DOE/ER/50212-1

ANALYSIS OF ENVIRONMENTAL FACTORS IMPACTING THE LIFE-CYCLE COST ANALYSIS OF CONVENTIONAL AND FUEL CELL/BATTERY-POWERED PASSENGER VEHICLES

FINAL REPORT

Prepared for:

U.S. Department of Energy
Chicago Field Office
Contract No. DE-AC02-93CE50212

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January 31, 1995

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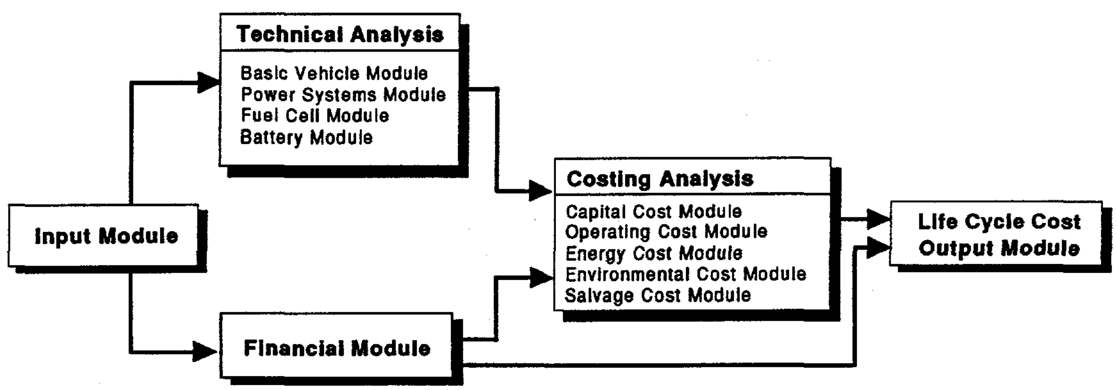
EXECUTIVE SUMMARY

This report presents the results of the further development and testing of the Life Cycle Cost (LCC) Model previously developed by Engineering Systems Management, Inc. (ESM) on behalf of the U.S. Department of Energy (DOE) under Contract No. DE-AC02-91CH10491.

The Model incorporates specific analytical relationships and cost/performance data relevant to internal combustion engine (ICE) powered vehicles, battery powered electric vehicles (BPEVs), and fuel cell/battery-powered electric vehicles (FCEVs). The Model is structured around twelve integrated modules as shown in the diagram below.



The original Model was used for performing comparative analysis between conventional gasoline and diesel fueled ICE vehicles, and fuel cell/battery-powered vehicles using either phosphoric acid fuel cells (PAFC) or proton exchange membrane fuel cells (PEMFC). It included the following fuel options:

ICEs:

- Gasoline
- Reformulated Gasoline (RFG)
- Diesel
- Reformulated Diesel
- Ethanol (E100)
- 85% Methanol/15% Gasoline Blend (M85)
- Compressed Natural Gas (CNG)

Fuel Cells:

- Ethanol (E100)
- Methanol (E100)

The prior work analyzed seven base vehicle configuration cases with a total of 21 vehicle class/powertrain/fuel combinations.

The specific emissions included in the original Model, as a life cycle cost element, were nitrogen oxides (NO_x), hydrocarbons (HC) and carbon monoxide (CO). The costing and inclusion of these externalities in the life cycle analysis indicated that they could have monetary significance on a par with other life cycle elements, for purpose of comparative evaluation of alternative systems. Accordingly, the present work under contract No. DE-AC02-93CE50212 expanded and further refined this LCC-oriented environmental analysis by survey of the literature and selection of additional emissions factors for inclusion in the Model. The selected additions to CO, NO_x, and HC were:

- Greenhouse Gases (GHGs), in terms of carbon dioxide (CO_2) equivalence;
- Sulfur Dioxide (SO_2);
- Particulate Matter (PM); and
- Toxics, including aldehydes, and the benzene, toluene and xylene (BTX) class of aromatics.

The Model allocates the cost of these "externalities" in terms of avoided costs. Table ES.1 summarizes these costs as they are represented in the Model.

The Model was also expanded to include the economic quantification of the impact of the higher volume of crude oil imports expressed by an incremental "national security premium" cost. The default value in the Model is \$25.00 per barrel of crude oil or \$0.275 per gallon of gasoline.

In addition, the timing of the HR-776 - The Energy Policy Act of 1992, Section 2026, had required DOE to look into the feasibility of utilization of hydrogen-fueled fuel cell/battery propulsion systems for vehicle applications. As a result, ESM included an LCC analysis of hydrogen-fueled proton exchange membrane (PEM) fuel cell/battery-powered cars and vans in

Table ES.1: Emissions Externality Costs

Emissions Component	Cost (1990$ per ton)
Hydrocarbons (HC)	$10,000
Carbon Monoxide (CO)	$850
Nitrogen Oxides (NO_x)	$5,000
CO_2 Equivalence	$16
Sulfur Dioxide (SO_2)	$450
Particulate Matter (PM)	$4,500
Aldehydes	$2,000
BTX	$2,000

the present work. Finally, ESM validated and refined the LCC Model in order that outputs can sustain peer review and be used for decisionmaking purposes.

Model Improvements

Various modifications were made to the Model under the current work including the following:

- Conversion of software platform from Excel® to Quattro Pro for Windows® in order to achieve greater flexibility in design and use;
- Complete revalidation and adjustment as required of all equations and data previously incorporated in the Model;
- Expansion and revision of included data on fuel cycle emissions;
- Expansion and revision of included data on the economic value/cost of such emissions;
- Addition of a hydrogen-fueled PEMFC/battery-powered vehicle to the set of vehicles included for analysis; and
- Addition of user-friendly dialog boxes and a speed bar interface to facilitate case selection, data input, and Model operation.

In fact, the Model is sufficiently user-friendly that a user's manual is almost unnecessary.

As an example of the cost component details contained in the current version of the Model, the Reference Car Case with a total life cycle cost of $35,378 is shown in Table ES.2. This case is based on:

- Model default values;
- Conventional ICE engine;
- Car body type;
- Automatic transmission; using
- Conventional Gasoline.

Table ES.2: Total Life Cycle Costs - Reference Car Case

Capital Cost	
Basic Vehicle	$11,187
Battery	$62
Motor	-
Engine	$1,492
Controller	-
Transmission	$188
Fuel Cell	-
Fuel Tank	$202
Accessories	$2,500
Total Vehicle Capital Cost	$15,630
Operating Cost	
Energy Cost	
Electricity	-
Fuel	$5,872
Repairs/Maintenance	$5,159
Replacement	
Tires	$546
Battery	-
Fuel Cell	-
Insurance	$4,785
Garage/Park/Tolls	$663
Title/Register/License	$627
Total Operating Costs	$17,653

Salvage Value	
Battery	-
Fuel Cell	-
Basic Vehicle	$(100)
Total Salvage	$(100)
Total Capital, Operating, and Salvage Costs	**$33,183**
Emissions Cost	
HC	$724
CO	$531
NO_X	$230
Particulates	$7
SO_2	$3
Aldehydes	$1
BTX	$15
CO_2 Equivalent	$684
Total Emission	$2,195
Total Life Cycle Cost	**$35,378**

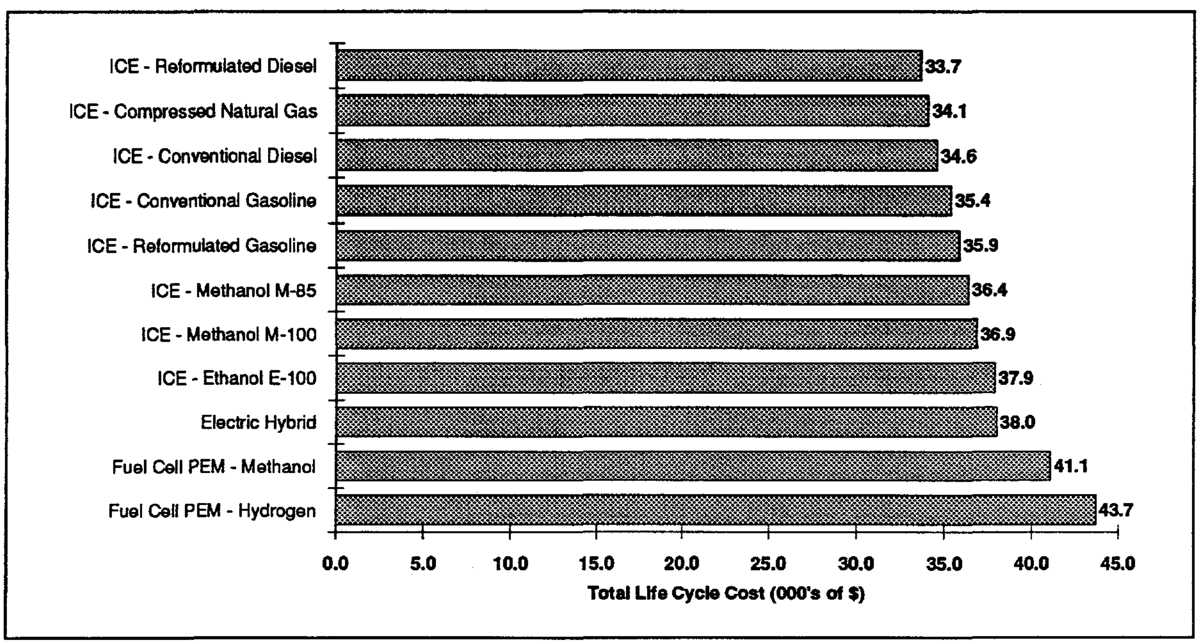
The user can obtain this case result and associated details by selecting the RESTORE DEFAULTS bar on the spreadsheet speedbar, selecting the CHOOSE VEHICLE bar, and then selecting the appropriate descriptions on the two dialogue boxes which are offered for this purpose.

Fourteen cases were analyzed as part of this stage of Model development. The Model input and output screens for each case are presented in Appendix D.

Results

The results for the Reference Vehicles and Default Assumptions of the Model in terms of the rank order listing are shown in Figure ES.1. All of the ICE cases, and the Reference Electric Vehicle, are within plus or minus 10 percent of the ICE - (Reformulated or Conventional) Gasoline current technology case. Since it is doubtful that advanced technology estimates are accurate within plus or minus 10 percent, this is equivalent to saying that there is no clear basis on which to judge the actual relative merits of those developmental concepts which are within this error band.

Figure ES.1: Initial Rank Order



For the Fuel Cell PEM Vehicles, which are outside the 10 percent range, it is understood that these concepts are still in the early stages of development, as compared to the Alternative - Fuel ICE Vehicle. Accordingly it should be noted that the differential life cycle cost of some $6,000 - $8,000 (relative to the ICE - gasoline cases) is only about a 20 percent premium. A cost reduction of this magnitude, as the result of successful R&D, is a credible target.

Sensitivity Analysis

The sensitivity analysis showed how the Model can be used for decisionmaking purposes. For example, a sensitivity test for avoided costs considered as an integral set, examines how rankings change if all of the established penalties (including the energy import premium) were twice their default values. Rather than all eleven vehicle/fuel types, one focuses for simplicity on five: conventional gasoline, compressed natural gas, ethanol, electric and the hydrogen fuel cell. These results are presented in Table ES.3.

Table ES.3: Comparative Life Cycle Costs Data (Relative Values)

	Life Cycle Ranking (Capital Excluded)		
Vehicle Type/Fuel	No Emission Penalties	Default Avoided Costs	Double Default Values
ICE - Conventional Gasoline	1	3	3-4
ICE - Compressed Natural Gas	3	2	2
ICE - Ethanol E-100	4	4	3-4
Electric	2	1	1
Fuel Cell PEM - Hydrogen	5	5	5

In this example, natural gas and electric vehicles appear superior to conventional gasoline when default values of avoided costs are considered. Hence, the inclusion of avoided costs leads to a significant result. Next, when the value of these costs are doubled, conventional gasoline vehicles appear even worse. However, much larger (and therefore not highly credible) changes in avoided costs would be needed before the cleanest fuels (biofuel ethanol and hydrogen) would appear economically competitive with either natural gas or electric fuels, even though these latter concepts do indeed release some undesirable emissions.

This sensitivity test reinforces the earlier conclusion that selected major R&D targets for the cleaner fuel concepts are associated with reducing the cost of fuel for ethanol, and reducing both the fuel cost and component weight and/or capital cost for the hydrogen fuel cell.

CONCLUDING REMARKS

The Model has the capability to explore a variety of comparative policy issues relating to costs, benefits and R&D targets. Additional features can readily be incorporated to examine still other questions and issues.

For example, in order to facilitate user control and conduct sensitivity studies of other-than-default fuel costs, an entry for a factor by which to multiply such default values was created on the Other Inputs dialog box.

The use of Embedded Data Sets which the user may overwrite (thus providing for easy updating of the Model), and the open architecture of the system (thus providing for future representation of any subarea in additional detail without having to modify other parts of the Model) should allow the Model to retain both currency and validity over time. The Embedded Data Sets should be routinely updated for this purpose. The current values of the Embedded Data Sets are shown in Appendix C.

The life cycle cost sensitivity analysis has identified various key elements for comparative analysis. These should now be modeled and examined in greater detail. Future versions could also incorporate representations of the R&D process (steps, cost and time) estimated to be required to achieve the target performance and cost objectives. The inclusion of probability features would enhance the ability to explore the value of alternative funding levels for the various R&D targets. The benefit information in the Model is for a single vehicle lifetime. This information needs to be combined with penetration curves to evaluate absolute benefits and to allow the calculation of benefit/cost ratios for R&D programs.

1.0 INTRODUCTION

This report augments the development and testing of the Life Cycle Cost (LCC) Model previously accomplished by Engineering Systems Management, Inc. (ESM) on behalf of the U.S. Department of Energy (DOE) under Contract No. DE-AC02-91CH10491. The preliminary results of the LCC Model concluded that incorporation of environmental costs (associated with the vehicle propulsion systems' air emissions resulting from the fuel combustion) have a major impact on the relative economic ranking of alternative vehicle propulsion systems. In addition, the timing of the HR-776 - The Energy Policy Act of 1992, Section 2026, had mandated DOE to look into the feasibility of utilization of hydrogen-fueled fuel cell/battery propulsion systems for vehicle applications. As a result, the present work, under Contract No. DE-AC02-93CE50212, was undertaken to focus upon the following:

- Expand the analysis of the environmental component emissions allocations, basis of cost assignments, time relative impacts of technology and regulatory development, and sensitivities to the LCC results for all vehicle classes;
- Perform LCC analysis of hydrogen-fueled proton exchange membrane (PEM) fuel cell/battery-powered cars and vans;
- Validate and refine the LCC Model to the point that outputs can sustain peer review and be used for decisionmaking purposes.

The work reported herein expands the capabilities of the Alternative Transportation Systems Life Cycle Cost Model which was developed in a preliminary form earlier. The Model incorporates specific analytical relationships and cost/performance data relevant to internal combustion engine (ICE) powered vehicles, battery powered electric vehicles (BPEVs), and fuel cell/battery-powered electric vehicles (FCEVs). The Model is structured around twelve integrated modules as shown in the diagram below.

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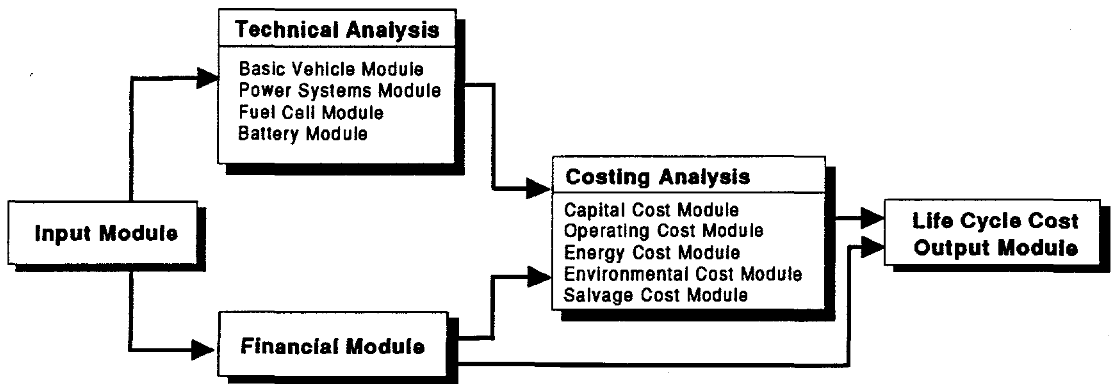

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The specific emissions included in the original Model, as a life cycle cost element, were nitrogen oxides (NO_x), hydrocarbons (HC) and carbon monoxide (CO). The costing and inclusion of these externalities in the life cycle analysis indicated that they could have monetary significance on a par with other life cycle elements for purpose of comparative evaluation of alternative systems. Accordingly, the present work expanded and further refined this LCC-oriented environmental analysis by survey of the literature and selection of additional emissions factors for inclusion in the Model. The selected additions to CO, NO_x, and HC were:

- Greenhouse Gases (GHGs), in terms of carbon dioxide (CO_2) equivalence;
- Sulfur Dioxide (SO_2);
- Particulate Matter (PM); and
- Toxics, including aldehydes, and the benzene, toluene and xylene (BTX) class of aromatics.

The present work incorporates the above-mentioned additional emission constituents and allocates them associated externalities costs as a function of avoidance costs. The concept of avoided cost is used to estimate the cost of controlling or avoiding the emissions in order to minimize or prevent damage.

The life cycle cost data for buses and heavy duty vehicle class was found to be sparse, incomplete and sometimes in conflict in the literature reviewed. At other times, the emissions data for this vehicle class did not appear to possess sufficient level of cross-detail or depth necessary to support selection of data points for the Model. As a result, the present life cycle cost analysis includes only cars and vans and not buses.

The Final Report is organized into the following sections. Section 1.0, Introduction, highlights the background of the present study and focuses on various issues addressed in this report. Section 2.0 contains detailed documentation of the expanded environmental analyses of the upgraded Life Cycle Cost Model, including a description of the methodology used for selecting additional emission cases and associated externalities costs. Section 3.0 discusses pertinent characteristics of the Life Cycle Cost Model for hydrogen proton exchange membrane fuel cell/battery-powered vehicles and performs a detailed life cycle cost analysis for both cars and vans. Section 4.0 describes the new operational features of the upgraded Model, including expanded fuel cycle emission data and value/cost assignments. This section also addresses user-friendly features of the Model. Section 5.0 provides cost analysis for various reference car and van cases under varying monetary, environmental and other parameters. Section 6 provides the results of sensitivity analysis/impact assessments for pertinent reference vehicle cases. Finally, Section 7.0 provides some concluding remarks that can be drawn from the analyses of the case esults conducted. A functional copy of the LCC Model is included on diskette (Appendix F).

1.1 General Approach

ESM conducted a comprehensive literature search of work done by government and private sectors in this area, since the completion of the prior work in November 1992. This search generated over 120 studies which were carefully reviewed and evaluated against the backdrop of present scope of work. After a systematic evaluation, a total of 34 studies were selected to be used for the present effort (Appendix A). Each study was carefully reviewed and analyzed to reflect incorporation of pertinent relevant information through the:

- Conduct of environmental analysis by analyzing the completeness as well as comparability of environmental costs. This included formulation of basis for cost assignment of various emissions and other environmental impacts including the development of reasonable uncertainty ranges for each impact measured. This took into account the impact of time on relative values and ranges for these impact, including changes in technology (e.g., increased energy efficiency, enhanced emissions control systems, etc.), changes in environmental standards (arising from the existing environmental regulatory legislation, such as Clean Air Act Amendments of 1990), and changes in fuel supply.

- Conduct of LCC analysis for hydrogen-fueled PEMFC/Battery-powered vehicles by performing a detailed review and analysis of existing data on peripheral, cost, performance, and emission characteristics of cars and vans with initial emphasis on the fuel storage systems. This was done for the purpose of modifying the LCC Model to include hydrogen-fueled vehicles analysis capabilities.

The existing Life Cycle Cost Model was upgraded, refined and developed for continuous updatings, as desirable, to be used as an effective policy tool in the decisionmaking processes. To demonstrate the new LCC Models capabilities, 14 vehicle class/propulsion system configuration cases were evaluated for this work and are reported in Section 5.0 (case runs are contained in Appendix D. A sensitivity analysis was performed with the results are presented in Section 6.0.

For the benefit of the reader, a bibliographical listing of the literature used for the earlier study is provided in Appendix B.

1.2 Interim Reports

During the course of the present work effort, three interim reports were generated and submitted to DOE as a part of the contractual requirements These included:

- Expanded Environmental Analysis for the Alternative Transportation Systems Life Cycle Cost Model, Interim Report Task 1 (Submitted May 31, 1994).

- Analysis of Hydrogen-Fueled PEMFC/Battery-Powered Vehicles using the Alternative Transportation Systems Life Cycle Cost Model: Interim Report: Task 2 (Submitted June 30, 1994).

- Upgraded Life Cycle Cost Model for Alternative Transportation Systems, Interim Report - Task 3 (Submitted August 31, 1994).

The present report incorporates, in abstract, the results of the three above-mentioned interim reports and discusses results of additional information and data generated since.

2.0 EXPANDED ENVIRONMENTAL ANALYSIS OF THE ALTERNATIVE TRANSPORTATION SYSTEM LIFE CYCLE COST MODEL

2.1 Methodology for Selection of Additional Emission Cases

The LCC Model developed earlier by ESM, Inc. for DOE (Reference 1) incorporated quantitative estimates of transportation fuel cycle emissions and their costs as part of total system costs over the life cycle of the cars, vans, and buses. The specific emissions included nitrogen oxides (NO_x), hydrocarbons (HC), and carbon monoxide (CO). The costing and the inclusion of these externalities in the life cycle analysis indicated that they could have monetary significance on a par with other life cycle elements for purposes of comparative evaluation of alternative systems.

The emissions incorporated into the initial version of the LCC (Reference 1) were selected for their significance as smog precursors (NO_x and HC) and deleterious health effects (CO). In addition, the DOE had proposed specific economic values to be assigned to these externalities.

In preparation for the conduct of the expanded scope of environmental analysis of the LCC Model, a survey of the extensive literature on transportation systems cross-technology comparisons indicated that a more complete set of emissions characterizations was needed to fully assess comparative environmental impacts. The set of emissions characterizations would have to consist of the following:

- Greenhouse gases which include methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O), volatile organic compounds (VOC), and chlorofluorocarbons (CFC) from automotive air conditioning systems;
- Acid rain precursors, primarily sulphur oxides (SO_x) and nitrogen oxides (NO_x);
- Other gases or volatile compounds generating deleterious health effects, such as formaldehyde (and other aldehydes), methanol, and carbon monoxide (CO);
- Solid emissions generating deleterious health effects, such as Respirable Suspended Particulates (particularly those below 10 microns in size) which embed themselves in the lungs; and
- Toxic compounds such as benzene, toluene, and xylene (BTX).

Some of the above compounds can be classified into more than one category. For example, some VOCs (also delineated as Reactive Organic Gases - ROG or Hydrocarbons - HC or Non-Methane Organic Compounds - NMOC) may be seen as greenhouse gases, smog precursors, toxic chemicals, and/or compounds generating less severe but still deleterious health effects. Some of these compounds are products of combustion, others of evaporative losses associated with fuel volatility.

2.1.1 Greenhouse Gases

Greenhouse gases (GHG) are included as a set because of their significance to President's Global Climate Change initiatives, the possible high costs of mitigation, the large fraction of such emissions from the transportation sector, the significant differences in these emissions among transportation alternatives, and the substantial number of recent studies available which provide good summary comparative data.

The impact of CFCs within this set was considered and then excluded from further consideration because they are being phased out over time, and because their impact does not necessarily differ as a function of vehicle fuel source.

The main GHG is CO_2. Some 25 percent of U.S. CO_2 emissions are generated from motor vehicles, and the importance of this source is increasing as the number of motor vehicles as well as vehicle miles traveled increases annually (Reference 2). While CO_2 will contribute about half of future global warming, the other GHGs, taken together, are of equal significance (Reference 3). Accordingly, it deems useful to analyze the full set, and express the emissions results in terms of metric tons of CO_2 equivalent (using the respective radiation forcing of the other gases to normalize them to the CO_2 equivalent basis).

In terms of the respective sources of the GHGs from automotive use (across both the full fuel cycle and vehicle manufacture), some 72 percent come from tail pipe emissions, 18 percent from the remainder of the fuel cycle, and 10 percent from the manufacturing process (Reference 4).

Table 2.1 presents the greenhouse emission data selected for use in the LCC Model from References 3 and 4.

2.1.2 Nitrogen Oxide, Carbon Monoxide, and Sulfur Oxides

Nitrogen oxide, carbon monoxide, and hydrocarbons continue to be included, as before, but now with updated data. Motor vehicles contribute more than half the CO, almost one-third of the NO_x, and more than one-quarter of the HC in the U.S. air emissions (Reference 5). Hydrocarbon emissions are presented in Section 2.1.5. Sulfur oxides are included for completeness as an acid precursor and because data is readily available, although it is of lesser significance as compared to other emissions. The following values (units in grams/kilometer) were selected:

Table 2.1: Greenhouse Gas Emission Data

Vehicle and Fuel (Source)	Greenhouse Gas Emissions Equivalent/Kilometer (Grams of CO_2 Equivalent/Kilometer) Full Cycle Plus[4]	Full Fuel Cycle[3]	Tail Pipe[3]
Light Duty Internal Combustion Engine (ICE)			
Gasoline	260		
Reformulated Gasoline (RFG)	263	307	209
Diesel	210		
Compressed Natural Gas (CNG)	231	264	168
Methanol (NG)	250	303	173
Methanol (Wood)	84		
Ethanol (Corn)	260		
Ethanol (Wood)	82	82	32
H_2 (Nuclear)	77		
Electric (U.S.)	244	317	

- For light duty vehicles using gasoline, the choice was Reference 19 as follows: CO at 1.4, NO_x at 0.22, and SO_2 at zero.

- For light duty vehicles using reformulated gasoline, the values were selected from Reference 6 as follows: CO at 3.8, NO_x at 0.28 and SO_2 at 0.035, all in grams per kilometer.

- For light duty vehicles using CNG, the choice was Reference 7 with CO at 0.08, NO_x at 0.36 and SO_2 at zero.

- For light duty vehicles using ethanol, the choice was Reference 8 with CO at 1.06, NO_x at 0.12, and SO_2 at 0.002.

- For light duty vehicles using M85 and neat methanol, the preference was to select Reference 9 for methanol 100, and to obtain the result for M85 by calculating a mathematical blend. This approach produced CO at 1.06, NO_x at 0.38 and SO_2 at zero for neat methanol; and CO at 1.47, NO_x at 0.365 and SO_2 at 0.005 for M85.

- Only single data points from Reference 34 were found for light duty vehicles using M85 (CO at 0.08, NO_x at 0.48) and H_2 (CO at 0.06, NO_x at 0.41) and light duty electric vehicles (Reference 6) using the U.S. average (CO at 0.04, NO_x at 0.12, and SO_2 at 0.15). The data appeared reasonable in light of the other relevant information.

- For light duty diesels, the values from Reference 10 for diesel (CO at 0.47, NO_x at 1.26) and biodiesel (CO at 0.13 and NO_x at 1.22) fuels also appear to be in line with the other data available.

- Data on vans and heavy duty vehicles was both quite variable, limited in coverage, and not clearly related to comparable information on the other vehicles. Accordingly, it did not appear appropriate to use it to derive inputs for the LCC Model.

2.1.3 Particulate Matter

Particulate Matter (PM) was included because of the seriousness of the health effects involved, the existence of real differences in emission levels across technologies, the potential high cost of control, and the likelihood that standards in this area would be tightened in the future. A study presented to the American Lung Associated in 1991 targeted PM as responsible for 60,000 deaths for that year in the United States (more people than are killed in traffic accidents) (Reference 11). A 1993 update of this study substantiated a 26 percent difference in mortality in cities with high and low PM exposure, and suggested the need for tightened standards (Reference 12).

The American Lung Association is active in pressing for change, and notes that 146 million Americans (more than 60 percent of the U.S. population) live in non-attainment areas for air quality generally, where populations are at risk to adverse health effects (Reference 13). PMs and other automobile emissions are particular targets because they are emitted at street level, and directly penetrate the lungs.

Data selected for PM_{10} for light duty ICE vehicles was as follows: Reformulated gasoline (0.01 gms/km) (Reference 6); methanol (0.01 gms/km) (Reference 6); and CNG (0.01 gms/brake HP Hour) (Reference 12). For light duty electric vehicles, the value selected was U.S. average of 0.025 gms/km (Reference 6). For light duty diesel vehicles, a value of 0.26 gms/brake HP hour (Reference 10) was used for biodiesel a value of 0.19 gms HP Hour was used (Reference 10). For heavy duty vehicle internal combustion engines, PM_{10} emissions can be reasonably represented at 0.02 for CNG (References 14 and 16) and 0.04 for methanol (References 9, 14, 15, and 16), both values expressed in grams per brake horsepower hour. For heavy duty diesels, a value of 0.57 for diesel fuel (References 3, 15, and 16) and a mid-range value of 0.15 for methanol (References 9 and 14) appeared appropriate, both values expressed in grams per brake horsepower hour.

2.1.4 Toxics (Including Hydrocarbons)

Toxics were included as a category because of their significant health threats and the potentially high cost of control. Benzene and formaldehyde are listed as two of the five most serious toxic chemicals in the air, as approximately 85 percent of air-borne benzene comes directly from motor fuel (Reference 17). There is no safe level of exposure to carcinogens such as benzene, and the Environmental Protection Agency has documented substantial relative increases in exposure that are transportation related (e.g., large cities versus rural areas, and car interiors in the California South Coast) (Reference 17). Increased formaldehyde exposure is, of course, linked to increased reliance on methanol as an alternative fuel. While reformulated gasoline will produce cleaner burning fuels, the benzene, toluene, and xylene (BTX) class of aromatic compounds are produced during combustion, and their generation can likely be avoided only by switching away from gasoline as a fuel (Reference 17). Separate accounting is maintained for the Toxics category for BTX-type emissions and for aldehydes.

- For light duty vehicles, the data on non-methane organic compound (NMOC) emissions in Reference 18 for gasoline (0.44 - 0.66 gms/km) and RFG (0.40 gms/km) appeared sufficiently representative, and had the benefit of coming from a single source. The approximate mid-range values of 0.045 gms/km for the BTX fraction and 0.003 gms/km for aldehydes fraction also appeared to be reasonable.

- For light duty vehicles using CNG, the values in Reference 14, with NMOC at 0.12 gms/km, BTX at zero, and aldehydes at a midrange .0065 gms/km were selected.

- For light duty vehicles using ethanol, the selections were NMOC at 0.24 gms/km, BTX at 0.009 gms/km, and aldehydes at 0.018 gms/km (References 9, 18, and 19).

- For light duty vehicles using methanol and M85, the selections were based on Reference 14 for methanol with NMOC at 0.58, BTX at 0.01, aldehydes at 0.0080 and vaporized methanol at a midrange of 0.71; and results for M85 to be obtained by mathematical averaging with gasoline, giving NMOC at 0.56, BTX at 0.015, aldehydes at 0.007 and vaporized methanol at 0.60. All units are in gms/km.

- References 6 and 10 provided single data point coverage (0.05 gms/km) of light duty fuel cell (methanol), electric (0.02 gms/km) (U.S. Average), diesel (0.13 gms/km) and biodiesel (0.03 gms/km).

2.2 Cost Basis for Externalities, Associated Unit Costs for Emission Avoidance, and Other Considerations

2.2.1 Cost Basis for Externalities and Associated Unit Costs

The approach used in the LCC analysis is to value externalities using an **avoided cost** methodology. The primary alternative is to use estimates of damage.

The concept of avoided cost attempts to estimate the cost of controlling or avoiding the emissions in order to minimize or prevent any damage. This is particularly appropriate in cases where there may be multiple sources, and where mitigation strategies may find that costs are different in terms of dealing with one source as compared to another. In addition, if economic nationality prevails, costs incurred (actually or potentially) to avoid should always be less than the threatened damage (otherwise it costs more to avoid than it does to accept the damage).

Dealing with avoided costs to value externalities also has the benefit of relating to real expenditures that are otherwise scheduled or required to be made. Savings are therefore intended to be real rather than hypothetical.

The social judgements necessary to define the degree and extent of avoidance are typically made through the regulatory process, and are therefore determined by public policy, not by the analyst.

Avoided cost to evaluate externalities has become increasingly common in recent years, particularly in the electric utility industry. Quantitative procedures, similar to those discussed subsequently in this study, are in use in California, Massachusetts, Missouri, Nevada, New Jersey, New York, and Wisconsin (Reference 20).

One key consideration, often overlooked in seeking to quantify avoided costs, is that the benefit earned by avoidance is typically greater than the average cost of avoidance. For example, if the concentration of a pollutant in the air is in excess of a desired standard, the policy actions to reduce its emission, given that a variety of sources may exist, will proceed from least costly to most costly. The average cost over this regime will be greater than the cost of the initial steps but lower than the cost of the final, most expensive, steps. Therefore, if the emission is avoided rather than removed, the value of the avoidance action is the savings of the final steps in the sequence of removal actions, not the average step.

Because of the interrelationship between degree of cleanup required, and the cost of the final cleanup steps, the appropriate avoided cost is a direct function of the tightness of the standard. The more extensive the cleanup required, the higher will be the costs of the final stage of that cleanup.

The two factors discussed above, namely that avoided costs are not appropriately estimated as average costs, and are direct functions of the standards to be achieved as well. The current degree of non-conformance to such standards, complicate their estimation. By these definitions, avoided costs for a given pollutant can readily differ from one region of the country to another, as well as between rural and urban areas. Nevertheless, the use of this approach still appears as the most objective technique available to quantify in economic terms those important differences in externalities associated with different technologies and fuels.

2.2.1.1 Greenhouse Gases

The relationships between carbon taxes, as an economic forcing function, and greenhouse gas reductions have been extensively modeled. The results of these studies are selected as the best currently available basis by which to derive an avoided cost estimate for greenhouse gases. One such study by Jorgensen and Wilcoxen (reported in Reference 21) calculated a tax stabilizing at $60 per ton carbon to reduce U.S. CO_2 emissions to 80 percent of 1990 levels and maintain them there indefinitely. Another study (by the Congressional Budget Office (Reference 22)) used a value of $100 per ton C. Reference 23 identifies this latter figure as a possible upper limit because renewable resources would likely be fully economically competitive at this level of carbon tax. Also, in testimony before public utility commission (Reference 22), externality values for CO_2 emissions as high as $300 per ton CO_2 ($82 per ton C) have been proposed. The National Conference on Environmental Externalities recommended a value of $50 per ton C for power plant emissions as an externality measure (Reference 24). Based on these and related data points, the value of $60 per ton C (or about $16 per ton CO_2) was selected.

2.2.1.2 Nitrogen Oxides, Carbon Monoxide, and Sulfur Oxides

DOE has previously used an avoided cost value of $300 per ton NO_x (Reference 25). Other estimates including those by the Gas Research Institute (GRI) vary between $200-2,000 (Reference 26), public utility commission's testimony supporting values of $3,250-6,770 (Reference 20) and from the California South Coast Air Quality District of over $25,000 (Reference 20). Accordingly, based on the regulatory studies, a lower mid-range value of $5,000 per ton NO_x was selected.

Similarly for CO, the value in use by DOE is $300 per ton (Reference 25). However, estimates by others include $500-1,000 by the GRI (Reference 26), and $820-870 by witnesses in public utility commission hearings (Reference 20). Accordingly, the approximately mid-range value of $850 per ton CO from the latter reference was selected.

The approach for valuation of SO_2 considers both regulatory testimony and the emissions trading market values derived from recent auctions of SO_2 emissions rights in accordance with the Clean

Air Act of 1990. Monetized control costs for SO_2 in regulatory testimony have been proposed at $1560-1910 generally and up to $19,000 for the California South Coast (Reference 20). An independent GRI estimate ranges from $350-1800 (Reference 26). On the other hand, trading allowances reported by the Energy Information Administration (Reference 27) were bid at prices up to $310 for use in the year 2000, whereas offers on the 1995 spot market were at a high of 1900, and on the year 2000 advance market of $449. These highs are viewed as more meaningful than the lows or averages because they represent more stringent cards of need and/or value.

The experience with trading allowances suggest that the utility industry has increasing confidence that actual SO_2 mitigation costs will not be extreme. Accordingly, the year 2000 allowance high offer of (rounded) $4,450 per ton SO_2 was selected for use.

2.2.1.3 Particulate Matter

Regulatory estimates for particulate mitigation are $4,164 per ton (Reference 20), whereas the National Conference on Environmental Externalities recommends a range of $2,360-4,720 (Reference 24). Because particulate matter generated from transportation sources are potentially more harmful and difficult to mitigate, being emitted at street level, a value in the higher side of this range, $4,500 per ton PM_{10} was selected.

2.2.1.4 Toxics (Including Hydrocarbons)

The avoidance value of toxics (BTX, aldehydes and methanol vapors) was estimated based on recent actions of the EPA to reduce industrial toxic emissions (Reference 28). Some 506,000 tons per year are expected to be removed at a capital investment (estimated by EPA) of $450 million accompanied by continuing costs of $230 million annually. If the capital investment is assumed to be associated with a 20 percent capital recovery factor as an annualized cost, then annual costs would approximate $90 million plus $230 million for a total of $320 million, or a unit cost of $640 per ton toxics reduced. The same reference cites an industry estimate of $1 billion, about three times higher. Assuming that current actions will direct lowest cost remedies first, and that later additional remedies will rise in cost, the industry estimate is the preferred basis, leading to a selected value of $2,000 for the LCC Model.

The DOE has previously used an avoided cost value of $3050 per ton hydrocarbon (HC) for this type of emission (Reference 25). Regulatory testimony has placed this value at $5,500 generally, and over $18,000 in California (Reference 20). The GRI estimate ranges from $500-5,300 (Reference 26). Studies by Resources for the Future (References 29) indicate that actual abatement strategies for reduction of Volatile Organic Compounds (VOC) generated in the transportation sector range in cost from $1,650-108,000 per ton of VOC reduced, and that a currently "low-cost" strategy of accelerated vehicle retirement showed costs ranging from $4,000-5,000. The references cite views ascribed to the Environmental Protection Agency (EPA):

> "In general, EPA considers any approach that costs less than $5000 per ton of emissions reduced to be highly cost-effective; options that reduce VOCs for less than $10,000 per ton are still considered reasonable."

Accordingly, given the likelihood that higher cost regulatory actions will likely be actually implemented, and should therefore be used to establish the avoided cost credit, the value of $10,000 was selected for the LCC Model.

2.2.2 National Security Premium

The economic quantification of the impact of the higher volume of crude oil imports typically expressed by analysts as an implied add-on cost for such imports as a dollar value per barrel premium. There is little if any agreement on the appropriate magnitude of this premium (Reference 21). Annual costs associated with maintenance of defense costs and the Strategic Petroleum Reserve estimate at $50 billion. If allocated against an import level of 7 million barrels per day, this would equate to $25 per barrel imported crude. Reference 31 summarizes a variety of studies from the 1979-1988 period which have generated estimates as high as $50 per barrel. Because the oil supply cartel appears to have weakened in the last decade, rather than strengthened, the more conservative estimate of $25 per barrel is selected for the LCC Model.

In order to use this premium as an avoided costs, it is more convenient to translate it into a cents per gallon gasoline equivalent. This can be accomplished by using the data for annual crude oil and U.S. gasoline prices from Reference 32 as reproduced in Table 2.2. When this data is sorted and subjected to regression analysis, the derived relationship is that the gasoline price in dollars per gallon is equal to $0.6855 plus the crude price in dollars per barrel times 0.022. This relationship has an R-squared correlation coefficient of 0.8673, indicating a reasonably good fit. If the $25 per barrel crude oil premium is multiplied by the 0.022 coefficient derived above, then divided by 2 to reflect an import level of half the total crude oil consumption, a resulting national security premium of $0.275 per gallon of gasoline is calculated.

Table 2.2: Price Trends in Crude Oil and Unleaded Gasoline

Year	Crude Oil Domestic First Purchase Price $/bbl	U.S. City Average Retail Price for Unleaded Regular Gasoline $/gal
1979	12.64	0.90
1980	21.59	1.25
1981	31.77	1.38
1982	28.52	1.30
1983	26.19	1.24
1984	25.88	1.21
1985	24.09	1.20
1986	12.51	0.93
1987	15.40	0.95
1988	12.58	0.95
1989	15.86	1.02
1990	20.03	1.16
1991	16.54	1.14
1992	15.98	1.13

2.2.3 Data Uncertainties

Emissions data for tailpipes are functions of driving cycle (all data in this report and the LCC Model are based on the Federal Test Procedure - FTP standard), vehicle, engine, catalyst, maintenance, mileage (use), and a host of similar factors. Cumulative emissions per mile depend on these factors plus other trip and driving factors such as total vehicle mile/traveled, number of cold starts (which generate greater emissions), idling, driving at low speeds in congested traffic situations and the like. Evaporative emissions are important contributors to total vehicle use emissions and reflect climate, refueling techniques and similar factors. The same make and model year cars may display different emissions under apparently similar conditions. Differences in usage and maintenance quickly increase the variability in data.

When tailpipe and evaporative emissions are expanded to include full fuel cycles, test data are replaced by calculations of probable emissions from fuel extraction, conversion and distribution. These additions can range from modest to extensive. The greenhouse gas emissions from a conventional gasoline car may show 73 percent associated with operation of the vehicle, 18 percent with fuel supply, and 10 percent with vehicle manufacture (Reference 4). On the other hand, the fuel production source and method for ethanol can alter the total greenhouse gas emissions from 82 grams CO_2 equivalent per kilometer (wood as fuel source) to 260 (corn as fuel source) (Reference 4). Uncertainties are explicitly calculated and displayed in Reference 4. They vary by a few percent in the simplest cases to plus or minus 100 percent in more complex cases.

Returning to tailpipe emissions, even where standard test procedures are used, the data is highly variable. Since the emphasis here is on cross-comparability of fuels and technologies, more than on absolute data values, the most useful results for these purposes are those which report such comparative results as achieved by a single researcher. Otherwise, it is desirable to look to a large body of data which displays general agreement and internal consistency. In this report, the first approach was used to select values for greenhouse gas emissions, and the second to select values for the other emissions.

The variability of individual data points is well illustrated by the initial information on alternative fuel fleets (Reference 33). For a given single model year car, CO emission is grams per mile ranged from 1 to 7. Efforts to analyze the data included the generation of regression parameters (Reference 33, Appendix 5, Table A.5-1). The value of R squared for these equations show that 23 of the 29 equations have a correlation coefficient below 0.5, indicating a low level of effective correlation. It should be recalled that these fleets are being managed and tested as an important source of experimental data.

Similar variability and diversity in range is shown in the data tables presented in this report. A meaningful representation of statistical ranges of uncertainty for comparative purposes did not appear appropriate at this stage of data development.

The uncertainty in these values includes not only issues associated with cost estimation, but also issues of the degree to which mitigation measures might actually proceed, and, therefore, what activities or events should be included within the cost estimate.

Since the selected emissions and unit avoidance costs are combined to yield economic values for comparison across fuels and technologies, the application of the LCC methodology should include a strong component of sensitivity analysis. In this way, uncertainties associated with experimental data points and postulated costs can be better taken into account in the comparisons.

2.2.4 Impact of Time

The passage of time will introduce important changes in technology, pollution levels, the perceived need for action, the level of agreed-upon standards, and related costs.

Perhaps the simplest conceptual path to reduced emissions is increased efficiency. Under a recent Cooperative Research and Development Agreement, the DOE and the three major U.S. automobile companies are seeking to triple fuel efficiency in about 10 years. Of course, more efficient vehicles can be produced today, but are not being sought by purchasers. Also, the beneficial impacts of efficiency can be undone by offsetting increases in vehicle miles traveled. Further, the main possibility for reducing emissions such as greenhouse gases appears to be more in changes in fuel sources (e.g., electric vehicles drawing upon renewable power sources, or ethanol vehicles drawing upon biofuels feedstocks). Still other changes, both technological and social, could be derived from greater use of mass transit and/or increased levels of telecommunication in which personal travel is replaced by electronic linkages.

While technology development may help to make certain activities possible, the establishment of standards may be necessary to ensure that they actually occur. For this reason, California and other states which are following California's lead, are mandating that annual sales containing an increasing number of low, ultra-low, and zero emission vehicles. The Clean Air Act of 1990 mandates the use of reformulated (oxygenated) gasoline to reduce the emission levels of unburned hydrocarbons. Starting in November of 1992, minimum oxygen levels are mandated for gasoline sold in the worst winter months in the 39 carbon monoxide non-attainment cities. By 1995, RFG will be available for all ozone and CO non-attainment areas, covering about half the U.S. gasoline supply. Reformulation will also address reductions in volatility and in toxic emissions.

As standards are tightened, and mitigation steps invoked, the estimated costs of future avoidance are likely to increase. Typically this has been so because low-cost solutions become exhausted, the volume of utilization increases, offsetting gains in reductions, experience shows that actual costs have been underestimated, and standards may be proposed for further tightening.

Because standards, technology, efficiency, avoidance costs and other key variables can change over time, the LCC Model provides for the values in the Model to be overwritten by the user, thus both maintaining an up-to-date view of the current state of comparative analyses, and also providing for ease of sensitivity analysis.

For example, cumulative emissions will be impacted by the actual penetration rate of new vehicles and alternative fuels into the present fleet. The emissions associated with electric vehicles will depend what portion of the installed electric power base is actually used for recharging, and the fuels and technology applied for that generation step.

It will be desirable to explore the significance of these and other input variables with respect to the ability of LCC Model results to contribute to a review of policy options.

3.0 EXPANSION OF THE LCC MODEL FOR HYDROGEN PROTON EXCHANGE MEMBRANE FUEL CELL/BATTERY POWERED VEHICLES

3.1 Characteristics of the LCC Model for Hydrogen PEMFC/Battery Vehicles

Expansion of the Model for analysis of vehicles powered by hydrogen fueled Proton Exchange Membrane (PEM) fuel cells with onboard hydrogen storage was accomplished due to modularity of the Model architecture. The complete power system consists of three major components: the fuel cell stack and auxiliary systems (air compressor, cooling system, and water management system), the fuel storage and delivery system, and the peak-power system. Specific model modification with regard to the fuel cell and fuel storage systems are discussed in the following sections. Peak-power for the vehicles under consideration is provided by batteries. Since the power density of hydrogen fueled PEMFC system is higher than the methanol fueled PEMFC system, design fuel cell power requirements are similar for both fuel types even though the hydrogen storage system is adds weight and bulk. Likewise, the design power requirements for the peak-power battery is also similar. Therefore, no Model modification to the peak-power battery module was required.

Model modifications were required to account for the significant improvement in emissions performance characteristics. The Model currently considers emissions associated with refueling and onboard combustion, not the full fuel cycle. Model modifications were required to various cost and performance parameters, most significantly fuel and maintenance and repair costs. The Model modifications are all predicated on technology availability by the year 2000.

3.1.1 Hydrogen PEMFC Characteristics

Table 3.1 shows the PEM fuel cell characteristics added to the fuel cell options in the Model. The selections were based on recent work by Delucchi (Reference 6) that suggests hydrogen PEMFC operating to 3.4 atmospheres provides an optimal mix of system complexity and energy density. These characteristics are supported by numerous research results as being commercially available at the quoted relative price in the year 2000. Delucchi cites one researcher who believes that it should be possible to achieve a specific power of 1,300 W/kg and a power density of 1,200 W/liter for a PEM fuel cell stack operating at atmospheric pressure. Salvage value is assumed to be $960 per unit in order to be consistent with other fuel cells in the Model. These parameters integrate fully with the JPL-based design relationships in the Model (Reference 1).

Table 3.1: Hydrogen PEM Fuel Cell Characteristics @ 3.4 Atmospheres

Specific Power (W/kg)		Power Density (W/liter)		Efficiency (%)	Capital Cost (1990$)	Salvage Value (1990$)
Continuous	Peak	Continuous	Peak			
230	465	340	688	53	$180	$960

3.1.2 Onboard Hydrogen Storage Characteristics

Compressed gas storage is chosen as the onboard hydrogen fuel storage method because of its simplicity, reasonable weight and space requirements, is commercially available at reasonable cost relative to other hydrogen storage methods, is safe, and can be refueled relatively quickly. Table 3.2 lists the storage system characteristics for a 400-kilometer (km) range car. System design is based upon recent work by Delucchi (Reference 6). Carbon wrapped aluminum lined vessels with pressure at 8,000 psi yields a sufficient storage capacity for a 400-km range with reasonably compact space requirements. The boundaries of ideal gas behavior and exponential increases in vessels weight, bulk and cost relative to incremental reductions in storage volume indicate storage pressure to 8,000 psi may be a good balance of capacity, bulkiness and cost. Delucchi observes that vehicle designers could take advantage of the simplicity, reliability, long life, and strength of high pressure storage tanks by permanently integrating them into the vehicle frame structure. This would reduce the obtrusive space requirements of the system.

Table 3.2: Hydrogen Storage System Characteristics

Hydrogen fuel energy needed, full tank	0.33 million Btu
Weight of hydrogen fuel	2.47 kg
Inner capacity of storage tank	81.52 liters
Weight of storage system, including valves, regulators, flowlines, etc.	66.82 kg
Retail price of storage system	$2,692 (1990$)

These characteristics are based on consultation with industry consultants to estimate the size, weight, and OEM cost of hydrogen storage vessels. Relationships developed by Delucchi were added to the Model (Reference 6).

3.1.3 Environmental Emissions Characteristics

It is noteworthy to mention that PEM fuel cells supplied with hydrogen stored onboard produce none of the emissions components analyzed in the current Model, namely CO, NO_x, HC, GHGs, SO_2, PM and toxics. The Model only considers emissions resulting from vehicle refueling and onboard combustion/conversion. The Model was modified to generate zero emissions for hydrogen fueled PEMFCs.

3.1.4 Hydrogen Fuel Characteristics

Hydrogen gas was added to the Model as a fuel option for PEM fuel cells. Table 3.3 shows the hydrogen fuel characteristics entered into the Model. The commercialized cost used is estimated by Delucchi based on the gasoline-equivalent price per btu delivered to the vehicle (Reference 9). These prices include average federal and state taxes of $0.31 per gallon-equivalent. This gasoline-equivalent cost does not account for the efficiency with which the vehicle uses that energy. The large advantage in energy efficiency for hydrogen fueled PEM FCEVs will likely provide upward pressure on market prices, all other things equal.

Table 3.3: Hydrogen Fuel Characteristics

Volumetric density	0.023 kg/liter
Energy density	3,056 Btu/liter
Estimated commercialized retail cost	$0.78 per liter $2.97 per gallon $23.74 per million Btu

3.1.5 Maintenance and Repair Characteristics

The maintenance and repair (M&R) costs of electric vehicles (EVs) are expected to be significantly lower than ICE vehicles after some level of significant commercialization. This is due to the relative simplicity and reliability of electric drivetrains. M&R costs generally include scheduled and unscheduled maintenance to the vehicle chassis, suspension and drivetrain, but excludes tires, brakes and fluids maintenance. The literature is replete with cost analyses, some based on the actual road experience of hundreds of vehicles, concluding M&R costs for Evs 35 to 66 percent lower than comparable ICE vehicles, depending upon assumption of individual analyses. Most of the available evidence and analyses pertain to BPEVs; not FCEVs.

FCEVs will have two additional major components: a fuel cell, and a fuel storage/processing system, which consists of either a hydrogen storage system or a methanol storage tank and reformer. FCEVs also have a smaller battery system which reduces overall M&R costs even though most analyses assume batteries are relatively maintenance-free. Battery replacement costs, if battery life is less than vehicle life, is a separate operating and maintenance cost item in the Model. While M&R costs for FCEVs will be related to the complexity of the system, the hydrogen PEMFC with compressed gas fuel storage system is a relatively simple, reliable power system.

The most recent work by Delucchi (1993) conservatively estimated annual M&R costs for a 400-km range hydrogen fueled PEM FCEV of $435 (1990$) assuming a maintenance-free battery and annual PEM M&R costs of $40. This cost is 16 percent less than a comparable gasoline ICE vehicle. For this analysis, a 16% reduction in baseline gasoline ICE vehicle M&R costs was assumed. To affect this change in the Model which calculates M&R costs based on a JPL algorithm (Reference 1), a maintenance factor of 0.0037 was used for cars. For vans, maintenance costs are assumed to be proportionally higher based on the rated power. A maintenance factor of 0.0052 was used for vans.

3.2 Life Cycle Cost Analysis

LCC analyses of hydrogen PEMFC/Battery powered vehicles was run for two cases: cars and vans. These case analyses were run and are reported here for the purpose of demonstrating the functionality of the Model's expanded capability to analyze hydrogen PEMFC/battery powered vehicles, not to perform a comparative analysis. The results are validated by comparison to the case analyses performed under the prior work (Reference 1).

3.2.1 Cars

Table 3.4 presents selected characteristics of the hydrogen PEMFC/battery powered car in the analysis. The vehicle type is a five-passenger mid-size automobile. The analysis base year is 2000. Vehicle life is set at 10 years and 160,000 kilometers life cycle distance traveled. Table 3.5 presents the results of the LCC analysis for the same car.

These results compare favorable with Delucchi who has done the most comprehensive work in the LCC analysis of hydrogen FCEVs. Delucchi's most recent modeling analysis of a comparable 1,238 kg, five/six-passenger, 400-km range vehicle with a total life of 256,800 km,

Table 3.4: Characteristics of a Hydrogen PEMFC/Battery Powered Car

Vehicle range	400 km
Hydrogen storage system	Carbon wrapped aluminum tank @ 8,000 psi full charge
Fuel cell full power rating	23 Kw
Fuel cell efficiency rating	53 %
Fuel cell weight	49 kg
Battery type	Medium performance generic
Battery power rating	13 kW
Battery weight	64 kg
Vehicle curb weight	1,472 kg
Coefficient of drag	0.32
Fuel economy	31.67 km/liter 74.49 mpg-equivalent

Table 3.5: LCC Results for a Hydrogen PEMFC/Battery Powered Car

Cost Element	Life Cycle Cost	Cost per km
Total vehicle capital cost	$22,671.03	$0.1417
Hydrogen storage system capital cost	$2,692.00	$0.0168
Fuel cell capital cost	$5,965.41	$0.0373
Battery capital cost	$2,088.83	$0.0131
Total operation cost	$18,223.88	$0.1139
Total fuel cost	$3,433.29	$0.0215
Total repair & maintenance cost	$3,767.76	$0.0235
Replacement battery cost	$1,809.10	$0.0113
Environmental cost	$0.00	$0.0000
Total Life Cycle Cost	$40,219.68	$0.2514

resulted in an initial capital cost of $25,446 (a variance of +12 percent) and an LCC cost of $0.2133 per kilometer (a variance of -15%) (Reference 6). The variance in total LCC cost per kilometer would converge further if the life of this analysis vehicle were extended to approximate Delucchi's vehicle life due to the spreading of capital costs over more kilometers.

3.2.2 Vans

Table 3.6 presents selected characteristics of the hydrogen PEMFC/battery powered van in the analysis. The vehicle type is a six-passenger plus mid-size urban van. The analysis base year is 2000. Vehicle life is set at 10 years and 160,000 kilometers life cycle distance traveled. Table 3.7 presents the results of the LCC analysis for that same van.

Table 3.6: Characteristics of a Hydrogen PEMFC/Battery Powered Van

Vehicle range	400 km
Hydrogen storage system	Carbon wrapped aluminum tank @ 8,000 psi full charge
Fuel cell full power rating	31 kW
Fuel cell efficiency rating	53 %
Fuel cell weight	66 kg
Battery type	Medium performance generic
Battery power rating	17 kW
Battery weight	86 kg
Vehicle curb weight	1,816 kg
Coefficient of drag	0.47
Fuel economy	22.17 km/liter 52.14 mpg-equivalent

Table 3.7: LCC Results for a Hydrogen PEMFC/Battery-Powered Van

Cost Element	LCC Cost	Cost per km
Total vehicle capital cost	$34,307.60	$0.2144
Hydrogen storage system capital cost	$3,845.71	$0.0240
Fuel cell capital cost	$8,002.15	$0.0500
Battery capital cost	$7,625.83	$0.0477
Total operation cost	$20,944.40	$0.1309
Fuel cost	$4,904.71	$0.0307
Repair & maintenance cost	$4,607.75	$0.0288
Battery replacement cost	$2,311.61	$0.0144
Environmental cost	$0.00	$0.0000
Total Life Cycle Cost	$54,439.26	$0.3402

No directly comparable work has been identified to provide validation. However, relative to the car case, the results seem reasonable given the vehicle size and configuration differentials.

4.0 NEW OPERATIONAL FEATURES OF THE UPGRADED LIFE CYCLE COST MODEL EXPANDED FUEL CYCLE EMISSION DATA AND VALUE/COST ASSIGNMENTS

Various modifications made to the Model as previously described in Sections 2 and 3 include the following:

- Transition to Quattro Pro for Windows® in order to achieve greater flexibility in design and use;
- Complete revalidation and adjustment as required of all equations and data previously incorporated in the Model;
- Expansion and revision of included data on fuel cycle emissions;
- Expansion and revision of included data on the economic value/cost of such emissions;
- Addition of a hydrogen-fueled PEMFC/battery-powered vehicle to the set of vehicles included for analysis; and
- Addition of user-friendly dialog boxes and as a speed bar interface to facilitate case selection, data input, and Model operation.

4.1 New Operational Features of the Life Cycle Cost Model

As a first step in enhancing functionality, the program was imported from a collection of individual Excel® spreadsheets into Quattro Pro for Windows®. The Quattro Pro® format and utilities permit the user to access all of the data on the individual notebook pages more rapidly and conveniently, provide superior audit trail capabilities for error checking, and facilitate the installation of a user-friendly set of speed bar buttons and dialog boxes for Model operation.

Two files are necessary. The main spreadsheet program is labeled LIFECOST.WB1, and its associated speedbar file is labeled LIFECOST.BAR. It is only necessary to load the spreadsheet. A macro in the spreadsheet automatically loads the speedbar, as long as the latter is in the same directory as the spreadsheet file.

The transfer in file form was achieved by direct importing of the twelve original individual Excel® files in to the Quattro Pro® notebook pages. This ensured that no errors in equations or references were introduced in the transfer process. Twelve of the pages of the Quattro Pro® notebook are directly equivalent to the prior set of Excel® files. An Introduction Screen has been added to provide instructions on how to use the model. In addition, two new notebook pages were added: one to describe the hydrogen-fueled PEM fuel cell (discussed below) and the other to contain the menus and macros for the user-friendly features.

The resulting LIFECOST notebook pages and their relationship to the files of the original Model are shown as follows:

Notebook Page (Version 4)	Source
INTRO	(NEW)
BASIC VEHICLE	BASIC VEHICLE
BATTERY	BATTERY
CAPITAL	CAPITAL COST
COSTOUT	LIFE CYCLE COST
ENERGY	ENERGY
ENVIRON	ENVIRONMENTAL COST
FINANCE	FINANCIAL
FUELCELL	FUEL CELL
H2PEM	(NEW)
INPUT	INPUT
OPCOST	OPERATING COST
POWERSYS	POWER SYSTEM
SALVAGE	SALVAGE
MENUS	(NEW)

Following importation into the new format, the audit trail and error checking features of the Quattro Pro® spreadsheet program were used to trace and verify the accuracy of the equations. Original data sources were reviewed, and the correctness of the embedded data sets were also reverified. In the course of this work, some errors in equations were in fact discovered and corrected. These were principally associated with techniques for calculating present value of cash flow streams. The numerical significance of such errors was small and they did not, in any case, impact relative rankings of alternative vehicles and fuels. The current values of the Embedded Data Sets are shown in Appendix C.

Version 4.0 of the Model, as included here, has now undergone a complete review and is believed to accurately reflect all of the data sources and relationships reflected in the literature which served as a basis for its construction.

Another problem area which existed in the initial version of the Model was the reliance upon user input being obtained through the entry of information directly into cells of the spreadsheet. Not only could incorrect entries be made inadvertently by the user (or even correct information into incorrect cells), but it was also possible to make sets of inputs that were logically incompatible in terms of vehicle/system/fuel combinations.

Accordingly, the Model has now been revised to receive all normal input through sets of dialog boxes which are logically related to each other, rely on selection of options from pre-established Pick Lists, and which exclude any possibility of incompatible option elements. When the dialog box closes (after selection of elements therefrom by the user) the selected data is introduced into the appropriate spreadsheet cell by internal program commands which do not depend on the user to be performed correctly. The spreadsheet then recalculates, and the results are presented for review, both graphically and in tabular form.

Advanced users are still free to move around the spreadsheet manually to examine components of the calculation in more detail, or to alter other factors used in the calculations (equations, embedded data sets, inputs not normally expected to be modified between cases, etc.). However, the normal and routine use of the program can now be accomplished entirely through dialog boxes and the speed bar buttons which call them up as well as perform other data management functions.

The speedbar and dialog boxes can be edited from the "graph page" of the Quattro Pro® system as described in the program manual. The macros and data repositories used by the speedbar and dialog boxes appear on the MENUS notebook page. Additional equations, which translate dialog box outputs into the form needed for model input and processing, appear at the bottom (cells B70 through E90) of the INPUT page.

All information on the various pages of the Model has been color coded. Yellow shading is used to identify non-numeric inputs (e.g., text cells). Blue shading is used to identify numeric inputs which advanced users may change (e.g, embedded data sets). Green shading is used for cells which contain equations. Purple shading is used for a few cells which contain "hard-wired" data inputs as part of the equation. Changing this data requires the user to edit the equation in the cell. All such "hidden data" input points will be extracted from equations and placed into identified blue cells for the final version of the Model to be delivered with the final report of task activity.

In addition to the validation review and functionality improvements summarized above, the Model capability has been expanded in terms of new quantitative data on emissions, the economic costs of emissions (and oil imports), and the inclusion of a new alternative system, the hydrogen fueled PEMFC/battery powered vehicle.

4.2 Expanded Fuel Cycle Emissions Data and Value/Cost Assignments

The emissions incorporated into the initial version of the LCC Model, CO, NO_X, and HC are augmented in Version 4.0 of the Model with GHGs, SO_2, PM, and Toxics. This model expansion was accomplished under Task 1 and is discussed in detail in the Task 1 Interim Report entitled "Expanded Environmental Analysis For the Alternative Transportation Systems Life Cycle Cost Model." The emissions incorporated into the initial version of the Model were selected for their importance as smog precursors (NO_X and HC) and deleterious health effects (CO). A survey of the extensive literature on transportation systems cross-technology comparisons indicated that a more complete set of emission characterization to assess comparative environmental impacts would be appropriate. Based on the analysis of the available data, the following decisions were made regarding emissions to be incorporated in the LCC Model.

- Greenhouse Gases emissions are valued at \$60 per ton (or about \$16 per ton CO_2) in Version 4 of the Model.
- Nitrogen oxide, carbon monoxide and sulfur oxides. These emissions are valued at \$5,000 per ton for NO_x; \$850 per ton for CO; and \$60 per ton of SO_2.
- Particulate Matter is valued at \$4,500 per ton.

- Toxics are valued at $2,000 per ton and hydrocarbons are valued at $10,000 per ton in Version 4 of the Model.

- A calculated national security premium of $0.275 per gallon of gasoline is used in the Model.

4.3 User's Manual

The program calculates Total Life Cycle Costs for cars and vans, including the costs of capital, operations, and the economic value of emissions. All results are presented on a present value basis for a user-selected discount rate.

The program is operated by a speedbar presenting the necessary commands. Advanced users of course enter the spreadsheet to modify default values and equations directly if desired.

The speedbar button CHOOSE VEHICLE brings up a dialog box for user input. Separate Pick Lists are provided in the box to select Vehicle Type (Internal Combustion Engine - ICE, Fuel Cell Vehicle - FCV or Electric Vehicle - EV), Body Type (Car or Van), and Transmission Type (Automatic or Manual). This box must be closed using the OK button in order to bring up a second related dialog box. This second box requests additional user selections which depend upon the original Vehicle Type selected in the first dialog box.

For ICE Vehicles, the follow-on choices allow the selection of one or eight possible fuels. For FCVs the follow-on choices allow the selection of the PEM type cell fueled with either Methanol 100 (produced from renewable biomass) or Hydrogen (produced from nuclear or solar electricity). System aspects of the associated battery system and electric drive train are also selected here. For EVs, the follow-on choices allow the selection of the battery type and technology.

In all the dialog boxes, selections are made by choosing one item from each Pick List by left-clicking with a mouse. When the second dialog box in the set is closed by left-clicking on the OK Button, the spreadsheet calculates, and displays a graphical and tabular presentation of the results.

The EMISSION COSTS button allows the selection of economic parameters to describe the avoided costs of the transportation fuel cycle emissions (For Greenhouse Gases only, the emissions include those incurred in the manufacturing step as well as the transportation fuel cycle).

The OTHER INPUTS button allows other performance and cost inputs to be selected. These items would typically be modified less frequently, or for explicit sensitivity analysis. Key financial inputs (base year of the analysis, discount and inflation rates) appear in this dialog box.

The RESTORE DEFAULTS button resets all entries from the EMISSION COSTS and OTHER INPUTS dialog boxes to their default values. These preset values appear in cells K11 through K38 of the Menus notebook page of the spreadsheet, and can be changed by the user overwriting data in those cells.

The SAVE button simply saves the program to its normal directory location under the existing file name. If a separately named version is to be saved, the user must employ the Save As. . . command from the spreadsheet's main File menu.

5.0 REFERENCE CASE ANALYSIS RESULTS

The following fourteen cases were analyzed for this work:

Case 1A	Reference Car - Conventional Gasoline/Automatic Transmission
Case 1B	Reference Car - Conventional Gasoline/Manual Transmission
Case 2A	Reference Van - Conventional Gasoline/Automatic Transmission
Case 2B	Reference Van - Conventional Gasoline/Manual Transmission
Case 3A	Reference Car - Conventional Diesel/Automatic Transmission
Case 3B	Reference Car - Methanol M-100/Automatic Transmission
Case 3C	Reference Car - Ethanol E-100/Automatic Transmission
Case 3D	Reference Car - Compressed Natural Gas/Automatic Transmission
Case 3E	Reference Car - Reformulated Gasoline/Automatic Transmission
Case 3F	Reference Car - Reformulated Diesel/Automatic Transmission
Case 3G	Reference Car - Methanol Blend M-85/Automatic Transmission
Case 4A	Reference Electric Car - High Technology Lead-Acid Battery/DC Brushless Motor/Automatic Transmission
Case 5A	Reference Fuel Cell/Battery Car - Methanol M-100/PEMFC/Medium Performance Generic Battery/DC Brushless Motor/Automatic Transmission
Case 5B	Reference Fuel Cell/Battery Car - Hydrogen/PEMFC/Medium Performance Generic Battery/DC Brushless Motor/Automatic Transmission

The case run LCC Model results are presented in detail in Appendix D.

5.1 Reference Car/Van Cases with Conventional Fuel

The details of a Total Life Cycle Cost of $35,378 are shown in Table 5.1.1 for the Reference Car. This case is based on:

- Spreadsheet default values;
- Conventional ICE Engine;
- Car Body Type, and
- Automatic Transmission; using
- Conventional Gasoline.

The user can obtain this case result and associated details by selecting the RESTORE DEFAULTS bar on the spreadsheet speedbar, selecting the CHOOSE VEHICLE bar, and then selecting the appropriate descriptions on the two dialogue boxes which are offered for this purpose.

Table 5.1.2 shows the results for this same Reference Car, and compares them to the same total cost elements for a car with manual transmission, and vans with both automatic and manual transmissions. All of the cases in this table are based on spreadsheet defaults, a conventional ICE engine, and conventional gasoline fuel. Note that in this and subsequent tables, salvage costs are included in capital cost totals unless indicated otherwise.

Table 5.1.1: Total Life Cycle Costs - Reference Car

Capital Cost		**Salvage Value**	
Basic Vehicle	$11,187	Battery	-
Battery	$62	Fuel Cell	-
Motor	-	Basic Vehicle	$(100)
Engine	$1,492	Total Salvage	$(100)
Controller	-	**Total Capital, Operating, and Salvage Costs**	**$33,183**
Transmission	$188	**Emissions Cost**	
Fuel Cell	-	HC	$724
Fuel Tank	$202	CO	$531
Accessories	$2,500	NO_X	$230
Total Vehicle Capital Cost	$15,630	Particulates	$7
Operating Cost		SO_2	$3
Energy Cost		Aldehydes	$1
Electricity	-	BTX	$15
Fuel	$5,872	CO_2 Equivalent	$684
Repairs/Maintenance	$5,159	Total Emission	$2,195
Replacement			
Tires	$546		
Battery	-		
Fuel Cell	-		
Insurance	$4,785		
Garage/Park/Tolls	$663		
Title/Register/License	$627		
Total Operating Costs	$17,653	**Total Life Cycle Cost**	**$35,378**

Table 5.1.2: Total Life Cycle Costs Reference Cases - Cars and Vans Conventional Gasoline Fuel/Conventional ICE Engine

Automatic Transmission		
	Car	Van
Capital	$15,530	$18,840
Operating	$17,653	$20,140
Emissions	$2,195	$2,633
Total	$35,378	$41,613
Manual Transmission		
	Car	**Van**
Capital	$15,612	$18,951
Operating	$17,655	$20,143
Emissions	$2,195	$2,633
Total	$35,462	$41,728

The small dollar difference between automatic and manual transmission shows up primarily in the basic vehicle capital costs as a constant amount. Accordingly, all subsequent case discussions will be on automatic transmission vehicles only.

The differences between the results shown in Table 5.1.2 for the car and the van (both with automatic transmission) are associated with the following:

- The more expensive capital cost for the van arises primarily from the basic vehicle cost (i.e., weight) with smaller companion increases in the costs of battery, engine and transmission;
- The more expensive operating cost of the van arises primarily from the Repairs/Maintenance category, with smaller companion increases in the costs of tire replacement, and title, registration and licensing costs; and
- The more expensive emissions cost of the van arises in somewhat uniform increases in the values ascribed to the four major emission sources: HC, CO, NO_x and CO_2 equivalent; this appears to be a direct consequence of assumed lower efficiency in fuel utilization.

Given the standard character of the dollar value of the life cycle deviations from the Reference Car case (for vans, as well as transmissions), subsequent results and sensitivity studies reported here focus on the Reference Car.

5.2 Reference Car Case with Alternative Fuels

Table 5.2 compares results for the Reference Car utilizing different fuels. The capital costs are nearly the same in all cases (since changes in fuel tank costs are small relative to the cost of the total vehicle). Accordingly, the cases primarily reflect trade-offs in the cost of fuels (in the operations category) relative to the value of the emissions. Since reformulated diesel is assumed to be manufactured from biofuels, it avoids an oil import premium as part of the fuel cost incurred by conventional diesel and by both conventional and reformulated gasoline. The results for total life cycle costs fall within a range of less than $\pm$ 10 percent of the central Reference Car case. Accordingly, apparent differences should be viewed with considerable caution. Some suggestive areas for further exploration appear to be as follows:

- Conventional natural gas vehicles look interesting here because they display both operating and emission cost reductions; so do the diesel cases, albeit on a much more modest scale.
- E-100 biomass cuts emission costs by 60 percent; however, reductions in fuel manufacturing costs would appear to be necessary to make its use attractive;
- Methanol appears to achieve only a modest benefit in emission reduction overall, which must be offset against a significant increase in fuel costs; and
- Reformulated gasoline, with the assumptions used here, trades higher costs of manufacture for reduced emission without achieving any clear overall net benefit.

Table 5.2: Total Life Cycle Costs Reference Car with Various Fuels

Fuel	← Costs →			
	Capital	Operating	Emission	Total
Conventional Gasoline	$15,530	$17,653	$2,195	$35,378
Conventional Diesel	$15,605	$17,098	$1,922	$34,624
Methanol M-100	$15,601	$19,631	$1,641	$36,873
Ethanol E-100	$15,500	$21,523	$866	$37,889
Compressed Natural Gas	$15,911	$17,053	$1,116	$34,080
Reformulated Gasoline	$15,534	$18,242	$2,084	$35,859
Reformulated Diesel	$15,605	$16,422	$1,662	$33,689
Methanol Blend M-85	$15,606	$19,112	$1,725	$36,443

On the spreadsheet, electric vehicles can be compared using a number of variables. These include:

- Generic battery type (low, medium, or high performance) or one of ten specific battery technologies (from Aluminum-Air to Zinc-Chloride);
- An overall indication of battery technology of either high or low; and
- Three different types of motor controllers, namely alternating current, direct current brushless, and direct current brush.

5.3 Reference Electric Car Case

Since the primary purpose of the current work is to examine fuel cell vehicles relative to conventional vehicles, only a single electric vehicle case is reported here; however, it is quite representative of the other electric vehicle combinations on the spreadsheet. Table 5.3 shows the complete life cycle cost results for Reference Electric Car Case with automatic transmission, using a high technology lead-acid battery with a direct current brushless motor. Emission costs include those incurred from the average U.S. electric generation mix.

Table 5.3: Total Life Cycle Costs Reference Electric Car Case

Capital Cost	
Basic Vehicle	$16,000
Other Components	$2,863
Accessories	$2,500
Salvage	$(194)
Total Capital	$21,169
Operating Cost	
Electricity	$2,771
Repairs/Maintenance	$5,066
Replacement	$1,971
Insurance	$4,785
Garage/Park/Tolls	$663
Title/Register/License	$795
Total Operating Cost	$16,051
Emissions Costs	
HC	$33
CO	$6
NO_X	$99
Particulates	-
SO_2	$11
Aldehydes/BTX	-
CO_2 Equivalent	$642
Total Emissions	$790
Total Life Cycle Cost	**$38,010**

The comparison of Tables 5.3 with 5.2 indicates that:

- Capital costs are estimated to be substantially higher than for a conventional vehicle, arising from increased cost both for the basic vehicle and for other drive train components, including the battery;
- Fuel costs for electric vehicles are lower, but battery replacement costs are higher leading, overall, to a modest reduction in operating costs;
- Emission costs are significantly reduced (below those from biofuel E-100 overall);

- A Life Cycle cost higher than for a Conventional Car, but still within 10 percent thereof.

5.4 Reference Fuel Cell/Battery Car Case

On the spreadsheet, fuel cell/battery vehicles can be compared using a number of variables. These include:

- Fuel cell type, either methanol or hydrogen fueled; proton electron membrane technology;
- Accompanying generic battery performance (high, medium or low);
- Three different types of motors and motor controllers, namely alternating current, direct current brushless, and direct current brush; and
- An overall indication of battery technology of either high or low.

In order to focus on the fuel cell type, and the factors which are technology and cost specific to that type, a Reference Fuel Cell\Battery Case is defined here which uses a medium performance battery with high technology and a direct current brushless motor. Table 5.4 shows the complete life cycle cost results for these Reference Fuel Cell vehicles, fueled with either methanol or hydrogen.

The comparison with the previous tables indicates that:

- The PEM fuel cell vehicles have the highest life cycle costs; however, most of this differential is in the other components category of the Capital Cost category, and hence should be subject to reduction through research and development; and
- The PEM fuel cell vehicles have the lowest calculated emission costs; hence, they have strong attractiveness on a long-term basis as environmentally superior vehicles; the hydrogen-fuel PEM reduced emissions (relative to the Reference Conventional Car) by more than a factor of ten.

Table 5.4: Total Life Cycle Costs PEM Reference Case Fuel Cell/Battery Cars

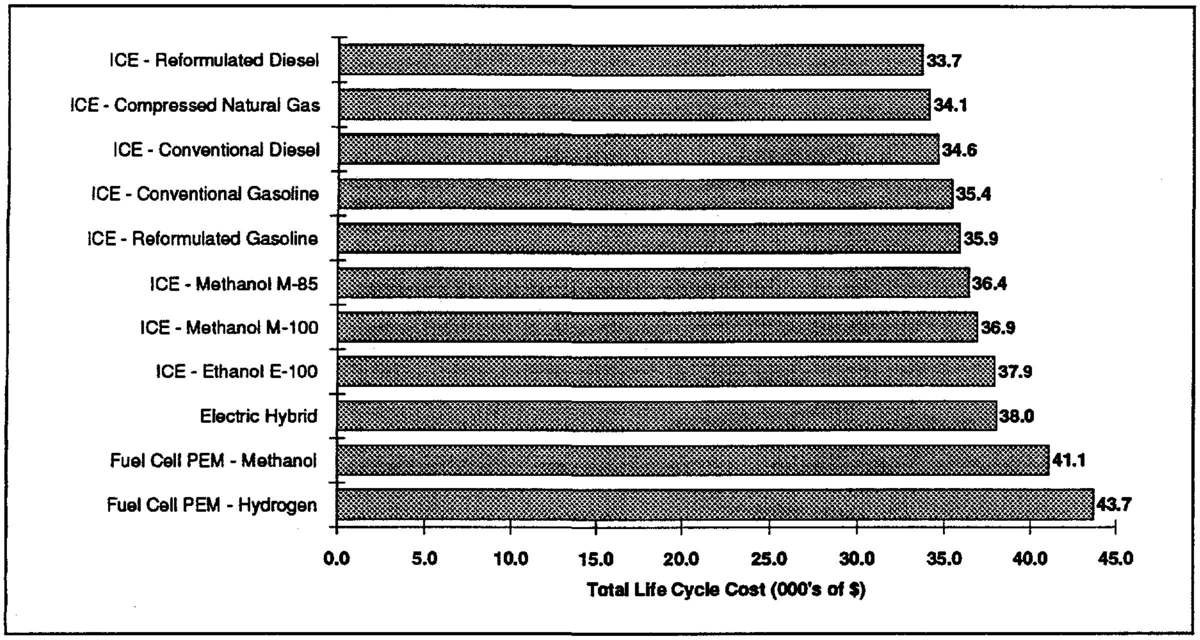
Cost Item	Fueled By	
	Methanol	Hydrogen
Capital Cost		
Basic Vehicle	$11,141	$12,324
Other Components	$9,439	$11,341
Accessories	$2,500	$2,500
Salvage	$(946)	$(525)
Total Capital	$22,134	$25,640
Operating Cost		
Fuel	$2,917	$6,763
Repairs/Maintenance	$7,050	$2,812
Replacement	$1,946	$1,946
Insurance	$4,789	$4,785
Garage/Park/Tolls	$663	$663
Title/Register/License	$845	$935
Total Operating	$18,207	$17,906
Emissions Cost		
HC	$82	-
CO	$11	-
NO_X	$394	-
Particulates	-	-
SO_2	-	-
Aldehydes/BTX	$6	-
CO_2 Equivalent	$221	$203
Total Emissions	$715	$203
Total Life Cycle Cost	**$41,056**	**$43,748**

6.0 SENSITIVITY ANALYSIS/IMPACT ASSESSMENT

6.1 Initial Rank Order of Case Results

The results of the previous section may be summarized for the Reference Vehicles and Default Assumptions of the Model in terms of the initial rank order listing shown in Figure 6.1.

Figure 6.1: Initial Rank Order Listing



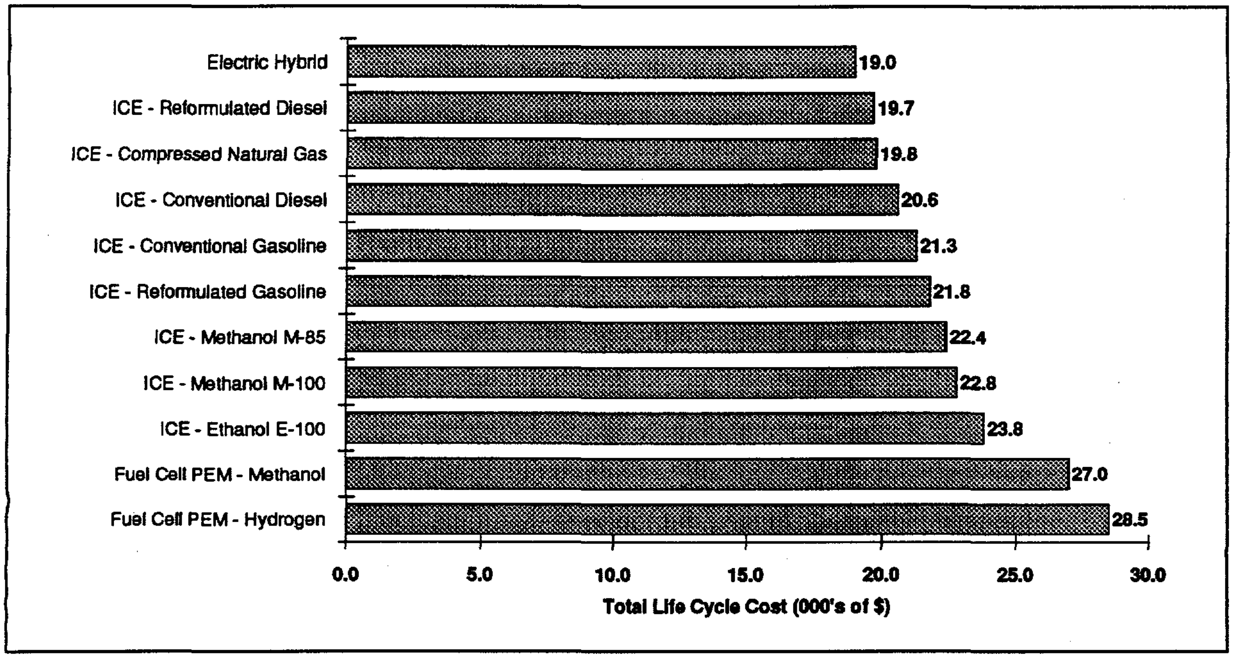
Thus, all of the ICE cases, and the Reference Electric Vehicle, are within plus or minus 10 percent of the ICE - (Reformulated or Conventional) Gasoline current technology case. Since it is doubtful that advanced technology estimates are accurate within plus or minus 10 percent, this is equivalent to saying that there is no clear basis on which to judge the actual relative merits of those developmental concepts which are within this error band.

For the Fuel Cell PEM Vehicles, which are outside the 10 percent range, it is understood that these concepts are still in the early stages of development, as compared to the Alternative - Fuel ICE Vehicle. Accordingly it should be noted that the differential life cycle cost of some \$6,000 - \$8,000 (relative to the ICE - gasoline cases) is only about a 20 percent premium. A cost reduction of this magnitude, as the result of successful R&D, is a credible target.

6.2 Result of Capital Cost Exclusions

It just might be asked as to how rankings would be changed if the major components of the capital cost were excluded from the comparison. In terms of Model operation, this means that the Other Inputs dialog box is brought up, and the entries therein for Base Vehicle Cost and Accessories Cost are set to zero. Retaining other default assumptions, we obtain the revised rank order listing for Life Cycle Cost as shown in Figure 6.2.

Figure 6.2: Revised Rank Order Listing



Thus, electric vehicles move from ranking order ninth on Figure 6.1 to ranking order first in Figure 6.2. All other rank orders remain the same. The dollar differential for Fuel Cell vehicles relative to the ICE remains the same as previously, but is therefore a larger percentage of the costs which are being counted. The size of the premium, however, is still within the range of being a credible R&D target.

The indication that the rank ordering of the electric vehicle concept may be highly dependent on vehicle weight (since the cost component depends on that weight times the Base Vehicle Cost in $/kilogram which we have set to zero for this sensitivity study) suggests that reduction of weight, and component complexity which may contribute to capital cost, should be one key target of electric vehicle R&D.

6.3 Energy Security Premium

As indicated previously, the default energy security premium for imported oil is set at $25 per barrel of crude oil. If this premium is set to zero, it makes the Reference ICE (Conventional Gasoline) case lower in cost. Specifically, the Life Cycle Cost (retaining the capital cost exclusion) then falls from 21.3 to 20.1 thousands of dollars. Conversely, if the premium is raised to $100 per barrel, the life cycle cost increases to 24.9 thousands of dollars. In the former case, the Compressed Natural Gas vehicle is still of higher rank than the gasoline vehicle; hence, the inclusion of a moderate energy security premium has relatively little impact on ranking. However, a significantly stronger level of concern about imports and domestic jobs will make all non-import-dependent ICE vehicles appear more attractive than petroleum-based ICEs.

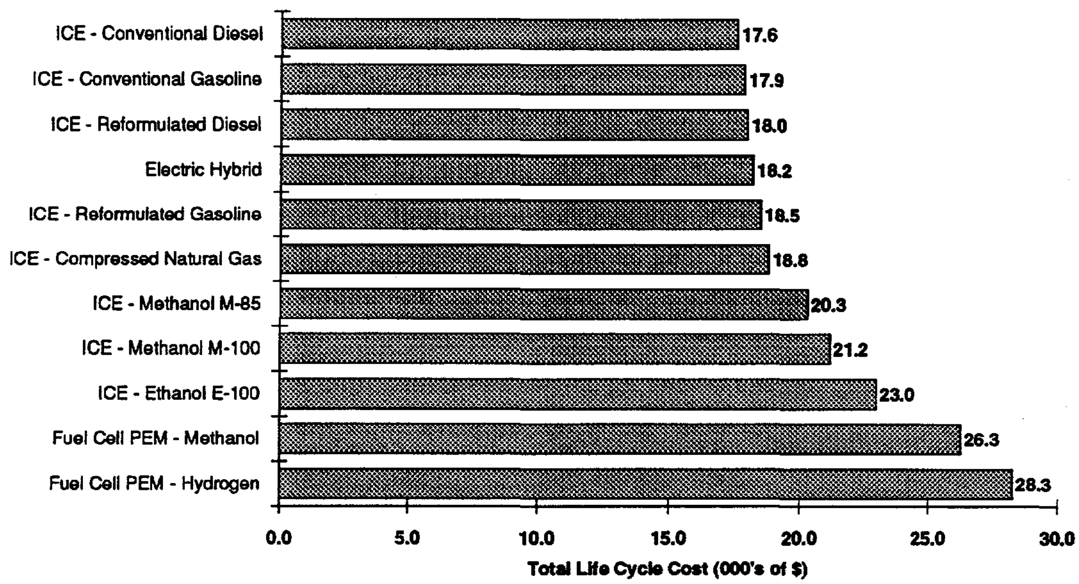
6.4 Total Environmental Emissions

If, in addition to the capital cost exclusion and a zero energy security premium, zero avoided costs for all environmental emissions are imposed, is it easier to focus essentially on other operating costs (including fuel costs) as the basis for comparison. The resulting rank ordering is shown is Figure 6.3.

The relatively lower life cycle cost for conventional and reformulated gasoline in this listing clearly illustrates that the conceptual benefits associated with pursuing higher capital or fuel costs for alternative fuel vehicles are associated with emission reductions from conventional fuel cycles which can offset such higher expenditures.

Of particular interest in the above listing is the fact that compressed natural gas and electric hybrid vehicles appear to be within 10 percent of the cost of conventional fuel vehicles, insofar as operating costs are concerned. This suggests that further reductions in emissions associated with these concepts would significantly add to their attractiveness. Unfortunately the fuels generating the lowest emission levels (biomass-based ethanol and hydrogen) show high fuel production and operating costs which undermine the economic value of their relative cleanliness.

Figure 6.3 Rank Order Listing with Additional Parameters



This consideration again identifies a significant R&D target, if development pathways for fuel cost reduction can be defined.

The focus on emission reductions and resulting avoided cost is further validated from this data by noting that, for conventional gasoline ICEs, the default value of the energy security premium is $1.2 thousands in life cycle cost (refer to section 6.3 and the difference between $21.3 and 20.1 thousands), whereas the differential for deletion of all environmental emissions is $2.2 thousands ($20.1 less the value of $17.9 thousands shown in the rank listing above in this section 6.4). Hence, the default avoided emissions costs have close to twice the value of the energy security premium.

As a final sensitivity test for avoided costs considered as an integral set, one examines how rankings may change if all of the penalties (including the energy import premium) were twice their default values. It could be accomplished by retaining the capital exclusion so that these new results may be compared with the data already presented in sections 6.2 and earlier in this section 6.4. Rather than all eleven vehicle/fuel types, one focuses for simplicity on five: conventional gasoline, compressed natural gas, ethanol, electric and the hydrogen fuel cell. The comparative life cycle costs in thousands of dollars are presented in Table 6.1.

Table 6.1 Comparative Life Cycle Costs Data (Absolute Values)

Vehicle Type/Fuel	Life Cycle Cost (000's of $) (Capital Excluded)		
	No Emission Penalties	Default Avoided Costs	Double Default Values
ICE - Gasoline	17.9	21.8	24.7
ICE - Natural Gas	18.8	19.8	21.0
ICE - Ethanol	23.0	23.8	24.7
Electric	18.2	19.0	19.8
Fuel Cell - H_2	28.3	28.5	28.7

By retabulating these results, and entering the relative rankings of the five concepts for each of the three assumptions about the value of avoided costs, the results are shown in Table 6.2

Table 6.2 Comparative Life Cycle Costs Data (Relative Values)

Vehicle Type/Fuel	Life Cycle Ranking (Capital Excluded)		
	No Emission Penalties	Default Avoided Costs	Double Default Values
ICE - Gasoline	1	3	3-4
ICE - Natural Gas	3	2	2
ICE - Ethanol	4	4	3-4
Electric	2	1	1
Fuel Cell - H_2	5	5	5

As noted earlier, natural gas and electric vehicles appear superior to conventional gasoline when default values of avoided costs are considered. Hence, the inclusion of avoided costs leads to a significant result. Next, when the value of these costs are doubled, conventional gasoline vehicles appear even worse. However, much larger (and therefore not highly credible) changes in avoided costs would be needed before the cleanest fuels (biofuel ethanol and hydrogen) would appear economically competitive with either natural gas or electric fuels, even though these latter concepts do indeed release some undesirable emissions.

This sensitivity test reinforces the earlier conclusion that selected major R&D targets for the cleaner fuel concepts are associated with reducing the cost of fuel for ethanol, and reducing both the fuel cost and component weight and/or capital cost for the hydrogen fuel cell.

6.5 Fuel Costs

Returning now to a base condition of default avoided costs, and retaining the capital exclusion, one examines the significance of doubling fuel costs for gasoline, electricity and/or natural gas on the one hand, and/or halving the fuel cost for ethanol and/or hydrogen on the other hand. These results, expressed as life cycle costs, are shown in Table 6.3.

Table 6.3 Life Cycle Costs Altered Values

Vehicle Type/Fuel	Life Cycle Cost (000's of $) (Capital Excluded)		
	Halved Fuel Cost	**Default Fuel Cost**	**Doubled Fuel Cost**
ICE - Gasoline	18.4	21.8	27.2
ICE - Natural Gas	17.2	19.8	25.1
ICE - Ethanol	19.0	23.8	33.6
Electric	17.6	19.0	21.7
Fuel Cell - H_2	25.1	28.5	35.3

Under the stated assumptions, Table 6.3 reveals the following:

- Even if hydrogen fuel costs are halved, they do not make the fuel cell concept economically equivalent unless other fuel costs are significantly increased (or, in the case of natural gas, doubled);
- After electric costs have doubled, the electric concept is still viable at default conditions;
- Doubling natural gas costs disadvantages this concept more than doubling electric costs;
- Doubling conventional gasoline costs nearly makes the hydrogen fuel cell viable under its default conditions; and

- Halving ethanol costs puts this concept in a tie for first place with electric, relative to the default fuel cost assumptions; in general, ethanol's relative position is the most sensitive to fuel cost.

6.6 Specific Emission Types

Obviously, each alternative fuel vehicle concept achieves a different level and type of emission reduction. One can inquire whether or not a credible revision of avoided cost values might radically alter the relative ranking of the concepts.

To simplify the analysis three groupings of emissions are used as follows:

- Greenhouse gases, expressed as CO_2 equivalent, and designated as GHG;
- Non-hydrocarbon chemicals, consisting of NO_x and SO_2, and designated as NHC; and
- All other contaminants, consisting of HC, CO, particulates, aldehydes and BTX, and designated as AOC.

The dollar values associated with avoided costs for these groupings, for the five illustrative vehicle type/fuel concepts, are shown in Table 6.4.

Table 6.4 Avoided Cost Comparative Values

Vehicle Type/Fuel	Avoided Cost Component of Life Cycle Cost (000's of $)			
	GHG	NHC	AOC	Total
ICE - Gasoline	0.68	0.23	1.28	2.19
ICE - Natural Gas	0.61	0.30	0.21	1.21
ICE - Ethanol	0.22	0.10	0.55	0.87
Electric	0.64	0.11	0.04	0.79
Fuel Cell - H_2	0.20	--	--	0.20

By inspection, and relative to gasoline:

- Natural gas generates a major decrease in the AOC category; so does electric, but the latter also significantly reduces the NHC component as well;

- Ethanol from biofuel generates a major decrease in the GHG category, and also halves NHC; the hydrogen fuel cell also displays similar GHG benefits, but then goes on to reduce NHC and AOC emissions to zero.

From the standpoint of economic impacts:

- If the NHC component is undervalued, it could prove to be as significant an economic determinant as GHG; in such circumstances, biofuels and electric alternatives would appear much more attractive than natural gas;

- If the GHG component is undervalued, the most important technology concepts could prove to be biofuels and fuel cell; and

- If the AOC is undervalued, the most important technology concepts could prove to be electric and fuel cells.

Thus, while natural gas systems may have the best near-term potential (because they combine immediate pollution reduction with reasonable capital, fuel and other operating expenses), the more critical longer-term technologies appear to be found in the diverse set of the electric, biofuels and fuel cell concepts.

In order to aid the acquisition of sustained R&D funding so that technical and cost issues can be addressed, it may be useful to target some R&D funds at obtaining a much better understanding of avoided cost penalties, so as to assess better the key aspects of relative benefit associated with each of the three most interesting competitors.

Obviously, it would also appear desirable to analyze better the likelihood that the needed weight/capital/performance/fuel cost etc. R&D targets can actually be achieved for each of the concepts, including a probabilistic estimate of the time and cost necessary to achieve these results with reasonable certainty.

7.0 CONCLUDING REMARKS

The discussions in the preceding sections illustrate the capability which resides in the Model to explore a variety of comparative policy issues relating to costs, benefits and R&D targets. Additional features can readily be incorporated to examine still other questions and issues.

For example, in order to facilitate user control and conduct sensitivity studies of other-than-default fuel costs, an entry for a factor by which to multiply such default values was created on the Other Inputs dialog box. This box reports its entry into cell J38 of the MENUS page. A default value of 1 was placed in cell K38. The default range was extended to K38 to include that new cell by invoking the Block Names Create dialog box from the main Quattro Pro menu, clicking on the listed DEFAULT range, and editing the range definition in the window provided for this purpose. The clarifying text used to label the fuel cost multiplier was added to the Other Inputs dialog box by going to the Quattro Pro graph page and editing Dialog 6 (the system name for the Other Inputs dialog box) which resides on that page. Finally, the variable factor by which fuel cost is to be multiplied was introduced into the equation for fuel cost (in $ per liter) which appears on the ENERGY page in cell B5. This equation now includes the factor which is reported from the Other Inputs entry system into cell J38 of the MENUS page. Pressing the Restore Defaults button on the Speed Bar resets this factor to one.

Similar processes can be used to incorporate additional areas of user control. Three "reserved" (unused) entry boxes in the Other Inputs dialog box have been left available for this purpose.

The use of Embedded Data Sets which the user may overwrite (thus providing for easy updating of the Model), and the open architecture of the system (thus providing for future representation of any subarea in additional detail without having to modify other parts of the Model) should allow the Model to retain both currency and validity over time. The Embedded Data Sets should be routinely updated for this purpose. The current values of the Embedded Data Sets are shown in Appendix C.

The life cycle cost sensitivity analysis has identified various key elements for comparative analysis. These should now be modeled and examined in greater detail. Future versions could also incorporate representations of the R&D process (steps, cost and time) estimated to be required to achieve the target performance and cost objectives. The inclusion of probability features would enhance the ability to explore the value of alternative funding levels for the various R&D targets. The benefit information in the Model is for a single vehicle lifetime. This information needs to be combined with penetration curves to evaluate absolute benefits and to allow the calculation of benefit/cost ratios for R&D programs.

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APPENDIX C - EMBEDDED DATA SETS

The Model contains the following sixteen (16) Embedded Data Sets:

EDS 1 - Consumer Price Index

EDS 2 - Vehicle Curb Weight

EDS 3 - Electric Drive Systems

EDS 4 - ICE Drive Systems

EDS 5 - Fuel Cell Performance & Cost Factors

EDS 6 - Battery Performance & Cost Factors

EDS 7 - Power System Maintenance Factors

EDS 8 - Vehicle Maintenance Factors

EDS 9 - Insurance Factors

EDS 10 - Emissions Cost

EDS 11 - Emissions Allocation

EDS 12 - Fuel Prices

EDS 13 - Import Premium

EDS 14 - Hydrogen Storage Systems

EDS 15 - Hydrogen Fuel Cost

EDS 16 - Performance of Hydrogen PEM Fuel Cells

EDS 1 is contained in the Finance Module (Model page FINANCE).

EDS 1- Consumer Price Indices

Year	CPI('82=1)	New Vehicles (1982-84=100)	Motor Fuel (1982-84=100)	Maintenance & Repair (1982-84=100)	Insurance (1982-84=100)
1980	0.82	88.50	97.40	81.50	82.00
1981	0.91	91.57	98.07	89.20	85.90
1982	0.97	96.88	98.73	96.00	91.40
1983	1.00	99.90	99.40	100.30	100.40
1984	1.04	102.60	97.40	103.80	108.20
1985	1.08	106.10	98.70	106.80	119.20
1986	1.10	110.60	77.10	110.30	135.00
1987	1.14	114.40	80.20	114.80	146.20
1988	1.18	116.50	80.90	119.70	156.60
1989	1.24	119.20	88.50	124.90	166.60
1990	1.31	121.40	101.20	130.10	177.90
1991	1.36	126.60	105.54	135.67	185.52
1992	1.41	130.69	108.94	140.05	191.51
1993	1.46	135.43	112.89	145.13	198.45
1994	1.51	140.26	116.92	150.31	205.53
1995	1.56	144.90	120.79	155.28	212.34
1996	1.61	149.92	124.97	160.66	219.69
1997	1.68	155.58	129.69	166.73	227.99
1998	1.74	161.53	134.65	173.10	236.70
1999	1.81	168.03	140.07	180.07	246.23
2000	1.89	175.09	145.95	187.63	256.57

Note: Data beyond 1990 is based on CPI projection from DOE/EIA.

EDS 2 is contained in the Basic Vehicle Module (Model page BASICVEH).

EDS 2 - Vehicle Curb Weight

		Curb Weight (kg) Battery Perfromance Category		
Type	Name	Low	Medium	High
1	Conventional Auto	1,178	NA	NA
2				
3	Conventional Van	1,461	NA	NA
4	Electric Auto	1,700	1,600	1,500
5	Electric Van	1,800	1,700	1,600
6	Fuel Cell/Battery Auto	1,656	1,548	1,472
7				
8	Fuel Cell/Battery Van	2,070	1,921	1,816

EDS 3 is contained in the Power Systems Module (Model page POWERSYS).

EDS 3 - Electric Drive Systems

Type	Name	Motor Cost Factor	Controller Cost Factor	Data Vintage
0	None	0	0	1982
1	AC	19	45	1982
2	DC Brushless	26.5	90	1982
3	DC Brush	79	62.5	1982

EDS 4 is contained in the Power Systems Module (Model page POWERSYS).

EDS 4 - ICE Drive Systems

Type	Name	Engine Cost Factor	Data Vintage
0	None	0	1982
1	Gasoline	360	1982
2	Diesel	390	1982

EDS 5 is contained in the Fuel Cell Module (Model page FUELCELL).

EDS 5 - Fuel Cell Performance & Cost Factors

Type	Name	Specific Power Continuous (W/kg)	Peak (W/kg)	Power Density Continuous (W/l)	Peak (W/l)	Efficiency (%)	Cost ($/kW)	Salvage Value ($/unit)	Data Vintage NA
0									
1	Phosphoric Acid	91	250	59	179	45%	$250	$960	1987
2	PEM - Methanol	100	300	98	200	55%	$165	$960	1987
3	PEM - Hydrogen	230	465	340	688	53%	$180	$480	1990

EDS 6 is contained in the Battery Module (Model page BATTERY).

EDS 6 - Battery Performance & Cost Factors

Type	Name	Specific Energy (Wh/kg) Low	High	Specific Power (W/kg) Low	High	Efficiency (%)	Cycle Life	A ($/kWh)	B ($/kW)	C ($)	Salvage Value ($/kWh) (1982 $)	Relative Maintenance Factor*	Data Vintage
A	Low Performance	38	45	80	100	70%	800	$50	$0	$0	$1.85	2.00	1985
B	Medium Performance	80	100	150	200	75%	600	$150	$0	$0	$2.03	1.00	1990
C	High Performance	200	200	400	400	80%	1000	$100	$0	$0	$1.35	1.00	1990
1	Aluminum-Air	158	158	157	157	18%	5000	$0	$42	$0	$0.00	4.50	1982
2	Bipolar	45	56	275	400	85%	750	$72	$0	$0	$1.85	1.00	1985
3	Iron-Air	55	100	102	146	50%	500	$91	$0	$0	$0.00	4.00	1985
4	Lead-Acid	38	45	80	100	70%	800	$50	$0	$0	$1.85	2.00	1985
5	Lithium-Iron	72	102	90	107	60%	750	$91	$0	$0	$2.23	2.50	1985
6	Nickel-Iron	48	56	75	110	58%	1500	$125	$0	$0	$7.31	2.50	1985
7	Nickel-Zinc	60	60	155	155	70%	600	$64	$0	$0	$11.41	1.50	1985
8	Sodium-Sulfur	75	130	130	210	80%	750	$91	$0	$0	$0.00	4.50	1985
9	Zinc-Bromine	40	75	52	94	60%	600	$75	$0	$0	$2.23	4.00	1985
10	Zinc-Chlorine	42	75	80	115	48%	1250	$75	$0	$0	$0.00	4.00	1985

EDS 7 is contained in the Operating Cost Module (Model page OPCOST).

EDS 7 - Power System Maintenance Factors

Data Vintage		1982
Type	Power System	Factor
1	ICE	1.675
2	Fuel Cell/Battery	2.250
3	Battery EV	1.750

EDS 8 is contained in the Operating Cost Module (Model page OPCOST).

EDS 8 - Vehicle Maintenance Factors

Data Vintage			1982
Type	Type of Vehicle	Vehicle Factors	
1	Conventional Auto	0.0123	78.67
2	Conventional Bus	0.0200	150.00
3	Conventional Van	0.0191	81.73
4	Electric Auto	0.0114	81.73
5	Electric Van	0.0114	81.73
6	Fuel Cell/Battery Auto	0.0037	90.00
7	Fuel Cell/Battery Bus	0.0060	160.00
8	Fuel Cell/Battery Van	0.0057	85.00

EDS 9 is contained in the Operating Cost Module (Model page OPCOST).

EDS 9 - Insurance Factors

Data Vintage Passengers		1982 Passenger Factors
2	748	243
4	748	243
5	919	256
6	748	243
10+ (Buses)	1500	260

EDS 10 is contained in the Environmental Cost Module (Model page ENVIRO).

EDS 10 - Emissions Cost

		1990 ($ per ton)	Year
Hydrocarbons (HC)		$10,000	1990
Carbon Monoxide (CO)		$850	1990
Nitrogen Oxides (NOx)		$5,000	1990

EDS 10 - Emissions Cost (continued)

	[$ per unit]				
	Partic	**SO2**	**Aldehyde**	**BTX**	**CO2 EQ**
Unit	TON	TON	TON	TON	TON
Value	4500	450	2000	2000	16
Year	**1990**	**1990**	**1990**	**1990**	**1990**

EDS 11 is contained in the Environmental Cost Module (Model page ENVIRO).

EDS 11 - Emissions Allocation

Fuel Type	Vehicle	NMOC (gm per km)	CO (gm per km)	NOx (gm per km)
1	Gasoline ICE	0.440	3.800	0.280
2	Diesel	0.130	0.470	1.260
3	Methanol ICE (M100)	0.580	1.060	0.380
4	Ethanol (E100) ICE	0.240	1.060	0.120
5	Methane (CNG) ICE	0.120	0.080	0.360
6	Gasoline ICE 2003 Limit	0.400	3.420	0.280
7	Reformulated diesel	0.030	0.130	1.220
8	M85 ICE	0.559	1.471	0.365
9	Fuel Cell/Hydrogen	0.000	0.000	0.000
10	1992 Limit	0.156	2.125	0.250
11	Fuel Cell/Methanol	0.050	0.080	0.480
12	Electric	0.020	0.040	0.120

EDS 11 - Emissions Allocation (continued)

Fuel Type	Partic [Gm per Km]	SO2 [Gm per Km]	Aldehyde [Gm per Km]	BTX [Gm per Km]	CO2 EQ [Gm per Km]
1	0.0100	0.0350	0.0030	0.0450	260
2	0.0733	0.0000	0.0000	0.0000	210
3	0.0000	0.0000	0.0080	0.0100	84
4	0.0000	0.0020	0.0180	0.0090	82
5	0.0028	0.0000	0.0065	0.0000	231
6	0.0100	0.0350	0.0030	0.0450	263
7	0.0536	0.0000	0.0000	0.0000	210
8	0.0015	0.0053	0.0073	0.0153	111
9	0.0000	0.0000	0.0000	0.0000	77
10					
11	0.0000	0.0000	0.0080	0.0100	84
12	0.0000	0.1500	0.0000	0.0000	244

EDS 12 is contained in the Energy Cost Module (Model page ENERGY).

EDS 12 - Fuel Prices

Type		Volumetric Density kg/l	Energy Density BTU/l	Energy Equivalent $/l	$/gal	Estimated Commercialized $/l	$/gal	Data Year Basis
1	Gasoline	0.737	30,154	$0.28	$1.34	$0.35	$1.34	1990
2	Diesel	0.827	34,188	$0.29	$1.38	$0.36	$1.38	1990
3	Methanol (M100)	0.791	14,943	$0.14	$0.53	$0.23	$0.89	1990
4	Ethanol (E100)	0.791	19,992	$0.19	$0.71	$0.39	$1.48	1990
5	Methane (CNG)*	0.161	6,526	$0.06	$0.23	$0.07	$0.26	1990
6	Reformulated Gasoline	0.731	29,824	$0.28	$1.33	$0.39	$1.46	1990
7	Reformulated Diesel	0.827	34,188	$0.29	$1.10	$0.32	$1.20	1990
8	M85	0.783	17,225	$0.16	$0.61	$0.25	$0.96	1990
9	Hydrogen @ 8000 psi	0.023	3,056	$0.03	$0.11	$0.78	$2.97	2000

* @ 3000 psig

EDS 13 is contained in the Energy Cost Module (Model page ENERGY).

EDS 13 - Import Premium

Import Premium	
$0.275	$/GAL

EDS 14 is contained in the Hydrogen PEM Module (Model page HEPEM).

EDS 14 - Hydrogen Storage Systems

Type	Description	Onboard System Energy Density (mJ/liter)	(mJ/kg)	Cost-OEM ($/gJ)	($/mmBtu)	Refuel Time (minutes)
1	H-Power Iron Oxidation/Reduction	5.8	5.0	500		?
2	Carbon-wrapped Aluminum Cylinder (8,000 ps	3.4	7.0	4000	$8,976	3-5
3	Liquid Hydrogen	5.0	15.0	1000-2000		5+
4	Cryoadsorption	2.1	6.3	2000-4000		5
5	Thermocooled Pressure Vessel	2.5	8.2	4000+		5+
6	FeTi Metal Hydride	2-4	1-2	3300-5500		20-30
7	Organic Liquid Hydride	0.5	1.0	?		6-10

Ref 52: Delucchi, Table 3, p. 59.

EDS 15 is contained in the Hydrogen PEM Module (Model page HEPEM).

EDS 15 - Hydrogen Fuel Cost in 2000

	$/mmBtu	$/Gal
Retail Price - 400-km range	$23.74	$2.97
Retail Price - 250-km range	$23.74	$3.04
Gasoline		$1.18

Ref 52: Delucchi, Table 8a and 8c, p. 73-75.

EDS 16 is contained in the Hydrogen PEM Module (Model page HEPEM).

EDS 16 - Performance of Hydrogen PEM Fuel Cells

	Specific Power W/kg Continuous	Peak	Power Density W/l Continuous	Peak	Efficiency (%)	Cost 1990$ ($/Kw)	Salvage Value ($/unit)
PEM @ 3.4 atm pressure	230	465	340	688	53.26%	$180	$960

APPENDIX D - REFERENCE CASE ANALYSIS RESULTS

The following fourteen cases were analyzed for this work:

Case 1A	Reference Car - Conventional Gasoline/Automatic Transmission
Case 1B	Reference Car - Conventional Gasoline/Manual Transmission
Case 2A	Reference Van - Conventional Gasoline/Automatic Transmission
Case 2B	Reference Van - Conventional Gasoline/Manual Transmission
Case 3A	Reference Car - Conventional Diesel/Automatic Transmission
Case 3B	Reference Car - Methanol M-100/Automatic Transmission
Case 3C	Reference Car - Ethanol E-100/Automatic Transmission
Case 3D	Reference Car - Compressed Natural Gas/Automatic Transmission
Case 3E	Reference Car - Reformulated Gasoline/Automatic Transmission
Case 3F	Reference Car - Reformulated Diesel/Automatic Transmission
Case 3G	Reference Car - Methanol Blend M-85/Automatic Transmission
Case 4A	Reference Electric Car - High Technology Lead-Acid Battery/DC Brushless Motor/Automatic Transmission
Case 5A	Reference Fuel Cell/Battery Car - Methanol M-100/PEMFC/Medium Perfromance Genreic Battery/DC Brushless Motor/Automatic Transmission
Case 5B	Reference Fuel Cell/Battery Car - Hydrogen/PEMFC/Medium Perfromance Genreic Battery/DC Brushless Motor/Automatic Transmission

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 1 **Option:** A

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	Conventional Auto	1-8
Power System	1	ICE	1-3
Type of ICE	1	Spark Ignition	0-2
Type of Fuel Cell	0	None	0-2
Type of Fuel	1	Conventional Gasoline	0-8
Type of Battery Propulsion	0	None	0,A-C:1-10
Type of Motor/Controller	0	None	0-3
Type of Transmission	1	Automatic	1-2
Status of Technology	Low	Low	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,314	Gradability (%)	7
Curb Weight (kg)	1,178	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	895	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	30.00
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	Spark Ignition	**Conventional Gasoline**	
Engine Power (kW)	30.00	Fuel Cost ($/l)	$0.38
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$50	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	67	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	None
Fuel Cell:	None	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	None
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	Automatic
Battery:	None	Peak Power (kW)	30.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	0	Weight (kg)	35
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	74

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary

1992

Case Number:	1	Option:	A
Conventional Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Conventional Gasoline	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,187	$11,186.92	$0.0699
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,492	$1,491.89	$0.0093
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,630	$15,630.27	$0.0977

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$5,872	$678.04	$0.0367
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$627	$72.39	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$17,653	$2,038.24	$0.1103

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($100)	$0.00	($0.0006)
Total Salvage Value	($100)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$33,183	$17,668.52	$0.2074

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$724	$83.54	$0.0045
Carbon Monoxide (CO)	$531	$61.33	$0.0033
Nitrogen Oxides (NOx)	$230	$26.57	$0.0014
Particulates	$7	$0.85	$0.0000
Sulfur Dioxide	$3	$0.30	$0.0000
Aldehydes	$1	$0.11	$0.0000
BTX	$15	$1.71	$0.0001
Carbon Dioxide equivalent - full cycle	$684	$78.98	$0.0043
Total Emission Cost	$2,195	$253.39	$0.01

TOTAL LIFE CYCLE COST	$35,378	$17,921.91	$0.2211

Life Cycle Cash Flow Analysis

1992

Conventional Auto		ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate: 0.045
Case Number:	1	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate: 0.080
Option	A	Fuel:	Conventional Gasoline	Distance:	160,000 kilometers	Present Value Discount Rate 0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,186.92	$11,186.92										$11,186.92
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,491.89	$1,491.89										$1,491.89
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$201.72	$201.72										$201.72
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$15,630.27	$15,630.27	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,630.27
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$5,872.40	$678.04	$708.55	$740.44	$773.76	$808.58	$844.96	$882.99	$922.72	$964.24	$1,007.63	$8,331.92
	Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.36	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$626.95	$72.39	$75.65	$79.05	$82.61	$86.33	$90.21	$94.27	$98.51	$102.95	$107.58	$889.54
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$17,652.86	$2,038.24	$2,129.97	$2,225.81	$2,325.98	$2,430.64	$2,540.02	$2,654.32	$2,773.77	$2,898.59	$3,029.02	$25,046.37
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($99.80)										($199.50)	($199.50)
	Total Salvage Value	($99.80)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($199.50)	($199.50)
Total Operating & Capital Cost		$33,183.34	$17,668.52	$2,129.97	$2,225.81	$2,325.98	$2,430.64	$2,540.02	$2,654.32	$2,773.77	$2,898.59	$2,829.53	$40,477.15
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$723.51	$83.54	$87.30	$91.23	$95.33	$99.62	$104.10	$108.79	$113.68	$118.80	$124.15	$1,026.54
	Carbon Monoxide (CO)	$531.13	$61.33	$64.08	$66.97	$69.98	$73.13	$76.42	$79.86	$83.45	$87.21	$91.13	$753.58
	Nitrogen Oxides (NOx)	$230.11	$26.57	$27.76	$29.01	$30.32	$31.68	$33.11	$34.60	$36.16	$37.78	$39.48	$326.48
	Particulates	$7.40	$0.85	$0.89	$0.93	$0.97	$1.02	$1.06	$1.11	$1.16	$1.22	$1.27	$10.50
	Sulfur Dioxide	$2.59	$0.30	$0.31	$0.33	$0.34	$0.36	$0.37	$0.39	$0.41	$0.43	$0.44	$3.67
	Aldehydes	$0.99	$0.11	$0.12	$0.12	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$1.40
	BTX	$14.80	$1.71	$1.79	$1.87	$1.95	$2.04	$2.13	$2.23	$2.33	$2.43	$2.54	$21.00
	Carbon Dioxide Equivalent GHGs	$684.05	$78.98	$82.54	$86.25	$90.13	$94.19	$98.43	$102.86	$107.48	$112.32	$117.37	$970.55
	Total Emission Cost	$2,194.57	$253.39	$264.79	$276.71	$289.16	$302.17	$315.77	$329.98	$344.83	$360.35	$376.56	$3,113.72
TOTAL LIFE CYCLE COST		$35,377.91	$17,921.91	$2,394.76	$2,502.52	$2,615.14	$2,732.82	$2,855.79	$2,984.30	$3,118.60	$3,258.94	$3,206.09	$43,590.87

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 1 **Option:** B

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	**Conventional Auto**	1-8
Power System	1	**ICE**	1-3
Type of ICE	1	**Spark Ignition**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	1	**Conventional Gasoline**	0-8
Type of Battery Propulsion	0	**None**	0,A-C:1-10
Type of Motor/Controller	0	**None**	0-3
Type of Transmission	2	**Manual**	1-2
Status of Technology	Low	**Low**	Low/High

Vehicle Physical Characteristics		**Vehicle Performance Characteristics**	
Conventional Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,314	Gradability (%)	7
Curb Weight (kg)	1,178	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	902	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	30.00
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		**Energy Source**	
ICE:	**Spark Ignition**	**Conventional Gasoline**	
Engine Power (kW)	30.00	Fuel Cost ($/l)	$0.38
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$50	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	67	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	**None**	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Manual**
Battery:	**None**	Peak Power (kW)	30.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	1.06
Energy Capacity (kWh)	0	Weight (kg)	28
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	74

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary

1992

Case Number:	1	Option:	B
Conventional Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Conventional Gasoline	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,269	$11,269.18	$0.0704
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,492	$1,491.89	$0.0093
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,713	$15,712.54	$0.0982

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$5,872	$678.04	$0.0367
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$629	$72.67	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$17,655	$2,038.52	$0.1103

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($101)	$0.00	($0.0006)
Total Salvage Value	($101)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$33,267	$17,751.06	$0.2079

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$724	$83.54	$0.0045
Carbon Monoxide (CO)	$531	$61.33	$0.0033
Nitrogen Oxides (NOx)	$230	$26.57	$0.0014
Particulates	$7	$0.85	$0.0000
Sulfur Dioxide	$3	$0.30	$0.0000
Aldehydes	$1	$0.11	$0.0000
BTX	$15	$1.71	$0.0001
Carbon Dioxide equivalent - full cycle	$684	$78.98	$0.0043
Total Emission Cost	$2,195	$253.39	$0.01

TOTAL LIFE CYCLE COST	$35,462	$18,004.45	$0.2216

Life Cycle Cost Summary

1992

Conventional Auto		ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Case Number:	1	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option	B	Fuel:	Conventional Gasoline	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,269.18	$11,269.18										$11,269.18
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,491.89	$1,491.89										$1,491.89
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$201.72	$201.72										$201.72
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$15,712.54	$15,712.54	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,712.54
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$5,872.40	$678.04	$708.55	$740.44	$773.76	$808.58	$844.96	$882.99	$922.72	$964.24	$1,007.63	$8,331.92
	Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$629.36	$72.67	$75.94	$79.35	$82.93	$86.66	$90.56	$94.63	$98.89	$103.34	$107.99	$892.95
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$17,655.27	$2,038.52	$2,130.26	$2,226.12	$2,326.29	$2,430.98	$2,540.37	$2,654.69	$2,774.15	$2,898.98	$3,029.44	$25,049.79
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($100.53)										($200.96)	($200.96)
	Total Salvage Value	($100.53)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($200.96)	($200.96)
Total Operating & Capital Cost		$33,267.27	$17,751.06	$2,130.26	$2,226.12	$2,326.29	$2,430.98	$2,540.37	$2,654.69	$2,774.15	$2,898.98	$2,828.47	$40,561.36
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$723.51	$83.54	$87.30	$91.23	$95.33	$99.62	$104.10	$108.79	$113.68	$118.80	$124.15	$1,026.54
	Carbon Monoxide (CO)	$531.13	$61.33	$64.09	$66.97	$69.98	$73.13	$76.42	$79.86	$83.45	$87.21	$91.13	$753.58
	Nitrogen Oxides (NOx)	$230.11	$26.57	$27.76	$29.01	$30.32	$31.68	$33.11	$34.60	$36.16	$37.78	$39.48	$326.48
	Particulates	$7.40	$0.85	$0.89	$0.93	$0.97	$1.02	$1.06	$1.11	$1.16	$1.22	$1.27	$10.50
	Sulfur Dioxide	$2.59	$0.30	$0.31	$0.33	$0.34	$0.36	$0.37	$0.39	$0.41	$0.43	$0.44	$3.67
	Aldehydes	$0.99	$0.11	$0.12	$0.12	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$1.40
	BTX	$14.80	$1.71	$1.79	$1.87	$1.95	$2.04	$2.13	$2.23	$2.33	$2.43	$2.54	$21.00
	Carbon Dioxide Equivalent GHGs	$684.05	$78.98	$82.54	$86.25	$90.13	$94.19	$98.43	$102.86	$107.48	$112.32	$117.37	$970.55
	Future												
	Future												
	Total Emission Cost	$2,194.57	$253.39	$264.79	$276.71	$289.16	$302.17	$315.77	$329.98	$344.83	$360.35	$376.56	$3,113.72
TOTAL LIFE CYCLE COST		$35,461.85	$18,004.45	$2,395.05	$2,502.83	$2,615.45	$2,733.15	$2,856.14	$2,984.67	$3,118.98	$3,259.33	$3,205.04	$43,675.08

LIFE CYCLE COST MODEL INPUT MODULE

Case Number:	2	**Option:**	A

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	3	**Conventional Van**	1-8
Power System	1	**ICE**	1-3
Type of ICE	1	**Spark Ignition**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	1	**Conventional Gasoline**	0-8
Type of Battery Propulsion	0	**None**	0,A-C:1-10
Type of Motor/Controller	0	**None**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	Low	**Low**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Van		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,756	Gradability (%)	7
Curb Weight (kg)	1,461	Rolling Friction Coefficient (km/km)	0.011
Base Vehicle Weight (kg)	1,141	Aerodynamic Drag Coefficient	0.470
Accessories (kg)	100	Peak Power: (kW)	40.86
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	Spark Ignition	**Conventional Gasoline**	
Engine Power (kW)	40.86	Fuel Cost ($/l)	$0.38
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$40	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	91	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	None	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	None	Peak Power (kW)	40.86
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	0	Weight (kg)	48
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	74

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	2	Option:	A
Conventional Van	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Conventional Gasoline	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$14,265	$14,264.56	$0.0892
Battery	$92	$92.38	$0.0006
Motor	$0	$0.00	$0.0000
Engine	$1,652	$1,652.14	$0.0103
Controller	$0	$0.00	$0.0000
Transmission	$256	$256.33	$0.0016
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$18,967	$18,967.14	$0.1185

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$5,872	$678.04	$0.0367
Repairs and Maintenance Cost	$7,500	$866.02	$0.0469
Replacement Cost			
Tires	$594	$68.59	$0.0037
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$725	$83.66	$0.0045
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$20,140	$2,325.40	$0.1259

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($127)	$0.00	($0.0008)
Total Salvage Value	($127)	$0.00	($0.0008)

Total Operating & Capital Cost ($)	$38,980	$21,292.54	$0.2436

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$868	$100.25	$0.0054
Carbon Monoxide (CO)	$637	$73.59	$0.0040
Nitrogen Oxides (NOx)	$276	$31.88	$0.0017
Particulates	$9	$1.03	$0.0001
Sulfur Dioxide	$3	$0.36	$0.0000
Aldehydes	$1	$0.14	$0.0000
BTX	$18	$2.05	$0.0001
Carbon Dioxide equivalent - full cycle	$821	$94.78	$0.0051
Total Emission Cost	$2,633	$304.07	$0.02

TOTAL LIFE CYCLE COST	$41,613	$21,596.61	$0.2601

Life Cycle Cash Flow Analysis
1992

Conventional Van	ICE/Fuel Cell: Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Case Number: 2	Battery: None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option A	Fuel: Conventional Gasoline	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$14,264.56	$14,264.56										$14,264.56
	Battery	$92.38	$92.38										$92.38
	Motor	$0.00	$0.00										$0.00
	Engine	$1,652.14	$1,652.14										$1,652.14
	Controller	$0.00	$0.00										$0.00
	Transmission	$256.33	$256.33										$256.33
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$201.72	$201.72										$201.72
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$18,967.14	$18,967.14	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$18,967.14
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$5,872.40	$678.04	$708.55	$740.44	$773.76	$808.58	$844.96	$882.99	$922.72	$964.24	$1,007.63	$8,331.92
	Repairs and Maintenance Cost	$7,500.41	$866.02	$904.99	$945.71	$988.27	$1,032.74	$1,079.21	$1,127.78	$1,178.53	$1,231.56	$1,286.98	$10,641.78
	Replacement Cost												
	Tires	$594.03	$68.59	$71.67	$74.90	$78.27	$81.79	$85.47	$89.32	$93.34	$97.54	$101.93	$842.82
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$724.60	$83.66	$87.43	$91.36	$95.47	$99.77	$104.26	$108.95	$113.86	$118.98	$124.33	$1,028.08
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$20,139.85	$2,325.40	$2,430.04	$2,539.39	$2,653.67	$2,773.08	$2,897.87	$3,028.27	$3,164.55	$3,306.95	$3,455.76	$28,574.98
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($127.25)										($254.38)	($254.38)
	Total Salvage Value	($127.25)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($254.38)	($254.38)
Total Operating & Capital Cost		$38,979.74	$21,292.54	$2,430.04	$2,539.39	$2,653.67	$2,773.08	$2,897.87	$3,028.27	$3,164.55	$3,306.95	$3,201.38	$47,287.74
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$868.22	$100.25	$104.76	$109.47	$114.40	$119.55	$124.93	$130.55	$136.42	$142.56	$148.98	$1,231.85
	Carbon Monoxide (CO)	$637.35	$73.59	$76.90	$80.36	$83.98	$87.76	$91.71	$95.83	$100.15	$104.65	$109.36	$904.29
	Nitrogen Oxides (NOx)	$276.13	$31.88	$33.32	$34.82	$36.38	$38.02	$39.73	$41.52	$43.39	$45.34	$47.38	$391.78
	Particulates	$8.88	$1.03	$1.07	$1.12	$1.17	$1.22	$1.28	$1.34	$1.40	$1.46	$1.52	$12.60
	Sulfur Dioxide	$3.11	$0.36	$0.37	$0.39	$0.41	$0.43	$0.45	$0.47	$0.49	$0.51	$0.53	$4.41
	Aldehydes	$1.18	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.19	$0.20	$1.68
	BTX	$17.76	$2.05	$2.14	$2.24	$2.34	$2.45	$2.56	$2.67	$2.79	$2.92	$3.05	$25.20
	Carbon Dioxide Equivalent GHGs	$820.86	$94.78	$99.04	$103.50	$108.16	$113.03	$118.11	$123.43	$128.98	$134.78	$140.85	$1,164.66
	Future												
	Future												
	Total Emission Cost	$2,633.49	$304.07	$317.75	$332.05	$346.99	$362.61	$378.93	$395.98	$413.80	$432.42	$451.88	$3,736.46
TOTAL LIFE CYCLE COST		$41,613.23	$21,596.61	$2,747.79	$2,871.44	$3,000.66	$3,135.69	$3,276.79	$3,424.25	$3,578.34	$3,739.37	$3,653.26	$51,024.20

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 2 **Option:** B

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	3	**Conventional Van**	1-8
Power System	1	**ICE**	1-3
Type of ICE	1	**Spark Ignition**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	1	**Conventional Gasoline**	0-8
Type of Battery Propulsion	0	**None**	0,A-C:1-10
Type of Motor/Controller	0	**None**	0-3
Type of Transmission	2	**Manual**	1-2
Status of Technology	Low	**Low**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Van		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,756	Gradability (%)	7
Curb Weight (kg)	1,461	Rolling Friction Coefficient (km/km)	0.011
Base Vehicle Weight (kg)	1,150	Aerodynamic Drag Coefficient	0.470
Accessories (kg)	100	Peak Power: (kW)	40.86
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**Spark Ignition**	**Conventional Gasoline**	
Engine Power (kW)	40.86	Fuel Cost ($/l)	$0.38
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$40	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	91	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	**None**	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Manual**
Battery:	**None**	Peak Power (kW)	40.86
Power Rating (kW)	0.00	Specific Power (kW/kg)	1.06
Energy Capacity (kWh)	0	Weight (kg)	39
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	74

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	2	Option:	B
Conventional Van	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Conventional Gasoline	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$14,377	$14,376.63	$0.0899
Battery	$92	$92.38	$0.0006
Motor	$0	$0.00	$0.0000
Engine	$1,652	$1,652.14	$0.0103
Controller	$0	$0.00	$0.0000
Transmission	$256	$256.33	$0.0016
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$19,079	$19,079.21	$0.1192

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$5,872	$678.04	$0.0367
Repairs and Maintenance Cost	$7,500	$866.02	$0.0469
Replacement Cost			
Tires	$594	$68.59	$0.0037
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$728	$84.04	$0.0045
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$20,143	$2,325.78	$0.1259

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($128)	$0	($0.0008)
Total Salvage Value	($128)	$0.00	($0.0008)

Total Operating & Capital Cost ($)	$39,094	$21,404.99	$0.2443

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$868	$100.25	$0.0054
Carbon Monoxide (CO)	$637	$73.59	$0.0040
Nitrogen Oxides (NOx)	$276	$31.88	$0.0017
Particulates	$9	$1.03	$0.0001
Sulfur Dioxide	$3	$0.36	$0.0000
Aldehydes	$1	$0.14	$0.0000
BTX	$18	$2.05	$0.0001
Carbon Dioxide equivalent - full cycle	$821	$94.78	$0.0051
Total Emission Cost	$2,633	$304.07	$0.02

TOTAL LIFE CYCLE COST	$41,728	$21,709.05	$0.2608

Life Cycle Cost Summary
1992

Conventional Van		ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate: 0.045
Case Number:	2	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate: 0.080
Option	B	Fuel:	Conventional Gasoline	Distance:	160,000 kilometers	Present Value Discount Rate 0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$14,376.63	$14,376.63										$14,376.63
	Battery	$92.38	$92.38										$92.38
	Motor	$0.00	$0.00										$0.00
	Engine	$1,652.14	$1,652.14										$1,652.14
	Controller	$0.00	$0.00										$0.00
	Transmission	$256.33	$256.33										$256.33
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$201.72	$201.72										$201.72
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$19,079.21	$19,079.21	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$19,079.21
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$5,872.40	$678.04	$708.55	$740.44	$773.76	$808.58	$844.96	$882.99	$922.72	$964.24	$1,007.63	$8,331.92
	Repairs and Maintenance Cost	$7,500.41	$866.02	$904.99	$945.71	$988.27	$1,032.74	$1,079.21	$1,127.78	$1,178.53	$1,231.56	$1,286.98	$10,641.78
	Replacement Cost												
	Tires	$594.03	$68.59	$71.67	$74.90	$78.27	$81.79	$85.47	$89.32	$93.34	$97.54	$101.93	$842.82
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$727.88	$84.04	$87.82	$91.78	$95.91	$100.22	$104.73	$109.45	$114.37	$119.52	$124.90	$1,032.73
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$20,143.13	$2,325.78	$2,430.44	$2,539.81	$2,654.10	$2,773.53	$2,898.34	$3,028.77	$3,165.06	$3,307.49	$3,456.33	$28,579.63
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($128.25)										($256.38)	($256.38)
	Total Salvage Value	($128.25)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($256.38)	($256.38)
Total Operating & Capital Cost		$39,094.09	$21,404.99	$2,430.44	$2,539.81	$2,654.10	$2,773.53	$2,898.34	$3,028.77	$3,165.06	$3,307.49	$3,199.95	$47,402.46
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$868.22	$100.25	$104.76	$109.47	$114.40	$119.55	$124.93	$130.55	$136.42	$142.56	$148.98	$1,231.85
	Carbon Monoxide (CO)	$637.35	$73.59	$76.90	$80.36	$83.98	$87.76	$91.71	$95.83	$100.15	$104.65	$109.36	$904.29
	Nitrogen Oxides (NOx)	$276.13	$31.88	$33.32	$34.82	$36.38	$38.02	$39.73	$41.52	$43.39	$45.34	$47.38	$391.78
	Particulates	$8.88	$1.03	$1.07	$1.12	$1.17	$1.22	$1.28	$1.34	$1.40	$1.46	$1.52	$12.60
	Sulfur Dioxide	$3.11	$0.36	$0.37	$0.39	$0.41	$0.43	$0.45	$0.47	$0.49	$0.51	$0.53	$4.41
	Aldehydes	$1.18	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.19	$0.19	$0.20	$1.68
	BTX	$17.76	$2.05	$2.14	$2.24	$2.34	$2.45	$2.56	$2.67	$2.79	$2.92	$3.05	$25.20
	Carbon Dioxide Equivalent GHGs	$820.86	$94.78	$99.04	$103.50	$108.16	$113.03	$118.11	$123.43	$128.98	$134.78	$140.85	$1,164.66
	Future												
	Future												
	Total Emission Cost	$2,633.49	$304.07	$317.75	$332.05	$346.99	$362.61	$378.93	$395.98	$413.80	$432.42	$451.88	$3,736.46
TOTAL LIFE CYCLE COST		$41,727.57	$21,709.05	$2,748.19	$2,871.86	$3,001.09	$3,136.14	$3,277.27	$3,424.74	$3,578.86	$3,739.91	$3,651.82	$51,138.93

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 3 **Option:** A

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	**Conventional Auto**	1-8
Power System	1	**ICE**	1-3
Type of ICE	2	**Compression Ignition**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	2	**Conventional Diesel**	0-8
Type of Battery Propulsion	0	**None**	0,A-C:1-10
Type of Motor/Controller	0	**None**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	Low	**Low**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,314	Gradability (%)	7
Curb Weight (kg)	1,178	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	891	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	30.00
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**Compression Ignition**	**Conventional Diesel**	
Engine Power (kW)	30.00	Fuel Cost ($/l)	$0.39
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$54	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	67	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	**None**	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**None**	Peak Power (kW)	30.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	0	Weight (kg)	35
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	78

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	3	Option:	A
Conventional Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Conventional Diesel	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,136	$11,136.29	$0.0696
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,616	$1,616.21	$0.0101
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,704	$15,703.97	$0.0981

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$5,315	$613.74	$0.0332
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$629	$72.64	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$17,098	$1,974.19	$0.1069

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($99)	$0	($0.0006)
Total Salvage Value	($99)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$32,703	$17,678.16	$0.2044

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$214	$24.68	$0.0013
Carbon Monoxide (CO)	$66	$7.58	$0.0004
Nitrogen Oxides (NOx)	$1,035	$119.56	$0.0065
Particulates	$54	$6.26	$0.0003
Sulfur Dioxide	$0	$0.00	$0.0000
Aldehydes	$0	$0.00	$0.0000
BTX	$0	$0.00	$0.0000
Carbon Dioxide equivalent - full cycle	$553	$63.79	$0.0035
Total Emission Cost	$1,922	$221.88	$0.01

TOTAL LIFE CYCLE COST	$34,624	$17,900.04	$0.2164

Life Cycle Cost Summary

1992

Conventional Auto		ICE/Fuel Cell:	Compression Ignition	Vehicle Life:	10	years	Cost Escalation [Inflation] Rate:	0.045
Case Number:	3	Battery:	None	Driving Cycle:	Mod. FUDS		Cost of Capital Rate:	0.080
Option	A	Fuel:	Conventional Diesel	Distance:	160,000	kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,136.29	$11,136.29										$11,136.29
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,616.21	$1,616.21										$1,616.21
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$201.72	$201.72										$201.72
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$15,703.97	$15,703.97	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,703.97
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$5,315.47	$613.74	$641.36	$670.22	$700.38	$731.89	$764.83	$799.25	$835.21	$872.80	$912.07	$7,541.74
	Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$629.11	$72.64	$75.91	$79.32	$82.89	$86.62	$90.52	$94.59	$98.85	$103.30	$107.95	$892.60
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$17,098.09	$1,974.19	$2,063.03	$2,155.86	$2,252.88	$2,354.26	$2,460.20	$2,570.91	$2,686.60	$2,807.50	$2,933.83	$24,259.25
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($99.35)										($198.60)	($198.60)
	Total Salvage Value	($99.35)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($198.60)	($198.60)
Total Operating & Capital Cost		$32,702.72	$17,678.16	$2,063.03	$2,155.86	$2,252.88	$2,354.26	$2,460.20	$2,570.91	$2,686.60	$2,807.50	$2,735.24	$39,764.63
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$213.77	$24.68	$25.79	$26.95	$28.17	$29.43	$30.76	$32.14	$33.59	$35.10	$36.68	$303.30
	Carbon Monoxide (CO)	$65.69	$7.58	$7.93	$8.28	$8.66	$9.05	$9.45	$9.88	$10.32	$10.79	$11.27	$93.21
	Nitrogen Oxides (NOx)	$1,035.48	$119.56	$124.94	$130.56	$136.44	$142.58	$148.99	$155.70	$162.70	$170.03	$177.68	$1,469.17
	Particulates	$54.22	$6.26	$6.54	$6.84	$7.14	$7.47	$7.80	$8.15	$8.52	$8.90	$9.30	$76.93
	Sulfur Dioxide	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Aldehydes	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	BTX	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Carbon Dioxide Equivalent GHGs	$552.50	$63.79	$66.66	$69.66	$72.80	$76.07	$79.50	$83.08	$86.81	$90.72	$94.80	$783.90
	Future												
	Future												
	Total Emission Cost	$1,921.67	$221.88	$231.87	$242.30	$253.20	$264.60	$276.50	$288.95	$301.95	$315.54	$329.74	$2,726.51
TOTAL LIFE CYCLE COST		$34,624.39	$17,900.04	$2,294.89	$2,398.16	$2,506.08	$2,618.85	$2,736.70	$2,859.85	$2,988.55	$3,123.03	$3,064.97	$42,491.14

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 3 **Option:** B

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	Conventional Auto	1-8
Power System	1	ICE	1-3
Type of ICE	1	Spark Ignition	0-2
Type of Fuel Cell	0	None	0-2
Type of Fuel	3	Methanol (M100)	0-8
Type of Battery Propulsion	0	None	0,A-C:1-10
Type of Motor/Controller	0	None	0-3
Type of Transmission	1	Automatic	1-2
Status of Technology	Low	Low	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,314	Gradability (%)	7
Curb Weight (kg)	1,178	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	893	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	30.00
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**Spark Ignition**	**Methanol (M100)**	
Engine Power (kW)	30.00	Fuel Cost ($/l)	$0.25
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$50	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	67	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	**None**	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**None**	Peak Power (kW)	30.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	0	Weight (kg)	35
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Stainless Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$7.50
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	76

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	3	Option:	B
Conventional Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Methanol (M100)	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,157	$11,156.54	$0.0697
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,492	$1,491.89	$0.0093
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$303	$302.59	$0.0019
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,701	$15,700.76	$0.0981

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$7,848	$906.19	$0.0491
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$629	$72.63	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$19,631	$2,266.63	$0.1227

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($100)	$0	($0.0006)
Total Salvage Value	($100)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$35,232	$17,967.39	$0.2202

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$954	$110.12	$0.0060
Carbon Monoxide (CO)	$148	$17.11	$0.0009
Nitrogen Oxides (NOx)	$312	$36.06	$0.0020
Particulates	$0	$0.00	$0.0000
Sulfur Dioxide	$0	$0.00	$0.0000
Aldehydes	$3	$0.30	$0.0000
BTX	$3	$0.38	$0.0000
Carbon Dioxide equivalent - full cycle	$221	$25.52	$0.0014
Total Emission Cost	$1,641	$189.48	$0.01

TOTAL LIFE CYCLE COST	$36,873	$18,156.87	$0.2305

Life Cycle Cost Summary

1992

Conventional Auto							
Case Number:	3	ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Option	B	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
		Fuel:	Methanol (M100)	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,156.54	$11,156.54										$11,156.54
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,491.89	$1,491.89										$1,491.89
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$302.59	$302.59										$302.59
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$15,700.76	$15,700.76	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,700.76
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$7,848.33	$906.19	$946.97	$989.58	$1,034.11	$1,080.65	$1,129.28	$1,180.09	$1,233.20	$1,288.69	$1,346.68	$11,135.43
	Repairs and Maintenance Cost	$5,159.10	$595.88	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$629.02	$72.63	$75.90	$79.31	$82.88	$86.61	$90.51	$94.58	$98.84	$103.28	$107.93	$892.46
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$19,630.86	$2,266.63	$2,368.63	$2,475.22	$2,586.60	$2,703.00	$2,824.63	$2,951.74	$3,084.57	$3,223.37	$3,368.43	$27,852.81
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($99.53)										($198.96)	($198.96)
	Total Salvage Value	($99.53)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($198.96)	($198.96)
Total Operating & Capital Cost		$35,232.09	$17,967.39	$2,368.63	$2,475.22	$2,586.60	$2,703.00	$2,824.63	$2,951.74	$3,084.57	$3,223.37	$3,169.47	$43,354.61
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$953.72	$110.12	$115.07	$120.25	$125.66	$131.32	$137.23	$143.40	$149.86	$156.60	$163.65	$1,353.17
	Carbon Monoxide (CO)	$148.16	$17.11	$17.88	$18.68	$19.52	$20.40	$21.32	$22.28	$23.28	$24.33	$25.42	$210.21
	Nitrogen Oxides (NOx)	$312.29	$36.06	$37.68	$39.38	$41.15	$43.00	$44.93	$46.96	$49.07	$51.28	$53.59	$443.08
	Particulates	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Sulfur Dioxide	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Aldehydes	$2.63	$0.30	$0.32	$0.33	$0.35	$0.36	$0.38	$0.40	$0.41	$0.43	$0.45	$3.73
	BTX	$3.29	$0.38	$0.40	$0.41	$0.43	$0.45	$0.47	$0.49	$0.52	$0.54	$0.56	$4.67
	Carbon Dioxide Equivalent GHGs	$221.00	$25.52	$26.67	$27.87	$29.12	$30.43	$31.80	$33.23	$34.73	$36.29	$37.92	$313.56
	Future												
	Future												
	Total Emission Cost	$1,641.09	$189.48	$198.01	$206.92	$216.23	$225.96	$236.13	$246.76	$257.86	$269.47	$281.59	$2,328.42
TOTAL LIFE CYCLE COST		$36,873.18	$18,156.87	$2,566.64	$2,682.14	$2,802.83	$2,928.96	$3,060.76	$3,196.50	$3,342.43	$3,492.84	$3,451.06	$45,683.03

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 3 **Option:** C

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	**Conventional Auto**	1-8
Power System	1	**ICE**	1-3
Type of ICE	1	**Spark Ignition**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	4	**Ethanol (E100)**	0-8
Type of Battery Propulsion	0	**None**	0,A-C:1-10
Type of Motor/Controller	0	**None**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	Low	**Low**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,314	Gradability (%)	7
Curb Weight (kg)	1,178	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	893	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	30.00
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**Spark Ignition**	**Ethanol (E100)**	
Engine Power (kW)	30.00	Fuel Cost ($/l)	$0.42
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$50	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	67	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	**None**	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**None**	Peak Power (kW)	30.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	0	Weight (kg)	35
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	76

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	3	Option:	C
Conventional Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Ethanol (E100)	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,157	$11,156.54	$0.0697
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,492	$1,491.89	$0.0093
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,600	$15,599.90	$0.0975

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$9,743	$1,124.97	$0.0609
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$626	$72.29	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$21,523	$2,485.07	$0.1345

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($100)	$0	($0.0006)
Total Salvage Value	($100)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$37,023	$18,084.97	$0.2314

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$395	$45.57	$0.0025
Carbon Monoxide (CO)	$148	$17.11	$0.0009
Nitrogen Oxides (NOx)	$99	$11.39	$0.0006
Particulates	$0	$0.00	$0.0000
Sulfur Dioxide	$0	$0.02	$0.0000
Aldehydes	$6	$0.68	$0.0000
BTX	$3	$0.34	$0.0000
Carbon Dioxide equivalent - full cycle	$216	$24.91	$0.0013
Total Emission Cost	$866	$100.01	$0.01

TOTAL LIFE CYCLE COST	$37,889	$18,184.98	$0.2368

Life Cycle Cost Summary

1992

Conventional Auto		ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Case Number:	3	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option	C	Fuel:	Ethanol (E100)	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components	Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs												
Basic Vehicle	$11,156.54	$11,156.54										$11,156.54
Battery	$61.59	$61.59										$61.59
Motor	$0.00	$0.00										$0.00
Engine	$1,491.89	$1,491.89										$1,491.89
Controller	$0.00	$0.00										$0.00
Transmission	$188.16	$188.16										$188.16
Fuel Cell	$0.00	$0.00										$0.00
Fuel Tank	$201.72	$201.72										$201.72
Accessories	$2,500.00	$2,500.00										$2,500.00
Total Vehicle Capital Cost	$15,599.90	$15,599.90	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,599.90
Operating & Maintenance Costs												
Energy Cost												
Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel	$9,743.16	$1,124.97	$1,175.59	$1,228.49	$1,283.78	$1,341.55	$1,401.92	$1,465.00	$1,530.93	$1,599.82	$1,671.81	$13,823.86
Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
Replacement Cost												
Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.06	$6,789.08
Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
Title, Registration, and License	$626.06	$72.29	$75.54	$78.94	$82.49	$86.20	$90.08	$94.14	$98.37	$102.80	$107.43	$888.28
Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Operating Cost	$21,522.73	$2,485.07	$2,596.90	$2,713.76	$2,835.88	$2,963.49	$3,096.85	$3,236.21	$3,381.84	$3,534.02	$3,693.06	$30,537.05
Salvage Value												
Battery	$0.00										$0.00	$0.00
Fuel Cell	$0.00										$0.00	$0.00
Basic Vehicle	($99.53)										($198.96)	($198.96)
Total Salvage Value	($99.53)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($198.96)	($198.96)
Total Operating & Capital Cost	$37,023.10	$18,084.97	$2,596.90	$2,713.76	$2,835.88	$2,963.49	$3,096.85	$3,236.21	$3,381.84	$3,534.02	$3,494.09	$45,937.99
Environmental Costs												
Emissions												
Hydrocarbons (HC)	$394.64	$45.57	$47.62	$49.76	$52.00	$54.34	$56.78	$59.34	$62.01	$64.80	$67.72	$559.93
Carbon Monoxide (CO)	$148.16	$17.11	$17.88	$18.68	$19.52	$20.40	$21.32	$22.28	$23.28	$24.33	$25.42	$210.21
Nitrogen Oxides (NOx)	$98.62	$11.39	$11.90	$12.43	$12.99	$13.58	$14.19	$14.83	$15.50	$16.19	$16.92	$139.92
Particulates	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Sulfur Dioxide	$0.15	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.03	$0.21
Aldehydes	$5.92	$0.68	$0.71	$0.75	$0.78	$0.82	$0.85	$0.89	$0.93	$0.97	$1.02	$8.40
BTX	$2.96	$0.34	$0.36	$0.37	$0.39	$0.41	$0.43	$0.45	$0.47	$0.49	$0.51	$4.20
Carbon Dioxide Equivalent GHGs	$215.74	$24.91	$26.03	$27.20	$28.43	$29.71	$31.04	$32.44	$33.90	$35.42	$37.02	$306.10
Future												
Future												
Total Emission Cost	$866.18	$100.01	$104.51	$109.22	$114.13	$119.27	$124.63	$130.24	$136.10	$142.23	$148.63	$1,228.97
TOTAL LIFE CYCLE COST	$37,889.29	$18,184.98	$2,701.41	$2,822.97	$2,950.01	$3,082.76	$3,221.48	$3,366.45	$3,517.94	$3,676.25	$3,642.72	$47,166.96

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 3 **Option:** D

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	**Conventional Auto**	1-8
Power System	1	**ICE**	1-3
Type of ICE	1	**Spark Ignition**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	5	**Methane (CNG)**	0-8
Type of Battery Propulsion	0	**None**	0,A-C:1-10
Type of Motor/Controller	0	**None**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	Low	**Low**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,314	Gradability (%)	7
Curb Weight (kg)	1,178	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	907	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	30.00
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	Spark Ignition	**Methane (CNG)**	
Engine Power (kW)	30.00	Fuel Cost ($/l)	$0.07
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$50	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	67	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	**None**	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**None**	Peak Power (kW)	30.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	0	Weight (kg)	35
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Aluminium
Weight (kg)	8	Specific Weight (gm/cc)	2.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$8.00
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	62

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary

1992

Case Number:	3	Option:	D
Conventional Auto	Vehicle Life:	10 years	
None	Passenger Cap.:	5 people	
None	Driving Cycle:	Mod. FUDS	
Methane (CNG)	Distance Traveled:	160,000 kilometers	

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,335	$11,335.02	$0.0708
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,492	$1,491.89	$0.0093
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$435	$435.33	$0.0027
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$16,012	$16,011.98	$0.1001

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$5,261	$607.45	$0.0329
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$638	$73.68	$0.0040
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$17,053	$1,968.95	$0.1066

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($101)	$0	($0.0006)
Total Salvage Value	($101)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$32,964	$17,980.93	$0.2060

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$197	$22.78	$0.0012
Carbon Monoxide (CO)	$11	$1.29	$0.0001
Nitrogen Oxides (NOx)	$296	$34.16	$0.0018
Particulates	$2	$0.24	$0.0000
Sulfur Dioxide	$0	$0.00	$0.0000
Aldehydes	$2	$0.25	$0.0000
BTX	$0	$0.00	$0.0000
Carbon Dioxide equivalent - full cycle	$608	$70.17	$0.0038
Total Emission Cost	$1,116	$128.89	$0.01

TOTAL LIFE CYCLE COST	$34,080	$18,109.82	$0.2130

Life Cycle Cost Summary

1992

Conventional Auto		ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate: 0.045
Case Number:	3	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate: 0.080
Option	D	Fuel:	Methane (CNG)	Distance:	160,000 kilometers	Present Value Discount Rate 0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,335.02	$11,335.02										$11,335.02
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,491.89	$1,491.89										$1,491.89
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$435.33	$435.33										$435.33
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$16,011.98	$16,011.98	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$16,011.98
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$5,261.06	$607.45	$634.79	$663.36	$693.21	$724.40	$757.00	$791.06	$826.66	$863.86	$902.74	$7,464.53
	Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$638.12	$73.68	$76.99	$80.46	$84.08	$87.86	$91.82	$95.95	$100.27	$104.78	$109.49	$905.39
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$17,052.69	$1,968.95	$2,057.55	$2,150.14	$2,246.90	$2,348.01	$2,453.67	$2,564.08	$2,679.46	$2,800.04	$2,926.04	$24,194.83
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($101.12)										($202.14)	($202.14)
	Total Salvage Value	($101.12)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($202.14)	($202.14)
Total Operating & Capital Cost		$32,963.55	$17,980.93	$2,057.55	$2,150.14	$2,246.90	$2,348.01	$2,453.67	$2,564.08	$2,679.46	$2,800.04	$2,723.90	$40,004.67
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$197.32	$22.78	$23.81	$24.88	$26.00	$27.17	$28.39	$29.67	$31.00	$32.40	$33.86	$279.97
	Carbon Monoxide (CO)	$11.18	$1.29	$1.35	$1.41	$1.47	$1.54	$1.61	$1.68	$1.76	$1.84	$1.92	$15.86
	Nitrogen Oxides (NOx)	$295.85	$34.16	$35.70	$37.30	$38.98	$40.74	$42.57	$44.49	$46.49	$48.58	$50.76	$419.76
	Particulates	$2.09	$0.24	$0.25	$0.26	$0.27	$0.29	$0.30	$0.31	$0.33	$0.34	$0.36	$2.96
	Sulfur Dioxide	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Aldehydes	$2.14	$0.25	$0.26	$0.27	$0.28	$0.29	$0.31	$0.32	$0.34	$0.35	$0.37	$3.03
	BTX	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Carbon Dioxide Equivalent GHGs	$607.75	$70.17	$73.33	$76.63	$80.08	$83.68	$87.45	$91.38	$95.50	$99.79	$104.28	$862.30
	Future												
	Future												
	Total Emission Cost	$1,116.33	$128.89	$134.69	$140.76	$147.09	$153.71	$160.63	$167.85	$175.41	$183.30	$191.55	$1,583.88
TOTAL LIFE CYCLE COST		$34,079.89	$18,109.82	$2,192.24	$2,290.89	$2,393.99	$2,501.71	$2,614.29	$2,731.93	$2,854.87	$2,983.34	$2,915.45	$41,588.56

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 3 **Option:** E

Basic Vehicle Configuration

Technology Options

	Input		Options
Type of Vehicle	1	Conventional Auto	1-8
Power System	1	ICE	1-3
Type of ICE	1	Spark Ignition	0-2
Type of Fuel Cell	0	None	0-2
Type of Fuel	6	Reformulated Gasoline	0-8
Type of Battery Propulsion	0	None	0,A-C:1-10
Type of Motor/Controller	0	None	0-3
Type of Transmission	1	Automatic	1-2
Status of Technology	Low	Low	Low/High

Vehicle Physical Characteristics

Conventional Auto	
Passenger Capacity (2,4,5,6+,10+)	5
Test Weight (kg)	1,314
Curb Weight (kg)	1,178
Base Vehicle Weight (kg)	895
Accessories (kg)	100
Vehicle Frontal Area (sq. m)	2.00
Basic Material Salvage Value ($/kg)	$0.15
Life of Vehicle (yr)	10
Distance Traveled (km/yr)	16,000
Life Cycle Distance Traveled (km)	160,000

Vehicle Performance Characteristics

Acceleration to 88Km/h (s)	20
Top Speed (km/h)	110
Gradability (%)	7
Rolling Friction Coefficient (km/km)	0.010
Aerodynamic Drag Coefficient	0.320
Peak Power: (kW)	30.00
Driving Schedule	Mod. FUDS
Battery Power-to-Energy Ratio	NA
Range (km)	400
Full Cycles per year	40
Partial Cycles per year	355

Propulsion System Characteristics

Power System

ICE:	Spark Ignition
Engine Power (kW)	30.00
Specific Power (kW/kg)	0.45
Specific Cost ($/kW)	$50
Engine Weight (kg)	67
Fuel Efficiency: (km/l) gasoline equiv	9.00
(mpg)	21.17

Fuel Cell:	None
Power Rating (kW)	0.00
Specific Power [Continuous] (kW/kg)	0.000
Power Density [Continuous] (kW/l)	0.000
Efficiency	0%
Specific Cost ($/kW)	$0
Weight (kg)	0
Fuel Efficiency: (km/l)	12.00
(mpg)	28.22

Battery:	None
Power Rating (kW)	0.00
Energy Capacity (kWh)	0
Specific Energy (Wh/kg)	0
Specific Power (W/kg)	0.000
Efficiency (%)	0%
Cycle Life	0
Specific Cost ($/kW)	$0.00
Weight (kg)	8
80% Full Range Discharge (km)	400
Number of Replacements	0

Energy Source

Reformulated Gasoline	
Fuel Cost ($/l)	$0.42
Fuel Efficiency (l/km)	0.11
Electricity Cost ($/kWhr)	$0.05
Fuel Efficiency (kWhr/km)	0.4

Drive Train

Motor	None
Peak Power (kW)	0.00
Specific Power (kW/kg)	0
Weight (kg)	0

Controller	None
Peak Power (kW)	0.00
Specific Power (kW/kg)	0
Weight (kg)	0

Transmission System	Automatic
Peak Power (kW)	30.00
Specific Power (kW/kg)	0.86
Weight (kg)	35

Drive Train Efficiency (%) 82

Fuel Tank

Material	Steel
Specific Weight (gm/cc)	7.8
Specific Cost ($/kg)	$5.00
Tank Capacity: (l)	45
Tank Weight (w/ Fuel) (kg)	73

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	3	Option:	E
Conventional Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
Reformulated Gasoline	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,190	$11,190.29	$0.0699
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,492	$1,491.89	$0.0093
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,634	$15,633.65	$0.0977

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$6,461	$746.04	$0.0404
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$627	$72.40	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$18,242	$2,106.25	$0.1140

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($100)	$0	($0.0006)
Total Salvage Value	($100)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$33,776	$17,739.90	$0.2111

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$658	$75.94	$0.0041
Carbon Monoxide (CO)	$478	$55.19	$0.0030
Nitrogen Oxides (NOx)	$230	$26.57	$0.0014
Particulates	$7	$0.85	$0.0000
Sulfur Dioxide	$3	$0.30	$0.0000
Aldehydes	$1	$0.11	$0.0000
BTX	$15	$1.71	$0.0001
Carbon Dioxide equivalent - full cycle	$692	$79.89	$0.0043
Total Emission Cost	$2,084	$240.58	$0.01

TOTAL LIFE CYCLE COST	$35,859	$17,980.47	$0.2241

Life Cycle Cost Summary
1992

Conventional Auto		ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Case Number:	3	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option	E	Fuel:	Reformulated Gasoline	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,190.29	$11,190.29										$11,190.29
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,491.89	$1,491.89										$1,491.89
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$201.72	$201.72										$201.72
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$15,633.65	$15,633.65	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,633.65
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$8,461.28	$746.04	$779.61	$814.69	$851.35	$889.66	$929.70	$971.53	$1,015.25	$1,060.94	$1,108.68	$9,167.45
	Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.95	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,788.06
	Garaging, Parking and Tolls	$683.43	$78.60	$90.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$627.05	$72.40	$75.66	$79.06	$82.62	$86.34	$90.22	$94.28	$98.53	$102.96	$107.59	$889.66
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$18,241.86	$2,106.25	$2,201.03	$2,300.08	$2,403.58	$2,511.74	$2,624.77	$2,742.89	$2,866.31	$2,995.30	$3,130.09	$25,882.04
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($99.83)										($199.56)	($199.56)
	Total Salvage Value	($99.83)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($199.56)	($199.56)
Total Operating & Capital Cost		$33,775.67	$17,739.90	$2,201.03	$2,300.08	$2,403.58	$2,511.74	$2,624.77	$2,742.89	$2,866.31	$2,995.30	$2,930.53	$41,316.13
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$657.74	$75.94	$79.36	$82.93	$86.67	$90.57	$94.64	$98.90	$103.35	$108.00	$112.86	$933.22
	Carbon Monoxide (CO)	$478.01	$55.19	$57.68	$60.27	$62.98	$65.82	$68.78	$71.88	$75.11	$78.49	$82.02	$678.22
	Nitrogen Oxides (NOx)	$230.11	$26.57	$27.76	$29.01	$30.32	$31.68	$33.11	$34.60	$36.16	$37.78	$39.48	$326.48
	Particulates	$7.40	$0.85	$0.89	$0.93	$0.97	$1.02	$1.06	$1.11	$1.16	$1.22	$1.27	$10.50
	Sulfur Dioxide	$2.59	$0.30	$0.31	$0.33	$0.34	$0.36	$0.37	$0.39	$0.41	$0.43	$0.44	$3.67
	Aldehydes	$0.89	$0.11	$0.12	$0.12	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$1.40
	BTX	$14.80	$1.71	$1.79	$1.87	$1.95	$2.04	$2.13	$2.23	$2.33	$2.43	$2.54	$21.00
	Carbon Dioxide Equivalent GHGs	$691.94	$79.89	$83.49	$87.25	$91.17	$95.27	$99.56	$104.04	$108.72	$113.62	$118.73	$981.75
	Future												
	Future												
	Total Emission Cost	$2,083.58	$240.56	$251.40	$262.71	$274.54	$286.89	$299.80	$313.29	$327.39	$342.12	$357.52	$2,956.24
TOTAL LIFE CYCLE COST		$35,859.25	$17,980.47	$2,452.43	$2,562.79	$2,678.12	$2,798.63	$2,924.57	$3,056.18	$3,193.70	$3,337.42	$3,288.05	$44,272.37

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 3 **Option:** F

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	Conventional Auto	1-8
Power System	1	ICE	1-3
Type of ICE	2	Compression Ignition	0-2
Type of Fuel Cell	0	None	0-2
Type of Fuel	7	Reformulated Diesel	0-8
Type of Battery Propulsion	0	None	0,A-C:1-10
Type of Motor/Controller	0	None	0-3
Type of Transmission	1	Automatic	1-2
Status of Technology	Low	Low	Low/High

Vehicle Physical Characteristics

Conventional Auto	
Passenger Capacity (2,4,5,6+,10+)	5
Test Weight (kg)	1,314
Curb Weight (kg)	1,178
Base Vehicle Weight (kg)	891
Accessories (kg)	100
Vehicle Frontal Area (sq. m)	2.00
Basic Material Salvage Value ($/kg)	$0.15
Life of Vehicle (yr)	10
Distance Traveled (km/yr)	16,000
Life Cycle Distance Traveled (km)	160,000

Vehicle Performance Characteristics

Acceleration to 88Km/h (s)	20
Top Speed (km/h)	110
Gradability (%)	7
Rolling Friction Coefficient (km/km)	0.010
Aerodynamic Drag Coefficient	0.320
Peak Power: (kW)	30.00
Driving Schedule	Mod. FUDS
Battery Power-to-Energy Ratio	NA
Range (km)	400
Full Cycles per year	40
Partial Cycles per year	355

Propulsion System Characteristics

Power System

ICE:	Compression Ignition
Engine Power (kW)	30.00
Specific Power (kW/kg)	0.45
Specific Cost ($/kW)	$54
Engine Weight (kg)	67
Fuel Efficiency: (km/l) gasoline equiv	9.00
(mpg)	21.17

Fuel Cell:	None
Power Rating (kW)	0.00
Specific Power [Continuous] (kW/kg)	0.000
Power Density [Continuous] (kW/l)	0.000
Efficiency	0%
Specific Cost ($/kW)	$0
Weight (kg)	0
Fuel Efficiency: (km/l)	12.00
(mpg)	28.22

Battery:	None
Power Rating (kW)	0.00
Energy Capacity (kWh)	0
Specific Energy (Wh/kg)	0
Specific Power (W/kg)	0.000
Efficiency (%)	0%
Cycle Life	0
Specific Cost ($/kW)	$0.00
Weight (kg)	8
80% Full Range Discharge (km)	400
Number of Replacements	0

Energy Source

Reformulated Diesel	
Fuel Cost ($/l)	$0.34
Fuel Efficiency (l/km)	0.11
Electricity Cost ($/kWhr)	$0.05
Fuel Efficiency (kWhr/km)	0.4

Drive Train

Motor	None
Peak Power (kW)	0.00
Specific Power (kW/kg)	0
Weight (kg)	0
Controller	**None**
Peak Power (kW)	0.00
Specific Power (kW/kg)	0
Weight (kg)	0
Transmission System	**Automatic**
Peak Power (kW)	30.00
Specific Power (kW/kg)	0.86
Weight (kg)	35
Drive Train Efficiency (%)	82

Fuel Tank

Material	Steel
Specific Weight (gm/cc)	7.8
Specific Cost ($/kg)	$5.00
Tank Capacity: (l)	45
Tank Weight (w/ Fuel) (kg)	78

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	3	Option:	F
Conventional Auto	Vehicle Life:	10 years	
None	Passenger Cap.:	5 people	
None	Driving Cycle:	Mod. FUDS	
Reformulated Diesel	Distance Traveled:	160,000 kilometers	

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,136	$11,136.29	$0.0696
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,616	$1,616.21	$0.0101
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$202	$201.72	$0.0013
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,704	$15,703.97	$0.0981

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$4,640	$535.69	$0.0290
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$629	$72.64	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$16,422	$1,896.14	$0.1026

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($99)	$0	($0.0006)
Total Salvage Value	($99)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$32,027	$17,600.12	$0.2002

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$49	$5.70	$0.0003
Carbon Monoxide (CO)	$18	$2.10	$0.0001
Nitrogen Oxides (NOx)	$1,003	$115.76	$0.0063
Particulates	$40	$4.58	$0.0002
Sulfur Dioxide	$0	$0.00	$0.0000
Aldehydes	$0	$0.00	$0.0000
BTX	$0	$0.00	$0.0000
Carbon Dioxide equivalent - full cycle	$553	$63.79	$0.0035
Total Emission Cost	$1,662	$191.93	$0.01

TOTAL LIFE CYCLE COST	$33,689	$17,792.04	$0.2106

Life Cycle Cost Summary

1992

Conventional Auto		ICE/Fuel Cell:	Compression Ignition	Vehicle Life:	10 years	Cost Escalation (Inflation) Rate:	0.045
Case Number:	3	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option	F	Fuel:	Reformulated Diesel	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,136.29	$11,136.29										$11,136.29
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,616.21	$1,616.21										$1,616.21
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$201.72	$201.72										$201.72
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$15,703.97	$15,703.97	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,703.97
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$4,639.54	$535.69	$559.80	$584.99	$611.32	$638.82	$667.57	$697.61	$729.00	$761.81	$796.09	$6,582.71
	Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$629.11	$72.64	$75.91	$79.32	$82.89	$86.62	$90.52	$94.59	$98.85	$103.30	$107.96	$892.60
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$16,422.17	$1,896.14	$1,981.47	$2,070.64	$2,163.82	$2,261.19	$2,362.94	$2,469.27	$2,580.39	$2,696.51	$2,817.85	$23,300.22
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($99.35)										($198.60)	($198.60)
	Total Salvage Value	($99.35)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($198.60)	($198.60)
Total Operating & Capital Cost		$32,026.79	$17,600.12	$1,981.47	$2,070.64	$2,163.82	$2,261.19	$2,362.94	$2,469.27	$2,580.39	$2,696.51	$2,619.26	$38,805.60
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$49.33	$5.70	$5.95	$6.22	$6.50	$6.79	$7.10	$7.42	$7.75	$8.10	$8.46	$69.99
	Carbon Monoxide (CO)	$18.17	$2.10	$2.19	$2.29	$2.39	$2.50	$2.61	$2.73	$2.86	$2.98	$3.12	$25.78
	Nitrogen Oxides (NOx)	$1,002.61	$115.76	$120.97	$126.42	$132.11	$138.06	$144.26	$150.75	$157.54	$164.63	$172.04	$1,422.53
	Particulates	$39.63	$4.58	$4.78	$5.00	$5.22	$5.46	$5.70	$5.96	$6.23	$6.51	$6.80	$56.22
	Sulfur Dioxide	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Aldehydes	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	BTX	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Carbon Dioxide Equivalent GHGs	$552.50	$63.79	$66.66	$69.66	$72.80	$76.07	$79.50	$83.08	$86.81	$90.72	$94.80	$783.90
	Future												
	Future												
	Total Emission Cost	$1,662.24	$191.93	$200.56	$209.59	$219.02	$228.88	$239.18	$249.94	$261.19	$272.94	$285.22	$2,358.43
TOTAL LIFE CYCLE COST		$33,689.03	$17,792.04	$2,182.03	$2,280.23	$2,382.84	$2,490.06	$2,602.12	$2,719.21	$2,841.58	$2,969.45	$2,904.48	$41,164.03

LIFE CYCLE COST MODEL INPUT MODULE

Case Number:	3	**Option:**	G

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	1	**Conventional Auto**	1-8
Power System	1	**ICE**	1-3
Type of ICE	1	**Spark Ignition**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	8	**M85**	0-8
Type of Battery Propulsion	0	**None**	0,A-C:1-10
Type of Motor/Controller	0	**None**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	Low	**Low**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Conventional Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,314	Gradability (%)	7
Curb Weight (kg)	1,178	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	893	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	30.00
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	NA
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**Spark Ignition**	**M85**	
Engine Power (kW)	30.00	Fuel Cost ($/l)	$0.27
Specific Power (kW/kg)	0.45	Fuel Efficiency (l/km)	0.11
Specific Cost ($/kW)	$50	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	67	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**None**
Fuel Cell:	**None**	Peak Power (kW)	0.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	0
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**None**
Specific Cost ($/kW)	$0	Peak Power (kW)	0.00
Weight (kg)	0	Specific Power (kW/kg)	0
Fuel Efficiency: (km/l)	12.00	Weight (kg)	0
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**None**	Peak Power (kW)	30.00
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	0	Weight (kg)	35
Specific Energy (Wh/kg)	0		
Specific Power (W/kg)	0.000	**Drive Train Efficiency (%)**	82
Efficiency (%)	0%		
Cycle Life	0	**Fuel Tank**	
Specific Cost ($/kW)	$0.00	Material	Stainless Steel
Weight (kg)	8	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$7.50
Number of Replacements	0	Tank Capacity: (l)	45
		Tank Weight (w/ Fuel) (kg)	76

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	3	Option:	G
Conventional Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
None	Driving Cycle:	Mod. FUDS	
M85	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,161	$11,161.04	$0.0698
Battery	$62	$61.59	$0.0004
Motor	$0	$0.00	$0.0000
Engine	$1,492	$1,491.89	$0.0093
Controller	$0	$0.00	$0.0000
Transmission	$188	$188.16	$0.0012
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$303	$302.59	$0.0019
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$15,705	$15,705.26	$0.0982

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$7,329	$846.28	$0.0458
Repairs and Maintenance Cost	$5,159	$595.68	$0.0322
Replacement Cost			
Tires	$546	$63.04	$0.0034
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$629	$72.64	$0.0039
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$19,112	$2,206.73	$0.1195

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	$0	$0.00	$0.0000
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($100)	$0	($0.0006)
Total Salvage Value	($100)	$0.00	($0.0006)

Total Operating & Capital Cost ($)	$34,718	$17,912.00	$0.2170

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$919	$106.13	$0.0057
Carbon Monoxide (CO)	$206	$23.74	$0.0013
Nitrogen Oxides (NOx)	$300	$34.63	$0.0019
Particulates	$1	$0.13	$0.0000
Sulfur Dioxide	$0	$0.04	$0.0000
Aldehydes	$2	$0.28	$0.0000
BTX	$5	$0.58	$0.0000
Carbon Dioxide equivalent - full cycle	$292	$33.67	$0.0018
Total Emission Cost	$1,725	$199.21	$0.01

TOTAL LIFE CYCLE COST	$36,443	$18,111.20	$0.2278

Life Cycle Cost Summary

1992

Conventional Auto		ICE/Fuel Cell:	Spark Ignition	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Case Number:	3	Battery:	None	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option	G	Fuel:	M85	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,161.04	$11,161.04										$11,161.04
	Battery	$61.59	$61.59										$61.59
	Motor	$0.00	$0.00										$0.00
	Engine	$1,491.89	$1,491.89										$1,491.89
	Controller	$0.00	$0.00										$0.00
	Transmission	$188.16	$188.16										$188.16
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$302.59	$302.59										$302.59
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$15,705.26	$15,705.26	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$15,705.26
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$7,329.47	$846.28	$884.36	$924.16	$965.75	$1,009.20	$1,054.62	$1,102.08	$1,151.67	$1,203.49	$1,257.65	$10,399.26
	Repairs and Maintenance Cost	$5,159.10	$595.68	$622.49	$650.50	$679.77	$710.36	$742.33	$775.73	$810.64	$847.12	$885.24	$7,319.87
	Replacement Cost												
	Tires	$545.99	$63.04	$65.88	$68.84	$71.94	$75.18	$78.56	$82.10	$85.79	$89.65	$93.69	$774.67
	Battery	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$629.15	$72.64	$75.91	$79.33	$82.90	$86.63	$90.53	$94.60	$98.86	$103.31	$107.95	$892.65
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$19,112.13	$2,206.73	$2,306.04	$2,409.81	$2,518.25	$2,631.57	$2,749.99	$2,873.74	$3,003.06	$3,138.20	$3,279.42	$27,116.82
Salvage Value													
	Battery	$0.00										$0.00	$0.00
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($99.57)										($199.04)	($199.04)
	Total Salvage Value	($99.57)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($199.04)	($199.04)
Total Operating & Capital Cost		$34,717.82	$17,912.00	$2,306.04	$2,409.81	$2,518.25	$2,631.57	$2,749.99	$2,873.74	$3,003.06	$3,138.20	$3,080.38	$42,623.04
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$919.19	$106.13	$110.91	$115.90	$121.11	$126.56	$132.26	$138.21	$144.43	$150.93	$157.72	$1,304.17
	Carbon Monoxide (CO)	$205.60	$23.74	$24.81	$25.92	$27.09	$28.31	$29.58	$30.91	$32.31	$33.76	$35.28	$291.71
	Nitrogen Oxides (NOx)	$299.96	$34.63	$36.19	$37.82	$39.52	$41.30	$43.16	$45.10	$47.13	$49.25	$51.47	$425.59
	Particulates	$1.11	$0.13	$0.13	$0.14	$0.15	$0.15	$0.16	$0.17	$0.17	$0.18	$0.19	$1.57
	Sulfur Dioxide	$0.39	$0.04	$0.05	$0.05	$0.05	$0.05	$0.06	$0.06	$0.06	$0.06	$0.07	$0.55
	Aldehydes	$2.38	$0.28	$0.29	$0.30	$0.31	$0.33	$0.34	$0.36	$0.37	$0.39	$0.41	$3.38
	BTX	$5.02	$0.58	$0.61	$0.63	$0.66	$0.69	$0.72	$0.75	$0.79	$0.82	$0.86	$7.12
	Carbon Dioxide Equivalent GHGs	$291.64	$33.67	$35.19	$36.77	$38.43	$40.16	$41.96	$43.85	$45.83	$47.89	$50.04	$413.79
	Future												
	Future												
	Total Emission Cost	$1,725.29	$199.21	$208.17	$217.54	$227.33	$237.56	$248.25	$259.42	$271.09	$283.29	$296.04	$2,447.90
TOTAL LIFE CYCLE COST		$36,443.12	$18,111.20	$2,514.21	$2,627.35	$2,745.58	$2,869.13	$2,998.24	$3,133.16	$3,274.15	$3,421.49	$3,376.42	$45,070.94

LIFE CYCLE COST MODEL INPUT MODULE

Case Number:	4	**Option:**	A

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	4	**Electric Auto**	1-8
Power System	3	**Battery EV**	1-3
Type of ICE	0	**None**	0-2
Type of Fuel Cell	0	**None**	0-2
Type of Fuel	6	**Reformulated Gasoline**	0-8
Type of Battery Propulsion	4	**Lead-Acid**	0,A-C:1-10
Type of Motor/Controller	2	**DC Brushless**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	High	**High**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Electric Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	500	Gradability (%)	7
Curb Weight (kg)	1,500	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	1,280	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	15.88
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	0.75
Life of Vehicle (yr)	10	Range (km)	200
Distance Traveled (km/yr)	16,000	Full Cycles per year	80
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**None**	**Electricity**	
Engine Power (kW)	0.00	Fuel Cost ($/l)	$0.42
Specific Power (kW/kg)	0	Fuel Efficiency (l/km)	NA
Specific Cost ($/kW)	$0	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	0	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00	**Drive Train**	
(mpg)	21.17	**Motor**	**DC Brushless**
Fuel Cell:	**None**	Peak Power (kW)	15.88
Power Rating (kW)	0.00	Specific Power (kW/kg)	0.64
Specific Power [Continuous] (kW/kg)	0.000	Weight (kg)	25
Power Density [Continuous] (kW/l)	0.000		
Efficiency	0%	**Controller**	**DC Brushless**
Specific Cost ($/kW)	$0	Peak Power (kW)	15.88
Weight (kg)	0	Specific Power (kW/kg)	0.88
Fuel Efficiency: (km/l)	12.00	Weight (kg)	18
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**Lead-Acid**	Peak Power (kW)	15.88
Power Rating (kW)	5.71	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	8	Weight (kg)	18
Specific Energy (Wh/kg)	45		
Specific Power (W/kg)	0.100	**Drive Train Efficiency (%)**	82
Efficiency (%)	70%		
Cycle Life	800	**Fuel Tank**	
Specific Cost ($/kW)	$46.19	Material	Steel
Weight (kg)	57	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	6	Tank Capacity: (l)	1
		Tank Weight (w/ Fuel) (kg)	2

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	4	Option:	A
Electric Auto	Vehicle Life:	10	years
None	Passenger Cap.:	5	people
Lead-Acid	Driving Cycle:	Mod. FUDS	
Reformulated Gasoline	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$16,000	$15,999.91	$0.1000
Battery	$264	$263.63	$0.0016
Motor	$568	$567.51	$0.0035
Engine	$0	$0.00	$0.0000
Controller	$1,927	$1,927.40	$0.0120
Transmission	$100	$99.58	$0.0006
Fuel Cell	$0	$0.00	$0.0000
Fuel Tank	$4	$4.48	$0.0000
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$21,363	$21,362.52	$0.1335

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$2,771	$320.00	$0.0173
Fuel	$0	$0.00	$0.0000
Repairs and Maintenance Cost	$5,066	$584.92	$0.0317
Replacement Cost			
Tires	$601	$69.35	$0.0038
Battery	$1,370	$158.18	$0.0086
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$795	$91.76	$0.0050
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$16,051	$1,853.29	$0.1003

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	($51)	$0.00	($0.0003)
Fuel Cell	$0	$0.00	$0.0000
Basic Vehicle	($143)	$0	($0.0009)
Total Salvage Value	($194)	$0.00	($0.0012)

Total Operating & Capital Cost ($)	$37,220	$23,215.81	$0.2326

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$33	$3.80	$0.0002
Carbon Monoxide (CO)	$6	$0.65	$0.0000
Nitrogen Oxides (NOx)	$99	$11.39	$0.0006
Particulates	$0	$0.00	$0.0000
Sulfur Dioxide	$11	$1.28	$0.0001
Aldehydes	$0	$0.00	$0.0000
BTX	$0	$0.00	$0.0000
Carbon Dioxide equivalent - full cycle	$642	$74.12	$0.0040
Total Emission Cost	$790	$91.23	$0.00

TOTAL LIFE CYCLE COST	$38,010	$23,307.04	$0.2376

Life Cycle Cost Summary
1992

Electric Auto	ICE/Fuel Cell:	None	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Case Number: 4	Battery:	Lead-Acid	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option A	Fuel:	Reformulated Gasoline	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$15,999.91	$15,999.91										$15,999.91
	Battery	$263.63	$263.63										$263.63
	Motor	$567.51	$567.51										$567.51
	Engine	$0.00	$0.00										$0.00
	Controller	$1,927.40	$1,927.40										$1,927.40
	Transmission	$99.58	$99.58										$99.58
	Fuel Cell	$0.00	$0.00										$0.00
	Fuel Tank	$4.48	$4.48										$4.48
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$21,362.52	$21,362.52	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$21,362.52
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$2,771.46	$320.00	$334.40	$349.45	$365.17	$381.61	$398.78	$416.72	$435.48	$455.07	$475.55	$3,932.23
	Fuel	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Repairs and Maintenance Cost	$5,065.85	$584.92	$611.24	$638.74	$667.49	$697.52	$728.91	$761.71	$795.99	$831.81	$869.24	$7,187.56
	Replacement Cost												
	Tires	$600.65	$69.35	$72.47	$75.73	$79.14	$82.70	$86.43	$90.31	$94.38	$98.63	$103.06	$852.21
	Battery	$1,369.94	$158.18	$165.29	$172.73	$180.51	$188.63	$197.12	$205.99	$215.26	$224.94	$235.07	$1,943.70
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$794.69	$91.76	$95.89	$100.20	$104.71	$109.42	$114.35	$119.49	$124.87	$130.49	$136.36	$1,127.53
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$16,051.01	$1,853.29	$1,936.69	$2,023.84	$2,114.91	$2,210.08	$2,309.54	$2,413.47	$2,522.07	$2,635.57	$2,754.17	$22,773.62
Salvage Value													
	Battery	($50.79)										($101.52)	($101.52)
	Fuel Cell	$0.00										$0.00	$0.00
	Basic Vehicle	($142.74)										($285.33)	($285.33)
	Total Salvage Value	($193.52)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($386.85)	($386.85)
Total Operating & Capital Cost		$37,220.00	$23,215.81	$1,936.69	$2,023.84	$2,114.91	$2,210.08	$2,309.54	$2,413.47	$2,522.07	$2,635.57	$2,367.32	$43,749.28
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$32.89	$3.80	$3.97	$4.15	$4.33	$4.53	$4.73	$4.94	$5.17	$5.40	$5.64	$46.66
	Carbon Monoxide (CO)	$5.59	$0.65	$0.67	$0.70	$0.74	$0.77	$0.80	$0.84	$0.88	$0.92	$0.96	$7.93
	Nitrogen Oxides (NOx)	$98.62	$11.39	$11.90	$12.43	$12.99	$13.58	$14.19	$14.83	$15.50	$16.19	$16.92	$139.92
	Particulates	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Sulfur Dioxide	$11.10	$1.28	$1.34	$1.40	$1.46	$1.53	$1.60	$1.67	$1.74	$1.82	$1.90	$15.75
	Aldehydes	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	BTX	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Carbon Dioxide Equivalent GHGs	$641.95	$74.12	$77.46	$80.94	$84.59	$88.39	$92.37	$96.53	$100.87	$105.41	$110.15	$910.82
	Future												
	Future												
	Total Emission Cost	$790.15	$91.23	$95.34	$99.63	$104.11	$108.80	$113.69	$118.81	$124.15	$129.74	$135.58	$1,121.09
TOTAL LIFE CYCLE COST		$38,010.15	$23,307.04	$2,032.03	$2,123.47	$2,219.02	$2,318.88	$2,423.23	$2,532.27	$2,646.23	$2,765.31	$2,502.90	$44,870.37

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 5 **Option:** A

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	6	**Fuel Cell/Battery Auto**	1-8
Power System	2	**Fuel Cell/Battery**	1-3
Type of ICE	0	**None**	0-2
Type of Fuel Cell	2	**PEMFC-Methanol**	0-2
Type of Fuel	3	**Methanol (M100)**	0-8
Type of Battery Propulsion	B	**Medium Performance Generic**	0,A-C:1-10
Type of Motor/Controller	1	**AC**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	High	**High**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Fuel Cell/Battery Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,608	Gradability (%)	7
Curb Weight (kg)	1,472	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	891	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	35.85
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	0.75
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**None**	**Methanol (M100)**	
Engine Power (kW)	0.00	Fuel Cost ($/l)	$0.25
Specific Power (kW/kg)	0	Fuel Efficiency (l/km)	0.08
Specific Cost ($/kW)	$0	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	0	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**AC**
Fuel Cell:	**PEMFC-Methanol**	Peak Power (kW)	35.85
Power Rating (kW)	22.98	Specific Power (kW/kg)	0.49
Specific Power [Continuous] (kW/kg)	0.100	Weight (kg)	73
Power Density [Continuous] (kW/l)	0.098		
Efficiency	55%	**Controller**	**AC**
Specific Cost ($/kW)	$188	Peak Power (kW)	35.85
Weight (kg)	230	Specific Power (kW/kg)	2.5
Fuel Efficiency: (km/l)	12.00	Weight (kg)	14
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**Medium Performance Generic**	Peak Power (kW)	35.85
Power Rating (kW)	12.87	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	17	Weight (kg)	42
Specific Energy (Wh/kg)	100		
Specific Power (W/kg)	0.200	**Drive Train Efficiency (%)**	82
Efficiency (%)	75%		
Cycle Life	600	**Fuel Tank**	
Specific Cost ($/kW)	$121.11	Material	Stainless Steel
Weight (kg)	64	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$7.50
Number of Replacements	1	Tank Capacity: (l)	34
		Tank Weight (w/ Fuel) (kg)	57

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary

1992

Case Number:	5	Option:	A
Fuel Cell/Battery Auto	Vehicle Life:	10	years
PEMFC-Methanol	Passenger Cap.:	5	people
Medium Performance Generic	Driving Cycle:	Mod. FUDS	
Methanol (M100)	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$11,141	$11,140.77	$0.0696
Battery	$1,559	$1,559.14	$0.0097
Motor	$919	$918.93	$0.0057
Engine	$0	$0.00	$0.0000
Controller	$2,176	$2,176.42	$0.0136
Transmission	$225	$224.90	$0.0014
Fuel Cell	$4,331	$4,331.39	$0.0271
Fuel Tank	$229	$228.62	$0.0014
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$23,080	$23,080.17	$0.1443

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$2,917	$336.81	$0.0182
Repairs and Maintenance Cost	$7,050	$814.06	$0.0441
Replacement Cost			
Tires	$596	$68.80	$0.0037
Battery	$1,350	$155.91	$0.0084
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$845	$97.56	$0.0053
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$18,207	$2,102.24	$0.1138

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	($31)	$0.00	($0.0002)
Fuel Cell	($815)	$0.00	($0.0051)
Basic Vehicle	($99)	$0	($0.0006)
Total Salvage Value	($946)	$0.00	($0.0059)

Total Operating & Capital Cost ($)	$40,341	$25,182.41	$0.2521

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$82	$9.49	$0.0005
Carbon Monoxide (CO)	$11	$1.29	$0.0001
Nitrogen Oxides (NOx)	$394	$45.55	$0.0025
Particulates	$0	$0.00	$0.0000
Sulfur Dioxide	$0	$0.00	$0.0000
Aldehydes	$3	$0.30	$0.0000
BTX	$3	$0.38	$0.0000
Carbon Dioxide equivalent - full cycle	$221	$25.52	$0.0014
Total Emission Cost	$715	$82.53	$0.00

TOTAL LIFE CYCLE COST	$41,056	$25,264.95	$0.2566

Life Cycle Cost Summary
1992

Fuel Cell/Battery Auto		ICE/Fuel Cell:	PEMFC-Methanol	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate: 0.045
Case Number:	5	Battery:	Medium Performance Generic	Driving Cycle:	Mod. FUDS	Cost of Capital Rate: 0.080
Option	A	Fuel:	Methanol (M100)	Distance:	160,000 kilometers	Present Value Discount Rate 0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$11,140.77	$11,140.77										$11,140.77
	Battery	$1,559.14	$1,559.14										$1,559.14
	Motor	$918.93	$918.93										$918.93
	Engine	$0.00	$0.00										$0.00
	Controller	$2,176.42	$2,176.42										$2,176.42
	Transmission	$224.90	$224.90										$224.90
	Fuel Cell	$4,331.39	$4,331.39										$4,331.39
	Fuel Tank	$228.62	$228.62										$228.62
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$23,080.17	$23,080.17	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$23,080.17
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$2,917.03	$336.81	$351.96	$367.80	$384.35	$401.65	$419.72	$438.61	$458.35	$478.97	$500.53	$4,138.76
	Repairs and Maintenance Cost	$7,050.46	$814.06	$850.70	$888.98	$928.98	$970.79	$1,014.47	$1,060.12	$1,107.83	$1,157.68	$1,209.78	$10,003.39
	Replacement Cost												
	Tires	$595.89	$68.80	$71.90	$75.14	$78.52	$82.05	$85.74	$89.60	$93.63	$97.85	$102.25	$845.47
	Battery	$1,350.34	$155.91	$162.93	$170.26	$177.92	$185.93	$194.30	$203.04	$212.18	$221.73	$231.70	$1,915.91
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$844.96	$97.56	$101.95	$106.54	$111.33	$116.34	$121.58	$127.05	$132.77	$138.74	$144.98	$1,198.85
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$18,207.11	$2,102.24	$2,196.84	$2,295.70	$2,399.00	$2,506.96	$2,619.77	$2,737.66	$2,860.86	$2,989.60	$3,124.13	$25,832.76
Salvage Value													
	Battery	($31.40)										($62.76)	($62.76)
	Fuel Cell	($815.30)										($1,629.78)	($1,629.78)
	Basic Vehicle	($99.39)										($198.68)	($198.68)
	Total Salvage Value	($946.08)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($1,891.22)	($1,891.22)
Total Operating & Capital Cost		$40,341.21	$25,182.41	$2,196.84	$2,295.70	$2,399.00	$2,506.96	$2,619.77	$2,737.66	$2,860.86	$2,989.60	$1,232.91	$47,021.71
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$82.22	$9.49	$9.92	$10.37	$10.83	$11.32	$11.83	$12.36	$12.92	$13.50	$14.11	$116.65
	Carbon Monoxide (CO)	$11.18	$1.29	$1.35	$1.41	$1.47	$1.54	$1.61	$1.68	$1.76	$1.84	$1.92	$15.86
	Nitrogen Oxides (NOx)	$394.47	$45.55	$47.60	$49.74	$51.98	$54.32	$56.76	$59.31	$61.98	$64.77	$67.69	$559.69
	Particulates	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Sulfur Dioxide	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Aldehydes	$2.63	$0.30	$0.32	$0.33	$0.35	$0.36	$0.38	$0.40	$0.41	$0.43	$0.45	$3.73
	BTX	$3.29	$0.38	$0.40	$0.41	$0.43	$0.45	$0.47	$0.49	$0.52	$0.54	$0.56	$4.67
	Carbon Dioxide Equivalent GHGs	$221.00	$25.52	$26.67	$27.87	$29.12	$30.43	$31.80	$33.23	$34.73	$36.29	$37.92	$313.56
	Future												
	Future												
	Total Emission Cost	$714.79	$82.53	$86.25	$90.13	$94.18	$98.42	$102.85	$107.48	$112.31	$117.37	$122.65	$1,014.16
TOTAL LIFE CYCLE COST		$41,056.00	$25,264.95	$2,283.09	$2,385.82	$2,493.19	$2,605.38	$2,722.62	$2,845.14	$2,973.17	$3,106.96	$1,355.56	$48,035.87

LIFE CYCLE COST MODEL INPUT MODULE

Case Number: 5 **Option:** B

Basic Vehicle Configuration

Technology Options	Input		Options
Type of Vehicle	6	**Fuel Cell/Battery Auto**	1-8
Power System	2	**Fuel Cell/Battery**	1-3
Type of ICE	0	**None**	0-2
Type of Fuel Cell	3	**PEMFC-Hydrogen**	0-2
Type of Fuel	9	**Hydrogen**	0-8
Type of Battery Propulsion	B	**Medium Performance Generic**	0,A-C:1-10
Type of Motor/Controller	1	**AC**	0-3
Type of Transmission	1	**Automatic**	1-2
Status of Technology	High	**High**	Low/High

Vehicle Physical Characteristics		Vehicle Performance Characteristics	
Fuel Cell/Battery Auto		Acceleration to 88Km/h (s)	20
Passenger Capacity (2,4,5,6+,10+)	5	Top Speed (km/h)	110
Test Weight (kg)	1,608	Gradability (%)	7
Curb Weight (kg)	1,472	Rolling Friction Coefficient (km/km)	0.010
Base Vehicle Weight (kg)	986	Aerodynamic Drag Coefficient	0.320
Accessories (kg)	100	Peak Power: (kW)	35.85
Vehicle Frontal Area (sq. m)	2.00	Driving Schedule	Mod. FUDS
Basic Material Salvage Value ($/kg)	$0.15	Battery Power-to-Energy Ratio	0.75
Life of Vehicle (yr)	10	Range (km)	400
Distance Traveled (km/yr)	16,000	Full Cycles per year	40
Life Cycle Distance Traveled (km)	160,000	Partial Cycles per year	355

Propulsion System Characteristics

Power System		Energy Source	
ICE:	**None**	**Hydrogen**	
Engine Power (kW)	0.00	Fuel Cost ($/l)	$0.59
Specific Power (kW/kg)	0	Fuel Efficiency (l/km)	0.08
Specific Cost ($/kW)	$0	Electricity Cost ($/kWhr)	$0.05
Engine Weight (kg)	0	Fuel Efficiency (kWhr/km)	0.4
Fuel Efficiency: (km/l) gasoline equiv	9.00		
(mpg)	21.17	**Drive Train**	
		Motor	**AC**
Fuel Cell:	**PEMFC-Hydrogen**	Peak Power (kW)	35.85
Power Rating (kW)	22.98	Specific Power (kW/kg)	0.49
Specific Power [Continuous] (kW/kg)	0.230	Weight (kg)	73
Power Density [Continuous] (kW/l)	0.340		
Efficiency	53%	**Controller**	**AC**
Specific Cost ($/kW)	$194	Peak Power (kW)	35.85
Weight (kg)	100	Specific Power (kW/kg)	2.5
Fuel Efficiency: (km/l)	12.00	Weight (kg)	14
(mpg)	28.22		
		Transmission System	**Automatic**
Battery:	**Medium Performance Generic**	Peak Power (kW)	35.85
Power Rating (kW)	12.87	Specific Power (kW/kg)	0.86
Energy Capacity (kWh)	17	Weight (kg)	42
Specific Energy (Wh/kg)	100		
Specific Power (W/kg)	0.200	**Drive Train Efficiency (%)**	82
Efficiency (%)	75%		
Cycle Life	600	**Fuel Tank**	
Specific Cost ($/kW)	$121.11	Material	Steel
Weight (kg)	64	Specific Weight (gm/cc)	7.8
80% Full Range Discharge (km)	400	Specific Cost ($/kg)	$5.00
Number of Replacements	1	Tank Capacity: (l)	34
		Tank Weight (w/ Fuel) (kg)	93

Economic Analysis Factors

Analysis base year	1992	Cost of Capital (%/100)	0.08
Present Value Discount Rate (%/100)	0.080	Loan Term (yr)	0
Cost Escalation[Inflation] Rate (%/100)	0.045	Down payment (%)	100%

End of Input Section

Life Cycle Cost Summary
1992

Case Number:	5	Option:	B
Fuel Cell/Battery Auto	Vehicle Life:	10	years
PEMFC-Hydrogen	Passenger Cap.:	5	people
Medium Performance Generic	Driving Cycle:	Mod. FUDS	
Hydrogen	Distance Traveled:	160,000	kilometers

Capital Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Basic Vehicle	$12,324	$12,323.73	$0.0770
Battery	$1,559	$1,559.14	$0.0097
Motor	$919	$918.93	$0.0057
Engine	$0	$0.00	$0.0000
Controller	$2,176	$2,176.42	$0.0136
Transmission	$225	$224.90	$0.0014
Fuel Cell	$4,453	$4,452.70	$0.0278
Fuel Tank	$2,009	$2,009.36	$0.0126
Accessories	$2,500	$2,500.00	$0.0156
Total Vehicle Capital Cost	$26,165	$26,165.18	$0.1635

Operating Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Energy Cost			
Electricity	$0	$0.00	$0.0000
Fuel	$6,763	$780.93	$0.0423
Repairs and Maintenance Cost	$2,812	$324.72	$0.0176
Replacement Cost			
Tires	$596	$68.80	$0.0037
Battery	$1,350	$155.91	$0.0084
Fuel Cell	$0	$0.00	$0.0000
Insurance	$4,785	$552.49	$0.0299
Garaging, Parking and Tolls	$663	$76.60	$0.0041
Title, Registration, and License	$935	$107.98	$0.0058
Interest Cost	$0	$0.00	$0.0000
Total Operating Cost	$17,906	$2,067.44	$0.1119

Salvage Value ($)	Life Cycle Cost	First Year Cost	Cost per km
Battery	($31)	$0.00	($0.0002)
Fuel Cell	($384)	$0.00	($0.0024)
Basic Vehicle	($110)	$0	($0.0007)
Total Salvage Value	($525)	$0.00	($0.0033)

Total Operating & Capital Cost ($)	$43,545	$28,232.62	$0.2722

Environmental Cost ($)	Life Cycle Cost	First Year Cost	Cost per km
Emissions			
Hydrocarbons (HC)	$0	$0.00	$0.0000
Carbon Monoxide (CO)	$0	$0.00	$0.0000
Nitrogen Oxides (NOx)	$0	$0.00	$0.0000
Particulates	$0	$0.00	$0.0000
Sulfur Dioxide	$0	$0.00	$0.0000
Aldehydes	$0	$0.00	$0.0000
BTX	$0	$0.00	$0.0000
Carbon Dioxide equivalent - full cycle	$203	$23.39	$0.0013
Total Emission Cost	$203	$23.39	$0.00

TOTAL LIFE CYCLE COST	$43,748	$28,256.01	$0.2734

Life Cycle Cost Summary
1992

Fuel Cell/Battery Auto		ICE/Fuel Cell:	PEMFC-Hydrogen	Vehicle Life:	10 years	Cost Escalation [Inflation] Rate:	0.045
Case Number:	5	Battery:	Medium Performance Generic	Driving Cycle:	Mod. FUDS	Cost of Capital Rate:	0.080
Option	B	Fuel:	Hydrogen	Distance:	160,000 kilometers	Present Value Discount Rate	0.080

Cost Components		Present Value 1992	First Year 1992	Year 2 1993	Year 3 1994	Year 4 1995	Year 5 1996	Year 6 1997	Year 7 1998	Year 8 1999	Year 9 2000	Year 10 2001	Cumulative Outlays
Capital Costs													
	Basic Vehicle	$12,323.73	$12,323.73										$12,323.73
	Battery	$1,559.14	$1,559.14										$1,559.14
	Motor	$918.93	$918.93										$918.93
	Engine	$0.00	$0.00										$0.00
	Controller	$2,176.42	$2,176.42										$2,176.42
	Transmission	$224.90	$224.90										$224.90
	Fuel Cell	$4,452.70	$4,452.70										$4,452.70
	Fuel Tank	$2,009.36	$2,009.36										$2,009.36
	Accessories	$2,500.00	$2,500.00										$2,500.00
	Total Vehicle Capital Cost	$26,165.18	$26,165.18	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$26,165.18
Operating & Maintenance Costs													
	Energy Cost												
	Electricity	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Fuel	$6,763.49	$780.93	$816.07	$852.79	$891.17	$931.27	$973.18	$1,016.97	$1,062.74	$1,110.56	$1,160.54	$9,596.23
	Repairs and Maintenance Cost	$2,812.33	$324.72	$339.33	$354.60	$370.56	$387.23	$404.66	$422.87	$441.90	$461.78	$482.56	$3,990.21
	Replacement Cost												
	Tires	$595.89	$68.80	$71.90	$75.14	$78.52	$82.05	$85.74	$89.60	$93.63	$97.85	$102.25	$845.47
	Battery	$1,350.34	$155.91	$162.93	$170.26	$177.92	$185.93	$194.30	$203.04	$212.18	$221.73	$231.70	$1,915.91
	Fuel Cell	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Insurance	$4,784.99	$552.49	$577.35	$603.33	$630.48	$658.85	$688.50	$719.48	$751.86	$785.69	$821.05	$6,789.08
	Garaging, Parking and Tolls	$663.43	$76.60	$80.05	$83.65	$87.41	$91.35	$95.46	$99.75	$104.24	$108.93	$113.84	$941.29
	Title, Registration, and License	$935.23	$107.98	$112.84	$117.92	$123.23	$128.77	$134.57	$140.62	$146.95	$153.56	$160.48	$1,326.94
	Interest Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Total Operating Cost	$17,905.71	$2,067.44	$2,160.47	$2,257.69	$2,359.29	$2,465.46	$2,576.40	$2,692.34	$2,813.50	$2,940.11	$3,072.41	$25,405.12
Salvage Value													
	Battery	($31.40)										($62.76)	($62.76)
	Fuel Cell	($384.14)										($767.90)	($767.90)
	Basic Vehicle	($109.94)										($219.77)	($219.77)
	Total Salvage Value	($525.48)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($1,050.44)	($1,050.44)
Total Operating & Capital Cost		$43,545.41	$28,232.62	$2,160.47	$2,257.69	$2,359.29	$2,465.46	$2,576.40	$2,692.34	$2,813.50	$2,940.11	$2,021.97	$50,519.86
Environmental Costs													
	Emissions												
	Hydrocarbons (HC)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Carbon Monoxide (CO)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Nitrogen Oxides (NOx)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Particulates	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Sulfur Dioxide	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Aldehydes	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	BTX	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Carbon Dioxide Equivalent GHGs	$202.58	$23.39	$24.44	$25.54	$26.69	$27.89	$29.15	$30.46	$31.83	$33.26	$34.76	$287.43
	Future												
	Future												
	Total Emission Cost	$202.58	$23.39	$24.44	$25.54	$26.69	$27.89	$29.15	$30.46	$31.83	$33.26	$34.76	$287.43
TOTAL LIFE CYCLE COST		$43,747.99	$28,256.01	$2,184.92	$2,283.24	$2,385.98	$2,493.35	$2,605.55	$2,722.80	$2,845.33	$2,973.37	$2,056.73	$50,807.29

APPENDIX E - ACRONYMS AND ABBREVIATIONS

ANL	Argonne National Laboratory
BPEV	Battery Powered Electric Vehicle
Btu	British Thermal Unit
BTX	Benzene, Toluene, Xylene
C	Carbon
CFCs	Chlorfluorocarbons
CH_4	Methane
CO_2	Carbon Dioxide
CO	Carbon Monoxide
DOE	U.S. Department of Energy
$/Km	Dollars Per Kilometer
E100	Ethanol (100%)
EDS	Embedded Data Sets
EVs	Electric Vehicles
FCEV	Fuel Cell/Battery Powered Electric Vehicle
GHG	Greenhouse Gases
GRI	Gas Research Institute
HC	Hydrocarbons
H_2	Hydrogen
ICE	Internal Combustion Engine
JPL	Jet Propulsion Laboratory
kg	Kilogram
km	Kilometer
LCC	Life Cycle Cost
M85	Blend of 85% Methanol and 15% Gasoline
M100	Methanol (100%)
M&R	Maintenance and Repair
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides
NMOC	Non Methane Organic Compounds
PAFC	Phosphoric Acid Fuel Cell
PEM	Proton Exchange Membrane
PEMFC	Proton Exchange Membrane Fuel Cell
PM	Particulate Matter
PM_{10}	Particulate Matter (particles smaller than 10 microns)
RFG	Reformulated Gasoline
SO_2	Sulfur Dioxide
SO_x	Sulfur Oxides
VOC	Volatile Organic Compounds