scheme used to direct focus during the analysis phase on setting priorities, opening the space for potential solutions during brainstorming and completing the feasibility analysis before implementing selected options.*

the hierarchy of the organisation and autonomy of individuals within the organisation. The style of leadership will also affect the efficiency of the creative process. Consider how information and communication moves through the company, the openness of the culture and the degree of internal standardisation of operations. Brainstorming ideas with company personnel is likely to be the best tool for identifying ideas for organisational change; brainstorming works best in a safe social environment where personnel are comfortable and encouraged to share ideas.

Brainstorming is a process in which a motivated group of people tries to identify new approaches to a known problem by finding associations, and building on their individual experiences and previous knowledge.There are four principles of brainstorming that should be strictly followed to support the creative process of brainstorming:

- **Any kind of criticism is strictly forbidden.**

As previously mentioned, in the creative innovation process there should be a strict separation between the phase of actual generation of ideas (brainstorming) and the evaluation phase. This is because criticism too early can break the flow of association and prevent the team from using all their experience and resources.

- **No limits to creativity.**

There are no stupid ideas and there are no ideas too wild to be considered in the process. The limits of our knowledge should be explored. Every association, every idea that possibly could contribute to the identification of a new way of solving a problem is welcome.

- **Quantity comes before quality.**

As already explained the idea of brainstorming is to explore the full width and range of possible innovative approaches to problem solving. This is sometimes known as 'blue sky thinking'. The individual quality of brainstormed ideas is assessed in the Evaluation Phase. The goal is to come up with as many ideas as possible.

- **Stealing is encouraged.**

Take up the ideas of others and develop them further. There is no right to intellectual property during the process of brainstorming. Many good deas are triggered when ideas are connected, combined or varied with the ideas of others. Starting with someone else's idea might stimulate new ones in the minds of the participants. So, connecting and building on other ideas is strongly encouraged in brainstorming.

The Role of the Moderator

It is the task of the moderator to facilitate a good meeting. The initial briefing should clearly describe the premise of the meeting and a description of brainstorming to create a common understanding throughout the team of what is going to happen. The moderator should describe the problem and the consequences of the problem for the organisation should be ignored for the time being. The description (typically verbally presented at the start of the meeting) should include consequences for the environment and for the business.

Meetings should not be too long; expect a brainstorming session to 'dry out' after 45 to 60 minutes. In addition meetings should not be held too frequently or the team will burn out. The tasks of the team should be clearly defined. This is the job of the moderator at the beginning of the meeting so that everybody knows the objective of the meeting, everybody is clear about the rules of the game and everybody shares the same understanding of the problem. This is also why there should be a clear briefing at the beginning of the session. If necessary, provide the team with briefing materials in advance of the brainstorming meeting so participants can prepare. During the meeting the discussion should always be objective and open.

It is essential that ideas be captured in writing or by drawings while they are being brainstormed. Participants can do this by jotting down ideas on large pads of paper or on a chalkboard. Tracking ideas in this way is called making a mind map. Ideas should be written down with little attention to formatting, spelling or grammar. Relevant ideas can be circled and connected by lines. Ideas can also be noted on small cards that are pinned or taped to the wall and which can be clustered by relevance later on. This provides an overview of the process and allows the participants to connect and build idea clusters.

3.4 Check

In the 'Check' phase, performance indicators are established and monitored and data is evaluated. It is good practise to document the old and the new situation for evaluation and learning. An example from a South Korean paint shop for TV frames is shown in Table 8.

$$\text{Specific water consumption} = \frac{\text{Water input in 2009}}{\text{kg of product produced in 2009}}$$

Project name: Install automatic paint gun	
Problem	**Methodology**
• Quality differs according to the painter	• Install automatic paint gun
• Paint is sprayed on walls and wasted	• Spray in an up and down movement
Before 	After 
Benefits	
• Resource Efficiency: 20% reduction of paint input (about 4000 litres), less manual operator involvement	
• Economical: 82,000 USD = Paint (32,000 USD) + reduced salary (50,000 USD)	
• Efforts: 130,000 USD	

Table 8: *Before and after photos documenting action taken for resource- efficient painting in a paint shop painting TV frames.*

Indicators help to condense relevant data to provide exact and useful information about the efforts of management, the environmental impact of a company's activities or the state of the environment. Benchmarks are chosen as a means to present quantity or quality data or information in an understandable and useful form. This information can be provided in the form of absolute or relative, normalised or indicated information.

In most companies, indicators are already part of the planning process. Indicators can also be used in a similar way for an environmental information system to compile company data in a clearly structured way so that it is easy to interpret.

The following types of indicators can be used for controlling Resource Efficiency:

Specific consumption

$$\text{Specific consumption, material A, 2009} = \frac{\text{Material input, raw material A in kg in 2009}}{\text{kg of product pr}}$$

$$\text{Specific water generation, 2009} = \frac{\text{in kg in 2009}}{\text{kg of product produced in 2009}}$$

Proportional values for presenting a part in relation to the whole
An example of a proportional value:

$$\text{Drinking water proportion 2009} = \frac{\text{Drinking water input in kg in 2009}}{\text{Water input in kg in 2008}}$$

Index figures comparing identical figures over a course of time
An example of an index figure:

$$\text{Water index 2009} = \frac{\text{Water input in 2009}}{\text{Water input in the base year 2007}}$$

The international standard ISO 14031 includes suggestions for how to select and formulate a benchmarking study for your company.

The International Organization for Standardization (ISO) describes two general indicator categories:

- Indicators for describing the environmental impact of an organisation
  - Indicators concerning management systems
  - Process indicators
- Indicators for describing the condition of the environment

The appendix to the ISO 14031 lists some examples of useful **indicators for benchmarking management systems** such as:

- Number of targets achieved
- Number of organisational units that have achieved their Resource Efficiency targets
- Number of Resource Efficiency options put into practice
- Number of employees with relevant responsibilities
- Number of employees participating in Resource Efficiency programmes
- Number of employees trained in Resource Efficiency matters
- Results of employees who attended training
- Number of environmentally relevant suggestions for improvement tabled by employees
- Results of employee survey about their knowledge/status of information about Resource Efficiency matters
- Number of suppliers with eco-management systems
- Number of products designed in a recycling-oriented way
- Degree of compliance with laws, ordinances and notices
- Time required to resolve relevant accidents
- Amount of corrective action taken
- Penalties, fines
- Number of audits carried out
- Number of emergency drills
- Time needed to recoup costs of relevant investments
- Savings engendered by relevant investments
- Number of neighbours' complaints
- Number of relevant newspaper articles
- Number of programmes for the community
- Number of production sites with an eco-management system
- Number of production sites with an eco-programme
- Number of local initiatives supported by the organisation

Examples of **process indicators**:

- Material consumption per product
- Input of recycling material
- Reuse of packaging material per product
- Process material input
- Cleaning agent input
- Water input
- Water recycling
- Production of hazardous waste
- Energy input
- Energy input according to types of energy
- In-house energy generation from waste
- Energy saved through energy-saving programmes
- Fuel consumption
- Freight kilometres according to means of transport
- Land use
- Business trips
- Number of recyclable products
- Rejects

Examples of product **life cycle indicators:**

- Energy consumption through product life cycle
- Waste generated
- Amount of hazardous waste produced
- Amount of recyclable waste produced
- Emission amounts (per year, per product)
- Ozone destruction potential of gaseous emissions
- Greenhouse effect caused by gaseous emissions
- Emissions in waste water
- Noise
- Radiation

Examples of **environmental health indicators:**

- Information about the condition of bodies of water
- Local air quality
- Endangered species
- Resource consumption
- Water temperatures
- Climate-relevant figures

More specific environmental health indicators may include:

- **Output indicators** (for solid waste, hazardous waste, waste water, gaseous emissions; these indicators show the observance of legal framework conditions)
- **Input-oriented corporate indicators** (have an early-warning function and facilitate the use of foresight and promptness in making statements on corporate material and energy use per household; they should at the same time be formulated as efficiency indicators)
- **Management indicators** (observance of laws, achievement of targets, neighbour and staff involvement, describe the efficiency of the corporate organisation)
- **Process indicators** (structured according to plants or procedures to make the material or energy flows of Resource Efficiency goals measurable)

If developing your own indicators, the following questions may help you to define them:

- What figures best reflect the targets?
- Which figures would best indicate that the target was not met?
- How critical deviations are best measured?
- What is the best way to show who is responsible for a critical deviation?
- For which indicators is information easy and inexpensive to get?

It is possible to learn from the indicator system by comparing in-house benchmarks with those of other enterprises. It is, of course, essential that the parameters of the companies to be compared are similar. It is also important that the benchmarks of the reference company have been determined in the same way as those in the company under analysis.

Lessons can also be learnt from the in-house comparison of indicators by:

- Finding out if and how the status quo deviates from predicted results
- Analysing variations in time
- Assessing the frequency of deviations
- Examining statistical correlations between indicators and variables

Spreadsheet analysis programs, such as MS-Excel, can be helpful in creating graphs and charts to illustrate the data.

Use the benchmarking data to identify measures. Suitable measures may include both organisational or technical approaches; feasibility is examined and, investment, costs and savings are determined. The schedule of implementation is planned.

Statistical analysis can help to identify the improvement potential of a process. In Figure 20, the dotted lines show the targets, the solid lines are the monthly average and the dots are the calculated daily specific water consumptions (m^3 water consumed per hl beer produced). From the deviation from the target and the variation of daily consumption we can conclude the potential for savings (difference of daily consumption to the respective average). If consumption can be low on some days, why should it be high on others in the same production environment?

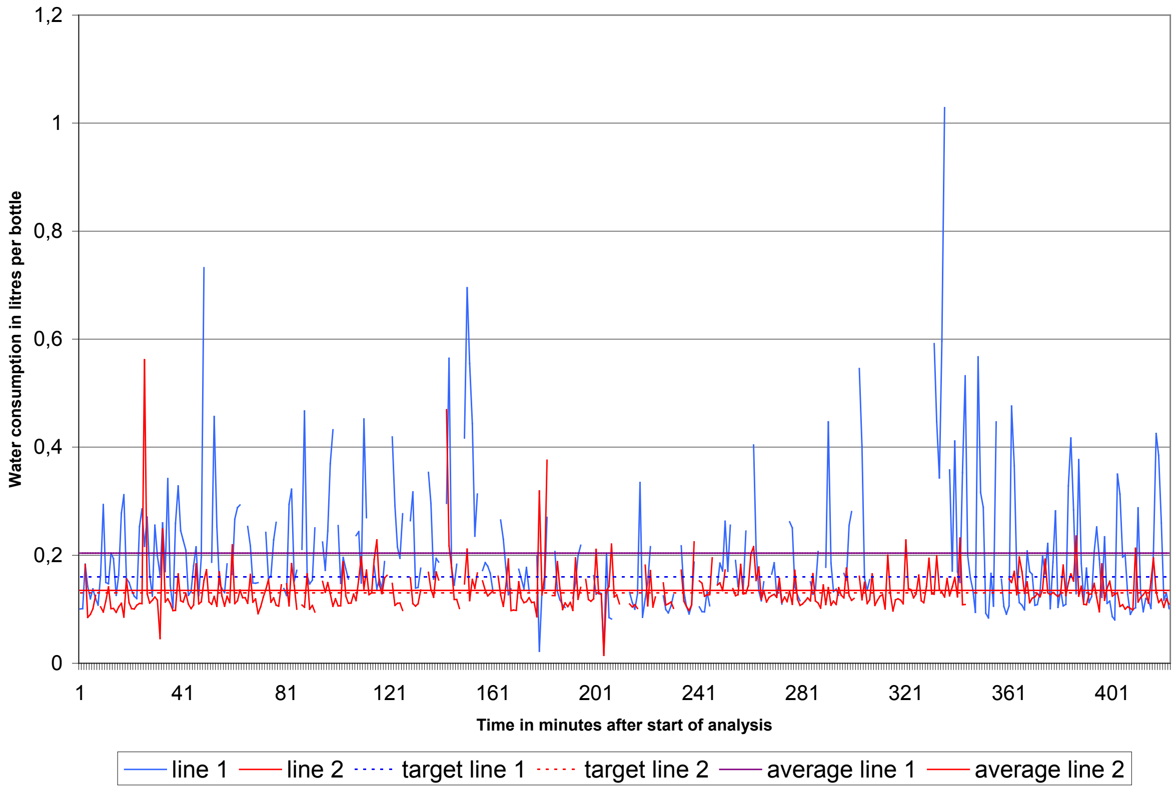


Figure 20: *Analysis of daily specific water consumption of two bottle-washing lines in a South African brewery (litres per bottle washed over time in minutes from start of analysis)*

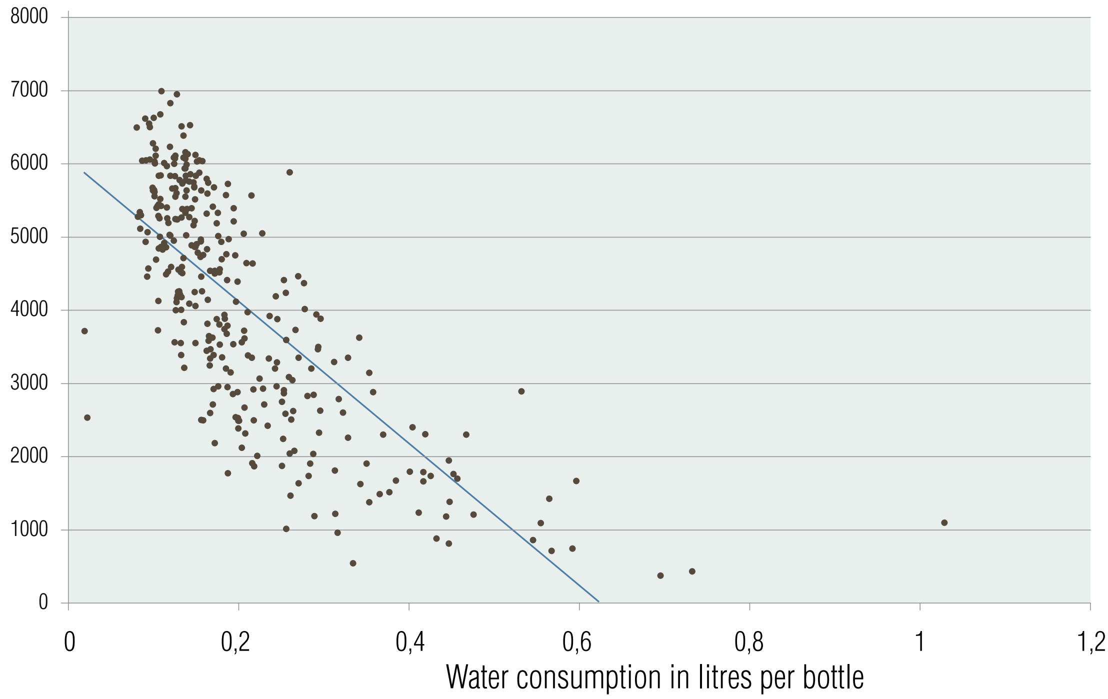


Figure 21: *The correlation between daily production (in hl) over water consumption in litres per bottle*

In Figure 21 the increase in variation that correlates to the decrease of production indicates a deficit of process control. From the extrapolation of the interpolation line towards high production, the optimum consumption can be derived. Plotting a similar diagram with total daily water consumption and extrapolation of daily water consumption towards zero production would show fixed consumption, e.g. for daily cleaning.

3.5 Act

In the 'Act' phase the following elements are important:

- Preparation of an action plan
- Continued implementation of Resource Efficiency options (maybe in another thematic area)
- Monitoring and reviewing of performance
- Rewarding good performance; do not forget to reward the ones behind the success!

Prepare an action plan to track implementation of Resource Efficiency goals and prepare regular reports to management on the progress to justify time and resources used on the programme.

3.6 Overlaps in the thematic areas

As shown in table 9, there are a number of overlaps in efficient use of water, energy, materials and chemicals.

3.7 Why Resource Efficiency is safe and profitable at the same time

Implementing Resource Efficiency will make your company more cost-effective. Use materials, energy, fuel and other resources more efficiently and cut the cost of waste disposal and input purchases. Resource Efficiency projects let you benefit from improved cash flow, because of reduced expenses for materials and energy and more rapid return on investment because of less fixed capital for stored materials and chemicals.

Companies practicing Resource Efficiency reduce environmental and business risks, thereby increasing their credit-worthiness. You can also improve your financial performance by building a portfolio of environmentally sound and socially responsible investments.

A basic premise behind safer production is that reducing hazard, rather than controlling exposure, most effectively manages chemical risk. This means it is safer to choose inherently less hazardous chemicals rather than attempt to control the exposure risk of a hazardous chemical, which is the traditional thinking behind risk management.

Exposure controls can and do fail, and products are used in ways that were never intended. Therefore the most effective means to reduce risk is to reduce hazard by using inherently safer chemicals.

Your company will become more competitive, as Resource Efficiency practices improve your image and the quality and safety of your products. Resource Efficiency also reduces environmental, health and liability risks and, by conforming to environmental standards, your company can export to new markets.

The following case study illustrates the importance of making Resource Efficiency an ongoing goal and the results to expect from a sustained effort.

The company in the following case study started implementing a Resource Efficiency programme in 1997 as part of a regional environmental programme. Over the years, the company continued stepping up their environmental management system and expanded to a full-fledged integrated management system, including quality management, health and safety, risk and innovation management.

Secondary Overlap	Water	Energy	Materials and waste	Chemicals	Health and safety
Water	-	Less water means less energy for pumping, less water as solvent means less energy e.g. for drying, recovery of hot water means less energy to heat water	Less water consumption means less need for treatment and often less sludge to treat and to dispose of	Less water means less chemicals for physical chemical treatment of water and wastewater	Water spills can cause slippery ground, electric defects and cause accidents
Energy	Less energy means less need for cooling (water for once through cooling or for boiler and cooling tower)	-	Less energy means less fuel and coal to transport and manipulate	Less need for water makeup means less need for water treatment (biocides, anti foulants, physical-chemical treatment of water)	Hot surfaces, steam leaks or hot liquids can hurt workers
Materials	Less material losses mean less need for cleaning	Less material losses mean less energy for recycling (for milling waste, for melting recycling material)	-	Less processing of materials often means less auxiliary materials (additives, lubricants)	Uncontrolled dust can cause lung problems for workers or even explosion problems
Chemicals	Less spills mean less water for cleaning, less chemicals mean less risk for wastewater load	Less chemicals require less use of ventilation, extraction and eventual treatment of exhaust gas (e.g. by post combustion)	Less use of chemicals means less need to clean up spillages by absorbents, generates less waste from neutralizing or disposing of residual chemicals	-	Spills of chemicals can cause accidents and emissions which endanger workers health

Table 9: *Overlaps between water efficiency, energy conservation, material efficiency and chemicals*

Case Study: Anodisieranstalt A. Heuberger Ltd

Anodisieranstalt A. Heuberger is an anodising company. It has 18 employees in Graz, Austria. Annually, some 40.000 m^2 of aluminium sheet metal, profile and small parts are treated in the plant. Anodising is a galvanic process in which the surface of the aluminium is converted to aluminium oxide, which protects the basic material against corrosion and wear. By grinding and polishing, the surface can be prepared in different decorative qualities prior to anodising. The company is specialised in processing orders within a very short time. Heuberger has participated in the ECOPROFIT programme, a Resource Efficiency programme run by the City of Graz since 1996.

Plan: During the planning phase an inventory of materials, water and energy was made by the consultant, the general manager and the accountant. The preliminary assessment indicated a focus on water was best because of the high consumption and cost as well as legal implications of wastewater generation. Wastewater mainly results from rinsing parts after pickling and anodising.

Do: Longer dripping times were introduced to minimize drag-outs. This reduces the amount of process solutions, which are carried from one process bath to the next on the surface of the parts, and therefore, decreases the need for rinsing. The racks were changed for the same purpose. Spray rinsing was introduced to increase the rinsing effect.

Check: A reduction of 30% of the production specific water consumption could be demonstrated after implementation of the measures. Therefore a continuation in 1997 was planned.

Act: With a modified focus (this time on hazardous waste and industrial waste) the programme was repeated in 1997.

Hazardous waste has been reduced to a minimum: less than five litres of used compressor oil annually and it is sent to a waste incineration plant for the generation of district heat. Non hazardous waste is separated into the fractions paper, metal, plastic, organic waste and industrial waste. Paper, metal and plastic are sent for recycling, organic waste to a compost facility.

Packaging materials are almost completely reused and the large quantity customers have developed returnable packaging systems. The annual quantity of industrial waste amounts to as little as 1,500 kg.

This represents a reduction of 50% in the amount of waste before the participation in the Resource Efficiency programme. The remaining industrial waste mainly resulted from cleaning the shopfloor.

Measures to reduce the consumption of natural gas included the introduction of covers for the baths when they are not in use and switching off the heating 30 minutes before production stopped at night. This saved 5% of the natural gas consumption.

In 1997 the company decided to continue and to introduce an environmental management system to systematize improvement.

The introduction of the management system started with an initial review using the information collected during the Resource Efficiency project. The information collected included:

- Comprehensive information on material and energy inputs and outputs as well as options for improvement
- Information on legal compliance
- Information on the organisation of the company

This drew attention to the overlap between health and safety, cleaner production and quality from the beginning of the job. In this company, it resulted that the used materials' effects on the environment were equally important as their effects on the employees handling them. Analysing the potential failures of the process resulted in a list of environmental aspects as well as potential quality problems. The legal compliance audit covered the relevant legislation regarding the environment, business law, and health and safety.

From this review, a working programme was drafted that included:

- Development of a project to guarantee compliance with current Austrian waste water legislation
- Evaluation and written documentation of the working conditions at all the workplaces to comply with this legal requirement
- Increased training activities to improve the understanding of the process and the handling of chemicals to prevent accidents and to increase the accuracy of process conditions
- Definition of exact working procedures for anodising, analysis of process baths, maintenance. From a quality perspective, lack in process control meant that approximately 5% of the parts had to be reworked, from an environmental point of view, this meant a 5% increase in use of chemicals, water, and energy
- Investment in an air-cooled plant to cool the anodizing bath. This reduces the water consumption of the plant significantly and provides for better control of anodizing temperature, especially during summer, thus improving the quality of the final product
- Definition of responsibilities, corrective measures and an auditing procedure
- Documentation of the management system

While evaluating the operators' workplaces, the possibilities of accidents were analysed and documented. Measures for accident prevention were defined and implemented immediately.

The first step to implement this programme was the introduction of indicators: the baths were analysed daily to optimise the use of chemicals. The quantities of chemicals used were recorded daily as were the quantities of water and methane. Changes in the specific consumptions were discussed in the meetings of the Resource Efficiency team.

The Resource Efficiency team was comprised of the manager, the production foreman, the employees in charge of maintenance and packaging, and the secretary. The production foreman was also in charge of quality assurance and health and safety. So in fact the team covered

Case Study

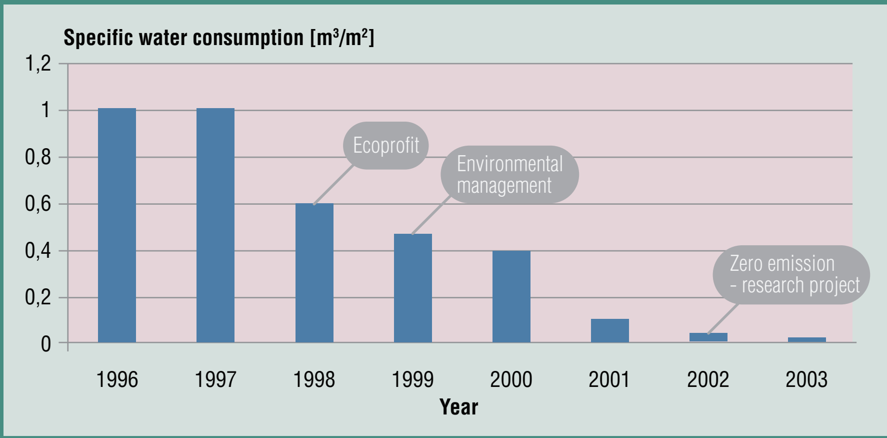


Figure 22: *Development of the specific water consumption at Anodisieranstalt Heuberger*

the environmental, quality, and health and safety departments and all the working areas in the company. During their meetings, the progress of the programmed activities and problems was discussed, regardless of the department they arose in. The experience with focused teamwork improved communication inside the company significantly.

In the meetings, the following topics were discussed:

- Progress of the company's RE programme
- Overview of new developments
- Current problems
- Compliance with existing regulations
- Training needs
- Discussion of current indicators of consumption of materials and energy
- Ideas for improvement

The documentation of the management system was kept as brief and concise as possible. The meetings were documented and minutes distributed to all employees to inform them about the results of discussions and measures taken. Current problems and solutions were noted on special forms then printed on red paper. Red paper was chosen to make it clear that these were urgent documents requiring quick discussions and adequate solutions. Additionally, there are forms for auditing, for the control of water, energy and chemical consumption, for the documentation of environmental effects and for the environmental programme.

Checklists were developed for the key variables of the anodising process, for adoption of orders and for purchasing. Plans were developed for training and for maintenance.

The managing director paid particular attention to formulating an inspiring company policy, discussing the formulations and their implications in a number of meetings with his team: The guidelines are a testimony of the commitment according to which the protection of the environment is an essential part of management that results in objectives and procedures for everyone in the company. The guidelines were accepted very well and the feedback from the employees was very positive, after they had been amended by examples showing how they affect daily practise.

Each of the employees was trained in first aid. Since 1997, there has been regular training regarding: the process, the physical and chemical background, the handling of materials, reduction of the use of chemicals as well as electronic data processing and personal skills such as leadership and communication.

In spite of doubling its production the company reduced water consumption by 60% between 1996 and 1999. This meant a cost reduction of US$20,000. The reduction in the use of chemicals (roughly 10%) meant cost reductions of US$2,000 and the reduction of gas consumption (also 10%) yielded US$4,000 annually.

The company started to involve the suppliers in its optimisation process. Step-by-step they were required to eliminate toxic additives and colours containing heavy metals.

The clients were asked to supply the company with details on the alloys and the auxiliary materials they used e.g. for turning and surface conservation. Together they tried to eliminate auxiliary materials which caused problems in the degreasing step at Anodisieranstalt A. Heuberger GmbH.

The company was presented with the Austrian KNEWLEDGE (meaning "new knowledge") award in 2000 for the best training programme of an Austrian small and medium sized enterprise, the ÖGUT award (Austrian national award for environmental excellence) in 2000 for their results in preventive environmental protection and the Styrian environmental award in 2001 (from the regional government).

The members of the environmental team showed active involvement in the meetings in the company by contributing many good and practical ideas. Their efforts were rewarded with additional training seminars and an invitation to the awarding ceremonies.

Today, the director is actively involved in presentations and conferences on a regional and national level discussing his motivation and the sustainable strategy of his company. He has initiated research programmes to help his company to approach the goal of becoming a 'zero emission company', as well as the development of sustainable new products and services, by using his knowledge in consulting his clients to improve their products to make them longer lasting or serving special requirements.

The combined approach was used to demonstrate the links between health and safety, environmental and quality management and to define a step by step strategy to help in understanding the ultimate goal of a sustainable management approach.

Figure 22 shows the reduction of water consumption over the years 1997 to 2003. The impact participation in the regional Resource Efficiency programme and introduction of an environmental management system can clearly be identified. The continuous work on Resource Efficiency reduced water consumption to 5%.

According to the owner, the success factors are: a clear and committed policy; the integrated approach considering resource efficiency, health and safety, and quality in combination; the detailed identification of costs; and a dedicated continuous follow up.

Detailed assessment: **Water efficiency**

Detailed assessment: Water efficiency

4.1 WHAT: Problems related to water consumption of SMEs

Water is crucial for the economy. Virtually every industry from agriculture, electric power generation and industrial manufacturing to tourism relies on it to grow and sustain their business.

Clean freshwater is becoming scarce globally and there is every indication that it will become even more so in the future. Decreasing availability, declining quality and growing demand for water are creating significant challenges to businesses and investors who have previously taken clean, reliable and inexpensive water for granted.

4.1.1. Increasing demand for water

Population growth and economic development are driving significant increases in agricultural and industrial demand for water. Agriculture accounts for more than two-thirds of global water use and as much as 90% in developing countries. Freshwater consumption worldwide has more than doubled since World War II and is expected to rise another 25% by 2030. Much growth is the result of expected increases in the world population from 6.6 billion currently to about 8 billion by 2030 and over 9 billion by 2050.[25]

4.1.2. Water scarcity and unsustainable supply

Water is already over exploited in many regions of the world. More than one-third of the world's population – roughly 2.4 billion people – live in water-stressed countries and by 2025 the number is expected to rise to two-thirds. Groundwater tables and river levels are receding in many parts of the world due to human water use.

In India, for example, farmers are now using nearly 80% of the country's available water, largely from groundwater wells; at current rates, the World Bank estimates that India will have exhausted available water supplies by 2050. Rainwater harvesting, made compulsory in Delhi in 2001 by a court order, has not been implemented as would have been desired, even though all government buildings with a built-up area of more than 100 m^2, all roads and flyovers, cooperative group housing societies and farmhouses are required to have rainwater harvesting. According to the latest survey by the Central Ground Water Board (CGWB), of the 178 wells inspected in Delhi, 129 receded or have dried-up in the last year.

Regions affected by drought also are increasing. The percentage of global land classified as 'very dry' has doubled since the 1970s, including large parts of Africa and Australia. Natural water storage capacity and long-term annual river flows are also declining, especially in the Northern Hemisphere, due to glacial/snow cap melting. Glacial melting in the Himalayas is one of the reasons that many of Asia's largest rivers, which have their source in the Himalayas, are projected to recede in coming decades.

4.1.3. Declining water quality

Declining water quality is an acute problem around the world, particularly in developing countries where there are notable increases in agricultural and industrial production, coupled with a lack of adequate wastewater treatment.[26] In many developing countries, waterways traditionally used for drinking water or other community needs have been heavily contaminated. In China, many

25) Department of Economic and Social Affairs, Population Division, undated

26) "Water Scarcity & climate change: Growing Risks for Businesses & Investors", February 2009, A Ceres Report

rivers are so badly polluted that not even industry can use the water and nearly two-thirds of the country's largest cities have no wastewater treatment facilities. Rising water demand and the lack of adequate sanitation facilities are key reasons why almost 900 million people worldwide lack access to safe drinking water and up to five million people die each year from water-related illness.

Business impacts of water insecurity may include:

- Decreased amount of water available for business activities
- Operational disruptions and associated financial loss
- Impacts on future growth and license to operate
- Conflicts with local communities and other large-scale water users
- Regulatory restrictions for specific industrial activities and investments
- Increased costs for water
- Growing demand for water efficient products and technologies
- Increased costs for pre-treatment to obtain desired water quality
- Increased costs for wastewater treatment to meet more stringent regulations

Taken together, this means that businesses will face vastly increased uncertainty about the availability and quality of their water supplies.

Similar to Resource Efficiency, water efficiency is the accomplishment of a function, task, process or result with the minimal amount of water feasible. In most sectors water is not a component of the product, but a cooling, heat transfer or cleaning medium.

Where water quality is concerned, zero effluent discharge is the ultimate goal, to avoid any release of contaminants to the water environment. Zero effluent discharge entails water recycling, which also contributes to raising water efficiency. If zero effluent discharge is not economically and technically feasible, there are some valuable intermediate strategies including safer production, which can be pursued to reduce pollution and to ensure that waste substances are recovered and water reused.

4.2 WHY: Water saving benefits for SMEs

Benefits of water efficiency for business:

- Saving water will reduce the cost of water for the community at large by lowering demand and thereby the associated costs of extraction, transport by pumps, treatment and wastewater disposal either in a company owned facility or a publically owned treatment plant.
- Saving water can provide opportunities for developing efficiencies in other areas. For example, using less water may mean that pumping water around the site is reduced leading to savings in electricity costs and greenhouse emissions.
- Saving water can reduce the risk of environmental contamination or pollution, as water efficiency initiatives will lead to less wastewater.

Additional general environmental benefits of water efficiency:

- Fewer sewage system failures caused from excess water overloading the system.
- Healthy, rather than depleted and dried-up, natural pollution filters such as downstream wetlands.
- Reduced water contamination caused by polluted runoff due to over irrigating agricultural and urban lands.
- Reduced need to construct additional dams and reservoirs or otherwise regulate the natural flow of streams, thus preserving their free flow and retaining the value of stream and river systems as wildlife habitats and recreational areas.
- Reduced need to construct additional water and wastewater treatment facilities.
- Elimination of excessive surface water withdrawals that degrade habitat both in streams and on land adjacent to streams and lakes.
- Efficient water use can also reduce the amount of energy needed to treat wastewater, resulting in less energy demand and, therefore, fewer harmful byproducts from power plants.

Figure 23 compares the operating and maintenance costs (labour, energy, chemicals, and materials such as replacement equipment and parts) of the various systems of 0.1 to 1 mgd (million gallons per day) treatment capacity. All costs were obtained from the USEPA Innovative and Alternative Technology Assessment Manual. They have been indexed to the USEPA Operation, Maintenance, and Repair Index of Direct Costs for the first quarter of 1993 (4.3). All costs are presented in United States dollars per million gallons of wastewater treated. The cost for mechanical systems is significantly larger than for any of the other systems, particularly at smaller flows. The cost of harvesting plants from aquaculture systems is not included; this could be a significant amount for some systems. Most of the cost data come from systems implemented in the United States. Similar systems in Latin America might be less expensive, in some cases, owing to lower labour costs and price differentials in construction materials. Nevertheless, the relative cost comparison among technologies is likely to be applicable to all countries.

Figure 24 compares of the capital cost of the wastewater treatment processes. The cost data is also from the Innovative and Alternative Technology Assessment Manual, with the exception of wetland and aquaculture data, which were obtained from more recent sources.[27] All natural systems are assumed to have a facultative lagoon as the primary treatment unit. The cost of chlorination/disinfection is included for all systems except the slow rate and rapid infiltration systems. The cost of land is excluded in all cases, as is the cost of liners for the aquatic treatment systems. The mechanical treatment plant cost was derived as the cost of an oxidation ditch treatment system, and includes the cost of a clarifier, oxidation ditch, pumps, building, laboratory and sludge drying beds. These costs also include the cost of engineering and construction management, in addition to the costs for piping, electrical systems, instrumentation and site preparation.

27) All costs are in March 1993 US$

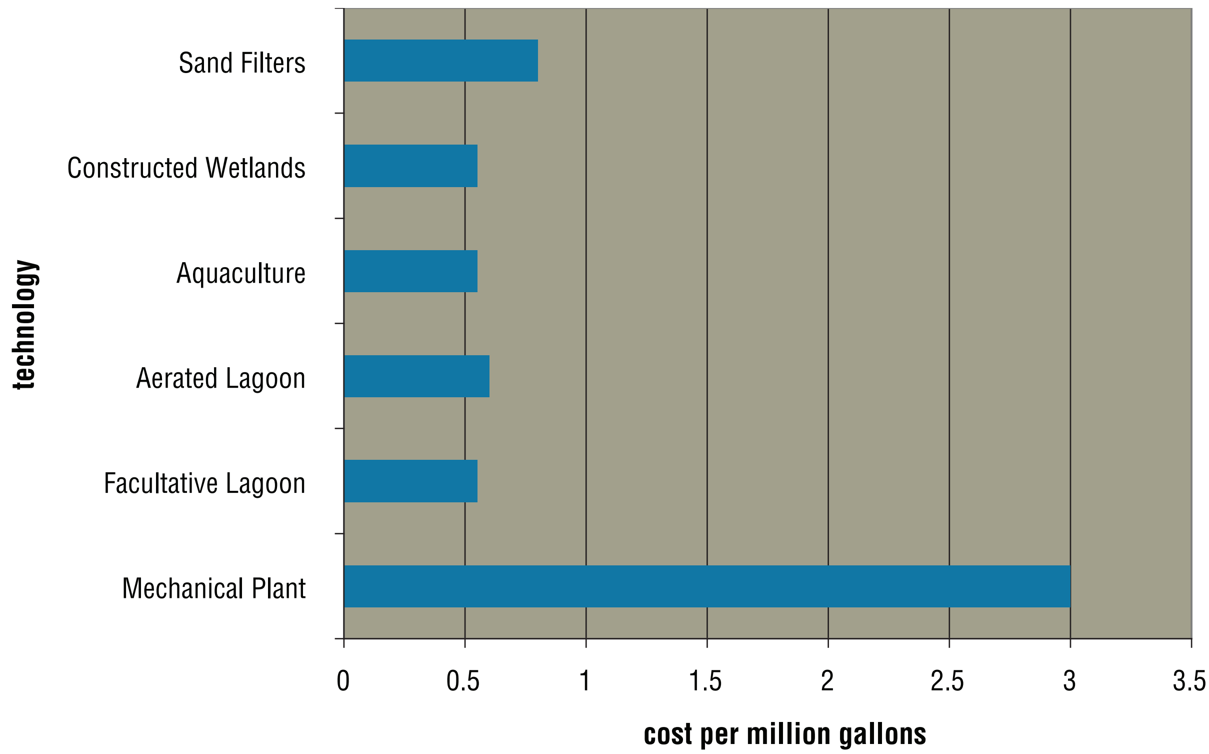


Figure 23: *Operation and maintenance cost for wastewater treatment options*

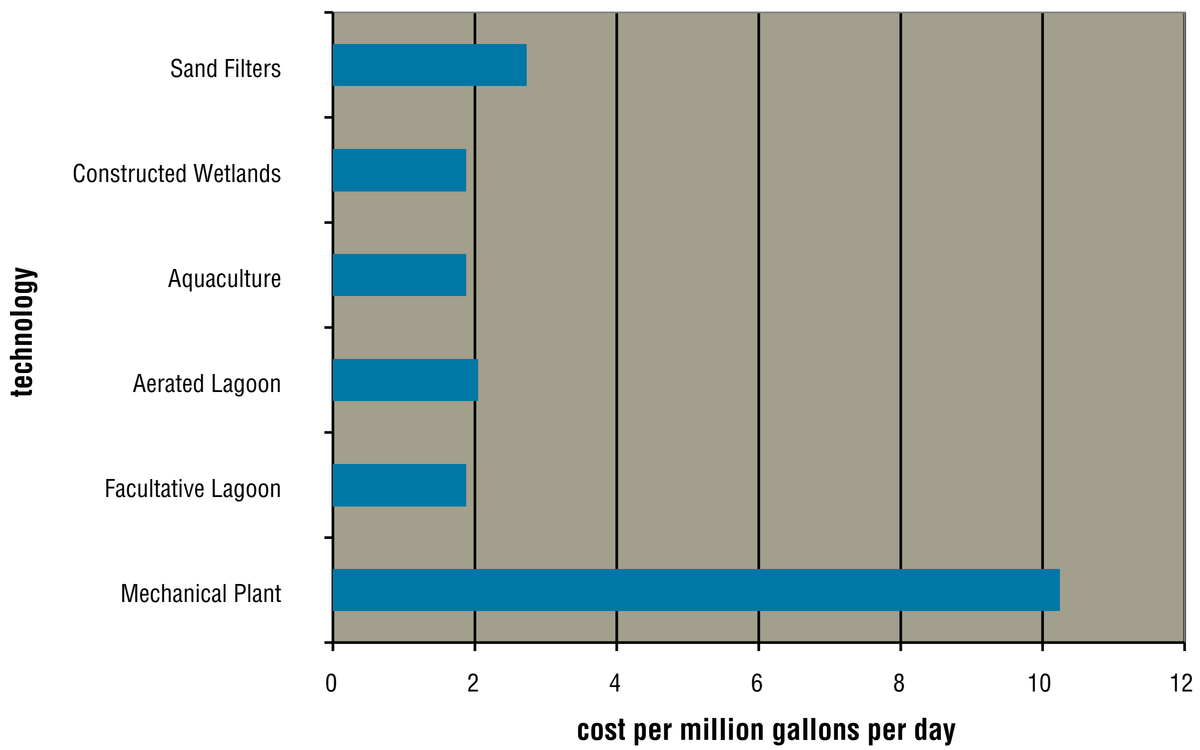


Figure 24: *Capital cost for wastewater treatment methods*

4.3 HOW: Implement a water saving programme

Quick Win Map	Explanation	Tools (in the electronic version of the toolkit)	Advanced Reference (in electronic version)
Step 1: Draw a Water Flowchart	Identify all uses of water by creating a water flowchart	Water Flowchart	• Water Flowchart (with examples and templates to fill in) • Flowcharter (Programme link) • Guide to Water Balance
Step 2: Collect Data	Collect and measure consumption data using resources available and log it	Collect Data	• Data Entry Form (see advanced reference "Water Flowchart")
Step 3: Benchmark Performance	Benchmark your consumption with best practice to determine improvement potential	Benchmark Performance	• Sectoral Benchmark • Unit Process Benchmark
Step 4: Consider Options	Consider options towards improving the plant's water efficiency from literature, other industries' experiences and/ or recommendations from RE, CP and SP service providers. Also undergo brainstorming sessions with your team.	Consider Options	• Option Evaluation Worksheet • Further detailed process and sector related options see Virtual Assessment
Step 5: Evaluate Option and Implement Program	Evaluate option, compile and implement programme (link to PDCA)	Link to DO-phase	

Table 10: *Quick Win Map for reducing water consumption*

A water efficiency programme starts with a bird's-eye view of water consumption. Draft a flowchart showing the water flows as suggested at the top of Table 10. Then take measurements to fill the flowchart with data. Benchmark water efficiency on the basis of specific water consumption per production unit. With this data on hand, options for reduction will become obvious. Selected options will be organised in the action plan, which is part of the PDCA-cycle.

Step 1: Draw a Water Flowchart

To identify potential water efficiency opportunities, it is first necessary to gain a thorough understanding of the site's water uses through a water assessment. The first important task is to construct a water flow diagram, which identifies all water use from its source through the on-site processes, machines, buildings and landscape irrigation to evaporation and wastewater discharge.

For further information on how to draw a water flowchart, please click on the advanced reference "Water Flowchart" on the Quick Win Map in the electronic resourcekit and follow the instructions.

Step 2: Collect Data

Once all types of sources, uses and discharges of water have been identified, it is necessary to quantify all single mass flows.

Compared to many other material flows, collecting data of water consumption is relatively easy because the following documents or tools are in most cases available:

- Annual payment to provider or to disposal companies
- Water meter, water counter
- Rotameter
- Design specifications by manufactures of equipment
- Indicators[28]
- Ultrasonic flow meter
- The bucket method
- Measuring wastewater e.g. by using the V-notch method

To account for all uses in the water balance, the total inflow should equal the total outflow plus irrigation, evaporation and other water losses.

In case water meters are not available to measure the consumption in single departments or at individual machines, use the bucket and a stopwatch to identify the water flow (Figure 25).

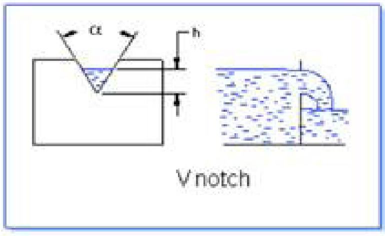
Use any bucket where you know the capacity or measure the capacity of the bucket before further steps (e.g. 10 liters or 2.5 gal). Take the bucket and fill the bucket with the hose where you want to know the flow. Count the time in seconds (e.g. 20 seconds) Divide the capacity by the time in seconds. You will get the water flow from the hose in litres per second or gallons per second.

An example: 10 litres / 20 seconds = 0.5 litres per second..

To get the water flow (from per second) to per minute: multiply by 60 (60 seconds per one minute), per hour: multiply by 3,600 (3,600 seconds per one hour) per day: multiply by 86,400 (86,400 seconds per one day).

Figure 25: *Measuring water volume with a bucket and a watch*

28) UNIDO Cleaner Production Toolkit, Textbook Material flow analysis, 2008.



$$Q = 1.373 * \tan(0.5 * \alpha) * h^{2.5}$$

Watch SI-units!
h … meters
Q … m^3 per second

Figure 26: *Using a Vnotch to measure water flows*

An alternative might be measuring the change in the level of the water tank (switch off the supply pump and measure the level drop in a certain time e.g. by using a dip stick, then calculate the volume flow from the difference in level and the cross section and the time elapsed). If you can install a Vnotch in the sewer, you can calculate the water flow as shown in Figure 26.

Figure 27: *Using an open hose for floor cleaning* [29]

The following data and charts can help to identify data on water losses due to leaks, open hoses, evaporation losses:

- Water loss by drips per second
- Loss by drips from hose
- Evaporation losses from open tanks

No. Drips per second	Litre per minute
1	.0.23
2	.045
3	.068
4	.091
5	.114
5 drips per second is a steady steam.	

Table 11: *Water loss by drips per second*

Hole size (mm)	Water loss (m^3/day)	Water loss (m^3/year)
0.5	0.4	140
1	1.2	430
2	3.7	1300
4	18	6400
6	47	17,000

Table 12: *Relation between size of leaks and water loss*

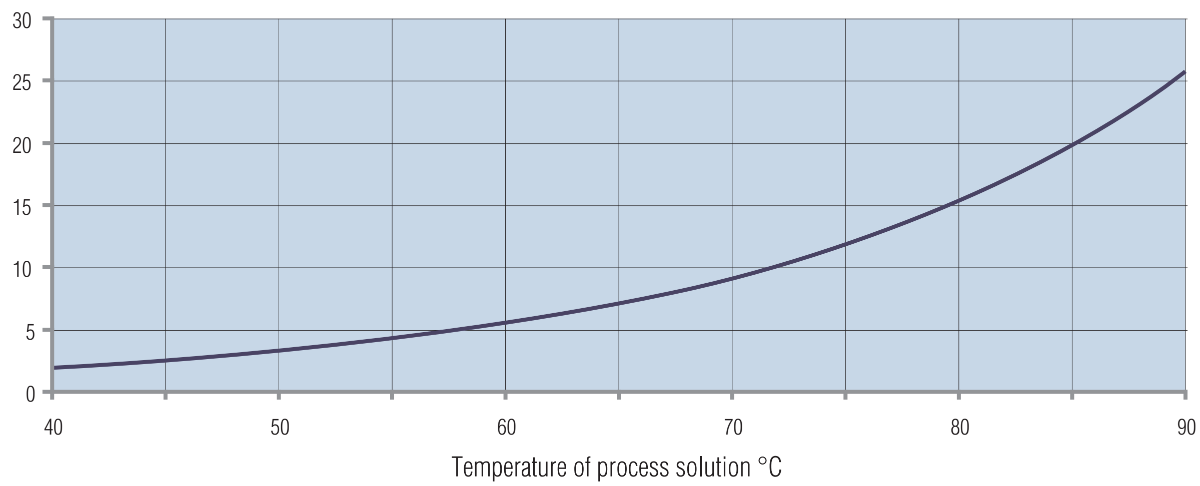


Figure 28: *Evaporation losses from open tanks* [30]

29) Fresner J., own picture

30) Fresner J., Bürki T., Sittel H., Ressourceneffizienz in der Produktion – Kosten senken durch Cleaner Production, ISBN 3939707481, 2009

Step 3: Benchmark Performance

Benchmarking is a process of comparing your organisation's operational formance to that of other organisations to become 'best in class' and make continual improvements. Benchmarking is more than simply setting a performance reference or comparison; it is a way to facilitate learning for continual improvement.

Benchmarks for the selection of unit operations listed below, are included in Chapter 8 of this handbook and in the electronic PRE-SME resource kit that accompanies this handbook:

- Paper
- Food processing
- Textile industry
- Leather manufacturing
- Metal manufacturing

Benchmarks for the selection of unit operations listed below are included in the accompanying electronic PRE-SME resource kit:

- Boilers
- Cooling towers
- Sanitary use

Step 4: Consider Options

Many general approaches exist for identifying water-saving opportunities. The installation of meters is the essential first step for monitoring usage and providing motivation for operators to save water. In addition to fixing leaks and stopping unnecessary use, the approaches listed below can be applied to become water efficient at any site.

Sanitary/Sewage Uses:

Often overlooked, are the water and cost savings achievable by reducing sanitary and sewage water usage by employees at commercial and industrial facilities. While water efficiency measures should begin with the most water-intensive operations such as cooling, cleaning, rinsing and heating, many businesses miss the benefits of the 'low-hanging fruits' that can be had in sanitary/sewage water consumption points such as toilets, urinals, sink faucets and showers. Sanitary/sewage water use at industrial and commercial facilities may range from a few percent in a food processing industry to more than 50% in an office setting. Average daily domestic demands in commercial and industrial settings range between 75 and 130 litres per day per employee, and a savings of 25 to 35% in this domestic usage is readily achievable.

Boilers:

Impurities in water add significantly to the cost of effectively operating a boiler. As steam is lost and water is added to the boiler to replace it, the concentration of impurities in the water 'cycle up', quickly moving beyond the concentration at which they can be adequately treated by chemicals. To prevent this, high-solids water must be bled from the boiler to maintain a manageable level of solids in the boiler water. This process is known as 'blowdown'. Unfortunately, blowdown – in addition to releasing high solids – also releases money that has been invested in the water. Specifically, the heat energy that brought the water up to temperature and the chemicals required to treat the water are lost during the blowdown process.

Improving condensate return is one way to minimise blowdown and maximise cycles of concentration at which a boiler operates. By increasing condensate return, operators will decrease chemical usage, decrease blowdown and conserve the heat contained in the high-temperature condensate.

Cooling:

The use of open cooling systems represents the largest use of water in industrial and commercial applications. Closed cooling water cycles that, are back-cooled with cooling towers, remove heat from air conditioning systems and from a wide variety of industrial processes that generate excess heat with less water. While all cooling towers continually cycle water in a closed loop, there is constant evaporation to take away the heat. Cooling towers can consume 20 to 30% or more, of a facility's total water use. Optimising operation and maintenance of cooling tower systems can offer facility managers significant savings in terms of water consumption. To minimise purge losses measure conductivity of the water in the sump. Try to minimise the input of salts with the cooling water.

Cleaning and Rinsing Applications:

Most industrial and commercial businesses have a variety of cleaning and rinsing applications that can consume large volumes of water.The water-efficiency techniques presented in Section 4.4 address general water efficiency for process changeovers, equipment clean-out, parts rinsing, tank rinsing, line flushing, floor cleaning and other applications. They include dry pre-cleaning, collection and cascaded use of water, (automatic) control of the contents of impurities of wastewater e.g. by conductivity measurement and control of chemicals or detergents to make optimum use of water. CIP (Cleaning in place) – plants recover soda lyes for reuse and the last rinsing water for pre-rinsing of the next cleaning sequence.

Reuse and Reclamation:

Maximising utility of in-process water is accomplished by using it more than one time to do work. Water quality characteristics will determine if multifunctional use of in-process water is acceptable for achieving necessary product quality control/assurance. Fortunately, many water-treatment technologies can provide cost-effective opportunities to reduce water-supply demand and the resultant savings can be used to justify capital costs. A simple approach in rinsing is the use of counter low cascades. Depending on water-quality requirements for the stage of use, water may simply be recirculated or require only basic treatment such as solid settling, oil skimming and/or filtration using cartridge, bag, disk, indexing fabric or sand filtration.

Water efficiency options for specific sectors within an industrial plant and its processes are included in detail in the electronic version of the toolkit.

To ensure that water consumption is optimised, consumption should be monitored on a regular basis. It is helpful to install water meters for separate departments and even for individual processes or pieces of equipment. Whether this is feasible depends on the level of water consumption and the expected savings in each instance.

Water consumption can be reduced by 10 – 50% simply by increasing employees' awareness and by educating them on how to reduce unnecessary consumption.

After the option generation (Plan) a draft implementation programme (Do) has to be made – see Basic Module PDCA.

Case study:
Chandaria Industries Ltd, Kenya (prepared by NCPC Kenya)

Chandaria Industries Ltd (CIL) is a leading Nairobi-based paper manufacturing and conversion company located at Baba Dogo in Nairobi, Kenya. The company's core business is tissue paper manufacturing through waste-paper recycling and virgin pulp blending into hygiene grades that include; toilet tissues, tissue napkins, paper towels, facial tissues and recycling of cotton fibres into absorbent cotton wool. The Resource Efficient and Cleaner Production (RECP) audit started in 2005 and monitoring has been going on since then. As a tool, Cleaner Production keeps on reminding CIL that the improvements meant to achieve these goals are continually enhanced. This has generally improved their operation through cost reduction, efficient resource use, improved environmental performance and increased their contribution towards sustainable development. The company now makes an annual saving of US$633,600. In water management the following measures were implemented:

- Metering & sub metering of all points of water use/discharge and setting performance indicators
- Preventive routine maintenance of machinery and fixing of all leak points
- Recycling of clarified water
- Reduced washing cycles of waste paper due to procurement of high quality waste paper
- Use of poly-electrolytes for wastewater treatment
- Recycling of clarified wastewater
- Reuse of clean water in paper washings

Cost Saving [$/yr]: Ksh. 1,598,400 (US$20,624)
Reductions in water use (per annum): 20,000 kl
Reductions in wastewater (per annum): 150,000 kl
Reduced pollution load to sewer: BOD from 750mg/l to 380mg/l

Case Study

Case Study:
Ngege Ltd, Uganda (Prepared by NCPC Uganda)

Founded in 1989, Ngege today has 250 permanent workers. 25 tons per day of fish are processed to Nile Perch fillets, Tilapia fillets, Head off Gutted Nile Perch. Ngege Ltd started a Resource Efficiency project in May 2002.

Collection and interpretation of data, convincing management and workers as well as changing staff's attitude during implementation were uphill tasks.

Water consumption before the application of Resource Efficiency in Ngege Ltd was at 11.8 m^3 per tonne of raw fish. Through measures such as encouraging dry cleaning, reducing cistern water levels from 13 litres to 8 litres, installing pressure guns on hosepipes and ensuring overall preventive maintenance, water consumption has improved to 8.2 m^3 per tonne of fish, achieving a reduction of 30.5% in water consumption and thus saving the company US$6,338 per year. This means that Ngege Ltd has effectively reduced the amount of water used and effluent discharged. Further improvement is expected with additional implementation of other measures such as installation of sensors and sub metering all sections of the plant to improve further monitoring of water use.

Case Study

4.4 CHECKLIST: Water saving

4.4.1 Transportation

- For cleaning of vehicles use efficient spray nozzles with automatic shutoffs on the end of hoses.
- Consider high-pressure washers to clean more quickly and efficiently.
- Install a wash-water recycle system for vehicle cleaning. Typical wash-water recycling systems consist of a sedimentation basin for grit/sand removal, an oil/water separator, filtration and a disinfection unit to prevent biological growth.

4.4.2 Toilets/urinals

- Check for leaks every six months.
- Adjust float valve to use as little water as possible without impeding waste removal or violating the manufacturer's recommendations.
- Replacing older commodes with High-Efficiency Toilets (HET) or at least 1.6 gallons per flush (gpf) / 6 litres per flush (lpf) models will provide the most water savings. Most HET or 1.6 gpf replacements will offer a payback period of less than three years.
- Use non-potable water for flushing, where codes and health departments permit.

Gravity flush toilets:
- Adjust ball-float position: to reduce the water level in the cistern, adjust the position of the ball float along the float arm of the ball/float valve. This improvement can save up to 0.3 gpf per 1 lpf.
- Install cistern volume adjusters: displacement devices, including bags, bricks or bottles, can reduce water flow by approximately 0.75 gpf per 2.5 lpf. They function by displacing flush water stored in the cistern.
- Install cistern dam: flexible synthetic material partitions the cistern, can reduce water flow by approximately 0.75 gpf (=2.5 lpf)
- Dual-flush adapters allow users to use a standard flush for solids removal or a modified smaller flush for liquid and paper. Dual-flush adapters can save between 0.6 to 1.2 gpf / 2.2 to 4.5 lpf.

Urinals:
- Check for leaks every six months.
- For tank style urinals, check the rubber diaphragm for leaks or wear, and replace as needed.
- A timer can be installed to stop water flow when a facility is not occupied; this can reduce water use by over 75%.
- Adjust float valve or timer to use as little water as possible without impeding waste removal or violating the manufacturers recommendations.
- Use electronic eye or passive infrared sensors to flush automatically; this can reduce water use over 75%.
- Use non-potable water for flushing, where codes and health departments permit.
- Waterless urinals – retrofit: a siphonic trap containing a barrier fluid is inserted in the urinal bowl. The urine passes through the siphon and drains to sewer, while the low-density barrier fluid (a deodorising disinfectant) remains in the siphon.

4.4.3 Taps/shower

Taps:
- Adjust flow valves to the tap. Keep in mind this modification can also be easily changed by users.
- Check regularly for leaks.
- Use aerators for taps flow control. The design of the nozzle mixes air with the water under pressure. When the water exits the nozzle the air expands, increasing the apparent water flow. Water savings of up to 2.6 gpm or 10 litres/min.
- Install flow restrictors. Flow restrictors can be installed in the hot and cold water feed lines to the tap. Common flow rate designs include 0.5, 0.75, 1 and 1.5 gpm. Flow restrictors can be used where aerators cannot be used or where the tap is being abused. Water savings of up to 2,6 gpm or 10 litres/min.
- Install self-closing taps (push-down taps). To deliver flow, the user pushes down on the tap head. When the user removes

their hand, the pressure generated inside forces the tap up and it automatically closes off the flow after a delay period (1 - 20 seconds, set at the time of installation).
- Install electronic tap with infrared sensor. The sensor is located on the underside of the tap head. The sensor is triggered when the user places their hands under the tap head. The temperature is preset.

Shower:
- Encourage users to take shorter showers (10 minute maximum).
- Check regularly for leaks.
- Install shower aerator or aerating showerhead. Water savings of up to 1.5 gpm or 6 litres/min.
- Install push button shower or a pull chain (mechanical timed flow control).

4.4.4 Cleaning

- Establish clear procedures.
- Promote dry clean-up: dry clean-up means using brooms, brushes, vacuums, squeegees, scrapers, microfibre rags and other utensils to clean material before water is used. By collecting the majority of wastes, residues or contaminants in a dry form, large volumes of water and wastewater can be eliminated. The bulk of solid materials can be more efficiently removed in dry form before water is introduced for secondary washing.
- Many floor surfaces (i.e., warehouses, offices, automotive garages, non-critical processing areas, facility support operations, etc.) do not need to be washed with water. If necessary, use dry absorbents and sweep or vacuum these areas. Find and eliminate the source of spills and leaks that may be the sole reason why water wash-downs are needed.
- Use floor mats, 'clean-zones' and other means to reduce the tracking of waste and dirt residuals throughout a facility.
- Turn off running water when not in use.
- Do not use a hose as a broom.
- Use efficient spray nozzles with automatic shutoffs on the end of hoses.
- Consider high-pressure washers to clean more quickly and efficiently.
- Consider pressurized air-assisted spray nozzles to provide more cleaning force with less water.
- Use flow restrictors in water lines that supply hoses and pressure washers.

4.4.5 Laundry

- Operate laundry equipment with full loads only.
- Reduce water levels, if possible, for partial loads.
- Replace or modify existing conventional laundry equipment to reduce water use.
- Replace traditional commercial clothes washers (vertical axis) with high efficiency washers (horizontal axis), which can save as much as two-thirds of the energy and water used by traditional models.
- Install a computer-controlled rinse-water reclamation system. These systems can save as much as 25% of a wash load's water demand by diverting rinse water to a storage tank for later reuse as wash-water
- Install a wash and rinse water treatment and reclamation system, except in very rare situations where health codes prohibit such. By recycling both wash and rinse water, these systems can reduce a laundry's water demand by about 50%.
- Consult service personnel and the laundry's supplier of chemicals for the washer-extractors to ensure that equipment is operating at optimal efficiency.
- Avoid excessive back washing of filters or softeners. Back wash only when necessary.

4.4.6 Canteen

- Install hands-free or foot-activated taps for sinks.
- Pre-soak and wash items in basins instead of under running water.
- Turn-off continuous flows used for cleaning unless required.
- Eliminate the need to thaw food with water.
- Dishwasher:
  - Educate staff about the importance of hand scraping before loading a dishwasher.
  - Run rack dishwashers only when full.
  - Try to fill each rack to maximum capacity.
- Reuse rinse water to pre-rinse or wash dishes.
- Use high-efficiency pre-rinse sprayers with an automatic shut-off valve at the hose head, so water is supplied only when needed.
- Keep flow rates as close as possible to manufacturer's specifications.
- Install advanced rinse nozzles.
- Install 'electric eye sensors' to allow water flow only when dishes are present.
- Install door switches for convenient on/off access.
- Use 'steam doors' to prevent loss of water due to evaporation.

4.4.7 Garden

- Use heat-resistant, drought tolerant plants in hot climates.
- Do not over-fertilise or over-prune.
- Limit turf (grass) areas.
- Use mulch around groundcover, trees and shrubs.
- Mow regularly and avoid scalping grass (high cut at approximately 70 millimetres).
- Water only when needed; determine water needs based on transpiration needs or soil moisture.
- Water in the early morning or late evening to maximise absorption and minimise evaporation and save as much as 30% of watering demand.
- Water infrequently, but deeply, not every day for a few minutes.
- Use drip irrigation wherever possible.
- Make sure automatic irrigation equipment is operating properly.
- Inspect system regularly to ensure there are no leaks and sprinkler heads are not broken.
- Adjust pressures to the manufacturer's specification for the equipment use.
- Check that sprinklers water the garden only, not the street or footpaths.
- Turn off system controller if it has rained or link the system to the rain gauge.
- Adjust controller times seasonally.
- Use treated wastewater or collected rainwater for irrigation.

4.4.8 Laboratory

- For cleaning and sterilising instruments, equip all stand-alone steam sterilisers with condensate-tempering systems (this can

reduce water use by 85%). Promote the use of condensate-return systems for sterilisers.
- Equip all vacuum sterilisers with mechanical vacuum systems.
- Install dry-vacuum systems that do not use water for the pump seal.
- Check type of fume hoods.
- Check if hood scrubber is equipped with recirculating system.
- Fume hoods should employ dry hood-exhaust systems wherever possible. Use recirculating systems in hood scrubbers.

4.4.9 Office

- Identify unnecessary water usage and fix leaks.
- Use minimum amounts of water to accomplish the task.
- Recirculate water within a process or group of processes.
- Reuse water sequentially (e.g. use cascades).
- Treat and reclaim used water.
- Replace potable water supplies with water from non-potable sources where appropriate.
- Install meters and probes (e.g. conductivity) on water-consuming equipment.
- Install pressure-reducing valves.
- Rainwater harvesting is the process of collecting, filtering and storing water from rooftops, paved and unpaved areas for multiple uses. The harvested water can also be used for potable purposes after testing and treatment. The surplus water after usage can be used for recharging groundwater aquifer through artificial recharge techniques. This can also result in improving the quality of the groundwater e.g. lower fluoride content in groundwater. Rainwater harvesting mechanisms are designed after assessing the site conditions such as incident rainfall, subsurface strata and their storage characteristics, infiltration tests and by building suitable structures to collect and store rainwater.
- A rainwater harvesting system provides a source of soft, high-quality water, reduces dependence on wells and other water sources and in many contexts is cost effective. A rainwater harvesting system can range in size from a simple PVC tank to a contractor-designed and built sump. Rainwater systems are inherently simple in form.

4.4.10 Water for cleaning and rinsing

- Sub-metering and monitoring allows excessive water consumption and leaks to be quickly detected and corrected.
- Use low-flow 'fogging' nozzles to rinse parts efficiently.
- Use flow restrictors in water lines that supply hoses and pressure washers.
- Use timers to shut off process water rinses when process is shut down.
- Turn off running water when not in use.
- Ensure stationary spray nozzles are aimed properly.
- Review nozzle spray patterns for optimum application. Fan, cone, hollow cone, air atomizing, fine spray and fogging are a few examples of nozzle spray patterns.
- Replace worn spray nozzle heads; they can result in poor spray patterns and excessive water consumption.
- Use counter current washing techniques.
- Use conductivity controllers to regulate rinse waterflow rates.
- Use spray washing/rinsing techniques for tank cleaning vs. refilling/dropping tank wash-water.
- Changes in the type, temperature and concentration of cleaning solutions can save water.
- Overflow controls should be in place for filling tanks and vessels.
- Cover hot water basins to avoid evaporation losses

4.4.11 Boiler

- Monitor blowdown rates, feed water quality and blowdown water quality regularly.
- Install an automatic blowdown control that constantly monitors boiler water conductivity and adjusts the blowdown rate accordingly to maintain the desired water chemistry. A probe measures the conductivity and provides feedback to the controller driving a modulating blowdown valve. An automatic blowdown control can keep the blowdown rate uniformly close to the maximum allowable dissolved solids level, while minimizing blowdown and reducing energy losses. Changing from manual blowdown control to automatic control can reduce a boiler's blowdown water losses by up to 20%.
- Implement or improve condensate return systems.
- Improving external and internal feed water treatment.

4.4.12 Steam system

- Steam lines and traps should be checked for leaks periodically and repairs should be scheduled.
- Condensate should be recovered as much as possible

4.4.13 Air conditioning

- Consider recycling of air conditioning condensate water. This is achieved by modifying the existing air conditioning drains to allow collection of the water and utilise where needed.

4.4.14 Cooling

- Consider replacing water-cooled equipment with air-cooled equipment.
- Reuse the once-through cooling water for other facility water requirements such as cooling tower make-up, rinsing, washing and landscaping.
- For most efficient cooling in cooling towers, the air and water must mix as completely as possible.
- When the dew point temperature is low, the tower air induction fans can be slowed by using a motor speed control or merely cycled on and off, saving both energy and water evaporation losses.
- Reduction in drift through baffles or drift eliminators will conserve water, retain water treatment chemicals in the system and improve operating efficiency.
- Replace or repair damaged baffles or drift eliminators.
- Optimisation of blowdown, in conjunction with proper water treatment, represents the greatest opportunity for water efficiency improvement.
- To better control the blowdown and concentration ratio, install sub-meters on the make-up water feed line and the blowdown line.
- Minimum blowdown rates must be determined in tandem with the optimum water-treatment programme (including controlling of parameters) for the cooling tower as maximum concentration ratio for proper operation will depend on the feed water quality (pH, TDS, alkalinity, conductivity, hardness and micro-organism levels)

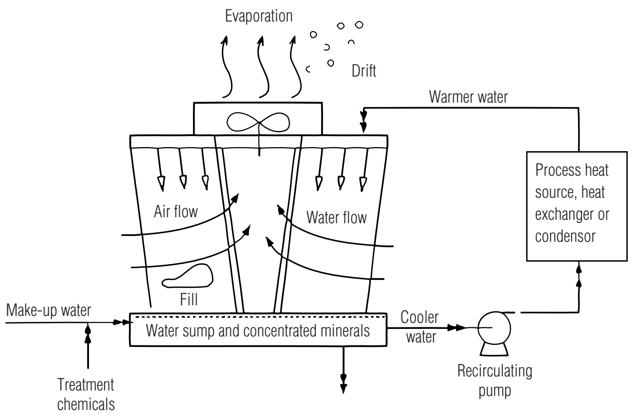


Figure 29: *Cooling Tower System Schematic*

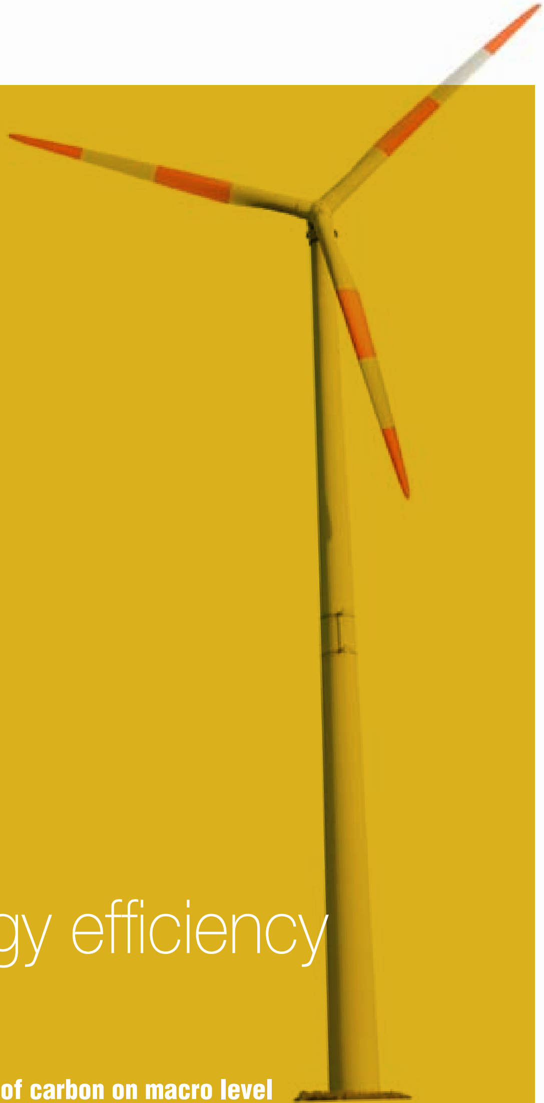
4.4.15. Water Treatment

- Use water treatment only when necessary.
- All ion exchange and softener systems should be equipped with controllers that are activated based upon the volume treated, not on timers. They should either be adjusted for the hardness of the water supply or be equipped with a hardness controller that actually measures the hardness and volume treated, if the hardness of the feed water varies.
- All filtration processes, require pressure gauges to determine when to backwash or change cartridges.
- For all filtration processes, base backwash upon pressure differential.
- Choose a reverse-osmosis or nano filtration system with the lowest reject rate for its size.
- Choose distillation equipment that recovers at least 85% of the feed water.
- Evaluate opportunities to reuse backwash waste streams.

4.4.16 Wastewater treatment

- To remove metals, silica and hardness use wastewater treatment technologies such as solids contact clarifiers, hot and warm lime softeners, ion exchange softeners and cross flow micro-filtration. Reuse applications: irrigation water, cooling system, boiler top-up water and boiler feed water.
- To remove suspended solids use wastewater treatment technologies such as media filtration and micro-filtration. Reuse applications: irrigation water, utility water, cooling system make-up water and boiler feed water.
- For disinfection use wastewater treatment technologies such as ozonation and UV disinfection systems. Reuse applications: irrigation water and utility water.
- To remove dissolved solids use wastewater treatment technologies such as reverse osmosis, ion exchange and evaporators. Reuse applications: irrigation water, utility water, cooling system make-up water and boiler feed water.

Detailed assessment: **Energy efficiency**



Detailed assessment: Energy efficiency

5.1 WHAT: Problems related to energy consumption in SMEs

Carbon is the problem, not energy

The main problem is not that we use energy, but how we produce and consume energy. As long as we continue to cover our energy needs primarily by combustion of fossil fuels or with nuclear reactors – which release carbon and GHG into the atmosphere or create toxic waste that cannot be re-absorbed by the planet – we are going to have environmental and social problems.

In 2005, worldwide per capita consumption of energy was 1,778 kg of oil equivalent. This figure includes all fuel used by industry, commerce and households. It also includes large quantities of wood and other biological fuels used mostly in developing countries. The figure of 1,778 kg of oil equivalent per person is an average for the world's population that conceals tremendous regional differences (e.g. 7,886 kg for the United States compared to 1,052 kg for the average of Asia or 1,766 kg for the average of the Middle East and Northern Africa).

The consequence of this type of energy consumption is global warming and the lack of fossil fuels in the future.[31]

According to Figure 30 by 2015, oil use is expected to exceed 100 million barrels per day, a consumption rate 50% greater than in 1995. That is why the international community is taking action; for example, Europe has implemented a CO2-capping strategy and a carbon trading scheme.

The effect of carbon on macro level

Eleven of the last twelve years (1995–2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850).

Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea-level rise. Mountain glaciers and snow cover have declined on average in both hemispheres and widespread decreases in glaciers and ice caps have contributed to sea-level rise.[32]

Supply problems

Many countries, especially in Asia, suffer from a severe shortage of electric capacity. According to the World Bank, roughly 40% of residences in India are without electricity. In addition, blackouts are a common occurrence throughout the country's main cities. The World Bank also reports that one-third of Indian businesses believe that unreliable electricity is one of their primary impediments to doing business. Further compounding the situation is that total demand for electricity in the country continues to rise and is outpacing increases in capacity. Adequate additional capacity has failed to materialise in India because of market regulations, insufficient investment in the sector, and difficulty in obtaining environmental approval and funding for hydropower projects. In addition, coal shortages are further straining power generation capabilities.

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31) International Energy Agency (IEA) Statistics Division. 2007. Energy Balances of OECD Countries (2008 edition) and Energy Balances of Non-OECD Countries (2007 edition)

32) IPCC, Direct Observations of Recent Climate Change, 2007

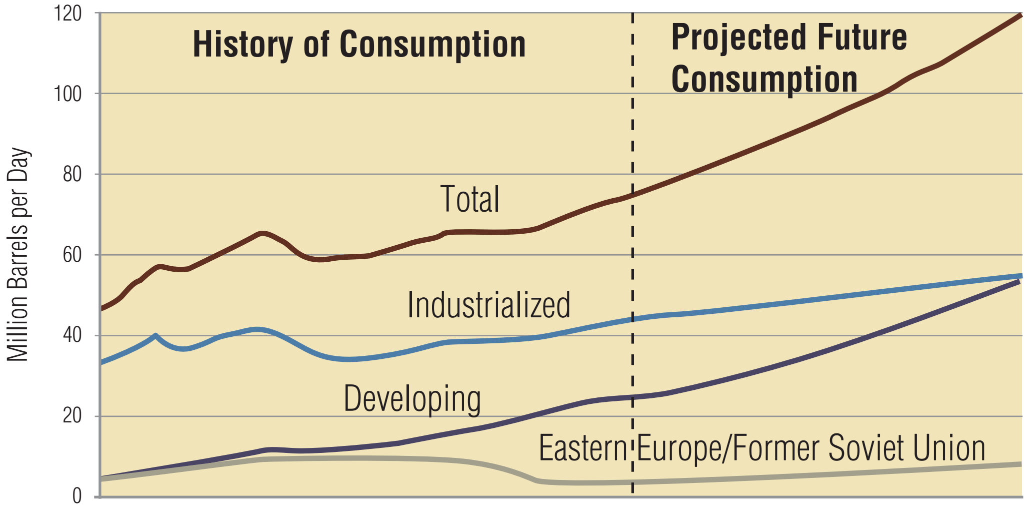


Figure 30: *World oil consumption per region 1970 - 2020* [33]

That is why several companies resort to diesel generators (a 'genset') as a power supply. Power from a genset comes at twice the price of power from the public grid.

A *rolling blackout,* also referred to as load shedding, is an intentionally engineered electrical power outage. Rolling blackouts are a last resort measure used by an electricity utility company in order to avoid a total blackout of the power system. They are usually in response to a situation where the demand for electricity exceeds the power supply capability of the network.

In many African and South Asian countries (e.g. Bangladesh, India, Nepal, Pakistan, Cameroon, Democratic Republic of the Congo, Nigeria, South Africa and Zimbabwe) rolling blackouts are a part of daily life. Sometimes, these blackouts are scheduled at fixed times of the day and week, allowing people to work around the known interruption times; however, in most cases, blackouts happen without any advanced notice, typically when the transmission frequency falls below the 'safe' limit.

Reducing energy without compromising comfort

To get an overview of the scope for savings, systematic research has been done in Europe. Some of the results are cited here to illustrate the potential for energy savings in buildings and in industry, which to some extent can be transferred globally.

Buildings represent 40% of energy consumption in Europe. According to the Commission's own research, there is an energy saving potential of 27% for residential buildings and 30% for commercial buildings by 2020.[34]

There is a massive potential for improving the efficiency of most energy-using products. Energy efficiency improvement potentials of 40-60% exist for most electrical appliances. A frequently used example is light bulbs: 80% of household lighting is provided by inefficient, incandescent light bulbs, which convert only 5% of the energy they use into light. A swift phasing-out of incandescent light bulbs would save around 20 million tonnes of CO_2 a year, as well as saving €5-8 billion. The EU has already adopted legislation to ban the most inefficient bulbs from 2012.[35]

In Europe, 25% of total electricity consumption was consumed by motor--driven systems in industry. The economic savings potential of these industrial motor-driven systems have been calculated to be 181 billion kWh, or 29%. This means a savings potential of more than 7% of the overall electricity consumption in the EU.[36]

The European Commission estimates that there is an energy-savings potential of at least 26% in the transport sector by 2020. The technology already exists but the lack of effective binding rules has meant progress has been almost non-existent. Between 1990 and 2006, transport emissions increased by 34.9% while emissions from other sectors decreased by 3.1%.[37]

Energy prices[38]

Crude oil prices continue to be volatile. The West Texas Intermediate (WTI) crude oil spot price for instance fell from US$71.47 on June 29 2009 to US$59.62 on July 14 2009 and then increased to US$71.59 by August 3 2009. The US Energy Information Administration (EIA) expects the price of WTI crude oil to grow year-over-year by 2.5 to 3% until 2030.[39]

Andris Piebalgs, the European Commissioner in charge of Energy from 2004 to 2009 said, "Energy efficiency is the cheapest and most effective way to reduce energy policy risks".[40]

33) Association for the study of peak oil, undated
34) European Commission, Energy Efficiency, 2010
35) European Greens, using energy better, undated
36) De Keulenaer H., Energy Efficient Motor Drive Systems, 2004
37) European Greens, using energy better, undated
38) EIA, U.S. Energy Information Administration, Short-Term Energy Outlook, 2010.
39) EIA International, International Energy Price Information, 2008.
40) REUK.co.uk., Saving Energy To Reduce Carbon Emissions, 2009

5.2 WHY: Energy saving benefits for SMEs

Studies show that SMEs can achieve a variety of benefits and create new possibilities and opportunities by saving energy including:

- Improved capacity for compliance with environmental demands
- Better marketing opportunities due to improved energy efficiency

Direct benefits of energy efficiency measures in SMEs are:

- Reduced operating costs
- Reduced risks through decreased dependence on volatile and rising energy prices
- Increased energy security
- Improved reliability of equipment and manufacturing processes
- Better positioning in production chains

Indirect benefits of energy efficiency measures in SMEs are:

- Internal effects on the employees and their working environment, such as:
  - Indoor Environment Quality (IEQ)/working conditions
  - Improved personnel attitudes
  - Minimized personnel fluctuations
- External effects: by the improved image of a company's management

The payback period for most investments in energy efficient motor systems are relatively short, ranging from 3 months to 3 years. The non-energy benefits of higher efficiency systems are: better process control, reduced disruption and improved product quality; sometimes reliability is also improved. Overall cost savings related to these benefits can be in the same order of magnitude as the energy cost saving itself.

The reasons why SMEs are not so keen on being energy efficient are:

- Lack of knowledge and expertise in the area of energy efficiency
- Lack of awareness about the benefits of energy efficiency
- Poor use of information, tools and training available
- Lack of financial and human resources
- Poor long-term planning
- Environmental behaviour is usually motivated by environmental legislation and public pressure.

5.3 HOW: Implement an energy efficiency programme

A successful energy efficiency programme should begin with a well-thought-out plan. Crucial to the development and use of this plan are management's commitment, sufficient technical staff and financial resources (see PDCA-method). Reference the Quick Win Map in Table 13 for further explanation.

Quick Win Map	Steps Explained	Tools (in the electronic version of the toolkit)	Advanced Reference (in the electronic version of the toolkit)
Step 1: Collect data	Find background information on the factory's energy sources by collecting annual input data	Benchmarks (see virtual assessment)	• Worksheet Energy Data
Step 2: Draw a list of equipment	Identify all uses of electricity. Draw a list of electricity and heat consuming equipment	Make a list of equipment including their energy consumption	• List of electricity-consuming equipment • List of heat-consuming equipment
Step 3: Record data	Record data on a monthly basis, relate to production and analyse trends	Record data	• MT calculator
Step4: Benchmark consumption	Benchmark energy consumption	Benchmarks (see virtual assessment)	
Step 5: Record load profile and analyse	Record load profile and analyse	Record load profile	
Step 6: Consider options	Identify energy-efficiency options from the literature on other industries' experiences and/or recommendations from resource efficiency, Cleaner production and Safer Production service providers. Also, undergo brainstorming sessions with your team	Consider Options	• Further detailed process and sector-related options see Virtual Assessment in the Toolkit
Step 7: Evaluate option and implement programme	Evaluate option, compile and implement programme (link to PDCA)	Link to DO-phase	

Table 13: *Quick Win Map*

Step 1: Collect data
The prime objective of energy efficiency is to create the company's product or service with the minimum energy input. Therefore, this background information focuses on the energy service and not on the use of energy.

Data on the annual consumption as well as costs have to be collected separately for each type of energy source. These data are available on energy bills (electricity, district heating, gas) or from suppliers of heating oil or diesel as well as in records of the in-company petrol station or electricity plant, etc. Peak loads and power factor are additional relevant information that will have an impact on the electricity bill.

Every company should strive to reduce its energy consumption. For expanding companies, trend charts are the most reliable indicator of energy efficiency, whereas overall energy consumption is not as telling.

Step 2: Draw-up a list of equipment
Drawing up a list of company equipment with respective consumption data will show which equipment is responsible for what energy use. Use this information to brainstorm improvement options.

Step 3: Record data
Based on specific energy consumption, the energy situation in a company can be analysed and controlled. In this case, the following points have to be considered:

- Has specific energy consumption increased?
  - What could be the reason? Which areas have expanded? Has this expansion caused the higher specific energy consumption? Have energy sources been substituted?
- If the specific energy consumption has decreased:
  - Is the decrease due to specific energy saving measures? Have the targets been met? Has the consumption decreased because energy sources were substituted?
- Where can I find appropriate benchmarks?
  - Ask colleagues for data from a particular sector
  - Ask plant manufacturers for data
  - Search in literature (Chapter 9 of this manual and research journals)

Carry out in-house calculations (calculate the efficiency boiler, efficiency of air compressor, heat losses from insulation using the respective worksheets in the electronic version of the toolkit).

To do this, measurements from your facility will be most helpful. Simple handheld thermometers can help to quickly get an idea of the temperatures of products, steam, condensate, water and refrigerants.

Figure 31: *Using a simple laser thermometer* [41]

Electricity meters (power clamps) help to meter electricity consumption of individual power consuming equipment. This will help to break down the overall daily or weekly consumption that is taken from the electricity meters.

Figure 32: *A digital power clamp* [42]

If the monthly consumption data are put together, they will form an annual consumption profile, from which the following conclusions can be drawn:

- Determination of the winter-summer ratio to estimate the percentage of energy required for heating, cooling and process heat
- Results achieved by the substitution of energy carriers, for instance if heating oil was substituted by electricity, etc. (in this case, several years need to be taken into account)
- Possibility of analysing energy carriers, e.g. for combined heat and power generation
- Determination of months with significant consumption peaks and measures to avoid them

The respective data can be taken from energy supplier bills and the company records.

Step 4: Benchmark consumption
For the evaluation of a company's energy consumption, key performance indicators are valuable . For instance, in the case of a brewery, an indicator can be the fuel oil consumption per hectolitre of beer. These reference values can differ substantially depending on the type of energy or the characteristics of the company. Typical reference values are production volume, turnover, number of staff, heated surface, transported volume, mileage, etc.

Some benchmarks are included in Chapter 9 of this manual. Please go to the Virtual Assessment section of the electronic toolkit for detailed sector and unit specific benchmarks.

Step 5: Record load profile and analyse
Before considering methods of load management, some terms used in connection with power supply need to be defined.

41) J. Fresner, own picture

42) FLUKE, 2010

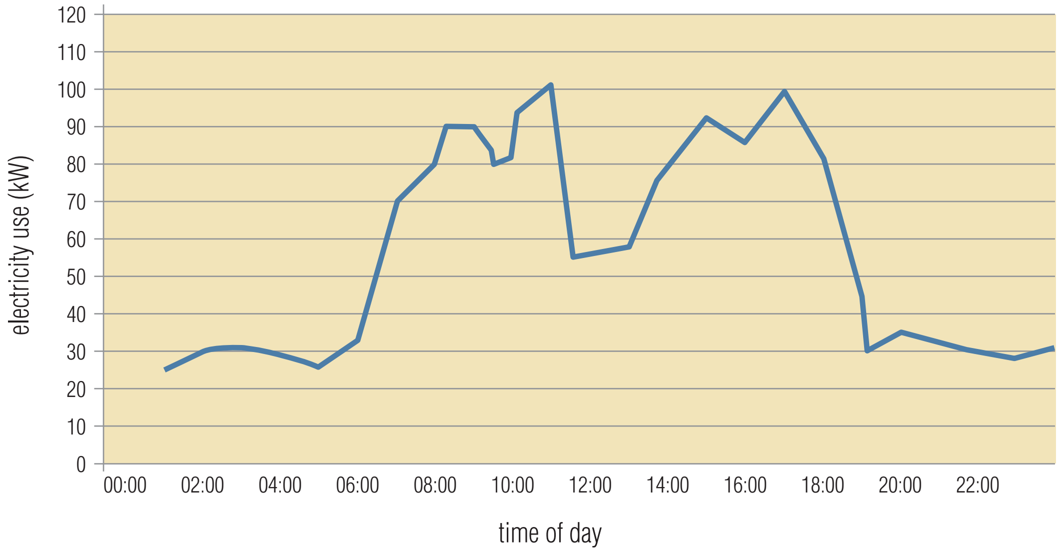


Figure 33: *Example of a load curve* [43]

- Connected load – the nameplate rating (in kW or kVA) of the apparatus installed at a consumer's premises.
- Maximum demand – the maximum load that a consumer uses at any time.
- Demand factor – the ratio of maximum demand to connected load.

Contact your power company to get a load curve. Implement peak load control and minimise base load consumption.

Electric load management and maximum demand control

If processes are not to be interrupted, electricity demand and supply must match instantaneously. This requires reserve capacity to meet peak demands, and the costs of meeting such demands – normally referred to as demand charges – are relatively high. Managing electricity supply costs therefore requires integrated load management that includes control of maximum demand and scheduling of its occurrence during peak/off peak periods.

Basically, there are two ways to reduce maximum load for an enterprise:

- Cut off the peaks
- Reduce base load

Controlling peak load by load management

There are a number of strategies to manage peak loads:

Rescheduling of loads

To minimise simultaneous maximum demands, running of units or carrying out operations that demand a lot of power can be rescheduled to different shifts. To do this, it is advisable to prepare an operation flowchart and a process run chart.

Analysing these charts and adopting an integrated approach make it possible to reschedule the operations and to run heavy equipment in such a way as to reduce maximum demand and improve the load factor.

Staggering of motor loads

When running large capacity motors, staggering their operation is advisable. This should be done with a suitable time delay (as permitted by the process) to minimise simultaneous maximum demand (depending on load conditions) from these motors.

Storage of products

It is possible to reduce maximum demand by using electricity during off-peak periods to build up storage of products/materials or chilled/hot water. Additional machinery and storage costs are often justified by reduction in demand charges, for example, storing chilled water at night to provide day-time air conditioning; adding raw material/clinker grinding facilities in cement plants; storing chipped wood in paper plants, etc. Off-peak operation can also help to save energy because of more favourable conditions, for example, lower ambient temperatures can reduce the needs for cooling, etc.

Before action is taken, a cost-benefit analysis has to be made for solutions such as those outlined above; they will then be considered for implementation if economically viable.

Shedding of non-essential loads

When maximum demand nears a preset limit it can be restricted by temporary shedding of non-essential loads. It is possible to install direct demand monitoring systems that switch off non-essential loads when a preset level of demand is reached. Simpler systems give an alarm and the loads are shut off manually.

Sophisticated microprocessor-controlled systems are available that provide a wide variety of control options:

- Accurate prediction of demand
- Graphic display of present load, available load, demand limit
- Visual and audible alarm
- Automatic load shedding in a predetermined sequence
- Automatic restoration of load
- Recording and metering

Simple load management systems with manual load shedding are employed in some industries.

Step 6: Consider Options

Thermal energy

Boilers

- 5% reduction in excess air increases boiler efficiency by 1% (or 1% reduction of residual oxygen in stack gas increases boiler efficiency by 1%)

43) Cleaner Production-Energy Efficiency Manual, UNEP, 2004

- 22°C reduction in flue gas temperature increases boiler efficiency by 1%
- 6°C rise in feed water temperature brought about by economiser/ condensate recovery corresponds to a 1% saving in boiler fuel consumption.
- 20°C increase in combustion air temperature, pre-heated by waste heat recovery, results in a 1% fuel saving.
- A 3 mm diameter hole in a pipe carrying 7 kg/cm^2 steam would waste 2,650 litres of fuel oil per year
- 100 m of bare steam pipe with a diameter of 150 mm carrying saturated steam at 8 kg/cm^2 would waste 25,000 litres furnace oil in a year
- 70% of heat losses can be reduced by floating a layer of 45 mm diameter polypropylene (plastic) balls on the surface of a 90°C hot liquid/condensate
- A 0.25 mm thick air film offers the same resistance to heat transfer as a 330 mm thick copper wall
- A 3 mm thick soot deposit on a heat transfer surface can cause a 2.5% increase in fuel consumption
- A 1 mm thick scale deposit on the inside could increase fuel consumption by 5 to 8%

Electrical energy

Compressed air
- Every 5°C reduction in intake air temperature would result in a 1% reduction in compressor power consumption
- Compressed air leaking from a 1 mm hole at a pressure of 7 kg/ cm2 means power loss equivalent to 0.5 kW
- A reduction of 1 kg/cm^2 in air pressure (8 kg/cm^2 to 7 kg/cm^2) would result in a 9% saving in input power
- A reduction of 1 kg/cm^2 in line pressure (7 kg/cm^2 to 6 kg/cm^2) can reduce the quantity leaking from a 1 mm hole by 10%

Refrigeration
- Refrigeration capacity reduces by 6% for every 3.5°C increase in condensing temperature
- Reducing condensing temperature by 5.5°C results in a 20 – 25% decrease in compressor power consumption
- A reduction of 0.55°C in cooling water temperature at condenser inlet reduces compressor power consumption by 3%
- 1 mm scale build-up on condenser tubes can increase energy consumption by 40%
- A 5.5°C increase in evaporator temperature reduces compressor power consumption by 20 – 25%

Electric motors
- High efficiency motors are 4 – 5% more efficient than standard motors
- Every 10 °C increase in motor operating temperature beyond the recommended peak is estimated to halve the motor's life
- If rewinding is not done properly, efficiency can be reduced by 5 – 8%
- Balanced voltage can reduce motor input power by 3 – 5%
- Variable speed drives can reduce input energy consumption by 5 – 15%; as much as 35% of energy can be saved for some pump/fan applications
- Soft starters/energy savers help to reduce power consumption by 3 – 7% of operating kW

Lighting
- Replacement of incandescent bulbs with CFL's offers 75 – 80% energy savings
- Replacement of conventional tube lights with new energy-efficient tube lights with electronic ballast helps reduce power consumption by 40 – 50%
- 10% increase in supply voltage will reduce bulb life by one-third
- 10% increase in supply voltage will increase lighting power consumption by an equivalent 10%

Buildings
- An increase in room temperature of 10°C can increase the heating fuel consumption by 6 – 10%
- Installing automatic lighting controls (timers, daylight or occupancy sensors) saves 10 – 25% of energy.
- Switching off 1 tonne window A/C for 1 hour daily during lunch hour avoids consumption of 445 kWh.

5.4 CHECKLIST: Energy saving

5.4.1 Domestic

Laundry
- Use lower temperature settings; use warm or cold water for the wash cycle instead of hot (except for greasy stains) and only use cold for rinses. Experiment with different laundry detergents to find one that works well with cooler water. By pre-soaking heavily soiled clothes, a cooler wash temperature may be fine. The temperature of the rinse water does not affect cleaning, so always set the washing machine on cold water rinse.
- Load the washing machine to full capacity when possible. Most people tend to under load rather than overload their washers. Check your machine's load capacity in pounds or Kg, then weigh out a few loads of laundry to get a sense of how much laundry 10 or 18 to 20 pounds or Kg represent to enable you to judge the volume of clothes for a load. Washing one large load will take less energy than washing two loads on a low or medium setting.
- Air or sun dry clothes on the line whenever possible.
- When using a drying machine, separate your clothes and dry similar types of clothes together. Lightweight synthetics, for example, dry much more quickly than bath towels and natural fibre clothes.
- Do not over dry clothes. Take clothes out while they are still slightly damp to reduce the need for ironing - another big energy user. If your dryer has a setting for auto-dry, be sure to use it instead of the timer to avoid wasting energy.
- Clean the dryer filter after each use; a clogged filter will restrict flow and reduce dryer performance.
- Dry full loads when possible as drying small loads wastes energy. However, be careful not to overfill the dryer so that air can circulate freely around the drying clothes.

Canteen
- Methods of cooking that minimise the area that must be heated (a toaster oven versus an oven, for example) saves energy. On the other hand, sometimes the most efficient cooking methods such as a microwave can sacrifice food quality. The trick is to find the right balance, or an appliance explicitly designed for a particular type of meal (crockpot, rice-cooker, etc.)
- Match the pan size to the element size; for example, when using an electric stovetop (hob), a 6" pan on an 8" burner will waste over 40% of the heat produced by the burner
- Buy sturdy, flat-bottomed cookware
- The ideal pan has a slightly concave bottom — when it heats up, the metal expands and the bottom flattens out. An electric element is significantly less efficient if the pan does not have good contact with the element. For example, boiling water for pasta could use 50% more energy on a cheap, warped-bottom pan compared to a flat-bottom pan.
- Use high-conductivity materials

- Certain materials also work better than others and usually result in more evenly cooked food; for instance, copper-bottom pans heat up faster than regular pans. In the oven, glass or ceramic pans are typically better than metal – you can turn down the temperature and food will cook just as quickly
- Keep your stovetop (hob) clean and shiny. Believe it or not, when burner pans become blackened from heavy use, they can absorb a lot of heat, reducing burner efficiency. You want them to remain shiny so they reflect heat up to the cookware.
- Reduce your cooking time...
  – Before you start, by defrosting frozen foods in the refrigerator before cooking; with conventional ovens, keep preheat time to a minimum.
  – While you cook, by keeping oven racks clear. Do not lay foil on the racks and, if possible, stagger multiple pans to improve air flow. Avoid peeking into the oven as you cook. On an electric burner or in the oven, turn off the heat just before the cooking is finished to prevent overcooking.
  – Next time, by cooking double portions so all you have to do is reheat prepared food. If you have a self-cleaning option in your oven use it infrequently and only after you have cooked a meal so it can use the residual heat.

5.4.2 Laboratory

Fume hoods can be the largest source of energy waste in laboratory buildings since they move large quantities of conditioned air directly outside. This air must be replaced by fresh air, which then must be heated or cooled, thereby adding to energy demand for indoor climate control. Energy-efficient fume hoods use variable air volume motors to drive fans whose speed is changed depending on the proximity of the user and the degree to which the sash is opened. As the sash is opened to a greater extent, flow is increased so that the face velocity of air over a given cross section of the sash opening is constant. This safeguards scientists while minimising airflow, thereby saving HVAC (Heating/Ventilation/Air Conditioning) energy. Efficient fume hoods also employ occupancy sensors that automatically increase exhaust air rates when users are close to the hood.

5.4.3 Office

- Turn off appliances completely - no standby at end of work
- Use wall outlet clock timer to switch off power supply at night and weekends
- Use energy consumption as decision criterion for future purchases
- Mount blinds outside the window
- Turn off unused devices (produce additional heat)
- Close doors in air-conditioned rooms
- Turn off air conditioning when no cold air is needed
- Increase room temperature on the air conditioner to not less than 25°C (77°F); every °C higher room temperature saves up to 6% electricity
- Maintain air-conditioning devices according to manufacturers information
- Cold air should be blown where used (flapper position)
- Use an air-conditioning unit that is appropriate for the room size and heat sources

5.4.4 Drives

Motors

- Size motors for efficient operation: motors should be sized to operate within a load window of between 65% and 100% of the rated load. The common practice of over sizing results in less efficient motor operation. For example, a motor operating at a 35% load is less efficient than a smaller motor that is matched to the same load.
- Rewinding reduces the motor efficiency by 1 to 3%. Therefore rewinding is not considered economical in the US and Europe.
- Select a new energy-efficient motor under any of the following conditions:
  – The motor is less than 40 hp.
  – An energy-efficient motor is recommended.
  – The cost of the rewind exceeds 65% of the price of a new motor.
- Install Variable Frequency Drives (VFDs) on fans and pumps which have to operate over a range of operating conditions and are controlled by valves. An exact analysis of the economics can be done knowing the frequency of operating conditions. As a rule of thumb: supplying an air flow of 50% with a VFD reduces electricity consumption by 70% as compared to control with a valve.

Belts

- Use energy efficient V-belt. V-belts have a trapezoidal cross section to create a wedging action on pulleys to increase friction and power transfer capacity. V-belt drives can reach a nominal efficiency of 93%. Regularly check the tension of the belts.

5.4.5 Light

- Make the most of daylight, e.g. by putting translucent tiles into the roof.
  - Consider using compact fluorescent lamps (CFL) instead of the standard incandescent lamp. For a typical 60 W incandescent light bulb, the replacement CFL is approximately 13 W, which is less than 25% of the power used.
  - Switch to energy efficient lighting. T-5 fluorescent lamps consume around 50% less energy than T-8 lamps while maintaining 89% of the light output over their lifetime; adaptors are available.
  - Use tubes to ‘transport’ daylight, for an example see www.solatube.com

Figure 34: *Solar tubes conduct daylight into a room*

- Paint ceilings and walls white.
- Use light-coloured flooring materials.
- Install occupancy sensors for restrooms, offices, etc. Determining which lights are most appropriate candidates for an occupancy sensor depends on how much electricity the light uses, the traffic of the area and how often lights are left on. Occupancy sensors can conserve more than 20% of the annual energy usage of an individual lighting system, depending upon the area.
- Use light timers and photosensors. Install photosensor devices to allow control of artificial (electrical) lighting during periods when natural sunlight from exterior windows (or skylights) is adequate.

5.4.6 Utilities

Boiler

- Fireside surfaces, waterside surfaces, the burner assembly and the stack should be regularly maintained. This includes visual inspection, and cleaning, if necessary.
- Seals, feed water pumps and safety valves should be checked for leaks and repaired, if necessary
- Minimise idle time at low fire. Try to operate one boiler at full load instead of two boilers at half load.
- Optimise blowdown by measuring conductivity of the boiler water and automatically controlling blowdown.
- Recover heat from flash steam (forming from blowdown or returning condensate). The flash tank acts as a separator allowing the remaining liquid to separate from flash steam. The low-pressure steam can then be used for process applications.
- Use warmest air as combustion intake. As a rule of thumb, an increase in boiler efficiency of approximately 1% is possible for each 20°C increase in intake combustion air temperature. Generally the area just below the roof will be warmer due to temperature stratification of air.
- Recover stack loss. The energy loss through the stack is a function of flue gas temperature and the excess air. Typically this contributes to about 15% energy loss. Energy from stack can be recovered for preheating combustion intake air or preheating water.
- Install condensing economisers if you use natural gas as a fuel. By cooling the flue gas below the dew point, they recover both sensible heat from the flue gas and latent heat from the condensed moisture. Condensing economisers may reach efficiencies above 100%, because of the recovery of the heat of condensation of the water vapour in the exhaust gas.
- Adjust air to fuel ratio. Best performance is obtained by the installation of an automatic air control system that will adjust the supplied air volume depending on the residual oxygen content in the exhaust gas.

Steam system

- Eliminate steam leaks. Significant savings can be realised by locating and repairing leaks in live steam lines and in condensate return lines. Leaks in the steam lines allow steam to be wasted, resulting in higher steam production requirements from the boiler to meet the system needs. Additional feed water is required to make up for condensate losses and more energy is expended to heat the cooler feed water than to heat the warmer condensate. Water treatment would also increase as the top-up water quantity increased. Leaks most often occur at the fittings in the steam and condensate pipe systems. Savings for this measure depend on the boiler efficiency, the annual hours during which the leaks occur, the boiler operating pressure and the enthalpies of the steam and boiler feed water (where enthalpy is a measure of the energy content of the steam and feedwater).

Electricity generator

- Investigate installing a combined heat and power system (CHP). When the ratio of heat to power is about 2:1, the installation of a CHP can supply both heat and power effectively without integration with the grid.
- Incorporate an absorption chiller into the design instead of a compression chiller. An absorption chiller can be driven by the waste heat from a CHP system instead of electricity.

Air compressor

- Recover waste heat from an air compressor. More than 80% of the electricity supplied to the compressor can be recovered as heat from cooling the compressor. In air cooled machines, the hot air can be used directly for room heating (where applicable). Water cooled compressors can provide hot water at about 75°C.
- Use outside air for compressor intake, as compressors require less energy to compress cooler and denser air. Typical results are savings of about 5%, with payback periods of less than a year for compressors with continuous operation. Every 4°C rise in inlet air temperature results in a higher energy consumption of 1% .

Compressed air system

- Repair compressed air leaks. In a typical industrial facility without a leak detection and repair programme, air leaks contribute to about 25 – 40% of the air demand. A leak detection and repair programme can reduce leaks to about 10% of compressor air demand. Air leaks occur mainly in the following areas:
  - Couplings, flexible hoses, rubber and plastic tubes, and fittings
  - Pressure regulators
  - Pipe joints and thread sealants
- Reduce line pressure to the minimum required. As a rule of thumb, 1% savings can be achieved with every 0.1 bar reduction in pressure for screw compressors.
- Segregate high and low-pressure requirements. If several appliances require higher pressure air, consider using a smaller separate high-pressure compressor
- Design for a minimum pressure drop in the distribution line. A properly designed system should have a pressure loss of much less than 10% of the compressor's discharge pressure, measured from the receiver tank output to the point-of-use.

Refrigerating machine

- Clean heat exchanger regularly
- Decrease condenser temperature
- Increase evaporator temperature
- Maintain refrigerating machine regularly
- Use free cooling devices; these are heat exchangers that use the outside (cold) air when colder than the inside air temperature instead of the chiller to cool the cooling brine

Air conditioning

- Mount blinds outside the window or in addition to inside the window
- Turn off unused devices (they produce additional heat)
- Close doors in air conditioned rooms
- Turn off air conditioning when no cold air is needed
- Increase room temperature on the air conditioner to not less than 25°C (77°F); every degree or higher room temperature saves up to 6% electricity in air conditioning
- Maintain air conditioning devices according to manufacturers' information
- Cold air should be blown where used (flapper position)
- Select an air conditioning unit appropriate for the room size and heat sources
- Use Free Cooling devices. There are air heat exchangers installed in the cooling brine line before the chiller, which use the outside air when cool enough to cool the brine whenever the

ambient air temperature allows (at night, and during the cold seasons) therby reducing the operation time of the chiller.

Cooling

- Keep doors of refrigeration chambers closed
- Clean heat/cold exchanger regularly
- Maintain appropriate temperature (not too cold) one degree warmer in the chamber saves up to 6% electricity
- Clean, fix rubber insulation of the doors regularly
- Defrost cold exchanger regularly

Ventilation, exhaust system

- Install occupancy sensors or timers for restrooms and offices that are not used 24 hours a day so that the fans are used only when they are needed.
- Switch off fans/blowers if not needed (e.g. during break time).
- Install variable frequency drives (VFDs) on all air handlers that have to cope with a range of operating conditions – savings of up to 40% of electricity are reported if the required air volume is 50% for 50% of the operation time.

Space heating

- Change interior temperature by 1 or 2°F (0.5 - 1°C) or use temperature setback while the space is unoccupied. As a rule of thumb, the potential savings from changing or adjusting the temperature settings on heating and air-conditioning units, commonly referred to as roof top units (RTUs), is that each degree (F) of temperature change (0.5°C) results in a 1.5% change in energy usage. Thus, if the normal temperature setting for a space is 70ºF (21°C) and the air conditioning setback temperature is 78ºF (25.5°C), the energy usage is reduced (8 x 1.5% = 12%) during the setback period, which is the non-operating hours. There are minimal operating/maintenance and implementation costs; therefore, payback would be immediate.
- Install programmable thermostats. Install automatic time clock thermostats to reduce space temperatures during unoccupied periods and thus reduce gas energy consumption for space heating. The thermostats could also shut off the cooling system during unoccupied periods of the cooling season, thereby reducing energy usage by the air-conditioning system. With programmable thermostats, a 10% energy saving for heating and cooling is possible. A programmable thermostat is inexpensive and costs about US$100. Usually, thermostats can be installed in about an hour.

Demand control

- A demand control system automatically limits operation of selected equipment in order to prevent exceeding set maximum demands. This prevents from paying penalty for overshooting contracted load limits.

Power factor correction

- An automatic power factor correction unit is a capacitor bank used to improve the power factor of an installation. The capacitors are switched on and off by a regulator that measures the power factor.
- Depending on the load and power factor of the network, the power factor controller will switch the necessary blocks of capacitors in steps to make sure the power factor stays above a selected value (usually demanded by the energy supplier).

Renewable energy

- Use solar heating to generate hot water for sanitary purposes or for cleaning
- Use (waste) biomass as fuel (e.g. bagasse in the sugar industry, rice husk or wood waste)
- Use biogas (e.g. from the treatment of organically-concentrated wastewater in dairies or breweries)

Case study:
PWANI OIL PRODUCTS LTD (prepared Kenya NCPC)

Pwani Oil Products Limited is a leading manufacturer of edible oils and fats as well as laundry bar soaps in Kenya. It started its operations in 1985 and has steadily expanded its capacity and improved its manufacturing technology to become an efficient and competitive company. It exports products to East and Central Africa, positioning the company strongly in the region.
After an initial (Resource Efficient) and Cleaner Production (RECP) audit carried out by KNCPC in 2001 (Nyakang'o and Khisa, 2001), the company implemented some of the options generated during the audit and as a result commissioned a new refinery plant to replace the old inefficient refinery as part of its technology change

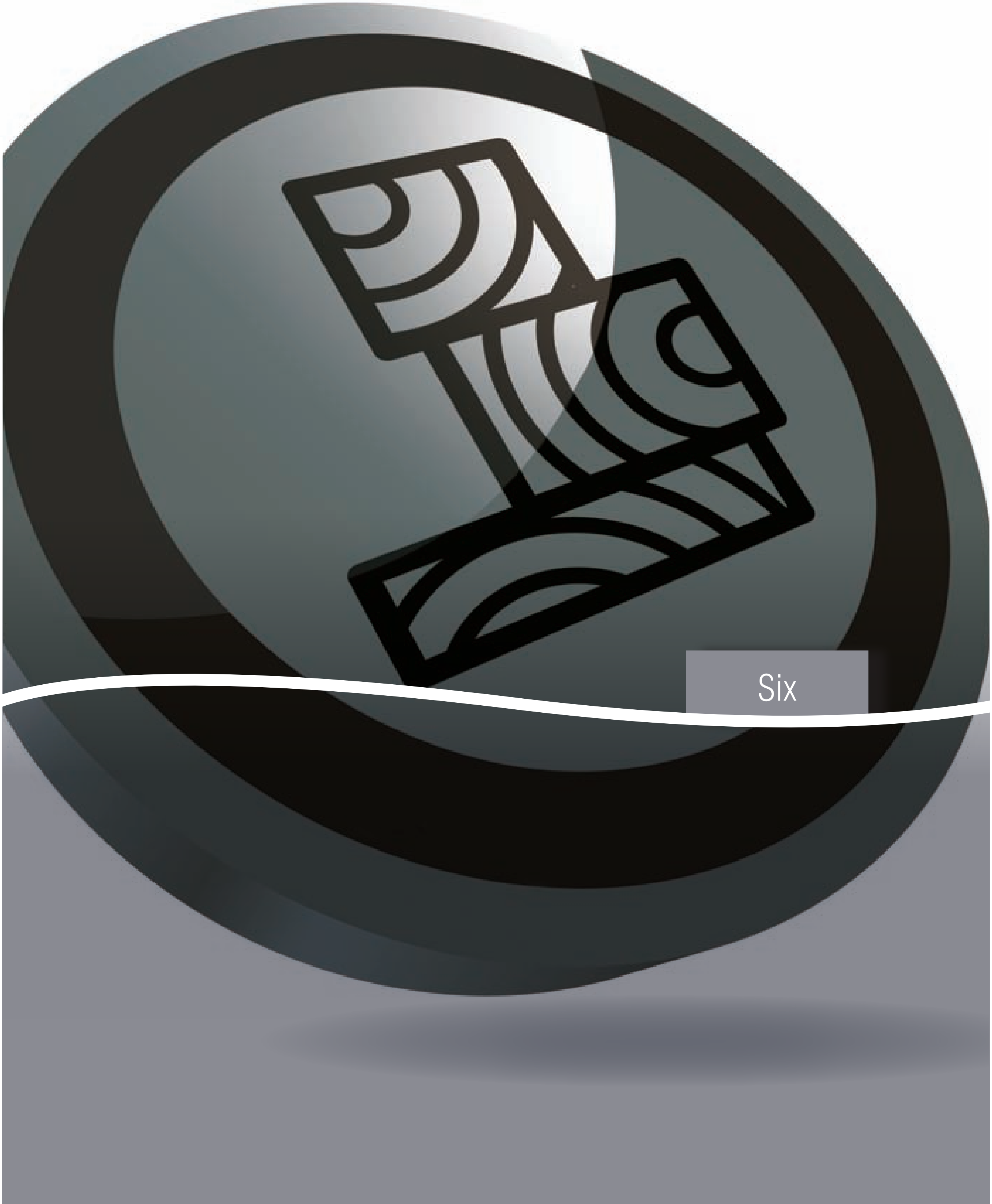
Energy efficiency improvements amounts to US$422,371 .6/yr, which means a 5% decrease in overall energy consumption.

Measures taken include:

- Installation of energy saving lamps
- Installation of timers to control security lighting; there are 20 security lamps each of 0.4 kWh
- Replacing old air compressors with efficient ones whose motors are fitted with variable speed drivers; the average consumption has dropped from 146.25 kWh/hr to 110 kWh/hr
- Replacing one sleeving machine which was using electric heaters with a steam sleeving machine (initial machine was using two heaters of 7.5 kWh each and running the machine for 24 hours. The current machine is using steam hence power saving.
- Investing in capacitor banks for quality and maintained power supply (power factor of 0.96 compared to previous 0.93); the cable and transformer losses have been reduced from 2.82% to 1.6%
- Servicing of steam traps
- Fixing steam leaks

Case Study

Detailed assessment:
Materials efficiency



Detailed assessment: Materials efficiency

6.1 WHAT: The challenge of sourcing raw materials for SMEs

Currently industrial countries around the world use between 31 – 74 tonnes of materials per capita per year; as future access to such resources becomes more difficult, efficient use of materials will be recognised as an important factor in competition and innovation.[44]

Figure 35 shows the overall material basis of the global economy (including only used materials) between 1980 and 2005. Four material categories are separately shown: fossil fuels, metal ores, industrial and construction minerals and biomass (from agriculture, forestry and fishery). The figure illustrates that global resource extraction grew more or less steadily over the past 25 years, from 40 billion tons in 1980 to 58 billion tons in 2005, representing an aggregated growth rate of 45%. However, growth rates were unevenly distributed among the main material categories. The extraction of metal ores showed the largest increase (by more than 65%), indicating the continued importance of this resource category for industrial development. The increase in biomass extraction was below the upward curve of the other categories. The share of renewable resources in total resource extraction is therefore decreasing on a global level.[45]

Material efficiency in industrial production focuses on the amount of a particular material needed to produce a particular product. Mathematically it is the ratio of the product divided by the raw materials used – so the number is never smaller than one. Material efficiency can be improved either by reducing the amount of the material contained in the final product ('light weighting'), or by reducing the amount of material that enters the production process but ends up in the waste stream. In a slightly broader sense, taking into account the industrial production-consumption cycle, material efficiency can refer to the amount of virgin natural resources required for producing a given amount of product, with recycling of post-consumption waste material back into production contributing to material efficiency.

Three components of material efficiency can therefore be identified:

- Light weighting in the production process
- Waste reduction in the production process
- Recycling of material in the production-consumption cycle[46]

Some facts and figures

Development of steel consumption

The world steel industry has entered a new phase. The finished steel consumption in the five years since the beginning of 2000 increased by 233 million tonnes – an average annual rate of around 6%. This compares with a 1.2% average yearly rise in the three decades previous to the year 2000.

Steel prices have increased substantially and the industry is profitable; however, margins have been reduced due to the dramatic increase in prices of raw materials and transportation. There are also some risks of shortages for scrap and coke.[47]

44) Wisions, Corporate Energy and Material Efficiency, 2006.

45) Material Flows, Global resource extraction my material category, 2008.

46) Peck, M. and Chipman, R., Industrial energy and material efficiency: What role for policies?, undated

47) OECD, Recent Steel Market Developments, 2004.

Development of copper consumption

The qualities of copper that have made it the material of choice for a variety of domestic, industrial and high-technology applications have also resulted in a steady rise in global copper consumption. Studies of copper consumption from the U.S. Geological Survey (USGS) show some interesting trends between 1980 and 2008. Copper consumption in emerging economies, such as China and India, rose considerably, whereas the consumption rate in industrialised economies, such as the United States, fell slightly. Until 2002, the United States was the leading copper consumer and annually used about 16% of total world refined copper (about 2.4 million tonnes). In 2002, the United States was overtaken by China as the world's leading user of refined copper. The booming economy in China contributed to a tripling of its annual refined copper consumption during the 8 years from 1999 to 2007. Data for 2008 are estimates based on data for three-quarters of the year.[49]

For a better understanding of material flows, there are different methods for measuring material flows in an industry. With these methods it is easier to localise sources of dissipation and define

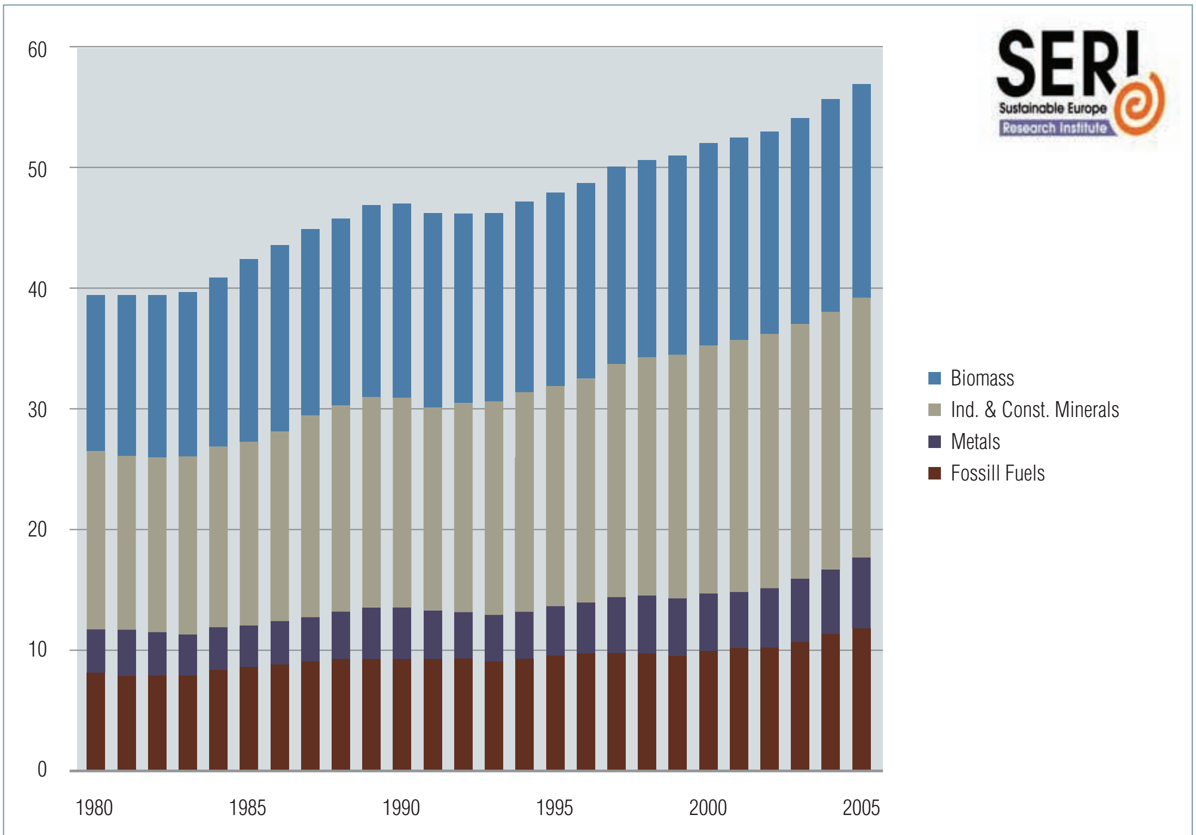


***Figure 35**: Global use of resources*

Region	2000	2001	2002	2003	2004	2005	2006	2007	2008
European Union 25	160.0	156.5	156.7	154.4	162.1	164.1	167.0	167.3	166.5
European Union 15	132.6	129.5	127.4	137.4	144.1	145.4	146.9	146.9	146.2
Other Europe	22.1	20.6	20.7	24.1	26.0	27.0	28.0	29.7	30.5
Former USSR	38.8	41.2	38.3	43.4	47.0	50.0	52.0	53.5	55.0
NAFTA	149.2	132.1	135.1	132.9	152.5	153.5	157.5	157.5	155.5
S America	28.1	28.4	27.4	28.1	31.5	32.3	34.5	35.5	38.5
Africa	15.0	16.3	17.4	17.1	17.5	18.0	18.5	19.0	19.0
Middle East	18.4	19.1	20.9	21.6	23.5	25.0	26.5	27.5	28.5
PR China	124.6	153.4	185.6	230.8	257.4	291.4	302.0	310.0	322.0
Other Asia	119.5	118.9	129.5	133.3	141.0	143.5	145.7	147.0	149.2
Oceania	6.4	6.3	7.1	7.5	7.5	8.0	8.0	8.5	8.5
World TOTAL	**758.2**	**766.0**	**810.4**	**867.0**	**941.5**	**989.5**	**1016.5**	**1032.5**	**1048.0**

***Table 14:** Summary of apparent consumption of finished steel 2000-2008 (in million tonnes)* [48]

48) OECD, Recent Steel Market Developments, 2004.

49) USGS, Copper – a Metal for the Ages, 2009

adequate strategies for a better use of resources. The most commonly used ones are:

- Life Cycle Analysis (see Chapter 2.3)
- The MIPS concept (see Chapter 2.4)

6.2 WHY: Material saving benefits for SMEs

Increasing material efficiency brings a number of benefits. First, natural resources are conserved, ensuring that the use of the most accessible and lowest-cost resources will be extended, reducing the cost of production, improving living standards and ensuring the resources will be available for future generations. While scarcity of natural resources, other than water and energy, does not appear to impose a substantial restraint on development, conserving those resources does provide benefits.

Second, reducing the demand for raw materials will reduce the impacts of raw material extraction, including both environmental and social impacts. The environmental impacts of mining and primary processing, in particular, can be severe, including water pollution, air pollution and land degradation. Environmental regulation of mining and primary processing has often been less effective than regulation of large-scale industry and the energy sector, in part because mining enterprises tend to be small, in some cases consisting of one mine. Small enterprises can disappear or declare bankruptcy after resource deposits are depleted, leaving the damage to be cleaned up by others. In the United States, for example, many of the largest Superfund toxic waste sites are metal mines and mining operations produce a large share of industrial toxic releases. The costs of these environmental impacts are not reflected in the market prices of raw materials. Analyses have generally found that the environmental impacts of recycling materials are substantially less than the impacts of extracting the same raw materials. The impacts of raw material extraction will not be examined here, other than to note that increasing material efficiency will reduce such impacts.

Third, energy will be conserved and greenhouse gas emissions reduced. As indicated in the chapter on Energy Efficiency, the metals sector in particular is very energy intensive. Recycling of materials can save most of the energy required for refining and processing. Typical energy savings from recycling relative to raw material extraction are estimated at: aluminium 95%, iron and steel 74%, plastic 80%, paper 64% and glass about 10%.

Fourth, increasing material efficiency will reduce the amount of waste material going to landfills or to be incinerated, reducing land use, water and air pollution and other negative impacts from waste handling. Industrial production and consumption are involved in almost all solid waste disposals in developed countries, whether through wastes from extraction of industrial raw materials, wastes from industry, or household or office waste of industrial products. In the United Kingdom, industrial production and consumption account directly for almost one-third of solid waste, with mining and quarrying, and construction and demolition accounting about equally for most of the remaining two-thirds. Within the 33% due directly to industrial production and consumption, 14% is directly from industry, 10% is from commercial sources and 9% is household waste. Only the 5% of solid waste due to dredging, and a few percent due to household yard waste (leaves and grass) and food waste, is independent of industrial production. Agricultural residues are generally not included in solid waste statistics, nor are livestock wastes, which are considered liquid waste.

Fifth, improved collection and recycling of waste, particularly drink containers and plastic bags, could reduce the amount of litter cluttering land and water and in some cases clogging drainage systems. In fact, the desire to reduce litter for aesthetic reasons has been a major driving force behind municipal recycling schemes in many areas.[50]

6.3 HOW: SMEs can improve their material efficiency

Material Flow Analysis[51]
The so-called 'material flow analysis' is a systematic approach aiming at:

- Presenting an overview of the materials used in a company
- Identifying the point of origin, the volumes as well as the causes of waste and emissions
- Creating a basis for an evaluation and forecast of future developments
- Defining strategies to improve the overall situation

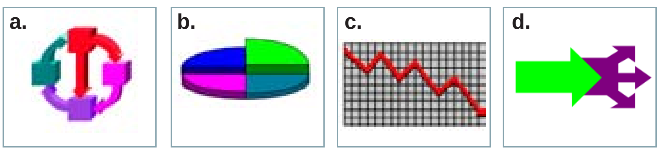
Problems of waste and emission for a company arise at those points of production where materials are used, processed or treated. If a company wants to find a strategic solution to environmental problems, it is essential to capture the current material flows in a model to identify points of origin, volumes and causes of waste and emissions. Furthermore, in a material flow analysis the composition of the used substances is analysed, their economic value is estimated and possible future developments are forecasted. The introduction of an information system will enable management to retrace material flows within the company, to direct them and to guarantee that they are efficiently used.

"A material flow analysis is a systematic reconstruction of the way a chemical element, a compound or a material takes through the natural and/or the economic cycle. A material flow analysis is generally based on the principle of physical balance."

German commission of inquiry "Schutz des Menschen und der Umwelt" – Protection of human life and the environment – of the Deutsche Bundestag, 1993

The following types of charts can be used for the graphical representation of a material flow analysis:

a. Flowcharts representing material flows and process steps
b. Pie charts and histograms illustrating ratios and compositions
c. Time-travel diagrams showing time relations
d. Sankey diagrams visualising material flows true to scale



Step 1: Draw a Materials Flowchart
- Define the objective of the material flow analysis and the parameters to be monitored
- Define the balance scope
- Define the balance period
- Identify and define process steps

Defining parameters:
One of the objectives of a material flow analysis is to retrace the flows of goods and/or certain chemical compounds or single elements through the company with regard to various criteria (costs, risks, safe disposal, volumes, etc.). It is important to decide at the beginning how exact this analysis will be.

50) Peck, M. and Chipman, R., Industrial energy and material efficiency: What role for policies?, undated

51) UNIDO, Textbook Material flow analysis, 2003

Quick Win Map	Steps Explained	Basic Reference (in the electronic version of the toolkit)	Advanced Reference (in the electronic version of the toolkit)
Step 1: Draw a Material Flowchart	Identify all uses of materials by creating a flowchart for materials	Material Flowchart	• Water and Material Flowchart • Use the flowcharting programme included in the electronic toolkit
Step 2: Create Material Balance	Get detailed information about what is going in and what is going out through the process.	Material Balance	Consider options from literature on other industries' experiences and/or recommendations from RE, CP and SP service providers. Also undergo brainstorming sessions with your team
Step 3: Consider Options	Consider options from literature on other industries' experiences and/or recommendations from RE, CP and SP service providers. Also undergo brainstorming sessions with your team	Consider Options	• Sector specific checklists • Further detailed process and sector related options, see Virtual Assessment
Step 4: Evaluate Option and Implement Programme	Evaluate option, compile and implement programme (link to PDCA)	Link to DO-phase	

Table 15: *Quick Win Map*

The best way of defining the objective is to start with a material flow analysis of the company as a whole. First of all, a global input/output analysis answers the following questions:

- What materials are used in the company?
- What quantities of materials are processed?
- What is their economic value?
- What quantities of waste and emissions are disposed of at the end of the production process?

Make a list of all raw and processed materials as well as all energy sources based on stock-keeping and accounting records. Make a list of products and emissions using the same procedure. In this context we can speak of a material balance at company level. A more detailed analysis will primarily investigate expensive and ecologically problematic materials. For the definition of priorities, the identified material flows are then ranked according to their value and toxicity.

The balance scope:
The balance scope can either comprise the company as a whole or be limited to individual processes. Its definition depends once again on the objective of the analysis. First, the company as a whole is analysed; in order to identify possible points for intervention, processes have to be divided into single steps.

The balance period:
Choosing a specific time span as a balance period has proved successful. This may be a balance year, a month, a production batch or a week of production.

Identifying and defining production steps:
In the next phase, processes are divided into steps and represented in a flowchart. This flowchart should be based either on activities or on equipment, on production units or on profit centres. Rectangles are used to indicate production steps and arrows for material flows.

Next, indicate all relevant data on material flows – such as components, values, volumes, data sources, ecological relevance – on the flowchart. In the same way, document all important data regarding process steps (or equipment) such as temperature and batch size. These flowcharts can be used to draw up a waste management plan.

The objective is to draw a clear map of your company's process flow to gain an understanding of how the system operates – i.e., who and what are involved in the process and what do they do. The map will help you understand where materials are used and located. Process flow means both the sequence of activities you undertake at your company and the external activities that you can influence in your business, ranging from the products and services you procure, to the products and services that you provide.

A: PREPARE YOUR PROCESS FLOWCHART
Discuss and decide the boundaries of your process. Take into account what information you have available and to what extent you can trace your raw materials upstream, and your products and services downstream.

- **Where or when does the process start?**
  To answer this question you will need to trace where your raw materials come from, what they are and how they get to your business. A good way to start gathering this information is to discuss this with the person responsible for procurement and acquisitions in your company. You may also want to contact your suppliers and contractors and ask them for further information.

- **Where or when does it end?**
  To answer this question you will need to trace where your products and services are being delivered to and for what purposes. A good way to start gathering this information is to contact the person responsible for sales in your company. You may also want to contact direct customers and ask them for further information. Ask your waste collectors for information on the material you hand over to them.

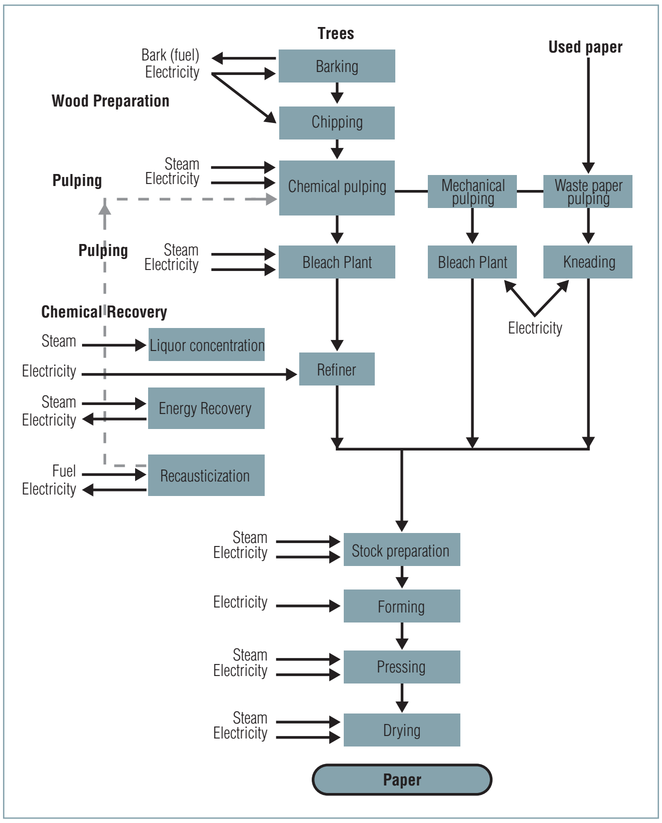


***Figure 36**: Example of a process flowchart in the pulp and paper industry* [52]

Discuss and decide on the level of detail to be included in the diagram.

- **List all of the steps and activities in the process**

- **Arrange the activities in sequence**
  Make sure to include activities undertaken by your direct suppliers, in the transportation of your products, by-products and waste materials and their use, and wastewater treatment and disposal.

- **Discuss** the sequence of activities with the relevant people in your company and confirm that it is correct.

- **Review the flowchart** with your workers and your business partners
  – e.g.,
  – Workers and supervisors
  – Suppliers
  – Transporters
  – Customers
    – Other relevant stakeholders
  Check if they agree that the process is drawn accurately.

B: IDENTIFY THE MATERIALS, THEIR QUANTITIES AND THE HAZARDS INVOLVED IN THE PROCESS
- Identify the materials involved in the individual steps of the production process.
- Mark the materials on your flowchart.
- Identify the quantities of the materials usually involved or present for this activity.
- Mark the quantities on your flowchart
- Repeat this process of identifying materials and quantities of materials for every arm of the flowchart.

You will notice immediately that information concerning activities undertaken outside your company will be relatively harder to get compared to activities conducted within your company. Do not get discouraged and ask for help from your business partners. You can find an example of a process flowchart below.

Step 2: Create a Material Balance
When drawing up a balance, remember the principle of conservation of masses. This applies to the entire company as well as to the system elements defined as 'production steps'. In a stable system the mass input into an element has to be equivalent to the output. All raw and processed materials entering a certain system have to leave it as a product, waste or emissions. For this reason we have to calculate in mass units [kg].

The data required for a material flow analysis can be obtained from different sources such as production data acquisition system, log books, routine measurements, individual measurements, information from the production department and documentation of equipment, but also by calculating or estimating. Data on the input of raw and processed materials are available from the accounts department or the logistics department. Data concerning process flows are available from the production planning and control departments, from the foremen or workshop masters themselves, from job planning or production records. If all these sources do not permit the collection of the necessary data on quantities and values you will have to carry out your own measurements or else rely on estimates.

Output data is usually detailed on control sheets. Thus the flow of a certain material can be retraced from the point of entry into the company following its way through diverse processes to the point of output. Ideally you will be able to draw up a coherent material balance: input has to be equivalent to output. The same applies to detailed balances and individual process steps. A good estimate is always preferable to having no balance at all. An estimate with an accuracy of 80 to 90% is usually sufficient.

Step 3: Consider Options
Finally, interpret your flowchart. Retrace material paths and calculate key efficiency and performance ratios for the individual production steps as well as for the company as a whole. To do this, pinpoint where waste is generated and determine the ratio between raw materials and waste; compare real efficiency to the estimated efficiency you projected previously.

Weak points in the system can be detected by comparing information on the real efficiency of processes to reference values. Rank weak points in order of priority and analyse them; conduct an open discussion of the weak points with the entire company. Updating process data on a regular basis will create an instrument for technical control and to document material use and material flows.

The following strategies can lead to an improved material utilisation:
- Good housekeeping in the sense of thoughtful use and handling of raw and processed materials (respecting product formulations, complete emptying of containers, sealing of leakages, etc.)
- Substitution of hazardous raw and processed materials (e.g., raw materials containing formaldehyde, heavy metals or chloride, etc.)
- Process modifications (automatic control, etc.)
- Product modifications
  – *Light weighting:* The simplest and most direct form of improving material efficiency in industry is reducing the amount of material that goes into a product, or 'light weighting'. The average weight of aluminium cans in the United States has decreased from 20.6g in 1972 to 15.6g today, a reduction of 24%. Glass bottles are now about 25% lighter than they were in 1984. Plastic soft drink bottles made of polyethylene terephthalate (PET) had an average weight of 67g in 1984 and 48g in 2000. Plastic milk jugs made of high-density polyethylene (HDPE) weighed 120g in the mid-1960s and 65g in 2000. The thickness of the most common

52) Bureau of Energy Efficiency, Material and Energy Balance, undated

plastic grocery bag has been reduced from 30 microns to 18 microns.[53]

Industrial light weighting has contributed substantially to improving material efficiency in the last few decades and to stabilising, but not reducing, total material requirements (see Figure 24). However, there is probably a limited opportunity for much more light weighting (distinct from material substitution) in today's products, perhaps with the exception of electronics, which are a modest but growing component of waste (considered below).[53]

With respect to material efficiency, increased recycling generally appears to offer the greatest potential for further progress, with material substitution contributing to eco-efficiency. Additionally, industrial light weighting is driven by internal production economics, production technologies and raw material prices, with limited influence from public policies. Light weighting will therefore not be analysed in detail here.[54]

- Recycling waste materials back into industrial production, as noted above, not only reduces requirements for the extraction and processing of virgin natural resources, but also saves much of the energy consumed by extraction and processing, and reduces the amount of waste going to landfills or incineration. It is therefore an important contributor to material efficiency.[55]
  - Internal recycling (closing water circuits, recycling valuable materials within the company, etc.)
  - External recycling (recycling of scrap, composting biodegradable materials, etc.)

Product modification
Product modification can be an important approach although sometimes hard to realise.

- Change of materials
  - Example: aerosol substitutes in refrigerating agents
- Use of recycled materials
  - Example: leather fibre scraps as filling material in leather production; granulated recycled plastic for the production of bumpers
- Avoidance of hazardous components
  - Example: asbestos as heat insulator in irons

Substitution or change of raw and processed materials
There is a whole range of possibilities available for substituting or changing raw or processed materials, which include the following measures:

- Substitution of organic solvents by aqueous agents
  - Examples: hydro soluble varnishes, water-based alkaline cleaning agents for metal degreasing.
- Substitution of halogenated solvents
  - Examples: substitution of aerosols in cleaning units, in the production of insulating materials and cooling units; halogen-free hydrocarbon solvents in dry cleaning instead of perchloroethylene (per)
- Substitution of petrochemical by biochemical products
  - Examples: cleaning agents of a soy or rape basis; natural dyeing substances instead of dyeing agents with petrochemical basis; lubricants with a biological basis
- Selection of materials with less impurities
  - Examples: fuels containing less sulphur (natural gas instead of coal); minerals containing less hazardous substances; use of clearly separated corrugated board in the packaging industry; use of de-ionized water to prepare process solutions
- Use of residues as raw materials
  - Example: use of fibre sludge from chemical pulp production for the brick industry, products from recycled materials (glass, paper, etc.)
- Use of biodegradable materials
  - Example: biodegradable detergents
- Reduction in the number of components
  - Examples: less plastic in car manufacture; use of standardised screws for assembly of do-it-yourself furniture
- Use of heavy-metal free substances
  - Example: heavy-metal free substances in paints and varnishes (especially lead and cadmium)
- In general: use of less toxic materials
  - Examples: cyanide-free galvanizing; chromating on the basis of chrome (III) instead of chrome (VI)
- Returnable packs
  - Examples: use of 1000 returnable skeleton containers rather than 70 throwaway packs; use of compostable packaging and/or filling materials (on the basis of pulp/paper or vegetable starch); cloths for furniture transport; packing units of the correct size (neither too big nor too small); complete emptying of packs

Closing internal loops
Closing internal loops involves, among others, the following measures:

- Reuse: Renewed use of materials or products for the same purpose as before
  - Examples: recovery of solvents used for the same purpose, returnable packs; washing cleaning rags; electrolytic or chemical recycling of caustic chemical solutions
- Further use: Use of materials or products for a different purpose
  - Examples: use of varnish residues for paint spraying invisible parts (e.g. for under-sealing)[56]

6.4 CHECKLIST: Materials efficiency

6.4.1 Dispatch materials

Stuffing/Padding Material
- Use shredded waste paper or shredded cardboard as stuffing/padding material

Disposable Pallet
- Sell disposable wood pallets for heating purposes

Duct Tape
- Use paper based tape

6.4.2 Domestic materials

Canteen
- Buy regional foods
- Use returnable dishes and cutlery

53) Rathje and Murphy, The Archaeology of Garbage, 2001
54) Peck, M. and Chipman, R., Industrial energy and material efficiency: What role for policies?, undated
55) Peck, M. and Chipman, R., Industrial energy and material efficiency: What role for policies?, undated
56) UNIDO; UNIDO Toolkit, undated, http://www.unido.org/index.php?id=o86205

6.4.3 Office materials

Material efficiency – Investigate your company's procurement policy to see if material efficiency is mentioned or if there is room for improvement. Open up communication and begin employee engagement around material efficiency.

Procurement policy

- Get an overview of raw and processed materials used in the company. Examine raw and processed materials and determine their environmental relevance and possible substitution.
- Ask the supplier for product information (e.g. safety data sheets).
- Collect information on environmental or sector-specific labels for materials used in the company and ask the suppliers for site certifications.
- Use the criteria and guidelines of environmental labels to define guidelines for the company's tenders.
- Ask the supplier to offer environmentally friendly alternatives.
- Does a central unit examine products before they are used in the company for the first time?
- If cleaning is carried out by an external cleaning team, does the company know which detergents are used?
- Are the procurement activities of the company documented?
- Does the company train its employees in the handling of a new product?
- Are all environmentally friendly purchased products marked and are the underlying criteria applied?
- Does the company have a list of products for which no environmentally friendly alternative has been found to date?
- Does the company regularly check the product packaging to see how environmentally friendly it is (multi-way packaging system, recyclability)?

Employee Engagement

- Is there a central purchasing unit in the company?
- Does the company's environmental policy mention green procurement?
- Do employees know who exactly is responsible for which type of procurement in the company?
- Are environmental safety managers consulted in procurement activities?
- Does the company inform its employees when a new product will be used in time for them to learn new safety and handling requirements?

Paper

- Print paper on both sides (duplex, double-sided)
- Save one side printed paper for scratch paper/notes

Toner Cartridge

- Buy refilled/refillable toners
- Use toner-conservation mode or 'Economode' if available as printer settings, at least for draft or internal printouts

6.4.4 Storage materials

Disposable Pallet

- Sell disposable wood pallets for heating purposes

6.4.5 Utilities materials

Air Conditioner

- Use clean air at inlet if possible, avoid the supply of dusty, unfiltered air to ensure a long useful life for air filter

Equipment	Conventional	HVLP	Airless	Air Assisted Airless	Electrostatic
Transfer Efficiency	20% - 60%	65% -	90%	40% - 60%	up to 95%
Air Pressure (bar)	0,3 - 2	0,2 – 0,7	None	0,2 – 2,0	Depends on gun type
Fluid Pressure (bar)	0,5 – 2,0	0,6 – 2,0	30 - 200	15 - 70	
Air Volume (m³/min)	0,15 – 0,30	0,42 – 0,84	None	0,15 – 0,45	
Comments	Good for wide range of paint viscosities	Best results for paints of moderate to low viscosity	Used for viscous paints, thick film, or high production; also used for conventional paints	Typically used for viscous paints with thick film build-up or high production rrates; also used for conventional paints	Available in all gun types. Problems with water-based paint and non-metallic work pieces
Spray Gun Cost					
Prices start at	□ 100 - □ 500	□ 100 - □ 500			
Turbine systems □ 700	□ 3,500	□ 2,500	□ 5,000		

Table 16: *Comparison of different paint application equipment* [57]

57) http://www.p2ad.org/documents/ma_spraypaint.html and http://www.p2pays.org/ref/09/08058.htm

- Clean air conditioning and refrigeration condenser/evaporator coils every three months
- Check the refrigerant charge and fix leaks if necessary
- Regularly clean or replace air filters on ventilation and heating/air conditioning equipment; clean grease traps on ventilation equipment
- Check freezer and walk-in seals for cracks and warping; replace if necessary

6.4.6 Production materials

Cooling lubricants[58]
The metal working process creates heat and friction during processes such as cutting, turning and grinding, which limits the tool life. Conventional coolants are emulsions of oil in water (approximately 5 to 7% of oil). Coolants take heat away from the tools and the material being processed.

The useful life of coolants is limited by a variety of reasons:
- Coolants break down because the organic molecules decompose by heat or by the activity of bacteria.
- Coolants accumulate foreign substances including tramp oil, swarf, dissolved minerals, and/or dirt from the process

The following hints will help to increase the useful life of coolants:
- Use de-mineralized water to prepare the coolant. This prevents the introduction of salts. The minerals present are not evaporated and accumulate in the sump increasing the concentration of minerals in the coolant.
- Anaerobic bacteria grow in environments lacking oxygen. They feed upon the coolant and produce noxious byproducts such as hydrogen sulphide. This is commonly referred to as the 'Monday morning' odour. It is possible to prevent the growth of anaerobic bacteria by agitating or aerating the sump over periods of time when the process is not in operation, including weekends.
- A process to remove surface oil and solids is also necessary for long coolant life.
- A variety of filter media, filtering devices and oil skimmers exist to remove impurities including swarf and tramp oil from the coolant.
- When coolant is changed the sumps should be cleaned thoroughly.
- Metal swarf and tramp oil may be able to be recycled. Oil may also be sold as a fuel.
- Separation of cooling lubricants from metal parts can be done effectively using centrifuges and vibrating screens.

Painting
The required fluid pressure in a conventional spray gun is based on delivering a certain amount of paint through the gun. The best way of setting the correct pressure is the following: atomising air is shut off and the pressure is set initially to about 0.5 pounds per square inch (psi). The atomising air is adjusted to zero and the paint gun is triggered. When the stream of paint leaving the gun tip is about 30 cm long, the fluid pressure setting is adequate.

Higher pressure will result in heavy paint flow and large particle size. In general, the fluid pressure should not be greater than 1.5 bar. If more pressure is required, a larger paint gun tip is probably needed.

It may be necessary to reset the guns and pot pressure several times per day if the temperature changes. The same is true when new or different batches of paint are used.

One way to avoid changing conditions is to use heating bands on paint pots. Not only will the guns remain set longer, fewer solvents will be needed for thinning. Heat can be used instead of solvent to provide paint thinning with some types of paint.

Today many paints are sold as water-based paints. Water-based paints use water in place of some or all of the solvent used for thinning and dispersion. Many water-based paints also contain increased content of solids resulting in greatly increased coverage. In addition water-based paints are comparable to solvent-based paints in performance. Some are as good or better than solvent-based paints in adhesion, scratch resistance, abrasion, salt spray resistance and UV resistance.

The skill of the person operatingthe spray gun has a tremendous effect on transfer efficiency and coverage. Often painters have not been properly trained or do not have the correct tools such as measuring equipment or high efficiency spray equipment. Basic training for operators can reduce problems greatly.

- Avoid clearing the gun when painting – triggering the paint gun when the gun is pointed at the floor or ceiling or anywhere but the part being painted wastes paint.
- Paint guns should be moved parallel to the surface and not by moving the paint gun in an arc which will cause the ends of the stroke to be too far away and too close in the middle.
- Avoid too much or too little overlap; a 50% overlap pattern is usually recommended to avoid heavy and light areas.
- Avoid thick coating; the applied thickness should be checked by measuring and comparing against the suppliers recommendations.
- Avoid using incorrect fan pattern; a wide fan pattern is great for wide open spaces but it is not so good for painting narrow edges, because a narrow edge will occupy only a small portion of the fan. The rest of the paint is overspray.
- Avoid increasing the pressure above the recommended setting; increasing fluid and atomising pressure well above the recommended setting is common and the result is usually wasted paint.
- Avoid holding the gun at an angle; spray guns should be pointed perpendicular to a surface as holding it at an angle results in some or the entire spray pattern being too far away from the surface.

The paint booth is important from a worker exposure, quality, and paint usage perspective. A paint booth is intended to collect overspray paint and to remove solvent fumes from the work area. If painting is done in an area with no ventilation, fumes will build, resulting in a fire and health hazard. Also, overspray paint will settle on newly painted surfaces causing quality problems. Paint booths also eliminate drafts of air that could carry paint away from the workspace and onto neighbouring cars and buildings.

It is important to provide make-up air for the booth. If a booth exhausts 100 m³/min, then an equal amount of air must be brought into the building to avoid negative pressure situations. Insufficient make-up air will result in reduced flow through the booth eliminating the booth's benefits.

Use a washing machine to clean guns.

58) http://www.p2pays.org/ref/01/00072.htm

Detailed assessment:
Waste minimisation



Detailed assessment: Waste minimisation

7.1 WHAT: Waste minimisation for SMEs

7.1.1 General definition[59]

Waste is defined as a non-product output with a negative or zero market value. Waste can be solid, liquid or have a paste-like consistency. Water and air-polluting emissions – although they are non-product output – are not regarded as waste. If the value of the waste fluctuates according to market conditions, accumulated net costs/revenues during the reporting period are used to determine the market value.

7.1.2 Definitions based on the quality of waste[60]

Waste is divided into the following sub-categories according to its quality:

- **Mineral**
  Mineral waste is an inert mineral, which is insoluble and will not decompose. Mineral quality waste is safe by nature. It can be discharged without requiring special landfill technology and/or long-term landfill management.

- **Non-mineral**
  Waste that is categorised as non-mineral has the potential to be chemically and/or biologically reactive; it is soluble and/or decomposable. Discharge requires special landfill technology and/or long-term landfill management. Non-mineral waste can be mineralised through waste treatment technology.

7.1.3 Waste treatment technology sub-categories

Waste treatment technology is divided into the following sub-categories:

- **Reuse, re-manufacturing, recycling**
  - Reuse is the additional use of a component, part or product after it has been removed from a clearly defined service cycle. Reuse does not include a manufacturing process, however cleaning, repair or refurbishing may be done between uses.
  - Re-manufacturing is the additional use of a component, part or product after it has been removed from a clearly defined service cycle into a new manufacturing process that goes beyond cleaning, repair or refurbishing.
  - Recycling is recovery and reuse of materials from scrap or waste for the production of new goods. Energy recovery (called 'thermal recycling') is not regarded as recycling but as incineration. Pre-treatment processes that condition the waste for recycling are regarded as part of the recycling path. For the purpose of eco-efficiency, reporting companies should further distinguish between open- and closed-loop reuse, re-manufacturing and recycling.
    > Open loop
    The recycled, reused or re-manufactured material is not returned to the processes of the reporting entity; instead, it is returned to the market.
    > Closed loop
    The recycled, reused or remanufactured material is returned to the processes of the reporting entity. In-process recycling is the shortest possible closed loop.

59) United Nations Conference on Trade and Development, United Nations, A Manual for the Preparers and Users of Eco-efficiency Indicators, 2004

60) United Nations Conference on Trade and Development, United Nations, A Manual for the Preparers and Users of Eco-efficiency Indicators, 2004

- **Waste incineration**
  Incineration of waste mineralises it and reduces the volume of solid residuals. Incineration results in the output of other waste streams such as: air emissions, ash, slag, heat, etc. that should be treated separately.

  Types of controlled incineration processes include:
  - Low-temperature (municipal) waste incinerators
  - High-temperature waste incinerators
  - Cement kilns

- **Sanitary landfill**
  Sanitary landfills provide outlets for the ultimate disposal of waste generated. A sanitary landfill is a controlled area of land on which waste is disposed of, in accordance with standards, rules or orders established by a regulatory body. Waste material is placed in trenches or on land, compacted by mechanical equipment and covered with earth and a final cover.

  Within the category of sanitary landfill three technologies can be distinguished:
  - Bioactive sanitary landfills – The material is of non-mineral quality. It is reactive and therefore needs extensive control systems covering the operational, closure and post-closure phase. The chemical composition of the residues is not known (sludges from mixed waste water treatment, mixed laboratory waste).
  - Sanitary landfills for stabilsed residues – Similar to bioactive sanitary landfills, but for materials that will not form either gases or water-soluble substances when in contact with water, air or other stabilised residues. The chemical composition of the residues is well known (household residues after separating biowaste, plastics, paper).
  - Sanitary landfills for inert materials – The material is inert. Therefore the landfill needs no control systems during the operation phase, closure and post-closure phase (concrete).

- **Open dumpsite**
  An open dumpsite is an uncontrolled area of land on which waste is disposed, either legally or illegally.

- **Special cases: Pre-treatment and temporary on-site storage of waste**
  - Pre-treatment processes prepare waste for incineration or landfill. For the purpose of this manual, pre-treatment does not constitute a separate category of waste treatment technology. Waste that undergoes external pre-treatment is dealt with under waste incineration and landfill. If the path is not known and documented, landfill is assumed.
  - Temporary on-site storage
  - Waste that is temporary stored on-site and for which the treatment technology is not yet known constitutes a separate category of waste treatment technology. The reporting entity should give special attention to include adequate information on the technology used and the processes involved in on-site storage.

7.2 WHY: Waste minimisation benefits for SMEs

7.2.1 Contaminated land

As early as 1996, a worldwide survey by UNEP showed that all countries are susceptible to land contamination from a wide range of industrial activities. Household waste increasingly contains chemical residues from domestic cleaning and other products. It should be stressed that because of the high cost of remediation of contaminated land, pollution prevention programmes are a preferred strategy for waste management.

7.2.2 Waste concerns[61]

Collecting, recycling, treating and disposing of increasing quantities of solid waste and wastewater remains a major challenge for developed and developing countries alike.

Growing landfills around the world mirror the global trends of increasing population, prosperity and urbanisation. What is more worrying is excessive waste generation itself: finite resources are transformed into single-use, GHG-emitting goods that all too quickly end up in landfills. At the same time, there is a growing realisation that waste can be a resource too.

Overall, the waste sector contributes less than 5% of global GHG emissions. The largest source is landfill methane (CH_4), followed by wastewater CH_4 and nitrous oxide (N_2O). Nitrous Oxide (N_2O) contributes to climate change; a major source is human sewage and emissions that occur during the wastewater treatment process. Methane is also emitted during wastewater transport, sewage treatment processes and leakages from anaerobic digestion of waste or wastewater sludge.

In addition, minor emissions of carbon dioxide (CO_2) emerge when waste containing fossil carbon is burnt (e.g. plastics; synthetic textiles) and by the non-biomass portion of incinerated waste. Open burning of waste in developing countries is a significant local source of air pollution, constituting a health risk for nearby communities. Composting and other biological treatments emit very small quantities of GHGs. It is worth noting that landfill emissions continue several decades after the waste is disposed in them, which makes it difficult to estimate emission trends.

61) UNEP, Climate Neutral Network, Waste, undated

7.2.3 Waste in numbers[62]

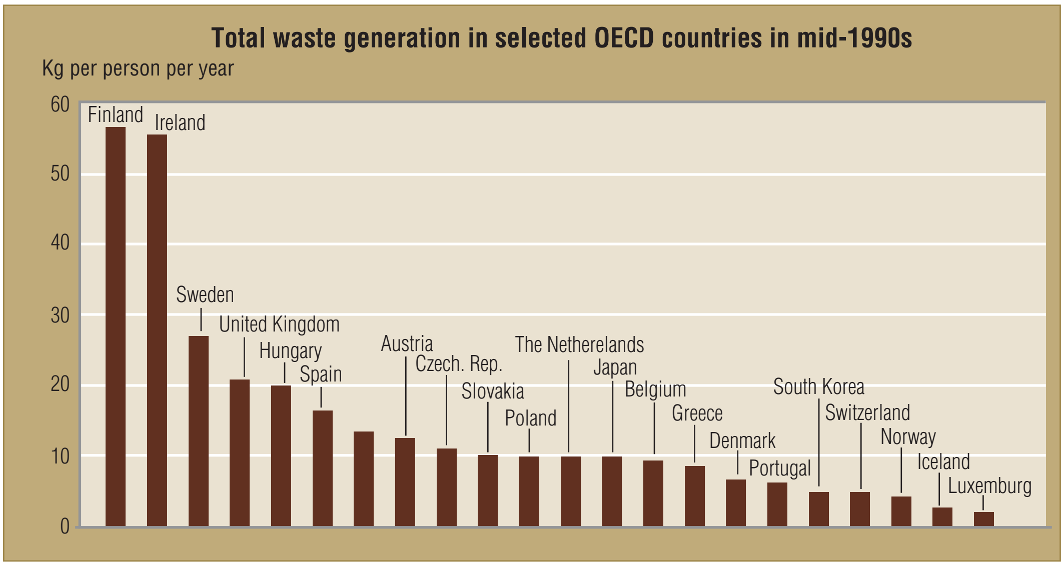


Figure 37: *Total waste generation in selected OECD countries in mid-1990s*

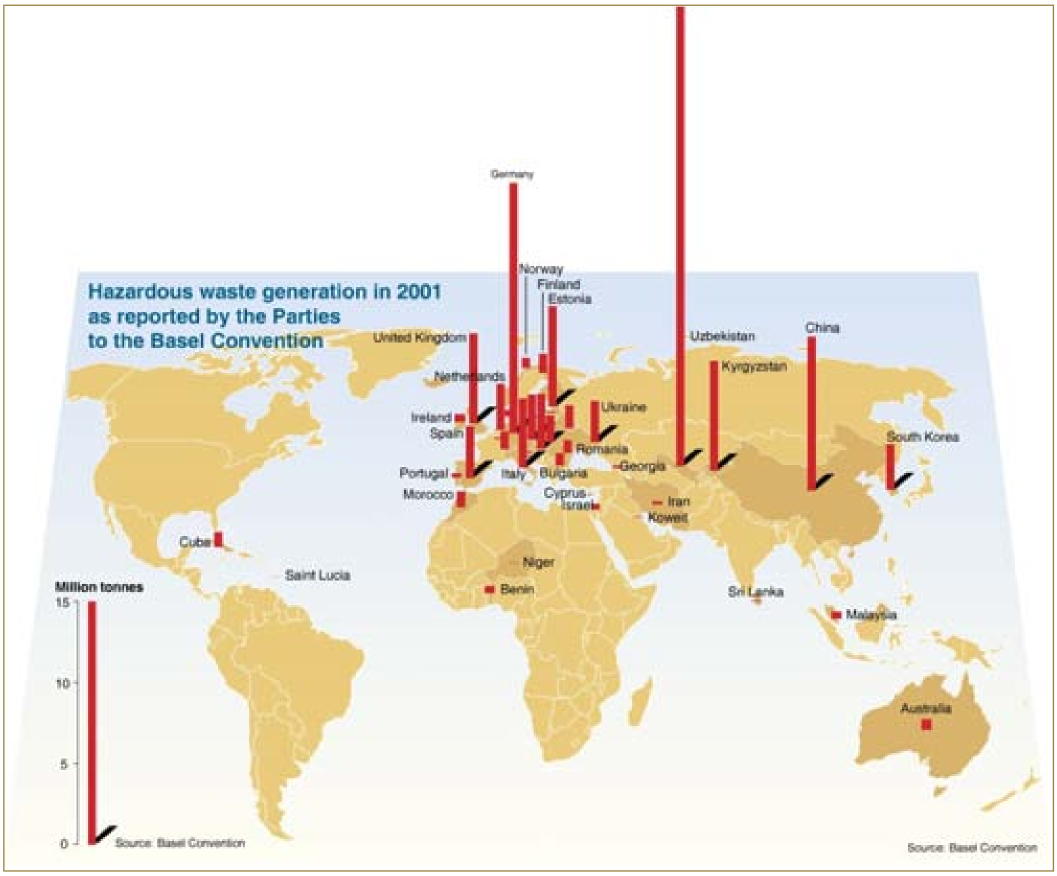


Figure 38: *Total hazardous and other waste generation as reported by the Parties to the Basel Convention in 2001*

62) Vital Waste Graphics, Basel Convention, Nairobi 2004

7.3 HOW: Conducting a waste minimisation programme in an SME

Quick Win Map	Steps Explained	Basic Reference (in the electronic version of the toolkit)	Advanced Reference (in the electronic version of the toolkit)
Step 1: **Draw a Flowchart**	Identify all waste streams by creating a waste flowchart	Waste Flowchart	• Flowchart Tool
Step 2: **Create Material Balance**	Get detailed information about what is going in and what is going out of the process.	Material Balance	
Step 3: **Locate Source of Waste**	Reduce, Reuse, Recycle	Sources of Waste	• 200 Tips for Reducing Waste • Creativity, Innovation and Option Generation • Waste Management • Further detailed process and sector-related options, see Virtual Assessment
Step 4: **Consider Options**	Consider options from literature, other industries' experiences and/or recommendations from RE, CP and SP service providers. Also undergo brainstorming sessions with your team.	Consider Options	
Step 5: **Evaluate Option and Implement Programme**	Evaluate option, compile and implement programme (link to PDCA)	Link to DO-phase	

Table 17: *Quick Win Map*

Step 1: Draw a Waste Flowchart

A good starting point for designing a waste management system is to determine the major problems/wastes associated with your particular process or industrial sector. Therefore all existing documentation and information regarding the process, the plant or the regional industrial sector should be collated and reviewed as a preliminary step. The following points give some guidelines on useful documentation:

- Is a site plan available?
- Are any process flow diagrams available?
- Have process wastes ever been monitored before?
- Is there a map of the surrounding area indicating watercourses, hydrology and human settlements?
- Are there other factories/plants in the area that may have similar processes?

Important questions:

- What are the obvious wastes associated with your process?
- Where is water used in greatest volume?
- Do you use chemicals that have special instructions for their use and handling?
- Do you have waste treatment and disposal costs – what are they?
- Where are your discharge points for liquid, solid and gaseous emissions?

- **Prepare a process flow diagramme**
  The objective is to clearly map the process flow to understand what waste is generated at which process step and why. Process flow means both the sequence of activities you undertake at your company and the external activities that you can influence in your business, ranging from the products and services you procure, to the products and services that you provide.

Discuss and decide on the boundaries of your process. Take into account what information you have available, to what extent you can trace your raw materials upstream, and your products and services downstream.

Where or when does the process start?
To answer this question you will need to trace where your wastes come from. A good way to start gathering this information is to discuss this with the person responsible for waste disposal in your company. You may also want to contact your contractors and ask them for further information.

Where or when does the process end?
To answer this question you will need to trace where your wastes are being delivered to and for what purposes. Discuss and decide on the level of detail to be included in the diagram.

- **List all of the steps and activities in the process.**

- **Arrange the activities in sequence**
  Make sure to include activities undertaken by your direct suppliers, in the transportation of your products, byproducts and waste

What Type of Waste Does Your Business Produce?

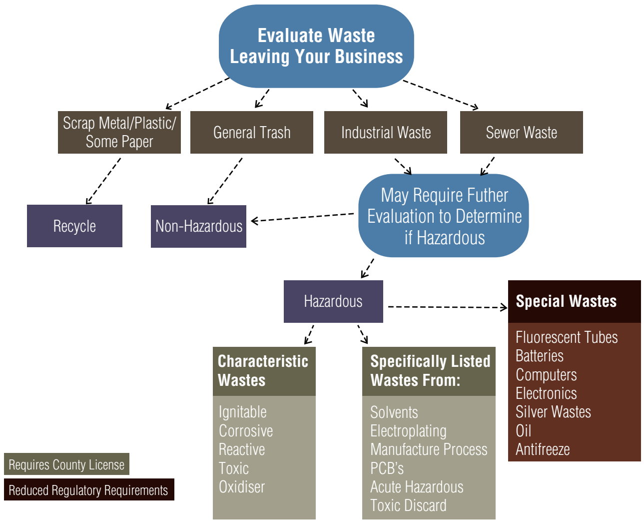


Figure 39: *Example of a waste flowchart* [63]

materials and their use, and wastewater treatment and disposal. Discuss the sequence of activities with the relevant people in your company and confirm that this is correct.
Review the flowchart with your workers and your business partners:

- Workers and supervisors
- Suppliers
- Transporters
- Customers
- Other relevant stakeholders

Check if they agree that the process is drawn accurately.

Step 2: Create a Material Balance

A material balance may be defined as a precise account of the inputs and outputs of an operation. The general form quoted for a mass balance is that the mass that enters a system must, by conservation of mass, either leave the system or accumulate within the system.

Steps:

a. Determine inputs
Quantify inputs such as raw materials, chemicals, water, air and power

b. Measure current levels of waste reuse/recycling
Take notice of the number of bins or containers that are removed. You might want to weigh them (or some of them and extrapolate). Some waste can be directly reused and may be transferred from one unit to another; others require some modification before they are suitable for reuse in a process. Quantify reuse waste streams.

c. Quantify process outputs
Outputs include primary product, by-products, wastewater, gaseous wastes, liquid and solid wastes that need to be stored or sent off-site for disposal and reusable or recyclable wastes.

d. Accounting for off-site waste
The process may produce waste that cannot be treated on-site. These need to be transported off-site for treatment and disposal. Waste of this type is usually non-aqueous liquids, sludge or solids. Minimisation of these wastes yields a direct cost benefit.

e. Assembling input and output information for unit operations
The total of what goes into a process must equal the total of what comes out. Preparing a material balance is designed to gain a better understanding of the inputs and outputs, especially waste, of a unit operation so that areas where information is inaccurate or lacking can be identified.

f. Deriving a preliminary material balance for unit operations
Make use of the conservation law: what goes in must come out. This must work out for the plant as a whole, as well as for each of the individual units and activities.

g Evaluating the material balance
The individual and sum totals making up the material balance should be reviewed to determine information gaps and inaccuracies. If outputs are less than inputs look for potential losses or waste discharges. Outputs may appear to be greater than inputs if large measurement or estimating errors are made or some inputs have been overlooked.

h. Refining the material balance
Do the material balance in iterations: do not struggle for 100% accuracy of data from the very beginning. Make the process a learning process, in which you and your team gradually build a better understanding of material flows, waste generation and waste sources.

Step 3: Locate Sources of Waste

Waste generation might be related to impurities in the raw materials, the production process itself (a chemical reaction might generate a certain quantity of byproducts; lubrication oils accumulate dirt over time and need to be replaced), the organisation of the process (start-up waste, shut down waste, expired chemicals), cleaning (cast-off materials cleaned out of machinery in between batches of different products), to quality control (off-spec products).

Taking a bird's-eye-view of the production process will help identify various sources of waste and take measures to prevent it. Waste reduction at the source is the first priority. What cannot be avoided should be reused (for example waste textiles as cleaning rags, waste sheet metal for setting up machines) and what cannot be reused should be recycled (for example metals, but also solvents, fibres).

The following are some examples for waste minimisation:
Resource optimisation: Optimised use of raw materials can mean optimising the pattern in which the parts in stamping are laid out on the sheet metal to minimise the area used.

Reuse of scrap: Scraps can be taken back into the process; paper mills return damaged paper from breakage into the pulper to recover the fibres.

Improved quality control and process monitoring: Inspection and even better automated continuous monitoring equipment can help to minimise lost batches, because it helps to identify process problems early.

Waste exchanges: Waste from one process can become raw material for another: spent catalysts of a chemical company can become raw material in the production of catalysts, collected motor oil can be used as fuel in a boiler.

63) Washington County, Does your business generate hazardous waste? 2008.

Segregation
Segregation of waste can offer enhanced opportunities for recycling and reuse with resultant savings in raw material costs. Concentrated simple wastes are more likely to be of value than dilute or complex wastes. Mixing wastes can enhance pollution problems. If a highly concentrated waste is mixed with a large quantity of weak, relatively uncontaminated effluent the result is a larger volume of waste requiring treatment. Isolating the concentrated waste from the weaker waste can reduce treatment costs. The concentrated waste could be recycled/ reused or may require physical, chemical and biological treatment to comply with discharge consent levels whereas the weaker effluent could be reused or may only require settlement before discharge. Therefore, waste segregation can provide more scope for recycling and reuse while at the same time reducing treatment costs.[64]

Step 4: Consider Options
Significant waste reductions can often be achieved by improved operation, better handling and generally taking more care.[65] The following list of waste reduction hints can be implemented immediately with little or no extra cost.

Specifying and Ordering Materials:
Do not over-order materials especially if the raw materials or components can spoil or are difficult to store. Try to purchase raw materials in a form that is easy to handle, i.e., pellets instead of powders. It is often more efficient and certainly cheaper to buy in bulk.

Receiving Materials:
Demand quality control from suppliers by refusing damaged, leaking or unlabelled containers. Undertake a visual inspection of all materials coming on to the site. Check that a sack weighs what it should weigh and that the volume ordered is the volume supplied. Check that composition and quality are correct.

Material Storage:
Install high-level control on bulk tanks to avoid overflows and bund tanks to contain spillages. Use tanks that can be pitched and elevated, with rounded edges for ease of draining and rinsing. Dedicated tanks, receiving only one type of material, do not need to be washed out as often as tanks receiving a range of materials. Make sure that drums are stored in a stable arrangement to avoid damaging drums while in storage. Implement a tank-checking procedure – dip tanks regularly and document the contents to avoid discharging a material into the wrong tank. Using covered or closed tanks reduces evaporation losses.

Material and Water Transfer and Handling:
Minimise the number of times materials are moved on site. Check transfer lines for spills and leaks. Is flexible pipe work too long? Catch drainage from transfer hoses. Plug leaks and fit flow restrictors to reduce excess water consumption.

Process Control:
Feedback on how waste reduction is improving the process motivates the operators – it is vital that the employees are informed of why actions are taken and what it is hoped they will achieve. Design a monitoring programme to check the emissions and wastes from each unit operation. Regular maintenance of all equipment will help to reduce fugitive process losses.

Cleaning Procedures:
Minimise the amount of water used to wash out and rinse vessels – indiscriminate water use contributes a large amount to wastewater flows. Ensure that hoses are not left running by fitting self-sealing valves. Investigate how washing water can be contained and used again before being discharged to drains. The same applies to solvents used to clean; these can often be used more than once.

Tightening up housekeeping procedures can reduce waste considerably. Simple, quick adjustments can be made to the process to achieve a rapid improvement in process efficiency. Examples of good housekeeping, include careful handling of bags and boxes to avoid spills; avoiding contamination by dust and dirt; observing recipes, process conditions and dosing recommendations to avoid quality waste or rework; optimising works planning to minimise losses from starting up, shutting down or cleaning equipment.

7.4 CHECKLIST: Waste minimisation

7.4.1 Dispatch waste

Damaged Products
- Return damaged products to production for repair.

Packaging Material
- Separate waste into paper, plastics and metals. Sell recyclable materials.

7.4.2 Domestic waste

Canteen
- Modify menu and menu size to minimise leftovers
- Make agreements with suppliers to get returnable packages for the deliveries
- Buy the right amount of foodstuffs
- Compost biodegradable waste
- Collect cooking oil and find a contractor (waste oil can be used for fuel, for the production of soap or lubricants or for the production of biodiesel)

7.4.3 Laboratory waste

Sample Waste
- Assure proper disposal of lab residues
- Reduce sample size
- Review sampling procedures
- Return unused sample to process (or client)

7.4.4 Office waste

Waste management
- Recycle or sell empty toner cartridges. In some areas, charity groups will pick up cartridges for free.
- Avoid the use of disposable batteries, use rechargeable batteries
- Print only what is necessary
- Print double sided
- Collect waste copies and use them for making notes

7.4.5 Production waste

Waste Materials
- Test materials first to determine whether they can be used in current manufacturing processes

64) UNEP, Audit and Reduction Manual for Industrial Emissions and Wastes, 1991

65) UNEP, Audit and Reduction Manual for Industrial Emissions and Wastes, 1991

- Return obsolete materials to suppliers
- Segregate waste streams
- Store packages to protect from weather
- Provide proper containers for hazardous materials
- Switch from powders to pellets to reduce waste through spillage
- Switch to reusable containers, tote-bins or bulk shipments
- Transfer liquid product in tank cars, tank pumps and piping systems
- Use dry disconnects
- Produce only the amount requested or needed
- Substitute less toxic or non-toxic raw materials
- Utilize a computer control system to:
  - Optimise daily operation
  - Automate start-ups, shutdowns and product changeover
- Find a market for waste products
- Install reusable insulation
- Segregate and reuse dust emissions in the production process
- Review sampling frequency and procedure to reduce number and quantity
- Recycle samples

7.4.6 Storage Waste

Damaged Products

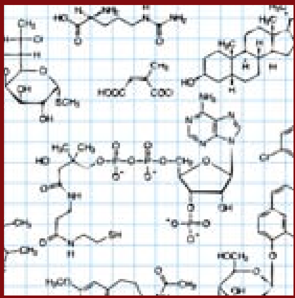
- Fix/repair damaged products and return damaged products to production

Packaging Material

- Separate waste into paper, plastics and metal; sell recyclable materials

Detailed assessment:

Chemical efficiency



Detailed assessment: Chemical efficiency

8.1 WHAT: Main challenges for chemical efficiency in SMEs

All chemical exposures have potential consequences on human health. Depending on the toxicology and concentration, the effects of chemical exposures may be immediate (acid burns) or long term (chronic beryllium disease or cancer). Chemical exposure may result in life-threatening outcomes. Air pollutants can cause respiratory diseases in humans and have an impact on the environment e.g. in the form of acid rain or the greenhouse effect. Chemicals discharged into water bodies can poison the organisms living in these ecosystems or lead to extreme algae growth, as is the case with nitrate.

Chemicals may cause physical damage such as explosions or fires resulting in serious injury and facility damage. Facility and emmission-related effects can include corrosive actions that degrade equipment performance and residual contamination that limits the future use of facilities and equipment. Environmental issues may arise as a result of spills, releases or waste chemical inventories. In addition to the health effects, physical damage or environmental effects that may result from a chemical incident, companies will need to pay for incident mitigation.[66] Because of safety risks to workers and the environment, and on the other hand losses of efficiency, it is very important for companies to implement a chemical management programme.

Although chemicals are a potential hazard for everyone, workers are more often exposed to hazardous chemicals than others due to their daily work. Therefore the use and handling of hazardous chemicals has to be controlled. This is the reason why the focus of this chapter is chemical safety – if a company implements safety measures, efficiency advantages will follow. It is important for companies to recognise chemical management as an integral part of their business operation. They should be proactive in planning for chemical safety and set objectives rather than solely responding to problems as they occur.[67] This will be explained in Section 8.3 (HOW).

Special hazardous chemicals

The following explanations are adopted from the Canadian Centre for Occupational Health and Safety.[68] The examples of the effects of these hazardous chemicals demonstrate the importance of a chemical management.

The effect of lead

Lead is a bluish-white, silvery gray, heavy, ductile, soft metal that tarnishes on exposure to air. It is often odourless. Lead is a combustible dust. When heated in air, it forms highly toxic lead oxide fumes. There is a danger of cumulative effects if lead is inhaled or ingested. Symptoms may include headache, fatigue, nausea, abdominal cramps, joint pain, metallic taste in the mouth, vomiting and constipation or bloody diarrhea. Lead can cause harmful effects to the nervous system.

66) U.S. Department of Energy, DOE Handbook – Chemical Management, 2006.
67) UNIDO, Textbook 6C – Green procurement and hazardous materials, undated
68) Canadian Centre for Occupational Health and Safety, Chemical Profiles, 1999

Exposure to lead may cause cancer and it is a reproductive hazard. It may cause harmful effects in the unborn child and may have adverse effects on the male and female reproductive systems. Lead is also a mutagen and may cause genetic damage.

Lead is used in the manufacture of storage batteries, ammunition, nuclear and X-ray shielding devices, cable coverings in the power and communication industries, lead sheet for roofing, restoration of old buildings and chemically resistant linings, noise control materials, electrical and electronic equipment, motor vehicles and other transportation equipment, and as a bearing metal. It is used in brass and bronze alloys, casting metals, glass making, ceramic glazes, plastic stabilisers and paints, pipes, traps and bends, and other extruded products for building construction, fuel and storage tanks, process vessels, and in some solders. Minor uses include products such as wheel weights, yacht keels, ornamental items and stained glass. The use of lead in gasoline, paints, pigments and coloured inks is restricted or eliminated in many countries.[69]

This material is a very toxic solid. There is a danger of cumulative effects if inhaled or ingested. Before handling, it is extremely important that engineering controls are operating and that protective equipment requirements and personal hygiene measures are being followed. Only authorised personnel should have access to this material. They should be properly trained regarding its hazards and its safe use. Maintenance and emergency personnel should be advised of potential hazards.[70]

People, animals and fish are mainly exposed to lead by breathing and ingesting it in food, water, soil or dust. Lead accumulates in the blood, bones, muscles and fat. Infants and young children are especially sensitive to even low levels of lead.[71]

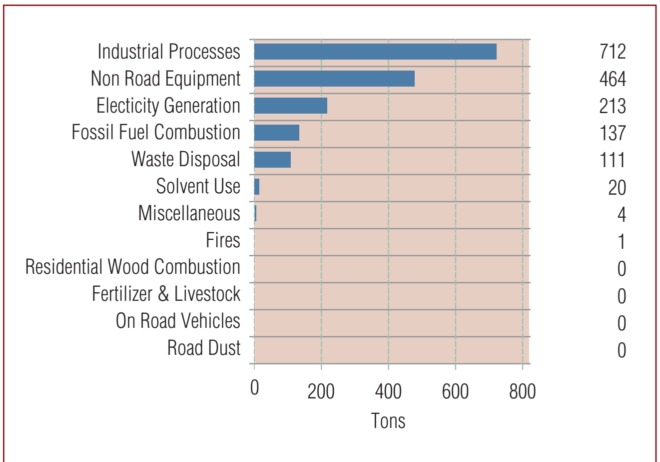


Figure 40: *National Lead Emissions by Source Sector in 2002* [72]

The effect of cadmium

Cadmium is an extremely toxic metal commonly found in industrial workplaces, particularly where any ore is being processed or smelted. Due to its low permissible exposure limit (PEL), overexposures may occur even in situations where trace quantities of cadmium are found in the parent ore or smelter dust. Cadmium is used extensively in electroplating, although the nature of the operation does not generally lead to overexposure. Several deaths from acute exposure have occurred among welders who have unsuspectingly welded on cadmium-containing alloys or worked with silver solders. Cadmium is also found in some industrial paints and may represent a hazard when sprayed. Operations involving removal of cadmium paints by scraping or blasting may similarly pose a significant hazard. Cadmium is also present in the manufacture of some types of batteries. Cadmium emits a characteristic brown fume (CdO) upon heating, which is relatively non-irritating, and thus does not alarm the exposed individual.[73]

Cadmium concentrations in agricultural soil and wheat have increased continuously during the last century. At present, soil cadmium concentrations increase by about 0.2% per year. Cadmium accumulates in the kidneys. Human kidney concentrations of cadmium have increased several fold during the last century.[74]

The effect of mercury

Mercury is a silver-white, heavy, mobile, odourless liquid. It will not burn. Mercury is very toxic and it may be fatal if inhaled and harmful if absorbed through the skin. It may cause harmful effects on the nervous, digestive and respiratory systems, and the kidneys. Mercury may also cause lung injury although the effects may be delayed. Mercury is corrosive to some metals. It is a skin sensitizer, it may cause allergic skin reaction, and it is a reproductive hazard that based on animal research, may cause behavioural effects.

Mercury is used mainly for the electrolytic production of chlorine and caustic soda from brine (chlor-alkali industry). It is also used in household batteries; in several types of electric lamps, including fluorescent lamps and high intensity discharge (HID) lamps; in electric light switches and thermostats; in mercury vapour diffusion pumps for producing a high vacuum; in industrial and medical equipment, such as thermometers, monometers, barometers and other pressure-sensing devices, gauges, valves, seals and navigational devices and in dental amalgams. Mercury compounds are used also in pigments; as a catalyst in polymer-forming reactions; in explosives; in pharmaceuticals; and in chemical applications.

The use of mercury compounds as a seed disinfectant, on food crops, as a biocide in paints and in antifouling paint formulations, as a coating for mirrors, for the manufacture of certain types of glass, the treatment of felt and as a fungicide in paper has been discontinued or banned.[75]

Mercury is used in the electrical industry, in control instruments in the home and industry, and in laboratory and medical instruments. A very large amount of mercury is used for the extraction of gold. Dental silver amalgam for tooth filling contains large amounts of mercury. Use of skin-lightening soap and creams can give rise to substantial mercury exposure. Occupational exposure to inorganic mercury has been investigated in chlor alkali plants, mercury mines, thermometer factories, refineries and in dental clinics. High mercury levels have been reported for all these occupational exposure situations, although levels vary according to work environment conditions.[76]

The effect of Tricloroethylene (TCE)

Trichloroethylene is a clear, colourless liquid with a sweet, ethereal, chloroform-like odour. It can probably burn if strongly heated, or be

69) Canadian Centre for Occupational Health and Safety, Basic Information on Lead, 1999
70) Canadian Centre for Occupational Health and Safety, Working safely with lead, 2003
71) Extraordinary Road Trip, Research Lab, Health and Environmental Impacts of Lead, undated
72) Environmental Protection Agency (EPA), Lead, 2009
73) United States Department of Labor, Cadmium, undated
74) IBIDS, Health effects of cadmium, 1998; UPMC, Cadmium Toxicity, undated
75) Canadian Centre for Occupational Health and Safety, Basic Information on Mercury, 1999
76) Hazardous Substances Data Bank, Mercury, undated

ignited by a high energy source. It can decompose at high temperatures forming toxic gases such as hydrogen chloride, chlorine and phosgene. Closed containers may rupture and explode if heated. Trichloroethylene vapours may accumulate in low-lying areas. The vapour causes irritation of the nose and throat. Trichloroethylene is also a central nervous system depressant. The vapour may cause headache, nausea, dizziness, drowsiness, incoordination and confusion. High vapour concentrations may cause unconsciousness and death. Trichloroethylene causes skin and eye irritation and it is an aspiration hazard. Swallowing or vomiting of the liquid may result in aspiration (breathing) into the lungs. Trichloroethylene is a suspect cancer hazard, which may cause cancer based on human information, and a possible reproductive hazard that may cause birth defects, based on animal information, and a mutagen that may cause genetic damage, based on animal information.

Trichloroethylene is predominantly used for vapour degreasing of metal parts in the automotive and metal industries. It is also used as a component of adhesives and as a solvent in paint-strippers, lubricants, paints, varnishes, pesticides, cold metal cleaners, rubbers and elastomers. It is used as a low temperature heat-transfer medium and as a chemical intermediate in the production of pharmaceuticals, flame retardant chemicals and insecticides. It is used in metal phosphatising systems, textile processing, the production of polyvinyl chloride and aerospace operations.[77]

Short-term exposure to trichloroethylene causes irritation of the nose and throat and central nervous system (CNS) depression, with symptoms such as drowsiness, dizziness, giddiness, headache, loss of coordination. High concentrations have caused numbness and facial pain, reduced eyesight, unconsciousness, irregular heartbeat and death.[78]

The effect of refrigerants with high ODP

The environmental friendliness of a refrigerant is a major factor in assessing the usefulness of a particular refrigerant. The important environmental and safety properties are:

Ozone Depletion Potential (ODP): The ODP of refrigerants should be zero, i.e., they should be non-ozone depleting substances. Refrigerants having non-zero ODP have either already been phased-out (e.g. R 11, R 12) or will be phased-out in the near future (e.g. R 22). Since ODP depends mainly on the presence of chlorine or bromine in the molecules, refrigerants having either chlorine (i.e. CFCs and HCFCs) or bromine cannot be used under the new regulations.

Other important environmental and safety properties:

- Global Warming Potential (GWP)
- Total Equivalent Warming Index (TEWI)
- Toxicity
- Flammability

Refrigerant	Application	Substitute suggested Retrofit (R)/New (N)
R 11 (CFC) ODP = 1.0 GWP = 3500	Large air conditioning systems Industrial heat pumps As foam blowing agent	R 123 (R,N)
R 12 (CFC) ODP = 1.0 GWP = 7300	Domestic refrigerators Small air conditioners Water coolers Small cold storages	R 22 (R,N) R 134a (R,N) R 227ea (N) R 401A, R 401B (R,N) R 411A, R411B (R,N) R 717 (N)
R 22 (HCFC) ODP = 0.05 GWP = 1500	Air conditioning systems Cold storages	R 410A, R 410B (N) R 417A (R,N) R 407C (R,N) R 507, R507A (R,N) R 404A (R,N) R 717 (N)
R 134a (HFC) ODP = 0.0 GWP = 1200	Used as replacement for R 12 in domestic refrigerators, water coolers, automobile A/Cs etc.	No replacement required - Immiscible in mineral oils - Highly hygroscopic
R 717 (NH_3) ODP = 0.0 GWP = 0.0	Cold storages Ice plants Food processing Frozen food cabinets	No replacement required - Toxic and flammable - Incompatible with copper - Highly efficient - Inexpensive and available
R 744 (CO^2) ODP = 0.0 GWP = 1.0	Cold storages Air conditioning systems Simultaneous cooling and heating (Transcritical cycle)	No replacement required - Very low critical temperature - Inexpensive and available
R 718 (H^2O) ODP = 0.0 GWP = 1.0	Absorption systems Steam jet systems	No replacement required - High freezing point - Large specific volume - Inexpensive and available
R 600a (iso-butane) ODP = 0.0 GWP = 3.0	Replacement for R 12 Domestic refrigerators Water coolers	No replacement required - Flammable

Table 18: *Applications of common refrigerants and suggested substitutes* [79]

77) Canadian Centre for Occupational Health and Safety, Trichlorethylene, 1999.

78) Canadian Centre for Occupational Health and Safety, Health effects of Trichloethylene, 1999.

79) Scribd, 26 Refrigerants, undated

- Chemical stability
- Compatibility
- Miscibility with lubricating oils
- Dielectric strength
- Ease of leak detection

Prior to the environmental issues of ozone layer depletion and global warming, the most widely used refrigerants were: R 11, R 12, R 22, R 502 and ammonia. Of these, R 11 was primarily used with centrifugal compressors in air-conditioning applications. R 12 was used primarily in small capacity refrigeration and cold-storage applications, while the other refrigerants were used in large systems such as large air-conditioning plants or cold storages. Among the refrigerants used, except ammonia, all the other refrigerants are synthetic refrigerants and are non-toxic and non-flammable. Although ammonia is toxic, it has been very widely used due to its excellent thermodynamic and thermo physical properties.

Since ozone layer depletion could lead to catastrophe on a global level, it has been agreed by the global community to phase out the ozone depleting substances (ODS). As a result, except for ammonia, all the other refrigerants used in cold storages had to be phased-out and a search for suitable replacements began in earnest. In view of the environmental problems caused by the synthetic refrigerants, options differed on replacements for conventional refrigerants. The alternate refrigerants can be classified into two broad groups:

- Non-ODS, synthetic refrigerants based on Hydrofluorocarbons (HFCs) and their blends
- Natural refrigerants including ammonia, carbon dioxide, hydrocarbons and their blends

The potential for a single molecule of the refrigerant to destroy the Ozone Layer is called ODP - The ODP or Ozone Depletion Potential. All refrigerants use R11 as a datum reference where R11 has an ODP = 1.0. The lower the value of the ODP - the better the refrigerant is for the ozone layer and the environment.

Examples:
Refrigerant R11:
R11 is a single chlorofluorocarbon or CFC compound. High chlorine content and Ozone Depletion Potential (ODP1) = 1. High Global Warming Potential (GWP2) = 4000. The use and manufacture of R11 and similar CFC refrigerants is now banned within the European Union even for servicing. Non flammable, non corrosive non toxic, stable.[80]

Refrigerant R12:
Difluorodichloromethane is related to the CFC group. It is characterised by high ozone depletion potential (ODP = 1) and big global warming potential (GWP = 8500). Clear gas with specific smell, 4.18 times as heavy as the air. One of the most widespread and safe in operation refrigerants.[81]

The effect of ammonia[82]

Ammonia can safely be used as a refrigerant provided the system is properly designed, constructed, operated and maintained. Ammonia however is toxic and can be a hazard to human health. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Level (PEL) is 50 parts per million (ppm), 8-hour time-weighted average. Although pure ammonia vapours are not flammable at concentrations of less than 16%, they may be a fire and explosion hazard at concentrations between 16 and 25%. Mixtures involving ammonia contaminated with lubricating oil from the system, however, may have a much broader explosive range. An important property of ammonia is its pungent odour. The threshold concentration at which ammonia is detectable varies from person to person; however, ammonia can be detected usually at concentrations in the range of 5 ppm to 50 ppm. Concentrations above 100 ppm are uncomfortable for most people.

The effect of Volatile Organic Compounds (VOC)

Volatile organic compounds are compounds that have a high vapour pressure and low water solubility. Many VOCs are human-made chemicals that are used and produced in the manufacture of paints, pharmaceuticals and refrigerants. VOCs typically are industrial solvents, such as trichloroethylene; fuel oxygenates, such as methyl tert-butyl ether (MTBE); or byproducts produced by chlorination in water treatment, such as chloroform. VOCs are often components of petroleum fuels, hydraulic fluids, paint thinners and dry cleaning agents. VOCs are common ground-water contaminants.[83]

VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of products numbering in the thousands. Examples include: paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers and photographic solutions.

Organic chemicals are widely used as ingredients in household products. Paints, varnishes and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing and hobby products. Fuels are made up of organic chemicals. All of these products can release organic compounds while you are using them and, to some degree, when they are stored.[84]

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. Eye and respiratory tract irritation, headaches, dizziness, visual disorders and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organic chemicals. At present, not much is known about what health effects occur from the levels of organic chemicals usually found in homes. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.[85]

80) The Energeering ToolBox, Refrigerants – Environmental Properties, undated

81) NBCC, Traditional Refrigerants, undated

82) EPA, Hazards of Ammonia Releases at Ammonia Refrigeration Facilities (Update), 2001

83) U.S.G.S., Volatile Organic Compounds (VOCs), undated

84) EPA – Environmental Protection Agency, An Introduction to Indoor Air Quality, undated

85) EPA – Environmental Protection Agency, An Introduction to Indoor Air Quality, undated

8.2 WHY: Chemical efficiency benefits for SMEs

In recent years, treatment and disposal costs for hazardous wastes have risen, while regulatory fees and paperwork associated with toxic materials have become increasingly steep.

Against the backdrop of the soaring costs and liability exposure associated with the use of hazardous materials, it makes increasing economic sense to invest in alternative substances and processes that reduce reliance on industrial toxics wherever possible. Reducing the usage of toxins helps manufacturers to improve their production efficiency and achieve other goals traditionally associated with quality improvement programmes. It can help businesses to economise on materials, cut production time, improve product quality, decrease transport, treatment and disposal costs, reduce regulatory fees and compliance headaches, improve worker safety and cut worker's compensation insurance rates.[87]

Of the 5-7 million known chemical substances, companies use more than 80,000 in their production processes and operations. Numerous new chemicals are discovered and produced each year. Today, almost every company uses some type of chemical. Those enterprises that manage chemicals efficiently can gain concrete benefits.

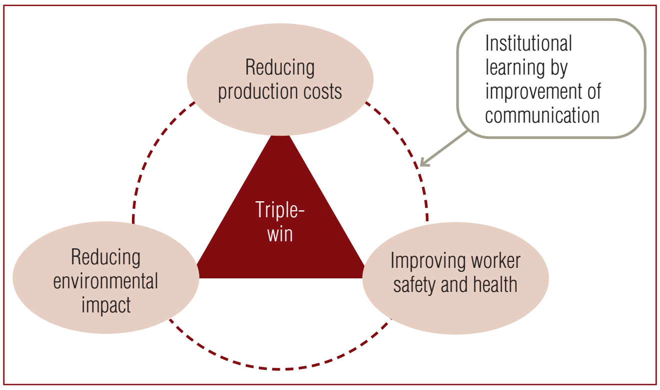


Figure 41: *Triple Win* [86]

Benefits of chemical efficiency

Adopted from the "Chemical Management Guide for SMEs" (Federal Ministry for Economic Cooperation and Development, Germany)

- Reduced cost and environmental impact
  Chemicals can represent a major part of the production cost for companies. Any measures that can be taken to reduce the loss, waste, contamination and expiry of these substances will bring cost savings to companies and at the same time, reduce their environmental impact.
- Competitive advantage
  While chemicals are often used to achieve certain characteristics and qualities in a product – consumers are increasingly resistant to the presence of harmful chemicals in the products they buy or in the environment. Companies that avoid using banned and restricted substances can avoid having their products rejected in the marketplace. Customers and the community will appreciate companies who voluntarily abstain from using illegal chemicals that have negative health and environmental attributes.

Growing consumer consciousness of environmental and social issues has led to the creation of requirements that suppliers must meet to have their products accepted in many international markets. By identifying and reducing the use of banned chemicals and hazardous substances, companies can improve their competitive position and make the communities where their operations are located safer. Moreover, by improving the management of chemicals, companies are simultaneously moving towards meeting the requirements of management system standards such as ISO 9000 (quality) and 14000 (environment). ISO certification would be helpful leverage for winning contracts. For example, many of the activities required for Environmental Management Systems (EMS) certification are aimed at reducing the use of hazardous substances, protecting the health of workers and reducing negative effects on the natural environment; these three improvements will in turn also improve the quality of a company's product.

- Improved worker health and safety
  Chemicals alone or mixed with other substances can cause injury, disease, or even death for people handling these materials. The misuse of chemicals may result in fires and explosions. Accidents involving chemicals create additional costs for companies in terms of lost materials, damaged equipment and facilities, and personal injury. Reducing health and safety risks for employees improves their motivation and productivity and reduces absenteeism due to injury and illness.[88]

8.3 HOW: Establish a chemical management programme

Step 1: Identify Substances

Step 1 explains how to create a structured information base that can be used to make continual improvements towards chemical efficiency in your company. It involves systematically identifying all chemical substances stored and in use in your company.

Chemical Inventory

Establishing an inventory of hazardous chemicals allows for:

- A better understanding of where some of the main chemical hazards in your company are located
- An opportunity to identify risk reduction actions through stock control and storage practices before tragedy strikes
- An opportunity to optimise stocks and orders, and to cut costs
- Identification of redundant products
- Identification of unknown substances, which can then be used before they expire or can be properly disposed of
- Reducing losses due to substances expiring in storage
- Checking the condition of the packaging (damaged, wet, leaking, etc.)
- Avoiding accidents, fires, and explosions from incompatible materials stored together or mixed inappropriately

What do you need to know about the chemicals stored and used at your company?

- Types of chemicals
- Characteristics/properties
- Place of use/storage
- Type of containment/container
- Average quantities

86) Tischer M., Scholaen S., Chemical Management and Control Strategies: Experiences from the GTZ Pilot Project on Chemical Safety in Indonesian Small and Medium-sized Enterprises, 2003.

87) Office Of Technical Assistance, A Practical Guide To Toxics Use Reduction, undated

88) GTZ, Chemical Management Guide for Small and Medium Sized Enterprises: Improve Chemical Management to Gain Cost Savings, Reduce Hazards and Improve Safety, 2008

Quick Win Map	Steps Explained	Basic Reference (included in the electronic version of the toolkit)	Advanced Reference (included in the electronic version of the toolkit)
Step 1: **Identify Substances**	Identify all substances used in the work area, their sources and transportation too and from the plant	Identify substances	• Hazardous Materials Worksheet
Step 2: **Determine Hazardous Substances**	Determine if substances are hazardous with labelling and MSDS	Hazardous substances	• Hazardous Materials Worksheet • Checklist hazardous materials
Step 3: **Draw a Flowchart**	Create a chemical flowchart	Flowchart	• Use the flowcharting programme to create a chemicals flowchart
Step 4: **Identify Risks**	Identity health, environmental, social and economic risks	Identify risks	• Hazard Classification and Control Banding
Step 5: **Consider Options**	Consider options from literature, other industries' experiences and/or recommendations from RE, CP and SP service providers. Undergo brainstorming session with your team	Consider options	• Further detailed process and sector related options, see Virtual Assessment
Step 6: **Evaluate Option and Implement Programme**	Evaluate option, compile and implement programme (link to PDCA)	Link to DO-phase	• Compile a programme and return to the PDCA cycle

Table 19: *Quick Win Map*

Where is this information found?

- Purchasing records
- Stock control records
- Inventories
- Suppliers product information
- Sales records
- On the product label

Minimum information to include in a Chemical Inventory:

- The chemical name, trade name/Chemical Abstract numbers (CAS) number
- Where it can be found, stored and/or used
- Amount in use
- R-Phrases/GHS classification
- The whereabouts of MSDS (Material Safety Data Sheets) and their availability in the language of the workforce
- Notes about handling, use, storage, disposal conditions, etc.
- Whether the chemical is an individual substances or mixes (formulas)
- Whether the chemical releases vapours in handling, mixing or production
- If the chemical is generated during work activities (e.g. dust, fumes from welding)
- Whether the chemical is used as an auxiliary (e.g. fats, liquors, dyes, paints, adhesives)
- Whether the chemical is used for purposes other than production, such as cleaning workplaces and maintaining machinery (e.g. detergents, disinfectants, solvents, greases, fuels)
- Whether the chemical is found in the final product

Step 2: Identify Hazardous Substances

The following sources can be used to obtain critical information on hazardous substances:

- Safety data sheets of chemical substances
- Labels attached to the chemicals packaging
- Technical manuals of the equipment
- Legal regulations and technical standards
- Scientific and technical literature
- Records of work accidents and occupational diseases
- Interviews with workers

Importance of Material Safety Data Sheets (MSDS)

An MSDS of a chemical substance contains details of the hazards associated with this specific substance and gives information on its safe use. Your chemical supplier should always include this information when delivering the chemical.

An MSDS:

- Helps you determine the effect of the chemical on end products (e.g. intended characteristics, quality, etc.)
- Allows you to determine chemical compatibility and do proper mixing
- Gives information about proper storage and handling (e.g. ventilation)
- Enables you to prevent losses from the expiry of materials
- Indicates appropriate security precautions and needed controls, including the use of personal protection equipment
- Spells out emergency procedures in case of spills, fire and explosion
- Indicates steps for first-aid
- Specifies the hazard level, which gives clues about the possible effects on water, soil, human health
- Specifies the flashpoint (the lowest temperature at which a chemical releases flammable vapour); the lower the flashpoint, the more hazardous the chemical is as a source of fuel for fire or explosion
- Specifies the boiling point, which is used to determine volatility; the lower the boiling point, the higher the volatility[89]

International Chemical Safety Cards in different languages are available from www.cdc.gov/niosh/ipcs/icstart.html indexed by their CAS. They can provide an orientation about chemicals, properties, and appropriate safety measures in case information on products is lacking.

Labelling:
To harmonize communication on hazardous chemicals and facilitate global trade, the United Nations, the International Labour Organization (ILO),

89) GTZ, Chemical Management Guide for Small and Medium Sized Enterprises: Improve Chemical Management to Gain Cost Savings, Reduce Hazards and Improve Safety, 2006

Exploding bomb	Flame	Flame over circle
		
Explosives Self-reactives Organic peroxides	Flammables Self-reactives Pyrophorics Self-heating Emission of flammable gases	Oxidizers Organic peroxides
Gas cylinder	**Corrosion**	**Scull and crossbones**
		
Gases under pressure	Corrosives	Acute toxicity (severe)
Exclamation mark	**Health hazard**	**Environment**
		
Irritant Dermal sensitizer Acute toxicity (harmful)	Carcinogen Respiratory sensitizer Reproductive Target organ toxicity Mutagenicity	Environmental toxicity

Table 20: *Explanation of GHS pictograms* [90]

the Organization for Economic Co-operation and Development (OECD) and various other governments and stakeholders developed a "Globally Harmonized System of Classification and Labelling of Chemicals (GHS)". The GHS includes the following elements:

- Harmonised criteria for classifying substances and mixtures according to their health, environmental and physical hazards
- Harmonised hazard communication elements, including requirements for labelling and safety data sheets.

The GHS addresses classification of chemicals by types of hazard and proposes harmonised hazard communication elements, including labels and safety data sheets. The major objective of the GHS is to ensure that information on physical hazards and toxicity from chemicals is available in order to enhance the protection of human health and the environment during the handling, transport and use of these chemicals. Target audiences for the GHS are consumers, workers, transport workers and emergency responders.

Provide this information to all employees (including maintenance workers and contractors) who may be exposed to the substances should be provided with GHS information and instruction chemical identification. The information should be provided in their language and make provision for employees who cannot read.

Table 20 shows the GHS symbols (pictograms) that are allocated to the different hazard classes:

Transport labelling:
For transport labelling two systems exist: labelling according to the GHS and labelling according to the transport regulations. The classification criteria of the GHS are based on the UN "Recommendations on the Transport of Dangerous Goods".

Within the UN classification system for the transport of dangerous goods, products (including mixtures and solutions) and articles subject to these regulations are assigned to one of nine classes according to the hazard or the most predominant of the hazards they present. Some of these classes are subdivided into divisions.

These classes are:

Class 1: Explosives (Divisions 1.1 – 1.6)
Class 2: Gases (Divisions 2.1 – 2.3)
Class 3: Flammable liquids
Class 4: Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases (Divisions 4.1 – 4.3)
Class 5: Oxidizing substances and organic peroxides (Divisions 5.1 – 5.2)
Class 6: Toxic and infectious substances (Divisions 6.1 – 6.2)
Class 7: Radioactive material
Class 8: Corrosive substances
Class 9: Miscellaneous dangerous substances and articles

90) Adopted from: UNECE, Globally Harmonized System of Classification and Labelling of Chemicals, undated

For transport the following symbols are used:[91]

Explosives			
			
Class 1 Division 1.1	**Class 1 Division 4**	**Class 1 Division 5**	**Class 1 Division 6**
			
Flammable gases		Non-flammable non-toxic gases	Toxic gases
Class 2 Division 2.1		**Class 2 Division 2.2**	**Class 2 Division 2.3**
			
Flammable liquids		Flammable solids	Spontaneous combustion
Class 3		**Class 4 Division 4.1**	**Class 4 Division 4.2**
			
Emits flammable gases in contact with water		Oxidizing substances	Organic peroxides
Class 4 Division 4.3		**Class 5 Division 5.1**	**Class 5 Division 5.2**
			
Toxic substances	Corrosive substances		

Step 3: Design the Flowchart

Prepare a process flow diagram

The objective is to clearly map the process flow to understand what the activities are and who is involved. This will help you understand where chemicals are used and located. Process flow means both the sequence of activities you undertake at your company, and the external activities that you can influence in your business, ranging from the products and services you procure, to the products and services that you provide.

A: PREPARE YOUR PROCESS FLOW DIAGRAM

Discuss and decide on the boundaries of your process. Take into account the information you have available, and to what extent you can trace your raw materials upstream, and your products and services downstream.

- **Where or when does the process start?**
  To answer this question you will need to trace where your raw materials come from, what they are and how they get to your business. A good way to start gathering this information is to discuss this with the person responsible for procurement and acquisitions in your company. You may also want to contact your suppliers and contractors and ask them for further information.

- **Where or when does the process end?**
  To answer this question you will need to trace where your chemical

91) UNIDO, Cleaner Production Toolkit, Vol. 6, Green Procurement and Hazardous Materials, undated UNECE – United Nations Economic Commission for Europe, Globally Harmonized System of Classification and Labelling of Chemicals (GHS), 2007

products and services are being delivered to and for what purposes. A good way to start gathering this information is to contact the person responsible for sales in your company. You may also want to contact customers direct and ask them for further information.

- **Discuss and decide on the level of detail to be included in the diagram.**

- **List all of the steps and activities in the process, remembering that some will occur simultaneously.**

- **Arrange the activities in sequence.** Make sure to include activities undertaken by your direct suppliers, in the transportation of your chemical products, byproducts and waste materials and their use, and wastewater treatment and disposal.

- **Discuss** the sequence of activities with the relevant people in your company and *confirm* that this is correct.

- **Review** the flowchart with your workers and your business partners.
    - Workers and supervisors
    - Suppliers
    - Transporters
    - Customers
    - Other relevant stakeholders

  Check if they agree that the process is drawn accurately.

B: IDENTIFY THE CHEMICALS, THEIR QUANTITIES AND THE HAZARDS INVOLVED IN THE PROCESS

- Identify the chemicals involved in the first activity of the process
- Mark them on your flowchart
- Identify the quantities of the chemicals usually involved or present for this activity
- Mark them on your flowchart
- Identify the hazards associated with the chemicals and the activity - such as the likelihood of fire, explosion, corrosion, acute toxicity, skin or eye irritation and other health hazards, and damage to the environment. You will find that most of this information is clearly explained in hazard/risk labels and Material Safety Data Sheets (MSDS) that should be made available from your suppliers.
- Make sure to identify the hazards for all the chemicals involved in each activity. If you do not have information on all the chemicals, contact your suppliers and ask them to provide you with the MSDS and other relevant hazard and risk information
- Mark the hazards on your flowchart
- Repeat until you have drawn a flowchart for the entire process. You will notice immediately that information concerning activities being undertaken outside your company will be relatively harder to get, compared to activities being conducted within your company. Do not get discouraged and if necessary, ask for help from your business partners

Step 4: Identify health, environmental, social and economic risks

Harm that can be caused to human health by chemicals includes, for example, skin irritations, respiratory problems or even cancer. In the environment, chemicals can harm animal populations and disturb the natural functions of ecosystems. The risks of all kinds of chemicals need to be assessed to determine which safety measures are necessary to prevent harm. When new information on a chemical becomes available, the risk assessment should be reviewed and, where necessary, revised to ensure the maximum safety possible at all times.

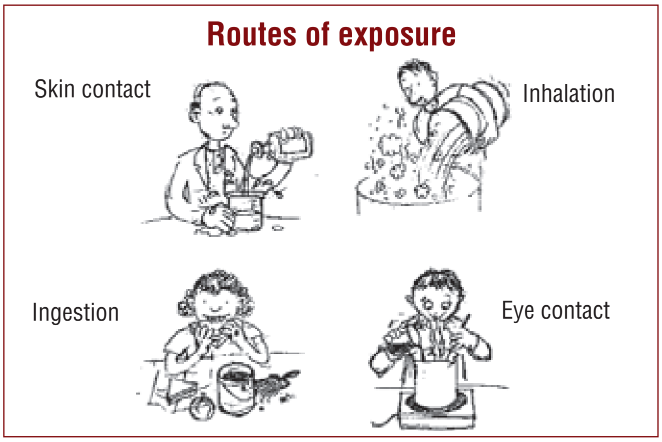


Figure 42: *Routes of exposure*[92]

1: Create a risk assessment team

Identifying and understanding the relationship between your chemical hazards and the potential impacts of an accident on the site, the community, business partners, clients and the environment is not a task that can be done by one person alone. At this stage, identify staff members that may help you in a simple but thorough preliminary assessment of the risks related to your chemical hazards.

2: Review hazard hotspots

Go back to your process flowchart and the hazard hotspots you have identified and marked in your flowchart. Take into account available information and start with the hotspots you have identified that relate directly to your business.

Pay particular attention to areas or process steps where you may be storing or handling large quantities of hazardous chemicals.

Ask yourself:

- Are very toxic chemicals present?
- Are fertilizers, herbicides and pesticides being stored or handled in your business?
- Are you storing or handling butane, propane, ammonia or chlorine?
- Could hazardous chemicals react with other chemicals nearby, or with water or with the atmosphere to create other hazardous chemicals?

In order to identify potential opportunities for reducing risks, walk around your facility and look for:

- Places where you see chemical substances spilled on the floor
- Places where you see dust clouds created during transferring or weighing operations
- Lids that are not tightly sealed where the contents are exposed to air, humidity, etc.
- Containers that are partially or completely uncovered where fumes may escape
- Chemical containers such as bags, drums, bottles, tins, etc. that are dented, damaged or defective
- Chemical packaging that is deteriorating due to leakage, damage, floor water, humidity, etc.
- Containers that have no labels or where the labels are damaged
- Chemical containers that are being used for other purposes, e.g., storing water, storing and transferring other materials
- Situations where workers have created and are using makeshift

92) Victorian Workcover Authority, A step by step guide for managing chemicals in the workplace, 2001

personal protection devices (e.g. a towel wrapped around face)
- Places in the factory where workers complain about health effects, loss of consciousness, etc.
- Incidents of fire, explosion or accident in the past year
- Ignition sources such as heat / sparks / open flames in the neighbourhood of flammable liquids / gases / dusts containers that are labelled with hazard symbols
- Situations where the skin of workers is contaminated with chemicals
- Spoiled or expired chemicals
- Situations where workers do not have appropriate tools for mixing, weighing, transportation, etc.[93]

3: Identify risk-prone and vulnerable groups, areas and assets in case of an accident

This step is all about identifying threatened people, environment and/or property. In case of an accident, ask yourself the following questions and discuss them in the team:

- How many workers are undertaking activities where hazardous chemicals are involved?
- How many workers are undertaking activities near areas where hazardous chemicals are being handled or stored?
- Are activities taking place in an area of high population density?
- Are there any hospitals, schools, markets or shopping areas located nearby?
- Are hazardous chemicals being handled, stored, processed or used in or nearby:
  - Areas prone to flooding?
  - Agricultural areas?
  - Areas where water for drinking, agricultural or recreational use is resourced?
  - Nature protection areas?

4: Identify potential accident scenarios related to the hazard hotspots you have identified

Reviewing and analysing past accidents from your business and within your industry will be extremely helpful for avoiding future accidents. Recalling well-known accidents in the sector may also help you in identifying potential types of accidents (or 'accident scenarios') related to the hotspots you have already identified.

Taking into account the types and quantities of hazardous chemicals involved in each of the steps on your process flowchart, try to list potential accidents related to the hazard hotspots you have already identified.

You may want to consider the following types of accidents (or 'accident scenarios'), and check if any of the hazards you have identified could have the potential to trigger or contribute to such an event:

- Containment failures due to corrosion, metal fatigue, creep, embrittlement or poor water management
- Toxic release
- Emission of toxic or irritant gases or fumes
- Explosions: unconfined vapour cloud explosion (UVCE), boiling liquid expanding vapour explosion (BLEVE), chemical explosion, dust explosion
- Explosion or fire from the handling of inflammable gases in liquid form
- Chemical fire producing harmful gases
- Chemical fire leading to polluted water escaping as a result of attempts to extinguish the fire
- Leakage of hazardous chemicals from storage and process areas, or during transport
- Other (discuss among the risk assessment team)

5: Identify the severity of related health, environmental, social and economic impacts in an accident situation

Taking into account the quantities and characteristics of the hazardous chemicals involved in your process, the threatened resources in case of a potential accident, and the potential accidents that may occur, identify what could be the related health, environmental, social and economic impacts – both inside and outside your facilities, and assign a 'severity' (importance) factor based on the scales given (note: scales should be first discussed and agreed upon by the members in your risk assessment team)

At this step, it will be helpful if you consult with your business partners and other relevant stakeholders to understand their view on the social, environmental and economic impacts related to the potential accidents you have identified.

Severity scale (Impact on community and social infrastructures):

- Negligible (temporary slight discomfort)
- Limited (injuries of neighbours)
- Serious (injuries resulting in temporary disablement)
- Very serious (death or serious injuries resulting in permanent disablement of a neighbour)
- Catastrophic (death or serious injuries resulting in permanent disablement of several neighbours)

Severity scale (Impacts on workers health):

- Negligible (temporary slight discomfort)
- Limited (injuries resulting in temporary worker absence)
- Serious (injuries resulting in temporary disablement)
- Very serious (death or serious injuries resulting in permanent disablement of a worker)
- Catastrophic (death or serious injuries resulting in permanent disablement of several workers)

Severity scale (Impacts on community health):

- Negligible (temporary slight discomfort)
- Limited (injuries resulting in temporary discomfort)
- Serious (injuries resulting in temporary disablement of a person in the community
- Very serious (death or serious injuries resulting in permanent disablement of a person in the community)
- Catastrophic (death or serious injuries resulting in permanent disablement of several persons in the community; community evacuation)

Severity scale (Impacts on land-use, agriculture and fisheries, on water resources or on quality of air):

- Negligible (no contamination, localised effects)
- Limited (simple contamination, localised effects, natural remediation)
- Serious (simple contamination, widespread effects with need for simple remediation)
- Very serious (heavy contamination, localised effects with need for remediation)
- Catastrophic (very heavy contamination, widespread effects with need for remediation)

93 GTZ, Chemical Management Guide for Small and Medium Sized Enterprises: Improve Chemical Management to Gain Cost Savings, Reduce Hazards and Improve Safety, 2008.

Severity scale (Impact on company image, site facilities or transport infrastructures):

- Negligible (small disturbance with no consequences)
- Limited (disturbance in the affected area of the company, without significant press coverage in the media)
- Serious (partial evacuation of the company and/or negative press coverage in the local media)
- Very serious (evacuation of the company and/or negative press coverage in the national media)
- Catastrophic (evacuation of the community and/or negative press coverage in the international media)

6: Estimate the likelihood of the identified accident taking place

Estimate the probability of occurrence of each identified accident situation taking into account the following scale (note: scales should be first discussed and agreed upon by the members in the team)

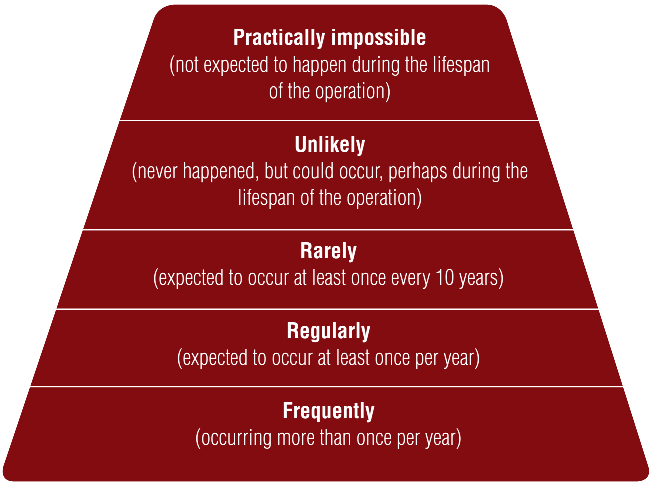


Figure 43: *Likelihood of accident occurence scale*

7: Assign a risk factor to each hazard hotspot.

Assign each hazard hotspot a risk factor (with the dimensions of frequency and severity) from 1/1 (lowest) to 5/5 (highest), taking into account the risk matrix (see Figure 44 risk assessment matrix).

Frequency 5	(5/1)	(5/2)	(5/3)	(5/4)	(5/5)
Frequency 4	(4/1)	(4/2)	(4/3)	(4/4)	(4/5)
Frequency 3	(3/1)	(3/2)	(3/3)	(3/4)	(3/5)
Frequency 2	(2/1)	(2/2)	(2/3)	(2/4)	(2/5)
Frequency 1	(1/1)	(1/2)	(1/3)	(1/4)	(1/5)
	Severity 1	**Severity 2**	**Severity 3**	**Severity 4**	**Severity 5**

Figure 44: *Risk assessment matrix*

- Consider different possible hazard scenarios related to hotspots when assigning risk factors
  - Repeat this for each activity in the process
  - Mark the risk factor on your flowchart for each process activity to identify risky process activities and document the completeness of the analysis

The application of the risk assessment matrix identifies process activities that are critical and require close monitoring and control (light red areas) and areas where the risks are considered unacceptable and immediate measures should be taken (dark red areas).

8: Prioritize your hazards hotspots

List your Hazard Hotspots and prioritize them according to the risk factor you have assigned. Risks to which you have assigned a risk factor considered unacceptable or critically requiring monitoring and control should be acted upon as soon as possible. Stakeholder concerns should be taken into account in evaluating hotspot priority.

The identified hotspots now should be mapped. The necessary activities are:

On-site:

- Draw a simple floor plan of the company or use an existing plan (drawing/graphics software and online mapping tools may be helpful)
- Note department locations on the floor plan
- Locate on the map each internal activity in the production process along with associated chemicals and risk factor
- Make sure you have marked on the map all the locations where chemical substances are used, stored and transported
- Indicate clearly your hazard 'hotspots'

Off-site:

- Get a map of the geographical region where your facility is located and clearly mark your site (this can also be done online)
- Identify the delivery routes to your site used by your chemical suppliers
- Identify the routes used to transport your chemical products, byproducts, or waste materials to their final destinations (end-use, recycling or disposal)
- Locate in the plan each external activity in the process and its associated risk factor. Make sure you have marked on the plan all the steps involving the handling of your chemical products, byproducts, or waste materials to their final destinations (end-use, recycling or disposal)
- Indicate clearly your hazard 'hotspots' by marking them with an 'X'

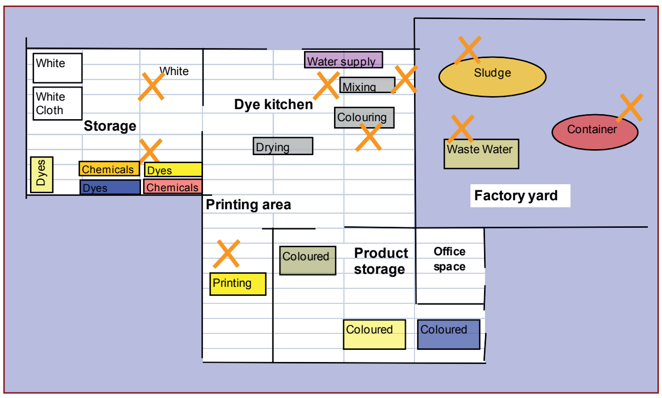


Figure 45: *Example of a hazard hotspot map* [94]

94) GTZ Chemical Management Guide for Small and Medium Sized Enterprises - Improve Chemical Management to Gain Cost Savings, Reduce Hazards and Improve Safety", GTZ, 2008

Figure 46: *Using pellets instead of powders and using water-based paint instead of oil-based* [96]

Advantages of hazard mapping:

- By going through the process of mapping chemical hazards it is possible to identify hazard hotspots that have been overlooked
- Overlapping hazards and potentially threatened areas on a single map allows for a better understanding of risk
- Visual aids such as hazard hotspot maps can help to identify opportunities for on-site risk reduction through:
- Changes in layout
- Identifying priority areas to improve housekeeping
- Identifying areas that should be kept off-limits
- Vulnerable zones where fences/guarding should be improved
- Identifying zones where hazard warnings and signs should be improved

Step 5: Consider options

- Determine and implement the appropriate measures to reduce and control risks
- Redo the risk assessment to check whether the measure actually reduces the severity and/or frequency of the identified hazards

Appropriate measures can include elimination, substitution, isolation, engineering or administrative measures.[95]

Elimination:

Where a task involves the use of a substance or process that is not essential, the substance or process should be eliminated, or the risk associated with the substance or process eliminated if practicable, e.g. using steam cleaning rather than washing with a solvent; using clips, clamps, bolts or rivets instead of an adhesive.

Substitution:

Substitution involves using a safer product or process. This includes exchanging the substance for one that is less harmful; using the same substance in a less hazardous form; or using the same substance in a less hazardous process.

- Safer substance: use detergent instead of chlorinated solvent for cleaning; use water-based chemicals instead of solvent-based chemicals where compatible
- Safer form or process: paint with a brush instead of spraying; purchase a substance in a safer form (e.g. use less concentrated liquids in ready-to-use form instead of concentrates that require decanting or mixing; use pellets instead of powder that reduces the amount of dust formed)

Isolation:

Isolation involves isolating the process or substance from employees, non-compatible materials and ignition sources using either distance or barriers, or both, to prevent or reduce employee exposure and risks associated with dangerous goods e.g. fire, explosion etc.

- Use closed systems
- Isolate the process to one room with restricted access or use appropriate barriers/screens to separate substances
- Move the process into a positive/negative pressure cabin/room
- Distance workers from substances/processes through the use of remote controls
- Distance property, incompatible chemicals and ignition sources (e.g. flames, sparks) from goods

Engineering controls:

Put in place engineering controls that involve the use of equipment or processes which:

- Stop or reduce new or unwanted substances from being generated
- Stop or contain substances so that they are not released into unwanted areas e.g. via ventilation
- Reduce the area of contamination in the event of spills or leaks

Examples:

- Use fully or partially enclosed ventilation booths
- Fully or partially enclose the process with exhaust extraction
- Use local exhaust or natural ventilation systems (e.g. air ducts, open doors/windows)
- Use robots
- Design buildings that are compatible with the intended goods; made of non-combustible construction as far as is practicable; designed to reduce contamination
- Use bunding to contain spillage
- Install drains, tanks or sumps to cope with spilled material
- Install automatic fire protection and chemical suppression systems

Administrative controls:

Administrative controls are systems of work or safe work practices that prevent or reduce risks to health, property and the environment.

Examples:

- Reduce the amount of property or the number of employees exposed
- Reduce the duration and/or frequency of exposure e.g. through job rotation
- Reduce the amount of goods/products stored and used
- Ensure safe interim storage of wastes/products (e.g. labelled properly in suitable containers stored away from people, the environment, incompatible chemicals, ignition sources etc.)

95) The description of these strategies is adapted from "A step by step guide for managing chemicals in the workplace" 2001 (Victoria, Australia).

96) Victorian Workcover Authority, A step by step guide for managing chemicals in the workplace, 2001

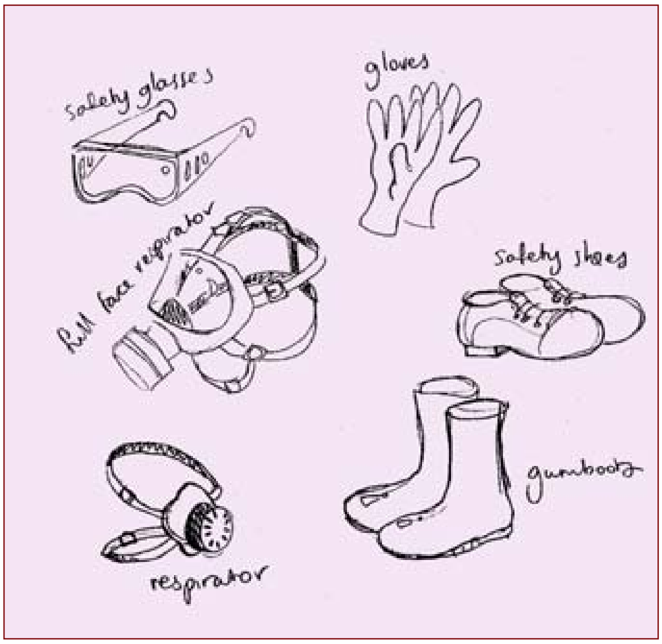


Figure 47: *Different types of personal protective equipment* [97]

- Vacuum or wet sweep to suppress dust being generated
- Cover containers and make sure lids are attached
- Clean up spills immediately (includes provision of suitable aids and equipment)
- Ensure there is no eating, drinking or smoking in areas where substances are used
- Provide suitable washing facilities
- Provide first-aid facilities
- Instruct employees on how to use substances/ equipment safely

Personal protective equipment (PPE):
PPE is protective clothing and equipment for employees, supervisors and visitors, and is the least effective safety measure. It should only be used where it is not practicable to use other measures, or when other measures do not adequately control exposure.

Examples:
- Overalls, aprons, gowns, chemical-resistant suits
- Footwear (enclosed shoes, safety boots)
- Gloves
- Chemical-resistant glasses (safety glasses)
- Face shields/masks, respirators full/partial
- Head protection

Training and information for the employees:
Employees need to know how to use and store substances safely. The regulations require employers to provide information, instruction and training to employees on the hazards and risks associated with hazardous substances and dangerous goods that they use or may be exposed to. Where dangerous goods are stored or handled, other persons on site such as contractors, maintenance workers, administrative staff and visitors may also need to be given information, instruction and training on associated risks and precautions to be taken.

Safe storage of chemicals:
Some basic rules and guidelines should be observed to minimise the risks associated with the storage of hazardous substances. Safety precautions are indispensable if a company uses a large number of different toxic substances, or if it stores large quantities of chemicals. The following issues need to be considered:

- *Spatial separation of stored chemicals according to their properties*
  Substances that may cause a powerful reaction (e.g. strong acids and alkaline solutions) as well as substances capable of releasing toxic reaction products (acids + solution of chlorinated lime) must be stored separately. The following illustration provides a simplified scheme for the storage of hazardous working materials.
- *Storage of liquids in collection trays close to floor level*
  Always store liquids in shelf-type racks on the lower shelves. If there is an accident (e.g. a container breaks or leaks), this will prevent the liquid from oozing into materials stored on the lower levels. Liquids kept in small tanks/containers (up to approximately 200 litres) must be stored in collection troughs suitable for their chemical properties.

						
	o	–	–	–	–	–
	–	+	–	–	o	–
	–	–	+	o	o	–
	–	–	o	+	+	o
	–	o	o	+	+	+
	–	–	–	o	+	+

Figure 48: *Safe storage key (+ Can be stored together, - Cannot be stored together, o Can be stored together if specific precautions are taken)*

97) Victorian Workcover Authority, A step by step guide for managing chemicals in the workplace, 2001

- *Separate storage of substances that can be extinguished with water and substances that cannot be extinguished with water*
  Chemicals that can be extinguished with water should be separated from chemicals that must not be extinguished with water. Wherever possible, store these two groups of substances in different rooms.
- *No storage of chemicals at the workplace*
  Often large amounts of hazardous substances are (temporarily) stored at the workplace (e.g. solvent containers under worktops). In case of an accident these substances are a major source of danger. Do not keep more than one day's requirement of any hazardous substance at the workplace. Refill daily from the central storage point.
- *Keeping storage records*
  At each storage point, the company must keep a storage list. The list should include the type, quantity and risk potential of the stored substance. If an accident occurs, the fire brigade will know how to fight the fire due to the information provided by the storage list.
- *Substitution of high risk substances*
  The best way of avoiding risks associated with the storage of chemicals is to eliminate high-risk substances altogether from the company and replace them by less dangerous alternatives. In particular, substances with a high potential to cause a fire or damage to human health or the environment (e.g. chlorinated hydrocarbons, products containing heavy metals and water-soluble substances that will not readily degrade, such as non-degradable surfactants) should be substituted.

8.4 CHECKLIST: chemical management

The following checklists provide a list of options to reduce the consumption of chemicals in the domestic area, offices, for the storage of chemicals as well as guidelines for the substitution of commonly used hazardous process chemicals. These options can also be taken as generic approaches to look for opportunities to reduce the hazards associated with chemicals in production sites.

8.4.1 Domestic chemicals

- Automate detergent dispensing to avoid accidental manual over-dosing
- Empty chemical dosing drums completely, drain any residue into the new drum
- Use of low-temperature detergents reduces energy costs, may rinse more easily, reduce the risk of colour run and retain better colour brightness
- Check dispensing instructions and measure detergents
- Set chemical dosing pumps for low, medium and high dip washes
- Check in-use detergent strengths, where possible

8.4.2 Office chemicals

- Reduce the number and volume of chemical products in use, especially for cleaning
- Inquire as to an updated safety data sheets (SDS) with each re-order and file updated SDS with the security administrator or purchasing department
- Return the SDS to the supplier or ask for a new one if:
  - The product identification does not correspond to the product
  - The SDS or parts of it are illegible
  - Date, manufacturer, distributor or product name are missing on the SDS
  - The information on the SDS does not correspond to the product identification
  - The SDS is not subdivided into the required 16 chapters
- Contact the supplier if:
  - The SDS is not up-to-date
  - The classification according to the chemical's regulation is missing, incomplete or incorrect
  - Part of the information is missing (e.g. environmental properties, disposal details)
- Substitute high-risk hazardous substances with less dangerous alternatives
- Eliminate CMR (carcinogenic, mutagenic, reprotoxic) substances as much as possible
- Use automated systems to apply hazardous chemical substances
- Segregate combustible and flammable hazardous chemical substances from each other
- Measure and monitor concentrations of hazardous chemical substances
- Install appropriate collective protection equipment
- Distribute necessary personal protective equipment to the workers
- Continuous local exhaust ventilation at all workplaces where the concentration of chemical substances exceeds the maximum admissible concentration
- Regular technical checks of the equipment used with chemicals
- Inspect and clean exhaust ventilation systems on a regular basis to maintain maximum efficiency
- Regular medical examinations for workers exposed to hazardous chemical substances, especially to CMR substances and substances with a biological limit value
- Use of ventilation and monitoring of concentrations
- Prevention or elimination of ignition sources
- Separation of substances that can form explosive mixtures with air from open flames, electrical equipment, sparks, etc.
- Avoid contamination of original containers caused by pouring back into them the products they contained
- Clearly mark explosive areas
- Clearly indicate escape and rescue routes and keep those routes free of obstacles

8.4.3 Storage of chemicals

The following strategies are re-printed from "Guidelines for the safe storage of chemicals" 2007 (University of Queensland, Australia):
The quantities of hazardous chemicals should be kept to a minimum, commensurate with their usage and shelf life. Some chemicals degrade in storage and can become more hazardous, e.g. chloroform can produce phosgene from prolonged storage. Such chemicals should be identified and managed appropriately. Schools are encouraged to develop centralised chemical purchasing policies and monitoring systems to minimise stockholding.

Ensure chemical containers and their seals or stoppers are appropriate for the type and quantity of chemical stored. As far as is practicable, chemicals should be stored in the containers in which they are supplied.

If you repack chemicals make sure the new containers are labelled properly. All packages in storage should be labelled to allow unmistakable identification of the contents and all labels should comply with the relevant regulations. Labels should be reattached or replaced, as necessary, to clearly identify the contents of the package.

Containers that have held hazardous chemicals should be treated as full, unless the receptacle or package has been rendered free from hazardous chemicals. Do not give away empty containers to workers, neighbours, etc. If you are in doubt whether containers might leak to the outside, crush them and make them unusable.

Storage of chemicals, including wastes, should be based on the properties and mutual reactivities of the chemicals. Incompatible chemicals should be kept segregated from one another, e.g. by fire isolation in a chemical storage cabinet or segregated by space. A separate spill catchment should be provided for each incompatible liquid.

Opening of packages, transferring of contents, dispensing of chemicals or sampling should not be conducted in or on top of a cabinet or a cupboard for storing chemicals unless it is specifically designed for this purpose and appropriate procedures and equipment are used.

Packages should be inspected regularly to ensure their integrity. Leaking or damaged packages should be removed to a safe area for repacking or disposal.

Where flammable vapours or combustible dusts may be present as part of normal or abnormal operations, the areas should be classified properly. The relevant requirements concerning avoidance of ignition sources should be complied with in situations other than those where the ignition source is controlled and is necessary for experimental purposes, such as the use of a Bunsen burner. Electrical equipment should comply with appropriate standards. Arrange a hazard zone assessment.

Procedures should be established to deal with clean up and safe disposal of spillages. Supplies and materials needed to control the spillages should be readily accessible.

Substances that are unstable at ambient temperature should be kept in a controlled temperature environment set to maintain an appropriate temperature range. Reliable alternative safety measures should be provided for situations when utilities, such as power, fail. Substances that can present additional hazards on heating should be clearly identified. Sunlight can affect some plastic containers or the chemical contents. Containers or chemicals that can be affected v not be stored in a laboratory where they can be exposed to direct sunlight.

8.4.4 Replacement of chemicals

The following table gives an overview of possible replacements for commonly used chemicals (Table 21).

Chemical	Application	Replacement
Chromium VI	Decorative surfaces, corrosion protection	Chromium III, Cobalt
Lead	Soldering	Tin/silver/copper alloy
Lead	Stabiliser in plastic manufacturing	Calcium/zinc systems
Solvent based paints	Corrosion protection and decoration of surfaces	Water-based paints
Solvent degreaser	Degreasing of metal surfaces	Aqueous alkaline degreaser
R 22	Refrigerant	R 404 a, R 417 a, R134 a
TCE	Degreasing	Modified alcohols

Table 21: *Replacements for commonly used toxic industrial chemicals*

Nine

Benchmarks

This chapter provides sector-specific benchmarks for a selection of industries including:

- Textiles
- Leather
- Paper
- Food and beverage
- Metal manufacturing

See Section 2.8 for a brief explanation of the process of benchmarking. As a first step, identify the relevant consumption from your thematic module: water, energy (electricity and/or heat), raw materials, waste. Then calculate the respective number for the company you are investigating and compare it to the numbers given here. Be aware of the range given. In case the range appears wide, or the numbers apparently do not match your experience, consult the relevant document for the technological description of the sector, the description of specifics of the companies sampled, the size of the enterprise or the product characterisation.

The benchmarks included in this training manual are a part of the benchmarks included in the electronic version of the toolkit. Most of the benchmarks included here are taken from the best available technology reference notes (also known as BREF-notes).

The European IPPC Bureau is a division of the Sustainable Production and Consumption Unit of the Institute for Prospective Technological Studies (IPTS), one of the scientific institutes of the European Commission's Joint Research Centre (JRC). The Bureau was set-up to organise an exchange of information between Member States and industry on Best Available Techniques (BAT) and BAT associated monitoring and developments.

In the international context, the European information exchange on BAT is considered to be a useful contribution from the EU to the global process initiated in 2002 at the World Summit on Sustainable Development so that non-EU countries can also reap the benefits of this work.[98]

The electronic version of the BATs includes tracking numbers from equipment suppliers, case studies and a variety of other pertinent manuals and studies. The benchmarks relation to different subsectors or to individual processes are indicated. Most of the benchmarks relate energy, water or raw materials consumption to production.

Also carefully check the units, especially when benchmarking energy consumption. Convert kJ or MJ to kWh where relevant, or convert kg of fuel to kWh. For your reference: 1 standard cubic metre of natural gas or fuel oil roughly has a calorific value of 10 kWh; coal, depending on the quality, about 6 to 7.

If your company is producing a variety of products, try to compose indicators by weighing indicators for the individual products e.g. for the tannery processing hide and sheepskin, you might weigh the indicators for hide processing and skin processing according to production and add to a benchmark.

For several sectors water and energy consumption for individual unit operations are given. Again combine them to generate a benchmark for your process, considering the relevant units e.g. for the case of water consumption of cotton processing to grey fabric, you will have to add the water consumption for de-sizing and scouring. In this case then mercerising, dyeing, wet finishing is not relevant.

98) European Commission, Joint Research Center, 2008.

European BREF notes are available for the following sectors and cross-sectoral topics[99]:

- Cement, Lime and Magnesium Oxide Manufacturing Industries
- Ceramic Manufacturing Industry
- Chlor-Alkali Manufacturing Industry
- Common Wastewater and Waste Gas Treatment
- Economics and Cross-Media Effects Emissions from Storage
- Energy Efficiency
- Ferrous Metals Processing Industry
- Food, Drink and Milk Industries
- General Principles of Monitoring
- Glass Manufacturing Industry
- Industrial Cooling Systems
- Intensive Rearing of Poultry and Pigs
- Large Combustion Plants
- Large Volume Inorganic Chemicals – Ammonia, Acids and Fertiliser Industries
- Large Volume Inorganic Chemicals – Solids and Others Industry
- Large Volume Organic Chemical Industry
- Management of Tailings and Waste-Rock in Mining Activities
- Manufacture of Organic Fine Chemicals
- Mineral Oil and Gas Refineries
- Non-Ferrous Metals Industries
- Production of Iron and Steel
- BREF Production of Polymers
- Production of Speciality Inorganic Chemicals
- Pulp and Paper Industry
- Slaughterhouses and Animals Byproducts Industries
- Smitheries and Foundries Industry
- Surface Treatment of Metals and Plastics
- Surface Treatment Using Organic Solvents
- Tanning of Hides and Skins
- Textiles Industry
- Waste Incineration
- Waste Treatments Industries

For a unit-operation-based approach to benchmarking, please refer to Chapter 5 (Energy Efficiency) for benchmarks on boilers, air compressors, etc. and to Chapter 4 (Water Efficiency) for benchmarks on cleaning.

You might also want to relate your process to the 'ideal' process. For example: if you are heating billets before forging, calculate how much heat it takes to heat one billet from ambient air temperature to 800°C (heat is mass times specific heat times temperature difference), multiply by the number of billets per hour and compare to the fuel consumption per hour for your furnace.

To capture the optimisation opportunities that internal benchmarking can offer, start recording the daily consumption numbers for your enterprise and analyse the numbers over time. Ask your team: is consumption stable and at the level you would expect or does it vary? Are there days with lower consumption compared to the average? What can you learn from these days?

9.1 Benchmarks for the textile sector

Table 22 gives benchmarks for the total water consumption (hot and cold) and hot water consumption of individual process steps for the production of cotton and viscose fabrics

	Water consumption (l/kg)	
	TOTAL	Of which HOT WATER
Pre-treatment Processes		
Washing for desizing	3 – 4	3 – 4
Washing after scouring	4 – 5	4 – 5
Washing after bleaching	4 – 5	4 – 5
Washing after cold bleaching	4 – 6	4 – 6
Washing after mercerisation - Washing to remove NaOH - Neutralisation without drying - Neutralisation and drying	4 – 5 (hot) 1 – 2 (cold) 1 – 2 (warm)	4 – 5 n/a < 1
Washing after dyeing		
Reactive dyestuffs	10 – 15	4 – 8
Vat dyestuffs	8 – 12	3 – 7
Sulphur dyestuffs	18 – 20	8 – 10
Naphtol dyestuffs	12 – 16	4 – 8

Table 22: *Achievable specific water consumption levels for continuous washing processes during finishing of open width woven fabric consisting of cotton or viscose and their blends with synthetic fibres*

Table 23 gives benchmarks for the total water consumption (hot and cold) and hot water consumption of individual dyeing processes for the production of cotton and viscose fabrics.

	Water consumption (l/kg)	
	TOTAL	Of which HOT WATER
Reactive dyestuffs	15 – 20	12 – 16
Vat dyestuffs	12 – 16	4 – 8
Naphtol dyestuffs	14 – 18	6 – 10
Disperse dyestuffs	12 – 16	4 - 8

Table 23: *Achievable specific water consumption levels for dyeing cotton and viscose*

99) European Commission, Joint Research Center, Reference documents, 2008

9.2 Benchmarks for the leather sector

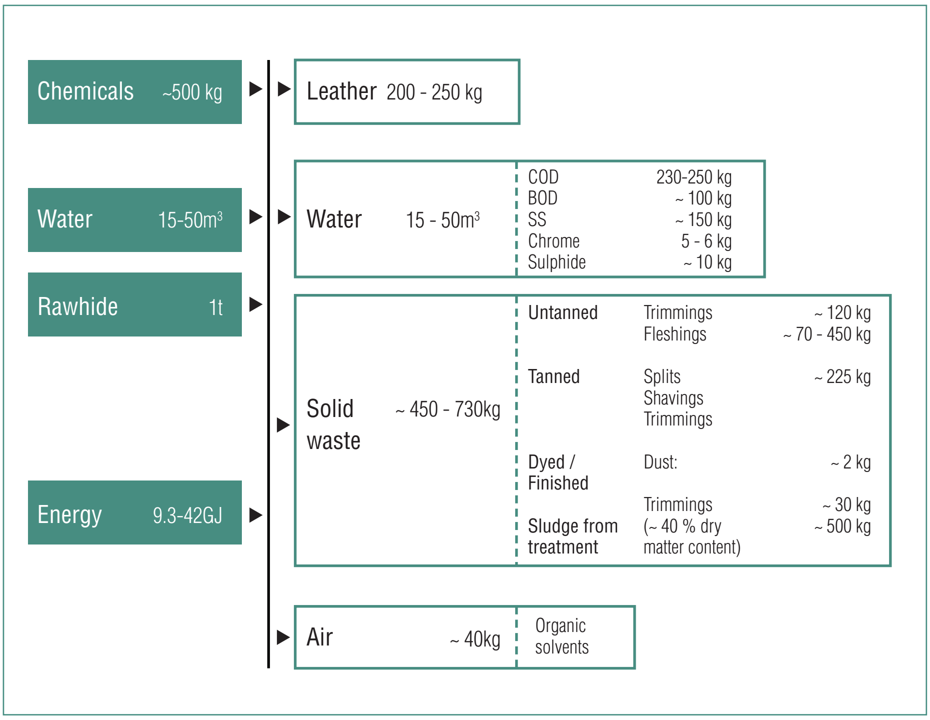


Figure 49: *Input/Output overview for a conventional (chrome-tanning) process for bovine salted hides per tonne of raw hide treated*

Table 24 gives benchmarks for the wastewater generation and wastewater load from hide tanning.

Untreated waste water	***Water***	***SS***	***BOD***	***COD***	***Cr***	***S^{2-}***	***TKN***	***Cl^-***
	m³/t raw hide	**Kg/t raw hide**						
Environmental[1)]	50	~ 150	~ 60 – 100	~ 175 – 250	~ 5 – 6	~ 6 – 10	~ 14	
		milligrams/litre						
Conventional[1)]	50	3000	800 – 2000	3500 – 5000	100	100 – 200	300	
Conventional[2)]	20 – 30			4000 – 9000	100 – 400	50 – 200	400 – 800	

Table 24: *Achievable specific water consumption levels for dyeing cotton and viscose*

1) *Source is tan/tm/04/Austria, tan/tm/11/Nordiske Seminar*
2) *Source is tan/tm/37/Germany, and the data are an example of homogenised overall (not treated) complete wastewater flow combinations for the manufacture of chromium leather made from cattle hides, based on raw hide weight*

Table 25 gives benchmarks for the waste water generation and waste water load from the different process stages of sheep skin tanning.

	Water l/ skin	SS g/skin	COD g/skin	BOD5 g/ skin	TKN g/skin	S^{2-} g/skin	Cr^{3+} g/skin	Cl^- g/skin	SO_4^{2-} g/ skin	TDS g/skin
					Sheepskins					
Beamhouse	65 – 150	150 – 300	250 – 600	100 – 260	15 – 30	6 – 20		150 – 400	5 – 40	
Degreasing – Tanning	30 – 70	15 – 30	50 – 300	20 – 100	4 – 10		8 – 12	40 – 200	30 – 50	
Post-tanning	15 – 35	10 – 20	30 – 100	15 – 35	2 – 4		1 – 3	20 – 40	10 – 20	
Finishing	0 – 10	0 – 2	0 – 5	0 – 2						
TOTAL	**110 – 265**	**175 – 352**	**330 – 1005**	**135 – 397**	**21 – 44**	**6 – 20**	**9 – 15**	**210 – 640**	**45 – 110**	
					Wool-on sheepskins					
Beamhouse	220	100	550	150	16			400		600
Tanning operations	40	15	150	45	2		15	460		650
Dyeing operations	100	80	80	25	3		5	50		270
TOTAL	**360**	**195**	**780**	**220**	**21**		**20**	**910**		**1520**

Table 25: *Achievable specific water consumption levels for dyeing cotton and viscose*

Table 26 gives benchmarks for the wastewater generation and wastewater load from the different process stages of bovine hide tanning.

		Chemicals used, composition and volume of effluents		
No.	***Operation***	***Chemicals used and effluent constituents***	***Concentration [mg/l]***	***Effluent volume [m³/t] raw hides***
1	Soaking	Alkali, wetting agents, biocides (AOX), dung, blood, soluble protein, curing salt	COD 2500 – 10000 BOD_5 1800 – 2300 pH 7 – 10	2 - 4
2	Liming and rinsing	Lime, alkali sulphides, thio alcohols, enzymes, residual protein from hair and skin, emulsified fat, degradation products	COD 17000 – 25000 BOD_5 ca. 3000 pH 12 – 13 Sulphide 600 – 4000	3 – 8
3	De-liming Bating Rinsing	Ammonium salts, oxalates, citrates, CO_2, enzymes, epidermis-, hair- and pigment residues, non collagenic proteins, soluble Ca salts	COD up to 10000 BOD_5 800 – 1700 pH 7 – 9 Sulphide ca. 50	1 – 4
4	Pickling and chrome tanning	Pickling salts (NaCl), organic and inorganic acids, $Cr_{(III)}$ salts, sodium carbonate, fat, fungicides, leather fibres	COD up to 10000 BOD_5 350 - 1500 pH 3 - 4 $Cr_{(III)}$ up to 5000	0.5 – 3
5	Dripping Samming	Residues from 4	As under 4	Ca. 0.2
6	Washing Neutralising Washing	Organic and inorganic acids, alkali salts, tanning agents for neutralisation, $Cr_{(III)}$ salts, leather fibres	COD 1000 – 4000 BOD_5 ca. 150 pH 4 – 6	Ca. 3 – 6
7	Re-tanning Dyeing Fat liquoring	Formic acid, $Cr_{(III)}$ and/or Zr salts, Al salts, vegetable and synthetic tanning agents, dyes, fat, ammonia (AOX)	COD 8000 – 22000 BOD_5 ca. 800 pH 4 – 5 $Cr_{(III)}$ -500	Ca. 2- 6
8	Washing Samming	Residues from 7	As under 7	3 – 5
9	Finishing	Lacquer polymers, solvents (lacquering with wet separator), dye and lacquer sludge, emulsifiers	150	45
			Total	**15 - 30**

Table 26: *Manufacture of chrome leather from bovine hides*

9.3 Benchmarks for paper production

Table 27 gives benchmarks for the water consumption for different types of products for paper mills.

Process	***Specific water consumption [m³/t]****
Uncoated folding boxboard	2 – 10
Coated folding boxboard	7 – 15
Corrugated medium & packaging paper	1.5 – 10
Newsprint	10 – 20
Tissue	5 – 100
Writing and printing paper	7 – 20

Table 27: *Water consumption in the paper industry*

Notes:
** It has been noted that about 1.5 m³ water per tonne of paper is vaporised in the dryer section of the paper machine, this means that it does not appear as wastewater.*

Table 28 gives benchmarks for the water discharge for different types of products for paper mills.

Paper grade	***Water discharge [m³/t]***	***Remarks***
Tissue	10[1] – 50	For recycled fibre based tissue: includes fibre processing
Printing/writing, uncoated	51 – 402	May include water used in pulp processing
Printing/writing, coated	51 – 50	May include water used in pulp processing
Paper board	01 – 20	Includes water used in pulp processing
Speciality paper	10 – 3003	

Table 28: *Water discharge in European mills*

Notes:
1) The lower end of the range is changed by EIPPCB according to current performance data
2) The higher end of the range is changed by EIPPCB because the given figure of 90 m³/ADt seems to be unrealistically high
3) The higher end of the range is changed by EIPPCB because the given figure of 400 m³/ADt seems to be unrealistically high

Table 29 and Table 30 give benchmarks for the energy consumption for different types of products for paper mills.

Type of mill	***Process heat consumption (net) in GJ/ADt***	***Power consumption (net) in MWh/ADt***	***Remarks***
Non-integrated bleached sulphite pulp	16 – 18	0.7 – 0.8	
Integrated bleached sulphite pulp and coated fine paper	17 – 23	1.5 – 1.75	Paper drying is more energy consuming than pulp drying
Integrated bleached sulphite pulp and uncoated fine paper	18 – 24	1.2 – 1.5	Fillers and surface size 10 – 30%

Table 29: *Heat and power consumption in paper-making*

Notes:
The units can be converted from MWh to GJ according to 1 MWh = 3.6 GJ and 1 GJ = 0.277 MWh

Type of mill	Process heat consumption (net) in GJ/ADt[1]	Power consumption (net) in MWh/ADt
Integrated machine finished newsprint (100% TMP (thermo mechanical pulp))	- 1.3[2]	2.2
Integrated magazine paper (100% TMP)	- 0.3[2]	2.1
Integrated newsprint (> 50% mechanical pulp)	0 – 3.0	2.0 – 3.0
Integrated lightweight coated paper (LWC) mill (> 50% mechanical pulp)	3.0 – 12.0	1.7 – 2.6
Integrated super calendared (SC) mill (> 50% mechanical pulp)	1.0 – 6.0	1.9 – 2.6
Integrated cardboard (> 50% mechanical pulp)	3.5 – 13.0	2.3 – 2.8
Non-integrated chemical thermo mechanical pulp	0	2.0 – 3.0

Table 30: *Heat and power consumption in paper-making by product*

Explanatory notes: (-) indicates surplus
The units can be converted from MWh to GJ according to 1 MWh = 3.6 GJ and 1 GJ = 0.277 MWh
Data from [J. Pöyry, 1998], [SEPA Report 4712-4, 1997], [Finnish BAT Report, 1997]
1) The net process heat consumption depends mainly on the type of refining and the degree of heat recovery
2) The values can only be reached if heat recovery, paper machine press section and the use of electricity are all implemented and operated in an ideal way. In existing processes this is rarely the case.

Table 31 gives benchmarks for the energy consumption for different production steps for paper mills.

Department	Process heat [MJ/t]	Electric power [kWh/t]
Wood handling	150	50
Refining	0	21101)
Washing and screening	0	50
Bleaching	0	75
Bleach chemical preparation	0	5
Bleached stock screening	0	35
Power boiler	0	25
Total pulp mill	**150**	**2350**
Stock preparation	0	235
Paper machine	5300[1) 2)]	350
Total paper mill	**5300**	**585**
Effluent treatment	0	39
Total per tonne of paper	**5450**	**2974**

Table 31: *Energy consumption for different production steps for paper mills*

Notes:
1) A Finnish integrated TMP mill higher electricity consumption in the range of 2400 kWh/t was reported for the refining stage (including reject refining) and a lower value of 4800 MJ/t process heat consumption for the paper machine respectively [Finnish comments].
2) A Swedish newsprint mill reports a heat demand of about 4 GJ/t for drying paper, a need that will be reduced by about 10% with a future shoe-press installation.

Table 32 gives options for the reduction of energy consumption of paper mills and assesses their impact on energy consumption

Energy efficient technology	***Type of energy demand and amount***	***% of energy saving and amount***	***Remarks***
High consistency slushing	Electricity for pumps and rotors; 60 kWh/t	33%; 20 kWh/t	Achieved through optimisation of rotor design
Best practise refining	Electricity to drive motors; 100 – 500 kWh/t	20%; 80 kWh/t	Depends on the product properties; varies between grades and furnish
High consistency forming	Electrical: 200 kWh/t	20%; 40 kWh/t	Already applied to recovered paper
Twin wire forming	Drive	No data	Not just applied for energy savings
Optimised vacuum system	Electricity	25%	
Variable speed drive system	Electricity	No data	
High efficiency electric motors	Electricity	No data	
Well sizing of electric motors	Electricity	No data	
Hot press	Heat in dryer section	15 – 20%	Mostly recovered fibres
Extended nip (shoe) presses	Heat in dryer section	15 – 20%	
Cross direction moisture profile correction with IR heaters	Heat in dryer section	1 – 2%	Reduces the extent of over drying
Exhaust air humidity control	Heat	10%	Allows adjustment and reduction of air flow
Exhaust air heat recovery	Heat	10%	See description below
Condensate recovery	Heat	10%	Water can be returned and used
Direct gas-fired ventilation air	Heat	40%	Mainly used in tissue paper machine hood
Increasing size press solids	Heat for after size press drying section	Drying load can be reduced by 48%	Leads to a reduction in broke level

Table 32: *Positions where energy savings could be made and their effect*

Notes:

1) A Finnish integrated TMP mill higher electricity consumption in the range of 2400 kWh/t was reported for the refining stage (including reject refining) and a lower value of 4800 MJ/t process heat consumption for the paper machine respectively [Finnish comments].

2) A Swedish newsprint mill reports a heat demand of about 4 GJ/t for drying paper, a need that will be reduced by about 10% with a future shoe-press installation.

9.4 Benchmarks for food and beverage

Table 33 gives benchmarks for the water consumption and wastewater generation for different subsectors of food processing.

Sector	Water consumption	Waste water volume
Meat and poultry	2 – 20 m^3/t	10 – 25 m^3/t
Fish		
Herring filleting	3.3 – 10 m^3/t	2 – 40 m^3/t
Mackerel	20 – 32 m^3/t	
White fish	4.8 – 9.8 m^3/t	
Shrimp processing	23 – 32 m^3/t	
Fruit and vegetable[1]		
Canned fruit	2.5 – 4.0 ^{3}/t	11 – 23 m^3/t
Fruit juices	6.5 m^3/t	
Canned vegetables	3.5 – 6.0 m^3/t	
Frozen vegetables	5.0 – 8.5 m^3/t	
Deep frozen vegetables	2.5 – 5.0 m^3/t	
Preserved vegetables	5.9 – 11 m^3/t	
Potato	2.4 – 9.0 m^3/t	
Jams	6 m^3/t	
Baby food	6.0 – 9.0 m^3/t	
Starch		
Maize	1.7 – 3 m^3/t	1.4 m^3/t
Wheat	1.7 – 2.5 m^3/t	1.8 m^3/t
Potato	0.7 – 1.5 m^3/t	2 m^3/t
Dairy[2]		1 – 5 l/kg
Milk and yoghurt	0.6 – 4.1 l/l	
Cheese	1.2 – 3.8 l/l	
Milk powder, cheese and/or liquid products	0.69 – 6.3 l/l	
Milk and yoghurt	0.8 – 25 m^3/t	0.9 – 25 m^3/t
Cheese	1 – 60 m^3/t	0.7 – 60 m^3/t
Milk powder, cheese and/or liquid products	1.2 – 60 m^3/t	0.4 – 60 m^3/t
Beer	0.32 – 1 m^3/hl	0.24 – 0.9 m^3/hl
Sugar beet	0.23[3] – 1.5 m^3/t	
Vegetable oil		
Crude oil production	0.2 – 14 m^3/t	0.2 – 14 m^3/t
Chemical neutralisation	1 – 1.5 m^3/t	1 – 1.5 m^3/t
Deodorisation	10 – 30 m^3/t	10 – 30 m^3/t
Hardening	2.2 – 7 m^3/t	
Chemical refining	0.25 – 0.8 m^3/t	14 – 35 m^3/t
Olive oil production	5 m^3/t	
Traditional extraction		2 – 5 m^3/t
Three-phase extraction		6 – 8 m^3/t
Two-phase extraction		0.33 – 0.35 m^3/t
Soft and alcoholic drinks	6 – 14 m^3/m^3	0.8 – 3.6 m^3/m^3

Table 33: *Positions where energy savings could be made and their effect*

Table 34 to Table 40 show bestpractice material and energy balances to process 1000 kg of iced fish for the de-icing and washing, grading, de-scaling, skinning, filleting, sauce filling, canning, can washing.

Inputs		Outputs	
Ice and fish	1000 kg	Fish	980 – 1000 kg
Water	1 m^3	Waste water	1 m^3
Electricity	0.8 – 1.2 kWh	COD	0.7 – 4.9 kg
		Solid waste	0 – 20 kg

Table 34: *Input and output data for de-icing and washing*

Inputs		Outputs	
Fish	1000 kg	Graded fish	980 – 1000 kg
Water	0.3 – 0.4 m^3	Waste water	0.3 – 0.4 m^3
Electricity	0.1 – 0.3 kWh	COD	0.4 – 1.7 kg
		Solid waste	0 – 20 kg

Table 35: *Input and output data for grading fish*

Inputs		Outputs	
Fish with scales	1000 kg	Scaled fish	960 – 980 kg
Water	10 – 15 m^3	Waste water	10 – 15 m^3
Electricity	0.1 – 0.3 kWh	Scales	20 – 40 kg
		Solid waste	0 – 20 kg

Table 36: *Input and output data for the scaling of white fish*

Inputs		Outputs	
Skin-on fillets	1000 kg	Skinless fillets	930 – 950 kg
Water	0.2 – 0.6 m^3	Waste water	0.2 – 0.6 m^3
Electricity	0.4 – 0.9 kWh	COD	1.7 – 5.0 kg
		Waste (skin)	~40 kg

Table 37: *Input and output data for skinning white fish*

Inputs		Outputs	
Skin-on fillets	1000 kg	Skinless fillets	930 – 950 kg
Water	0.2 – 0.6 m^3	Waste water	0.2 – 0.9 m^3
Electricity	0.2 – 0.4 kWh	COD	3 – 5 kg
		Waste (skin)	~ 40 kg

Table 38: *Input and output data for skinning oily fish*

Inputs		Outputs	
Fish bodies	1000 kg	Skin-on fillets	700 – 810 kg
Water	1 – 3 m^3	Waste water	1 – 3 m^3
Electricity	1.8 kWh	COD	4 – 12 kg
		Waste (frames and offcuts)	200 – 300 kg

Table 39: *Input and output data for filleting of de-headed white fish*

Inputs		Outputs	
Whole fish	1000 kg	Fillets	550 kg
Water	1 – 2 m^3	Waste water	1 – 2 m^3
Electricity	0.7 – 2.2 kWh	COD	7 – 15 kg
		Waste (entrails, tails, heads and frames)	~ 440 kg

Table 40: *Input and output data for filleting of un-gutted oily fish*

Table 41 to Table 45 show electricity and heat consumption benchmarks for the production of frozen vegetables (sorting, washing, peeling).

Inputs		Outputs	
Cans with fish	1000 kg	Drained cans with fish	800 – 900 kg
Electricity	0.3 kWh	Waste water	0.1 – 0.2 m³
		COD	3 - 10 kg

Table 41: *Input and output data for canning fish*

Inputs		Outputs	
Drained cans containing fish	1000 kg	Cans containing fish and sauce	1100 kg
Sauce and additives	N.A.	Waste (spillage of sauce and oil)	varies

Table 42: *Input and output data for sauce filling*

Inputs		Outputs	
Cans with fish and sauce	1000 kg	Sealed cans	1000 kg
Electricity	5 – 6 kWh		

Table 43: *Input and output data for can sealing*

Inputs		Outputs	
Sealed cans	1000 kg	Washed cans	1000 kg
Water	0.04 m³	Wastewater	0.04 m³
Electricity	7 kWh		

Table 44: *Input and output data for washing of cans*

Inputs		Outputs	
Sealed cans	1000 kg	Washed cans	1000 kg
Water	0.04 m³	Wastewater	0.04 m³
Electricity	7 kWh		

Table 44: *Input and output data for washing of cans*

Product	Electricity consumption (kWh/t) frozen vegetables
Spinach	0
Cauliflowers	1
Peas	4
Sprouts	4
Beans	5
Carrots	8

Table 45: *Electricity consumption during the sorting of vegetables*

Product	Electricity consumption (kWh/t) frozen vegetables
Sprouts	0
Cauliflowers	0
Beans	0.5
Carrots	2.5
Salsifies	3
Peas	3
Spinach	5

Table 46: *Electricity consumption for the washing of vegetables*

Energy carrier	Approximate consumption
Hot water (kWh/t frozen vegetables)	0
Steam (t/t frozen vegetables)	0.9
Steam pressure (bar)	4 – 15
Electricity (kWh/t frozen vegetables)	3.5

Table 47: *Energy carrier and consumption for the steam peeling of vegetables*

Energy carrier	Approximate consumption
Hot water (kWh/t frozen vegetables)	0
Steam (t/t frozen vegetables)	0.16
Steam pressure (bar)	7
Electricity (kWh/t frozen vegetables)	2

Table 48: *Energy carrier and consumption for the caustic peeling of vegetables*

Product	Electricity consumption (kWh/t) frozen vegetables
Peas	0
Sprouts	0
Spinach	0
Carrots (sliced)	1
Carrots (diced)	2.5
Salsifies	6
Beans	9
Peas	0

Table 49: *Electricity consumption of mechanical processing of vegetables before freezing*

Table 50 shows benchmarks for solid waste production during fruit and vegetable processing

Raw material processed	Solid waste produced per tonne of product (kg)
Maize	40
Peas	40
Potatoes	40
Strawberries	60
Apples	90
All vegetables	130
Peaches	180
Broccoli	200
Carrots	200
Frozen peaches*	200

Table 50: *Solid waste produced during fruit and vegetable processing*

** Product*

Table 51 and Table 52 show energy consumption in beet sugar and starch industry.

Total energy (kWh) consumed			
Specific value per tonne of beet processed		Specific value per tonne of sugar produced	
Average	Range	Average	Range
307	232 – 367	1987	1554 - 2379

Table 51: *Energy consumption in Danish sugar factories*

** Product*

Energy	Raw material	Min	Max
	(kWh/t raw material used)		
Electrical energy	Maize	100	200
	Wheat	200	500
	Potato	40	80
Thermal energy	Maize	200	500
	Wheat	800	1300
	Potato	50	250

Table 52: *Energy consumption in the starch industry*

9.5 Benchmarks for dairies

Table 53 to Table 55 show benchmarks for water consumption and energy consumption for dairies. The data for 1973 and 1990 allow for an assessment of the technological developments in the sector.

Water consumption (l/kg milk)		
	1973	1990
Low consumption	2.21	
Medium consumption	3.25	1.3 – 2.5
High consumption	9.44	

Table 53: *Water consumption for dairies*

Product	Electricity consumption (GJ/t product)	Fuel consumption (GJ/t product)
Market milk	0.20	0.46
Cheese	0.76	4.34
Milk powder	1.43	20.60
Butter	0.71	3.53

Table 54: *Specific energy consumption for various diary products[1]*

1 Joyce and Burgi, 1993 (based on a survey of Australian dairy processors in 1981 – 82)

Energy consumption for a selection of milk plants[1]	
Type of plant	Total energy consumption (GJ/tonne milk processed)
Modern plant with high-efficiency regenerative pasteuriser and modern boiler	0.34
Modern plant using hot water for processing	0.50
Old, steam-based plant	2.00
Range for most plants	0.5–1.2

Table 55: *Benchmarks for water, electricity and total energy consumption for dairies*

1 Joyce and Burgi, 1993. (based on a survey of Australian dairy processors in 1981–82)
Source: UNEP; Cleaner Production Assessment in dairy processing

9.6 Benchmarks for bread production

Inputs and outputs associated with industrial baking of bread are shown in the table below.[100] Data are provided per kg non-frozen bread at the factory gate without packaging. Frozen bread requires about 0.2 kWh extra electricity per kg.

		Quantity		
	Unit	Rolls 60 g	Wheat bread 175 g	Rye bread 500 g
Inputs	kg	0.7	0.7	0.2
	kg	--	--	0.5
	l	0.4	0.4	0.4
	l	1.5	1.5	1.5
	kWh	0.05	0.02	0.02
	MJ	2.0	1.0	1.0
Outputs	kg	1.0	1.0	1.0

Table 56: *Benchmarks for the production of bread*

9.7 Benchmarks for tyre manufacturing

Table 57 shows benchmarks for the production of tyres.[101]

	2004	2008
Water consuption [m³/tonne FP]	18.56	16.21
Energy consuption [GJ/tonne FP]	12.34	11.21
Solvent consuption [kg/tonne FP]	3.40	3.49
Waste [kg/tonne FP]	102.28	102.00
Recycled waste as total of waste [%]	72.20	72.41
CO2 emissions [tonnes/tonne FP]	1.01	0.92
NOX emissions [kg/tonne FP]	1.88	1.60

Table 57: *Benchmarks for tyre production*

9.8 Benchmarks for metal manufacturing

Table 58 shows the application efficiency for application of paint in painting metal surfaces.

3 bar conventional gun	30 – 50%
Airless	40 – 75%
HVLP	50 – 70%
Immersion painting	90%
Electrostatic	50 – 85%
Powder painting	98% +
NOX emissions [kg/tonne FP]	1.60

Table 58: *Application efficiency for different paint application systems*

Table 59 shows the applicability of dry machining and minimum quantity lubrication in machining metal.

Parameter	Dry	MQL	Air/gas
Material:			
Low alloy steel	√	√	√
Medium alloy steel	√	√	√
High alloy steel	#	√	#
Stainless steel	X	√	X
Cast iron	√	√	√
Nodular iron	√	√	√
Aluminium	X	√	X
Exotic materials	#	#	#
Operation:			
Turning	√	√	√
Milling	√	√	√
Drilling	√	√	√
Tapping	√	√	√
Reaming	X	√	X

Table 59: *Application of dry machining and minimum quantity lubrication*

Key:
√ Practical
 # By application
X Poor

100) source : www.lcafood.dk/processes/industry/baking.html

101) Source: www.pirelli.com/web/sustainability

Table 60 shows rinsing criteria for the design of rinsing systems in galvanising. The rinsing criterion is the dilution factor defined by the concentration of the substance to be diluted in the adhering film when taking the part out of the active bath divided by the desired final concentration after rinsing.

Degreasing	35-100
Pickling	100-200
Anodising	2000-4000
Copper	1000
Phosphatising	2000
Nickel	3000-5000
Chrome	10000+

Table 60: *Rinsing criteria in galvanising*

In stamping sheet metal, the bar between the parts should be as wide as the material is thick.

Heating steel in a furnace typically causes high losses in oil or gas fired furnaces to the exhaust gas. The heat consumption of a typical furnace is about 3000 kJ/kg. Heat recovery to preheat the combustion air and improved control can reduce this by 30%. Induction heating reduces energy requirement further to less than 2000, supra-conductive coils for induction heating to almost 1000 kJ/kg.

9.9 Kitchen, office, sanitary use

Table 61 and Table 62 show typical water consumption for kitchen operations and toilets.

Equipment	Type	Water use			Savings potential	Comments
		Traditional	Existing standard	High efficiency		
Commercial dishwashers	Under counter	1 – 1.8 gal/rack	no standard	1 gal/rack	up to 0.8 gal/rack	Machines with an overall height of less than 36“; rack of dishes remains stationary within machine during sequential wash and rinse sprays. High temp machines are most water efficient.
	Stationary single tank door	1.1 – 2.2 gal/rack	no standard	0.95 gal/rack	up to 1.2 gal/rack	Includes machines commonly referred to as pot, pan and utensil washer. Also applies to machines in which the rack revolves on an axis during the wash and rinse cycles. High temp machines are most water efficient.
	Single tank conveyor	0.7 – 1.4 gal/rack	no standard	0.7 gal/rack	up to 7 gal/rack	A single tank conveyor machine has a tank for wash water followed by a final sanitising rinse and does not have a pumped rinse tank.
	Multi tank conveyor	0.54 – 1.2 gal/rack	no standard	0.54 gal/rack	up to 0.58 gal/rack	Machines with one or more tanks for wash water and one or more tanks for pumped rinse water. Followed by a final sanitising rinse.
Pre-rinse spray valves	Handheld hose-mounted dish sprayers	2 – 5 gpm	1.6 gpm at 60 psi		0.4 – 3.4 gpm	
Commercial steam cookers	Compartment steamers	25 – 35 gal/hr	no standard	ENERGY STAR qualified cookers average 2 gal/hr	up to 33 gal/hr	

Table 61: *Benchmarks for dishwasher*

Years manufactured	Gravity tank style	Flush valve style
Pre-1977	5.0 – 7.0 gpf	4.5 – 5.0 gpf
1977 to mid 1990s	3.5 (some 5.0 gpf)	3.5 gpf
Mid 1990s	1.6 gpf maximum	1.6 gpf maximum
2003 + best in class	1.3 gpf maximum	1.3 gpf maximum

Table 62: *Typical water consumption for toilets*

Type	No. of uses per day per person		Duration per use
	Male	Female	
Shower	Varies	Varies	5 minutes
Wash basin and kitchen sinks	2.5	2.5	9 seconds

Table 63: *Typical water consumption for showers and wash basins*


Ten

Laws, regulations and standards

10.1 REACH[102]

REACH is a new European Community Regulation on chemicals and their safe use (EC 1907/2006). It focuses on the Registration, Evaluation, Authorisation and Restriction of Chemical substances. The aim of REACH is to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances.

Manufacturers and importers will be required to gather information on the properties of their chemical substances, which will allow their safe handling, and to register the information in a central database run by the European Chemicals Agency (ECHA) in Helsinki. The Regulation also calls for the progressive substitution of the most dangerous chemicals when suitable alternatives have been identified.

10.2 ROHS

The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment 2002/95/EC commonly referred to as the Restriction of Hazardous Substances Directive or RoHS, was adopted in February 2003 by the European Union. The RoHS Directive took effect on 1 July 2006. This Directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment:

1. Lead (Pb)
2. Mercury (Hg)
3. Cadmium (Cd)
4. Hexavalent chromium (Cr^{6+})
5. Polybrominated biphenyls (PBB)
6. Polybrominated diphenyl ether (PBDE)

PBB and PBDE are flame-retardants used in several plastics.

The maximum permitted concentrations are 0.1% or 1000 ppm (except for cadmium, which is limited to 0.01% or 100 ppm) by weight.

10.3 WEEE

Electronic waste, e-waste, e-scrap, or the Waste Electrical and Electronic Equipment (WEEE) Directive describes regulations concerning waste electrical or electronic devices. The processing of electronic waste in developing countries causes serious health and pollution problems because electronic equipment contains some very serious contaminants such as lead, cadmium, beryllium and brominated flame-retardants.

The Directive requires equipment manufacturers to take financial or physical responsibility for their equipment at the end of its life. Manufacturers must arrange for the ecological disposal, reuse or refurbishment of electrical and electronic waste at the end of its useful life.

102) European Commission - Environment, REACH, undated

It internalises the end-of-life costs and provides a competitive incentive for companies to design equipment that is easy to collect and to recycle. The Directive also sets goals for recycling.

10.4 Kyoto protocol

The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC). It aims at taking global action against global warming. The Protocol was adopted on 11 December 1997 in Kyoto. As of October 2009, 184 states have signed and ratified the protocol (not the United States). Under the Protocol, 37 industrialised countries agreed to reduce their collective greenhouse gas emissions by 5.2% taking the 1990 level as a reference. Emissions from international aviation and shipping are not included in the protocol.

The so-called Clean Development Mechanism (CDM) allows for partnerships between developing and industrialised countries[103]. Under the CDM, a developing country can implement emission reductions projects that can be traded or sold to industrialised countries as certified emission reduction (CER) credits.

The CDM is supervised by the CDM Executive Board (CDM EB) under the guidance of the Conference of the Parties (COP/MOP) of the United Nations Framework Convention on Climate Change (UNFCCC).

10.5 ISO 9001

The ISO 9000 family of standards represents an international consensus on good quality management practices. It consists of standards and guidelines relating to quality management systems and related supporting standards.

ISO 9001:2008 provides a set of standardised requirements for a quality management system, regardless of what the user organisation does, its size, or whether it is in the private or public sector. It is the only standard in the family against which organisations can be certified – although certification is not a compulsory requirement of the standard.

The other standards in the family cover specific aspects such as fundamentals and vocabulary, performance improvements, documentation, training, and financial and economic aspects.[104]

10.6 ISO 14001

The ISO 14000 family addresses various aspects of environmental management. The first two standards, ISO 14001:2004 and ISO 14004:2004 deal with environmental management systems (EMS). ISO 14001:2004 provides the requirements for an EMS and ISO 14004:2004 gives general EMS guidelines.

The other standards and guidelines in the family address specific environmental aspects, including: labelling, performance evaluation, life cycle analysis, communication and auditing.

An EMS meeting the requirements of ISO 14001:2004 is a management tool enabling an organisation of any size or type to:

- Identify and control the environmental impact of its activities, products or services
- Improve its environmental performance continually
- Implement a systematic approach to setting environmental objectives and targets, to achieving these and to demonstrating that they have been achieved[105]

10.7 OHSAS 18000

OHSAS 18001 has been developed to be compatible with the ISO 9001 (Quality) and ISO 14001 (Environmental) management systems standards, in order to facilitate the integration of quality, environmental and occupational health and safety management systems by organisations, should they wish to do so.

The (OHSAS) specification gives requirements for an occupational health and safety (OH&S) management system, to enable an organisation to control its OH&S risks and improve its performance. It does not state specific OH&S performance criteria, nor does it give detailed specifications for the design of a management system.[106]

103) UNFCCC, Kyoto Protocol, undated

104) ISO – International Standard Organisation, ISO 9000 essentials, 2008

105) ISO – International Standard Organisation, ISO 14000 essentials, 2004

106) OHSAS 18001 HEALTH & SAFETY STANDARD, The Health and Safety & OHSAS Guide, undated

Worksheets

This chapter contains worksheets for:

- Input/Output
- Flow analysis
- Energy analysis
- Risk assessment for hazardous materials
- Evaluation of options
- Resource Efficiency programme
- PRE-SME report template

Worksheets here illustrated are also included as templates in the electronic resource-kit under the *tools folder* which can be downloaded and filled-in accordingly

Eleven

Worksheet 1: Main products/services

Company: **Responsible:** **Page:**

No.	Product or service/purpose	Annual quantity	Unit
1			
2			
3			
4			
5			
6			
7			
8			

Worksheet 2: Main raw and processed materials

Company: **Responsible:** **Page:**

No.	Material	Annual quantity	Unit	Specific costs in	Total costs in	Purpose/use	% incorporated into the product
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Worksheet 3: Energy data

Company: **Responsible:** **Page:**

No.	Energy		Annual amount	Unit	Spec. costs	Conversion into kWh	Consumption in kWh	Share in%	Total costs in ….	Share in%
1	Electricity			kWh						
	Peak load			kW						
2	District heating			GJ		x 277.8				
	Peak load			kW						
3	Oil			kg		x 11.4				
4	Gas			Nm^3		x 10.0				
5	[107]…………									
6	…………									
7	…………									
8	…………									
9	Fuels:	Diesel		Litre		x 10.0				
		Petrol		Litre		x 9.0				
10	…………									
	Total:							100%		100%

107) Other energy sources such as: coal, liquid gas, wood, pellets, solar energy, etc.

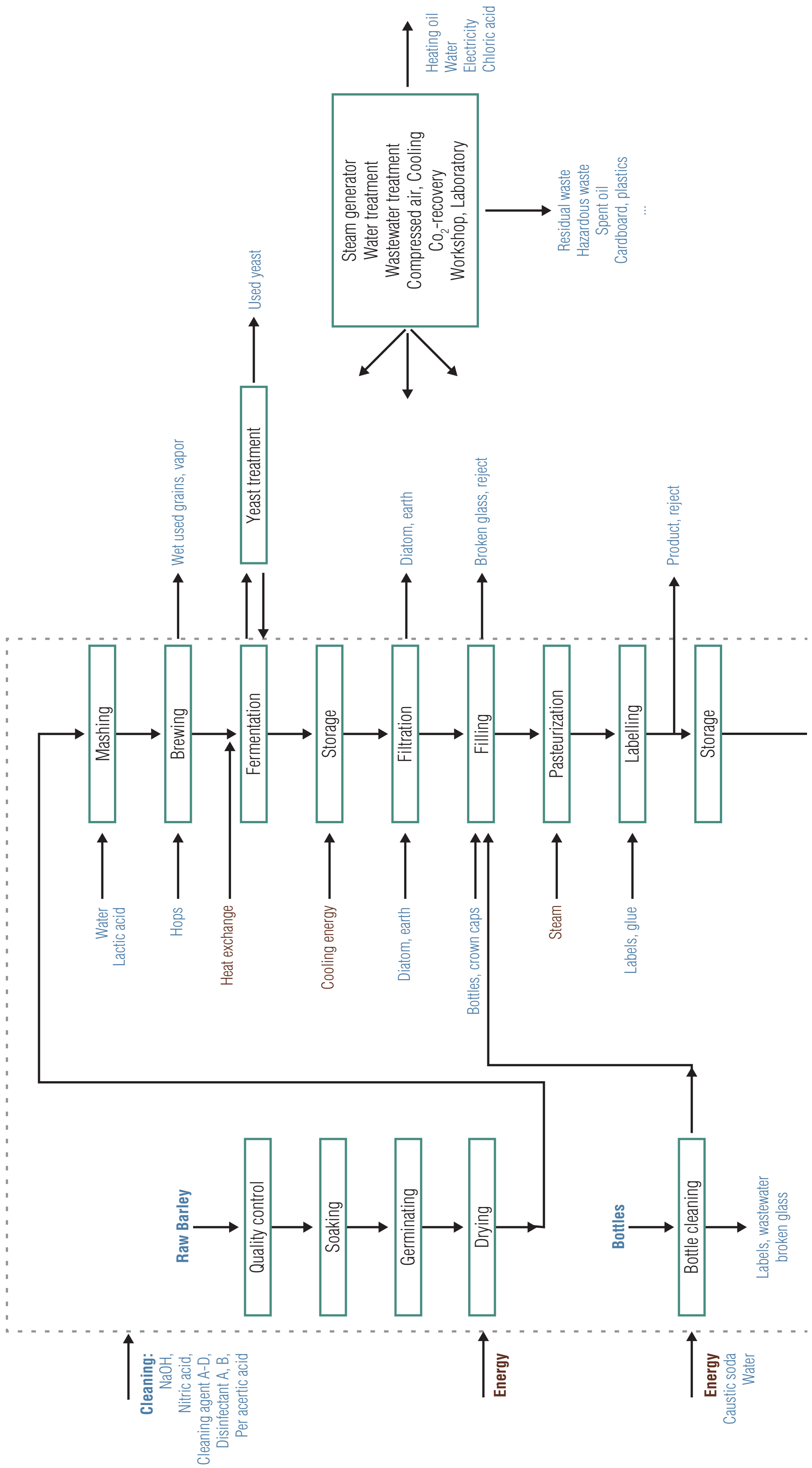
Worksheet 4: Main types of waste and emissions

Company: **Responsible:** **Page:**

No.	Waste or liquid or gaseous emissions	Annual quantity	Unit	Specific disposal costs	Purchasing costs	Disposal costs	Total costs
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Worksheet 5: Flowchart (example)

No.: 3 **For:** Production process **Company:** Cheers Beers Ltd



Empty worksheets:
Worksheet 6: Energy consumers

Company: **Period:**

No.	Consumer – use	Year of construction	Power in kW	Operating hours per year	Consumption (kWh/y)	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
	Total: Percentage of total consumption:					

Worksheet 7: Register of hazardous materials

Company: **Period:**

No.	SDS.[108]	Product name	Use	Hazardous ingredient(s)	Classification according to GHS	Container volume	Maximum of quantity stored	Storage area
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

108) SDS = safety data sheet

Worksheet 8: Evaluation of risk potential, definition of measures

Company: **Period:**

Workplace:	Product(s):
Department:	Hazardous substances:
Responsible:	Material number:
Potential risks:	
Possible consequences:	Employees: Plant/equipment/machinery: Environment:

1. Dangerous situation/behaviour:	Risk	Probability		
	Danger	Improbable	Possible	Frequent
	Minor	A		
	Medium		B	
2. Available safety precautions:	High			C
3. Options to improve the situation, proposed measures:	A: Situation acceptable B: Situation could be improved C: Action urgently required			

Worksheet 9: Risk assessment sheet

Directions for Worksheet 9

1) Complete the basic information requested at the top of the worksheet
2) Record identified hazards in Column 2 of the RISK ASSESSMENT SHEET
   For each identified hazard:
   - Record classification according to GHS in Column 3
   - Record preventive/protective measures used to limit the risks arising from a hazard in Column 4
   - Record the results of risk assessment (e. g., high/unacceptable) in Column 5
   - Record actions planned to reduce the risks in Column 6

Company name and address:			Risk assessment carried out by:		Date: ____
Workplace (designation of the workplace):			Name of employee (name of person working at the workplace):		
No.	Hazard	Classification	Prevention/protective measures used	Risk estimation/ evaluation	Actions planned to reduce risk
1	2	3	4	5	6

Worksheet 10: Evaluation of options

Company: ______________________

General evaluation									
Positive (y/n)									
	Payback time [a]								
	Annual savings								
	Annual cost of operation, maintenance, ...								
Financial feasibility	Investment cost								
Positive (y/n)									
	Less waste								
	Less water consumption								
	Less hazardous materials								
Ecological feasibility	Less energy consumption								
Positive (y/n)									
	Operators will be able to run equipment								
	Infrastructure (electricity, heat, water if applicable) is in place								
Technical feasibility	Space is available								
Descrip-tion of option									
Option Nr.									

Worksheet 11: Resource Efficiency programme

Company:

No.	Activity	Responsible	Date	Investment – resources	Benefit (environmental, economic, etc.)	Checked
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Worksheet 12: PRE-SME Report template

Promoting Resource Efficiency in Small and Medium Sized Enterprises (SMEs)
Template for the Development of a Resource Efficiency Improvement Programme in SMEs

Company's name:	
1. Profile of the company: describe the general profile of the company including year of establishment, start-up capital (registered capital), production capacity, total number of workers, annual turnover (at the start and current; use national currency, indicate exchange rate to US$), physical location of the industry (industrial/residential, environmental sensitivity, etc.).	
Type of activity (sector, industry or service) and ownership (state or private owned)	
Year of establishment	
Start-up capital	
Production capacity (by types of product)	
Total number of workers	
Annual turnover - start-up	
Annual turnover - last business year (if available, last three years)	
Physical location (industrial/residential, types of neighbouring facilities (hospitals, schools, markets, natural reserves); resulting limitations; evaluation of environmental sensitivity (water consumption, potential impact on drinking water, impact on agriculture, chemicals, noise, dust, smell, social impact etc.)	

2. Products description

Type of product	% of total product	% of material input (local/foreign)	Produced for local/export market

3. Process description: Describe the key steps of the production process. Reference your material flow diagram (on a separate full page), clearly indicating the specific inputs and outputs from each stage and the potential hazards and accidents associated within your production process.

Selected focus area:

4. Process review: Identify the specific thematic issues related to the key steps of the process for the main product and determine their relative importance for improvement. *(Please use the relevant checklists from your handouts in undertaking the thematic reviews)*					
Unit operations	Energy by sources (renewable and non-renewable)	Water (by sources)	Materials	Chemicals (with highlight on hazardous)	Waste (liquid, solid and air emissions)
UO-1					
UO-2					
UO-3					
UO-4					
UO-5					
At this stage you may determine the specific area (process step and/or thematic area) you would like to focus on for the initial intervention that will improve environmental performance and/or increase resources utilisation and/or reduce risks.					

5. Detailed assessment and benchmarking: conduct the required input/output analysis and benchmark your industry's performance against the sector's average performance values. *(Please use the relevant calculation tools and benchmarking information for this section)*: please insert in each cell three numbers: - Your actual consumption (AC) - The global average consumption (GA) - The possible target (PT)[109]					
Unit operations	Energy by sources (renewable and non-renewable) [kWh/unit]	Water (by sources) [m³/unit]	Materials [kg/unit]	Chemicals (with emphasis on hazardous) [kg or m³/unit]	Waste (liquid, solid and air emissions) [kg or m³/unit]
UO-1					
UO-2					
UO-3					
UO-4					
UO-5					

109) This needs to be defined as a moving target taking into consideration the existing gap between the current consumption and the global average and the possibilities for organisational and technological improvement.

6. Improvement options: based on the outcome from the preview and detailed assessment identify all possible measures and options that could be considered for improving the Resource Efficiency of the factory.
6.1 Organisational: this covers factors that have direct bearing on the efficiency of the factory, including factors such as production planning, working procedures, training of personnel, etc
6.2 Product specifications and design: covering aspects related to changing the specification and/or design of a product in order to have a better yield with the same or improved functionality.
6.3 Materials acquisition and management: covering possible changes that could be made on the material selection procurement and handling of inputs required for the production process.
6.4 Process control and modifications: this covers the specific improvements that could be made in controlling the relevant process parameters and the related modifications that could be made to improve the efficiency of the industry.
6.5 Technology substitution: this covers the specific areas where there is a need to invest in acquisition of new technologies in order to address significant bottlenecks for moving towards a higher Resource Efficiency level.
6.6 Safer production and accident prevention: covering the specific areas and practices where actions need to be taken to promote safer production and prevent or reduce the potential for industrial accident. (You may wish to refer to UNEP's toolkit on responsible production)

7. Options analysis: Analyse generated options from the perspective of required resource input, and the possible results and outcomes to be obtained. Please insert here the results of feasibility analysis only for 'high' cost (feasibility study for two technical options, which are considered most practical). No detailed analysis for no/low cost options is required.
7.1. Economic cost and benefit analysis: calculate the possible payback period of each option based on the investment it requires and the direct economic return it generates (simple payback calculation).
7.2. Tangible and intangible benefits: identify other tangible and intangible benefits that could be obtained from the implementation of one option or a combination of options.
7.3. Thematic complementarities: analyse the specific complementarities between the different thematic interventions with a focus on identifying the positive influence of action taken in one thematic area resulting in improvement in another area and vice versa, (thematic complementarities are also known as synergy).
8. Implementation plan: develop an implementation plan taking into consideration the outcome from the option analysis.
8.1 Short-term: This covers an improvement option that can be implemented immediately or in a short period of time with zero or minor costs (also known as 'low-hanging fruit').
8.2 Medium-term: this covers options that may require some level of organisational preparation or investment, which also involves going through different stages of planning and budgeting.
8.3 Long-term: these are options that are aimed at making some basic changes in the technological base of the production process and which may require more long-term investment decisions. Options under this category usually provide a good basis for rehabilitation and expansion programmes.

9. Review and monitoring mechanism: this covers the allocation of specific responsibilities for implementations, performance indicators for reviewing implementation and monitoring, and a reporting schedule for the programme implementation.		
10. Adjust and redefine: this covers the mechanism for adjusting and revising set goals and targets as per the findings of the review and monitoring, and defining the specific focus for the next cycle of improvement. Describe briefly (five lines) what will remain in the company from the project and which activities will be continued and the Resource Efficiency management system elements (responsibilities for periodic data collection, monitoring, analysis, identification of improvement options, targets and indicators) used.		
Team Leader:	Members of the team	Date:
	1: 2: 3: 4:	

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Twelve

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12.2 Websites

UNEP homepage
UNEP works to promote Resource Efficiency and sustainable consumption and production in both developed and developing countries. The focus is on achieving increased understanding and implementation by public and private decision makers of policies and actions for Resource Efficiency and sustainable consumption and production.
http://www.unep.org/resourceefficiency/

UNIDO homepage
UNIDO is the specialized agency of the United Nations that promotes industrial development for poverty reduction, inclusive globalization and environmental sustainability.
www.unido.org

Envirowise homepage
Envirowise offers free, independent support to your business helping businesses to become more resource efficient and save money. Since 1994, Envirowise has helped UK industry save more than £1 billion by reducing waste early on in their business processes.
http://www.envirowise.gov.uk/

UK EEBPP - UK Energy Efficiency Best Practice Programme
The Energy Efficiency Best Practice Programme (EEBPP) is the UK Government's principal energy efficiency information, advice and research programme for organisations in the public and private sectors.
http://www.energy-efficiency.gov.uk

Cleaner Production
A comprehensive information portal providing case studies, resources and links to the German environmental technologies and environmental services.
www.cleanerproduction.de/en/

PIUS
This website has been illustrating operational experiences of procedures, technology and tried and tested measures online since April 2001. This substantiated information and experience comes from results of consultation and projects in Germany in the area of Cleaner Production/ sustainable economy, which were carried out in cooperation with companies, service providers, associations, chambers and public offices.
www.pius-info.de/en/

Energy Manager Training
The Government of India and Federal Ministry of Economic Cooperation and Development (BMZ) of the Government of Germany jointly finance the Indo-German Energy Programme (IGEN). The Bureau of Energy Efficiency (BEE) and the German Development Cooperation GTZ are charged with implementation. The Programme is the major contributor to the implementation of the Energy Conservation Act of India. This Website is the portal for all energy managers and energy auditors, which will be empowered by the Energy Conservation Act.
http://www.energymanagertraining.com/

Industrial Technologies Program Energy Efficiency and Renewable Energy U.S. Department of Energy
The Industrial Technologies Program (ITP) leads national efforts to improve industrial energy efficiency and environmental performance. ITP is part of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy and contributes to its efforts by partnering with U.S. industry in a coordinated program of research and development, validation, and dissemination of energy efficiency technologies and operating practices.
www.eere.energy.gov/industry

Action Energy
Action Energy is a programme run by the Carbon Trust and funded by the Department for Environment, Food and Rural Affairs, the Scottish Executive, Invest Northern Ireland and the National Assembly for Wales.
www.actionenergy.org.uk

Wikipedia
Free information on almost everything
www.wikipedia.com

National Cleaner Production Centres
Ethiopia
Website of the Ethiopian Cleaner Production Centre
http://www.ecpc.org.et

Vietnam
Website of the Vietnamese Cleaner Production Centre
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US-EPA
The Pollution Prevention Information Clearinghouse (PPIC) is a free information service of the U.S. EPA dedicated to reducing and eliminating industrial pollutants through technology transfer, source reduction, education and public awareness.
http://www.epa.gov/oppt/ppic/

International Labour Organisation – health and safety
Its goal is to ensure that workers and everyone concerned with their protection have access to the facts they need to prevent occupational injuries and diseases.
http://www.ilo.org/public/english/protection/safework/cis/index.htm

Norway - NORAD
http://www.norad.no/en/

Denmark - DANIDA
http://www.danidadevforum.um.dk/en

Switzerland – SECO
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Engineering calculations

Thirteen

13.1 Unit Conversions

APPROXIMATE CONVERSIONS FROM STANDARD/US CUSTOMARY UNITS TO SI/METRIC UNITS (Scroll down for conversions from metric to standard measurements)				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	square millimetres	mm^2
ft^2	square feet	0.093	square metres	m^2
yd^2	square yard	0.836	square metres	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometres	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft3	cubic feet	0.028	cubic metres	m^3
yd^3	cubic yards	0.765	cubic metres	m^3
mi^2	square miles	2.59	square kilometres	km^2
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE		
^oF	Fahrenheit	(F-32) x 5 / 9 or (F-32) / 1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	pound force	4.45	newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft3	cubic feet	0.028	cubic metres	m^3
yd^3	cubic yards	0.765	cubic metres	m^3
mi^2	square miles	2.59	square kilometres	km^2

APPROXIMATE CONVERSIONS FROM SI/METRIC UNITS TO STANDARD/US CUSTOMARY UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres	0.0016	square inches	in^2
m^2	square metres	10.764	square feet	ft^2
m^2	square metres	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometres	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	cubic metres	35.314	cubic feet	ft^3
m^3	cubic metres	1.307	cubic yards	yd^3
mi^2	square miles	2.59	square kilometers	km^2
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2000 lb)	T
TEMPERATURE				
^oC	Celsius	1.8C + 32	Fahrenheit	^oF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	pound force	lbf
kPa	kilopascals	0.145	pound force per square inch	lbf/in^2

13.2 Steam Tables of Water

Absolute pressure	Boiling point	Specific volume (steam)	Density (steam)	Specific enthalpy of liquid water (sensible heat)		Specific enthalpy of steam (total heat)		Latent heat of vaporisation		Specific heat
(bar)	(oC)	(m3/kg)	(kg/m3)	(kJ/kg)	(kcal/kg)	(kJ/kg)	(kcal/kg)	(kJ/kg)	(kcal/kg)	(kJ/kg)
0.02	17.51	67.006	0.015	73.45	17.54	2533.64	605.15	2460.19	587.61	1.8644
0.03	24.10	45.667	0.022	101.00	24.12	2545.64	608.02	2444.65	583.89	1.8694
0.04	28.98	34.802	0.029	121.41	29.00	2554.51	610.13	2433.10	581.14	1.8736
0.05	32.90	28.194	0.035	137.77	32.91	2561.59	611.83	2423.82	578.92	1.8774
0.06	36.18	23.741	0.042	151.50	36.19	2567.51	613.24	2416.01	577.05	1.8808
0.07	39.02	20.531	0.049	163.38	39.02	2572.62	614.46	2409.24	575.44	1.8840
0.08	41.53	18.105	0.055	173.87	41.53	2577.11	615.53	2403.25	574.01	1.8871
0.09	43.79	16.204	0.062	183.28	43.78	2581.14	616.49	2397.85	572.72	1.8899
0.1	45.83	14.675	0.068	191.84	45.82	2584.78	617.36	2392.94	571.54	1.8927
0.2	60.09	7.650	0.131	251.46	60.06	2609.86	623.35	2358.40	563.30	1.9156
0.3	69.13	5.229	0.191	289.31	69.10	2625.43	627.07	2336.13	557.97	1.9343
0.4	75.89	3.993	0.250	317.65	75.87	2636.88	629.81	2319.23	553.94	1.9506
0.5	81.35	3.240	0.309	340.57	81.34	2645.99	631.98	2305.42	550.64	1.9654
0.6	85.95	2.732	0.366	359.93	85.97	2653.57	633.79	2293.64	547.83	1.9790
0.7	89.96	2.365	0.423	376.77	89.99	2660.07	635.35	2283.30	545.36	1.9919
0.8	93.51	2.087	0.479	391.73	93.56	2665.77	636.71	2274.05	543.15	2.0040
0.9	96.71	1.869	0.535	405.21	96.78	2670.85	637.92	2265.65	541.14	2.0156
1	99.63	1.694	0.590	417.51	99.72	2675.43	639.02	2257.92	539.30	2.0267
1.1	102.32	1.549	0.645	428.84	102.43	2679.61	640.01	2250.76	537.59	2.0373
1.2	104.81	1.428	0.700	439.36	104.94	2683.44	640.93	2244.08	535.99	2.0476
1.3	107.13	1.325	0.755	449.19	107.29	2686.98	641.77	2237.79	534.49	2.0576
1.4	109.32	1.236	0.809	458.42	109.49	2690.28	642.56	2231.86	533.07	2.0673
1.5	111.37	1.159	0.863	467.13	111.57	2693.36	643.30	2226.23	531.73	2.0768
1.5	111.37	1.159	0.863	467.13	111.57	2693.36	643.30	2226.23	531.73	2.0768
1.6	113.32	1.091	0.916	475.38	113.54	2696.25	643.99	2220.87	530.45	2.0860
1.7	115.17	1.031	0.970	483.22	115.42	2698.97	644.64	2215.75	529.22	2.0950
1.8	116.93	0.977	1.023	490.70	117.20	2701.54	645.25	2210.84	528.05	2.1037
1.9	118.62	0.929	1.076	497.85	118.91	2703.98	645.83	2206.13	526.92	2.1124
2	120.23	0.885	1.129	504.71	120.55	2706.29	646.39	2201.59	525.84	2.1208
2.2	123.27	0.810	1.235	517.63	123.63	2710.60	647.42	2192.98	523.78	2.1372
2.4	126.09	0.746	1.340	529.64	126.50	2714.55	648.36	2184.91	521.86	2.1531
2.6	128.73	0.693	1.444	540.88	129.19	2718.17	649.22	2177.30	520.04	2.1685
2.8	131.20	0.646	1.548	551.45	131.71	2721.54	650.03	2170.08	518.32	2.1835
3	133.54	0.606	1.651	561.44	134.10	2724.66	650.77	2163.22	516.68	2.1981
3.5	138.87	0.524	1.908	584.28	139.55	2731.63	652.44	2147.35	512.89	2.2331
4	143.63	0.462	2.163	604.68	144.43	2737.63	653.87	2132.95	509.45	2.2664
4.5	147.92	0.414	2.417	623.17	148.84	2742.88	655.13	2119.71	506.29	2.2983
5	151.85	0.375	2.669	640.12	152.89	2747.54	656.24	2107.42	503.35	2.3289
5.5	155.47	0.342	2.920	655.81	156.64	2751.70	657.23	2095.90	500.60	2.3585
6	158.84	0.315	3.170	670.43	160.13	2755.46	658.13	2085.03	498.00	2.3873

Absolute pressure	Boiling point	Specific volume (steam)	Density (steam)	Specific enthalpy of liquid water (sensible heat)		Specific enthalpy of steam (total heat)		Latent heat of vaporisation		Specific heat
(bar)	(oC)	(m3/kg)	(kg/m3)	(kJ/kg)	(kcal/kg)	(kJ/kg)	(kcal/kg)	(kJ/kg)	(kcal/kg)	(kJ/kg)
6.5	161.99	0.292	3.419	684.14	163.40	2758.87	658.94	2074.73	495.54	2.4152
7	164.96	0.273	3.667	697.07	166.49	2761.98	659.69	2064.92	493.20	2.4424
7.5	167.76	0.255	3.915	709.30	169.41	2764.84	660.37	2055.53	490.96	2.4690
8	170.42	0.240	4.162	720.94	172.19	2767.46	661.00	2046.53	488.80	2.4951
8.5	172.94	0.227	4.409	732.03	174.84	2769.89	661.58	2037.86	486.73	2.5206
9	175.36	0.215	4.655	742.64	177.38	2772.13	662.11	2029.49	484.74	2.5456
9.5	177.67	0.204	4.901	752.82	179.81	2774.22	662.61	2021.40	482.80	2.5702
10	179.88	0.194	5.147	762.60	182.14	2776.16	663.07	2013.56	480.93	2.5944
11	184.06	0.177	5.638	781.11	186.57	2779.66	663.91	1998.55	477.35	2.6418
12	187.96	0.163	6.127	798.42	190.70	2782.73	664.64	1984.31	473.94	2.6878
13	191.60	0.151	6.617	814.68	194.58	2785.42	665.29	1970.73	470.70	2.7327
14	195.04	0.141	7.106	830.05	198.26	2787.79	665.85	1957.73	467.60	2.7767
15	198.28	0.132	7.596	844.64	201.74	2789.88	666.35	1945.24	464.61	2.8197
16	201.37	0.124	8.085	858.54	205.06	2791.73	666.79	1933.19	461.74	2.8620
17	204.30	0.117	8.575	871.82	208.23	2793.37	667.18	1921.55	458.95	2.9036
18	207.11	0.110	9.065	884.55	211.27	2794.81	667.53	1910.27	456.26	2.9445
19	209.79	0.105	9.556	896.78	214.19	2796.09	667.83	1899.31	453.64	2.9849
20	212.37	0.100	10.047	908.56	217.01	2797.21	668.10	1888.65	451.10	3.0248
21	214.85	0.095	10.539	919.93	219.72	2798.18	668.33	1878.25	448.61	3.0643
22	217.24	0.091	11.032	930.92	222.35	2799.03	668.54	1868.11	446.19	3.1034
23	219.55	0.087	11.525	941.57	224.89	2799.77	668.71	1858.20	443.82	3.1421
24	221.78	0.083	12.020	951.90	227.36	2800.39	668.86	1848.49	441.50	3.1805
25	223.94	0.080	12.515	961.93	229.75	2800.91	668.99	1838.98	439.23	3.2187
26	226.03	0.077	13.012	971.69	232.08	2801.35	669.09	1829.66	437.01	3.2567
27	228.06	0.074	13.509	981.19	234.35	2801.69	669.17	1820.50	434.82	3.2944
28	230.04	0.071	14.008	990.46	236.57	2801.96	669.24	1811.50	432.67	3.3320
29	231.96	0.069	14.508	999.50	238.73	2802.15	669.28	1802.65	430.56	3.3695
30	233.84	0.067	15.009	1008.33	240.84	2802.27	669.31	1793.94	428.48	3.4069

Example - Boiling Water at 100°C, 0 bar Atmospheric Pressure
At atmospheric pressure (0 bar g, absolute 1 bar), water boils at 100°C, and 417.51 kJ of energy are required to heat 1 kg of water from 0°C to its evaporating temperature of 100°C.

Therefore the specific enthalpy of water at 0 bar g (absolute 1 bar) and 100°C is 417.51 kJ/kg, as shown in the table.

Another 2257.92 kJ of energy are required to evaporate 1 kg of water at 100°C into 1 kg of steam at 100°C. Therefore at 0 bar g (absolute 1 bar) the specific enthalpy of evaporation is 2257.19 kJ/kg, as shown in the table.

Total specific enthalpy for steam:
hs = (417.51 kJ/kg) + (2257.92 kJ/kg) = 2675.43 kJ/kg

Example - Boiling Water at 170°C, 7 bar Atmospheric Pressure
Steam at atmospheric pressure is of a limited practical use because it cannot be conveyed under its own pressure along a steam pipe to the point of use.

At 7 bar g (absolute 8 bar), the saturation temperature of water is 170.42°C. More heat energy is required to raise its temperature to saturation point at 7 bar g than would be needed if the water were at atmospheric pressure. The table gives a value of 720.94 kJ to raise 1 kg of water from 0°C to its saturation temperature of 170°C.

The heat energy (enthalpy of evaporation) needed by the water at 7 bar g to change it into steam is actually less than the heat energy required at atmospheric pressure. This is because the specific enthalpy of evaporation decreases as the steam pressure increases. The evaporation heat is 2046.53 kJ/kg as shown in the table.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

- **The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

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In many developing countries, small and medium enterprises (SMEs) are the backbone of economic and industrial activity, contributing to approximately 75% of industrial activity. With increasing resource prices and expanding environmental market demands, continuous improvement of the efficient use of energy, water, materials, and the safe management and use of chemicals, will increasingly become key factors in determining the competitiveness and sustainability of global industrial markets. SMEs operating under limited technical and institutional capacities require support to overcome these challenges and to continue to contribute to their national economies. The challenges of SMEs in developing countries are further compounded by the lack of technical capacities necessary to provide support services to these industries. Over the years, UNEP and UNIDO have been working to overcome this challenge by promoting the establishment of National Cleaner Production Centres (NCPCs) and by developing cleaner production tools and techniques that industries can customise and implement.

The PRE-SME Resource Kit builds upon the lessons and experiences from the cleaner production activities and presents a comprehensive technical resource kit that could serve as a basis for the development and implementation of an integrated and continuous Resource Efficiency programme in SMEs. The Resource Kit is primarily targeted to NCPCs and Technical Support Institutions involved in promoting Resource Efficient and Cleaner Production (RECP) in Developing and Transition Economies. The Kit also provides SMEs' executive level management with the rational for implementing more resource efficient operations as well as a management tool for setting-up an industrial Resource Efficient implementation plan . Furthermore, a detailed step-by-step guide is included for SME's production and technical managers, focusing on key areas for the development and implementation of a Resource Efficiency improvement programme. The Kit is designed to be accessible, interactive, and can be customised to fit individual and site-specific needs for the maximum benefit of each SME. Users are very much encouraged to make use of the material in the Kit by repackaging the information provided in response to the specific case of application.

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