The Bio Battery

An Enzymatic Fuel Cell

The Problem

We all want to use renewable green energy solutions but do we

In New Zealand despite our best efforts **60%** of our energy consumption still comes from burning fossil fuels.

The Problems of Renewable Energy.

For most renewables we can not generate electricity when the sun is not shining and the wind is not blowing.

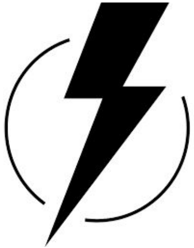
We need portable energy storage solutions for transportation and our portable electronic devices.

Our electricity grids need solutions to handle fluctuations in demand and generation capacity.

Chemical fuels are a fantastic means of energy storage

Energy Storage

The key problem in the renewable energy sector is not generation its energy storage



We need better batteries

Lithium ion batteries are offer the best cost per kW storage technology but they have major downsides.

They have terrible energy storage potential vs chemical fuels

There are fire and explosion hazards

Charging takes time

They are an environmental hazard to dispose of.

They depend on rare earth metals.

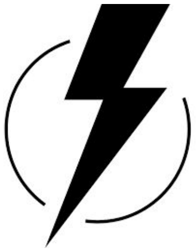
We can’t manufacture enough of them at scale even if we wanted to right now

The Solution

Enzymatic Fuel Cells provide a promising alternative solution

Enzymatic Fuel Cell

(EFC) Uses Enzymes as a catalyst to oxidize a fuel releasing electrons



Enzymatic Fuel Cells

EFC have several advantages over lithium ion batteries and other chemical fuel cells

In comparison to lithium ion the energy density you get is at least 10x better

Biological enzymes are relatively easy to mass produce using common bacteria

We can use cheaply readily available carbon neutral fuels (like glucose or starch)

They don't explode are stable at room temperature, naturally biodegradable, and use liquid fuel easily transportable non toxic or dangerous

No long refueling / recharge times

Existing Research

EFC Technology is still at an early stage and yet to be fully commercialized

nature COMMUNICATIONS

A high-energy-density sugar biobattery based on a synthetic enzymatic pathway

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Nature Communications **volume 5**, Article number: 3026 (2014)

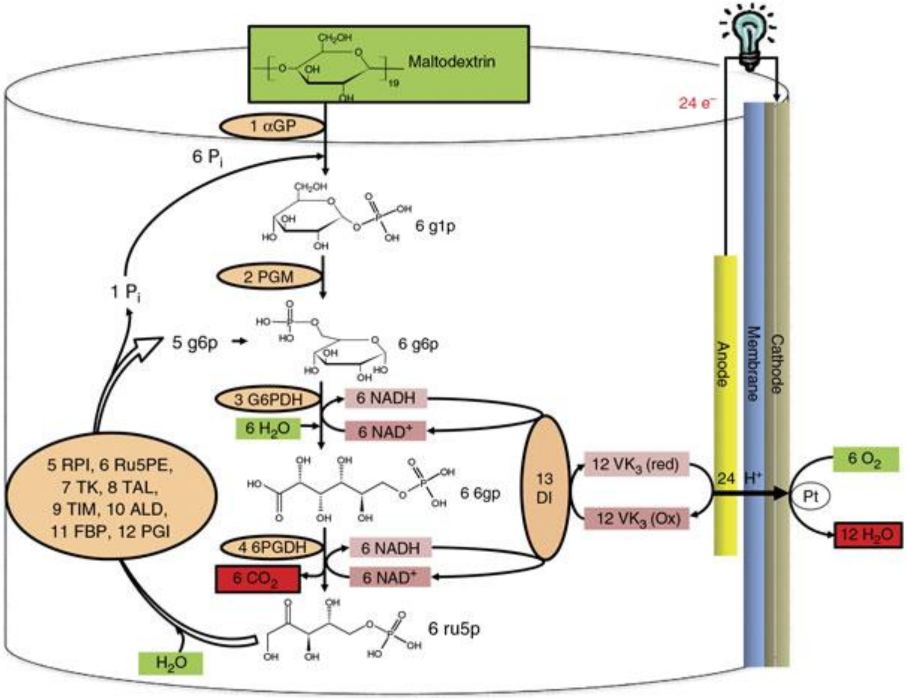
Abstract

High-energy-density, green, safe batteries are highly desirable for meeting the rapidly growing needs of portable electronics. The incomplete oxidation of sugars mediated by one or a few enzymes in enzymatic fuel cells suffers from low energy densities and slow reaction rates. Here we show that nearly 24 electrons per glucose unit of maltodextrin can be produced through a synthetic catabolic pathway that comprises 13 enzymes in an air-breathing enzymatic fuel cell. This enzymatic fuel cell is based on non-immobilized enzymes that exhibit a maximum power output of 0.8 mW cm^{-2} and a maximum current density of 6 mA cm^{-2}, which are far higher than the values for systems based on immobilized enzymes. Enzymatic fuel cells containing a 15% (wt/v) maltodextrin solution have an energy-storage density of 596 Ah kg^{-1}, which is one order of magnitude higher than that of lithium-ion batteries. Sugar-powered biobatteries could serve as next-generation green power sources, particularly for portable electronics.

Project Proposal

The Sugar Battery

We know it works in the lab



Our process is easy

Tesla in Space

The Lab

Building a Closed System

There are 13 enzymes required for a full oxidation

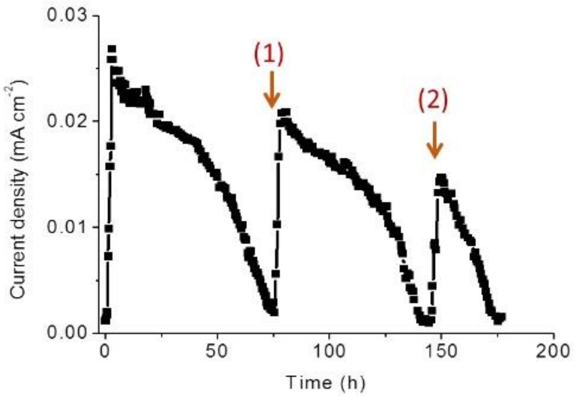
Over time enzymes deteriorate reducing the the efficiency of the cell

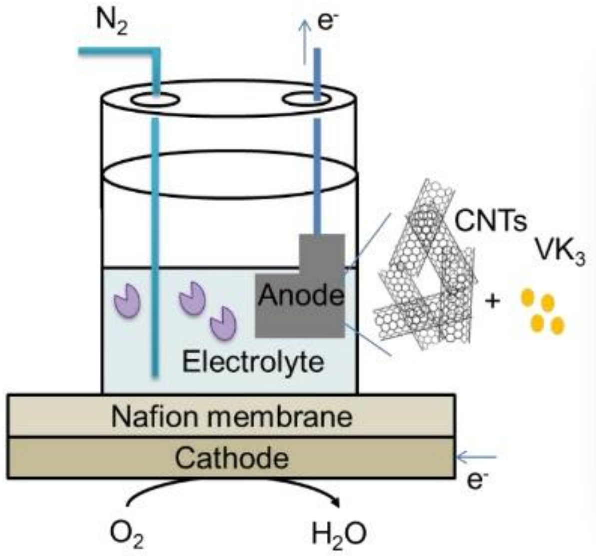
Can we engineer a biological organism to replenish the required enzymes in a closed system

#	Enzyme	EC	ORF	Purification	Sp. Act.* (U mg^{-1})	Load (U/EFC)
1	α-Glucan phosphorylase (αGP)	2.4.1.1	Cthe0357	His/NTA	0.2	5
2	Phosphoglucomutase (PGM)	5.4.2.2	Cthe1265	CBM/intein	151	5
3	Glucose-6-phosphate Dehydrogenase (G6PDH)	1.1.1.49	GenBank accession# JQ040549	His/NTA	4.0	5
4	6-phosphogluconate Dehydrogenase (6PGDH)	1.1.1.44	Moth1283	His/NTA	2.8	5
5	Ribose-5-phosphate Isomerase (RPI)	5.3.1.6	Tm1080	Heat precipitation	60	1
6	Ribulose-5-phosphate 3-Epimerase (Ru5PE)	5.1.3.1	Tm1718	Heat precipitation	0.8	1
7	Transketolase (TK)	2.2.1.1	Ttc1896	His/NTA	1.3	1
8	Transaldolase (TAL)	2.2.1.2	Tm0295	His/NTA	4.1	1
9	Triosephosphate Isomerase (TIM)	5.3.1.1	Ttc0581	Heat precipitation	102	1
10	Fructose 1,6-bisphosphate aldolase (ALD)	4.1.2.13	Ttc1414	Heat precipitation	2.9	1
11	Fructose 1,6-bisphosphatase (FBP)	3.1.3.11	Tm1415	CBM/intein	3.0	1
12	Phosphoglucose Isomerase (PGI)	5.3.1.9	Cthe0217	CBM/intein	201	1
13	Diaphorase (DI)	1.6.99.3	GenBank accession# JQ040550	His/NTA	896	4

*Specific activity was measured at 23°C.

Building a Closed System

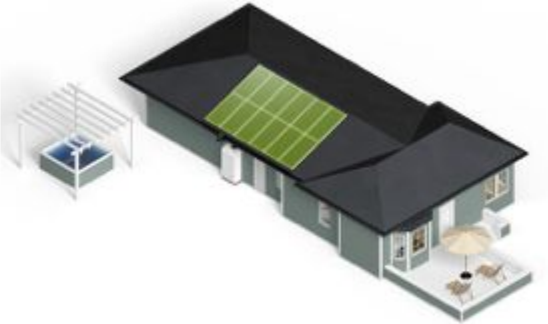


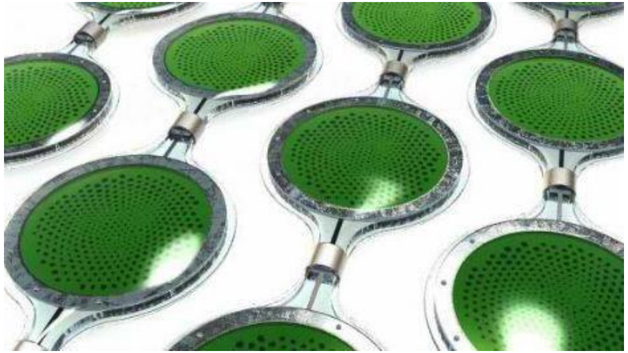


Sugar refilling at Point 1 and 2

Building a Closed System

Algae can be grown in vertical panels, typically this is used as a bio fuel however it can also be engineered to produce cheaper glucose. An MIT startup is currently doing this.





Building a Closed System, Consumer Electronics

In 2007 Sonny released a low power consumer electronics power source.

In 2010 ENE made a soft drink powered remote control car

Efficient Renewable Energy Grid Storage.

Scaling the technology for grid storage

In New Zealand electricity is traded on an wholesale market with the price fluctuating around peek demand.

Could we design a prototype for a EFC on a commercial industrial scale.

Significant funding is available to meet this challenge

Pros & Cons

1. Research we can build off
2. Important problem
3. Fits environmental agenda
4. High commercial interest
5. Funding potential
6. Linkage with VIC enzymatic research strengths
7. Several paths to take using same technology at different scales
8. Cool factor, helps promotion to build working prototype to show off at clubs day etc.

1. Industrial interest and a crowded topic
2. Not the holy grail hydrogen fuel cells and nuclear on paper provide more energy but with higher risks
3. Constructing a battery probably outside our current skill set (not if we recruit a chemist)