Screening of Options for VOC Emissions Reductions in Manufacturing Office Furniture Partitions

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Abstract: Volatile organic compound (VOC) emission reduction options in manufacturing office furniture partitions are screened using the pollution prevention (P2) methodology as defined by the Ontario Ministry of the Environment. The purpose is to identify viable options that can allow a VOC P2 plan for manufacturing office furniture partitions to be developed. The concepts also apply generally to the wood furniture industry. Baseline VOC emissions for a typical plant are estimated using a mass balance approach. Pollution prevention measures are identified and screened using realistic criteria and weightings. Several measures are deemed viable, including implementing several best management practices, not painting of non-visible parts, switching gluing processes, recycling solvent and modifying attachments. A feasibility analysis is performed in a follow-up article for the screened measures based on technical, environmental and economic considerations.

Key-Words: volatile organic compound, manufacturing, office furniture, pollution prevention, emissions

1 Introduction
Canada’s furniture industry is the second largest exporter in the world, with 52% of production being shipped outside Canada [1]. Canadian furniture companies thus face competitive pressures domestically and globally. Competition and worldwide trends in environmental protection and due diligence are forcing companies to consider the environmental impacts of their products and to take steps to reduce them. Market forces and environmental regulations have led to the development of pollution prevention (P2) programs. P2 is defined by the Ontario Ministry of the Environment as any action that reduces or eliminates the creation of pollutants or wastes at the source. P2 is achieved through activities that promote, encourage or require changes in the basic behavioural patterns of industrial, commercial, institutional, community and government generators or individuals.

Wastes from manufacturing furniture impact land, air and water. The most significant environmental impact of the wood furniture industry is air pollution in the form of volatile organic compounds (VOCs), organic hydrocarbons that can volatize to form organic vapour in air. VOC emissions top all pollution categories in the wood furniture industry, with toluene, methanol and xylene leading all other chemicals [2].

The objective of this investigation is to identify strategies for reducing VOC emissions in the wood furniture industry and to apply these concepts to the manufacturing of office furniture partitions.

In the remainder of this article, current VOC emission levels are assessed in the wood furniture industry and in typical manufacturing plants for office furniture partitions; current legislation and regulations regarding VOC emissions in Ontario are examined; potential P2 measures are identified, such as best management practices (BMPs), equipment and production process modifications, recycling, reuse and abatement technologies; feasibility analyses are performed for selected measures based on technical, environmental and economic considerations; factors affecting the implementation of feasible measures are considered; and metrics are developed for tracking and evaluating the impact of the measures.

2 Background

2.1 Impact and prevention of VOC emissions
VOCs describe a carbon containing substance that rapidly evaporates or is emitted into the atmosphere. VOCs react with oxides of nitrogen in the presence of...
sunlight to form ozone in the lower atmosphere. Low-level ozone is a component of photochemical smog. Smog is a persistent air quality problem in many parts of Canada. The environmental impact of smog can have effects on both health and property. High levels of ground-level ozone can damage plants, cause respiratory irritation and create haze. Current agricultural losses from ground-level ozone are estimated to be nearly $70 million in Ontario and $9 million in the Lower Fraser Valley of British Columbia [3]. VOCs also contribute to acid rain and the greenhouse effect.

Regulatory drivers are important in the development of VOC reduction initiatives in many industrial sectors. Since the 1990s, the trend in Canada and the US has been towards significant reductions in the emission of VOCs. For example, Ontario has a stated VOC reduction objective of 45% based on the 1990 levels by the year 2010 [4]. Guidelines have been developed for the wood furniture sector by the Canadian Council of Ministers of the Environment (CCME) to provide a basis for provincial and regional governments to develop regulatory or non-regulatory management instruments to achieve their own specific reduction objectives.

### 2.2 Comparison of air emissions for the wood furniture and other industries

Table 1 summarizes the annual release of carbon monoxide (CO), nitrogen dioxide (NO₂), particulate material of 10 microns or less (PM10), total particulate matter (PT), sulphur dioxide (SO₂) and VOCs of various industries in the United States. Industrial sources of air pollution are frequently exceeded by domestic, commercial, agricultural and transportation-related sources [5]. This is demonstrated in cities such as Toronto or Los Angeles, where air quality deteriorates closer to the city core even though most industrial sources are outside the city centres. Industrial sources, however, are more noticeable because emissions are concentrated and discharged through stacks.

VOC emissions are seen in Table 1 to be the most significant contributors to air pollution, in terms of quantity, from the wood furniture industry (59,400 US tons per year). The wood furniture industry is the ninth largest contributor of VOC emissions in the U.S. VOC emissions normally represent the majority of air pollutant releases in the manufacturing of office furniture partitions.

<table>
<thead>
<tr>
<th>Industry</th>
<th>VOC</th>
<th>CO</th>
<th>NO₂</th>
<th>PM10</th>
<th>PT</th>
<th>SO₂</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum refining</td>
<td>309</td>
<td>419</td>
<td>381</td>
<td>18.8</td>
<td>36.9</td>
<td>648</td>
<td>1,810</td>
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<tr>
<td>Organic and inorganic chemicals</td>
<td>254</td>
<td>313</td>
<td>346</td>
<td>30.6</td>
<td>83.0</td>
<td>314</td>
<td>1,340</td>
</tr>
<tr>
<td>Rubber, miscellaneous plastic products</td>
<td>141</td>
<td>2.1</td>
<td>11.9</td>
<td>2.4</td>
<td>5.4</td>
<td>29.4</td>
<td>192</td>
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<tr>
<td>Fabricated metals</td>
<td>102</td>
<td>3.9</td>
<td>16.4</td>
<td>1.2</td>
<td>3.1</td>
<td>4.0</td>
<td>131</td>
</tr>
<tr>
<td>Printing</td>
<td>102</td>
<td>8.5</td>
<td>4.9</td>
<td>0.4</td>
<td>1.0</td>
<td>1.7</td>
<td>118</td>
</tr>
<tr>
<td>Motor vehicle bodies, parts, accessories</td>
<td>101</td>
<td>35.3</td>
<td>23.7</td>
<td>2.4</td>
<td>12.9</td>
<td>25.5</td>
<td>201</td>
</tr>
<tr>
<td>Pulp and paper</td>
<td>96.9</td>
<td>624</td>
<td>394</td>
<td>35.6</td>
<td>114</td>
<td>341</td>
<td>1,610</td>
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<tr>
<td>Iron and steel</td>
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<td>1,519</td>
<td>139</td>
<td>42.4</td>
<td>83.0</td>
<td>238</td>
<td>2,100</td>
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<td>Wood furniture and fixtures</td>
<td>59.4</td>
<td>2.1</td>
<td>3.0</td>
<td>2.2</td>
<td>3.2</td>
<td>1.7</td>
<td>71.4</td>
</tr>
<tr>
<td>Lumber and wood products</td>
<td>41.4</td>
<td>124</td>
<td>42.7</td>
<td>14.1</td>
<td>63.8</td>
<td>9.1</td>
<td>295</td>
</tr>
<tr>
<td>Stone, clay, glass, concrete</td>
<td>30.3</td>
<td>58.0</td>
<td>338</td>
<td>74.6</td>
<td>172</td>
<td>339</td>
<td>1,010</td>
</tr>
<tr>
<td>Nonferrous metals</td>
<td>27.4</td>
<td>449</td>
<td>55.7</td>
<td>20.1</td>
<td>22.5</td>
<td>373</td>
<td>947</td>
</tr>
<tr>
<td>Dry cleaning</td>
<td>7.3</td>
<td>0.1</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Electronics</td>
<td>4.9</td>
<td>0.4</td>
<td>1.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Mining</td>
<td>3.0</td>
<td>9.9</td>
<td>57.4</td>
<td>98.7</td>
<td>308</td>
<td>106.3</td>
<td>585</td>
</tr>
<tr>
<td>Total</td>
<td>23,300</td>
<td>97,200</td>
<td>23,400</td>
<td>45,500</td>
<td>78,400</td>
<td>21,900</td>
<td></td>
</tr>
</tbody>
</table>

* Adapted from AIRS database [2].
3 Processes in Panel Manufacturing

In a typical manufacturing operation for panels, medium density fibreboard (MDF) is milled to specific shapes (trims) using industrial wood working equipment. Veneer is applied to the trims using a hot melt adhesive. The trims are coated by primer and paint or by stain, sealer and lacquer. The coating material is solvent-based and is applied manually or automatically in ventilated booths. The parts are air-dried on heating racks or in an air tunnel or by baking in an industrial oven. Sheets of acoustical fibreglass are cut and fitted with metal clips, which are adhered to the panels using a polyester resin. The product is sprayed with an adhesive, and moved to an assembly area where fabric is applied. Aluminium frames are assembled and the trims and panels are applied to the frames.

The main processes that contribute to VOC emissions are surface coating, adhesive application and cleaning, and are described in more detail.

3.1 Surface coating

Surface coating and painting protect surfaces, inhibit corrosion and rusting, enhance weatherability and durability, and provide resistance to harsh environments, abrasion, scratching and staining [6]. In the furniture industry, surface coatings are mainly used to enhance the aesthetics of wood surfaces. Coating material typically consists of solutions of organic resins, organic and inorganic colour pigments, stabilizers and extenders [6]. The organic solvent is used for transporting the components and for giving the liquid properties (e.g., flow characteristics, viscosity, surface tension) necessary for consistent application of coating layers [6]. Fugitive evaporation during drying of organic solvents leads to the main environmental emissions from the wood furniture industry. In addition, emissions result from coating materials that do not bind to the substrate, wastes generated during equipment cleaning or colour changeovers, and the removal of coating material from defective parts.

3.2 Adhesive application

Common adhesives used in the furniture industry include polyvinyl acetate, hot melts, urea formaldehyde (UF), and pressure sensitive adhesives. While not a significant source of releases, gluing operations are a source of atmospheric VOC emissions. Adhesives are used in such operations as applying metal clips to fibreglass, veneer to MDF, fabric to fibreglass and polyvinyl chloride, and solid wood end caps to MDF.

3.3 Cleaning

In wood coating operations, industrial solvents are used to clean the piping in finishing application equipment, manufacturing booths and glue application equipment, and to remove coating from non-conforming parts [2]. Finishing application equipment must be flushed to clean residual material each time there is a colour change, and when the equipment is idle for a long period of time. Spray guns, storage pots and fluid lines must be cleaned in a spray coating operation. Roller and spray bars must be cleaned in a roller coating operation. Spray equipment is cleaned by pumping clean solvent through the system into a container. Spray nozzles and spray guns are soaked in solvent for cleaning.

4 Baseline Emissions

Emission rates are best determined by performing source testing. Since air-sampling techniques are costly, emissions are often estimated using a mass balance approach [7]. A mass balance expresses the mass of a compound emitted in terms of other mass flows and accumulations in the system:

\[ m_e = m_i - m_p - m_a - m_c \]

Here, \( m_e \) denotes the mass emitted in an unconstrained manner, \( m_i \) the mass of the input stream, \( m_p \) the mass of the finished product, \( m_a \) the mass accumulated in the system, and \( m_c \) the mass captured for recovery or disposal.

The mass balance approach, which is a widely accepted and cost-effective method of estimating VOC emissions [4], is used here to calculate emissions because VOC and material usage data are often available. In the present investigation, the main VOC sources are considered to be coatings and adhesives, which consist of resins, pigments, additives, solvents, diluents and thinners. Resins, pigments and additives are the solid (non-volatile) portion of the coating or adhesive, while solvents, diluents and thinners are the volatile portion, which evaporate during the mixing, application and curing of the coating or adhesive [7].

During manufacturing, it is assumed that there is no accumulation of coating or adhesive in the system, since any coating that is deposited on the equipment is removed during cleaning and captured for waste disposal or the volatile portion will evaporate. Typically, 15-20% of coating and cleaning materials for finishing
material like trims and 3-5% of upholstery-related adhesive and cleaning materials used in the clip application process are collected for waste disposal. All other volatiles in the material are assumed are emitted to the atmosphere.

The total VOC emissions $E_{voc}$ (in kg) from coating and adhesive applications are calculated as follows [7]:

$$E_{voc} = \frac{Q \rho d}{100}$$

where $Q$ denotes the total annual consumption of material (L), $\rho$ the density of the material (kg/L) and $d$ the VOC content by weight in the material (%). The VOC content for each material used in the facility is calculated using the “percent by weight” data. Table 2 summarizes the annual VOC emissions by material type and plant area for a typical plant, using the mass balance approach. The VOC emissions for each material used in a plant are based on examinations of several actual plants. The typical facility is assumed to produce 200,000 panels annually, and to have a total floor area of approximately 15,000 m$^2$.

Table 2. Annual VOC emissions (in kg) by area

<table>
<thead>
<tr>
<th>Area</th>
<th>Surface coating</th>
<th>Adhesive</th>
<th>Cleaning</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trims</td>
<td>20,000</td>
<td>0</td>
<td>5,500</td>
<td>25,500</td>
</tr>
<tr>
<td>Upholstery</td>
<td>0</td>
<td>14,000</td>
<td>1,500</td>
<td>15,500</td>
</tr>
<tr>
<td>Total</td>
<td>20,000</td>
<td>14,000</td>
<td>7,000</td>
<td>41,000</td>
</tr>
</tbody>
</table>

5 Identification of Relevant Pollution Prevention Measures

5.1 Best management practices (BMPs)
The simplest and least expensive way to reduce pollution is to implement BMPs, such as standard operating procedures (SOPs), preventative maintenance (PM), employee training, production scheduling, inventory management and scrap reduction. BMPs are practices that a government or planning agency determines to be the most effective and practical means of reducing the amount of pollution generated by point or non-point sources.

5.1.1 Standard operating procedures
The correct operation of equipment can help in pollution prevention. Written SOPs should be readily available which describe the tasks an operator must perform, safety parameters, and safety precautions for operations and maintenance activities [8].

SOPs for manual spray operations can improve transfer efficiencies, thereby reducing the overall contribution to air emissions. The following guidelines should be followed when operating manual spray equipment [9]: maintain 50% overlap between spray patterns, hold spray gun perpendicular to the part to be coated to prevent inconsistencies in coating depth, maintain 6-8 inch distance between spray gun and workpiece, trigger the gun at the beginning and end of each pass, and avoid excessive air pressure for coating atomisation.

5.1.2 Preventative maintenance
Programs should be established for the regular maintenance, inspection and testing of equipment to ensure that it is fit for the purpose for which it was designed [8]. Routine maintenance of spray guns, fluid lines and pumps can prevent equipment from breaking down and leaking. Also, accurate record keeping of equipment checks, repairs and cleaning may reduce the likelihood of accidental releases to the environment.

5.1.3 Employee training and involvement
Personnel need to be made aware of the contribution of emissions generated outside the primary coating operation, which are comparatively small for furniture manufacturing, and be involved in reducing VOC emissions. Training should be provided in operation of production equipment to minimize energy use and material waste, proper material handling to reduce waste and spills, detecting and minimizing material losses to air, land and water, emergency procedures to minimize lost materials during accidents, and solvent conservation and management.

5.1.4 Production scheduling
The way that orders are scheduled can impact the amount of waste generated. Reduced emissions can be achieved when creating the master production schedule using the following guidelines: optimize batch size to reduce frequency of cleaning, and schedule colour sequence to minimize cleaning requirements (light to dark colours).

5.1.5 Inventory management
The wide range of chemicals used in the wood furniture industry requires an efficient material tracking program to ensure that older chemicals are not needlessly discarded. A computerized inventory system can assist
in controlling and tracking materials to reduce overstocking. Using inventory on a first-in first-out basis reduces the volume of waste generated from expired chemicals [2]. Also, more accurate forecasting of material requirements for production reduces the frequency of material expiration due to overstocking. Just-in-time ordering, characterized by small delivery lot sizes, reduces the total volume of chemical stored at the facility, which reduces the likelihood of accidental spills [10].

5.1.6 Scrap reduction
Statistical process control can control process capabilities and quality. Statistical methods help monitor and predict process variations, and minimize the occurrence of defective products. These methods can reduce overall VOC emissions. In addition, design of experiment, a structured method for determining the relationship between factors affecting a process and the output of that process, can ensure the repeatability and reduction of process variations.

5.2 Paint Equipment Modifications
Manufacturers can change paint application equipment to improve transfer efficiencies and reduce waste. Spray equipment and spray patterns both influence transfer efficiency.

5.2.1 High volume, low pressure spray guns
High volume, low pressure (HVLP) spray application guns limit the air flow and convert high pressure, low volume air into low pressure, high volume air. Air is only used when the gun is operated so ‘bounce back’ and ‘overspray’ are reduced. Bounce back refers to coating material which hits the substrate but does not adhere and overspray refers to coating material which misses the substrate when sprayed. Transfer efficiency and the working environment are improved by decreasing bounce back and overspray [11]. Most office partition manufacturing utilizes conventional spray guns which operate at high pressures and have low transfer efficiencies.

5.2.2 Spray pattern optimization
Spray patterns for automated spray equipment can be optimized for the size and geometry of the part to be coated. In addition, it is important to ensure that air and fluid pressure settings are correct. Although increasing the pressure is often thought to increase spray rate and efficiency, operating at too high a pressure increases spray bounce back, excessively wears machine components and increases compressed air demand and energy consumption [12].

5.2.3 Air purge of paint lines
Using compressed air to clean solvent lines can significantly reduce solvent consumption. A colour change manifold can force compressed air through pump lines, whereby air is gently forced through the line to utilize paint in the line and then air is input to empty the line and a small quantity of solvent is used to clean the lines prior to switching to the new colour.

5.3 Production Process Modifications
The production process modifications considered are manufacturing changes that substitute less toxic materials or reduce waste generation (e.g., UV-based coatings, water-based coatings, high solids adhesives).

5.3.1 Water-based surface coatings
Water-based coatings, which are neither flammable nor toxic, can replace solvent based coatings and contain a small fraction of the VOC content of traditional solvent-based coatings. A small amount of solvent is needed for softening the resin [11]. Some office partition manufacturers have implemented a water-based finish on some of their wood furniture. Water-based systems can help meet anticipated VOC emission regulations, decrease fire hazards, and improve working conditions, colour consistency, and brushability and adhesion of stain.

5.3.2 Hot melt backwrapping adhesive
The glue used to apply the fabric to the back edge of fibreglass panels (referred to as backwrapping) contains a small percentage of toluene, which facilitates mixing of the activator and the adhesive. Utilizing an alternative adhesive, such as a hot melt which is solvent-free, can eliminate VOCs. The glue is melted and then pumped through a heated hose where it is deposited onto the substrate, cools and hardens.

5.4 Product redesign
P2 is usually most effective during the planning, design and development of a product or process [13]. Design changes to prevent pollution should not adversely affect function [9]. Some measures to consider for improving environmental aspects when designing products include use of renewable and recycled materials, use of fewer toxic solvents, reuse of scrap and excess materials, reduction of packaging, and production of more durable goods.
5.4.1 Mechanical clip attachment
Panel manufacturing often utilizes a polyester resin to adhere metal clips to tiles made of fibreglass or other materials for the application to frames, usually made of metal. The metal clips engage with U-clips that have been fastened to the inside of the frame. The equipment that dispenses the polyester resin is cleaned using products like acetone. This process contributes significantly to VOC emissions, increases the fire hazard, is odorous and can cause health problems.

Redesigning to use a clip with a mechanical attachment can reduce the requirement for this hazardous process. The mechanical clip can be designed to attach to the tile without adhesives and snap directly onto the frame. Switching to a mechanical clip affects the cost of the panel by eliminating the material cost of the resin, catalyst, solvent and U-clips as well as the labour cost to apply the resin. The panel and tile connector need to be redesigned to accept mechanical clips, adding costs.

5.4.2 Cease painting non-visible parts
Parts that are not visible to the customer may not require surface coating. Aluminium and plastic components on furniture partitions are coated for aesthetic purposes only, as the surface coating does not provide additional protection from damage or corrosion. Generally, the application of coating materials contributes to VOC emissions, with the exception of some powder-coated and water-based finishes. In office panels, some parts are typically not visible to the customer, like upper horizontal and vertical frame members and corner posts. Removing the painting process for these parts reduces VOC contribution of the product for the manufacturing (unless done by a supplier external to the plant). In this study, it is assumed that these parts are coated at an external supplier, as that is often the case.

5.5 Recycling and reuse

5.5.1 Solvent recycling
Recycling spent solvent eliminates the need to transfer solvent during hazardous waste disposal pickup (reducing the opportunity for spills), reduces the demand to manufacture virgin solvent and reduces the volume of hazardous waste generated for disposal. Ovesspray from surface coating operations and dirty solvent from cleaning operations can be distilled to separate the waste coating material from the solvent. The solvent can then be reused for cleaning operations.

5.6 Abatement technologies

5.6.1 Oxidation
The most widely employed type of VOC destruction is currently thermal or catalytic oxidation, which raises the temperature of the exhaust gas above 800°C to destroy organic compounds. Heat recovery is incorporated in most systems to reduce energy use. Catalytic incineration operates at around 350°C with organic compounds being oxidized in a catalytic bed [11].

5.6.2 Biological abatement
Biological treatment represents a more cost-effective method for the destruction of VOCs. The treatments have similar capital and lower operating costs than oxidation. Biofiltration is a control technology that sends exhaust gas through a filter of micro-organisms, which use the organic matter in the air stream as a food source [6]. Biotreatments are able to degrade a wide range of organic solvents.

6 Initial Screening of Measures
To prioritise P2 alternatives and streamline the process for selecting the most advantageous measures, the P2 measures defined in the previous section are screened according to several criteria. The criteria deemed most relevant for the present manufacturing operation were developed based on examinations of several manufacturers, and are as follows:

- Internal VOC emissions (fugitive and point source emissions within the facility)
- External VOC emissions (raw material manufacturing and waste disposal emissions)
- Raw material cost
- Waste disposal cost
- Employee health and safety
- Product quality
- Operating cost
- Capital cost
- Implementation time
- Resources required

The weighted-sum method is used for screening and rating pollution prevention measures, as suggested by the Ministry of the Environment [9]. Each screening criterion is given a weight based on its perceived importance. Typical manufacturers in this industry were
examined and it was observed that many place 1) a high emphasis on employee safety, cost improvement and product quality, so these are given a higher value here, and 2) a lower emphasis on capital costs, implementation time and external VOC reductions, so these are given a lower value here. Each measure is then rated based on how it impacts each criterion, using the scale in Table 3.

The rating for a particular criterion is multiplied by the weight of the criterion (listed at top of Table 4). The weight of each criterion was developed based on examinations of several manufacturers. A measure’s overall rating is the sum of the products of the rating times the weight of the criterion [9]. The weighted sum method is used in Table 4 to rate the P2 measures. Only measures with an overall rating of 115 or greater are considered for a comprehensive feasibility analysis. Other measures may still be beneficial in other conditions, but are not considered further here.

Table 3. Pollution prevention impact rating criteria

| High positive impact | 5 |
| Low positive impact   | 4 |
| Minimal or no impact  | 3 |
| Low negative impact   | 2 |
| High negative impact  | 1 |

Table 4. Pollution prevention screening based on the weighted sum method

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight of criterion</th>
<th>BMPs</th>
<th>Equipment modifications</th>
<th>Process modifications</th>
<th>Product redesign</th>
<th>Recycling and reuse</th>
<th>Abatement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal VOC emissions</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<td>External VOC emissions</td>
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<tr>
<td>Raw material cost or use</td>
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<td>5</td>
<td>4</td>
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<td>3</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Employee health &amp; safety</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
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<td>Waste disposal cost</td>
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<td>112</td>
<td>119</td>
<td>113</td>
<td>116</td>
<td>131</td>
</tr>
</tbody>
</table>
The following sections discuss the reasoning for the assigned values in the screening rating. No explanation is given if there is minimal or no impact on the criterion.

6.1 Best management practices
In general, BMPs maintain product quality, have low capital and operating costs and short implementation times, and have been used successfully in industry. But they do not reduce VOC emissions as significantly as other measures, and do not result in significant waste disposal or raw material savings.

6.2 Equipment modifications

6.2.1 HVLP guns
Purchasing and installing HVLP spray guns reduces slightly VOC emissions. The main negative impacts are the capital expenditure required to purchase the equipment and the likely decrease in operating efficiency.

6.2.2 Spray pattern optimization
The shape of the product to be coated is relatively constant since the different trim types normally exhibit only minor differences in profile. Preliminary observations indicate that adjusting spray pattern according to product shape results in minimal reductions in VOC emissions, raw material usage and waste disposal costs. Manual spray pattern adjustments reduce efficiency since more work time is required to adjust the spray patterns based on the production schedule. Automated spray pattern adjustments require a significant capital investment. In addition, frequent machine adjustments increase the risk of parts becoming defective.

6.2.3 Air purge
An air purge system decreases VOC emissions and raw material costs, since less solvent is required to purge the fluid lines.

6.3 Process modifications

6.3.1 Water-based finishes
The implementation of a water-based coating system reduces significantly VOC emissions and hazardous waste disposal costs since the solvent content of the coatings is reduced. In addition, the reduced risk of explosion and exposure to solvent vapours improves employee health and safety. The major impediment to implementation is the high cost of water-based coatings.

6.3.2 Hot melt backwrapping
The implementation of a hot melt backwrapping system reduces slightly VOC emissions as typical glue materials contain less than 3% toluene. The main advantage of hot melt glues are their resistance to UV radiation, as the current glue discours over time when exposed to UV radiation. Another benefit is a decrease in operating costs since hot melt glues do not require ventilation. Currently three spray booths are dedicated to ventilation for the backwrapping adhesive. Removing these spray booths eliminates the cost of booth maintenance, filter pads, electricity to run the fans and natural gas to heat plant make-up air.

6.4 Product modifications

6.4.1 Mechanical clip
The mechanical clip modification reduces the demand for polyester resin, cadox and acetone, reducing VOC emissions and material and disposal costs. The major obstacles for this measure are high capital and development costs and a long implementation time.

6.4.2 Cease painting of non-visible parts
Purchasing parts without coatings reduces external VOC emissions and the cost of the part, and requires minimal internal resources.

6.5 Recycling and reuse

6.5.1 Solvent recycling
Waste disposal and material expenses are reduced by distilling dirty cleaning solvent. The disadvantages are capital funding, operating costs, internal resources and implementation time.

6.6 Abatement

6.6.1 Thermal oxidation and biological abatement
Thermal oxidation and biological abatement are effective end-of-pipe solutions to VOC emissions. These processes have high operating and capital costs.

7 Conclusions
The screening performed here suggests that the measures with the greatest potential for reducing VOC
emissions in an acceptable manner, and thus most suitable for detailed feasibility analyses, are BMPs, air purge of paint lines, water-based finishes, hot melt backwrapping, cease painting non-visible parts, mechanical clip attachment, and solvent recycling. A detailed feasibility analysis, which determines which measures are technically, environmentally and economically feasible, is presented in a separate article. The initial screening suggests that it would likely be advantageous for manufacturers of office panels to undertake several pollution prevention measures, selected after performing feasibility assessments. The specific measures depend on the particular circumstance. To be comprehensive, the feasibility analysis should consider intangible and indirect benefits resulting from the pollution prevention measures as well as tangible direct advantages.

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List of Acronyms:
BMP best management practice
HVLP high volume, low pressure
MDF medium density fibreboard
P2 pollution prevention
PM preventative maintenance
PM10 particulate matter of 10 microns or less
PT total particulate matter
SOP standard operating procedure
UV ultraviolet
VOC volatile organic compound

References: