



4 December, 2007

Steve Church, Research Division,  
California Air Resources Board,  
P.O Box 2815,  
Sacramento, CA 95812

Re: ISE Corporation, Hydrogen fueled buses, and the ETAAC Report Discussion Draft

Dear Mr: Church

ISE is a California Corporation which has focused for over a decade on developing low emission heavy duty electric drive vehicles. Our gasoline hybrid electric bus, certified by the ARB, is in service at several California transit authorities and has provided millions of miles of revenue transit service with reduced fuel consumption and much lower emissions than conventional drive systems.

We are also the leading provider of hydrogen fueled buses, having delivered six hybrid electric transit buses which operate with hydrogen as a fuel. These buses have accumulated up to 60,000 miles each over the past couple years.

We presently have major orders for additional hydrogen fueled hybrid electric buses, 20 for Canada and 10 for London, England. The choice of these buyers was influenced by Ballard now offering a 12,000 hour/5 year warranty on their bus fuel cell, combined with the experience of ISE customers operating hydrogen fueled buses. It appears we will get additional orders for hydrogen buses to operate in the USA, perhaps as many as five in the coming year.

I suggest that this very specific information is pertinent to the further development of the planning for AB32 implementation, particularly as exemplified in the comprehensive ETAAC Draft which I have briefly reviewed.

Among the several points that should be clearly made are:

1. There is a major local success story, which happened with the stimulus of the ARB ZEB program and with aid of SCAQMD, ARB and CEC funding, such that a California firm – now approximately 130 employees – has made hydrogen fueled buses sufficiently attractive as to attract pre-commercial orders for the ISE drive systems (10 or more vehicles each) from other countries.
2. More essential, that Zero and Near-Zero emission transit buses are available.
3. ISE has, under separate SCAQMD funding, demonstrated the ability to make the fuel for these buses from Coachella Valley (North Palm Springs) wind. Thus it is, in principal, possible to field transit buses that are fueled from locally sourced renewable fuel.
4. ISE will strongly support measures that provide substantial support for California firms which have ZEV capabilities, and for hydrogen fuel infrastructure development.

ISE welcomes the interest of the legislature, as well as that of the CEC and ARB, in furthering the continued and renewed development of alternatives to conventional transportation fuels. ISE has made some specific contributions in this area (including heavy duty electric drive development and hydrogen hybrid buses using both fuel cell and HICE engines) and is fully engaged in several new approaches to zero and near zero emission vehicle development using hydrogen and electric energy storage.

We offer some more descriptive commentary:



## Hydrogen Fueled Fuel Cell and HHICE Buses:



The first picture, at left, shows the hydrogen hybrid fuel cell bus as delivered to SunLine Transit. AC Transit operates three more of these buses in the Berkeley-Oakland area, and another is in service in Connecticut.

This bus uses a hybrid electric drive such that the fuel cell is solely an electricity provider. It is quiet and efficient, as well as being a ZEB. The bus operates from 6-8 miles per kg (gallon gasoline equivalent), has the ability to operate in the city or at freeway speeds, and has range in excess of 300 miles.

At right, in the second photo, we see the prototype HHICE (Hydrogen Hybrid electric Internal Combustion Engine) bus positioned to fuel with hydrogen made from the wind powered hydrogen generation system which was SCAQMD funded and located in North Palm Springs. The bus is a 40' New Flyer transit bus with hybrid electric drive (similar to the fuel cell bus) which uses electricity from an induction generator driven by a hydrogen fueled 6.8 liter Ford V10 engine. This bus also has the capability of operating either stop to stop in city service or with freeway speed.



In work recently funded by BC Transit, of British Columbia, ISE is designing a new fuel cell bus which will be powered by a Canadian made Ballard fuel cell. This is preliminary to a pre-commercial deployment of 20 buses, which will be based in Whistler, BC so as to serve the transit needs of the 2010 Canadian Winter Olympics.

Separately, London's "Transport for London" agency has ordered 10 buses which will serve central London starting in 2010. Half of these are fuel cell buses, and half are HHICE. Due to the lower cost of the engine the HHICE buses are notably less expensive than the fuel cell buses. The London order includes ISE as prime contractor including service and maintenance for operation of the buses during the 2010-2014 period.

It is hoped that similar buses will be added to the California transit bus fleet, although there is no indication of forthcoming orders. There is a requirement, through the ZEB program, for additional zero emission buses in the 2009 period.

California now has the opportunity of assuring these are truly zero emission vehicles through investing in renewable sources for the hydrogen.

This is important for several reasons:

1. The real advantages of hydrogen as a transport fuel are realized if energy can be "harvested" from local sustainable resources, such as wind, solar and biomass. Such a capability has been demonstrated in the ISE 2002-2004 wind to hydrogen program. Years before the AQMD along



- with the USDOE funded a demonstration solar to wind system. As such fuel sources become commonly known and offer a real alternative source the arguments *against* hydrogen melt away.
2. Estimates from several sources indicate that sustainably sourced hydrogen, combined with distribution of the fuel, would become fully competitive with conventional liquid hydrocarbon fuels *if* investment capital of the scale commonly used for the liquid fuels is available for implementation.

The fuel cell buses come at a premium, due partly to the “hand made” small quantity nature of the manufacture of these vehicles. Likewise, sustainably sourced hydrogen can be viewed as very high in price – as one considers small, designed for demonstration systems. If one harks back to the early days of oil refining, the price was likely increased by the limited production capabilities.

Investing in renewable resources for fuel may be viewed as expensive, until one requests suppliers of fossil fuel resources to provide *firm fixed price quotes* for delivery over the next quarter century.

The arguments regarding cost are generally inane, as the argument is framed by the energy firms who count as their costs only what they directly pay for, the crude, the refining, and the delivery. The price at the pump does not include the cost ... now hundreds of billions of dollars per year ... of “defending” the oil sources, nor the health damage costs of the diesel particulates and the hard to specify sources of the asthma epidemic, nor the costs of cleanup of bays and shores and water supplies. And then add in the costs of the other air quality and environmental degradation. Were the accounting done such that all those costs were added on the the per gallon cost of diesel and gasoline... the public acceptance of alternatives would be quite a different matter.

#### **Battery Electric Buses – an Emerging Opportunity with possibly Big Payoff**

ISE vehicles are all electric vehicles, and they use a variety of engine drives to generate the power to charge the batteries. Batteries with high power and energy capability are central to the effective hybrid electric vehicles, and as a result we track carefully the recent rapid improvement in high technology batteries. We believe that an all electric bus with range capability in excess of 200 miles, suitable for many transit applications, will be possible in the near future. If such battery vehicles become available, they will make possible night time charging with emissions generation only at the power-plant.

ISE has considerable experience with the high power, high voltage electrical energy storage used in these hybrid electric buses. We have used lead-acid, high temperature nickel sodium chloride, and nickel-metal hydride batteries. The demands are severe with voltage levels of 500-700 volts, power to over 100 kW, and current pulses exceeding 300 amperes. Each battery has advantages, all are troublesome, and with these very high energy storage there is always potential for sudden and dramatic out of control discharge or energy release. The foibles of high energy batteries are, in part, what prompted us to pioneer in the use of ultra-capacitors for buses. We manufacture, for others as well as for our own use, a high energy (600 volt) ultra-capacitor system which is used on most of our buses.

Much attention has been provided to plug-in hybrid technology. The experience has been that the casual customer has been reluctant to invest in a vehicle with 60 mile range, and so the “plug-in hybrid” marketing offers a gasoline vehicle which has battery-only operation capabilities as well. We question whether the vehicle with both ICE and battery technologies is going to be warrantable for long battery life, but note additional healthy incentives to battery system manufacturers.

To the extent that the “plug-in hybrid” will have full battery life with deep discharge of the batteries, so will a battery only electric bus. The battery only bus offers simplicity and cost savings, offsetting the high battery cost.

ISE has committed to investment towards development of battery-electric technology for transit buses, with the Los Angeles MTA having indicated interest in a parallel and supportive investment.



The ARB, through its ICAT program, has invested in this ISE program. ISE has invested heavily in battery test technology and is actively engaged in high power battery system as well as ultra-capacitor energy storage development.

**Comparing the Technologies:**

This table provides an ad hoc quasi-quantitative comparison of the technologies:

	Total Efficiency	Infrastructure Cost Effectiveness	Vehicle Price	Emissions	Domesitic Fuel	Overall Rating
Trolley Bus	57%	\$2M	\$1M	Low	97%	Medium
Battery Bus	51%	\$250k	\$750k	Low	97%	High
Fuel Cell						
Hybrid Bus	34%	\$250k	\$1.5M	Low	86%	Medium
HHICE Bus	25%	\$250k	\$700k	Low	86%	Med-high
Ethanol Bus	24%	\$30k	\$350k	Medium	90%	Med-high
CNG Bus	24%	\$150k	\$400k	Medium	85%	Low-med
Diesel Bus	28%	\$20k	\$330k	High	40%	Low

Note that the Fuel Cell Bus rates highly in many respects, but there is only limited experience on the fuel cell durability. The Battery Bus is rated most highly, but until someone makes one and demonstrates safety and durability it is a questionable entry. The HHICE and the Fuel Cell Bus, as well as the electric and ethanol vehicles, offer the possibility of operation solely from domestic fuel. Thus these are the real “alternate fuel” pathways, and warrant the highest level of attention and funding.

**Summary:**

ISE suggest serious statewide commitments towards:

- Hydrogen generation from sustainable resources, with substantial funds committed in collaboration with leading firms to make possible large scale production such that tens of buses, even a whole agency, will be powered from sustainably sourced hydrogen. The key here is not so much more research, but development of producible hardware which can be widely deployed, with hundreds of stations to be developed in the next five years. This requires a substantial commitment, perhaps in the form of a guarantee to buy the hydrogen at some minimal price, such as \$8/kg reducing over the years to \$4/kg.
- HICE engine development by the most skilled and capable development laboratories directed towards efficient and durable high power hydrogen engines.
- Substantial co-funding of development of high voltage, high energy density battery packs with tested and proven safety suitable for public transit applications in the most environmentally challenged city centers.
- Support for fuel cell, battery and HHICE transit buses.

Yours truly,

Paul B. Scott, Chief Science Officer