JUNE 16, 2021

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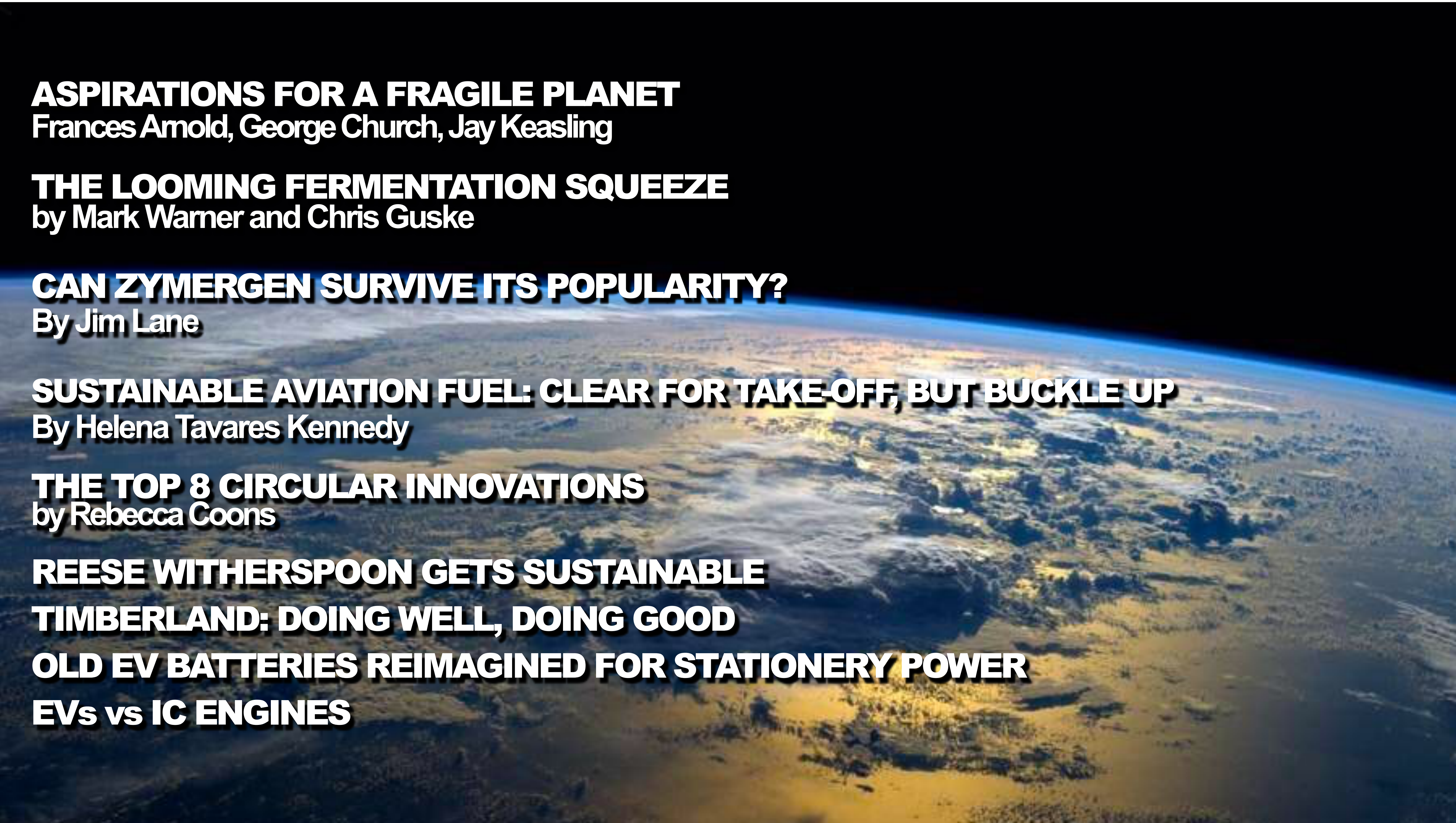

ASPIRATIONS FOR A FRAGILE PLANET
Frances Arnold, George Church, Jay Keasling

THE LOOMING FERMENTATION SQUEEZE
by Mark Warner and Chris Guske

CAN ZYMERGEN SURVIVE ITS POPULARITY?
By Jim Lane

SUSTAINABLE AVIATION FUEL: CLEAR FOR TAKE-OFF, BUT BUCKLE UP
By Helena Tavares Kennedy

THE TOP 8 CIRCULAR INNOVATIONS
by Rebecca Coons

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THE TOP 8 CIRCULAR INNOVATIONS

By Rebecca Coons

1. Lab-grown lamb: don't be sheepish about ordering chops: In Australia, a cultured meat startup has claimed production of the world's first lab-grown lamb. Magic Valley is prototyping lab mince, strips, steaks, and chops.

2. Living architecture, in-home algae farms: Bit.Bio.Bot, designed by London's EcoLogicStudio, consists of algae bioreactor sheets and a vertical garden.

3. Coconut cooler startup raises cash: Fortuna Cools is repurposing coconut waste into biodegradable coolers. Coconut Cooler are meant to replace Styrofoam alternatives used by food distributors.

4. Denmark funds grass-based packaging efforts: SinProPack hopes their efforts could eventually displace the more than 10,000 tons of plastic packaging.

5. In Mexico City, a trio of designers has created a biodegradable razor made from partially renewable plastics. Dubbed Oquari, the razor is made with PBS Bionelle biodegradable plastic.

6. SEALIVE has received EU funding to help prevent maritime harm due to ghost nets—fishing nets that are lost or abandoned by fisherman but still trap and kill marine life.

7. In Germany, skincare brand Beiersdorf has started using biobased polypropylene jars for its popular Nivea face cream. The jars are made from tall oil, a forestry industry byproduct.

8. Dell Technologies is using biobased materials in the casings for its Precision and Latitude series of laptops. The Precision 3560 and Latitude 5320 are the first in Dell's portfolio to use bioplastic from tree waste.

REESE WITHERSPOON

Synthetic biology pioneer Amyris has partnered with acting powerhouse Reese Witherspoon to promote clean beauty products. Witherspoon, whose credits include *Walk the Line* and *Legally Blonde* will be the global brand ambassador for Amyris's Biossance line of sustainable skincare products.

"I have always been conscious of what's being put on my skin, but after all the time I've spent on-sets throughout my career, I've learned so much," Witherspoon said.

"As my knowledge has grown so has my desire to use clean and consciously created products. I not only fell in love with Biossance's products. My skin has never felt healthier and I'm proud to work with such a strong industry leader in sustainability and care for our planet."

PRODUCT OF THE WEEK: IMPOSSIBLE BURGER PATTIES

Just in time for Summer: Impossible Burger frozen patties are hitting the frozen meat aisles at grocery stores nationwide. Impossible Burger is so beefy, it now comes in a juicy 6-pack. Each patty is packed with 19 g protein per 4 oz serving (same amount of protein as ground beef from cows) but with no animal hormones or antibiotics. Impossible Burger cooks, sizzles, and tastes like ground beef from cows.*

TIMBERLAND IS DOING WELL, DOING GOOD WITH FATES™ ECO-FOAM

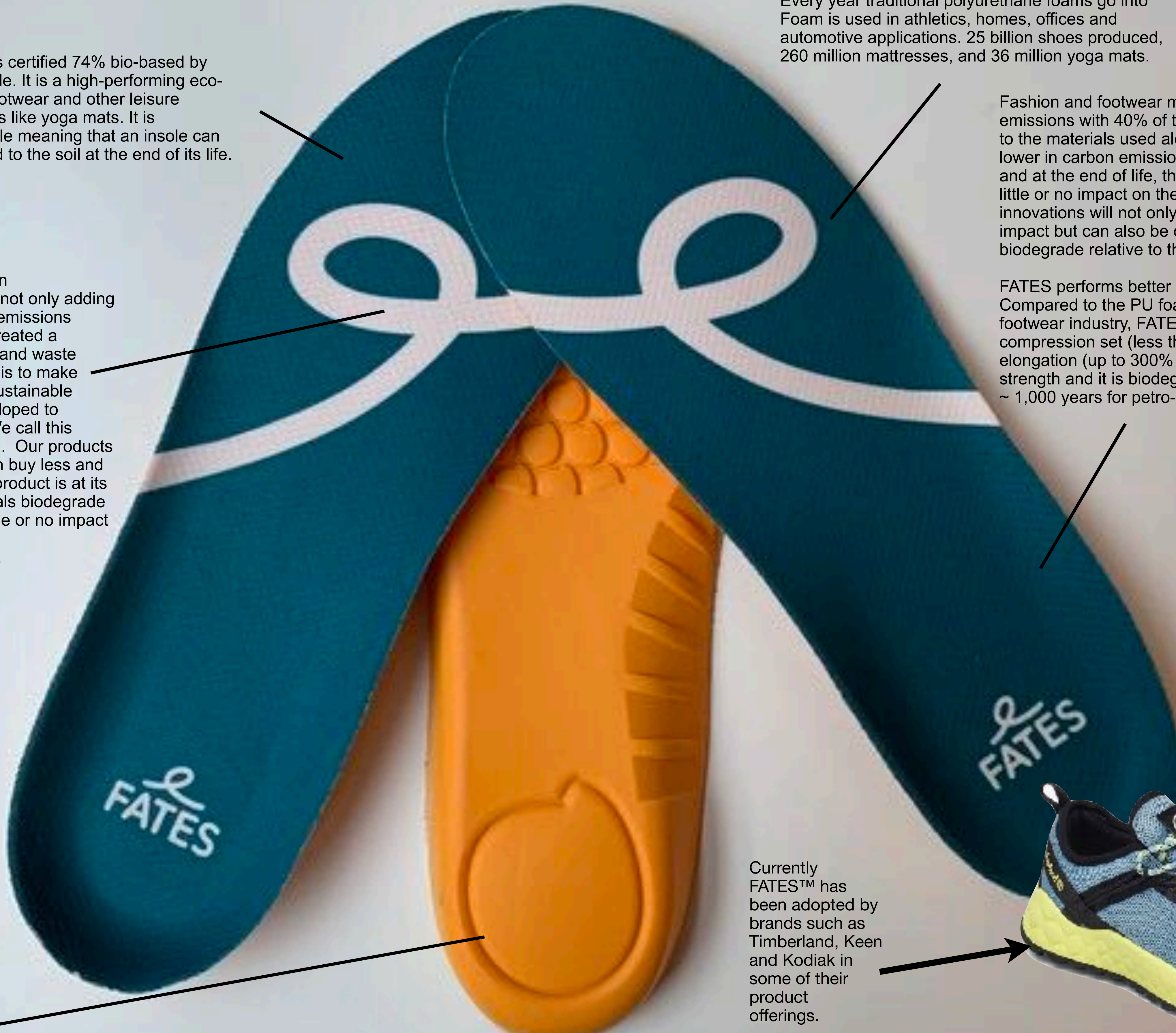
Every year traditional polyurethane foams go into Foam is used in athletics, homes, offices and automotive applications. 25 billion shoes produced, 260 million mattresses, and 36 million yoga mats.

FATES™ is certified 74% bio-based by Green Circle. It is a high-performing eco-foam for footwear and other leisure applications like yoga mats. It is compostable meaning that an insole can be returned to the soil at the end of its life.

Fashion and footwear make up 10% of global emissions with 40% of those emissions attributed to the materials used alone. FATES™ is 300% lower in carbon emissions than traditional foam and at the end of life, the materials degrade with little or no impact on the environment. New innovations will not only reduce FATES™' carbon impact but can also be designed to perform and biodegrade relative to the application.

"Fast fashion based on hyperconsumerism is not only adding to the world's carbon emissions problem, it has also created a catastrophic pollution and waste issue. The alternative is to make products from more sustainable sources that are developed to perform and to last. We call this enduring performance. Our products last longer, so you can buy less and when the material or product is at its end of life, our materials biodegrade naturally with negligible or no impact on the environment."
- JASON ROBINSON,
CEO, EVOCO

FATES performs better than the alternatives. Compared to the PU foam commonly used in the footwear industry, FATES has 5 times better compression set (less than 5%), superior elongation (up to 300% more), increased tensile strength and it is biodegradable in 2 to 5 years vs ~ 1,000 years for petro-based foams.



Evoco uses plant-based chemistry to make renewable materials and products. Throughout the supply chain, they remove hazardous additive chemicals like heavy metals and solvents.

Currently FATES™ has been adopted by brands such as Timberland, Keen and Kodiak in some of their product offerings.

Six science and technology innovators from across the United States will join the fifth cohort of Oak Ridge National Laboratory's Innovation Crossroads program in June. As the Southeast's only research and development program for entrepreneurs based at a U.S. Department of Energy national laboratory, Innovation Crossroads provides unique support to science-based startups to help advance game-changing technologies from the laboratory to the marketplace.

Caleb Alexander: Sodium ion membrane for high energy, low-cost sodium-air battery. Alexander holds a doctorate in chemical engineering from the University of Texas.

Sam Evans: Carbon supported magnetic nano-absorbent. Evans holds a doctorate in energy science and engineering from the University of Tennessee, Knoxville.

Tommy Gibbons: Energy-efficient, carbon-negative, bio-based insulation. Gibbons holds an undergraduate degree in public policy from Princeton University and is a certified green associate from the Leadership in Energy and Environmental Design.

Shuchi "SK" Khurana: Real-time monitoring of metal additive manufacturing. Khurana holds master's degrees in business administration and science from Ohio State University.

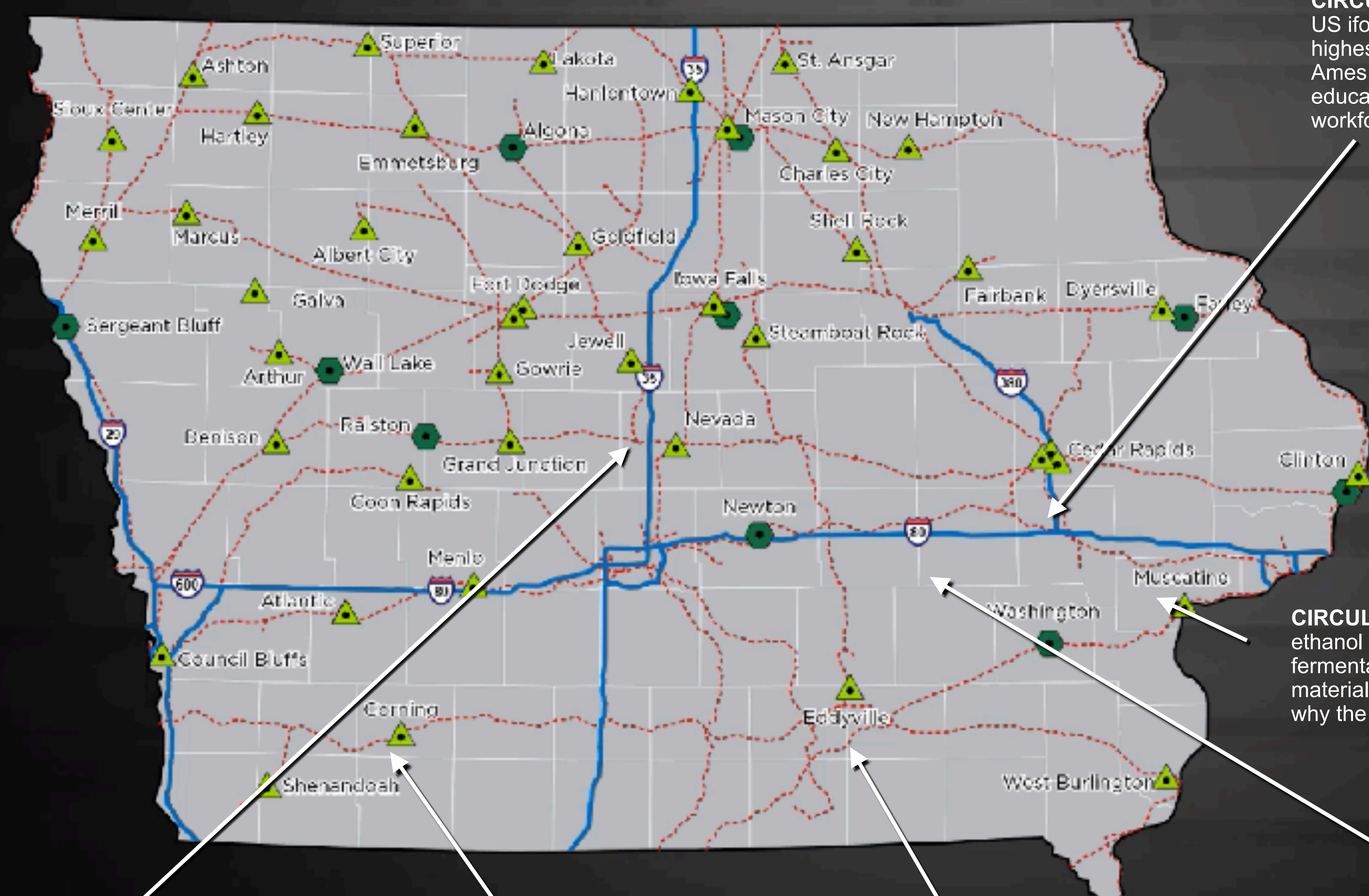
Forrest Shriver: Database construction using machine learning for cyber-attack detection . Shriver holds a doctorate in nuclear engineering from the University of Florida.

Philip Stuckey: 3D hierarchical separator and catalyst support system for fuel cells . Stuckey holds a doctorate in chemical engineering from Case Western Reserve University.

CIRCULAR IOWA REVEALED

When Cargill VP Jill Zullo explained why Cargill and HELM AG chose to put the flagship biobased BDO plant in Eddyville, Iowa — it was partly about the raw materials but the story has become vastly more sophisticated in recents years. Zullo told CIRCULAR, “throughout the pandemic we were able to keep this new product line at a 93 percent reduction in greenhouse gas emissions, and the reason for that was Iowa and Eddyville”

CIRCULAR MEANS EDUCATION. Iowa ranks #1 in the US ifor High School Graduation Rate and has the 3rd highest 4-year College graduation rate. Making towns like Ames and Iowa City a happy hunting ground for highly-educated R&D, operators, sales, finance and supply chain workforce.



CIRCULAR MEANS INFRASTRUCTURE. Iowa ranks #1 in US ethanol production and #1 in biodiesel production, providing critical fermentation capacity not only for fuels but for pharmaceuticals, materials, intermediate chemicals and foods. One of the reasons why the spider silk developer Spiber is scaling up in Clinton.

CIRCULAR MEANS ADVANCED MANUFACTURING. Manufacturing represents 17.6% of Iowa’s GDP and employs 15% of Iowa total workforce. One of the reasons why the US entered part of its 10th Manufacturing US Institute at Iowa State.

CIRCULAR MEANS AFFORDABLE RAW MATERIALS. Iowa ranks #2 in biomass capacity.

It’s about getting feedstocks, but also about amazing practices, access to wind power, a team built around Cargill’s historically first fermentation facility that has tremendous experience. For this intermediate for the apparel, authomoribe, electronics and packaging industry, we think we can get this down even past that 93 percent reduction. But already, people will know they don’t have to choose any longer between the products they love and clear skies.”

CIRCULAR MEANS AFFORDABLE LOW-CARBON POWER. Iowa ranks #1 in Renewable energy capacity - 11,780 MW. 53% of Iowa power comes from renewable energy.

1 in 3 U.S. Consumers Would Do All Their Shopping At A Sustainable Clothing Store, If Only One Existed

A new survey of 2,000 teenagers and adults in the U.S. from clean manufacturing leader

Genomatica set out to understand consumers' awareness, perspectives and behaviors around sustainability in fashion, finding that 86% of consumers believe sustainability is a good goal, yet nearly half (48%) don't know how or where to find sustainable clothes and 42% are confused about what makes clothing sustainable.

Key findings were:

• Nearly 3 in 4 (72%) consumers have heard of environmental sustainability issues in the fashion industry — listing excess consumption, carbon emissions and water pollution from dye processes as issues they're aware of.

• Half (51%) believe that Americans' clothing purchases each year result in substantial greenhouse gas emissions. The pandemic may have helped grow consumer awareness: 38% who are aware of sustainability issues in fashion have only become aware of them over the past year.

Consumers want to make better choices, but they're confused about what makes clothing sustainable and how or where to find it

Half (52%) of consumers believe sustainability is important and they consciously make choices to be more sustainable and 47% want to make more sustainable clothing choices, but they give into what's more convenient.

• 55% are interested in purchasing so-called "sustainable clothing," but 48% don't know how or where to find sustainable clothes and 42% are confused about what actually makes clothing sustainable.

• Over a third (34%) say, "If there was a store for sustainable clothes, I'd do all my shopping there," about the same number (33%) who say availability in chain clothing stores would make them want to purchase sustainable clothing. 31% would even support a "fast fashion tax" on clothing that's unsustainable.

One respondent said it plainly: "It's somewhat difficult to make sustainable choices because I'm never really sure what sustainable means, particularly with clothing." Another said: "It's kind of hard to make sustainable choices because most companies where I live aren't making sustainable clothes.

How clothing is made and what it's made from are important considerations for consumers

• 58% of consumers care about the materials that make their clothes and want them to not be harmful to the planet.

- Nearly half (47%) rank clothing made with renewably-sourced or natural materials as a top sustainability characteristic, with around the same percent (46%) that list production processes with few to no toxic chemicals in their top three.
- 53% of consumers believe the majority of clothes are made of primarily synthetic material, slightly more than the number of consumers (47%) who realize fossil fuels (crude oil, coal, etc.) are the main building blocks of synthetic clothing.

Other findings from the study include:

Consumers are on the lookout for "greenwashing" in the fashion industry, but they still want brands to do the legwork to make sustainable choices easier

• Nearly 9 in 10 (88%) consumers don't immediately trust brands that say they are sustainable and half (51%) believe "greenwashing" is common in the fashion industry.

• 55% want clothing brands to help them understand how their products are more sustainable than alternatives.

• Half (50%) say that a sustainability label would help them identify sustainable clothes while shopping, and 38% say clearer information about sustainability features would make them want to purchase sustainable clothing.

• 44% believe brands are to blame for not prioritizing or providing enough convenient sustainable alternatives.

The COVID-19 pandemic has changed consumer purchasing behaviors around clothing

• During the pandemic, 44% of consumers say they purchased less clothing compared to before the pandemic, with more women saying so (50%) than men (39%).

• Nearly 1 in 3 (30%) who purchased more clothing since the start of the pandemic say they used shopping to help them deal with anxiety, depression and loneliness.

- Half (49%) say the pandemic reduced the pressure they feel to wear a different outfit every day.

"Consumers are demanding more sustainable options and we're seeing time and time again that it's information and availability that would help shoppers make the choices they're seeking. There's a significant opportunity for fashion and apparel brands to show real leadership and make a substantive impact by providing consumers with the clear information they desire on the sourcing and environmental impact of their products," said Christophe Schilling, Genomatica's CEO.
"With consumers on the side of sustainability and renewably-sourced options for common apparel materials like nylon becoming available, the choice for brands should become easy."

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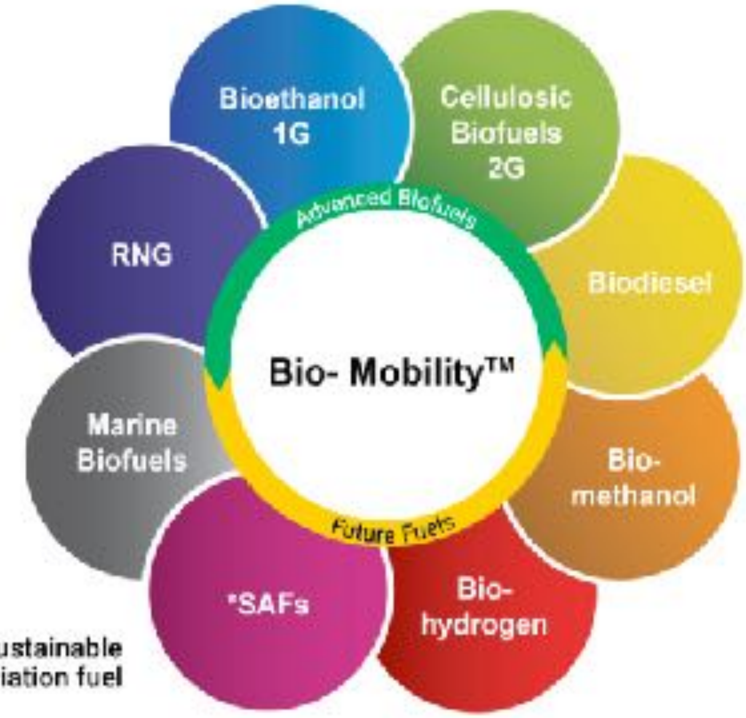

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ASPIRATIONS FOR A FRAGILE PLANET
with Frances Arnold, Jay Keasling, George Church

A CIRCULAR conversation moderated by Jim Lane

JL: The topic comes from Frances Arnold, something you said actually when you were in DC recently, what strikes you as particularly fragile about this place in time?

FA: I'm really distressed at the state of our natural world. In my lifetime, I've watched the planet go from largely unknown and unexplored to completely overrun with human activities that have destroyed many civilizations, many populations of human beings, and even more so destroyed a very large fraction of the habitat for other species. It's a beautiful planet, it's a fantastic biological world that we are watching disappear before our very eyes. I would like to see science and technology direct their skills and power towards maintaining, in a sustainable way, human well-being but also the well-being of all other species.

JK: es, I agree with Frances completely. I think so many of our activities could be much better for the environment, much better for the planet. In some cases, the science is there but the economics or the will to do it aren't there. In many other cases, the science isn't there or hasn't delivered an economically viable solution. I think there's so much more that we can be doing, and, for me, I've tried to do that in the science I do in my laboratory, but also with the companies that I've started that have come out of the laboratory. In almost every case, those have been tied in some way to the environment.

GC: I think one of the biggest things we are faced with is carbon sequestration. A lot of the discussion around being carbon neutral or reducing our anthropogenic sources of carbon seem pathetic compared to the opportunities and risks. There's 1,400 gigatons of carbon, possibly in the form of methane, in the Arctic that could be released by any kind of positive feedback loop, which seems to be going on. That's a lot more than the 10 gigatons of human anthropogenic carbon per year. Plus, there's the opportunity of restoring some of the regions of the world that have lost their photosynthetic and sequestration capabilities, notably the edges of deserts and the Arctic. That's something they we're actively working on: the various ways of doing that. [Former vice president Al] Gore described this as an inconvenient truth. The problem with inconvenience is that a lot of people will vote against it, no matter how many books you write. So, you have to make it more convenient. I think technology has a big role there. Technology can make amazing things free. Smallpox and rinderpest are examples of things that have affected the entire planet and now are extinct. We need to look for creative solutions like that.

JL: Frances, what have we learned about how to encourage people to to take the right steps and to get into these fields, as we learn more about the power of biology?

FA: I can only speak from my own experience; everybody has a different path. It's very important to recognize that if everyone follows the same path, everybody's going to think alike and do alike, and that wouldn't be effective. I think my path was effective because I tried so many different things. I was everything from a taxi driver to a cocktail waitress to a mechanical engineer, aerospace engineer, and biophysical researcher. I'm not particularly good at any of those professions but they gave me material I could re-combine in different ways. I think we spend a lot of time teaching our young people to follow "the" path or choose "the" path early on instead of exploring. Science is all about exploration, taking risks, doing things that are really hard. I'm not sure we encourage that risk-taking very much.

Frances Arnold *won the Nobel Prize in chemistry and is a professor at Caltech. She was recently nominated by President Biden as co-chair of the President's Council on Science and Technology. She co-founded Gevo, Provivi and Aralez Bio.*

George Church *s Professor of Genetics at Harvard Medical School and Professor of Health Sciences and Technology at Harvard and MIT. He is Director of the Wyss Institute and co-founder of Joule, LS9 and many other companies.*

Jay Keasling *is Professor of Chemical engineering and Bioengineering at the University of California, Berkeley. He is also CEO of the Joint BioEnergy Institute and a co-founder of Amyris, Lygos and other companies.*

"We need to connect with people rather than to convince them of things that they couldn't care less about, like GMOs and evolution and things that really don't affect or help their life."

JK: I think that specializing too early is a mistake, and we force our young people in many ways to specialize too early. Getting a broad background, I think, is super important. Like Frances said, you get some exposure to a lot of things and can build on that. This applies to companies as well, and building companies that have people with a lot of broad backgrounds. In almost every case of the companies that I've been a part of— either that I've started or have advised—they were founded by creative people who have broad-based backgrounds and a lot of experience in the world. A lot of VCs invest in people, and not necessarily in the idea. This is for a good reason. If the idea is wrong, good, smart people will be able to come up with a follow up that is maybe even better.

JL: George, what about this alignment of commercial and technical — also, what about this pressure to "publish or perish" on young academics, and the pressure to find a specialization?

GC: I think the three of us are inclined towards multi-disciplinary attitudes. That doesn't mean that it's right for everyone but it seems to be right for us. I haven't seen that much "publish or perish" among my students and postdocs, but I'm sure it is quite prevalent. It is good to share—I think sharing pre-prints, especially, has been an enabling force. It's not the same as a peer-reviewed paper, but even peer-reviewed papers aren't adequately peer reviewed—there aren't enough peers weighing in on it. I think it's sort of a bad system, but it's better than all the other systems.

FA: I have to agree with George. I've done a lot of thinking about the innovation system in this country compared to other systems. George and Jay's groups have been so successful because they empower young people. It's not this hierarchy that you'd find in many other places, but young researchers, when they are at their most creative, being empowered. Of course, that's frightening too, because they do have to eventually publish or they perish, but they have the opportunity to really go out and take risks. The people who go into independent careers in science and who start companies are those who have had the ability to take risks and have not had their ability to see the future beaten out of them by the educational system.

JK: They're not jaded by the failures that we've had and others have had.

FA: Yes, exactly. They still have that optimism that makes great artists!

GC: I kind of encourage failure if it's high-throughput failure. I would prefer to do an experiment where I have a million failures and one success than an experiment where we have a brilliant hypothesis and the outcome is entirely dependent upon on that hypothesis checking out. And that's why we do so much in our libraries; the library is the perfect way to fail a million times and succeed once or twice.

JL: Frances just to follow up on that — in the pandemic, have we learned anything good about how to collaborate in the past year that we didn't know before?

FA: I think we're all mighty sick of flat screens, that I have to say, but there are some advantages to being able to connect with people much easier, and for being able to get the same people on the same screen a lot easier. I think you miss some of the transfer of ideas, but there are things to make up for no doubt about it. I'm sure you've had that experience Jim, that you've been able to connect with more people by not having to have them all physically in the same space.

JK: I do miss face-to-face interactions, but I think we've learned that we can do a lot by video and maybe we were just traveling too much and some of this could be handled by video. I've also noticed a sense of cooperation. I've always encouraged cooperation in my own lab, but I've sensed even more of it. In our particular case, we've got very limited time in the lab. The labs are controlled by the Department of Energy, so there's a certain number batches and a certain number of hours, and people are helping each other through Slack and saying, "Would you take my plates up, they are ready to go," things like that. There has been a sense of collaboration and working together to keep things moving. I think it's been really eye opening and nice to see.

JL: George, are there any things that you'll miss in terms of collaboration in this new environment we find ourselves in?

GC: Well, I found the old environment pretty collaborative, really. Genomics was expensive enough that you had to collaborate at some level, and we had a tendency to publish everything within a week. We credit COVID with more sharing but I think it's about the same. The ability to be in three continents in a few hours is great though. I don't think that the 2D is that limiting, I think we just haven't finished getting the technology. Before COVID, everyone was dismissive of any video conferencing. Whenever I would suggest it as an alternative to travel, the sense was it doesn't work. And now we see that does work, but that we could do a little bit better on body language. It could be better, but I do like the freedom that comes from being able to travel at the speed of light and being able to really say "yes" to almost any invitation without worrying about where I am going to be.

JK: Like George said, I don't know that they're necessarily better, but I can do a lot more of them. I have my calls with Europe in the morning, between five and nine. And in the evening I can have my calls with Asia. So I can traverse three continents in a full day and many days are that way. I don't I don't know that it's necessarily richer, but I don't miss travel at all.

“Science is a process, we can change our minds, we can change our interpretations, but we need to have exploration, and the obtaining of facts on which to build those interpretations.”

JL: Frances a popular saying in the last six months is ‘follow the science’, and I wanted to ask you in the context of science being a journey. Some times of late, it's presented like a set of firm conclusions. Yet, today's truth may not be quite so true thirty years from now — how can we take what’s best from “follow the science” without treating science as something prescriptive.

FA: You could probably go into the history of science at length with many great examples of how ideas have been overturned over and over again. And the ideas that we have today will also be overturned and refined. Science is a process. We can change our minds, we can change our interpretations, but we need exploration and the obtaining of facts on which to build those interpretations. Also, a lot of the things that we’re interested are very complicated, right? And so we may know something about one piece of a problem—look at climate change, for example—but not know important other pieces and how they all fit together. So, it’s a process of integration. It’s a process of discussion and a process of learning.

JL: Frances mentioned that science is getting more complex, yet the world population is getting more connected, we're all talking about these ideas in very short bursts on Facebook Twitter. Jay, there’s an idea that science can lead us, how does it lead us at a time like this?

JK: First of all, we have to make sure that politics doesn’t shut down science, because the politicians don’t like the scientific answers.

JL: I want to broaden that beyond politics and talk about the ordinary person sharing on Twitter or Facebook who may say, “I hate GMOs, give me my Impossible Burger” without understanding that the Impossible Burger contains GMOs.

JK: It’s a challenge. How do you talk about some of these really complicated issues in short sound bites that might interest someone? In some cases, you have to rely on them getting interested enough that they’ll dig deeper. It’s sad to say that I’m not sure that all of these topics are for everyone. I would love them to be for everyone, and I’d love to get everyone excited about some of these deep scientific topics. But they’re hard to cover in a sound bite, and you often get it wrong when you try to do a short sound bite. Or they don’t get the full picture.

GC: Well, I think a way not to do it is to argue or lecture about the way things are from a scientist’s perspective [to nonscientists]. I think a better way is to engage them in media that they trust or that they enjoy. So, for example, TV and movies, like *Grey’s Anatomy*. My wife and I have worked with those screenwriters. And there was a genomics lab in *Grey’s Anatom*y as a result. And that’s something where you can have a long conversation over many episodes. We’ve done briefings with Congress, not so much to talk to Congress, but [so that] when they go back to their districts they can distribute what we’ve said to hundreds of places.

JL: George, I want to ask you about the topic of space. You've done work on radiation and I wonder if you think it’s possible that organisms could evolve defenses against the radiation that you see for instance on Mars that it might be or become something more than a sterile planet.

GC: Earth’s protection from radiation comes down to two relatively modest effects; one is it our atmosphere, which is equivalent to about ten meters of water, and the other is our electromagnetic field, the van Allen belts and so on. Both of these could be simulated with physics alone—not cheaply, but it’s still possible. Furthermore, the biological solution is quite potent. We have examples of making a radiation-sensitive organism into a radiation-resistant one—ten thousand-fold more resistant, in fact—with just four mutations. And many more mutations are certainly feasible at this point. We’ve designed up to 23,000 mutations in a single human cell. So, I think there are physics and biology solutions to this. Another [problem] is that we’ve never actually operated an ecosystem that’s completely closed with human beings. So, I think if we are going to have colonies in space, it shouldn’t be our first colony. If there is a mistake or problem, it’s a long trip back from Mars to Earth. We should establish a cost-effective and maybe even economically attractive solution here on Earth.

JL. As you think about recovery and reuse and the implications for space travel, Jay, what can we learn from biotechnology about being less wasteful, as nature is?

JK: Well, I think we can learn a lot from our plastics problem right now. Plastics are great, I have a whole bunch in my office here. And they last forever. But that’s the challenge: they last forever. They weren’t made to be degradable. I think we have to think about the full cycle as we design the next generation of plastic. Materials are a fantastic area of innovation for the future. We can use biology to design new materials with new properties—in addition to the properties we’re already getting from plastics, because you also have to compete economically. But it also doesn’t have to be completely biology—it can be biology in conjunction with chemistry, for instance, but with the goal of making things that are renewable and recyclable.

JL: Frances, on materials, I wanted to ask you to say perhaps a word or two about organosilicates, hey have applications in space, and here. New platforms, new materials, what’s in the works?

FA: Human chemistry has explored bonds and transformations that biology has never developed for one reason or another. One reason may be that she [nature] never cared about them. Another might be that there’s no precursors for a lot of these transformations. But that doesn’t mean that nature can’t do it. So, I’ve been exploring the future of evolution and chemistry using directed evolution to make enzymes do transformations that nobody ever thought was possible. We made the first carbon-silicon bonds with genetically encoded chemistry. We made the first carbon-boron bonds using enzymes. There’s whole swathes of the periodic table we can now start filling in by creating this new chemistry in biological systems.

“We're not training these people who are really expert in what we call unit operations and scaling up processes to large scale.”

JL: George, speaking of hard-to-find metal catalysts, there’s been effort reported in the news to go hoovering the bottom of the ocean looking for precious metals that have sunk to the floor of the ocean. Do you believe as Frances does that we can do better through biology and can this become a technology that we can count on every day.

GC: I think we need to maintain a of diverse portfolio, but when you say, “it’s a long way away,” I would say, a long away isn’t as far as it used to be. A lot of things that we thought were six decades away, it turns out we’re six years away from. For example, affordable genomes. I think the same thing is true for catalysis. A lot of the things that synthetic biology can do are things that never happened in biology but are inspired by biology and can not only happen without these rare materials that require environmental sacrifice, but they can happen at the lower temperatures as well. So, I agree that there are a variety of very commonly available metals that can be used catalytically and in biological or pseudo-biological systems at low temperatures.

JL: George alluded to the sort of Moore's law environment in biology, and I want to ask you what we do on scale-up, on the engineering side to build bigger, faster, it is taking a long time to get from the lab to success.

JK: If you’ve seen one of the latest presentations from Amyris, the time from initial discovery of a molecule that they want to make to the time they into tanks has dropped to something like six months, which is amazing. And it’s through all the technologies that have been developed in synthetic biology that this is possible. What we’re challenged by, though, is scale-up, the cost of building these facilities, especially when you’re talking about the scale of biofuels, is large. And one of the big challenges companies face right now is finding people who have experience with scaling up. This used to be taught in a lot of chemical engineering departments. But, because there was no funding for this kind of research from the federal government, a lot of these people either changed directions or eventually retired. And so we’re not training people who are really expert in what we call unit operations and scaling up processes to large scale. One of the things that we’ve done at Berkeley is create a master’s program for bioprocess engineering. We’re not the first one, there’s others around the country that are very good at this, but I think training people who know how to do it is an important aspect of getting these process less expensive faster.

FA: Well, it turns out Jay and I are both card-carrying engineers who were brought up right at the tail end of the bioprocess engineering era. There were a number of great chemical engineers who did research to make sure that the process of engineering scale-up would not be the slow step, or the rate limiting step. But, if you don’t invest in it, it goes away. I think that will change with the current administration. There are a couple of bills going through Congress right now that would dramatically increase use-inspired research funding. We all know that scale up and industrialization of these fundamental discoveries is going to become rate-limiting, and that just can’t happen.

JL: George, artificial intelligence and machine learning are very much in the in the news, can that help make industrialization faster and cheaper?

GC: There’s been a revolution in protein design. As a teenager, I was working with molecular mechanics and that genre of protein design. The new wave is not just machine learning but large libraries that are designed—not random, and highly designed. For example, we made over a million different designs for the viral capsid AAV that’s used for gene therapy and found a wide variety of tissue tropism and immune evasion. Those are both very complex systems and would be hard to do with molecular mechanics. Machine learning allows you to take very big steps. It was hard to take even four amino acid steps before, and now we can take 29 at once.

JL: With machine learning and artificial intelligence, there's there's a lot of fear about what AI might mean for us — how do you about creating a safe space for discovery, and communicating that our human values will not be compromised by the journeys that we might take to create the materials of the future

FA: How the sequence of DNA relates to the function of biology is the big question of biology. What is the relationship between the DNA sequence and what you get out on the other side? Protein design is exactly that, and these complicated pattern-recognition problems are exactly what machine learning and AI are good at. biotechnology is showing that benefit.

FA: So, the future of genetic engineering and design will be tremendously empowered by these technologies. The ethics side of it comes down to whether you a lot more good than you do harm. Any technology has the potential for harm. Every technology that we’ve ever developed as human beings has potential for harm. But those technologies that do a lot more good than harm are the ones that are successful. I think

JK: There could have been a lot of solutions that would have been very viable if they had been promoted in the right way. And I’m not saying that everything is about promotion, but it is important how you talk about these things and how you present them to the public.

JL: George, where are the broad areas where biotechnology discovery really passes that test, of having that high degree of social utility.

GC: Well clearly, medicine, preventative medicine in particular, is very cost-effective and we need to be using it more. There’s a lot of financial rewards for doing reactive medicine at the late stage, but preventative medicine is a tremendous opportunity for synthetic biology. I think carbon sequestration is another one. Some of the same tools you use for food but it’s quite distinctive.

JL: Frances, is there another one that stands out for you?

FA: It goes along with food, but I’d add agriculture. There’s so much opportunity for improvement in agriculture, like reducing pesticide and fertilizer use. So many things about the ways we grow and obtain our food are harmful to the planet. There are enormous opportunities there and that’s one of the things I’ve been working over the last ten years. C

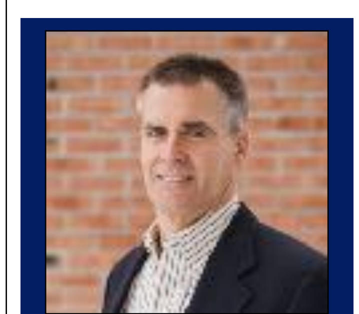
THE LOOMING FERMENTATION SQUEEZE

By Christopher J. Guske, Ph.D. and Mark Warner, PE

There are storm clouds on the horizon and those of us actively entrenched in scale-up and manufacturing for Industrial Biotech see the coming apocalypse…and it will likely not be pretty. We make this assertion knowing we are in a superlative-saturated society, where getting even an eyebrow raise over another pending apocalypse is wishful thinking. That does not make the assertion any less likely.

Over the last couple of decades, VCs have been showering money on start-ups, which seem to be multiplying like rabbits; technology advances are staggering; and strain development times have been reduced – all of which signal a flourishing industry. Entrepreneurs can hold up flasks, proudly showcasing their products, declaring commercial readiness. But there is a problem…

Over the same couple of decades, "capital light" has been the scale-up/commercialization mantra: why build when one can use someone else's facility? Well, the problem is this: Riffing off of Margaret Thatcher's assessment of socialism, "Capital Light is great until you run out of someone else's capital." As multi-decade Industrial Biotech veterans, we are seeing more start-up companies "dressed up with nowhere to go."



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How dire it this situation? It is definitely getting worse at the wrong time. North America contract research and manufacturing organization (CRO/CMO) capacity is tightening. In 2020, one CRO/CMO completely shut down its facility to all fermentation work and laid off staff. A second quit conducting outside work as internal demand filled capacity. A third was rumored to be considering shutting down or selling.

The situation in Europe is less dire but even that market is tightening. Additionally, EU regulations (e.g., REACH) make things more challenging. Producing in the EU and then transporting back to the US can be challenging, driving a reluctance to use European facilities, where the bulk of available capacity currently exists. On a positive note, the EU has done a far superior job of promoting and supporting its capabilities through programs like Pilots4U, something the US should consider.

Does un-utilized industrial biotechnology capacity in the US exist? Well, yes, sort of. Tate & Lyle's Decatur, IL, refinery has large fermentation capacity, once used for producing xanthan gum and Amyris' farnesene. But the facility has remained idle for several years with no evidence of interest to recommission it despite numerous inquiries. ADM's Clinton, IA, facility (built to support the defunct ADM-Metabolix JV) operates at fractional capacity with the majority of commercial-scale fermentors still not commissioned.

Fermic's Hannibal, MO, facility remains idle. The issues in bringing sites back into operation are common stumbling blocks: (1) these fermentors are rather large for most early-stage companies, and (2) there needs to be a sustained commitment to bring these up to/back to operational status.

There is some pharma capacity available for CRO/CMO work in the US, but if one has to displace another internal product (which would be the common scenario) and/or operate in a pharma cGMP environment, this is not an economically attractive option unless one has a high-value product, i.e., $100/kg or more.

The other subtle nuance is equipment-related: Fermentors, if properly designed, are fairly flexible pieces of equipment and adaptable to many different fermentation scenarios. DSP (downstream processing) is often process specific and a controlling factor, except in the case of limited DSP processes (whole cell or cell-free). While pilot plants can often maintain a high level of flexibility, this needs to be sacrificed with increasing scale because of the cost of larger equipment.

Hence, while a CMO may be able to handle the fermentation requirements, it may be inadequately equipped to provide the requisite DSP, often requiring significant capital investment to complete the process or requiring the use of another third party.

Back in late 2018 at an ABLC event, one author had an *impromptu* conversation with a well-known VC Managing Partner: When asked about the "coming apocalypse" (and a subsequent explanation of what that phrase meant), the MP indicated that his firm had been thinking about this issue for a while and were tailoring their investment strategy away from technologies which would require large-scale fermentation capacity.

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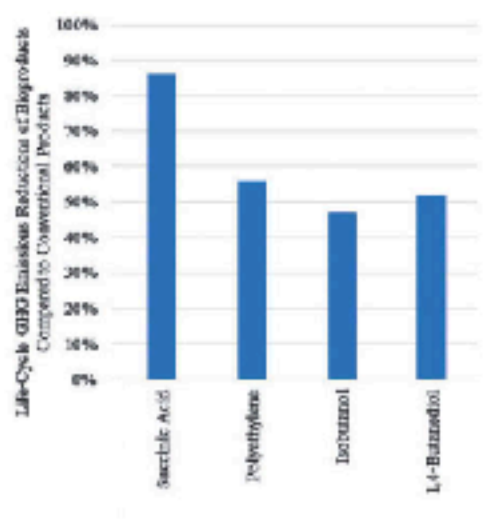
Advantaged biobased molecules are being produced today and will pave the way for future molecules

Today thousands of metric tons of biobased products are being produced which are difficult/impossible to make from petrochemical sources or have a significant advantage for environmental performance or both.



Biobased Chemical	Production(KTA)	Fermentation	Category[1]
Ethanol	80,800	Yes	1
Citric acid	2000	Yes	1
Sorbitol	1800	No	1
Glycerol	1500	No	1
Lysine	1100	Yes	1
Lactic Acid	>600	Yes	1
Furfural	360	No	1
Sebacic acid	200	No	1
Propylene glycol	120	No	1
Itaconic acid	90	Yes	1
1,3-propanediol	77	Yes	1
Epichlorohydrin	540	No-derivative	2
Ethylene	200	No-derivative	2
Ethylene glycol	175	No-derivative	2

[1]Category 1 molecules cannot be cost-effectively produced from hydrocarbons. Category 2 molecule have lower environmental footprints from biomass compared to production from hydrocarbons and may support comparable or slightly higher pricing than the equivalent petrochemical.

Greenfield facilities are not cheap to build. Most VCs are more focused on developing technology…and then exiting at high multipliers. Fortunately, the authors have begun to see a rise in investors more interested in developing infrastructure and manufacturing capabilities, but these remain in the minority. Time is required for design, permitting, construction, and commissioning…and then the facility is not initially operated at full capacity as sales have to ramp up. This all requires deep pockets and patience. Fermentum has tried for years to generate interest in investment: still no steel in the ground.

Running a CRO/CMO is not an easy business, particularly when there is a high turnover in clients. Much "unproductive" time is spent on legal agreements, tech transfer, set up, clean up, scale up/validation steps, equipment procurement and modifications, analytical methods transfer and validation, etc., all before a demonstration trial or actual production can even take place. Hence why CMOs much prefer long-term commitments or extended campaigns. And pricing can be high as CMOs need to recover capital depreciation and labor costs during unproductive/unscheduled times.

Purchasing a brownfield site is not without challenges: As one author's Dad used to say, "When you buy a used car, you are buying someone else's problems." If the facility has been left idle and unmaintained for an extended period of time, this is like a misery multiplier. However, there have been some companies who have gone this route – and this will likely benefit them in the long run against their competitors: Manus Bio purchased the old NutraSweet plant in Augusta, GA.

Danimer Scientific purchased the former Martek/DSM/Alltech facility in Lexington, KY. (DS is rumored to be at full capacity and looking to expand: this will be greatly facilitated by DS's acquisition by a SPAC [Special Purpose Acquisition Corporation], allowing immediate access to capital for expansion activities.) Corbion snapped up the Solazyme/TerraVia facility in Peoria, IL. But brownfields are few and far between.

Raising awareness seems to be growing. In November 2019, MIT and Manus Bio hosted a workshop entitled Reinventing Chemical Manufacturing: Transitioning to Industrial Biomanufacturing. A key thrust was how to grow biomanufacturing: facilities, training, etc.

A white paper will be published and is currently under review. Some federal monies have been earmarked as evidenced by the recently announced BioMADE project. (Unfortunately, while intended to support biomanufacturing, this will not address the existing capacity shortage.)

Going it alone can be prohibitive for numerous reasons; partnering with other companies to share resources and capital spend has a certain attractiveness, but then there are logistical issues and challenges associated with this route.

At the end of the day, it boils down to capital: you can't operate what has not been built.

While the federal government seems like an obvious choice, this is probably not the most efficient, least bureaucratic approach. There are strategics out there with deep pockets, but you might end up selling your soul. Perhaps it would be better to be acquired, though acquisition values are higher for demonstrated technology. Hence, a Catch-22.

Circling back to comments made at the outset of this article, startups are multiplying like rabbits. Clearly not all will be successful and many will disappear. However, statistically, considering the diversity of the Industrial Biotech space, there will be more and more winners. But if there is no place to produce, many could "wither on the vine"…and be snapped up deep-pocket strategics for pennies on the dollar. **C**

Molecules identified in the 2004 Werpy and Petersen paper have made good progress

Chemical	Status	Notes	Uses
3-Hydroxybutyrolactone	Early research and development		Polymers, pharma precursor
3-Hydroxypropionic acid	Significant development, currently not commercial	OPX, Novozymes Cargill and BASF for polyacrylates, DOE efforts to convert to acrylonitrile	Intermediate
Aspartic Acid	Limited Research		Nutrition, sweeteners
Furan dicarboxylic acid	Significant commercial activity	ADM and DuPont, Annikki	Packaging polymers
Glycerol	Commercial	ADM for PG, Solvay and others for epichlorohydrin	intermediate, humectant
Glutamic acid	Commercialized for food uses	Ajinomoto others	Flavor
Glucaric acid	Commercial	Riverlop (Left market), Kalion	corrosion inhibitor, detergent
Itaconic acid	Commercialized	Itaconix	Stabilizers and detergents
Levulinic acid	Commercialized	GF Biochemicals	Solvents and intermediates
Sorbitol	Commercialized	Many (Roquette, ADM, Sorbitol)	Sweeteners
Succinic acid	Commercialized	Many, some of which have left market–BASF, Roquette, DSM,	Polymers
5-Carbon Sugar alcohols Xylitol, arabinitol)	Commercialized	Via Hydrogenation	Sweeteners

SUSTAINABLE AVIATION FUEL: CLEARED FOR TAKE-OFF.

But buckle up, it may be a bumpy flight.

By Helena Tavares Kennedy

There were 22 weekdays this past April. There were 15 announcements about sustainable aviation fuel progress, advancements, implementations, and production. What does that mean? Why is SAF suddenly taking off like never before, even as the aviation industry was turned upside down due to the COVID-19 pandemic?

Let's start with the most recent big news that Neste will convert up to 500,000 tons of its existing renewables production capacity at Rotterdam refinery for SAF. Currently the refinery produces mainly Neste MY Renewable Diesel. The modifications to the refinery, an investment of approximately €190m, will enable Neste to optionally produce up to 500,000 tons of SAF per year as part of existing capacity.

Neste expects the project to be completed in the second half of 2023. This extends Neste's growing footprint in the Netherlands and demonstrates the shared sustainability ambitions of Neste, the Dutch government, and the Port of Rotterdam in particular.

Together with the company's ongoing Singapore refinery expansion, Neste will have the capacity to produce 1.5 million tons of sustainable aviation fuel annually by the end of 2023. Currently Neste's sustainable aviation fuel annual production capacity is 100,000 tons. Neste MY Sustainable Aviation Fuel, in neat form and over the life cycle, reduces greenhouse gas emissions up to 80% compared to fossil jet fuel

And as the aviation industry is likely to resume on a growth trajectory after its recovery from the COVID-19 pandemic, there is a growing need and urgency to act on aviation-related emissions. Here sustainable aviation fuels offer considerable potential", says Peter Vanacker, President and CEO at Neste.

Additionally, Neste aims at creating readiness for a final investment decision by the Board of Directors for a new world-scale renewable products refinery project in Rotterdam towards the end of 2021 or early 2022.

This is quite a change in the way Neste has been organizing itself as we see them leaning out beyond renewable diesel and more towards SAF.

So, what is Neste up to? Is this because their technology now allows them to make SAF more cost-competitively? Is it because the airlines are starting to move on price?Is it because Neste sees the RD market becoming saturated at some stage and they want to build up SAF as a secondary market even if the margins are less?

Well, whatever the reason, Neste even teamed up with Finnair this past month to join forces to reduce carbon emissions related to Neste employees' business travel by using SAF

Neste recently made 300 tons of Neste MY Sustainable Aviation Fuel available at Helsinki Airport in Finland for Finnair's use.

By replacing a part of the fossil jet fuel with SAF on its flights departing from Helsinki Airport, Finnair will reduce its greenhouse gas emissions by 900 tons of CO2 equivalent. This represents a significant share of the emissions accumulated from Neste employees' global air travel in 2020.

Who's making it?

First, Neste isn't the only one jumping into the SAF action. In France, **Total** has begun producing SAF at its La Mède biorefinery in southern France and its Oudalle facility near Le Havre. The biojet fuel, made from used cooking oil, is already being delivered to French airports (started in April 2021).

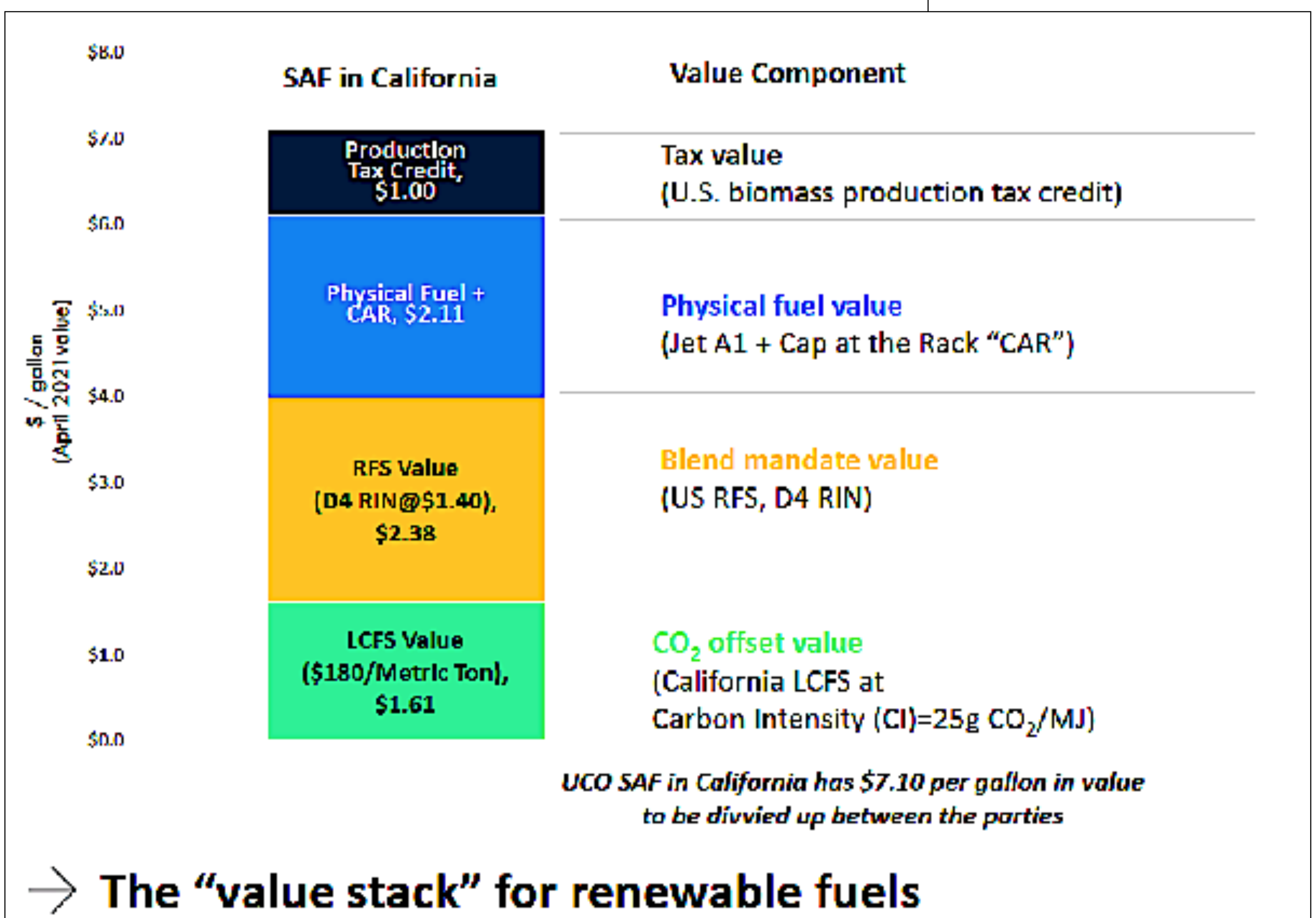
Total will also be able to produce SAF as from 2024 at its zero-crude Grandpuits platform, southeast of Paris. All of these sustainable aviation fuels will be made from animal fat, used cooking oil and other waste and residues. Total will not use vegetable oils as feedstock. In this way, Total will be in a position to respond from its production sites in France to new French legislation that calls for aircraft to use at least 1% biojet fuel by 2022, 2% by 2025 and 5% by 2030

Neste already has other customers for its SAF, in addition to Finnair. Delta Air Lines and Takeda Pharmaceutical Company Limited entered into a SAF agreement that will address carbon emissions from the company's business travel with Delta – AND they will be using Neste MY Sustainable Aviation Fuel. Through this agreement, Takeda joins the growing roster of corporate customers entering into SAF agreements facilitated by Delta.

Neste and NuStar Energy are also teaming up on supplying SAF to California airports. Supply trucks are now able to load Neste MY Sustainable Aviation Fuel at the NuStar-operated Selby Terminal near San Francisco, California.

The first gallons have been safely picked up and delivered to the nearby Monterey Regional Airport. Due to the strategic location of the Selby Terminal, Neste and its partners Avfuel and Signature Flight Support are now able to supply sustainable aviation fuel to a growing number of airports across the western United States. In 2020, Neste established a continuous supply of SAF to San Francisco International Airport from NuStar's Selby Terminal using an existing pipeline – a first for the industry.

In California, **Aemetis**, is now using Axens Vegan Renewable Hydroprocessing technology for its "Carbon Zero 1" production plant in Riverbank, California which makes both SAF and renewable diesel.



Slides courtesy of: ICF.

The Axens scope will include technology license, basic engineering, catalyst supply, and proprietary equipment for the conversion of ultra-low carbon intensity, non-edible vegetable and other non-edible oils along with renewable cellulosic hydrogen to produce a flexible mix of SAF and renewable diesel fuel.

In South Africa, **Sasol Ltd** will work with a consortium comprising Linde PLC, ENERTRAG AG and Navitas Holdings – the LEN Consortium – to bid in concept for the production of SAF under the auspices of the German Federal Government's H2Global auction platform. The LEN Consortium will enable Sasol to work with world-class partners on the opportunity, employing its extensive experience to produce liquid fuels and chemicals with Fischer-Tropsch (FT) technology.

Who's buying it?

In the UK, **International Airlines Group** said it will purchase one million tonnes of SAF per year enabling it to cut its annual emissions by two million tonnes by 2030 – which is about 10% of its flights with SAF. In addition, IAG will become the first airline group worldwide to extend its net zero commitment to its supply chain. The Group will be working with its suppliers to enable them to commit to achieving net zero emissions by 2050 for the products and services they provide to IAG.

IAG is investing US$400 million in the development of SAF in the next 20 years. The Group is partnering with sustainable aviation fuel developers, **LanzaJet and Velocys**. This includes Europe's first household waste-to-jet fuel plant in the UK which will start operations in 2025. British Airways will also purchase sustainable jet fuel from LanzaJet's US plant to power some of its flights from late 2022.

United Airlines launched first-of-its-kind Eco-Skies Alliance to boost SAF demand. Working with the airline, more than a dozen leading global corporations will collectively contribute towards the purchase of approximately 3.4 million gallons of SAF this year. As inaugural participants, the following companies are taking a lead within their respective industries, reducing their aviation-related impact on the environment at the source, and creating demand for more SAF production:

- Autodesk
- Boston Consulting Group
- CEVA Logistics
- Deloitte
- DHL Global Forwarding
- DSV Panalpina
- HP Inc.
- Nike
- Palantir
- Siemens
- Takeda Pharmaceuticals

United has made the airline industry's single largest investment in SAF and has purchased more SAF than any other airline in the world. **World Energy**, a long-term partner of United, will supply the SAF to Los Angeles International Airport (LAX), which makes it conveniently accessible to United's operations.

Speaking of airlines making a difference, **Alaska Airlines and SkyNRG Americas** signed an MOU to boost SAF investment. The MOU builds on a long history of Alaska leadership advancing SAF and partners the airline with the global SAF pioneers at **SkyNRG Americas**

Under the MOU, SkyNRG Americas will initially focus on the development of dedicated SAF production facilities to supply Western U.S. airports.

These facilities will use commercially available technologies that enable the use of municipal solid waste and other waste-based inputs as feedstocks, as well as incorporating green hydrogen and renewable energy for minimizing carbon intensity. Beyond the focus of building out SAF production capacity, SkyNRG Americas and Alaska Airlines will continue to build awareness and understanding of SAF technologies, and advocate for public policies to accelerate the development of the SAF industry and infrastructure. This collaboration builds on the Alaska-Microsoft partnership announced in October 2020, aiming to use SAF to offset Microsoft employee travel between Seattle and San Francisco, San Jose, and Los Angeles.

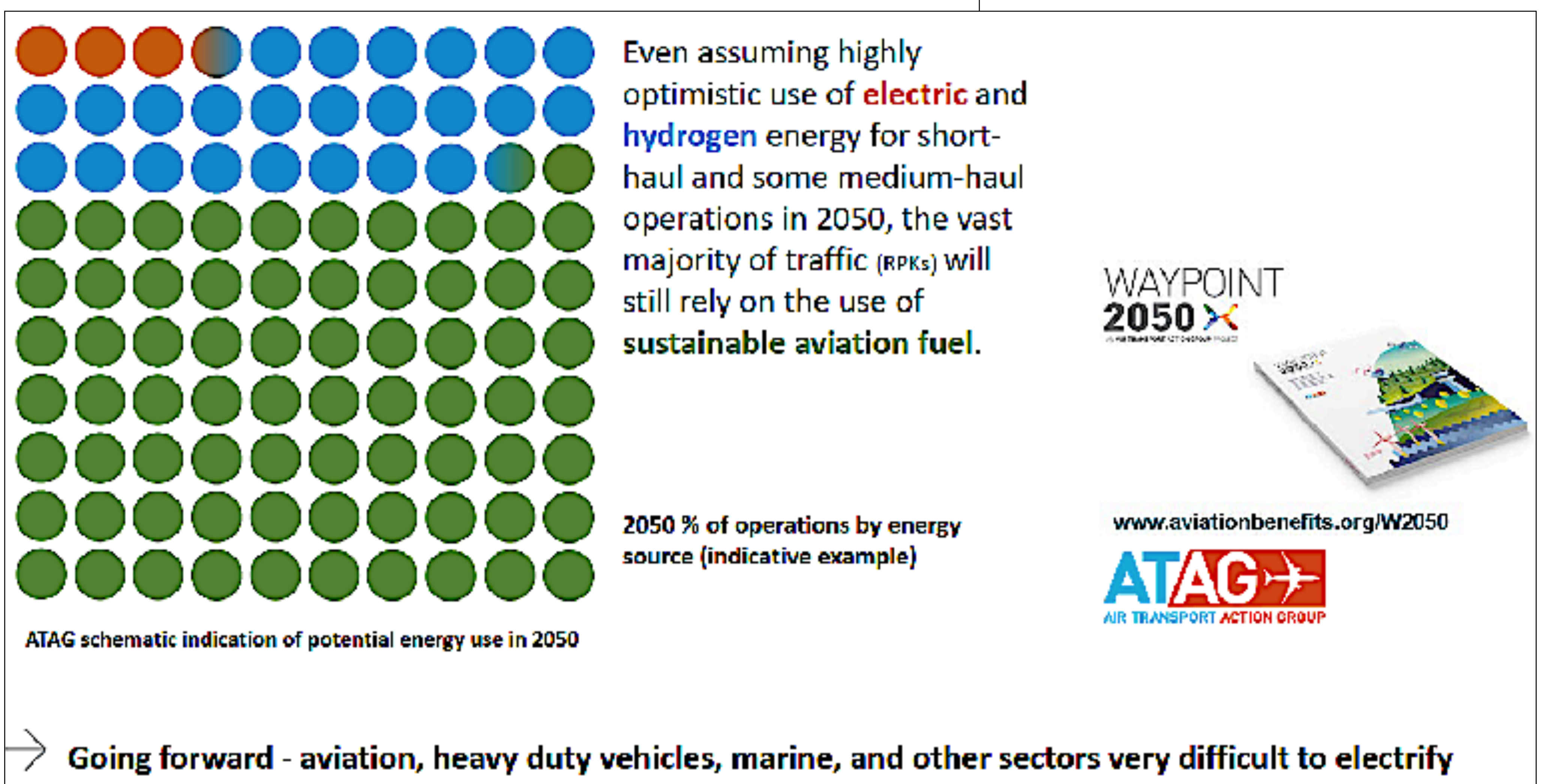
In France, Clermont-Ferrand Auvergne Airport becomes the country's first airport supplying SAF. This step, initially expressed by **Michelin Air Services**, demonstrates the desire of VINCI Airports, SMACFA and the Auvergne-Rhône-Alpes Region to promote low-carbon air mobility, with biofuels representing an effective and mobilizable short-term response to the challenges of the ecological transition in aviation. The fuels are supplied by **Air BP** under a refueling contract with VINCI Airports. These biofuels are produced from used cooking oil.

The Sustainable Aviation Buyers Alliance was also just launched to promote investment in SAF. Launched by RMIand Environmental Defense Fund, SABA is also supported by founding companies Boeing, BCG, Deloitte, JPMorgan Chase, Microsoft, Netflix, and Salesforce. SABA's mission is to accelerate the path to net zero aviation by driving investment in high quality SAF, catalyzing new SAF production and technological innovation, and supporting member engagement in policy-making.

Bottom Line

The only thing constant is change, and while we don't necessarily know the reasoning behind some of these latest changes at Neste for example, we know there are a myriad of possibilities. Nonetheless, the changes show promise for the future and further expansion and implementation of sustainable aviation fuel. After all, in a mere 21 days in April, the sheer number of announcements and news coming in on SAF is astounding. As you can see there are lots of SAF producers and buyers and promoters and it's inspiring to see them all collaborating and working together towards a common goal.

SAF – you've got clearance for take-off. **C**



Above: Outlook for 2050.. Slides courtesy of: ICF.

ZYMERGEN'S IPO: CAN ZY SURVIVE ITS POPULARITY?

By Jim Lane

Recently, Zymergen raised $500 million in its IPO and the stock closed the Monday following at $43.00, up 39 percent over its Wednesday trading debut. The company sold an unexpectedly robust $16.1 million shares at $31, the top end of its expected range. It still trades well above the IPO price.

In short, every sign from the market is bullish.

For many companies, the hard yards to be gained lie in developing and sustaining public confidence — there are reliably profitable media companies selling at 3.5 times earnings, to quote an example. It's clear that Zymergen has mastered the arts of communicating a story — for, with $13 million in revenue and $260 million in losses last year, to go with $12 million in revenue and $240 million in losses in 2019, Zymergen is one of the definitive story stocks.

But, what a story. As Zymergen tells it skillfully:

The Zymergen Story

The demand for innovative materials has never been greater. Human civilization is material. The materials in the things we use, the clothes we wear, the rooms where we live, the vehicles that take us from place to place, as well as the inputs that grow the food we eat, are the products of a half dozen chemical building blocks invented over the last several decades, mostly derived from cracking hydrocarbons.

We believe the chemicals and materials companies that make these materials have struggled to innovate because they employ a limited molecular palette and have substantial capital expenditures. In addition, they are among the planet's worst industrial polluters. Recently, synthetic biology companies suggested a better alternative, where microorganisms are coaxed to produce chemicals, but most synthetic biology companies have struggled to manufacture novel molecules at industrial scales. Yet while the traditional chemical industry is stagnant and synthetic biology companies have disappointed, the demand for materials that solve important problems and are environmentally sustainable has never been greater.

Having set the problem, that existing producers have exhausted their potential and exhausted our skies, while newcomers in synthetic biology have failed to deliver, Zymergen provides Biofacturing.

Defined succinctly as creating "better products faster, cheaper and more sustainably." Thereby hitting all the required notes for success in today's market excepting perhaps "saves us from COVID" or "ensures electoral reliability".

Insofar as 'biofacturing" is defined as the 'design, development and commercialization of bio-based breakthrough products, economically, at industrial scale, where microorganisms create the biomolecules that are the key ingredients in those products,' there's not much that Zymergen brings new to the table. What materials company is opposed to affordable, breakthrough products at industrial scale. As a goal, it is more obvious than what the presence of a net affords to soccer.

No, Zymergen 'taint about whatcha do, it's the way that you do it. As they note in their prospectus:

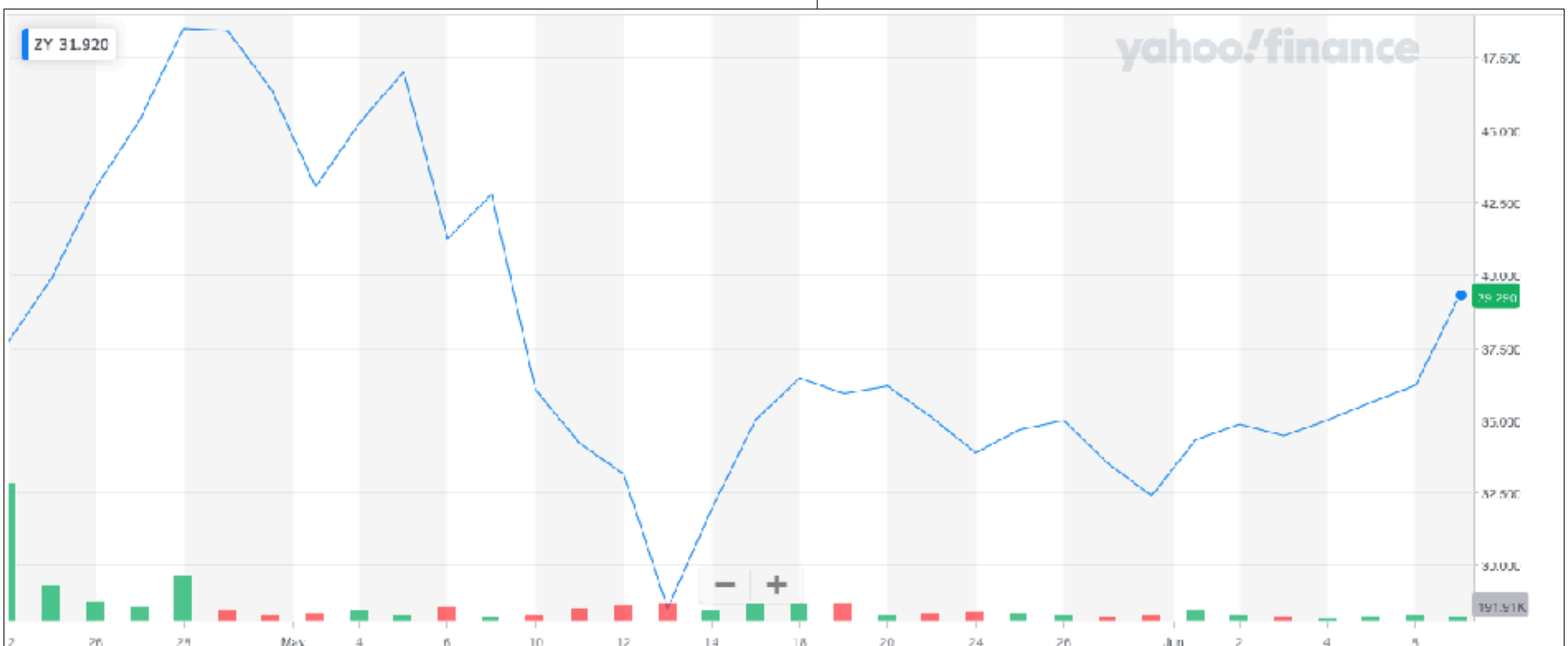
Our biofacturing platform, a unique end-to-end fusion of biology, chemistry and technology…is designed to:

1. *Identify and create novel biomolecules that are the basis of new materials with engineered characteristics that possess improved performance compared to existing products;*
2. *Insert genes into a host microbe that produces the desired biomolecules; and*
3. *Develop and scale up a production process, including optimizing the microbe to produce biomolecules economically at scale, while retaining product functionality via time-and-cost efficient optimization, leading to commercialization at attractive margins.*

Our goal is to launch our products in about half the time and 1/10th of the cost of what traditional chemicals and materials companies can deliver,

Traditional chemicals and materials companies have struggled to create novel materials that satisfy end-market demand. Many of the materials we use today were invented decades ago—cellophane was invented in the 1920s, nylon in the 1930s, Teflon in the 1960s, Kevlar in the 1970s. DuPont spent over 10 years and around $500 million (on a non-inflation-adjusted basis) (according to Delaware Online) in the late 1960s and early 1970s developing Kevlar."

Half the time, a tenth the cost? Where do I sign up? With that kind of power, why is Zymergen still a story stock?



Above: Zymergen's wild and lucrative ride as a story stock, with a price that has jumped nearly 30 percent post-IPO and supports a $3.93 billion company valuation

Of ZyPhones and iPhones: metrics from the device market

One factor is timing. Zymergen has come to the public markets 4 months post-launch of its first product, which has an '8-18 month cycle of sampling and customer engagement'. In short, we'll find out about Hyaline's success in the market some time between late this year and late next.

Another factor is company strategy. As one CEO in the biotechnology toolkit and development business remarked to me, "it's an interesting way to build a company," referring to the large costs and light revenues, it's not every company that can create a narrative to support such an investment. Those who have signed NDAs and looked deeply into the technology horizons and customer pipeline will be in better position to judge this diagram of opportunity. It looks a lot like Amyris in some ways — a company which had a lot of irons in the fire, delivered, albeit late. It also looks a lot like LS9, a company with a core technology filled with immense promise that did not work out so well for its investors.

The comparisons are not drawn as criticism, or even as cautionary tales — they are drawn to illustrate why Zymergen remains a story stock. Today is where your book begins, the rest is still unwritten" as the song by Natasha Bedingfield put it.

Let's have a think about Hyaline for a second. What is it? It's a high optical quality film — specifically, a tightly foldable film. That's extraordinary. Here's a picture to illustrate.

What are screens worth? The screen of an iPhone is worth $66.50 in hard costs. . TechInsight suggests that the cost is more like costs $80.50. There are 1.4 billion smartphone sold a year, doubtless other makers have cheaper materials, but if you're not seeing a bigger market than $20 billion it's because you believe other manufacturers spend 70+% less than Apple on smartphone screens. Really?

How much of that could go to a product like Hyaline? Zymergen says that "the display market alone for Hyaline was over $1 billion in 2020". That's real money. The margins are bound to be tighter for components than the 300% mark-up for a high-end iPhone, but you get the idea.

As we say in the Department of Early Stage Meetings about Disruptive Technology, if you have technology that will completely disrupt a $10+ billion market that is growing, you have something very special. As product #1 out the door, that's not quite a black swan but for sure it's a Trumpeter Swan, something on the Venture Capital Endangered Species List.

So, that's one of the reasons to be extremely bullish about a company like Zymergen. Do they really have it? Have they nailed it? Time will tell, but you can see why there are investors willing to take the technology bet. The original iPhone cost something like $150 million to develop about 16 years ago. The number sounds outrageous until you consider the returns.

About that Launch Acceleration

Now, having addressed the case for optimism, let me turn to two cautionary tales. Earlier, I mentioned I would not draw one by comparison to Amyris or LS9. But I do want to draw something here from the IPO documentation.

First, I want to draw attention to something called "Launch Acceleration". Zymergen avers:

Our goal is to make our biomolecules by fermentation, where all biofacturing reactions occur inside the engineered cell in standard fermentation vats, rather than the expensive, purpose-built chemical plants used in synthetic chemistry. However, in some cases, so that we may achieve commercial launch faster, we may initially launch products using molecules that are first produced with non-fermentation based methods, which is a strategy we refer to as "Launch Acceleration."

Someone is going to shout "Fake it until you Make it!" at this point, that's not where I am going, I don't think that's as respectful to the Zymergites as they deserve. I don't think there's a case for fakery here — though there have been some pretty weird stories in the advanced bioeconomy, I don't surmise this is one of them. I think this is a simple matter of dual-tracking the marketing and the technology development, there are advantages to scaling a market faster than you can scale fermentation. It can be risky — the company might never exactly shake out the costs and bugs of a process, we have to be clear about that.

Also, it undermines the sustainability story, the ESG investment and purchase story. We had better assume that when Zymergen proposes "Launch Acceleration" that the alternative near-term process is going to be less sustainable, perhaps far less so. If the company had a completely low-carbon, sustainable way to alternatively manufacture and didn't mention that in the IPO, well, we'll dismiss this concern but would someone fire the S-1 writing team, please? On the assumption that the "Launch Acceleration" approach involves trade-offs on sustainability, how much, and for how long?

So, let's look at that, the answer might be "not long".

Zymergen writes:

Hyaline is the first in a franchise of optical films, designed for electronics companies to use for display touch sensors in personal devices and other applications. Hyaline will allow our customers to make robust foldable touchscreens and high density flexible printed circuits.

Hyaline uses a biomolecule that was identified through our biofacturing platform. In order to accelerate product launch and meet customer demand, we launched Hyaline with a non-fermentation produced biomolecule sourced from a third party. We are in the process of converting to a fermentation-produced molecule for Hyaline by using a microbe that has a demonstrated ability to produce the molecule through fermentation. We are currently developing commercial scale processes so we can produce the molecule through fermentation at sufficient volumes and costs to support commercial manufacturing. We expect this process to be complete in 2022.

About those Easy to Come by Affordable Industrial Processes at Scale

So, we have 2022 as a target, so, somewhere in the 9-21 month range. That's not so bad. But we do note a couple of items.

"We are currently developing commercial scale processes."

Commercial-scale bioprocess can be a tricky and pesky thing. Timelines have been known to get crushed by real-world experience. Gevo is an example of a company that took much longer than expected to perfect their system. Genomatica is an example of a company that brought a process up to massive commercial scale without a hitch and in record time. Is Zymergen a Genomatica or a Gevo? It is not a question of failure, it is a question of timelines — mighty companies like Solazyme found tremendous trouble as a public company with a burn rate and timelines to reach cost targets stretched out.

The difficulties of the past do not predict the experiences of the future — rather, we can assume that Zymergen has learned prodigiously from what went awry in the past for others and has plans to avoid corporate trauma. But, honestly.

While we're here, let's take up one other disclosure in the above-cited section of the S-1.

In order to accelerate product launch and meet customer demand, we launched Hyaline with a non-fermentation produced biomolecule sourced from a third party.

Ah. Let's put this together with something else that shows up in the S-1.

We launched our first product Hyaline in December 2020 to customers in the electronics industry, beginning the expected 6-18 month product qualification process with customers. We have not yet generated revenue from product sales (except for nominal revenue related to the sale of samples of Hyaline)

OK, what do we have here. We have nominal revenue so far: so far, so good,, biotech companies are known to complete IPOs with limited or no revenue. We have a disclosure that "Substantially all of our revenue to date has been generated from R&D service contracts and collaboration arrangements" and that samples were distributed at nominal costs to catalyze the "expected 6-18 month product qualification process with customers." Again, unsurprising. Yet, we also discover that that Hyaline has been launched 'with a non-fermentation produced biomolecule sourced from a third party.'.

Is it not fair to assume that the customers are not testing an actual Zymergen product. Rather, they are testing someone else's product. Now, for the purposes of performance testing, we're going to assume that all bets are off until the customer is actually testing Zymergen's Hyaline. That's not the only point of performance testing, but it it is one of the points of it.

Further, what if Zymergen never really does produce a commercially-viable process for Hyaline — how valuable is the market seeding.
So, these are risks. They are not deal-breakers. They are decisions made by sober management under time and financial pressure to create a successful company — pressures that mount when the cash burn is north of $200 million per year

Thou Shalt Avoid the Billions: The Efficiency Gambit.

Let me move to another disclosure in the S-1. Zymergen avers:

We then design and develop engineered microbes that manufacture the novel biomolecule that will be the key ingredient in a breakthrough product. Next, we leverage Contract Manufacturing Organizations ("CMOs") to manufacture the product for us. Finally, once we have launched our product, we use our own sales force and marketing capabilities to contract with customers and sell our products to them.

I don't see much about "we'll build a plant later" or "our customers will build a plant later", so we are left to consider how many Contract Manufacturing Organizations are out there, how much spare capacity they have, and how that fits with the Zymergen ramp-up schedule.

Now, remember, we are issuing a caution, not ringing the fire alarm. There may well be sufficient toll manufacturing capacity to support Zymergen's growth phase, and Zymergen may well have it locked down. But, do they? If so, why not disclose that?

As Christopher J. Guske, Ph.D. and Mark Warner, PE wrote in CIRCULAR this week:

North America contract research and manufacturing organization (CRO/CMO) capacity is tightening. In 2020, one CRO/CMO completely shut down its facility to all fermentation work and laid off staff. A second quit conducting outside work as internal demand filled capacity. A third was rumored to be considering shutting down or selling.

Does un-utilized industrial biotechnology capacity in the US exist? Well, yes, sort of. Tate & Lyle's Decatur, IL, refinery has large fermentation capacity, once used for producing xanthan gum and Amyris' farnesene. But the facility has remained idle for several years with no evidence of interest to recommission it despite numerous inquiries.

It's relevant to the Zymergen story. and not just because capacity may be tight, After all, capacity can be built. That's the American way. So, there's something more to this — Zymergen in its S-1 described the building of capacity to support molecule manufacturing not as a strength of the American business system but more or less as a weakness.

Zymergen added:

Commercial-scale plants cost hundreds of millions to billions of dollars to construct. For example, in 2010, GE Plastics (now SABIC), completed the construction of a PEI resin plant in Spain for EUR300 million. DuPont recently announced an expansion of capacity for its polyamide film franchise of $220 million to meet growing global demand.

What is the purpose of these notes by Zymergen in the S-1 — to point out the prodigious costs and associated risks experience by industrial biotechnology? Perhaps. An alternative explanation would be that Zymergen is telling investors it hopes to avoid these kind of expenses and duress.
'Zymergen avers:

Based on our experience and expectations with our first four products which are electronic films and insect repellent products, and subject to any regulatory requirements, which could lead to longer timelines and increased cost, we estimate the timelines and costs of launching our products to be roughly five years and $50 million.

Further, our machine learning workflows can We estimate that the first step can be accomplished in roughly one-two years and at a typical cost of approximately $5 million, the second step in roughly one year and at a typical cost of approximately $5 million and the third step in roughly three years and at a typical cost of approximately $40 million. Our biofacturing platform is flexible, allowing for each step to be completed in parallel or independently. The platform is designed to accelerate launch of our products, satisfying customer needs more rapidly and increasing the returns of our pipeline investments.

The message here is that biofacturing is cheaper. The reasons are left a little vague, but we do see phrases like "flexible", "Rapidly". Machine learning", and "deepening our proprietary data moat" that suggest efficiency is the key to Zymergen's appeal.

Efficiency that leads to effectiveness that is the key to the company's success, for they point out that "only six major polymers have been commercially launched since about 1980" but mention that they have 10 in the pipeline, "Our long-term objective is to generate revenue from the sale of numerous breakthrough products across a variety of industries. Our goal is to launch our products in about half the time and 1/10th of the cost of what traditional chemicals and materials companies can deliver."

One More Thing

Let me head back to the iPhone for a second. We read earlier that Zymergen estimates that the market for Hyaline in the smartphone screen sector is worth $1 billion or so. We estimated that the screen market as a whole has sales of $20 billion. So, that leaves us with the concept here that smartphone screen operators would focus in on a component that represents 4 percent or less of the total cost.

Which product companies do — all the time — but only when they see transformative performance opportunities,. Could be physical performance — or, these days, carbon performance. It's not an area that's going to be targeted because of a drive on costs — just too small.

It brings the focus right onto Zymergen's value proposition. It's a performance company. As ZY points out in discussing its insect repellent opportunities, "the consumer need to repel insects is global, big and likely to get bigger with current solutions being unsatisfactory, suggesting that there is a large latent demand for better products."

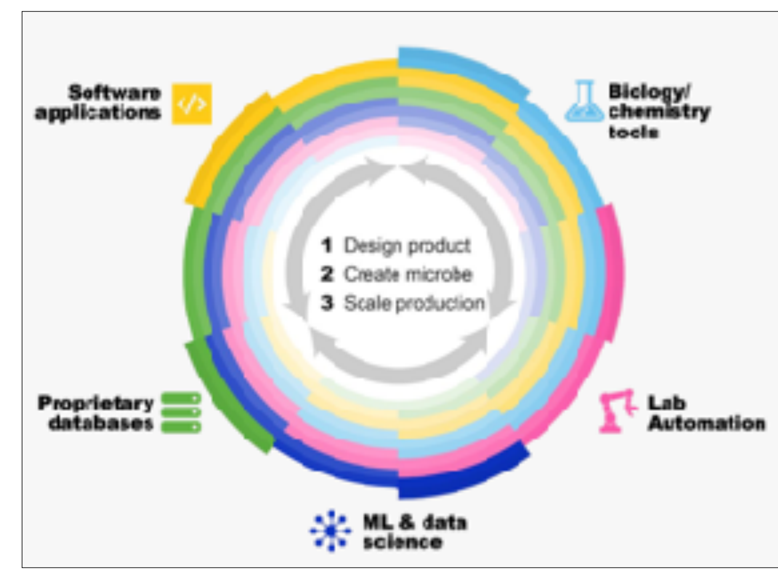
Better products, that's the Zymergen promise. Of course, that's what makes it a risky bet because, today, there are no shipped products, excepting the afore-mentioned product marketed as Hyaline which is made by someone else using a process that won't be used by Zymergen.

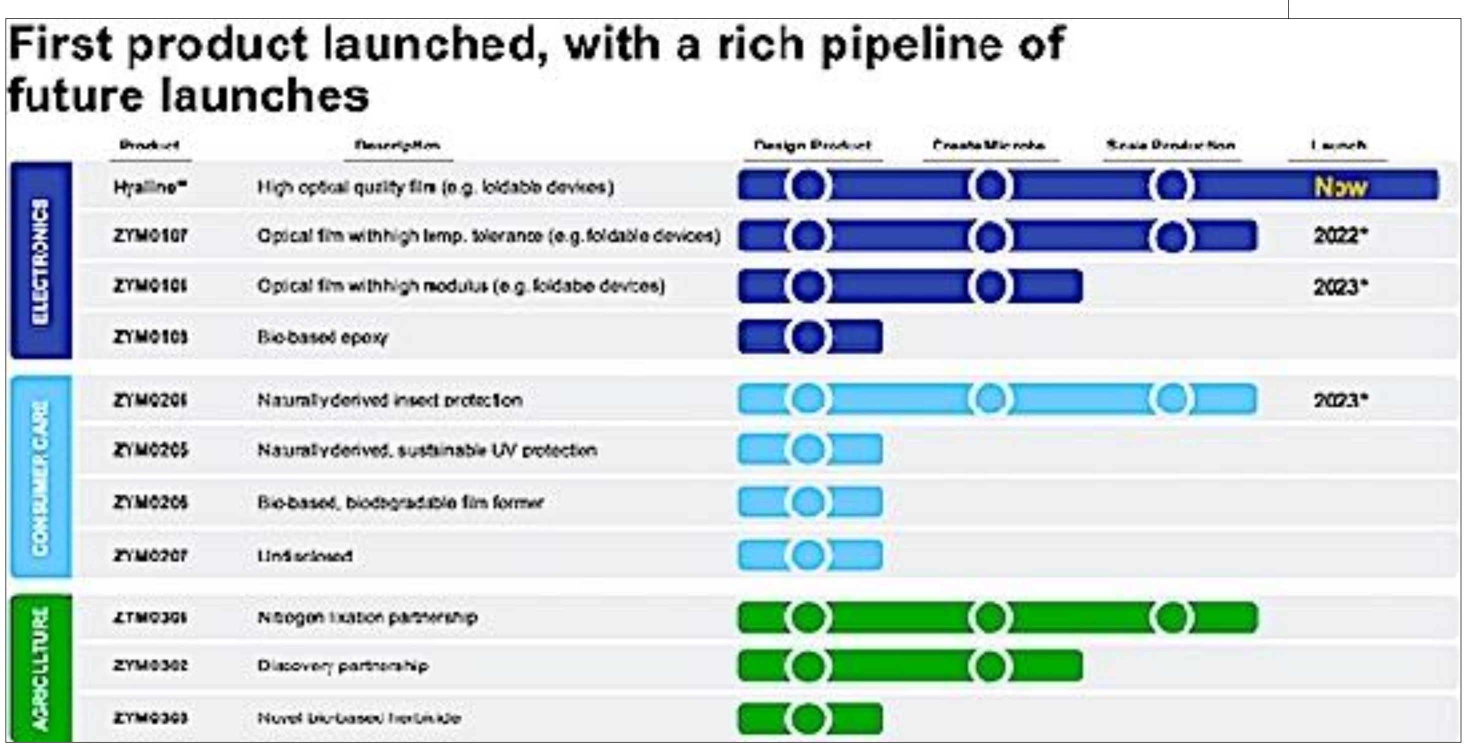
Do you like the bet? If you've spent time around the company, there's real reason to feel good about it. The company is stuffed to the gills with smarts.

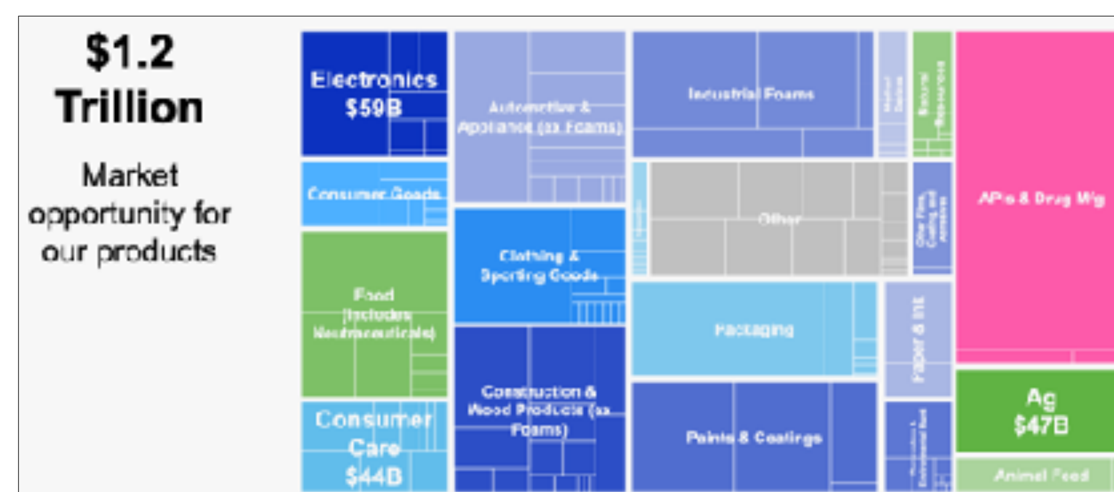
So was Solazyme in many ways, a technology which marches on today under the Corbion brand but was did not work out as a standalone company. So was Twist in many ways, which has been a NASDAQ darling. So was Renewable Energy Group, which has over performed spectacularly.

The jury is out, it's going to be out for a while. 2022 is the next inflection point, that's when Hyaline shifts over to the actual fermentation-based product and we can then judge whether the machines that are learning at Zymergen are learning well.

So far, the market votes that ZY is a good bet. The cash raised covers about two years of the current burn rate and that puts Zymergen well over the expected Hyaline finish line in 2022 — so, the IPO has been well-timed. Now, cometh the execution. C







Left: The Zymergen product pipeline. Right above: The ZY design, build, test, learn engine; below right: the addressable markets and early targets.

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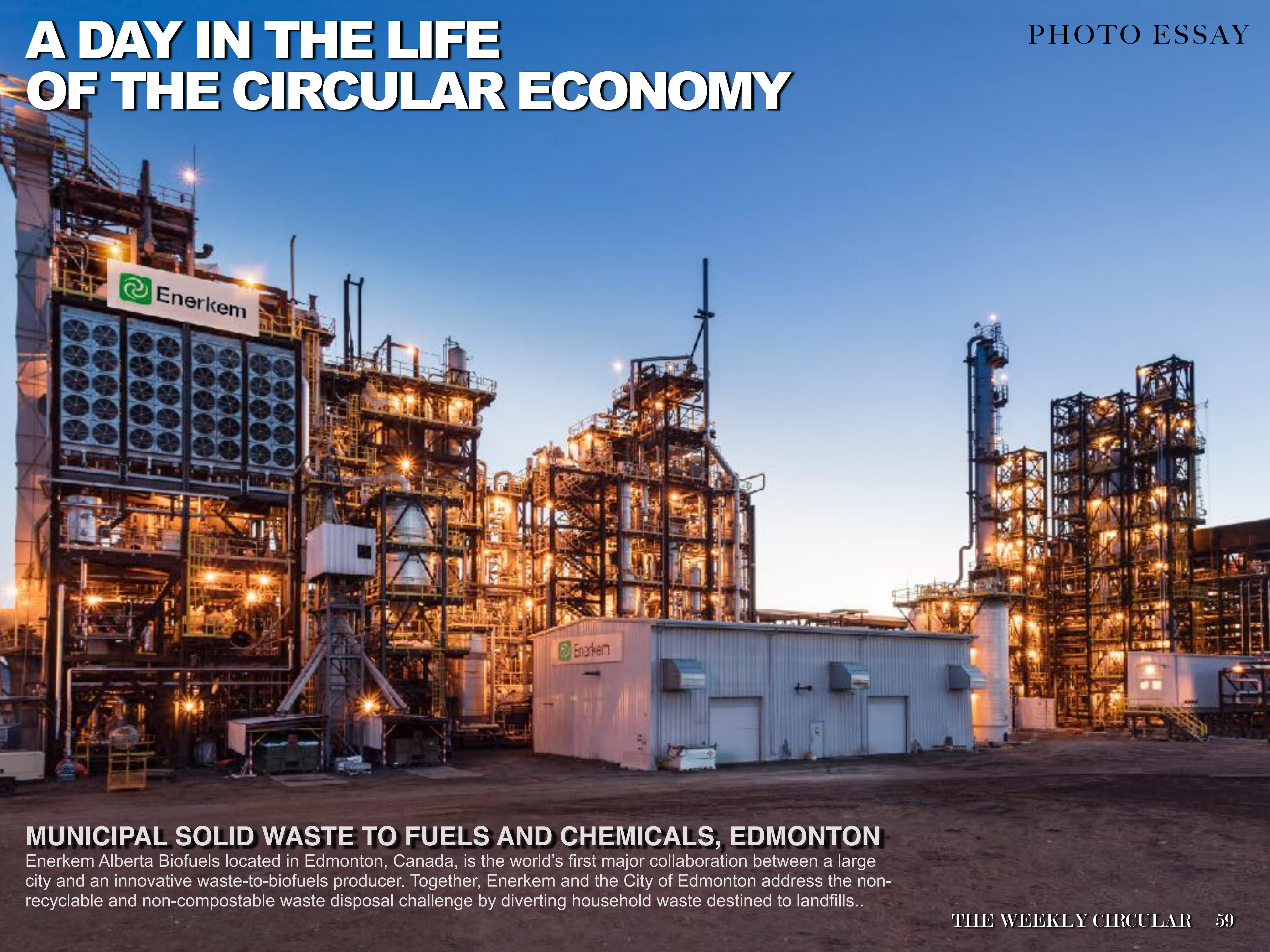
A DAY IN THE LIFE OF THE CIRCULAR ECONOMY



MUNICIPAL SOLID WASTE TO FUELS AND CHEMICALS, EDMONTON

Enerkem Alberta Biofuels located in Edmonton, Canada, is the world's first major collaboration between a large city and an innovative waste-to-biofuels producer. Together, Enerkem and the City of Edmonton address the non-recyclable and non-compostable waste disposal challenge by diverting household waste destined to landfills..

NOORZEEWIND, NORTH SEA

The Egmond aan Zee wind farm off the Dutch coast was set up as a 50-50 joint venture between European utility company Nuon/Vattenfall and Shell. It was the first wind farm over 100MW to be built in the Dutch North Sea and comprises 36 wind turbines that produce enough renewable electricity for more than 100,000 Dutch households. In March 2021 Shell agreed to take over Vattenfall's share in NoordzeeWind and became the wind farm's sole owner.

CO2 DIRECT CAPTURE, SQUAMISH, BRITISH COLUMBIA

In 2017, Carbon Engineering incorporated fuel synthesis capability into the Direct Air Capture pilot plant, creating the world's first AIR TO FUELS™ pilot based entirely on industrially-scalable technologies. When operating,, the AIR TO FUELS pilot produces roughly 1 barrel of fuel per day.

CO2 to OMEGA-3s: COLUMBUS, NM

in 2017, Qualitas Health unveiled a long-term partnership with commercial crop producer Green Stream Farms to triple its algae production to 45,000 pea-equivalent acres, achieving critical mass to become a sustainable omega-3 alternative, worldwide, at commercial scale.

WASTE FOOD, BIOGAS AND METHANOL TO FUELS: BRAWLEY, CA

Oberon is converting waste methanol into rDME at its upgraded facility in Brawley, Calif. It is the first time this feedstock has been used to make rDME at commercial scale. In addition to waste methanol, other potential feedstocks include: biogas from dairy waste, food wastes, agricultural waste, as well as excess electricity and CO_2, resulting in ultra-low carbon to carbon-negative DME.

RENEWABLES FROM SUNLIGHT, PLANT/WASTE OILS CHÂTEAUNEUF-LES-MARTIGUES, FRANCE

Located in Châteauneuf-les-Martigues, near Marseille, France, the TOTAL Energies La Mède complex includes a biorefinery with a production capacity of 500,000 metric tons of renewable fuel per year, an AdBlue production plant, a logistics and storage hub, an industrial-scale training center and a solar farm.

HYDROGEN FROM SEAWATER: Q13A PLATFORM, NORTH SEA

In 2018, Nexstep and TNO selected Neptune Energy to participate in the exciting PosHYdon project with the Q13a platform. Neptune Energy, TAQA, EBN B.V., NAM and TNO are cooperating in order to place an electrolyser on the Q13a platform in 2020this year with which hydrogen can be produced.

SUGAR CANE WASTE TO FUELS/PLASTICS, PUNE, INDIA

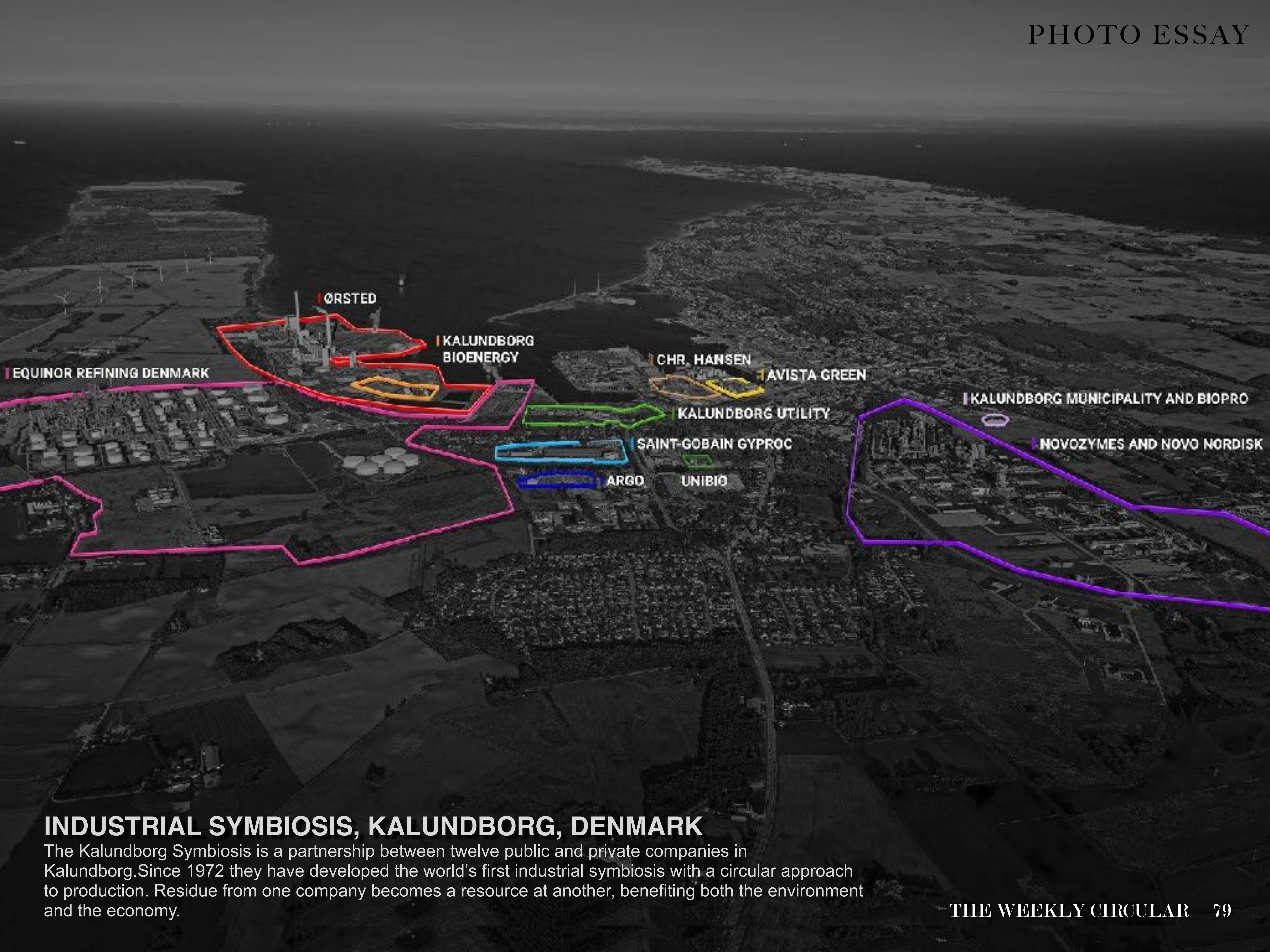
At the Praj Matrix R&D Center in Pune, India, products being developed for commercial projects include biogas, water treatment, solar energy, and cellulosic ethanol from sugarcane trash and bagasse, corn cobs, rice and wheat straw and cotton stalks — and the ethanol is being studied for upgrade to chemicals and materials in addition to fuels. including plastics and packaging materials as well as bio-bitumen.

FOREST WASTE TO FUELS, CHEMICALS, SOMERSBY, NSW

Licella's hydrothermal upgrading platform, the Cat-HTR (Catalytic Hydrothermal Reactor), can rapidly transform a wide range of biomass, waste plastic and industry residues into a synthetic oil or biocrude. The company established a JV with Canfor to convert forest waste (such as beetle-killed pine and other fire hazards into fuels and chemicals that displace petroleum drilling.

AGRICULTURAL WASTE TO FUELS, PODARI, ROMANIA

Clariant is building a new commercial-scale plant for the production of cellulosic ethanol from agricultural residues based on the sunliquid® technology. The plant with an annual capacity of 50,000 tons of cellulosic ethanol will be located in Podari near Craiova in the southwestern part of Romania.



INDUSTRIAL SYMBIOSIS, KALUNDBORG, DENMARK

The Kalundborg Symbiosis is a partnership between twelve public and private companies in Kalundborg.Since 1972 they have developed the world’s first industrial symbiosis with a circular approach to production. Residue from one company becomes a resource at another, benefiting both the environment and the economy.

WASTE INDUSTRIAL GASES TO T-SHIRTS: SHOUGANG, CHINA

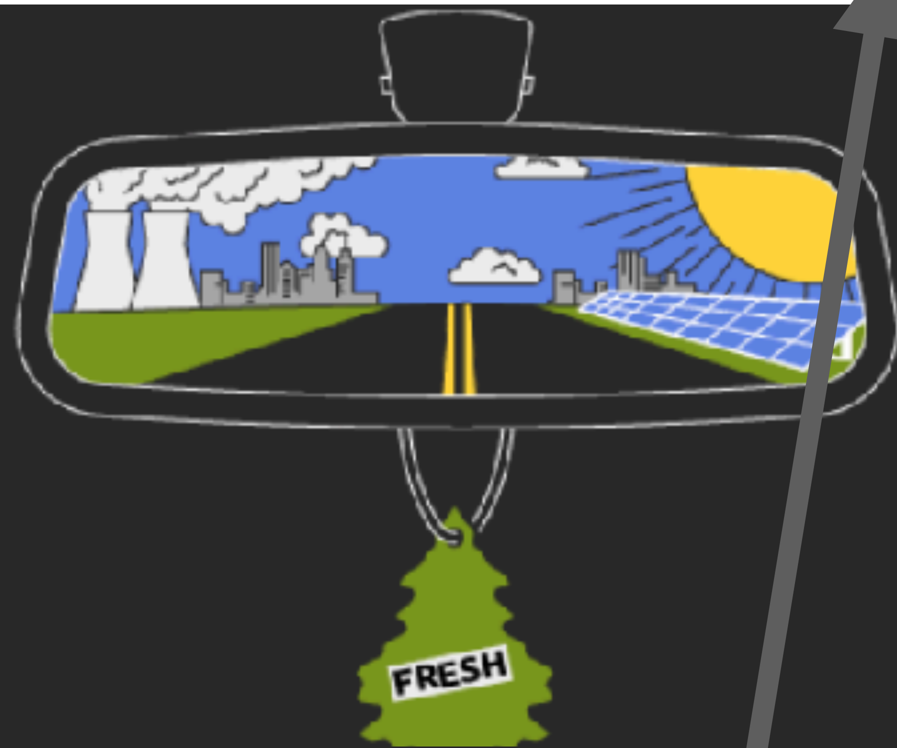
Beijing Shougang LanzaTech successfully produced over 9M gallons of ethanol from recycled steel mill emissions in its first year of operation. Currently being sold to the road transport market as a low carbon fuel blend, ethanol from this facility will now be converted into PET to be used for production of CarbonSmart consumer goods such as T-shirts, bottles, and packaging.

EV VS ICE

ELECTRIC MOTORS VS INTERNAL COMBUSTION ENGINES

WHO ROCKS? WHO RULES?

The Wall Street Journal looked at this topic recently. Let's look at those caveats.



Are Electric Cars Really Better for the Environment?

EVs produce fewer emissions overall than their gas-powered counterparts, but there are caveats

Why the Debate Drives Everyone Nuts

The costs and emissions depends on engine settings as much as energy system.

Here's a 2014 Ford Focus flex-fuel

It has a 2.0l engine, and DPS6 automatic transmission

EPA Gasoline
26/36
City/Highway

EPA E85
20/27
City/Highway

This is what you see on the mileage sticker.

E100 Group's E85R
23/35
City/Highway

This is what you get with modest engine improvements.

What happened?

In a E100 Group test, new pistons raised the compression ratio to 13.5 from 12.0, engine timing was advanced 4 – 6 degrees depending on engine load; the air/fuel ratio moved to 11.3 from 9.8 under light load and to 9.7 from 8.3 under heavy load.

Did the modified vehicle lose power with ethanol?

Actually, it gained. Horsepower at the wheels was increased from ~128 to 147 HP.

Mileage is energy density and octane

High octane fuels can run in high compression engines that get better mileage

Here's a 2010 Mazda 6

Here's a 2017 Mazda 6

A Classic of the Old School.
The 2010 Mazda 6 runs on on a Mazda L-engine with 10:1 compression and its EPA mileage rating is 21 city / 30 highway

What happened by 2017?
The 2017 runs on the SKYACTIV engine with 13:1 compression and has a fuel economy rating of 26 city / 35 highway.

Why the big improvement?
Mazda credits "significantly improved engine efficiency thanks to the high compression combustion, resulting in 15 percent increases in fuel efficiency and torque" yet cautions that US models will have 3-5 percent less fuel economy because of running on 87 octane instead of 91 octane fuels.

What's the bottom line?
There's a gain of roughly 1 point of fuel efficiency for every 1 point of extra octane. How does this compare to the Ford Focus test? In that case, the gain was 23 points with a 21 point jump in octane. About the same.

Comparison vehicles matter

Sedan vs sedan is more fair than than sedan vs SUV

Here's a 2021 Tesla Model 3

MSRP is $37,490

Here's a same-class Toyota Camry

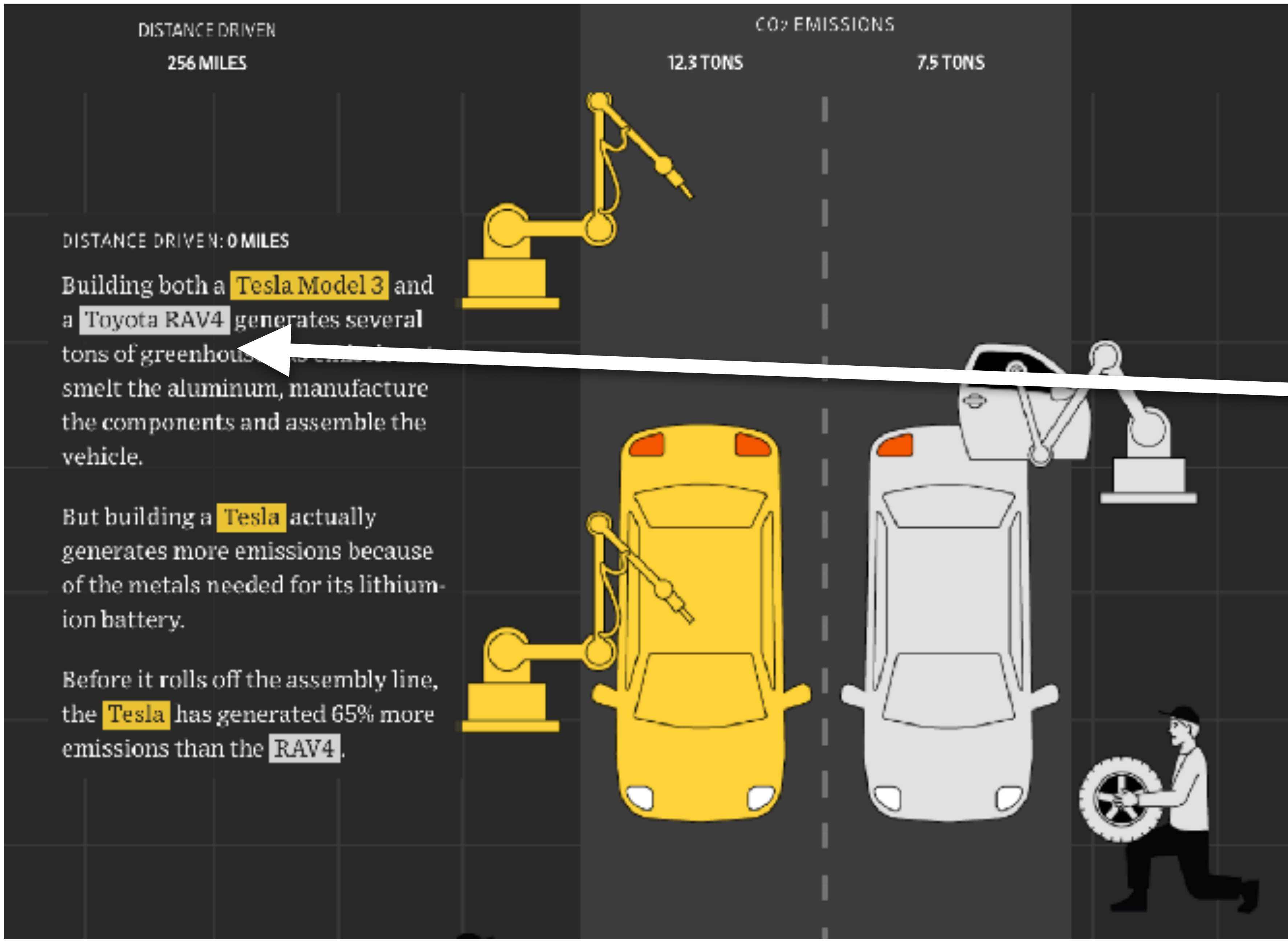
MSRP is $24,425

A recent Wall Street Journal special report aimed to settle the debate about EVs vs IC engines… by comparing a Model 3 to a RAV4 that costs more and has 12% higher GHG emissions than the Camry. Cheeky!

Here's a Toyota RAV4

MSRP is $26,250

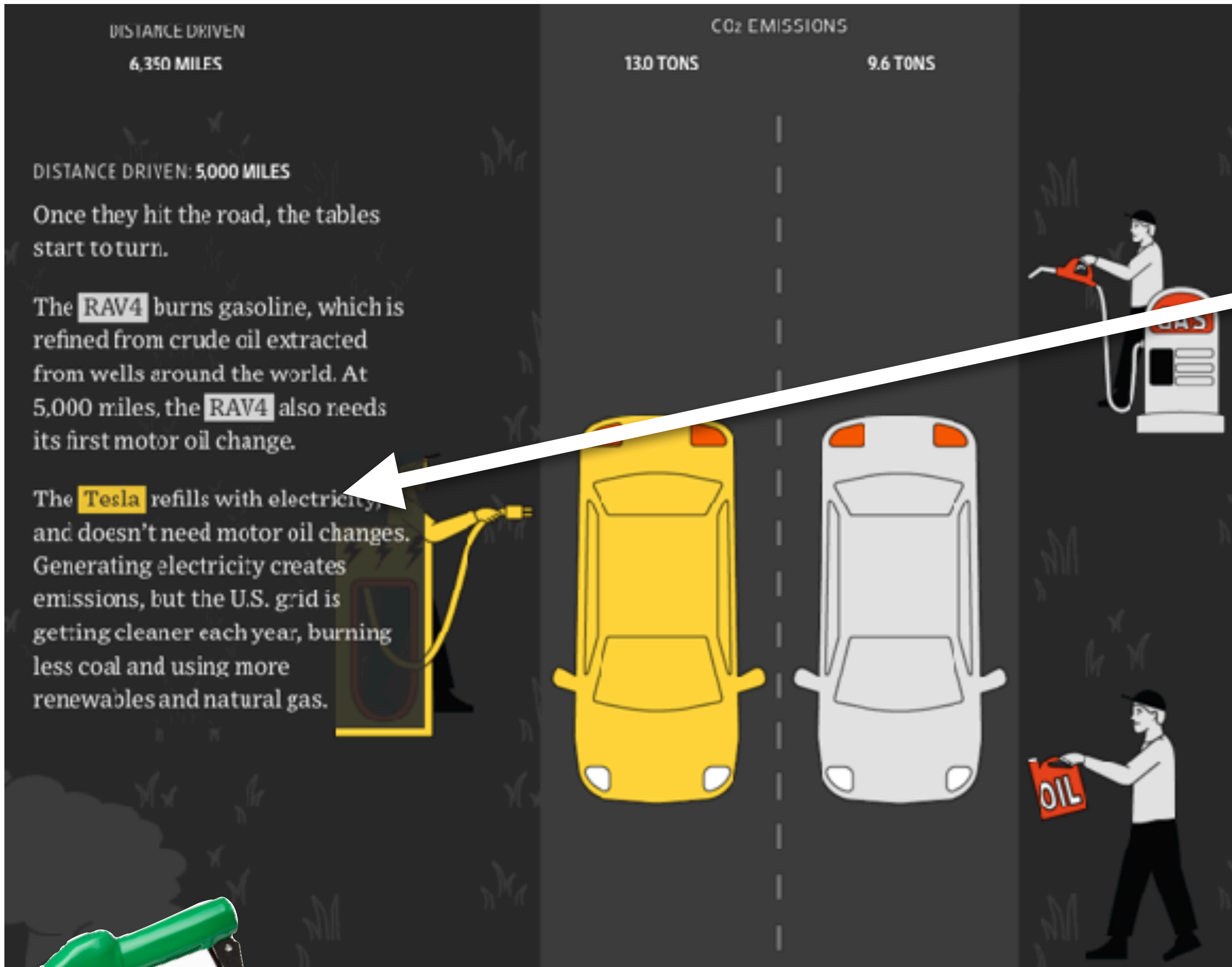
Yep, swappin' that Camry for a RAV4



Watch out! The researchers are comparing a mid-size sedan (EV) to an SUV (ICE engine). A more fair comparison is a mid-size sedan to a mid-size sedan. The Toyota Camry costs 7% less and gets 13% better mileage than the Toyota RAV4.

VS

Beware of comparisons to hard-to-find fuels

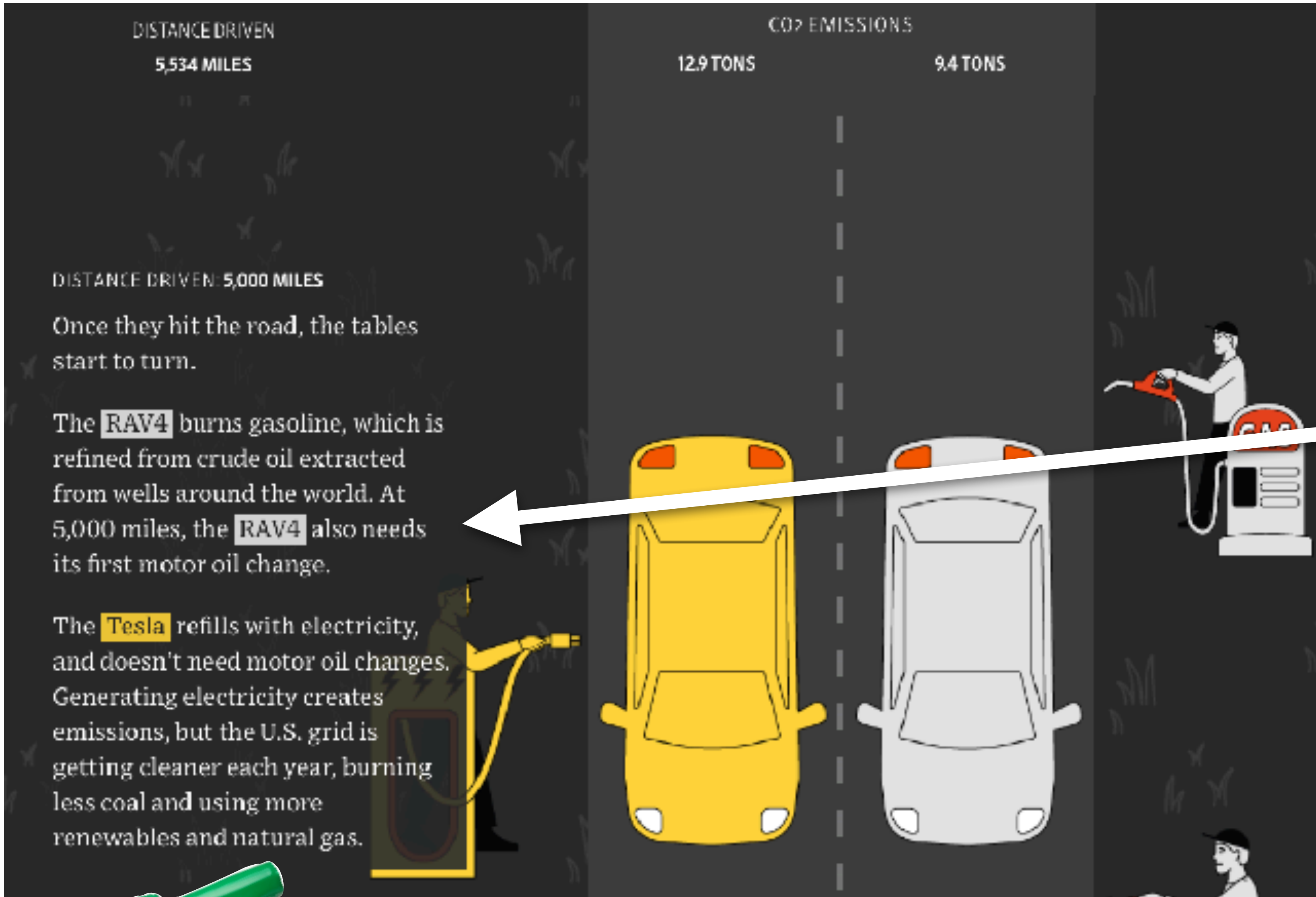


Watch out! The researchers are comparing an EV to an all-gasoline burning experience. A better comparison is to E15 ethanol, which is increasingly the standard fuel used in the United States. That fuel has 6 percent lower emissions than straight G100 gasoline, which is difficult to find in the US.

Freddie the Fact Checker found this at ethanolrfa.org:

> E10 is a 10 percent ethanol-blended fuel. Today all vehicles can run on E10, which is interchangeable with gasoline. Since 2010, nearly all gasoline sold in the United States has contained 10 percent ethanol.

'Don't over-change the oil, bub'

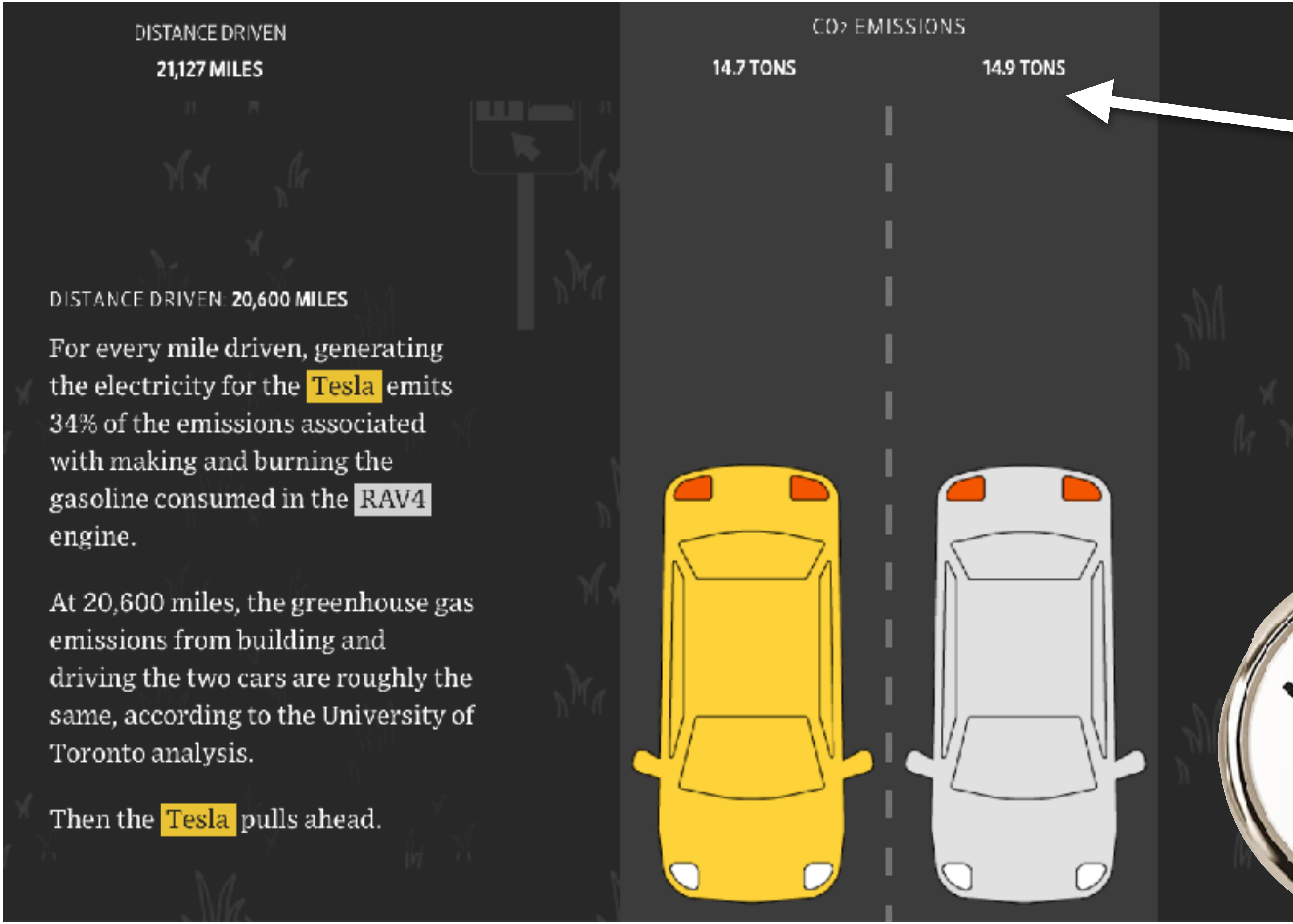


Watch out! Yes, you change oil with an IC engine, you don't with an electric. But 5,000 miles, really? All modern Toyotas recommend synthetic oil, which needs to be changed every 7,500 to 10,000 miles, says Toyota.That's for the Camry or the RAV4.

Freddie the Fact Checker found this at aaa.com:

It used to be normal to change the oil every **3,000 miles**, but with modern lubricants most engines today have recommended oil change intervals of 5,000 to 7,500 miles. Moreover, if your car's engine requires full-synthetic motor oil, it might go as far as **15,000 miles** between services!

If You Really Count It Fairly...

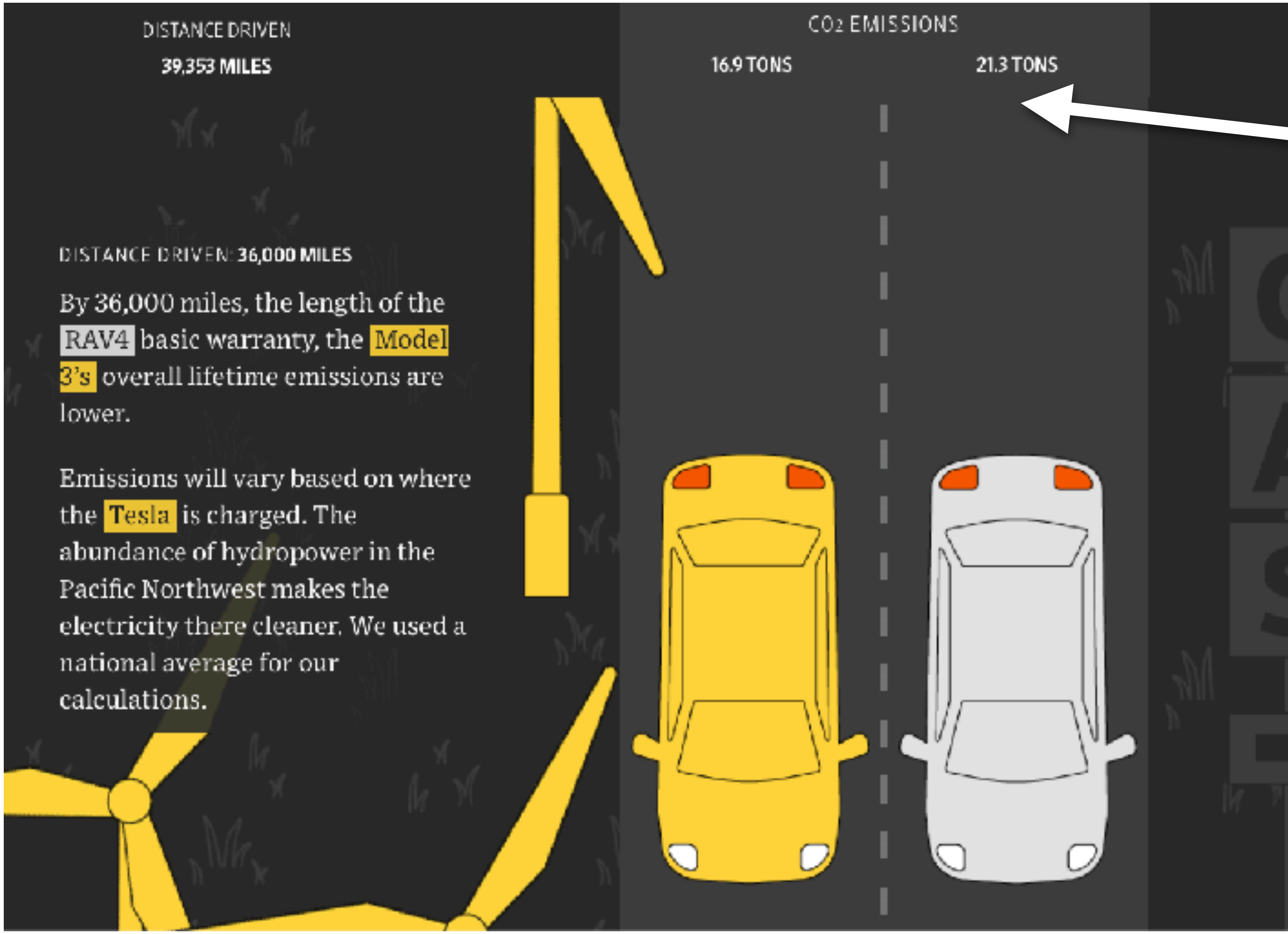


Watch out! At 20,000 miles, a Toyota Camry on conventional fuels (E15 ethanol) will have emitted **12.9** tons, not **14.9** tons.

The Circular's Fair Comparison Detector

VS

If You Really Count It Fairly...

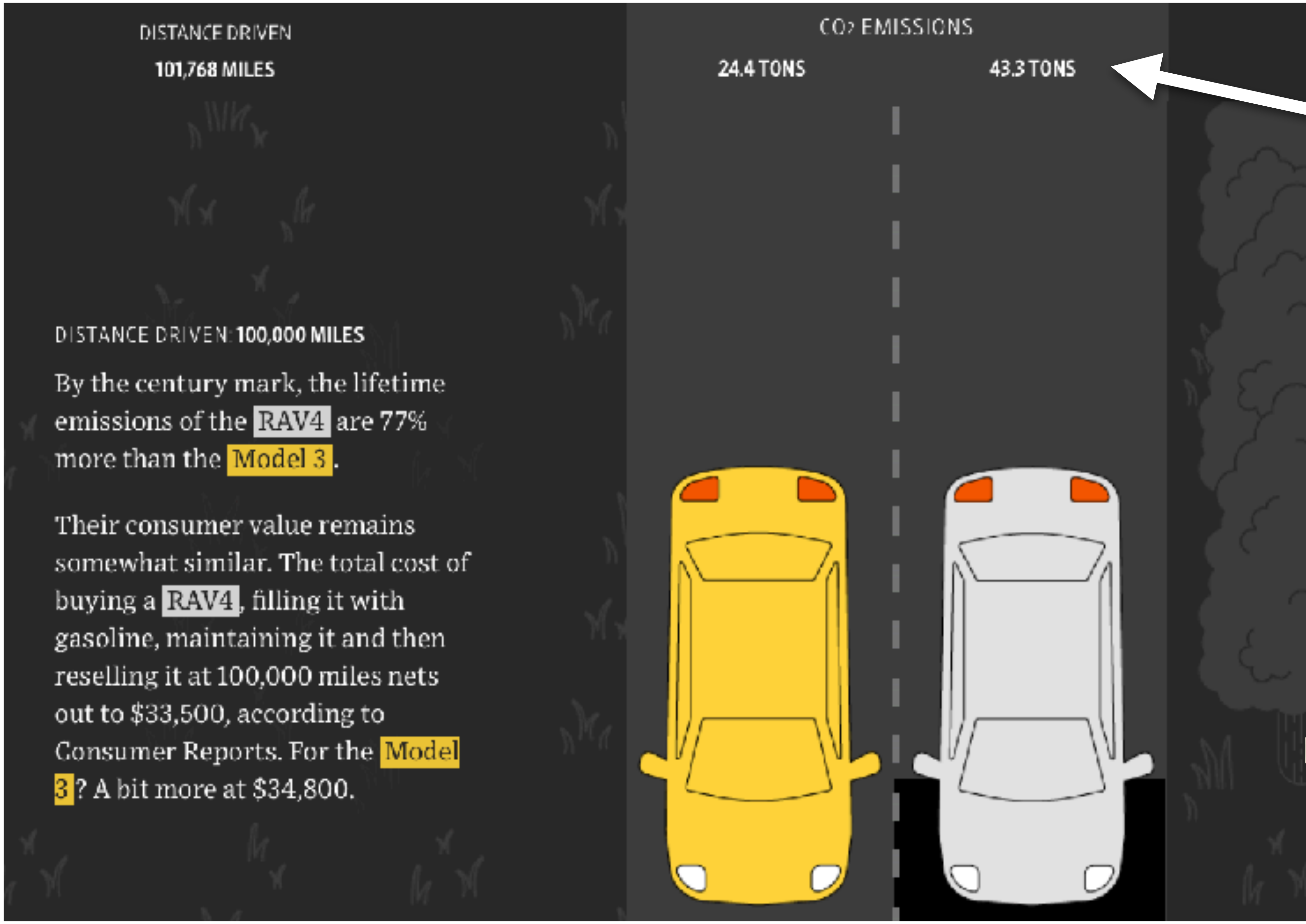


Watch out! By 36,000 miles, the Toyota Camry would have emitted 17.2 tons, not 21.3 tons. **The Model 3 is lower.** But, the fair figure should be 1.8 percent, not 20.7 percent.

The Circular's Fair Comparison Detector

VS

If You Really Count It Fairly…

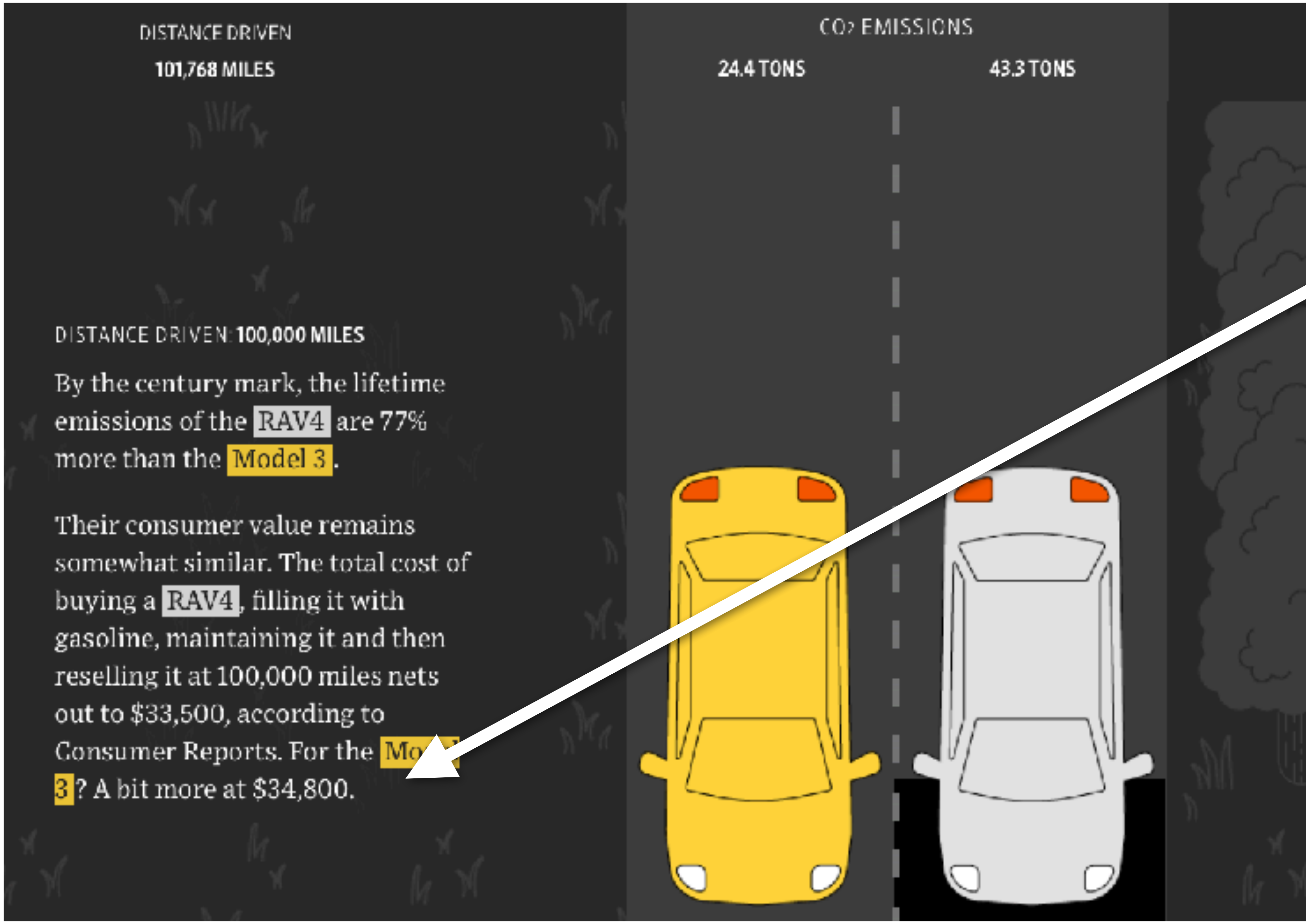


Watch out! By 100,000 miles, the Toyota Camry would have emitted 34.3 tons, not 43.3 tons. The Model 3 is lower by 29 percent, not 77 percent.

VS

The Circular's Fair Comparison Detector

The IC engine is more cost effective at the 100,000 mile mark

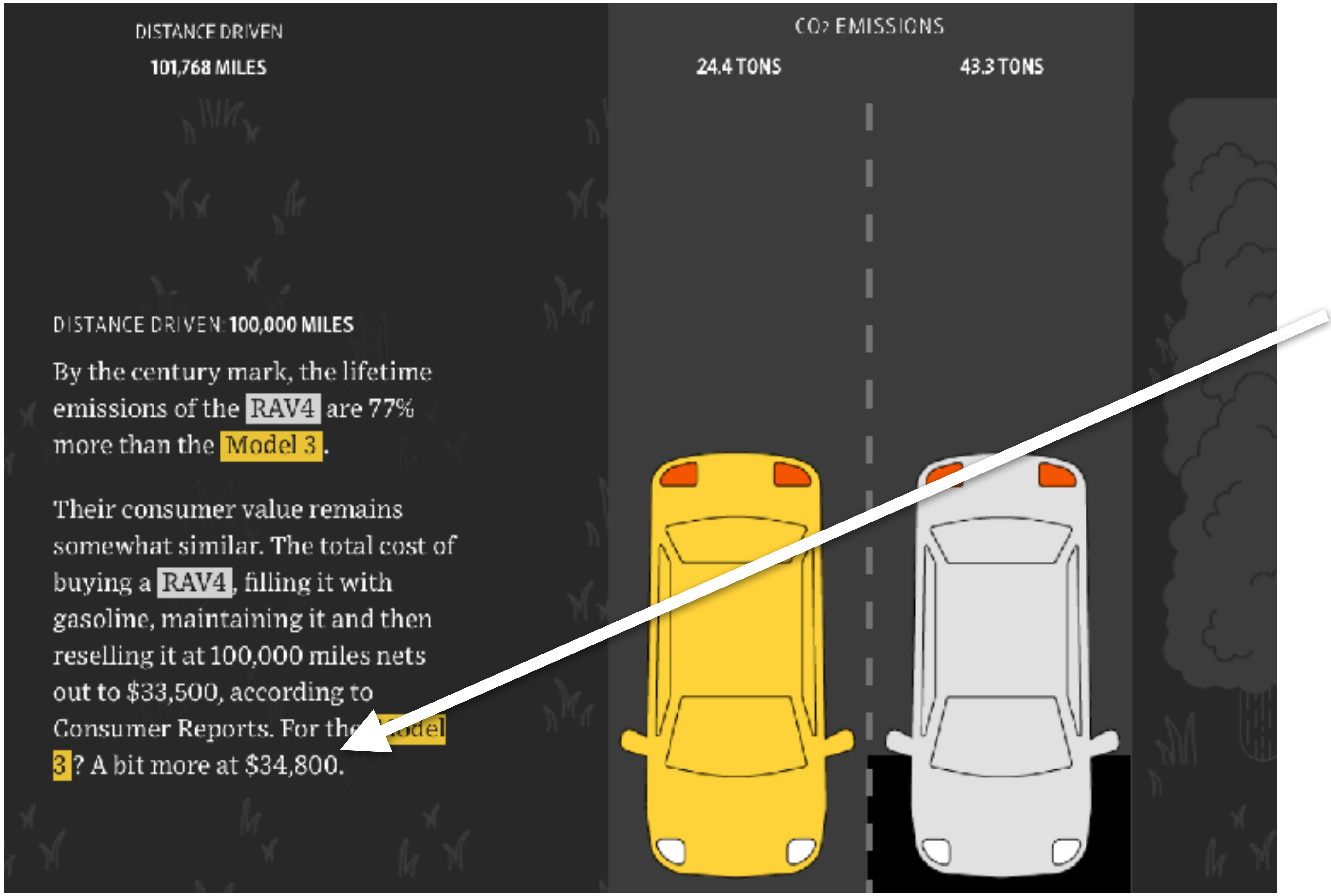


Watch out! When it comes to resale price, that's really a guess in 7 years; there are no 7-year old Model 3s in existence.

A fairer comparison would be to the total cost of buying (MRSP), oil changing, and refueling an ICE engine. Both cars need comparable routine maintenance (e.g. tires, dings). At current electricity and fuel prices, it's $33,270 for the Camry and $42,990 for the Model 3.

VS

If everyone is going to re-charge at home, why are we building charging stations?



Watch out! In comparing costs here, the researchers used home retail electricity, which averages $.13/KwH. But charging at a Supercharger costs $.26/KwH. If using a Supercharger, it's not $9,970 more for the Model 3, it's $15,520 more, over 100,000 miles.

Is it really worth paying $981 per ton for carbon reduction?

Why is this so significant, the cost differential between a Model 3 and a Camry?

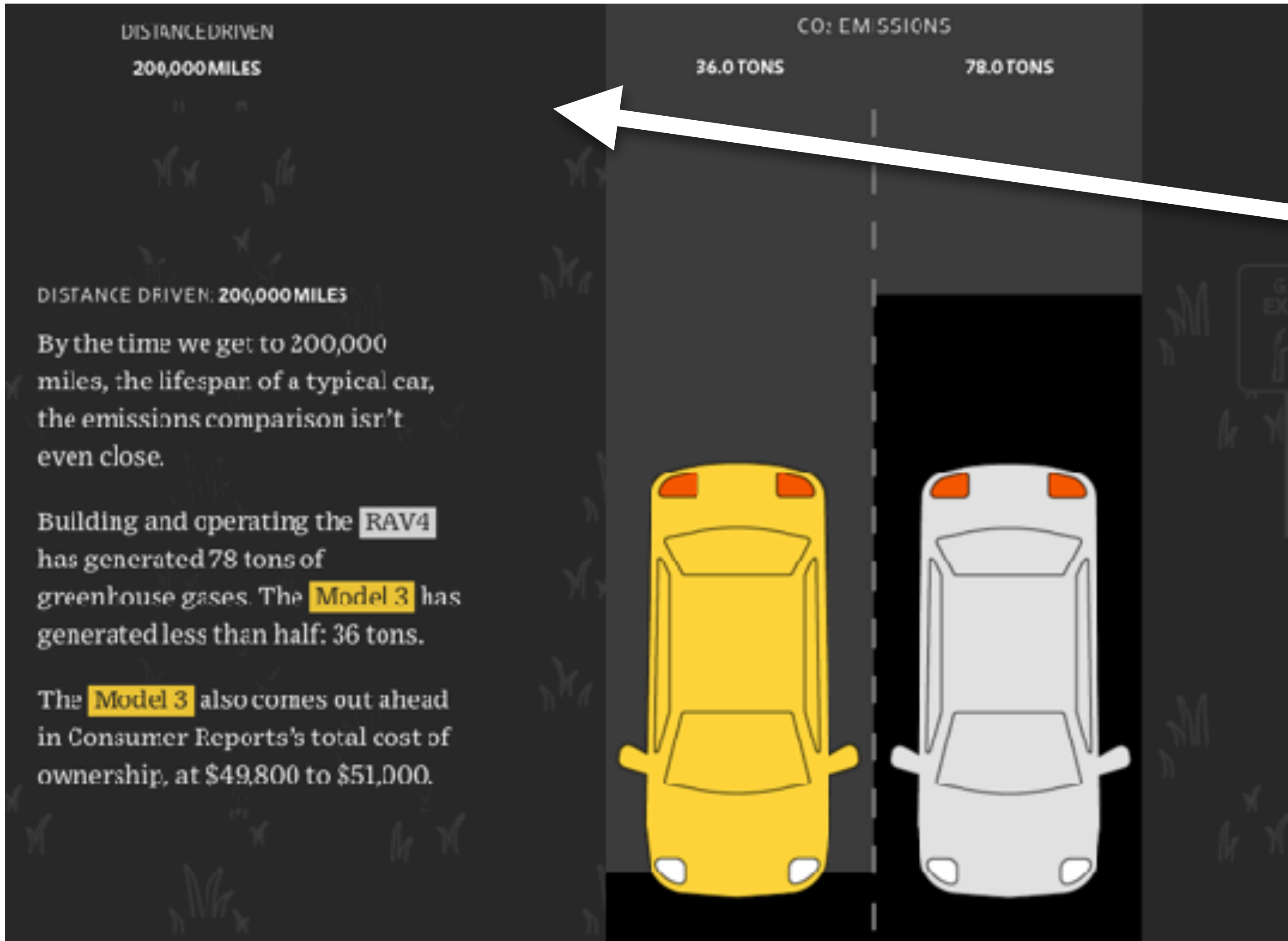
Well, think of it in terms of a carbon price. The Tesla Model 3 is emitting 9.9 tons of carbon less than the Camry, over 100,000 miles, And **that's 29 percent less.** But, at what cost? We're paying $9720 to reduce 9.9 tons of CO2. That's **$981 per ton** of GHGs avoided.

If we're exclusively Supercharging the Model 3, the cost of carbon reductions rises to **$1567 per ton**. That's 40 times more than current models on long-term carbon prices.

Freddie the Fact Checker found this at quartz.com:

The cost of saving the world is $40 per ton of carbon. Here's what that means.

If the average person keeps a car for 15 years, why is there a resale market for Tesla?



Watch out! Do people keep Teslas for 15 years and 200,000 miles? in 2019, automakers sold 16.9 million light duty vehicles to 119 million US car-owning (or leasing) households. That's a replacement rate around every 7 years, or 91,000 miles. And 30 percent of cars are leased (see below), which have 3-5 year terms in most cases.

Some final thoughts.

The hard data tell us that IC engines have a powerful economic rationale, and that EVs such as the Model 3 have a powerful emissions rationale.

We also know that Low Carbon Fuel Standards are capable of dramatically disrupting fossil fuel markets in the $200-$300 per ton range as a carbon price. At those prices, innovation moves fast, renewable fuels deploy with 70+ percent reductions in emissions compared to baseline gasoline, using waste feedstocks that fill sewers and landfills. Big numbers, major players. That's steeper than the emissions reduction you get with a Tesla. At a far lower price. C

Freddie the Fact Checker found this at evannex.com.

WHY TESLAS MAY KEEP THEIR RESALE VALUE BETTER THAN GAS-BURNERS

HNSI:
REPURPOSING EV BATTERIES FOR POWER SUPPLY

We find this one fascinating. Why not take one problem — the massive number of used EV batteries that are going to pile up around the world — and use them to provide clean, uninterrupted power storage for critical industry. Applications like the cell phone towers come to mind — they need back-up power supplies, usually provided by diesel generators.

Is HNSI crazy to think that you can kill two important birds — resilient power supply and the waste battery problem — with one stone? Former Undersecretary of the Navy Tom Hicks does't think so. "t's not crazy," he told CIRCULAR. "The second life applications resulting from the coming transition to electrification will present all sorts of opportunities. The deck seems to suggest to me they are pretty early in the process. It would be interesting to understand who they see as their competitors and how they are doing in their development. And it would be interesting to know more about their EV [supplier] deals."


Massive Lack of Electrical Storage
• Industry is moving away from diesel power generation
• Dearth of large scale clean, reliable, and affordable storage solutions
• > One million telco locations need back up power
• New lithium-ion storage costs $175 to $600/kWh
• Dept of Energy predicts 27% CAGR for stationary energy storage through 2030
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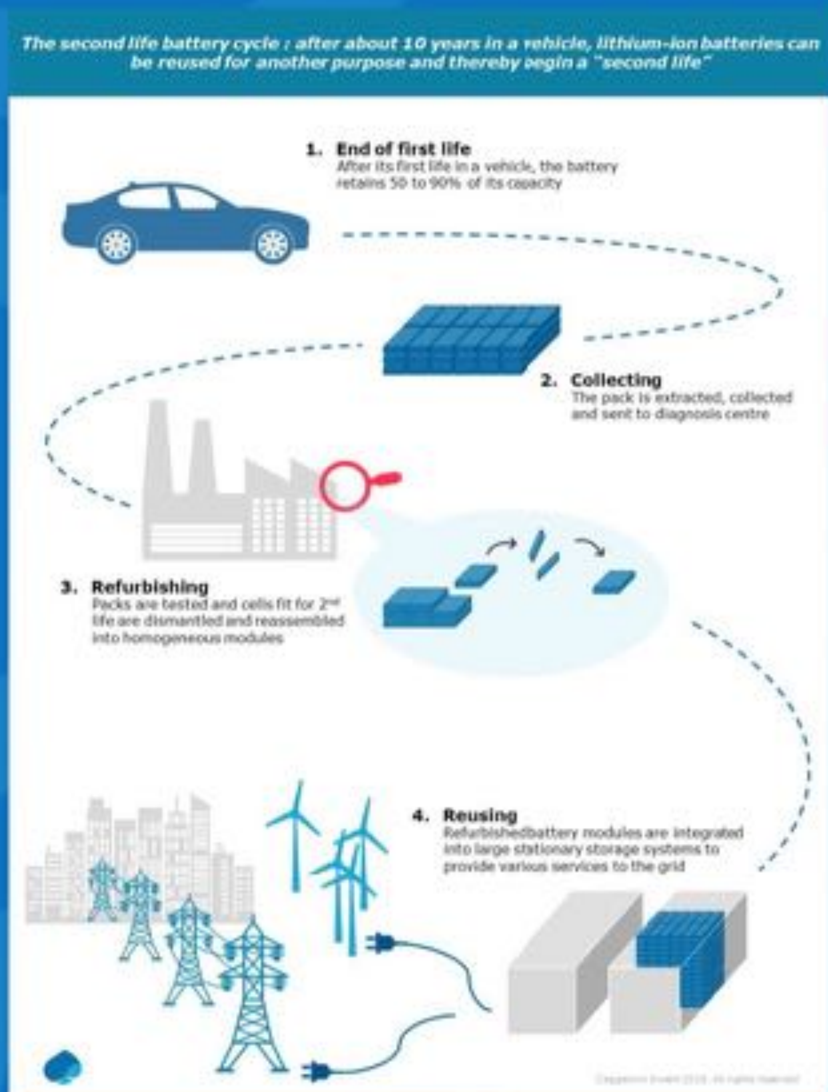
Electrical Storage as a Service (ESaaS)



- Both a power storage and recycling solution
- Used EV batteries to provide utility and industrial storage
  - Clean, affordable, and resilient ($100-$150/kWh)
  - Large, low-cost feedstock (< $20/kWh)
  - Subscription-fee based model/not capital intensive
- Current solutions are:
  - Diesel *(Dirty & out of favor)*
  - Inefficient (JIT Delivery/No Energy Storage)
  - Expensive ($600-$1200/kWh)
  - Capital Intensive
  - Not ESG Compliant

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HNSI at a Glance
• Turn waste batteries into high performance, high margin, stationary battery systems
• $10B+ addressable market
• Market disrupting technology. EBITDA margins 3X competitors'
• Low tech risk, defensible IP, trade secrets and price flexibility
• Market demands commercialization of industrial scale, stationary power storage
• Checks all the ESG boxes
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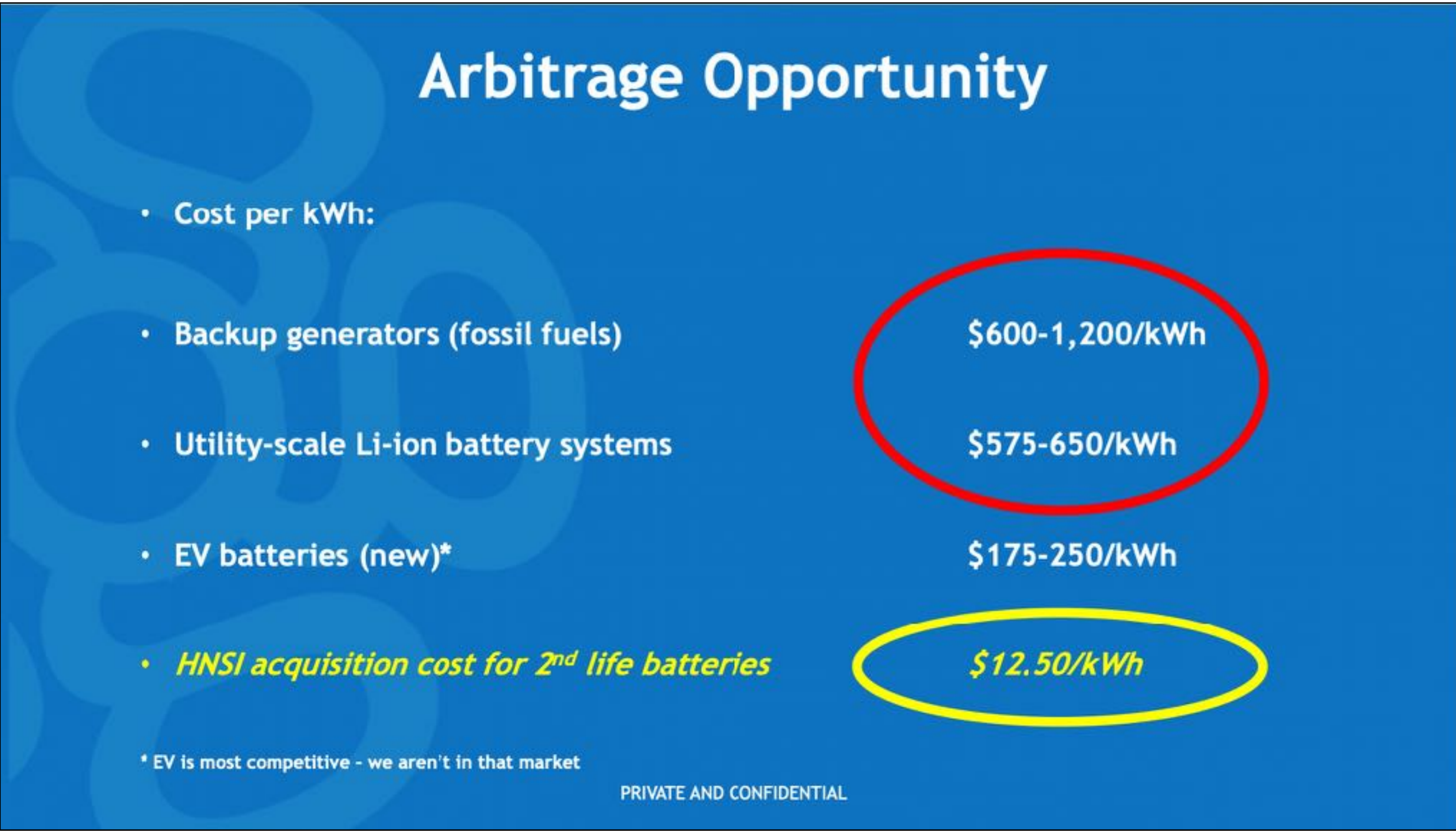
Arbitrage Opportunity
• Cost per kWh:
• Backup generators (fossil fuels)
$600-1,200/kWh
• Utility-scale Li-ion battery systems
$575-650/kWh
• EV batteries (new)*
$175-250/kWh
• HNSI acquisition cost for 2nd life batteries
$12.50/kWh
* EV is most competitive - we aren't in that market
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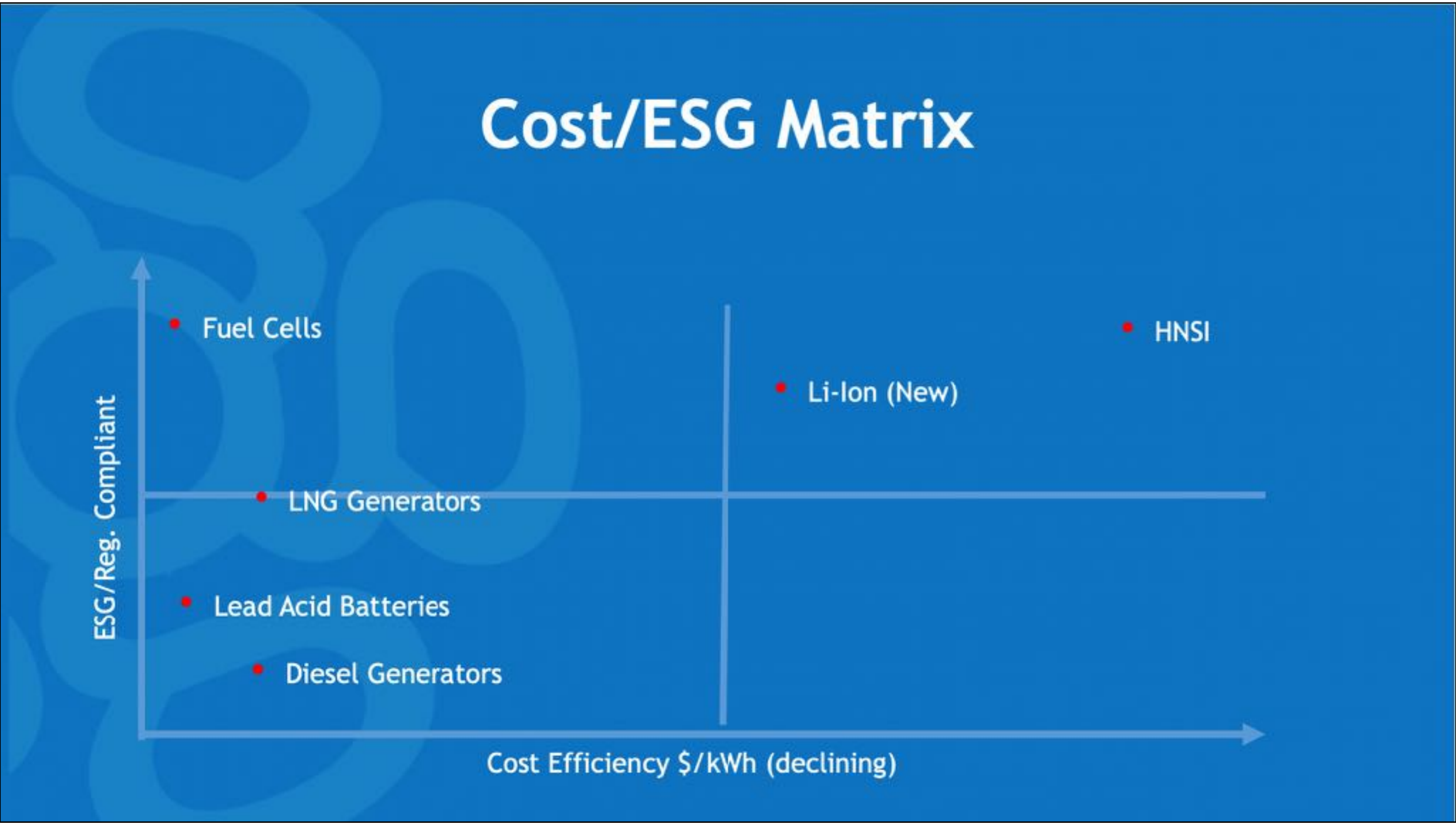
Cost/ESG Matrix
Fuel Cells
HNSI
Li-Ion (New)
LNG Generators
Lead Acid Batteries
Diesel Generators
ESG/Reg. Compliant
Cost Efficiency $/kWh (declining)


Technology
• Proprietary hardware and software
• Plug and play power aggregation
• Charging from any source (solar, wind, grid, etc.)
• Intelligent charging capabilities
• Intelligent management systems that prolong battery life
• Remote monitoring and control via satellite modems
• Hardware and software hardened from cyber activity
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Commercialization
• Mobile wireless industry will be first to commercialize
• Network resilience is fundamental operating element
• Customer demand
• Regulatory demands
• Frequent or prolonged outages cause customer churn
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Adoption Drivers

- Market (customer) pressure
  - End users don't tolerate network outages
  - "New" customers are mostly churn from other carriers
- Regulatory
  - California recently mandated 3 days of backup power at cell sites
  - Florida, Texas, SC, VA, CT and others considering mandates
- Tower companies
  - Need new revenue streams
    - Can pass backup power costs onto telco tenants via existing leases
    - Partner for access in exchange for commissions
- Price
  - Lowest cost operator (pricing flexibility)
  - More resilient, reliable, flat cost curve for customers

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Competition is One Dimensional
• Generator Manufacturers (OEMs: Generac, Deere, Cummins, etc.)
• Not in the recycling business
• Not in the ESaaS business
• Offer just-in-time delivery, not storage
• Sell products into customers with long sales cycles CAPEX) vs. subscription solutions (OPEX)
• Many power storage strategies are focused the residential market
• Recyclers (i.e. Redwood, WMI, etc.)
• Not in the ESaaS business
• Not looking to direct recycle or 2nd life applications
• Competition for feedstock
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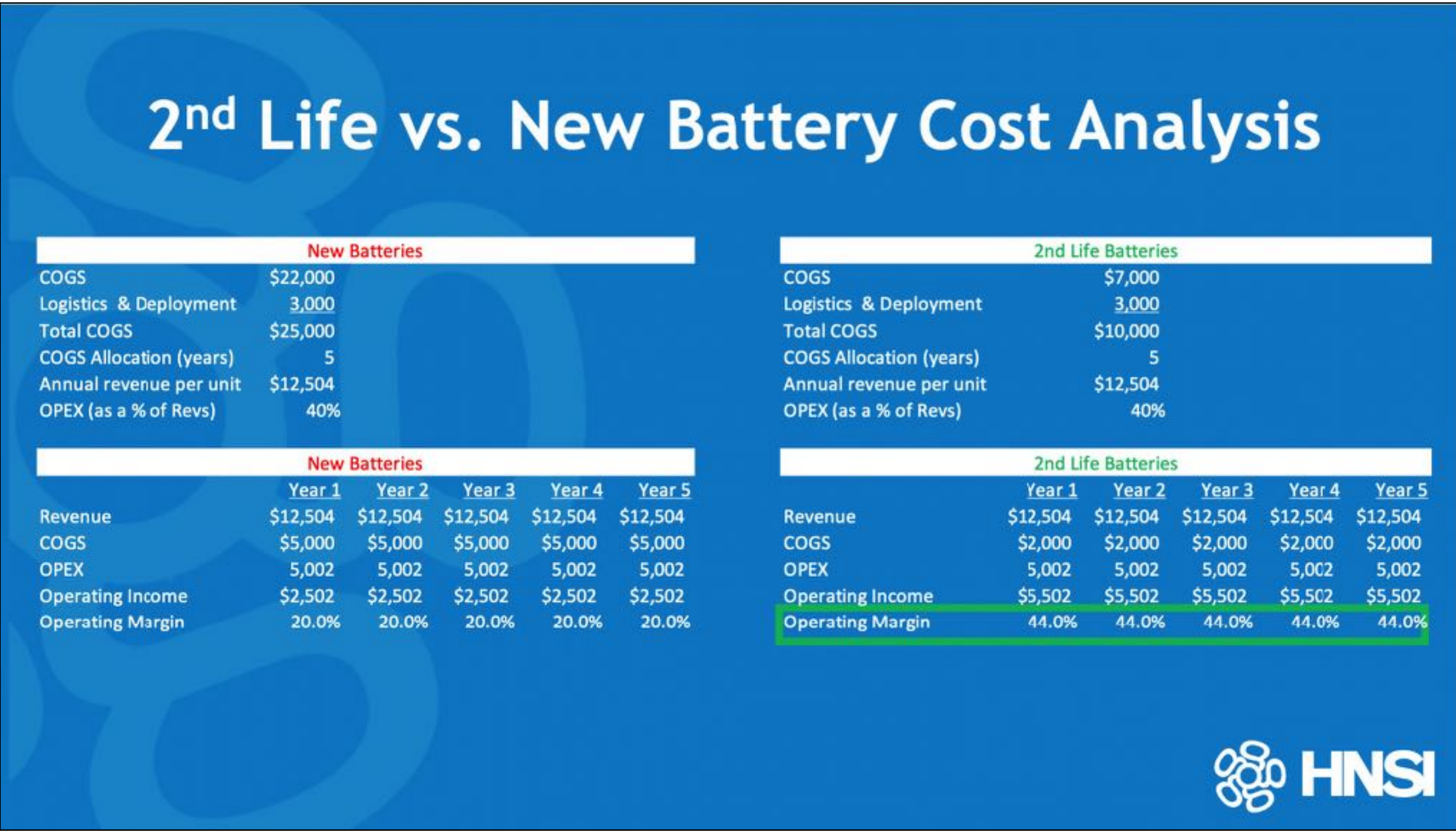


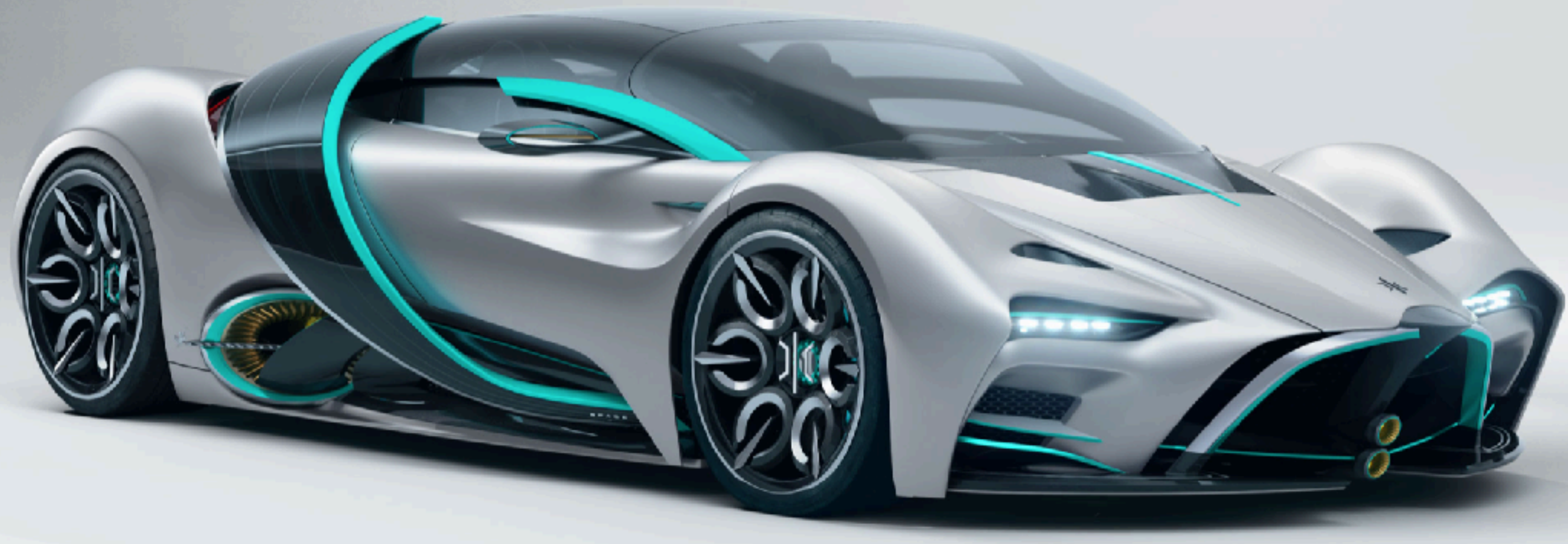
2nd Life vs. New Battery Cost Analysis

New Batteries	
COGS	$22,000
Logistics & Deployment	3,000
Total COGS	$25,000
COGS Allocation (years)	5
Annual revenue per unit	$12,504
OPEX (as a % of Revs)	40%

2nd Life Batteries	
COGS	$7,000
Logistics & Deployment	3,000
Total COGS	$10,000
COGS Allocation (years)	5
Annual revenue per unit	$12,504
OPEX (as a % of Revs)	40%

New Batteries	Year 1	Year 2	Year 3	Year 4	Year 5
Revenue	$12,504	$12,504	$12,504	$12,504	$12,504
COGS	$5,000	$5,000	$5,000	$5,000	$5,000
OPEX	5,002	5,002	5,002	5,002	5,002
Operating Income	$2,502	$2,502	$2,502	$2,502	$2,502
Operating Margin	20.0%	20.0%	20.0%	20.0%	20.0%

2nd Life Batteries	Year 1	Year 2	Year 3	Year 4	Year 5
Revenue	$12,504	$12,504	$12,504	$12,504	$12,504
COGS	$2,000	$2,000	$2,000	$2,000	$2,000
OPEX	5,002	5,002	5,002	5,002	5,002
Operating Income	$5,502	$5,502	$5,502	$5,502	$5,502
Operating Margin	44.0%	44.0%	44.0%	44.0%	44.0%



THE HYPERION XP-1

They've only made one of these, so far. It's a hydrogen fuel cell concept car from Hyperion, striking not only in the powertrain but in the styling. It's a kandy-kolored mint-flake streamline baby, for sure. And, if they make the hydrogen via photolysis — using photons as nature has long intended, to split water in order to support advanced life — it would by the most circular car, ever.

Thank you for reading this issue of

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