

## **Transit Bus Exhaust Emissions and Costs Making the Right Decision for a Small City**

### **Big Idea:**

- Transit agencies that provide transportation services throughout the country are faced with making decisions regarding which fuels and propulsion options are best for their bus fleets -- clean diesel, natural gas, hybrid-electric, hydrogen fuel cell, or battery electric. Each has advantages and disadvantages.
- The decisions they make will influence their budgets locally and the environment globally.

### **Essential Questions:**

- How do various propulsion options influence the environment, budgets, and the reliability of vehicles and related equipment?
- Given limited budgets, how can people of a small city best influence the environment in the long term without affecting existing transportation services?
- How best to present the environmental impact of the city's decision regarding new buses to the public?

### **Goal:**

Your goal is to examine the various bus propulsion options available to transit agencies. You will recommend an approach to a small city faced with wanting to improve the environment while at the same time avoiding imposing any new taxes or reducing bus service in an area already faced with economic hardship. Your recommendations, once accepted, will become part of a marketing campaign to inform the public of the changes. As part of the marketing campaign you will show the public how the new transit buses improve air quality without imposing financial hardship by way of new taxes.

### **Role:**

You have been hired as a consultant by a small city in the United States to help reduce exhaust emissions and improve the city's image without adversely affecting transportation services and taxpayers who fund those services.

### **Audience:**

You will be presenting your bus propulsion recommendations to the Board of Directors responsible for approving a new fleet of buses that will best serve the environment and transportation needs of the community. If your recommendations are accepted, you will need to develop information to share with the public who will be concerned with the changes the city is making to its bus fleet and the impact those changes will have on existing bus services and taxes.

### **Situation:**

A small US city is getting ready to replace its fleet of aging diesel buses and is faced with several new propulsion options. While all of them meet federally mandated emissions standards, some are cleaner than others, some cost more, and some have not been tested and may be unreliable. Although the Board of Directors would like to buy a fleet of buses that emit the lowest emissions levels and reduces our dependency on foreign oil, they also have a responsibility to provide transportation to the taxpayers and those communities who depend on the buses for daily transportation. Your knowledge of propulsion options will be critical for helping this city make the right decision. You will need to research which propulsion option is the best for the city's new fleet of buses, and communicate the recommendations to the public.

### **Products**

#### **Initial Research Analysis**

Directions: Your first task is to conduct initial research to become familiar with the various propulsion options available to transit buses. All of these options -- clean diesel, bio diesel, natural gas, hybrid-electric, hydrogen fuel cell, and battery electric – are also available for other vehicles, which will simplify your research assignment. For each propulsion option write a short description including historical background, along with the advantages and disadvantages associated with emissions and the environment, fuel storage and dispensing, maintenance and storage facilities, maturity of technology and reliability, vehicle modifications needed to accommodate the technology, cost and other factors associated with each of the propulsion options. Cite the references used for each propulsion option described. Your paper should be no longer than five pages.

#### **Making a Research Plan**

[http://www.sciencebuddies.org/science-fair-projects/project\\_background\\_research\\_plan.shtml#makingabackgroundresearchplan](http://www.sciencebuddies.org/science-fair-projects/project_background_research_plan.shtml#makingabackgroundresearchplan)

#### **Introductory Webcast**

**Directions:** Create a short webcast (3-5 minutes) reviewing, in basic terms, the various propulsion alternatives available to the city for replacing their buses. Describe how each technology works, how each contributes to reducing exhaust emissions, potential impacts on cost and bus reliability, and your role in the project. The web cast will be used to inform citizens of the various bus propulsion choices available to their city and the approach you will use to make your recommendation to the city council.

Your webcast should be objective (neutral) and provide just enough factual information to introduce citizens to the various propulsion choices. Include video, graphics,

interviews, and any other visuals that will help your viewers better understand the various propulsion options and the tough decision facing the city council.

### **Webcast Example**

1. Webopedia – define webcast

<http://www.webopedia.com/TERM/W/Webcast.html>

2. Website – NY Dept of Transportation Previously Held Webcasts

<https://www.dot.ny.gov/webcast>

### **Detailed Technology Analysis**

**Directions:** Conduct more extensive research regarding the available propulsion technologies available for city buses (clean diesel, bio diesel, natural gas, hybrid-electric, hydrogen fuel cell, and battery electric) and prepare a report that you will provide to the city council detailing each technology with illustrations and photos as needed to make your points. Describe in detail how each technology works using terminology that people who are not engineers will understand. Include the advantages and disadvantages associated with each technology. Using the existing 50-bus fleet as a baseline, describe the environmental and cost implications of switching to each new propulsion technology. Also include any cost implications that each of the propulsion alternatives may have regarding bus storage facilities, bus maintenance facilities and routine maintenance performed on the buses as applicable. The current 50-bus diesel fleet is fueled outdoors, stored in a separate indoor garage, and are maintained in another building, all of which are located on the same property. The property has plenty of room for expansion if needed to accommodate new propulsion technologies.

After all of the propulsion alternatives have been analyzed, present your recommendations to the city council on how they should proceed with their new bus purchase based on the available technologies. Remember, all of the existing buses are old and need to be replaced when the new fleet arrives. You can recommend replacing the entire fleet with one or more of the new alternatives in varying quantities (e.g., 100% battery electric, 50% clean diesel, 50% natural gas, etc.). Provide the detailed reasons for making your recommendations. Again, use language that members of the city council and general public will understand. This Detailed Technology Analysis Report should be no longer than 15 pages.

### **Oral Presentation/ Photostory**

**Directions:** The city council will be given a copy of your Detailed Technology Analysis Report. Based on that report and your recommendations contained in it, create an oral presentation based around a 10-15 minute PowerPoint presentation to be presented to the city council. The purpose of this presentation is to review your findings and make a

persuasive argument for council members to adopt your recommendations regarding which bus propulsion technology or technologies they should choose when buying a new fleet of buses. In order for your audience to make an informed decision, they will be interested in a variety of information including: the estimated impact of each technology on maintenance, what if any facility modifications will be needed, emissions reductions, how the propulsion technology will affect cost (vehicle, facilities, and maintenance), durability and reliability of the new technologies, and the environmental impact of such technologies. Make sure to provide evidence along with the source of your information for any claims that you make about a technology.

### **Photostory Example**

Impact of Bridges on Environment in Oregon:

[http://www.oregon.gov/ODOT/HWY/OTIA/Pages/Environmental\\_Photo\\_Story.aspx](http://www.oregon.gov/ODOT/HWY/OTIA/Pages/Environmental_Photo_Story.aspx)

### **Press Release**

**Directions:** While the city council considers your recommendations, create a one-to-two page narrative for the local city newspaper that describes the findings of your research, your recommendations to the city council, and the reasons why your recommendations should be adopted. If the new propulsion technology or technologies you are recommending will end up costing the city more money or may result in decreased bus reliability or other potential hardships, explain your reasoning for it. Include in your narrative why the citizens of this small town will benefit from your recommendations.

### **Press Release Example**

<http://transport.house.gov/news/documentquery.aspx?DocumentTypeID=2545>

### **References/Resources:**

#### **Alternative Fuel Bus Video**

<http://video.mit.edu/watch/energy-101-vehicle-propulsion-8278/>

*Note: This video, 10 minutes in length, applies to automobiles but contains commentary on all of the propulsion alternatives included in this exercise.*

#### **Alternative Fuel Bus Resources**

Here are some up-to-date resources on alternative fuel buses. These include guidance on both vehicle selection and fueling facility design. The most recent publications are listed first.

### **WestStart publications (quarterly)**

- The Hydrogen Bus Source: a quarterly publication that will report on fuel cell and hydrogen technology in transit bus applications. Published by WestStart-CALSTART, its goal is to assist fuel cell bus technology developers, manufacturers, and operators by providing information and analysis about the latest developments relevant to the industry. [www.calstart.org](http://www.calstart.org)
- Hybrid Truck Users Forum (H-TUF): The *Hybrid DiaLog* newsletter, which captures all recent H-TUF activities, studies, news and decisions. [www.calstart.org](http://www.calstart.org)

### **Clean Cities Coalition Vehicle Buyer's Guide for Fleets (continuously updated)**

- Complete listing and specs of currently available, alternative-fuel transit buses, shuttle buses, trolleys, trucks and more. <http://www.eere.energy.gov/cleancities>
- A wealth of information on alternative fuels infrastructure development for a variety of fuels, including [biodiesel](#), [electricity](#), [hydrogen](#), [natural gas \(CNG and LNG\)](#), and [propane](#). <http://www.eere.energy.gov/cleancities>

West Virginia University, Center for Alternative Fuels, Engines and Emissions (CAFEE) (<http://cafee.wvu.edu/>)

Guidebook for Evaluating Fuel Choices for Post-2010 Transit Bus Procurements, Report 146, National Academy of Sciences, Transportation Research Board (TRB). Includes Excel spreadsheet for calculating cost and emissions for various bus propulsion options. [http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp\\_rpt\\_146.pdf](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_146.pdf)

### **Analysis of Electric Drive Technologies for Transit Applications: Battery-Electric, Hybrid-Electric, and Fuel Cells (2005)**

In the last five years, hybrid-electric buses have grown from a demonstration technology to a popular option for transit agencies looking to "green" their fleets and reduce fuel use, with over 700 buses in service at over 40 transit agencies across North America. The Federal Transit Administration (FTA) and the Northeast Advanced Vehicle Consortium (NAVC) have released a report that documents the current understanding of hybrid bus technology, as revealed through the latest hybrid bus data and the views of transit industry representatives. The report, entitled *Analysis of Electric Drive Technologies For Transit Applications: Battery-Electric, Hybrid-Electric, and Fuel Cells*, explores the current state of hybrid buses, the benefits of major market penetration of hybrid buses for transit and communities, and the barriers that remain to achieving this goal. The report also looks at the current state of battery and fuel cell buses. The report's findings are that transit believes that hybrids are an appealing clean option, with good performance, low emissions, and lower fuel costs. However, major hurdles remain to make hybrids commercially competitive with current diesel buses. These hurdles involve the higher

purchase price of a hybrid bus; uncertainties about lifecycle costs; durability of the batteries; and emissions certification issues.

[http://www.fta.dot.gov/documents/Electric\\_Drive\\_Bus\\_Analysis.pdf](http://www.fta.dot.gov/documents/Electric_Drive_Bus_Analysis.pdf)

### **Analysis of Fuels and Propulsion System Options for BRT Vehicles (2005)**

This new publication is a must read for those who are making decisions about new buses. It will answer the questions: What BRT fuels and technologies are currently available? Which are emerging? Will they meet the preferences and requirements of transit purchasers while also satisfying long-term emissions and energy considerations? This publication is an important tool for transit professionals as they develop their vehicle technology/fuels roadmap.

[http://www.calstart.org/Libraries/Publications/Analysis\\_of\\_Fuels\\_and\\_Propulsion\\_System\\_Options\\_for\\_BRT.sflb.ashx](http://www.calstart.org/Libraries/Publications/Analysis_of_Fuels_and_Propulsion_System_Options_for_BRT.sflb.ashx)

### **Emergency Response Procedures for Natural Gas Transit Vehicles (2005)**

TRB's Transit Cooperative Research Program (TCRP) Synthesis 58: Emergency Response Procedures for Natural Gas Transit Vehicles identifies and documents the state of the practice on emergency response protocols to incidents involving natural gas-filled transit buses. The report is designed to assist first responders to natural gas incidents—emergency response professionals such as police officers and fire-fighters; transit agency operations and maintenance employees, police, and security guards; and certain members of the general public. [http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp\\_syn\\_58.pdf](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_syn_58.pdf)

### **Characteristics of Bus Rapid Transit (2004)**

"Characteristics of Bus Rapid Transit for Decision-Making", published by the Federal Transit Administration, should be a very useful tool for evaluating and planning potential bus rapid transit projects. [http://www.nbrti.org/docs/pdf/Characteristics\\_BRT\\_Decision-Making.pdf](http://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf)

### **Bus Axle Weight Regulations (2003)**

This study examines the pavement damage cost that results from heavy bus operation, and the costs and benefits of several weight reduction strategies. The benefit-cost evaluation considers many things.....

<http://caltransit.org/cta/assets/File/FTA%20Study%20on%20Axle%20Weights.pdf>

### **Design Guidelines for Bus Transit Systems Using Electric and Hybrid-Electric Propulsion as an Alternative Fuel (2003)**

The use of alternative fuels to power transit buses is steadily increasing. Several fuels, including Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), and Methanol/Ethanol, are already being used. At present, there are no available comprehensive facility guidelines to assist transit agencies contemplating converting from diesel to electric or hybrid electric propulsion. This document addresses that need. This guidelines document presents various facility and bus design issues that need to be considered to ensure safe operations when using electric or hybrid electric propulsion. Fueling facility, garaging facility, maintenance facility requirements and safety practices are indicated. Among the issues discussed are electric storage device properties, potential hazards, requirements for specified level of service, and applicable codes and standards. Critical fuel related safety issues in the design of the related systems on the bus are also discussed. A system safety assessment and hazard resolution process is also presented. This approach may be used to select design strategies which are economical, yet ensure a specified level of safety.

[http://bussafety.fta.dot.gov/uploads/resource/3924\\_filename](http://bussafety.fta.dot.gov/uploads/resource/3924_filename)

### **TCRP Report 61 Analyzing the Costs of Operating Small Transit Vehicles (2000)**

This User's Guide explains the accompanying Small Transit Vehicle economics (STVe) model—a tool designed for transit planners and others making decisions about the purchase of small transit vehicles for different services and operating environments.

[http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp\\_rpt\\_61.pdf](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_61.pdf)

### **Clean Air Program: Design Guidelines for Bus Transit Systems Using Hydrogen as an Alternative Fuel (1998)**

The purpose of this document is to: discuss the various safety issues related to the use of hydrogen; provide guidance and information on safe practices followed in the industrial gas and chemical industries (which produce, store, transport, and use hydrogen in a number of industrial processes); discuss applicable regulations, codes and standards (both national and regional, if any); and, in general, discuss issues to be considered when converting an existing diesel facility, or building a new facility, to service hydrogen fueled vehicles.

<http://ntl.bts.gov/lib/8000/8700/8707/BTSDesignGuidelines.pdf>

### **Guidebook for Evaluating, Selecting, and Implementing Fuel Choices for Transit Bus Operations (1998)**

TRB's Transit Cooperative Research Program (TCRP) Report 38: Guidebook for Evaluating, Selecting, and Implementing Fuel Choices for Transit Bus Operations This guidebook and its accompanying cost-model spreadsheet (FuelCost 1.0) will be of interest to transit managers, policymakers, operations and maintenance professionals, and others considering the deployment of, or conversion to, alternative fuel buses. The

guidebook and FuelCost 1.0 provides tools to simplify the process of developing an alternative fuel strategy by clearly identifying the issues, and the costs and benefits associated with the conversion to various available alternative fuel technologies.

[http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp\\_rpt\\_38-a.pdf](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_38-a.pdf)

### **Safe Operating Procedures for Alternative Fuel Buses (1993)**

TRB's Transit Cooperative Research Program (TCRP) Synthesis 1: Safe Operating Procedures for Alternative Fuel Buses includes information on the use of methanol, ethanol, compressed natural gas (CNG), liquefied petroleum gas (LPG), liquefied natural gas (LNG), and other alternative fuels for buses.

<http://onlinepubs.trb.org/onlinepubs/tcrp/tsyn01.pdf>

### **Other References:**

<http://editorial.autos.msn.com/the-future-of-alternative-propulsion>

<http://www.completecoach.com/electric-bus/>

<http://www.slideshare.net/marcusforpresident2012/alternative-propulsion-systems-study>

<http://www.hybridrive.com/hybrid-transit-bus.asp#>

<http://www.citrusdaily.us/story/county-investigating-alternative-vehicle-fuels/2014/03/11/3228.html>

<http://www.informinc.org/pages/research/sustainable-transportation/reports/122.html>

[http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp\\_syn\\_72.pdf](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_syn_72.pdf)

[http://www.afdc.energy.gov/pdfs/public\\_transit.pdf](http://www.afdc.energy.gov/pdfs/public_transit.pdf)

[www.nps.gov/](http://www.nps.gov/)

## **Twenty First Century Student Outcomes**

### **Creativity and Innovation**

#### ***Works Creatively with Others***

- Develop, implement and communicate new ideas to others effectively
- Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work
- Demonstrate originality and inventiveness in work and understand the real world limits to adopting new ideas
- View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes

### **Critical Thinking and Problem Solving**

#### ***Reason Effectively***

- Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation



### ***Use Systems Thinking***

- Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems

### ***Make Judgments and Decisions***

- Effectively analyze and evaluate evidence, arguments, claims and beliefs
- Analyze and evaluate major alternative points of view
- Synthesize and make connections between information and arguments
- Interpret information and draw conclusions based on the best analysis
- Reflect critically on learning experiences and processes

### ***Solve Problems***

- Solve different kinds of non-familiar problems in both conventional and innovative ways
- Identify and ask significant questions that clarify various points of view and lead to better solutions

## **Communication and Collaboration**

### ***Communicate Clearly***

- Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts
- Listen effectively to decipher meaning, including knowledge, values, attitudes and intentions
- Use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade)
- Utilize multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact
- Communicate effectively in diverse environments (including multi-lingual)

### ***Collaborate with Others***

- Demonstrate ability to work effectively and respectfully with diverse teams
- Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal
- Assume shared responsibility for collaborative work, and value the individual contributions made by each team member

## **Information Literacy**

### ***Access and Evaluate Information***

- Access information efficiently (time) and effectively (sources)
- Evaluate information critically and competently

### ***Use and Manage Information***

- Use information accurately and creatively for the issue or problem at hand
- Manage the flow of information from a wide variety of sources
- Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information

### **Media Literacy**

#### ***Analyze Media***

- Understand both how and why media messages are constructed, and for what purposes
- Examine how individuals interpret messages differently, how values and point of view are included or excluded, and how media can influence beliefs and behaviors
- Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of media

#### ***Create Media Products***

- Understand and utilize the most appropriate media creation tools, characteristics and conventions
- Understand and effectively utilize the most appropriate expressions and interpretations in diverse, multi-cultural environments

### **ICT (Information, Communication and Technology Information) Literacy**

#### ***Apply Technology Effectively***

- Use technology as a tool to research, organize, evaluate and communicate information
- Use digital technologies (computers, PDAs, media players, GPS, etc.), communication/networking tools and social networks appropriately to access, manage, integrate, evaluate and create information to successfully function in a knowledge economy
- Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies

### **Leadership and Responsibility**

#### ***Guide and Lead Others***

- Use interpersonal and problem-solving skills to influence and guide others toward a goal
- Leverage strengths of others to accomplish a common goal