



## Israel makes an ambitious move on alternative fuels

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Israel is a tiny country with minimal natural resources. It generates one-tenth of the energy it uses and relies on imports from other nations to meet its energy needs.

What the country of eight million has, however, is plenty of innovation, risk-takers, and willful policymakers. That is the reason it leads the world in the number of high-tech start-up companies per capita, as Dan Senor and Saul Singer lay out in their book *Startup Nation: The Story of Israel's Economic Miracle*.

Israel now wants to be a global leader in alternative fuel technologies. Through a 10-year US\$430 million program called the Fuel Choices Initiative (FCI), it is investing heavily in cutting-edge research on batteries, biofuels, and solar water splitting. It is backing startups developing green transport technologies and offering an annual US\$1 million prize to innovators. It aims to be a local test bed for sustainable transport, collaborate with entities across the world, and raise global awareness of alternative fuels. And to lead by example, it has set itself an ambitious energy goal: Cut oil use in transportation by 60% by 2025.

“We’d like to change the world,” says Eyal Rosner, chair and director of administration of FCI.

Reducing dependence on oil is a strategic need for Israel. It produces just a few thousand barrels a day, which means it imports nearly all the oil it uses. But recent technological advances in transportation, rising oil prices, and a growing global understanding of oil’s environmental impact make the time right for such an initiative, Rosner said. “When I talk to the Chinese, they don’t care about price, they worry that people aren’t able to breathe,” he said. “So a shift away from oil isn’t just nice, it’s a necessity.”

The initiative’s goal is to escort new green fuel technologies from the drawing board to the international market, said Rosner. This means not just funding and promotion, but also establishing the right regulatory support. The initiative encompasses 10 government ministries—the Prime Minister’s Office, energy, transport, economy, environmental protection, science, finance, defense, agriculture, and foreign affairs—and brings together over 100 companies, 130 research groups, and hundreds of entrepreneurs.

“The idea is to create one organization that will try to create a collaboration and coordinate all these players,” said Ophir Gore, director of the Energy and Alternative Fuels Department in the National Energy & Water Program, which helps startups market themselves internationally and connect them with non-Israeli investors and research collaborators. “Every ministry has an agenda, but there was no coach telling all the players how to play together. The Fuel Choices Initiative is now the coach,” said Gore.

Natural gas will play an important role as the country transitions away from oil to batteries and sustainable biofuels. Two large offshore natural gas fields were recently discovered in Israeli waters. Israel plans to use compressed natural gas (CNG) and natural gas-based methanol and other liquid fuels for transportation. Israel’s first CNG station should be complete by late 2014. Startup Engineuity has

set up a pilot-scale reactor that converts natural gas into diesel, gasoline, and other drop-in fuels. Separately, a field trial involving a dozen cars running on various gasoline-methanol mixes is under way.

FCI, along with private venture capitalists, is also supporting over a dozen demonstrations of next-generation alternative transportation technologies.

One of these is a pilot of a supercapacitor-powered bus led by Israeli defense company Elbit Systems. Elbit claims that its aqueous supercapacitors have high power and low cost. The e-bus, which will be tested by early 2015, should be able to charge fully during a bus stop in less than 20 seconds and be fully autonomous for 1.5 kilometers with maximum air-conditioning.

An electric car fitted with startup Phinergy’s aluminum-air batteries, meanwhile, has already logged more than 15,000 miles. In the demo car, the new batteries extended the driving range of a lithium ion battery from 60 km to 350 km. In metal-air batteries, a highly porous, catalyzed cathode breathes oxygen from air instead of a traditional cathode, which binds oxygen inside heavy materials. Carbonization has shortened the lifespan of traditional air electrodes. Phinergy states that its silver-based catalyst and novel electrode structure keep CO<sub>2</sub> out, giving a lifespan of thousands of operating hours.

CellEra, another e-mobility player, promises to cut the cost of fuel cells with its platinum-free technology. In conventional polymer electrolyte membrane (PEM) fuel cells, a platinum catalyst at the anode splits hydrogen into hydrogen ions and electrons. The ions flow through a polymer membrane to the cathode, while the electrons go through an external circuit. CellEra’s fuel cell combines PEM technology with that of alkaline fuel cells. It has a solid polymer electrolyte that conducts hydroxyl ions instead of hydrogen ions, creating a mildly alkaline environment as opposed to the acidic environment in conventional PEM cells. This allows the use of a much cheaper transition metal catalyst.

Other ventures are making sustainable liquid fuels. New CO<sub>2</sub> Fuels has built a small-scale prototype reactor that can produce five liters of liquid fuel from CO<sub>2</sub> and water. Large mirrors concentrate sunlight to generate temperature of 1000°C, and a proprietary catalyst helps to strip an oxygen ion off each CO<sub>2</sub> and water molecule to give syngas, a mixture of CO and H<sub>2</sub> that can be converted into liquid fuel. CEO David Banitt said their process's energy efficiency of 40% is one of the highest reported for CO<sub>2</sub>-to-fuel technologies.

The basic research being funded by FCI could lead to many other alternative transportation technologies. At the Israel National Research Center for Electrochemical Propulsion, which spans four universities, researchers are working on projects that cover the gamut of electrical mobility technologies: high-capacity silicon anodes for lithium batteries; platinum-free catalysts for metal-air batteries and fuel cells; carbon nanomaterials for energy storage; lithium-oxygen and lithium-sulfur systems; and novel supercapacitors.

The center is led by Doron Aurbach, director of the Nano Cleantech Center at Bar-Ilan University in Ramat-Gan. Aurbach and his colleagues are collaborating with German chemical giant BASF to develop lithiated silicon-sulfur batteries and new materials for lithium-air batteries.

Aurbach has also teamed up with materials science and engineering professor Gerbrand Ceder at the Massachusetts Institute of Technology to create startup Pellion, which is making a rechargeable magnesium-ion battery. The technology could potentially be safer, lighter, and cheaper than lithium batteries because magnesium is abundant and can theoretically hold more energy per unit volume than lithium. The first working prototype of the battery, made in Aurbach's lab over a decade ago, suffered from low energy density. Pellion is using combinatorial approaches to identify improved electrolyte and cathode materials that could boost energy density.

The FCI also supports the Center for Solar Fuels, where scientists are trying to tap into Israel's plentiful sunshine to make green gasoline, diesel, and jet fuel. The center brings together researchers



Concept car from Phinergy.

at Ben-Gurion University of the Negev, Technion-Israel Institute of Technology, and the Weizmann Institute of Science. Projects include processing cellulosic agricultural waste to extract sugars that can be fermented into alcohol; finessing the thermal conversion of plant biomass into H<sub>2</sub> and CO<sub>2</sub>; using sunlight to split water and reduce CO<sub>2</sub>; and developing novel ways to produce various liquid fuels from H<sub>2</sub>, CO, and O<sub>2</sub>.

Researchers at the center have genetically altered plants to grow with a third of the water required by normal plants and to grow continually irrespective of season. "So we can get more biomass for the same root system and grow these plants in uncultivable land so we're not competing with food," says Gideon Grader, chemical engineering professor at Technion who leads the solar fuels center. The researchers are perfecting the technique on tobacco plants and trying to implement it in biofuel plants such as jatropha.

The center's efforts around photoelectrochemical water splitting, also called artificial photosynthesis, look promising, Grader says. In a photochemical cell, sunlight excites free electrons at the anode, triggering reactions that result in oxygen molecules forming at the anode and hydrogen molecules forming at the cathode. The Israeli team is using proprietary catalysts to aid the reaction. They are playing with different photoelectrode materials—oxides of metals such as iron, titanium, and copper are candidates—and various ways to couple the catalyst with the cell

to increase the cell's efficiency from the current 5% to about 8%.

Partnerships with international alternative fuel players are a big part of the Initiative's aims. Israel has signed working agreements with governments, corporations, and research institutes in the United States, China, Australia, France, and Germany to exchange ideas and research delegations. A joint pilot by Israeli Dan Bus Company and China BYD, for instance, is testing an e-bus for six months, and another pilot on a supercapacitor-powered bus is in the works. Australia's Coogee Energy is running a field trial on methanol and is collaborating with Israeli researchers running a similar pilot through the Initiative.

Access to foreign markets and investment will be crucial for the initiative to have its intended global impact. The domestic market is simply not big enough. But the roster of technologies being supported by the FCI keeps growing. More than 120 startups have been launched in the last 18 months, Rosner pointed out, and yet more are in stealth mode. Most likely won't make it to market, he admits. But the main goal is to make Israel a breeding ground and a test bed.

"Israel is a small place but it's very tech-oriented and new solutions can be adopted very quickly," Rosner said. "Even if most startups fail, at the end of the day, we want to have a couple that make an impact. And even if the final product is developed somewhere else, we've done our part." □