The Environmental Impact of Pick-and-place Machines

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Energy labels are a key part of global attempts to reduce consumption of environmental resources. They inform customers of the future consequence of their purchases. There are now many national and other energy labels covering houses, cars, lamps, washing machines and dryers, air conditioners, etc. The EU Energy using Products (EuP) directive also is working on classifying industrial applications to set rules for future energy reductions. These rules are at least three years away; until then, there are no energy labels for industrial manufacturing equipment.

Electronics manufacturing companies committing to ISO 14000 and other environmental standards must report and try to minimize their environmental effects. For an electronics manufacturer, the most important environmental issues are the materials going through manufacture. For example, cell phone circuits and displays can contain toxic compounds like arsenic (As), beryllium (Be), cadmium (Cd), copper (Cu), and lead (Pb). The plastic shells of the cell phones have been treated with brominated flame retardants. The energy consumed by manufacturing lines is also significant, because machines can be working virtually nonstop 24 hours a day.

The two major energy consumers are soldering equipment and pick-and-place machines. Soldering is a high-energy process, but the temperature profile of the solder bath is determined strictly by process requirements. Energy consumption is largely calculated from the melting point of the solder, the heat capacity (length of the oven and related number of temperature zones), and quality of insulation. For both solder ovens and component placement equipment, much comes down to equipment design quality. Heat released by working equipment also normally must be removed by air-conditioning equipment, so lower-energy designs bring double savings.

SUMMARY

EMS companies committing to environmental standards have to report and try to minimize their effects. The energy consumed by manufacturing lines is significant because machines can be working 24 hours a day. Because a pick-and-place machine will normally last seven years or more, the most significant effects come from energy consumption over the machine's lifetime. Comparing environmental effects requires standardized measurement and labeling.

Comparing environmental effects requires standardized measurement methods. In Europe, the EuP covers eco-design requirements for household electrical equipment, and requires a measure of environmental impacts. A widely accepted method to investigate the environmental impact of products is the Eco Indicator 99 (ISO 14042), which uses lifecycle assessment (LCA). This assigns "Eco points" to estimate the total environmental damage that products will cause over their given lifetime. For pick-and-place equipment, points consider manufacture, transport, installation, use, and disposal of the equipment. Most of the steel, aluminum, copper, and plastics used during manufacture can be recycled, leaving transport, installation, and use factors.

Because a placement system normally lasts seven years or more, energy consumption over the machine's lifetime is most significant. In countries like China, energy demand is growing faster than power plant capacity. Frequent power shortages are persuading the country to build more coal-fired power plants. Coal is already the most important source of environmental pollution and the thermal quality of Chinese coal is worsening. This power situation emphasizes the importance of machine-level energy efficiency.

Calculations according to Eco-Indicator 99 method show the major impact of pick-and-place machines to be the electricity they use, driving motors and controls, supplying compressed air, and eating up lighting and air conditioning for machine factory floor occupation, as well as the residual effect of power consumption at rework caused by poor placement.

Life Cycle Assessment (LCA) and Eco-points

All products damage the environment to some extent. Raw materials are extracted; products are manufactured, packaged, and distributed. During use, they can consume energy and/or materials. Ultimately, they're disposed of in some fashion. Minimizing effects on the environment starts with an assessment studying the whole lifecycle. Eco-Indicator 99 is an excellent way of calculating the environmental load of a pick-and-place machine over its life in an electronics assembly line.

Eco-Indicator 99 has three steps. It first makes an inventory of all flows from and to all processes in the product lifecycle (LCA tree). Then, it calculates the damage of these flows in terms of Eco-points for three major categories. The normalized data is multiplied by a weighting and summed for each category to give the final Eco-points score: 1,000 Eco-points/year is an average European citizen's impact.

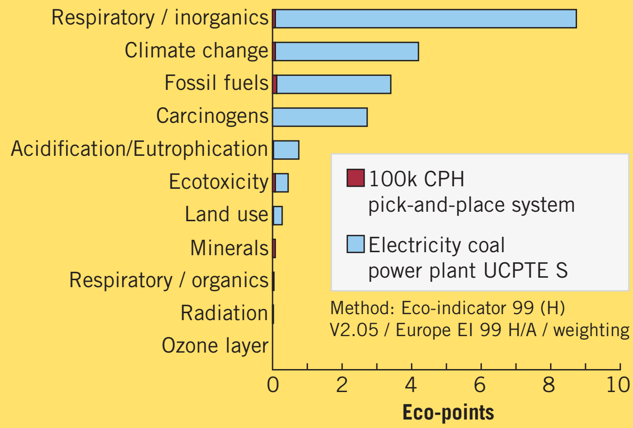

Figure 1. Environmental impact of a new-generation pick-and-place machine* (scaled at 100,000 components per hour), expressed in Eco-points. The effects are overwhelmingly determined by energy consumption (blue bars) during use, rather than manufacture (red bars).

Lifetime Effect of a Pick-and-place Machine

A simplified LCA tree reveals that the most significant material and energy flows during the lifecycle of the pick-and-place machine are steel, aluminum, plastic and copper; and machine assembly/packaging, transport, and in-factory use. During manufacture, the largest environmental impact comes from the steel that is the main materials content. Machine transport by road and particularly by air is significant.

The main environmental impact during operation is the electricity or other energy used to power the machine. It also includes the electricity for air conditioning the volume of air surrounding the pick-and-place machine. To calculate factory air conditioning, consider the placement machine as surrounded by a virtual box comprising machine length, depth + 1 m operator handling space at each side, and a 4-m-high factory hall ceiling.

Although energy consumption is the main effect during use, even waste tapes from component packaging will have their environmental impacts, and can be reduced by bulk feeding.

During disposal at end of life (EOL), the machine is dismantled, in various processes, into materials that can be recycled, and the rest go to landfills.

Calculating and Ranking Eco-points

Calculate the damage model for these flows. There are three damage categories: resources, ecosystems, and human health. Under resources fall the extra energy needed in future to extract mineral and fossil resources. Ecosystem quality includes the effect on species diversity from factors like eco-toxicity, acidification, eutrophication, climate change, ozone layer depletion, and land use. Human health effects include the number and duration of any associated carcinogenic effects or respiratory diseases, and any life years lost due to premature death from environmental causes.

Ranking is essentially a subjective process. The Hofstetter research method is most popular, wherein human health is considered to be the most important value. Ecosystem health is second, with conservation of natural resources third. This biases the environmental impact assessment, with 40% weighted for both human health and ecosystem quality categories and a 20% weighting for resources. Factors include upstream effects like pollution emitted by power plants and steel and plastics producers. The most important is energy use.

Results are heavily dependant on how energy is supplied to the factory. The contribution from renewable supplies is small, while that from fossil fuels is much larger, and dominates the effects from the machine.

With so much production located in China, the figures have been calculated for the worst case of coal-fired power stations. That includes greenhouse gas emissions (CO_2, NO_x, and SO_2) and residual emissions (U, Th, and Hg). The major effects of energy consumption are respiratory problems due to organic substances, followed by climate change, carcinogens, and fossil fuels (Figure 1).

Machine-level Changes*

Energy consumption is a good measure of overall machine quality and efficiency. High output from a machine improves all the environmental factors by spreading the effects across more assembled boards. A simple software upgrade can increase real-world output of a component placement system, and that can mean only one machine is needed instead of two. Both factors decrease environmental consequences.

Machines designed to reduce weight ease transport burdens. High-energy-efficiency motors with energy-recuperating controllers and reduced moving masses and friction improve reliability and quality as well as environmental impact. Cutting compressed air consumption and adding energy-saving modes enable new-generation systems to avoid unnecessary power drains.

Minimized machine footprints lower air conditioning and lighting per m2 of facility space. Even factors like modular design extend equipment lifetime, delaying disposal. Off-line program preparation means less redundant equipment use. So do high yields, meaning fewer components are placed uselessly. That leads to less rework, which is often neglected as a source of waste but actually represents pure waste of all energy and resources put into it.

Good design also minimizes waste when equipment comes to EOL. If more than 99% of machine materials, by weight, can be reused, EOL impact is significantly mitigated.

Assessing a Telecom PCB Assembly

Figure 2 shows the environmental impact of different tasks for board assembly, which relates to a typical mobile phone assembly with 1,456 components on a four-fold board (364 components per phone).

The contribution from 0 to 100% for each influence factor shows that the printed wiring board (PWB) has most significant influence (average around 50%), while solder and SMT processing are less influential.

Energy consumption for lead-free solder is substantially higher than for tin/lead solder, mainly because the melting point of lead-free solder is higher. Lead-free solders are, however, less toxic than tin/lead types.

Rework is a particularly wasteful operation, which can be reduced at the source with pick-and-place advancements like parallel placement. Parallel placement has typical defects per million opportunities (DPMO) of less than 10, while machines that use sequential placement see typical DPMO of 50. This DPMO creates a first pass yield difference of above 20%. Avoiding rework reduces solder paste usage from 14.5 kg, in a period of seven years, down to 3.5 kg) and reduces energy for reflow soldering. More importantly, it means three less rework stations (drawing 2.5 kW each) per line than for sequential pick-and-place systems for an average application.

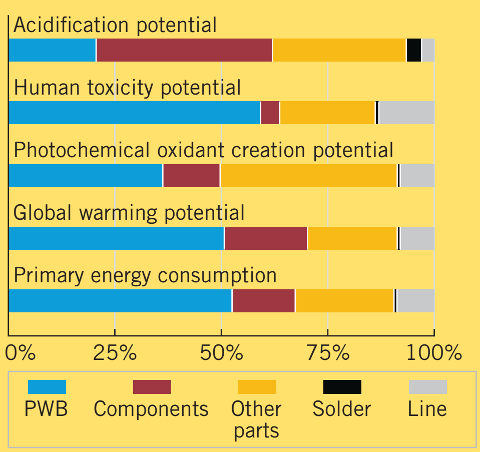

Figure 2. The environmental impact of the different board assembly tasks for a typical telecom PCB assembly (PCBA). *Source: University of Stuttgart, GaBi.*

Energy Labels

With energy consumption's overwhelming role in environmental effects, one solution is an energy label for pick-and-place machines. EuP requirements have so far focused on consumer markets, but industrial products also are important. Here, R&D departments can have the strongest future environmental impacts of the products they design. Their downstream effects can be spread across millions of products.

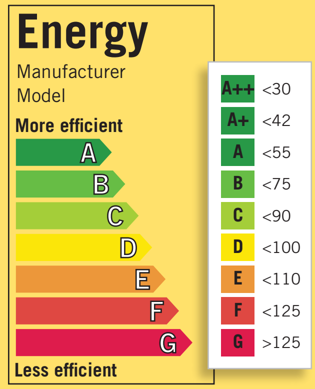

Figure 3: Suggested energy label for placement machines (taken from existing energy label for refrigerators/freezers). Class A products have an energy consumption that is 55% of the average for products on the market.

The method outlined here takes guidance from the EuP. That covers eco-design requirements for design and development of products that consume significant energy and natural resources. A comparison of six component placement systems using Eco-Indicator 99, suggests that an energy label system would be important. However, ISO 14042 does not allow use of this method alone to compare different products.

Energy labels can be simple; the EuP directive proposes labels with 6 to 9 classes. The average energy consumption of all available products is rated 100. If the energy consumption of a certain product is, for example, 55% or below average, then it is rated as class A (Figure 3).

Help reduce impact and waste by ensuring machines keep working at top performance and efficiency, taking steps to improve output, quality and yield, uptime, and efficiency. That helps ensure that lines continue to work efficiently over the machine's whole working life.

* Machine changes and environmental assessment were performed on the Assembléon A Series equipment.

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