HOW TO PREVENT POLLUTION ON THE BEAUTIFUL NORTH COAST WITH ZERO EMISSION VEHICLES

Feasibility for Public Transit in a Rural Region

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ABSTRACT

A proactive approach of anticipating pollution problems before they occur can be a valuable planning tool for maintaining livable communities. While rural areas with good air quality status receive low priority for clean-air vehicle deployment by state and federal agencies and manufacturers, local governments may choose to participate on their own initiative. Three main factors are driving development and use of zero emission vehicles: clean air goals, global warming impacts, and energy security issues.

Mendocino Council of Governments, as the Regional Transportation Planning Agency in a rural area, conducted a planning project demonstrating zero emission vehicles. Current-model electric vehicles were tested in this mountainous, remote environment. Infrastructure and renewable energy were explored. Local planning staff and decision makers were given hands-on experience, and the public was educated. A report of this Zero Emission Vehicle Demonstration Project was produced.

Based on experience with DaimlerChrysler's Electric Powered Interurban Commuter (EPIC), further research was made of technology options, focusing on public transit applications. MCOG's public-private partners include Mendocino Transit Authority, the Renewable Energy Development Institute, and County of Mendocino Air Quality Management District.

The only currently practical option for rural use of alternative vehicles in public transit are small electric-powered vans. This conclusion may change as new technology develops and becomes available. Electric vehicles are the only vehicles widely available with zero emissions. Mendocino Clean Air Transportation coalition has identified a variety of resources and will continue pursuing pollution prevention in this region of natural beauty on California's North Coast.

INTRODUCTION

A proactive approach of anticipating pollution problems before they occur can be a valuable planning tool for maintaining livable communities. While rural areas with good air quality attainment status receive low priority for clean-air vehicle deployment by state and federal agencies and vehicle manufacturers, local governments may choose to participate on their own initiative. Three main factors are driving development and use of zero and low emission vehicles: clean air goals, global warming impacts, and energy security issues.

The Zero Emission Vehicle (ZEV) Demonstration Project

The Mendocino Council of Governments (MCOG), as the Regional Transportation Planning Agency, found a high level of local interest and available public-private resources for conducting a planning project that demonstrated zero emission vehicles. Five current-model electric vehicles were tested in the mountainous environment, and issues of infrastructure and renewable energy were explored. Local planning staff and decision makers were given the opportunity for hands-on experience. Drivers were trained and the public was educated about the project. A report of "the ZEV Project" was produced (*1*).

Mendocino Clean Air Transportation

This paper builds on MCOG's report and focuses on public transit applications. Based on the ZEV Project experience with DaimlerChrysler's Electric Powered Interurban Commuter (EPIC), further research was conducted of available technology options. MCOG and cooperating local agencies are continuing to evaluate the practicality and benefits of using commercially produced zero emission (electric) vehicles in Mendocino County. MCOG's partners include Mendocino Transit Authority (MTA), the Renewable Energy Development Institute (REDI), County of Mendocino Air Quality Management District, and others. Staff members network as an informal working coalition called Mendocino Clean Air Transportation.

Rural Emphasis

This is a rural effort and therefore different from work done to date with alternative fuel vehicle technology, which so far has been focused on urban areas with problems of air quality attainment status. It deals with pollution prevention in a relatively pristine environment, as a practical strategy to keep air attainment status through good planning. It is well known locally that some people have settled in Mendocino County for health reasons, as their doctors advised them to seek cleaner air and avoid exposure to toxic chemicals. The challenges for electric vehicles of rugged and mountainous terrain and remote locations also are addressed. Rural regions with similar concerns may find this research useful.

Clean Air Goals

California's Clean Air Act of 1990 is enforced by the Air Resources Board (CARB) rules known as the ZEV Mandate, which has been weakened in recent years but is still in force. The most recently amended schedule of zero and low emission vehicle deployment calls for four percent zero emission vehicles in the state by 2003 (*2*). Further, CARB adopted new fleet regulations on February 24, 2000 requiring replacement of diesel buses with a low emission propulsion system (*3*). The federal Clean Air Act must also be considered. In addition, the Clinton-Gore Administration has a National Environmental Technology Strategy, which emphasizes pollution avoidance, innovation, and sustainable communities (*4*).

Global Warming and Energy Security

Greenhouse gas emissions from burning of fossil fuels, largely from transportation sources, are becoming universally recognized in the scientific community as a cause of harmful global warming and climate change. Opportunities with clean renewable energy sources, energy efficiency and conservation are available to reduce the risk of damage to the biosphere. New advanced vehicle technologies offer these advantages while helping to address fuel price instability currently impacting public transit operators using fossil fuels.

Electric propulsion uses an energy source with much more predictable pricing then vehicles propelled by internal combustion. The recent (March 2000) spike in gasoline and diesel prices ruptured transit agency budgets around the country, but electricity rates remained stable.

The general manager of Fresno County Rural Transit reported the fuel cost-per-mile for his electric bus was about one-third that of a comparable gasoline vehicle during the price peak.

AVAILABLE TECHNOLOGIES AND INFRASTRUCTURE REQUIREMENTS

For all these compelling reasons, alternative fuel vehicle technologies were researched for rural feasibility and availability, along with their associated fueling equipment needs.

Electric Vehicles (EVs)

This is the best choice for rural areas today, despite some limitations. The limited availability of EVs and their high capital cost can make the initial purchase difficult. Large electric buses are still prohibitively expensive; however, smaller consumer electric vehicles are becoming affordable through lease and purchase options. Specialized maintenance and driver training are required to optimize performance. Initial pilot projects in Santa Barbara and Chattanooga indicate that EVs are feasible and cost effective. The supplemental heating and/or cooling required in most climates rely on other fuel inputs. This technology needs full life cycle testing and evaluation in rural areas.

There is still a lack of standardization in the EV industry, with competing inductive and conductive charging designs. However, compared to other alternative vehicle fuels, infrastructure for EVs is cheap. Large electric vehicles require high volumes of energy to re-charge their batteries, but since most transit yards are located in industrial areas, the electric utility infrastructure is in place and all that is needed is to upgrade the service to the charging site. In rural transit where vehicles are sometimes parked out over night, satellite charging stations may need to be installed.

Compressed Natural Gas (CNG)

CNG is a low emission, not a zero emission fuel. Infrastructure is too costly for startup in a rural area. There is a small-scale device called the Fuel Maker designed for home garage use, which can handle one or two vehicles at a slow fill (*5*). Low fuel volumes make even vendor-supplied fueling stations too costly. Required safety modifications to maintenance facilities are costly and force agencies to make a large-scale commitment to the new fuel to justify the costs. Current research by the local Air Quality Management District confirms MCOG's earlier finding (*6*) that due to small fleets, cost of fueling and maintenance infrastructure, and total lack of access to natural gas in most of the county, CNG is not feasible for Mendocino County as a rural region.

Liquid Propane Gas (LPG)

Mendocino Transit Authority has expressed interest in trying out a propane-electric hybrid bus. It would be a perfect application for several MTA fixed routes, and the propane infrastructure is in place. The batteries are charged during driving. Unfortunately, this fuel is currently unavailable because certified engines are not being produced by chassis manufacturers and the California Air Resources Board has mandated that a specially formulated LPG is required for on-road use. This LPG is only produced in limited quantities and locations.

Hybrids

These bifuel vehicles are emerging in the marketplace, but as with CNG and LPG, they are not zero emission, but low emission vehicles. The automotive industry is moving in this direction, which may create a source of hybrid chassis for conversion to small buses and paratransit vehicles. Several hybrid full-size buses are being successfully tested around the country and may become available to rural areas in the near future.

Fuel Cells

Hydrogen and other fuel cells are not in full production yet and are still under development. These are considered the next step for the alternative fuel vehicle industry. Hydrogen fuel cells are a clean, zero emission power source. Those from other energy sources have low emissions. Modular fuel cell power packs designed to replace diesel power plants are being advertised by DBB Fuel Cell Engines, Inc. (*7*). If original equipment manufacturers are able to successfully integrate this into their current chassis, development costs could be reduced significantly.

Electric Rail Vans

A research and development proposal by the Renewable Energy Development Institute has suggested conversion of existing vans to electric powered rail shuttles for small scale commuter transit service on short line railroad tracks. This concept needs a more extensive technology feasibility analysis and prototype vehicles, but could be a possibility for rural regions with rail.

Fleet Buyer's Guides

The CALSTART consortium publishes an online list of makes and models available that are state approved for purchase with public funds (*8*). Another online publication is available from the U.S. Department of Energy's Clean Cities program, *Alternative Fuel Vehicle Fleet Buyer's Guide* (*9*).

REAL WORLD TEST IN MENDOCINO COUNTY

A Chrysler EPIC (Electric Powered Interurban Commuter) minivan was acquired from DaimlerChrysler Corporation for three weeks, May 13 to June 6, 1999, for use by the Zero Emission Vehicle (ZEV) Demonstration Project. The EPIC was driven 1,008 miles over the 24 days, by nine trained drivers. Several passengers of Mendocino Transit Authority's demand response service received rides. This vehicle was requested specifically by MTA, to try out on their Dial-A-Ride door-to-door service routes in Ukiah, Willits and Fort Bragg. Intercity commute and other endurance tests also were performed.

The EPIC was new, with only 419 miles on the odometer upon delivery in Ukiah. This minivan was tested over the challenging terrain of the North Coast, with elevation changes from nearly sea level at the coast in Fort Bragg, to 600 feet in the Ukiah inland valley, to 2,500 feet in the mountain ridges above Willits (Brooktrails and Spring Creek subdivisions).

Summary of Local EPIC Test

Accomodating up to eight passengers, or a 925 lb. payload, this minivan with nickel-metal-hydride (NiMH) batteries is well suited to public transit and family use. Despite the relatively heavy weight by electric vehicle standards, power seemed sufficient for all of the rural tests, although it was not tested fully loaded with passengers on the more challenging routes. With few passengers, it had no trouble with Mendocino County's steep terrain. The loaded vehicle did well with the flat valley driving of the transit demand-reponse routes tested, and its already fast charge time can be improved with the 440-volt charging option. This electric vehicle does use more energy than EVs of lighter weight.

Driving and Vehicle Statistics

The EPIC is the same model minivan as the Dodge Caravan (and Plymouth Voyager), used by MTA in their mixed paratransit fleet. While not wheelchair accessible, this body style works well for MTA's elderly and paratransit clientele, with low profile for stepping in and out, and slider doors on both sides. The EPIC has a larger passenger capacity than other EVs and is therefore suitable to paratransit service.

The car was driven an average of 42 miles per day throughout the deployment. The longest trip was 60 miles from Ukiah to Fort Bragg on May 24. On May 25, the EPIC was tested on the Fort Bragg local Dial-A-Ride route. It was driven back to Ukiah on May 26. This trip involves an elevation change of approximately 2,000 feet. The one-way trip from Ukiah to Fort Bragg (via Willits) used 66 percent of the battery charge, and the return from Fort Bragg to Ukiah used 62 percent. Steve Miller, MTA Coast Supervisor, logged the following comments: "*Great! Climbed Highway 101 grade and Route 20 easily. Primarily kept power level between 1.5 and 2.5 on the amp meter*." Though somewhat larger and heavier than most EVs, the EPIC handles extremely well, for a safe and secure driving feel on the winding roads of Mendocino County.

The EPIC climbed well up the steepest ridges, from 1,300 feet in elevation at the Willits valley floor to 2,500 feet or so at Ridge and Blue Lake Roads in Brooktrails and Spring Creek. The amp meter climbs correspondingly, but because of the low speed limits in the neighborhood, it can make the climbs without entering the upper zone that triggers the "Power Limit" feature.

This Power Limit feature prevents driving at excessively high power levels, helping to save energy for more mileage range on a single charge and preventing possible damage to the vehicle. There is a regenerative braking system to recover energy that automatically engages when the brakes are applied; there is no manual control. Several drivers noticed a two-phase regenerative action.

Drivers noticed the action of the EPIC's cooling system, which uses fans to prevent the vehicle parts from overheating when parked in the sun. The car also has many of the same comfort features as mainstream consumer cars, such as air conditioning and audio systems.

Training

Kevin Morrow of E-Tech (Electric Transportation Engineering Corp.--Chrysler's contractor in Phoenix for the EPIC infrastructure) provided orientation by phone before and after arrival of the EPIC. The ZEV Project Manager then trained the other main drivers and MTA's maintenance

supervisor, including charging procedures. MTA was responsible for orientation of their own personnel. The controls and displays were explained in detail to familiarize drivers with energy and power indicators and other features. Charging procedures were reviewed as well. Drivers were instructed to make entries in a logbook to record energy, mileage data, and anecdotal experiences.

Energy displays were "transparent," meaning they appeared similar to instrument panels in typical consumer vehicles. Where an RPM meter would be, the dial is used to display a continuous needle readout of amps, so the driver has some control over energy efficiency. The best efficiency is at "2" or 20 amps per hour--several drivers noticed this. Where a fuel gauge would be, the needle gauge is used for battery state of charge. There is also a volt meter, which should stay fairly constant.

A "low power" indicator lights up on the dash when approaching battery depletion, so the driver has advance warning of about ten miles. Other indicators on the instrument cluster give error messages, although none lit up during deployment (except during the EPIC's normal startup routine).

Mendocino Transit Authority had one occasion when the vehicle was stranded in town. In this case the driver was not mindful of energy usage and dashboard warning indicators during driving. She used the air conditioning and headlights all day, carried passengers, and enjoyed the responsive acceleration. With a bit more training and experience, drivers can learn to drive more efficiently and get more miles per charge from the vehicle. No harm was done, but the episode was an inconvenience. The driver made this log entry: "*Everyone liked it. Good pickup from dead start and on freeway. The day went great until battery situation. Many people said they like the quiet, as I do. Enjoyable to drive and sport people around in. Under hood looks great and clean*."

Training is crucially important to using EVs. Driving style needs to adapt to a more energy-efficient technique. It should not take any longer to deliver passengers to their destinations in an electric vehicle. The issue is awareness of energy consumption. Drivers need to take advantage of regenerative braking, coast up to traffic stops, accelerate gradually, and consider when to use accessories or not. These simple techniques will provide more driving range on a charge. Drivers should be selected and trained for awareness of these issues in order to operate electric vehicles successfully. Monterey Transit has reported a 40 percent difference in electric vehicle performance between drivers.

Electric Charging

The EPIC comes with a sophisticated, off-vehicle conductive charger unit made by Lockheed Martin that is usually installed as a permanent fixture in a fleet garage or at home. E-Tech worked extensively with staff to customize the vehicle for the ZEV Project demonstration. The sizable charger was mounted in the rear of vehicle so as to be available at the various locations tested, taking out the last row of seats. Designed to operate on a 240-volt, 60-amp circuit, the charger was programmed for the project at 40 amps to accommodate all existing public charging stations in Mendocino County. This should have the effect of slowing down charge time somewhat, although it charged relatively quickly even so. An optional 440-volt configuration is available for even faster charge time. There is no 120-volt option. The EPIC uses a standard 1450-R receptacle. It worked fine with the recreational vehicle (RV) type outlet installed by the project manager at home.

The charger is a “smart” box situated between the power source and the vehicle. It has a vocal readout of charge status on demand, with state of charge expressed as a percentage during charging. When the charge cycle is complete, the unit reads out charge time and kilowatt-hours used. The arrangement is quite user friendly and simple to operate.

The Electric Xpress Shuttle service at Los Angeles International Airport (*9*) has demonstrated the usefulness of the fast charger option with a fleet of EPIC minivans. According to Sam Smith of Sentry Hill Management Group, consultant to that project, rapid charging puts two miles of range back into the vehicle for every one minute charged, so that charging the EPIC for ten minutes adds an additional 20 miles of range. Strategic location of fast chargers along paratransit service routes can work well in a rural area. A driver can charge during a coffee break to add significant mileage range in a short period of time. (Note: As of this writing, an employee of the shuttle service reports that the EPICs are “running just fine with no problems at all.”)

Commuting experience during deployment in Mendocino County supports use of the EPIC as a countywide demand responsive vehicle, especially with fast "opportunity charging" if many passengers are transported to a central facility such as a senior center or multimodal terminal. Optimum placement of fast chargers would enhance success in serving outlying areas to pick up passengers for transportation to lunch programs, medical appointments and other services.

A regular Dial-A-Ride shift is 6 to 8 hours; some shifts are 5 hours. The incident with battery depletion occurred after 3 hours or so. During extreme weather over four months of the year, two EPICs could cover the shift by swapping mid-shift for a fully charged one. The rest of the year, one EPIC could work. Charging could be done on lunch breaks, or special fast chargers such as the 440-volt option demonstrated by the Electric Xpress Shuttle at Los Angeles Airport could be used to overcome range concerns.

Energy Use and Cost

During the deployment, the EPIC averaged 562 watt-hours per mile (349 w-h/km). 567 kilowatt-hours were used over the total 1,008 miles driven (1,623 km). The round-trip commute from Brooktrails to Ukiah consistently logged 30 kW-hours for 61 miles of daily use (98 km), using three-quarters of a battery charge. The average daily consumption was 24 kilowatt-hours for 42 miles (68 km). This is compatible with the overnight off-peak charging recommended throughout the ZEV Project report.

At the average electricity rate used in the ZEV Project report of 14 cents/kW-hour, this puts the cost at $3.36 for the average daily use, or 8 cents/mile (5 cents/km). However, charging at the after-hours “time of use” rate of 8.5 cents, the cost is only $2.04 for the same daily use, or 5 cents/mile (3 cents/km), comparable to a fuel-efficient gas-powered compact sedan. Mendocino Transit Authority pays 13 cents/kW-hour at its Ukiah offices, consistent with the average rate used in the ZEV Project report, equivalent to $3.12 or 7 cents/mile (4.5 cents/km).

All three results are less than the cost of gasoline for the Dodge Caravan when estimated at 14 miles per gallon, the typical consumption of MTA's Dial-A-Ride vehicles. This works out to 11 cents/mile (7 cents/km) at their current fuel cost of $1.60/gallon, and 9 cents/mile (5.5 cents/km) for fuel during the same period as the EPIC was tested (Summer 1999).

Various commercial rates would have to be researched to find conclusive evidence;

however electricity prices appear to be relatively stable compared to gasoline. Energy costs and rates are an important issue for fuel cost comparison with present gas-powered vehicles.

Informal Public Survey

A guest register was kept in the EPIC for comments by passengers. Most of the comments mentioned the quiet operation, comfortable ride, good acceleration and performance. Several said they wanted to own one. All those who made remarks in the register enjoyed the demonstration.

FUNDING RESOURCES

In general, state and federal funding programs do not reward regions already in air quality attainment status or working proactively on prevention. This strategy only serves the purpose of crisis intervention. The proactive next step would be to expand support to those areas voluntarily doing the right thing by complying with clean air and other environmental regulations.

Some funding sources are available to rural California regions and elsewhere. Identified sources include the Carl Moyer grant program for replacing diesel vehicles, Assembly Bill 2766 local air district funds from vehicle registration fees, and the federal Petroleum Violation Escrow Act administered by the states that funds energy conservation projects with oil company fines.

The Renewable Energy Development Institute (REDI) is building a new program with the California Alternative Energy & Advanced Transportation Financing Authority (CAEATFA) to fund installation of solar and other renewable energy systems in public infrastructure and of clean air transportation systems by offering long-term, low-interest, state-subsidized loans. Fuel savings achieved using the new power systems can recover the cost of loans so that local service districts save money, save energy, and come out ahead.

CONCLUSIONS AND RECOMMENDATIONS

Research to date by staff at Mendocino Council of Governments, the Renewable Energy Development Institute, Mendocino Transit Authority, and the Mendocino County Air Quality Management District confirms that the only practical option today for rural use of alternative vehicles in public transit are small electric-powered vans. This conclusion will change as new technology develops and more options become available.

Electric Vehicles

Electric vehicles fit pollution prevention objectives, as they are the only vehicles currently and widely available that truly have zero emissions. (The most recent California Air Resources Board regulations allow some percentage of certain hybrid vehicles to qualify as zero emission vehicles, so not all are genuinely ZEVs. Hydrogen fuel cell buses do have zero emissions, but only a few are built and actually operating.)

One of the five zero emission vehicles tested by the local ZEV Project, the Chrysler Electric Powered Interurban Commuter electric minivan described in this paper, was found feasible for public transit purposes, specifically in demand response service. A full life cycle of this vehicle needs to be tested to determine cost and viability. However, this particular model is

out of production until 2002 while DaimlerChrysler Corporation refines and improves the EPIC with the best available technology.

Replacing Fleets

Mendocino Transit Authority's recently updated Five Year Plan policy element includes goals and objectives for replacing fleet vehicles with clean-fuel, energy-efficient ones wherever practical and feasible. The Dodge Caravans currently in use for their demand response service (with the same body style as the Chrysler EPIC) have a five-year life cycle for MTA's purposes. The present fleet is new, but after that life cycle expires, they could be replaced with EPICs or hybrids. An electric bus for fixed-route service in Willits has been considered, but the buses are still too expensive. Cost, availability and funding might be more conducive in the future.

Multimodal transit center plans also were identified as a key focus for future efforts, to help link other modes of transportation. In addition to public transit, MCOG's ZEV Project report and subsequent research clearly indicates there are other practical uses for clean-air vehicles that benefit the public in a rural area, such as in city and county service and maintenance fleets, school district fleets, and commercial and personal use.

Work in Progress

The outlook for alternative fuel and clean air vehicles is continuously evolving. Local partnering agencies will continue working together in this effort. It can be helpful also to network with neighboring regions, as Mendocino County is doing with the Redwood Empire Clean Air Vehicle Coalition, involving larger cities and semi-rural areas. That group is applying to be a "clean region" under U.S. Department of Energy's Clean Cities program. Larger coalitions can afford the financial commitment required to participate and can then share their experience with outlying rural regions. Clean Cities coalitions have reported measurable success in their goals over the past five years (*9*).

The Mendocino Clean Air Transportation coalition has identified a variety of resources for more information and further activity to pursue pollution prevention in rural places of great natural beauty such as Mendocino County and California's North Coast.

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