HB

9

Alaska State Legislature

House of Representatives

Alaska State Capitol
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Representative Harry Crawford
District 21

SPONSOR STATEMENT FOR HB 9

House Bill 9 establishes a hydrogen energy partnership within the Department of Community and Economic Development. The partnership is tasked with facilitating the development of a hydrogen fuel industry in Alaska.

Hawaii has already established a similar commission in preparation for potentially using their geothermal energy resource for producing hydrogen for dispersal throughout the Pacific Rim. If Alaska is going to remain competitive in the field of energy in the United States and throughout the world, we must prepare for the possibility that hydrogen will become a viable fuel.

House Bill 9 addresses this eventuality and establishes the structure necessary for the State of Alaska to accept funding for a hydrogen project in the state.

E-mail: Representative_Harry_Crawford@legis.state.ak.us

IOUSE COMMITTEE REPO

(9)
Date Referred to Committee: April 12, 2005 **FURTHER REFERRALS: Finance**

Date of Committee Action: 4/18/05

The RESOURCES Committee considered: **HB 9**

HOUSE BILL NO. 9 **HYDROGEN ENERGY RESEARCH PROGRAM**

"An Act establishing the Hydrogen Energy Partnership in the Department of Commerce, Community, and Economic Development; requiring the commissioner of commerce, community, and economic development to seek public and private funding for the partnership; providing for the contingent repeal of an effective date; and providing for an effective date."

Recommends it be replaced with [ ] HCS *or* [ ] CS for ________________ (________)
For Senate Bills with new title: [ ] Technical Title [ ] New Title: HCR_______ **[ ] Same Title [ ] New Title**

[ ] attach amendments
[ ] add new referral to ____________Committee
[ ] Letter of Intent___________Committee

List of Abbrev for Depts.:
ADM
CED
COR
CRT
EED
DEC
DFG
GOV
HSS
LEG
LAW
LWF
MVA
DNR
DPS
REV
DOT
UA

***NEW* FISCAL NOTES** *Assigned by Chief Clerk's Office

List by Dept(s):	*FN#	Fiscal	Indet.	Zero

***PREVIOUS* FISCAL NOTES**

List by Dept(s):	FN#	Fiscal	Indet.	Zero
UA	1			✓
CED	2	✓		
CED	3	✓		
CED	4	✓		

Signing with recommendations	Printed Last Name	DP	DNP	NR	AM
Harry T. Crawford Jr.	CRAWFORD	✓			
[signature]	ELKINS	✓			
Paul K. Seaton	SEATON	✓			
[signature]	GATTO				X
Mary Kapsner	KAPSNER	✓			
[signature]	OLSON			✓	
Chair: [signature]	RAMRAS	X			
Chair:					

FISCAL NOTE

STATE OF ALASKA		Fiscal Note Number:	
2005 LEGISLATIVE SESSION		Bill Version:	HB 9
		() Publish Date:	
Revision Date/Time (Note if correction):		Dept. Affected:	Commerce
Title	Hydrogen Energy Research Program	RDU	Executive Admin and Dev (119)
		Component	Office of Economic Development
Sponsor	Crawford, Berkowitz, Ramras		
Requester	House Community & Regional Affairs	Component No.	2743

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

OPERATING EXPENDITURES	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Personal Services						
Travel						
Contractual	95.0	*	*	*	*	*
Supplies						
Equipment						
Land & Structures						
Grants & Claims						
Miscellaneous						
TOTAL OPERATING	95.0	*	*	*	*	*
CAPITAL EXPENDITURES						
CHANGE IN REVENUES (1108)	95.0	*	*	*	*	*

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts						
1003 GF Match						
1004 GF						
1005 GF/Program Receipts						
1037 GF/Mental Health						
1108 Statutory Designated Program Rcpts	95.0	*	*	*	*	*
TOTAL	95.0	*	*	*	*	*

Estimate of any current year (FY2005) cost: 0.0

Mark this box (X) if funding for this bill is included in the Governor's FY 2006 budget proposal: [ ]

POSITIONS

Full-time						
Part-time						
Temporary						

ANALYSIS: *(Attach a separate page if necessary)*

This legislation creates the Hydrogen Energy Partnership to facilitate the development of a hydrogen fuel industry in Alaska. The partnership would consist of nine members and be housed in the department. The department is charged with securing federal and private funding sources to cover the costs of establishing and operating the partnership. The department does not currently have sufficient resources to actively seek funding. If funding is secured, the department would appoint partnership members, RSA funds to the Alaska Energy Authority and begin to provide staff support.

After FY06, federal and/or private funding sources, if obtained, would fund partnership operations and staff. In the event funds are not obtained, provisions would be repealed as outlined in the bill.

Prepared by:	Albert Clough, Deputy Commissioner	Phone	907-465-2500
Division	Commerce, Community, and Economic Development	Date/Time	4/11/05 3:45 PM
Approved by:	Edgar Blatchford, Commissioner	Date	4/11/2005
Agency	Commerce, Community, and Economic Development		

(Revised 9/23/2004 OMB)

FISCAL NOTE

STATE OF ALASKA
2005 LEGISLATIVE SESSION

Fiscal Note Number:
Bill Version: HB 9
() Publish Date:

Revision Date/Time (Note if correction):

Title	Hydrogen Energy Research Program	Dept. Affected:	Commerce
Sponsor	Crawford, Berkowitz, Ramras	RDU	AIDEA (125)
Requester	House Community & Regional Affairs	Component	AIDEA
		Component No.	1234

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

OPERATING EXPENDITURES	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Personal Services	74.0	*	*	*	*	*
Travel						
Contractual						
Supplies						
Equipment						
Land & Structures						
Grants & Claims						
Miscellaneous						
TOTAL OPERATING	**74.0**	*	*	*	*	*
CAPITAL EXPENDITURES						
CHANGE IN REVENUES ( )						

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts						
1003 GF Match						
1004 GF						
1005 GF/Program Receipts						
1037 GF/Mental Health						
1007 Interagency Receipts	74.0	*	*	*	*	*
TOTAL	**74.0**	*	*	*	*	*

Estimate of any current year (FY2005) cost: 0.0

Mark this box (X) if funding for this bill is included in the Governor's FY 2006 budget proposal:

POSITIONS

Full-time	1	*	*	*	*	*
Part-time						
Temporary						

ANALYSIS: *(Attach a separate page if necessary)*

This legislation creates the Hydrogen Energy Partnership to facilitate the development of a hydrogen fuel industry in Alaska. The partnership would consist of nine members and be housed in the department. The department is charged with securing federal and private funding sources to cover the costs of establishing and operating the partnership. The department does not currently have sufficient resources to actively seek funding. If funding is secured, the department would appoint partnership members, RSA funds to the Alaska Energy Authority and begin to provide staff support.

AIDEA provides staff support for AEA programs.

Prepared by:	Sara Fisher-Goad, Financial Analyst	Phone	907 269.4623
Division	Alaska Industrial Development & Export Authority	Date/Time	4/11/05 3:38 PM
Approved by:	Ron Miller, Executive Director	Date	4/11/2005
Agency	Alaska Industrial Development & Export Authority		

(Revised 9/23/2004 OMB)

FISCAL NOTE

STATE OF ALASKA
2005 LEGISLATIVE SESSION

Fiscal Note Number:
Bill Version: HB 9
() Publish Date:

Revision Date/Time (Note if correction):
Title: Hydrogen Energy Research Program
Sponsor: Crawford, Berkowitz, Ramras
Requester: House Community & Regional Affairs

Dept. Affected: Commerce
RDU: Alaska Energy Authority (453)
Component: AEA Rural Energy Operations
Component No. 2600

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

OPERATING EXPENDITURES	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Personal Services						
Travel	15.0					
Contractual	74.0	*	*	*	*	*
Supplies	6.0					
Equipment						
Land & Structures						
Grants & Claims						
Miscellaneous						
TOTAL OPERATING	95.0	*	*	*	*	*

CAPITAL EXPENDITURES						

CHANGE IN REVENUES ( )						

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts						
1003 GF Match						
1004 GF						
1005 GF/Program Receipts						
1037 GF/Mental Health						
1007 Interagency Receipts	95.0	*	*	*	*	*
TOTAL	95.0	*	*	*	*	*

Estimate of any current year (FY2005) cost: 0.0

Mark this box (X) if funding for this bill is included in the Governor's FY 2006 budget proposal: [ ]

POSITIONS

Full-time		*	*	*	*	*
Part-time						
Temporary						

ANALYSIS: *(Attach a separate page if necessary)*

This legislation creates the Hydrogen Energy Partnership to facilitate the development of a hydrogen fuel industry in Alaska. The partnership would consist of nine members and be housed in the department. The department is charged with securing federal and private funding sources to cover the costs of establishing and operating the partnership. The department does not currently have sufficient resources to actively seek funding. If funding is secured, the department would appoint partnership members, RSA funds to the Alaska Energy Authority and begin to provide staff support.

AEA estimates needing a Development Specialist II ($74.0) to secure the federal or private funding sources and begin organizational work for the partnership. Because responsibilities could not be absorbed by existing staff, one new FTE would be required along with funds ($6.0) for a computer and supplies. Travel funds ($15.0) are included for partnership members to meet up to three times annually and to cover cost of in-state and out-of-state travel for the Development Specialist for organizational purposes and to secure federal grants. After FY06, federal and/or private funding sources, if obtained, would fund partnership operations and staff. In the event funds are not obtained, provisions would be repealed as outlined in the bill.

Prepared by: Sara Fisher-Goad, Financial Analyst — Phone 907 269 4623
Division: Alaska Energy Authority — Date/Time 4/11/05 4:05 PM

Approved by: Ron Miller, Executive Director — Date 4/11/2005
Agency: Alaska Energy Authority

(Revised 9/23/2004 OMB)

FISCAL NOTE

STATE OF ALASKA
2005 LEGISLATIVE SESSION

Fiscal Note Number:
Bill Version: HB9
() Publish Date:

Revision Date/Time (Note if correction):
Title: HYDRO EN ENERGY RESEARCH P
Sponsor: Representativ) Crawford, Berkowitz
Requester:

Dept. Affected: University of Alaska
RDU:
Component:
Component No.:

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

OPERATING EXPENDITURES	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Personal Services						
Travel						
Contractual						
Supplies						
Equipment						
Land & Structures						
Grants & Claims						
TOTAL OPERATING	0.0	0.0	0.0	0.0	0.0	0.0
CAPITAL EXPENDITURES						
CHANGE IN REVENUES ( )						

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts						
1003 GF Match						
1004 GF						
1005 GF/Program Receipts						
1037 GF/Mental Health						
1048 University Receipts						
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0

Estimate of any current year (FY2005) cost: 0.0
Mark this box (X) if funding for this bill is included in the Governor's FY 2006 budget proposal: [ ]

POSITIONS

Full-time						
Part-time						
Temporary						

ANALYSIS: *(Attach a separate page if necessary)*

Any additional faculty and staff resources required would be grant funded from industry or federal sources. Staffing requirement will be dependent on specific grant proposal and may vary widely and are difficult to predict given the infancy of the program.

Prepared by: Pat Pitney
Division: UA SW Planning and Budget Development
Phone: 907-450-8191
Date/Time: 4/11/05 9:07 PM

Approved by: Pat Pitney
Agency: University of Alaska
Date: 4/11/2005

(Revised 12/2003 OMB)

Fuel Cells Provide Reliable Power to U.S. Postal Service Facility in Anchorage, Alaska

Combined heat and power project provides reliable power at reduced cost

Combined Heat and Power

Case Study

Overview

Working together, the U.S. Postal Service (USPS) and Chugach Electric Association, partnering with the Department of Defense (DOD), Department of Energy (DOE), US Army Corps of Engineers Construction Engineering Research Laboratories (USA CERL), Electric Power Research Institute (EPRI), and National Rural Electric Cooperative Association (NRECA), developed and installed one of the largest fuel cell installations in the world.

The one-megawatt fuel cell combined heat and power plant sits behind the Anchorage U.S. Postal Service Mail Processing and Distribution Facility. Chugach Electric owns, operates, and maintains the fuel cell power plant, which provides clean, reliable power to the USPS facility. In addition, heat recovered from the fuel cells, in the form of hot water, is used to heat the USPS Mail Processing and Distribution Facility. By taking a leadership role, the USPS will save over $800,000 in electricity and natural gas costs over the 5½-year contract term with Chugach Electric.

"Fuel cells solved a handful of problems."

—Cathe Grosshandler, Alaska District Environmental Coordinator, U.S. Postal Service

Background

The U.S. Postal Service Mail Processing and Distribution Facility, adjacent to the Anchorage International Airport, serves as the postal hub for all of Alaska. The facility processes, on average, over one million pieces of mail every day, operating 24 hours per day, 365 days per year. Annual energy costs for the 270,000-square-foot facility exceeded $300,000 for electricity and $35,000 for natural gas.

The facility faced a series of issues that needed to be addressed. To meet new environmental codes, the facility needed to upgrade an existing underground fuel oil tank serving the facility's 600-kW emergency generator. As a result of an expansion to the facility and adding new optical mail processing equipment, the facility's peak electric demand had grown larger than the existing emergency generator could support. Upgrades were also needed to the UPS (uninterruptible power supply). In addition, the two 80-horsepower boilers (2,700,000 Btu/h), which heat the facility, also needed some improvements.

The Mail Processing and Distribution Facility, adjacent to the Anchorage International Airport, is key to the Alaska mail system.

Rather than solving each issue separately, the District Environmental Coordinator wanted a comprehensive solution. The answer seemed to lie in a highly reliable, highly efficient combined heat and power plant.

Project Summary

Initially, a combined heat and power plant using natural gas engine generators was proposed. However, after attending a local energy technology show, the USPS began to consider fuel cells. By coincidence Chugach Electric Association, the serving electric utility, was developing expertise in fuel cell technology and supported the USPS interest in the emerging technology.

Fuel cells produce electricity through an electrochemical reaction rather than combustion. While more expensive than conventional power generating equipment, fuel cells provide efficient, reliable power with minimal emissions. (For more information on fuel cells, see FEMP's Federal Technology Alert, "Natural Gas Fuel Cells," at http://www.eren.doe.gov/femp/prodtech/fed_techalert.html.)

To increase overall reliability, the combined heat and power plant consists of five fuel cells with room for a future sixth unit. Thus, the system can meet the facility's peak 800-kW demand even when one fuel cell is off-line. The resulting one-megawatt (1,000-kW) combined heat and power plant consists of five fuel cells, a nitrogen tank, heat recovery equipment, a pump house, and the site management system (SMS).

The fuel cells, manufactured by International Fuel Cells, Inc. (formerly ONSI), are rated at 200 kW each and are fueled by natural gas. Nitrogen is used to purge the fuel cells during startup and shutdown cycles. The pump house is used to move the heat generated by the fuel cells to either the facility for space heating or to the cooling modules, where the excess heat is rejected.

What makes the system a success is the site management system. The SMS includes fuel cell load control, grid interconnection, and a high-speed switching system. The SMS allows the multiple fuel cell system to transfer between grid-parallel and grid-independent in under 4 milliseconds (1/4 cycle in a 60-Hz system), fast enough that the highly sensitive computer systems in the USPS facility are not interrupted by the transfer. Normally, the fuel cells operate in parallel with the Chugach electric grid. Excess power generated by the fuel cells flows out into the Chugach grid. However, in the case of a grid outage, the SMS identifies the outage, isolates the USPS facility from the grid and allows the fuel cells to transfer to grid-independent mode seamlessly. The SMS was developed under this project but is now commercially available and being specified for use in other fuel cell power systems.

Set against the Chugach Mountains, five fuel cells supply reliable and clean power to the USPS facility.

The entire project cost $5.5 million, including the research and development for the SMS. Funding for the project came from the many partners involved in the effort. What made the project work economically for the U.S. Postal Service is a special contract between the USPS and Chugach Electric. Chugach Electric owns, operates, and maintains the fuel cell power plant, which is located on the USPS property. The plant is remotely operated by Chugach Electric. The only cost to the USPS was the $1 million up-front cost as part of a 5½-year contract for baseline electrical service. In return, Chugach Electric provides electricity to the mail processing facility for the 5½-year term. If electricity requirements at the USPS facility grow above the set baseline, which the USPS believes is unlikely, additional electricity is purchased at standard rates.

In addition, the USPS facility owns the use of the heat recovered from the fuel cells. Heat energy from the fuel cells is available in the form of hot water at two temperatures: 240°F and 140°F. At this time, the higher temperature water is used for heating the facility. The lower temperature heat is rejected through the cooling modules.

Benefits

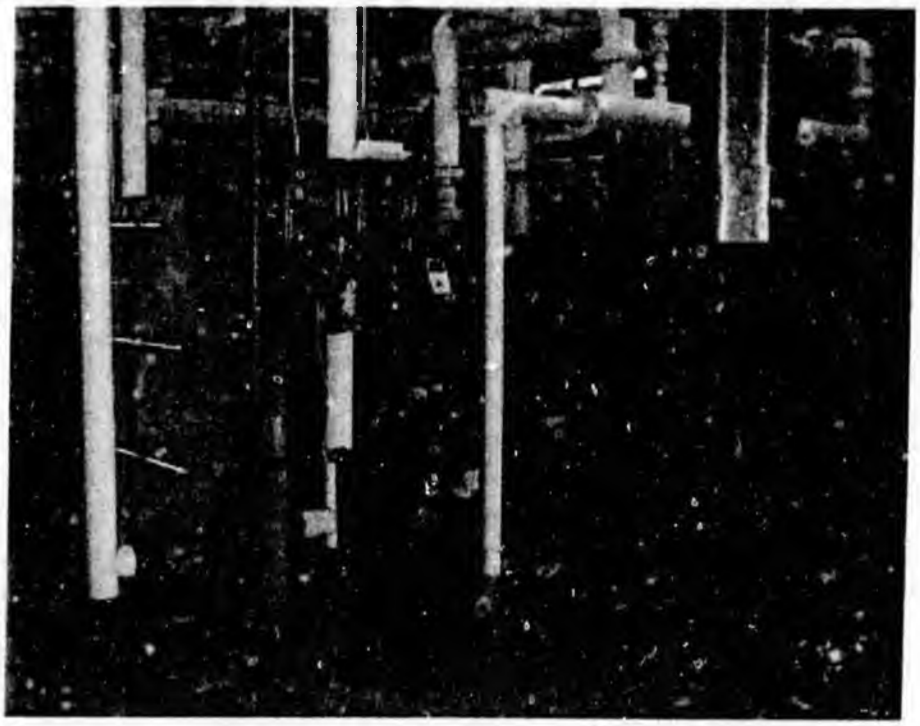
The fuel cell CHP plant provides a number of benefits to the USPS. The most significant benefit has been the increased reliability of electric service.

Restarting the mail processing equipment after a power outage requires a significant level of effort. The increased reliability results in fewer power outages, thereby avoiding unscheduled shutdowns and restarts. The fuel cell and SMS have worked flawlessly since commissioned. In fact, the week before Christmas, on one of the busiest days of the year, construction at the airport caused a local power outage. The entire area was without power for over 4 hours. All, except the U.S. Postal Service, that is. The SMS system automatically switched the facility to operate grid-independent with no interruption. The USPS facility went on to set records, processing over 1.4 million letters and parcels that day, while the neighbors were sitting in the dark.

While the combined heat and power project does not reduce electricity consumption at the USPS facility, it does significantly reduce USPS energy costs. The contract between the USPS and Chugach Electric provides baseline electrical service to the USPS facility for 5½ years at a cost of $1 million. Previously, electricity for the USPS facility averaged over $300,000 per year.

Heat recovered from the fuel cells is being used for space heating in the mail processing facility, thereby displacing the load on the original boiler heating system. In fact, savings have exceeded the original estimate. Initially, it was determined that the fuel cell heat energy could meet around 50% of the total facility space heating needs. During the first year of operation, the heat recovered has satisfied all the space heating needs. Although the winter of 2000-2001 was milder than average, heat recovered from the fuel cells has exceeded expectations.

Some capital cost reductions were also achieved. The demonstrated reliability of the fuel cell and site management system has eliminated the need to upgrade the existing emergency generator. However, the old 1000-gallon, single-wall, below-grade fuel oil tank still needed to be replaced. A new dual-wall, 500-gallon, above-ground fuel oil tank was determined to be sufficient because of the increased reliability of the new power supply system. In addition to the cost reduction from the less expensive, smaller tank, the environmental code features were also less expensive for the smaller tank size. Avoiding the need to upgrade the emergency generator and installing a smaller fuel oil tank saved the USPS an estimated $500,000 in capital costs.



Heat recovered from the fuel cells offsets heat supplied by the boiler system. The boilers were not needed during the winter of 2000–2001.

Lessons Learned

The USPS recommends that any site thinking about a similar project should consider the following:

- Projects of this nature require "champions." Each of the parties involved in the project recognized the value of local champions who could think outside the box, overcome barriers, and push the project through.
- Consult with the local utility, DOE regional office, and other organizations to investigate potential partnerships. Both the USPS and Chugach Electric Association believe a more effective solution was achieved as a result of the partnership.
- Take a holistic approach to solving facility needs. The USPS had to address a series of issues. Although each facility need could have been solved individually, the fuel cell combined heat and power plant solved several of the needs simultaneously and at a lower cost.

Being the largest fuel cell installation of its time made this a distinctive installation. However, it will not remain unique. The development of the SMS will lead to more multi-unit fuel cell power plants with high-speed reliability.

Looking Ahead

The USPS facility is looking for additional uses for the heat recovered from the fuel cells. While the high temperature heat recovered is perfect for space heating, there is still significant heat energy available at 140°F, which has yet to be utilized. The USPS is still investigating several potential uses for this valuable heat energy.

The SMS has additional capabilities that the USPS may use in the future. In addition to controlling fuel cell operation, the SMS is also capable of controlling peak electrical demand through load shedding. This feature could be used to prevent overloading the power plant when the electric grid is down and the fuel cells are operating independent of the electric grid. The ability to load shed while operating grid-independent could prevent a shutdown of the fuel cell power plant as a result of an overload condition.

At the end of the contract period, the USPS and Chugach Electric will renegotiate the future of the fuel cell combined heat and power plant. No one knows what the future may bring, but all agree the project has been a success.

For More Information

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Web site: www.eren.doe.gov/femp

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Produced for the U.S. Department of Energy (DOE) by the Pacific Northwest National Laboratory

PNNL-SA-35098

February 2002

Nova: Science in the news

Back to the normal view

Published by the Australian Academy of Science

Which way ahead for hydrogen cars?

Rising petrol prices and diminishing oil supplies may drive motorists to demand alternative forms of fuel – such as hydrogen.

Contents

Back to basics
You will get more from this topic if you have mastered the basics of energy – this link will take you to an annotated list of sites with helpful background information.

Key text

Competitors in the men's and women's marathons at the 2000 Sydney Olympics had an exciting glimpse of the future. The pace vehicle that led them round the 42-kilometre circuit looked like a typical family wagon, but looks were deceptive. Under the bonnet was a stack of fuel cells, not an internal combustion engine. And as the car glided silently forward it emitted no smelly fumes or greenhouse gases – just a little water vapour.

The car was powered by hydrogen, the simplest and most abundant of all chemical elements. The fuel cells under the bonnet converted the hydrogen directly into electricity.

Many experts think hydrogen will replace petrol, diesel and natural gas as the main fuel for cars, buses and trucks over the next few decades. Already car manufacturers around the world have invested billions of dollars in research and development.

The advantages of hydrogen are enormous: no more smog-forming exhaust gases, no more carbon dioxide emissions that contribute to global warming, no more worries about diminishing oil supplies and rising prices.

But some tricky questions need to be answered before mass-produced hydrogen cars start appearing on the streets:

- Where will the hydrogen come from?
- How will motorists fill up?
- How will cars store the fuel?

And there's also the question of how best to tap the energy in the fuel for good on-road performance.

The choice – combustion or fuel cells?

Two kinds of engines can use hydrogen as a fuel – those that have an internal combustion engine converted to use hydrogen and those that are made up of a stack of fuel cells.

Internal combustion engines

Internal combustion engines have powered cars since they first began to replace horse-drawn carriages more than 100 years ago. These engines can be converted to run on a variety of fuels, including hydrogen. When hydrogen burns, the only by-product is water – not the polluting cocktail given off by burning petrol and other fossil fuels.

BMW successfully demonstrated this technology in a fleet of 15 sedans used to ferry people to and from EXPO 2000, the world fair in Hanover, Germany. The fact that no major changes need to be made to the basic internal combustion engine design is a major attraction.

Fuel cell engines

However, most car makers think that fuel cells powering an electric motor offer a better alternative. Electric cars are hardly a new idea, but the need to recharge heavy stacks of batteries after relatively short journeys has stopped them becoming popular. Now fuel cells have made electric cars practical.

Unlike batteries, which store electricity, fuel cells make electricity as they go. Recent developments in technology have greatly increased the amount of power that a stack of cells – small enough to fit under a car's bonnet – can provide. This has opened up the prospect of non-polluting electric cars with the levels of performance we expect from conventional vehicles.

Fuel cell technology sounds simple. The hydrogen fuel reacts with oxygen from the air to produce water and electricity – the reverse of the familiar electrolysis process that releases oxygen and hydrogen from water. In reality it's much more complicated. Box 1 outlines how fuel cells will power our cars.

The big advantage of a fuel cell engine over an internal combustion engine running on hydrogen is its greater efficiency. The same amount of hydrogen will take a fuel cell car at least twice as far as one with a converted internal combustion engine.

Fill 'er up please

Hydrogen has many advantages as a fuel for vehicles, but a big disadvantage is that it is difficult to store. This is because at normal temperatures hydrogen is a gas. The hydrogen must be packed tightly into a car's tank, otherwise a filling stop will be needed every few kilometres.

The obvious solution is to strongly compress the hydrogen, or liquefy it. However, large amounts of energy are needed for this – an estimated 20–40 per cent of the energy content of the fuel. Also, tanks designed to hold hydrogen at extremely high pressures, or at temperatures approaching absolute zero, are heavy and expensive.

A futuristic filling station kept EXPO 2000's fleet of converted BMWs running. Drivers pulled up at the pump, pressed a button on their dashboard, and watched from inside the car as a laser-guided robotic arm connected the store of liquid hydrogen to their tank. Filling took about 3 minutes. It was wise to keep well out of the way – at minus 253°C, liquid hydrogen is unimaginably cold.

The special insulated tanks in the BMWs held 140 litres of hydrogen, enough to drive at least 300 kilometres. (That's a reasonable range, although a 95 litre tank of petrol would take the same cars twice as far.) The hydrogen-powered marathon car at the Sydney Olympics also ran on liquid hydrogen. Its much smaller tank (75 litres) gave it a range of about 400 kilometres, a sign of the greater efficiency of fuel cell cars.

High cost and the large amount of energy needed to liquefy the fuel are likely to be the main problems with refuelling with liquid hydrogen. Filling up with compressed hydrogen gas will probably prove more practical, even though it may reduce the distance between fills. Cars could store the hydrogen in high pressure tanks similar to those used for compressed natural gas. Or, if current research proves successful, some high-tech alternatives could be employed.

Scientists have found that various metals can absorb up to a thousand times their own volume of hydrogen gas. Specially treated carbon may also hold large amounts. These discoveries could shape the fuel tanks of the future (Box 2).

But where will the hydrogen come from?

There's no risk that we'll ever run out of hydrogen, it's by far the most plentiful element in the universe. On Earth, however, it exists naturally only in chemical compounds, not as hydrogen gas. Water and the main components of coal, oil and natural gas are prime examples of these compounds.

Natural gas currently provides most of the hydrogen used in industry. The relatively simple technology employed – **steam reforming** – could also produce hydrogen gas for cars at central plants or filling stations. Alternatively fuel tanks could be filled with petrol or methanol, with the cars using on-board 'reformers' to generate hydrogen for their fuel cells. This shows promise as a transitional measure while research proceeds on the problems of storing hydrogen.

In steam reforming the hydrocarbon fuel reacts with water at high temperatures to produce hydrogen gas. A major drawback is that carbon dioxide and smog-causing gases such as nitrogen oxides are given off too, although emissions per kilometre of car travel would be less than from petrol-burning vehicles.

An alternative approach now under development, **autoreforming**, should increase the attractiveness of on-board hydrogen production. Use of a catalyst will allow the reforming to occur at much lower temperatures – too low for the production of nitrogen oxides.

Water is the only potentially pollution-free source of hydrogen. Researchers are looking at new ways of producing hydrogen – using algae, bacteria or photovoltaic cells to absorb sunlight and split water into hydrogen and oxygen. But the technology most likely to be adopted on a large scale is electrolysis, which uses an electric current to split water into oxygen and hydrogen.

Is it safe?

'Remember the Hindenburg' – that's a phrase often heard when hydrogen is discussed. This German passenger airship, kept aloft by hydrogen, crashed in flames as it came in to land at Lakehurst, New Jersey, USA in May 1937. Thirty-five people died. Nowadays helium, which can't burn, is the gas of choice for lighter-than-air craft.

Hydrogen is highly flammable, but recent research has indicated that the airship's fabric, not hydrogen, was the culprit in the Hindenburg disaster. Properly handled, there's no reason to think hydrogen is any more dangerous as a fuel than petrol, the explosive liquid now carried safely in the tanks of untold millions of motor vehicles.

Looking forward

Recent technological advances, particularly in fuel cell design, have made hydrogen-powered cars a practical proposition, and car makers expect to start mass-producing them within the next decade or so. Their power and acceleration should match those of today's petrol-powered vehicles, but they may have to be refuelled more often.

The best ways to produce, distribute and store the hydrogen still have to be sorted out. In the short term fossil fuels may remain in demand as a hydrogen source. However, the idea that in the not too distant future most of us will be driving non-polluting cars fuelled by hydrogen from a clean, renewable source is no longer a flight of fantasy.

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Box 1. Plenty of power from fuel cells

The fuel cells in the Opel wagon that stole some of the limelight at the marathons at the 2000 Sydney Olympics took up no more space than a normal car engine. A few years ago the stack of fuel cells needed to run such a car would have taken up the whole boot and back seat area. And the hydrogen-powered Opel has good performance credentials – it can accelerate from 0 to 100 kilometres per hour in 16 seconds and has a top speed of 140 kilometres per hour.

Fuel cells have been around for a long time – Sir William Grove, a Welsh physicist, invented one that ran on hydrogen way back in 1839 – but their potential as a commercial power source is only now beginning to be realised. With different applications in mind (from large-scale power generation to electricity for portable electronic devices), researchers are working on many types of cells – **alkaline, phosphoric acid, molten carbonate** and **proton exchange membrane** (PEM). In Australia, CSIRO and industry researchers are collaborating in developing a **solid oxide** fuel cell.

A fuel cell for vehicles

For vehicles, attention has focused on the PEM fuel cell. Its key component, the membrane, is a sheet of rubbery plastic coated with a platinum catalyst. The catalyst splits hydrogen gas into protons and electrons (a hydrogen atom comprises just one proton and one electron). The protons pass through the membrane and the electrons leave the cell along wires; this is the electric current generated by the cell. When the protons and electrons meet again on the other side of the membrane, they combine with oxygen to form water. As long as hydrogen is supplied the cycle continues, with hydrogen and oxygen being turned into water while generating electricity. A great advantage of this type of fuel cell is that it operates at 60-90ºC whereas other types require temperatures of 500-1000ºC.

The breakthroughs that turned stacks of PEM cells into suitable power packs for cars came in the 1990s. Ballard Power Systems of Canada, whose two largest shareholders are DaimlerChrysler and Ford, discovered a way to multiply a stack's power output per litre from less than 200 to more than 1300 watts. With such a stack under the bonnet, an electric car can match the performance of petrol-powered models.

Trials of PEM fuel cell buses in Perth

Trials of Mercedes-Benz buses powered by Ballard's PEM fuel cells have been conducted successfully over the past few years in Chicago and Vancouver, and now Perth has been chosen as one of eleven cities around the world to host a bigger series of trials. Beginning in 2002, these trials will involve a total of 33 fuel cell powered buses. The three buses in Perth will slot into the regular commuter fleet and be fuelled by hydrogen produced at the BP