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ALTERNATIVE FUELS ASSESSMENT: THE INTERNATIONAL EXPERIENCE

Authors
Sathaye, J.
Atkinson, B.
Meyers, S.

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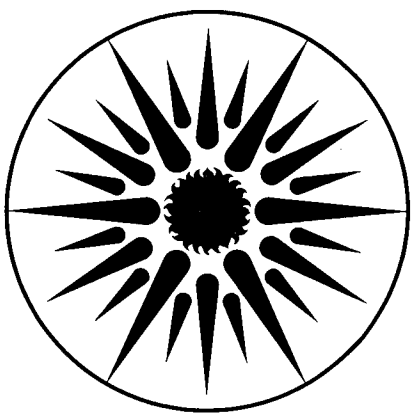
Alternative Fuels Assessment: The International Experience

J. Sathaye, B. Atkinson, and S. Meyers

March 1988



APPLIED SCIENCE DIVISION

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ALTERNATIVE FUELS ASSESSMENT:

THE INTERNATIONAL EXPERIENCE

Jayant Sathaye, Barbara Atkinson, and Stephen Meyers

International Energy Studies Group

Applied Science Division

Lawrence Berkeley Laboratory

University of California

Berkeley, CA 94720

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EXECUTIVE SUMMARY

Alternative transportation fuels such as CNG, LPG, and ethanol are in use in many countries. The market share of alternative fuel vehicles now ranges from 1% in Canada to 4% in Italy to about 10% in New Zealand and Holland to 20% in Brazil. In some cases, such as with LPG in Holland and CNG in Italy, the use has a long history, while in others, it is a product of more recent government policies. In Brazil, New Zealand, and to a lesser extent, Canada, governments implemented programs designed to result in large-scale use of alternative fuels. The primary motivation for promoting alternative transport fuels were similar: a desire for greater energy self-sufficiency, and reduction of the sudden large expenditures for oil imports.

CNG and LPG were the fuels chosen for implementation in New Zealand and Canada, though New Zealand also invested in synthetic gasoline production. The main reason for this was the desire to utilize domestic natural gas and the considerable commercial experience in Europe with use of CNG and LPG in vehicles. Lack of such experience was one reason why methanol was not chosen. New Zealand also did not have a large enough automobile industry to produce alcohol-powered vehicles.

Canada first targetted LPG, which was mostly produced from natural gas and was surplus in the early 1980s. Expansion of LPG fueling capacity was relatively easy, and vehicle conversion equipment was readily available. With the assistance of federal government grants for for vehicle conversion and new vehicle purchase, and reduced taxes on LPG, 130,000 vehicles were converted between 1980 and 1985. Most of these were commercial vehicles. When the grant program was discontinued in 1985, sales of dedicated LPG vehicles and conversions fell sharply. The propane industry is expected to assume responsibility for continuing the program's momentum. LPG conversions and new vehicles now number about 20,000 per year, slightly lower than the level in 1985-86.

The Canadian government began programs for CNG in 1983, giving sizable grants for vehicle conversion and for establishment of CNG refueling stations. The latter grants, which covered 20-25% of the cost, were important, since fuel availability was a major concern expressed by consumers. While the fuel station goal was met, the number of vehicles converted through 1986 was only about 12,000, much less than the goal of 35,000. Two-thirds of the vehicles converted were in fleets, where concerns about fuel availability were less strong. The grants are still in effect and are supplemented by incentives from gas companies, some of whom have adopted low profit margins in order to help establish the market for CNG. The gas industry views transportation as a promising market.

New Zealand was more heavily dependent on oil imports than Canada and implemented a more ambitious program to displace oil with natural-gas-based fuels. Synthetic gasoline was emphasized because its use require little infrastructure change and no adjustment of consumer behavior, and oil price expectations made it appear cost-effective. Although this has not been the case -- revenue from sales covers direct operating costs only -- by 1986 synfuel displaced 35% of gasoline demand.

The government also launched a major CNG program in 1979. With the help of grants, loans, and substantial government and private sector involvement, 110,000 vehicles, or 11% of all cars and light trucks, had been converted by 1986, and 400 fueling stations were established. When a new administra-

tion reduced government incentives in 1985, the conversion rate fell sharply. As in Canada, consumers were cautious because of fuel availability concerns, difference of the fuel from gasoline, and the cost of conversion. New Zealand promoted LPG less vigorously than CNG because supplies and distribution facilities were limited. LPG use was mainly promoted on the South Island because of the difficulty of transporting natural gas there.

Brazil based its alternative fuels program on ethanol produced from sugar cane. By 1986 ethanol supplied about 20% of automotive transport energy demand, and 90% of new cars were dedicated ethanol vehicles. The ambitious program, which included substantial incentives for alcohol production, was intended both to displace petroleum imports and to bolster the sugar industry, which had suffered from a drop in world sugar prices.

The program began in 1975 with the goal of increasing the ethanol percentage in gasohol to 20% nationwide. This level of ethanol production was not difficult to achieve, as many distilleries at sugar mills were underutilized. The next, more ambitious phase of the ethanol program called for a massive switch to dedicated ethanol vehicles. Incentives were targetted at carbuyers, ethanol producers, and automakers. These included lower taxes and fees and favorable credit terms for vehicle purchase and a promise of lower retail ethanol price compared with gasoline on an energy-basis. Producer incentives continued, and evidence of strong government commitment enlisted the support of auto manufacturers.

The program went through several ups and downs, and there were problems of vehicle quality and insufficient ethanol supply. Government maintenance of ethanol's price advantage, along with incentives for carbuyers and fears of gasoline shortages, led to a rapid increase in ethanol car sales in 1983. Demand for vehicles remained strong in 1984 and 1985, though expansion of alcohol production capacity is now uncertain. While ethanol is now entrenched in the economy, the government has embarked on a new program to displace diesel use by substitution of CNG in buses and trucks.

In other countries, LPG fuels about 10% of Holland's vehicles, and is also used elsewhere in Europe and in Australia, substituting for both gasoline and diesel. In Asia, LPG has been promoted for use in taxis in Japan, South Korea, and Thailand, primarily out of air quality concerns. The largest use of CNG is in Italy, which has some 300,000 vehicles, and plans for expanded use. A number of developing countries with abundant gas resources have begun programs to use CNG in transport, most notably Argentina. These programs mostly target diesel buses and trucks. Ethanol is used in gasohol in several countries that have sought other uses for their sugar crop. Methanol has been tested and studied in Europe, though its use has been limited to low-level blends.

The international experience shows that creating a large market for alternative fuels in a relatively short time is possible, but it is difficult and costly, and requires a strong government committment. Consumers have been reluctant to make the initial investment for vehicle conversion, even though payback periods are often less than three years. In Canada, New Zealand, and Brazil, the federal government played a strong role in the development and adoption of alternative fuels by private industry and consumers. Without this commitment and support, use of alternative fuels would have been much more limited than it was.

Government programs included grants and low-interest loans for conversion of vehicles and fuel stations, reduced taxes on alternative fuels, and promotion and marketing campaigns. Building the confidence of the public, the automobile industries, and fuel companies was very important. Each time the government reduced financial incentives for vehicle conversions or price-support sub-

sidies for alternative fuels, conversions and sales of vehicles dropped sharply. Revitalization of the programs required added incentives from the federal governments. Programs also had to address concerns about fuel availability, which market surveys have shown to be a major factor in consumer decision-making. Thus, it was important for the government to take the initiative in promoting development of a fueling infrastructure.

The performance of the private sector in vehicle conversion and production of dedicated alternative fuel vehicles, has been mixed. Poor quality has been a problem requiring government involvement to bolster consumer confidence. In New Zealand and, to a lesser extent, Canada, the gas industry has played a major role in promoting use of CNG. In both cases, the industry took up some of the momentum started by government programs after the government efforts were scaled back.

Most of the experience with alternative fuels has been with spark-ignition rather than compression-ignition (diesel) engines. There was already considerable experience with conversion of spark-ignition engines to use LPG and CNG. In recent years, diesel engine conversion technology has been further developed, and urban air pollution has generated more concern, so countries are turning their attention to diesel substitution. Diesel vehicles tend to have high mileage, and thus shorter payback time, and are often fueled from a central location.

The experience with alternative fuels in other countries indicates the need for strong government support to help overcome uncertainty in the early stages of market development. In addition to providing incentives, the government should develop policies and standards to regulate both the initial and subsequent stages of the program. The challenge for government policy is to determine a level of support that is adequate to encourage the market to seriously consider alternative fuels, but is not so large that it becomes difficult to sustain, creates unrealistic expectations on the part of consumers, or places a burden on the economy.

Decisions to strongly promote use of alternative fuels were made when most observers expected oil prices to remain above $30 per barrel. The government commitment created an institutional momentum and consumer expectation that did not allow for easy change of course when oil market conditions shifted. More recent alternative fuels efforts in other countries are targetting high-mileage vehicles where the economics and convenience of alternative fuel use are most favorable. This generates familiarity and experience with alternative fuels with the least expenditure of government resources. As market acceptance increases, industries with vested interest in alternative fuels may be willing to assume some of the support initially provided by government.

CONTENTS

INTRODUCTION

In the fall of 1986, the President directed the Department of Energy (DOE) to undertake a study of U.S. energy security in order to assess the implications of declining domestic oil production and rising oil imports. The study concluded that if current trends continue, the U.S. and its principal allies are likely in the next decade to become much more dependent than at present on oil supplies from the historically unstable Persian Gulf.

While substitution for oil has occurred in industry, power generation, and buildings, the transportation sector remains almost totally dependent on oil. The study found that even with widespread use of more fuel-efficient vehicles, the U.S. will remain heavily dependent on oil for transportation in the foreseeable future, and that the most promising technological opportunities for further reductions in oil consumption rest in the development of alternative fuel systems. The energy security report recommended that DOE conduct a technical analysis of the costs and benefits of developing a flexible-fuel transportation system.

As part of this analysis, Lawrence Berkeley Laboratory (LBL) has conducted a review of the experience with alternative transport fuels outside the U.S. The purpose of this review is to better understand what kinds of policies and programs other countries have instituted, and what the response by consumers and the private sector has been. While the experience in other countries grows out of their unique resource, economic, and institutional conditions, it is possible to draw lessons that are useful for evaluating options to develop a flexible-fuel transportation system in the U.S. The programs of other countries also affect U.S. policy and planning related to alternative fuel supplies and vehicle and conversion technology.

The international experience ranges from relatively routine use of LPG for air quality or price advantage reasons to very ambitious national campaigns designed to achieve a high degree of substitution for imported oil (Brazil and New Zealand). A number of developing countries with natural gas resources are in the early stages of alternative transport fuel development. The fuels that have received the main attention, and are the focus of this report, are compressed natural gas (CNG), liquefied petroleum gas (LPG), ethanol, and methanol. The report briefly describes the international experience with synthetic gasoline, which is different in character from the other fuels in that it substitutes for gasoline without requiring modification of vehicles or fueling infrastructure, and with electric vehicles.

The total number of alternative fuel vehicles in the world is about 7 million, or 1.4% of the world total fleet of cars, trucks, and buses (Table 1). Over half of the alternative fuel vehicles run on LPG, and 10% use CNG. The rest, which operate on ethanol, are all in Brazil, which has more alternative fuel vehicles than any other country. The share of alternative fuel vehicles out of the country's total number of motor vehicles is over 20% in Brazil, around 10% in the Netherlands and New Zealand, 4% in Italy, 3% in Australia and Japan, 1% in Canada, and less than 1% elsewhere.

This report focuses on three countries in which government programs played a significant role in promoting use of alternative transport fuels: Canada, New Zealand, and Brazil. Canada was selected because it has a transportation market similar to that of the U.S. Brazil's ethanol program has been the world's most ambitious alternative fuels program, while New Zealand's experience demonstrates the benefits and costs of a policy designed to achieve a high degree of

oil substitution. In the case of Canada and New Zealand, the alternative fuels programs were designed to utilize each country's considerable resources of natural gas. CNG and LPG (and in New Zealand, synthetic gasoline produced from natural gas), were the main fuels promoted. In Brazil, efforts focused on ethanol produced mainly from sugar cane. In each case, reducing oil imports was the major aim of government programs, and in Brazil supporting the agricultural sector was also an important goal.

Chapters on each country describe the rationale and goals of their alternative fuels programs, review the history of the programs, describe the institutional relationship between government and the private sector, and evaluate program success in terms of consumer acceptance, private sector performance, and economic criteria. The report also reviews the experience with alternative transport fuels in Western Europe, Asia, Latin America, and Africa.

In reviewing and assessing the programs in other countries, LBL has drawn on published information and analysis, and has conducted interviews with experts on alternative fuels in the countries with major programs. There are differing views both within and outside the countries as to how successful programs have been, depending in part on the criteria applied. LBL has not conducted an independent analysis of the quantitative costs and benefits attributed to the programs described in the report. This report seeks to describe what happened, why it happened, and what can be learned from the experience in other countries, not to judge the success or failure of policies pursued by other countries.

The final chapter of the report summarizes the lessons that the U.S. can learn from the international experience. The common issues that any country must face are: overcoming barriers to adoption of new technology, the effective use of incentives, the extent of reliance on market forces, pricing of alternative fuels, environmental and social impacts, and the respective roles of national and state government and the private sector. By understanding what has and has not worked well in other countries, and the reasons for success or failure, the U.S. will be better able to develop an alternative fuels policy that is best suited to its unique characteristics and national goals.

Table 1

Alternative Fuel Vehicles in Use, 1985/86

	LPG ('000)	CNG ('000)	Ethanol ('000)	Total Vehicles* (million)
Canada	140	15	-	14.3
New Zealand	50	110	-	1.8
Netherlands	530	-	-	5.3
Italy	585	300	-	23.3
Brazil	-	-	2400	12.1
Australia	90-110	130-200	-	9.0
Japan	1400-1700	-	-	46.2
United States	300-370	30	-	171.1
Other W. Europe	300	-	-	
World Total	3900	680	2400	490

Sources: This report. U.S. Dept. of Energy for world totals.

CANADA: LPG AND CNG HAVE RECEIVED GOVERNMENT SUPPORT

Canada has a population of 25.5 million, mostly clustered in cities along the southern border. There are 14 million vehicles (11 million cars and 3 million trucks and buses), 85% of which are in areas served by natural gas pipeline. Canadian supplies of conventional crude oil are dwindling, but the country is well endowed with natural gas, most of which is produced in Alberta. In 1985, Canada exported roughly a third of its natural gas production to the U.S.

The National Energy Policy, formulated in 1980, called for increased security of fuel supply and energy independence. It called for oil self-sufficiency by 1990, with a combined strategy of conservation and oil substitution. Use of alternative fuels in transportation was part of the strategy. In recent years, Canada has deemphasized the goal of energy independence, and has pursued diversification of the energy mix.

Canada's alternative fuels effort focused first on LPG and then on CNG. Conversion technology for LPG, and later to some extent for CNG, was perceived as well-established when the alternative fuels programs were being planned. Alcohol fuels have received less emphasis, although all provinces now have incentives for alcohol/gasoline blends.

The success of Canada's alternative fuels programs has been influenced by the policies of both federal and provincial governments. The LPG program distributed C$28 million (US$20 million)[1] in federal government grants, and lasted from 1980 through March 1985. The goal of 130,000 vehicles converted was met with the help of incentives for vehicle and fuel station conversion. Now that a degree of market acceptance has been achieved, the propane industry is expected to assume responsibility for continuing the program's momentum. The total of conversions and new vehicles using LPG is running at about 20,000 per year, slightly lower than the level in 1985-86.

The CNG program has cost the government C$7 million (US$5 million) for grants, and is still in place. The fuel station target has been met, but the conversion goal of 35,000 vehicles has not. The federal incentive programs will probably be extended until at least 1991. Provincial government and gas industry incentives supplement the federal CNG programs.

Along with the expenditures on grants, the federal government has spent C$1-2 million (US$0.7-1.4 million) on research, development and demonstration for alternative transport fuels.

LPG: Strong Federal Government Program Stimulated Use

In 1980, Canada was producing surplus LPG, and exported 60,000 barrels per day. About 80% of Canadian LPG is produced from natural gas. Prompted by the surplus, expectations of higher gasoline prices, proven LPG use in vehicles, and ready availability of conversion equipment, the federal government began to promote use of LPG. It supported a strong program because it believed that a threshold level of market penetration was necessary for sustained use of the fuel. The propane supply industry was neither large nor organized. The objective of the program was to create an LPG market of 1-2% of road gasoline demand, eventually to reach a level of 5%, or about 400,000 vehicles.

Federal and provincial governments launched a coordinated program in 1980 to

[1] The exchange value of the Canadian dollar has fluctuated from US$0.66 in 1980 to US$0.77 in 1984 to US$0.60 in 1986. The figures given in US$ were calculated using a rate of C$1=US$0.70.

remove regulatory, supply, capital and information barriers to expanded use of LPG. The primary federal program was the Propane Vehicle Grant Program, which gave a taxable grant of C$400 (US$280) for converting a commercial vehicle to LPG or for purchasing a new LPG vehicle. In 1984, this program was extended to cover private vehicles as well. The federal government also reduced the tax on LPG.

Provincial government incentives also promoted use of LPG. The main incentive was removal of taxes on LPG (Table 1).[2] LPG pump prices have been 66-78% of those of gasoline on an energy equivalent basis. In British Columbia and Ontario, the sales tax was removed for dedicated LPG vehicles and conversion kits.

Vehicle Sales and Conversions Declined Without Government Incentives

Government programs helped to achieve a high degree of market penetration, meeting the goal of 130,000 vehicles converted between 1980 and 1985. Most of these were commercial vehicles. At the end of 1984, LPG vehicles had captured 3.3% of the commercial market. The largest market was the manufacturing/wholesale industry, followed by the service industries, especially taxis, and then private vehicles, mostly light trucks.

Sales of tanks and vehicles declined after the program was discontinued in March 1985. Sales of dedicated LPG vehicles declined by 42% from calendar year 1985 to 1986 and those of conversion tanks fell by 30% (Figure 1). The price of gasoline did not decrease until after March 1986 and thus was not a factor in the decline in LPG tank sales, but may have influenced calendar 1986 sales of vehicles. The decline in sales occured despite the relatively short payback period, which in a typical case was four years without the government grant (and about three years with it).

Deterrents to LPG Use

Although LPG is favorably priced compared with gasoline, there are deterrents to its use. There are more stringent conditions on the sale of LPG than on gasoline: no self-service stations are permitted and there are more requirements on the location and configuration of stations. LPG vehicles are not allowed to park indoors in public garages. (This is a safety precaution to avoid explosions from ignition of spills of LPG, which is heavier than air and accumulates near the ground.) In the cold Canadian climate this regulation is a deterrent to LPG use.

Evaluation

The government discontinued the grant programs because the vehicle conversion target was met successfully. It continues R&D support to improve LPG conversion technology to keep pace with engine development. Further federal subsidies are not planned, although some provincial incentives continue. The government expects industry to continue the momentum, and the Propane Gas Association to increase its marketing effort.

CNG: Government and Gas Utility Programs Promote Use

Industry and government interest in CNG began to grow in the late 1970s, prompted by favorable experience with the fuel in other countries and the growing price spread between natural gas and gasoline. Also, LPG supply was recognized as limited.

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[2] Delmas, P. (1986). "The Supply, Demand and Pricing of Natural Gas for Motor Vehicle Use in Canada," pp. 71-99.

In 1980, CNG as a transportation fuel was well behind LPG in terms of technology, convenience, acceptance, awareness and market penetration. The Natural Gas Vehicle Research and Development Program was initiated by the British Columbia government in 1980 and supported by the federal government in 1981. The purpose was to evaluate and improve existing CNG technology. This work led to the establishment of safety regulations, design of carburetion equipment suited to the Canadian environment, and a knowledge base concerning natural gas vehicle combustion and performance.

The conversion costs for CNG vehicles of about C$2500 (US$1750) were much larger than for LPG. Establishment of CNG fueling stations initially cost C$200-250,000 (US$140-175,000), and the current cost is about C$300,000 (US$210,000). In July 1983 the federal government began two grant programs to overcome these first cost obstacles:

- the Natural Gas Vehicle Program, and
- the Refueling Station Program.

The station goal was set at 125 by November 1985. The target for converted vehicles of 35,000 was lower than that of LPG, since the natural gas utilities were expected to supplement government incentives.

The Natural Gas Vehicle Program (NGVP) gave grants of C$500 (US$350) to vehicle owners converting to CNG. It was complemented by removal of the provincial sales tax on conversion kits and/or vehicles in some provinces (Table 2). A grant of C$50,000 (US$35,000) was available for establishment of CNG refueling stations. While the program's fuel station goal was met and exceeded, the number of vehicles converted was less than planned. By December 1986, 11,400 natural gas vehicles were operating in Canada.[3] Of the vehicles converted, 45% are automobiles, 23% are light trucks and 21% vans. These are all retrofits since auto manufacturers produce no dedicated CNG vehicles as they do for LPG. Two-thirds are in fleets and the remainder in private use.

Many gas utility companies in the country offer grants and financial packages to encourage vehicle conversions and fuel station construction. (Typical gas consumption for a public refueling station is 35-50 million SCF per year.) Some gas utilities have adopted low profit margins for natural gas destined for CNG use. Other utilities have adopted the strategy of taking a somewhat higher margin on gas and giving a substantial rebate on conversion costs. Gaz Metropolitain offers a C$900 (US$630) conversion rebate. Several companies are also developing CNG cylinder leasing programs. A second approach is to offer easy financing for conversion. B.C. Hydro offers 36-month, 9% financing for conversion. A customer using 1300 gallons of motor fuel per year saves more each month than the monthly finance payment. Some utilities in Ontario and British Columbia have been able to negotiate rate-basing of new refueling stations with the natural gas regulatory boards. Convinced that gas use in transport is beneficial to all gas consumers, the boards allow the cost of new stations to be entered in the rate base and thus be spread over all users.

Fuel Price Incentive

The price of natural gas was controlled by agreement between the federal and provincial governments at 85% (on an energy basis) of that of crude oil from 1975 to 1981 and at 65% from 1981 to 1985. Since then the price has been gradually decontrolled, with retail prices staying well below 65% of oil. With the plunge in the oil price in 1986, the spread between gasoline and CNG prices

[3] Liko, K. and Deeg, K. (1987). "Natural Gas for Vehicles, Industry Survey 1986". Energy, Mines and Resources, Canada. Report No. TE87-3.

decreased dramatically. It is widening again as natural gas prices continue to drop, but will not go back to the 1985 levels until gasoline prices rise.

Market Acceptance

Despite the incentives, the conversion rate has been low, even in Vancouver where the majority of the fueling stations are located. For a vehicle using 1300 gallons per year of CNG, the payback period for conversion (with financial incentives) was estimated to be about 12 months in Toronto and about 20 months in Vancouver in December 1985.[4] In June 1986, with lower gasoline prices, the payback period in the two cities was about 18 months and 32 months respectively. In the U.S. (Phoenix) in 1986, a comparable payback period was estimated to be 40 months.

Market surveys show the cost of conversion, fuel availability and driving range limitation to be the largest barriers to public willingness to use CNG. Reasons given by those in favor of conversion are lower fuel price, lower emissions, natural gas availability in Canada, reasonable cost, better mileage and longer engine life.

There is competition between LPG and CNG in some provinces. However, they may also be viewed as complementary, since LPG broke the ground as an innovative fuel. LPG can serve areas where the natural gas network does not reach, and its fueling stations are less expensive.

Future Incentives and the Private Sector

Increased use of CNG will depend on a combination of price behavior and government support. Since the natural gas deregulation in 1986, prices depend on the supply of western gas, as well as on U.S. prices. The trend to market prices has tended to lower natural gas prices and therefore to favor it over gasoline as a transport fuel.

In 1987 the federal government extended the NGVP until March 1988, and in 1988 will likely extend it to 1991. Funds for the continuation of the federal grant program will come from the Market Development Incentives Program. This was set up by the federal government based on financial contributions from Alberta gas producers to seek non-traditional natural gas markets. The plan is to place more emphasis on high volume users in key target areas to form a base of consumers who continue to use CNG vehicles. Natural gas utilities and provincial governments are expected to continue to support CNG usage.

The Natural Gas Vehicle Development Committee of the Canadian Gas Association has prepared a strategy which calls for a network of visible fast-fill fueling stations, possibly as joint ventures between the utility and the retailer, selling several fuels. The industry recommends extensive promotion and publicity, cooperation with federal and provincial governments, and better relations with the automobile industry on technical matters.

ALCOHOL

Canada has an extensive resource base for alcohol fuel production, as well as surplus methanol production capacity. Each province has alcohol fuel incentives, such as reduced road taxes for alcohol blends. "Gasohol" is sold across Western Canada by Mohawk Oil Ltd. Mohawk produces ethanol from barley, corn or other locally grown grains, and blends it with methanol and premium gasoline. The fuel, called "Mohawk EM", consists of 92% gasoline, 5% methanol, and 3% ethanol. The Govern-

[4] Flynn, P. (1986). CNG as a Vehicle Fuel: North American Economics and Markets.

ment of Manitoba subsidizes the production of this fuel. Mohawk is also studying production of ethanol from wood.

Use of higher-level methanol blends is not compatible with the existing gasoline infrastructure, and modifications would be costly. Warranty restrictions for vehicles using methanol blends are another hindrance to methanol use. Nevertheless, the government is supporting research and development, primarily on low- and high-level methanol blends. In Hamilton, a fleet of diesel buses has been converted to methanol. More efficient production of methanol from natural gas, as well as production of methanol, ethanol and higher alcohols from biomass, are all under study.

Table 1

Canada: Taxation of Alternative Fuels and Equipment, 1987

Province	LPG	CNG	Reg. Gaso.	Other Taxes
	(US cents per gallon)*			
British Columbia	0	0	22	27 in Vancouver No provincial sales tax on conversion kits
Alberta	0	0	14	
Saskatchewan	0	0	20	
Manitoba	16	0	23	
Ontario	0	0	24	No provincial sales tax on LPG vehicles or conversion kits 6% sales tax on gasoline vehicles
Quebec	23	0	41	8% sales tax on vehicles and conversion kits
Federal	**	0	16	

Source: For gasoline, personal communication with Maureen Monaghan, Petroleum Products Division, Energy, Mines and Resources, Canada, Oct. 1987.
For LPG and CNG, various sources.

* Using 1987 exchange rate: 1C$=0.75US$.

** The tax rate is about 2% of the wholesale price.

Table 2

Canada: CNG Incentives

Federal Government	
Natural Gas Vehicle Program	C$500 conversion grant to private and commercial vehicles with a limit of 35,000
Refuelling Station Program	C$50,000 grant to fuel stations.
Provincial Government (Examples)	
British Columbia	C$200 grant for vehicle conversion
Ontario	Sales tax rebate for vehicles converted within 90 days of purchase
All Provinces	No road tax on CNG
Gas Utility Companies (Examples)	
Gaz Metropolitain, Quebec	C$900 conversion rebate
B.C. Hydro, British Columbia	36 month, 9% financing for conversion cost

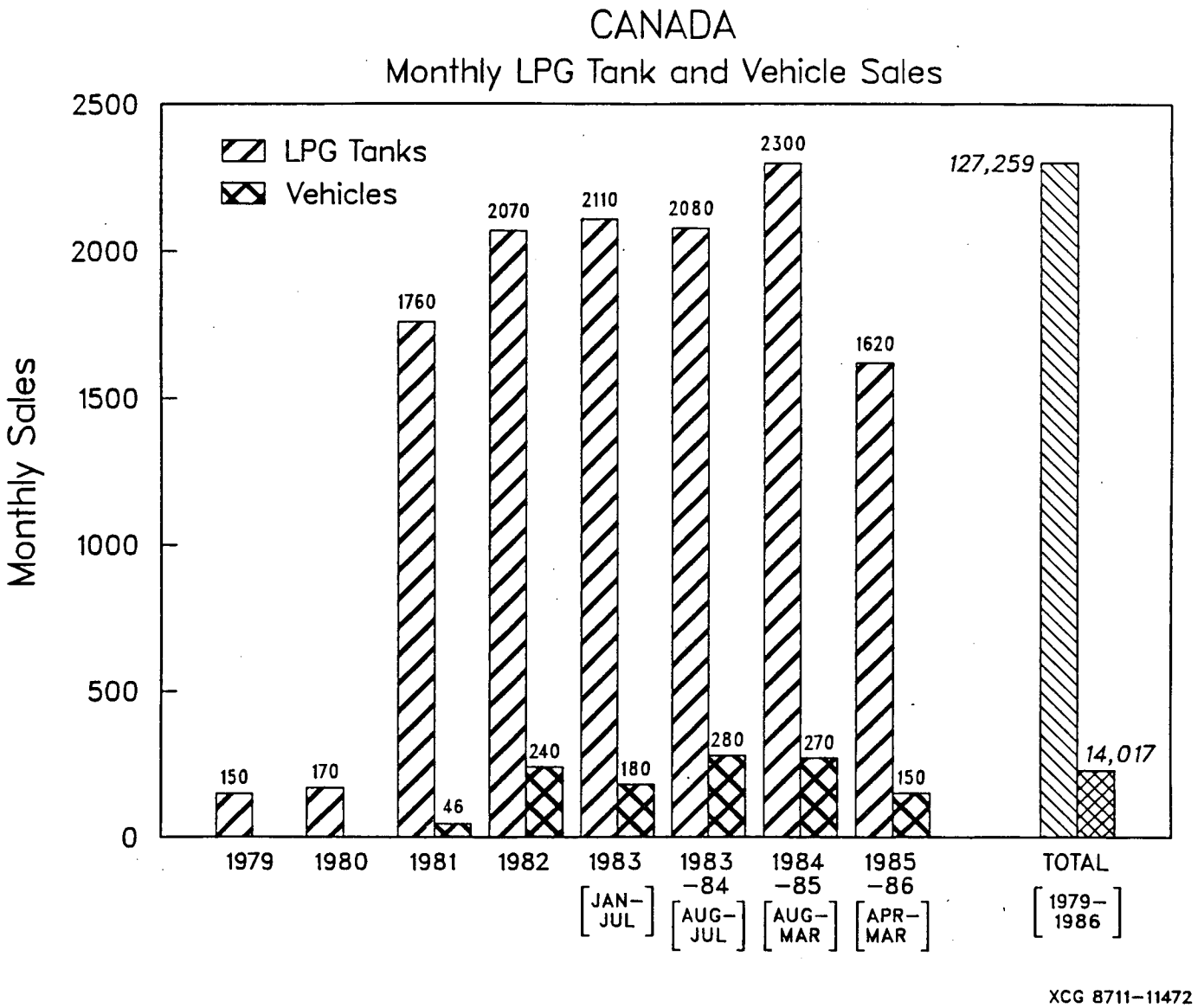
CANADA
Monthly LPG Tank and Vehicle Sales
Monthly Sales
2500
2000
1500
1000
500
0
LPG Tanks
Vehicles
150
170
1760
46
2070
240
2110
180
2080
280
2300
270
1620
150
127,259
14,017
1979
1980
1981
1982
1983
[JAN–JUL]
1983–84
[AUG–JUL]
1984–85
[AUG–MAR]
1985–86
[APR–MAR]
TOTAL
[1979–1986]
XCG 8711–11472

Figure 1

NEW ZEALAND: SYNTHETIC GASOLINE, CNG AND LPG SATISFY HALF THE GASOLINE DEMAND

New Zealand has a population of approximately 3 million people and about 1.8 million motor vehicles. Roughly two-thirds of the population and three-fourths of the vehicles are on the North Island. In the 1970s, the country was largely dependent on imports for oil supply, but possessed substantial natural gas reserves. The alternative fuels effort began in 1979 and was prompted by a large increase in the country's oil import bill, which by 1980 had risen to NZ$1270 million (US$1230 million), about 21% of export earnings. The government's strong commitment to increase energy self-sufficiency included substantial subsitution of petroleum used in transportation.

The Liquid Fuels Trust Board (LFTB) was formed to manage efforts to reduce the use of oil in transportation. The LFTB concluded that a combination of synthetic gasoline, CNG and LPG was necessary to reach the goal of 50% oil self-sufficiency by the mid-1980s.[1] By 1985, a combination of higher domestic oil production, use of natural gas-based alternative transport fuels, and lower demand for oil in other sectors had reduced dependence on imports to 72% of oil demand. After implementation of a major alternative fuels effort, gasoline demand in 1986 was displaced 35% by synthetic gasoline, 10% by CNG and 3% by LPG.

Methanol use and LNG exports were not considered viable options for utilizing New Zealand's natural gas. The country did not have its own integrated auto industry nor extensive expertise in automotive engineering, although several manufacturers had vehicle assembly plants in the country. Its domestic automotive market was small (about 90,000 new cars per year) and thus it had limited leverage in convincing overseas automobile manufacturing companies to produce methanol cars. Low-level methanol blends would have had too small an impact on overall gasoline consumption. LNG export was impractical because of the country's location and the large investment required for gas liquefaction and shipping.

Synthetic gasoline was emphasized because its use required little infrastructure change and no adjustment of consumer behavior. The large government expenditure on conversion of natural gas to gasoline is now a questionable investment in light of current oil prices.

CNG was the next fuel to be promoted by the government. Using vehicle and fuel station incentives, considerable market penetration was achieved. Promotion is now primarily in the hands of the private sector. LPG was also promoted, mainly on the South Island. A distribution network was constructed and incentives similar to those for CNG instrumented, with significant conversion rates achieved. Vehicle conversion incentives for LPG and CNG are no longer very extensive.

In 1988, New Zealand appears committed to synthetic gasoline and to CNG for the medium term. It is unlikely that other alternative fuels will be promoted for some time, given present oil price expectations.

SYNTHETIC GASOLINE: Expensive Yet Reliable Hedge against Higher Oil Imports

The New Zealand Synthetic Fuels Corporation (Synfuels) owns and operates a 14,450 barrels per stream day plant, which has operated since July 1985. Synfuels is 75% owned by the New Zealand government and

[1] In its later years the LFTB also investigated use of lignite and biomass in transportation. The Board has now been disbanded.

25% by Mobil. The two-step process converts methanol derived from natural gas to a gasoline-like liquid fuel. Synfuels converts natural gas owned by the government into gasoline for a processing fee. The synfuel is sold at the best price on the open market. In recent years, the majority of the output has been exported, rather than being sent to the refinery, because it commands a price premium on the international market as a blending stock for the production of unleaded gasoline. In 1986, the government sold synfuel to marketing companies at the same price as refined gasoline. Now the fuel is sold at the gasoline import price, which in the domestic market is somewhat lower than the locally refined price.

The synfuel market penetration of 35% indicates the technological success of the program. The plant cost US$1200 million, 17% less than budgeted due to lower inflation rates during plant construction, higher labor productivity, and other factors.[2] However, the plant economics are unfavorable; the decision to produce synthetic gasoline was based on the price of oil rising to US$40 per barrel by 1987.[3] Estimates when the plant was built indicated that if crude oil prices averaged US$28 per barrel (1980 dollars) over the life of the project, the project would be commercially viable. When oil prices plummeted in 1986, the government considered shutdown of the synfuel part of the process. With the help of an excise tax on synfuel, revenue now covers direct operating costs, and there are no plans to stop production.[4]

[2] Maiden, Colin J. (1987). The New Zealand Gas to Gasoline Project. Presented to the Methane Conversion Symposium, University of Auckland.

[3] Anderson, Brent (1987). Alternative Fuels for Transport -- A New Zealand Policy Overview.

[4] Personal communication, Peter Graham, New Zealand Ministry of Energy, March 1988.

CNG: In New Zealand, Unlike Canada, the Main Emphasis was on CNG

The CNG program, launched in July 1979, was a joint effort by the government and the private sector. The target was the conversion of 150,000 vehicles to CNG by the end of 1985. This included all suitable government vehicles with access to CNG fueling stations, as well as post office vehicles with their own fueling stations. The goal was later modified to 200,000 vehicles by the end of 1990. By 1986, 110,000 vehicles, or 11% of all cars and light trucks, had been converted, and 400 fueling stations were in operation.

The country was initially ill-prepared for introducing a new technology such as CNG. To overcome institutional barriers, the government established a series of standards covering both the vehicle conversion and refueling station industries, and set up a CNG Coordinating Committee to address technical and regulatory issues confronting the industry.

Initial Grants for CNG Conversion and Stations Proved Inadequate

With the incentive of government grants, conversions began as planned in 1979, but in 1980 the rate began dropping off. In November 1980, the government increased the amount of the grant for conversion kits from NZ$150[5] to NZ$200 (Table 3). The cost of vehicle conversion then was about NZ$1500: about US$1400 (US$750 after the 1984 devaluation of the NZ$). The new grant amount offset the import tax levied on imported CNG cylinders and conversion components, as well as the sales tax, while the earlier grant had covered the sales tax only.

[5] The exchange value of the New Zealand dollar has fluctuated greatly: from US$0.97 in 1980 to US$0.67 in 1983 to US$0.52 in 1986. The figures expressed in US$ were calculated using the exchange rate in the relevant year.

The 25% grant for fueling stations now included related expenditures as well as equipment. Tax write-offs were extended to new vehicles converted in the factory. The road user tax for CNG vehicles was replaced by a lower fuel tax.

The government actively promoted the program with information and publicity campaigns. It encouraged dealers to maintain the price of CNG at half that of gasoline, and publically stated that any fuel tax changes would not disadvantage CNG. The retail price of CNG has varied between 40% and 65% of the price of gasoline (Table 4). The average payback period for conversion, with government grants, was about two years. By the end of 1980, the conversion rate was 1000 per month. 32,000 vehicles had been converted by the end of 1982 (Figure 2), and 83 public and 33 private fuel stations had been constructed.

Despite the attractive incentives, the program moved slower than expected. Private motorists were reluctant to convert to a new technology, preferring to pay higher gasoline prices. Fuel cylinder approvals were delayed, causing the most popular make to be withdrawn from the market. The quality of conversions performed by some installers was poor. Because of the slow rate of conversions, no large company moved into the refueling business. The private sector saw promotion as the responsibility of the government.

Overcoming Conversion Cost and Extending Infrastructure Were Key

In 1983 the government moved to strengthen support of the program. It amended the target to 200,000 vehicles by 1990, and began its third reinforcement of the CNG incentive package. A low-interest loan program was introduced to overcome motorists' reluctance to incur a high first cost for conversion kits. This program complemented the existing energy conservation loan program, which had a loan minimum of NZ$5000 (US$3200) and was operated by a government financial agency according to commercial criteria. The new alternative fuels loan program was run by the Ministry of Energy through the trading banks. The loans ranged from NZ$500 (US$320) to NZ$5000 (US$3200), and ran from 6 months to 3 years. No down payment was initially required, and interest rates were around 10%. This program proved to be a crucial incentive and market research indicated that the availability of the loan was a deciding factor for over 60% of those converting their vehicles. Over 70,000 loans had been issued by the end of 1986.

A second important development was the financial commitment of Caltex to the establishment of a CNG network involving online stations and two mother/daughter systems[6] servicing stations. Industry formed the Alternative Fuels Association and the CNG Federation, and launched the CNG voucher scheme, under which motorists could receive up to NZ$300 (US$200) worth of free CNG in the two years following conversion. The need to improve the quality of conversions was recognized.

In 1984 the Ministry of Energy reviewed the CNG program. It concluded that the level of public confidence remained fragile, the program was viewed as "belonging" to the government, the spread of refueling facilities was uneven, and certain features of the programs (quality of conversions) remained vulnerable to abuse.[7] To bolster the program, the government enlisted greater support of the private sector for marketing and publicity strategy. The fuel station grant

[6] Mother/daughter systems feature a main station connected with the natural gas pipeline which serves remote satellite stations by means of trucks carrying compressed natural gas.

[7] Ryder C.J. (1986). The New Zealand CNG Programme: A Partnership Between the Government and the Private Sector. Presented at the Gaseous Fuels for Transportation Conference, August 1986, Vancouver, Canada.

program focused on priority areas, using mother/daughter stations to fill gaps and to extend the coverage of CNG stations to the entire North Island. An installer registration program was tied to loan eligibility, and consumer complaints dropped sharply.

An announcement that financial incentives would terminate on December 31, 1987, coupled with rising gasoline prices, resulted in a 40% increase in conversions in 1984 over 1983. By the end of 1985, about 100,000 vehicles had been converted, representing about 10% of light duty gasoline vehicles. About 300 refueling stations were supplying CNG. Industry was optimistic as the government was considering a large aid package for the following year.

CNG Conversions Declined after Government Pullout

The dependence of the program on government incentives was demonstrated in 1985. A newly-elected administration believed that the rapid growth in conversions indicated that government support could be reduced without greatly impairing the program. The number of CNG conversion loans was limited to 1600 per month, interest rates increased from 10% to 17%, and cash deposits equal to 25% of the conversion cost were required (the amount of deposit was later reduced to 10%). These changes were introduced overnight in June 1985. The only remaining government incentives were for fueling stations established in new areas. Conversions fell off dramatically, from 4200 in June to 1000 in July to 240 in December, as the public no longer perceived sustained support for the alternative fuel. The conversion industry felt abandoned with their new equipment stocks no longer moving. The oil price drop in early 1986 decreased activity even more. The price of CNG reached about 60% of that of gasoline.

In July 1986, the government attempted to revive the program by enlisting private industry to take over the leadership. Gas wholesalers are now promoting lower-priced retrofits (often below cost). Conversion prices have fallen by as much as 50% as the industry struggles to remain competitive in the face of falling oil prices. Gas Association no-deposit conversion loans at market interest rates replaced government loans in November 1986. The expectation is that this effort will be coordinated by a single organization.

Favorable Economics Were Insufficient to Promote Conversions

Since CNG was sold at market prices, the program cost less than it would have had fuel price supports been used. Three-fourths of the government expenditure was in repayable loans, and a savings on foreign exchange of NZ$83 million was realized between 1980 and 1985. The CNG program saved 875,000 barrels of gasoline in 1985, which amounted to about NZ$49 million (US$25 million).[8] The savings thereafter have been less because of the lower price of gasoline. The CNG industry employed about 500 people by the end of 1985, but is now in a period of retrenching with sales of new conversion kits much lower in 1986 and 1987. The industry is also actively trying to export CNG technology to countries in Southeast Asia, Latin America, Canada and Australia.

Conversion levels were lower than the original target despite the favorable payback period, which was estimated in 1985 to be 1.8 years for a typical small car. Without the industry vouchers for CNG and the government grant, the payback period would have been 2.4 years. The lower price of gasoline since 1986 has increased the payback period. Even with incentives, consumers were cautious because of fuel availability concerns, difference of the fuel from gasoline, and the cost of conversion. Surveys showed that consumers intended to use CNG

[8] CNG Federation (1985). CNG Information Brief.

as much as possible and were discouraged when they had to resort to gasoline.

LPG: Government Promoted LPG Less Vigorously than CNG

LPG distribution facilities were slower in being constructed, and the rate of vehicle conversions to this fuel was much more gradual. There was a definite bias towards CNG in the government-backed publicity programs, which offset some of the disadvantages of that fuel compared to LPG. LPG supply and distribution facilities were limited, and a greater national benefit was perceived from the use of CNG. At first LPG supply was constrained by production capacity. After the construction of the Maui extraction facilities in November 1981, the bottleneck became transport capacity. A new bulk LPG distribution company, LiquiGas, was formed comprising national and international petroleum companies. The national bulk distribution system came into operation in 1985, and LPG supply finally surpassed demand. LPG was promoted more vigorously on the South Island, because it was difficult to transport natural gas from the North Island.

Incentives

The government promoted LPG use by providing grants and soft loans to the distribution system. LPG installations received grants, and the government paid a 19 cents/gallon subsidy for LPG shipped to the South Island. A single national price for LPG from the bulk depots was established (which is then varied at distribution points downstream). A road tax on LPG similar to that on gasoline and CNG was incorporated into the pump price in 1982. The 25% fueling station grant program for CNG was extended to LPG once supply was readily available. Conversion incentives applied to LPG as well as CNG. Grants of NZ$150 (US$110) for conversion kits were also available for LPG on the South Island. The energy conservation loan program, new car grants, and tax write-offs were available for LPG facilities and conversions. Government funding of LPG publicity also increased, and promotional schemes were similar to those for CNG.

In 1988, the only remaining government incentive for LPG is the grant for fueling stations, which applies mainly to the South Island.

Market Penetration and Economics

LPG conversions climbed strongly in 1984 and 1985, but dropped sharply in 1986 and declined further in 1987. Analysis done by the Ministry of Energy shows payback periods for LPG conversion ranging from 2.4 to more than 5 years, depending on annual distance travelled. For a car travelling 18,000 miles a year, the internal rate of return for conversion was estimated to be 15%.[9]

METHANOL: Small and Incomplete Domestic Automobile Industry and Lack of Infrastructure Dissuaded the Government from Promoting Methanol

New Zealand produces a significant amount of methanol from a plant opened in 1983 (part of the synfuel plant complex). Methanol is also an intermediate product in synfuel production, and could be a final product if necessary. Government studies considered low-level blends and neat methanol implementation in 1979 and again in 1984 but decided against it. Perceived issues were vehicle driveability, technological readiness, availability of methanol conversion kits, and the need to construct a methanol distribution system. The Liquid Fuels Trust Board considered use of methanol in heavy tran-

[9] Personal communication, Peter Graham, New Zealand Ministry of Energy, November 1987.

sport vehicles by conversion of locally manufactured diesel engines.

Alternative fuels other than alcohol were introduced with considerable government assistance. Recent changes in economic policy make it unlikely that methanol will receive similar assistance. These changes are aimed at improving the flexibility and competitiveness of the New Zealand economy. The previous emphasis on a state-coordinated approach to energy development is largely inconsistent with current economic policy. For the transport sector, this means greater deregulation of the wholesale and retail markets.

Table 3

New Zealand: Government CNG Incentives

Grant Programs	
1979	NZ$150 grant for conversion kits.
	Grants to station owners to cover 25% of the wholesale cost of CNG compressors and storage equipment.
	Balance eligible for tax write-offs.
1980	NZ$200 grant for conversion kits.
	Fuel station grant extended to include related expenditures.
1982	NZ$200 grant extended to cover compressed biogas.
	Conversions encouraged on assembly lines.
1983-85	NZ$150 grant for conversion kits
Loan Program	
1983	Low-interest loan program;
	NZ$500-5000, 6 to 36 month loan
Reduced Incentives	
June 1985	Limited loans to 1600 a month
	Raised interest rate from 10 to 17%
	Required cash deposits -- 25% of conversion cost.

Table 4

New Zealand: Price of CNG and Gasoline

(NZ$/gallon of gasoline equiv.)

Year	CNG	Gasoline	CNG % of Gasoline
1979	1.06	1.63	65
1980	1.14	2.04	56
1981	1.21	2.42	51
1982	1.32	2.69	49
1983	1.36	2.69	51
1984	1.44	3.41	42
1985	1.59	3.75	42
1986	-	3.10	

Source: CNG Information Brief, CNG Federation, 1985.

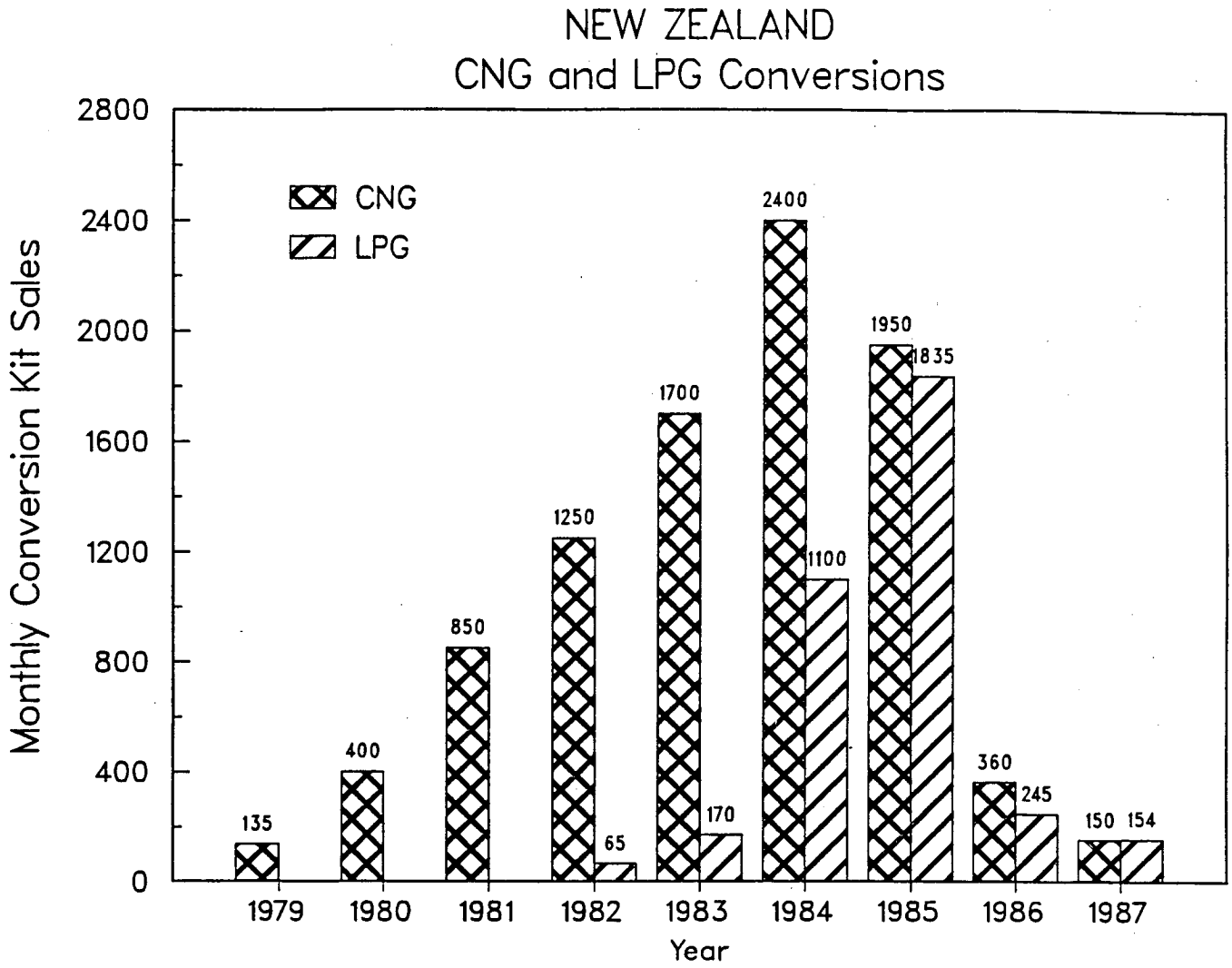
NEW ZEALAND
CNG and LPG Conversions
Monthly Conversion Kit Sales
2800
2400
2000
1600
1200
800
400
0
CNG
LPG
135
400
850
1250
65
1700
170
2400
1100
1950
1835
360
245
150
154
1979
1980
1981
1982
1983
1984
1985
1986
1987
Year
XCG 8711-11470

Figure 2

BRAZIL: MAJOR EFFORT TO SUBSTITUTE ETHANOL FOR GASOLINE WAS SUCCESSFUL BUT COSTLY

Brazil is a country of 138 million people with 12.5 million vehicles, of which 10 million are cars. The country has some domestic oil production, and non-associated gas fields were discovered in 1982. A substantial portion of energy demand has been met historically by hydropower and biomass-derived fuels. For the past two decades the country has been rapidly industrializing. Between 1967 and 1974, annual petroleum consumption doubled to 0.84 million barrels per day. In 1974, oil supplied 46% of domestic energy demand, and 76% of this was imported. By 1985, oil demand was 0.96 million barrels per day, but petroleum supplied only 31% of domestic energy demand, with 44% imported.

The reduction in oil demand was due in large part to substitution of ethanol for gasoline. Brazil has had the most extensive program for alternative transportation fuels in the world. Domestically-produced ethanol supplied 22% of automotive transport demand in 1985, and ethanol use was nearly as great as gasoline use (Figure 3). In 1986, 90% of new car sales were dedicated ethanol vehicles. In addition, an ambitious program to use natural gas as a diesel substitute in transport began in 1986, with a goal of eventually converting one-third of the truck and bus fleet to CNG.

PROALCOOL : A National Program to Support the Sugar Industry and Reduce Oil Import Payments

The ethanol fuel program began in 1975 as a response to a combination of world and domestic economic conditions. When the world oil price rose, the annual growth rate of the economy fell and the foreign debt rose from $6.2 billion in 1973 to almost $80 billion in 1982, the highest of all developing countries. At the same time, the large sugar industry, which had modernized and increased its output by the 1970s, suffered from a sharp drop in world sugar prices in 1975. Alcohol in the form of ethanol produced from sugar cane had already been used in some gasoline as a 5% blend since 1931, mainly to aid the sugar industry.

Against this backdrop, Proalcool, the National Alcohol Program, was born and implemented in two phases. The first phase (1975-1979) focused on increasing the ethanol percentage in gasohol to 20% nationwide. The second phase (1979-1985) was a major shift to produce and supply dedicated ethanol vehicles. A third phase, proposed in 1985 to expand the use of dedicated ethanol vehicles and increase ethanol production, is now on hold due to the world oil price drop. However, the popularity of ethanol in the automobile sector achieved in the second phase continues.

Phase 1: Expanding Ethanol Production

Responsibility for the Proalcool program was distributed among various agencies that managed distillery construction, ethanol production and prices, gasoline blending, and credit. As a producer incentive, ethanol was purchased by Petrobras (the national petroleum company) on a sugar-equivalent basis: prices and quotas were fixed by the National Institute for Sugar and Alcohol on a cost basis. Additional incentives included producer credit subsidies, which paid for up to 75% of investment. The government assured that sugar mill/distilleries received a 6% return on their investment, as long as they promised to produce ethanol and not export the sugar instead. They were thus able to diversify their investment, and sell ethanol to the government while sugar prices were low.[1] In the initial phase, the govern-

[1] Sperling, Daniel (1987), "Brazil, Ethanol and the Process of System Change", Annual Review of Energy,

ment loan subsidy amounted to about $0.23 per gallon of ethanol.

Despite early difficulties, Proalcool's first production goal was reached in 1979. Alcohol fuel use in transport rose from 2,600 barrels per day oil equivalent (BDOE) in 1970 to 33,000 BDOE in 1979. This first phase was successful because it required little technological or institutional change. Since ethanol was already being blended with gasoline, and the new blend was only 20%, vehicles and fueling stations did not require modification. Nor was supply a problem. Distillery equipment was already manufactured domestically. Many distilleries at existing sugar mills were underutilized, and were easily brought into production. Annex distilleries at mills could be built within one year.

The automobile industry played a supportive but cautious role regarding future expansion of the program. They did research demonstrating that there were no technical barriers to dedicated ethanol use in automobiles, but were reluctant to produce ethanol vehicles in large quantities without a guaranteed market.

Phase 2: Promoting All-Ethanol Vehicles

By 1978, excess ethanol production capacity had been used up as the 20% substitution goal was approached. The 1979 oil price rise, combined with a mounting foreign debt, caused the government to launch a new phase of the ethanol program. The new effort called for a massive switch to dedicated ethanol vehicles, aiming to reach 50% of vehicle sales by 1985. Alcohol was to fill 23% of transport fuel demand in this phase. The ethanol production target was 2.8 billion gallons by 1985, which required capacity to increase by 150%. The investment goal was $5 billion in fuel production and distribution facilities. Most of the funds came from an Energy Mobilization Fund, which was to generate $1.25 billion annually from fuel taxes, vehicle licensing fees and other sources. In addition, $1.2 billion was borrowed from a consortium of 51 foreign banks, mostly for the distillery and sugar production credit program. The World Bank also made a $250 million loan.

Consumer incentives to buy the new vehicles were lower purchase taxes, lower registration fees, smaller down payments and tripled repayment periods, and lower fuel costs. The pump price of ethanol, previously set by producers, was now guaranteed to be no more than 65% of gasohol, giving ethanol about a 20% advantage in cost per mile. Automobile manufacturers were encouraged by the strong government commitment, consumer incentives, and assurance of sufficient fuel supplies.

Initial sales of ethanol cars and retrofits were so high that some Brazilian vehicle manufacturers implemented only the minimum modifications required for all-ethanol vehicles, resulting in less-than-optimum efficiency and consumer dissatisfaction. Unauthorized mechanics began to offer inferior conversions at lower prices. Mounting complaints, especially from taxi drivers, caused a fall of sales from December 1980 to July 1981 from 73% to 9% of all auto sales.

Meanwhile, other problems had been emerging. Alcohol supplies were insufficient to meet the automotive demand. It became more profitable for some producers to export the alcohol than to make ethanol.

It appeared that the economic consequences of the program were not as beneficial as had been hoped. The generous credit required to begin the program had contributed to inflation. World sugar prices were predicted to rise again, increasing interest in exporting sugar rather than producing alcohol. In

1987, and Sperling (1988), *New Transportation Fuels: A Strategic Approach to Technological Change*, U.C. Press: Berkeley, CA.

response to these conditions, in late 1980 the government began to increase ethanol prices from as low as 40% of gasoline toward the 65% limit. In June 1981 credit subsidies for distilleries were suspended. Sales of ethanol vehicles plummeted, revealing the dependence of the program on strong government support, as well as the speed of consumer response to a change in commitment.

Meanwhile, the massive foreign debt continued to rise, petroleum import supplies were uncertain and prices were unpredictable, and world sugar prices remained low after all. The government reassessed its position and moved to bolster the ethanol program in late 1981 and 1982. To restore consumer confidence, ethanol prices were held at 59% of gasoline prices for two years. This gave ethanol about a 29% cost advantage over gasohol. Previously-removed incentives such as reduced ethanol automobile sales taxes, favorable credit conditions, and ethanol availability on Saturday were restored. Manufacturers were encouraged to improve vehicle quality and increase consumer incentives.

Alcohol producers received more attractive credit and were exempt from an agricultural production tax imposed in 1982. Even though the level of investment subsidy was reduced from Phase 1 levels, the government still paid an estimated two-thirds of capital costs for the portion it financed.

Production of ethanol began to increase, and a substantial reserve had built up during the bust period. Consumer incentives and fear of gasoline shortages caused ethanol vehicle sales again to increase rapidly in 1983 (Figure 4). Demand remained strong in 1984 and 1985.

A third phase was proposed calling for increasing ethanol production to 3.7 billion gallons by 1987. This was partly to be met by enlarging the cultivated area of sugar cane, and partly by improved production efficiency and management. A proposed World Bank loan, evaluated at projected world oil prices in 1984, emphasized these improvements as well as environmental, social and land use monitoring. At a fairly advanced stage in the negotiations, this loan was frozen due to the 1986 oil price drop.

Economic Evaluation

While the technical and implementation success of Proalcool is certain, critics vary in their economic evaluation. Many tend to argue that with today's oil prices, the program's costs exceed its benefits. Government investment for Proalcool amounted to $3.7 billion between 1976 and 1985, and industry invested $2.7 billion. Estimated foreign exchange savings from 1976 to 1985 were $8.9 billion. Some analysts placed the real cost of ethanol in 1983 at $40 to $65 per barrel of gasoline displaced for Southeastern production, and $100 for Northeast production.[2]

Weiss argues that replacement of gasoline imports by producing ethanol and dedicated ethanol cars is not justified at an oil price less than $30 per barrel, assuming operation of existing ethanol plants with current technology (Table 5).[3] With improved production technology, the threshold drops to $23 per barrel.

Evaluation of Proalcool is difficult, since the costs of alternatives are uncertain. The major alternative to ethanol production is increasing domestic petroleum exploration and production, and exporting sugar. Domestic oil exploration is expensive; marginal investment in alcohol production is probably equivalent or less than that of petroleum production. Exporting sugar

[2] Lizardo de Araujo, J. and Ghirardi, A. (1987). Substitution of Petroleum Products in Brazil. Energy Policy, Vol.15, No.1.

[3] Weiss, C. (1986). Fuel Ethanol in Brazil: Technology and Economics. First Conference on Macroengineering, Crystal City, Va. (Draft).

rather than producing ethanol with it would tend to depress the world market sugar price.

Proalcool has social benefits and costs not directly treated by economic analysis. One widely-debated issue is that of "food-vs-fuel", whether sugar production decreases the amount of land available for food crops, or whether sugar is grown on lands that would be otherwise marginal or pastureland. Job creation has certainly occurred through the huge infrastructure of the program; the nature and distribution of these jobs is again controversial. The effect on concentration of land ownership is another issue of debate. Environmental impacts seem to have been redistributed, with greater damage from distillery emissions in rural areas, and improved air quality in the cities from burning alcohol rather than gasoline.

Future Prospects

Despite unfavorable economic conditions, the government has remained committed to the ethanol program. While construction of new distilleries was prohibited after the oil price drop, fuel price subsidies continued. In 1985 ethanol prices were decreased to below the cost of production to maintain the relative advantage for consumers compared with gasoline. While IMF austerity measures have been implemented throughout most of the economy, alcohol production programs have been partially exempt from subsidy cuts. Investment subsidies are smaller but are more available than to other industries. The large expenditures for the ethanol program (17% of the 1983 budget) have been justified by the belief that the balance of payments deficit would benefit. This perception has been encouraged because distillery equipment as well as ethanol vehicles are produced domestically.

CNG: Promoted for Diesel Fleet Vehicles

In 1982, extensive natural gas fields were discovered in Brazil. Previously, all natural gas had been associated with petroleum extraction. Half of the known reserves are offshore, and pockets of natural gas are scattered throughout the country. A pipeline from the new fields to Sao Paulo should be completed in 1988. The national energy plan calls for increased use of natural gas in the transportation sector.

Currently, the focus is on substitution of natural gas for diesel fuel in urban transit. The first target is diesel buses, with trucks and light vehicles expected to form an additional market. Eventually, 40,000 city buses are slated for conversion. A dozen cities now have CNG-powered buses, and the municipal bus company of Sao Paolo has plans for using 500. Mercedes Benz of Brazil has developed an advanced diesel engine with a full gas mode option, and three prototype articulated buses. Mercedes has started production of these dedicated CNG buses.

Conclusions

Proalcool was successfully implemented because the government played a critical role in moving past the blending stage to use of neat ethanol. By putting a ceiling on ethanol prices, it circumvented market signals which would otherwise have delayed a transition to alternative fuels. The strategy of concentration in one region also benefited the program. Initially more than half the alcohol was produced in the state of Sao Paulo, and most of the fuel was consumed there. This allowed economies of scale in production and distribution, and increased the density of fuel outlets and support services. Consumer and producer incentives were demonstrated to work hand-in-hand.

Despite the criticism from some quarters, Brazil's ethanol program has become entrenched within the economy. Powerful interests have been created in the sugar cane and alcohol production industries, and over one million jobs depend on the survival of Proalcool. The generation of such strong interest groups is a consideration in any program which causes a significant restructuring of the economy. To dismantle Proalcool would require a substantial government effort. Should oil prices rise enough, the program would again become an economic asset. Brazil now appears committed to alternative fuels and expansion into diesel fuel substitution.

The importance of Proalcool in the Brazilian economy has a significant lesson for countries considering major commitments to alternative fuels. As in New Zealand, the irreversibility of the program requires careful economic planning and evaluation based on various world oil price and commodity market scenarios.

Table 5

World Price of Crude Oil to Justify

Substitution by Ethanol in Brazil

($/barrel)

Alcohol Use	Operation of Existing Plants	Construction of New Plants
Replacement of:		
Gasoline in gasohol	18	22
Gasoline imports by all-alcohol cars (new technology)	23	29
Gasoline imports by all-alcohol cars (current technology)	30	36
Gasoline for re-export	35	42

Source: Weiss (1986)

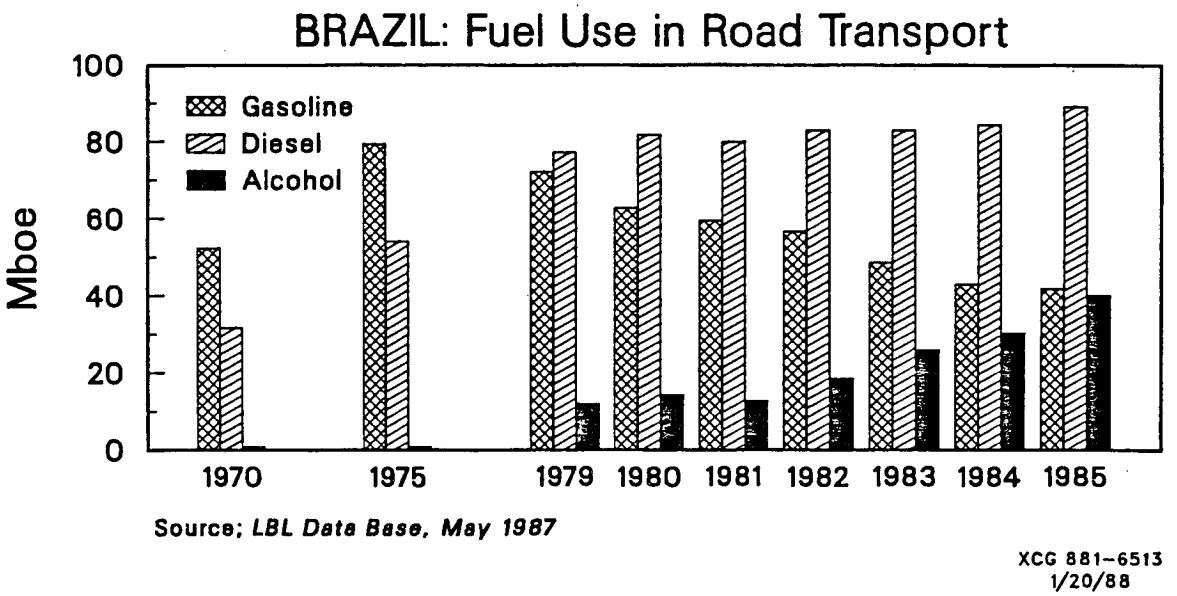
BRAZIL: Fuel Use in Road Transport
Mboe
100
80
60
40
20
0
Gasoline
Diesel
Alcohol
1970
1975
1979
1980
1981
1982
1983
1984
1985
Source; LBL Data Base, May 1987
XCG 881-6513
1/20/88

Figure 3.

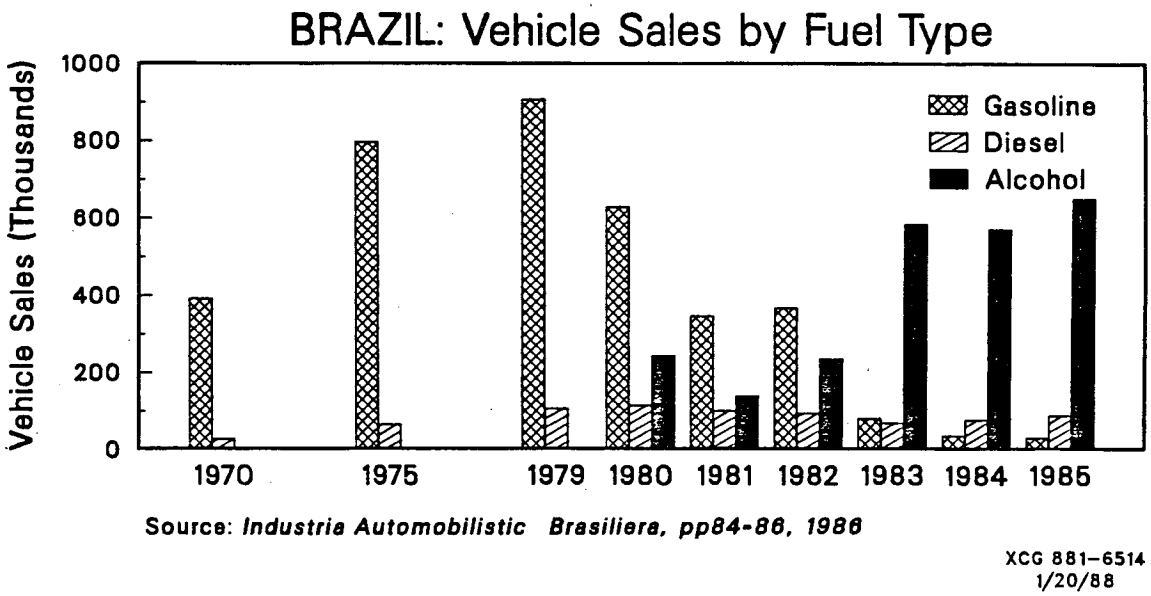
BRAZIL: Vehicle Sales by Fuel Type
Vehicle Sales (Thousands)
1000
800
600
400
200
0
1970
1975
1979
1980
1981
1982
1983
1984
1985
Gasoline
Diesel
Alcohol
Source: Industria Automobilistic Brasiliera, pp84-86, 1986
XCG 881-6514
1/20/88

Figure 4.

OTHER COUNTRIES: CNG AND LPG FAVORED

WESTERN EUROPE
LPG Main Fuel in Use; Methanol Used in Blend in Germany

LPG and CNG were used in Europe to alleviate fuel shortages during World War II, and their use has continued to some extent in several countries. LPG is presently the predominant alternative fuel in the Netherlands and a dozen or so other nations, although its share of the market has been slowly declining. CNG is used extensively in Italy only.

The European Economic Community (EEC) has issued a directive recommending the use of unleaded gasoline beginning in October 1989. There is substantial interest in some countries to use alcohol fuels as octane boosters in place of lead. Methanol is already used as a low-level blend in 80% of the gasoline sold in West Germany. Growing agricultural surpluses have given rise to increasing debate on ethanol production. Governments of countries with large grain surpluses are advocating ethanol-gasoline blends.

LPG: Used to Reduce Air Pollution

All Western European countries have an automotive LPG market except for Finland and Switzerland, where the tax is high, and Portugal, where LPG use for transport is prohibited. No government grant or loan programs appear to be in place in Europe, though the Greek government has provided incentives for LPG use in taxis. Buses in Vienna use LPG also. This governmental promotion of LPG is mainly designed to reduce air pollution in cities.

Transport use of LPG in Western Europe amounted to 14.7% of the total LPG sales in 1985 (Table 6). This represented 1.2% of total motor fuel consumption. LPG use in transport declined slightly for two straight years beginning in 1983 because of substitution by diesel in the commercial market. LPG cars comprise 1.1% of the total in these countries. The larger fraction of fuel consumption indicates that higher mileage vehicles and/or more fuel-intensive ones use LPG.

Automotive LPG prices vary among countries because of different tax rates (Table 7). On the average, the tax level on LPG is much lower than on gasoline or diesel. In 1981, the average European fuel taxes on LPG and diesel were 10% and 58% respectively of the tax on gasoline. These percentages decreased to 6% and 50% respectively by 1985.[1] In Italy and the Netherlands, which have much greater consumption of LPG than the other countries, a tax on LPG cars was introduced during this period.

LPG substitutes for both gasoline and diesel in the motor vehicle market. In West Germany, Ireland and the U.K., the comparable price of diesel is slightly lower than that of LPG. There is thus no economic incentive to convert from diesel to LPG, and the number of LPG vehicles is smaller in these countries.

The most important incentive for LPG conversion is favorable price compared to gasoline. However, potential buyers are also concerned with engine performance. In most of the European countries the quality of LPG is not consistent, which makes car performance uneven. European automobile manufacturers have not been interested in producing dedicated LPG vehicles because

[1] Bo, E. (1986). Automotive LPG Market Development in Europe. Gaseous Fuels for Transportation Conference, Vancouver, August, 1986.

there is little market. They are also reluctant to manufacture dual-fuel cars, because the inconsistency of fuel quality might affect the reputation of their vehicles. Oil companies prefer to sell LPG in markets where quality standards are not as strict, such as residential cooking. Thus government policies and economic incentives will be critical to the establishment or expansion of LPG programs. If LPG is cheaper than unleaded gasoline, it may benefit from the European Economic Community (EEC)'s new lead phaseout policy.

CNG: Widespread Use in Italy; Little or No Use Elsewhere

During World War II, CNG was tested as a fuel substitute in France, West Germany and Britain. Italy had used CNG since the 1930s. Of these countries, only Italy and France continued their programs.

CNG consumption in Italy declined through the 1960s but revived after the 1973 oil price increase. By 1979, consumption had increased to 4,900 barrels per day oil equivalent (BDOE), though it had fallen somewhat by 1985, when it amounted to 1% of total natural gas consumption. The new gas pipeline from Algeria has increased supply and encouraged CNG use. The 1986 national energy plan called for more natural gas use in the transportation sector.

Three hundred thousand CNG vehicles are in use in Italy, mostly dual-fuel private cars but some trucks and diesel buses. They are primarily in northern and central Italy where natural gas is produced and the 230 fueling stations are located. Availability of stations has been a major obstacle to increased CNG use. In the 1960s "decanting" stations unconnected to the gas pipeline, served by mobile banks or storage cylinders, were introduced to take advantage of the higher gas pressure in the trunk lines and extend the network beyond pipeline limits. These "travasi" stations now comprise 40% of the total.

Use of CNG has never been actively promoted, and instead has resulted from high gasoline prices and perceived fuel shortages. Relative price incentives still exist for CNG use. A disincentive is the high payback period for conversion (due to low fuel usage in efficient vehicles and short travel distances). Problems encountered with converted CNG vehicles have included increase in weight (which in some cases allows one less legal passenger in the car), a slight loss of power, an increase in refuelling time, and reduction in driving range. The regulations governing conversions are strict, especially for factory conversions. Cylinders must be tested every five years, but are replaced at no charge if they fail, as an incentive to undergo the test. These tests are paid for by a quarterly or annual fee paid by cylinder owners. The fee also covers liability from lawsuits from cylinder accidents. The safety record for CNG vehicles in Italy is good.

Methanol: Environmental Concerns Push Use of Blend in West Germany

Interest in methanol use has risen in Western Europe in the last decade as a result of high prices of petroleum products in the early 1980s and air quality problems. There is increasing experience with methanol technology. Unlike New Zealand or most developing countries, Europe has a strong automobile industry and vehicle market. If governments in the EEC adhere to the lead phaseout policy, there may be a significant market for methanol as a blending agent. In 1985, the EEC adopted specifications to approve methanol blending up to 3%, a practice which had already begun in West Germany and Switzerland.

Of the European countries, West Germany has done the most research and implementation with methanol. In 1982, an informal agreement between the Ministry of Economy, the auto industry and fuel suppliers led

to the introduction of a 3% methanol blend in all gasoline. The motivation was initially to save gasoline and later to meet unleaded gas specifications. This M3 blend now comprises 80% of the gasoline market.

Research on higher-level blends and neat methanol began in the early 1970s. Test fleets using 15% a methanol blend were technically successful, and a 5-year research and testing program was instituted. A 1983 study in cooperation with the oil and automotive industries indicated that M15 introduction would be costly with limited benefits, and that neat methanol was more promising. Using M15 would require a larger number of vehicles than M100 to displace an equivalent quantity of gasoline. Traffic across borders would encounter problems. In contrast, use of M100 in a few segmented markets could displace fairly large amounts of gasoline and require a less extensive distribution infrastructure.[2]

Programs on methanol research and development are ongoing in Sweden, other Nordic countries, and France. Sweden's energy policy calls for the use of alternative motor vehicle fuels, but implementation is slow because its own market is small and highly dependent on the international vehicle and fuel market. The country's plans hinge upon the actions of its European neighbors. Research has concentrated on methanol feedstocks from indigenous materials, in addition to engine development. In 1982, the Swedish Commission for Oil Substitution report indicated that economic analysis could not justify M15 dedicated vehicles, and work on introduction of M100 in limited fleets was recommended.

The government is gradually moving towards introduction of alcohol fuels as the research and demonstration phase moves towards development. In this spirit, the volume based alcohol fuel tax was reduced in May 1984 to correct for the energy disparity between alcohol and gasoline.[3] In 1984 the national oil company began to sell a 3-5% methanol blend.

Electric Vehicles

Electric vehicle technology is presently in the research and development stage in Europe, with both electric and hybrid vehicles under study. The U.K. and the Netherlands have used electric delivery vans for several years. Since 1974, newer designs have been operating in test fleets in a number of countries. Government support of automobile, battery and equipment manufacturers is the predominant pattern on the continent. In the UK, private firms collaborate with U.S. (GM) and Canadian companies. Spain uses electric buses in several cities, and Switzerland uses EVs for mountain transit, and Denmark, Finland and the Netherlands are developing this technology. In Sweden and Austria the postal services use EVs.

ASIA/AUSTRALIA
LPG in Use, CNG in Pilot Programs

LPG: Environmental Concerns Push Use, Mainly in Taxis

LPG is an important alternative to gasoline in Asia. In India, LPG is also being considered as a diesel substitute to reduce expensive imports. LPG is used extensively in taxis in Japan, Korea and Thailand. In the former two nations, taxis are required to use this fuel. In 1983, there were about

[2] Bernhardt, W. and Menrad, H. (1984). Alcohol Fuels in Germany. Proceedings of 6th International Symposium on Alcohol Fuels Technology, Ottawa, Canada.

[3] Brandberg, A. (1984). Alcohol Fuels in Sweden. 6th International Symposium, op cit.

75,000 LPG vehicles in Korea, half of which were in Seoul.[4] Between 1981 and 1985, LPG consumption increased several-fold, and reached 90% of the level of gasoline consumption. In Thailand, 75% of the LPG vehicles were taxis in 1984.

In Korea, LPG is promoted to reduce taxi fares and to improve urban air quality. The taxi fare is regulated and is based on fuel price. In 1986, the LPG price was about half of the gasoline price (US$2.45 per gallon), which includes heavy taxation. Use of LPG is not permitted for private passenger cars in order to preserve the limited LPG supply for household and industrial use and to maintain gasoline tax revenues.[5]

In Thailand, the retail price of LPG is regulated to be about 60% lower than that of gasoline on an energy-equivalent basis. Since the cost of vehicle conversion to LPG is around US$300, the fuel savings potential has encouraged high mileage vehicle owners, primarily taxis, to convert.

LPG use will continue in the above markets in Korea, Thailand and Japan and will be promoted in segmented markets on a limited basis in other countries as well. In the Philippines, Shell Pilipinas has had a program to market LPG for transport use (mainly for fishing fleets and vehicle fleets) since 1984. In India, LPG supply is soon expected to exceed cooking fuel demand in India. About 2.5 million tonnes of LPG will be available by 1990-91, and domestic cooking will require only half this amount. Indian municipal governments are also considering the use of LPG as a diesel substitute to meet rapidly growing demand.

[4] Korea Energy and Economics Institute (1986). Yearbook of Energy Statistics, 1985, p.188.

[5] Personal communication, Park Chung Hee, Ministry of Energy and Resources, Republic of South Korea, 1987.

In Australia, the government began to promote LPG use in 1979, around the same time that New Zealand began its CNG program. The Australian LPG program has not been as extensive as New Zealand's CNG program, converting only 40,000 vehicles and substituting for 1-2% of gasoline use. The New Zealand program achieved twice the percentage penetration in the same period. The primary reason for the difference has been the lower level of government commitment in Australia, where the government considered marketing to be the role of the private sector. Most of the industries involved, with the exception of LPG retailers, lacked the resources and skills to perform this role. Thus, during the early part of the program when high visibility was essential to public acceptance, promotion was lacking. The government believed that the establishment of broad implementation ground rules would be sufficient.[6] In contrast, the New Zealand government promoted its CNG program and modified its policies to reflect market conditions. It took on the initial marketing effort during the crucial early period.

CNG : Countries With Abundant Gas Resources Are Targetting CNG For Use in Trucks and Buses

Most Asian countries with large reserves of natural gas have begun programs to use CNG as a substitute for gasoline and diesel fuel.[7] Pakistan and Bangladesh have completed pilot projects, while Thailand, Malaysia and Indonesia are conducting projects to build refueling stations, test equipment, and demonstrate the use of CNG in vehicles. China, Burma and India have embarked on feasibility studies and planning for pilot

[6] West, J.P. (1986). "A Review of the Marketing of LPG in Australia", Proceedings of Gaseous Fuels for Transportation Conference, Vancouver, August 1986, pp. 35-53.

[7] World Bank (1986). Natural Gas in Transport in Developing Countries.

CNG projects. The first two are working with New Zealand, while Korea, an LNG importer, has been approached by a U.S. vehicle conversion company. Australia has a very small CNG automobile program, but has converted the first passenger ship in the world to run on CNG and diesel fuel.

Pakistan has been producing natural gas since the 1950s, but imports have met most of the oil demand. Conditions for CNG use are promising, since gas pipelines extend throughout the urban areas. Pakistan uses natural gas in urban households, unlike many other gas-rich developing countries. A pilot program, concentrating on gasoline substitution, is operated by the Hydrocarbon Development Institute of Pakistan (HDIP). The program was initiated in 1981, with the conversion of 100 gasoline vehicles and 1 diesel truck, and construction of a fueling station in Karachi.[8]

The natural gas price varies by sector; in 1985 it was about US$2.50 per thousand cubic feet for industrial customers. An HDIP feasibility study concluded that at this fuel price and with excise and sales taxes at half those of gasoline, investment in CNG refueling stations is profitable even at 50% to 60% capacity utilization. In 1986, HDIP recommended conversion of 21,000 gasoline vehicles to CNG, to be fueled by 33 CNG stations. CNG would displace 320,000 barrels of gasoline, about 5% of 1985 gasoline consumption.

Thailand has significant natural gas resources which are in the initial stage of commercial development. The government has targeted natural gas use mainly for power generation. The national oil company (PTT) is experimenting with a CNG pilot program for diesel substitution. The location of the existing pipeline network restricts the use of CNG to metropolitan Bangkok and markets near the pipeline. Fifty buses of the Bangkok Metropolitan Transit Authority are being retrofit, with an eventual goal of 5000. The initial pilot project ran into conversion problems because the buses were old or inadequately maintained and required a complete engine overhaul prior to introducing CNG. The next target vehicles are inter-urban buses along the East Thailand pipeline route. Use of mother/daughter fueling stations is also being studied. Fleets are emphasized because of the scarcity of conversion and maintenance facilities. Technologies and equipment used are from Italy and New Zealand.[9]

Methanol: Used in China for Agricultural Vehicles; Considered in Japan as a Long-term Alternative

Methanol has been considered as an octane booster in some Asian countries but not as a primary gasoline substitute, except in China. China has large deposits of coal in several provinces and has been making small amounts of methanol for transport use. Although it is recognized in government studies as one of the major alternatives to petroleum products, there are no immediate plans for major use. Currently, methanol is produced and used in a 10% blend with gasoline in Shanxi, Sichuan and Jilin provinces. Shanxi has plans to build a large coal-to-methanol factory.[10]

In Japan, the Ministry of Transport (MOT) and the Ministry of International Trade and Industry (MITI) are preparing strategies for methanol introduction, primarily for M85 to

[8] "CNG Experience in Pakistan" (1986). Proceedings, International Congress, Bologna, Italy, op cit, pp. 179-194.

[9] Natural Gas Vehicles Reporter, Volume 4 No 2, March/April 1987; and "Report of Overseas Visit to Investigate Compressed Natural Gas in Italy", (Liquid Fuels Trust Board of New Zealand, Feb. 1980).

[10] Mao, Y. and Hu, G. (1985). China's Transport and Its Energy Use. International Development Research Center, Canada.

M100. The Nippon Methanol Fueled Vehicles Company, a private company, was formed in 1985 to lease methanol vehicles and provide fueling stations for field tests. MOT has planned a 3-year program for diesel buses and trucks. However, replacement of diesel vehicles with gasoline ones might prove equally economically attractive, so government incentives would be necessary for the choice of methanol instead.[11]

Electric Vehicles

Japan seems to be taking an active "watch and wait" attitude toward electric vehicles. An active trade delegation appears at major electric vehicle conventions. Some observers estimate that if a strong market develops, Japan will be able to respond with a product within 18 months. Electric vehicles are used in intra- and inter-urban transit in India, and the International Research Center for Electric Vehicles was founded in Hong Kong in 1986.

LATIN AMERICA

CNG Invesigated in Argentina, Colombia and Brazil; LPG Used Mainly in Mexico

Alternative fuel use in Latin America, except for Brazil's ethanol program, is in the initial stage in several countries with natural gas reserves. LPG from both natural gas and petroleum production, and CNG, are the most widely used alternative fuels. In Argentina and Mexico, LPG was tried first, being the most readily available fuel. Its limited availability prohibits expansion of its use for transportation, however. Recently, Argentina has embarked on an ambitious CNG program, with assistance from the World Bank. Colombia evaluated several transportation fuel options and chose CNG. Mexico is beginning CNG use in its diesel city buses, and Trinidad and Bolivia have pilot CNG programs. Outside of Brazil, alcohol fuels appear to be receiving little attention in Latin America.

LPG: Subsidized Price Encouraged Use in Mexico

The use of LPG as an automotive fuel in Mexico has grown because its price is heavily subsidized for use as a cooking fuel. Use of LPG as a transportation fuel increased nearly 40-fold in 1983, when the LPG price became lower than that of both gasoline and diesel on an energy equivalent basis. Use increased further in 1984 and 1985, and LPG substitution in all sectors was so widespread that Mexico had to import it.[12] Private cars were converted, but many drivers simply used LPG cylinders in their cars without going through the engine conversion procedure. The government first made this dangerous practice illegal, and then raised the LPG price in 1986.[13] It is unlikely that usage will increase without a reversal of government pricing policy and/or a major increase in LPG supply related to petroleum and associated gas production. Nevertheless, Mexico is interested in alternative fuels both for optimal use of gas and petroleum products and for air quality improvement. Municipal buses use LPG in most large cities.

CNG: Gas-Rich Countries Experimenting with CNG for Use in Diesel Fleet Vehicles

[11] Fujime, K., Hirai, K., and Morita, Y. (1986). Long-Term Prospects for Transport Demand and Transport Energy Demand, Institute of Energy Economics, Tokyo.

[12] Guzman, O.M., Yunez-Naude, Antonio, Wionczek, M.S. (1985). Uso Eficiente y Conservacion de la Energia en Mexico: Diagnostico y Perspectivas, El Colegio de Mexico, D.F.

[13] Personal communication, Sr. Betancourt, PEMEX.

Interest has turned to CNG in several countries. Programs are underway in Argentina and Colombia. In Mexico, CNG is being promoted for air quality improvement. The Mexico City municipal bus company first completed a few conversions with U.S. equipment, and is now undertaking a comparative evaluation of various foreign CNG conversion technologies and equipment.[14] Trinidad has a pilot CNG conversion program launched, financed and operated on a commercial basis by a private entrepreneur. Bolivia is considering a taxi and minibus CNG conversion program, and is performing a feasibility study and market survey, using consultancy services from New Zealand, with financing from the World Bank.

Discoveries of large natural gas reserves in Argentina have led to formulation of a National Energy Policy that calls for use of gas as a transport fuel. A National Plan for CNG was formed in July 1984, with targets for conversion of 134,000 vehicles and construction of 366 fueling stations over 10 years. This represents 3-5% of the current total vehicle fleet, and is comparable to the rate of conversion in New Zealand. The goal is substitution of 5 million barrels per year of gasoline and diesel. The first target vehicles were public and private fleets, urban taxicabs, and light trucks. However, taxis have comprised almost all of the conversions to date.

The major consumer incentive is the relatively low CNG price. The government has made a commitment to hold the CNG price at 45% of the premium gasoline price. Since the price of diesel has been subsidized, it will be increased from about 33% to 60% of that of gasoline to encourage diesel conversions to CNG. The private sector is expected to provide 90% of the total required investment. They are responsible for conversion and fuel retailing. The national oil and gas companies will construct the stations until the market has reached a critical size. The Ministry of Energy supervises the implementation phase, and determines fuel price and gas allocation policy. The national gas company, regulates compliance with technical and public safety standards, while the national oil company plans, organizes and administers the program.

The first CNG pilot project began in 1983 with conversion of 20 vehicles in Buenos Aires. By June 1986, eight fueling stations had been constructed, and approximately 4,500 vehicles had been converted. The rate of conversions was faster than anticipated, causing lines at the stations, and the government is now promoting construction of a larger station network. Incentives for station construction are targeted in areas where the market has begun or is likely to grow quickly. The government recently decided to allow 20 new gasoline/diesel stations to open only if they also supplied CNG, and plans to finance station construction in more remote areas.

The World Bank is aiding the CNG conversion project and has done extensive economic analysis. Using 1985 fuel and equipment prices (oil at $25/barrel), 1% escalation, and a natural gas cost of $1.25/MMBtu, the World Bank estimated an economic rate of return (ERR) for the CNG program of approximately 50%, based on equity investment. This assumed conversion goals to be met by 1995, and included the price subsidy for CNG. Further analysis in late 1986, with oil prices around $15 per barrel, found a rate of return around zero.[15] The Bank has recently recommended that the government consider introducing CNG in diesel bus and truck fleets. These vehicles would be outfitted using dedicated CNG engines patterned after those being manufactured by Mercedes of Brazil.

[14] Personal communication, Pierre Moulin, World Bank, December 1987.

[15] World Bank (1986), op. cit.

Colombia has extensive natural gas reserves on the Atlantic Coast, and only half of the production is now used. A distribution network is in place. The OAS supported feasibility studies of a variety of transportation alternatives, and recommended CNG after a comparison of refinery restructuring, vehicle conversion from gasoline to diesel, and increased gasoline imports. The Ministry of Mines and Energy (MEM) has pursued both CNG and diesel-to-gasoline conversion. In 1984, MEM began a pilot project in Cartagena for dual-fuel CNG vehicles, converting 21 pickup trucks using Canadian equipment. This was followed by construction of a fueling station network, with plans for satellite stations on the main highway between Medellin and Bogota.

City gasoline buses are the next target for conversion. (Diesel-fueled vehicles are relatively scarce in Colombia.) MEM estimated a 6-month payback period for conversion of an urban gasoline-powered bus, and a oil savings of US$90 million with conversion of 90% of urban buses. The government decided to fix the CNG price at 60% of gasoline, and reduce taxes on imported conversion equipment to 1%.[16]

AFRICA

Energy Independence Behind South Africa's Synthetic Fuels Program; Elsewhere Ethanol Programs Support Sugar Industry and Reduce Oil Imports

South Africa's desire for energy independence has led it to substantial production of synthetic gasoline and methanol from coal. Elsewhere, the primary alternative fuel has been ethanol produced for blending with gasoline. The economies of several sub-Saharan African countries have depended highly on sugar cane production, and have been considerably weakened by the decline in world sugar prices in the 1970s. Some of these nations have begun programs to produce ethanol from cane juice and molasses. Ethanol substitution is especially attractive for landlocked countries where costs of petroleum product imports and molasses exports are high. There is also interest in CNG in countries with natural gas reserves.

Synthetic Gasoline: South Africa

South Africa has promoted alternative transportation fuels since World War II as a safeguard against a potential international petroleum embargo. The government has maintained its commitment despite large financial losses. Little public information is available on its programs, which make use of the large domestic coal reserves.

Gasoline and a diesel-like fuel are produced from coal. These fuels are directly substituted for petroleum fuels with no engine conversion necessary. The first plant opened in 1955, using a modified German process. In 1973 a larger plant opened, and in 1979 a third and identical plant began operation. Each of these units demonstrated slow incremental design improvements on an originally inefficient process. South Africa also produces methanol as a byproduct of these coal plants. Most of this methanol is used as a 10% blend in gasoline sold in urban areas.[17]

Ethanol: Used in Several Countries

Zimbabwe has a highly-developed sugar industry and several years of operating experience with ethanol production, blending and distribution.[18] In 1982 the ethanol con-

[16] Simahan, C.M. (1984). "Gas Natural: Un Cambio Energetico Radical en el Sector Transporte", General Assembly of the National Transportation Association, Cartagena, Colombia.

[17] Sperling, D. (1988). New Transportation Fuels: A Strategic Approach to Technological Change, U.C. Press.

[18] AID/TDP Memo, July 14, 1987, and Stuckey, D.C., Juma, C. (1986). "The Implementation

tent of gasoline was 15-20%; it has since declined to 10% due to a large increase in gasoline demand. Implementation of the ethanol production program was carried out primarily by a private company. Their plant uses a West German design and was largely fabricated locally; 60% of its cost was financed nationally. The government is now considering doubling ethanol production capacity.

Malawi has been producing ethanol and blending it with gasoline since 1982. The initial percentage blend was 13-14%, which has declined due to a rise in gasoline consumption. The private sector is promoting an expansion of production from both sugar cane and from wood for all-ethanol vehicles, or for export to Zambia and Botswana for blending there. Kenya constructed an ethanol production plant through a parastatal company, in a turn-key project using an Austrian design. In Zambia, an ethanol production project for blending to replace premium gasoline was postponed due to declining gasoline demand in 1983/84. Since then the demand has increased and there is renewed interest in ethanol production.

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of Power Alcohol in Kenya and Zimbabwe," Proceedings of 7th International Symposium on Alcohol Fuels, Paris, October 1986.

Table 6

Transport LPG in Europe, 1985

Country	LPG Cars (Thousands)	Fueling Stations	LPG Consumption (Thousand BOE)
Italy	585	1500	5450
Netherlands	530	2200	6470
Belgium/Lux	63	400	570
France	53	1300	490
U.K.	50	500	475
Spain	33	200	540
Other	89	1640	810
Total	1403	7740	14800

Source: Bo, E. (1986)

Table 7

Comparative Fuel Prices in Europe, 1985

(Gasoline = 100)*

Country	Gasoline	Diesel	LPG
Spain	100	51	46
Netherlands	100	65	49
Greece	100	44	55
Italy	100	42	59
Denmark	100	58	67
France	100	66	68
West Germany	100	79	84
Ireland	100	84	85
U.K.	100	88	76

Source: Bo E., 1986.

* Expressed on energy-equivalent basis:

1 unit gasoline=0.9 units diesel=1.2 units LPG

CONCLUSION AND LESSONS FOR THE U.S.

The international experience to date demonstrates that countries can develop a large market for alternative fuels within a reasonable time period. However, a strong commitment of effort and resources is required by the government, particularly in the early stages. Sustaining a major government commitment has depended on strong national goals such as greater energy self-sufficiency and supporting the domestic economy.

Fuel suppliers, the vehicle conversion industry, and automakers have been wary of investing in new technology for which the market is uncertain. Consumers have been reluctant to spend sizable sums for vehicle conversion, even when the return on investment is quite favorable. Assurance of fuel availability and technical quality of vehicles have proven to be important factors.

Important considerations for U.S. development of alternative transportation fuels include the role of national and state government, the participation of the private sector, the type of vehicles targetted for conversion, the flexibility of an alternative fuels system, and consumer attitudes. Below we discuss some lessons learned from the international experience with respect to these issues.

The Role of Government

The strong alternative fuels policies pursued by some countries were shaped by world oil market conditions prevailing in 1979 and the early 1980s. It was expected that oil prices would continue to rise, or at least remain at their high levels. In the countries with abundant natural gas or biomass resources that chose to substitute them for imported oil, the goals of increasing energy self-sufficiency and reducing the oil import bill generated the political support necessary for major programs.

In Canada, New Zealand, and Brazil, the federal government played a strong role in the development and market adoption of alternative fuels. Government programs included: (1) grants and low-interest loans for conversion of vehicles and fuel stations, (2) reduced taxes and guarantees of competitive prices for alternative fuels, (3) regulation of the conversion and equipment industries, and (4) promotion and marketing campaigns. In each country, the confidence and cooperation of the public, automobile manufacturers, conversion industries, and fuel companies was extremely important. Strong government incentives and financial involvement overcame some uncertainty on the part of the private sector, and considerable market penetration was achieved, especially in Brazil and New Zealand. But they also created institutional momentum and consumer expectations that made change of course difficult when oil market conditions shifted and rendered uncertain the economics of the selected alternative fuels.

The degree of financial and other support waxed and waned in the countries where major programs were instituted. This was due to concerns about outflow of government revenue and balance of payments, perceptions of fuel supply and petroleum product mix, and changing philosophy about the roles of government and the private sector. Lessening of government support for alternative fuels caused substantial reduction in vehicle conversions and/or sales of new alternative fuel vehicles. The international experience demonstrates the importance of consistency of government policy, but also suggests that it is not easy to achieve.

Participation of the Private Sector

The willingness and capability of the private sector to provide services for vehicle conversion, to produce dedicated alternative fuel vehicles, and to renovate or construct fuel

stations has varied among countries. Capability to convert vehicles to alternative fuels developed relatively rapidly in the first phase of the Brazilian program, and in New Zealand, though problems of quality control were encountered. Generally, government regulation was required to ameliorate these problems and to restore the reputation of the programs. In Brazil, the only country to produce large numbers of dedicated vehicles, car manufacturers were encouraged by strong government commitment, consumer incentives, and assurance of sufficient ethanol supplies. Fuel station owners were reluctant to provide a new fuel for which the demand was uncertain in New Zealand.

Recent government policies in Canada and New Zealand have encouraged the private sector to partially replace public sector support, now that market acceptance has been demonstrated. In Canada, there is now support for CNG usage from the natural gas companies, who see motor vehicles as an emerging market with potential to offset their diminishing heating markets. As of 1988, the experience with relaxation of the government's role in New Zealand and Canada, with consequent greater participation of the private sector, is limited. Developments in these countries in the next few years will be significant for U.S. evaluation of both public/private sector issues and federal/state government program interface.

Types of Vehicles Targetted for Alternative Fuels

Policies have differed in the emphasis placed on conversion of vehicles in public and private fleets vs. vehicles owned by households and small businesses. These choices were influenced by the degree of fuel substitution desired, as well as by the distribution of vehicle ownership. Brazil and New Zealand desired widespread substitution by alternative fuels, so programs were aimed at both fleets and personal vehicles. Canada's programs were much less ambitious, and tended to emphasize commercial vehicles somewhat more than private vehicles. In many developing countries, alternative fuels efforts are aimed at urban buses and taxi fleets because these high-mileage vehicles offer short payback periods and account for a significant percentage of transport fuel use.

Fleet vehicle operators have been more likely to use alternative fuels with a lesser degree of incentives than individual owners. Payback periods for fleet vehicles tend to be shorter because they travel more miles per year, and travel within a limited range, facilitating refueling. Fleet vehicles are usually converted in quantity by the operating company, which may construct its own central refueling station. Government and public fleets can be converted as examples to the private sector.

The main focus of alternative fuel efforts has been on gasoline substitution. There was considerably more experience with conversion of spark ignition engines to fuels such as LPG and CNG than there was with conversion of compression (diesel) engines. In recent years, diesel engine conversion technology has been further developed, and urban air pollution has generated more concern, so countries are turning their attention to diesel substitution. Diesel vehicles tend to have high mileage, and thus shorter payback time, and are often fueled from a central location. Both Brazil and Argentina are embarking on a program of urban diesel fleet conversion to CNG. In the U.S., where diesel prices are more comparable to gasoline, and air pollution is a major concern in many cities, targetting diesel vehicles may be a desirable strategy.

Fuel Flexibility

Except for Brazil, most countries have emphasized dual-fuel as opposed to dedicated vehicles. In New Zealand and Canada, the main target of programs has been conversion of existing vehicles. In the case of New Zealand, the automobile market was

not large enough to warrant production of dedicated vehicles. A factory-manufactured flexible fuel vehicle (which can easily switch between alcohol or gasoline) has generated considerable interest in the U.S. and in Europe, but has not yet been demonstrated on a large scale in any country. Thus, the remarks on consumer attitudes below apply to dual-fuel and dedicated vehicles.

Consumer Attitudes Toward Alternative Fuels

Though reducing the initial cost of conversion through grants and low-interest loans has produced considerable consumer response, many private motorists have been reluctant to convert to alternative fuels. In Brazil, consumers readily bought dedicated alternative fuel vehicles when they offered a clear economic advantage, and supply and cost-advantage of the new fuel were assured by government committment. National pride was also a factor in the countries with major proograms designed to enhance national self-reliance. When governments reduced financial incentives for vehicle conversions or price subsidies, however, conversions and sales of vehicles dropped sharply. Revitalization of the programs required restoration of government incentives.

Market surveys have shown that concerns about alternative fuel availability are a major factor in consumer decision-making. Thus, it was important for the government to take the initiative in promoting development of a fueling infrastructure. In New Zealand and Brazil, poor quality of vehicle conversions reduced consumer confidence, and government standards were required to ensure satisfactory performance. In Canada, the cost of vehicle conversion and low gasoline prices have also been cited as barriers to public willingness to use CNG. Fuel cost savings, less harmful emissions, and reliability of Canadian natural gas supplies were factors given in favor of conversion. The shorter driving range was the major problem cited by those who had converted to CNG.

In conclusion, the experience with alternative fuels in other countries indicates the need for strong government support to help overcome uncertainty in the early stages of market development. In addition to providing incentives, the government should develop policies and standards to regulate both the initial and subsequent stages of the program. The challenge for government policy is to determine a level of support that is adequate to encourage the market to seriously consider alternative fuels, but is not so large that it becomes difficult to sustain, creates unrealistic expectations on the part of consumers, or places a burden on the economy. Beginning with high-mileage vehicles where the economics and convenience of alternative fuel use are most favorable will generate familiarity with alternative fuels with the least expenditure of government resources. As market acceptance increases, industries with vested interest in alternative fuels may be willing to assume some of the support initially provided by government.

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720