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COMMITTEE ON ENVIRONMENT & PUBLIC WORKS
SUBCOMMITTEE ON CLEAN AIR & NUCLEAR REGULATION
SENATOR JOSEPH I. LIEBERMAN, CHAIRMAN

HEARING ON
"Efforts to Design and Produce a Cleaner Car"

Tuesday, April 27, 1993
9:30 a.m.

Dirksen Senate Office Building
Room 406

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**TESTIMONY BEFORE THE SENATE COMMITTEE
ON ENVIRONMENT AND PUBLIC WORKS
SUBCOMMITTEE ON CLEAN AIR
AND
NUCLEAR REGULATION**

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APRIL 27, 1993

Good morning, Mr. Chairman, and members of the Committee. My name is Michael P. Walsh and I am an independent technical consultant in the field of motor vehicle pollution control. During much of your deliberations leading up to the adoption of the 1990 Clean Air Act Amendments, I was a consultant to the Senate Environment and Public Works Committee and have worked closely with several states, especially California and the Northeast in the implementation of this critically important law. Most of my current work is overseas and I am actively involved in projects in Manila, Sri Lanka, Bangkok and China at the present time. I am also the Chairman of the External Advisory Panel to the World Bank and the Mexican Government on the Mexico City Motor Vehicle Pollution Control Project.

I am not representing anyone but myself in my testimony today. In my testimony, I would like to emphasize two key points:

- 1. Future continued growth in the global automobile industry is dependent on its ability to build clean, efficient vehicles, and**
- 2. Those companies which will be most successful in meeting that market demand will be those which produce highly efficient (low CO₂) and clean (low HC, NOx and CO) vehicles.**

Across the entire globe, motor vehicle usage has increased tremendously. In 1950, there were about 53 million cars on the world's roads; only four decades later, the global automobile fleet is over 430 million, more than an eightfold increase. (See Figure 1) On average, the fleet has grown by

FIGURE 1: GLOBAL TRENDS IN VEHICLE REGISTRATIONS

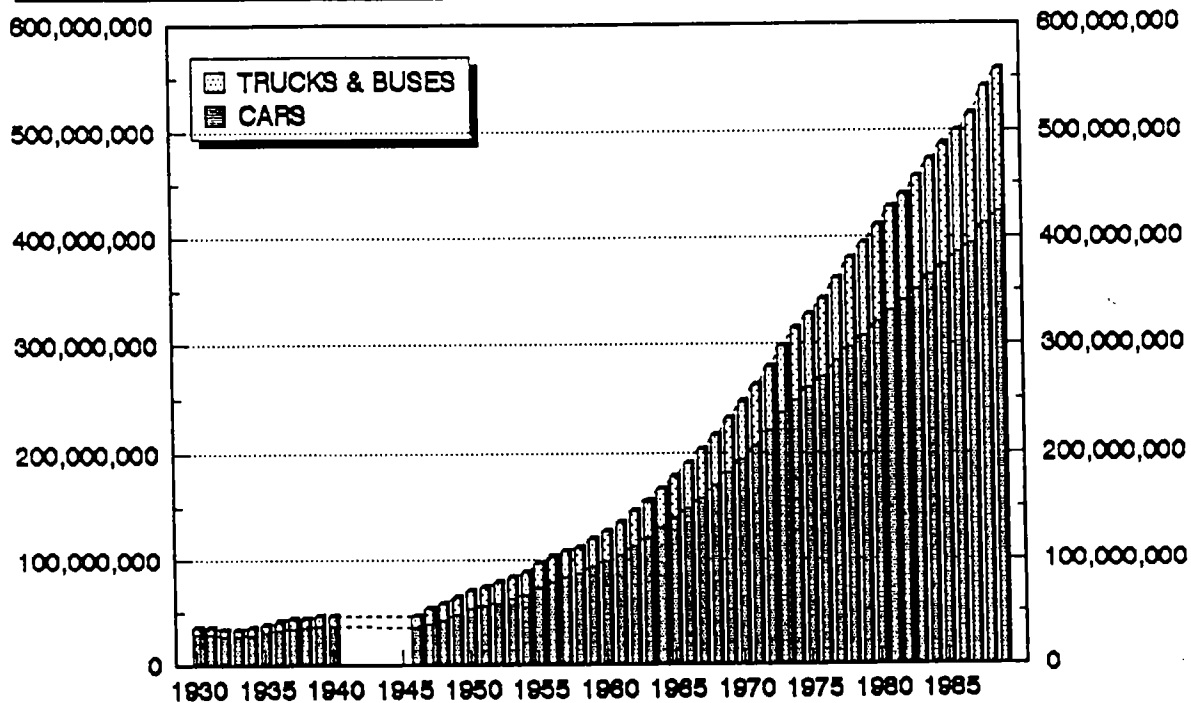
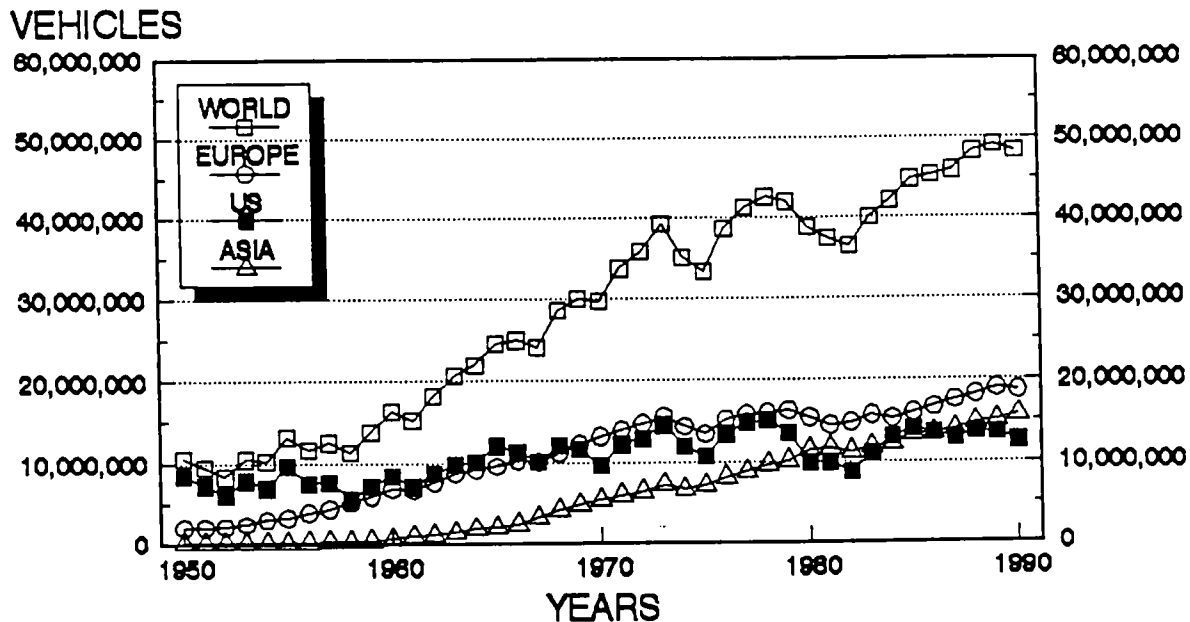


FIGURE 2: WORLD MOTOR VEHICLE PRODUCTION
1950-1990



about 9.5 million automobiles per year over this period. Simultaneously, the truck and bus fleet has been growing by about 3.6 million vehicles per year. While the growth rate has slowed in the highly industrialized countries, population growth and increased urbanization and industrialization are accelerating the use of motor vehicles elsewhere.

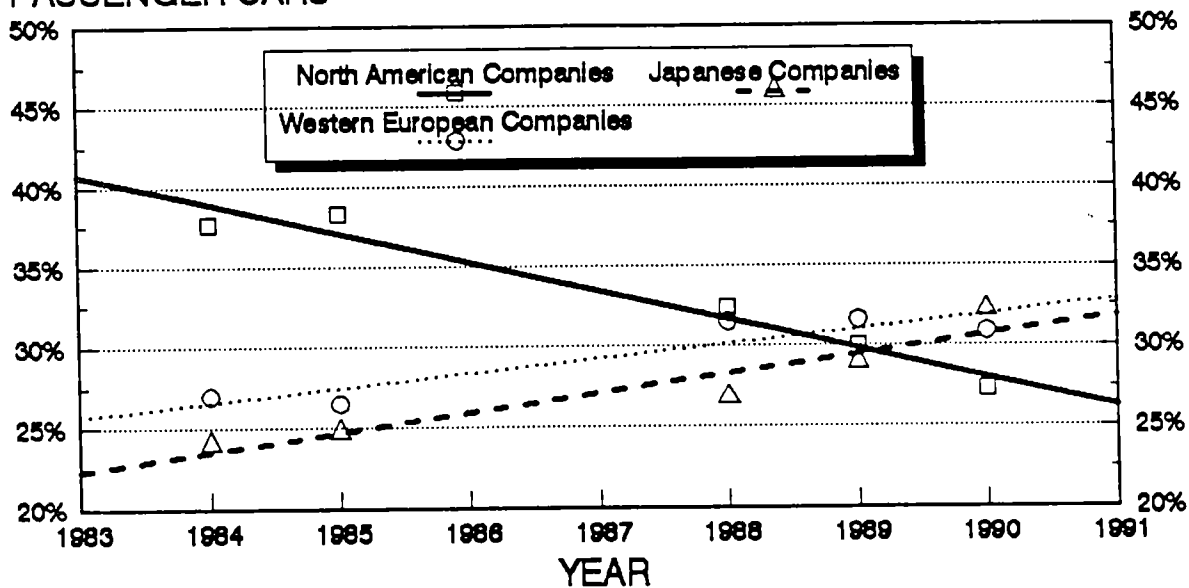
Overall growth in the production of motor vehicles, especially since the end of World War II, has been equally dramatic. Between 1950 and 1990, production increased almost linearly from about 10 million vehicles per year to about 50 million per year, approximately 1 million additional vehicles produced each year compared to the year before. (See Figure 2)

Over the past several decades, motor vehicle production has gradually expanded from one region of the world to another. Initially and through the 1950's, it was dominated by North America. The first wave of competition came from Europe, and by the late 1960's European production had surpassed that of the United States. Over the past two decades the car industry in Asia, led by Japan, has grown rapidly and now rivals both those in the United States and Europe. The downward trend in the U.S. share of the global marketplace continues unabated to this day and may actually be increasing. (See Figure 3)

One result of the growth in vehicles and their production is that worldwide, cars, trucks, buses, and other motor vehicles are playing an ever increasing role in global climate change and air pollution. As large oil consumers, motor vehicles are major sources of carbon dioxide; volatile organic compounds (VOCs) and nitrogen oxides, the precursors to

FIGURE 3: GLOBAL MOTOR VEHICLE PRODUCTION TRENDS
COUNTRY OF ORIGIN OF COMPANIES

PASSENGER CARS

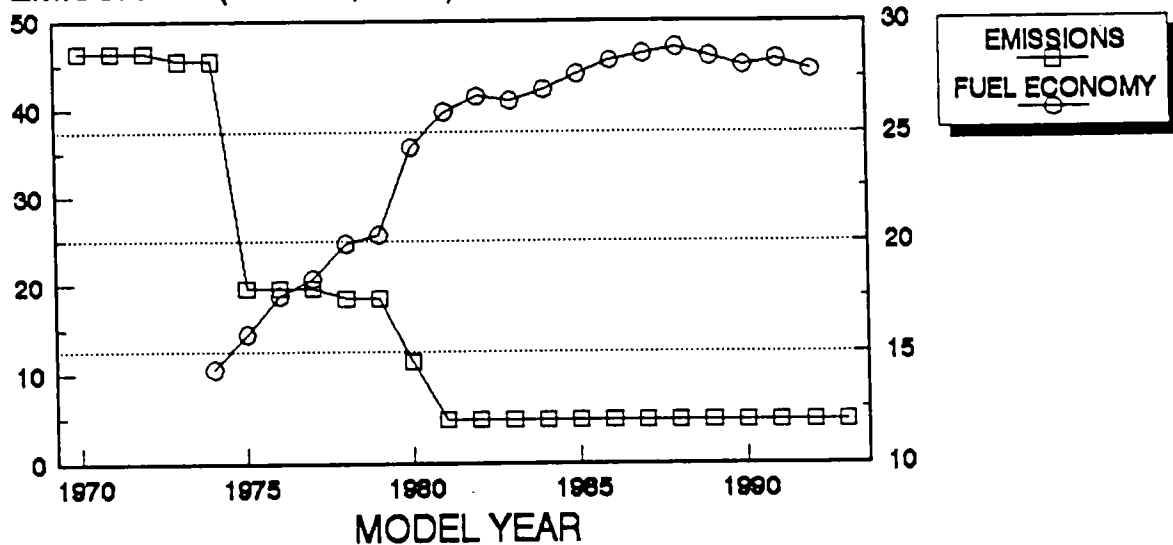


Source: MVMA Facts & Figures

FIGURE 4: EMISSIONS AND FUEL EFFICIENCY TRENDS
NEW CARS

EMISSIONS (GRAMS/MILE)

MPG



Emissions=CO+HC+NOx Standards Combined

both tropospheric ozone and acid rain; carbon monoxide (CO); and chlorofluorocarbons (CFCs).

Virtually the entire global motor vehicle fleet runs on fossil fuels, primarily oil. For every gallon of oil consumed by a motor vehicle, about 19 pounds of carbon dioxide (containing about 5.3 pounds of carbon) go directly into the atmosphere.¹ In other words, for every 15 gallon fill up at the service station, about 300 pounds of carbon dioxide are eventually released into the atmosphere. Globally, motor vehicles account for about a third of world oil consumption and about 14 percent of the world's carbon dioxide emissions from fossil fuel burning. For the United States, motor vehicles cause about 50 percent of oil demand and about 25 percent of carbon dioxide emissions.

Although ozone in the lower atmosphere does not come directly from motor vehicles, they are the major source of the ozone precursors, hydrocarbons and nitrogen oxides, throughout the industrialized world. Over the past 100 years, "background" ozone levels have approximately doubled, and monitoring data suggest that ozone concentrations are increasing by about 1 percent per year in the northern hemisphere.

Besides contributing to the greenhouse problem, ozone pollution also adversely affects human health, crops, other vegetation, and materials.

¹Direct tail-pipe emissions only. Transportation, refining, and distribution account for perhaps 15 to 20 percent of total emissions.

Eye irritation, coughing and chest discomfort, headaches, upper respiratory illness, increased asthma attacks, and reduced pulmonary function can all plague people exposed to ozone. This gas has also been shown to reduce crop productivity, with U.S. annual losses of several billion dollars, and to kill ponderosa and Jeffrey pines in California and eastern white pines in the eastern United States.

Widespread and pervasive, smog looks to be a long term problem in many areas of the world unless more stringent controls on vehicles and other sources are adopted. Areas of rapid industrialization are now starting to note similar air pollution problems to those of the industrialized world. Cities such as Mexico, Delhi, Seoul, Singapore, Hong Kong, Sao Paulo, Manila, Santiago, Bangkok, Taipei and Beijing to cite just a few already experience unacceptable air quality or are projecting that they will in the relatively near future. Some of these cities - especially Bangkok, Mexico City, and Athens stand out - are already in crisis with alarming levels of pollution a daily reality. As the vehicle population has grown and become increasingly concentrated in the world's growing number of megacities, the number of people subjected to unhealthy levels of pollution continues to rise.

Fortunately, advances in automotive technologies have made it possible for countries to respond to these health and environmental concerns by dramatically lowering emissions from motor vehicles. Increasingly, countries around the world have been taking advantage of them. Initial crankcase HC controls were first introduced in the early '60's followed by exhaust CO and HC standards later that decade. During the mid to late

1970's, advanced technologies including catalytic converters were introduced on most new cars in the U.S. and Japan. These technologies resulted from a conscious decision to "force" the development of new approaches and were able to dramatically reduce CO, HC and NOx emissions beyond previous systems. As illustrated in Figure 4, at the same time that pollution levels were being reduced, vehicle fuel economy doubled. U.S. industry can and should take great pride in the fact that new cars produced in the U.S. today emit but a small fraction of the pollution that they did a generation ago for each mile they drive and consume only half the volume of fuel.

With knowledge of these technological developments on cars spreading, and the adverse effects of motor vehicle pollution becoming more widely recognized, more and more people across the globe began demanding the use of these systems in their countries. During the mid 1980's, Austria, the Netherlands and the Federal Republic of Germany adopted innovative economic incentive approaches to encourage purchase of low pollution vehicles. Australia, Canada, Finland, Austria, Norway, Sweden, and Switzerland all decided to adopt mandatory requirements. Even rapidly industrializing, developing countries such as Brazil, Chile, Taiwan, Hong Kong, Mexico, Singapore and South Korea have adopted stringent emissions regulations. After years of delay, the European Economic Community has begun to move rapidly toward state of the art pollution controls. As 1990 came to a close, the European Council of Environmental Ministers reached unanimous agreement to require all new models of light duty vehicles by 1992/1993 to meet emission standards roughly equivalent to current U.S. levels. Further they voted to require the Commission to develop a proposal

which, taking account of technical progress, will require a further reduction in limit values. (Figure 5 and 6 illustrates that most major countries of the world and many rapidly industrializing ones have or are moving toward U.S. type auto emission standards.)

Just as the world was catching up with the U.S. auto standards, the U.S. and California during 1990, decided to push technology toward the next generation of controls. (See Figures 7 and 8) As California's standards are much more stringent than Federal requirements and mandate the development of Zero Emission vehicles (so called ZEV's), many other states with serious air pollution problems have decided to opt into the California program. (See Figure 9)

On a technological level, the response to California's requirements has been tremendous. For example, just about a year ago, on April 14, 1992 Ford Motor Company announced that the 1993 model Ford Escort and Mercury Tracer powered by a new 1.9 liter engine "achieved a major milestone, four years ahead of schedule, making it the first auto maker to meet the first in a series of very stringent air quality standards adopted by California for the 1990's." As Ford further noted, "the engine in these vehicles was designed and is manufactured in the United States, using U.S. components". EPA has also tested a 2 stroke engine manufactured by Orbital engine company and found it to have exceptional fuel economy while virtually achieving California's Ultra Low Emission Levels. In addition, tremendous advances in electric vehicles and fuel cells are starting to emerge in response to California's specific mandate for 10% Zero Emissions Vehicles by early in the next century.

FIGURE 5: ASIA PACIFIC REGION

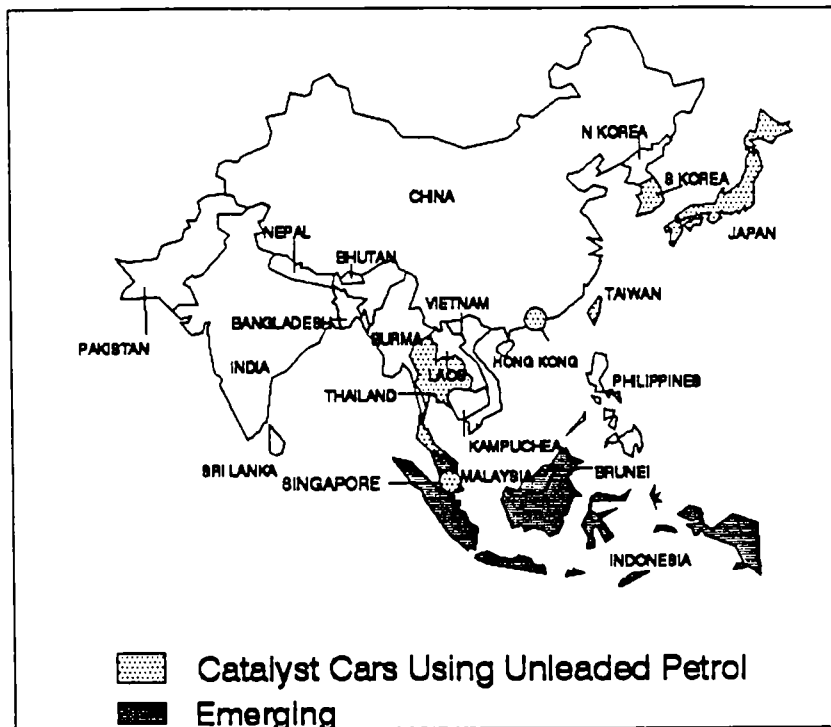


FIGURE 6: WORLDWIDE OVERVIEW

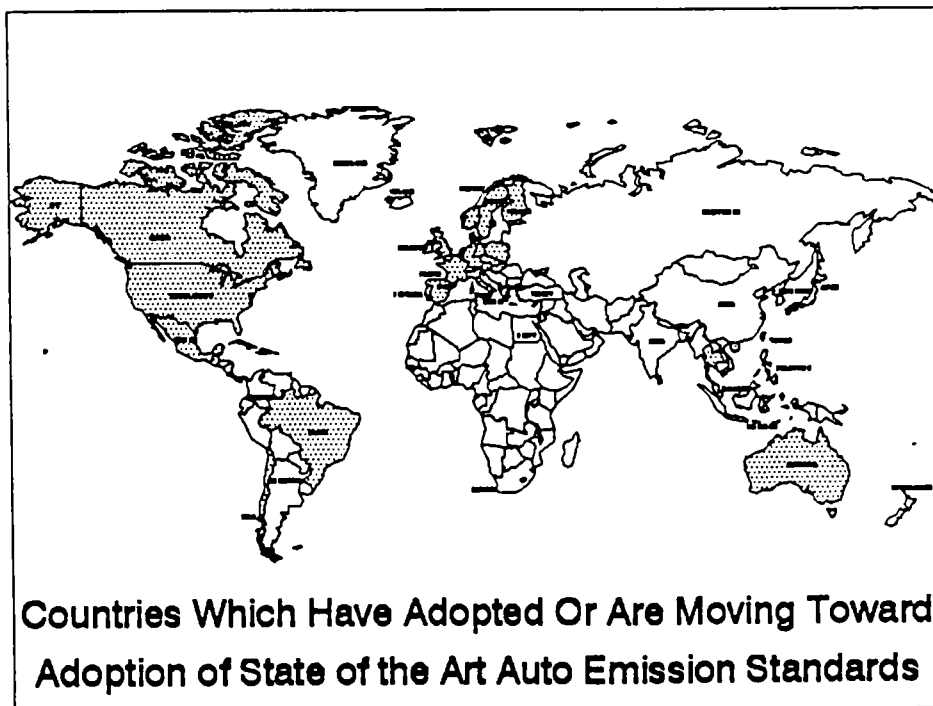


FIGURE 7: AUTO AND LIGHT TRUCK STANDARDS IN USE
OXIDES OF NITROGEN

GRAMS PER MILE

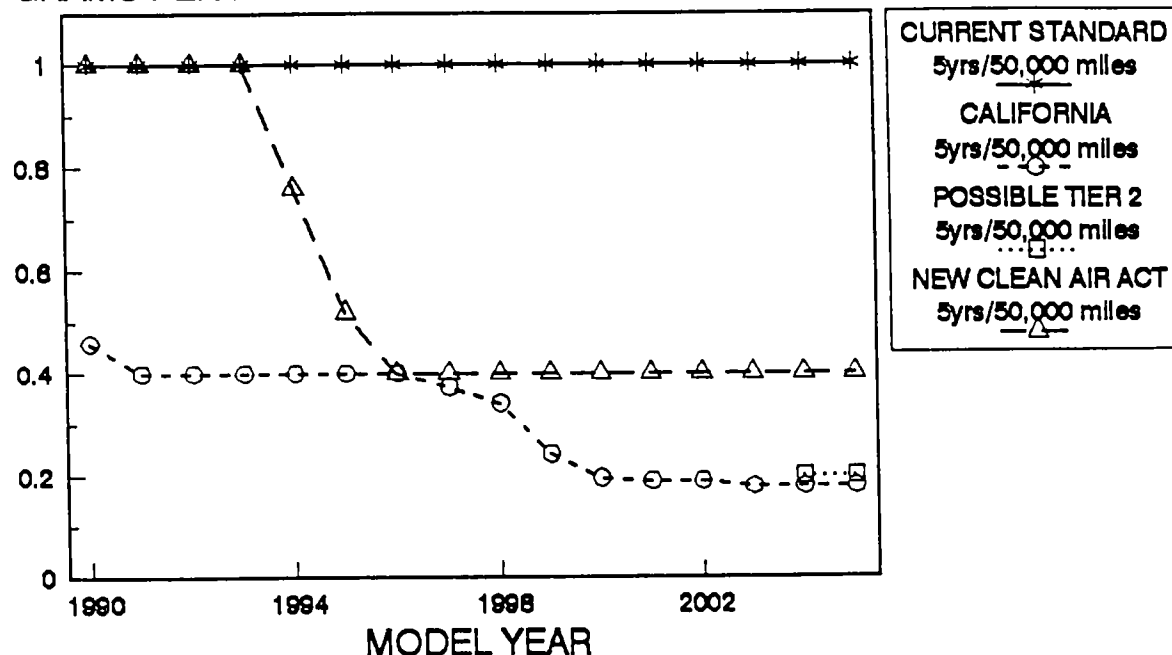


FIGURE 8: AUTO AND LIGHT TRUCK STANDARDS IN USE
HYDROCARBONS

GRAMS PER MILE

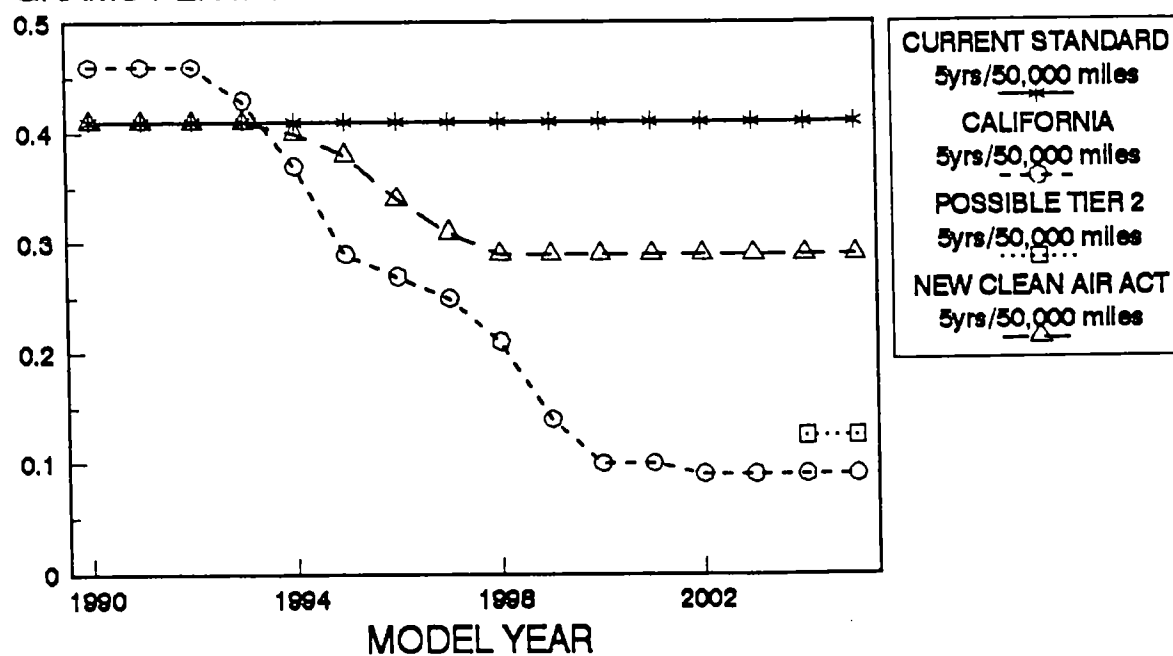


FIGURE 9: MOVEMENT TOWARD "CALIFORNIA" STANDARDS

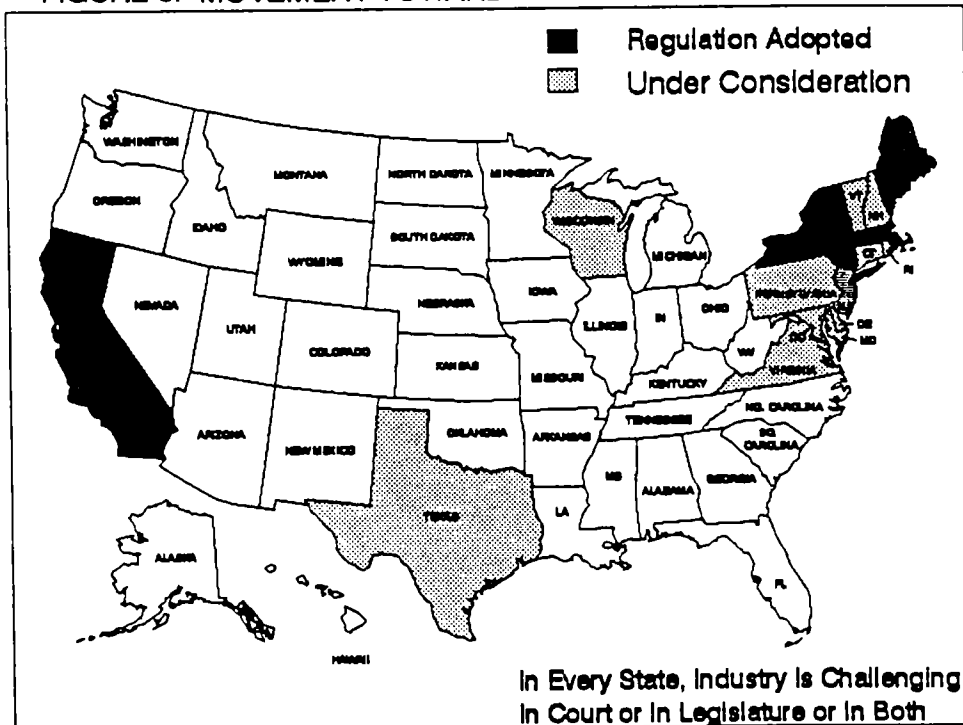
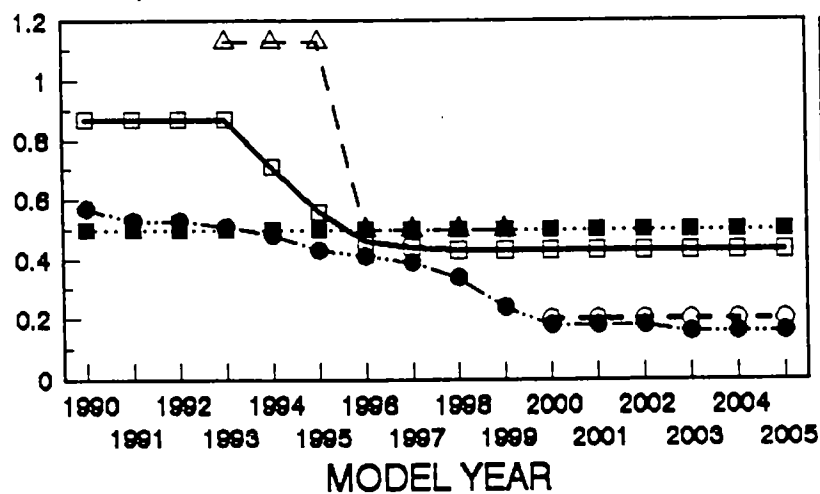


FIGURE 10: CURRENT LIGHT DUTY VEHICLE STANDARDS
HC PLUS NOx COMBINED

GRAMS/KILOMETER



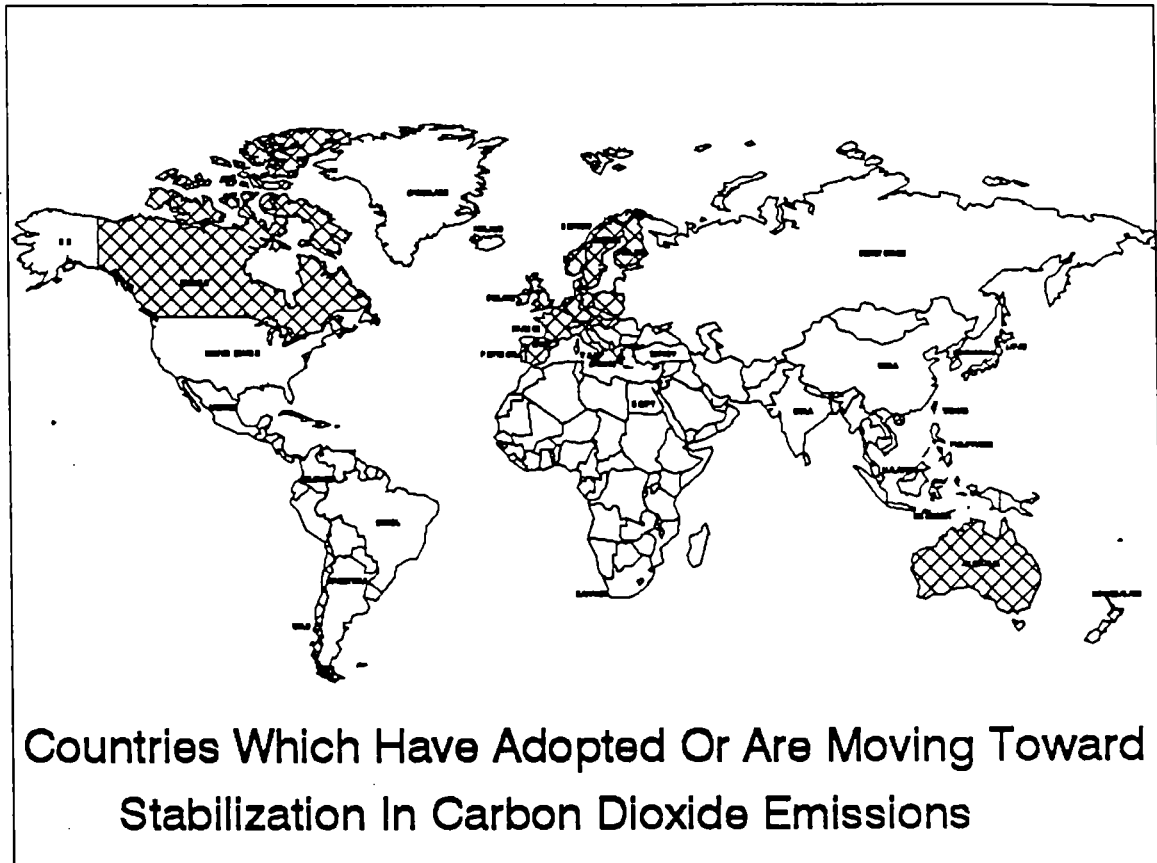
The US, Europe and Japan Use Different Test Procedures Which Influences The Actual Stringency of the Requirements

Ironically, while the technology continues to advance, and the domestic car industry has publicly reacted very positively to President Clinton's Green Car initiative, they continue to aggressively oppose these state efforts in the Courts and in State legislatures. This is especially puzzling and troubling because the development of these clean vehicle technologies would tend in my view to give the domestic vehicle industry a leg up on the rest of the world, as the rest of the world follows the U.S. and California toward tighter standards. This is already beginning. For example, Germany has proposed that the entire European Community, the largest car market in the world, adopt standards similar to California's by the year 2000. (see Figure 10)

In looking to the future motor vehicle marketplace, two trends stand out. First, it is expected that continuous high growth in vehicle production will remain the norm, at least for the next several decades as countries with much lower per capita vehicle populations advance economically. The major threat to this growth in new car sales, in my judgement, is the serious environmental problems which they cause. In effect, therefore, the future of the automobile industry is dependent on its ability to build clean, efficient vehicles.

Thus the second conclusion that those companies which will be most successful in meeting that market demand will be those which produce highly efficient (low CO₂) and clean (low HC, NOx and CO) vehicles. With European and other countries committed to stabilization of CO₂ emissions (See Figure 11), the demand for more fuel efficient vehicles

FIGURE 11: WORLDWIDE OVERVIEW



will continue to increase. Further, as pollution problems become more severe in the rapidly developing countries, they are increasingly moving toward stringent control of conventional pollutants. In order to compete successfully, car companies of the future will need to produce efficient, clean vehicles. If U.S. companies aggressively pursue this market, it will lead to more jobs and greater profitability. Conversely, those which cannot or choose not to compete in this aspect of the market will fall further and further behind. As an aside, it should be noted that clean vehicles by contributing to clean cities will also improve those economies by reducing the costs of pollution.



NEWS FROM THE WORLD OF FORD

IMMEDIATE RELEASE

Contact: Rex M. Greenslade
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The 1993 model Ford Escort and Mercury Tracer powered by a new 1.9 liter engine are the world's first automobiles to be certified by the California Air Resources Board (CARB) as mass production vehicles that meet the most stringent exhaust emissions standards ever adopted.

With California's certification of the Ford Escort and Mercury Tracer as Transitional Low Emissions Vehicles (TLEVs), Ford has achieved a major milestone, four years ahead of schedule, making it the first auto maker to meet the first in a series of very stringent air quality standards adopted by California for the 1990s.

"What makes the 1.9L Ford Escort and Mercury Tracer unique is that they accomplish this while operating on regular unleaded gasoline available at gas pumps everywhere," said Thomas H. Howard, assistant chief engineer of Ford's Powertrain Systems. "In other words, consumers don't need any extra equipment or special fuel to help improve air quality significantly. However, as the California vehicle standards become more stringent, we will need California's reformulated gasoline to assist us with compliance."

Donald R. Buist, director of Ford Motor Company's Automotive Emissions and Fuel Economy Office, said: "Ford has long been sensitive to the issue of lowering harmful emissions. The engine used in the 1993 1.9L Ford Escort and Mercury Tracer was designed from the start with this in mind."

"As a result," Buist added, "Ford technology has been able to provide Californians with vehicles that can make a significant contribution to air quality improvement in a state with the worst air-quality problems in the nation."

The engine technology in the new Ford Escort and Mercury Tracer allows the new TLEVs to emit lower levels of non-methane organic gasses (NMOG) that contribute to smog formation.

"Moreover, the engine in these vehicles was designed and manufactured in the United States, using U.S. components," Howard said. "This is proof positive that Ford is a technology leader in very demanding market."

In certifying the vehicles, CARB officials said that although the 1993 1.9L Ford Escort and Mercury Tracer have been certified as 1993 models, their actual emissions are as low as the that will be imposed on 25 percent of all new cars sold in California in 1997.

At that time, the state's emission standards will be 70 percent stricter than similar limits set by the U.S. Environmental Protection Agency for the rest of the nation.

The 1.9L Ford Escort and Mercury Tracer also are the first vehicles certified by CARB for durability of emissions control systems by meeting standards for 100,000 miles, which is double the previous standard required by CARB.

While California regulations permit new vehicles sold today to emit 0.39 grams per mile (gpm) hydrocarbons, that figure is reduced to 0.25 gpm in 1994, which is equivalent to the first level of new federal standards contained in the Clean Air Act Amendments of 1990. A TLEV must cut NMOC emissions by another 50 percent -- to 0.125 gpm -- reducing hydrocarbons by 99 percent from pre-1972 uncontrolled levels.

TLEVs are the first step in the Low Emissions Vehicle program recently adopted by CARB. This program runs through the 1990s and requires manufacturers to build their vehicles to increasingly stringent emissions levels.

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4/14/92

TESTIMONY ON THE CLEAN CAR TASK FORCE

Presented Before the United States Senate
Committee on Environment and Public Works
Subcommittee on Clean Air and Nuclear Regulation
Washington, D.C.
April 27, 1993

Alan C. Lloyd, Ph.D.
Chief Scientist
South Coast Air Quality Management District
Diamond Bar, California

This testimony addresses the proposed efforts of President Clinton's Clean Car Task Force. It is structured to provide background on the magnitude of air quality problems in the Los Angeles Basin, with specific emphasis on how motor vehicles contribute. Perspectives are offered about technology development based on the South Coast Air Quality Management District's small but effective program. Recommendations are provided on the thrust of this program and its ability to provide world leadership and global sales for the automobile industry.

This testimony comes directly from the District's experience with forcing development of advanced technologies through standards and deadlines. However, we have put equal emphasis on our responsibility to help develop the needed technologies. I oversee the District's \$7 million per year technology advancement program, which has cumulatively supported more than 75 demonstration programs since 1988. We have been able to leverage each of our dollars with about three outside dollars from industry, academia, state and national agencies, and other sponsors. We are pleased to see the new interest here in Congress and at the White House to launch a much-needed Clean Car Task Force. Drawing on my experience, I offer the following information and responses to your specific questions about how to set up a large national program in cooperation with the auto industry.

Introduction

Motor vehicles are the major source of air pollution in America's urban areas. The South Coast Air Quality Management District (the District) is very supportive of the idea proposed by the Administration to develop new and progressively cleaner power-plant technologies for the automobile. At stake is not just healthful air and better quality of life in our cities, but also restoration of the U.S. auto industry's world leadership.

Since the introduction of the California Low Emission Vehicle/Clean Fuel (LEV/CF) Program in 1990 by the California Air Resources Board (CARB), there have been dramatic advances in automotive emission control technologies and clean-burning alternative fuels, including electricity and hydrogen. We applaud the efforts and accomplishments of the automobile and emissions control industries

leading up to, and subsequent to, adoption of this revolutionary program. To date, the LEV Program has been a major catalyst for substantial worldwide research and development, which has resulted in greater than anticipated progress towards the ultra-low and zero-emission vehicles.

We see the proposed Clean Car Task Force as an important and unprecedented opportunity for the U.S. auto industry to leapfrog current vehicle technology and provide the type of leadership for which it was once recognized. Our agency has not just the desire -- but the undeniable need and obligation as well -- to rapidly deploy advanced zero-emission vehicles using non-combustion propulsion systems such as fuel cells and advanced batteries. To illustrate this need, I will provide a brief background on the description of the Los Angeles area, its ambient air quality, and the health impacts faced by the citizens of this region.

Scope of the Air Pollution Problem in Southern California

The South Coast Air Basin (Basin) is a 6,600 square-mile area bounded by the Pacific Ocean to the west and the San Gabriel, San Bernardino, and San Jacinto mountains to the north and east. The Basin includes all of Orange County and the non-desert portions of Los Angeles, Riverside, and San Bernardino Counties.

The Basin currently is home to more than 13 million people and 9 million motor vehicles. These vehicles are driven about 280 million miles each day, which explains how this relatively small area has become the world's largest gasoline market. The pollutants that pour from these on-road motor vehicles in staggering amounts are cooked in Southern California's abundant sunlight, with the effects intensified by topographical features and a climate that are highly conducive to air pollution formation. Summer months are typically characterized by an inversion layer that inhibits the upward dispersion of air pollutants, trapping them. In addition, calm breezes further limit ventilation and air mass mixing. The result is a virtual photochemical smog factory and America's most unhealthy air.

The Basin's principal air pollution concern is ozone, and the precursor emissions come largely from motor vehicles. On- and off-road motor vehicles contribute approximately 50% of the reactive organic compounds (ROC) and 75% of the oxides of nitrogen (NO_x). In addition to its ozone nonattainment status, the Basin is

also significantly above standards for carbon monoxide (CO) and fine particulate matter (PM₁₀), of which more than 90% and 6%, respectively, come from these vehicle categories. Finally, these vehicles emit carbon dioxide, methane, and nitrous oxide, all of which contribute significantly to global climate change.

While significant emissions reductions from all sources are needed to restore healthful air in the Basin, the key lies in rapidly developing much cleaner modes of transportation. We believe that such a strategy makes economic as well as environmental sense. A recent study conducted for the District by California State University found that the annual cost of the Basin's poor air quality -- just in terms of adverse human health effects -- is at least \$9 billion.

Since the end of World War II, the Basin has experienced faster population growth than the rest of the United States. Although growth today has slowed somewhat, the region's population will continue to increase significantly. By 2010, it is estimated that the Basin's population will be approximately 18 million, representing about a 35% increase from current levels.

As the result of effective emission controls, per capita emissions have been brought down substantially in the Basin. In particular, progress in lowering emissions from new automobiles has been encouraging, thanks to California's 25-year history of technology-forcing regulations and the automotive industry's successful response to them. However, increases in the Basin's population and vehicle trips over that time have made significant overall emission reductions more difficult. Increases in the number of sources, particularly those growing proportionately to population, reduce the potential air quality benefits of new controls. The net result is that unless dramatic steps are taken to control air pollution at a much faster rate than ever before, growth will overwhelm the improvements expected from the existing control programs. In terms of mobile source control strategies, the Basin must have a wide influx of non-polluting vehicles over the next 15 years.

The District's Air Quality Management Plan

The District, as the regional regulatory body with responsibility for air pollution control in the Basin, is developing and implementing the world's most comprehensive air quality management plan for stationary and mobile sources. The

District is responsible for establishing and enforcing regulations for stationary sources and is actively involved in research to advance control technologies in this area, including several related to fuel cells and other advanced technologies. Efforts to control Basin vehicular air pollution are directed and enforced by state, regional, and local agencies, with the District responsible for the overall clean up plan. The District also funds, either partially or fully, mobile source research in emission controls and alternative fuels technologies for both on-and off-road categories. This funding includes numerous projects to research, develop, and demonstrate vehicles powered by fuel cells and storage batteries.

In cooperation with the state and local agencies, the District has taken a comprehensive approach to reduce the impact of vehicular emissions. Goals of this strategy include: enforcement of existing standards; implementation of broader, more stringent emission standards; continued promotion of clean fuel vehicles and low-emissions technology; and an increased emphasis on transportation control measures.

The CARB LEV/CF program is the foundation for California's long-term plan to clean up mobile source emissions. For the lighter vehicle classes, four standards levels have been defined by the CARB. Vehicles types based on the four standards levels, in order of increasing stringency, are transitional low-emission vehicles, low-emission vehicles, ultra-low-emission vehicles, and zero-emission vehicles (ZEV).

In addition to sales-weighted non-methane organic gas (NMOG) standards that take effect in 1994, the CARB regulations established a revolutionary mandate for ZEV sales. In 1998, two percent of each major manufacturer's sales for passenger cars and light-duty trucks must be ZEVs. In 2003 and subsequent model years, ten percent of sales of these vehicle classes must be ZEVs. At this time, only battery-powered electric vehicles and pure-hydrogen fuel cell vehicles will meet the ZEV definition.

It is anticipated that California will, in the near future, consider low-emission vehicle regulations for heavy-duty vehicles and urban buses. In addition, emission limits for California off-road vehicle classes such as construction and farm equipment, utility equipment, marine vessels, and locomotives are under consideration.

Responses to Questions

1. **How can the work of the Clean Car Task Force, recently established by President Clinton, and other industry and public initiatives, assist in developing approaches that will help ensure that the requirements of the Clean Air Act Amendments of 1990 are met?**

The Clean Car Task Force offers a significant opportunity to pool the technical and strategic resources of the private and public sector. To best ensure that this Task Force reinforces the Clean Air Act requirements, as well as the Energy Policy Act, a process should be established to include the maximum input from California air pollution and energy regulatory bodies. The following are specific suggestions in this regard.

Recognize California's Leadership

The program should formally recognize the California LEV/CF and ZEV program as the central point of departure for an environmentally sound renaissance of American auto manufacturing. There is no need for the federal government to re-invent or delay these technology milestones.

Build on the California Program

The pace of design, development, demonstration and commercialization of all LEV and ZEV technologies needs to be expedited and augmented. One consideration may be to introduce another LEV category such as a hybrid electric vehicle (HEV) category, whose requirements would lie between a ULEV and ZEV. This would provide the incentives for producing HEVs without compromising the integrity of ZEVs. Also, by expediting compliance with the California timetable the federal government can maximize the potential "spill-over" benefits for other states such as New York and Massachusetts.

2. What other environmental benefits can result from developing cleaner cars?

The environmental benefits of more efficient, cleaner cars powered by alternatives to petroleum will have far-reaching effects that go well beyond immediate health concerns. For example, greater use of alternative fuels like natural gas and methanol -- initially in internal combustion engines, and subsequently as hydrogen sources for highly efficient fuel cells -- will substantially reduce the environmental exposures associated with extraction, transport, and storage of gasoline and diesel fuel. A comprehensive approach to clean cars will lead to vehicles with high efficiency and fuel economy, the lowest possible cradle-to-grave emissions including global warming gases, no stratospheric-ozone-depletion gases, and a high percentage of recyclable parts. In the end, however, we must get to true zero emissions vehicles running on renewable electricity or solar-generated-hydrogen fuel cells. If we do not find a way to do so, we may lose the luxury of personal mobility as we know it.

**3. What impediments, if any, exist to designing and producing cleaner cars?
How can these impediments be overcome?**

There are numerous barriers which need to be addressed in commercializing low-emission and clean-fuel vehicles. One important approach to removing these barriers will be to build on the progress of California. There are several key issues which should be addressed to obtain the maximum economic stimulus from the President's initiative while reducing technological and institutional barriers.

Establish Specific Aerospace Industry Targets

The federal government should establish specific research goals, timetables and strategic targets on ZEVs that take fullest advantage of the nation's defense aerospace electronics industrial base. Numerous prime contractors and subcontractors have expertise in designing defense-oriented energy systems that can be re-focused on commercially viable zero emission technologies such as fuel cells for automotive application.

Commit Federal Funding Now

The efforts of California's CALSTART and other similar ZEV programs should receive immediate federal commitment towards technology development and commercialization programs. Major California defense contractors such as Hughes are downsizing and relocating out-of-state, due in part to a lack of federal funding for fuel cell and other ZEV technologies.

Think in Terms of Billions, not Millions of Dollars

A "big science" commitment equivalent to the super-collider is needed to address the scope of development needed to develop ZEV technologies for large market segments. By at least matching the investments of the Japanese and Europeans on long-term technology, the U.S. will have the opportunity to remain competitive in international markets. If the U.S. underinvests today in the crucial area of long-term environmental technology, we will quickly lose our ability to shape the specifications and timetables.

Establish Small Business Initiatives

Small start-up, high technology industries are likely to be the key to maximizing the job growth anticipated from the Clean Car Task Force. Government needs to expand its outreach and provide special assistance to small- and medium-sized firms, and provide major incentives to expand their businesses into these new environmental technologies. One specific element of the Clean Car Task Force should be focused exclusively on small business. While the major advances may occur through the large auto manufacturers, history teaches us that it would be prudent to provide federal risk sharing for small businesses, so that they have a funded avenue for their potential breakthrough technologies.

An Infrastructure Component is Needed

The Initiative should also recognize the critical need to expedite the establishment of an infrastructure to supply the clean fuels (such as electricity, hydrogen, natural gas, methanol, or other hydrogen-precursor sources) needed for LEV and ZEV

vehicles. If the Task Force assumes that the conventional fueling infrastructure is adequate to fully accommodate the commercialization of LEV and ZEV technology, the clean car initiative will fail.

There are major infrastructure synergies that the federal government can and should leverage. Natural gas, and methanol derived from natural gas, have significant near-term potential to replace conventional gasoline and diesel fuels. These fuels, if made readily available today, can be used to help expedite manufacturers' efforts to develop and commercialize LEV vehicles. The key transition to bear in mind is the potential to use these fuels as hydrogen precursors. That is, these fuels can be used as a means of carrying hydrogen on-board or off-board a vehicle, for use in fuel cells. This hydrogen can then be converted electrochemically to electricity for use in powering an electric motor. A network of alternative fuel stations would significantly accelerate California's ability to introduce cleaner combustion vehicles, followed by hybrids and ZEVs, all of which could be at least as clean as ultra-low emission vehicles.

The development of a hydrogen economy may depend in part on the early introduction of easier and lower cost storage media for hydrogen, such as natural gas or methanol. The federal government therefore needs to directly augment the Clean Car Task Force with a broad-based Clean Fuel Infrastructure component.

Breakthrough Technologies Offer High Rewards

Above all, the federal government must share the risk and costs of advanced technology research and development. After all, that is the purpose of federal research support: to help fund the high risk, high reward, breakthrough technologies that have a longer term payoff than most businesses can aim for in today's short-term business world. It is these breakthrough technologies and not "business as usual" that will assure the long term health of the U.S. industry.

For example, the District was the founding member of the Ad Hoc Coalition on Fuel Cells for Transportation, which now has nearly 30 members. We have developed a seven-year plan that relies heavily on federal purchases to stimulate the commercialization of this technology. A copy of the plan is appended to my testimony. This plan largely depends on earmarking existing federal transit subsidy

and vehicle purchase programs. The \$4.4 billion cost is less than the nation pays for imported oil in a single month.

4. **What is the potential export market for clean cars and clean car technology? What factors in the design and production of automobiles will help increase American industry's share of the export market?**

In the past 15 years, foreign manufacturers have proven to be extremely adept at providing vehicles that simultaneously have good driveability, low emissions, and good fuel economy. Their gain in the U.S. market share was inevitably at the expense of domestic manufacturers. Based on the technical updates that we frequently get, foreign manufacturers are working harder than ever to gain a competitive advantage by meeting the challenges of California's LEV standards. The market in California alone consists of more than two million new vehicles each year. With many other states and countries looking to California's program with the intention of copying it, the potential worldwide market for advanced low-emission vehicles is enormous. The U.S. auto makers will compete quite well if they focus on highly efficient, progressively advanced technologies that minimize emissions of air pollutants and global warming gases, while maximizing fuel economy. The latter two qualities seem to be especially important in the European car market.

Clearly, the export potential of clean vehicles is very significant. There are several issues that will be key to strengthening U.S. leadership in the emerging international market.

Maximize the Potential for Synergies

The Initiative should also formally recognize that the development and commercialization of ZEVs is directly benefitted by expediting LEV technologies such as electrically heated catalysts, dedicated natural gas vehicles, and flexible-fuel vehicles. It is impossible to anticipate all of the creative engineering synergies which may occur between these and other technologies. Addressing long-term goals is best accomplished by ensuring that near-term progress continues and accelerates. Two examples of such synergies are the Volvo 850 "Environmental Concept Car: with a high speed turbine and battery system, and Volvo's 940 "Environmental

Impact Vehicle" which has an electrically heated catalyst with methanol flexible-fuel capability.

The First Priority Should be Expanding the Number of LEVs and ZEVs in California

There are major developments already underway to offer LEVs and ZEVs for sale in California. Indeed, the industry has been more successful and ahead of schedule than expected in meeting these standards. Ten electric vehicle models produced by four manufacturers are already certified as ZEVs in California. One Low-Emission Vehicle (LEV) is also certified on compressed natural gas. This Chrysler Dodge B350 Van is the cleanest medium-duty vehicle ever certified in California. Three methanol compatible passenger cars are certified as TLEVs (the Chrysler Spirit Acclaim, Chevrolet Lumina and the Ford Taurus). Two TLEV passenger cars are also certified on conventional gasoline, while two other car models are conditionally certified as TLEV using Phase II California gasoline. This progress can best be accelerated by careful coordination with the federal Clean Car Task Force. California's successful market launch can therefore help establish a springboard for international export activities.

Conclusions

In summary, I want to applaud the Administration for its visionary approach to leapfrogging existing technologies and providing a goal to restore America's world leadership in the auto industry. This will provide the maximum benefit to the environment both in the lower and upper atmosphere, thereby providing maximum protection for public health. At the same time, it will create a climate with unprecedented opportunities for the U.S. auto industry to expand into new automobile markets worldwide. We think it would be a major mistake to dilute efforts to address existing programs which are advancing at a significant pace. Instead, they should be expanded, and the limited federal dollars should be maximized to share risks with industry. The challenges are great, but the payoffs will be tremendous.

FUEL CELLS FOR TRANSPORTATION

Dr. Alan Lloyd
Chairman

Robert Rose
Coordinator

NATIONAL INITIATIVE ON FUEL CELLS FOR TRANSPORTATION

The National Initiative on Fuel Cells for Transportation is a seven-year plan to develop energy efficient, pollution free motor vehicles for the American marketplace by the year 2000, using hydrogen fuel cells. Fuel cells create energy without combustion, with zero emissions at up to 80 to 90 percent overall energy efficiency.

What Will the Initiative Do?

- o It will create or save almost 6,000 permanent, high-tech jobs in the first year alone.
- o It will support small and expanding businesses, the nation's primary source of jobs.
- o It will stimulate private investment by providing markets for emerging products.
- o Most importantly, it will preserve our personal mobility without the sacrifice of our environment.

How Will It Work?

- o By concentrating on demonstration projects and fleet government purchases, it will get fuel cell vehicles out of the laboratory and into the marketplace quickly, and with maximum public benefit.
- o The Energy Department will manage an expanded RD&D program; the Transportation Department will make fuel cell vehicle purchases part of its ongoing transit programs; Defense will support dual use technologies and purchase fuel cell products; and Commerce can play a coordinating role.

What Will It Cost?

- o The federal share is \$4.4 billion through the year 2000, about one month's worth of imported oil.
- o Industry will carry an increasing share of the cost as the technology matures. This is one way to implement President Clinton's proposal to provide "patient capital" to revitalize the US technology base.

Can We Afford It?

- o Yes. Most of the money will come from current fleet and transit purchase programs, the rest from reordering priorities at the Departments of Defense and Energy. DOE's nuclear weapons program, for example, cost \$12 billion in 1993. The \$40 million we advocate to advance transportation fuel cell technologies represents less than two days spending for the weapons program.
- o The initiative is in line with President Clinton's plan to develop a Clean Car using fuel cells, and with the Defense Reinvestment program developed by Congress in 1992 and expanded by President Clinton in 1993.
- o It would fully implement the National Energy Policy Act, which set the nation's energy agenda in 1992.

What Are the Benefits?

- o Transportation causes more pollution than any other single source, creating nearly 100 million tons of pollution a year. Fuel cell vehicles are the only truly "zero emission" vehicles.
- o Passenger vehicles alone consume more than 6 million barrels of oil every day, equivalent to 85 percent of oil imports. Fuel cell vehicles are three times more fuel efficient than conventional vehicles.
- o Vehicles create one-fourth of the nation's emissions of carbon dioxide, the key to global warming. Fuel cell vehicles will reduce carbon dioxide emissions dramatically.
- o Fuel cell vehicles will enable the nation to use renewable energy such as solar and wind power for transportation, creating true zero emission systems.

What if We Don't Act?

- o If nothing is done, pollution and declining oil supplies will restrict and ultimately choke off economic growth and impose an increasing health burden on our cities.
- o Energy is one of the world's primary economic battlegrounds. Our national security depends on our developing, utilizing, and exporting technologies that produce energy with maximum efficiency and minimum environmental cost. The U.S. lead in fuel cell technology is eroding; we face competition from Europe, Japan and Canada.

Aren't Fuel Cells a Long Way Off?

- o Fuel Cell Vehicles are not a far distant technology. Fuel cells have been utilized in stationary and mobile applications. Fuel cell buses can be ready for the marketplace by 1995, given adequate funding and incentives.

FUEL CELLS FOR TRANSPORTATION

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Coordinator

NATIONAL INITIATIVE ON FUEL CELLS FOR TRANSPORTATION

- Goal:** To develop energy efficient, zero-pollution motor vehicles for the American marketplace by the year 2000.
- Purpose:** To commercialize fuel cells and related technologies for motor vehicle and other mobile uses.
- Program:** The program has three components: 1) research, development and demonstration, with manufacturability a key consideration; 2) pre-commercial scale-up and regulatory adjustment; and 3) market entry.
- Benefits:** The initiative would support development of a new high-tech U.S. manufacturing industry, saving or creating almost 6000 jobs in the first year alone.
- The technology developed would reduce and ultimately could eliminate oil imports, and provide personal mobility to the American people without environmental degradation.
- Funding:** The initiative would be funded jointly by government and industry, with industry paying an increasing matching share as the technology approaches commercialization.
- The federal share, including purchase of vehicles under existing transit programs, would be \$4.4 billion over seven years, about what the U.S. pays for imported oil in a single month.
- Structure:** The initiative can stand alone, but would work best in the context of a broader program to focus and coordinate the federal effort in fuel cells and related technologies.
- The initiative is consistent with the National Energy Policy Act, President Clinton's technology initiatives and with other federal research programs.

Phase I: Department of Energy Programs

A. RD&D Focus

The focus of the department's research and demonstration effort should be on products with greatest commercialization potential and biggest environmental and energy conservation payoff. DOE research should concentrate on:

- o Developing **proton exchange membrane** technology, addressing durability, water and thermal management, energy output, stability, manufacturing, lower electrical resistance. PEM is regarded as the most promising fuel cell technology for passenger vehicles; aggressive PEM efforts are under way in Canada, Europe and Japan.
- o Optimizing **phosphoric acid** fuel cell capability for transportation applications.
- o Maintaining leadership in **solid oxide** technology, through system oriented development and integration programs.
- o Research in **advanced fuel cell** stack and related system technologies, and assess **alkaline fuel cells** for civilian transportation.
- o **Balance of system** work should take full advantage of research under way in conjunction with the DOE's hybrid vehicle program. Hydrogen storage and utilization work should be funded under an expanded DOE effort.
- o Fuel cell related system research in areas such as thermal management (waste heat for climate control) should be funded from the fuel cell budget.

B. Fully Fund DOE's Integrated Fuel Cell Program

The DOE's Integrated Fuel Cell Power System Development Program should be fully funded, including a passenger vehicle program, a new locomotive program, a new heavy duty (long haul) truck; reformer/hydrogen storage program, Phase III of the of the current bus program, and a full-size 40-foot transit bus.

C. Implement Energy Policy Act Requirements

The National Energy Policy Act requires the Secretary of Energy to develop and implement a comprehensive transportation fuel cell program, phased in over several years. The Act calls for demonstration programs involving passenger vehicles, vans and utility vehicles, light rail systems and/or locomotives, heavy duty vehicles, mobile refrigeration systems, marine vessels and non-road engines such as generators and construction equipment. Among the new programs:

- o One or more additional PEM passenger car programs;
- o One or more solid oxide vehicle demonstrations;
- o The construction of a test fleet of 10 phosphoric acid fuel cell buses, for safety and durability testing, etc.

Small Company Set Aside

While the Big-3 auto makers must be involved in the program, Congress should assure a maximum level of competition, and job creation, through a substantial set aside for small business and other companies seeking to enter the transportation field.

A Matching Share From Industry

Industry should pay its fair share of the cost of cooperative RD&D programs. But in today's economy, dollars are scarce, particularly in the defense and aerospace industries. Industry concentrates its dollars on near-term products. The initiative proposes allowing industry to meet an increasing matching share for research, rising as the technology approaches commercialization. This approach is consistent with the National Energy Policy Act, that grants the Secretary of Energy authority to set a matching share at 20 percent in important research areas.

Phase II: Pre-Commercial Scale-up

A. Manufacturing and Product Development

The research phase of the initiative will yield products with commercial potential beginning in 1994. The federal government must play an activist role in helping industry scale up to manufacture these products to specifications that will assure market acceptance.

- o To ease the path to commercialization, the Defense and Transportation Departments should finance nonrecurring, pre-commercial manufacturing scale-up, process improvements and material optimization;
- o Product specifications should be developed for the purchase of fuel cell vehicles and systems by federal agencies;
- o DOD purchases of fuel cell units, now limited to stationary units, should be expanded to include passenger vehicles and other mobile systems;
- o The federal government should lead an assessment of changes needed in federal, state and local laws and regulations to facilitate the commercialization of fuel cell technologies for mobile use.

During the 1990's the primary costs will be associated with purchase of buses and locomotives financed through DOT, and passenger vehicle purchases financed through DOD and possibly other federal agencies, such as GSA. Depending on the timing of development of mobile technologies under the Energy Policy Act, additional purchases of mobile fuel cells would be appropriate.

The lion's share of these purchases will be made under existing federal transit agency subsidy programs, thus assuring that the nation's transportation infrastructure is renewed through the purchase of leading edge technologies.

B. Defense Reinvestment

Fuel cells are an ideal dual use technology. Programs are already under way at NASA and in various Defense agencies to develop fuel cells for space, for surface ships and submarines, for tanks and for the individual soldier, among other applications.

The Defense Reinvestment program approved by Congress in 1992 recognizes the potential of fuel cell technologies by making them specifically eligible for funding. Fuel cells should retain a central place in the expanded effort outlined by President Clinton in March, which may be led by the Commerce Department.

Given the Defense Department's current manufacturing technology programs, one excellent use for Defense Reinvestment funding would be to support the development of fuel cell manufacturing technology and balance-of-system development.

Phase III: Market Entry

The National Energy Policy Act recognizes the potential of the federal government to provide an initial marketplace for advanced vehicles and energy generation systems. The legislation takes the significant step of requiring the purchase of alternative fuel vehicles rather than setting numerical targets. It requires the purchase, lease or acquisition of 25,000 alternative fuel vehicles by the federal government between 1993 and 1995 (5,000 in 1993; 7,500 in 1994; 10,000 in 1995). For later years, the purchase requirement is expressed as an increasing percentage of the fleet (25% in 1996; 33% in 1997, 50% in 1998; 75% in 1999).

- o Congress should require a small but increasing percentage of these purchases be for fuel cell vehicles, beginning with buses in 1995 and other vehicles beginning in 1997.
- o This will allow a substantial number of vehicles to be built, tested and sold in time to meet Zero Emission Vehicle standards by 1998. Purchase programs are the best method of attracting private capital to the fuel cell effort.

The Energy Policy Act contains a tax deduction for alternative fuel vehicles at \$2,000 per car and for refueling property, and a 10% tax credit for electric vehicles, up to \$4,000 per vehicle. Fuel cell powered vehicles qualify as electric vehicles. Congress should maintain these incentives and federal agencies should publicize the fact that fuel cell vehicles are eligible.

FUEL CELLS FOR TRANSPORTATION

Seven Year Commercialization Plan (Federal Share, Dollar Amounts in Millions)

PROGRAM ELEMENT	1994 \$	1995 \$	1996 \$	1997 \$	1998 \$	1999 \$	2000 \$
DEPARTMENT OF ENERGY Fuel Cell Bus Program Fuel Cell Passenger Cars Other Applications Fuel Cell Research	\$ 40	\$ 50	\$ 80	\$170	\$200	\$200	\$200
DEPT. OF TRANSPORTATION Manufacturing Scale-up Buses Locomotives Vehicle Purchases Urban Buses Locomotives	\$ 11	\$ 10 \$ 20	\$ 4 \$ 25	\$ 10			
	\$ 10	\$ 24 \$ 50	\$ 64 \$ 60	\$122 \$120	\$165 \$200	\$200	\$250
DEPTS. OF DEFENSE/COMMERCE Defense Reinvestment Defense Utilization Mobile Fuel Cells	\$ 50	\$150	\$100	\$100	\$ 50		
	\$ 10	\$ 50	\$100	\$100	\$100		
FEDERAL FLEET PURCHASES Fuel Cell Fleets	\$ 50	\$100	\$200	\$200	\$200	\$300	\$300
TOTALS	\$ 171	\$ 454	\$ 633	\$ 822	\$ 915	\$ 700	\$ 750

SEVEN YEAR TOTAL: \$4,445 Million

JOBS TALLY

First Year Direct Jobs: 5,825
Average Annual Direct Plus Indirect Jobs: 38,002

MEMBERSHIP LIST
March, 1993

***FUEL
CELLS
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AeroVironment Inc., Monrovia, CA
Allied Signal, Inc., Torrance, CA
Arthur D. Little, Inc., Cambridge, MA
California Air Resources Board, Sacramento, CA
CALTRANS, Sacramento, CA
Center for Environmental Research and Technology
University of California, Riverside, CA
Clean Air Now, Riverside, CA
Economic Roundtable, Los Angeles, CA
Energy Partners, West Palm Beach, FL
Engineering Research Center, Texas A&M University, College Station, TX
Georgetown University, Washington, DC
H-Power Corp., Belleville, NJ
Institute of Gas Technology, Chicago, IL
Institute of Transportation Studies
University of California at Davis, CA
Loker Hydrogen Research Institute
University of Southern California, Los Angeles, CA
Los Angeles Metropolitan Transit Authority, Los Angeles, CA
Natural Resources Defense Council, Washington, D.C.
Northeast States Coordinated Air Use Management (NESCAUM), Boston, MA
New York Department of Environmental Conservation, Albany, NY
PACE, Arlington Heights, IL
Pennsylvania Energy Office, Harrisburg, PA
Sacramento Municipal Utility District, CA
Science Applications International Corporation (SAIC)
San Diego, CA
South Coast Air Quality Management District, Diamond Bar, CA
Southern California Gas Co., Los Angeles, CA
TECOGEN, Waltham, MA
Transportation Manufacturing Corp., Roswell, NM
ZTEK Corp., Waltham, MA

Dr. Alan Lloyd
Chairman

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FUEL CELLS FOR TRANSPORTATION

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Mission Statement

The mission of the Ad Hoc Coalition on Fuel Cells for Transportation is to accelerate the development, demonstration and commercialization of fuel cells and related technologies for cars, trucks, buses and other mobile energy needs.

FCT will accomplish this goal by:

- o advocating full implementation of the transportation fuel cell provisions of the National Energy Policy Act of 1992;
- o advocating a jointly-financed cooperative program among government, industry and other public and private sector agencies to develop and demonstrate a wide variety of mobile applications for fuel cells and related systems;
- o advocating changes in federal, state and local laws and regulations to facilitate the demonstration and commercialization of fuel cell technologies for mobile use;
- o educating policy makers, opinion leaders and the general public on the energy, environmental and economic benefits of fuel cell technologies for transportation;
- o promoting an understanding and acceptance of fuel cell technology among equipment manufacturers, purchasers, operators and other end users;
- o promoting the export of U.S. fuel cells and related systems for mobile applications world wide;
- o improving the advocacy skills of its members through training and professional support.

TESTIMONY FOR SENATE HEARING
SUBCOMMITTEE ON CLEAN AIR AND NUCLEAR REGULATION
OPPORTUNITIES TO REDUCE
AUTOMOTIVE EMISSIONS

Albert J Sobey
April 27 ,1993

Thank You Senator Liebermann:

I appreciate this opportunity to discuss ways to reduce automotive emissions and describe some problems a "Clean Car" initiative may face. The comments I will make are my own. They do not represent any single company or organization.

The comments are based on my recent contacts with people in the automotive industry and government as well as my prior experience which included; directing research on aircraft engines and rockets, managing demonstrations of innovative cars and transportation system equipment, founding and serving as President of a company which builds transportation systems, as Director of Advanced Product Economics for GM and a cosponsor of the Automotive Industry Small Supplier Forum. Since retiring from GM, in 1987, I have been a consultant to several California agencies on transportation and energy, to the U.S. Department of Energy on Commercialization of Fuel Cells and to other companies and organizations interested in transportation or energy innovation.

This experience provides a basic understanding of the potential for - and the problems of - introducing new transportation concepts, from both the public and private viewpoints. I will discuss several ways to reduce emissions from cars. But if they are to be successfully implemented, we must also find ways to minimize what I call - the non technical barriers.

It appears that the intent of the "Clean Car" initiative outlined in the Clinton, Gore report of February 22, 1993, is to go beyond the amendments of the clean air act to determine how to achieve the lowest practical level of noxious emissions and to reduce the generation of carbon dioxide and green house gases, in the least time at the lowest societal cost.

While the emphasis of the "Clean Car" initiative is on propulsion, the automobile is only one element of the personal transportation system. The infrastructure, roads, freeways, traffic controls all influence the generation of emissions, as does use of public transit.

The emissions from automobiles may be reduced by:

1. Improving propulsion systems
2. Reducing power requirements
3. Reducing traffic delays

There is still some potential for reducing the noxious emissions from piston engines - but it is limited. This is an area where invention is still possible - unlike efficiency, where the best piston engine designs are approaching the theoretical limits of the second law of thermodynamics or the "Carnot" limits.

Automobile engine researchers indicate that significant reductions in the emissions from piston engines will be difficult, expensive and involve devices or gadgets which have questionable life. It seems that we are near the practical limits of improvements to the piston engine. Even utility powerplants where weight and dynamic response are not critical seldom exceed 50% efficiency. Their emission control devices can be a major share of the total cost of the powerplant.

The automotive industry, in cooperation with energy companies, has been developing specifications for "reformulated" gasolines which reduce the emissions of piston engines. They and alternative fuels like natural gas and methanol, can provide some near term benefits, if they can be used in existing engines. The linkage between the engine and fuel characteristics will be increasingly important in the future.

The energy companies have to take a longer view than the automobile companies. Their investments in refineries, pipelines etc. are planned for the better part of a century, not several model years. They have to plan for an uncertain future. Billions of dollars of investments may be wiped out by changes in fuel requirements or engine types.

The lowest emission piston engines will be those fueled with hydrogen. They will still generate NOx. Hydrogen may be an ideal fuel - in the engine - but it is anything but an ideal fuel to transport and store in an automobile. Hydrogen will leak (seep) through anything and causes embrittlement of metals. When viewed as a total system I suspect that reforming methanol, on the car, to generate hydrogen will have technical and economic advantages - but we do not have enough economic information to confirm this.

The new propulsion systems which should be considered for near "clean

cars" include:

- o Gas Turbines
- o Stirling engines
- o Battery Electric
- o Fuel Cells

Gas turbines are excellent aircraft engines - but early automotive designs were at a disadvantage because their efficiency falls off rapidly as power is reduced. Automotive companies: GM, Ford and Chrysler have spent large amounts of money on gas turbines - with no successful products to show. The recent development of high temperature ceramic turbines (by DOE contractors) holds the promise of gas turbines which are; competitive in fuel consumption, can meet California's Ultra Low Emission Standards and - while still not confirmed - can be priced competitively.

The stirling engine is an external combustion engine. It should have the lowest emissions of any thermal power plant. GM and Ford both had large stirling engine propulsion programs - which came to naught. GM even built a "zero emission" stirling powered car which ran off stored thermal energy.

Unfortunately the first generation of stirling engines, based on a design by Phillips was expensive and had mechanical problems. A recent design by Stirling Thermal Motors, of Ann Arbor Michigan, appears to solved these problems. Detroit Diesel Corp. is planning to offer a small stirling engine for sale at about the same price as a comparable diesel.

All of the thermal engines can generate carbon dioxide, if not in the engine, during fuel processing. Carbon dioxide neutral fuels from renewable energy resources are being developed, but it is probable that the oil produces will be able to undercut their prices, if they want to discourage their use, for several decades.

Battery electric propulsion appears to be one way to create a "clean car". But, except for some niches, which I will get to later, it appears unlikely that battery cars can compete, in range or costs, with chemically fueled cars. I understand why the general public would expect a "battery breakthrough". But most engineers know how low a probability this is, they were exposed to the electrochemical series in school. It defines the energy which can be released by batteries. I directed research on high energy batteries for NASA. They used materials which I would not want in my car and they still were far short of the performance required for a car.

The size of the market for battery electric cars will depend on how many people, who can make their daily trips, reliably, within the practical range of available batteries (30 to 60 miles with existing batteries), will find the benefits of avoiding the hassle of going to a filling station, the ease of starting and other advantages, sufficient to overcome their cost and range deficiencies. There is no experience to use to determine whether industry can bank on this market - or whether the benefits are illusionary. We need real world research, demonstrations with cars which have the same feel and finish as that people expect, used over long enough times to overcome the novelty effects.

This leaves Fuel Cells - which have become fashionable lately. I have long been an advocate of fuel cells. I believe that they will ultimately be the propulsion system of choice for all ground vehicles.

I am concerned that the problems of developing and commercializing fuel cells which are performance and cost competitive with existing engines - are under estimated - even if the competitive engines require costly environmental controls. My concerns include:

- o The fact that fuel cells have been shown to be technically feasible can be misleading. It will take many years and a major commitment by industry, with government support, to reduce costs to an acceptable level for cars.
- o There are at least five types of fuel cells, each of which has advocates which say theirs is the answer - for some vehicle applications.
- o Private companies will not be able to justify investments in fuel cell research and development until there is enough information to prepare business plan which have a high probability of leading to profits.
- o The research and development costs are very high. If a private company were to commit to the development of a fuel cell, recovering its research and development costs could make the first production fuel cell propulsion systems prohibitively expensive - even if the manufacturing costs were attractive.

I doubt if fuel cells, or other advanced propulsion systems, will be commercialized in the U.S. unless ways are found to subsidize, or write off, their research costs.

Another way to reduce emissions from cars is to reduce the power requirements by reducing weight, aerodynamic drag, tire resistance and limiting

accelerations. Progress in these areas is approaching the point of diminishing return.

Only weight reduction offers much further promise. The automobile manufacturers and suppliers are developing new light weight economical materials. Candidate materials exist - and are used in aircraft. The problem is that what is acceptable for aircraft may not work for automobiles. A major problem is manufacturing cycle time. When the manufacturing and cost problems are solved - and I am confident that they will - we may look at the ownership of cars in new ways.

There has been growing environmental concern over the disposal of cars and components when they have exhausted their useful life. This will continue to be a problem for tires, batteries and similar components, but a majority of the materials in cars (70% by one source) are now or can be recycled.

There may be an interesting result of the increasing life of cars. Maintaining environmental standards for 100,000 miles will require designs with even longer life expectancy. Use of corrosion resistant materials which are less subject to damage or wear and new propulsion systems (such as fuel cells) may extend the life of cars to the point where people may have them upgraded or remanufactured, rather than purchase a new car. People may request changes in accommodations, appearance, and accessories to match their life style changes. This may be done in the dealers back service shops, which might otherwise be under utilized as cars become more reliable. We may not need to dispose of nearly as many car carcasses as in the past.

I suspect that we could do about as much to reduce energy consumption (and pollution) by reducing the routing errors and delays by traffic signals and congestion on streets and expressways, as can be done - practically - with internal combustion engines. There are two basic approaches:

- First Tailoring cars to serve specific travel purposes.
- Second The use of intelligent vehicle - highway technologies.

Work is in process on what California calls "narrow lane" cars for commuting. Since in over 80% of the commuting trips the driver is the only occupant, well designed, economic, single (or one and a half) passenger cars may be attractive. One concept has an estimated fuel economy of over 120 miles per gallon.

In most cities over half the trips take less than 10 minutes. Most shopping

trips take less than 5 minutes. Small cars which can serve these trips can be powered by conventional batteries. A Southern California Edison study estimated that the use of this category of car, for all trips under 8 miles, could reduce noxious emissions by 45 to 50%.

The use of "alternative" cars would permit people to continue their present life styles - and be environmentally responsible. If 20% of the commuting trips were made by narrow lane cars and a like number of the shopping trips by shoppers, the use of petroleum in major cities would be reduced 15 to 20%. There should be even greater reductions in emissions. It is the short trips, before cars warm up, that are the most difficult to control.

Intelligent vehicle-highway technologies can reduce emissions and energy consumption by showing drivers the best route to new destinations and by reducing the frustrating delays at traffic signals when there is no other traffic and by reducing congestion. The benefits will be site specific, but some estimates have ranged up to a 20% reduction in emissions by implementing real time scheduling of traffic signals alone. They will reduce fuel waste during idling and accelerating as well as braking energy losses.

The "clean car" technologies can be used in other ground vehicles, including locomotives, buses, and heavy trucks. Use of public transit has been advocated to save energy and reduce pollution. But in fact diesel buses no longer do either, as a recent University of California Berkeley paper shows. Rail transit is only slightly more energy efficient than the latest generation of automobiles. Public transit should be advocated for the important services it provides - not energy savings.

Fuel cells will probably be used first in buses. They can reduce the complaints about the emissions, noise and smell of diesel engines. The first economically competitive application is expected to be in locomotives, where their life cycle costs may be less than the existing diesel powerplants.

Experience in these less cost sensitive applications should provide some of the "hands on" experience needed to develop lower cost versions which will be competitive with piston engines in automobiles.

One of the questions asked of presenters at this hearing was *"What impediments if any, exist to the designing and producing clean cars? How can these impediments be overcome"*. Let me summarize some of the impediments which I have encountered sponsoring innovative technologies and transportation systems, which apply to the development of a new

generation of automobiles.

- o Foreign Competition
- o Availability of Resources
- o Inadvertent delays results of regulations
- o Safety and product liability concerns
- o The culture of the industry

The automobile industry, as a whole, has experienced major financial losses in the last few years. The primary (but not only) cause was foreign competition. The industry is rapidly correcting the reliability and design problems, but it will take years to recover the buyer loyalty which has been lost. It has to be more than just - as good as - the competition. To recover the market share the manufacturers must make major investments in new product designs and facilities.

A study by the University of Michigan estimated that the U.S. manufactures would have to spend \$225 billion on new cars and trucks in the next four to five years to remain competitive. Foreign competitors are expected to spend \$375 billion in the same period on products aimed at the U.S. market. The Japanese seem to make more effective use of the money they invest. By 1996 less than half of the automobile platforms which will be marketed in the U.S. will be produced by U.S. companies, down from 1991 when 70% were produced by U.S. manufacturers.

In addition to the investments to improve its products, the industry is investing a major share of its resources in what can be called "second best" solutions. It has no choice - it has to meet federal and state regulation time schedules. Money is not the only constraint. Relatively few engineers and designers have the background to work on advanced propulsion systems.

Engineers and scientists, who became redundant during the military cutbacks are a potential source of technical personnel. But, as I know from personal experience, the difference in the two cultures is so great that it takes years to make the cultural changes. The education of these scientists and engineers on automotive technology and culture will be a challenge for our academic institutions.

Many federal and state regulations and laws were prepared on the implied assumption that there would be only minor "evolutionary" changes in transportation equipment and technologies. The "narrow lane" cars should be able to meet the intent of automotive safety regulations - but they may

not be able to meet all the details. A simple illustration - there would be a problem if lights were required to be five feet apart. Regulations intended to insure the safe use of natural gas and propane in buildings, can slow, or prevent the use of new fuels and propulsion concepts. Even when it is agreed that regulations should be changed to permit use of a new technology or system concept, it may take longer to revise the regulations than design the product.

The government procedures for research and development contracts, which require periodic renegotiation, cost time in the development of new technologies. When companies have confidence in developing a profitable product many have found it less expensive and faster to fund the programs internally. The problems they avoid include; the increased paper work required to document what is done, delays in getting approval for changes when new opportunities are identified, delays for periodic re-bidding and concern over intellectual property rights.

The governments share of research costs should reflect the level of risk and the problem of amortizing research and development cost. I believe that the governments share should be high at the beginning (say 80%) decreasing as confidence in the technical and economic feasibility of the product increases. The final product design and commercialization efforts should be privately funded. This would parallel the process followed by some of our international competitors.

The automobile industry places safety at the top of its priority list, but the growth of product liability litigation has made companies reluctant to introduce radically new concepts. New operating technologies will seldom be introduced until there is a safety record, which insurance companies can use. It may have to be developed in some other nation. One engineer from a major company (not GM) told me, in frustration, that unless something was done about product liability, he doubts if his company would introduce any new technologies in this country.

I know that many people suspect that the culture of the automobile industry is one of the reasons for the industries reluctance to invest in new technologies. Not surprisingly some middle technical management who based their careers on the continued use and improvement of "conventional" concepts and technologies will resist change.

My experience is that this is not true of top management. It is true that most were not concerned about the threat of imported cars --until too late. Many of those that were concerned, underestimated the risk. Management

now is serious about trying to balance the market, energy and environmental imperatives, an at times inconsistent set of requirements.

What is also true, but would not be admitted officially by most companies (because they are either too polite, too proud, or concerned about being misunderstood) is that the industry feels that it has done its share. It believes that many of the things which are being suggested - by people without experience in the industry - are either impractical, unnecessary, counter productive or destructive.

- o The industry understands why the public is interested in "clean cars" - but points out that no car is, or ever will be, completely clean. Experience shows that the cost of the strategies to control emissions increase exponentially as the allowable emissions decrease.
- o The emission level has been reduced to the point that nearly one hundred new cars generate fewer noxious emissions than one 1966 car. Not totally facetiously - I hear automotive engineers claim that the exhaust of a ULEV would be cleaner than the ambient air in Los Angeles.
- o Automobile marketers fear that technologies which increase cost, or reduce the utility, of cars will lead people to hold onto old cars longer. As a result emissions may not decrease as rapidly as would be possible with less costly approaches.
- o Manufacturers are concerned that the combination of requirements, for low emissions and high mileage, will force them to build products which will not be saleable to most people. This could seriously damage the industry. Even without any changes in existing regulations, some industry observers are concerned about its survival - at least in this country - in its present form.
- o One belief that industry spokes people will never state (except late at night after a couple of drinks) is that they suspect that some of the regulations being advocated are not based on technical feasibility or health requirements, but on a belief that it is immoral to drive large cars - or some times any car. This contrasts with the automobile culture which holds that the mobility that the automobile provides is responsible for the high quality of life that recent generations have enjoyed.

Cooperation between the industry and government in the development of near "clean car" automotive and propulsion technologies will require a new approach and a willingness to understand each other's problems and objectives. At times the two sectors do not seem to hear each other - or

even talk the same language.

The industries emphasis is on near term survival - meeting competition and legal mandates. This makes it difficult to justify diverting significant resources to the development of near "clean cars". It is unlikely that much will be done unless there are government initiatives, not only research and development funds (although that is critical) but for changes in laws and regulations which will make it possible to proceed expeditiously and draw effectively from all available resources.

What does industry need? Research support is only one element. The problems the industry has in raising working capital and earning a profit, have lead some companies to sell off non automotive divisions which have provided them with a "window" on new technology.

I am not comfortable discussing the industries financial needs, but investment tax credits and caps on health costs (which now approach 40% of the wages for many small suppliers) are among the steps which have been suggested to make it easier for industry to devote additional resources to long range solutions.

The problems facing the industry have already caused the failure of many small suppliers (foundation companies) which provide about half the value added and employ over half of the workers in the automobile industry. The majority of these companies employ fewer than 200 people. The specialty manufacturers, shops and design services represent a unique resource and one of the primary strengths of the U.S. automobile industry. We cannot afford to loose them.

Formation of consortia, or teams, has been suggested as one way to accelerate the development of near "clean cars". They would be made up of government laboratories and private companies, working toward common goals and benefits. The consortia would conduct all the research and demonstrations, including development of manufacturing processes, facilities and marketing strategies to expedite the commercialization of near "clean cars". Competing consortia should work on different approaches. The charters of the consortia should enable them to avoid some of the procedural delays usually encountered in government contracting - as long as milestones are achieved.

This may surprise some readers, but I have reservations on the wisdom of joint research and development activities by the industry. I have no problem with cooperation on basic research, although this is the area

where government investment will be most helpful.

My concern goes back to one of the roots of the complacent attitude the industry took to foreign competition. The U.S. automobile manufacturers all had similar labor costs, similar material costs, similar suppliers and what they thought was buyer loyalty. Their history of exploring a wide range of new ideas by their research and development activities (a luxury they can no longer afford) lead to a "not invented here" attitude. They had little reason to innovate. At least the separate research and development staffs did lead to some product differences.

If the companies all draw from the same research and technology base, we may inhibit technical and product innovation - just when it is most needed. We need to encourage competition to evaluate parallel technical and design paths. The path most obvious now - may not be the ultimate winner - or there may be more than one winner. Perhaps the best analogy is the military aircraft fly offs.

The final question which was asked is "*What is the potential export market for clean cars and clean car technology*". Of course there are international markets - but based on past experience we will probably only export the basic technology - and buy the developed products from other nations.

A final note. I do not see the "clean car" initiative as concluding with a futuristic family sedan with exceptional emission characteristics or by setting specific environmental objectives for future products. I see it leading to the creation of a process for determining how to continue to reduce emissions as new technologies are developed. Creating incentives for innovation not mandates. The governments primary role would be in sharing the risks during initial research on new technologies and demonstrations until product acceptance (price, performance, profitability) is not in doubt. The "clean car" process should provide information for agreeing on time schedules which do not require industry to use "second best" solutions, or hurry products to the market before they are ready. After this process has been in effect for a period of years, the resultant emission levels should be much lower than now expected, or possible with existing technology.

Any Questions?

Albert Sobay and Associates
730 North Valley Chase
Bloomfield Hills, Michigan
48304 313 642 5508

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 - *Performance*
 - *Cost*
- *Safety*
- *Product Availability*
- *Southern California Gas Company Program*
- *Current NGV Customers*

Emissions

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ALTERNATIVE FUEL REGULATIONS **AIR QUALITY**

Federal Clean Air Act

- ***Reduced Tailpipe Emissions 75% by 2003***

CARB Low Emissions Vehicle

- ***Reduced Tailpipe Emissions 50% - 95%***
- ***Fuels Availability - Directives***

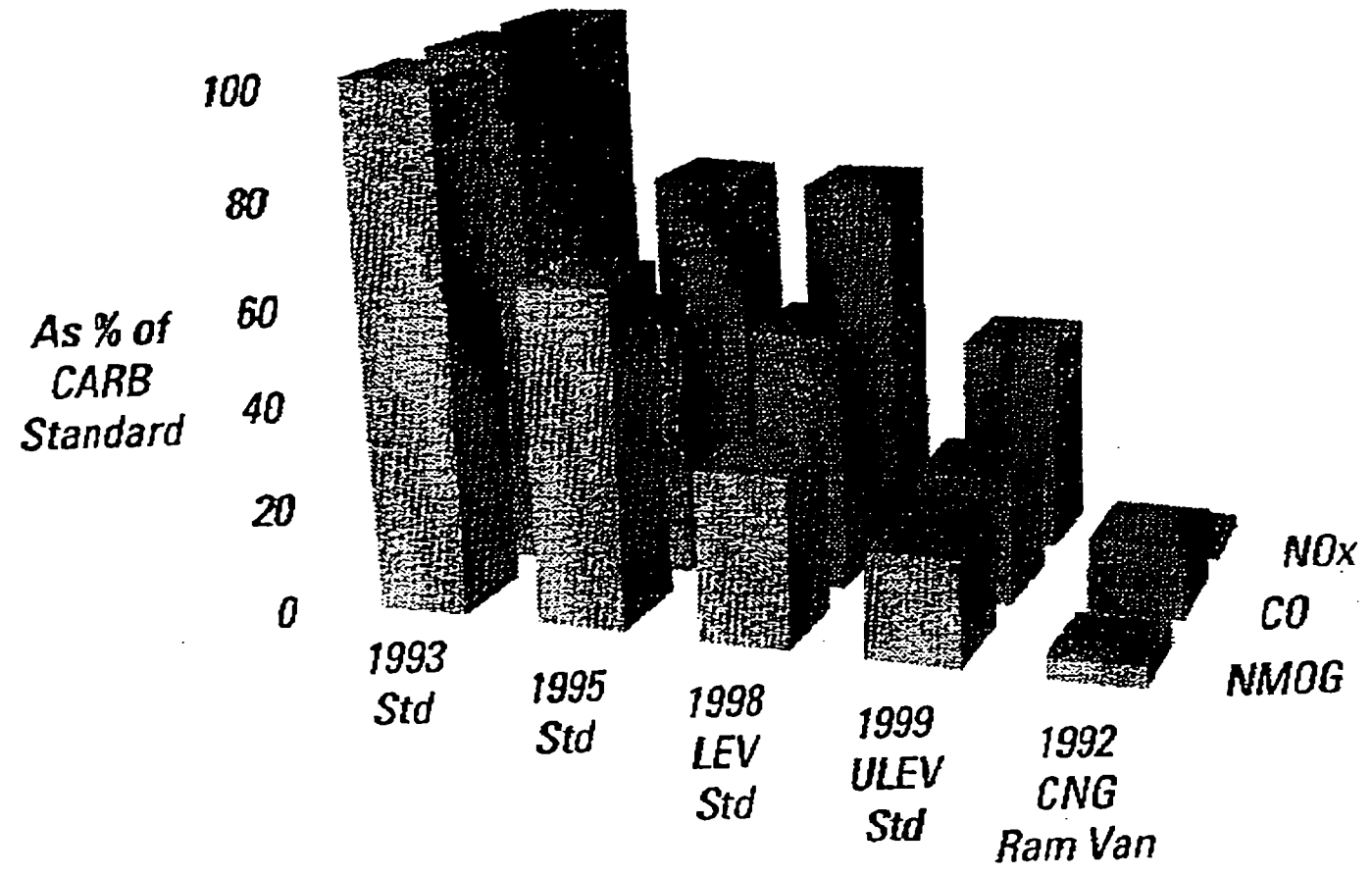
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Emissions

NATIONAL ENERGY POLICY ACT

- *Fleet Conversion Initiatives*
- *Tax Deductions for Vehicles*
- *Tax Deductions for Fuel Stations*

1992 Dodge Ram Van

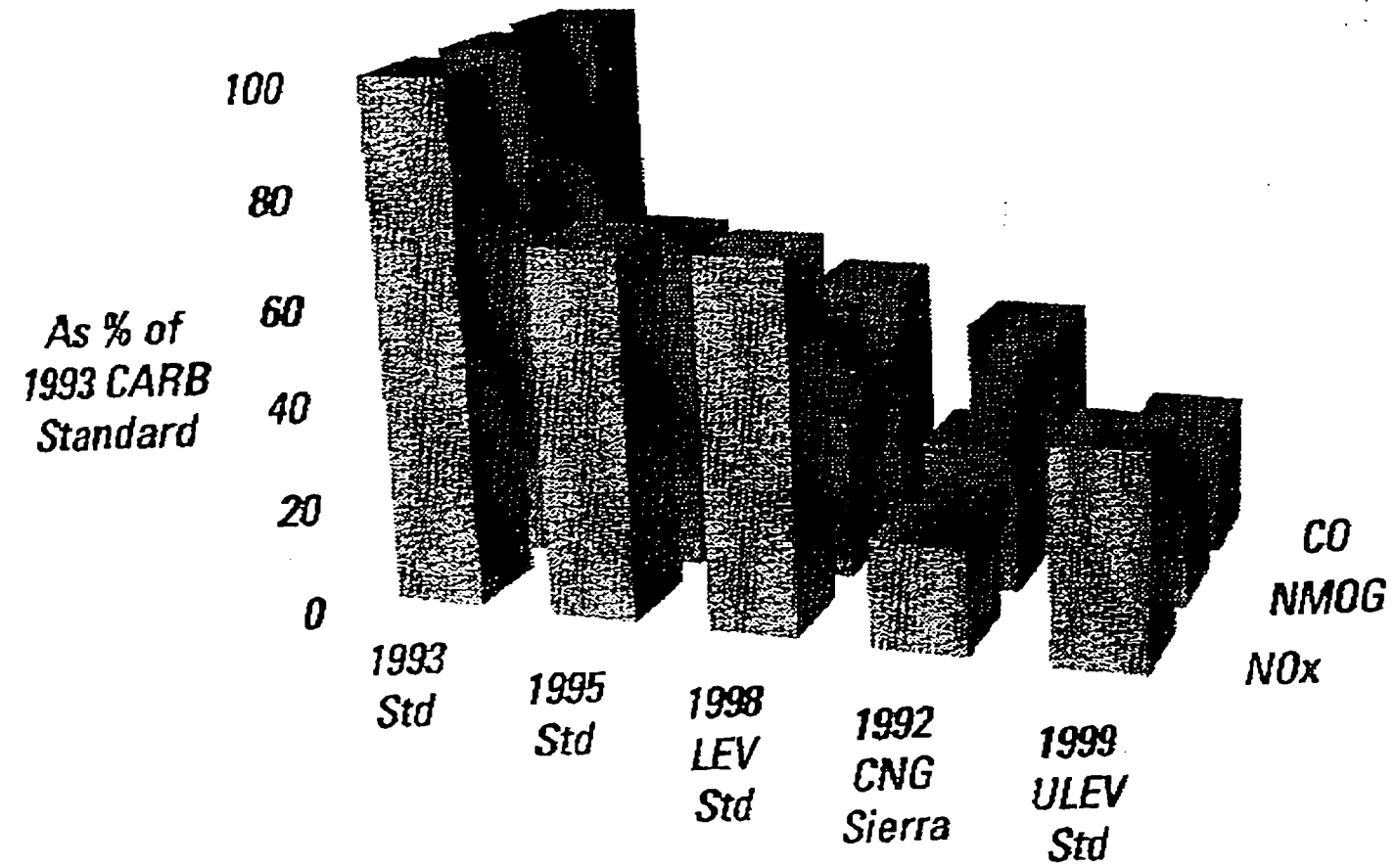


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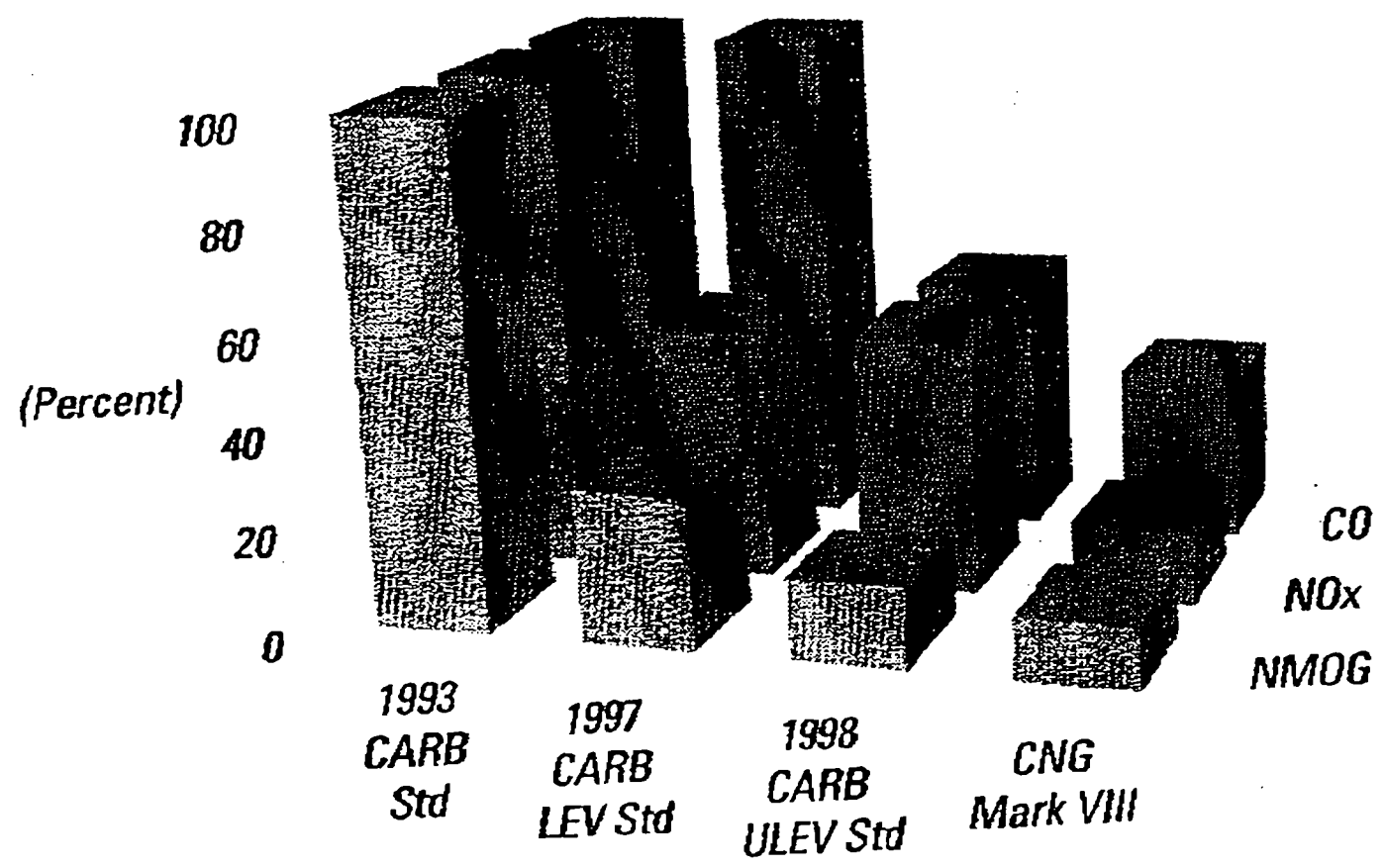
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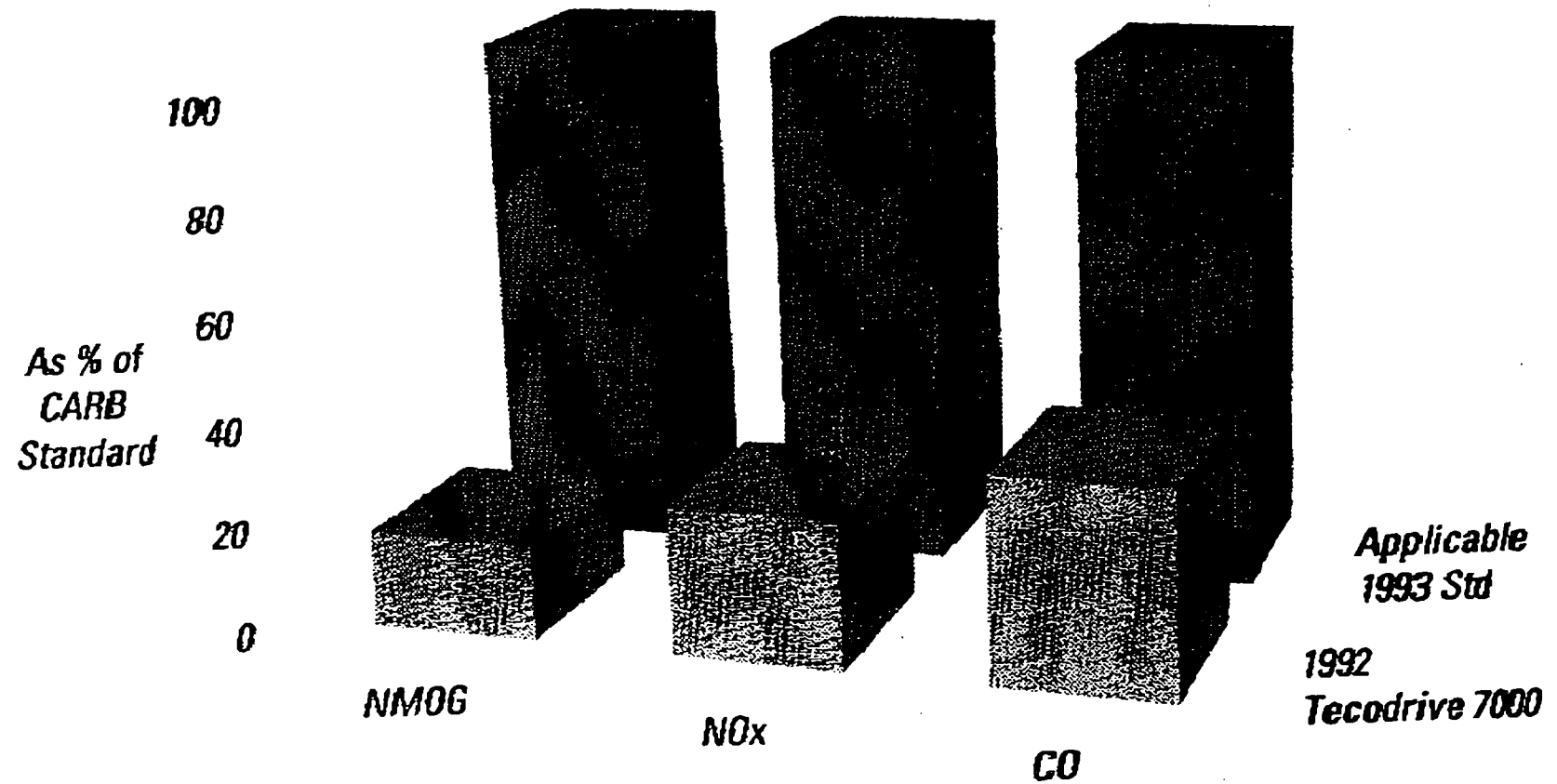
1992 GMC Sierra Pickup



CNG Lincoln Mark VIII Emissions



Tecodrive 7000 Schoolbus Engine



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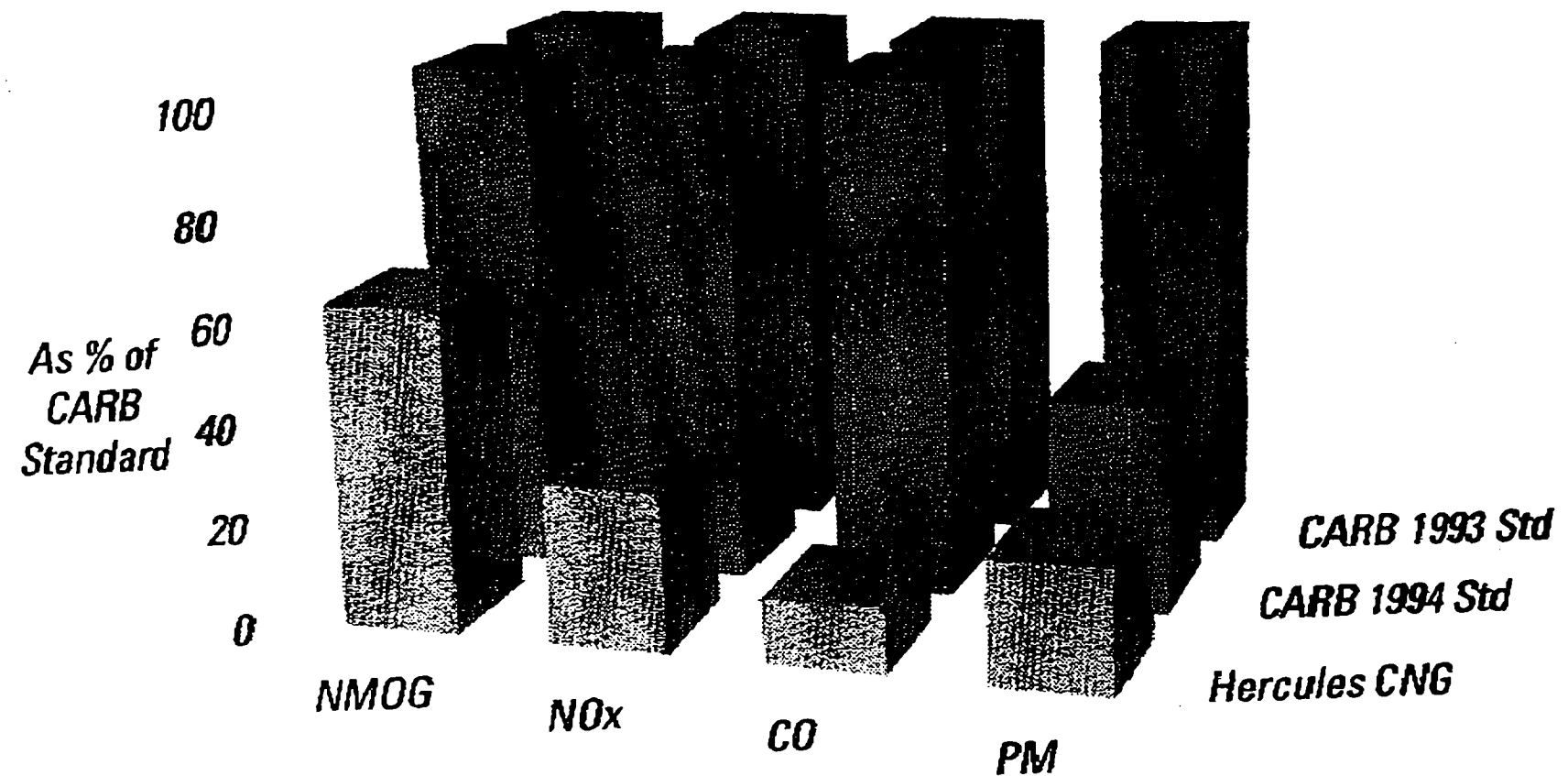
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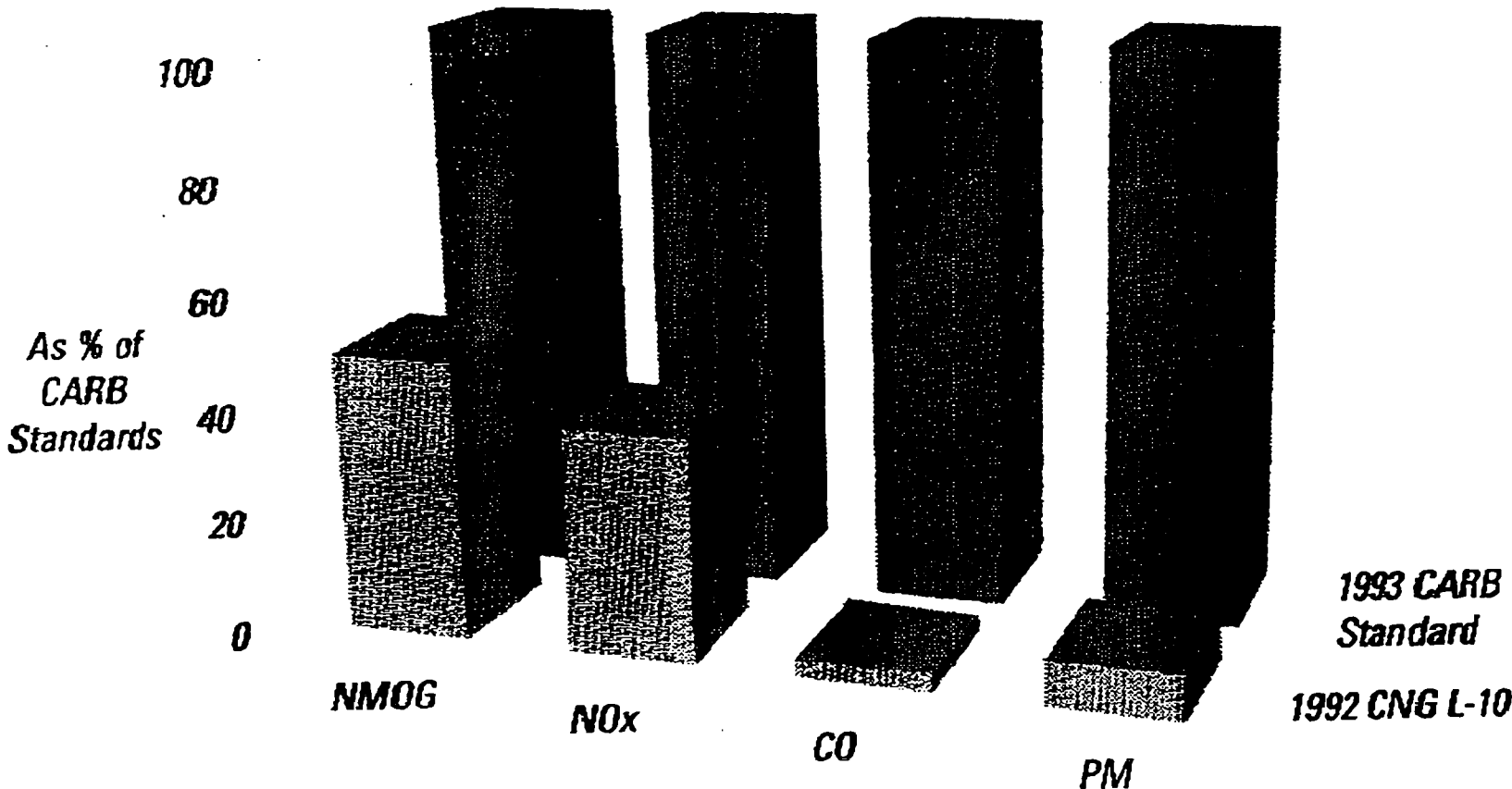
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Hercules GTA 5.6 Emissions



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Cummins L-10 Transit Bus Engine



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- *Higher Compression Ratios*
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Costs **NGVs Today**

COST PREMIUMS TODAY
OEM VEHICLES

Pickups/Van ***\$3500 - \$4000***

Medium Duty ***\$5000 - \$7000***

Costs **NGVs Today**

VEHICLE CONVERSION COSTS

<i>Autos</i>	<i>\$2500 - \$3000</i>
<i>Pickups/Vans</i>	<i>\$3500 - \$4000</i>
<i>Lg. Delivery Van</i>	<i>\$4000 - \$4500</i>

Costs

NGVs Today

PAYBACK EXAMPLE (Partial)

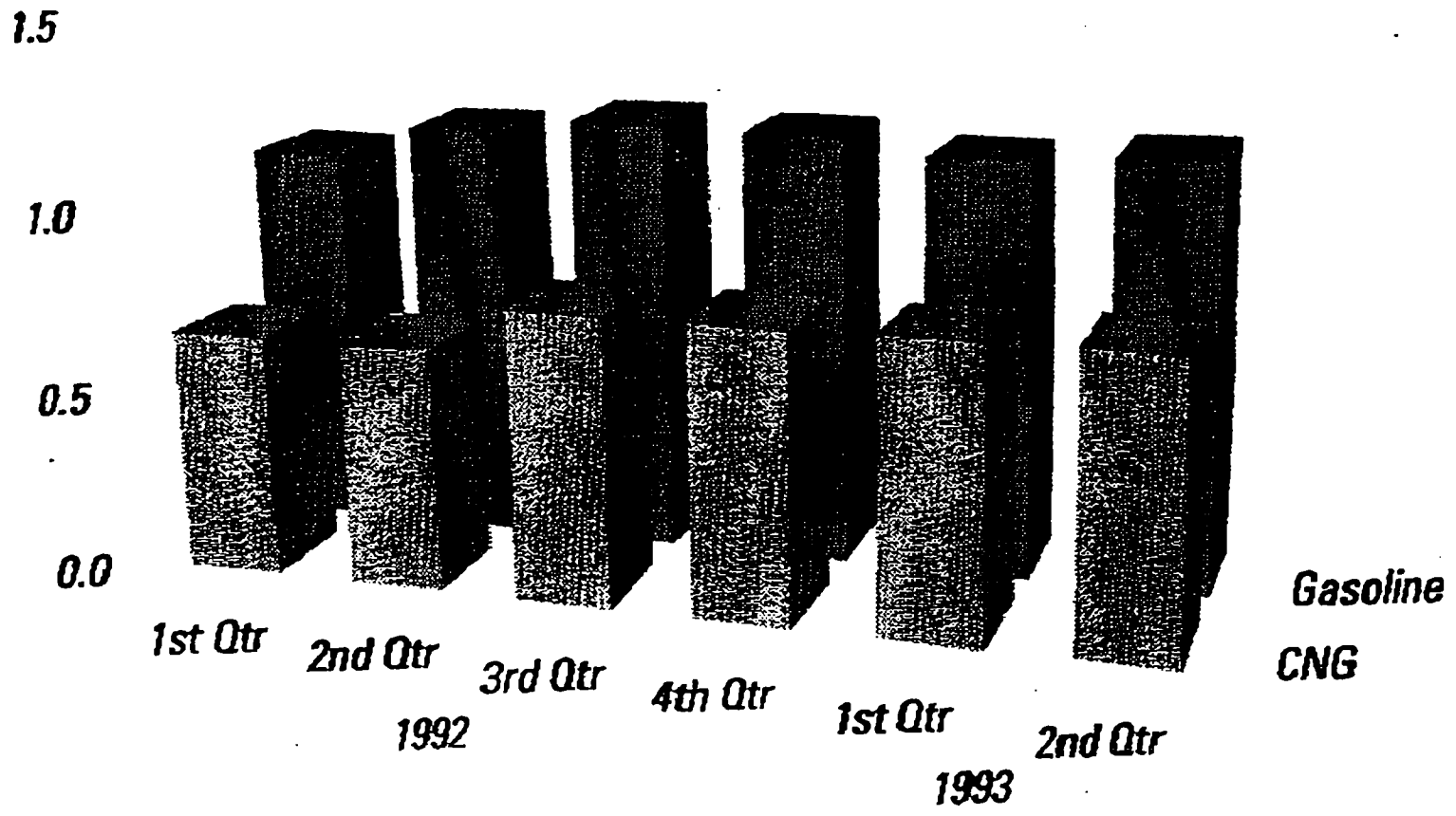
	<u>Vehicle Differential</u>	<u>Ave. Fuel Savings*</u>	<u>Payback Years</u>
20 Pickups Vans	\$ 35,000	\$ 6,961	5.0
20 Lg. Delivery Vans	\$ 40,000	\$ 10,429	3.8
20 Medium Trucks	\$ 150,000	\$ 58,529	2.6

* Net of depreciation differences resulting from the 1992 Energy Policy Act tax consequences.
Mileage and gallon usage are assumptions used in NGV Program filing 91-06-032

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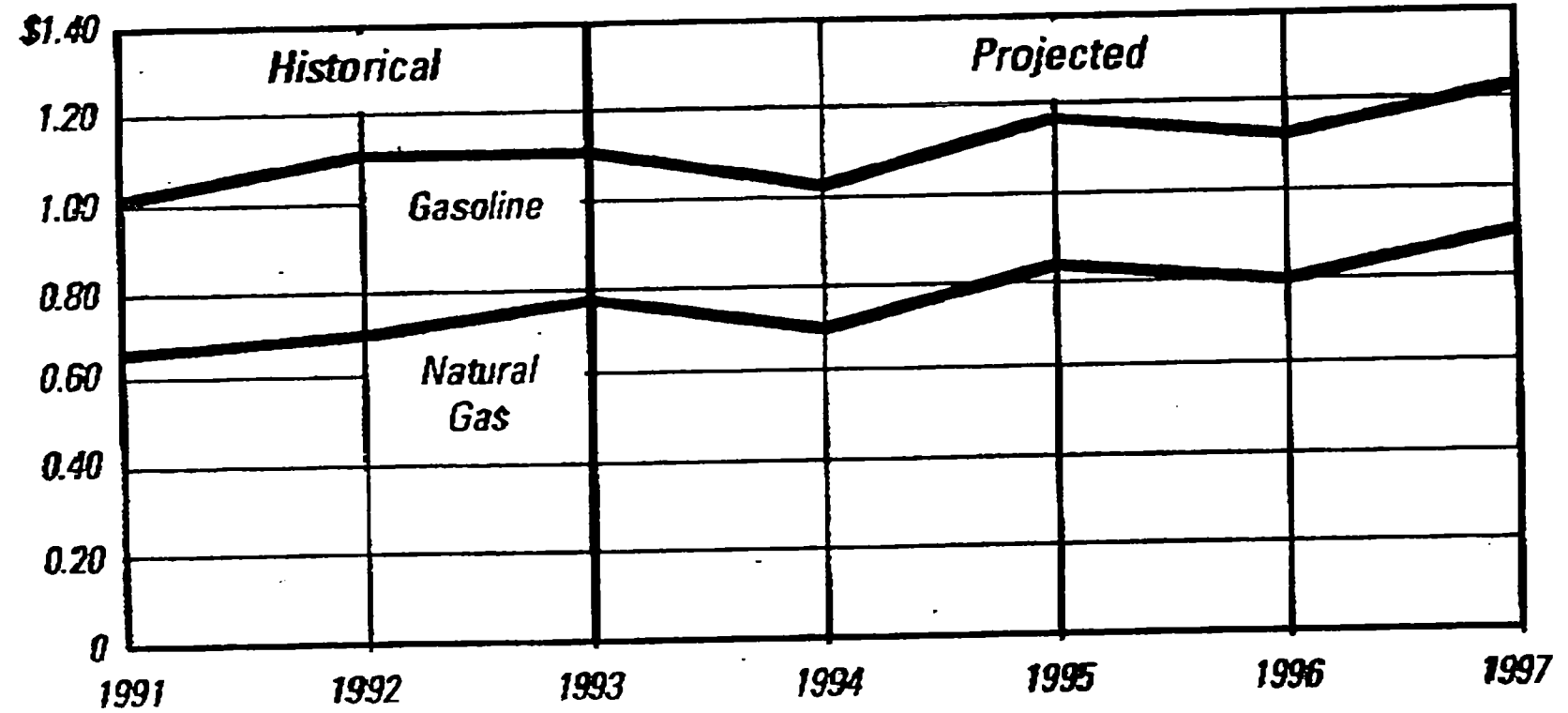
Competitive Fuel Price

● Indexed to Wholesale Gasoline Price



Fuel Cost Comparison NGVs Today

Cents per Gallon



Safety

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FUEL SAFETY

- ***Non-toxic***
- ***Less Flammable***
- ***Lighter than Air***

Safety

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FUEL TANKS

- ***NHTSA Approved***
- ***DOT Approved***
 - ***Crash Tested***
 - ***Burst Tested***
 - ***Bullet Tested***
 - ***Bonfire Tested***
 - ***Dynamite Tested***

Product Availability

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OEM VEHICLE AVAILABILITY

- ***Pickups/Vans***
- ***Medium Duty Trucks***
- ***Shuttle Buses***
- ***School Buses***
- ***Transit Buses***
- ***Street Sweepers***
- ***Forklifts***

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CONVERSION EQUIPMENT AVAILABLE

Electronic Closed Loop Fuel Control

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- AFE
- OHG

Gas Co. Program

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GAS COMPANY PROGRAM OUTLINE

- ***Goals***
- ***Incentives***
- ***Competitive Fuel Prices***
- ***Developing Fueling Infrastructure***

Gas Co. Program NGVs Today

GOALS

- *1,600 NGVs by end of 1993*
- *100,000+ NGVs by 2000*
- *150 Stations by end of 1996*

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Gas Co. Program

NGVs Today

VEHICLE INCENTIVES

SoCalGas will co-fund up to 50% of the incremental cost of CNG vehicles.

<u>Vehicle Type</u>	<u>GVW</u>	<u>Typical Incentive</u>
Class 1 & 2	10,000 & less	\$1,250
Class 3 - 5	10,000 - 19,500	\$2,000
Class 6	19,501 - 26,000	\$3,500
Class 7 & 8	26,001 & over	\$5,000

Saturn Corporation Recycling Painted Thermoplastic Bumper Fascia

R. T. Louis-Ferdinand
Saturn Corporation

Saturn Corporation Recycling Painted Thermoplastic Bumper Fascia

R. T. Louis-Ferdinand
Saturn Corporation

ABSTRACT:

Saturn Corporation has developed a system to recycle painted thermoplastic elastomer olefin (TEO) bumper fascia. Traditionally, automotive thermoset paints in combination with thermoplastic parts offered limited recycling potential. Saturn's goal was to develop and implement the most cost effective method for reclaiming painted fascia scrap. By evaluating polymer parts on current vehicles, the wheel liner was targeted as a potential application for the painted fascia regrinds. The painted TEO regrind is blended with a polypropylene copolymer and injection molded into wheel liners. In addition to serving as an outlet to recycle the painted fascia scrap generated during production, the wheel liner is a promising application for recycling painted fascias once the useful life of a Saturn vehicle is complete.

INTRODUCTION:

The advancements in engineering thermoplastic materials for major body panels have created the formidable challenge to recycle the composite parts. With increasing environmental concerns, government legislation, and continuing cost reduction efforts, original equipment manufacturers must incorporate solid waste reduction programs focused on recycling. One approach is to utilize an

advantage inherent to thermoplastics in that the material can be repeatedly softened by heating and hardened by cooling.

This paper illustrates how painted thermoplastic bumper regrind can be used as an effective material substitute for alternative applications. At the Saturn assembly plant major exterior body panels are injection molded and transferred through a waterborne paint system. At this point they are delivered to general assembly as a finished composite. Rejected unpainted molding and runners are recycled into the fascia material feed system. Painted parts with non repairable defects such as warpage, and other severe defects enter a recycling system for painted regrinds.

The development of the materials recovery system was part of a program established to recycle both painted and unpainted scrap. During the initial stages of the program optimal unpainted regrind concentrations were established for production, and metering and drying systems were brought on-line. At this point, work efforts concentrated on developing and implementing the most cost effective method for recycling painted polymer scrap.

PAINTED THERMOPLASTIC REGRINDS EVALUATION

The first task towards reclaiming the painted fascia scrap was to characterize the interaction of the paint and polymer resin

at elevated temperatures. Once this was completed we began to evaluate the painted TEO regrind for its physical and process properties. Physical properties for the painted fascia regrind were evaluated from both mechanically ground and repelletized samples molded into ASTM specimens.

In conjunction with the material evaluation, the vehicle was surveyed for potential applications for the painted fascia regrind. Several factors favored the wheel house liner as the target application. One, the current part material, polypropylene co-polymer (PP), is compatible with the painted regrind. Two, the physical properties of the painted regrind passed the requirements of a wheel liner material. Three, the wheel liner is a non-class A surface, therefore any paint particles that are at the surface will not affect the part esthetics. Four, the volume requirements of the wheel liner will consume 100% of the painted fascia scrap.

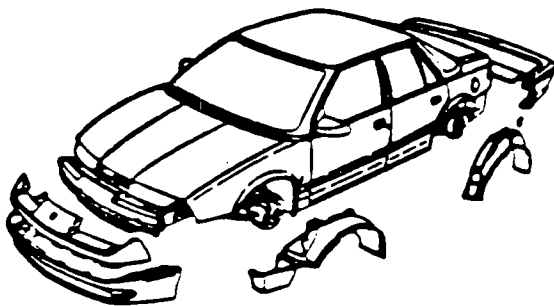


Figure 1. Vehicle parts layout for fascia and wheel liners.

Mold trials were completed with repelletized and mechanically ground blends to evaluate the process capabilities. Part evaluations were completed to test the performance of the wheel liners.

EXPERIMENTAL:

The thermal properties of the paint coats were evaluated by differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA).

Painted fascia scrap was mechanically ground to 95 cm² in a twin 100 hp hog grinder. This was repelletized on a 65 mm twin co-rotating Werner Pfleiderer extruder with a 150 mesh screen pack. ASTM specimens were molded from both samples on a 309 metric ton, Cincinnati Milacron injection molding machine.

Methods for tests cited in this paper: Specific Gravity ASTM D792, Melt Flow ASTM D1238, T

Strength and Elongation ASTM D638, Multiaxial Impact ASTM D 3763, Flexural Modulus (tangent) ASTM D790.

Wheel house liner parts were injection molded a 1364 metric ton, HPM injection molding machine. Parts evaluated for on car durability, gravelometer and dimensional inspection.

RESULTS and DISCUSSION:

There is no evidence that there is thermal decomposition of the paint during the processing of materials. The paint particles are treated as inert fillers.

Paint composition was calculated to be less than 5%. Thin film sections of non-repelletized (diagram 1) repelletized (diagram 2) samples show the distribution of the paint particles within the specimens. The reprocessed sample shows a decrease in average particle size and particle content.

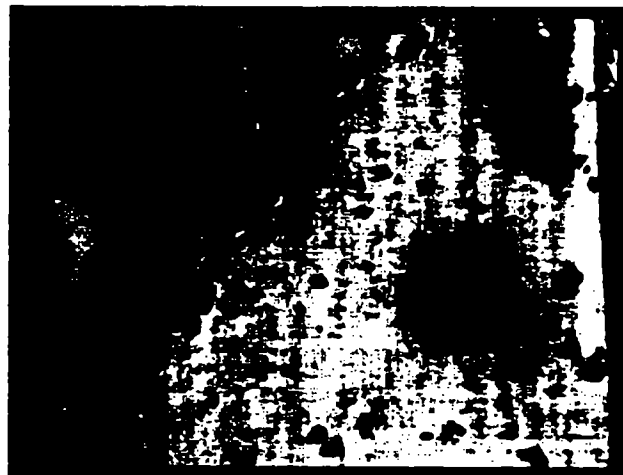


Diagram 1. Mechanically Ground Painted Regrind Film



Diagram 2. Reprocessed Painted Regrind Film

Both non-repelletized and repelletized samples retained toughness properties. Graphs I-II demonstrate the multiaxial impact at 23°C and -30°C as well as strength of the recycled material. Ultimate elongation of both materials exceeded 500%.

The modulus of the painted regrind is too low for ideal build conditions of the wheel liner. The most effective process to increase the part modulus would be to blend the PP copolymer with the recycled material. Additional material ng was completed to establish the blending concentration.

The optimum concentration of painted regrind with the co-polymer was qualified on a component level for production. Parts were sent through durability requirements at cold and ambient temperatures. Dimensional gage evaluations demonstrated no deviation for part build tolerances. All of the blends of product one and two equalled or exceeded current material and part performance requirements.

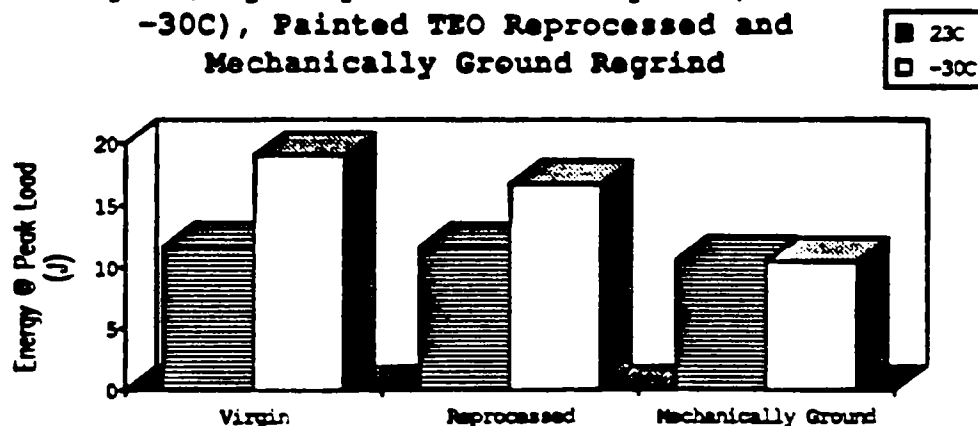
During production the painted TEO regrind and PP are volumetrically blended in a proportional loader and mixed as the blend is gravity fed into a surge bin. The blend of the painted TEO regrind and PP is loaded into gaylord

boxes transferred to the injection molding machine. Regrind generated from the rejected wheel liners is also introduced into the material feed stream through a proportional loader and surge bin. The injection molding process window for the wheel liner is large enough to accommodate for any minor deviations in TEO/PP concentrations.

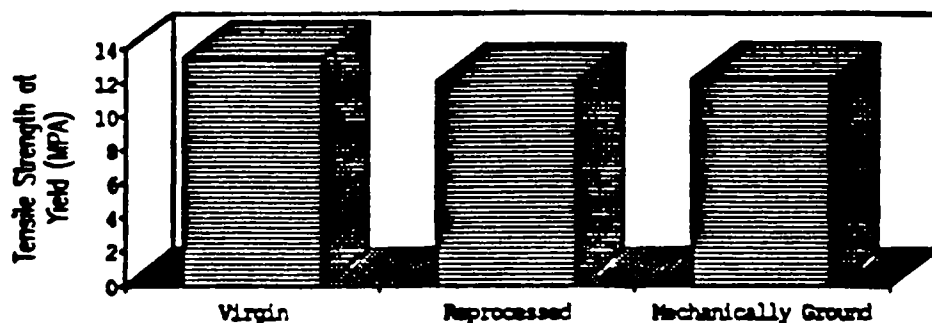
CONCLUSIONS:

Recycled painted TEO fascia scrap may be used an effective material in wheel liner parts. The properties of parts molded from both reprocessed and mechanically ground materials pass the part requirements for a wheel liner. The mechanically ground material is the most economical option for usage in production. The reprocessed material properties demonstrate that the recycled material has potential for use in more demanding applications where better surface appearance and physical properties are required.

Graph I, Dynatup Multiaxial Impact (23C and -30C), Painted TEO Reprocessed and Mechanically Ground Regrind



Graph II, Tensile Strength at Yield, Painted TEO Reprocessed and Mechanically Ground Regrind



CAR RECYCLING AND ENVIRONMENTAL IMPROVEMENT IN WESTERN EUROPE

University of Tennessee
Center for Clean Products and Clean Technologies

Gary A. Davis, Principal Investigator
Lori E. Kincaid, Project Manager
Barbara R. Griffith, Research Assistant

Prepared for Saturn Corporation
February 1993

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Appendix B. Future Contacts in Western Europe

1.0 INTRODUCTION

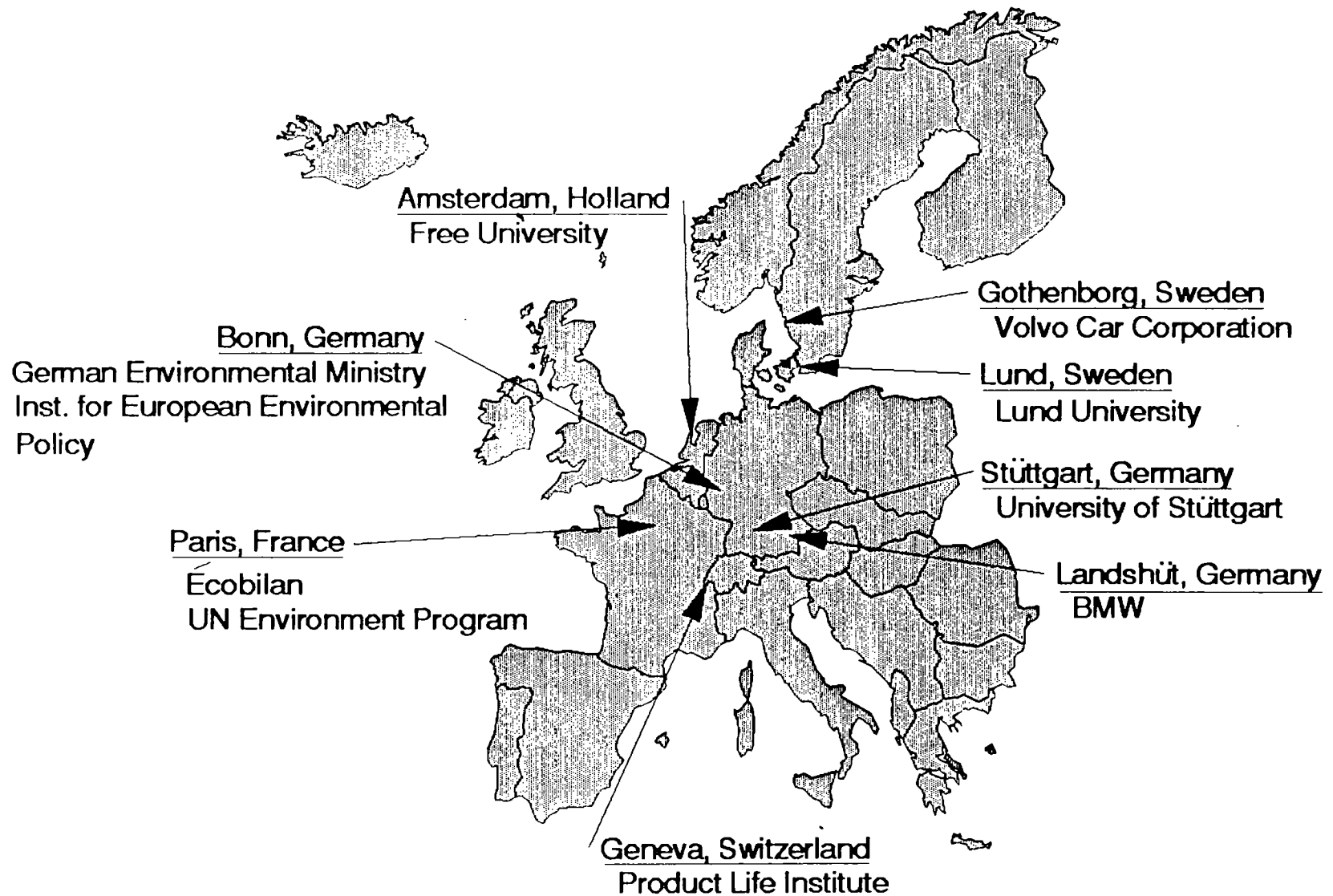
Saturn has a strategic initiative to design its vehicles for recycling by focusing on the vehicle life cycle, from design through disposal. As part of this recycling initiative, Saturn requested the University of Tennessee Center for Clean Products and Clean Technologies through the Saturn/UT Partnership to assess the status of car recycling and environmental improvement in western Europe. Many western European countries have proposed or pending regulations that affect the life-cycle of the automobile. As a result, European auto manufacturers are the current world leaders in car recycling and the use of life cycle assessment (LCA) to design environmentally superior cars.

The Center for Clean Products conducted a research trip to Europe in October 1992 where we visited auto manufacturers, government representatives and policy and technical researchers working with the automotive industry. Figure 1 shows the organizations that we visited during the research trip. Appendix A lists the names, addresses and telephone numbers of the persons that we interviewed at these organizations. Many of our contacts in Europe provided the names and addresses of additional contacts, who we were unable to visit because of time or other constraints. Appendix B lists these potential future contacts.

The information provided in this report is mainly derived from interviews and from documents we obtained in Europe. It is clear from our research that most European car manufacturers have formulated a recycling strategy and are well advanced in its implementation. Pilot disassembly facilities are being used to develop detailed information about disassembly methods, recycling technologies and the costs of disassembly and recycling. Car manufacturers and their suppliers are collaborating to develop or evaluate innovative technologies for materials recycling, chemical recycling and energy recovery of plastics.

We do not provide a detailed evaluation of the new technologies like pyrolysis in this report, since much of this research is in the development stage and the persons we interviewed were only able to provide limited information. We do, however, expect to receive two reports in the near future that should provide some of the latest information on these emerging technologies. One report, *Innovation in the Context of Plastic Waste Management: The Automotive Industry*, was prepared by researchers at Free University in Holland for the European Community (EC) and reportedly contains detailed information about materials use by European automakers and plastics waste management. The other, *Plastics in Motor Vehicles, Problems and Recycling Opportunities*, is being used extensively by the Institute for European Environmental Policy to develop policy options for a future EC rule on vehicle recycling.

Figure 1. Organizations Visited in Europe



While vehicle recycling technology is well-advanced in Europe, the use of LCA as a product improvement tool is gaining ground as a tool for designing environmentally superior products. Many European automakers are starting to incorporate LCA into their vehicle recycling programs to determine the best recycling approach for the environment. Furthermore, they are using LCA to evaluate how their cars are designed and to determine what environmental improvements can be made to the car without loss of performance, useful life, or function. Automakers using this emerging tool may be one step ahead of the next potential legislative trend in Europe, environmental product policy that looks at the entire life cycle of products. Even without such product policies, the use of LCA should allow these automakers to develop defensible design guidelines that incorporate environmental attributes into the design of the car.

We have organized this report into five sections, including this introduction. Section 2.0 is a review of regulations in Europe that affect the disposal of the automobile. Section 3.0 is a discussion of the response of European automakers to these regulations. Section 4.0 is a summary of the use of LCA in the automotive industry. Section 5.0 presents our conclusions and recommendations.

2.0 REGULATIONS AFFECTING DISPOSAL OF THE AUTOMOBILE

Several European countries and the European community have proposed or pending regulations that affect the disposal of the automobile. In the Scandinavian countries these laws have been in effect for some time, and are similar to bottle-bill legislation where a deposit is paid at the time of purchase and returned when the car is disposed of properly. More recently, mainly at the instigation of the German government, regulators are considering legislation that would require the automaker to take the car back from the last owner at the end of its useful life. These laws have tremendous implications for U.S. automakers who wish to compete in the global marketplace. The proposed German law, and several other proposed or current laws that affect the disposal of the automobile, are discussed below.

2.1 Summary of the Proposed German Automotive Recycling Ordinance

The most far-reaching regulation affecting the automobile industry is the "Draft Regulation about the Avoidance, Decrease and Recycling of Wastes from the Disposal of Automobiles", issued by the German Environment Ministry on 17 August 1992. The draft regulation, commonly known as the Scrap Car Rule, was issued under the authority of the 1986 German Waste Management Act, which sets a hierarchy for waste management and provides the Environment Ministry with a mandate to develop regulations for managing the disposal of certain products. The Scrap Car Rule represents the culmination of five years of effort by the German Environment Ministry, which first initiated discussions on recycling regulation for the automobile industry in 1987. From the inception of these discussions, a goal of the Ministry has been to catalyze joint research efforts among manufacturers, suppliers and auto dismantling companies.

The first ordinance under the 1986 Act was the Waste Oil Regulation, issued in 1987, which sets a hierarchy for managing waste oil of 1) recycling, 2) recovery of energy and 3) proper disposal as a last resort. It is this ordinance that established the precedent in Germany for the take-back of a waste product without charge.

Other take-back ordinances that have been developed under the German Waste Management Act are ordinances for chlorinated solvents, chlorofluorocarbons (CFCs), plastic packaging used for drinks, and an overall packaging ordinance. In addition to the Scrap Car Rule, ordinances are pending for batteries, electronic products, construction, demolition and excavation wastes, and wastepaper.

The goals of the proposed Scrap Car Rule are to avoid or decrease wastes from the disposal of automobiles by:

- 1) developing, designing and producing automobiles and automotive parts and accessories that have a service life of "as long as possible" and that can be easily disassembled for reuse or material recycling;
- 2) using materials that facilitate material recycling and that are marked in a uniform way so that they can be disposed of in an environmentally compatible way if material recycling is not feasible; and
- 3) after disassembly, reusing parts in automobile manufacture or as spare parts or, for parts that can not be reused, recycling the materials back into the manufacture of new automobiles.

The draft Scrap Car Rule applies to the commercial producers or marketing agents of automobiles, spare and exchange parts, and accessories or other parts that are used for the operation of an already registered automobile, and to the last owner of an automobile.

The draft regulation sets out a number of "Withdrawal and Recycling Obligations." Withdrawal Obligations include:

- 1) The automobile producer must take back from the last owner cars of its automobile brand at the end of their useful life, "principally" free of charge. Not taken back free of charge are:
 - exploited car wrecks from which parts necessary for operation have been removed;
 - cars which carry or are contaminated with parts, solids or liquids that impair material recycling or disposal;
 - cars involved in an accident where disassembly is technically not possible; and
 - cars registered before the regulation takes effect, provided that the disposal cost exceeds the profits from valuable materials and for which the producer has published the type, year of construction and amount of disposable material.
- 2) The withdrawal network must be at least in equal density to the sales network and have one withdrawal place or one pick-up system for each area engaged in disposal, even where there are no marketing offices of the automobile brand concerned.

Similar requirements apply to producers or sellers of spare and exchange parts, accessories and other parts.

The Recycling Obligations require producers and sellers to reuse parts if it is technically possible or to recycle material back into the car. After withdrawal, all fuels and other parts which impair recycling must be removed and disposed of in an environmentally compatible manner. Reusable or recyclable materials and components must be disassembled to the extent technically feasible. Table 1 shows the reuse or material-recycling goals to which producers and sellers must aspire.

Table 1. German Goals for Material Reuse or Recycling Back into the Automobile

Material	Reuse or Recycling Goal for 1996 (%)	Reuse or Recycling Goal for 2000 (%)
Steel	about 100	about 100
Non-ferrous metals	85	90
Plastics	20	50
Tires	40	50
Other elastomers	20	30
Glass	30	50

The draft regulation allows producers or sellers of automobiles to use third parties to act on their behalf. Annual reports are required to show progress toward the recycling goals.

To ensure environmentally compatible disposal, the proposed regulation requires the last owner of a car to leave the car with the producer, a third party authorized by the producer, or another recycling company. Incentives are provided to the last owner in the form of a certificate of disposal, which must then be provided to the automobile registration office to relieve the owner of annual vehicle or road-use taxes.¹

2.2 Perspective of the German Environment Ministry

Germany's Parliament has a Special Committee composed of members of various groups, including academia and environmental groups. The special committee is tasked with

¹ German Environment Ministry, "Draft Regulation about the Avoidance, Decrease and Recycling of Wastes from the Disposal of Automobiles: Unauthorized Translation," August 17, 1992.

evaluating various environmental issues, like using LCA to "close the loop" back to production or breaking down polymers back into mineral oil. The Waste Management Group, headed by Dr. Helmut Schnürer, is looking at environmental problems from the perspective of waste management. Since it is difficult to site waste disposal facilities in Germany, they look at recycling and waste minimization as the primary mechanisms to reduce the volume of waste streams.

Environmental issues are starting to have a lower priority in Germany because of some of the more compelling problems posed by reunification and the economy. These problems make it more difficult to reach a consensus on environmental regulations with, for example, the Ministry of Economy. The Scrap Car Regulation, however, should not be affected because the automotive industry wants the regulation to establish uniform goals. Many auto manufacturers have started recycling programs but will not make significant financial investments until it is clear which path the government intends to take.

The main point of contention within the German government on the Scrap Car Rule is that the regulation only mandates to the auto manufacturers the responsibility for recycling and allows the manufacturer to bring in a third party to act on its behalf. The Ministry of Economy feels that this requirement could put existing, small dismantlers out of business, because they would become too dependent on the auto industry for a supply of scrap cars. The Environment Ministry is evaluating the possibility of allowing dismantlers to take cars back directly and assume responsibility for the proper disassembly, recycling and disposal of the car. The problem with this approach is that it would be hard to track the stages of the dismantling/recycling process by the third party. The third party question and its effect on anti-trust regulations was scheduled for review at a meeting of manufacturers, dismantlers and government agencies on October 23, 1992.

Another conflict exists with the sections of the Environment Ministry that are tracking air pollution and energy efficiency regulations. One of the aims of the proposed rule is for autos to have a service life "as long as possible", but these sections have an interest in replacing cars more quickly because of rapid changes in technologies that improve fuel economy and reduce air pollutants from combustion of fuels.

The German Environmental Ministry is firmly committed to the concept that the cars registered after initiation of the rule must be taken back free of charge. This is the central concept that gives auto manufacturers an incentive to make cars easier to recycle. Although the "unauthorized" English translation of the rule that we obtained from the Ministry implies that material recycling goals are goals for recycling back into automobiles, the Ministry's position is that "material recycling" means back into new products, not necessarily just automobiles. The Ministry feels it cannot compel auto manufacturers to put the recycled materials back into their cars because of safety and a number of other issues. Thus, the recycling goals listed in the ordinance are not binding, but manufacturers unable to meet these goals must show why they can not meet the goals in their annual reports. If it is

technically feasible to meet the goals, then the manufacturer must demonstrate that there is no market for the recycled materials or that the costs are unacceptable.²

2.3 Other European Laws for Scrap Cars

2.3.1 The Netherlands

The Dutch vehicle recycling program is not nearly as comprehensive as the proposed German regulation. The Dutch Environmental Ministry has established a longer-term, more collaborative approach to auto recycling as part of the overall Dutch Environmental Plan. In the Netherlands, a Working Group composed of industry and government representatives has set targets of 10% reduction of shredder waste and incineration of the remainder instead of landfilling by 2000. Currently, shredder residue in the Netherlands goes to landfills.

Since there is little auto manufacturing industry in the Netherlands, the government has also taken an active role in the development of disassembly technology. The Environmental Ministry set up and subsidized an industry association of automobile shredders to improve their environmental performance. This trade association developed a pilot disassembly line.³

2.3.2 Sweden

The Swedish car scrapping law is bottle-bill type legislation, established by the Swedish Parliament in 1975. The law is applicable to private cars and light trucks with a total weight less than 3500 kg and places a scrapping fee on all new cars which are sold in Sweden. In 1992, the fee was SEK 850 (about \$142).

The law requires car scrappers to be authorized by the County Administrative Board, and requires them to guarantee that cars will be disposed of properly to receive authorization. Authorized car scrapping companies can issue a certificate of disposal, which is required to deregister a car.

A car owner who takes a car to an authorized car scrapping company receives a car-scrapping premium after sending the car's certificate of disposal to the County Administrative Board. The premium, currently SEK 1500 (about \$250), is designed to cover the car

² Schnürer, Dr. Helmut, Leader Waste Management Section, German Environmental Ministry. Personal Communication, October 16, 1992.

³ den Hond, Dr. Frank and Dr. Peter Groenewegen, Free University, Holland. Personal Communication, October 22, 1992.

owner's expenses for transporting the car and paying the car scrapping company, plus provides the car owner a small profit.⁴

The Swedish model places the burden for proper disposal of the car more squarely on the consumer than does the proposed German regulation. Consequently, many consumers were not turning in their cars at the end of their useful life. Researchers at Lund University in Sweden are trying to obtain funding from the Swedish Environmental Protection Agency, the Swedish Transportation Agency, and a private foundation called Reforsk to evaluate possible changes to the Swedish system. The proposed 2-year project would include data gathering and compilation, followed by development of a Swedish model that would follow the EC model.

The Swedish government is very interested in looking at possible revisions to its recycling law. The government is launching an LCA approach to look at the whole transportation network, from infrastructure to car manufacturing and disposal. The government plans to evaluate different aspects of the vehicle life cycle and to develop projects based on this evaluation.⁵

2.4 European Community Regulations for Car Recycling

The European Community (EC) has established waste from automobile disposal as a "Priority Waste Stream" which must be more efficiently managed. As a result, the EC formed an End-of-Life Vehicles Working Group and tasked the group with developing an EC Rule for automobiles. The EC process works by assigning responsibility to individual member countries for analysis of a particular waste stream on a Community rather than a national basis. France was assigned the "End-of-Life Vehicles" waste stream at the instigation of Commission Directorate DG XI in June 1991. The draft timetable proposed for the DG XI project is:⁶

Completion of Analysis	November 1992
Strategy Formulated	March 1993
Approval of Implementation Plan	September-December 1993
Operational phase	1994-2000

⁴ Magnell, Mats, and Erik Rydén, "The Swedish Car Scrapping System", in *Cleaner Production Strategies for the Automotive Sector: International Expert Seminar, Trolleholm Castle, Sweden, December 11-12, 1991*, Lund University, January 1992.

⁵ Ryden, Eric, Lund University, Sweden. Personal Communication, October 20, 1992.

⁶ ACEA, "Position of the European Automobile Industry on Automobile Waste Management," October, 1991.

EC Directive 91/156/EEC sets a waste management hierarchy of 1) prevention, 2) recycling through materials recycling, 3) thermal treatment with energy use, and 4) final treatment with strict environmental standards. It was this directive that identified end-of-life vehicles, demolition wastes and hospital wastes as priority waste streams, because these waste streams, coupled with plastics used in packaging, which are covered by a packaging directive, account for 80 to 90% of the plastics waste stream. The disposal issue prompted the legislative moves.

The EC process involves roundtable discussions among all interested parties, directed by the pilot country, in this case France. Although it is usually difficult to get a consensus between the member nations on EC regulations, consensus on the automobile regulation should be relatively easy to achieve since the auto industry is concentrated in relatively few countries. An overall recommendation on how to implement an end-of-life rule should be available in 1994 or 1995.⁷

The anticipated form of the EC rule changes depending on which country you are in. In Germany, both BMW and the German Ministry expressed the expectation that the rule would follow the German model. Researchers at the Institute for European Environmental Policy (IEEP) in Bonn, Germany, were more cautious, saying only that the German model seemed to be one likely scenario, but that the Germans tend to set higher standards than the EC. Conversely, in the Netherlands, the expectation was that the rule would follow the Dutch model.

The IEEP has been tasked with developing a menu of policy options for the EC's End-of-Life-Vehicles Working Group. The IEEP report presents an analysis of alternatives for three types of systems: 1) collection systems, 2) recovery systems, and 3) disposal systems. Collection systems are the systems or networks used to retrieve the vehicle from the consumer. Recovery systems are physical, chemical and cascade recycling methods, and other methods for improving the recyclability or recovery of materials in the car. Examples include reducing the number of plastics in the car, dismantling and recycling technologies, and preventive or design measures, such as reducing the use of plastics that are not easily recycled. Disposal systems include incineration technologies or land disposal systems and options for minimizing the costs of disposal.

Some of the main issues addressed in the IEEP report are ways to design the collection systems on an EC-wide basis, whether to include registration or deregistration with fees and credits to provide incentive to consumers, and licensing for dismantlers. A specific collection issue is whether the last owner should pay a take-back fee to the party receiving the car and responsible for its dismantling and disposal. The IEEP group feels, however, that some incentive is probably necessary to persuade consumers to turn in cars. Another

⁷ Schnürer, Dr. Helmut, Leader Waste Management Section, German Environment Ministry. Personal Communication, October 16, 1992.

issue is the caloric value of plastics; some argue that plastics should remain in the waste stream to enhance its value as fuel.

The IEEP project was scheduled to be completed in November, at which time the Director of the Program, Jan Bongaerts, was expected to meet with Hans Erasmus of the EC to discuss the report. After the November meeting, the IEEP group was expected to proceed with a third draft. The report will not be available to the public until it is issued in final form by the EC.⁸

In a similar line of research, Frank den Hond and Peter Groenigen of Free University in Amsterdam, Holland, prepared a study of plastics innovation in the automobile industry for the EC. Their report consists of a strategic analysis of the science and technology of plastics waste management and assesses the composition and amount of auto shredder residue. The report looks in detail at six auto manufacturers and their strategies for end-of-life vehicles, including strategies for both cars now on the road and future cars.⁹ The Center for Clean Products is on the mailing list for the EC report, but has not yet received a copy.

2.5 Japanese Recycling Regulations

The Japanese government recently enacted legislation designed to promote resources conservation and recovery in all sectors and products, including the automotive sector and its products. The Law for the Promotion of Utilization of Recycled Resources (the so-called Recycling Law) was promulgated on April 26, 1991 and went into effect on October 25, 1991.

The Japanese law defines "First Class Specified Products", including automobiles, air conditioners, television sets, refrigerators, and washing machines as products that must be recovered or reused, as a whole or partly, after their first use.

The Japan Ministry of International Trade and Industry and the Ministry of Transportation have established criteria under the law for the automotive production industry and the automotive maintenance industry to promote recycling. The criteria are summarized as follows:

- 1) Recyclable materials should be used in vehicle parts,

⁸ Webber, Audrey, Institute for European Environmental Policy. Bonn, Germany. Personal Communication, October 15, 1992.

⁹ den Hond, Dr. Frank and Dr. Peter Groenewegen, Free University, Holland. Personal Communication, October 22, 1992.

- 2) The automotive industry should adopt methods that ensure the parts of vehicles are more removable.
- 3) Parts made of synthetic resins should be labeled for easier sorting;
- 4) The automotive industry should ensure safety in the treatment of end-of-life vehicles by noting the toxicity of materials used for parts;
- 5) The previous criterion should be compatible with the safety of the vehicles, and their durability;
- 6) The automotive maintenance industry should use recyclable parts when they exchange parts, and should sort old parts according to material labels;
- 7) Both the production and maintenance industries should make efforts to develop relevant technologies;
- 8) The production industry should implement vehicle design practices according to criteria 1 to 4; and
- 9) Both industries should provide relevant information to promote recycling.¹⁰

The Japanese law, as written, is actually more of a guideline to encourage design for recyclability. In response to the law, the Japanese Automobile Manufacturers Association (JAMA) has established a Recycle Technology Task Force to promote automaker cooperation on the common technical issues related to recycling.

2.6 Other Government Regulations and Guidelines Affecting End-of-Life Vehicles

Several EC countries have drafted legislation that affects end-of-life vehicles. For example, Switzerland has developed legislation which prohibits the land disposal of shredder residue by 1996.¹¹ Current plans are to construct two or three high- temperature, energy-recovery incinerators to dispose of the 80,000 tons of shredder waste generated annually.¹² Austria is reportedly drafting proposals for new legislation to regulate car recycling.¹³ France issued a law in July 1992 that prohibits the landfilling of untreated waste, including shredder waste, after 10 years (2002), unless no technology exists to recycle or treat the

¹⁰Moriguchi, Yuichi, Shimizu, Hiroshi, and Yoshinori Kondo, "Analysis and Management of Life Cycle Environmental Impacts of Automobiles - CO₂ Emission Analysis, New Policy on Recycling, and Other Recent Topics," in *Cleaner Production Strategies for the Automotive Sector: Invitational Expert Seminar, Trolleholm Castle, Sweden, December 11-12, 1991*. Lund University, January, 1992.

¹¹ Stauber, Dr. Rudolf, BMW, Landshüt, Germany. Personal Communication, October 13, 1992.

¹² "Car Recycling Around the World", World Action for Recycling Materials and Energy from Rubbish, Bulletin No. 35; November 1992.

¹³ Ibid.

waste or the waste is inert. The law does not specify particular criteria to demonstrate that waste has been recycled or treated.¹⁴

One guideline that appears to be widely adopted by EC automakers is the Association of German Auto Manufacturers (VDA) guideline on the labeling of plastics, commonly called VDA-260. This guideline provides a standard labeling structure and a standard method for labeling thermoplastics, thermosetting plastics and elastomers. The standard is recommended for use on all parts made from polymeric material in the automobile.

¹⁴ Schnürer, Dr. Helmut, Leader Waste Management Section, German Environmental Ministry. Personal Communication, October 16, 1992.

3.0 RESPONSE OF EUROPEAN AUTOMAKERS

3.1 Positions of European Automotive Consortia on Auto Recycling

In response to the flurry of legislative interest in discarded automobiles, European automakers have banded together to form a number of automotive consortiums. A common goal of the different consortiums is to collaborate with government to develop workable regulations that suit both the industry and government objectives. Without exception, the consortiums acknowledge that the automaker has responsibility for proper management of scrap cars. The positions of the various European automotive consortiums on auto recycling are summarized below.

3.1.1 PRAVDA

In response to the proposed German recycling law, first drafted in August 1990, PRAVDA was formed in early 1991 by a consortium of automobile manufacturers and major plastics suppliers to develop a recycling network and strategy. Participants in PRAVDA include BMW, which was probably the driving force that initiated the group, Mercedes-Benz, Opel, Volkswagen, and Ford Europe, and the materials suppliers Huls, Himont, BASF, Bayer, DOW, PCD, and GEP. PRAVDA established seven pilot disassembly sites. The results of current PRAVDA disassembling experiments and polymer recyclability experiments will be disseminated to all members.

PRAVDA's recycling concept closely resembles the strategy that BMW developed internally: a network of licensed dismantlers to be authorized by auto manufacturers; "certificates of disposal" to be provided by dismantlers as a condition of deregistration; a market-based reward system that involves free bargaining between dismantlers and owners over disposal costs; and partnerships with plastics companies to research characteristics of recycled polymers.¹⁵

3.1.2 ACEA

The "Association des Constructeurs Europeens d'Automobiles" is a consortium representing fifteen European automobile manufacturers, including BMW, DAF, Daimler Benz, Fiat, Ford of Europe, GM Europe, MAN, Porsche, Renault, Rolls-Royce, Rover Group, Saab-Scania, Volkswagen, Volvo Car B.V. and AB Volvo. ACEA published a position paper in October 1991 entitled "Position of the European Automobile Industry on Automobile Waste Management". Acknowledging its responsibility to manage automobile

¹⁵ Management Institute for Environment and Business, *BMW: A Proactive Approach to Vehicle Recycling*, contractor's report prepared for the Office of Policy, Planning and Evaluation, U.S. EPA, 1992.

waste, the consortium's objective is "to come to market-economy related solutions which will render potential legislative measures in this field superfluous." The group advocates worldwide adoption of VDA-260 on the "Marking of Parts made of Polymeric Materials", which was developed on the basis of ISO standards and is currently being used in Europe and Japan (see Section 2.6).¹⁶

3.1.3 ACORD

Major vehicle manufacturers and representatives of the disposal and reclamation industries in the United Kingdom formed the "Automotive Consortium on Recycling and Disposal" (ACORD) in December 1991. ACORD published a preliminary concept for end-of-life vehicle disposal in July 1992 that takes a life-cycle approach. ACORD's stated objective is to minimize the adverse impact of end-of-life vehicle disposal without detriment to the overall environmental effect of a vehicle during all phases of its manufacture and use.

In its concept paper, ACORD sets a waste management hierarchy of prevention, recovery (including reuse of parts, recycling of material and recovery of energy), and disposal and sets out nine basic waste management principles. The ACORD principles are essentially the same as the PRAVDA model for car recycling, with the same emphasis on a market-based reward system. ACORD describes three key areas of change to improve the automobile disposal process:

- fluids should be drained and contained at the vehicle disposer, prior to recycling;
- material which can be removed cost effectively should be stripped and sold to recyclers for further use; and
- non-metallic residue left after shredding the shell should be used for energy generation rather than consigning it to a landfill.

ACORD proposed a joint effort between the automotive industry, the UK government and other affected parties to develop an Operating Plan by March 1993.¹⁷

¹⁶ ACEA, "Position of the European Automobile Industry on Automobile Waste Management," October 1991.

¹⁷ ACORD, "End of Life Vehicle Disposal: Preliminary Concept," July 1992.

One result of the ACORD concept paper is a formal partnership between ACORD and the UK government. Representatives of both groups are exploring economically feasible ways to implement the recycling ideas put forth in the concept document.¹⁸

3.1.4 EGARA

Recently, another consortium was formed by the joining of a Dutch and Danish Group. The European Group of Automotive Recycling Associations will promote the interests of the automotive and scrap car industries at the EC level and hopes to have members from each European country. The Group believes it is important to include the views of the automotive and scrap car industries when developing legislation that would affect car recycling.¹⁹

3.2 BMW: A Case Study

3.2.1 Vehicle Recycling Program

One of the surprising aspects about the BMW recycling program is how long it has been in the making. The first organized, internal discussions on recycling at BMW took place in 1984 and 1985 among several production departments, well before regulatory discussions began. BMW's internal recycling group analyzed the impacts of environmental concerns on vehicle disposal and on BMW's business system and concluded that vehicle disposal would become a significant environmental problem and that BMW should take responsibility for the entire life cycle of its cars.

The group's first action was to develop a general rule of thumb for recycling: that the "cost of disassembly plus treatment plus logistics must be equal to or less than the cost of virgin materials plus the cost for disposal (incineration or landfill)."²⁰ They also developed a waste management hierarchy called the "Cascade Model", illustrated in Figure 2. The Cascade Model hierarchy prioritizes waste management activities in the following order: 1) parts recycling, 2) materials recycling, 3) chemical recycling, 4) energy utilization, and 5) disposal. The goals of the BMW recycling project are to reduce shredder residue by 50% and to reduce the use of natural resources in car manufacturing.

¹⁸Broughton, Anne Claire, "British Step Up Car Recycling", Recycling Today, October 15, 1992.

¹⁹ "Car Recycling Around the World", *World Action for Recycling Materials and Energy from Rubbish*, Bulletin No. 35, November 1992.

²⁰ Management Institute for Environment and Business, *BMW: A Proactive Approach to Vehicle Recycling*, contractor's report prepared for the Office of Policy, Planning, and Evaluation, U.S. EPA, 1992.

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Figure 3 shows the flow of materials in a cascade-type recycling model. Operating materials and parts are dismantled from the car at a recycling facility. Parts and components are sent to the spare parts market for recycling of high-value parts. Materials are sorted and sent to materials suppliers for recycling. The shell of the car and parts that can not be economically disassembled and sorted by material type are sent to the shredder where additional recyclable metals are collected. Shredder residue can be chemically recycled or used to generate energy. Theoretically, only a small amount of inorganic, inert materials should be left for landfilling.

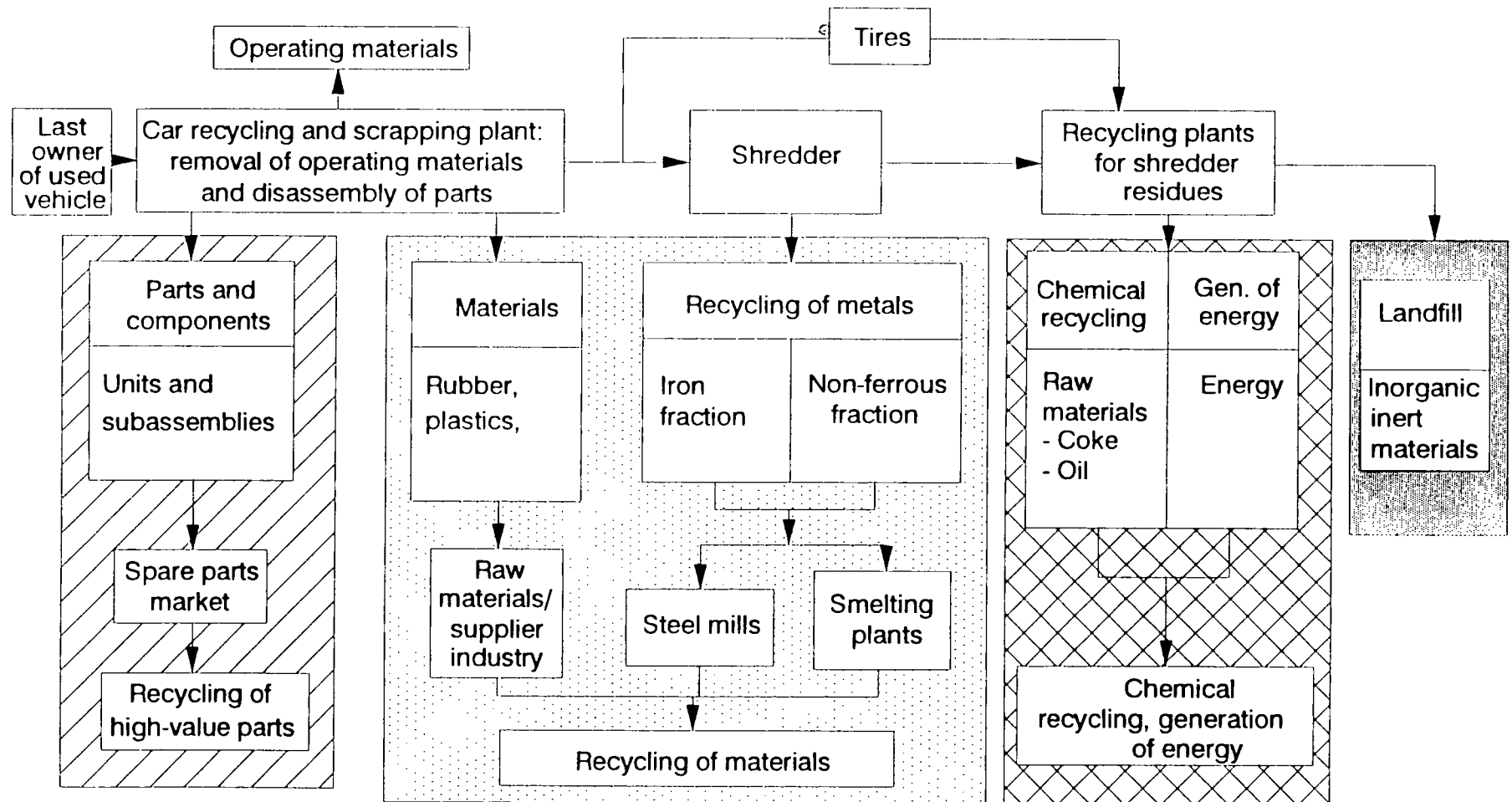
BMW initially envisioned setting up its own dismantling infrastructure, independent of existing dismantlers. Toward that end, BMW purchased a large piece of land in July 1988 in western Germany to serve as a pilot disassembly facility, to be opened in the mid-1990s. Later, BMW reconsidered this plan and decided instead to cooperate with various partners in the market to establish a nationwide recycling network. This decision was made largely because:

- there is already a large infrastructure of existing dismantlers that could be trained to use BMW methods, and
- an independent infrastructure would require unnecessary transportation of end-of-life vehicles and recyclable materials, resulting in more energy consumption and less benefit to the environment.

The concept of a nationwide recycling network, developed in collaboration with existing dismantlers and other auto manufacturers, is now central to BMW's recycling strategy. BMW anticipates setting up a network of about 100 dismantlers that will remove fluids by BMW's methods and will remove certain plastics and upholstery materials that can be returned to the auto in secondary materials. One prerequisite for the success of this concept was the introduction of legislation that would allow the end-of-life vehicle owner to take the car directly to the dismantler. In order to be successful, the legislation would also provide incentives to the car owner to dispose of the vehicle properly by providing for some type of certificate for disposal. The proposed German legislation incorporates these concepts.

With impending German legislation, and because it had reconsidered establishing an independent dismantling infrastructure, BMW altered its schedule for opening a pilot disassembly facility and converted an existing facility at Landshüt into the pilot site for dismantling and recycling. The Landshüt facility was already the site of BMW's recycling program for catalytic converters, established in April 1987. In that program, which has proven quite profitable, BMW disassembles the component, crushes the monofilaments which contain the precious metals platinum and rhodium, and sends the materials back to the manufacturer for reuse.

Figure 3. BMW Recycling Concept and Flow of Materials



(Source: A Consistent Initiative to Protect the Environment: BMW Car Recycling, 1992)

The 1000-square-meter facility at Landshüt operates with five people on the floor, tasked with disassembling five cars per day when the operation is in full gear. BMW employs a four-station disassembly line at the Landshüt facility, but anticipates moving to a 10-station disassembly line that can dismantle 100 cars per day.

One of BMW's goals is to develop disassembly manuals for each of its models built since 1981. Fortunately for BMW, this encompasses a six-or seven-year period when the materials used were essentially the same, indicating that there is little variation between different model years. The disassembly manuals include color-coded schematics and parts lists that show type and mass of material, type of connection, and recommended disassembly methods.

BMW is pushing for the international adoption of its plastics color-coding scheme to be used in conjunction with the VDA-260 plastics labelling method. Representatives from GM, Ford, and Chrysler were scheduled to visit the Landshüt facility in late October 1992 to discuss the BMW recycling concept and labelling of plastics.²¹

3.2.2 Parts Reconditioning Program

BMW began a program in the mid-1960's to recondition high-value parts from used vehicles for resale to the public. Initially, only a few parts, such as engines, were reconditioned. Today, the program has evolved into a large-scale program for approximately 1,700 individual parts, including engines, starters, alternators, transmissions, water pumps, final-drive gearing and electronic components. BMW uses its reconditioning program to marketing advantage by noting that "this high-value recycling is referred to as High-Tech recycling", emphasizing the recycling advantages in the environmentally aware European market. Parts are reconditioned at BMW's Recycling Center in Landshüt. BMW offers warranties on reconditioned parts equal to those on new parts.²²

3.2.3 In-Plant Pollution Prevention Strategies

Besides its work in vehicle recycling, BMW practices a number of pollution prevention strategies in the production processes. These include:

- increased emphasis on separation, collection, and reuse of production waste (used oils, gases, glass, etc.);

²¹ Stauber, Dr. Rudolf, BMW, Landshüt Germany. Personal Communication, October 13, 1992.

²² Management Institute for Environment and Business, BMW: A Proactive Approach to Vehicle Recycling, contractor report prepared for the Office of Policy, Planning and Evaluation, U.S. EPA, 1992.

- recycling of cuttings of plastic parts, which are fed back into plant grinders and extruders;
- requiring suppliers to take back homogeneous plastic waste; and
- development of a system to reuse water as much as six times before it is disposed as effluent.²³

Evidently, one key to BMW's success in reusing production waste was to make the waste management function independent of the technical department. Instead, the logistics department that supplies production materials was put in charge of waste, giving BMW's purchasing agents more incentive to choose only those materials that are easy to reuse and dispose.

BMW hopes to continue to reduce waste by developing more influence over the materials chosen by its suppliers. Companies that score poorly on a list of BMW recycling criteria are asked to make adjustments to their products. Contracts between BMW and parts suppliers require suppliers to use the best dismountable and recyclable materials possible.²⁴

3.2.4 Benefits to BMW

BMW has invested a considerable amount of time and resources to develop and promote its recycling strategy. It is quite likely that the company was motivated in large part to improve its environmental image with consumers, to influence the German government's development of recycling regulations and to gain a marketing edge by having easily (and cheaply) dismountable and recyclable cars when the German regulation takes effect.

Although BMW is widely regarded as a leader in car recycling by the automotive community, consumers still do not see BMW as a particularly environmentally aware company. According to one BMW employee, if consumers are asked to list car companies in order of environmental awareness, they usually list Volkswagen first, followed by Mercedes Benz, and then BMW.²⁵ This was also our experience with taxi drivers or train

²³ Management Institute for Environment and Business, *BMW: A Proactive Approach to Vehicle Recycling*, contractor's report prepared for the Office of Policy, Planning and Evaluation, U.S. EPA, 1992.

²⁴ Webber, Audrey, Institute for European Environmental Policy, "Memo: Report of the Visit to BMW, 25 September 1992, Pilot Plant Landshüt," Undated.

²⁵ Stauber, Dr. Rudolf, BMW, Landshüt Germany. Personal Communication, October 13, 1992.

passengers that we talked to while in Europe.) It appears that BMW's public role in promoting car recycling has not been particularly noticed by consumers.

BMW has worked with the German government since the beginning of discussions about a car recycling regulation. This involvement has paid off to some degree since several of the cornerstones of BMW's recycling concept are included in the draft German regulation. Other important elements, however, are not included or in BMW's view, place an undue burden on the automotive industry. In particular, BMW's position is that:

- the material recycling goals for plastics, glass and tires are set too high;
- take-back fees should be negotiated based on market forces by the last owner of the car and the dismantler; and
- the car manufacturer should not be held completely responsible for the actions of the dismantler, especially with regard to older model cars.²⁶

Perhaps the greatest point of contention that BMW had with the German regulation was the requirement that cars be taken back free of charge. Not only does this mean that some increase in price is likely to be tacked on to the initial sale price of a car, but BMW had hoped to gain a marketing edge by being the first to design and build easily dismantled and recycled cars. This would mean that BMW cars would have more value to the last owner and provide a market incentive to buy BMWs.

3.3 Summary of Recycling Approaches of Other European Automakers

BMW is far from alone in its efforts to develop a workable car recycling program. Most EC auto manufacturers have either established their own pilot disassembly plants or are collaborating in joint pilot plants with other manufacturers, government, scrap metal industries, secondary material suppliers, or dismantlers' associations. In addition to having public relations value, the goals of these projects include:

- identifying the plastics used in older model autos that were built to performance specifications, but not to material specifications;
- determining the most effective disassembly methods;
- determining disassembly time and costs; and
- developing design guidelines to enhance future disassembly operations.

Some of the projects are described below.

²⁶ Ibid.

3.3.1 Fiat

In November 1991, Fiat organized a research center for disassembly to investigate the materials composition and develop disassembly methods for older model Fiats, and to determine how to best redesign new cars for recycling and disassembly. Approximately 30 to 50 cars are disassembled each day. Specific data being developed are information on preferred disassembly methods and tools required, time required for disassembly, and cost of disassembly.

Around late September 1992, Fiat launched a new program in association with ADA, an association of shredder companies; Falk, a steel producer; and Himont, a plastics manufacturer; called "Fare e Disfare," which means literally, "make and unmake." Fiat has selected certain dismantlers to dismantle their cars according to Fiat-prescribed methods. Scrap Fiats taken to these dismantlers by the last owner are guaranteed to be dismantled. Falk takes back the steel from the car and Himont takes back the polypropylene bumpers and gasoline tanks. The remaining material is taken to the shredder, and shredder fluff is returned to Falk to be used as fuel in their furnaces.

Fiat is using a cascade recycling concept in its program, because of technical and aesthetic issues. Bumpers are recycled into internal ducting and channels, which are recycled into the flooring under carpet. Since the useful life of a car in Europe is estimated to be around 10 years, this concept theoretically keeps plastics in functional use for 30 years.

Fiat is working mainly with Himont to develop ways to use polypropylene as a "polyfunctional mono-material." As the name implies, this concept involves using a single polymer to perform multiple functions. For example, dashboards are typically composed of a number of different materials like polypropylene, PVC and ABS. The Fiat-Himont concept is to make the dashboard from a single material, in this case polypropylene, without loss of function. Fiat and Himont have already been successful in developing a one-material door.²⁷

Fiat has also been taking a proactive role with the Italian government, by pushing the government to establish uniform goals for car recycling.²⁸

3.3.2 Mercedes Benz

Mercedes Benz has developed a recycling scheme in cooperation with Voest-Alpine Stahl (Austria) that, in theory, would make it possible to bypass shredding during vehicle disposal. The Mercedes Benz process includes the following:

²⁷ Manzini, Ezio, Domus Academy. Personal Communication, October 28, 1992.

²⁸ den Hond, Dr. Frank and Dr. Peter Groenewegen, Free University, Holland. Personal Communication, October 22, 1992.

- draining of fluids from the car;
- disassembly of the engine and other useful parts such as the battery and the catalytic converter;
- disassembly of easily removable plastic parts; and
- use of the remaining hulk in a "melt-reactor".

In the final step of this process, the melt-reactor gassifies the organic parts (e.g., plastics), volatilizes the heavy metals like lead and zinc, and melts the steel. Oxygen and natural gas are supplied to the reactor for heat and to minimize the formation of dioxins and furans. Gas purification for recovery of heavy metals and recovery of heat are the last stages of the proposed process.²⁹ Mercedes Benz maintains that about 85% of the plastic's energy content can be recovered.³⁰

Mercedes Benz also has a fluids recycling program. Engine oil, which Mercedes Benz has included on its approved list of fluids since the 1970s, can be recycled by distilling the oil to remove contaminants and additives and then reprocessed to reclaim the base oil. Mercedes Benz is also planning on recycling engine coolant and transmission oils, and is developing methods to reprocess brake fluids into other products like chemical diluting or cleaning agents.³¹

3.3.3 Rover Group

The Rover Group, Great Britain's largest auto manufacturer, recently announced a joint venture with the Bird Group, a leading reclamation and recycling organization. The venture is aimed at developing a systematic approach to auto recycling with the goal of developing an almost-100% recyclable car within the next 15 to 20 years.

The Rover-Bird joint venture is being conducted in three stages: feasibility, pilot and demonstration. The feasibility stage, which is currently underway, involves information gathering and developing techniques for disassembly and materials separation. One feasibility project involves the controlled disassembly of vehicles to develop a disassembly line approach and to tell the dismantler which parts to remove at which stage. The venture will also involve the University of Warwick's Advanced Technology Center which will

²⁹ ACEA. "Position of the European Automobile Industry on Automobile Waste Management." October 1991.

³⁰ Siuru, Bill, "Car Recycling in Germany," *Resource Recycling*, February, 1991.

³¹ Ibid.

investigate the recycling of various materials and develop a computer simulation of the logistics of disassembly and the recovery of the recyclable materials.

In the pilot stage, the Rover-Bird project will investigate the use of different equipment, like portable hydraulic cutting equipment, to find the safest method of disassembly. The demonstration portion of the project will involve the construction of a computer-based model of the recycling chain, including the associated economics.³²

3.3.4 Toyota

In 1990, Toyota established a Recycling Committee to oversee corporate recycling activities. The Committee became part of a newly established Environmental Committee in 1992. The Recycling Committee enjoys high-level leadership, which enables it to coordinate recycling activity and to receive high levels of cooperation throughout the Toyota organization.

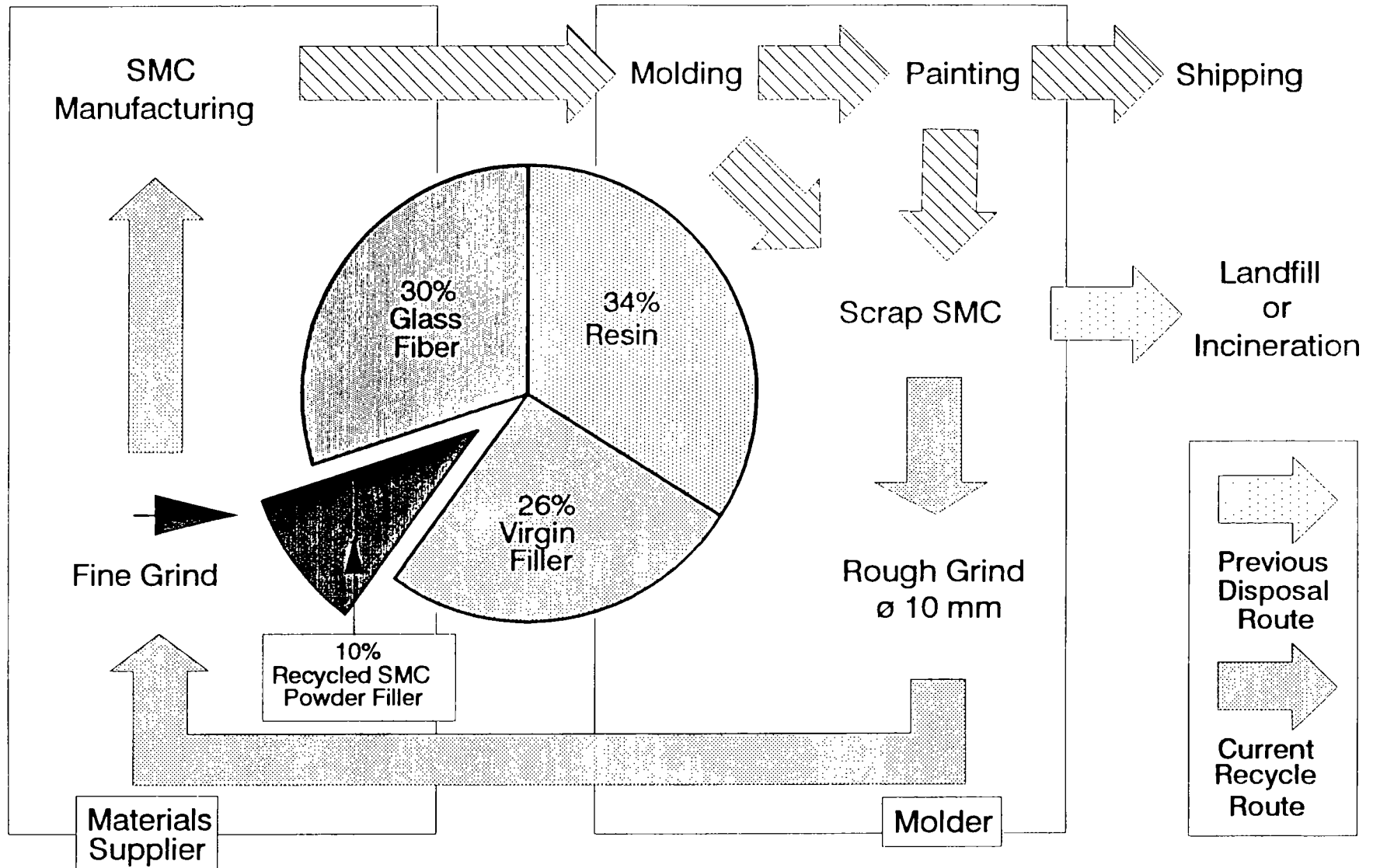
Toyota's early efforts have focused on development of in-plant recycling technologies, resulting in the recovery of approximately 86% of in-plant wastes. Examples of the in-plant recycling technologies used by Toyota include:

- unpainted polyurethane from scrap bumpers and trim is recovered, granulated, and thermoformed at 180°C with a special urethane adhesive to produce mudguards for Toyota trucks;
- PVC in the instrument panel trim is separated from polyurethane foam using a cyclone-type weight separation process, recovered, granulated, hot rolled into sheets and stamped into dash silencer sheets; and
- carpet trim is ground, chemically modified, remelted, pelletized, and added to virgin carpet backing material at a 30% level.

Perhaps of more interest to Saturn, is the recently developed process for recycling the sheet molding compounds (SMC) that Toyota uses. Figure 4 is a schematic of the Toyota process, which involves the material supplier and the molder. Scrap generated in the molding and painting processes is roughly ground to approximately 10 mm pieces, returned to the material supplier, where it is ground to fines, and used in virgin SMC production as a replacement for one-third of the calcium carbonate filler. Toyota uses this SMC to manufacture an inner roof rack used in the four-wheel-drive Corolla Station Wagon. According to Toyota, the specific density of the recycled SMC is 5% less than that of virgin SMC, with no loss in flexural modulus.

³²Broughton, Anne Claire. "British Step Up Car Recycling", Recycling Today, October 15, 1992.

Figure 4. SMC In-Plant Recycling Process



(Source: K. Esaki, K. Webber, S. Sakurai and A. Nozawa, Recent Progress in Closing the Loop of Automobile Recyclability - Japan)

Like its European counterparts, Toyota's recycling strategy involves marking plastic parts with a uniform code to enhance material identification. Toyota has been marking parts with its own system since 1981, but recently adopted the SAE J1344 and VDA 260 protocols for parts in new models.

Also like its European counterparts, Toyota is working toward closing the materials loop with back-into-the-car recycling, based on a system of cooperation with its suppliers. Toyota's goal is to achieve a target recyclability rate of 85% by 1996, beginning with the selection of 25 top-priority parts that represent 80% by weight of all plastic parts in the vehicle. Of these, the bumpers, seats, instrument panel and carpet, which collectively represent 40% by weight of all plastic vehicle parts, have been assigned the highest priority. Toyota is conducting assessments of physical or melt-type recycling technologies; chemical recycling technologies like hydrolysis, glycolysis and pyrolysis; and energy recovery technologies. Concurrent with the assessments of recycling technologies are assessments of related technologies like paint removal technologies. Toyota's focus is on developing and providing economical recycling technologies, not on developing a dismantling, shredding or collection network.

Finally, Toyota has defined a set of criteria to find the most promising recycling technologies. Preference is given to:

- 1) closed-loop technologies that recycle materials back into the car, and thus simplify the recycling infrastructure, and allow other industries to be independent of the automotive industry;
- 2) technologies that minimize total energy consumption to meet the ultimate goal of protection of the global environment; and
- 3) technologies that fit into and strengthen the current recycling infrastructure.

In addition, the recycling technology must be economically feasible. Designers are also directed to consider building components from alternative materials.³³

3.3.5 Volkswagen

Volkswagen has established a pilot recycling facility in Leer, in northwestern Germany. The Leer plant is a cooperative venture between Volkswagen, the East Friesland trade corporation, the Leer labor office and a local metal scrapyard. The plant employs

³³ Esaki, Kenji, Webber, Kevin, Sakurai, Shigenori, and Akira Nozawa, "Recent Progress In Closing the Loop of Automobile Recyclability - Japan," Undated.

almost 30 workers who are charged with determining how many parts can be extracted and recycled at a profit, and the swiftest ways to disassemble cars and segregate the parts.³⁴

3.4 Design Rules of Thumb

Many of the recycling design concepts used by European car manufacturers are not revolutionary, but are simple, reliable rules of thumb. These include:

- reduce the number of different polymers used in a vehicle to allow easier sorting;
- produce entire subcomponents with a single polymer to further reduce sorting;
- select materials that can be easily recycled (e.g., prefer thermoplastics over thermosetting plastics);
- label polymers with a standard code to make it easy to identify the type of polymer and speed up the sorting process;
- reduce the application of paints or other contaminants like glue, fiber or talc onto polymers, unless the material can be easily removed from the polymer during disassembly;
- use simple fittings and fasteners that can be disassembled with minimum effort.

Design rules of thumb could also be developed from a life cycle perspective to give a hierarchy of, for example, plastics use, from least polluting to most polluting (see Section 4.0). With such a hierarchy, designers could start at the top with the least polluting material, and go down the list until technical and economic criteria are met.

³⁴Corcoran, Elizabeth, "Green Machine: Volkswagen Gears up to Recycle Autos," *Scientific American*, January 1992.

4.0 LIFE CYCLE ASSESSMENT AS A PRODUCT IMPROVEMENT TOOL

All the materials used in the car have environmental impacts, as do all alternative recycling schemes. When the environmental attributes of alternative materials or recycling scenarios are considered, it is usually necessary to evaluate the whole life cycle of each alternative, unless some portions of the life cycle present clearly insignificant environmental impacts or present indistinguishable impacts for each of the alternatives. A quantitative life cycle assessment (LCA), including a life cycle inventory (LCI) and some form of environmental impact evaluation, may be required to make truly environmentally superior choices.

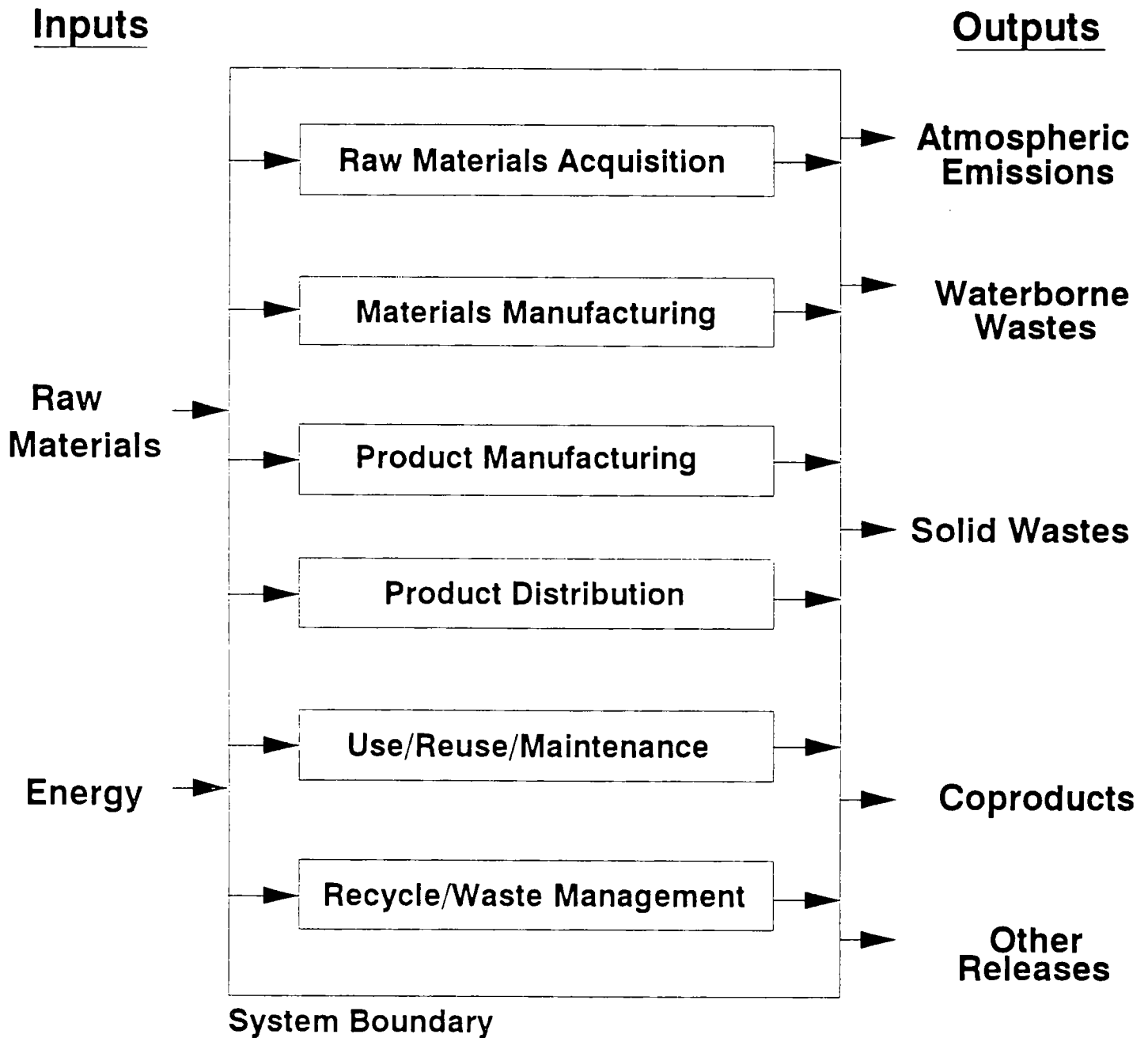
LCA is the cradle-to-grave evaluation of the environmental attributes of a product, from raw materials extraction, through the manufacturing process and consumer use and disposal of the product. A complete LCA consists of three complementary components: a LCI, impact analysis, and product improvement analysis.³⁵ The LCI is developed to quantify resource and energy use and environmental releases throughout the life-cycle of a product or process. Figure 5 shows a typical system boundary of an LCA and the inputs and outputs usually quantified during the LCI. Impact analysis can be a qualitative or quantitative process to characterize or value the potential environmental and human health impacts associated with the resource and energy use and environmental releases identified in the LCI. Improvement analysis is a process to identify opportunities for environmental improvement, based on the LCI and impact analysis.

The use of LCA as a product improvement tool is rapidly taking hold in Europe, perhaps because European environmental policy is beginning to focus more on products instead of on end-of-the-pipe control technologies that manage manufacturing waste streams.³⁶ LCA has long been used to evaluate alternative packaging materials, but in the last few years, there has been a surge in the use of LCA for durable goods like automobiles and washing machines. As we discovered when we visited western Europe, automobile

³⁵ Fava, J.A., Denison, R., Jones, B., Curran, M.A., Vigon, B., Selke, S., and J. Barnum, *A Technical Framework for Life-Cycle Assessments*, Washington DC: Society of Environmental Toxicologists and Chemists & SETAC Foundation for Environmental Education, Inc. 1991.

³⁶ U.S. policymakers may soon begin to incorporate environmental product policy into the regulatory mix. In its recent report, *Green Products by Design: Choices for a Cleaner Environment*, the U.S. Office of Technology Assessment promotes green design of products as a tool for improving U.S. industrial competitiveness while safeguarding environmental quality. OTA emphasizes the importance of a life cycle and a systems approach to green design and identifies policy measures to encourage green design.

Figure 5. System Boundaries of a Typical LCA



manufacturers in Germany, Sweden, and France, in collaboration with their suppliers, are beginning to use LCA as a tool for environmental improvement of parts of the car, of the car as a whole, or of recycling systems.

4.1 Life-Cycle Assessment to Improve the Design of Components of the Car

Both the University of Stuttgart in Germany and Écobilan in France have large-scale projects with auto manufacturers and their suppliers to develop LCAs for parts of the car. These projects are discussed below.

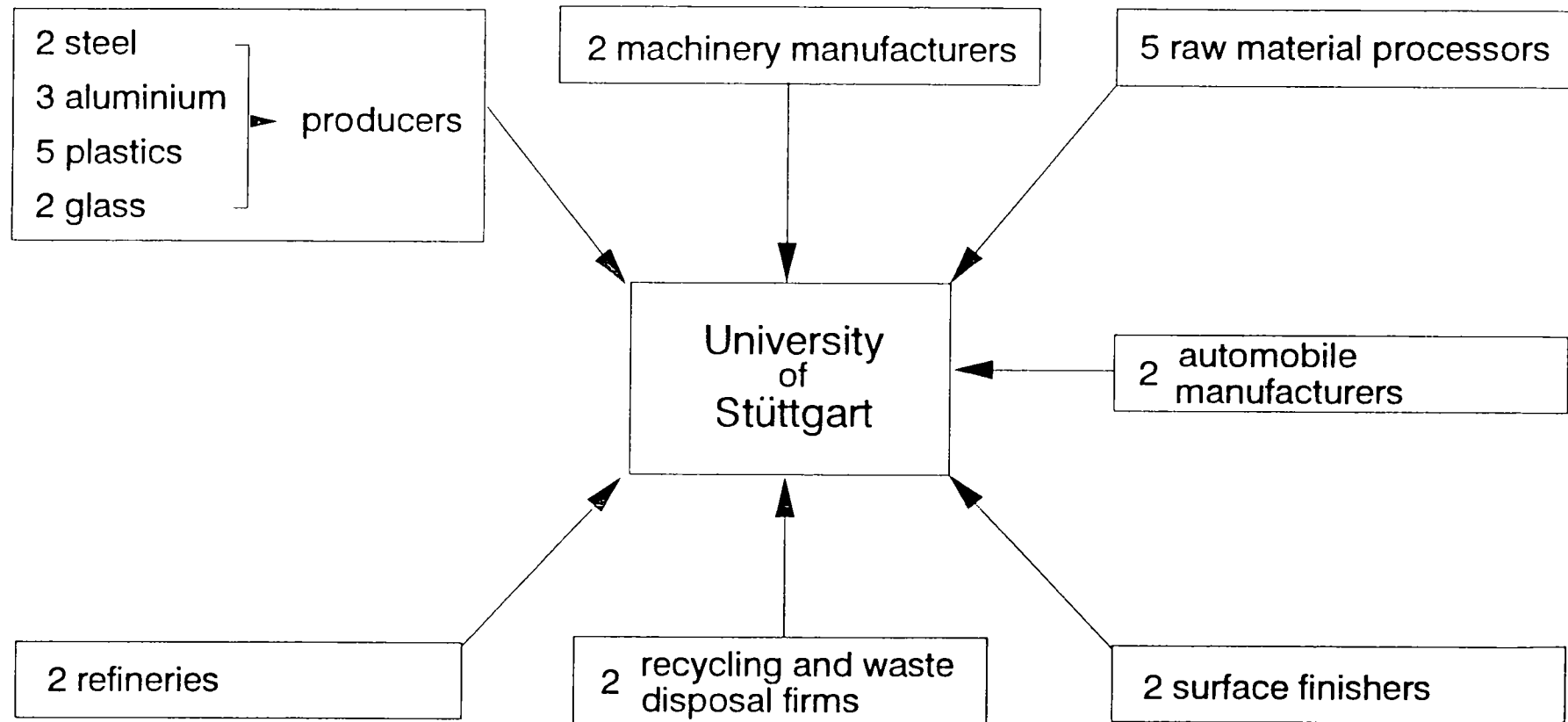
4.1.1 University of Stuttgart, Germany

The Institute for Polymer Science and Polymer Testing at the University of Stuttgart in Germany has been involved in the LCA field since July 1989. The Institute has projects to develop LCIs for car fenders, bumpers, fuel tanks, air intake manifolds and air filters as well as paint sludge recovery and coating methods. LCA projects mainly in the conceptual stage include a project to determine how to conduct an LCA for the entire car and an LCI on the insulation used on cables for electrical and mechanical parts.

The University of Stuttgart is using the "Car Fenders Project" to develop and demonstrate its LCA software package. This project was initiated in January 1990 and is currently sponsored by about 25 to 30 companies. Figure 6 shows the industry sectors to which companies involved in the project in 1991 belonged. Manufacturers have been guaranteed confidentiality of their process and materials data. We were unable to obtain an up-to-date list of the individual manufacturers who are participating in the project, although the Association of German Automobile Manufacturers is a known contributor. VDA includes Audi, BMW, Ford Europe, Mercedes Benz, Opel, Porsche, and Volkswagen.

The materials and associated technologies being evaluated in the Car Fenders Project include steel, galvanized steel, aluminum and various plastics (thermoplastic injection molding, sheet molding compound, structural reaction injection molding, glass mat reinforced thermoplastics, reinforced reaction injection molding, resin transfer molding, and advance composite casing). The Institute sends a detailed questionnaire to each participant requesting material consumption, energy use and environmental release data. A graduate student frequently travels to the plant to help prepare material flow diagrams and complete the questionnaire. Confidentiality is guaranteed to those participating in the project, meaning that at least two companies from each sector must participate. The data reported by different companies for the same industrial process are averaged to ensure confidentiality and entered into a database. Data are verified by comparing data from producers of the same product or

Figure 6. Participants in the University of Stuttgart Car Fender Project



(Source: P. Eyerer, Th. Dekorsy and M. Schuckert, Stuttgart, Integral Assessment of Products and Processes, Hanser Publisher, 1991)

by calculations. The Institute plans to update the database continuously as technologies change.³⁷

The LCI includes a transportation module that can be included at the discretion of the user. Most practitioners of LCA who are working with the auto industry acknowledge that vehicle use is by far the most significant stage of the life cycle for energy consumption. For example, BMW estimates that 90% of the total energy consumption of a car is from consumer use, 8% is from production and 2% is from the recycling of materials.³⁸ Stuttgart researchers cite figures of 83% of total energy use (including 1.5% for repairs) during consumer use, 6.9% during manufacture, 2.3% during assembly, and 7.8% by utilization of residual materials.³⁹ The Environment Ministry of Japan has used life cycle assessment to estimate that 5% of the life cycle energy use of the car is from the vehicle manufacturing process, about 9% from materials production, and about 86% from the use of the car.⁴⁰ Obviously, the weight of alternative materials and its effect on fuel economy can significantly affect the results of material comparisons.

The Institute developed its LCA software in Windows on an IBM PC-type desktop computer. The program is designed to be used with a minimum of a 386 system with 4 MB RAM; a 486 system with 16 MB RAM is recommended. The program uses a relational database concept which is similar to an expert system approach. The interactive software is designed so that the user can document assumptions and input the material specifications (e.g., type of material, weight of material used in the part, etc.). The computer pulls up the material process chain and calculates the LCI based on the data input by the designer. The software uses material and energy flows to estimate the inventory. Currently, the system does not evaluate materials performance or cost, leaving those considerations to the designer.

Releases are assigned to impact categories to allow an evaluation of their relative environmental impacts. The program allows the user to vary the weighting factors applied to

³⁷ Pfleiderer, Ingrid, University of Stuttgart, Germany. Personal Communication, October 12, 1992.

³⁸ Stauber, Dr. Rudolf, BMW, Landshüt Germany. Personal Communication, October 13, 1992.

³⁹ Eyerer, P., Dekorsy, T. and M. Schuckert, "Integral Assessment of Products and Processes," *Kunststoffe German Plastics*, No. 81, 1991.

⁴⁰ Moriguchi, Yuichi, Shimizu, Hiroshi and Yoshinori Kondo, "Analysis and Management of Life Cycle Environmental Impacts of Automobiles - CO₂ Emission Analysis, New Policy on Recycling, and Other Recent Topics," in *Cleaner Production Strategies for the Automotive Sector: Invitational Expert Seminar Trolleholm Castle, Sweden, December 11-12, 1991*. Lund University, January 1992.

each impact category to evaluate the sensitivity of the results. The Institute plans to distribute the software for an as yet undetermined fee after the project is complete, projected for March 1993. Researchers expect to publish portions of the results of the study in the peer-reviewed literature, pending the agreement of the companies participating in the study.

The Institute sees long-term applications for the LCA system not only for internal environmental improvement efforts but also for possible future legislation. For example, the concept of requiring something like an environmental impact statement for products is already being considered in Germany. Manufacturers one day may be required to report environmental data for the entire life cycle of their products.⁴¹ This is already being demonstrated in some of the eco-labeling programs in Europe where decisions on what constitutes an environmentally superior product are being made from a life cycle perspective.

4.1.2 Écobilan, France

Écobilan is an independent consulting firm with offices in Paris, Brussels and Amsterdam. In the last 2 years, the company has become a major player in the LCA field. In late 1992, the company had 28 engineers in the Paris office working on LCA projects.

Écobilan's main clients in the LCA area are in five industry sectors: 1) packaging manufacturers, including representatives from the paper, steel, aluminum, glass and plastics industries; 2) the automotive industry 3) the building material industry; 4) electronics companies; and 5) the food industry. Écobilan collects actual site-specific data from its clients to develop the LCI. They currently do not perform any impact assessment or any aggregation of impact categories. Most of Écobilan's current efforts are focussed on developing the LCI software package, mainly for use with a computer workstation.

Écobilan's clients in the automotive sector are Peugeot, Renault and Matra. Peugeot is interested in an LCI on the car body, Renault is supporting work on specific parts, and the Matra project includes the car body and certain technical parts. None of the LCIs being prepared by Écobilan are looking at the motor, although they have used an LCI to compare an electric car to a gasoline car and reportedly found no clear advantage for electric cars.

Écobilan is developing three LCI databases: 1) an automotive material suppliers database, 2) an auto manufacturing plants database, and 3) a post-consumer database. The suppliers LCI is the key link to the project and, in fact, the suppliers provided the funding to Écobilan to gather data on their sites. The supplier data are not shared with the automobile manufacturers with out aggregation to protect confidentiality. The overall objective of the automotive LCA project is to environmentally improve the design of the automobile, using the inventory results.

⁴¹ Ibid.

The final deliverable of the automotive project will be software that automakers can use to design different parts of the car. The software will use 25 criteria for the designer to consider, including cost. It will also provide different design scenarios and policy advice. Écobilan encourages its clients to not use the inventory results as simply a means for selecting between suppliers. Instead, the inventory can be used to improve the environmental attributes of materials through specifications for the suppliers.⁴²

4.2 Life-Cycle Assessment To Improve the Design of the Entire Car

Volvo Car Corporation appears to be the leader in the use of LCA as a product improvement tool for the entire car. The University of Stuttgart also has a group that is beginning to evaluate the issues associated with developing an LCA for an extremely complex product like the car. Researchers at Lund University, although not developing LCAs directly, have conducted a critical evaluation of the use of LCA in the automotive industry. The Product Life Institute, while also not conducting LCAs, has some interesting ideas about the life cycle of the car. Each of these programs are discussed below.

4.2.1 Volvo Car Corporation, Sweden

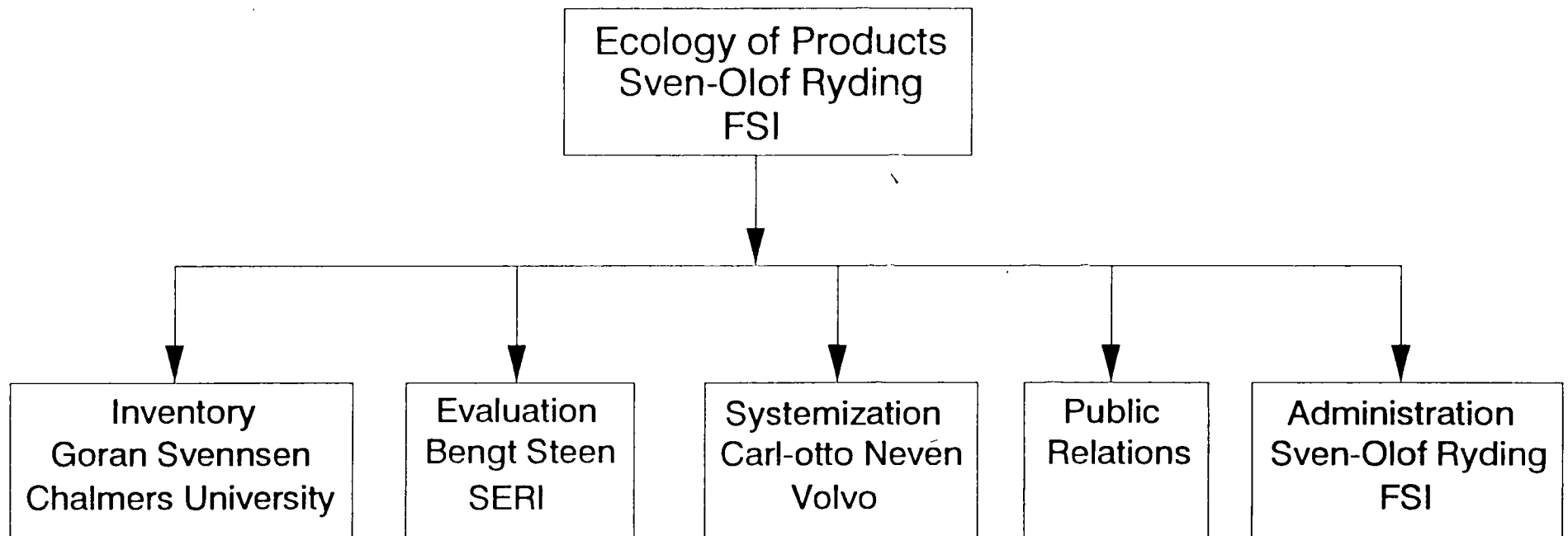
Volvo Car Corporation is cooperating with the Federation of Swedish Industries (FSI) and the Swedish Environmental Research Institute (SERI) to develop an LCA system for calculating the environmental impact of products. The "Ecology of Products" project is probably one of the more ambitious undertakings in the LCA field today, with plans to develop an LCA system that can be linked with a computer-aided design station to allow environmental attributes to be incorporated into the design process.

Although the "Ecology of Products" project is primarily a joint effort between Volvo, FSI and SERI, several other institutions and companies with a vested interest in the environmental improvement of products are participating in the project. These include raw material (e.g., oil companies) and other material (e.g., steel, plastics, etc.) suppliers, other representatives from the chemical industry, the pulp and paper industry, and packaging, soap and detergents and washing machine manufacturers. Also participating in the project is Chalmers Industriteknik, a university institute that provides a university-industry interface.

The Ecology of Products project is managed by FSI. Representatives from Volvo, Chalmers, FSI and SERI lead working groups on inventory development, impact evaluation, systemization (including classification and software and equipment development), public relations, and future administration of the system. Figure 7 is an organization chart for the project, showing the various working groups and the persons serving as group leaders.

⁴² Heintz, Bruno, Écobilan, Paris France. Personal Communication, October 26, 1992.

Figure 7. Organization of the EPS Project



The Volvo project uses the Environmental Priority Strategy (the so-called EPS-system) to calculate environmental load values for materials or processes. Environmental load values are calculated by multiplying environmental indices expressed in ELU (Environmental Load Unit/quantity) times the quantity used. Environmental indices are calculated by multiplying the environmental scores estimated for a set of six factors (Table 2). Quantities can either be expressed in units of weight for materials or in other suitable units for manufacturing processes (e.g., ELU/m² for surface coatings or ELU/number of welds for welding).

Table 2. Factors for Calculating Environmental Index

Factor	Meaning
Scope	General impression of the environmental impact
x	
Distribution	Extent of affected area
x	
Frequency or Intensity	Regularity and intensity of the problem in the affected area
x	
Durability	Permanency of the effect
x	
Contribution	Significance of 1 kg of the emission in relation to the total effect of all emissions
x	
Remediability	Cost to reduce the emission by 1 kg (Relative to 100 SEK)
=	
Environmental Index	

Source: Federation of Swedish Industries, Swedish Environmental Research Institute, and Volvo Car Corporation, "A System for Calculating Environmental Impact," Version 1, May 1991.

The "scope" factor is calculated as a percentage of the average cost of preventing the death of 1 person in an OECD-Country. The "frequency or intensity" factor is calculated relative to the average frequency or intensity. Both "distribution" and "durability" are

calculated in percentages of an infinite geographical spread or durability, respectively. The "contribution" is calculated as 10^{-7} of the total global emissions in kg.⁴³

Obviously, several of these factors address complex social and technical issues for which there is no set standard of measurement, although some precedent may exist. For example, the U.S. EPA uses risk-based models to determine the risk from emissions of hazardous air pollutants, then determines the risk reduction that could be achieved with control technologies and the cost of controls to estimate the cost of preventing the death of a person in the U.S. This complicated process may be similar to the method used in the EPS-system to calculate the scope factor, although we were unable to obtain information about the methods used to develop factors. Bengt Steen at the Swedish Environmental Research Institute is responsible for developing the evaluation criteria.

Even if precedents and calculation methods exist, a criticism of the EPS-system is that to calculate these factors requires assumptions that can skew the results of the analysis. Perhaps more importantly, unless the assumptions are clearly documented for the designer to see, the system loses "transparency" and the designer becomes too removed from the decision process.

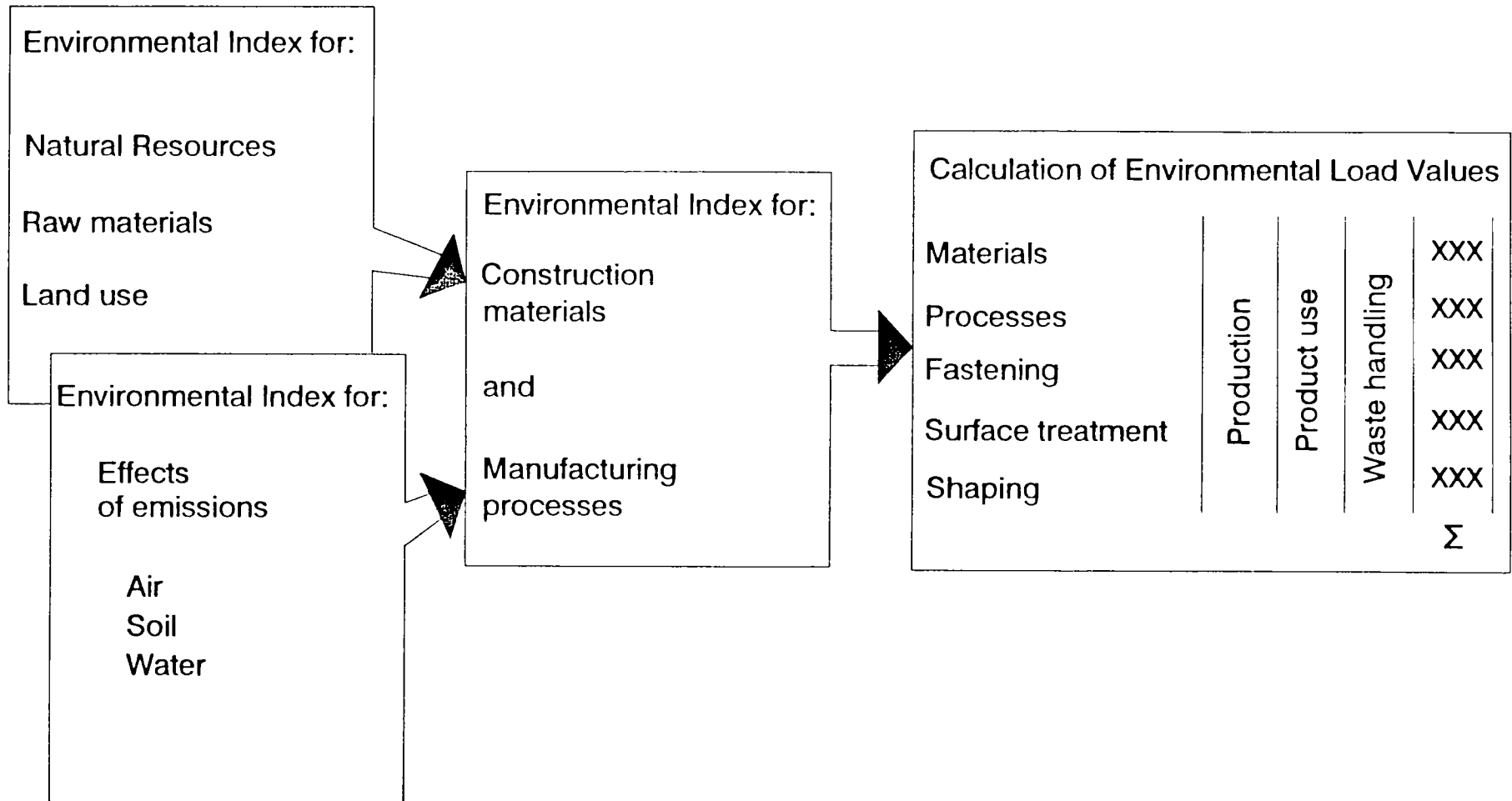
The Ecology of Products system uses the environmental indices developed for raw materials and their associated energy consumption and pollutant emissions to establish environmental indices for materials and processes. For example, the environmental unit load for polypropylene is developed by adding the environmental unit loads from all phases of the production of 1 kg of polypropylene. This concept is illustrated in Figure 8, which shows the flow of information in the EPS-system. The two data sheets on the left in the figure are used to establish the information for materials and processes shown on the center data sheet. The designer usually will only use information from the center data sheet, which in turn is used to calculate the environmental load values for specific parts or products.

The first prototype of the system has incorporated a limited number of environmental indices, but Volvo feels that more indices and more data on solid or hazardous waste disposal are needed before the system is presented for peer-review. A long-term goal is to develop sufficient indices to allow analysis of broad design questions, such as identifying the most polluting part of the car, but such indices will most likely require debugging as technologies or priorities change. The systemization group is looking at this and other issues that will ultimately be the responsibility of the administrator, who will distribute and continuously upgrade the system, once it becomes operational.

⁴³ Kisch, Peter, Lindqvist, Thomas and Håkan Rodhe, "Life Cycle Assessment - An Emerging Tool in the Automotive Industry", in *Cleaner Production Strategies for the Automotive Sector: International Expert Seminar Trolleholm Castel, Sweden, December 11-12, 1991*. Lund University, January 1992.

Figure 8. Overview of the EPS-System

39



(Source: Federation of Swedish Industries, Swedish Environmental Research Institute, Volvo Car Corporation)

Current plans are to have the system ready to be passed to the administrator by late 1993 or early 1994. Volvo also hopes to have a prototype of the system ready for presentation at the June 1993 meeting of the United Nations Environment Program. The Ecology of Products project team feels a slight sense of urgency to get the system on the market, since competition may be forthcoming from the Danish government. Denmark recently announced that the Danish government is initiating a similar project to determine the environmental impacts of products by using a life cycle approach. The Danish project is projected to be complete in 1995 and will involve a joint effort between various industries and the Danish government. The expectation is that the Danish system will be a public system, as is planned for the EPS-system.⁴⁴

4.2.2 University of Stuttgart, Germany

Researchers at the University of Stuttgart are exploring ways to use LCA as a product improvement tool for the entire auto. One of the main issues is how to accommodate incomplete data, since it appears unlikely that a complete inventory could be assembled for every component of the car. This project is mainly in the conceptual stage and is expected to be complete in about two years.

4.2.3 Lund University, Sweden

The Department of Industrial Environmental Economics at Lund University in Sweden does not actually perform LCAs, but members have contributed substantially to the understanding and development of LCA methodology. In their article, "Life Cycle Assessment - An Emerging Tool in the Automotive Industry," Peter Kisch, Thomas Lindqvist and Håkan Rodhe explore the possible applications and limitations of LCAs in the auto industry.⁴⁵

Kisch, et.al. have worked directly with the data and the EPS-system being developed by Volvo. Not surprisingly, they have reservations about the scoring system used to evaluate environmental impacts, since they feel this method is subjective with results likely to be influenced by the choices made by the designer of the system. This, of course, gives rise to uncertainty in the final results. Furthermore, they found that there is a fairly wide range in the data that are aggregated from plants with the same manufacturing process, which further decreases the sensitivity of the method and limits the transparency of the system. They

⁴⁴ Nevén, Carl-Otto, Volvo Car Corporation, Gothenborg, Sweden. Personal Communication, October 23, 1992.

⁴⁵ Kisch, Peter, Lindqvist, Thomas and Håkan Rodhe, "Life Cycle Assessment - An Emerging Tool in the Automotive Industry," in *Cleaner Production Strategies for the Automotive Sector: International Expert Seminar, Trolleholm Castel, Sweden, December 11-12, 1991*. Lund University, Sweden, January 1992.

acknowledge that these are problems common to most LCAs, particularly while the international community is still striving to develop standards for LCA methodology.

They do, however, find certain applications for LCAs, even while standards are being developed that will resolve some of these issues. The most pertinent applications for manufacturers are:

- for use as a product improvement tool, to develop products with a decreased negative impact on the environment;
- to help manufacturers design distribution and collection networks for new and discarded products, respectively; and
- to transmit information on materials from suppliers to manufacturers.

Although not mentioned by the Lund University researchers, an equally important application of LCA could be for manufacturers to influence the materials choices of their suppliers.

4.2.4 Product-Life Institute, Switzerland

The Product-Life Institute in Geneva, Switzerland is a non-profit institution that has conducted research for a number of government agencies (including the U.S. EPA) and industrial clients. The Institute advocates the re-use of goods and product-life extension through a change in the way that industrial economies view goods and services: instead of selling goods, manufacturers should sell the utilization of goods, leading to a service economy. According to the Institute, this implies a broad quality and service liability for the manufacturer which changes the manufacturer's liability from liability for "cradle and grave" (e.g., manufacture and disposal) to liability for "cradle to grave," including the consumer use stage of the product. The end result is a new definition of technical quality as a system functioning over long periods of time. The Product-Life Institute believes that this redefinition of quality and the manufacturers role will result in economically feasible, sustainable development that promotes technical progress and self-responsibility by economic actors.⁴⁶

The obvious application of the Product-Life Institute's concept in the automotive industry is the leasing instead of selling of cars. This creates a built-in incentive for manufacturers to produce cars with longer service lives. The Institute carries the concept

⁴⁶ Stahel, Walter R., "Re-Use and Re-Cycling", presented at the Seminar on Clean Technologies at the University of Surrey, Guildford, September 19, 1991.

further to advocate the leasing of materials, such as steel or aluminum, by the producers to automobile manufacturers, creating a strong incentive for recovering the materials.⁴⁷

Using this concept for materials can reduce price fluctuations. Fluctuations in the price of aluminum, for example, have the potential to limit the use of aluminum in the car. These fluctuations could be controlled, however, if the aluminum manufacturer supplied a service (e.g., leased aluminum), instead of a commodity.

4.3 Life-Cycle Assessment to Evaluate Recycling Options

The University of Stuttgart plans to use life cycle assessment to evaluate different recycling processes to determine which have the best environmental attributes. Écobilan is currently looking at different recycling scenarios and organizational methods.

The focus of Écobilan's work is to identify ways to environmentally improve alternative waste management methods such as incineration and recycling, instead of making simple choices between the two. For example, the preliminary results of Écobilan's research reportedly indicate that clean incineration of plastic is no worse than recycling. Furthermore, HDPE recycling reportedly pollutes the air more than incineration, depending on the organizational structure used in the recycling network. This is because air emissions and energy consumption from fuel combustion are a key part of the environmental impacts of recycling.

⁴⁷ Stahel, Walter R., Product-Life Institute, Geneva, Switzerland. Personal Communication, October 16, 1992.

Appendix A.
Persons Visited in Western Europe

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SATURN STRATEGIES FOR PROTECTION AND PRESERVATION OF THE ENVIRONMENT

Saturn Environmental Mission

To Develop and Manufacture World-Class Vehicles While Protecting and Preserving our Natural Environment, by Conserving, Developing and Recycling Resources.

Environmental Objectives

Corporate Citizenship/Community

To Promote Broad Corporate Citizenship Concerning Environmental Issues by:
Generating Community Awareness of Saturn's Commitment to the Environment;
Creating Strong Environmental Consciousness Among Saturn Team Members and Supplier and Retailer Partners;
Promoting Reasonable, Effective Environmental Policy in Government Regulation;
And Participating in Environmental Activities Which Extend Beyond the Scope of Automotive Vehicle Operations.

To Foster Cooperation Among Supplier Partners in the Protection and Preservation of the Environment, with Emphasis Placed on Supplier Partner Roles in our Vehicle Design and Processing Efforts.

To Foster Cooperation Among Retailer Partners in the Protection and Preservation of the Environment, with Emphasis Placed on Retailer Partner Roles in Promoting Broad Corporate Citizenship in their Communities and Throughout the Vehicle Delivery and Vehicle Disposal Processes.

To Extend the Implementation of Saturn Strategies for Protection and Preservation of the Environment to Worldwide Markets.

Vehicle Design: Design for Recycling

Long Term: To Develop World-Class Vehicles Which are Environmentally Compatible (approach 100% recyclable) by the Year 2000.

Mid Term: To Incorporate Design for Recycling Guidelines in 1995 - 1996 Platform/Product Programs.

Immediate: To Assess Current Platform/Product Program Recyclability Status.

SATURN DESIGNS FOR THE ENVIRONMENT

Vehicle Design: Design for Recycling

Design for Recycling Priorities

1. "Cars into Cars" Developing future Saturn parts/products from recycled Saturn/automotive parts/products (e.g., using Saturn painted recycled bumpers to produce new Saturn wheel liners).
2. "Cars into Non-Car Products" Developing productive (and profitable) waste streams for reuse or disposal of material [i.e., working with suppliers to identify productive (and profitable) non-automotive uses for material (e.g., using excess recycled painted plastic from bumpers, door panels, etc. as a raw material for producing non-automotive products such as children's toys, garden equipment, packaging, etc.)]

Saturn Current Vehicle Recycling Assessment

Designing products for recycling involves the consideration of two major elements:

Design for Disassembly

Saturn is establishing a relative competitive advantage in design for disassembly, due to a continuing focus on exceeding customers' expectations for serviceability. Future design for disassembly/design for recycling developments should work in parallel with serviceability enhancements to improve Saturn's ability to further exceed our customers' expectations (e.g., design for disassembly development, enlarging the size of fluid drain holes in order to facilitate ease of removal of operating fluids like engine oil, transmission fluid, etc., should translate into a service advantage, namely, faster oil changes for the customer).

Material Selection

Saturn pioneered the use of thermoplastics (e.g., door panels, bumpers, fenders, quarters, etc.) in initial product development. Saturn is also pioneering product development using reprocessed and recycled thermoplastics.

Saturn Environmental Champions

John Ressler

Lori Robins

Bill Miller

Engineering

Sales, Service & Marketing

Manufacturing

SATURN'S ENVIRONMENTAL AWARDS

1987 INDUSTRIAL CONSERVATIONIST OF THE YEAR

Presented by: Tennessee Conservation League

For Saturn's efforts to reduce the environmental impacts of the largest private construction project in Tennessee's history. These efforts include conducting extensive environmental baseline studies and air water modeling to discover and reduce impacts, installing double containment on all below-ground structures and pipeline to reduce the danger, leakage and groundwater contamination, extensive erosion and sediment control measures, as well as involving the communities in environmental decisions and actions.

1988 OVERALL ENVIRONMENTAL EXCELLENCE

Presented by: Tennessee Association of Business

In recognition of Saturn's "extraordinary commitment to protecting the environment." Efforts cited include the reduction of the construction impact in the area by creating a nursery for trees on site, the restoration of Haynes Haven, the materials management on site, and soil conservation and erosion control (noting the extraordinary efforts of crossing Carter's Creek 12 times during the construction of a sewer line).

1989 TACD CATEGORY 11-AREA V WINNER

Presented by: Tennessee Association of Conservation Districts

Awarded for Saturn's overall attitude on soil and erosions control. Some of the efforts include using ground cover in the winter, not tilling areas of high erosion, using hay on hills, etc. Normally awarded to agricultural groups or individual farmers.

1989 OUTSTANDING EFFORTS AT SITE PRESERVATION AND ENVIRONMENTAL EXCELLENCE

Presented by: Take Pride in America

For Saturn's overall team effort at protecting the environment and conserving natural resources.

1989 TAKE PRIDE IN AMERICA NATIONAL WINNER

Presented by: Take Pride in America

Recognizes those who have made outstanding contributions to protecting and enhancing public resources.

Saturn's Technical Environmental Challenges

Product Lifecycle:	Design	Manufacture	Consumer Use	Post Consumer Disposal
	Future Product Focus - Design for Recycling/Lifecycle Assessment Level I Specs Powertrain Alternative Fuel e.g., EV, Hybrid	Current Product Focus - Short Term Cost Savings - Rocker Panel Support - Wheelhouse Liners - Fender Liners (Pilot) - Wheel Covers (Pilot) Knowledge Base Development Opportunity - Design: Future Product Focus - Post Consumer Disposal: Recycling Infrastructure Development	Market/Public Positioning - Corporate Citizenship - Product Design - Design for Recycling/Lifecycle Assessment - Serviceability Improvements - Powertrain/Air. Fuels - Other - Process/Facilities & Waste Mgmt. - Supplier Partner Relationships - Retailer Partner Relationships	Recycling Infrastructure - Saturn - Retailer - Industry/Government

SATURN DESIGN FOR RECYCLING
Cost Savings as a Percent of Material Cost

Rocker Panel
Support
Dow Pulse B250

62%

Wheelhouse Liners
TPO

30%

Wheel Covers
GE GTX 910

47%

Fender Lowers
GE GTX 910

40%

**SATURN CORPORATION RECYCLED MATERIAL APPLICATIONS
FOR PAINTED POLYCARBONATE and ACRYLONITRILE-
BUTADIENE-STYRENE REGRINDS**

**R.T. LOUIS-FERDINAND
SATURN CORPORATION**

**S.W. PATTERSON
SATURN CORPORATION**

**F.M. PLAVER
DOW PLASTICS**

ABSTRACT:

Saturn Corporation has studied various automotive applications for painted polycarbonate acrylonitrile-butadiene-styrene (PC+ABS) blend regrinds. Traditionally, automotive thermoset paints in combination with thermoplastic parts offer limited recycling potential. Saturn's goal was to evaluate various automotive applications and to identify areas for usage of painted PC+ABS recycled material. Polymer parts such as rocker cover supports, spare tire covers and wheel covers were molded from recycled material blends and tested per automotive specifications. In addition to serving as an outlet to reclaim the painted scrap generated during production, these applications can potentially be used to recycle painted PC+ABS parts once the useful life of a Saturn vehicle is complete.

INTRODUCTION:

As greater emphasis is placed on being environmentally conscious, it is paramount that OEMs and material suppliers work together to reduce solid manufacturing waste. One formula for success is to develop

economically and environmentally sound applications and outlets for all solid manufacturing waste streams. From a thermoplastic material perspective, blending unpainted regrind with virgin resin prior to molding (or extrusion) is very common. This "closed system" approach improves overall manufacturing efficiency while reducing solid waste.

Typically, unpainted regrind is used back into the original application. Painted regrind may also be blended with virgin resin and molded or extruded. The following text focuses on evaluations of three potential automotive applications (spare tire cover, wheel cover and rocker support) for reinforced PC+ABS painted regrind.

Recycled Material Applications:

Evaluating applications for the recycled materials as with any part, involves an understanding of the recycled material properties, part property requirements, material volume requirements, manufacturing processes and part design. First, initial material property evaluations were conducted with the recycled materials to define limits of material properties. Vehicles were then surveyed and

material engineering studies were completed to target select applications for recycled materials. The spare tire cover, wheel cover and rocker support panel (figure 1) were selected as potential candidate applications for recycled material usage. Molding trials were completed to evaluate process and part performance of the individual parts.

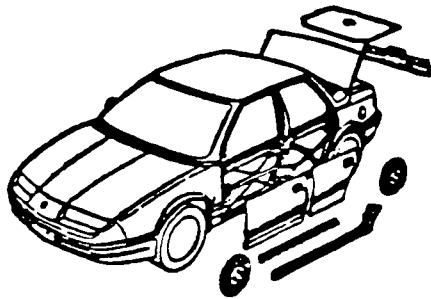


Figure 1. Layout of Recycled Material Applications with Painted PC+ABS Applications.

Mold Trial and Part Performance:

Production tools were located for targeted applications, and molding trials conducted.

Trial A (Rocker Cover Support)

Rocker cover supports containing 0%, 40%, 70% and 100% reinforced PC+ABS painted regrind were molded on a 4545 metric ton UBE injection molding machine. The reinforced PC+ABS painted regrind and unpainted PC+ABS resins were fed separately into the injection molding machine at the appropriate level by an auger metering system. The parts were then submitted for laboratory characterization, component impact, and vehicle evaluations including static load testing.

Trial B. (Spare Tire Cover)

Spare tire covers were injection molded on 909 metric ton injection molding machine from 100% painted regrind. The parts were then submitted for component impact evaluation. Test fixtures simulating current vehicle design were used for -30°C impact. Ambient temperature impacts occurred on vehicles. Automotive specifications include a vertical drop (6 in.) of 25 LB weight over various locations of spare tire cover.

Trial C. (Wheel Cover)

Wheel covers were molded on a 454 metric ton injection molding machine using a 20% (reinforced PC+ABS) painted regrind/80% (PC+ABS) virgin resin blend and 100% (PC+ABS) virgin resin as control. Unlike the rocker support and spare tire cover applications, the surface roughness of the wheel covers were of primary importance

because they are painted. The wheel covers were painted immediately following the molding process and submitted for laboratory surface roughness analysis, standard paint adhesion tests, and durability evaluation.

Results and Discussion:

Paint composition was calculated to be less than 5% of reinforced PC+ABS painted regrind. During the initial recycled material evaluation, standard test (virgin, painted regrinds and blends of both) specimens were injection molded and tested. Graph I demonstrates the retention of flexural modulus properties. Graph II demonstrates notched izod impact properties of recycled materials. There is no significant loss in flexural modulus properties of the material. However there was increased notch sensitivity in the recycled material. As expected, addition of virgin materials to recycled material improved physical properties.

Rocker supports with 100% painted regrind passed pendulum component impact evaluations. Parts were impacted with energies exceeding 10 ft-lbs and loads over 1000 lbs at -30°C. Parts passed a static load evaluation of over 200 lbs with acceptable deflection in part.

Spare tire covers made from 100% painted regrind performed to automotive specification in the areas of the parts most likely to receive impacts. Some fractures did occur when spare tires were impacted in areas containing ribs. However, the part design used contained design features for a low modulus material, and these design features were not optimum for painted regrind.

Wheel covers molded were evaluated for surface roughness on both as-molded and painted parts. Surface roughness of unpainted and painted wheel covers containing 0% and 20% reinforced PC+ABS regrind was determined by using a profilometer (table I). The surface measurements of the unpainted parts were identical. Following painting, the surfaces of wheel covers molded from both materials were three to four times as rough. Comparing the surfaces of the painted wheel covers, the wheel covers containing the 20% painted regrind exhibited slightly rougher surfaces ($RA=0.426 \pm 0.0016$) than wheel cover made from virgin resin ($RA=0.314 \pm 0.046$). This difference was not detectable without usage of profilometer.

TABLE I Wheel Cover Roughness Measurements.

<u>Sample</u>	R_a^1	R_q^2
Unpainted Surface		
0% Painted Regrind	.115+/-0.021	0.157+/-0.029
20% Painted Surface	.115+/-0.008	0.157+/-0.010
Painted Surface		
0% Painted Regrind	.314+/-0.046	0.412+/-0.077
20% Painted Surface	.426+/-0.116	0.557+/-0.115

Standard short term paint adhesion tests were conducted to automotive specifications. Wheel covers molded from both materials passed all tests. Testing included, tape adhesions, dime scrape, thumbnail hardness, paint coat cure, humidity/tape adhesion and chip resistance evaluations. Wheel covers were sent out for continued durability on vehicles in hot and cold climate.

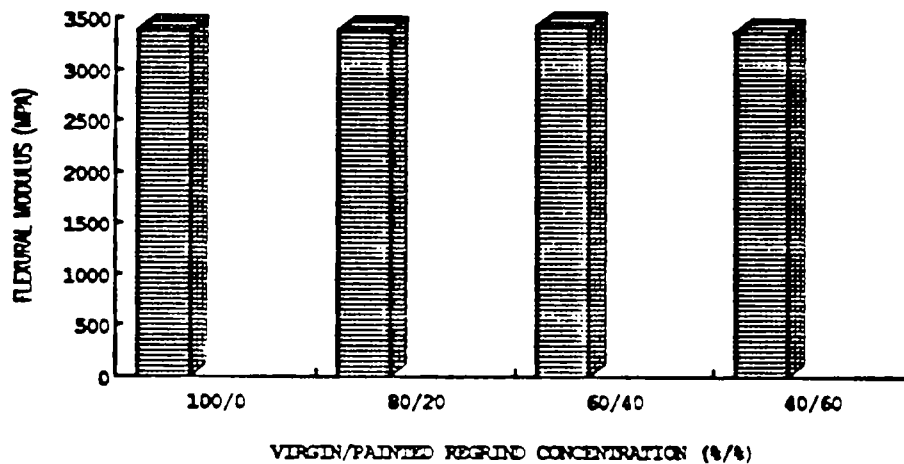
Summary:

Recycled painted PC+ABS materials can be used as an effective material in automotive applications. Rocker cover support parts molded with recycled material passed part performance requirements. Spare tire covers molded with recycled materials demonstrated potential for high volume consumption of recycled material. Wheel covers molded from recycled material passed paint coat aesthetics and short term durability requirements. It was shown that

there is a minor face difference of painted recycled material parts. From the initial property screening of the recycled material to the part performance testing it can be concluded there is an array of applications in which recycled painted PC+ABS regrinds can be used to reduce overall solid waste to the environment. The Saturn Corporation is currently recycling its painted PC+ABS regrinds into vehicle rocker cover supports.

- 1) R_a is the roughness average or arithmetic average deviation of the absolute values of the roughness profile from the mean line obtained from the wav correction of the raw data.
- 2) R_q is the RMS roughness or the root-mean-square, geometric, average deviation of the roughness profile from the mean line.

GRAPH I FLEXURAL MODULUS OF REINFORCED PC+ABS PAINTED REGRIND AND VIRGIN BLENDS



GRAPH II, NOTCHED IZOD IMPACT OF REINFORCED VIRGIN AND PAINTED REGRIND BLENDS, 23C AND -30C

