ENERGY STAR® Guides for Energy Efficiency Opportunities, Featuring the Motor Vehicle Assembly Industry

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ABSTRACT

As manufacturers face an increasingly competitive environment, energy efficiency improvements can be a way to reduce costs without negatively affecting product quality or yield. One major barrier to reducing energy costs and associated environmental impacts is access to the information that is available. The U.S. Environmental Protection Agency's ENERGY STAR® Program works with industries to address the need for strong and strategic corporate energy management programs. As a part of this voluntary program, one tool ENERGY STAR provides is a guide for energy and plant managers on energy efficiency opportunities for their industry. We present the results from the energy guide for the motor vehicle assembly industry. After describing the industry's trends, structure and production and the process's energy use, we examine energy efficiency opportunities for motor vehicle assembly plants. Where available, we provide energy savings and typical payback periods for each measure based on case studies of plants that have implemented it. Our findings suggest that although most motor vehicle companies in the U.S. have energy management teams or programs, there are still opportunities available at individual assembly plants to reduce energy consumption cost effectively. Furthermore, we find that even in light industries like vehicle assembly, many energy efficiency improvement opportunities exist in processes in addition to the cross-cutting measures typically included in assessments of light industries.

Introduction

As U.S. manufacturers face an increasingly competitive global business environment, they seek out opportunities to reduce production costs without negatively affecting the yield or the quality of the product. Uncertain energy prices in today's marketplace negatively affect predictable earnings. This is a concern, particularly for publicly traded companies like those in the motor vehicle industry. Successful, cost-effective investment into energy efficient technologies and practices meets the challenge of maintaining the output of high quality product with reduced production costs. This is especially important, as energy efficient technologies often include additional benefits, such as increasing the productivity of the company further. Finally, energy efficiency is an important component of a company's environmental strategy. End-of-pipe solutions are often expensive and inefficient while energy efficiency can be the lowest cost opportunity to reduce pollutant emissions.

Voluntary government programs aim to assist industry to improve competitiveness through increased energy efficiency and reduced environmental impact. ENERGY STAR, a voluntary program operated by the U.S. Environmental Protection Agency (EPA), stresses the need for strong and strategic corporate energy management programs. ENERGY STAR provides energy management tools and strategies for successful programs. ENERGY STAR works directly with a set of "focus" industries to improve their energy performance. Additional tools are developed and provided to the industry such as benchmarks/measures of efficient plant energy performance and an Energy Guide for energy and plant managers in specific industries. This paper reports on the research we conducted to support the U.S. EPA and its work with the vehicle assembly industry in developing its Energy Guide. This Energy Guide is currently available online (Galitsky and Worrell, 2003). It provides information on potential energy efficiency opportunities for vehicle assembly plants. ENERGY STAR can be contacted (www.energystar.gov) for additional energy management tools that facilitate stronger corporate energy management practices in the vehicle assembly and other U.S. industries.

Industry Overview

The motor vehicle industry is the largest industry in the U.S., producing 12-13 million cars and light trucks annually and generating almost $350 billion in output, more output (in dollars) than any other single U.S. industry (Fulton et al. 2001). In this paper, we focus on vehicle assembly plants. The vehicle assembly industry in 2001 was composed of 15 companies operating 76 plants, which include automobiles, sport utility vehicles (SUVs), light trucks, minivans, as well as buses and heavy-duty trucks. Total energy expenditures in the transportation equipment manufacturing industry as a whole (NAICS code 336)[1], are estimated at $3.6 billion for 1999 (DOC, 2000). In vehicle assembly plants categorized in SIC 3711, about $700 million is spent annually on energy.

Motor Vehicle Assembly Process

Because many of our measures focus on the light vehicle sector (including light trucks, SUVs and minivans), we have included a description of this process. Automobile manufacturing consists of four basic steps: parts manufacture, vehicle body production, chassis production and assembly. Although we focus on vehicle assembly plants, some of the plants have other manufacturing facilities on-site (e.g. stamping), and generally include painting lines. Therefore, we touch on elements of the whole production process in this section, while providing more detail on the assembly process.

Engine and Parts Manufacture

The vehicle industry produces many parts itself (e.g. by subsidiaries), while other parts are purchased. Engines are cast from aluminum or iron, and further processed in engine plants. Metal casting is an energy intensive production process. Engine parts must be assembled to produce the finished engine. Other major cast parts are axles and transmissions.

Vehicle Body Production

Automotive and other vehicle bodies (the exterior skins) are generally formed out of sheet steel, although we are seeing plastic and aluminum parts more in vehicle bodies.

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[1] Transportation equipment manufacturing (NAICS code 336) includes manufacturing of automobiles and parts, as well as aerospace, railroad, ship, boat and other transportation equipment like motorcycles and armored cars.

Different steel alloys are used because of their general availability, low cost and good workability. For certain applications, however, other materials, such as aluminum, fiberglass and reinforced plastic are used because of their special properties. Tooling for plastic components generally costs less and requires less time to develop than that for steel components, making it an attractive material for vehicle makers, despite its potentially higher cost per pound. The relative low-weight also contributes to higher fuel efficiency in cars.

Chassis

The chassis of the vehicle, or frame, is the main structure of the vehicle. In most designs, a pressed-steel frame forms a skeleton on which the engine, wheels, axle assemblies, transmission, steering mechanism, brakes and suspension members are mounted. Modern designs combine the chassis frame and the body into a single structural element. In this arrangement, the body shell is designed as a reinforced system that makes it rigid enough to resist the forces that are applied to it, and in order to pass all Federal Motor Vehicle Safety Standards (FMVSS).

Painting

To protect metal vehicle bodies from corrosion, special priming and painting processes are used. Bodies are first dipped in cleaning baths to remove oil and other substances. They then go through a succession of painting cycles, which help to maintain the visual quality of the paint and give the required hardness. Enamel and acrylic lacquer are both in common use. The latter is water-based and reduces the output of smog-forming volatile organic compounds (VOCs). There is disagreement among experts whether water based paints cause higher or equal energy consumption in the drying process (Leven 2001). Electrostatic painting, a process in which the paint spray is given an electrostatic charge (50 – 80 kV) and then is attracted to the surface of the car (which is at ground potential), helps assure that an even coat is applied over the total car body. Ovens with conveyor lines are used for the drying process. Alternative technologies use infrared-curing to save energy and production time and decrease the size of the dryer (see Energy Efficiency Section, below). After painting, the vehicle body is checked for inaccuracies in paint coverage and repaired if needed.

Assembly

Virtually every new car and light truck comes from the moving assembly line although the process has been refined by various companies through such concepts as ‘just-in-time’ (e.g. especially by Toyota) and other manufacturing experiments (e.g. Volvo’s human-centered assembly operations). An accurately controlled flow of materials and parts is essential to maintain vehicle production in the assembly plants, to avoid high inventory costs and possible disruptions in the manufacturing process.

The automobile assembly process itself has a uniform pattern between different plants. Generally, there are two main assembly lines, body and chassis. On the body assembly line, the body panels are fastened together, the doors and windows installed, and the body painted and trimmed (wiring, interior). On the chassis assembly line, the frame has the springs, wheels, steering gear, and power train (engine, transmission, drive shaft) installed, as well as the brakes and exhaust system. The two lines merge at the point where the body is fastened to the chassis. A variation on this process is "unitized" construction, whereby the body and frame are assembled as a unit. In this system, the undercarriage proceeds down the chassis line. The power train, front suspension and rear axle, are supported on pedestals until they are joined to the unitized body structure.

Assembly lines have been elaborately refined by automatic control systems and transfer machines, which have replaced many manual operations. Automatic transfer machines were first introduced by Austin Motors in Britain in 1950, and were first used in the U.S. by Ford in 1951. Today, computers manage the assembly process, offering the opportunity to build different versions of the same model, or even different car models on one assembly line, while welding robots do most or all of the welding. After assembly, the car is finished for shipment to dealers and customers.

Energy Use

Total energy expenditures in the transportation equipment manufacturing industry as a whole (NAICS code 336)[2], are estimated at $3.6 billion for 1999 (DOC 2000). In vehicle assembly plants (SIC code 3711), about $700 million is spent annually on energy. About two-thirds of the energy budget for assembly plants is spent on electricity, while fuels (coal natural gas, etc.) are used to generate hot water and steam (mainly for paint booths), as well as for heat in curing ovens.

Total energy costs are equivalent to approximately 1% of the production output by the vehicle assembly plants, making it a small cost factor in the total production process. The energy costs for the assembly of a car have declined from about $70/car in 1990 to about $60/car in 1995. This cost reduction may be due to reduced energy prices during that period, increased capacity utilization at assembly plants or improved energy efficient processing. It is our understanding that relatively low energy costs have led to relatively little attention to energy in the manufacturing processes, despite examples of very cost-effective energy efficiency improvement projects in the industry in the U.S. and abroad (see below).

Electricity use has increased over time from 8.6 TWh in 1987 to 10 TWh in 1995, while the average specific electricity consumption per car has decreased from almost 1000 kWh/car in 1987 to 860 kWh/car in 1995 (DOC 2000). This latter figure compares well to the average electricity use of Daimler Chrysler in 1999, estimated at 840 kWh/car (Daimler-Chrysler 2001). Fuel use is more difficult to track as it is only reported in the Manufacturing Energy Consumption Surveys (MECS) of 1994 and 1991. In 1994 (the last public data point on fuel use in the vehicle assembly industry), the industry consumed 77 TBtu of fuel, valued at $250 million. On a final energy basis, fuels represent 72% of the energy use, while on a primary energy basis, fuels represent 45% of total energy use.[3] In 1994, the specific fuel

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[2] Transportation equipment manufacturing (NAICS code 336) includes manufacturing of automobiles and parts, as well as aerospace, railroad, ship, boat and other transportation equipment like motorcycles and armored cars.

[3] Final energy is the purchased energy by the final user (or plant). Primary energy is calculated using the average efficiency for public power generation to estimate the fuels used to generate the power consumed by the automotive industry. We use an average efficiency of 32%. Hence, primary energy is roughly three times final energy.

consumption is estimated at 6.5 MBtu/car, while the primary specific energy consumption is estimated at 14.3 MBtu/car, demonstrating the importance of optimizing electricity use.

Electricity is used throughout the facility for many different purposes, such as compressed air, metal forming, lighting, ventilation, air conditioning, painting (fans and infrared (IR) curing), materials handling and welding. Estimates of the distribution of electricity and fuel use in vehicle assembly plants are rare and may vary among plants based on the processes used in that facility. Also, not many plants have separate metering of energy use at different locations and processes in the plants. Table 1 provides an estimate of the typical electricity end-use distribution in vehicle assembly plants, based on studies of vehicle assembly plants in the U.S. (Price & Ross 1989), Belgium and Sweden (Dag 2000), and Germany (Leven & Weber 2001). Around 70% of all electricity is used in motors to drive the different pieces of equipment in the plant, underlining the importance of motor system optimization in energy efficiency improvement strategies.

Table 1. Distribution of Electricity Use in Vehicle Assembly Plants

End-Use	**Share of electricity use (%)**	**Estimated typical electricity consumption (1995) (kWh/car)**
HVAC	11-20%	95-170
Paint systems (e.g. fans)	27-50%	230-320
Lighting	15-16%	130-140
Compressed air	9-14%	80-120
Materials handling/tools	7-8%	60-70
Metal forming	2-9%	20-80
Welding	9-11%	80-95
Miscellaneous	4-5%	35-45
Total	100%	730-1040

Source: Price & Ross 1989; Dag 2000; Leven & Weber 2001

The data represent typical uses based on a number of plants in the U.S. and Europe. The actual distribution in an individual plant may be different due to variations in processes found in different plants around the U.S.

Fuel is mainly consumed for space heating and for drying and conditioning the air (for temperature and humidity) in the painting line (although IR drying may have partially replaced it), but some facilities may have casting facilities for engines or other parts onsite that also require fuel. In Germany, paint shops use 50 to 60% of the fuel in the plants (Leven & Weber 2001). These fuels are mainly used for heating the vats (that carry the vehicles through the paint booths), conditioning the process air and thermal oxidation of VOCs in the exhaust. Some plants have engine and stamping plants onsite, and so may use extra electricity for machining metal. For the purposes of this study, we focus on assembly operations. Large amounts of energy may be used in the manufacture of automotive (or other vehicle) parts, and should be part of a comprehensive energy efficiency strategy for a vehicle manufacturer.

To study the opportunities for energy efficiency improvement, it is important to assess the total amount of energy used in each operation, as well as the load curve of the plant. Price & Ross (1989) and Dag (2000) both show that there may still be a substantial amount of energy used during regular, non-production shutdown. Energy management systems may help to reduce the non-productive energy consumption by controlling lighting and HVAC equipment. Electricity demand at shutdown can vary between a low of 20% (Price & Ross 1989) and a high of 40-50% (Dag 2000; Price & Ross 1989; Leven 2001).

Energy Efficiency Improvement

In this section, we briefly describe the energy efficiency opportunities that we have identified for vehicle assembly plants. We have gathered this information primarily from the technical and trade literature, discussions with industry, and information from vendors and suppliers. Due to the extent and wide variety of industry sources used, we will refer to the original report for a more extensive discussion and listing of sources (Galitsky and Worrell 2003). Not all of the descriptions may be applicable to an individual plant. In addition, this list is not presumed to be exhaustive and additional opportunities may exist.

Opportunities exist within the U.S. vehicle assembly plants to reduce energy consumption while maintaining or enhancing the productivity of the plant. Tables 2 and 3 list the energy efficiency measures that we identified. We categorized energy efficiency measures by their utility systems (general, motors, compressed air, heat and steam distribution, lighting, HVAC, material handling) or by process (painting, welding, stamping). We collected data from case studies for U.S. motor vehicle assembly plants where available; otherwise, we reference data for similar facilities (for example, metal shops) or for automobile or other motor vehicle assembly plants around the world. We provided specific energy and cost savings data when available, and calculated simple payback as a first measure of profitability. For U.S. vehicle assembly plants, actual payback and savings for the measures will vary, depending on plant configuration and size, plant location (particularly for the painting operations) and plant operating characteristics. The values presented in this paper are offered as guidelines; only a detailed study of a specific location can produce reliable estimates for that plant. We also acknowledge that paybacks vary from country to country and for newer plants versus older plants. To account for these differences, we sought comments from energy personnel and engineers at U.S. assembly plants and incorporated those comments. Wherever possible, we have provided a range of savings and paybacks found under varying conditions. Many of the measures in Tables 2 and 3 will now be discussed in detail.

Participation in voluntary programs like the EPA ENERGY STAR program or gaining ISO 14001 certification can help companies to track energy and implement energy efficiency measures. General Motors notes that using energy management programs in combination with the ISO program has had the greatest effect on conserving energy at their plants (General Motors 2001).

Changing or implementing an *overall energy program* is often the most successful and cost effective way to bring about energy efficiency improvements. In the U.S., most motor vehicle manufacturers have instituted energy management programs, which include energy policies, goals, measurement and benchmarking of energy use, and practices such as submetering and control systems. Ford's programs have a focus on shutdown procedures. As a part of this plan, Ford's Edison Assembly Plant (NJ) found energy savings of 14% in one year (Galitsky and Worrell 2003). GM achieved over $3.6 million in annual savings. Paybacks for improved energy management can be immediate; however, specific energy savings and payback periods for overall adoption of a strategic energy management system vary from plant to plant.

Improvements in *motor systems* include downsizing of motors to match load requirements, introducing variable speed drives (VSDs) and voltage controls (VVCs) and upgrading to better designed motors. All of these measures can have short payback periods of fewer than three years (Galitsky and Worrell 2003). In addition to energy savings, high efficiency motors run cooler and therefore have higher service factors, longer bearing and insulation life and less vibration; VSDs improve overall productivity, control and product quality and reduce wear on equipment and thus maintenance costs.

Because conversion of energy into compressed air is so inefficient, using *compressed air* should be avoided if possible and otherwise minimized. Major improvements for this area are listed in Table 4 along with available data on typical payback periods and percent energy savings for the compressor. Every plant should have a maintenance, monitoring, control system and leak reduction program in place. Other opportunities may be more appropriate

Table 2. Cross-Cutting (Utilities) Energy Efficiency Measures

General Utility
- Energy management systems/programs
- Combined heat and power (CHP)
- CHP with absorption cooling
- Alternative fuels
- District Heating

Motors
- Sizing
- Higher efficiency motors
- Switched reluctance drives
- Adjustable speed drives
- Variable voltage controls

Compressed air
- Maintenance
- Monitoring
- Leak reduction
- Turning off unnecessary air
- System modification
- Use sources other than compressed air
- Load management
- Use air at lowest possible pressure
- Minimize system pressure drop
- Cold air intake
- Controls
- Correctly sizing pipe diameter
- Properly size regulators
- Systems improvements
- Heat recovery for water preheating
- Energy efficient chillers
- Natural gas engine-driven compressors

Compressor motors
- Adjustable speed drives
- Higher efficiency motors

Boilers
- Improve process control
- Reduce flue gas
- Reduce excess air
- Correct sizing in design
- Improve insulation
- Boiler maintenance
- Recover heat from flue gas
- Return condensate
- Recover steam from blowdown
- Optimized boilers

Heat and steam distribution
- Improve insulation
- Maintain insulation
- Improve steam traps
- Maintain steam traps
- Monitor steam traps automatically
- Repair leaks
- Recover flash steam

Lighting
- Controls
- Setting lighting standards
- Daylighting
- Replace incandescents with fluorescents
- Replace T-12 with T-8 or metal halides
- Replace mercury with metal halide or high pressure sodium
- Replace metal halide HID with high-intensity fluorescents
- Electronic ballasts
- Reflectors
- LEDs or radium strips
- System improvements

HVAC
- Electronic controls
- Weekend setback temperatures
- Ventilation and cooling design improvements
- Recover cooling water
- Solar heating (Solarwall)
- Building shell
- Modifying fans
- Others

Materials handling/tools
- High efficiency belts

Miscellaneous
- Electric harmonic filter improvements
- Energy efficient transformers

Table 3. Process Related Energy Efficiency Measures

Paint Systems
- Maintenance and Controls
- Minimize stabilization period
- Reduce air flow in paint booths
- Insulation
- Heat recovery
- Efficient ventilation system
- Oven type
- Infrared paint curing
- UV paint curing
- Microwave heating
- Wet on wet paint

Paint Systems (cont)
- New paint—powders
- New paint—powder slurry coats
- New paint—others
- Ultrafiltration/reverse osmosis wastewater cleaning
- Carbon filters
- High pressure water jet system

Stamping
- Variable voltage controls
- Air actuators

Body Weld
- Computer controls
- High efficiency welding/inverter technology
- Multi-welding units
- Frequency modulated DC-welding machine
- Hydroforming
- Electric robots

during retrofits. Many opportunities to reduce energy in the compressed air systems are not prohibitively expensive; payback periods for some options are extremely short – often less than one year.

Energy efficiency measures in *boilers and steam distribution* center around improved process control, reduced heat loss and improved heat recovery. In addition to the measures listed in Table 2, new boilers should be constructed in a custom configuration that meets the needs of the particular system. Generally, savings for boiler measures are only 1-10% but paybacks are short. Table 5 lists typical energy savings and payback for these measures.

Table 4. Energy Efficiency Measures for Compressed Air

Measure	Payback (Years)	Energy Savings (%)
Maintenance	<2	
Monitoring	n/a	
Leak reduction	<1	10-20
Turning off unnecessary air	n/a	
System modification	n/a	
Use sources other than compressed air	≤1	
Load management	2-3.5	
Use air at lowest possible pressure	n/a	
Minimize system pressure drop	n/a	5-6
Cold air intake	≤1	12
Controls	1-2	2-3
Correctly sizing pipe diameter	n/a	4 (total plant electric)
Properly size regulators	n/a	
Systems improvements	≤1	
Heat recovery for water preheating	1-2	
Energy efficient chillers	3	
Natural gas engine-driven compressors	3	

n/a = data not available

Table 5. Energy Efficiency Measures for Boilers and Steam Distribution

Measure	Payback (Years)	Energy Savings (%)
Boilers		
Improve process control	1-2	
Reduce flue gas	n/a	2-5
Reduce excess air	<1	1-3
Correct sizing in design	n/a	3-8
Improve insulation	<1	
Boiler maintenance	<1	10
Recover heat from flue gas	1-2	1
Return condensate	1-2	10
Recover steam from blowdown	1-2	
Optimized boilers	2	
Heat and steam distribution		
Improve insulation	≤1	3-13
Maintain insulation	n/a	
Improve steam traps	n/a	
Maintain steam traps	<1	10
Monitor steam traps automatically	1	5
Repair leaks	<1	
Recover flash steam	1	

n/a = data not available

Additional cross-cutting efficiency measures include combined heat and power (CHP) (with or without absorption cooling), alternative fuels, district heating and upgrades in lighting, HVAC and materials handling. Daimler Chrysler (Germany) installed CHP and claims an overall efficiency of 85%, compared to 40% for conventional power plants (Galitsky and Worrell 2003). Where capital costs are prohibitive, it is possible to work with a utility company who will operate and sometimes own the CHP system but pass on the benefits of energy efficiency to the assembly plant. GM (U.S.), Ford (U.S.) and Land Rover (UK) have worked with utilities. In addition to energy savings, CHP systems have comparable or more reliable service than utility generation. In many plants in Germany and several Ford plants in the U.S., district heating supplies heat. Both Ford and GM have also successfully applied the use of landfill waste as an alternative fuel, replacing as much as 30% of the fuel used for heating the plant, reducing emissions and fuels costs (Galitsky and Worrell 2003).

Improvements in *lighting* include controls, lamp, fixture and ballast replacement, and system improvements. Although Daylighting systems generally require installation at the design stage, most other measures can be economical as retrofits as well. Table 6 summarizes typical payback periods and energy savings from implementing lighting upgrades. In addition to energy savings, lighting retrofits can increase productivity and the attractiveness of the workplace.

Table 6. Energy Efficiency measures in Lighting

Measure	Payback (Years)	Energy Savings (%)
Controls	1-2	Varies
Setting standards	Immediate	≥ 30
Daylighting	1-2	≥ 75
Replace incandescents with fluorescents or CFLs	<1	≥ 80
Replace T-12 with T-8 or metal halides	1-2	> 60
Replace mercury with metal halide or high pressure sodium	<1	50-60
Replace metal halide HID with high-intensity fluorescents	<1	50
Electronic ballasts	n/a	≥ 65
Reflectors	1.4	n/a
LEDs or radium strips	<1	90
System improvements	Varies	50-60

n/a = data not available

HVAC comprises a significant amount of the energy used in assembly plants – about 11 to 20% of the electricity and much of the fuel (Galitsky and Worrell 2003). In addition to the HVAC-related measures discussed above for motors, compressed air and heat and steam distribution, other additional HVAC measures are listed in Table 2. Some of these are as simple as planting shade trees to cool the building shell or rolling back the weekend temperatures to a higher temperature in the summer or a lower temperature in the winter. These yield immediate savings. Other measures may have a longer payback period but produce larger energy savings. For example, electronic controls can save as much as 50% of the energy used in ventilation in the paint shop, with a payback of 1 to 2 years.

Paint shops are the major energy-consuming center at vehicle assembly plants. Energy is used to condition the air for the painting and drying steps, as well as for the drying process and for treatment of the emissions. Ford reports that 70% of the total energy costs in its assembly plants is due to painting operations. Within the painting process itself, relatively little energy is required for curing (drying) the thin paint film in comparison to the energy used in raising the temperature of the dollies and the carriers as well as the car bodies (Galitsky and Worrell 2003). Related to the painting process, the painting booths must be purged to remove evaporated solvent, oversprayed paint particles and regulated pollutants (like VOCs) from the spray application. Like the HVAC-energy needs, ventilation energy requirements are significant (Galitsky and Worrell 2003).

Table 7 lists typical energy savings and payback periods for energy efficiency measures in the paint shop. Every plant should regularly maintain the paint booth and install proper controls for its system. Most plants do not operate continuously and should, therefore, minimize the startup periods for heating up the ovens. Both of these measures should show immediate or short paybacks. Other measures may have longer payback periods but have large energy savings. Much heat is vented in the exhaust or lost to the oven walls and often much of this heat can be recovered. Ventilation systems can be improved through reduction of ventilation speed, turning down airflow during breaks, and computer controlled ventilation demand control. Replacing gas-fired bake ovens with infrared ovens speeds up the stoving procedure and reduces oven size, lowering energy consumption. New paints, in addition to possible energy savings, reduce VOC emissions as well. Some measures in Table 7 are noted as emerging technologies or have not been thoroughly tested in commercial applications.

Table 7. Energy Efficiency Measures in Painting

Measure	**Payback (Years)**	**Energy Savings (%)**
Maintenance and Controls	Immediate	2-10
Minimize stabilization period	Immediate	n/a
Reduce air flow in paint booths	n/a	n/a
Insulation	Varies	20
Heat recovery	1-3	30-60
Efficient ventilation system	≤ 2	≤ 60
Oven type	n/a	n/a
Infrared paint curing	1-3	≤ 85
UV paint curing	E.T.	E.T.
Microwave heating	E.T.	E.T.
Wet on wet paint	n/a	n/a
New paint—powders	2-3	18-30
New paint—powder slurry coats	n/a	n/a
New paint—others	n/a	n/a
Ultrafiltration/reverse osmosis wastewater cleaning	2	n/a
Carbon filters	≥ 4	n/a
High pressure water jet system	≤ 1	n/a

n/a = data not available

E.T. = emerging technology; no commercial applications have yet been installed

In addition to energy savings, many of the measures in *body welding* have other benefits as well. For example, computer controls enable more effective, less expensive, faster and more reliable welding. In high efficiency welding, power to the transformer is shut off during system idling and cooling fans only run when needed. Energy savings of 10-40% are expected. In addition, high efficiency welding has a wider power range than traditional technologies, power supplies are smaller and lighter and therefore portable, welding quality, precision and control is improved, productivity is increased through higher possible heat rates and maintenance costs are decreased. Multi-welding units have reduced cleanup time, reduced down time, increased deposition rates, smoother running with less spatter and are lighter and portable. Hydroforming is a process that produces lighter, co-fabricated parts that have fewer welds with high stiffness, tensile strength properties and structural integrity.

Stamping efficiency measures include variable voltage controls and air actuators. Variable voltage controls can be used on any variable loads with constant speed, such as stamping presses, with a payback of about 2 to 3 years. Air actuators reduce the leakage associated with conventional die cushions on large stamping presses. One assembly plant in Michigan reported 25% reduction in compressed air by converting half of its presses (Price & Ross 1989). Maintenance savings are generally equal to the energy cost savings.

Discussion and Conclusion

The motor vehicle industry in the U.S. annually spends about $3.6 billion on energy. In this paper, we focus on vehicle assembly plants. In the U.S., over 70 assembly plants produce 13 million cars and trucks each year. In assembly plants, energy costs are a relatively small cost factor in the total production process. Still, as manufacturers face an increasingly competitive environment, energy efficiency improvements can be a way to reduce costs without negatively affecting the yield or the quality of their product. In addition, reducing energy costs reduces the unpredictability associated with variable energy prices in today’s marketplace, which negatively affect predictable earnings, an important element for publicly traded companies like those in the motor vehicle industry.

We found that although most companies in the U.S. motor vehicle industry have energy management teams or programs, there are still opportunities available at individual plants to reduce energy consumption cost effectively, both in utilities and in the process. We identified over 90 energy efficient practices and technologies. Where possible, we provided specific energy savings data for each efficiency measure based on case studies that describe implementation of the measures as well as references to technical literature.

Cross-cutting utility energy efficiency measures that do not interfere with the assembly process show immediate potential for cost-effective energy savings. We have discussed 68 cross-cutting energy efficiency improvement measures that can reduce energy consumption in the supply and use of motors, compressed air, lighting, hot water and steam generation and distribution, power supply and HVAC. Savings of individual measures may be relatively small. However, the cumulative effect of these measures can potentially be large. Generally, the majority of these measures have relatively fast paybacks. The degree of implementation of these measures will vary by plant and end-use and continuous evaluation for these opportunities will help to identify further cost-savings.

For process-specific measures, some new technologies both reduce energy and improve product quality consistency or yield. We identified 25 different energy efficient practices and technologies in painting, welding and stamping. Implementation of most of these measures will be part of strategic investment and innovation at assembly plants. Selected technologies have large additional benefits including product quality improvement.

Further research on the economics of the measures for individual assembly plants, as part of an energy management program, is needed to assess the potential impact of selected technologies at individual assembly plants.

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