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# Part I. VEHICLE CONVERSION TO HYBRID GASOLINE/ALTERNATIVE FUEL OPERATION

Final Report
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by

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# SUMMARY

This report presents the results of a preliminary technical and economic feasibility study of converting vehicles to alternative fuels at the Goldstone Deep Space Communications Complex (GDSCC). This study was motivated by the continued price rises of gasoline and its potential unavailability. The vehicles are used for commuting between Barstow, California and GDSCC, a round trip of about 140 km (90 miles). This fleet consists of 70 vehicles. The alternative fuels considered are compressed natural gas (CNG), liquefied natural gas (LNG), liquid petroleum gas (LPG), and methanol; vehicles were required to operate in a hybrid or dual-fuel gasoline/alternative fuel mode.

Economic feasibility was determined by comparing the costs of continued use of gasoline fuel with the use of alternative fuel and retrofitted equipment. Differences in the amounts of future expenditures are adjusted by means of a total life-cycle costing. This methodology was based on NBS Handbook 135.[1]

We found that all fuels studied are technically feasible to allow a retrofit conversion to hybrid gasoline/alternative fuel operation except for methanol. Conversion to LPG is not recommended for vehicles with more than 100,000 km (60,000 miles) of prior use. Methanol conversion is not recommended for vehicles with more than 50,000 km (30,000 miles).

The alternative fuel station may best be located in Barstow because of the existing fuels supply infrastrucure there and a small construction cost penalty for locating the facility at Goldstone.

The total life-cycle cost (TLCC) without retrofit conversion is $2.2 million. TLCC for liquid petroleum gas (LPG) is $1.7 million, for compressed natural gas (CNG) it is $1.8 million, for liquefied natural gas (LNG) it is $1.7 million, and for methanol it is $2.6 million.

The fuel with the highest savings-to-investment ratio (SIR) is liquid petroleum gas (LPG), with a SIR of 5.55. Following LPG were compressed natural gas (CNG), SIR of 3.33, liquefied natural gas (LNG), SIR of 2.44, and methanol, SIR of minus 2.28. The SIR is based on current fuel prices including applicable taxes, and a 15-year lifetime for the retrofit equipment.

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[1] References are cited on page 18.

We recommend that JPL pursue the following items:

- Development of a special natural gas tariff for CNG vehicle customers by the utility supplying Barstow, Southwest Gas Corp.
- Projected natural gas price of the proposed pipeline to Fort Irwin, California, which is adjacent to GDSCC.
- Waiver of California motor fuel tax for clean-burning alternative fuels.

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# I. INTRODUCTION

The Goldstone Deep Space Communications Complex (GDSCC) consists of several satellite tracking stations managed by the Jet Propulsion Laboratory (JPL) for the National Aeronautics and Space Administration (NASA). The Goldstone complex is located in the Mojave Desert, approximately 70 km (45 miles) north of Barstow, CA. Since the complex is in a relatively isolated area, the work force must be transported each work shift for the 90 miles roundtrip from Barstow to Goldstone and back. This is accomplished by a fleet of vans and sedans which also serve as inter-site transportation as the need arises. Originally, about 100 vehicles were used for the transportation but the current number is about 70 due to the relocation of some personnel to a new facility at Barstow. The vehicles are powered by unleaded gasoline, which is trucked to Goldstone and distributed from a single storage tank via two gasoline pumps. Each vehicle is refueled as needed through the day and night by the driver.

This report presents the results of a preliminary technical and economic feasibility study of converting vehicles to alternative fuels at the Goldstone Deep Space Communications Complex (GDSCC) of the Jet Propulsion Laboratory, Pasadena, California. This study was motivated by the continued price increases of gasoline and its potential unavailability. The fleet consists of 47 vans, 22 sedans, and 1 pickup truck. The alternative fuels we considered were compressed natural gas (CNG), liquefied natural gas (LNG), liquid petroleum gas (LPG), and methanol; vehicles were required to operate in a hybrid or dual-fuel gasoline/alternative fuel mode.

## II. OBJECTIVES

Because of the sizeable gasoline consumption each month by the transportation vans along with the rising fuel prices and uncertainty in supplies, JPL is considering the possibility of alternative fuel supplies to power these vehicles. The purpose of this study was to determine both the economic and practical feasibility of converting these vehicles to run on an alternative fuel as well as gasoline and the associated logistics of fueling said vehicles.

The objective of determining economic feasibility was met by calculating the total life-cycle cost and savings-to-investment ratios, based on NBS Handbook 135 and vendor-supplied data. Technical feasibility was determined by the availability of commercial conversion kits and refueling stations for alternative vehicles.

# III. TECHNICAL FEASIBILITY

## Fuels Characterization

Pertinent characteristics of the selected fuels are shown in Table 1. Parameters compared affect storage requirements (density, heating value), engine operations (stoichiometric air for combustion, flammability limits, flash point, octane rating) and safety (flammability limits, flash point, autoignition temperature).

## Fuel Efficiency

### A. Theoretical Considerations

The higher octane number of all the alternative fuels can be used to increase engine efficiency. By internal engine modifications compression ratios can be raised to affect this increase. In the case of CNG and LNG (methane) about a 10% increase in efficiency is possible.[2] Ignition timing changes can also be used to increase energy efficiency.

Opposing the possible gains for the gaseous fuels of methane and LPG (propane) is the displacement of the combustion air by fuel gas; this causes engine breathing difficulties and reduces the specific power (power per unit fuel rate) available from a gaseous-fueled engine.

Efficiency can also be raised relative to a gasoline engine by operating at a low equivalence ratio, or lean fuel mixture. Methanol-fueled engines can operate on leaner fuel mixtures than gasoline engines; efficiencies can be raised up to 20% and nitogen oxides emissions reduced.[2] Leaning the engine reduces power, however.

### B. Practical Considerations

Methane vehicles have been observed to consume between 0.7 and 0.9 $Nm^3$ to travel the same distance as with one liter of gasoline. (100 SCF to 120 SCF per gallon). On an energy equivalent basis this is reduction in energy use of 5% to 20% or an increase in efficiency of about 5% to 20%. There have been reports of less power with methane-fueled vehicles, such as when climbing long hills.[3] When operating in dual-fuel modes, gasoline fuel economy may suffer because the engine must still partly remain "tuned" for CNG or LNG. Methane vehicles are particularly efficient in stop and go driving, relative to gasoline vehicles; their efficiency advantage decreases in highway driving.

When operating on LPG, dual-fueled vehicles can show an energy efficiency gain of 6% to 23%; however, when running on gasoline energy efficiency can decrease 5% to 15%.[4,5]

Table 1. GASOLINE AND ALTERNATIVE FUELS CHARACTERISTICS[2]

| Characteristic | Gasoline | Compressed Natural Gas (CNG) | Liquefied Natural Gas (LNG) | Liquid Petroleum Gas (LPG) | Methanol |
|---|---|---|---|---|---|
| Density, kg/ℓ | 0.73 | 0.14* | 0.42 | 0.52 | 0.79 |
| Higher, or Gross Heating Value, kcal/kg | 11,500 | 13,300 | 13,300 | 12,100 | 5,700 |
| Stoichiometric Air for Combustion, ratio | 14.9 | 17.3 | 17.3 | 15.7 | 6.48 |
| Flammability Limits, % | 1.4-7.6 | 5.0-15.0 | 5.0-15.0 | 2.1-10.1 | 6.7-36.5 |
| Flashpoint, °C | -37 | <-106 | <-106 | -104 | 11 |
| Autoignition Temperature, °C | 258 | 634 | 634 | 431 | 470 |
| Octane Rating** | 87 | 130 | 130 | 104 | 99 |

* CNG at 16,500 kPa (2400 psi).

** Research octane number plus motor octane number divided by two.

Methanol-fueled vehicles are expected to have efficiency gains of 10% to 20% over gasoline.[6] Additionally, engine power should increase 15% to 20%.[7]

## Fuel Availability

Natural gas (methane) for CNG is supplied to Barstow, California by Southwest Gas Corp., Las Vegas, Nevada. A commercial account can be opened there. Southwest Gas hopes to have a more economical rate available for CNG customers.[8]

A new LNG plant has been opened near Carson City, Nevada.[11] This location is considerably distant from Barstow.

LPG is available in Barstow from Petrolane, Inc. of Long Beach, California. They currently are supplying LPG for a vehicle fleet in Barstow.

Methanol should be available from a number of suppliers in the Los Angeles area. For example, Air Products and Chemicals sells bulk methanol.

## Hybrid-Fuel Vehicle Technology

### A. Compressed Natural Gas (CNG)

Several organizations will handle complete conversion of vehicles to dual-fuel gasoline and CNG. Principal components of the converted system are pressure cylinders (2 to 3, depending on fuel storage requirement and availability of storage space), high-pressure gas lines, high and low pressure regulators, gas/air mixer, dual spark-advance ignition, fuel gage, and fuel selector. Compressed natural gas at 16,500 kPa (2400 psi) is let down in 2 stages; first to 410 kPa (60 psi) and then to 7 kPa (1 psi) in the gas/air mixer. Fuel metering for proper engine operation is controlled by the mixer. The system can be quickly installed by the vendor or owner mechanics.

The converted vehicles require no special start-up procedures. Starting can be achieved on either fuel. Because of methane's extremely low flash point, cold weather starting is much improved relative to gasoline.

Switching between fuels while operating is accomplished by a dashboard switch that activates appropriate solenoid valves.

Refueling is done by connecting the refueling probe to the fill connection under the hood and turning on the gas supply. Gas flow will stop when the tank reaches maximum pressure. The gas supply is then shut-off, which automatically bleeds the remaining gas in the line, and the hose is disconnected from the vehicle. An interlock prevents engine starting while refueling.

Operator training requirements are minimal; drivers can refuel their own vehicles after receiving instructions. Mechanics and installers typically receive two weeks of training at the vendor's home office. Training costs are often included with the conversion cost.

Conversion to vehicles for CNG fuel began in a limited scale in 1970 in the United States. Therefore long-term reliability is still an unknown. Components are mechanically relatively simple and should last at least

15 years.[9] Considerable margins of safety are built into components (for example, pressure cylinders are tested to a pressure of 82,700 kPa (12,000 psi), a factor of 5 larger than normal maximum pressure). An American Gas Association report states that no deaths and only 1 injury has been associated with the fuel systems of CNG vehicles in over 280 million kilometers (175 million miles).[13] If a tank should be breached, methane is lighter than air (much lighter than gasoline vapors) and would tend to rise and dissipate, thereby lessening the hazard.

B. Liquefied Natural Gas (LNG)

LNG systems consist of a cryogenic tank, integral heater, vapor or liquid lines, pressure regulator, gas/air mixer, fuel gage and fuel selector switch. Components are similar to those in CNG systems, except storage is by a double-walled cryogenic tank, which weighs less than a comparable pressure cylinder. This system is not difficult to install.

If starting on LNG, the liquid must be first vaporized by the integral heater. Good cold-start capability has been demonstrated.

During refueling vapor is vented from the tank air space as it is generated. Trained operators are not required for refueling.[11] Typical tank pressures are 34 kPa to 410 kPa (5 psi to 60 psi); a 14-day standby condition without venting has been reported.[12]

Experience with LNG vehicles is very limited, although LNG is commonly imported and used extensively for peak-shaving purposes in the gas industry. Because the cryogenic tank is not designed to withstand high pressures, it could be susceptible to rupture during a collision. A vacuum leak in the double-wall tank is also possible, which would greatly inhibit storage capacity.

C. Liquid Petroleum Gas (LPG)

LPG is mainly propane. Vehicle conversion consists of the addition of 2 or 3 pressure tanks, liquid fuel lines, a pressure regulator/evaporator, gas mixer, fuel gage and fuel selector switch. Pressure in the tank, about 690 kPa (about 100 psi) moves the liquid to the engine compartment, without the use of a pump, where it is vaporized by engine coolant. It is preferable to convert vehicles with engine mileage of less than 100,000 km (60,000 miles) because older engines may not withstand the increased power.

Cold starts on LPG may require an auxiliary heater, depending on the ambient temperature. If the engine has been operting on gasoline, warmed coolant can be used to vaporize the LPG for starting.

Fuel alternating while under way is accomplished by dash-mounted switches that control solenoid valves in the engine compartment.

Refueling is done by connecting a hose from the central LPG tank to the vehicle tank and allowing the liquid to be pumped in. Refueling is accomplished in about 5 minutes.[13] No special skills are required for fueling the vehicles. The tanks cannot be completely filled with liquid, or thermal expansion may cause dangerous internal pressures (complete filling is limited by a pressure regulator).

Propane is heavier than air and would tend to settle near the ground, prolonging the hazard of an accidental spill. In sedan-type vehicles, where the tanks are located in the trunk, the passenger compartment must be sealed-off as a safety precaution.[14] LPG tanks are not built to withstand the high pressures of CNG, thus their puncture resistance is probably intermediate between CNG pressure cylinders and conventional gasoline tanks.

D. Methanol

Conversion kits for methanol fuel are available but not for dual-fuel operation. California is the only state where methanol conversions are legal. The conversion consists of modification to the gasoline tank and carburetor, stainless steel or nylon fuel lines, and an intake manifold heater or propane-injection cold start system. Vehicles with less than 50,000 km (30,000 miles) are preferable for conversion because the increased power from methanol may damage older engines.[7]

Below about 10°C (50°F) methanol has a cold starting problem unless additives such as isopentane are present in the fuel. Alternatively, the intake manifold is heated or propane injected prior to starting the engine.

Because vehicles converted to methanol cannot be operated on dual-fuels, switching of fuels while underway is not possible.

Refueling procedures are very similar to refueling with gasoline.

Because the methanol vehicle is similar to a gasoline-powered one, no special operator training is required. Maintenance requirements and procedures will be different, requiring some training of mechanics.

The major automotive manufacturers have experience with alcohol fuels through the Brazilian ethanol program. A major difference between these fuels and gasoline is the different solvent properties. Many gaskets and seals are not compatible with methanol. Clogs and leaks in the methanol fuel systems have been reported, especially for conversions. Methanol flames are nearly colorless and would increase the hazard from a fire. Methanol vapor is regarded as more toxic than gasoline.[10]

E. Conversion Vendor Summary

Names and locations of some vendors of alternative fuel conversion systems are shown in Table 2.

## Refueling Station Technology

A. Compressed Natural Gas (CNG)

Natural gas is compressed from the distribution lines, typically at 100 kPa (15 psi) to pressures of 25,000 kPa (3600 psi) for storage. Either a time-fill or quick-fill sequence is available for refueling. With a time fill the compressors fill the vehicle storage tanks directly in a period of about 16 hours. With a quick fill the compressors have previously charged a bank, or cascade, of cylinders in the station. Vehicles are filled by withdrawal from the cylinders, first the low-pressure section, then the medium-pressure section, and then the high-pressure for final top-off. Refilling takes 3 to 5 minutes. Switching between sections of the cascade is automatic. Methanol is often injected to lessen hydrate formation.

Table 2. SUPPLIERS OF ALTERNATIVE FUEL AUTOMOTIVE CONVERSION SYSTEMS

| Vendor | Fuel | Location |
|---|---|---|
| Advanced Fuel Systems, Inc. | CNG | Wichita, Kansas |
| Beech Aircraft Corp. | LNG | Boulder, Colorado |
| Dual Fuel Systems, Inc. | CNG | Culver City, California |
| Essex Cryogenics of Missouri, Inc. | LNG | St. Louis, Missouri |
| Future Fuels of America, Inc. | Methanol | Sacramento, California |
| Gas Service Energy Corp. | CNG | Kansas City, Missouri |
| Methanol Performance World, Inc. | Methanol | Sacramento, California |
| Petrolane, Inc. | LPG | Long Beach, California |
| The Propane Shop, Inc. | LPG | Romulus, Michigan |

A time-fill station would require 3 compressors rated at 0.67 $Nm^3$ per minute each (25 SCF per minute). Each vehicle would require a time-fill hose assembly (70 total). A quick-fill station would require 3 compressors of the same rating and 9 storage cascades and hose assemblies with a storage capacity of 2100 $Nm^3$ (80,0000 SCF).[9] A diagram of a combined time-full, quick-fill refueling station is shown in Figure 1.

Refueling operations would probably be more complex for JPL because compressors would require maintenance and some operating labor. We feel the increased complexity would be minor.

Currently the CNG fueling station must be sited at Barstow because natural gas is unavailable at Goldstone. If natural gas becomes available at nearby Fort Irwin (estimated to be not sooner than 5 years), a quick-fill station could be constructed at GDSCC (a time-fill station could not refill commuter vehicles adequately). A quick-fill station would be approximately 50% more expensive. Additionally, a construction labor premium of roughly 10% to 20% above the station cost would be required at Goldstone. Conceivably, natural gas from the Fort Irwin line could be less expensive than at Barstow.

B. Liquefied Natural Gas (LNG)

Natural gas could be liquefied on-site (Barstow) but considerable expense and complexity would result. Volume of LNG use may be insufficient for a cost-effective plant. It would be preferable to purchase LNG from peak-shaving facility.

LNG is stored in a cryogenic tank at a temperature of -161°C (-259°F). Two 42,000ℓ (11,000 gallon) tanks would be required.[15] Double-walled hoses are used to refill the vehicles; drivers should be able to refuel vehicles themselves.[11]

The LNG refilling station could be located in Barstow or Goldstone. Again, a labor premium must be paid for construction at Goldstone.

C. Liquid Petroleum Gas (LPG)

LPG is typically stored at a pressure of 690 kPa (100 psi) in cylindrical pressure vessels called "bullets" or "blimps". They are painted a reflective silver to minimize heat gain and corresponding pressure increase. Liquid is drawn off the bottom or pumped to the vehicles for refueling. For the JPL fleet a tank of 76,000ℓ (20,000 gallons) would be typical.

Refueling complexity would only slightly increase in that fuel deliveries in addition to gasoline would have to be scheduled.

The LPG filling station could be located in either Barstow or Goldstone. LPG has been used at Goldstone for heating and cooking; some "extra" storage capacity probably currently exists at Barstow for this fuel because the cafeteria has recently been closed. The LPG station would cost more at Goldstone because of the higher effective labor cost.

D. Methanol

Of all the alternative fuel stations, a methanol refueling station would most resemble a gasoline station. About a 150,000ℓ (40,000 gallon) tank would be required. Fuel is pumped through hoses and nozzles into the vehicles.

Complexity of refueling operations is increased by deliveries of methanol in addition to gasoline.

The methanol station could be located in Barstow or Goldstone. Again, a construction labor premium would be paid in Goldstone.

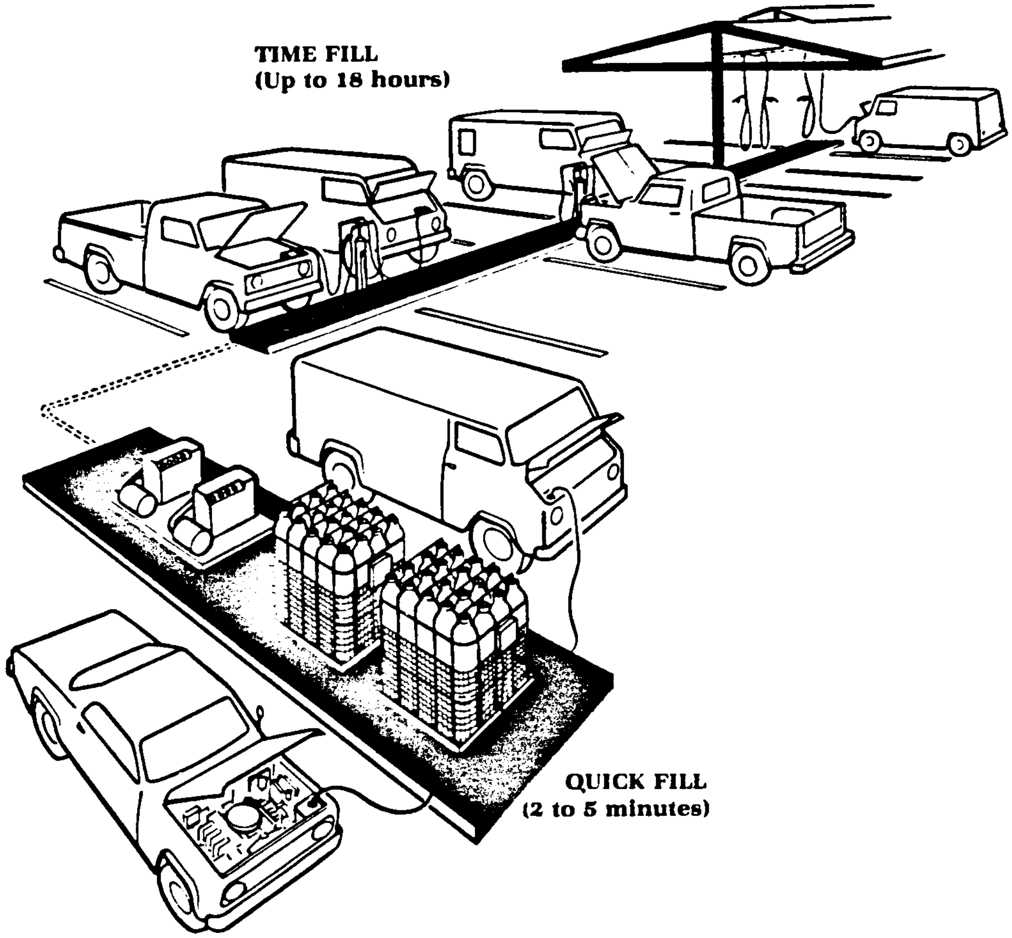


Figure 1. CNG REFUELING STATION (Source: Dual-Fuel Systems, Inc.)

## IV. ECONOMIC FEASIBILITY

### Cost Data

#### A. CNG Systems

Vendor estimates were obtained from Gas Service Energy Corp. and Dual Fuel Systems, Inc.[16,9] The conversion estimate for 70 vehicles by Gas Service was $81,700; Dual Fuel's estimate was $83,400. The fueling station was estimated by Gas Service at $110,000 (combination time-and quick-fill); Dual Fuel's estimate was $93,700 (time-fill only). We assumed the refueling station was located in Barstow so that a construction labor premium would not be required. The estimated actual investment cost for this retrofit is the average of the vendor estimates, or $184,400.

Natural gas price estimates were obtained from Southwest Gas Corp., which supplies the Barstow area.[8] Current commercial rates are $0.70 per therm ($7.00 per million Btu).

Use of CNG should reduce vehicle maintenance costs (less frequent oil and spark plug changes). Additional maintenance would be required for the gas compressors. For our analysis we assumed no increase or decrease in maintenance costs, which probably is conservative.

#### B. LNG Systems

Estimates for conversion of the fleet to LNG were obtained from Beech Aircraft Corp. and Essex Cryogenics of Missouri.[11,15] Beech estimated the conversion of 70 vehicles to cost $151,800; Essex estimates $165,500 for the vehicles. Beech estimates the fueling station would cost $250,000; Essex estimates about $270,000. The estimated actual investment cost for the LNG conversion is the average of the vendor estimates, or $411,800.

We estimate the price of liquefied natural gas from a peak-shaving facility in California to have a delivered cost of about $6.00 per million Btu.

We assume no change in overall maintenance costs for purposes of the life-cycle cost analysis.

#### C. LPG Systems

Estimates for LPG conversions were supplied by Petrolane, Inc. and the Propane Shop.[5,14] Petrolane estimates 70 vehicle conversions to cost $70,000;

the Propane Shop estimates a cost of $81,000. A 20,000 gallon tank and refilling equipment would cost about $35,000. The estimated actual investment cost for LPG is the average of the vendors estimates, or $110,500.

LPG is available in Barstow from Petrolane, which currently is supplying an LPG fleet there. Estimated price for bulk sales is $0.75 per gallon or about $8.00 per million Btu.

Again, we assume no increase or decrease in maintenance costs, which is probably conservative.

D. Methanol Systems

Only one vendor could supply cost estimates for fleet conversion to methanol. Future Fuels of America projects a 70-vehicle conversion to cost $76,300. We estimate a 40,000 gallon methanol storage tank and hoses to cost about $45,000. Thus the estimated actual investment cost for methanol is $121,300.

Methanol fuel sells for $0.99 per gallon, or $14.50 per million Btu (including taxes). The fuel contains up to 15% non-methanol additives.[7]

We assume fleet and system maintenance costs neither increase nor decrease.

E. Road and Sales Taxes

The above quoted prices excluded taxes (except the methanol prices). A waiver of California motor fuels tax can be obtained for LPG (and probably the other alternative fuels), ostensibly because it is clean burning. Federal and state sales tax in California amounts to about $0.10 per gallon of gasoline, or $0.80 per million Btu.

F. Cost Summary

Estimated actual investment costs for the conversions and corresponding base fuel prices, including applicable tax, is shown in Table 3. Gasoline price is shown for reference.

Table 3. ALTERNATIVE AUTOMOTIVE FUEL INVESTMENT AND UNIT FUEL COSTS

| System | Investment, $ | Base Fuel Price, $/10⁹J ($/10⁶ Btu) Including Tax |
|---|---|---|
| Gasoline (baseline) | none | 9.80 (10.30) |
| Compressed Natural Gas | 184,400 | 7.40 (7.80) |
| Liquefied Natural Gas | 411,800 | 6.45 (6.80) |
| Liquid Petroleum Gas | 110,500 | 8.30 (8.80) |
| Methanol | 121,300 | 13.70 (14.50) |

Life-Cycle Cost Analysis

Costing procedures of the National Bureau of Standards Handbook 135 were followed. The analysis determines the total life-cycle cost (TLCC) and the savings to investment ratio (SIR) for a retrofit-type project. Future expenses are adjusted to present values. First, the total life cycle cost without the retrofit is determined. A 15-year time period is assumed (expected life of the conversion, or retrofit). Savings with the retrofit are then calculated and the SIR determined.

A. Quantities of Fuel Purchased

Estimated amounts of alternative fuels purchased each year are shown in Table 4.

B. Savings-to-Investment Ratios

The ratios are shown in Table 7; life-cycle cost calculations appear in Appendix A. Besides the base fuel prices we have added single values higher and lower than the base case. This allows an estimate of sensitivity to fuel price changes.

C. Total Life-Cycle Costs

Total costs are determined for each system, based on annual fuel, operating, and equipment cost. The total is adjusted to a present value by means of uniform present worth (UPW) discount factors for each of the fuels. These factors are presented in Table 5. Total life-cycle costs are presented in Table 6; calculations are shown in Appendix A.

Table 4. ANNUAL FLEET FUEL PURCHASES

| Fuel | SI Units | Conventional Units | Millions of Btu | Amount Relative to Gasoline Energy |
|---|---|---|---|---|
| Gasoline | 570,000ℓ | 150,000 gal | 18,900 | 1.00 |
| CNG | 480,000 $Nm^3$ | 18 x $10^6$ SCF | 18,000 | 0.95 |
| LNG | 810,000ℓ | 215,000 gal | 18,000 | 0.95 |
| LPG | 650,000ℓ | 172,000 gal | 16,100 | 0.85 |
| Methanol | 840,000ℓ | 222,000 gal | 15,100 | 0.80 |

Table 5. UNIFORM PRESENT WORTH FACTORS
(15-year Study Period, DOE Region 9, Commercial Sector)

| Fuel | Factor |
|---|---|
| Unleaded Gasoline | 11.52 |
| Compressed Natural Gas | 10.15 |
| Liquefied Natural Gas | 10.15 |
| Liquid Petroleum Gas | 11.52 |
| Methanol | 11.52 |
| Electricity | 9.05 |

Table 6. TOTAL LIFE-CYCLE COSTS (TLCC)

| | Gasoline | CNG | LNG | LPG | Methanol |
|---|---|---|---|---|---|
| | | | $\$10^6$ | | |
| TLCC | 2.25 | 1.81 | 1.65 | 1.74 | 2.64 |
| ΔTLCC* | -- | 0.44 | 0.60 | 0.51 | -0.39 |

*Gasoline TLCC minus alternative fuel TLCC.

Table 7. SAVINGS-TO-INVESTMENT RATIOS (SIR)
FOR THE ALTERNATIVE FUELS STUDIED

| | CNG | LNG | LPG | Methanol |
|---|---|---|---|---|
| Base Case | 3.33 | 2.44 | 5.55 | -2.28 |
| Low Case* | 5.32 | 2.88 | 7.23 | 2.02 |
| High Case** | 1.36 | 1.99 | 3.88 | -6.58 |

* Based on CNG prices of $5.80/MBtu, LNG prices of $5.80/MBtu, LPG prices of $7.80/MBtu and Methanol prices of $11.50/MBtu.

** Based on CNG prices of $9.80/MBtu, LNG prices of $7.80/MBtu, LPG prices of $9.80/MBtu, and Methanol prices of $17.50/MBtu.

## V. RECOMMENDATIONS

Conversion to liquid petroleum gas (LPG) offers JPL the greatest savings-to-investment ratio, based on current fuel prices. Behind the LPG conversion came compressed natural gas (CNG), followed by liquefied natural gas (LNG). Methanol conversions cannot be operated in a hybrid manner with gasoline; additionally, we estimate that conversion to methanol would result in a net loss to JPL.

An external factor that could affect the competitive position of CNG is the possibility of a special natural gas tariff for CNG vehicle users. Southwest Gas Corp. policy in this regard should be monitored.

A CNG conversion would also be enhanced by cheaper gas prices. The pipeline project to bring natural gas to Fort Irwin should be investigated to determine estimated price of the gas.

For all the alternative fuels we assumed that California motor fuels tax could be waived for a small fee, as is currently practiced for LPG. The availability of this waiver should be discussed with state taxing officials.

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# APPENDIX A. LIFE-CYCLE COST WORKSHEETS

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# TOTAL LIFE-CYCLE COST WITHOUT THE RETROFIT (GASOLINE)

RETROFIT LCC WORKSHEET

A. Calculating the Present Value of Energy Costs Without the Retrofit

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE | ______ | $ ______ |
| | | | $ ______ DEMAND CHARGE | | $ ______ |
| | | | $ ______ TIME OF DAY CHARGE | | $ ______ |
| | | | $ ______ CONTRACT CAPACITY CHARGE | | $ ______ |
| | | | $ ______ OTHER CHARGE COMPONENT | | $ ______ |
| OIL | | | | | |
| GAS | | | | | |
| ~~OTHER~~ UNLEADED GASOLINE | 18,900 MBtu | $10.30/MBtu | $195,000 | 11.52 | $2,246,000 |
| TOTAL | | | | | $2,246,000 |

B. Calculating Investment Costs for the Existing System Without the Retrofit

✓ (1) Base-Year Resale, Salvage, or Reuse Value of the Existing System to be Replaced $ 0

(2) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Not Implemented $ 0

C. Calculating Annually Recurring Nonfuel Operation and Maintenance (O&M) Costs Without the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

## TLCC WITHOUT THE RETROFIT (GASOLINE)



D. Calculating Non-Annually Recurring O&M (Non-fuel) Costs, Replacement Costs, and Salvage Value Without the Retrofit.

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| TOTAL | X | X | X | X | 0 | 0 | 0 |

E. Calculating TLCC Without the Retrofit

(1) Present Value of Energy Costs $ 2,246,000

(2) Present Value of Investment Costs + $ 0

(3) Present Value of Annually Recurring (Nonfuel) O&M Costs + $ 0

(4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs + $ 0

(5) Present Value of Replacement Costs + $ 0

(6) Present Value of Salvage - $ 0

(7) TLCC Without the Retrofit = $ 2,246,000

[1] For example, if nonannually recurring (nonfuel) O&M costs, replacement costs, or salvage value occur in 1990 and you are using 1980 as the base year, base-year dollars means stating the 1990 costs in 1980 dollars, i.e., without future inflation.

## BASE-CASE TLCC (COMPRESSED NATURAL GAS)

**Retrofit LCC WORKSHEETS (Continued)**

**Parts F through J Calculate TLCC with the Retrofit**

**F. Calculating the Present Value of Fuel Costs With the Retrofit**

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | 270,000 kWh | $0.084/kWh | $ 22,700 BASE CHARGE | 9.05 | $ 205,400 |
| | | | $ ____ DEMAND CHARGE | | $ ____ |
| | | | $ ____ TIME OF DAY CHARGE | | $ ____ |
| | | | $ ____ CONTRACT CAPACITY CHARGE | | $ ____ |
| | | | $ ____ OTHER CHARGE COMPONENT | | $ ____ |
| OIL | | | | | |
| GAS | 18,000 MBtu | $7.80/MBtu | $140,400 | 10.15 | $1,425,000 |
| OTHER ____ | | | | | |
| TOTAL | | | | | $1,630,400 |

**G. Calculating Investment Costs with the Retrofit**

| | | |
|---|---|---|
| (1) | Estimated Actual Investment Costs for the Retrofit Project | $184,400 |
| (2) | Investment Cost Adjustment Factor | x 1.0 |
| (3) | Adjusted Investment Costs for the Retrofit Project | = $184,400 |
| (4) | Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + 0 |
| (5) | Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = $124,400 |

## BASE-CASE TLCC (CNG)

RETROFIT LCC WORKSHEETS (Continued)

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
| --- | --- | --- |
| $ 0 | — | $ 0 |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
| --- | --- | --- | --- | --- | --- | --- | --- |
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| | | | | | | | |
| TOTAL | | | | | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | |
| --- | --- | --- |
| (1) Present Value of Energy Costs | | $. 1,650,400 |
| (2) Present Value of Adjusted Investment Costs | + | $. 184,400 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $. 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $. 0 |
| (5) Present Value of Replacement Costs | + | $. 0 |
| (6) Present Value of Salvage | - | $. 0 |
| (7) TLCC With the Retrofit Project | = | $. 1,814,400 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

# BASE-CASE SAVINGS-TO-INVESTMENT RATIO (CNG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,2[illegible],[illegible] |
| (2) TLCC with the Retrofit | - | $ 1,[illegible]4,400 |
| (3) Net Savings (+) or net losses (-) | = | $ 4[illegible]1,600 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ 615,600 |
| (b) Change in Nonfuel O&M Costs | - | $ 0 |
| (c) SIR Numerator | = | $ [illegible] |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 1[illegible]4,[illegible] |
| (b) Change in Replacement Costs | + | $ [illegible] |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ 1[illegible]4,400 |
| (3) SIR for Ranking the Retrofit Project | | 3.33 |

# BASE-CASE TLCC (LIQUEFIED NATURAL GAS)

**Retrofit LCC WORKSHEETS (Continued)**

**Parts F through J Calculate TLCC with the Retrofit**

**F. Calculating the Present Value of Fuel Costs With the Retrofit**

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE | ______ | $ ______ |
| | | | $ ______ DEMAND CHARGE | | $ ______ |
| | | | $ ______ TIME OF DAY CHARGE | | $ ______ |
| | | | $ ______ CONTRACT CAPACITY CHARGE | | $ ______ |
| | | | $ ______ OTHER CHARGE COMPONENT | | $ ______ |
| OIL | | | | | |
| GAS | | | | | |
| OTHER LNG | 18,001 MBtu | $6.80/MBtu | $122,400 | 10.15 | $1,242,400 |
| TOTAL | X | X | X | X | $1,242,400 |

**G. Calculating Investment Costs with the Retrofit**

| | | |
|---|---|---|
| (1) Estimated Actual Investment Costs for the Retrofit Project | | $411,800 |
| (2) Investment Cost Adjustment Factor | x | 1.0 |
| (3) Adjusted Investment Costs for the Retrofit Project | = | $411,800 |
| (4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + | 0 |
| (5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = | $411,800 |

# BASE-CASE TLCC (LNG)

RETROFIT LCC WORKSHEETS (Continued)

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ ______ | ______ | $ ______ |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| TOTAL | X | X | X | X | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ 1,2[illegible],400 |
| (2) Present Value of Adjusted Investment Costs | + | $ 411,800 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | - | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ [illegible]54,200 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

## BASE-CASE SIR (LNG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | = | $ 1,654,200 |
| (3) Net Savings (+) or net losses (-) | = | $ 591,800 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ 1,003,600 |
| (b) Change in Nonfuel OM Costs | = | $ 0 |
| (c) SIR Numerator | = | $ 1,003,600 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 411,800 |
| (b) Change in Replacement Costs | = | $ 0 |
| (c) Change in Salvage Value | = | $ 0 |
| (d) SIR Denominator | = | $ 411,800 |
| (3) SIR for Ranking the Retrofit Project | | 2.44 |

## BASE-CASE TLCC (LIQUID PETROLEUM GAS)

**Retrofit LCC WORKSHEETS (Continued)**

**Parts F through J Calculate TLCC with the Retrofit**

**F. Calculating the Present Value of Fuel Costs With the Retrofit**

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE | ______ | $ ______ |
| | | | $ ______ DEMAND CHARGE | | $ ______ |
| | | | $ ______ TIME OF DAY CHARGE | | $ ______ |
| | | | $ ______ CONTRACT CAPACITY CHARGE | | $ ______ |
| | | | $ ______ OTHER CHARGE COMPONENT | | $ ______ |
| OIL | | | | | |
| GAS | | | | | |
| OTHER LPG | 16,100 mBtu | $8.80/mBtu | 141,700 | 11.52 | $1,632,400 |
| TOTAL | | | | | $1,632,400 |

**G. Calculating Investment Costs with the Retrofit**

| | | |
|---|---|---|
| (1) Estimated Actual Investment Costs for the Retrofit Project | | $110,500 |
| (2) Investment Cost Adjustment Factor | x | 1.0 |
| (3) Adjusted Investment Costs for the Retrofit Project | = | $110,500 |
| (4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + | 0 |
| (5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = | $110,500 |

## BASE-CASE TLCC (LPG)

RETROFIT LCC WORKSHEETS (Continued)

**H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit**

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | – | $ 0 |

**I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit**

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| | | | | | | | |
| TOTAL | | | | | 0 | 0 | 0 |

**J. Calculating TLCC With the Retrofit Project**

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ 1,632,400 |
| (2) Present Value of Adjusted Investment Costs | + | $ 110,500 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | – | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ 1,742,900 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

## BASE-CASE SIR (LPG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,[illegible]6,000 |
| (2) TLCC with the Retrofit | - | $ 1,7[illegible],[illegible]00 |
| (3) Net Savings (+) or net losses (-) | = | $ [illegible]8,100 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ 613,600 |
| (b) Change in Nonfuel O&M Costs | - | $ 0 |
| (c) SIR Numerator | = | $ 613,600 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ [illegible]0,5[illegible] |
| (b) Change in Replacement Costs | + | $ 0 |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ [illegible]0,500 |
| (3) SIR for Ranking the Retrofit Project | | 5.55 |

## BASE-CASE TLCC (METHANOL)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

**F. Calculating the Present Value of Fuel Costs With the Retrofit**

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE | ______ | $ ______ |
| | | | $ ______ DEMAND CHARGE | | $ ______ |
| | | | $ ______ TIME OF DAY CHARGE | | $ ______ |
| | | | $ ______ CONTRACT CAPACITY CHARGE | | $ ______ |
| | | | $ ______ OTHER CHARGE COMPONENT | | $ ______ |
| OIL | | | | | |
| GAS | | | | | |
| OTHER [illegible] | 15,100 mbtu | $14.50/mbtu | $219,000 | 11.52 | $2,522,[illegible] |
| TOTAL | X | X | X | X | $2,5[illegible] |

**G. Calculating Investment Costs with the Retrofit**

(1) Estimated Actual Investment Costs for the Retrofit Project — $121,[illegible]

(2) Investment Cost Adjustment Factor — x 1.0

(3) Adjusted Investment Costs for the Retrofit Project — = $12[illegible]

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented — = 0

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project — = $[illegible],300

RETROFIT LCC WORKSHEETS (Continued)

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| TOTAL | X | X | X | X | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | | |
|---|---|---|---|
| (1) Present Value of Energy Costs | | $ | 2,522,900 |
| (2) Present Value of Adjusted Investment Costs | + | $ | 121,300 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ | 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ | 0 |
| (5) Present Value of Replacement Costs | + | $ | 0 |
| (6) Present Value of Salvage | - | $ | 0 |
| (7) TLCC With the Retrofit Project | = | $ | 2,644,200 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

## BASE-CASE SIR (METHANOL)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | - | $ 2,644,200 |
| (3) Net Savings (+) or net losses (-) | = | $ -398,200 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ -276,900 |
| (b) Change in Nonfuel O&M Costs | - | $ 0 |
| (c) SIR Numerator | = | $ -276,900 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 121,300 |
| (b) Change in Replacement Costs | + | $ [illegible] |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ 121,300 |
| (3) SIR for Ranking the Retrofit Project | | -2.28 |

## LOW-CASE TLCC (CNG)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

### F. Calculating the Present Value of Fuel Costs With the Retrofit

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | 270,000 kWh | $0.084/kWh | $ 22,700 BASE CHARGE | 9.05 | $ 205,400 |
| | | | $ ____ DEMAND CHARGE | | $ ____ |
| | | | $ ____ TIME OF DAY CHARGE | | $ ____ |
| | | | $ ____ CONTRACT CAPACITY CHARGE | | $ ____ |
| | | | $ ____ OTHER CHARGE COMPONENT | | $ ____ |
| OIL | | | | | |
| CNG GAS | 18,000 MBtu | $5.80/MBtu | $104,400 | 10.15 | $1,059,700 |
| OTHER ____ | | | | | |
| TOTAL | | | | | $1,265,100 |

### G. Calculating Investment Costs with the Retrofit

(1) Estimated Actual Investment Costs for the Retrofit Project — $184,400

(2) Investment Cost Adjustment Factor — x 1.0

(3) Adjusted Investment Costs for the Retrofit Project — = $184,400

(4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented — + 0

(5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project — = [illegible]

## LOW-CASE TLCC (CNG)

RETROFIT LCC WORKSHEETS (Continued)

**H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit**

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

**I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit**

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
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| TOTAL | X | X | X | X | 0 | 0 | 0 |

**J. Calculating TLCC With the Retrofit Project**

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ $1,265,100 |
| (2) Present Value of Adjusted Investment Costs | + | $ 184,400 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | - | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ 1,449,500 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

## LOW-CASE SIR (CNG)

RETROFIT LCC WORKSHEETS (Continued)

| | | |
|---|---|---|
| **K. Net Savings or Excess Cost of the Retrofit Project** | | |
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | - | $ 1,449,500 |
| (3) Net Savings (+) or net losses (-) | = | $ 796,500 |
| **L. SIR Calculation** | | |
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ 980,700 |
| (b) Change in Nonfuel O&M Costs | - | $ 0 |
| (c) SIR Numerator | = | $ 980,700 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 184,400 |
| (b) Change in Replacement Costs | + | $ |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ 184,400 |
| (3) SIR for Ranking the Retrofit Project | | 5.32 |

# LOW-CASE TLCC (LNG)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE<br>$ ______ DEMAND CHARGE<br>$ ______ TIME OF DAY CHARGE<br>$ ______ CONTRACT CAPACITY CHARGE<br>$ ______ OTHER CHARGE COMPONENT | ______ | $ ______<br>$ ______<br>$ ______<br>$ ______<br>$ ______ |
| OIL | | | | | |
| 1.11 GAS | 18,000 MBtu | $5.80/MBtu | $104,400 | 10.15 | $1,059,700 |
| OTHER ____ | | | | | |
| TOTAL | | | | | $1,059,700 |

G. Calculating Investment Costs with the Retrofit

| | | |
|---|---|---|
| (1) | Estimated Actual Investment Costs for the Retrofit Project | $411,800 |
| (2) | Investment Cost Adjustment Factor | x 1.0 |
| (3) | Adjusted Investment Costs for the Retrofit Project | = $411,800 |
| (4) | Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + 0 |
| (5) | Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = $411,800 |

LOW-CASE TLCC (LNG)

RETROFIT LCC WORKSHEETS (Continued)

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| | | | | | | | |
| TOTAL | | | | | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ 1,059,700 |
| (2) Present Value of Adjusted Investment Costs | + | $ 411,800 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | - | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ 1,471,500 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

# LOW-CASE SIR (LNG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | = | $ 1,814,400 |
| (3) Net Savings (+) or net losses (-) | = | $ 431,600 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ 1,186,800 |
| (b) Change in Nonfuel O&M Costs | + | $ 0 |
| (c) SIR Numerator | = | $ 1,186,800 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 411,800 |
| (b) Change in Replacement Costs | + | $ 0 |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ 411,800 |
| (3) SIR for Ranking the Retrofit Project | | 2.88 |

## LOW-CASE TLCC (LPG)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

### F. Calculating the Present Value of Fuel Costs With the Retrofit

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE | ______ | $ ______ |
| | | | $ ______ DEMAND CHARGE | | $ ______ |
| | | | $ ______ TIME OF DAY CHARGE | | $ ______ |
| | | | $ ______ CONTRACT CAPACITY CHARGE | | $ ______ |
| | | | $ ______ OTHER CHARGE COMPONENT | | $ ______ |
| OIL | | | | | |
| GAS | | | | | |
| OTHER LPG | 16,100 mBtu | $7.80/mBtu | $125,600 | 11.52 | $1,446,900 |
| TOTAL | | | | | $1,446,900 |

### G. Calculating Investment Costs with the Retrofit

| | | |
|---|---|---|
| (1) | Estimated Actual Investment Costs for the Retrofit Project | $110,500 |
| (2) | Investment Cost Adjustment Factor | x 1.0 |
| (3) | Adjusted Investment Costs for the Retrofit Project | = $110,500 |
| (4) | Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + 0 |
| (5) | Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = $110,500 |

## LOW-CASE TLCC (LPG)



H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| | | | | | | | |
| TOTAL | X | X | X | X | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $. 1,446,900 |
| (2) Present Value of Adjusted Investment Costs | + | $. 110,500 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $. 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $. 0 |
| (5) Present Value of Replacement Costs | + | $. 0 |
| (6) Present Value of Salvage | - | $. 0 |
| (7) TLCC With the Retrofit Project | = | $. 1,557,400 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

# LOW-CASE SIR (LPG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | - | $ 1,55[illegible] |
| (3) Net Savings (+) or net losses (-) | = | $ 688,600 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ 794,1[illegible] |
| (b) Change in Nonfuel O&M Costs | - | $ 0 |
| (c) SIR Numerator | = | $ 7[illegible], 10[illegible] |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 110,8[illegible] |
| (b) Change in Replacement Costs | + | $ 0 |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ 110,8[illegible] |
| (3) SIR for Ranking the Retrofit Project | | 7.[illegible] |

# LOW-CASE TLCC (METHANOL)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

**F. Calculating the Present Value of Fuel Costs With the Retrofit**

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE<br>$ ______ DEMAND CHARGE<br>$ ______ TIME OF DAY CHARGE<br>$ ______ CONTRACT CAPACITY CHARGE<br>$ ______ OTHER CHARGE COMPONENT | ______ | $ ______<br>$ ______<br>$ ______<br>$ ______<br>$ ______ |
| OIL | | | | | |
| GAS | | | | | |
| OTHER Methanol | 15,100 MBtu | $11.50/MBtu | $173,700 | 11.52 | $2,001,000 |
| TOTAL | X | X | X | X | |

**G. Calculating Investment Costs with the Retrofit**

| | | |
|---|---|---|
| (1) Estimated Actual Investment Costs for the Retrofit Project | | $121,300 |
| (2) Investment Cost Adjustment Factor | x | [illegible] |
| (3) Adjusted Investment Costs for the Retrofit Project | = | $121,300 |
| (4) Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + | 0 |
| (5) Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = | $121,300 |

## LOW-CASE TLCC (METHANOL)

RETROFIT LCC WORKSHEETS (Continued)

**H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit**

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

**I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit**

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| TOTAL | | | | | 0 | 0 | 0 |

**J. Calculating TLCC With the Retrofit Project**

| | | | |
|---|---|---|---|
| (1) | Present Value of Energy Costs | | $ 2,001,000 |
| (2) | Present Value of Adjusted Investment Costs | + | $ 121,300 |
| (3) | Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) | Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) | Present Value of Replacement Costs | + | $ 0 |
| (6) | Present Value of Salvage | - | $ 0 |
| (7) | TLCC With the Retrofit Project | = | $ 2,122,300 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

## LOW-CASE SIR (METHANOL)

RETROFIT LCC WORKSHEETS (Continued)

K. Net Savings or Excess Cost of the Retrofit Project

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | = | $ 2,122,300 |
| (3) Net Savings (+) or net losses (-) | = | $ 123,700 |

L. SIR Calculation

| | | |
|---|---|---|
| (1) SIR Numerator | | $ 245,000 |
| (a) Energy Cost Savings from the Retrofit | | |
| (b) Change in Nonfuel O&M* Costs | = | $ 0 |
| (c) SIP Numerator | = | $ 245,000 |
| (2) SIP Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 121,300 |
| (b) Change in Replacement Costs | = | $ 0 |
| (c) Change in Salvage Value | = | $ 0 |
| (d) SIF Denominator | = | $ 121,300 |
| (3) SIP for Ranking the Retrofit Project | | 2.02 |

## HIGH-CASE TLCC (CNG)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

**F. Calculating the Present Value of Fuel Costs With the Retrofit**

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | 270,000 | $0.0841 / kWh | $ 22,700 BASE CHARGE | [illegible].05 | $ [illegible]05,[illegible]00 |
| | | | $ ____ DEMAND CHARGE | | $ ____ |
| | | | $ ____ TIME OF DAY CHARGE | | $ ____ |
| | | | $ ____ CONTRACT CAPACITY CHARGE | | $ ____ |
| | | | $ ____ OTHER CHARGE COMPONENT | | $ ____ |
| OIL | | | | | |
| 11. GAS | 18,000 mBtu | $9.80/mBtu | $176,400 | 10.15 | $1,790,500 |
| OTHER ____ | | | | | |
| TOTAL | | | | | $1,995,900 |

**G. Calculating Investment Costs with the Retrofit**

| | | |
|---|---|---|
| (1) | Estimated Actual Investment Costs for the Retrofit Project | $184,400 |
| (2) | Investment Cost Adjustment Factor | x 1.0 |
| (3) | Adjusted Investment Costs for the Retrofit Project | = $184,400 |
| (4) | Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + 0 |
| (5) | Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = $184,400 |

## HIGH-CASE TLCC (CNG)

RETROFIT LCC WORKSHEETS (Continued)

### H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

### I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| TOTAL | | | | | 0 | 0 | 0 |

### J. Calculating TLCC With the Retrofit Project

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ 1,995,900 |
| (2) Present Value of Adjusted Investment Costs | + | $ 184,400 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | - | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ 2,180,300 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

HIGH-CASE SIR (CNG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | - | $ 2,[illegible]0,300 |
| (3) Net Savings (+) or net losses (-) | = | $ 65,700 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | |
| (a) Energy Cost Savings from the Retrofit | | $ [illegible]50,[illegible]00 |
| (b) Change in Nonfuel O&M Costs | - | $ 0 |
| (c) SIR Numerator | = | $ [illegible]0,100 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ [illegible] |
| (b) Change in Replacement Costs | + | $ [illegible] |
| (c) Change in Salvage Value | - | $ [illegible] |
| (d) SIR Denominator | = | $ 184,[illegible]0 |
| (3) SIR for Ranking the Retrofit Project | | 1.36 |

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

**F. Calculating the Present Value of Fuel Costs With the Retrofit**

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE | ______ | $ ______ |
| | | | $ ______ DEMAND CHARGE | | $ ______ |
| | | | $ ______ TIME OF DAY CHARGE | | $ ______ |
| | | | $ ______ CONTRACT CAPACITY CHARGE | | $ ______ |
| | | | $ ______ OTHER CHARGE COMPONENT | | $ ______ |
| OIL | | | | | |
| I.N. GAS | 18,000 MBtu | $7.80 /MBtu | $140,400 | 10.15 | $1,425,100 |
| OTHER ____ | | | | | |
| TOTAL | X | X | X | X | $1,425,100 |

**G. Calculating Investment Costs with the Retrofit**

| | | |
|---|---|---|
| (1) | Estimated Actual Investment Costs for the Retrofit Project | $411,800 |
| (2) | Investment Cost Adjustment Factor | x 1.0 |
| (3) | Adjusted Investment Costs for the Retrofit Project | = $411,800 |
| (4) | Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + 0 |
| (5) | Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = $411,800 |

RETROFIT LCC WORKSHEETS (Continued)

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | – | $ 0 |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
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| TOTAL | | | | | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ 1,425,100 |
| (2) Present Value of Adjusted Investment Costs | + | $ 411,800 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | - | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ 1,836,900 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

## HIGH-CASE SIR (LNG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

(1) TLCC without the Retrofit $ 2,246,000

(2) TLCC with the Retrofit − $ 1,836,900

(3) Net Savings (+) or net losses (−) = $ 409,100

**L. SIR Calculation**

(1) SIR Numerator

(a) Energy Cost Savings from the Retrofit $ 820,900

(b) Change in Nonfuel O&M Costs − $ 0

(c) SIR Numerator = $ 820,900

(2) SIR Denominator

(a) Adjusted Differential Investment Cost $ 411,830

(b) Change in Replacement Costs + $ 0

(c) Change in Salvage Value − $ 0

(d) SIR Denominator = $ 411,830

(3) SIR for Ranking the Retrofit Project [illegible]

## HIGH-CASE TLCC (LPG)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE | ______ | $ ______ |
| | | | $ ______ DEMAND CHARGE | | $ ______ |
| | | | $ ______ TIME OF DAY CHARGE | | $ ______ |
| | | | $ ______ CONTRACT CAPACITY CHARGE | | $ ______ |
| | | | $ ______ OTHER CHARGE COMPONENT | | $ ______ |
| OIL | | | | | |
| GAS | | | | | |
| OTHER LPG | 16,100 mBtu | $9.80/mBtu | $157,800 | 11.52 | $1,817,600 |
| TOTAL | X | X | X | X | $1,817,600 |

G. Calculating Investment Costs with the Retrofit

| | | |
|---|---|---|
| (1) | Estimated Actual Investment Costs for the Retrofit Project | $110,500 |
| (2) | Investment Cost Adjustment Factor | x 1.0 |
| (3) | Adjusted Investment Costs for the Retrofit Project | = $110,500 |
| (4) | Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + 0 |
| (5) | Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = $110,500 |

HIGH-CASE TLCC (LPG)

RETROFIT LCC WORKSHEETS (Continued)

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| | | | | | | | |
| TOTAL | X | X | X | X | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ 1,817,600 |
| (2) Present Value of Adjusted Investment Costs | + | $ 110,500 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | - | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ 1,928,100 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

# HIGH-CASE SIR (LPG)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,246,000 |
| (2) TLCC with the Retrofit | - | $ 1,928,100 |
| (3) Net Savings (+) or net losses (-) | = | $ 317,900 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | $ 428,400 |
| (a) Energy Cost Savings from the Retrofit | | |
| (b) Change in Nonfuel O&M Costs | - | $ 0 |
| (c) SIR Numerator | = | $ 428,400 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ 110,500 |
| (b) Change in Replacement Costs | + | $ 0 |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ 110,500 |
| (3) SIR for Ranking the Retrofit Project | | 3.88 |

## HIGH-CASE TLCC (METHANOL)

Retrofit LCC WORKSHEETS (Continued)

Parts F through J Calculate TLCC with the Retrofit

F. Calculating the Present Value of Fuel Costs With the Retrofit

| TYPE | (1) ANNUAL UNITS OF ENERGY PURCHASED | (2) BASE-YEAR ENERGY PRICE PER UNIT | (3) BASE-YEAR ENERGY COSTS | (4) UPW* FACTOR | (5) PRESENT VALUE OF ENERGY COSTS |
|---|---|---|---|---|---|
| ELECTRICITY | ______ | ______ | $ ______ BASE CHARGE<br>$ ______ DEMAND CHARGE<br>$ ______ TIME OF DAY CHARGE<br>$ ______ CONTRACT CAPACITY CHARGE<br>$ ______ OTHER CHARGE COMPONENT | ______ | $ ______<br>$ ______<br>$ ______<br>$ ______<br>$ ______ |
| OIL | | | | | |
| GAS | | | | | |
| OTHER Methanol | 15,100 mBtu | $17.50/mBtu | $264,300 | 11.52 | $3,044,700 |
| TOTAL | | | | | $3,044,700 |

G. Calculating Investment Costs with the Retrofit

| | | |
|---|---|---|
| (1) | Estimated Actual Investment Costs for the Retrofit Project | $121,300 |
| (2) | Investment Cost Adjustment Factor | x 1.0 |
| (3) | Adjusted Investment Costs for the Retrofit Project | = $121,300 |
| (4) | Base-Year Renovation Costs for the Existing System if the Retrofit Project is Implemented | + 0 |
| (5) | Total Adjusted Present Value Investment Costs Attributable to the Retrofit Project | = $121,300 |

RETROFIT LCC WORKSHEETS (Continued)

H. Calculating Annually Recurring (Nonfuel) Operation and Maintenance (O&M) Costs With the Retrofit

| (1) Amount of Annually Recurring Costs in Base Year | (2) UPW Factor | (3) Present Value of Annually Recurring Costs |
|---|---|---|
| $ 0 | — | $ 0 |

I. Calculating Nonannually Recurring (Nonfuel) O&M Costs, Replacement Costs, and Salvage Value With the Retrofit

| (1) YEAR IN WHICH EXPENDITURE IS EXPECTED TO OCCUR | (2) AMOUNT OF NON-ANNUALLY RECURRING O&M COSTS (IN BASE-YEAR $)[1] | (3) AMOUNT OF REPLACEMENT COSTS (IN BASE-YEAR $)[1] | (4) AMOUNT OF SALVAGE VALUE (IN BASE-YEAR $)[1] | (5) SPW FACTORS | (6) PRESENT VALUE OF NON-ANNUALLY RECURRING O&M COSTS | (7) PRESENT VALUE OF REPLACEMENT | (8) PRESENT VALUE OF SALVAGE VALUE |
|---|---|---|---|---|---|---|---|
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| | | | | | | | |
| | | | | | | | |
| TOTAL | X | X | X | X | 0 | 0 | 0 |

J. Calculating TLCC With the Retrofit Project

| | | |
|---|---|---|
| (1) Present Value of Energy Costs | | $ 3,044,700 |
| (2) Present Value of Adjusted Investment Costs | + | $ 121,300 |
| (3) Present Value of Annually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (4) Present Value of Nonannually Recurring (Nonfuel) O&M Costs | + | $ 0 |
| (5) Present Value of Replacement Costs | + | $ 0 |
| (6) Present Value of Salvage | - | $ 0 |
| (7) TLCC With the Retrofit Project | = | $ 3,166,000 |

[1] See footnote on page 57 for explanation.

[2] Worksheet format is expanded to allow for comparison of the two choices.

# HIGH-CASE SIR (METHANOL)

RETROFIT LCC WORKSHEETS (Continued)

**K. Net Savings or Excess Cost of the Retrofit Project**

| | | |
|---|---|---|
| (1) TLCC without the Retrofit | | $ 2,7[illegible],000 |
| (2) TLCC with the Retrofit | - | $ 3,166,000 |
| (3) Net Savings (+) or net losses (-) | = | $ -[illegible],000 |

**L. SIR Calculation**

| | | |
|---|---|---|
| (1) SIR Numerator | | $ -[illegible],700 |
| (a) Energy Cost Savings from the Retrofit | | |
| (b) Change in Nonfuel OM Costs | - | $ 0 |
| (c) SIR Numerator | = | $ -7[illegible],700 |
| (2) SIR Denominator | | |
| (a) Adjusted Differential Investment Cost | | $ [illegible] |
| (b) Change in Replacement Costs | + | $ 0 |
| (c) Change in Salvage Value | - | $ 0 |
| (d) SIR Denominator | = | $ [illegible]00 |
| (3) SIR for Ranking the Retrofit Project | | -6.58 |

**End of Document**