Wright Spirit Energy Storage Discussion Paper

Wright Electric
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Introduction
Wright is evaluating energy storage options for a retrofitted zero-emissions 100 passenger regional jet aircraft targeting entry into service (EIS) in 2026. Two energy storage options under consideration are hydrogen fuel cells and aluminum fuel cells.[1] [2]

The purpose of this discussion paper is to present these options to the aerospace community and seek your feedback. If you have a moment to fill out this google form and provide us with your comments, we would be grateful. Google form:
https://forms.gle/CjEu7KSGrgUrndCZ9
Thank you in advance.

Preliminary conclusions:
- Hydrogen fuel cell: longer range, smaller payload, harder operations, higher cost
- Aluminum fuel cell: shorter range, larger payload, easier operations, lower cost

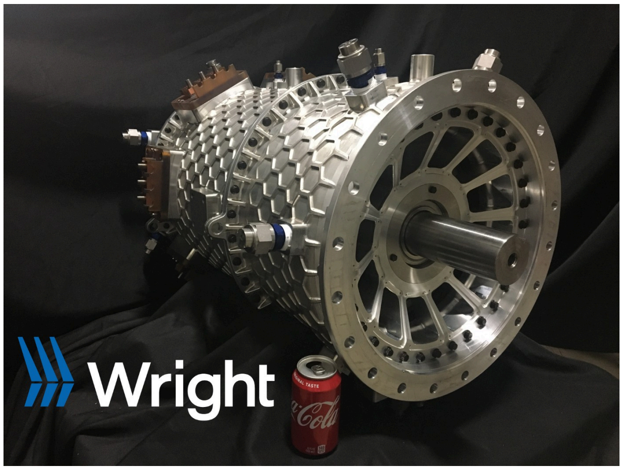
Opportunity
Wright is launching the Wright Spirit, a BAe 146 100-passenger regional jet retrofitted for zero-emissions one-hour flights.

The Wright Spirit

[1] Biofuels, hydrogen combustion, and next-generation batteries such as lithium-sulfur are outside the scope of this discussion paper, but they might be considered in a future paper. If you have a perspective about these or other technologies we should consider, please let us know in the form above.
[2] Aluminum fuel cells are also known as "aluminum-air batteries." They share similarities with batteries and with fuel cells. For the purposes of this paper we're calling them "aluminum fuel cells."

We're working with easyJet and Viva Aerobus to define requirements and establish routes.

Wright built the world's most powerful industry-leading megawatt class propulsion system, so we can build the world's largest zero-emissions aircraft retrofit directly serving the world's busiest routes. Ideally the airplane will enable zero-emissions flights, but jet fuel (for example in a turbogenerator) might be necessary for reserves.



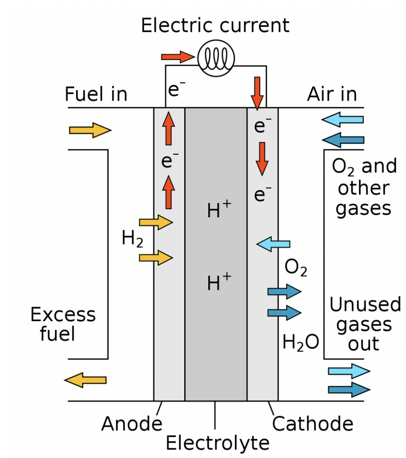
Wright 2 MW motor

Requirements

The energy storage system needs to be sufficiently light weight to fit within the energy storage weight envelope of a regional jet: mass specific energy density at least 750 wh/kg at the system level. It also has to be high enough Technology Readiness Level (TRL) for 2026 EIS, and it needs a pathway to 90% reduction in global warming equivalent. Total energy is ~10 MWh. We chose hydrogen fuel cells and aluminum fuel cells because we believe both have the ability to meet these requirements.

What is a Hydrogen Fuel Cell?

A hydrogen fuel cell is an electrochemical cell that converts the chemical energy of hydrogen and an oxidizing agent (often oxygen) into electricity. There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows ions, often positively charged hydrogen ions (protons), to move between the two sides of the fuel cell. At the anode a catalyst causes the fuel to undergo oxidation reactions that generate ions (often positively charged hydrogen ions) and electrons. The ions move from the anode to the cathode through the electrolyte. At the same time, electrons flow from the anode to the cathode through an external circuit, producing direct current electricity. (Source: Wikipedia)



Proton-Conducting Fuel Cell (Source: Wikipedia)

Pros and Cons of Hydrogen Fuel Cells

The mass specific energy of hydrogen is 33,313.9 wh/kg, which is 160x higher than that of Tesla's lithium-ion batteries and nearly 3x higher than even jet fuel, at ~12,000 wh/kg.

In exchange for this light weight, hydrogen has these challenges:

- While hydrogen itself is light, the fuel cells that convert hydrogen into electricity are heavy. Experts believe power densities in excess of 4 kW/kg will be possible as early as 2024, but as of October 2021 the state of the art balance of plant is below 1 kW/kg. This means the fuel cell alone could take up nearly a quarter of the useful load of an aircraft.[3]
- Hydrogen as a molecule is difficult to work with:
    - Hydrogen embrittles metal and burns clear, so leaks on a plane are dangerous.
    - Further, liquid hydrogen needs to be stored at 10 degrees Kelvin.
    - Even the best tanks generally can't keep hydrogen in liquid form for more than a day or so. This means any airport that intends to use liquid hydrogen might need to have a hydrogen liquefier at the airport, which is expensive and complicated.
    - Keeping hydrogen at high pressure results in explosion risk.
- Perhaps the biggest challenge with hydrogen is that while it has a high mass specific energy, it has a low volumetric energy density. In other words, the hydrogen tanks need a lot of space on the aircraft. With a clean sheet aircraft, this challenge could have less consequence because the aircraft can be designed for extra volume from the start. But with a retrofitted aircraft, the hydrogen tanks have to go somewhere, and the general solution has been to put them in the body of the plane, where passengers usually sit. And these tanks are so large that they reduce passenger seating space by as much as 20%.

It's this last challenge - volume - that led us to look at other energy storage technologies beyond hydrogen fuel cells. The airline asked for an energy storage technology with high mass specific energy (i.e., light weight) and high volumetric energy density (i.e., won't reduce seat count revenue by 20%).

[3] Using an ATR-72 as an example: two PW127 engines, 1,846 kW each, or 3,692 kW max takeoff power. If the fuel cell is sized for cruise power, at 50% of max takeoff power, this means a 1,846 kW fuel cell. If the fuel cell is 1 kW/kg, 1,846 kW = 1,846 kg. The useful load of an ATR-72 is 7,500 kg. 1,846 / 7,500 = 25%.

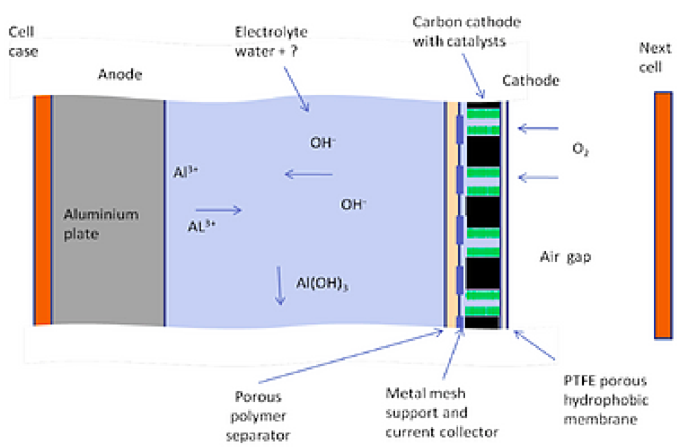
What is an Aluminum Fuel Cell?
Aluminum is the most abundant metal, and the third most abundant material overall, on earth. It's also high in mass specific energy and volumetric energy density. See the comparison table below:

	Aluminum	**Liquid Hydrogen (LHV)**	**Jet Fuel**	**Li-Ion Batteries (maximum)**
Mass specific energy (wh/kg)	8,611.1	33,313.9	~12,000	500
Volumetric energy density (wh/l)	23,277.9	2,358.6	~9,000	500

Aluminum has a much higher volumetric energy density than hydrogen, and its theoretical maximum mass specific energy is only 30% below that of jet fuel.

An aluminium fuel cell is built of three layers:

1. The first layer is an aluminium or aluminum alloy anode.
2. This plate reacts with the second layer, which is an electrolyte.
3. The third layer is the cathode, allowing increased accuracy of cell function. See the figure below:



Aluminum-Air Cell Diagram ("?"= Salt) (Source: Metalectrique)

An aluminum-air battery needs an electrolyte to enable the aluminum-oxygen reaction. The electrolyte is generally a basic liquid. When aluminum is combined with the electrolyte, plus the air cathode, the weight increases, and the mass specific energy drops from 8,611.1 wh/kg.

Pros and Cons of Aluminum Fuel Cells
Aluminum fuel cells (a.k.a. aluminum-air batteries) are a cross between a battery and a fuel cell. Like a battery, they use the chemical reaction of an anode and a cathode to create electricity. Like a fuel cell, they need oxygen for this reaction.

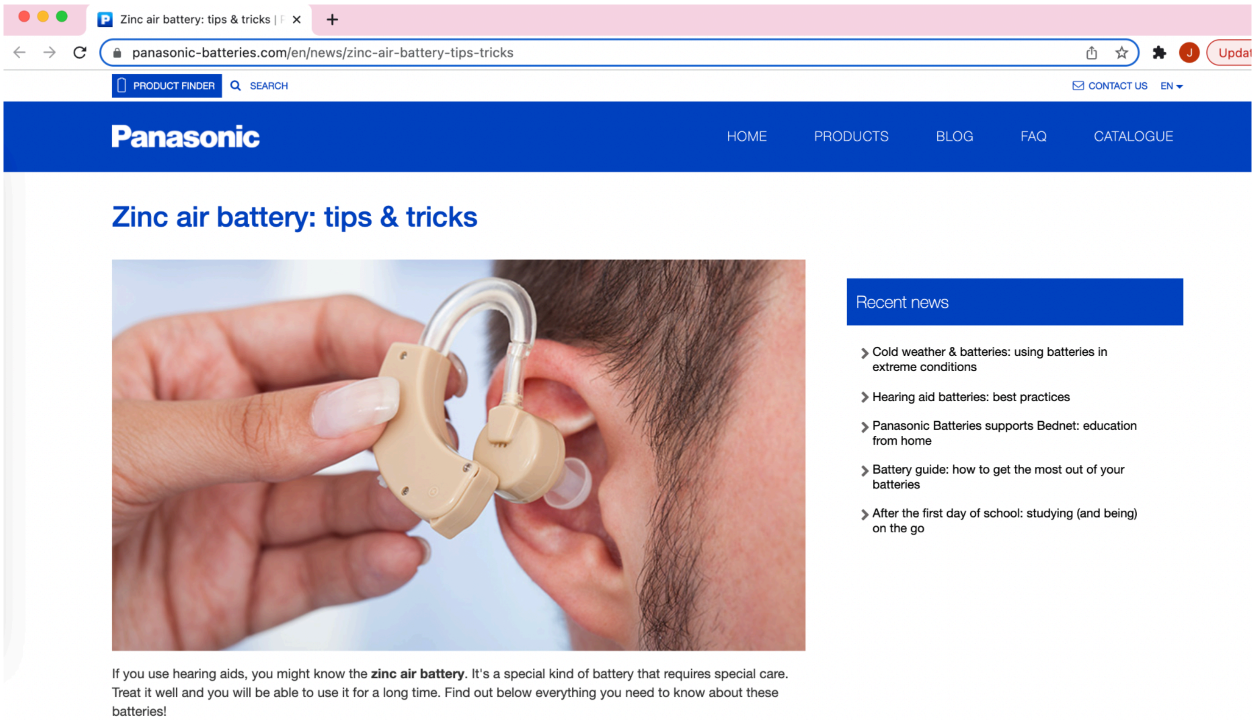
The main advantages of aluminum fuel cells are:
1. High mass specific energy (but not as high as hydrogen),
2. High volumetric energy density (much higher than hydrogen),
3. Non-challenging aircraft integration, and
4. Non-challenging airport infrastructure.

The main disadvantage compared to hydrogen is weight: At a system level (factoring in fuel cells, thermal management, air compression, etc. - balance of plant) the ceiling of the mass specific energy of an aluminum fuel cell system is 30%-40% lower than the mass specific energy ceiling of hydrogen fuel cells. Also the weight of aluminum fuel cells increases by up to 20% as the plane flies, as the aluminum takes on oxygen.

See the section below titled System Weight for Clean Sheet Aircraft. Note that this ceiling assumes Technology Readiness Level advances in both hydrogen and aluminum fuel cells. But since half of the single aisle market is flights shorter than 800 miles, the range penalty might not be as consequential as it might initially seem. And the aircraft taking on weight during flight is also potentially less of an issue because the largest usage of power is during takeoff, when the plane is lightest. A modified flight profile might be required, in which the plane descends slightly over the course of cruise, as opposed to a traditional flight profile in which the plane ascends slightly over the course of cruise as the plane gets lighter, and considerations need to be given to landing gear, max landing weight, and takeoff during the reserve segment, but we believe this is not an impossible challenge.

History of Metal-Air Fuel Cells
Metal-air batteries (of which aluminum fuel cells are a sub-category) have been used commercially since the 1970s, so there is a rich U.S.-based supply chain to use for manufacturing and commercialization. Small zinc-air button cells have been used in hearing aids (see figure below), and larger batteries have been used in film cameras and in military missions. The annual market size for zinc-air and aluminum-air batteries in 2020 was $344 million and $274 million, respectively[4].

[4] Global Aluminum-air / Zinc-Air Battery Market Research Report 2020, 360 Research. 2020.



Commercial Application Example of Metal Air Batteries: Hearing Aid

<u>Recharging - the Biggest Marketing Challenge of Aluminum Fuel Cells</u>

The main marketing challenge with aluminum is it can only be used once before it has to be returned to the smelter. Aluminum is infinitely recyclable, but the "recharging" process happens at the smelter. This is why we don't call them "batteries," because as soon as we say the word "battery" people think about recharging with an electrical outlet, whereas with a fuel cell people generally don't have the same mental model of the charge/discharge cycle process.

For a car (or laptop computer), mechanical recharge would be a deal breaker - who wants to give up being able to plug into a wall - but for an airplane it's less consequential, for three reasons:

1. Every airport is a gas station, so there's no need to go to a separate place to swap cartridges (see Concept of Operations section below)
2. All airports are familiar with loading and unloading cargo because they do this with luggage
3. Compared to hydrogen, in which tanks also have to be returned to a facility for refueling, the difficulty of returning a spent aluminum cartridge isn't substantially higher.

Concept of Operations

<u>Hydrogen</u>

In one hydrogen fuel cell system concept of operations, tanks of hydrogen would be loaded onto an airplane like cargo is today. After the flight, the tank would be replaced with a new tank, and the empty tank would be returned to the hydrogen processing facility for refilling.

In another hydrogen fuel cell system concept of operations, hydrogen would be made at airports using an on-airport hydrogen production facility, or transported to airports. Hydrogen could be converted to liquid hydrogen at airports, and then piped onto an aircraft. Gaseous hydrogen is liquefied by cooling it to below −253°C (−423°F) (10°Kelvin) . Liquid hydrogen can be stored in liquid form for only a day or so, so the liquefaction plant would need to be physically near to the airport.

<u>Aluminum</u>
In an aluminum fuel cell system, cartridges of aluminum would be loaded onto an airplane like cargo is today. After the flight, the cartridge would be replaced with a new cartridge, and the spent cartridge would be returned to the smelter for recharging. There are ~200 smelters in 40 countries worldwide (source: Wikipedia) and 15 in Europe alone - this makes ground logistics for returning spent cartridges and delivering new ones straightforward. See the figure below:

Aluminum smelters in Europe (Source: European Aluminum)

Aluminum is stable at many temperatures, which means storing aluminum at the airport is nearly as easy as storing jet fuel. Further, aluminum is also stable at many altitudes, so safety on an aircraft is much less complicated than for hydrogen.

Other considerations involving aluminum include:

- Aluminum is easily transported and has a mature logistics model for both transportation and recycling, unlike hydrogen.
- It can be shaped into small pellets, which enables movement through pipelines.

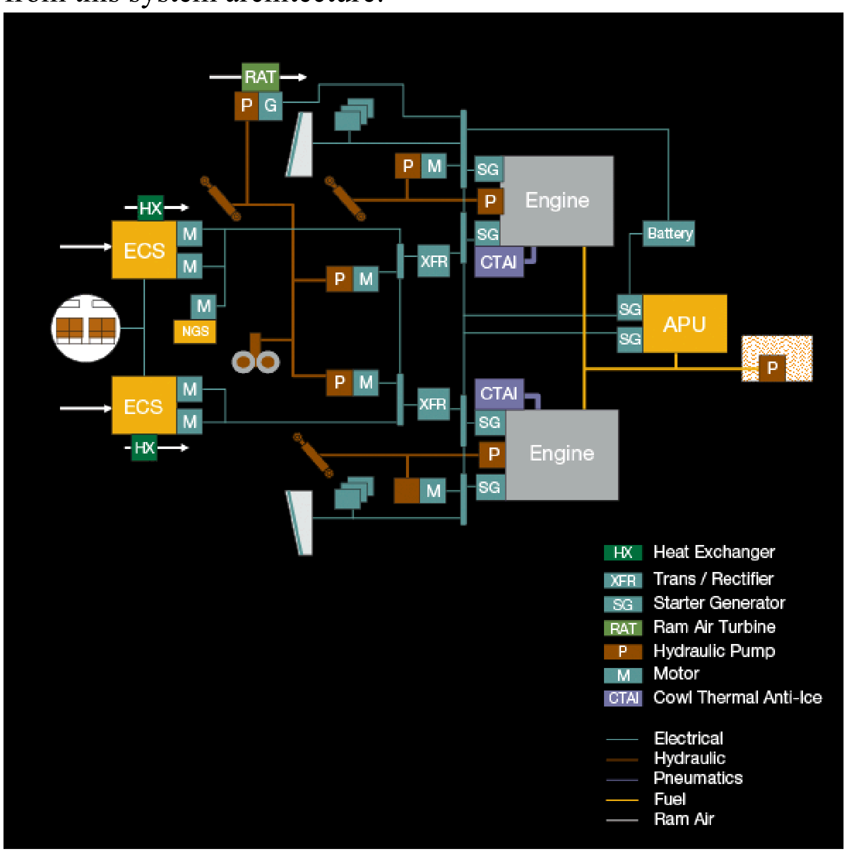
What's Needed to Mature / Scale the Technology
Technology advances are required for both hydrogen and aluminum fuel cells.

<u>Hydrogen: Power Density of Fuel Cell</u>
Today's hydrogen fuel cells have balance of plant power densities below 1 kW/kg, some as low as 0.5 kW/kg. For effective aircraft applications, balance of plant power densities that exceed 2 kW/kg are considered state of the art.

<u>Hydrogen: Mass Fraction of Tanks</u>
Today's hydrogen tanks have mass fractions below 20%, some as low as 15%. For effective aircraft applications, hydrogen tanks that exceed 25% are considered state of the art.

<u>Hydrogen and Aluminum: Altitude Capability</u>
For aviation, a more complex fuel cell design is required because oxygen content at high altitude is so thin. A practical fuel cell system for aircraft will require a complicated set of heat exchangers for thermal management, plus an air compressor to enable the fuel cell to get enough oxygen to produce high power. This means the weight of the system is the fuel cell plus the auxiliary systems, which can double or triple the weight of the overall system.

Boeing's 787 pioneered the concept of an electrical pressurization system, and Wright intends to apply learnings from this system architecture:



787 No-Bleed System (Source: Boeing)

Aluminum: Mass Specific Energy of Aluminum Cell
The starting point for aluminum fuel cells is already substantially higher than lithium-ion; an aluminum fuel cell used in the 1990s had a specific energy of ~700 wh/kg. This cell, from the 1990s, has nearly 3x higher specific energy than the best Tesla cells today, of 260 wh/kg. As impressive as this is, it was from the 1990s, and Métalectrique, a company founded in the past decade, has demonstrated aluminum fuel cells at 1,350 wh/kg.

Wright believes aluminum cells can achieve 2,000 wh/kg mass specific energy density. As a general rule, a metal-air battery can achieve a specific energy that is 25% to 30% of its theoretical maximum. For example, the actual specific energy of a modern zinc-air cell is 415 wh/kg, which is 28% of its theoretical maximum of 1,472 wh/kg. 28% of aluminum is 2,411 wh/kg.

wh/kg	**Today**	**Theoretical**	**Ratio**
Zinc-Air	415[5]	1,472[6]	28%

wh/kg	**Eventual**	**Theoretical**	**Ratio**
Aluminum-Air	2,411	8,611[7]	28%

Eventual Specific Energy of Aluminum

Aluminum: Power
Substantial work is being conducted to increase the power of aluminum fuel cells. Today's aluminum cell designs are focused on low-C-rate energy applications and aren't designed for high power. Most of this work revolves around increasing the surface area of the chemical reaction, for example from a large plate of aluminum to a powder.

Momentum
Both hydrogen and aluminum fuel cells are gaining momentum. Hydrogen is benefitting from a large European push[8] for hydrogen. Aluminum is benefitting from a push from India[9], where concerns about lithium supply from China are leading the country to consider alternatives.

[5] Handbook of Batteries. 5th edition. Editor Kirby W. Beard. McGraw-Hill. 2019 Table 1.2.
[6] Wikipedia - Energy Density.
[7] Wikipedia - Energy Density.
[8] Abnett, Kate. Europe pulls ahead in race for hydrogen, as global project pipeline grows: report. February 17, 2021. Reuters.
[9] Chakraborty, Debjit and Rajesh Kumar Singh. A Major EV Battery Bet for India Is on Aluminum Over Lithium. July 1, 2021. Bloomberg.

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COMMODITIES FEBRUARY 17, 2021 / 1:18 AM / UPDATED 9 MONTHS AGO

Europe pulls ahead in race for hydrogen, as global project pipeline grows: report

By Kate Abnett 3 MIN READ

BRUSSELS (Reuters) - Most of the world's planned hydrogen projects and the biggest chunk of related investments this decade are expected to be in Europe, an industry report said on Wednesday, as the continent races to scale up the low-carbon fuel to meet climate goals.

Hydrogen in the News

Bloomberg Green

Hyperdrive

A Major EV Battery Bet for India Is on Aluminum Over Lithium

By Debjit Chakraborty and Rajesh Kumar Singh
July 1, 2021, 5:00 PM EDT

Aluminum in the News

System Weight for Clean Sheet Aircraft
Wright built a model of a hydrogen fuel cell system and an aluminum fuel cell system, including air compressors, thermal management, and a jet fuel powered turbogenerator to partially power reserves, on a clean sheet aircraft targeting Entry into Service in 2035 that resembles a next-generation A320 aircraft. The resulting effective mass specific energies are below, along with comparisons to lithium-ion and lithium-sulfur batteries. Note that 750 wh/kg is considered the mass specific energy at which electric single-aisle aircraft such as the A320 become viable (source: NASA SUGAR, others).

Wright used a simplified flight profile from ARPA-E ASCEND for the analysis, along with additional considerations for the reserve portion:

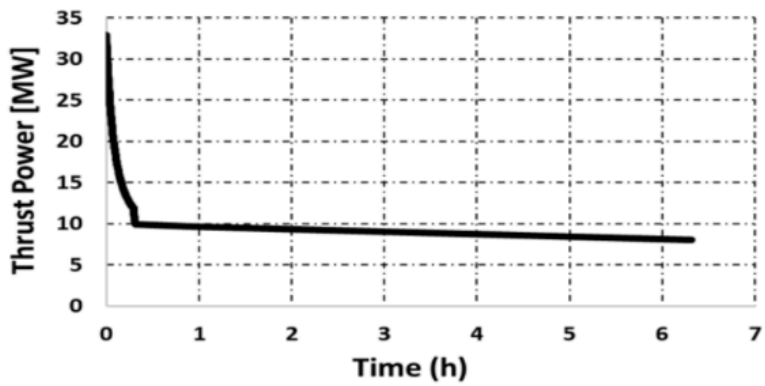
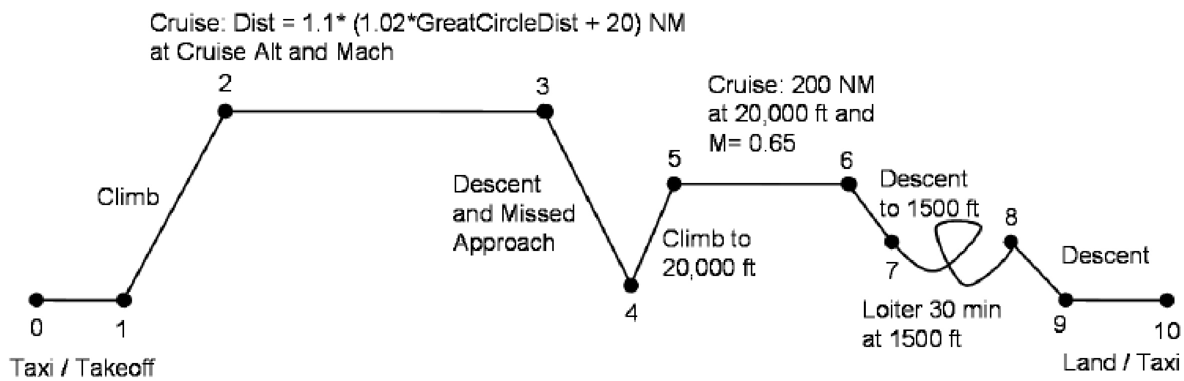


Figure 2: Modeled delivered thrust power profile for a typical flight of a narrow-body commercial airliner.

ARPA-E ASCEND Flight Profile



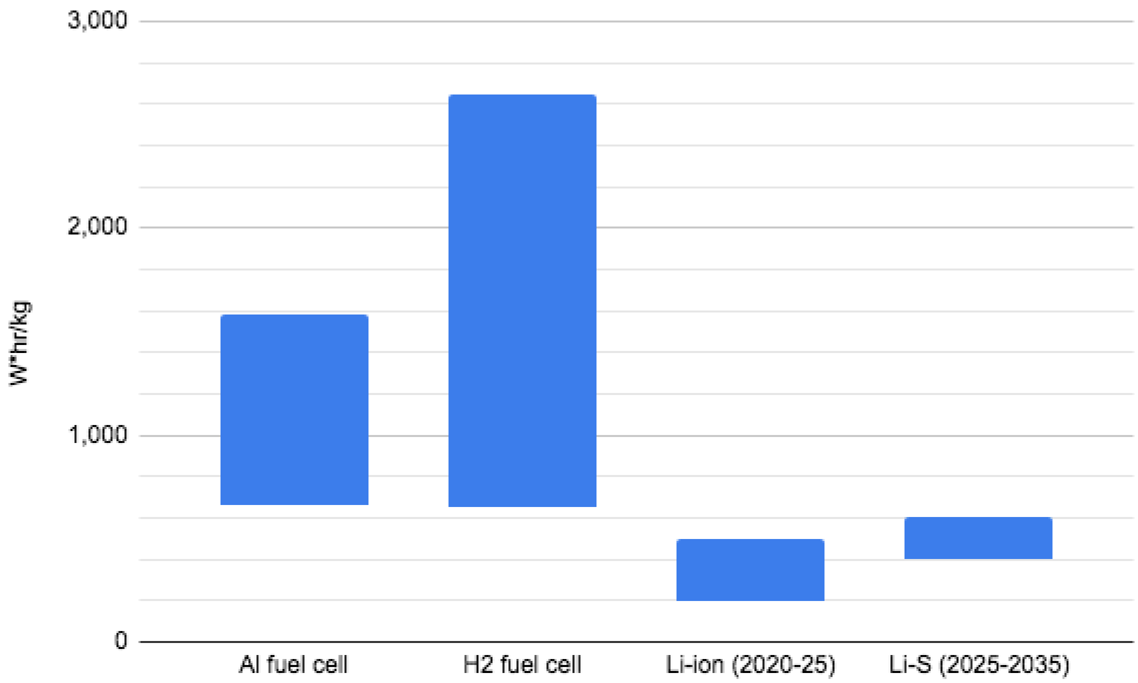
Reserves Segment

This model provides a range of outcomes by providing baseline, optimistic, and pessimistic assumptions for numerous parameters including:

- Mass specific energy of aluminum-air cell
- Weight of thermal management system
- Compressor efficiency
- Usage of turbogenerator for reserves, plus power density of the turbogenerator
- Power density of hydrogen fuel cell
- Efficiency of fuel cell
- Mass fraction of hydrogen tank
- Others

The model assumes a 600 mile flight, with reserves, at Mach 0.72, carrying 150 passengers. It assumes advances in aerodynamics and lightweighting for next-generation aircraft, and it also factors in the higher skin friction drag associated with larger fuel tanks with hydrogen.

The resulting mass specific energy plot is here:



Note that both hydrogen and aluminum fuel cells easily exceed the 750 wh/kg barrier, and Li-S is the only traditional battery chemistry with the possibility of doing so.

Range & Payload Results

Single-Aisle

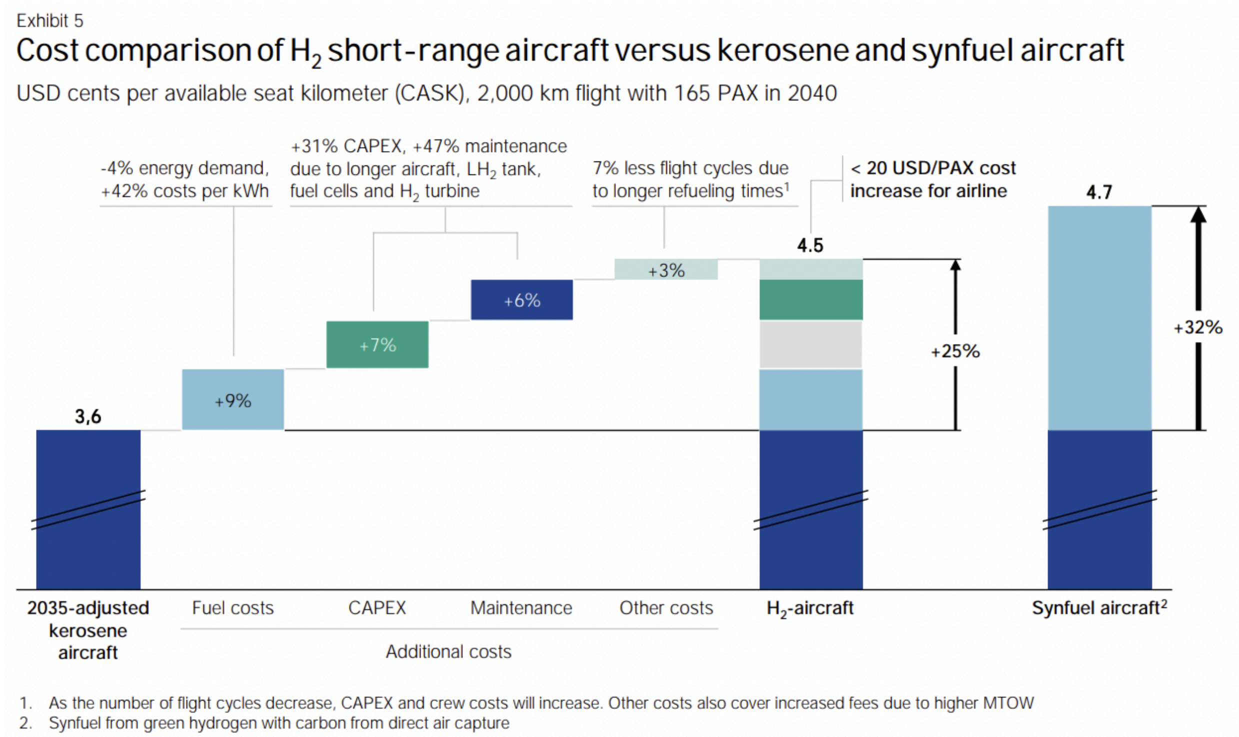
At mass specific energies above 750 wh/kg, ranges and payloads can start to achieve mission requirements at the single-aisle class, for example 400 mile flights carrying up to 150 or more passengers. The system level mass specific energy densities of aluminum and hydrogen above, as high as 1,500 and 2,250 wh/kg, respectively, are more than sufficient for these flights.

Retrofit Timeline

The model above assumes a 2035 EIS and a clean sheet aircraft. A retrofitted aircraft won't take advantage of advances in aerodynamics and lightweighting, and hydrogen tanks will likely need to go into the body of the aircraft, decreasing passenger capacity. Similarly, with an aluminum design, Wright might need to strengthen the landing gear to factor in the higher landing weight of the aircraft. Further, a clean sheet aircraft might not enter service until 2030 or later, whereas the Wright Spirit is targeting Entry into Service in 2026, so Technology Readiness Level timeline is crucial. We need to make the decisions not on what might be possible in a decade, but what will be certifiable this decade.

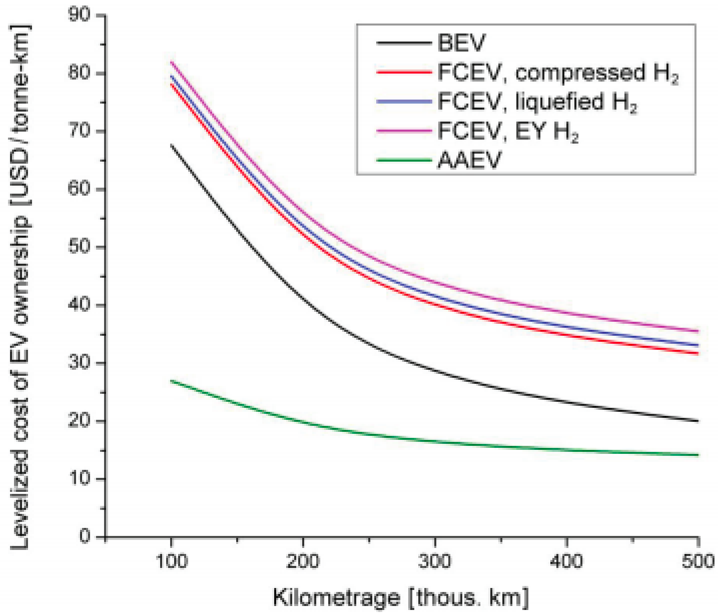
Costs
Wright built an ultra-simplified airline operating model for a single-aisle category aircraft to evaluate the operating costs of hydrogen and aluminum fuel cells as compared to those of traditional liquid fuels. Because fuel and engine maintenance costs are the two major variables in novel aircraft, we built a model that broke those out and kept the other line items constant. We assumed fuel costs at 25% total of operating costs (Source: ResearchGate) and engine maintenance costs at 5% of total (Source: Boeing), and we bucketed all other costs into an "other" category.

We then compared a traditional airplane to an airplane running on biofuels, hydrogen fuel cells, and aluminum fuel cells. We assumed that biofuels would be 4x more expensive than traditional jet fuel (Source: Compensaid). For hydrogen, we used cost figures from the CleanSky 2 Hydrogen-powered aviation study:[10]



For aluminum, we used cost figures from a 2020 comparative economic analysis of electric, hydrogen, and aluminum light duty trucks[11] and extrapolated to aircraft. This study concluded that aluminum fuel cells could have as little as one third the cost of operations as hydrogen fuel cells. The chart below depicts cost of ownership over time, comparing electric vehicles, hydrogen fuel cell vehicles, and aluminum fuel cell vehicles:

[10] CleanSky 2. Hydrogen-powered aviation. McKinsey and Company. May 2020.
[11] Buzoverov, E., & Zhuk, A. (2020). Comparative Economic Analysis for Different Types of Electric Vehicles. *International Journal of Sustainable Energy Planning and Management*, *29*, 57–68. https://doi.org/10.5278/ijsepm.3831



Levelized costs of EV energy carrier and. the power unit ownership, light duty commercial trucks, USD/tonne-km

Wright used a conservative 50% reduction in costs compared to hydrogen vehicles in our model.

We assumed engine maintenance costs for the hydrogen fuel cell and aluminum fuel cell airplanes would be 20% lower due to the historically lower cost of operations of electric motors versus turbine engines.

The results are here:

	Jet Fuel	Biofuel	Hydrogen Fuel Cell	Aluminum Fuel Cell
Cost of fuel	$25	$57	$27	$14
Cost of engine maintenance	$5	$5	$4	$4
Other operating costs	$70	$70	$70	$70
Additional fuel cell costs	-	-	$24	$12
	$100	$132	$125	$100
% compared to jet fuel		*32%*	*25%*	*-1%*

Substantial additional work needs to be done, but at a first pass it appears that hydrogen fuel cells can be expected to be 25% more expensive than jet fuel, but less expensive than biofuels, and aluminum fuel cells can be expected to achieve price parity with jet fuel today.

Hydrogen and Aluminum Emissions

Neither hydrogen nor aluminum are green at the moment, but both have potential to become green.

Hydrogen[12]

Green hydrogen

Green hydrogen is extracted using a method that does not produce GHG emissions. As the name suggests, its production is sustainable and environmentally friendly. Green hydrogen is most commonly produced using a device called an electrolyser. Electrolysers use electricity to split water into hydrogen and oxygen. The key to this method of producing green hydrogen is that the electricity that powers the electrolyser comes from renewable sources, such as wind, solar, which have no associated GHG emissions. There are also pathways to produce green hydrogen from waste biomass.

According to the International Energy Agency, less than 0.1% of hydrogen today is produced through water electrolysis, but that could soon change.

Blue hydrogen

Blue hydrogen is produced using a process called 'steam reforming', which uses steam to separate hydrogen from natural gas. This process does produce GHGs, but carbon capture and storage technologies capture and store those emissions.

Grey hydrogen

Grey hydrogen is also extracted from natural gas using steam reforming but in this case, relevant technologies don't capture resulting emissions. Instead, they are released into the atmosphere.

Brown and black hydrogen

Brown hydrogen (made from brown coal) and black hydrogen (made from black coal) are produced via gasification. It's an established process used in many industries that converts carbon-rich materials into hydrogen and carbon dioxide. As a result, gasification releases those by-products into the atmosphere.

Aluminum

The aluminium industry generates more than 1.1 billion tonnes of CO2e (carbon dioxide equivalent) emissions annually – around 2% of global anthropogenic emissions.[13] Emissions come from three general areas: electricity, heat, and carbon, and there are technologies in development to address all three areas:

[12] Source: Brown, Fiona and Daniel Roberts. Green, blue, brown: the colours of hydrogen explained. *And* Petrova, Magdalena. "Green hydrogen is gaining traction, but still has massive hurdles to overcome." CNBC, December 4, 2020.

[13] Aluminium for Climate: Exploring pathways to decarbonize the aluminium industry. World Economic Forum and Accenture. November 2020. http://www3.weforum.org/docs/WEF_Aluminium_for_Climate_2020.pdf

	Bauxite mining	Alumina refining	Anode production	Electrolysis	Casting	Recycling*	Semis production	Internal scrap remelting	Total
Electricity (indirect)	0.6	16.9	-	670.6	-	3.1	9.5	2.5	703
Non CO_2 GHGs (direct)	-	32.2	-	35.4	-	-	-	-	68
Process CO_2 (direct)	-	-	6.4	92.6	-	-	-	-	99
Ancillary materials (indirect)	-	14.8	19.3	6.4	-	-	-	-	41
Thermal energy (direct/indirect)	2.6	124.3	6.4	-	6.4	15.6	19.0	8.4	183
Transport (indirect)	-	15.4	-	18.7	-	-	-	-	34
Total (cradle to gate)	3	204	32	824	6	19	29	11	1,127

*2018 total aluminium sector emissions (Mt CO2e) heat mapped, by process and source (*recycling of pre- and post-consumer scrap)*[14]

Opportunities for decarbonization:

- Electricity is the easiest to decarbonize: The industry would switch from coal to renewable sources.
- Heat is the second easiest: Numerous startups, for example Heliogen, which has raised $108M in venture capital, are building concentrated solar power (CSP) facilities to reach temperatures of more than 1,000ºC.[15]
- The hardest is the carbon anodes needed for aluminum smelting. Alcoa, Rio Tinto, and Apple formed a joint venture called Elysis specifically to build carbon neutral anodes for smelting.[16]

Learn More

- Aluminum - Tech for Luddites video: We Can Get 1600 KM of Range With Aluminium Batteries
- HyPoint white paper: [HyPoint - we make zero emission air transport possible]

[14] Aluminium Sector Greenhouse Gas Pathways to 2050. March 2021. https://www.world-aluminium.org/media/filer_public/2021/03/16/iai_ghg_pathways_position_paper.pdf
[15] Aluminium for Climate.
[16] Aluminium for Climate.

Conclusion
Wright is evaluating two energy storage options for the Wright Spirit, a retrofitted zero-emissions 100-passenger regional jet aircraft targeting entry into service in 2026: hydrogen fuel cells and aluminum fuel cells.

- Hydrogen fuel cell: longer range, smaller payload, harder operations, higher cost
- Aluminum fuel cell: shorter range, larger payload, easier operations, lower cost

Your thoughts would be greatly appreciated. Here's the link for the feedback form so you don't have to scroll to the top: https://forms.gle/CjEu7KSGrgUrndCZ9

Thank you again!

Appendix: Additional Detail about Airline Partners and Requirements

- Juan Carlos Zuazua, CEO from Viva Aerobus says, "Viva Aerobus is excited to support the development of the Wright Spirit as a member of the advisory board. As the Greenest Airline in Mexico, we are focused on aviation's commitment to greenhouse gas reductions. We look forward to collaborating with Wright to analyze the integration of a zero-emissions 100-passenger aircraft into airline operations."
- David Morgan, Director of Flight Operations at easyJet added, "We believe zero emissions aircraft are key to addressing aviation's environmental impact and so we fully support Wright Electric in their ambition to bring a zero-emissions aircraft to market. Wright have come a long way since we first started working with them in 2017 and we welcome this announcement as another important step on their journey."

95% of the carbon footprint of aerospace comes from Boeing and Airbus sized planes. Each Boeing airplane will generate 1 million tonnes of emissions over its lifetime. Airlines are desperately looking for ways to actually reduce emissions, but they're stuck with "net carbon reduction" using biofuels and carbon offsets until they can find a viable replacement for a Boeing-sized plane.

In order for airlines to consider a replacement plane viable, however, they're asking for three attributes:
1. Jet speeds
2. Jet altitudes
3. 100+ passengers

Airlines are asking for these attributes so the replacement plane fits within their existing business model.

The Wright Spirit builds on the BAe 146 platform, a 100 passenger, 4-engine aircraft known for its operation out of noise-sensitive airports. The Wright Spirit flies at jet speeds and jet altitudes, and it carries 100 passengers.

By focusing on a proven 100-passenger aircraft and one-hour flights, the Wright Spirit addresses the world's busiest routes. These include:

- Seoul-Jeju (world’s busiest route, 14 million passengers annually)
- London-Paris
- Rio de Janeiro-São Paulo
- San Francisco-Los Angeles