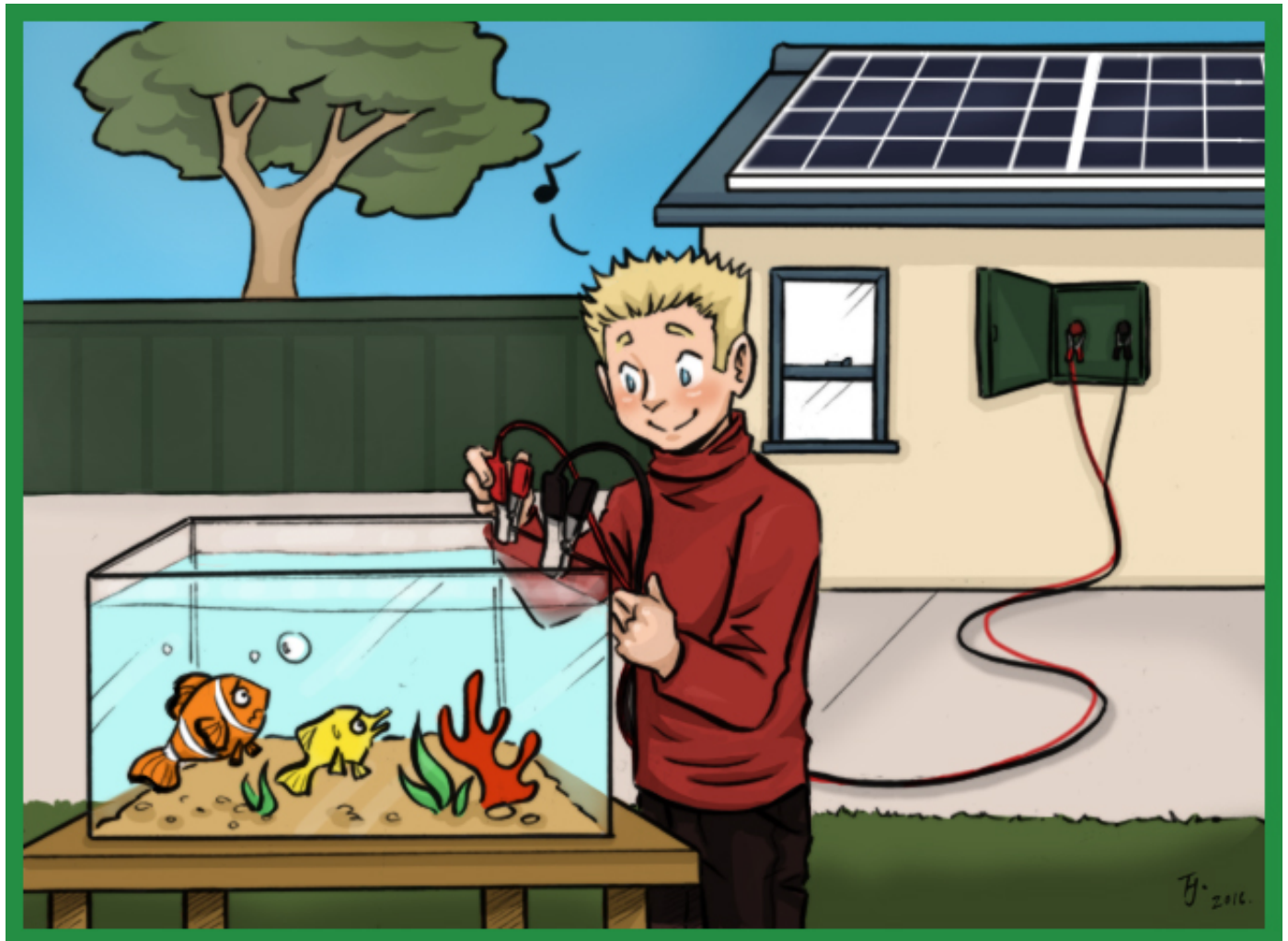


Aquion Battery Review: Safe... But Limited Power & Efficiency

[Ronald Brakels](#)



You can now buy an Aquion salt water battery to power your home. Nemo not included.

UPDATE MARCH 2017: [As of March 8, 2017, Aquion has filed a voluntary petition under Chapter 11 of the United States Bankruptcy Code](#)

UPDATE JULY 2017 : [Aquion Energy is resuming operations](#)

Keen on storing your excess solar in a big battery? Worried about having a

big box of toxic and/or flammable chemicals in your home? Then you'll want to know about the Aquion battery and its salt water technology.

Salt water batteries are making a splash in Australia right now. Or rather, since they are completely sealed, they haven't splashed at all. But the good news is if they did splash you it would not be a problem, as the liquid inside is simply salt water. They are almost certainly the safest battery around. Although their low toxicity does not make them the most environmentally friendly battery, for reasons I'll go into a little later.

Australia is a world leader in salt water battery technology with Western Australia's [Dr Manickam Minakshi](#) doing ground breaking work in the area. Unfortunately, as is far too often the case, lack of support for locally developed clean technology means that the only salt water batteries you can buy here come from the United States.

Salt water batteries are not a new invention, but the first ones practical for home energy storage were produced by the American company [Aquion](#) in 2011. By the middle of 2015 they had sold around 2 [megawatt-hours](#) worth of them in Australia. They are one of the few new battery types that are readily available without the need to go on a waiting list.



A very nice NZ Aquion install using 5 batteries for ~10kWh of storage. I've drawn around a single battery so you can see their shape. They are 94cm high. The red box is the solar inverter. The yellow box is the battery inverter. *Pic courtesy of [SkySolar NZ](https://www.skysolar.co.nz/).*

The Aquion salt water battery has the disadvantage of being very heavy per kilowatt-hour stored. You won't want to lug one around with you to charge your phone when hunting Pokemon.

It also has a low power output. Although the spec sheet claims 1 kilowatt peak power, this is only for 5 minutes. Their usable steady-state power is closer to 400 watts per battery. The power of multiple batteries is additive, so for a typical Aussie home, which can easily draw 5kW for sustained periods, you'd be looking at 12 or more batteries.

It is also important to know that the rate at which you charge and discharge the batteries affects both their:

- storage capacity, and
- roundtrip efficiency.

The details of their current model, the [Aspen 48S-2.2](#) battery, are shown in the table below:

And the official Aquion battery specs are here:

[Download \(PDF\)](#)

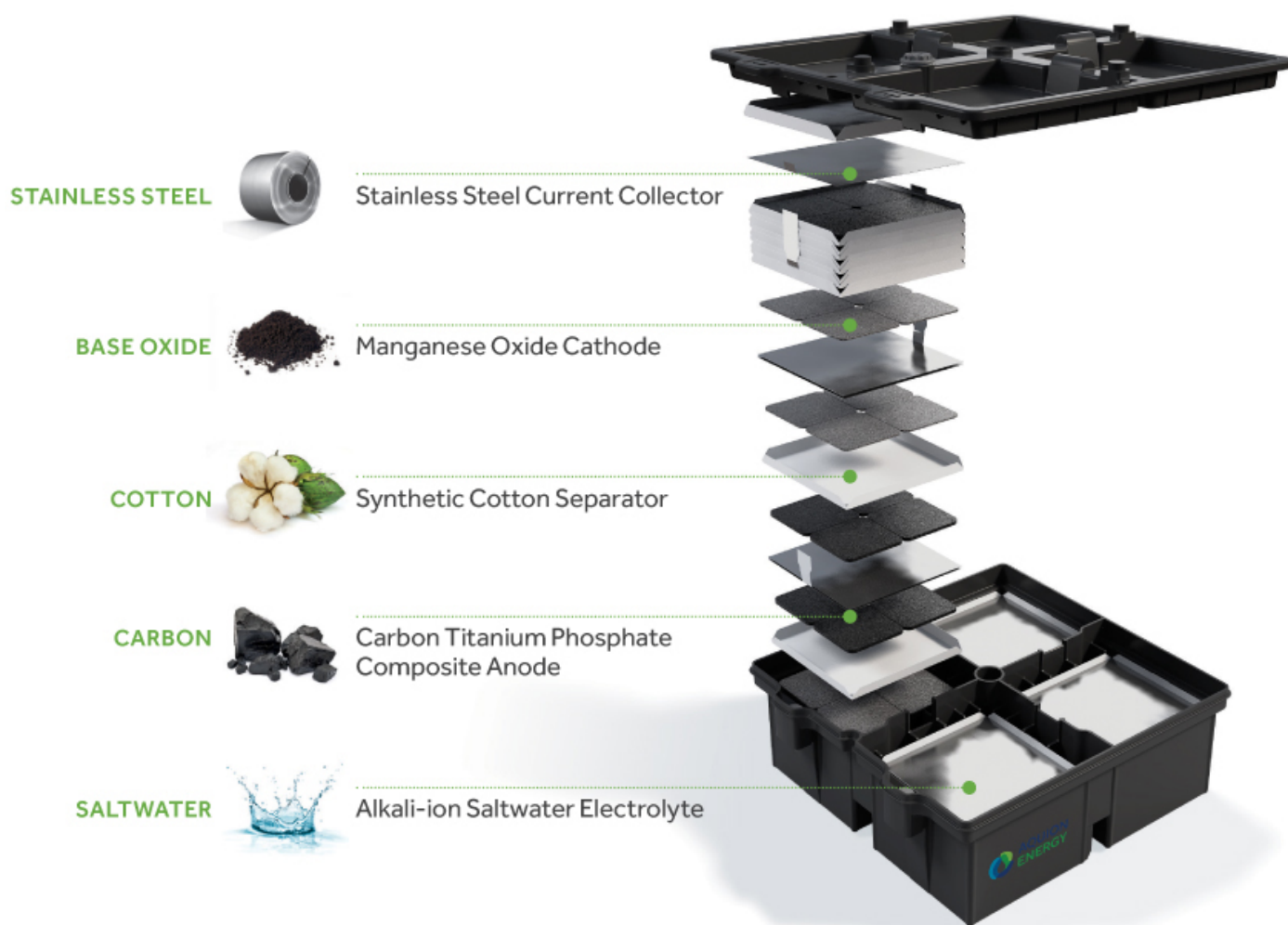
Saltwater Battery Design Philosophy

The Aquion salt water battery was designed by Professor Jay Whitacre. I don't know if he is as smart as Australia's Manickam Minakshi, but he has worked for NASA and he did help develop batteries that are currently in a rover on Mars, so he should know a thing or two about designing reliable batteries.

Jay Whitacre, or J. Whit, as no one calls him, set out to design a battery that was not only low cost, but could also be rapidly put into production to assist

the integration of renewable energy into electricity grids. He created a list of materials that were both common and cheap and set to work creating a battery from them.

He succeeded in making a salt water battery quite literally using the shirt off his back. He cut it up to make cotton separators for his first effective cells. While a salt water battery was not a new invention, his design was innovative and, very importantly in the world of business, beat the competition into manufacturing.



The great thing about the Aquion salt water battery is its simple construction and its use of abundant, non-toxic materials. The downside is the sheer amount of material needed due to its enormous size. The image shows a cell that will store 0.275 kWh. So 8 of these make up a single 2.2kWh battery. *Image: Aquion*

Australia Received The Very First Aquion Batteries

Aquion sent their very first commercial batteries to Australia for testing. So many battery companies have selected Australia for their first installations it makes me feel very special. I haven't felt a warm glow like this since the time Britain shipped some of the [very first atomic bombs](#) they made to South Australia.

Aquion Battery Technology

The Aquion salt water battery consists of a plastic case with layers of stainless steel charge collectors, manganese oxide [cathodes](#), [anodes](#) that are mostly carbon, and separators made of what Aquion call synthetic cotton but normal people call rayon.

The entire cell assembly soaks in a salt water electrolyte solution that makes use of sodium, lithium, and hydrogen ions to transport charge between the cathodes and anodes. This is about as non-toxic as a battery can get. If you are low on electrolytes I don't recommend drinking it because I don't know the lithium concentration, but if for some reason it leaks you can just mop it up and pour it down the drain. It is likely to cause less environmental harm than one [mediocre](#) cow fart.

Salt Water Batteries Are Fire Resistant

Similar to the ocean, salt water batteries are very unlikely to catch fire. However, because they contain water, if something goes wrong and they are overcharged, then electricity can split water into hydrogen and oxygen which does burn.

If salt water batteries are located outside, which they often will be due to their large size, even if a significant amount of hydrogen is released it is

extremely unlikely it could become concentrated enough to result in an explosion.

The Aquion website suggests fire resistance gives them a major advantage over lithium-ion batteries, but given the number of Australians who are happy to have lithium-ion batteries in their laptops and even shove them in their pants when they're not using their mobile phones to chase Pokemon, I'm not sure how big a selling point that will be here.

Usable Energy Storage May Only Be 1.6 kilowatt-hours

Aquion batteries are low power and slow to charge and discharge. The faster they are charged or discharged the more energy is lost as waste heat and the lower their efficiency and capacity. To provide the maximum amount of stored electricity they need to be discharged very slowly. If one is slowly discharged over 20 hours, providing an average power of only 110 watts, it would be possible to get 2.2 kilowatt-hours of electricity from it.

But slowly discharged over 20 hours is not how household battery storage is normally used. As Churchill always said, "Ain't nobody got time fo' dat." Note it is possible we are thinking of different Churchills.

A more realistic discharge time would be 8 hours or less. When discharged over 8 hours it will only provide 1.78 kilowatt-hours. The shortest discharge period Aquion provides data for is 4 hours. When discharged this rapidly their salt water battery can only provide 1.6 kilowatt-hours.

Their Power Is Low And Inconsistent

The highest power output the Aquion battery can maintain over 5 minutes is 1 kilowatt. The 5 minute peak power drops to 900 watts by the time the

battery is only one-third charged and then falls rapidly to 200 watts when the battery is almost fully discharged.

When discharged over 4 hours with a depth of discharge of 90% it should be able to manage a continuous output of around 400 watts.

Round Trip Efficiency Is 80-90%

The rate at which the Aquion battery is discharged has a large effect on its efficiency. If it is charged over 20 hours and discharged over 20 hours its efficiency can be 90%, but as already mentioned, ain't nobody got time fo' dat. If it is instead charged over 4 hours and discharged over 4 hours its efficiency will fall to around 80% or less.

They Can Be Discharged 100% Without Harm

One clear advantage of salt water over lithium-ion and lead-acid batteries is they can be fully discharged without suffering harm. This makes them very safe to transport and store. Unlike lithium-ion batteries they do not gradually decay over time when not in use and so a retailer could store them for months without affecting their warranty. Their ability to be completely discharged and left flat without suffering harm makes them particularly useful for any off-grid use where they may be left inactive for extended periods of time.

Operating Temperature Is -5 To 40°C

Aquion salt water batteries operate from -5 to 40°C. In Australia the lower limit is not likely to be a problem. Even if the temperature does fall below -5°C overnight the batteries are large and have a lot of thermal mass and so they are not likely to have time to freeze before the cold snap is over.

If you do somehow manage to freeze your batteries, you can thaw them out and they will still work. They will be damaged and their capacity will be reduced, but it's a lot better than turning one into a 118 kilogram conversation piece.

In this country higher temperatures are more likely to be a problem. The good news is, provided they are installed out of the sun, they should very rarely if ever exceed their maximum operating temperature in most of Australia. Their massive size is an advantage because it will take them time to heat up. Also, because they are so massive, the waste heat they generate will only slightly increase their temperature, despite their low efficiency.

On the product specification sheet, Aquion states the tests with which they determined their battery's performance were performed at 30°C. This strikes me as an odd temperature to use because, even in a warm location such as Brisbane, a salt water battery installed out of direct sunlight is unlikely to ever reach 30 degrees. As no reason is given I am wondering if the battery functions optimally at around 30°C and its real world performance will be slightly less at typical operating temperatures.

They Will Gradually Degrade

As most batteries do, salt water batteries will degrade with use. Aquion claims they can be cycled 3,000 times while falling to 70% of their original capacity. So after 8 years one should still be able to provide 1.1 kilowatt-hours when discharged over a 4 hour period. While some battery systems do considerably better than this, the rate of degradation is comparable to many lithium-ion systems.

Aquion Batteries Are Big. Really Big.

Per kilowatt-hour of storage, salt water batteries are the heaviest batteries on the market. They are more than twice as heavy as lead-acid batteries. Put [12 of them on a pallet](#) and it will be 1.2m high, 1.3m wide, 1m deep, and weigh 1.5 tonnes. Here are Aquion's specs for such a beast:

[Download \(PDF\)](#)

Aquion Salt Water Battery Warranty

The Aquion battery has a 5 year warranty. In addition, after the five years are up, it has a three year pro rata warranty. And I can only assume "pro rata" is Latin for "half-arsed". In those three years they will repair or replace your battery, but only if you pay 63% to 100% of the cost of a new one, depending on how much of the three year period is left. Any new batteries you purchase under this half-arsed warranty will not have a new warranty, despite the fact you that you may have paid almost full price for them.

Pro rata warranties are normal for lead-acid batteries because they are so easy to destroy through misuse. But with the much more durable Aquion battery, I'd much rather have just a 6 year full warranty and nothing else, than 5 years of full warranty followed by 3 half-arsed years.

Not The Most Environmentally Friendly Battery

The salt water battery is the least toxic battery that doesn't involve sticking pieces of [metal into fruit](#). However, this doesn't necessarily mean it is the most environmentally friendly battery available.

Batteries used for home energy storage contribute to carbon emissions in two main ways:

- **Embodied energy:** Carbon emissions from producing the materials

used in its manufacture and a smaller amount from manufacturing and transport.

- **Lost solar generation:** Carbon emissions that result from clean solar energy being lost when batteries are charged and discharged.

Not many people consider the second point. Each kilowatt-hour of solar electricity lost from charging and discharging grid connected batteries usually results in one extra kilowatt-hour of electricity being generated from fossil fuels. This applies even in Tasmania and South Australia, the two states with high levels of renewable generation, because they can normally export electricity to Victoria.

Lower Embodied Energy Than Lithium-ion

Both salt water and lithium-ion batteries result in CO₂ emissions from their manufacture. But because a large portion of the weight of Aquion batteries are just salty water, their carbon footprint will be considerably less per kilogram.

A rough estimate of the amount of CO₂ released from producing complex manufactured goods is 2kg per 1kg of a product's weight. If the Aquion battery's footprint is assumed to be half this and its usable energy storage is 1.78 kilowatt-hours, then its carbon footprint would be 66kg of CO₂ per kilowatt-hour of usable capacity.

The lithium-ion LG Chem RESU weighs 60kg and has 5.12 kilowatt-hours of usable storage. At 2kg of CO₂ per kg of weight its carbon footprint would be 23kg per kilowatt-hour of usable capacity. But others who have thought about the embodied energy of lithium-ion batteries a lot more than I have come up with a much higher number than this. This [review of the literature](#), from two and a half years ago, estimates about 170kg of CO₂ is used to

manufacture 1kWh of Li-ion storage¹. But because the technology is developing rapidly I suspect the figure has improved since then.

I can't find similar estimates of saltwater battery embodied energy – so we'll have to go with my guesstimate of 66kg. Let me know in the comments if you think this is way-out.

Lifecycle Emissions Worse Than Lithium-ion

When used for home storage, Aquion batteries are likely to have a [round trip efficiency](#) of 83% or less. A lithium-ion energy storage system such as the [LG Chem RESU](#) has a round trip efficiency of 95%.

Aquion lifecycle emissions

If the Aquion battery is cycled once a day for 8 years until the end of its pro rata warranty it would have stored a total of around 4,441 kilowatt-hours². At 83% efficiency, 755 kilowatt-hours would have been lost in total corresponding to about 717kg of CO₂ emissions³. With an average of 1.52 kilowatt-hours of usable storage, that's 472kg of CO₂ emissions per kilowatt-hour of capacity lost to inefficiencies.

Add that to the guesstimated 66kg embodied energy per kilowatt-hour of capacity, and the total environmental impact of the Aquion is 538kg of CO₂ per usable kilowatt-hour of capacity.

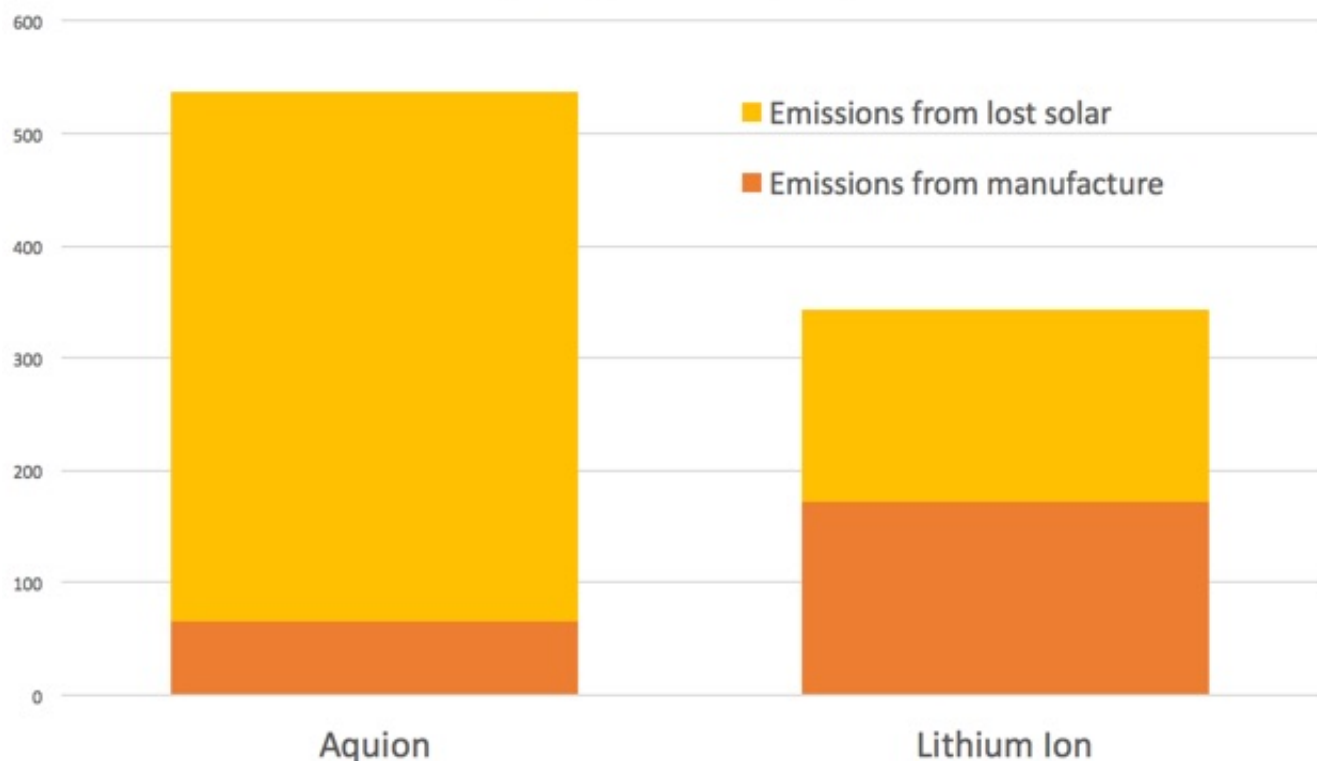
Lithium-ion lifecycle emissions

Cycled once per day the LG would store 17,386 kilowatt-hours over its 10 year warranted life. With its 95% roundtrip efficiency it would lose 869 kilowatt-hours of solar electricity. That's 173kg Co₂ emitted per kilowatt-hour of storage due to inefficiencies.

Add that to the 170kg embodied energy per kilowatt-hour for lithium-ion, and the total environmental impact of the LG Chem Resu is 343kg CO₂ per kilowatt-hour of usable capacity.

That is just over half the emissions of the Aquion battery per kWh capacity. As optimistic assumptions were made about the rate at which it would be charged and recharged, the Aquion battery's actual performance is likely to be worse.

Estimated lifecycle emissions: Saltwater vs. Lithium-ion.
kgCO₂ per kWh capacity



Saltwater batteries may have a lower carbon footprint from manufacture – due to their simple design, but their low roundtrip efficiency means that their total lifecycle emissions are likely to be higher than li-ion.

Salt Water Batteries And The Future

Aquion's salt water battery is touted as being made out of low cost materials. But looking at its uninstalled price of around \$2,200 it is not

cheap compared to other new battery chemistries on the market, per kilowatt-hour of usable storage.

But at the moment, new generation home battery storage is not sold for cost plus a reasonable margin, they are sold for as much as their manufacturers can get for them. This is not unreasonable, as they can cost a fortune to develop. So just because the Aquion battery isn't cheap at the moment doesn't mean they can't afford to lower its price in the future.

The battery is made of low cost components, but because it uses so much of them that is not as large an advantage as it may seem. It can still fall a very long way in cost per kilowatt-hour of storage before its price approaches the cost of the materials used. But in the long run, because the competition requires much less material per kilowatt-hour of storage, salt-water may not be able to beat lithium-ion or other battery chemistries on material costs per kilowatt-hour.

Cost Comparison With Lithium-Ion Batteries

On-grid battery storage does not yet pay for itself in Australia. But which type of battery storage will result in you losing the least amount of money is a question I can try to answer. Let's look at how much they cost per kilowatt-hour of usable stored electricity over their lifetime.

Aquion states their battery's life is 3,000 cycles and it will have declined to around 70% of its original capacity by then. When cycled once a day it will take over eight years to reach that point, which is well beyond its 5 year full warranty period. If the battery is allowed to fully discharge over 8 hours at a constant rate each cycle, which is optimistic for one that is used for home energy storage, then the average amount of usable energy it can store is approximately 1.5 kilowatt-hours which would come to a total of 4,500

kilowatt-hours over its cycle life. Dividing its cost of approximately \$2,200 by that figure gives 49 cents per kilowatt-hour stored.

The lithium-ion LG Chem RESU costs approximately \$7,500 and can store 5.12 usable kilowatts of usable electricity when new. It is warranted for 4,125 cycles and taking into account loss of capacity can store a total of 17,386 kilowatt-hours when cycled once a day over its 10 year warranty period. Dividing its price by total stored kilowatt-hours gives 43 cents a kilowatt-hour which is around 11% cheaper than the Aquion battery.

Should You Buy Saltwater Batteries?

While the Aquion is a little more expensive than lithium-ion per kWh stored, there's not much in it. And factors other than price can determine which type of battery people will consider best. For example, some may place a high value on the Aquion battery's non-toxicity, extremely low fire risk, and ability to be fully discharged and left unused for long periods without deteriorating.

However, given the power limitations of the Aquion battery, their low efficiency, large footprint and high lifecycle CO2 emissions, I doubt they will remain competitive in the on-grid energy storage market without a big fall in price.

Footnotes

1. "caused mainly by the production chains of battery cell manufacture, positive electrode paste, and negative current collector." ↩
2. 1.78 kilowatt-hours per cycle at first with a decline in battery capacity of 29.2% over 8 years. This decline is assumed to occur at a steady rate. ↩

3. Australia emits 0.95 kg CO₂ to generate 1 kilowatt-hour of electricity from fossil fuels, including emissions from extraction and processing.
↩