CONF-7905105--3

TRANSPORTATION TECHNOLOGY ENERGY OPTIONS

by

Martin J. Bernard III

MASTER

Prepared for

Using Land to Save Energy

Ill. (Ill-Ind. Bi-State Commission)

Chicago Illinois

May 18, 1979

U of C-AUA-USDOE

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Operated under Contract W-31-109-Eng-38 for the

U. S. DEPARTMENT OF ENERGY

DISCLAIMER

TRANSPORTATION TECHNOLOGY ENERGY OPTIONS

a presentation by
Martin J. Bernard III
Transportation Energy Systems
Energy and Environmental Systems Division
Argonne National Laboratory

Introduction

At Argonne my research group is working in a very exciting field. For the Department of Energy (DOE), but through third-party contract with the University of Chicago, we are evaluating on a very wide range of criteria, solutions to the problem of transportation with limited energy. Many of the proposed solutions are technological. New transportation technologies and their potential contribution to the solution of the energy problem is an area seldom discussed in public forums. Therefore, this is my topic this afternoon. Unfortunately I can touch on only a few examples.

Exhibit 1 is the list of the transportation technologies that the Department of Energy is now pursuing through research, development and demonstration. Others are studying different technologies. First on the DOE list are the Stirling engine and the gas turbine. These new automotive engines can use a variety of fluids for fuel, including synthetic fuels, alcohols, and perfume. Both are quite clear with respect to exhaust emissions but neither will be available until the late 1980s at best. The Department of Energy is not pursuing the diesel since it is commercialized, although I am going to discuss the light-duty diesel this afternoon.

There are some add-on devices for your car next on the list. The constant speed accessory drive allows accessories (for example, air conditioning and water pump) to run at a constant speed no matter what the engine speed is. Then the accessories can be optimized to reduce energy. Think about how you use your air conditioner: you get inside your car and it's 100^{o} or more, you turn the air conditioner on full blast as soon as the engine is idling and expect maximum output from that air conditioner. When your car is on the road at high engine speed, your air conditioner therefore has more capacity than it needs. So if automotive air conditioning systems are optimized and run at constant speed, a 3 to 5% energy savings is possible.

I must remark here that many strategies save only a few percent of the energy used. People argue that the effort may not be worth it, but it is the sum of all savings that really counts. There are very few big payoffs that save a lot of energy. The automobile is one of the few, but each way you find to save is a small percentage at a time.

Next on the list is a bottoming cycle for heavy-duty trucks. This is a very interesting concept which will be discussed shortly.

Exhibit 1: DOE Transportation Technologies

Technology	Subprogram
1. Stirling Engine	Highway Systems
2. Gas Turbine Engine	
3. Constant Speed Accessory Drive System	
4. Heavy Duty Diesel Truck Bottoming Cycle	
5. Continuously Variable Transmission	
6. Turbocompound Diesel Engine	
7. Gas Turbine Bus	
8. New Hydrocarbons - Broad Cut Petroleum Fuels	
9. Alcohol Fuels	
10. Synthetic Fuels	
11. Advanced Fuels - Hydrogen	
12. Electric Vehicles	Electric and Hybrid Vehicle Systems
13. Hybrid Vehicles	
14. Marine Diesel Bottoming Cycle	Non-highway Transport Systems
15. Coal-Oil Slurry Marine Steam Turbines	
16. Pipeline Bottoming Cycle	
17. Medium Speed Diesel Alternative Fuels	

The engine of your car runs at different speeds as you shift from first gear to second gear to third gear, or as your automatic transmission does it for you. But there is an optimal engine speed for maximum energy efficiency and for minimum exhaust emissions. A continuously variable transmission which is next on the list allows the engine speed to remain constant while the rear wheels rotate at different speeds. However, a technological hurdle for this transmission exists: it is too noisy. It has a high-pitched whine and therefore may never make it into automobiles, but there is 4-5% energy savings is we can make it work.

Turbo-compound diesels for heavy-duty trucks is a very near-term technology. The heavy-duty gas turbine program is for urban buses in cooperation with UMTA. This technology can be used in trucks and intercity buses also, and besides having a potential for better fuel economy, it can burn a variety of fuels.

There are several types of fuels listed. The most interesting one to us today is #9 - alcohol fuels. I'll mention a little about gasohol in a minute.

Next on the list are electric and hybrid vehicles. I'll talk a little about them this afternoon. A hybrid vehicle has two independent energy sources and normally would be powered by combination of a heat engine (which might be the Otto cycle as in your car now) and a battery running electric motors.

There are several non-highway systems technologies that DOE is studying: the pipeline bottoming cycle; medium-speed diesel alternative fuels for the heavy-duty applications, such railroad and marine; coal oil slurry marine fuels (mixing very fine particles of coal in with residual fuels); and the marine-diesel bottoming cycle.

The main reason DOE is developing the technologies on this list is because of high risk, the chance of failure. However, success will result in large benefits to society not benefits stockholders of private firms will be able to bank. DOE is cost sharing with private industry to reduced the risk and to assure technology transfer of government research and development results to private enterprise.

Gasohol

Exhibit 2 is directly from a PR blurb of an alcohol manufacturer. These are the advantages of gasohol according to the manufacturer. Gasohol is 10% grain ethanol (the stuff a few of us like to drink, as opposed to methanol which is highly toxic to man, but fish like it, get drunk on it) blend with unleaded gasoline.

The first point, no engine adjustments are required. At a 10% blend that is true, but adjusting your engine is against the law anyway. A lot of the carburetors in the new cars are sealed. There is not much the average mechanic can do to electronic ignition systems.

Exhibit 2: Advantages of Gasohol?

1. No Engine Adjustment Required
2. Improved Mileage
3. Increased Octane
4. Eliminates "Pinging" and "Dieseling"
5. Cuts Exhaust Emissions
6. Improves Cold Weather Starting
7. Reduces Gas Line Freeze Potential
8. Extends Allocated Unleaded Supply by 10%
9. Reduces Oil Import Requirements
10. Reduces Need for Farm Set Aside Programs
11. Each Tankful Uses 1 Bushel of Domestic Corn

Point 2, improved mileage, test results are mixed. If you put it in an older vehicle it seems to lean out the engine; you do get improved mileage. I think it has something to do with the added water. With carburetor adjustment however, MPGs can usually be improved. There is a lower Btu (energy) content per gallon of alcohol than for gasoline so thermodynamic efficiency, if your engine was optimized for gasoline, should be less. For the same amount of energy content, you need about half again as much ethanol as you do gasoline.

It does increase octane. Eliminate pinging and dieseling -- true because it has a better octane number.

Cuts exhaust emissions -- because the engine burns leaner, some exhaust emissions are cut. But it is what is in the gasohol exhaust that may cause major problems. One type of exhaust component from alcohol fuels are called aldehydes. When you were in high school biology, remember formaldehyde. That's what they pickled the frogs in. Also unburned alcohols possibly get through. Evaporative emissions increase. It is not at all clear what the health effects might be, if any. The research has not advanced far enough along to make a statement of scientific fact. We are working on it.

Improves cold-weather starting -- I doubt it. The flash point of alcohol is lower than gasoline. So on a cold morning you should have more trouble starting. In cool climates, pure ethanol is very hard to get started in the morning. Reduces gas line freeze -- sure. We do that all the time in the winter when we add methanol to our gas tank.

Extends petroleum supplies by 10% -- possibly true, but very complex, depending on future regulations on fuel economy and how gasohol is included.

Reduces the need for farm set-aside programs -- current participation in set-aside is quite low -- so insignificant. What this means is a farmer sets aside part of his land to maintain a lower level of production and is compensated by the government.

Each tankful of gasohol takes more like 3/4 bushel of domestic corn. Somebody is not going to get their corn bread. The impact of the use of corn for gasohol certainly is not very well understood. The research is not complete. I hate to put food in gas tanks to run automobiles.

The manufacturer forgot to mention that ethanol will remain more costly than gasoline for the remainder of this century and will continue to require a subsidy.

Electric and Hybrid Vehicles

The first schematic in Exhibit 3 is for an electric vehicle. The batteries are very much like the one that starts your car. However, you cannot deep discharge it often, that is take all the charge out of it very often and expect it to continue to work as you would in using an electric vehicle. Current batteries do not have good energy density, the amount of energy stored per pound of battery. In short, you cannot go a long distance in a battery car. You would be lucky to get a hundred miles per day if your vehicle were all batteries, no body, just batteries and wheels and you. Then you would have to charge it, plug it in for eight hours or so. Actually, most people don't drive more than

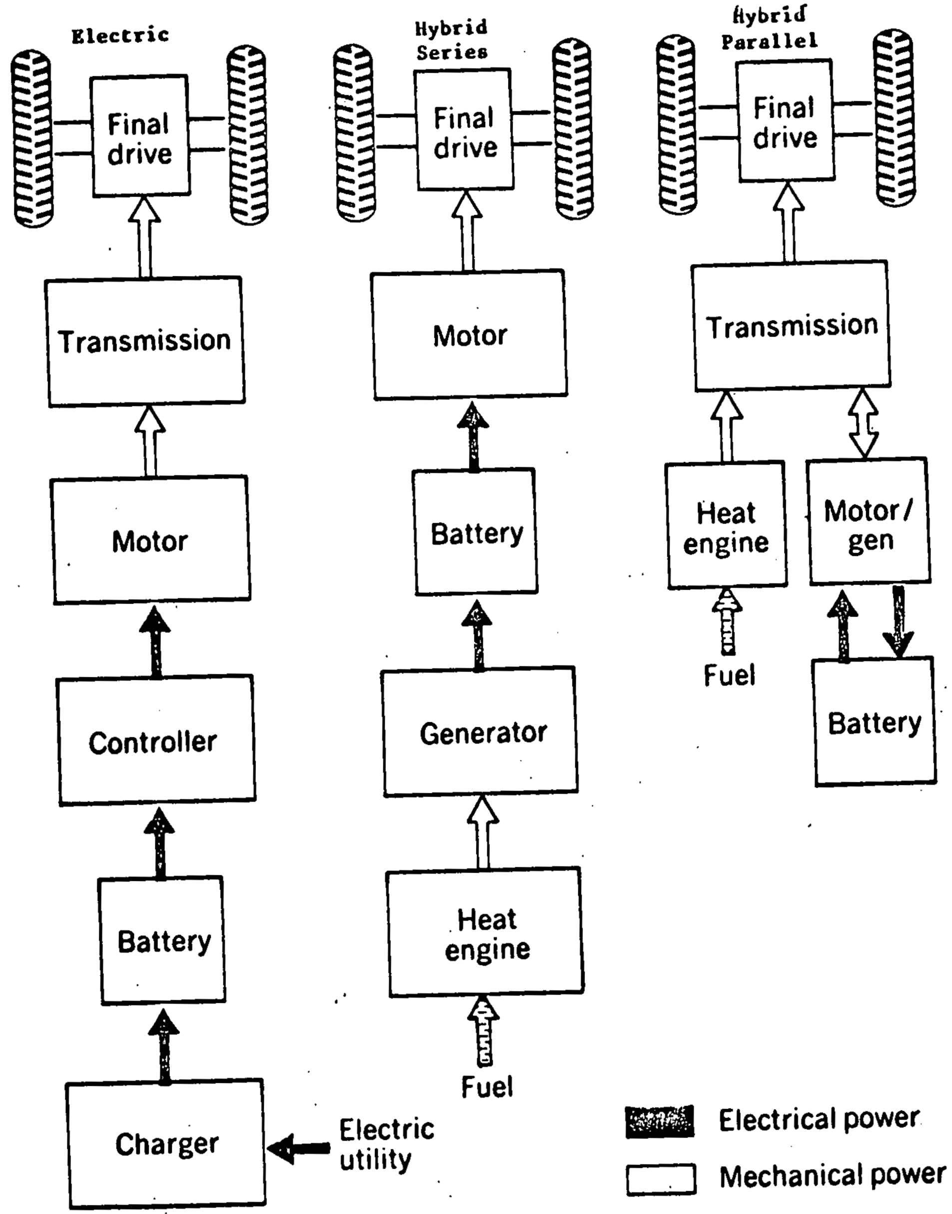


Exhibit 3: Schematics of Electric and Hybrid Vehicles

about 30 miles per day so the 50-mile range vehicle possible now might not be so bad. But the day you want to go to grandmother's house in Milwaukee, the big bad wolf gets you at about Racine.

Research on battery technology however is making strong advances and very possibly by mid-1990s we'll have battery cars that can do everything your VW or Honda can do, or if you want to pay for it, your Pontiac or Cadillac, except go over 250 miles. But maybe there will be no gas for your Caddy.

There are two types of hybrids as shown in Exhibit 3. A hybrid is basically an electric vehicle except for the heat engine. No range problem, but one of complexity. A few have been built. If we can teach the mechanic at your local Amoco station to fix them, maybe they have a chance in the late 1980s.

Light Duty Diesels

Our research at Argonne on light duty diesels shows that there is going to be a big controversy in the near future. In about 1983 General Motors intends to come out with a full line of diesels, small, medium and large. Let me tell you a little about the thing you were thinking about buying. There are 10 known manufacturers world-wide -- GM, VW, BMW, Mercedes, etc. The light duty diesel for automotive uses (light truck, medium truck, car, taxi-cab) is different than the heavy-duty one for heavy trucks, buses and railroad diesels, and probably significantly different. Unfortunately we do not know enough about the differences -- about lifetime, odor, noise and several other important parameters. There is little doubt about fuel savings: at idle, 70% relative to the gasoline engine; in taxi-cab type service, up to 50%; for suburban type driving, 30%; and for freeway and expressway type driving, no savings. This is due to the high compression ratio of the engine and the higher heating value of diesel fuel.

On an average, last winter diesel was selling for about 3¢ a gallon cheaper than gasoline, but there are many problems. Poor starting in cold weather. There has already been spot shortages of diesel fuel and transit agencies are having difficulty getting it. (I'm talking about pre-May).

Refineries can shift their product mix between residual fuels, diesel fuels and gasoline -- for a barrel of crude they have some leeway on what proportions of each they make. It seems they have been producing a large proportion of gasoline because gasoline has the biggest profit margin. We should be making more diesel in most of our refineries to be at the energy optimum.

A major problem with diesels is particulate emissions. You see some particulates as smoke, but the problem is what you don't see. Ninety percent of diesel particulates are smaller than one micron in diameter. That allows them to get into your lower lungs and they are not cleaned out by your normal breathing. Some 20,000 to 30,000 chemical substances (some of which are known to be toxic, carcinogenic or mutanogenic) in diesel exhaust are adsorbed on to these fine particulates. At the moment, there has not been enough research to identify if there is a link between human health effects and diesel exhaust. But GM wants to sell tens of thousands in the next few years.

We may have difficulty with the diesel meeting the NO_x standard, and what about the impact on American Motors? If the industry goes big toward diesels, what is poor American Motors going to do? It doesn't have the resources to build diesel production facilities, probably will have to buy diesels, just like it buys transmissions from Chrysler, but probably from the Japanese.

Bottoming Cycles

Exhibit 4 is a schematic of a diesel truck bottoming cycle. The vapor generator on the exhaust system is up behind the driver outside the cab. The waste heat from the exhaust boils the fluid in the vapor generator which expands and drives the turbine. The turbine adds mechanical energy to the drive train. Thus the waste heat that would have gone up the stack is converted to useful work. Unfortunately the fluid is extremely toxic.

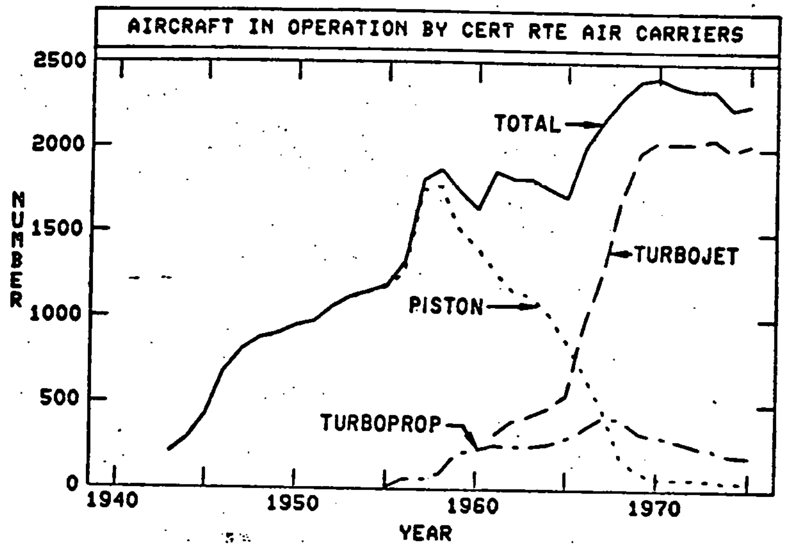
Technological Change

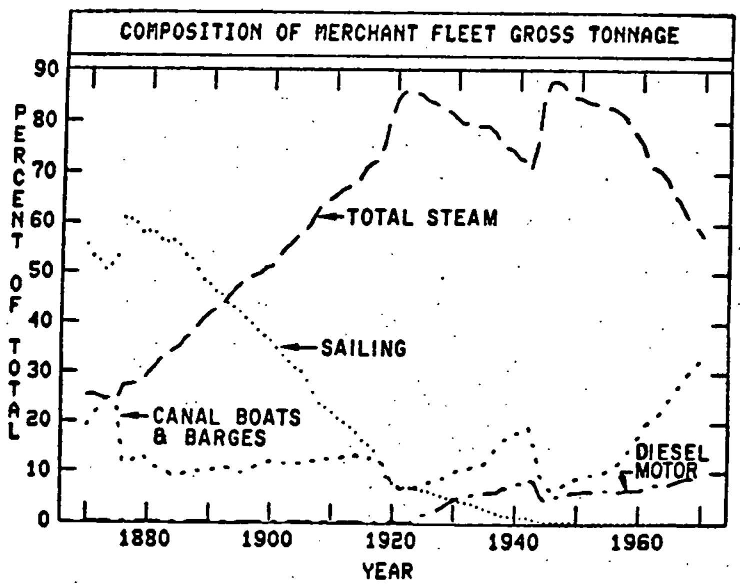
How fast can new technology penetrate markets and have an impact? I have a couple graphs here that address that question. In Exhibit 5 for 1955 most commercial air craft were prop planes. Turbo-props started coming on and something better came along -- the turbo-jet. Turbo-jets basically captured the market in 10 years. This is an example of a tremendously fast substitution of one type technology for another. The turbo-prop was relegated to the regional air carriers.

Exhibit 6 shows a slow substitution. The economics was much different in this case. Ships have long useful lifetimes and passenger comfort and speed were not of prime importance. Steamships probably started penetration in about the late 1870 or earlier, but not until 1920 was a large part of the fleet captured.

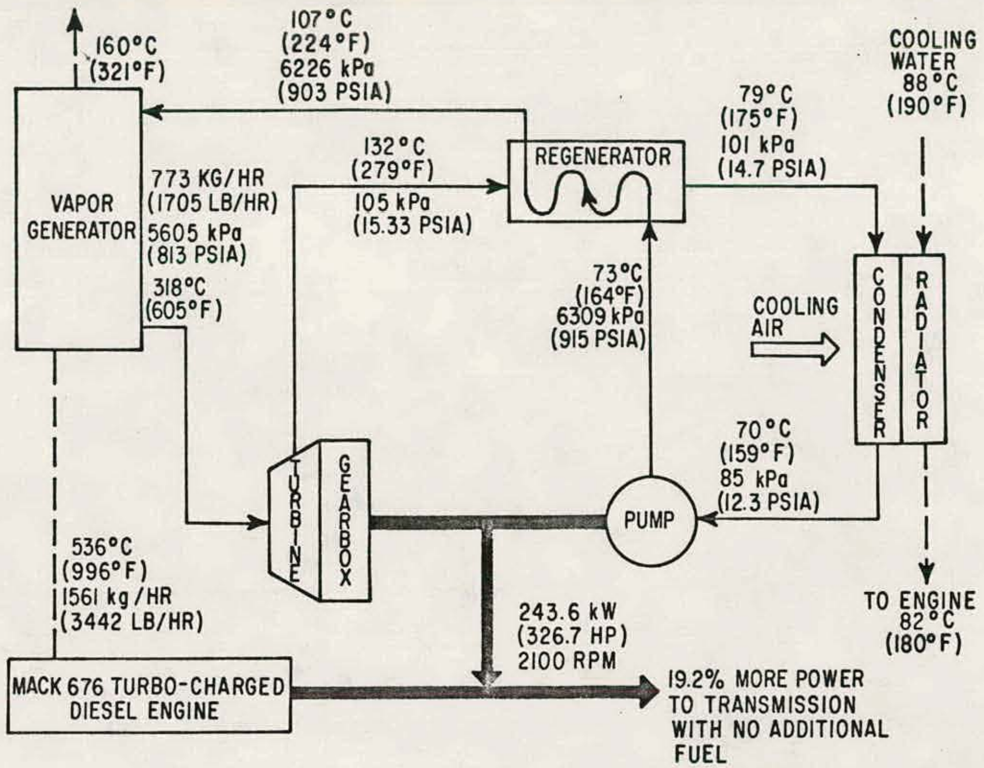
Conclusions

I guess the bottom line, if I could draw you a conclusion, is that there are many technologies on the drawing board, some of which, like the electric vehicle are both expensive and may not have the performance we


AIRCRAFT IN OPERATION BY CERT RTE AIR CARRIERS
NUMBER
2500
2000
1500
1000
500
0
TOTAL
TURBOJET
PISTON
TURBOPROP
1940
1950
1960
1970
YEAR


COMPOSITION OF MERCHANT FLEET GROSS TONNAGE
PERCENT OF TOTAL
90
80
70
60
50
40
30
20
10
0
TOTAL STEAM
SAILING
CANAL BOATS & BARGES
DIESEL MOTOR
1880
1900
1920
1940
1960
YEAR

expect out of our vehicles. Thus, they are not going to penetrate the free market nearly as fast as the jet did. Other of the new technologies may not be ready for a decade, some may never make it. However, potential payoffs are large. So are the environmental and health effects impacts if we make a mistake. But don't wait for the technologist to solve our problems. He may produce too little, too late. He has improved our lifestyle many times over this century. Maybe he will invent a way out -- only maybe.


160°C
(321°F)
107°C
(224°F)
6226 kPa
(903 PSIA)
COOLING
WATER
88°C
(190°F)
79°C
(175°F)
101 kPa
(14.7 PSIA)
REGENERATOR
132°C
(279°F)
105 kPa
(15.33 PSIA)
VAPOR
GENERATOR
773 KG/HR
(1705 LB/HR)
5605 kPa
(813 PSIA)
318°C
(605°F)
73°C
(164°F)
6309 kPa
(915 PSIA)
COOLING
AIR
CONDENSER
RADIATOR
70°C
(159°F)
85 kPa
(12.3 PSIA)
TURBINE
GEARBOX
PUMP
536°C
(996°F)
1561 kg/HR
(3442 LB/HR)
243.6 kW
(326.7 HP)
2100 RPM
TO ENGINE
82°C
(180°F)
MACK 676 TURBO-CHARGED
DIESEL ENGINE
19.2% MORE POWER
TO TRANSMISSION
WITH NO ADDITIONAL
FUEL