# Technology Assessment Report

# Twin Rivers Technologies

# Quincy, MA

Prepared for
The Massachusetts Strategic
Envirotechnology Partnership
STEP

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Prepared by

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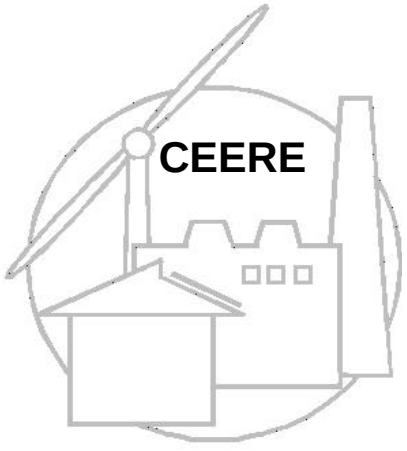


*Center for Energy Efficiency and Renewable Energy*

## PROJECT FUNDING

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## PREFACE

The STEP technology assessment process is designed to identify those technologies that will support the economic and environmental/energy goals of the Commonwealth of Massachusetts and may benefit from STEP assistance. The process is meant to be one of screening, in which technologies are evaluated by independent technical specialists. Recommendation from this process does not constitute an endorsement of the technology or of the absolute validity of the technology. Rather, STEP technical assessments attest only that, through the screening process, the reviewers feel there may be benefit to the Commonwealth of Massachusetts.

# EXECUTIVE SUMMARY

## APPLICANT

Twin Rivers Technologies, Inc.
780 Washington St.
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Twin Rivers Technology, Inc. (TRT) was formed in 1994 to manufacture fatty acids for the soap and cosmetic industries from virgin vegetable oils and animal fats. TRT also manufactures, markets and distributes biodiesel, an alternative fuel that can be made from natural animal and vegetable oils. This product has been submitted to the STEP program as an innovative environmental technology.

Biodiesel is an ester-based oxygenated fuel derived from renewable biological sources which can be used in diesel engines in either its neat form (100%), or blended with petroleum diesel. It is a methyl or ethyl ester made of vegetable oils, typically soybean oils. It could potentially be produced from recycled restaurant grease and waste oil provided that this feedstock can be purified before processing. Due to its cost, biodiesel is generally blended with petroleum diesel at the 20 percent level (B20) before being used in transportation appications.

## APPLYING THE TECHNOLOGY

For existing diesel vehicles, especially for the urban bus fleet, biodiesel is a potentially desirable fuel because under the right conditions, it reduces emissions of particulate matter (PM), unburned hydro-carbons (UHC) and carbon monoxide (CO) in certain families of diesel engines. In existing diesel engines, biodiesel blends can cause nitrogen oxides (NOx ) increases, however, by fitting the engine with an oxidation catalyst and retarding the fuel injection timing, the engine can be adjusted to bring NOx levels back to the baseline levels or on occasion slightly below.

It is convenient for existing fleets to use because it requires only simple timing changes and equipment additions and no changes in fuel handling and delivery. Perhaps, most significantly, biodiesels main advantages over conventional diesel fuel are that it is biodegradable, non-toxic and essentially free of sulfur and aromatics. Also, of great importance is that it is a renewable resource that can be produced domestically, from soybeans. As we become more concerned with global climate change, this benefit may become of greater importance.

## COMPETING TECHNOLOGIES

The transit industry is looking for least-cost methods to meet one portion of the Clean Air Act, the Urban Bus Retrofit/ Rebuilt Program which focuses on the clean-up of existing transit fleet vehicles. Options include retrofitting buses with emission control equipment, such as catalytic converters and particulate traps, converting the vehicles to run on cleaner fuels (such as Compressed Natural Gas (CNG)) or retiring vehicles early to replace them with new vehicles that have lower emissions.

It is likely that future transit vehicle purchases will focus on non-diesel alternatives; vehicles that burn cleaner fuels but the question of what to do with the existing vehicles is an important one. Based on a study done in 1996 by Rizzo and Associates for the Massachusetts Bay Transit Authority (MBTA), compared to early retirement of older buses, biodiesel blends can meet the Clean Air Acts Urban Bus Retrofit/Rebuilt Program cost-competitively, based on a present value analysis of the total life-cycle costs.

There are a number of large companies that have the knowledge and resources to manufacture biodiesel, but they are currently not doing so. The biodiesel market is still small and provides too low a rate of return on investment for these companies to find it attractive. TRTs goal is to develop their product and manufacture biodiesel from alternative sources, and thus gain a competitive advantage over companies that are trying to enter the market.

## STEP SUPPORT REQUESTED

TRT has asked STEP to evaluate their biodiesel product as a substitute technology for petro-diesel, and compare it to other alternative fuels such as methanol, ethanol or compressed natural gas (CNG) for the purpose of cleaning up the existing fleet of buses and heavy-duty diesel vehicles. In particular, the question of using B20 in meeting the requirements of the urban bus retrofit/rebuild program is to be evaluated.

Opportunities exist to greatly improve biodiesel production economics and eventually offer an even more competitive product. TRT is requesting support from the STEP program on initiatives that would offer economic development, improved energy security and environmental benefits to the state:

Agricultural programs involving local cultivation of rapeseed would have an immediate effect on biodiesel production economics, on biodiesel availability, and would help increase options for struggling Massachusetts farms.

Support for swift implementation and refinement of processing and recycling technology would improve already attractive economics

Consider strict enforcement of grease handling and disposal regulations would enable the recycling portions of the biodiesel program to proceed more quickly.

Biodiesel could be vetted by the Clean State Program as a substitute technology for state fleets subject to EPA and DOE mandates or in conjunction with State Implementation Plans, Transportation Improvements Plans or in order to meet other policy goals.

## ASSESSMENT FINDINGS

The data presented show that the biodiesel and petro-diesel fuel blend, B20, can perform as claimed and can be used to meet the Clean Air Acts Urban Bus Retrofit/ Rebuilt Program. Biodiesel blend has high cost. However, based on the present value analysis of the total life-cycle costs, for existing buses required to meet the Urban Bus Requirements, B20 can compete with the option of retiring still-productive vehicles and replacing them with cleaner alternative fuel vehicles.

The authors of this report recommend that the STEP program provide further assistance to TRT and help with any permitting and regulatory needs in the state of Massachusetts for the urban bus retrofit/rebuild program.

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# TECHNICAL ASSESSMENT

## DESCRIPTION OF TECHNOLOGY

Biodiesel is defined as the mono-alkyl ester of long chain fatty acids. Vegetable oils contain a molecular structure called tri-glycerides, which are made up of fatty acids and glycerol, one of many alcohols. Scientists have long realized that the fatty acids in vegetable oil were more valuable as a fuel without these added glycerides. Since then, the process of producing fuel from vegetable and animal oils has been continuously refined and improved. The process involves the transformation of the large, branched, tri-glyceride molecules of bio-oils and fats into smaller, straight chain molecules, similar in size to components of diesel oil. The oil is filtered and preprocessed to remove free fatty acids. Then it is mixed with methanol and a catalyst, usually sodium or potassium hydroxide. The resulting esters and the glycerols can then be separated and purified.

Biodiesel, a fuel oxygenate (acetane enhancer), can be used in diesel engines in either its neat form, or blended with petroleum diesel fuel. Generally, biodiesel is blended with petroleum diesel at the 20 percent level (B20) due to its cost. Biodiesel can be blended with conventional diesel in any percent but the current TRT focus is on the 20% mixture combined with a particular exhaust system oxidation catalyst and retarded fuel injection timing. Biodiesel performs similarly to petroleum diesel, delivering nearly the same torque, horsepower and miles per gallon. Biodiesel has a high flashpoint and is non-toxic and biodegradable which makes it safer to handle than petroleum diesel. The idea of neat biodiesel for use in marine vessels is very appealing because compared to conventional diesel, biodiesel is more biodegradable and less toxic in an aquatic environment and, therefore, less of a danger to water quality and ecological balance (Zhang, et al. 1995). Finally, biodiesel, as all vegetable oils, contains negligible levels of sulfur and thus reduces emissions of sulfur dioxide in direct relation to the amount of biodiesel used.

TRT has developed a technology that will allow the economical production of biodiesel from agricultural feedstock, either soy or rapeseed oil. One potentially exciting feature is the possibility of making biodiesel from waste oil and grease products such as rendered yellow grease or inedible tallow. Although TRT would need to refine the existing purification technology to produce waste oil fuels with clean-burning performance, the reuse of waste oil products would have considerable environmental benefits.

Furthermore, such recycling technologies could provide cheaper raw materials that will make biodiesel production more competitive with petroleum diesel and other alternative fuels. The TRT estimate is that the use of rendered waste oil feedstock could reduce raw material cost by 50%.

## PERFORMANCE CLAIMS RELATIVE TO EPA'S URBAN BUS RETROFIT/REBUILD PROGRAM

In April of 1993, the EPA published the final Retrofit/Rebuild Requirements for 1993 and Earlier Model Year Urban Buses (58-FR-21359) program. The Program requires the rebuild or replacement of older bus engines of large urban transit fleets. Specifically, buses with 1993 or earlier engines and which operate in a large urban area (operating within a metropolitan area with 750,000 or more people) must have their engines rebuilt or replaced. The program calls for a reduction in the ambient levels of PM in urban areas.

**Program 1**. This is a performance based requirement, demanding that affected buses meet a particulate standard of 0.1 g/bhp-hr at the time of engine replacement or rebuild. If no equipment has been certified as meeting this criterion at an acceptable life cycle cost, engine replacement or rebuild must provide a 25% reduction in particulate emission relative to the original engine configuration. This program does not require retirement or replacement.

**Program 2**. This program requires affected bus fleets to meet an annual average particulate emission level. The Target Level for a Fleet (TLF) is based upon the pre-1994 fleet as of January 1, 1995, and is based upon existing emission levels in 1996. The Target Level Emission for a fleet (TLE), for each year of the program, is based upon the pre-1994 fleet, and is calculated for each year of the program. Starting in 1996, pre-1994 fleets must be at or below the TLE for a fleet for the given year of operation until all pre-1994 models have been retired. Compliance under the program is determined by comparing the TFL with the annual Fleet Level Attained (TFA) of particulate emission. The TLF and FLA can be calculated using a spreadsheet model that has been developed by the EPA.

To be eligible for use in the program, certification of the fuel and or equipment configuration is required by EPA. TRT applied for certification for two configurations of equipment:

1) B20 blend of biodiesel and petroleum diesel in combination with a particular exhaust system oxidation catalyst; and,

2) B20 and the oxidation catalyst, plus retarded fuel injection timing.

The oxidation catalyst used here is the CMX$^{TM}$ catalyst which was previously certified under the urban bus program by the Engelhard Corporation. The review of test data, Table 1, indicate that the B20 plus catalyst configuration reduced PM by between 25 and 40% compared to the baseline of neat petroleum diesel. Retarded fuel injection timing is used to reduce exhaust emissions of NOx . Data also indicate a reduction in CO and UHC emissions compared to 1988 EPA standard.

Using engine dynamometer (transient) testing in accordance with the Federal Test Procedure for heavy-duty diesel engines, TRT demonstrated a reduction in PM emissions.

Data from testing the candidate equipment, two stroke/cycle engines manufactured by Detroit Diesel Corporation (DDC), for different configurations are presented in Table 1. The oxidation catalyst used

here is the CMX™ catalyst previously certified under the urban bus program by the Engelhard Corporation. Review of the data indicate that B20 plus the catalyst configuration reduced PM by 25-40%, depending on the driving cycle used. Retarded fuel injection timing is used to reduce exhaust emission of $NO_x$ below 1988 EPA standards. If retarded fuel injection is not used, the emission of $NO_x$ increases above the EPA standard. Data also indicate a reduction in CO and UHC emissions.

The data also show that emissions for the same engine configuration with the B20 blend compared to baseline, low sulfur #2 diesel fuel, are closely matched. $NO_x$ emissions are always lower when a baseline diesel fuel is used. Emissions of CO and UHC are lower when the B20 blend is used.

**Table 1: Two stroke engine emissions test results**

| Engine | Gaseous and Particulate | | | | Comment |
|---|---|---|---|---|---|
| | UHC | CO | $NO_x$ | PM | |
| | g/bhp-hr | | | | |
| Engine Dyno | 1.3 | 15.5 | 10.7 | 0.60 | 1988 EPA standard |
| 1977 6V71N | 0.38 | 3.18 | 11.72 | 0.282 | 2D[1] |
| | 0.42 | 1.64 | 11.72 | 0.159 | 2D + OC[2] |
| | 0.38 | 0.86 | 12.11 | 0.166 | B20 + OC |
| | 0.53 | 1.37 | 8.1 | 0.247 | 2D + OC + 4° retard |
| | 0.42 | 0.94 | 8.47 | 0.213 | B20 + OC + 4° retard |
| 1988 6V92 TA | 0.6 | 1.6 | 8.52 | 0.20 | 2D |
| | 0.21 | 0.95 | 9.06 | 0.11 | B20 + OC |
| | 0.29 | 1.21 | 8.18 | 0.14 | 2D + OC + 1° retard |
| | 0.25 | 1.05 | 8.35 | 0.12 | B20 + OC + 1° retard |

2D[1] = Baseline, low Sulfur #2 diesel fuel
OC[2] = Oxidation Catalyst

On October 22, 1996, EPA s Compliance Division determined that two specific configurations of Biodiesel combined with catalysts could meet the requirements for certification and have been certified.

The EPA issued a Notice of certification of equipment supplied by Twin Rivers Technologies for the urban bus retrofit/rebuild program (Federal Register, V61, N205). Both configurations of equipment are certified for DDC engines originally installed in urban buses of model years 1979 through 1993, excluding 1990 model year DDC 6L71TA engines.

## REVIEW OF ALTERNATIVE TECHNOLOGIES (COMPETITION)

In addition to TRT, the following companies have applied or are in the process of applying to be listed as biodiesel fuel suppliers with the National Biodiesel Board (NBB):

Environmental Products, Lenexa, KS

NOPEC Corporation, Lakeland, FL

Pacific Biodiesel, Kahului, HI

The price at which these companies are offering their product are not known.

## REVIEW OF OPTIONS FOR MEETING THE URBAN BUS REQUIREMENTS

When considering the option of replacing the existing older buses prematurely and substituting cleaner alternative fuels, fuel cost is one factor to consider but other costs such as retrofitting garages, eliminating open fired heaters (ie. For working around natural gas) and installing refueling equipment (fueling pumps, fuel storage tanks, maintenance equipment and emergency fire equipment) all are part of the calculation. In addition, the purchase price for engines that run on diesel (biodiesel) and methanol are comparable but other alternative fuel buses are far more expensive. The vehicles low production volumes currently may add as much as $20,000 to $55,000 to the price of the bus (Motta et al. 1996). However, decisions should be based not only on fuel cost and usage, but on the full life-cycle maintenance, repair, and in-service costs for the total operational life of the buses.

The National Renewables Energy Laboratory. (NREL) study (Motta et al., 1996) also estimates the total incremental cost of the necessary modifications to the fueling and maintenance facilities for a bus fleet of 160 alternative fuel buses. They found a range from $100,000 for a methanol and ethanol fueled fleet up to $3.75 million for CNG facilitate. The TRT option consists of adding an Engelhard CTX catalytic converter that is listed for under $2,000 (Rizzo Associates, 1996).

An experiment of the Denver, Colorado, regional transportation district, as part of a commitment to meet Clean Air regulations, which dated from June 1989 to December 1993, compared expenditures with bus fleets run on diesel, biodiesel, methanol and CNG (Ahouissoussi & Wetzstein, 1995). Buses were exposed to similar operating conditions such as scheduled speeds, stops per mile, traffic conditions and passenger loading. They were also maintained under the same preventive maintenance program. The

analysis indicates that, although the biodiesel and biodiesel blends have higher costs than diesel fuel, they have the ability to compete with CNG and methanol fuels. As concerns about the impact of fossil fuels on the environment and health increase, the market for alternative fuels is expected to grow. Based on this present-value analysis of total life-cycle costs, biodiesel seems positioned to compete with other alternative fuels in the transit bus market.

The NREL program to study the performance, reliability, cost and emission of alternative fuels involved collecting data from more than 100 buses at eight transit agencies across the country (Motta et al., 1996). Emissions were measured on a transportable chassis dynamometer using Central Business District (CBD) driving cycle. The CNG and alcohol buses were shown to have potential to lower PM and $NO_x$ emissions significantly. Most ethanol and all methanol powered buses emitted less $NO_x$, but had significantly higher amounts of UHC and CO, than the diesel with emissions controls. With CNG, PM emissions were virtually eliminated and an engines exhibited lower CO and $NO_x$ emissions. The total UHC emission levels from the CNG buses are higher then those from the diesel powered engines. Tests were also run on buses using B20, but the limited number of buses (four) , and the relative scatter in the data, prevented drawing any conclusions. The chassis dynamometer testing has shown that emissions are highly dependent on the engine technology and the condition of the vehicle.

The biodiesel industry has targeted niche fuel markets, such as existing diesel vehicles in the Federal and state fleets, construction and mining equipment, and marine vessels for commercialization. These markets may all bear fruit, but one market in particular, the urban bus fleet, is especially viable given the federal goals of EPACT and CAA.

Another study conducted in Massachusetts shows that target emission levels for the fleets could be achieved without having to retire any buses early, before their assumed 15-year lifetime (Rizzo Associates 1996) using several options including use of a B20 blend and catalytic oxidizer or the use catalytic oxidizer alone.

A general review of emissions data indicates that the B20 plus catalyst configuration and retarded fuel injection timing reduced PM by between 5 and 47% depending on the engine type and driving cycle used. $NO_x$ emissions were mostly held to current levels or showed a slight decrease mostly on the order of 2-5%. In addition, the reduction of unburned hydrocarbons, comparable with the 20% lower petroleum hydrocarbon content in B20 is of note, especially given its reduced toxicity as described above. The use of the catalytic oxidizer alone was not analyzed.

The emission test results, presented in this assessment, were obtained for an early assessment of alternative fuel engines. Both diesel and alternative fuel technologies have changed substantially since then. Newer diesel engines are electronically controlled and have lower PM emissions to meet the latest EPA standards. Newer generation CNG engine designs have much better control of the air-fuel ratio, and hence more consistent emissions characteristics. Diesel engines also continue to improve especially in new diesel/ electric combination vehicles.

## ENERGY IMPLICATIONS AND PRICE OF USING BIODIESEL

According to a study by the Institute for Local Self-Reliance (ILSR), the ratio of the amount of Energy Required to produce biodiesel to the total Energy Output from the biodiesel (EREO) is 1:2.51 (Ahmed, Decker & Morris, 1992). The total energy input is based on the data for the total agricultural and processing energy input. The energy output consists of the amount of energy in soydiesel and in the soymeal and glycerol produced during the soy oil extraction. According to the same study, the industry best for EREO is 1:3.24 and the industry potential is 1:4.1. At the same time the industrial average EREO for ethanol is 1:1.34 and the industrial best is 1:1.93. Production of methanol has less favorable EREO over ethanol.

However, the price of biodiesel compared to methanol and ethanol is not in proportional to EREO. The current price of methanol is $0.84/gal compared to $1.00/gal ethanol (Renewable Energy: Biomass and Biofuels). The cost of biodiesel produced from soybean oil varies considerably over time. TRT has stated that the price is approximately equal to 12 times the price of soybean oil (Rizzo Associates, 1996). Based on data from the Chicago Board of Trade from 1990 to 1996 the cost of soybean diesel should vary between $2.50 and $3.50 per gallon. This high cost remains the greatest obstacle to market penetration for biodiesel in blends or as a neat fuel.

Table 2 can be used to make a price comparison between different fuels per unit of energy. The price of natural gas is set at $4.00/ million Btu. This price is usually set by the local utility and approved by state public utility commission. Thus, fleet operators around the country face different prices for CNG as for all alternative fuels used.

**Table 2: Costs for Standard and Alternative fuels**

| Fuel | Lower Heating Value [Btu/unit] | Price [$/unit] | Price [$/MMBtu] |
|---|---|---|---|
| Methanol | 56,560/gal | $0.84/gal | 14.85 |
| Ethanol | 76,000/gal | $1.00/gal | 13.16 |
| Biodiesel (BD) | 132,902/gal | $2.50/gal<br>$3.50/gal | 18.81<br>26.34 |
| Low sulfur #2 oil | 140,000/gal | $0.69/gal | 4.93 |
| B20 @ $2.50/gal for BD<br>@ $3.50/gal for BD | 138,500/gal | $1.05/gal<br>$1.25/gal | 7.58<br>9.04 |
| Natural Gas | 100,000/ccf | $0.40/ccf | 4.00 |

## SUMMARY AND RECOMMENDATIONS

For the particular use highlighted in this study, biodiesel is a suitable, environmentally acceptable fuel. Its benefits are that it can make emissions from existing diesel engines less toxic. Before mixing with conventional diesel, it is less harmful to the environment in cases of accidental spills. The fuel is more biodegradable than diesel fuel, and will break down more quickly, reducing long term damage to soil or water. It is also a renewable fuel and has a positive energy balance, especially important as we look for ways to reduce greenhouse gases going into the atmosphere. The TRT biodiesel blend is more expensive, however, based on the present value analysis of the total life-cycle costs, it can compete with CNG, ethanol and methanol fuels for use in existing transit buses.

Production of biodiesel could be made more efficient since up to 4.1 Btus could be recovered for each Btu used in its production and processing. Production costs depend on the price of feed stock seed, the value of the meal left after the oil extraction from the seed, the value of product glycerol, the price of alcohol, and the government programs for production, research and fuel substitutes.

Added benefits of the B20 strategy are a decrease in PM, UHC and CO emission levels when compared to a catalyst only strategy, and to a limited extent, a reduction in petrodiesel use. Although tests show an increase in $NO_x$ emissions,Ttis increase can be managed or held level with timing changes and the use of the catalyst as described above. The B20 strategy appears to be competitive and the EADC recommends that STEP provide further assistance to TRT and help with any permitting and regulatory needs in the state of Massachusetts for the urban bus retrofit/rebuild program.

# BUSINESS ASSESSMENT

## COMPANY BACKGROUND AND MISSION

Twin Rivers Technologies was founded in 1994. The company purchased the former Proctor and Gamble facility in Quincy, MA and began to manufacture fatty acids for sale to a variety of customers in the commercial and industrial manufacturing markets, including Proctor and Gamble. The manufacture of fatty acids has become the major product line for Twin Rivers and the success of this endeavor has provided support for the biodiesel product.

Twin Rivers is currently conducting several pilot projects with transit systems using biodiesel in their bus fleets, including with the Massachusetts Bay Transportation Authority. They also provide MassPort with biodiesel for their airport shuttle buses.

Twin Rivers Biodiesel is certified by the Environmental Protection Agency as an approved alternative fuel under the Clean Air Act's Urban Bus Retrofit/Rebuild program, when produced from virgin stock and used with a catalytic converter and/or retarded timing.

## THE MARKETPLACE

Biodiesel is of interest to owners of heavy-duty vehicles, especially those owners looking to improve the public image of their vehicles or company. Twin Rivers is focusing on the transit marketplace, especially the approximately 45,000 diesel buses already owned by transit authorities. Twin Rivers estimates that this creates an opportunity for over 16 million gallons of biodiesel per year, assuming an 80-20 mix of diesel to biodiesel.

Biodiesel represents only one option for transit systems to meet regulatory standards for the Urban Bus Program. For future purchases, given the need to make further NOx reductions and the problems of diesel particulates, diesel vehicles, are not expected to be a large portion of the market, especially not for transit vehicles. TRT itself publicly stated its support of environmental organizations and others urging the MBTA (the Boston area transit authority) to forego new purchases of diesel buses and to focus on cleaner alternatives.

A secondary market for biodiesel may be other existing heavy duty diesel fleets, construction equipment, marine diesel engines and stationary diesel engines engaged as back up and peak load generators, etc..

In addition, other markets that Twin Rivers is examining for potential long term exploitation is the cleaning solvents and lubricants markets. These are smaller markets than the fuel related market and will represent a smaller percentage of Twin Rivers's ideal sales mix.

## FINANCIAL POSITION

STEP staff reviewed limited information relative to the financial position of Twin Rivers. The company indicates that the fatty acid manufacturing side of their business continues to be successful and provides support for the early market penetration efforts related to biodiesel. The company was able to successfully finance the original purchases of the Proctor and Gamble facility as well recent upgrades of its fatty acid manufacturing equipment.

## MANAGEMENT TEAM

The management team is headed by James Ricci, who has many years of experience working with government entities within a regulatory market though his development and operations of two refuse fired power plants. The rest of the team represents a mix of individuals with long time management and operations experience at the Proctor and Gamble facility in Quincy and individuals with experience in marketing and sales within the oleo-chemical industry and sales to government entities.

## SALES AND BUSINESS DEVELOPMENT STRATEGIES

As stated above, it is the intention of Twin Rivers to penetrate the urban bus market in the near term while they develop longer term opportunities in other markets. Twin Rivers does recognize that the urban bus market is expected to convert to fuel sources other than diesel. This makes their long term market development efforts critical to the viability of biodiesel as a Twin Rivers product.

In addition to being their short term (10-12 year) focus, the urban bus market provides Twin Rivers with a high profile market to demonstrate the performance of their product. The company anticipates that the successful performance of biodiesel in the urban bus market will enhance their ability to succeed in other mobile and stationary diesel engine markets.

Twin Rivers has plans to expand their use of waste oils as a feed stock in the production of biodiesel. This would enhance the commercial appeal of the product as it is expected that the use of waste oil will reduce the cost of biodiesel. This will also add the a further selling point to the product through the appeal solving a difficult disposal issues surrounding waste oil by recycling.

## SUMMARY OF BUSINESS VIABILITY CONSIDERATIONS

To the extent that biodiesel provides a practical and cost effective alternative fuel for the urban bus market in their efforts to comply with the bus requirements of the Clean Air Act, Twin Rivers Technologies should have success in this market in the short term. It is critical to the long term viability of biodiesel as a commercially successful product that Twin Rivers is able to expand into other markets. They must continue their efforts to reduce the cost the product to make them more attractive in the diesel fuel market, including fully implementing the use of recycled waste oil. STEP staff believes that the Twin Rivers Management team has the resources and experience to achieve this success.

# REGULATORY AND POLICY ASSESSMENT

## ENVIRONMENTAL POLICY

### Air Quality Issues

Diesel engine emissions are a significant part of the air pollution inventory. With more than 10,700 diesel buses operating in the Commonwealth, mostly for transporting school children, and slightly over 29,000 diesel trucks, heavy-duty diesel engines, add about 26% of the Commonwealth's total NOx pollution. Diesel engines are also very high emitters of nitrogen oxides and carbon dioxide. As an ozone forming pollutant, nitrogen oxides are being controlled in all other sectors of the economy and in the future will need to be controlled in heavy-duty engines as well.

### Diesel Emissions and Human Exposure: Nitrogen Oxides, Particulates and Air Toxics

Diesel exhaust is a complex mixture of gases, vapors and fine particles emitted by an engine burning diesel fuel. Depending on the engine type, operating conditions, fuel mixture, lubricating oil and the presence of an emissions control system, the characteristics and quantity of the gases and particles will differ. Primarily, however, diesel exhaust consists of particles with a solid carbon core coated with soluble organic compounds. The remainder of the gaseous fraction will be nitrogen oxides, oxygen, carbon dioxide and unburned hydrocarbons, as well as over 40 other substances including benzene, formaldehyde, 1,3-butadiene, arsenic and nickel. Some of these are suspected or known to cause cancer in humans and with over 30 studies finding increased likelihood of cancer risk in workers exposed to constant diesel exhaust.

In addition to breathing in particles, exposure to diesel emissions can occur to humans and ecosystems when particulates are deposited into water, soil and vegetation by direct deposition and by roadway runoff. Furthermore, people are exposed to inhaling these particles when they are in re-entrained from dust on roadway and other surfaces.

#### *Air Toxics and Diesel Exhaust*

Research shows that B20 is less toxic by composition than pure diesel fuel by weight and therefore provides an added benefit. In California, diesel exhaust has been proposed to be a Toxic Air Contaminant by the California Air Resources Board and the California Office of Environmental Health Hazard Assessment. This designation is currently undergoing public comment and review.

#### *NOx Emissions Reductions*

NOx is a major component of both smog and acid rain. Ozone is a highly reactive pollutant that inflames and damages lung tissue, causing congestion and reducing vital lung capacity. It is responsible for shortness of breath, asthma attacks and premature death in some cases. Massachusetts is in serious

nonattainment of the federal health-based ozone standards and is under federal Clean Air Act requirements to meet the standards by November of 1999.

The only regulatory controls that the Commonwealth currently has is the control of idling trucks and buses, and in the ability to cite smoking diesel engines (through the Registry of Motor Vehicles authority). Also, a diesel testing program will be included in the revised vehicle inspection and maintenance (I/M) program. Long understood as an important place to make significant NOx reductions, existing diesel engines have not yet been regulated in the State Implementation Plan.

#### *Proposed New Particulate and Ozone Standards*

Massachusetts is currently in compliance with the national ambient air quality standards (NAAQS) for particulate matter (PM), however in December 1996, EPA proposed major changes in the NAAQS for ozone and PM, including a proposal to promulgate a standard for fine particulate matter: particles less than 2.5 microns in diameter (PM-fine). PM-fine is viewed as a significant threat to public health, and diesel engines contribute to PM-fine emissions. Massachusetts status regarding fine particulate attainment is unknown at this time.

EPA is under a court order to finalize the PM standards by July 19, 1997. These new standards could require new emission control programs for PM and perhaps diesel engines will be one of the next logical choices for PM reductions.

## The Clean Air Act Requirement for Urban Buses

Beginning in 1996, the operators of pre-1994 urban bus fleets must meet the requirements of EPA's Urban Bus Rebuild/Retrofit Program. This program offers two routes of compliance, described earlier. With a basic goal of reducing particulates in the existing urban bus fleet; the rule requires that all fleets be at or below the Target Level for a Fleet (TLF) for the given year of operation until all pre-1994 models have been retired. The vehicle rebuild/retrofit program doesn't favor any one control technology over another, however, because Massachusetts is also in non-attainment for ground level ozone, NOx controls need to be part of any effort to comply with the Urban Bus Retrofit/Rebuild program. The Twin Rivers system (B20, retarded fuel injection and a catalyst) certified by EPA meets the regulatory requirement for this program.

#### *Purchasing New Fleet Vehicles*

For these reasons, as a matter of environmental and public health policy, the state is interested in moving away from the use of diesel engine technologies. The MBTA Board, for example, has pledged to buy "No New Diesel" buses and they are looking at other options for reducing all types of pollutants in newer bus purchases. The environmental agencies acknowledge the importance of developing a renewable energy resources while using less toxic fuel blends, however, they cannot support the expanded use of B20 biodiesel fuel beyond the Urban Bus Program at this point because of the generally

toxic effects of the 80% of conventional fuel which is still inherent in a B20 fuel mix. TRT itself has been supportive of foregoing additional diesel purchases for new transit equipment.

In the meantime, options for cleaning up the existing fleet of buses is an important environmental and public health question.

## FUTURE RECOMMENDATIONS

The environmental agencies should encourage the following biodiesel research efforts:

Most importantly, research should be conducted into the in-use emissions, toxicity and performance data from transit buses using Biodiesel. Most interesting would be a comparison of several engine types, including some from the newer portion of the fleet. This study would help the state make informed policy decisions about using biodiesel beyond the Urban Bus retrofit/rebuild program. Current biodiesel data is insufficient for the purpose of broader recommendations because past studies have been too narrowly focused: using different engine types or evaluating emissions based on neat biodiesel fuel.

Test the feasibility of generating Biodiesel from restaurant waste oils and greases as proposed by Twin Rivers. The agencies are interested in the exploring the potential to beneficially reuse another environmentally difficult waste product providing the reuse doesn't have a significant impact in PM emissions.

Develop and refine biodiesel manufacturing to lower the cost of biodiesel production, allowing for blends greater than B20 blends.

## ENERGY POLICY

During the past decade, the United States has become increasingly dependent on oil to meet its energy demands. This dependence on foreign trade conditions and the actions of foreign governments has generated considerable interest in producing alternative liquid fuels including renewable ones. This desire for greater energy security and clean domestic energy supplies is incorporated in federal policy, especially in the National Energy Policy Act (EPACT) of 1992 which focuses on the need to switch to new transportation fuels.

EPACT directs federal and state government vehicles to begin to convert their own fleet vehicles (under 8,500 lbs.) to alternative fuels; with a target of 75% of their purchases being alternative fuel vehicles by the year 2000. Centrally fueled fleets with 20 or more light-duty vehicles (less then 8500 lb) operating in major urban areas will also likely be covered by similar regulation in the next two years. These requirements are only for light duty passenger vehicles and thus do not provide a market for biodiesel.

The biodiesel industry has worked with the Department of Energy (DOE) to allow for the use of biodiesel and in March of 1996, the DOE approved neat (100%) biodiesel, as an alternative fuel under EPACT. Fleet operators may include medium and heavy duty diesel vehicles (above 8500 lb) into the program on a voluntary basis.

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