GREEN TRANSITION
Implementing Industrial Emissions Directive in Serbia

IED SERBIA

GUIDELINES FOR THE APPLICATION OF BEST AVAILABLE TECHNIQUES
IN ACCORDANCE WITH THE REQUIREMENTS OF THE INDUSTRIAL EMISSIONS DIRECTIVE

IMPLEMENTATION OF BEST AVAILABLE TECHNIQUES IN SURFACE TREATMENT USING ORGANIC SOLVENTS WITH A SPECIAL FOCUS ON FLEXOPRINTING, PRINTING METAL PACKAGING, COIL AND WOOD COATING

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Belgrade, May 2024

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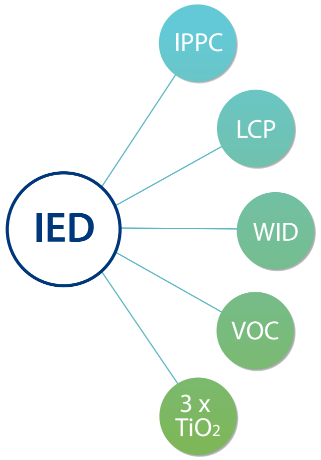
GLOSSARY

BAT	Best Available Techniques
BAT-AEL	BAT Associated Emission Levels
BAT-AEPL	BAT Associated Environmental Performance Levels
BATC	BAT Conclusions
BREF	Best Available Techniques Reference Document
ELV	Emission Limit Value
EMS	Environmental Management System
EN	European norm
Flexo	Flexo printing
H-phrases	Hazard phrases
IPA	Isopropyl alcohol, isopropanol
ISO	International standardisation organisation
MSDS	Material safety data sheet
OTNOC	Other than normal operating conditions
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RTO	Regenerative Thermal Oxidiser
SMB	Solvent Mass Balance
STS	Surface Treatment Using Organic Solvents
TO	Thermal Oxidiser
TOC	Total Organic Carbon
TVOC	Total Volatile Organic Compounds
VOC	Volatile Organic Compounds

INTRODUCTORY REMARKS

Industrial Emissions Directive (IED)



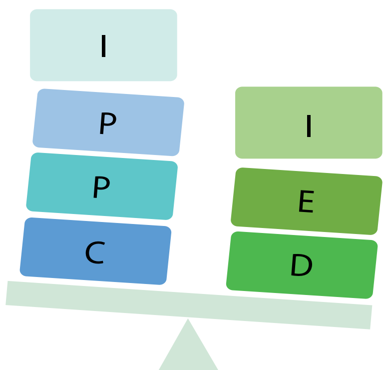
The Industrial Emissions Directive (2010/75/EU) is the main EU instrument regulating pollutant emissions from industrial installations that have harmful effect on human health and the environment, in particular through the better application of Best Available Techniques (BAT).

The decision of the European Commission on the revision of the legislation on industrial emissions led to the preparation of the Industrial Emissions Directive, which replaced seven separate existing directives, namely:

- Integrated Pollution Prevention and Control (IPPC) Directive;
- Large Combustion Plants (LCP) Directive;
- Waste Incineration Directive (WID);
- Directive on reducing emissions of Volatile Organic Compounds (VOCs);
- Three existing directives on titanium dioxide (TiO_2).

The IED established a stricter approach to the application of Best Available Techniques, as BAT Associated Emission Levels are considered a condition that must be met within the integrated permit, and are prescribed in the documents derived from the BREF documents, the so-called BAT Conclusions (BATC). BAT conclusions are the final evaluations of Best Available Techniques. They determine the reference points used to set permit conditions for installations covered by the IED[1]. The Industrial Emissions Directive (IED) has not yet been fully transposed into the legislation of the Republic of Serbia, and this process is ongoing.

Integrated Pollution Prevention and Control (IPPC)



The European Union (EU) defines the obligations and conditions that operators of industrial activities with a high pollution potential must comply with. It establishes an integrated permitting procedure for these activities and sets minimum requirements to be included therein, particularly in terms of pollutants released into water, air, and soil. The aim is to regulate emissions to air, water, and soil, generation of waste, use of raw materials, energy efficiency, noise, prevention of accidents, and restoration of the site upon closure. The permit conditions including emission limit values (ELV) must be based on the Best Available Techniques (BAT). The definition of BAT and the BAT-associated environmental performance at the EU level is coordinated by the European IPPC Bureau at the EU Joint Research Centre in Seville (Spain).

[1] https://www.sepa.org.uk/

This process of exchanging information with experts from Member States, industry, and environmental organisations results in producing Best Available Techniques Reference Documents (so-called BREF documents). The majority of BREFs cover specific industrial activities and such BREFs are referred to as "sectoral BREFs". However, there is also a number of "horizontal BREFs" dealing with cross-cutting issues such as energy efficiency, industrial cooling systems or emissions from storages.

The Integrated Pollution Prevention and Control (IPPC) Directive (2008/1/EC), a part of the Industrial Emissions Directive, was transposed into the Republic of Serbia's legislation in 2004 through the Law on Integrated Pollution Prevention and Control ("Official Gazette of RS", no. 135 of December 21, 2004; 25 of March 13, 2015; and 109 of November 19, 2021) and connected bylaws.

The objective of this document

The bases for this document are the two following publications:

- Best Available Techniques Reference Document on Surface Treatment Using Organic Solvents[2]
- Best available techniques conclusions[3]

These BAT conclusions pertain to the activities specified in Annex I to Directive 2010/75/EU, 6.7: Surface treatment of substances, objects, or products using organic solvents, for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with an organic solvent consumption capacity of more than 150 kg per hour or more than 200 tonnes per year.

This brochure focuses on activities that are considered strategic in Serbia: flexoprinting, coating of coils, printing metal packaging, and coating of wood surfaces. Its primary goal is to provide technical support to competent authorities and operators from this sector for the selection and assessment of the most effective and appropriate techniques in order to secure the full implementation of the IPPC concept.

PROCESS DESCRIPTIONS, ENVIRONMENTAL ASPECTS AND RELEVANT CONTROL TECHNIQUES

Coil Coating

According to the EN-10169-1:2010, a coil coating is defined as "a process in which an (organic) coating material is applied on a rolled metal strip in a continuous process which includes cleaning, if necessary, and chemical pre-treatment of the metal surface and either one-side or two-side, single or multiple application of (liquid) paints or coating powders which are subsequently cured or/and laminating with permanent plastic films". The substrate is normally either cold-rolled, zinc- or zinc-alloy-coated steel (75%) or aluminium (25%) expressed as a percentage of the surface area. Of the coatings, 95% consist of paints and 5% of plastic laminates.

[2] Best Available Techniques (BAT) Reference Document on Surface Treatment Using Organic Solvents including Preservation of Wood and Wood Products with Chemicals, 2020

[3] COMMISSION IMPLEMENTING DECISION (EU) 2020/2009 of 22 June 2020 establishing the best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions, for surface treatment using organic solvents including preservation of wood and wood products with chemicals

Pre-painted sheet metal products are widely used in various industries such as building and construction, consumer products, the automotive industry, furniture, lighting, consumer packaging, etc.

A coil coating line coats both sides of a metallic substrate with either paint or laminate or both. One side is coated with a primer and topcoat, which provides the aesthetic and functional performance of the product; the reverse side is coated with a primer and/or backing coat. Materials that are used in organic coil coating processes are metallic substrates (i.e., steel, zinc-coated steel, aluminium, etc.), paint, solvents, cleaning, and pre-treatment chemicals, engineering oils, (demineralised) water, and others: biocides, grease, cleaning materials. The flowchart diagram of a modern coating line, along with possible VOC inputs and outputs, is presented in Figure 1. As it can be seen, the main VOC outputs arise from cleaning, washing, chemical pretreatment, and drying processes.

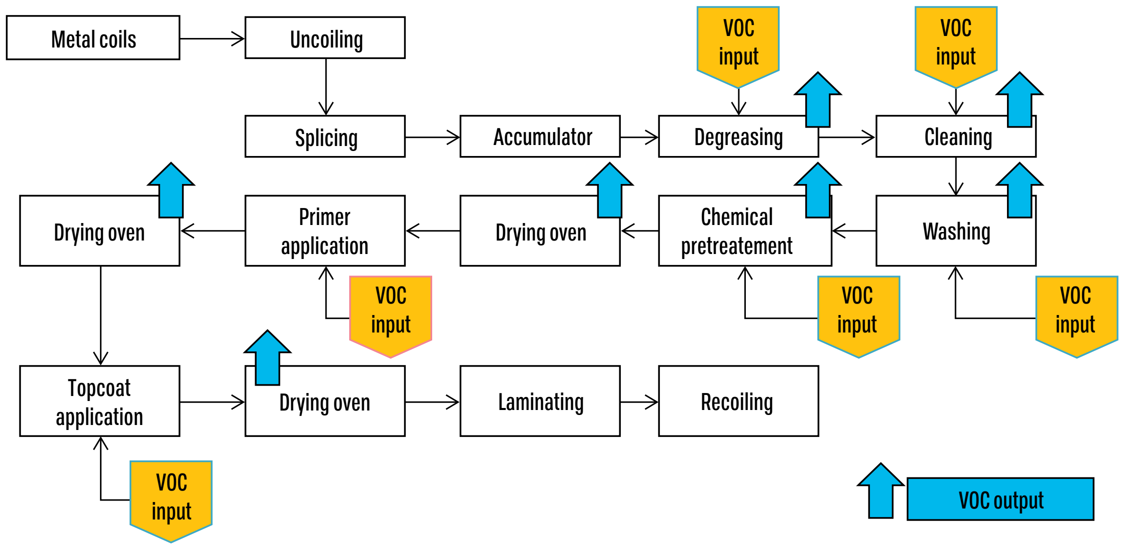


Figure 1: Flowchart for coil coating[4]

Coating and Printing of Metal Packaging

Metal packaging is manufactured from steel and aluminium, and is commonly referred to as cans, components and drums used for food and beverage processing, product protection and storage, and transport facilitating. This kind of packaging is used for a wide range of different products, such as food and beverages, dairy products, paint, cosmetics, pharmaceuticals, chemicals, mineral oils, etc.

Metal packaging has a variety of different manufacturing techniques but it can be summarised primarily into whether the container is formed first and then the coating and printing process application is carried out on the finished shape or whether coating and printing is performed on flat sheets before assembly into finished products. The finished shape process is usually called coating and printing in the round and this covers industrial drums, beer and beverage cans and some aerosol containers. Coating and printing on flat sheets are the older process that covers a wider range of products.

The example of producing a two-piece food can, along with the main VOC inputs/outputs, is presented in Figure 2. As it can be seen, the main VOC outputs arise from external coating and decoration, internal can protection, and curing. The metal-forming operations use a water-based synthetic coolant which is removed in the can washer in a reverse cascade arrangement, while the water is filtered, treated and reused. External coating, decoration and curing are followed by other steps which also include internal can protection, and curing. The emissions of the curing process are collected and exhausted by fans to the atmosphere or to abatement equipment.

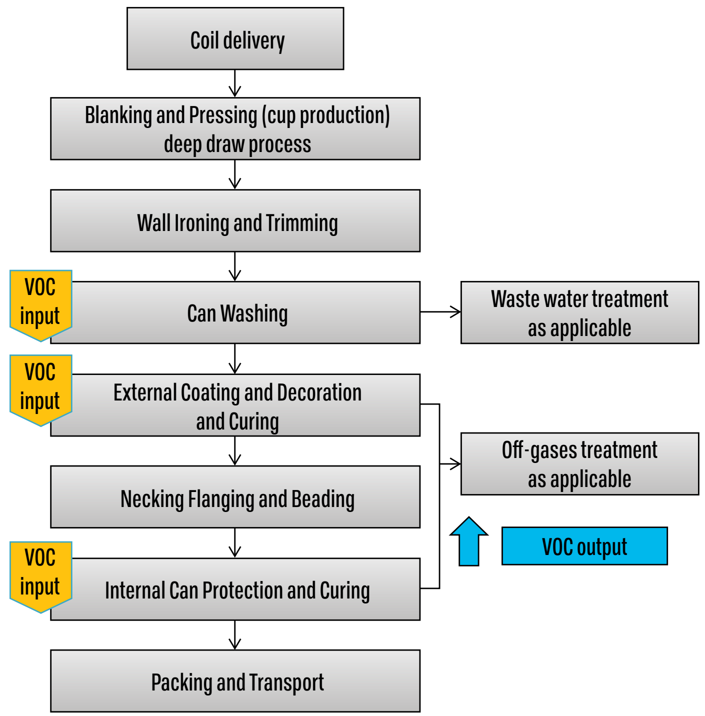


Figure 2: Flowchart for the production of a two-piece food can[5]

[4] http://processflowsheets.blogspot.com/2011/08/coil-coating-process-flow-sheet.html

[5] https://eippcb.jrc.ec.europa.eu/sites/default/files/2021-06/jrc122816_sts_2020_final.pdf

Flexography and Non-Publication Rotogravure Printing

Typical products printed using flexography include brown corrugated boxes, flexible packaging including retail and shopping bags, food and hygiene bags and sacks, milk and beverage cartons, flexible plastics, self-adhesive labels, disposable cups and containers, envelopes and wallpaper.

Flexographic printing uses the process of direct rotary printing with elastic, raised printing forms (Figure 3). The printing plates are mounted on plate cylinders with different circumferences. The non-printing areas are recessed and are not coloured. The printing elements are raised in relief and printed against a counter-pressure cylinder.

The low-viscosity ink is transferred to the printing cylinder. This can be done either in "squeezing mode" or in "squeegee mode". In squeezing mode, the dosage of the ink quantity is controlled by varying the contact pressure between two transfer rollers. Newer machines are largely equipped with paint chamber squeegees (also called doctor blades), where the dosage of the transferred amount of paint is carried out by the adjustment of a blade (Figure 4).

Figure 3: Flexography printing process

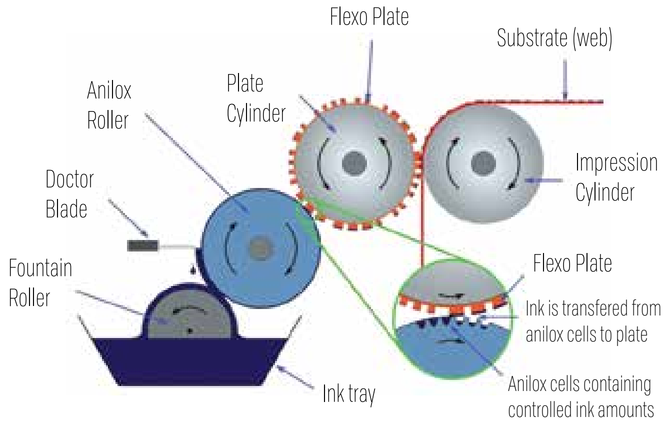


Figure 4: Working principle of a flexography printing machine[6]

VOC emissions occur in the following process stages:

- Ink supply and conditioning
- Printing
- Machine cleaning
- Solvent distillation if a distillation unit is present
- Paint drying
- Processing

[6] https://commons.wikimedia.org/wiki/File:Flexographic_printing_diagram.svg

Coating of Wooden Surfaces

Wooden surfaces are coated in order to preserve or strengthen the colour, surface structure and/or porosity. The coating is applied to provide resistance against: chemical impacts, mechanical stress, climatic impacts, and staining. Currently, the wood and furniture industry faces new market requirements, as complicated product geometry and higher qualities (e.g. colour variety, new surface effects) are demanded. To meet these expanding requirements, spray application techniques are increasingly being utilised.

Materials in the wood and furniture industry are processed and coated for various applications, including exterior and interior construction, commercial and public uses like schools, and domestic settings including wet applications such as swimming pool decking, saunas, kitchens, and bathrooms.

The process of applying coating materials to wooden surfaces involves several steps, as illustrated in Figure 5, which also highlights the main VOC inputs and outputs. The main processes which are potential VOC sources are: pretreatment of the wooden surface, application of a base coat, application of a topcoat, application of the paint and flash-off and drying/curing.

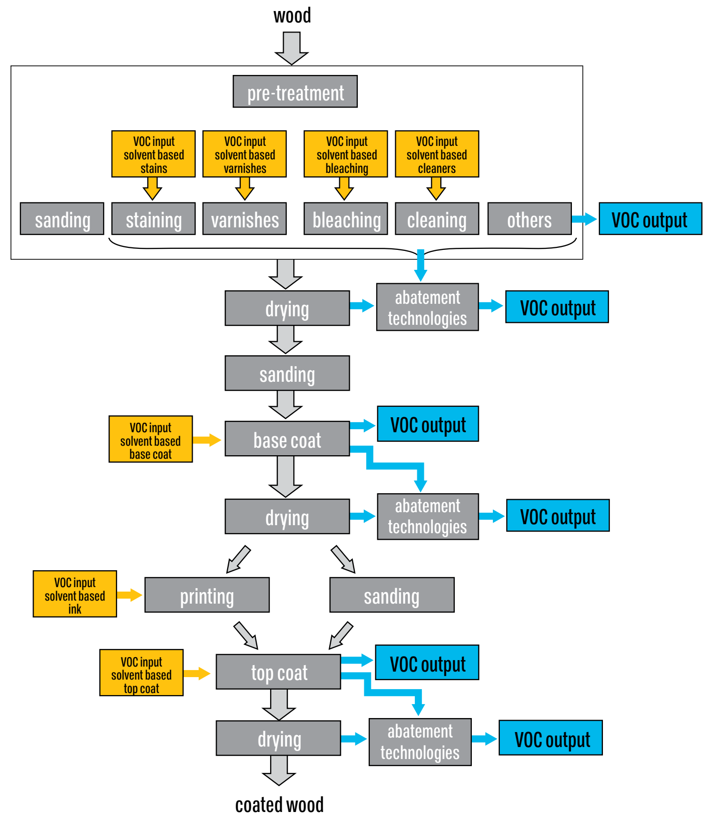


Figure 5: Wood coating process along with VOC inputs/outputs[7]

[7] http://processflowsheets.blogspot.com/2011/08/coil-coating-process-flow-sheet.html

Most Important BATs for Selected Activities

As mentioned above, the Best Available Techniques for this sector are defined by the BAT Conclusions (BATC), which is a document that identifies the best available techniques, their description, information to assess their applicability, emission levels related to the best available techniques (BAT-AELs), accompanying monitoring, associated consumption levels and, where appropriate, relevant site remediation measures. The European Commission adopted BATC STS in 2020.

This document identifies 54 Best Available Techniques and it is divided into 2 parts. The first part, from BAT 1 to BAT 29, covers the following plants for surface treatment of materials, objects, or products using organic solvents:

- printing (heatset web offset printing, flexography, rotogravure for packaging, and rotogravure for publications);
- painting and other coating activities (of wire threads, cars, trucks, buses, trains, agricultural and construction equipment, ships and yachts, airplanes, wood and mirrors, furniture, sheets, metal packaging and other metal, and plastic goods);
- application of glue (in the production of abrasives and adhesive tapes);
- cleaning and degreasing in combination with other surface treatment activities.

The second part, from BAT 30 to BAT 54, covers plants for preservation of wood and wood products with chemicals; this sector is not the object of this brochure.

The 29 techniques identified for surface treatment of materials comprehend 23 general BATs, referred to different environmental aspects, and 6 specific for every different sector treated by BAT Conclusions. The organisation of the document is described in Figure 6.

This brochure doesn't describe all the techniques applicable to surface treatment of materials, objects, or products using organic solvents; it includes a selection of the most significant and important for the companies operating in this field. Complete information about applicable best available techniques can be found in the BAT Conclusions document.

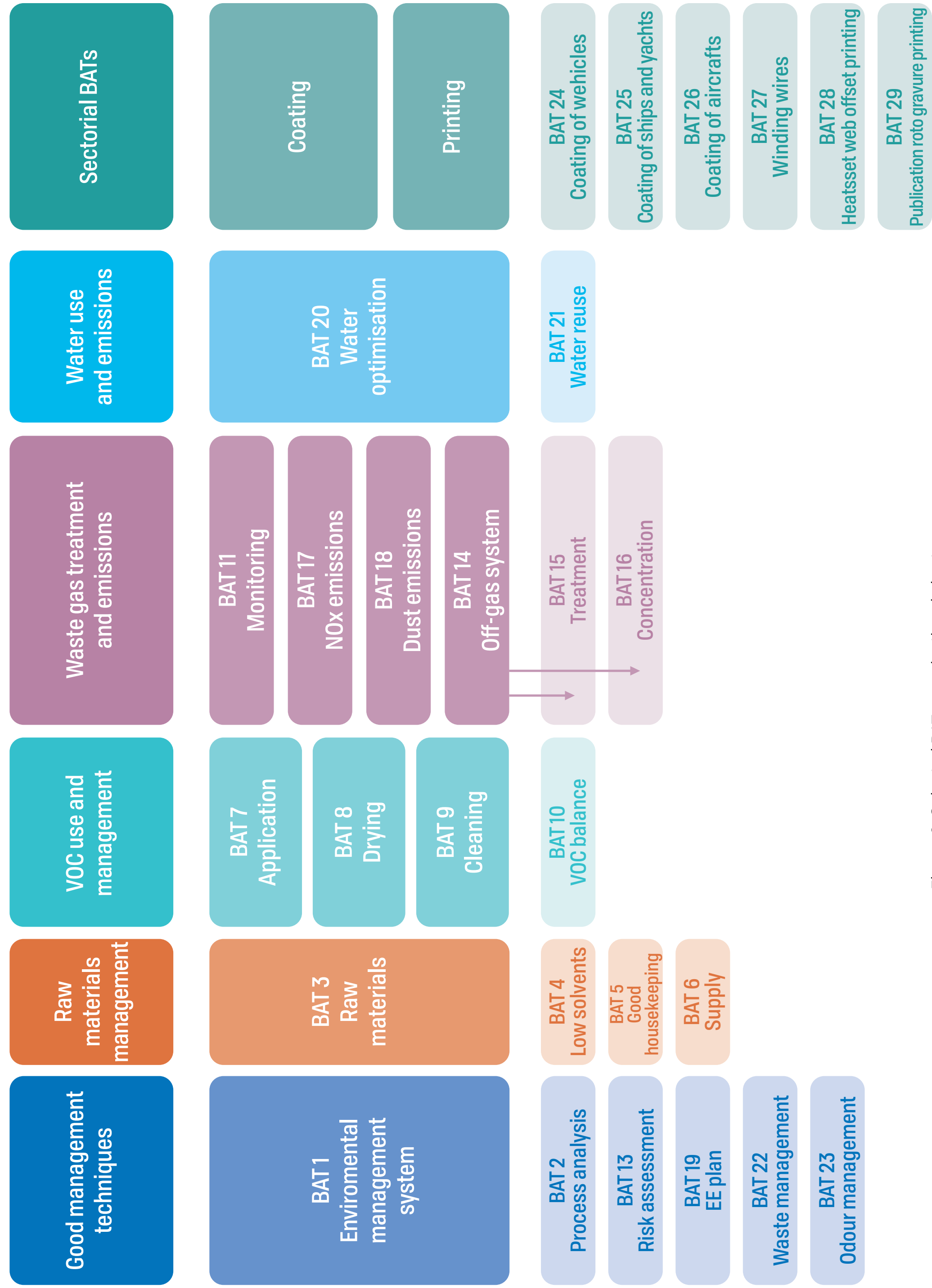


Figure 6: Selected BAT organisational chart

BAT 1. In order to improve the overall environmental performance, BAT is to elaborate and implement an Environmental Management System (EMS)

An EMS is a set of processes and practices that follow a repeating cycle. The organisation commits to an environmental policy and then uses its policy as a basis for establishing a plan, which sets objectives and targets for improving environmental performance. Consequently, the organisation evaluates its environmental aspects and impacts to check if it meets objectives and targets. In case of non-compliance, corrective action is taken. The results of this evaluation are summarized in a report to top management. Management revisits the environmental policy and sets new targets in a revised plan. The cycle repeats, and continuous improvement occurs. The most commonly used framework for an EMS is the ISO 14001 standard, but also EMAS registration [8] is promoted at EU level.

BAT 2. To improve the overall environmental performance of the plant, concerning VOC emissions and energy consumption, BAT is

- to identify the process stages/sections/steps that represent the greatest contribution to the VOC emissions and energy consumption and have the greatest potential for improvement;
- identify and implement actions to minimise VOC emissions and energy consumption;
- regularly (at least once every year) update the situation and follow up the implementation of the identified actions.

This can be achieved most effectively by developing annual solvent mass (BAT 10) and energy (BAT 19) balances for the plant. These balances provide a breakdown of organic solvent and energy consumption in the plant on an annual basis and allow for the setting of key performance indicators for the activity [9].

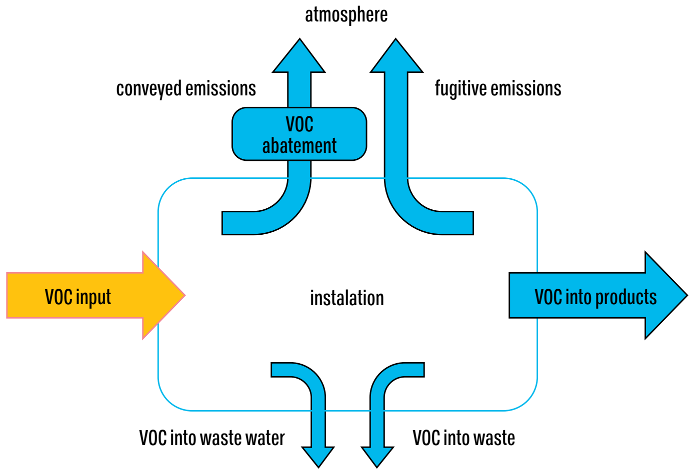


Figure 7: Principle of a solvent mass balance

[8] EU webpage on EMAS Registration https://europa.eu/youreurope/business/running-business/developing-business/emas-registration/index_en.htm
[9] as defined in Part 7(2) of Annex VII to Directive 2010/75/EU

The outputs of organic solvents in the waste gas and as fugitive emissions are more difficult to determine than other emissions, such as in water. However, not all solvents emitted to water can be accurately measured, because for some no monitoring method is available. Emissions are determined by a mass balance, referred to as a solvent mass balance (SMB). SMB provides information for the solvent management plan which includes objectives, responsibilities, processes, and control measures. Figure 7 shows the principle of a solvent mass balance, detailed description of the methodology can be found in BAT 10.

BAT 3. In order to prevent or reduce the environmental impact of the raw materials used, BAT is to use raw materials with low environmental impact and optimise the use of organic solvents in the production process

Taking into consideration the product quality requirements or specifications, systematically evaluate the adverse environmental impacts of the substances used, especially those that are carcinogenic, mutagenic, and toxic to reproduction, as well as substances of very high concern. Where possible, consider their substitution by others with no or lower environmental and health impacts.

To evaluate materials, check their material safety data sheets (MSDS) for carcinogenic, mutagenic, and toxic properties. The European Printing Ink Association's policy provides concrete guidance [10], banning substances characterised by hazard statements H300, H310, H330, H340, H350, H360, H370. The supplier of a chemical/solvent is obligated to provide an MSDS in accordance with the requirements of the REACH Regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals).

BAT 4. In order to reduce solvent consumption, VOC emissions and the overall environmental impact of the raw materials used, BAT is to use one or a combination of the techniques given below (types of paints and adhesives)

- use of high-solids-solvent-based inks
- use of water-based inks

The use of paints, coatings, liquid inks, varnishes, and adhesives containing a low amount of solvents and increased solids content is necessary. Risks regarding workers´ health and the environment can be reduced by using inks, cleaning agents, and adhesives that contain a lower percentage of VOCs. Another option is the use of paints, coatings, liquid inks, varnishes, and adhesives where organic solvent is partially replaced by water. At present, printing with water-based inks is mainly feasible for absorbent, porous printing materials such as paper and cardboard. Further options include the use of paints, coatings, liquid inks, varnishes, and adhesives suitable to be cured by the activation of specific chemical groups by UV or IR radiation. High-volatility VOC substances need to be replaced with others containing organic compounds that are non-VOCs or VOCs of a lower volatility (e.g., esters).

On-site solvent recovery, which reduces the consumed quantity in comparison to the ink input is usually only relevant in the field of cleaning agents. If recovery plants are used, one can assume that the solvent consumption quantities are reduced by 50%, in special cases up to 100%.

[10] https://www.eupia.org/wp-content/uploads/2022/09/20210310_Exclusion_Policy_for_Printing_Inks_and_Related_Products_final_March_2021.pdf

BAT 5. In order to prevent or reduce fugitive VOC emissions during storage and handling of solvent-containing materials and/or hazardous materials, BAT is to apply the principles of good housekeeping.

VOC mitigation techniques include:

- sealing containers;
- minimisation of storage;
- leak prevention;
- overflow prevention;
- capture of VOC vapour;
- spill containment;
- containment of cleaning solvents and cleaning cloths.

Recording chemical purchases and disposal can help to keep a minimum inventory. For example, hazardous waste can be minimised by labelling inks with the date and having a "first-in, first-out" rule. By keeping all cans, drums, and open ink fountains covered, printers can reduce odours and worker health risk concerns by minimizing uncaptured VOC emissions.

BAT 6. In order to reduce raw material consumption and VOC emissions, BAT is to use one or a combination of the techniques given below:

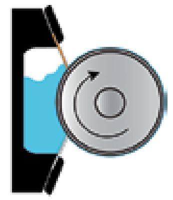
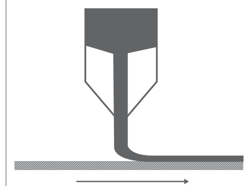
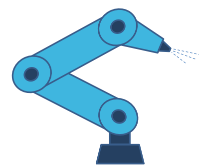
- advanced computer-controlled mixing equipment;
- centralised supply;
- automation of colour change;
- colour grouping;
- supply of VOC at point of application.

Computer software and dedicated equipment help printers blend ink, reduce surplus ink, and reuse press return ink. By running lighter jobs before darker jobs, printers can reduce the number of clean-ups.
VOC-containing materials (e.g., inks, coatings, adhesives, cleaning agents) should be supplied to the application area by direct piping with ring lines, including system cleaning such as pig cleaning or air flushing.

Figure 8: Computerised ink mixing system[11]

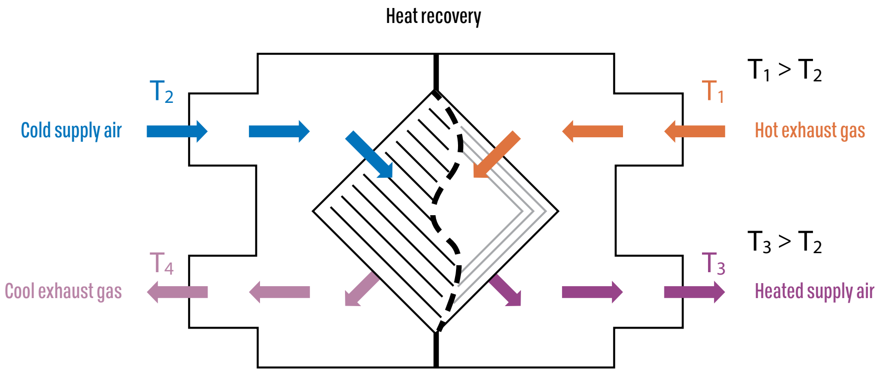
[11] https://www.inkmaker.com/solution-details/12/PICCOLO.html

BAT 7. In order to reduce raw material consumption and the overall environmental impact of the coating application processes, BAT is to use one or a combination of the techniques given below:

No	Technique	Description	Applicability	Benefit
a)	Doctor blade over roller 	Use enclosed doctor blade chambers where rollers are used to transfer or meter the liquid coating onto a moving strip of material.	Applicable to flat substrates, e.g., in flexographic printing.	- Reduces ink evaporation; - Results in better usage of ink and more consistent colour; - Minimises worker exposure to hazardous chemicals.
b)	Curtain coating (casting) 	Work-pieces are passed through a laminar film of coating discharged from a header tank.	Applicable to flat substrates.	- Optimises material consumption. Material efficiencies up to 90-98% can be achieved.
c)	Flooding	The work-pieces are transported via conveyor systems into a closed channel, which is then flooded with the coating material via injection tubes. The excess material is collected and reused.	Generally applicable. Especially suitable for large workpieces with a large surface area and winding wire.	- Optimises material consumption. Material efficiencies up to 95-99% can be achieved.
d)	High-volume low- pressure (HVLP) atomisation	Atomisation of paint in a spray nozzle by mixing paint with high volumes of air with a low pressure (max. 1,7 bar).	Generally applicable to spraying techniques.	- HVLP guns have a paint transfer efficiency of > 50%.
e)	Machine/robot application 	Use of paint machines for the handling of the spray-head/spray gun/nozzle, or robot application of coatings and sealants to internal and external surfaces.	Generally applicable.	- Optimises material consumption; - Minimises overspray and waste generation; - Ensures consistent quality.

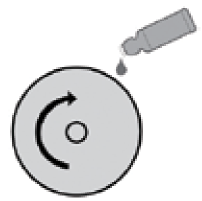
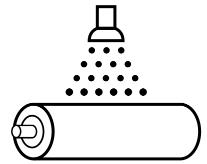
BAT 8. In order to reduce energy consumption and the overall environmental impact from drying/curing processes, BAT is to use one or a combination of the following techniques:

No	Technique	Description	Applicability	Benefit
a)	Induction drying/curing	Online thermal curing or drying by electromagnetic inductors that generate heat inside the metallic work-piece by an oscillating magnetic field.	Only applicable to metal substrates.	- No local emissions from fossil fuel use.
b)	Radiation curing	Radiation curing is applied based on resins and reactive diluents (monomers) which react on exposure to radiation (infrared (IR), ultraviolet (UV)), or high-energy electron beams (EB).	Only applicable to specific coatings and inks. Worker health and safety has to be considered.	- Lower energy consumption; - Little floor space requirement.
c)	Combined convection and infrared radiation drying		Generally applicable.	- Infrared drying speeds up drying times, and improves print quality.
d)	Convection drying combined with heat recovery		Generally applicable.	- Saving 70% of cost of hot air-dry energy can be achieved by exhaust heat recovery with a heat pump and a high efficiency inverter.



Ilustracija 9: Povrat toplote iz ispusta

BAT 9. In order to reduce VOC emissions from cleaning processes, BAT is to minimise the use of solvent-based cleaning agents and to use a combination of the following techniques:

No	Technique	Description	Applicability	Benefit
a)	Use of low-volatility cleaning agents 	Application of low-volatility solvents as cleaning agents, for manual or automated cleaning, with high cleaning power.	Types of material and contamination have to be considered.	- Reduced emissions to air during cleaning, storage of used solvents; - Reduced hazardous waste generation; - Lower risk of soil contamination from solvent-enriched air.
b)	Water-based cleaning 	Water-based detergents or water-miscible solvents such as alcohols or glycols are used for cleaning.	Types of material and contamination have to be considered.	- Reduced solvent consumption and fugitive VOC emissions.
c)	Enclosed washing machines	Automatic batch cleaning /degreasing of press/ machine parts in enclosed washing machines using either: (a) organic solvents (with air extraction followed by VOC abatement and / or recovery of the used solvents); or (b) VOC-free solvents; or (c) alkaline cleaners (with external or internal waste water treatment).	Types of material and contamination have to be considered.	- Reduced solvent emissions.
d)	Purging with solvent recovery	Collection, storage and, if possible, reuse of the solvents used to purge the guns/applicators and lines between colour changes.	Types of material and contamination have to be considered.	- Solvents can be recovered for reuse.

No	Technique	Description	Applicability	Benefit
e)	Cleaning with high-pressure water spray	High-pressure water spray and sodium bicarbonate systems or similar are used for automatic batch cleaning of press/ machine parts.	Types of material and contamination have to be considered.	- Reduced solvent emissions.
f)	Ultrasonic cleaning	Cleaning in a liquid using high-frequency vibrations to loosen the adhered contamination.	Types of material and contamination have to be considered. Increases energy consumption.	- Eliminated or significantly reduced VOC emissions.
g)	Dry ice (CO_2) cleaning	Cleaning of machinery parts and metallic or plastic substrates by blasting with CO_2 chips or snow.	Types of material and contamination have to be considered. Long preparation times.	- No VOC emissions.
h)	Plastic shot-blast cleaning	Excess paint build-up is removed from panel jigs and body carriers by shot-blasting with plastic particles.	Types of material and contamination have to be considered.	- Harmful chemicals are not used; - Reduces cleaning costs by 50%; - Extends life of production equipment and tools; - Minimises scrap plastic painted parts.

If cleaning is done manually, a multi-stage cleaning procedure for the printing decks can reduce solvent consumption. Typically, in such a procedure pre-used solvent is used in the first stage to remove most of the ink, while the clean solvent is used in the last stage, to remove any remaining ink.

Alternatively, in the case of an ink washing system on the anilox, after clearing up the ink from the system, the cleaning agent is added and recirculated in the ink supplying system[12]. In this way, the dry foreign substance in the anilox cells will be dissolved and cleaned thoroughly by circulating water. The other way is to apply the anilox surface with acid and alkaline chemical solution.

[12] https://www.linkedin.com/pulse/flexo-anilox-cleaning-maintenance-hailun-yao/

BAT 10. BAT is to monitor total and fugitive VOC emissions by compiling, at least once every year, a solvent mass balance of the solvent inputs and outputs of the plant.

In line with BAT 2, the procedure to calculate a solvent mass balance (SMB) is presented.

The annual solvent mass balance is elaborated every year for the previous year and should be retained as evidence for two years. According to Serbian Regulation[13], VOC operators should regularly submit the annual solvent mass balance data to the Environmental Protection Agency. The form that the operators fill in and submit to the Agency, which is in the form of an Excel spreadsheet (VOC Regulation form) is available on the Agency's website.

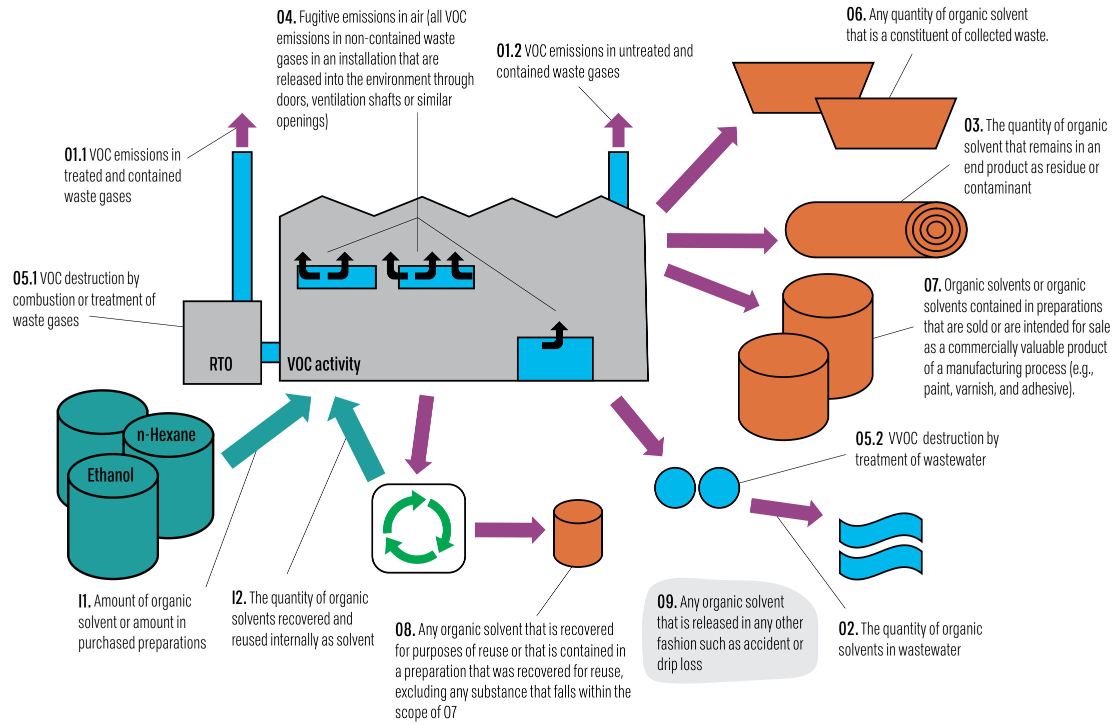


Figure 10: Solvent Mass Balance calculation

The solvent mass balance follows the simple principle of a balance between inputs and outputs. It covers the total annual solvent input and output for an installation. However, not all of these quantities are relevant for the production of coatings, varnishes, inks, and adhesives.

[13] Regulation on the list of installations using VOC https://www.ekologija.gov.rs/dokumenta/zastita-vazduha-i-ozonskog-omotaca/uredbe

$$\underbrace{I1 + I2}_{\text{Total input}} = \underbrace{O1.1 + O1.2 + O2 + O3 + O4 + O5 + O6 + O7 + O8 + O9}_{\text{Total output}}$$

Using the solvent mass balance Fugitive emissions can be calculated:

$$F = I1 - O1.1 - O5 - O6 - O7 - O8$$

As well as Total emissions:

$$E = F + O1.1 \rightarrow E = I1 - O5 - O6 - O7 - O8$$

These values are required to check the compliance with BAT-AEL defined by BATC for each type of production, as reported in Table 1 of this document.

Additional information and detail explanation of the solvent mass balance calculation can be found at https://evocs.org/.

BAT 11. BAT is to monitor emissions in waste gases with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

TVOC needs to be measured for any stack with a TVOC load less than 10 kg C/h, according to EN 12619 once every year (BAT 14, BAT 15). For any stack with a TVOC load ≥ 10 kg C/h, continuous measurement is required according to EN standards EN15267-1, EN15267-2, EN15267-3, and EN 14181. NO_X from thermal treatment of off-gases is to be monitored according to EN 14792 once every year (BAT 17). CO from thermal treatment of off-gases is to be measured according to EN 15058 once every year (BAT 17). If the TVOC load of a stack is less than 0,1 kg C/h, the monitoring frequency can be reduced to once every 3 years.

BAT 14. In order to reduce VOC emissions from the production and storage areas, BAT is to use an off-gas system.

An efficient off-gas system needs to be designed properly to collect VOC containing off-gases as close as possible to the emission source with full or partial enclosure of solvent application areas. It has also to include other points of emissions, like raw material storage, dryers, cooling zones, and the areas where machine parts and equipment are cleaned with organic solvents, either by hand or automatically. The following priorities shall be considered for the system selection:

- segregation of off-gases with high and low VOC concentrations;
- techniques to homogenise and increase the VOC concentration (BAT 16);
- techniques for the recovery of solvents in off-gases (BAT 15);
- VOC abatement techniques with heat recovery (BAT 15);
- VOC abatement techniques without heat recovery (BAT 15).

BAT 15. In order to reduce VOC emissions in waste gases and increase resource efficiency, BAT is to use condensation, carbon adsorption, zeolite adsorption, liquid absorption, thermal treatment, or biological off-gas treatment.

Thermal oxidation system

Thermal oxidation refers to the oxidation process of VOCs by heating off-gases with air or oxygen above their autoignition point in a combustion chamber and maintaining it at a high temperature long enough to complete the combustion of VOCs to carbon dioxide and water.

The classic thermal oxidation system is comprised of a fibre or refractory-lined combustion chamber, within which the oxidation temperature of at least 700°C is maintained by either a primary or secondary air burner, depending on the required degree of control. The system requires the use of auxiliary fuel, but its thermal efficiency can be optimised by recuperative heat exchangers, integrated or separate, achieving up to 75% efficiency. The recovered energy can be used to preheat the exhaust air at the inlet of an oxidiser, as well as for additional steam generation or heating of process air, heat transfer oil, or hot water.

Regenerative-thermal afterburning

Regenerative-thermal oxidiser (RTO) is an oxidiser with multiple beds (three to five) filled with ceramic packing (heat storage media). These beds act as heat exchangers and are alternately heated by waste gases from oxidation that passes through them. Once the bed is heated, the flow of gas is reversed and the bed is used to preheat the inlet air to the oxidiser. The exothermic energy released during the oxidation of the pollutants is thus used to heat the inlet gases, reducing the need for additional heating by primary energy sources. Due to this internal regenerative heat exchange, the system is highly energy-efficient, with thermal efficiencies of up to 97% and more being possible.

The system includes an auxiliary burner, however, autothermal operation is achievable with VOC concentrations above 1-2 g/Nm^3.

Catalytic oxidation

Catalytic oxidation refers to oxidation of VOCs assisted by a suitable catalyst to reduce the oxidation temperature, and reduce the fuel consumption. Typically, combustion reactions start at 250°C to 300°C and autothermal operation is possible from a pollutant concentration of 3-5 g/Nm^3 in the exhaust air. Exhaust heat can be recovered with recuperative or regenerative types of heat exchangers.

Solvent recovery

Solvent recovery generally involves the capture and recovery of solvents in off-gases using techniques such as condensation, carbon or zeolite adsorption and liquid absorption for further reuse. Depending on the further use, captured solvents often have to be purified in an additional process like distillation. Using only one type of solvent optimise the recovery process, increasing the possibility to re-use the recovered product.

Condensation is a technique for removing VOCs from off-gases by reducing the temperature of gas in a cooling unit below the VOC dew point, causing the VOC vapours to liquefy. Depending on the required operating temperature range, different refrigerants such as cooling water, chilled water, ammonia or propane are used.

In an adsorption process, VOCs in the off-gas are captured on the surface of activated carbon, zeolites or carbon fibre paper. The captured VOCs are subsequently desorbed, e.g., with steam (often on site), for reuse or disposal and the adsorbent is reused. For continuous operation, typically more than two adsorbers are operated in parallel, one of them in desorption mode. Each adsorber remains in the adsorption phase if the outgoing TOC concentration complies with the pre-established limit; when this value is reached, the saturated adsorber is placed in the regeneration (desorption) phase. Using an analyser to monitor TOC concentration automatically optimises plant operation, activating regeneration only when the limit is reached at the stack. Adsorption is also commonly used as a concentration step in combination with other techniques.

In general, solvent recovery can reduce solvent makeup to a minimum. The proportion of the recovered solvents which is not reusable in house and which needs to be sold, depends largely on the ratio between the amounts of solvents that are used in the production process. This ratio, in turn, depends on the processes in use and the products that are made. Generally, where one of the solvents makes over 90% of the total, the reusable amount may be such that the plant becomes almost self-sufficient and no longer needs to buy that solvent for dilution purposes. An example of such a plant exists in Austria.

Each of the presented techniques is most efficient and most suitable for a specific range of off-gas flow rate and VOC content. Which technique or combination of the techniques will be selected to treat VOC emissions depends on factors like off-gas flow rate, VOC content, type of VOC, environmental and health and safety requirements, as well as size of investment and operating costs.

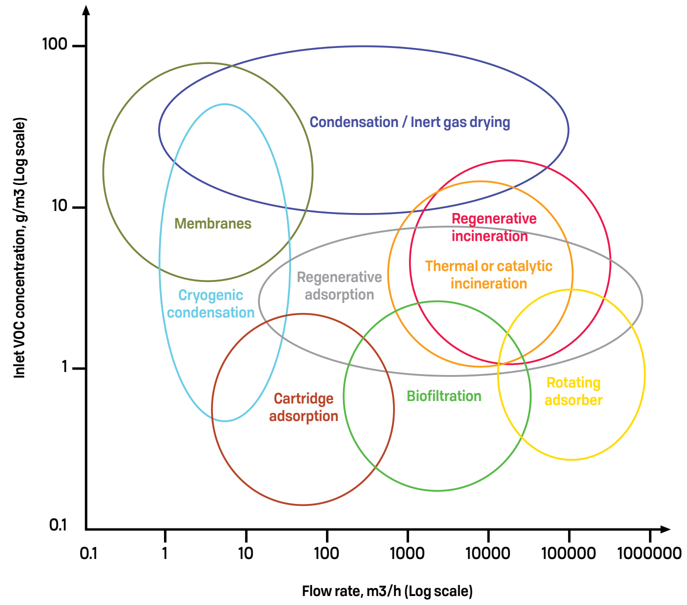


Figure 11: Overview of application ranges of the available VOC abatement technologies

An overview of estimated required investments and average operating costs for the selected techniques is presented in the table below.

Technique	Investment cost	Operating cost	Viability
Regenerative thermal oxidation	Minimum €200,000 for a capacity between zero and 10,000 m^3/h, plus €10 to €15 for each additional m^3/h above 10,000	~ €15,000 per year for each 10,000 m^3/h	Generally viable. The investment and operational costs are largely determined by the maximum airflow that needs to be treated. The recovery and transportation of excess heat requires additional investment, which can be viable only if recovered energy is actually used.
Catalytic oxidation	€300,000 to €700,000 for a capacity between 15,000 and 60,000 m^3/h		Generally viable, but has additional operational costs due to the required periodic replacement of catalyst.

Technique	Investment cost	Operating cost	Viability
Solvent recovery	About €500,000 to €1,000,000 more than the investment in an oxidiser	€0.15 to €0.25 per kg of recovered solvent	Where the solvent consumption is less than 500 tons per year, it is very unlikely that solvent recovery will be an economically attractive alternative to incineration.

BAT 16. In order to reduce the energy consumption of the VOC abatement system, BAT is to use variable speed drives to control air flows, recirculate air, and external concentration.

Running costs of a thermal VOC abatement system can be very high due to the excessive use of auxiliary fuel. In order to keep the costs low, the VOC content in the inlet gas stream of the thermal VOC abatement system has to be high enough, so that very little or no auxiliary fuel is needed for combustion (achieving autothermal conditions). VOC content in the inlet stream can be maintained at the required level either by using variable frequency drive fans to modulate the airflow, by recirculating the exhaust gases within the process to concentrate VOCs, or by using the adsorber as external concentrator. The applicability of these techniques in a specific plant depends on the plant configuration, health and safety factors (e.g., LEL), and product quality requirements.

BAT 17. In order to reduce NO_X emissions in waste gases while limiting CO emissions from the thermal treatment of solvents in off-gases, BAT is to use low NO_X burners or an appropriate design of the oxidation chamber.

No	Technique	Description	Applicability	Benefit
a)	Optimisation of thermal treatment conditions (design and operation)	Good design of the combustion chambers, burners and associated equipment/devices is combined with optimisation of combustion conditions (e.g., by controlling combustion parameters such as temperature and residence time) with or without the use of automatic systems and the regular planned maintenance of the combustion system according to suppliers' recommendations.	Design applicability may be restricted for existing plants.	- Compliance with ELVs; - Lower operational costs.
b)	Use of low-NO_X burners	Low NO_X burners reduce the peak flame temperature in the combustion chamber, delaying but completing the combustion and increasing the heat transfer. This principle is combined with increased residence time to achieve the desired VOC destruction.	Applicability may be restricted at existing plants by design and/or operational constraints.	- Compliance with ELVs.

BAT 18. In order to reduce dust emissions in waste gases from substrate surface preparation, cutting, coating application and finishing processes for coating of wooden surfaces and metal packaging, BAT is to use one or a combination of the following techniques:

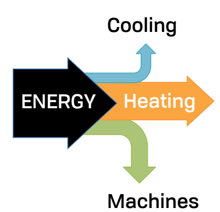
No	Technique	Description	Applicability	Benefit
a)	Wet separation spray booth (flushed impact panel)	A water curtain cascading vertically down the spray cabin rear panel captures paint particles from overspray. The water-paint mixture is captured in a reservoir and the water is recirculated.	Applicable both to water- and solvent-based paints. Generates waste water.	- Efficiencies of 98-99% can be achieved; - Potentially collected paint can be reused.
b)	Wet scrubbing	Paint particles and other dust in the off-gas are separated in scrubber systems by intensive mixing of the off-gas with water.	Generally applicable, but generates waste water.	- Dust removal efficiencies up to 95% can be achieved; - Can be used to remove other contaminants such as NO_X
c)	Dry overspray separation with pre-coated material	A dry paint overspray separation process using membrane filters combined with limestone as pre-coating material to prevent fouling of the membranes.	Generally applicable, but generates additional types of waste	- Reduces water and energy consumption; - High-efficiency removal.

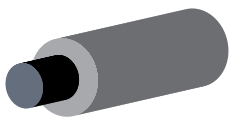
No	Technique	Description	Applicability	Benefit
d)	Dry overspray separation using filters	Mechanical separation system, e.g., using cardboard, fabric, or sinter.	Generally applicable, but generates additional type of waste.	- Reduces water and energy consumption; - Does not require chemicals, water, or additives.

Figure 12: Filter to separate overspray[14]

[14] https://www.ultrimaxstore.com/ardagh-glass-spray-booth/ultrimax-3-tier-dry-filter-spray-booths-3000mm.dfb3003

BAT 19. In order to use energy efficiently, BAT is to use the following techniques:

No	Technique	Description	Applicability	Benefit
a)	Energy efficiency plan	An energy efficiency plan is part of the EMS and entails defining and calculating the specific energy consumption of the activity, setting key performance indicators on an annual basis (e.g. MWh/tonne of product) and planning the periodic improvement targets and related actions. The plan is adapted to the specificities of the plant in terms of process(es) carried out, materials, products, etc.	The level of detail and nature of the energy efficiency plan will generally be related to the nature, scale and complexity of the installation and the types of energy sources used. May not be applicable if the STS activity is carried out within a larger installation.	- Reduces energy consumption and associated emissions.
b)	Energy balance record  	The drawing up once every year of an energy balance record which provides a breakdown of the energy consumption and generation (including energy export) by the type of source (e.g., electricity, fossil fuels, renewable energy, imported heat and/or cooling). This includes: (i) defining the energy boundary of the STS activity; (ii) information on energy consumption in terms of delivered energy; (iii) information on energy exported from the plant;	The level of detail and nature of the energy balance record will generally be related to the nature, scale and complexity of the installation and the types of energy sources used. May not be applicable if the STS activity is carried out within a larger installation.	- Optimises energy consumption; - Allows effective process control and monitoring.

No	Technique	Description	Applicability	Benefit
b)		(iv) energy flow information (e.g., Sankey diagrams or energy balances) showing how the energy is used throughout the process. The energy balance record is adapted to the specificities of the plant in terms of process(es) carried out, materials, etc.		
c)	Thermal insulation 	This may be achieved for example by: — using double-skinned tanks; — using pre-insulated tanks; — applying insulation to combustion equipment, steam pipes and pipes containing cooled or heated liquids.	Generally applicable.	- Reduces heat loss and saves energy.
d)	Heat recovery by cogeneration – CHP (combined heat and power) or CCHP (combined cooling, heat and power)	Recovery of heat (mainly from the steam system) for producing hot water/steam to be used in industrial processes/activities. CCHP (also called trigeneration) is a cogeneration system with an absorption chiller that uses low-grade heat to produce chilled water.	Applicability may be restricted by the plant layout, the characteristics of the hot gas streams (e.g., flow rate, temperature) or the lack of a suitable heat demand.	- High fuel efficiency up to 90%, much higher than conventional systems; - Reduced associated air emissions.
e)	Heat recovery from hot gas streams	Energy recovery from hot gas streams (e.g., from dryers or cooling zones), e.g., by their recirculation as process air, through the use of heat exchangers, in processes, or externally.	Applicability may be restricted by the plant layout, the characteristics of the hot gas streams (e.g., flow rate, temperature) or the lack of a suitable heat demand.	- Reduces energy consumption and associated air emissions

In flexography an energy consumption per printed area of 50-350 Wh/m^2 can be reached. Energy records on a daily or weekly basis, results of energy audits, and an energy efficiency plan are part of an EMS.

In coil coating, BAT-AEPL for specific energy consumption is 0,2 to 2,5 kWh/m^2 of coated coil, in coating and printing of metal packaging 0,3 to 1,5 kWh/m^2 of coated surface.

Figure 13 shows heat recovery from the thermal oxidiser to preheat make-up air as another option to increase the thermal efficiency of a plant.

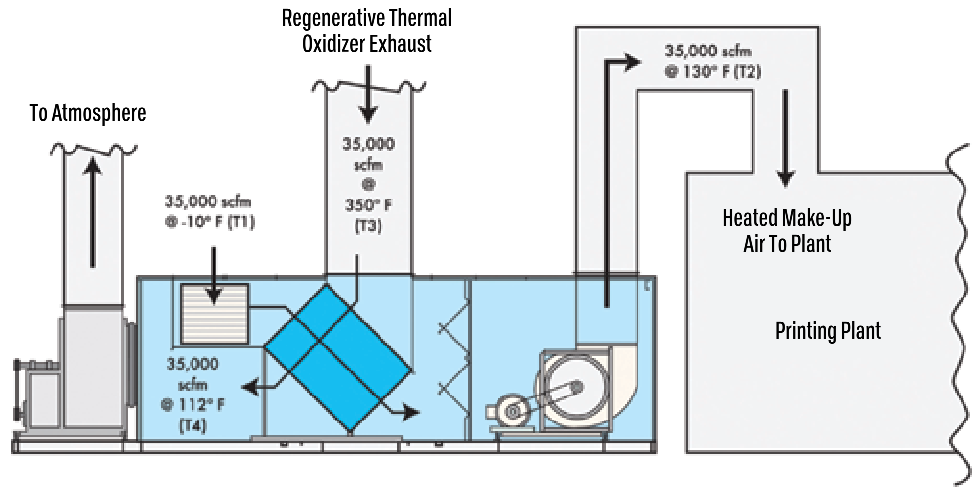


Figure 13: Heat recovery from the thermal oxidizer to preheat make-up air [15]

BAT 20. In order to reduce water consumption and waste water generation from aqueous processes (e.g., degreasing, cleaning, surface treatment, wet scrubbing), BAT is to use a water management plan and to cascade and recycle water.

A water management plan and water audits are part of the EMS (see BAT 1) and include flow diagrams and a water mass balance of the plant; water efficiency objectives; implementation of water optimisation techniques like control of water usage, counter current cascades, water recycling, detection and repair of leaks. Audits with a focus on efficient use of water are carried out at least once every year. In coil coating, BAT-AEPLs for specific water consumption is 0,2 to 1,3 l/m^2 of coated coil.

[15] https://www.munters.com/globalassets/inriver/resources/clearlam-diagram-2020.jpg

BAT 21. is to reduce emissions to water and/or to facilitate water reuse and recycling from aqueous processes (e.g., degreasing, cleaning, surface treatment, wet scrubbing), BAT is to use a combination of equalisation, neutralisation, physical separation, adsorption, vacuum distillation, precipitation, chemical reduction, ion exchange, stripping, biological treatment, coagulation and flocculation, sedimentation, filtration, flotation.

BAT 22. In order to reduce the quantity of waste sent for disposal, BAT is to use a waste management plan, monitoring of waste quantities, recovery and recycling of solvents, and specific treatment techniques (filter press, reducing cleaning cycles, reusable containers, cement kiln).

A waste management plan is part of the EMS (see BAT 1). This includes annual recording of waste quantities generated for each type of waste. There must be measures to minimise the generation of waste, optimise the reuse, regeneration and/or recycling of waste and/or the recovery of energy from waste, and ensure the proper disposal of waste. Techniques may include:

- recovering/recycling solvents from liquid waste by filtration or distillation on site or off site;
- recovering/recycling the solvent content of wipes by gravitational draining, wringing or centrifugation;
- recovery and recycling of solvents;
- reducing the water content of the waste by pressing the sludge;
- reducing the sludge and waste solvent generated, e.g., by reducing the number of cleaning cycles (see BAT 9);
- using reusable containers, reusing the containers for other purposes, or recycling the container material;
- specific treatment techniques (filter press, reducing cleaning cycles, reusable containers, cement kiln).

Reworking press return ink can reduce ink purchases and reduce hazardous waste. Printing with Four-Color Process can minimise the amount of mixed coloured inks used and eliminate residues of unusual colours at the end of each job.

Set up times and waste can be significantly reduced if the operators consider the anilox roll linecount and cell volume, the sequence of colours applied, and ink parameters.

BAT 24. In manufacturing of vehicles in order to reduce the consumption of solvents, other raw materials and energy, as well as to reduce VOC emissions, BAT is to use one or a combination of the coating systems given below.

- Mixed coating;
- Water-based coating;
- Integrated coating process;
- Three-wet process;

BAT 27. In manufacturing of winding wire, BAT is to reduce total emissions of VOCs and energy consumption, using VOC oxidation (like Catalytic oxidation, BAT 15), solvent-free lubricants, self-lubricating coatings or high-solids enamel coating with of up to 45% of solids.

BAT 28. For heatset web offset printing BAT is to reduce total VOC emissions, using a combination of the material-based and printing techniques aimed to reduce or eliminate the use of isopropanol (IPA) as a wetting agent in dampening solutions, cleaning techniques based on use of VOC-free or low VOC solvents and previously mentioned off-gas treatment techniques (e.g., BAT 15).

BAT 29. In order to reduce VOC emissions from publication rotogravure printing, using a toluene recovery system based on adsorption (BAT 15), retention inks and/or an automatic cleaning system connected to the toluene recovery system.

The emission levels for the selected activities are associated with the general BAT conclusions. Total VOC emissions, ELV for VOC emissions in waste gases, or fugitive emissions of VOCs are given in the Table below.

Emission standards

Table 1: BAT-associated emission level (BAT-AEL) for VOC emissions in waste gases from different activities

Activity	Parameter	Unit	BAT-AEL
Coil Coating	TVOC	mg C/Nm^3	1–20**(1)(2)
	Fugitive VOC emissions as calculated by the SMB	Percentage (%) of the solvent input	< 1–3*
Coating and printing of metal packaging	Total VOC emissions as calculated by the SMB	g VOCs per m^2 of coated/ printed surface	< 1-3.5*
	TVOC	mg C/Nm^3	1- 20**(2)
	Fugitive VOC emissions as calculated by the SMB	Percentage (%) of the solvent input	< 1-12*
Flexography and non-publication roto-gravure printing	Total VOC emissions as calculated by the SMB	kg VOCs per kg of solid mass input	< 0.1–0.3*
	TVOC	mg C/Nm^3	1–20**(1)(2)
	Fugitive VOC emissions as calculated by the SMB	Percentage (%) of the solvent input	< 1–12*
Wood Coating	Total VOC emissions as calculated by the SMB	kg VOCs per kg of solid mass input	< 0.1* (flat substrates)
			< 0.25* (other than flat substrates)
	TVOC	mg C/Nm^3	5–20**(2)
	Fugitive VOC emissions as calculated by the SMB	Percentage (%) of the solvent input	< 10*

*Yearly average;
**Daily average or average over the sampling period;
(1) The upper end of the BAT-AEL range is 50 mg C/Nm^3 if techniques are used which allow the reuse/recycling of the recovered solvent;
(2) For plants using BAT 16 (c) in combination with an off-gas treatment technique, an additional BAT-AEL of less than 50 mg C/Nm^3 applies to the waste gas of the concentrator.