www.adn.com /alaska-news/wildlife/2023/01/12/national-park-service-proposes-ban-on-controversial-hunting-and-trapping-method…

National Park Service proposes ban on 'controversial' hunting and trapping methods in Alaska's federal preserves

Alex DeMarban ⁝ 8-10 minutes ⁝ 1/12/2023

A grizzly bear walks along the edge of the Teklanika River in Denali National Park and Preserve on Sept. 13, 2019. (NPS Photo/Emily Mesner)

The National Park Service wants to reinstate bans on what it describes as "controversial" hunting and trapping activities on Alaska's federal preserves, including luring bears with bait, shooting swimming caribou or killing wolf pups in their dens.

The agency, saying the activities do not meet traditional notions of sport hunting, is also proposing to ban predator reduction efforts on its preserves, according to an eight-page notice of the proposed rules published Monday in the Federal Register.

The publication launches a two-month public comment period ending March 10.

The Biden administration's proposal marks the third time in eight years the federal government has visited the subject of hunting and trapping in Alaska's federal preserves. If enacted, the current proposal would reinstate

Obama-era rules authorized in 2015 and reversed in 2020 under the Trump administration.

The state of Alaska and a hunting guide group expressed opposition to the proposal, saying it would erode the state’s ability to manage wildlife and could jeopardize some efforts that reduce predator numbers.

Conservation groups praised the plan, saying it will stop inhumane hunts in preserves, increase tourism by protecting wildlife and improve visitor safety by reducing the potential for encounters between bears and people.

The National Park Service said in a statement last week that the proposal, if enacted, will “properly reflect the federal government’s authority to regulate hunting and trapping” on national preserves in the state.

“This proposed rule would realign our efforts to better manage national preserve lands in Alaska for natural processes, as well as address public safety concerns associated with bear baiting,” said Sarah Creachbaum, Alaska regional director for the National Park Service.

But state wildlife officials say the federal government’s contention is wrong: If the Park Service regulates hunting and trapping on federal preserves, that cuts into the state’s statutory responsibilities.

Doug Vincent-Lang, commissioner of the state Department of Fish and Game, said in an interview that the proposed change will affect Alaska’s right under federal law to manage hunting and fishing in the state, including on federal lands.

“In my initial read of this, this raises some significant issues regarding the ability of the state to manage fish and wildlife on federal lands, which was guaranteed to us at statehood and under” federal law, Vincent-Lang said.

“I’m guessing that if this survives the rule-making process it will go to court and (we’ll) defend our authority to manage fish and wildlife on federal lands,” he said.

Vincent-Lang said the state is disappointed that the Park Service has already been consulting with tribal organizations and Alaska Native corporations, but did not reach out to the state.

In a two-page letter to National Park Service Director Charles F. Sams III on Wednesday, Vincent-Lang said the Park Service is legally required to consult with the state on the proposed rule. He asked the director to rescind publication of the proposed rule and delay public comment until Alaska Fish and Game receives the same level of consultation that the tribes and Native corporations have received.

‘Sport’ hunting, not subsistence

The National Park Service notice said that in addition to prohibiting predator control on preserves, the proposed rules would ban practices that are “not consistent with generally accepted notions of ‘sport’ hunting.”

They would prevent the taking of:

• Black bears, including cubs and sows with cubs, with artificial light at den sites.

• Black bears and brown bears using bait.

• Wolves and coyotes, including pups, during the denning season.

• Swimming caribou.

• Caribou from traveling motorboats.

The proposed changes would not affect federal subsistence harvests in national parks and preserves, the agency said.

"This affects sport hunting only," said Peter Christian, a spokesman in Alaska with the National Park Service. It also does not apply to national parks, where sport hunting is already banned.

The agency manages 10 preserves in Alaska totaling 22 million acres, including at Denali National Park and Preserve, where the preserve lies west of the park.

The Park Service believes the hunting and trapping practices allowed in 2020 have occurred only in limited circumstances, Christian said. They're only allowed in the preserves after authorization by the state, he said.

But now the Park Service has determined that the "factual, legal and policy conclusions that underlie the (2020) rule are incorrect," he said.

The proposal also represents a significant shift from the Trump administration's rule change when it comes to bear baiting.

In its proposed rule, the Park Service says it didn't fully consider expert input in 2020 when it determined bear baiting was justified in preserves.

For this rule-making, however, officials interviewed numerous national park resource managers and wildlife biologists in Alaska who said bear baiting will alter the animals' behavior, increase the likelihood of bear kills in defense of life and property, and create "moderate to high" risks for the visiting public of injury or perhaps death in a bear encounter, according to the Federal Register filing.

The National Park Service now says bears can become habituated to human food used in baiting, and says bears are more likely to attack when defending a food source.

The agency points out that steps the state has taken to mitigate human-bear encounters around bear baiting, such as outlawing stations within a quarter-mile of a trail or road, don't adequately reduce risks because bears range widely, and hunters transporting food to a station may use the same path, road or waterway as other park visitors.

The 2020 rule was largely opposed by members of the public who commented, the agency says. More than 99% percent of more than 200,000 public comments opposed the 2020 rule.

U.S. District Court Judge Sharon Gleason in September found that the 2020 rule violated the Administrative Procedure Act. But she did not set aside the rule, noting that the National Park Service was already reassessing it.

Wildlife management, wildlife values

Thor Stacey, director of governmental affairs for the Alaska Professional Hunters Association, which represents many hunting guides in Alaska, said the group opposes the proposed rule.

In particular, it could harm rural residents who rely primarily on caribou, moose and other wild animals for most of their diet, Stacey said.

The proposed rule will prevent the state from allowing hunts for predators such as bears, even if the hunt is not a predator-control action by the state, he said. That could result in, say, reduced moose populations, a key problem in areas with limited access to store-bought food.

“If the state can’t manage wildlife effectively, which includes hunts for bears and wolves, you really don’t have wildlife management anymore because you can’t have a predator season anymore if it has any kind of benefit to a prey species,” Stacey said.

But Nicole Schmitt, executive director of Alaska Wildlife Alliance, the lead plaintiff in the case against the 2020 rules, said the group is “excited” about the ban.

Bear baiting can involve the use of human foods, such as doughnuts or bacon grease, creating potential safety issues for preserve visitors if bears connect humans with those foods, she said.

“We fundamentally believe these practices should not be allowed and are not lawful on preserve lands for sport hunting,” she said. “Allowing sport hunting for bears while hibernating and wolves while denning is problematic.”

*[**Editor’s note:** This article has been updated to include comments in a letter from Alaska Department of Fish and Game Commissioner Doug Vincent-Lang to the head of the National Park Service.]*

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Earth MRI for Alaska critical minerals

North of 60 Mining News ⁝ 9-12 minutes

USGS investing $6.75M for Last Frontier mapping, geophysics North of 60 Mining News – August 26, 2022

Alaska is known to be a trove of the minerals and metals critical to every segment of the American economy. This critical mineral richness is despite the fact that Alaska is a vast state that remains largely underexplored. To help gain a better understanding of the Last Frontier State's potential to provide domestic supplies of the 50 critical minerals, the U.S. Geological Survey has allotted $6.75 million to explore specific regions of the state for 29 critical minerals.

The new funding includes grants to the Alaska Division of Geological & Geophysical Surveys (DGGS) for geologic mapping and sampling of a portion of the Yukon-Tanana Upland near the Canadian border.

In addition, the USGS funding will support new airborne geophysical surveys in the Kuskokwim River region and on the Seward Peninsula, areas of western Alaska known for their antimony, graphite, rare earth elements, tin, tungsten, and other critical minerals.

These programs are being carried out under the Earth Mapping Resources Initiative, or Earth MRI, a cleverly named partnership between the USGS, Association of American State Geologists, and state geological surveys to better understand America's geology and mineral resource potential through new mapping, geophysics, and geochemical sampling.

USGS says the new Earth MRI surveys of Alaska are a key step in securing a reliable and sustainable supply of the critical minerals and metals that power everything from smartphones and household appliances to clean energy technologies like electric vehicle batteries and wind turbines.

"All the way back to the days of the Gold Rush, Alaska has been famous for its mineral wealth. These new projects represent the next steps in understanding the mineral potential for commodities that are critical to our national economy and defense," said USGS Director David Applegate.

Exploring the Yukon-Tanana Upland

While best known for its rich gold endowment, including being home to Kinross Gold Corp.'s Fort Knox Mine near Fairbanks and Northern Star Resources Ltd.'s Pogo Mine near Delta Junction, the Yukon-Tanana Upland is a past producer and future domestic source of many of the minerals and metals considered critical to the U.S.

Antimony, bismuth, platinum group metals, rare earth elements, tin, and tungsten are among the critical metals known to be found in potentially economic quantities across this roughly Maine-sized region of eastern Alaska.

This 100-mile-wide swath of Interior Alaska that extends about 300 miles west from the Yukon border to the town of Tanana at the confluence of the Yukon and Tanana rivers offers up another advantage when it comes to being a domestic source of critical minerals – excellent transportation infrastructure. This includes the Alaska Highway, which transects the Yukon-Tanana Upland from the Canadian border to the city of Fairbanks; a road that extends further west to Tanana; several highways that extend both north and south; and the Alaska Railroad that runs from Fairbanks to the port town of Seward.

This readily available access will make it easier and less expensive to transport metals from future critical mineral mines to market.

With the new Earth MRI funding, DGGS will focus on geologic mapping for critical mineral commodities in an area of the Yukon-Tanana Upland near Alaska's border with Canada's Yukon Territory.

The geologic mapping efforts, which are managed through the USGS National Cooperative Geologic Mapping Program, will refine our understanding of the geology underlying areas of interest.

In addition to gaining a better understanding of the critical mineral potential, USGS says these maps will support decisions about land use; provide information on water, energy, and minerals resources; and can help mitigate the impact of geologic hazards on communities.

Western Alaska geophysics

DGGS and USGS are also carrying out airborne magnetic and radiometric surveys of the Kuskokwim River region of Southwest, which has potential for antimony, gold, rare earths, tin, tungsten, and other critical minerals, and an airborne electromagnetic survey over the Seward Peninsula in areas with potential for graphite.

Several critical mineral prospects – including occurrences with antimony, arsenic, bismuth, niobium, rare earths, tin, and tungsten have been identified in the Kuskokwim Mountains.

The Earth MRI magnetic and radiometric geophysical surveys flown over the Kuskokwim region will provide geologists with data on the magnetic levels of natural radioactivity in the rocks, which will help pinpoint areas for further exploration for critical minerals.

The Seward Peninsula survey will primarily be looking for graphite, and for good reasons.

It is forecast that by 2030 the world will need roughly 5 million metric tons of graphite per year for the lithium-ion batteries going into electric vehicles. This compares to only about 1 million metric tons that were mined globally to meet the demands of all industrial sectors during 2021, according to "Mineral Commodity Summaries 2022," an annual report published by the USGS.

The Graphite Creek project on the Seward Peninsula, which is being advanced toward production by Graphite One Inc., is the largest known deposit of graphite in the U.S.

Airborne electromagnetic surveys, such as those to be flown over the Seward Peninsula as part of Earth MRI, help identify areas that are electrically conductive, such as areas with near-surface graphite.

In addition, USGS says the data compiled from these surveys can also be used to locate geothermal energy resources, groundwater resources, and potential earthquake hazards in the region.

"Data provided through these projects will have many applications and will create a foundation for better understanding of mineral and geothermal resources, earthquake hazard potential, carbon storage capacity and many other geoscience opportunities," said Applegate.

Part of a larger Alaska strategy

The 2022 Bipartisan Infrastructure Law provided the USGS with an additional US$74 million in funding to Earth MRI for accelerated mapping in areas with potential for hosting critical mineral resources both still in the ground and mine waste. Overall, the Infrastructure Law is providing a $510.7 million investment to USGS to advance scientific innovation and map critical minerals.

Given its known rich mineral endowment, even with being less explored and mapped than other states, Alaska is one of four priority regions in the U.S. being explored under Earth MRI

The critical mineral commodities that are included in the Yukon-Tanana Uplands, Kuskokwim, and Seward Peninsula research projects are:

• **Arsenic** – used in lumber preservatives, pesticides, and semiconductors

• **Antimony** – used in flame-proofing compounds, alloys, and rechargeable batteries.

• **Bismuth** – Stomach remedies, weighting agent, solar power and atomic research.

• **Cobalt** – used in rechargeable batteries and superalloys.

• **Graphite** – used for lubricants, lithium batteries, and fuel cells.

• **Indium** – mostly used in LCD screens for smartphones, monitors, and televisions.

• **Platinum group metals** – used for catalytic agents.

• **Rare earths** – primarily used in magnets, batteries, and electronics.

• **Tantalum** – used in electronic components, mostly capacitors, and in superalloys.

• **Tellurium** – used in solar cells, thermoelectric devices, and as a steelmaking alloy.

• **Tin** – used as protective coatings, alloys for steel, and solder for electronics.

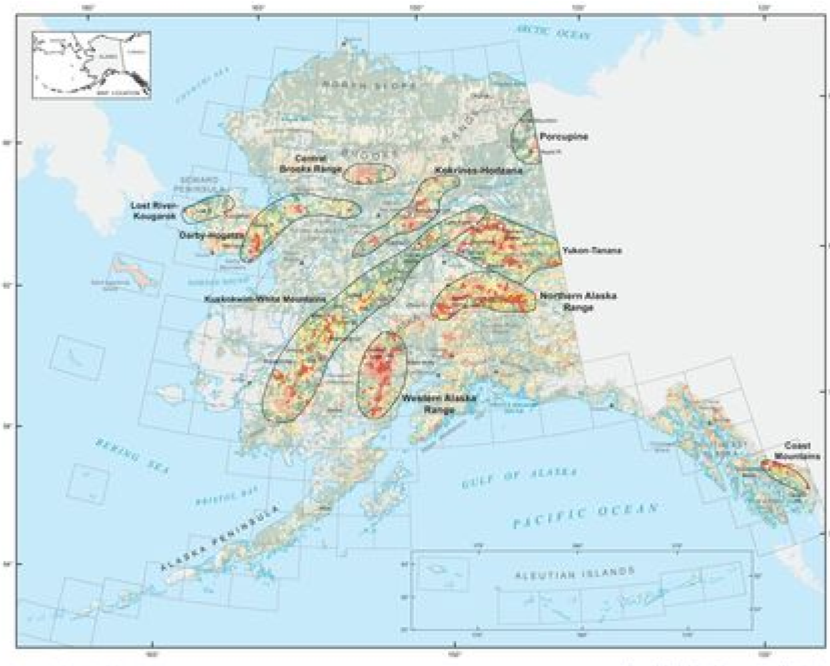
• **Tungsten** – primarily used to make wear-resistant metals.

In addition to the Yukon-Tanana Uplands, Kuskokwim, and Seward Peninsula, USGS announced updates to two reports representing Earth MRI investigations on Alaska's potential for 38 of the 50 minerals and metals critical to the U.S.

These reports can be accessed at the links below:

Focus Areas for Data Acquisition for Potential Domestic Resources of 11 Critical Minerals in Alaska-Aluminum, Cobalt, Graphite, Lithium, Niobium, Platinum Group Elements, Rare Earth Elements, Tantalum, Tin, Titanium, and Tungsten.

Alaska Focus Area Definition for Data Acquisition for Potential Domestic Sources of Critical Minerals in Alaska for Antimony, Barite, Beryllium, Chromium, Fluorspar, Hafnium, Magnesium, Manganese, Uranium, Vanadium, and Zirconium.



U.S. Geological Survey

A 2018 USGS map of areas of Alaska prospective for tin. More than 20 minerals and metals critical to the U.S. have been found associated with over 100 alluvial and hardrock tin occurrences that have been identified across the Last Frontier.

**EDITOR'S NOTE: At the time of the original publication of these updated reports, rare earth elements and platinum group elements were each considered as one critical mineral. The 2022 U.S. Critical Minerals list includes 14 rare earths and elements, as well as five platinum group elements listed individually, which accounts for the 38 critical minerals. Also, uranium is not included on the critical minerals list due to being considered a fuel mineral, which falls outside the definition of minerals critical to the United States.*

Further details on the 2022 critical minerals list can be read at USGS finalizes 2022 critical minerals list in the February 23, 2022 edition of Metal Tech News.

Information on proposed legislation that would allow uranium to be added back to the U.S. critical minerals list can be found at Without a word uranium becomes critical in the July 6, 2022 edition of Metal Tech News.

Author Bio

Shane Lasley, Publisher

Over his more than 15 years of covering mining and mineral exploration, Shane has become renowned for his ability to report on the sector in a way that is technically sound enough to inform industry insiders while being easy to understand by a wider audience.

Email: publisher@miningnewsnorth.com
Phone: (907) 726-1095
https://www.linkedin.com/in/shane-lasley-ab073b12/

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Robert F. Service ⁝ 19-25 minutes
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SYDNEY, BRISBANE, AND MELBOURNE, AUSTRALIA—The ancient, arid landscapes of Australia are fertile ground for new growth, says Douglas MacFarlane, a chemist at Monash University in suburban Melbourne: vast forests of windmills and solar panels. More sunlight per square meter strikes the country than just about any other, and powerful winds buffet its south and west coasts. All told, Australia boasts a renewable energy potential of 25,000 gigawatts, one of the highest in the world and about four times the planet's installed electricity production capacity. Yet with a small population and few ways to store or export the energy, its renewable bounty is largely untapped.

That's where MacFarlane comes in. For the past 4 years, he has been working on a fuel cell that can convert renewable electricity into a carbon-free fuel: ammonia. Fuel cells typically use the energy stored in chemical bonds to make electricity; MacFarlane's operates in reverse. In his third-floor laboratory, he shows off one of the devices, about the size of a hockey puck and clad in stainless steel. Two plastic tubes on its backside feed it nitrogen gas and water, and a power cord supplies electricity. Through a third tube on its front, it silently exhales gaseous ammonia, all without the heat, pressure, and carbon emissions normally needed to make the chemical. "This is breathing nitrogen in and breathing ammonia out," MacFarlane says, beaming like a proud father.

Companies around the world already produce $60 billion worth of ammonia every year, primarily as fertilizer, and MacFarlane's gizmo may allow them to make it more efficiently and cleanly. But he has ambitions to do much more than help farmers. By converting renewable electricity into an energy-rich gas that can easily be cooled and squeezed into a liquid fuel, MacFarlane's fuel cell effectively bottles sunshine and wind, turning them into a commodity that can be shipped anywhere in the world and converted back into electricity or hydrogen gas to power fuel cell vehicles. The gas bubbling out of the fuel cell is colorless, but environmentally, MacFarlane says, ammonia is as green as can be. "Liquid ammonia is liquid energy," he says. "It's the sustainable technology we need."

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Ammonia—one nitrogen atom bonded to three hydrogen atoms—may not seem like an ideal fuel: The chemical, used in household cleaners, smells foul and is toxic. But its energy density by volume is nearly double that of liquid hydrogen—its primary competitor as a green alternative fuel—and it is easier to ship and distribute. "You can store it, ship it, burn it, and convert it back into hydrogen and nitrogen," says Tim Hughes, an energy storage researcher with manufacturing giant Siemens in Oxford, U.K. "In many ways, it's ideal."

Researchers around the globe are chasing the same vision of an "ammonia economy," and Australia is positioning itself to lead it. "It's just beginning," says Alan Finkel, Australia's chief scientist who is based in Canberra. Federal politicians have yet to offer any major legislation in support of renewable ammonia, Finkel says, perhaps understandable in a country long wedded to exporting coal and natural gas. But last year, the Australian Renewable Energy Agency declared that creating an export economy for renewables is one of its priorities. This year, the agency announced AU$20 million in initial funds to support renewable export technologies, including shipping ammonia.

Australia's windy coasts offer a bounty of energy, which it might one day export as a carbon-free fuel.

COAST PROTECTION BOARD, SOUTH AUSTRALIA

In Australia's states, politicians see renewable ammonia as a potential source of local jobs and tax revenues, says Brett Cooper, chairman of Renewable Hydrogen, a renewable fuels consulting firm in Sydney. In Queensland, officials are discussing creating an ammonia export terminal in the port city of Gladstone, already a hub for shipping liquefied natural gas to Asia. In February, the state of South Australia awarded AU$12 million in grants and loans to a renewable ammonia project. And last year, an international consortium announced plans to build a US$10 billion combined wind and solar plant known as the Asian Renewable Energy Hub in Western Australia state. Although most of the project's 9000 megawatts of electricity would flow through an undersea cable to power millions of homes in Indonesia, some of that power could be used to generate ammonia for long-distance export. "Ammonia is the key enabler for exporting renewables," says David Harris, research director for low-emissions technologies at Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) Energy in Pullenvale. "It's the bridge to a whole new world."

Advertisement

First, however, the evangelists for renewable ammonia will have to displace one of the modern world's biggest, dirtiest, and most time-honored industrial processes: something called Haber-Bosch.

The ammonia factory, a metallic metropolis of pipes and tanks, sits where the red rocks of Western Australia's Pilbara Desert meet the ocean. Owned by Yara, the world's biggest producer of ammonia, and completed in 2006, the plant is still gleaming. It is at the technological vanguard and is one of the largest ammonia plants in the world. Yet at its core are steel reactors that still use a century-old recipe for making ammonia.

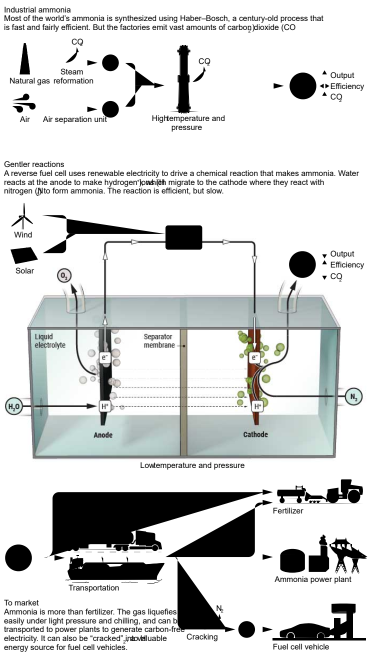
Until 1909, nitrogen-fixing bacteria made most of the ammonia on the planet. But that year, German scientist Fritz Haber found a reaction that, with the aid of iron catalysts, could split the tough chemical bond that holds together molecules of nitrogen, N_2, and combine the atoms with hydrogen to make ammonia. The reaction takes brute force—up to 250 atmospheres of pressure in the tall, narrow steel reactors—a process first industrialized by German chemist Carl Bosch. The process is fairly efficient; about 60% of the energy put into the plant ends up being stored in the ammonia's bonds. Scaled up to factories the size of Yara's, the process can produce vast amounts of ammonia. Today, the facility makes and ships 850,000 metric tons of ammonia per year—more than double the weight of the Empire State Building.

Most is used as fertilizer. Plants crave nitrogen, used in building proteins and DNA, and ammonia delivers it in a biologically available form. Haber-Bosch reactors can churn out ammonia much faster than natural processes can, and in recent decades the technology has enabled farmers to feed the world's exploding population. It's estimated that at least half the nitrogen in the human body today comes from a synthetic ammonia plant.

Haber-Bosch led to the Green Revolution, but the process is anything but green. It requires a source of hydrogen gas (H_2), which is stripped away from natural gas or coal in a reaction using pressurized, super-heated steam. Carbon dioxide (CO_2) is left behind, accounting for about half the emissions from the overall process. The second feedstock, N_2, is easily separated from air, which is 78% nitrogen. But generating the pressure needed to meld hydrogen and nitrogen in the reactors consumes more fossil fuels, which means more CO_2. The emissions add up: Ammonia production consumes about 2% of the world's energy and generates 1% of its CO_2.

A green way to make ammonia

Reverse fuel cells can use renewable power to make ammonia from air and water, a far more environmentally friendly technique than the industrial Haber-Bosch process. Renewable ammonia could serve as fertilizer—ammonia's traditional role—or as an energy-dense fuel.



V. ALTOUNIAN/*SCIENCE*

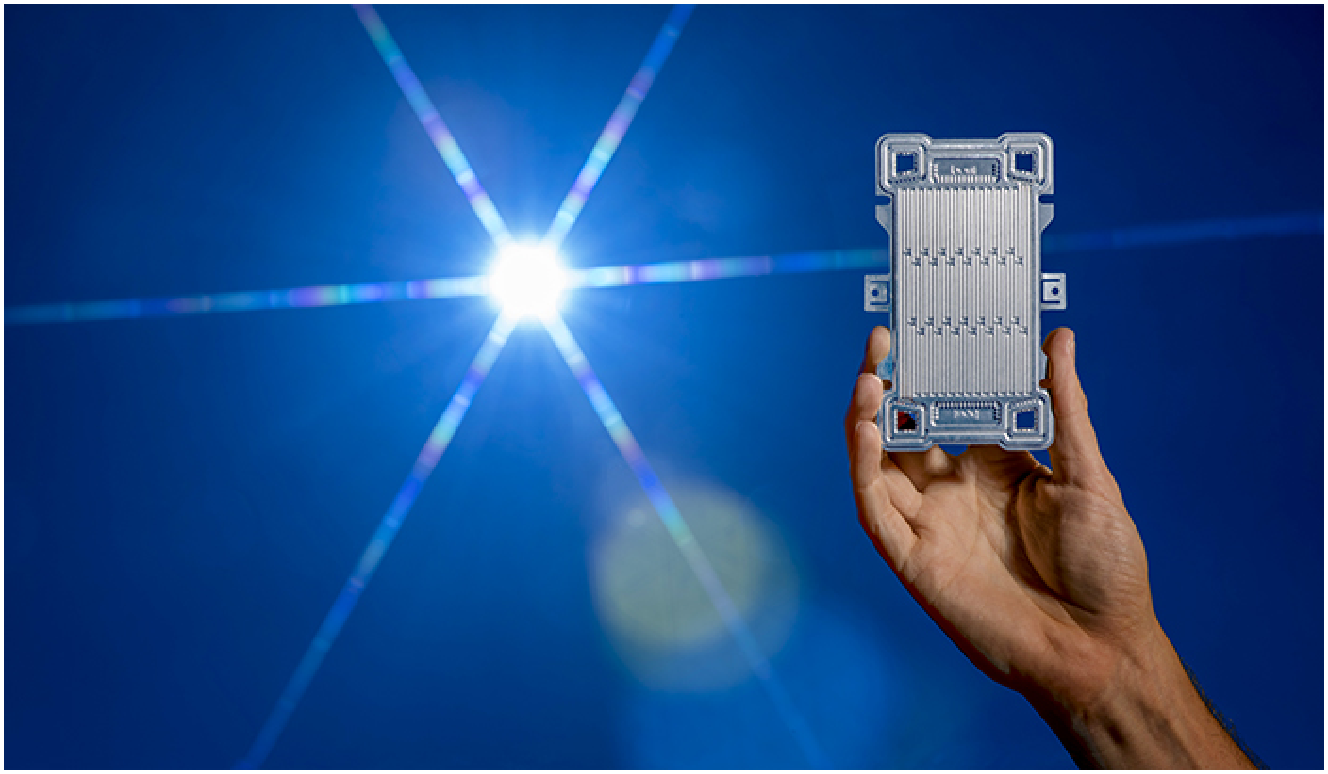
Yara is taking a first step toward greening that process with a pilot plant, set to open in 2019, that will sit next to the existing Pilbara factory. Instead of relying on natural gas to make H_2, the new add-on will feed power from a 2.5-megawatt solar array into a bank of electrolyzers, which split water into H_2 and O_2. The facility will still rely on the Haber-Bosch reaction to combine the hydrogen with nitrogen to make ammonia. But the solar-powered hydrogen source cuts total CO_2 emissions from the process roughly in half.

Other projects are following suit. The state of South Australia announced plans in February to build a AU$180 million ammonia plant, again relying on electrolyzers powered by renewable energy. Slated to open in 2020, the plant would be a regional source of fertilizer and liquid ammonia, which can be burned in a turbine or run through a fuel cell to make electricity. The supply of liquid energy will help stabilize the grid in South Australia, which suffered a debilitating blackout in 2016.

Ammonia made this way should attract buyers in places such as the European Union and California, which have created incentives to buy greener fuels. And as the market grows, so will the distribution routes for importing ammonia and the technologies for using it, Harris says. By then, fuel cells like MacFarlane's could be ready to displace Haber-Bosch itself—and the half-green approach to ammonia production could become fully green.

Instead of applying fearsome heat and pressure, reverse fuel cells make ammonia by deftly wrangling ions and electrons. As in a battery being charged, charged ions flow between two electrodes supplied with electricity. The anode, covered with a catalyst, splits water molecules into O_2, hydrogen ions, and electrons. The protons flow through an electrolyte and a proton-permeable membrane to the cathode, while the electrons make the journey through a wire. At the cathode, catalysts split N_2 molecules and prompt the hydrogen ions and electrons to react with nitrogen and make ammonia.

At present, the yields are modest. At room temperature and pressure, the fuel cell reactions generally have efficiencies of between 1% and 15%, and the throughput is a trickle. But MacFarlane has found a way to boost efficiencies by changing the electrolyte. In the water-based electrolyte that many groups use, water molecules sometimes react with electrons at the cathode, stealing electrons that would otherwise go into making ammonia. "We're constantly fighting having the electrons going into hydrogen," MacFarlane says.



A component in a reverse fuel cell uses renewable power to knit together water and nitrogen to make ammonia.

STEVEN MORTON/FELLOW OF THE ROYAL PHOTOGRAPHIC SOCIETY

To minimize that competition, he opted for what's called an ionic liquid electrolyte. That approach allows more N_2 and less water to sit near the catalysts on the cathode, boosting the ammonia production. As a result, the efficiency of the fuel cell skyrocketed from below 15% to 60%, he and his colleagues reported last year in *Energy & Environmental Science*. The result has since improved to 70%, MacFarlane says—but with a tradeoff. The ionic liquid in his fuel cell is goopy, 10 times more viscous than water. Protons have to slog their way to the cathode, slowing the rate of ammonia production. "That hurts us," MacFarlane says.

To speed things up, MacFarlane and his colleagues are toying with their ionic liquids. In a study published in April in *ACS Energy Letters*, they report devising one rich in fluorine, which helps protons pass more easily and speeds ammonia production by a factor of 10. But the production rate still needs to rise by orders of magnitude before his cells can meet targets, set for the field by the U.S. Department of Energy (DOE), that would begin to challenge Haber-Bosch.

Next to Monash University, Sarb Giddey and his colleagues at the Clayton offices of CSIRO Energy are making ammonia with their "membrane reactor." It relies on high temperatures and modest pressures—far less than those in a Haber-Bosch reactor—that, compared to MacFarlane's cell, boost throughput while sacrificing efficiency. The reactor designs call for a pair of concentric long metallic tubes, heated to 450°C. Into the narrow gap between the tubes flows H_2, which could be made by a solar- or wind-powered electrolyzer. Catalysts lining the gap split the H_2 molecules into individual hydrogen atoms, which modest pressures then force through the atomic lattice of the inner tube wall to its hollow core, where piped-in N_2 molecules await. A catalytically active metal such as palladium lines the inner surface, splitting the N_2 and coaxing the hydrogen and nitrogen to combine into ammonia—much faster than in MacFarlane's cell. So far only a small fraction of the input H_2 reacts in any given pass—another knock to the reactor's efficiency.

Other approaches are in the works. At the Colorado School of Mines in Golden, researchers led by Ryan O'Hayre are developing button-size reverse fuel cells. Made from ceramics to withstand high operating temperatures, the cell can synthesize ammonia at record rates—about 500 times faster than MacFarlane's fuel cell. Like Giddey's membrane reactors, the ceramic fuel cells sacrifice some efficiency for output. Even so, O'Hayre says, they still need to improve production rates by another factor of 70 to meet the DOE targets. "We have a lot of ideas," O'Hayre says.

Whether any of those approaches will wind up being both efficient and fast is still unknown. "The community is still trying to figure out what direction to go," says Lauren Greenlee, a chemical engineer at the University of Arkansas in Fayetteville. Grigorii Soloveichik, a manager in Washington, D.C., for the DOE's Advanced Research Projects Agency-Energy program on making renewable fuels, agrees. "To make [green] ammonia is not hard," he says. "Making it economically on a large scale is hard."

“

It looks like there's enough interest to get this industry started.

- David Harris, CSIRO Energy

However distant, the prospect of Asia-bound tankers, full of green Australian ammonia, raises the next question. "Once you get ammonia to market, how do you get the energy out of it?" asks Michael Dolan, a chemist at CSIRO Energy in Brisbane.

The simplest option, Dolan says, is to use the green ammonia as fertilizer, like today's ammonia but without the carbon penalty. Beyond that, ammonia could be converted into electricity in a power plant customized to burn ammonia, or in a traditional fuel cell, as the South Australia plant plans to do. But currently, ammonia's highest value is as a rich source of hydrogen, used to power fuel cell vehicles. Whereas ammonia fertilizer sells for about $750 a ton, hydrogen for fuel cell vehicles can go for more than 10 times that amount.

In the United States, fuel cell cars seem all but dead, vanquished by battery-powered vehicles. But Japan is still backing fuel cells heavily. The country has spent more than US$12 billion on hydrogen technology as part of its strategy to reduce fossil fuel imports and meet its commitment to reduce CO_2 emissions under the Paris climate accord. Today the country has only about 2500 fuel cell vehicles on the road. But by 2030 Japanese officials expect 800,000. And the nation is eyeing ammonia as a way to fuel them.

Converting hydrogen into ammonia only to convert it back again might seem strange. But hydrogen is hard to ship: It has to be liquefied by chilling it to temperatures below −253°C, using up a third of its energy content. Ammonia, by contrast, liquefies at −10°C under a bit of pressure. The energy penalty of converting the hydrogen to ammonia and back is roughly the same as chilling hydrogen, Dolan says—and because far more infrastructure already exists for handling and transporting ammonia, he says, ammonia is the safer bet.

That last step—stripping hydrogen off ammonia molecules—is what Dolan and his colleagues are working on. In a cavernous metal warehouse on the CSIRO campus that has long been used to study coal combustion, two of Dolan's colleagues are assembling a 2-meter-tall reactor that is dwarfed by a nearby coal reactor. When switched on, the reactor will "crack" ammonia into its two constituents: H_2, to be gathered up for sale, and N_2, to waft back into the air.

That reactor is basically a larger version of Giddey's membrane reactor, operating in reverse. Only here, gaseous ammonia is piped into the space between two concentric metal tubes. Heat, pressure, and metal catalysts break apart ammonia molecules and push hydrogen atoms toward the tube's hollow core, where they combine to make H_2 that's sucked out and stored.

Ultimately, Dolan says, the reactor will produce 15 kilograms per day of 99.9999% pure hydrogen, enough to power a few fuel cell cars. Next month, he plans to demonstrate the reactor to automakers, using it to fill tanks in a Toyota Mirai and Hyundai Nexo, two fuel cell cars. He says his team is in late-stage discussions with a company to build a commercial pilot plant around the technology. "This is a very important piece of the jigsaw puzzle," Cooper says.

Beyond 2030, Japan will likely import between $10 billion and $20 billion of hydrogen each year, according to a renewable energy roadmap recently published by Japan's Ministry of Economy, Trade and Industry. Japan, Singapore, and South Korea have all begun discussions with Australian officials about setting up ports for importing renewably produced hydrogen or ammonia. "How it all comes together economically, I don't know," Harris says. "But it looks like there's enough interest to get this industry started."

Cooper knows how he wants it to end. Over coffee on a rainy morning in Sydney, he describes his futuristic vision for renewable ammonia. When he squints, he can see, maybe 30 years down the road, Australia's coast dotted with supertankers, docked at offshore rigs. But they wouldn't be filling up with oil. Seafloor powerlines would carry renewable electricity to the rigs from wind and solar farms on shore. On board, one device would use the electricity to desalinate seawater and pass the fresh water to electrolyzers to produce hydrogen. Another device would filter nitrogen from the sky. Reverse fuel cells would knit the two together into ammonia for loading on the tankers—a bounty of energy from the sun, air, and sea.

It's the dream that nuclear fusion never reached, he says: inexhaustible carbon-free power, only this time from ammonia. "It can never run out, and there is no carbon in the system."