1. Describe the range of hybrid truck technologies and applications being explored for the near and medium term, and the major technical hurdles for deployment.

2. Please characterize Dueco's experience with government technology development programs, and how the federal role can be enhanced.

Testimony of Joseph T. Dalum Vice President of DUECO

Before the House Committee on Science and Technology

Energy and Environment Subcommittee – Hearing

Hybrid Technologies for Medium- to Heavy-Duty Commercial Trucks

Introduction

Good morning Chairman Lampson, Ranking Member, Inglis and distinguished members of the Subcommittee on Science and Technology. Thank you for inviting me here today. Also thank you for the opportunity to offer the views of DUECO and for soliciting the views of others on hybrid technologies for medium to heavy duty commercial trucks

My name is Joe Dalum, and I am Vice President of DUECO. Headquartered in Waukesha Wisconsin, DUECO is one of the largest final stage manufactures of utility trucks in the country, with facilities also located in South Dakota, Minnesota, Indiana, Ohio and Pennsylvania. We produce aerial devices, digger derricks and cranes that are sold to electric utilities for the maintenance of their transmission and distribution power lines in a 15 state region and are also used by utilities throughout the country through UELC, our rental and leasing company, with direct facilities in Florida, Texas and California. DUECO also provides equipment and services for the telecommunications, contractor, electric cooperative, municipality, gas utility and tree care markets.

In 2006, DUECO began to assess alternative hybrid vehicle technologies. Those activities lead to a collaborative development program between DUECO and Odyne Corporation. Odyne Corporation is a developer of Plug-In Hybrid Electric Vehicle (PHEV) power trains for Class 6,7 and 8 vehicles. Our efforts resulted in the introduction of the utility industry's first commercial plug-in hybrid medium duty truck in the Fall of 2007.

Background

Medium and heavy duty trucks, used by the utility industry are typically built in multiple stages. During the first stage an original equipment manufacturer builds an incomplete vehicle, commonly known as a chassis. The vehicle is then often completed by a final stage manufacturer. Final stage manufacturers typically evaluate the intended application of the vehicle, perform engineering analysis, and then install an appropriate body, equipment and interface components with chassis systems in a manufacturing operation.

Hybrid drive systems may be installed by an original equipment manufacturer or by another entity during an intermediate or final stage of manufacturing process. DUECO installs the plug-in hybrid drive system and interfaces the system with the chassis and installed equipment during the latter stage of manufacturing.

Hybrid drive systems may be installed only on newly manufactured truck chassis or some designs may facilitate either an installation on a new chassis or a retro-fit on an existing chassis for certain applications. The plug-in hybrid system developed by DUECO and Odyne can be either installed during the manufacturing process of a new truck or it can be installed as a retro-fit on an existing chassis. Retro-fit applications must be carefully engineered, installation of a system on an existing truck requires sufficient payload, packaging space and specific chassis data communications interfaces.

Trucks used by utilities typically drive to a job site and then conduct stationary operations. In a conventional truck, the diesel or gas powered engine provides the sole source of propulsion for the vehicle and is also used to power truck mounted equipment, such as an aerial device, digger derrick, crane, compressor, winch or other equipment. While at the job-site, the vehicle may idle for many hours to provide power for the equipment and provide heat or air conditioning in the cab. A medium duty truck may average approximately 8 mpg while being driven and while at idle will typically consume approximately 1 gallon per hour.

A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle with batteries that can be recharged by plugging into our nations electric power grid. It shares the characteristics of both conventional hybrid electric vehicles and battery electric vehicles, having an internal combustion engine and batteries for power.

Hybrid systems used in larger trucks, greater than class 4, have typically utilized two basic design configurations – a series design or a parallel design.

Series design configurations typically use an internal combustion engine (heat engine) with a generator to produce electricity for both the battery pack and the electric motor. There is typically no direct mechanical power connection between the internal combustion engine and the wheels in an electric series design. Series design hybrids often have the benefit of having a no-idle system, include an engine-driven generator that enables optimum engine performance, typically lack a transmission (on some models), and accommodate a variety of options for mounting the engine and other components. However, series design hybrids also generally include a larger, heavier battery; have a greater demand on the engine to maintain the battery charge; and include inefficiencies due to the multiple energy conversions.

Parallel design configurations have a direct mechanical connection between the internal combustion engine and the wheels in addition to an electric or hydraulic motor to drive the wheels. Parallel design hybrids have the benefit of being capable of increased power due to simultaneous use of the engine and electric motor or hydraulic motor, having a smaller engine with improved fuel economy while avoiding compromised acceleration power, and increasing efficiency by having minimal reduction or conversion or power when the internal combustion engine is directly coupled to the driveshaft, typically through a transmission. However, parallel design hybrids typically lack a no-idle system and may have non-optimal engine operation (e.g., low rpm or high transient loads) under certain circumstances. Existing systems on trucks of class 4 or higher have traditionally not had a system that combines the benefits of a series system and a parallel system.

DUECO has produced plug-in hybrid electric trucks, hybrid electric trucks and conventionally powered trucks for the utility industry.

The need for plug-in hybrid and conventional hybrid trucks:

There are several factors that favor the development and use of hybrid and plug-in hybrid trucks:

- Rising fuel prices.
- Increased pressure for environmentally friendly and green operations with lower carbon emissions.
- A national priority to reduce foreign oil dependency.
- Increased maintenance costs.

Differences between plug-in hybrid electric trucks and hybrid electric trucks:

The following compares some of the benefits of a plug-in hybrid to that of a conventional hybrid. The primary difference between the plug-in hybrid and the conventional hybrid is the size of the battery system and the ability to recharge the battery system from the domestic power grid.

While a plug-in hybrid truck offers some of the same benefits as a conventional hybrid truck, plug-in hybrids offer advantages in several areas:

- Reduced fuel consumption
    - A plug-in hybrid system has a large battery system that operates in a charge depleting mode. The energy from the battery is typically used to help propel the vehicle and operate equipment. Energy required to recharge the battery is ideally provided by the power grid or from regenerative braking, displacing the use of petroleum. A vehicle with a large enough battery system could potentially eliminate fuel consumption by operating in an all electric driving mode for a limited distance and operating in an all electric stationary mode. All electric trucks are available in Europe, while there are disadvantages such as limited range; electric trucks demonstrate that the technology is available for emission free operation.
    - A conventional hybrid typically uses power from the diesel and gas engine to recharge the battery or may be recharged from regenerative braking. Since much of the energy in the battery system results from recharging through the engine, fuel consumption may be higher.
- Reduced emissions, potentially eliminates emissions at the job site.
    - A plug-in hybrid typically reduces fuel consumption and corresponding CO2 emissions during urban driving and has a large battery system that can allow the engine to stay off the entire day at the job-site. The large battery system is used to power truck mounted equipment such as an aerial device or electrically powered air conditioning system. Electricity to recharge the battery system may be generated by sources with lower emissions; some utilities generate a sizable portion of power from non-emitting sources. As an example, PG&E generates over 50% of their energy from renewable sources.
    - A conventional hybrid due to a smaller battery system often may need to restart the engine at the job-site to recharge the battery and may not have enough energy in the battery system to power large loads, such as an electrically driven air conditioner, with the engine off. When the engine is started periodically for short durations in the field to recharge the smaller battery system, emission systems may not be at optimal effectiveness, potentially resulting in greater emissions of harmful pollutants.
- Lower noise levels during stationary operations.
    - The engine typically stays off with a plug-in hybrid, resulting in lower noise levels. A conventional hybrid may require the engine to restart to charge the batteries.
- Uses low cost, domestically produced energy from nation's electric grid.
    - Off-sets fuel consumption by displacing petroleum with electricity. Ability to recharge at off-peak hours.

- Maintains a charge or is recharged at any time with conventional engine.
  - While a plug-in hybrid is typically designed to deplete the charge in the battery system and recharge through the grid, the system can be designed to maintain a minimum state of charge in the battery system by recharging through the engine if needed. This allows extended operations in the field during situations where it is impossible to recharge through the grid. In other words, while it is desirable to recharge a plug-in hybrid through the grid, it is not necessary to plug it in. Charging using the engine is similar to how a conventional hybrid recharges.
- Improved vehicle acceleration.
  - Electric motors provide additional power and torque to the drive train of the truck. The larger battery system of a plug-in hybrid provides more energy for extended use of the electric motor. The smaller battery system of a conventional hybrid may become depleted more quickly, reducing available power when needed for climbing grades or other demanding situations.
- Standby power capability: option for 9 kW or more exportable power for applications such as job site power tools, lighting and temporary restoration of power to facilities.
  - The large battery system of a plug-in hybrid offers the ability to export power from the vehicle for external uses. In the more distant future it may be possible to export power from the vehicle to the grid (Vehicle to Grid, or V2G) to reduce peak loads on grid generation systems. The smaller battery system in a conventional hybrid typically does not have enough energy for export without turning on the engine to provide additional power.
- Reduced maintenance costs.
  - Utility vehicles often are serviced based upon hours of engine operation. A plug-in hybrid truck has reduced hours of engine operation, potentially extending maintenance intervals.

Benefits of Electricity as a Fuel:

A plug-in hybrid electric truck uses electricity to supplement or replace the use of fossil fuels. There are several benefits to using electricity as a fuel.

- Feed Stock diversity promotes stability
  - Hydro, Wind, Bio-Mass, Natural Gas, Coal, Nuclear

- A portion of our nations existing generation fuel mix is currently CO_2 free.
    - Example: approximately 56% of PG&E’s energy portfolio is CO_2 free
- Recent and ongoing legislation promotes cleaner generation mix over time
    - Renewable Portfolio Standard (RPS) legislation enacted in 21 states
- Low fuel cost and minimal additional infrastructure required
    - Preferential rates for off-peak consumption
- Projected future renewable energy sources tend to be an off-peak energy resource
    - Wind can often produce more energy at night

Plug-in Hybrid Electric Truck, bucket truck application:

A plug-in hybrid electric medium duty bucket truck is shown above. This type of truck is typically used by utilities of maintenance and installation of power lines. The truck has many of the benefits listed previously. Specifically this vehicle has the following features:

- Hybrid launch assist and regenerative braking
- All Electric Operation at a job-site for a typical day

- 35 kWh Energy storage (note: a traditional hybrid may have 2 kWh of energy storage)
    - Electrically powered hydraulic system moves Aerial lift & outriggers, this function is also known as E-PTO
    - Electrically powered air conditioning
- 110/220VAC Electric shore power 9 kW, more optional
- Interfaces with an Allison transmission, the system may also interface with other transmissions (testing with other transmissions has not been completed).
- Modular design with standard components.
- Enhanced reliability with redundant power for critical operations.
- Advanced diagnostics & data acquisition available, ability to monitor vehicle via satellite
- Very versatile design:
    - Basic system design can be used on for a variety of truck weight classes: 5, 6, 7, 8 (19,500 - > 33,000 GVWR). Testing of the system on class 5 and class 7 trucks has begun, testing on class 6 and class 8 is planned within the next year.
    - Basic design can be used on a variety of chassis configurations: 2x4, 4x4, tandem. Testing has begun on the 2 wheel drive application, testing on the tandem will begin within the next year. Testing on the 4x4 has not been scheduled.
    - System should be able to interface with multiple power trains from multiple chassis manufacturers. Testing has begun on GMC and International units and on chassis with gas and diesel engines.
- Ability to tow trailer.
- No special diagnostic software.
- Enhances stability of vehicle for aerial device applications.
- Utilities can power their fleet with their own fuel: Electricity

Fuel savings are dependent upon the application. The current vehicle reduces fuel consumption during driving in urban areas by approximately 10 – 15%. The vehicle will typically save 100% of fuel consumption during stationary operations at a job site, resulting in approximately 1 gallon per hour reduction. There is little to no fuel savings during higher speed highway driving.

Anticipated fuel savings for a plug-in hybrid in comparison to a conventional truck depend upon many factors such as the type of system architecture, size of battery and field application. The following is an estimate for two types of plug-in systems, one with parallel system architecture and one with series system architecture. The sample application is a 20 mile drive, a 5 hour idling period, and an additional 20 mile drive.

Parallel system with plug-in battery system compared to a conventional truck:

Stated Assumptions:

Conventional chassis: approximately 8 mpg fuel efficiency during driving and approximately 1 gallon per hour fuel consumption during idle.

Parallel system with plug-in: approximately 12% decrease in fuel consumption for a plug-in hybrid during driving and 0 gallons per hour fuel consumption during idle.

Estimated fuel savings: 56% reduction in fuel consumption, or approximately 1400 gallons of fuel saved per year, based upon 250 work days per year.

Series system with plug-in battery system compared to a conventional truck:

Stated Assumptions:

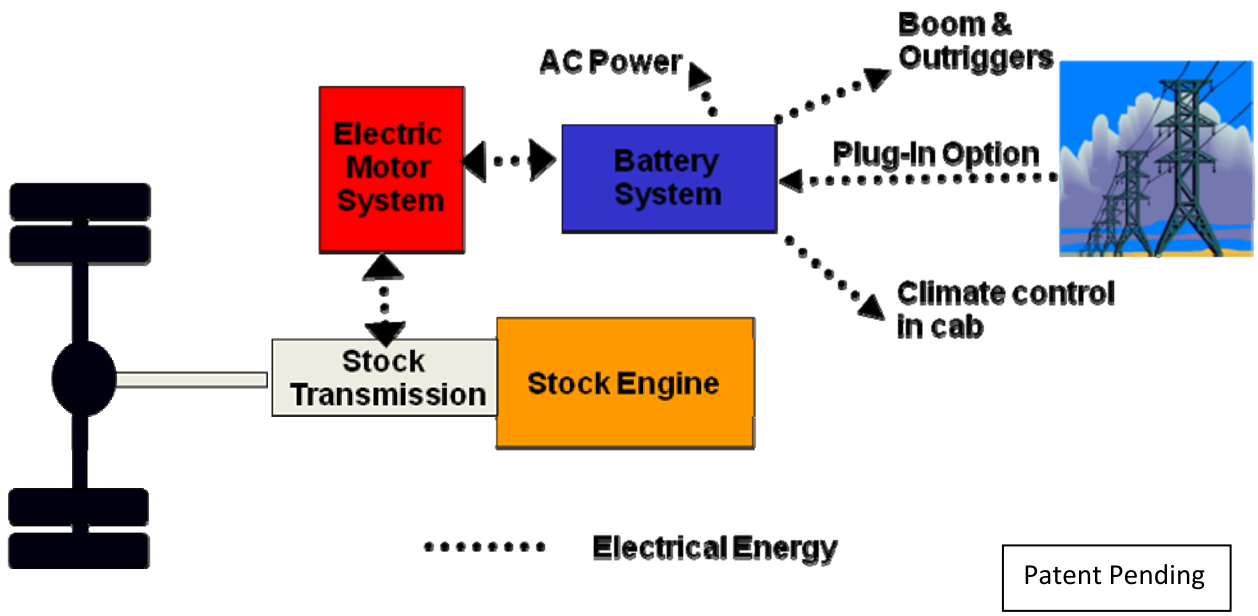
Conventional chassis: approximately 8 mpg fuel efficiency during driving and approximately 1 gallon per hour fuel consumption during idle.

Series system with plug-in: 50% decrease in fuel consumption for a plug-in hybrid during driving and 0 gallons per hour fuel consumption during idle.

Estimated fuel savings: 75% reduction in fuel consumption, or approximately 1875 gallons of fuel saved per year, based upon 250 work days per year.

Due to the large amount of savings, medium and heavy duty trucks with plug-in hybrid technology may be able to reach an attractive return-on-investment more quickly than other vehicles.

A diagram of a plug-in hybrid electric system for a truck is shown below. Electrical energy is used to increase efficiency while driving through hybrid launch assist and regenerative braking. Electrical energy also powers equipment loads at a job site, potentially eliminating the need to run the engine.



Major technical hurdles for deployment of plug-in hybrid trucks:

There are several technical hurdles for the deployment of plug-in hybrid trucks.

Battery system technology:

Existing battery technology either tends to offer battery systems that are relatively low cost, but heavy, large and of limited life or are relatively expensive, but much lighter, smaller and with potentially longer life. While certain applications of trucks may be able to carry lower cost, heavier battery systems, it is generally desirable to minimize battery system weight, size and cost. Development of cost effective larger advanced battery systems, potentially with energy storage in excess of 35 kWh, or even in excess of 100 kWh, would improve the performance and reduce the operating cost of plug-in hybrid trucks.

In order to accelerate deployment of plug-in hybrid trucks using existing technology, it may be desirable to design battery systems that are modular, that allow for newer technology battery systems to be placed on existing vehicles when the original battery system no longer performs to acceptable standards.

System architecture:

Existing hybrid systems for trucks tend to utilize system architectures that are similar in many ways to that of existing truck power trains. The internal combustion engine typically remains operating while the vehicle is driven to power auxiliary loads such as power steering systems, brake systems and HVAC systems. Keeping the engine running while stationary or in low speed stop and go traffic increases fuel consumption. Some vehicles also do not have a clutch in between the internal combustion engine and the transmission. While such systems utilize an automatic transmission, it may be desirable to create a method to uncouple from the transmission from the engine for improved regenerative braking or an all-electric drive mode.

In order to improve fuel economy further, different system architectures that are designed for high volume production in which the internal combustion engine can remain off during driving need to be developed. The development of electrically driven sub-systems such as braking, power steering, HVAC and others need to be brought to high volume production for medium and heavy duty trucks.

Existing parallel hybrid electric vehicle systems for trucks also tend to use relatively small electric drive components with relatively low power output, compared to the power provided by the internal combustions engine. Larger electric motors and higher capacity battery systems may allow smaller engines to be used that operate at higher efficiency without a reduction in vehicle performance, or allow the vehicle to be driven entirely by electric propulsion. Future system architectures could also combine the benefits of plug-in hybrid technology, which requires battery systems with high energy densities, with that of hydraulic hybrids that have high power densities. The combined plug-in electric hybrid system with hydraulic hybrid components could offer high horsepower during acceleration and recapture more energy during braking while providing enough energy for sustained operation with the engine off.

Alternative power train architectures, such as a combined series/parallel hybrid system with plug-in battery system are also recommended for consideration. A combined series/parallel system would allow the vehicle to operate in an all electric mode, a series hybrid configuration or a parallel hybrid configuration, depending upon which is most advantageous given operating requirements.

Utility infrastructure:

While studies tend to indicate that there is sufficient capacity in the nation's energy grid at off-peak periods to provide power for charging a large number of plug-in vehicles, there has been little testing on the effects of charging a large number of commercial plug-in hybrid trucks. A commercial fleet of 1000 vehicles, each with a 35 kWh battery system, could require approximately 25,000 kWh (or 25 MWh) of power to recharge overnight. Assessment and testing on the effects of charging a large number of plug-in hybrid trucks is suggested.

Research into specific medium and heavy duty applications:

Plug-in hybrid technology for medium and heavy duty trucks may reduce fuel consumption and emissions in a wide variety of applications. Besides aerial utility trucks and delivery trucks, other truck applications such as those that use cranes, compressors, welding equipment, or are used in gas utility maintenance, refrigeration, rescue, refuse and construction may benefit from plug-in hybrid technology.

Specific information about the energy required for various mobile and stationary applications is typically not available. In order to optimize the design of a plug-in hybrid medium or heavy duty truck, it is recommended that data be collected on actual fleet utilization, including miles driven, time at idle, power requirements, fuel consumption and other operational factors. The development of plug-in hybrid systems for vehicles that operate at especially low efficiency should be a priority and testing should be undertaken to validate improved efficiency and reliability.

DUECO's experience with government technology development programs and how the federal role can be enhanced:

Federal technology development programs focused on plug-in hybrid systems for medium and heavy duty trucks have been very limited. DUECO has not obtained federal assistance in this area, with the exception of possible general research tax credits. Most of the funding in this area has focused on the development of plug-in technology for automobiles or has been focused on large original equipment manufacturers. The medium and heavy duty truck industry is unique in that many of its products are often manufactured in multiple stages and brought to market by companies that are not directly affiliated with the original equipment manufacturer.

DUECO encourages the federal government to develop programs that help to specifically fund research into the development of plug-in hybrid systems for medium and heavy duty trucks used in specific applications and that are open to final stage manufacturers and other entities. Assistance with testing, certification, the creation of tax incentives for customers, and modification of government purchasing policies to favor the acquisition of more fuel efficient trucks using plug-in hybrid technology can also accelerate development and deployment.

Commercial fleets consume large amounts of fuel, developing more efficient trucks that utilize domestically sourced power from the nation's energy grid would have several benefits.

The development of this technology in the United States would provide opportunities for job creation, export opportunities, reduce the costs for businesses competing in a global market, reduce greenhouse gas emissions and emissions of other pollutants, reduce dependency on foreign oil, reduce noise within our cities and potentially improve productivity for certain applications, such as electric crews who could perform work at night in residential areas.

This is potentially a historic opportunity to develop the technology needed for the electrification of medium and heavy duty trucks. I would ask for your support of the proposed legislation that would help to accelerate research into plug-in hybrid technology for medium and heavy duty trucks and encourage the development of partnerships between manufacturers and utilities.