Sustainable Energy Practices in the Automotive Industry: Challenges and Opportunities

by

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Abstract

Automobiles are estimated to contribute one-fourth of carbon into the atmosphere, contributing to the potential for damaging climate change. 450 gallons of oil per person per year are combusted from exhaustible sources to power the automobile. The dependence of the United States on foreign oil comes at a cost of $60 billion per year directly, not including the amount spent to bolster foreign defense. Seven billion pounds of unrecycled scrap and waste per year are disposed of from automobile use. The land area demands of the automobile have resulted in paved area equal to all arable land in the states of Ohio, Indiana, and Pennsylvania. Automobile use restricts the mobility of non-car owners, and even car-owners in congested urban areas. Moreover, automobiles have "killed more Americans than have died in all wars in the country's history."[1]

Who is responsible for the automobile and its array of problems?

- Is it the vehicle owner, who drives the car around, emitting tons of carbon per year that contribute to the greenhouse effect?
- Is it the auto dealer or marketer, who sold the car to the unwitting vehicle owner?
- Is it the gas station attendant, who tops off the tank with exhaustible and carbon-containing fossil fuel with each visit?
- Is it the government, whose policies have created transportation systems that require the use of an automobile to get around?
- Is it the automobile manufacturer, who churns out 38 million vehicles per year, maintaining competitive prices through mass-production?[2]
- Is it the oil refinery, who converts extracted energy reserves into emission-ready usable fuel?
- Is it the creators and controllers of an economic system that cannot account for the natural capital that has no substitutes and that sustains life on this planet?

This paper explores the barriers to sustainable energy practices in the automotive industry from the perspective of multiple stakeholders, seeking ways the barriers can be overcome through holistic systems analysis.

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I. Introduction

This paper explores barriers to sustainable energy practices in the automotive industry. These energy practices span the range of the product life cycle of the automobile, from raw material extraction and transport, to powering production processes, to its end use as a mobility enabler, to disposal or recycling of retired product.

I. A. Proposition

This paper proposes that the structure of the automotive industry itself poses barriers to sustainable energy practices. Given this structure, the question is then raised of what a corporation within that industry can do, as one player in the larger scheme. This paper suggests that committed corporations can overcome these structural barriers by finding leverage points using a systems approach. The following section explores the meaning of the terms embedded in this proposition.

I. B. The Meaning of Terms

Sustainability

"Sustainability" is a complex, imprecise term that can have different meanings in different contexts. The working definition of sustainability for this paper, which comes from the World Commission on Environment and Development (WCED), is the ability to meet "the needs of the present without compromising the ability of future generations to meet their own needs."[3] In more concrete terms, it means that stocks of raw materials are not depleted faster than they are regenerated, and net waste generation is driven to zero.[4]

For automotive energy practices, this means that fossil fuel reserves come into question, as these reserves are regenerated on the order of millennia, but can be depleted on the order of centuries. More critically, the waste generated by fossil fuel combustion includes carbon dioxide emissions that contribute substantially to the stock of carbon dioxide in the atmosphere. The increased presence of carbon dioxide in the atmosphere enhances the earth's "greenhouse effect" of trapping energy in the form of heat, effectively warming the earth with all else equal.[5]

The impact of carbon dioxide emissions on the earth depends on the interaction between this warming effect and other feedback mechanisms. Some of the many interconnected

mechanisms of climate change include deep ocean absorption of carbon dioxide, land use effects on both surface reflectivity, forestation effects on absorption of carbon dioxide, and the local cooling effect of other compounds. Nevertheless, the most sophisticated models of outcomes under extremely different feedback assumptions illustrate substantial warming from business-as-usual emissions over the next century, beyond the noise of temperature fluctuation.[6]

Structure of the Automotive Industry

In the automotive industry, the central player typically considered is the vehicle manufacturer. In reality, this "vehicle manufacturer" is not one entity, but rather a collection of entities working to make the component parts and materials for the vehicle, and using considerable energy in the process.

The structure of the automotive industry refers to the connections between stakeholders. **Figure 1** illustrates the connections of the automotive industry and the energy industry to the end user, where the boxes represent stakeholders and the ovals represent sources and sinks. Two cycles are shown, both resulting in material or energy that is recycled or disposed of after vehicle use: the Fuel Cycle originates with the Energy Source, and the Vehicle Cycle originates with Raw Materials and Parts. Exogenous to this structure is the policy-maker, governing the connections between stakeholders.

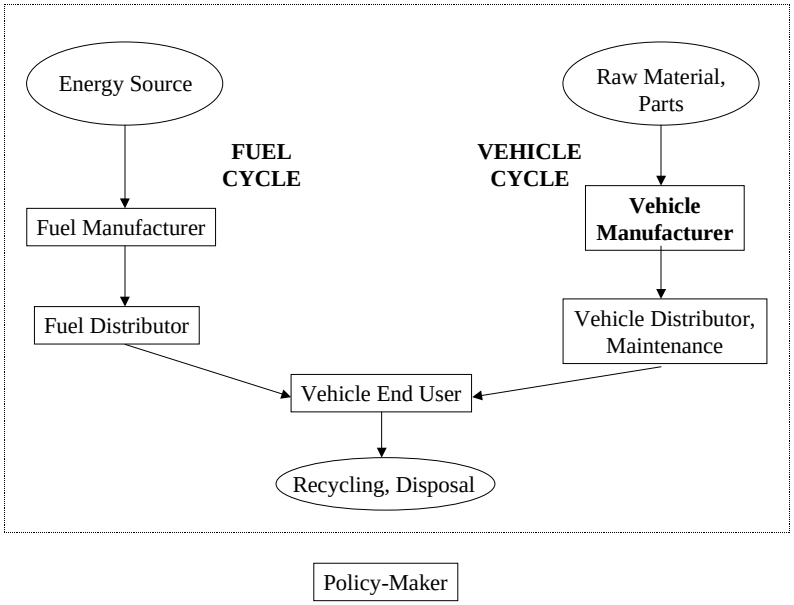

Figure 1. Schematic of Automotive Industry Structure[7]

Although **Figure 1** represents the material and energy flows between the stakeholders in the automotive industry, it does not represent the myriad of connections through relationships, partnerships, and information sharing between stakeholders. These connections can be critical to achieving progress toward sustainable energy practices. Indeed, vehicle and fuel manufacturers have worked intimately (though not always amiably) over the last century to introduce vehicles that meet changing customer demand and regulatory requirements.[8]

Energy Practices

The energy practices in the automotive industry include both energy of vehicle production and energy of vehicle use. These practices are dependent upon fossil-fuel extraction for the purposes of powering manufacturing plants and the vehicles themselves. Not only does this fuel extraction lead to depletion of an exhaustible resource, but also its combustion results in environmental degradation due to emissions of energy byproducts. The following section examines these energy practices in more depth.

I. C. Energy Context

This section explores the context of energy practices in the automotive industry, encompassing vehicle production, vehicle use, and the supporting infrastructure. **Figure 2** below illustrates the flow of fuel for the purposes of vehicle production and vehicle use. In this diagram, stocks are represented by boxes, and flows are represented by arrows with valves. Information feedback links are represented by arrows with plus (+) or minus (-) symbols. A plus symbol indicates that an increase in the originating variable causes an increase in the receiving variable, whereas a minus symbol indicates that an increase in the originating variable causes a decrease in the receiving variable. The magnitude of these changes in value depends upon the exact nature of the relationship, which is built into the model but not represented in the diagram.

In **Figure 2**, the *Environmental Degradation from Energy Byproducts* derives both from the *Rate of Energy Consumption for Vehicle Production* and the *Rate of Energy Consumption During Vehicle Use*. The extent of this impact is determined by the carbon content of the fuel used, along with the level of efficiency. *Production Efficiency* encompasses energy efficiencies from raw material extraction all the way through vehicle assembly. *Vehicle Fuel Efficiency* encompasses energy efficiencies from the engine, aerodynamics, braking, and weight.

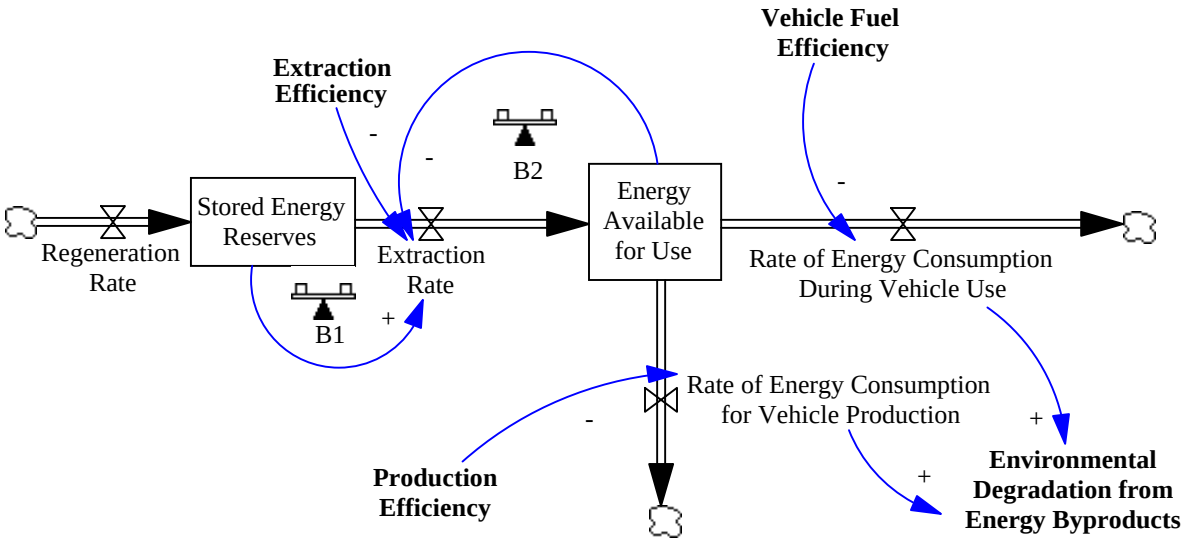

Figure 2. Stock and Flow Diagram with Simple Feedback Mechanisms[9]

The rates of energy consumption for vehicle use and production draw from the stock of *Energy Available for Use*. This stock represents manufactured fuel in usable form, and is supplied by the *Extraction Rate* of Fuel from the stock of *Stored Energy Reserves*. The extraction rate is affected by the *Extraction Efficiency* of the energy expended to obtain usable fuel. Additionally, the stock levels of both energy reserves and energy available for use provide balancing feedback to extraction rate through mechanisms B1 and B2. The balancing feedback mechanism B1 indicates that as energy reserves increase, the energy extracted is also likely to increase, thereby depleting the reserves. The balancing feedback mechanism B2 indicates that as the stock of energy available increases, the need for additional energy to be extracted decreases. **Figure 2** also indicates the *Regeneration Rate* entering into the stock of energy reserves. For fossil fuels, this regeneration rate is negligible.

The most visible work to reduce environmental damage in the automotive industry has focused on end-use fuel efficiency. Though this component is indeed critical, other system efficiencies and energy demands also play a major role in working toward sustainable energy practices.

Annabette Wils investigated the relative advantages of investing in demand-side end-use (vehicle production and use) efficiency versus supply-side extraction efficiency. Her research indicated that the end-use efficiency had a greater impact on reducing the rate of resource depletion than extraction efficiency. However, a mixture of both end-use and extraction efficiency was optimal from a systems perspective.[10]

Vehicle Production

Over two-thirds of the energy use for vehicle production is comprised mostly of energy needed to manufacture iron and steel, as illustrated in **Figure 3** below. The diversity of energy distribution in vehicle production underscores the interdependence of different stakeholders in the automotive industry.

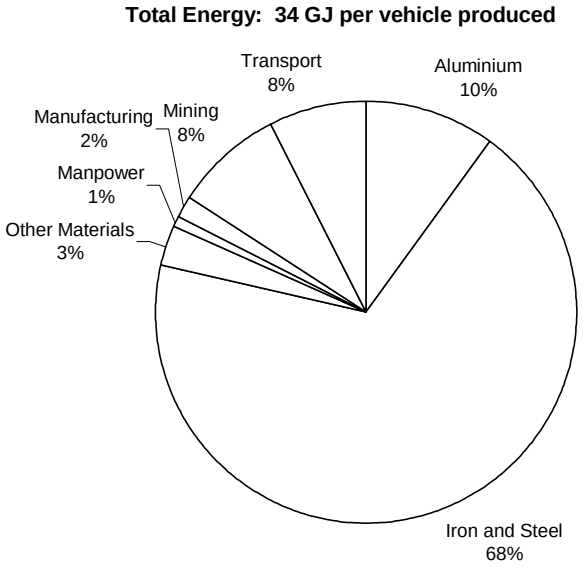

Figure 3. Energy Consumption for Vehicle Production[11]

Vehicle Use

Energy use during vehicle operation results in environmental degradation through emission during combustion. The catalytic converter plays a major role in abatement of many of these emission byproducts. Recent work has investigated more accurate assessments of catalytic performance in reducing pollutant emissions over the entire drive cycle. Kandylas and Stamatelos note that "the requirements for cleaner air will continue to place great demands on the catalyst."[12] Moreover, they note that this difficulty is exacerbated for aged catalytic converters. However, the catalytic converter is not designed for carbon dioxide abatement, as carbon dioxide is not considered a pollutant in the official sense. The approach to carbon

dioxide emission reduction has focused on vehicle efficiency, addressing the many causes of energy loss during vehicle use.

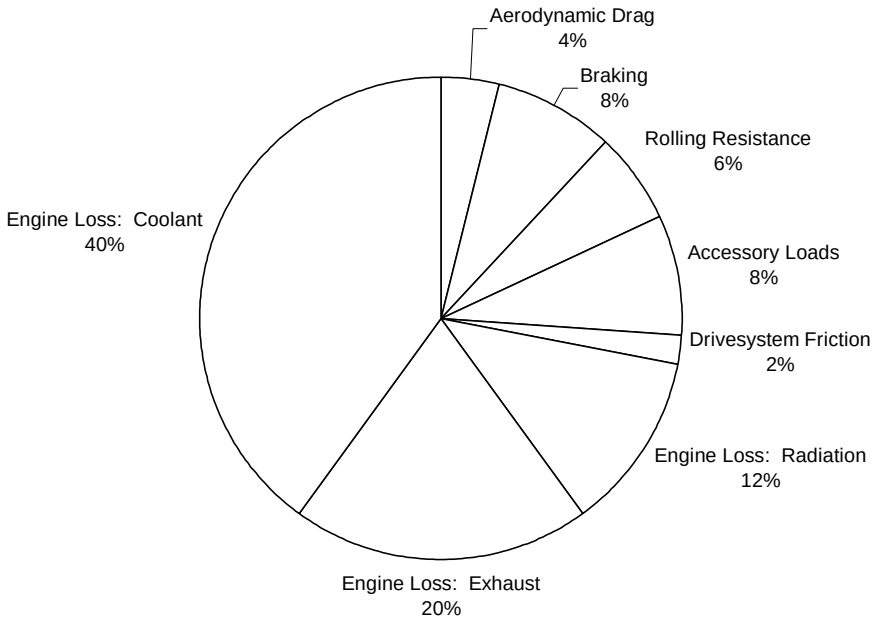

Figure 4. Energy Losses in Vehicle Use[13]

Figure 4 illustrates the energy losses associated with vehicle use. In sum, 72% of energy is lost from the engine through coolant, exhaust, and radiation. Only 18% of the energy loss goes directly toward providing motion (aerodynamic drag, braking, and rolling resistance). **Figure 5** illustrates a physical representation of these losses.

Figure 5. Physical Representation of Energy Losses in Vehicle Use[14]

Vehicle Infrastructure

In addition to vehicle production and use, a significant amount of energy is required for auxiliary services, such as parts repair, car washes, and land use for parking and roads. Naturally, the amount of energy required for these services varies, as does their corresponding effect on environmental degradation. But an infrastructure that has "paved an area equal to all the arable land in the states of Ohio, Indiana, and Pennsylvania, requiring maintenance costing more than $200 million per day" cannot be ignored.[15]

II. Demanding Customers

One structural barrier facing members of the automotive industry looking toward sustainable energy practices is that of demanding customers. The phrase "demanding customers" is appropriate, as it suggests both a responsiveness to demand, and the act of demanding that customers buy a product. Although corporations do not outwardly intend to pursue the latter, many marketing strategies are quite coercive. This section illustrates the notion that consumer demand is not exogenous to the structure of the automotive industry.

II. A. Demand Influences

To understand how demanding customers connect with the behavior of the automotive industry, an understanding of the influences on demand is needed. This section explores some dynamics of demand reinforcement and balancing through feedback mechanisms. An illustration of selected feedback mechanisms is provided in **Figure 6** below. Essential to the structure of **Figure 6** is the presence of a choice in strategy, indicated by "Choice 1" and "Choice 2" boxes.

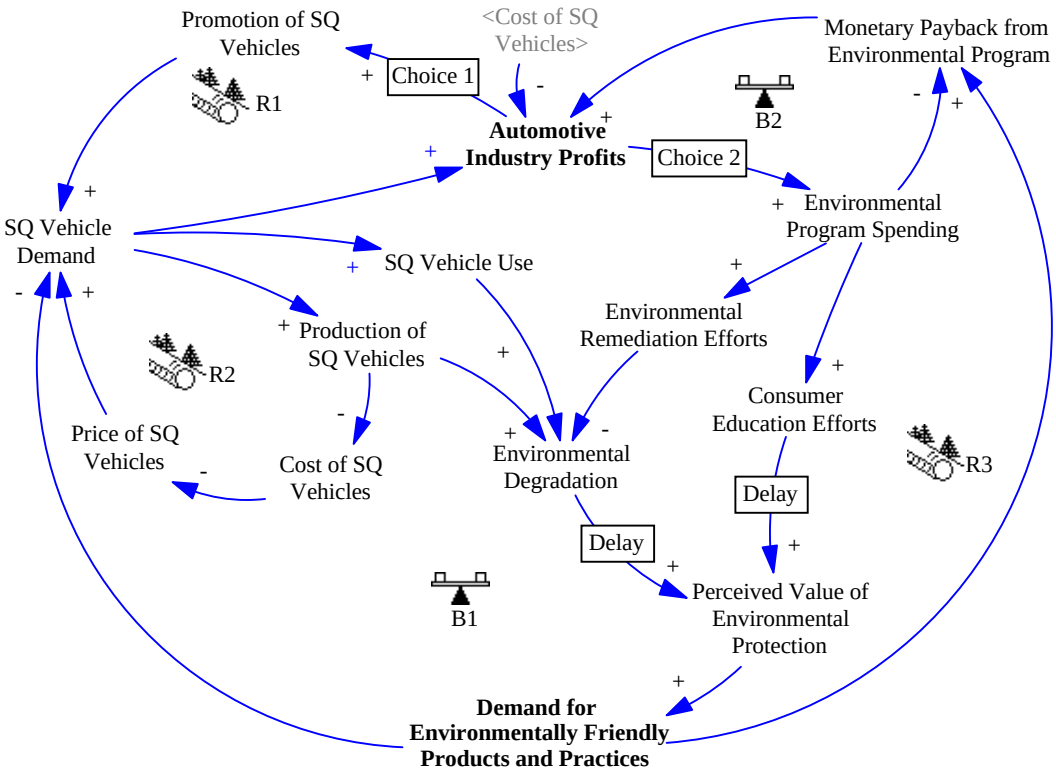

Figure 6. Causal Map Depiction of Some Influences on Status Quo (SQ) Vehicle Demand[16]

Reinforcing Feedback

Consumer demand for Status Quo (SQ) vehicles is reinforced through a variety of feedback mechanisms, a few of which are illustrated in **Figure 6**. One mechanism is illustrated through the reinforcing loop R1: as status quo vehicle demand increases, profits increase because of the associated revenues, and more status quo vehicles are promoted through the "Choice 1" allocation of income. Furthermore, as illustrated in reinforcing loop R2, status quo vehicle demand induces increased production, which in turn lowers unit costs through economies of scale. This lowered cost enables lower prices that ignite more vehicle demand.

Other factors reinforce status quo vehicle demand besides the ones illustrated in **Figure 6**. These factors include network effects from word of mouth, product enhancements from R&D investment, and convenience from the supporting infrastructure.

Balancing Feedback

The balancing feedback influence on demand, as demonstrated through balancing loop B1, involves a substantial time delay. Specifically, as status quo vehicle demand increases, the

environmental degradation from vehicle production and use increases. This degradation may not be immediately apparent, as in the case of global warming from carbon dioxide emissions. Over time, however, the negative externalities of environmental degradation become apparent to the consumer, increasing the perceived value of environmental protection. This sensitivity in turn increases the demand for environmentally friendly products, at the expense of status quo vehicle demand.

II. B. Industry Implications

Although corporations can capitalize on the shift in demand by providing environmentally friendly products and practices, this is easier said than done, as will be explored in the next section. The delay of consumers' perceived value of environmental protection can cause the production and use of vehicles to overshoot the sustainable level, then collapse with the shift in demand. This behavior is typical for reinforcing growth that extends beyond its sustainable limit because of delayed feedback.[17]

Fortunately, the corporation is not isolated from this demand behavior. A proactive corporation can allocate resources through "Choice 2" to increase environmental program spending. Effective spending can both mitigate environmental degradation through remediation efforts, and can increase perceived value of environmental protection through consumer education efforts.

Consumer education can be achieved through extensive communication. Shulz and Holbrook survey a sampling of studies that reinforce the positive potential communication can have on addressing commons dilemmas through cooperation.[18]

Again, a time delay stands between the corporations' efforts to educate consumers and the actual increase in perceived value of environmental protection. However, the length of the delay may vary by the scope and method of consumer education.

Once the demand for environmentally friendly products and practices increases, the corporation can earn revenues from its products and practices, in turn increasing the monetary payback from the environmental program. It should be noted that the immediate effect of environmental program spending is draining on profits, so that a short-term cost consideration will not opt for this program.

III. Conflicts of Interest

As introduced in the previous section, shifts in consumer demand can create barriers to sustainable energy practices (and thereby to sustainable competitive advantage) in the automotive industry. This section explores barriers from conflicts of interest that develop within the automotive industry as it embarks on the difficult pursuit of sustainable energy.

III. A. Status Quo Challenge

To truly challenge the status quo vehicle demand, sales of alternative "green" or "environmentally friendly" vehicles compete with sales of status quo vehicles. Thus far, this paper has not defined the terms "green" and "environmentally friendly". These terms have many dimensions, and are frequently perceptions rather than reality. It could be argued that in the most fundamental sense, after all, no human influence is completely "environmentally friendly". Unfortunately, the lack of a clear and consistent definition among stakeholders exacerbates the status quo challenge further.

Auto makers have attempted to market "green" vehicles as a niche category, so that product cannibalization is less likely. However, this neat categorization places the auto makers under sever scrutiny with regards to real intentions. The target market for this "environmentally friendly" vehicle consists of the most difficult consumers—those who already have money (else they could not afford the premium) but who are inherently frugal (because of the simple "green" lifestyle) and would prefer to manage without a vehicle at all if they could. As one spokesperson for Friends of the Earth noted: "If you really wanted to change things, you wouldn't buy unleaded petrol, you would sell your car and get a bicycle."[19]

Credibility

In addition to this formidable market, one 1989 study indicated that "nine of ten Americans believe that business will lie, deceive, harm, endanger, or cheat to make more money."[20] With this lack of trust, the credibility of a company's intention can be quickly questioned in consumers' eyes.

As introduced above, niche marketing of "green" vehicles begs the question of whether a company that sells sport-utility vehicles (SUVs) alongside its zero-emission vehicles (ZEVs) can

really be working for a sustainable future. Because of the subjective nature of "green", issues of credibility pose substantial barriers to progress toward sustainable energy practices.

In The Ecology of Commerce, Paul Hawken provides a lucid example of corporate credibility in question with Chevron. When the Clean Air Act was revisited in 1990, Chevron joined other entities in the oil and gas industry to lobby against more stringent requirements because of the cost to shareholders. Prior to lobbying, Chevron conducted an internal survey in which 85% of its employees and customers indicated that they were "pro-environment". With this backing, Chevron declared itself an "environmental company" and entered into the negotiations saying that it cared about the environment, as demonstrated by its complying "fully with the letter of and spirit of all laws" affecting its operations.[21] Unfortunately, to make a pro-environmental statement in conjunction with a business-as-usual plea seriously undermined Chevron's credibility.

Internal Consistency

Organizational divisions are created within large firms to enable focus and reduce redundancy. In spite of the many advantages of clear organizational divisions on operational efficiency, these divisions can isolate groups within an organization. With this isolation, communication between the "truck group" and the "alternative vehicle group" might be limited within an automobile manufacturing firm. When the objectives of these groups differ substantially, local optimization can lead to organizational "gridlock", effectively blocking the ability of the organization to change fundamentally.[22]

One way to overcome organizational "gridlock" to make organizational change is through communication between divisions. However, if this communication involves a strategy that sidesteps the status quo manufacturing process, the information transmitted might pose a perceived threat to employees' futures. The grounding for this threat depends largely on what the corporation's plans for the future are, both in terms of competence development and of human resource redeployment.

As one senior employee for a major auto maker noted, "advanced composite material development is outside our core technology, so we do not have manpower or facilities assigned to that development area."[23] This quote highlights the momentum keeping much of the

automobile manufacturing industry from pursuing such a seemingly simple idea as lightweight material.

III. B. Delving Deeper

As mentioned above, the energy used to produce and fuel even "green" vehicles are unlikely to be sustainable in the truest sense. Given this limitation, how can consumers make meaning from the information available? And at what point can companies claim that they are "environmentally friendly" credibly?

The difficulty of defining "green" can lead to apathy by consumers and corporations alike. Nonetheless, its very complexity reinforces the importance of understanding environmental impacts in full. This section delves deeper into the conflicts of interest plaguing the automotive industry, to reveal some of the production and fuel issues contributing to these conflicts.

Production Considerations

A zero-carbon emission vehicle may sound wonderful to a novice environmental enthusiast, but a closer look would reveal the full extent of its greenness. The method of investigating the entire life cycle of a product to understand the full environmental impact has been increasingly applied under the Life Cycle Analysis (LCA) approach.[24] Considering the complexity of vehicle manufacturing, the emissions reductions would need to span the raw material extraction and processing, as well as the joining of parts. The energy efficiency from materials processing could be reduced substantially by recycling or using less-intensive material requirements (from changes in total mass or material type). Moreover, vehicles designed with substantially reduced body weight require less power from the engine so that the engine can be smaller, in turn reducing overall vehicle weight even more.[25] As this brief analysis shows, the emissions from production are not limited to the auto maker, but span the material and energy supply structure on which that entity depends.

Fuel Considerations

Further exacerbating the corporate conflicts of interest is the variety of potential fuel sources. For example, electricity is viewed by many as a "clean" or "zero-emission" fuel source. However, indeed, the electricity is not a source. Rather, the electricity is a form of energy

supplied from another source, be it fossil-fuel, geothermal, nuclear, wind energy, biomass, or solar. Most electricity generation plants currently rely upon fossil fuels for cost-effective and dependable energy supply. Naturally, this means that electric vehicles relying on fossil-fuel generated electricity are far from zero-emission. However, this does not mean that electric vehicles are inherently "unclean", either. It simply means that it depends upon the source. In considering a "green" vehicle, a full "well to wheel" analysis can effectively compare the alternative to the baseline.[26]

Another fuel consideration for "green" alternatives is quantity. When fuel economy improves, the direct effect is a reduction in quantity of fuel demanded. However, the longer-term effect can be an increase in vehicle use to take advantage of the lower driving cost, offsetting the gain in fuel economy with a drag on fuel supply. Indeed, the trends in automobile use demonstrate the powerful presence of the latter effect.[27]

IV. Indecision

Indecision becomes a major barrier to sustainable energy practices in the automotive industry because it precludes action. This section explores the elements of indecision that plague the automotive industry, from time horizon limitations to cost and benefit uncertainty.

An illustration of indecision is provided in **Figure 7** below, representing the "Floorboards" dilemma.[28] This dilemma makes an analogy between corporate knowledge of environmental liabilities and homeowner knowledge of damaged floorboards. Although the floorboards may need renovation, this cannot be determined unless they are pried up. And if, after the floorboards are pried up, damage to the floorboards is present, the homeowner is legally bound to repair the damage. So long as the floorboards remain untouched, the homeowner is not responsible for damage contained therein. In the long term, however, the homeowner will need to repair the floorboards to have a safe home.

As the corporation's perceived vulnerability to environmental problems (e.g., susceptibility to lawsuit) increases, the corporation can choose either a risk-avoidance strategy (leaving the floorboards untouched), or an inquiry strategy (looking to see what kind of damage there is). The risk-avoidance strategy has immediate effects of tapering the perceived vulnerability through balancing feedback B1, which ameliorates the corporation's concerns. Conversely, the inquiry strategy has the short-term effect of increasing credibility and thus the

environmental imperative, in turn increasing perceived vulnerability through reinforcing mechanism R2. In time, though, the inquiry strategy results in changed practices that reduce the perceived vulnerability through balancing feedback B2, thus shifting the reinforcing feedback toward environmental remediation. The long-term impact of the risk-avoidance strategy is an inability to gather information about environmental practices, and thus an inability to solve REAL problems, exacerbating the perceived vulnerability through the reinforcing mechanism R1. These behaviors are depicted in **Figure 7** below.

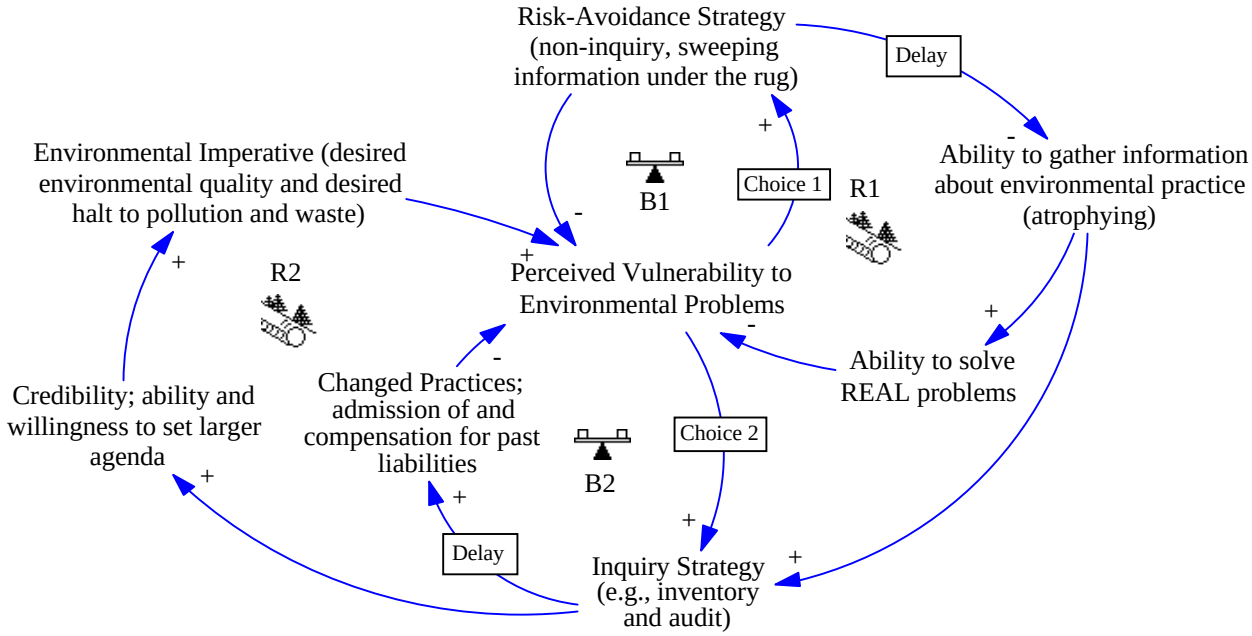

Figure 7. The "Floorboards" Dilemma: Consequences of Environmental Strategies[29]

IV. A. Time Horizons

As **Figure 7** shows, time is a critical element to internalizing appropriate feedback. The shift to sustainable energy practices involves different considerations for different time horizons. Of course, when looking to the future in any of the time horizons, expectations can range from those derived from past experiences to those created from the optimal use of existing technologies. It has been said that "the best way to predict the future is to create it yourself." This section explores how the time horizons faced by the automotive industry spawn indecision, and where the sources of creative passion might lie.

Short Term

Short-term considerations (within 5 years) are typically characterized by profit-driven motives. Unfortunately, a series of short-term considerations add up to a long-term strategy, whether intended or not. Members of the automotive industry do not necessarily need to sacrifice short-term objectives to work toward sustainable energy practices, as many energy efficiency projects reduce vehicle production cost in the short term. These corporations must, however, consider whether they are investing in more status-quo technologies, or whether they are investing in environmental program efforts.

In the short term, corporations can meet consumer needs for mobility with status quo vehicles, while developing and introducing alternative products. In addition, corporations can begin advertising to educate. This marketing strategy does not mean touting blanket statements of wonderful environmental performance, but rather being honest about products and possibilities. To help hurdle this burden, corporations can collaborate with other entities such as NGOs. These strategic alliances can help raise the public image of the corporation, and provide the corporation with information and scope it might not otherwise experience.[30]

If the short term time horizon is used as an opportunity to take small steps toward sustainability, change is possible. If, however, the short term time horizon is used as an opportunity to defer decisions, the likelihood of making real change diminishes.

Medium Term

In contrast to the short term, medium-term considerations are often overlooked in corporate planning, or are lumped in with a generic "long-term" strategy. However, to work toward fundamentally sustainable energy practices, a transitional medium-term strategy is critical to building an infrastructure that supports environmentally friendly products. This medium term might range anywhere from 5 to 20 years out on the corporation's time horizon.

During the medium term, corporations could plan to proliferate "green" alternatives to reduce emissions. The fear of product cannibalization of status quo vehicles is most likely to occur during the medium term, as increase in environmental awareness not only increases demand for "green" alternatives but also decreases the demand for status quo vehicles.

While sustaining the advertising to educate campaigns, corporations in the automotive industry can utilize the medium term time horizon to funnel profit and time gains into rebuilding the energy infrastructure to one compatible with low-carbon, renewable energy sources.

The medium term is a necessary transition toward long-term sustainability, given the myriad of hurdles to overcome. The difficulty of addressing the medium term comes from both its uncertainty and its inherently unstable state. Entities can easily state what the "current state" is, and with a little more creativity, what the "desired state" is. The difficult part is comprehending and creating the "transitional state" in between.

Long Term

In contrast to the short- and medium-term considerations, the long-term horizon is virtually limitless, depending upon assumptions about how far it is "reasonable" to peer into the future. For the purposes of this paper, long term is considered greater than 20 years out on the time horizon.

The advantage of long-term considerations is that the absence of a deadline encourages creative vision. Unfortunately, this creativity can then be rejected by "realists" who can only see in the short term, and view the medium term as an insurmountable obstacle rather than a transition period. In spite of (or perhaps because of) this criticism, long term planning. Without a vision to move toward, organizations can flounder in chaos.

Essential elements of the long term strategy might include product responsibility from cradle to grave. Increasingly, corporate responsibility is becoming expected from the automotive industry and associated energy infrastructure.[31] Additionally, the automotive industry can rethink its goal to be a mobility enabler rather than vehicle provider.

As anyone familiar with life in the Silicon Valley can attest, car ownership does not mean unlimited mobility. With congestion in urban areas resulting in average commute times of close to one hour, the act of driving to a destination may be less attractive than the alternatives. With the advent of information technology, "telecommuting" to work may not only eclipse this time sink, but also may enhance work productivity and personal balance.

Although the long term might seem too far away to worry about, it is a critical element of planning for change. The long term strategy can be incorporated into a vision of the future that is shared among stakeholders.[32]

IV. B. Cost and Benefit Uncertainty

While the time horizons considered add multiple, complex objectives to indecision barrier, so does the uncertainty of costs and benefits associated with environmental remediation alternatives within the automotive industry. This section examines the uncertainty of costs and benefits that derive both from the approach (and from the underlying assumption) to innovation, and from differences in values that enter the cost and benefit analyses.

Innovation Approaches

Many approaches toward sustainable energy practices exist. Incremental improvement is considered grounded in reality by those who found the future on past experiences. Indeed, the Partnership for a New Generation of Vehicles (PNGV) has endorsed evolutionary improvements in fuel economy with an aggressive target to achieve an 80 mpg standard in prototype form by 2007.[33] The advantage of incremental improvement is that the foundation is established and accepted, so that risks of a lack of market demand are less. However, to make a substantial impact on the environment, the innovation must venture beyond the incremental.

Radical change, or "clean sheet design", can have a much more substantial impact on environmental remediation than the incremental approach. Although this radical approach is most likely to yield technological advance toward the Hypercar that weighs 520 kg and has a 200 mpg fuel efficiency, the automotive industry is least receptive to this approach.[34]

In addition to the path chosen for innovation, the assumptions underlying the approaches are critical. These assumptions might affect what fuel source is chosen for a "wells-to-wheels" comparison of technologies. Moreover, the measures used to determine the most effective technology are also based on assumptions. Assumptions determine whether the "best" technology is the most energy-efficient, the least damaging to the environment, or the least expensive.

Values

Differences in values among individuals, nations, and economies can also contribute to indecision, as illustrated by the slow pace of the Framework Convention on Climate Change, which seeks to obtain agreement among nations on an approach to mitigate global warming.[35]

Nations have pressing priorities, in which the impact of the automobile may not be foremost. It may be that the car is welcomed as a means of transport over vast expanses. It may

also be that the car is an additional source of existing pollution and congestion, only adding to the nation's woes.

Individuals also have a wide range of value-based interpretations for similar experiences. Edward Ayres, in What's Good for GM, noted that "in all this automania, there lurks the danger of a slowly diminishing quality of existence, of a fading appreciation of the experiences cars have usurped from the bodies and senses of men."[36] In contrast, Edward McDonagh said that "the car has become a secular sanctuary for the individual, his shrine to the self, his mobile Walden pond."[37]

Economic valuation of resources and emissions has been insufficient to represent the natural capital that provides sustenance for the planet and that has no substitute. Gross Domestic Product (GDP) is our quantifiable measure of quality based on consumption patterns, while in reality consumption does not always correspond with increased well-being.[38] A point of diminishing returns exists, beyond which extra "stuff" does not increase happiness. More often, this excess can actually undermine true enjoyment of life, as Edward Ayres so eloquently noted above.

Ultimately, the value of human welfare varies as would be expected. Donella Meadows reflected that "at best, societies and economies are devoted to the measurable components of human welfare. But by definition anything measurable is quantity, not quality."[39]

V. Counterpoints

It can be argued that the barriers to sustainable energy practices in the automotive industry are too massive to overcome, given that each stakeholder in the automotive industry has insufficient power to change the structure of the system. The following sections explore the economic, political, and social dimensions of this argument.

V. A. Economic

As Paul Hawken noted in The Ecology of Commerce, "markets are superb at setting prices, but incapable of recognizing costs."[40]

Standard plant economics indicates that cost-minimization enables optimal use of resources. Often, an investment in environmental risk-mitigating technologies does not provide minimal costs. However, this approach depends largely on what is considered a cost. For example, inventory is accounted for as an asset, but recently manufacturers have worked to lower

their inventory levels because of the opportunity costs they represent. Similarly, accounting for environmental costs can be justified along the same rationale.

V. B. Political

Government is responsible for setting regulations, levies, and subsidies. Many reports assessing alternative technologies are contingent on what regulations government will impose. Although government plays a major role in determining appropriate levels of emission for overall welfare, it is an institution driven often by political motives rather than scientific or rational ones. Moreover, government policies are ineffective if not backed by consumer and industry support.

The automotive industry and supporting energy infrastructure have consistently demonstrated political influence in the form of PAC contributions to the U.S. Congress. In the 1997-1998 election cycle, the oil and gas industry contributed over $6 million to Federal candidates, while the automotive sector contributed close to $5 million.[41]

Rather than waiting to see what government will decide next, industries that are proactive in seeking the benefits of environmental stewardship will avoid the anxiety of political uncertainty and gain credibility in the meantime.

V. C. Social

A social consideration in critiquing the feasibility of attempting to shift demand through consumer-targeted programs, is that the consumer needs must be met.

Unfortunately, needs are frequently not distinguished from wants in marketing language. Moreover, use of such terms as “latent requirement”, used to describe a need that the customer has not yet recognized, blur the distinction further.[42]

As argued previously, the automotive industry carries a substantial role in defining needs. Because the delays until perception of an environmental problem are strong, the customers’ demand may represent short-term wants that are in direct conflict with their long-term needs. Although industry or individuals alone may not determine what the true needs are, an active multilateral communication program can help to work out the social needs.

VI. Conclusions

This concluding section reiterates the barriers described above, highlights the leverage points for action, and explores ways a stakeholder in the automotive industry can reach out to collaborate with other stakeholders.

VI. A. Leverage Points

The barriers to sustainable energy practices in the automotive industry have been explored above as internal to the automotive industry structure.

The barrier of reinforcing consumer demand for the status quo was illustrated by **Figure 6**. The leverage to proactively shift this demand can be achieved through consumer education efforts whereby honest and open dialogue. Although the immediate payback may not be apparent, the long-term disadvantage of misperception can cannibalize profits.[43]

Barriers also derived from conflicts of interest within the automotive industry. Here the communication of coherent and consistent corporate goals internally, coupled with consistent outward involvement in environmental alliances, could substantially impact the corporation's credibility. This credibility is essential for the extremely critical "green" consumer.

The barrier of indecision was also investigated, from risk aversion to uncertainty and conflicting objectives over different time horizons. Indeed, complex solutions to a complex problem spawn indecision. Communication between diverse groups can enhance cooperation. Distinct goals should be set for different time horizons, understanding the need for short-term realism, medium-term transition, and long-term vision.

VI. B. Reaching Out

In addition to utilizing leverage points to work toward sustainability within the automotive industry structure, stakeholders can reach out to collaborate with players in other pieces of the puzzle, all around the world. An essential part of collaboration is communication.

Consumers and Employees

Building relationships is a widely recognized aspect of marketing today. According to Tapscott et al, "relationship capital", or the economic benefit from relationships with customers, could be worth more than that of tangible assets such as land, buildings, and factories.[44] But how can a corporation educate consumers and still get them to buy its product? The answer is that the

corporation never really has control over the latter, because consumers exercise free will. Moreover, manipulative marketing will not work in the long term.[45] A corporation can sponsor conferences, educational programs, and work with other groups (e.g., NGOs and policy-makers) to demonstrate commitment.

Part of sustainability involves the value of "good" a job creates. At a recent visit to Ford Motor Company's Windsor Engine Plant, the tour guide, who was also an area technician, explained the product as she shrugged: "We make engines for the gas-guzzlers."[46] It is not an easy task to reconcile hard-earned productivity efforts with more efficient destruction of natural ecosystems. And treading lightly, as the slogan goes, is nearly impossible in today's interconnected and inconsistent world. Nevertheless, corporations can at least be honest from the inside out, working to integrate employees and not simply manipulate them.

Shareholders and Policy-makers Worldwide

Public responsibility increasingly requires looking at measures other than stock market performance and communicating this to stockholders.[47] Moreover, some investors have begun specifically to seek out corporate responsibility in stocks for mutual funds.

Stakeholders in the automotive industry can work to understand the implications of policy decisions through collaboration with policy-makers and non-government organizations (NGOs).

Globalization is increasingly becoming yesterday's news, as the internet spans households, neighborhoods, country borders, oceans, and languages, to connect people as never before. The automotive industry must consider how globalization of information transport affects mobility providers.

Endnotes

[1] These facts are provided in Hawken, Lovins and Lovins 1999 at 22-23.
[2] Brown, Renner and Halweil 1999 at 82.
[3] From the Brundtland Commission's definition of sustainable development, in "Our Common Future," 1987.
[4] Adapted from draft article provided by Peter Senge. "Integrating Frameworks for Sustainability." 2000.
[5] Houghton 1994.
[6] Prinn et al. 1999 at 529
[7] Weiss et al. 1999 at 2
[8] Rinschler and Asmus 1995.
[9] Adapted from Senge et al. 1999.
[10] Wils 1998.
[11] From Hughes 1993 at 32, using data from the Society of Motor Manufacturers and Traders (SMMT) (1990). The Motor Industry and the Greenhouse Effect, London.
[12] Kandylas and Stamatelos 2000 at 428.
[13] Adapted from Hughes 1993 at 38, using data from the OECD (1982). Automobile fuel consumption in actual traffic conditions, OECD Road Research Group, Paris.
[14] Image obtained from the Hypercar Center online. <http://www.hypercarcenter.org/>
[15] Hawken, Lovins and Lovins 1999 at 22.
[16] Adapted from Zamudio-Ramirez 1996.
[17] Meadows et al 1992 at 1.
[18] Shultz and Holbrook 1999 at 223.
[19] Boulding 1990. "Making Products Squeaky Green." Marketing Week 7 December 1990. Quoted in Prothero 1994 at 182.
[20] Hawken 1993 at 118.
[21] Hawken 1993 at 113.
[22] Kim 1994 at 169.
[23] Quoted in Lovins 1996 at 60.
[24] See Kasai 1999 for specific applications of LCA, and Drake 2000 for an overview of the method.
[25] Field and Clark 1997 at 30.
[26] Weiss et al. 1999.
[27] Schipper 1995 at 375.
[28] McDonagill and Kleiner 1994 at 460.
[29] McDonagill and Kleiner 1994 at 463.
[30] Milne, Iyer and Gooding-Williams 1996.
[31] Mitchell 1999.
[32] Senge et al. 1994.
[33] Field and Clark 1997 at 30.
[34] Brooke 1998 at 63.
[35] Agarwal, Narain, and Sharma 1999.
[36] Ayres, Edward. What's Good for GM. 1970. Quoted in Rodes and Odell 1992 at 8.
[37] McDonagh, Edward. Interview in Time 10 May 1963. Quoted in Rodes and Odell 1992 at 8.

[38] Ger 1997.
[39] Meadows, Donella. Speech in Washington, D.C. January 1988. Quoted in Rodes and Odell 1992 at 113.
[40] Hawken 1993 at 75.
[41] Data on PAC donations collected from <http://www.opensecrets.org/pacs/sectors/1998/>
[42] Shiba, Graham, Walden 1990 at 11.
[43] Tapscott, Ticoll, Lowy 2000.
[44] Id.
[45] Prothero 1994.
[46] Conversation recalled from notes taken during Leaders for Manufacturing (LFM) Plant Tour. 11 January 2000. Windsor, Canada.
[47] Malone et al. 1999.

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