





INTRODUCTION

Pangaea Ventures' 2023 Impact Report provides an in-depth look at the value and potential of our growing portfolio of hardtech solutions that have the ability to solve the world's most fundamental challenges.

Our team invests in entrepreneurs to make an impact on the world

“There is an immediate and urgent need to deploy hard technology solutions that address some of the world’s biggest problems.

Our climate is changing which can jeopardize food security and human health & well-being. Pangaea’s portfolio continues to work tirelessly to help mitigate these problems and we have bold ambitions for our collective impact by 2030.”



Chris Erickson
Founder & General Partner



Purnesh Seegopaul
General Partner



Andrew Haughian
General Partner



Janelle Goulard
Partner



Sarah Applebaum
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Tracy Hedberg
Director, Finance & Admin



Sayuri Nonaka
Director of Asia



David Weekes
Associate



Tara Nietzold
Associate

A message from Pangaea Ventures

Just three years in, the 2020s are shaping up to be a difficult decade for the world. Escalating global conflict continues to shake economic and social foundations. A volatile market and rising inflation are affecting the cost of food and shelter, making it difficult for people to meet their basic needs.

Record-high carbon dioxide emissions levels in 2023 and mounting challenges across food security and healthcare underscore the codependent relationship between humans and the world we live in. As worldwide uncertainty and instability increases, our commitment to adapt, evolve, and change is perhaps more necessary than ever.

The World Health Organization (WHO) projects that 89% of deaths will be caused by chronic diseases by 2050, causing overwhelming healthcare costs and a reduction in quality of life for a majority of individuals. Preventing and treating chronic disease has the potential to turn these oncoming tides. Human health and sustainability are inextricably linked. For example, to reduce obesity and mitigate complications like diabetes, people need access to more nutritious foods, especially fruits and vegetables. This requires the agriculture industry to provide affordable produce despite the effects of soil depletion and climate change.

Although 2023 was a challenging fundraising year for many start-ups, we saw an acceleration of capital formation within

the Pangaea portfolio. This included new investments such as Ardent Technologies and PH7 Technologies, where Pangaea led oversubscribed Series A rounds with a fantastic group of syndicate partners. Portfolio veterans such as CarbonCure closed significant growth equity rounds. We believe that this success demonstrates a systematic change in how investors view the opportunity to participate in the emergence of a more sustainable future.

We continue to invest in companies that deliver hardtech solutions to ensure a sustainable future. For us, sustainability means healthy air, healthy water, healthy land and healthy people. Each time a viable solution comes to market, it inspires people to see that change is possible. That inspiration motivates buy-in and spurs investment, creating exponential impact.

As Larry Fink says in his 2023 Letter to CEOs, “Investing is an act of hope and optimism. People only invest if they believe in the future.” We hope that, like us, you choose to believe in the future, too

How we measure impact

Using and improving internal assessment metrics like quality adjusted life years (QALY) and our impact money multiplier (IMM) helps us quantify the impact of our portfolio, enabling us to see exactly how each invested dollar is shaping the economies and communities of tomorrow.

This year, we used IMM to quantify the value of impact created by the companies in our portfolio versus the investment made. For example, we estimate the value of carbon dioxide savings using the EPA's Social Cost of Carbon estimate. The impact of healthtech portfolio companies is the most challenging to quantify and we use QALY, a metric that reflects the value of health interventions in terms of both longevity and quality of life lived during those years.



Pangaea's 2030 Impact Strategy

Deal Flow Sourcing

Focusing on discovering companies that can contribute meaningfully to Pangaea's identified impact targets.



Due Diligence & Selection

Quantify and qualify the economic and social impacts of business's activity using metrics like QALY and IMM.



Investment Management

Continuously measuring, reporting on and managing impact to assess progress towards Pangaea's goals.



Exit

Determining lifetime impact and measuring and reporting progress towards global 2030 impact goals.

METRICS & METHODOLOGY

We measure what matters. Pangaea's internal metrics establish a multidimensional view of each portfolio company's impact, providing insight into their potential for social, ecological and economic good.

About Pangaea Ventures

Pangaea Ventures is an unparalleled hard-tech investor that invests in companies utilizing the latest breakthroughs in materials science, chemistry and biology to solve many of society's most pressing issues.

Established in 2000, our team has spent decades standing shoulder-to-shoulder with our entrepreneurs, rolling up our sleeves to help them solve problems. We invest with impact.

We strive to maximize returns by quantifying the impact generated by our portfolio companies. Our due diligence process takes into account the size of the problem and the scalability and sustainability of the solution.

By 2030, our portfolio companies will contribute

55M

tons of
CO₂ reduction



50M

tons more
food made



153B m³

fresh water
saved



1.8M

Quality Adjusted
Life Years



WE BELIEVE

Hard tech has the ability to solve the world's most fundamental challenges.

WE INVEST IN

Entrepreneurs who figure out how to go farther and faster with the same resources.

Entrepreneurs who solve the world's most fundamental problems with hard tech.

Entrepreneurs who are making a meaningful impact.

Our investment themes



Climate change

We recognize the severity of climate change and the need for urgent action. We invest in decarbonization, energy transition, circular economy, green chemistry, resource & industrial efficiency and more.



Food and water security

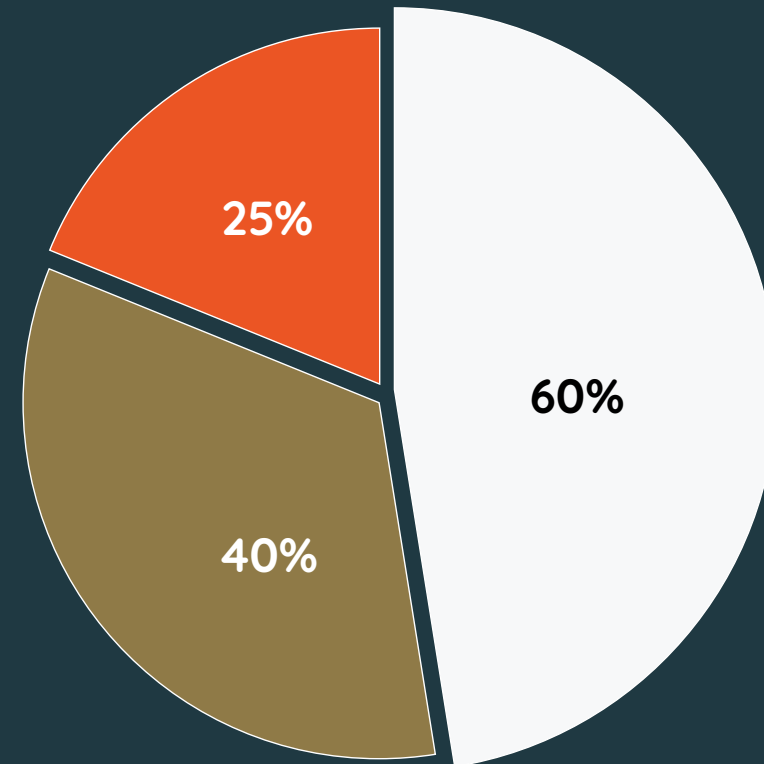
As the world's population continues to grow, we will need to produce 70% more food to meet our needs. We invest in sustainable agriculture, water treatment, supply chains, alternative & plant-based proteins and more.



Poor health outcomes

Poor health outcomes can have a significant economic and social burden. We invest in medical devices, point-of-care diagnostic tools, biomaterials, personalized health and more to improve health outcomes.

Pangaea's Portfolio*



- Climate change
- Food & water security
- Healthcare

*Total does not sum to 100 as Pangaea portfolio companies often contribute towards more than one theme.

Our progress on CO₂ emissions

The effects of climate change – including fires, floods, droughts and heat waves – continued to pose overwhelming challenges in 2023. In 2022, we set a new record for global emissions at 57.4 gigatons of CO₂ equivalent (GtCO₂e) and that number increased by an additional 1.1% in 2023.

Over the past year, Pangaea’s portfolio companies in the carbon capture and emissions reduction sector closed over \$100M in new funding. The uptick in investment in these technologies is a promising sign of imminent change as more financial resources flow towards solutions that can eliminate emissions in the near-term and increase momentum around the energy transition.



Our progress on food production

More than 333 million people faced acute food insecurity in 2023, rising by nearly 200 million since 2019. Food and fuel prices have increased significantly in light of energy challenges, sanctions and inflation. Climate change continues to contribute to crop failures and famine. Global fertilizer prices have also skyrocketed to a ten-year high.

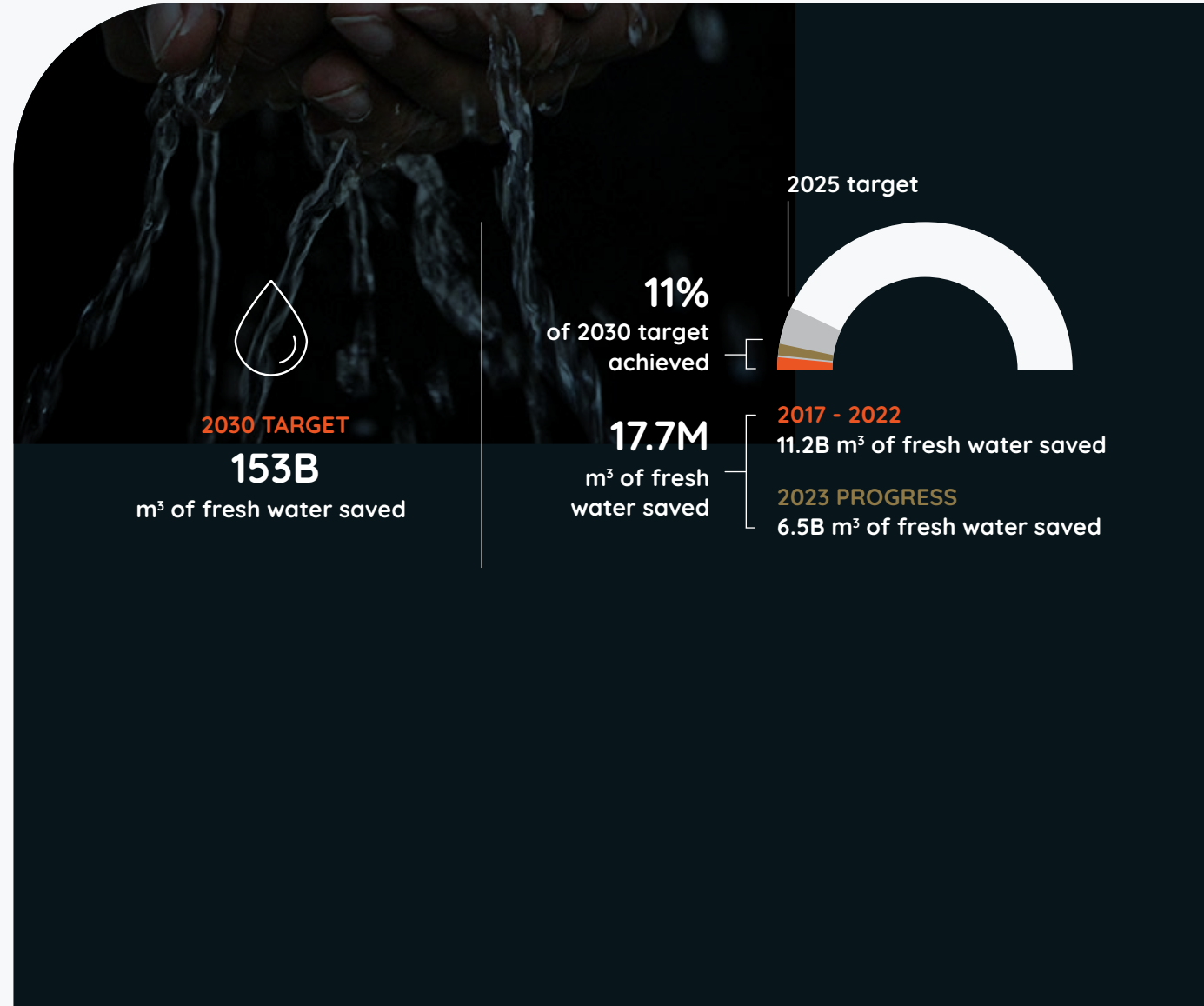
Pangaea continues to invest in companies creating technology to address the multifaceted issue of food security. We're focused on solutions that reduce the need for fertilizer and water and improve soil health as well as those that bolster food supply chains and provide greater access to nutrition through supplements and sustainable meat alternatives.



Our progress on fresh water

In March 2023, UNESCO released a report revealing that 2 billion people do not have access to safe drinking water. People in urban communities are at higher risk of experiencing water scarcity, with the population of urban dwellers facing water scarcity projected to double by 2025.

Water is a multi-impact investment due to its interconnection with climate change, the agri-food value chain, industrial productivity, healthcare, renewable energy, ecosystem services and biodiversity. Due to the wide-ranging scope of water-related issues, almost every company in Pangaea’s portfolio has an impact on global water use and availability.



Our progress on lives impacted

The US spends over \$4.1 trillion annually on healthcare. The majority of that spending goes towards treatment of chronic conditions such as diabetes, heart disease and cancer which could be significantly improved by preventative care and advances in treatment technologies.

Prior to 2023, we measured health impact based on the number of patients touched by a portfolio company, regardless of how long those impacts endured. While this provided us with an indicator of technology reach, it did not highlight the magnitude of impact. This year we have restated the historical health metric from Lives Impacted to Quality Adjusted Life Years (QALY). QALY combines the quality of life gained over a certain period with the number of years that improvement will last. This lets us calculate the lasting value of the impact that we are investing in. As this is a more accurate quantification we have changed our 2030 target from 18M Lives impacted to 1.8M QALY.



2030 TARGET

1.8M

Quality Adjusted
Life Years (QALY)

7%
of 2030 target
achieved

2025 target



2017 - 2022

109,398 Quality Adjusted
Life Years (QALY)

2023 PROGRESS

20,351 Quality Adjusted
Life Years (QALY)

From initial screening and through the due diligence process, Pangaea evaluates opportunity through an impact lens in order to gain insights into the magnitude of the problem being solved and the scalability of the solutions being developed. With the 2030 impact goals in mind, Pangaea's deal analysis includes consideration of impact criteria that the technology must address in order to be approved for investment. The impact considerations are not meant to replace financial returns but to provide us with an holistic view of potential investment candidates.

Our companies use hard tech to create products that lead to a world with

- less CO₂

Companies with technologies that reduce carbon-based energy consumption, improving energy efficiency or lowering embodied energy.

+ more food

Companies with technologies that increase food production using existing resources to provide more food to a growing population, while helping to preserve vital ecosystems.

+ more water

Companies with technologies that reduce fresh water consumption or produce fresh water.

+ more lives impacted

Companies with healthcare technologies that can have a significant impact on patient outcomes while also reducing healthcare costs.



AFFORDABLE &
CLEAN ENERGY



INDUSTRY, INNOVATION &
INFRASTRUCTURE



CLIMATE
ACTION



CLEAN WATER &
SANITATION



RESPONSIBLE
CONSUMPTION &
PRODUCTION





























ZERO
HUNGER












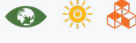




GOOD HEALTH &
WELL-BEING

Current Portfolio Companies

COMPANY	PANGAEA'S IMPACT TARGET	SDGS	FOCUS
 AEPONYX	CO ₂ Reduction		Optical switching for high broadband, 5G, and data center
 Ardent	CO ₂ Reduction		Scalable membrane technology for efficient point source carbon capture
 Aspect Biosystems	Lives Impacted		3D bioprinting of tissue for drug screening and regenerative medicine
 Biodel AG Inc™	CO ₂ Reduction & Food Production		Regenerative agriculture technology that improves soil health and removes atmospheric CO ₂ .
 CALYSTA	Food Production & Water		Protein production using methane feedstock
 CARBON CURE	CO ₂ Reduction		Lower carbon concrete using a CO ₂ mineralization process
 CORRELIA Biosystems	Lives Impacted		Developing protein measurement tools that are cost-efficient, rapid, and customizable
 ESS INC	CO ₂ Reduction & Water		Low-cost energy storage with iron-based battery
 hazel technologies	CO ₂ Reduction, Food Production & Water		Freshness preservation solution for produce and fresh proteins
 Hinalea	Food Production		Hyperspectral imaging for quality assurance, testing, and inspection
 modulim	Lives Impacted		Imaging solution for diabetic foot ulcers and wound care
 NewLeaf symbiotics	Food Production & Water		Microbial crop treatment for plant health and yield enhancement
 polySpectra	CO ₂ Reduction		Functional photopolymer resins for advanced additive manufacturing

Current Portfolio Companies

COMPANY	PANGAEA'S IMPACT TARGET	SDGS	FOCUS
	CO ₂ Reduction, Food Production & Water		Plant-based meats based on Koji superfood protein
	CO ₂ Reduction & Water		Closed loop, low temperature process for critical metal extraction
	Lives Impacted		Microbiome analysis for precision probiotics
	CO ₂ Reduction, Food Production & Water		Chitosan based formulation for agriculture, water and textiles
	Lives Impacted		Nanoparticles with unique signature for product safety and authentication
	CO ₂ Reduction		Low cost green hydrogen production using anion exchange membrane electrolyzers
	Food Production & Water		Peptide based insecticides with performance equaling synthetics

IMPACT CASE STUDIES

In 2023, our portfolio companies demonstrated measurable social, environmental and economic potential for positive, long-term impact across key sectors including chronic illness treatment, carbon capture and sequestration, and metal mining and recycling.



Diabetes innovation offers transformative outcomes

Treatment of chronic diseases, like diabetes, account for 86% of US health-care spending. This has contributed to a mounting crisis in which people cannot access the care they need to thrive.

Diabetes is the most expensive chronic health condition in the US, costing over \$400B in direct and indirect costs in 2022. Up to 64% of the total costs of treating diabetes are for complications like nerve damage, blindness, stroke and heart disease. Improved blood sugar control throughout an individual's lifetime can reduce the risk of diabetes-related complications by up to 40%.

In light of the tremendous burden diabetes places on the medical system and patients, the market for new interventions is heating up.

GLP-1 (glucagon-like peptide-1) products like Novo Nordisk's Ozempic provide game-changing weight loss and blood sugar control benefits for individuals living with type 2 diabetes. The company reported a 52% growth in diabetes treatment sales in 2023, revenue that boosted its market capitalization above \$500B.

GLP-1 drugs have been shown to reduce the risk of long-term cardiovascular complications, with the potential to slash the

total cost of care by between \$175B and \$245B over the next decade in the US.

Last April, our portfolio company Aspect Biosystems announced a partnership with Novo Nordisk for the co-development of products to support diabetes and obesity treatment. The possibility of delivering therapeutic tissues that can help the body improve glucose management from within or even allow individuals to regain pancreatic function has wide-ranging implications.

Supporting patients with intensive blood sugar control improves quality adjusted life years (QALY) and has been shown to be cost-effective. A UK study showed that patients who reduce their A1C (average glucose levels) by just 1% benefit from an estimated 0.61 additional QALYs. Losing 6.6 lbs. increases QALY by 0.10. Keeping A1C at 6%—below the suggested target A1C of 7%—results in an additional 2.8 QALYs compared to an A1C of 10%. Reducing A1C from 10% to 6% can reduce per-patient cost by \$24,000.

Advancing clinical care for type 1 diabetes has been shown to increase QALY with each QALY gained costing about \$20,000. For those newly diagnosed with type 2 diabetes, intensive blood sugar control resulted in a cost of \$4,318 per QALY. Novo Nordisk research also revealed that for type 2 patients, once-weekly use of GLP-1 injections resulted in a 0.19-0.27 increase in QALY compared to using insulin.

Technologies that improve blood sugar control and promote weight loss will have a meaningful impact on cost of care, alleviating the burden on the medical system. Overcoming obstacles to diabetes care today has the potential to transform not only the lives of the individuals experiencing the condition but also the quality and stability of healthcare in our communities in the years and decades to come. With the high cost burden of diabetes, these technologies can truly be seen as a high impact investment.



Customized Probiotics offer a brighter future for diabetes patients

Disruptions in gut health, such as a major loss in gut microbiome diversity and an increase in leaky gut, have been shown to precede the onset of type one diabetes. Those with type two diabetes also often have compromised microbiome diversity and improving gut microbiome diversity may help decrease insulin resistance. Research reveals that personalized probiotic supplementation is far more effective than a standardized mix of microbial strains.

Our portfolio company Sun Genomics is making custom probiotics widely available, offering supplements that can be tailored to an individual's unique gut microbiome to improve specific health issues.

Exponential impact with scalable carbon capture

In 2016, the Paris Agreement set goals for world leaders to limit global warming to 1.5°C, setting critical milestones for greenhouse gas (GHG) emission reduction.

This agreement proposed that emissions should peak by 2025 and decline by at least 43% by 2030. We are not even close to meeting this target. Emissions grew by 1.2% between 2021 and 2022, reaching a record high of 57.4 GtCO₂e. In 2023, emissions rose again by 1.1% and, for the first time, global warming exceeded 1.5°C across the entire year.

There is a need for accelerated action on GHG emission mitigation and carbon removal to reverse this trend and achieve net-zero goals to bridge the projected 2030 emissions gap.

Direct air capture (DAC) enables carbon dioxide to be absorbed from the air and either sequestered underground, mineralized or reused in industrial processes. This has been an active area for VC investment, for example DAC trailblazer Climeworks raised \$650M in 2022, the largest funding round ever closed by a carbon capture company, and Carbon Engineering was acquired by Occidental Petroleum in 2023 for \$1.1B.

However DAC is expensive, with costs ranging between \$250 and \$600 per ton of carbon removed from the atmosphere. Costs are projected to decline with scale and technology maturity, but cheaper alternatives are needed to drive adoption. Additionally, DAC technology is energy intensive. At scale, leading companies estimate that the energy requirements will be between 2.2-2.6 MWh per ton of CO₂ removed.

For the foreseeable future, incremental energy usage around the world will generally continue to be supplied by energy production from natural gas. With the most modern natural gas fired power plants generating 0.4T of CO₂/MWh, the resulting CO₂ emissions almost equal the amount of carbon dioxide removed via DAC, unless waste heat is used. This rough analysis does not even include the embodied carbon of the steel and concrete used for the facility construction. With the high capital needs of DAC companies, we believe that impact money multiplier (IMM) for a prospective investment opportunity would be less than 1X.

While DAC technology extracts carbon dioxide from the atmosphere, targeting flue gas with post-combustion carbon capture is much lower cost. Heavy industries, including cement, steel, and chemical manufacturing, are responsible for almost 20% of GHG emissions. The capital intensity of existing infrastructure combined with the economic necessity of these processes make these sectors difficult to abate. This is where retrofitted solutions like Ardent Technologies' Optiper™ Carbon Capture come in.

Ardent's membrane technology captures carbon dioxide emissions from flue gas. The company has developed a modular, bolt-on membrane system that can be customized to any facility. Ardent's membrane technology is also fully electrified and is far more energy efficient than DAC, using just 150 to 500 kWh/t-CO₂. It is also expected to be significantly lower cost than DAC at \$20 to \$55 per ton of CO₂ abated.

In addition to being low-cost, low-energy and small-footprint, Ardent's membrane technology doesn't require chemical

solvents such as amines, currently the most mature post-combustion carbon capture option. Amine use is energy-intensive and results in chemical waste, making it far less scalable (and environmentally viable) than non-chemical membrane solutions.

The series A funding of \$16M in 2023 allowed the company to expand its team by 50% and significantly scale up module production and installation. As Ardent continues to grow, its impact on heavy industries' emissions will be significant. Our forecasts project that Ardent's technology will capture 23 million tons of carbon by 2030. Our IMM estimate for the company is currently 37X due to the lower capital intensity of the technology, the capital-efficient nature of the company, and its energy-efficient operations (proven in industrial pilots conducted less than a year after closing series A funding).

Prioritizing investment in scalable post-combustion carbon capture technology will ensure that heavy industries can aggressively tackle their emissions in a practical and economical way.



Monetizable solutions kickstart the carbon removal flywheel

Carbon removal is generally seen as contributing to the common good, but to achieve widespread adoption, clear benefits are needed in the short term. Carbon capture is one of the essential strategies we can deploy to limit climate change, however, uptake is still a major barrier on the road to reducing emissions.

Rapid adoption of economically viable, high-impact carbon removal technology can help move the needle on climate change. New carbon removal solutions must be easy to implement and deliver tangible value today. However, carbon capture typically relies on government spending or subsidies and additional costs are often passed down to consumers. To ensure that carbon capture initiatives are just as economically sustainable as they are ecologically sustainable, our portfolio companies CarbonCure and Biodel have developed solutions that combine carbon removal with additional benefits. These solutions deliver multiple outcomes from the carbon capture process in a positive feedback loop we call the Carbon Removal Flywheel.

CarbonCure provides a ready-to-install solution that works by injecting recycled CO₂ into fresh concrete where it mineralizes, creating a stronger concrete that requires 5 to 10% less cement content. This process allows concrete to act as an artificial carbon sink similar to natural soil and rock. To date, the company has enabled savings of over 400,000 tons of CO₂. With cement production responsible for up to 8% of

global CO₂ emissions, there is still a long way to go. Cement is also the most costly component of concrete and the savings achieved by customers make the technology economically attractive.

CarbonCure has a process to measure and verify the carbon removal that occurs when their technology is used by customers. After verification, the resulting carbon credits can be delivered to carbon offset buyers and a portion of that revenue is distributed to CarbonCure's customers. This improves the ROI of the technology and incentivizes customers to increase adoption, keeping the Flywheel accelerating.

The earth and ocean remain our most valuable carbon sinks. Reforestation and ecosystem restoration are currently the most cost-effective carbon removal solutions. In the past, focusing on these options meant compromising on much-needed agricultural land — affecting food security and livelihoods. Regenerative agriculture has the potential to turn farmland into carbon sinks that are just as effective as

wildlands. Crops cover 10% of the Earth’s surface and, we believe, agricultural lands have the potential to sequester over 5 billion tons of atmospheric CO₂ each year.

Bidel is a regenerative agriculture company that develops solutions for rebuilding depleted farmland soil. Its products are designed to power the Carbon Removal Flywheel by incentivizing farmers and improving the earth’s natural capacity to capture and store carbon.

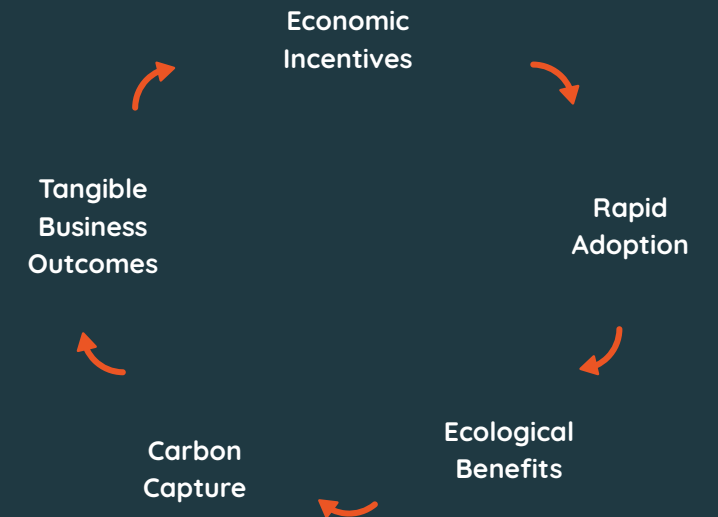
Sequester, one of its core products, is a microorganism-based soil amendment designed to help the soil sequester more carbon. The company plans to scale its technology to over 3 million acres, nine US states and northern Mexico by the end of 2024. Bidel estimates that the soil regenerated using its products has the potential to remove 45 million tons of CO₂ from the atmosphere by 2030.

In addition to marketable carbon removal credits, farmers and agricultural landowners can reap the rewards of more abundant crop yields and lower operating costs. Bidel’s

products help improve the soil’s ability to retain water and also increase water use efficiency. They also support enhanced nutrient cycling in the soil, reducing the need for fertilizers. The near-term costs savings of reducing both fertilizer and water provide immediate farmer ROI. Verified carbon removal credits that result from the implementation of their technology serve to further accelerate the Carbon Removal Flywheel.

Pangaea’s impact modeling highlights that the carbon savings from fertilizer reduction and increased crop yields exceeds that of the soil carbon sequestration. When we include the impact of water reduction—which has a significant impact in the company’s initial market of the Southwestern US—and total equity raised of just over \$3M, Bidel’s IMM of 190X is by far the highest in the Pangaea portfolio.

The Carbon Removal Flywheel



Unlocking metal resources sustainably is key to the energy transition

Emissions from fossil fuels account for over 90% of all CO₂ emissions. As emissions continue to increase, the transition to sustainable energy is more important than ever. A successful energy transition relies on sustainably expanding the supply of metals, a key input to sustainable energy equipment such as solar panels, batteries, electric motors, fuel cells and hydrogen electrolyzers.

The demand for copper is projected to rise by 40% in the next 20 years. The demand for platinum group metals (PGMs) like iridium, which is essential for some hydrogen electrolyzers, far exceeds the amount available in the earth — just 412 tons were available annually in 2021 compared with an annual demand of 592 tons.

Metals are a finite resource and mining has a significant—and growing—environmental footprint. The energy requirements for copper mining increased by 46% between 2006 and 2016. Mining operations typically produce large tailings ponds and use a huge amount of fresh water: up to 110 m³ per ton of copper ore and over 330,000 m³ per ton of platinum.

Recycling and lower-impact mining will play a critical role in scaling up the production of these critical metals to enable the energy transition. Pangaea portfolio company pH7 Technologies offers a method of recycling PGMs that uses 95% less water and requires 84% less energy than traditional metal recovery processes like smelting and hydrometallurgy, delivering a recovery rate of over 95%. The process

generates no hazardous waste and reduces the carbon footprint of PGM extraction and refinement by 99%. This represents a massive opportunity.

Over 50 million tons of electronic waste was generated in 2019, representing \$50B in resources that could have been recycled or repurposed, the vast majority include metals that could be recovered by pH7. Each ton of mined ore contains less than 1% usable copper, which means a huge volume of ore needs to be mined to yield the copper we need. Every ton of recycled copper typically saves 100 tons of ore—representing reduced environmental impact, lower labor costs, and less water usage.

pH7 Technologies also has an answer to the mounting copper deficit that's growing by 5 to 6% annually. Copper ore grade decreased by about 25% between 2006 and 2016. pH7 Technologies is developing a heap leaching process to extract copper from low-grade sulfide ores. This process will unlock the potential of the largest remaining copper resources in the world. Production of copper typically

emits about five tons of CO₂ per ton of copper while pH7 Technologies' method is expected to emit under two.

Metal resource recovery and preservation pave the way for the energy transition. High efficiency heap leaching and recycling innovations promise to support a revolutionary shift in the way human energy needs affect the planet.



Clean hydrogen is the green fuel of the future

Hydrogen is a clean fuel that is a ready alternative to fossil fuels to decarbonize heavy industry and long-haul transport. If produced sustainably and adopted in these sectors, it could contribute 10% of the emissions savings required to reach 2050 net zero goals.

Both fuel cells and some types of green hydrogen electrolyzers require PGMs. pH7 Technologies' PGM recovery methods will not only reduce the environmental impact of mining and boost the supply of PGMs, but support the production of hydrogen electrolyzers — multiplying its impact.

Our portfolio company Versogen develops high-performance anion exchange membranes (AEMs) and zero-emission electrolyzers. AEM electrolyzers are advantageous over more traditional Proton Exchange Membrane electrolyzers due to the significant reduction in precious metal catalysts. While Versogen will not ramp its electrolyzer capacity until later in the decade, we estimate that 600 kT of carbon dioxide emissions will be reduced from its electrolyzers by 2030.

REGENERATIVE AGRICULTURE MEETS CARBON FINANCE

Regenerative agriculture has massive potential to drive carbon removal while supporting human health and economic sustainability through the carbon credit market.

Paul Zorner is a PhD advisor at our portfolio company Bidel. As President of BleuJaune Advisors, Paul also works with many other organizations to increase agricultural productivity and strengthen the economic health of rural communities.

In addition to his work as a board member for several organizations, Paul serves as the Chairman of the Alternative Fuels & Chemicals Coalition Executive Committee. He has been an adjunct professor in the Department of Horticulture at North Carolina State University for the last 36 years.

Through his experience at the intersection of science, agriculture, venture capital and private equity, Paul has an insiders perspective of the growing bio-based economy. In this exclusive interview, he provides his insights on the carbon credit market and the potential for regenerative agriculture technology to drive both economic and social impact.



PV: What role do you see agriculture playing in the economy and in society as a whole as we work towards global climate goals?

PZ: I believe agriculture truly is the most scalable tool humanity has to not only help mitigate – or at least become resilient to – climate change, but to provide remarkable rural economic and environmental security and, therefore, greater social equity. This is an extremely important time right now for agriculture. I think agriculture is a pathway to peace. It's not just economic security that a bio-based economy offers, but self-esteem: we're recruiting really high-value jobs so that people can feel good about staying in rural communities. People are waking up to the fact that they can have really interesting careers dedicating their skills to agricultural productivity and environmental science.

PV: What's your perspective on the current viability and level of maturity of the carbon credit market?

PZ: The carbon credit market is confusing. The problem right now is that there aren't a lot of standardized methodologies. There are registries like Verra, which is the gold standard, and the Climate

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Firms like Pangaea help find the brightest and the best in the carbon capture analytics space, help capitalize these companies, and provide the guidance they need to integrate into the whole carbon credit value chain.

Action Reserve. But farmers who want to participate are faced with contracts that have confusing terms and the requirements for collecting data over the contract period are too burdensome. If you have 1000 acres of farming, you have to go out and take 1000 sub-samples, combine them into 100 samples and send those off to a lab. That could cost \$65 per acre in addition to the time it takes to collect samples when you're busy with running your farm. For growers, it's just not worth it.

There's also the problem of additionality, which means farmers aren't able to evaluate past practices and count those towards their credits. If they've already been doing regenerative practices like minimum tillage or cover crops for the last 40 years, they can't participate. There are also concerns about liability. I talk to a lot of growers who say, "If over this 15-year contract I've been given 100 credits, but it turns out that I can only validate 90 of them, who is liable for that gap?"

On the credit buyer side, it's been difficult to measure and demonstrate the efficacy of carbon capture. Until recently, the analytical technology used to determine that you've sequestered a certain volume of CO₂ equivalents in the soil can provide,

at best, plus or minus 30% variance, and most of the time it's plus or minus 40%. The problem is that current technologies usually measure gas in the air or a single, small area of soil. Nitrous oxide, for example, collects in hot spots in the soil and typically gets flushed out at night, so the overall levels of nitrous oxide vary significantly from spot to spot and throughout the day, making it very difficult to measure accurately.

PV: Where do you see opportunities to overcome some of these barriers to the scalability of the carbon credit market?

PZ: Companies are emerging that are reducing the variance in analytical technology and offer solutions that provide measurements that are accurate with up to 95% confidence. These options are also far less labor intensive and can, for example, analyze soil over acres of farmland using a tractor that drives over the fields and measures every molecule of carbon. This increased level of accuracy contributes to high-quality credits that can be trusted by energy and consumer packaged goods companies. Credits with accurate data behind them have been shown to receive up to a 90% premium in the carbon credit marketplace.



Enter firms like Pangaea that help find the brightest and the best in the carbon capture analytics space, help capitalize these companies, and provide the guidance they need to integrate into the whole carbon credit value chain. Accurate, reliable analytics technology takes care of the liability concerns and it alleviates the burden on farmers to take thousands of samples and pay to get them analyzed. When credit buyers have solid data to back up the claims that their own products are net-zero or carbon-negative, they can win consumer trust and avoid the specter of greenwashing.

PV: Are there geographical differences in how carbon markets are maturing?

PZ: There are two main markets, globally, the Compliance Market and the Voluntary Market. The Compliance Markets are changing the name of the game. Voluntary Market prices can be between \$0.50 and \$15 per credit, while in Compliance Markets like Europe and California, credits can range from \$28 to \$70. Legislation, for example recent legislation in California, is helping to standardize data collection, analysis and reporting for Scope 3 Emissions — which are emissions from throughout an organization’s value chain. So companies are going to need to

hold their suppliers accountable. Standardizing the market creates more trusted, high-quality credits. Authenticity creates trust, trust creates value and value creates a premium.

PV: How can growers and companies in both markets create more valuable credits? Are there premium credits out there?

PZ: There are absolutely premium credits, but you have to have all the supporting pillars in place. That means accurately reporting sequestration, showing that you’ve been certified by a reliable organization, and also demonstrating the other impacts that go along with carbon reduction like water conservation, social equity and community building. We need to move away from self-certification. With companies like Pangaea as an investor and companies like Bidel that can consolidate all the data and reporting across multiple avenues of impact, we can simplify the process for growers and offer them real value in return. I think that’s going to open the floodgates of regenerative agriculture adoption to generate the credits and meet the growing demand for them while allowing all this capital to flow back into rural communities.

PV: How do you see Bidel and regenerative agriculture solutions supporting the carbon credit value chain?

PZ: Bidel is not just a products company offering microbial soil amendments, they are actually a regenerative carbon project developer. The idea is to integrate these new analytical technologies with their products and provide advice on how to enter and interact with these markets to get the highest quality credit we possibly can. This can also show growers, with confidence, that the changes they’re implementing really are resulting in increases in soil carbon and decreases in emissions.

Growers are natural environmentalists. They provide food but they also want to create a legacy: the soil is their resource and they are creating biomass that, in this day and age, can be made into anything from takeout clamshells to fuel. It’s been clearly shown that growers who adopt regenerative farming practices have greater productivity with reduced inputs like water and fertilizer. Why pay for inputs that biology offers for free? Add carbon credits on to that and it’s the most remarkable and massive transfer of wealth that I think we’ll ever see.

References

“COP28 Agreement Signals “Beginning of the End” of the Fossil Fuel Era.” United Nations Climate Change, December 13, 2023. <https://unfccc.int/news/cop28-agreement-signals-beginning-of-the-end-of-the-fossil-fuel-era>

“Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again).” United Nations Environment Programme, November 2023. <https://wedocs.unep.org/20.500.11822/43922>

“Record carbon dioxide emissions impeding progress on meeting climate goals.” NOAA Research, December 5, 2023. <https://research.noaa.gov/2023/12/05/record-fossil-carbon-dioxide-emissions-impeding-progress-on-meeting-climate-goals-report/>

“UN Climate Change Conference - United Arab Emirates” United Nations Climate Change, accessed February 23, 2023. <https://unfccc.int/cop28>

“Wildfire Season Summary - Province of British Columbia.” Government of British Columbia, December 7, 2023. <https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/wildfire-history/wildfire-season-summary>

“World health statistics 2023: monitoring health for the SDGs, sustainable development goals.” World Health Organization, May 19, 2023. <https://www.who.int/publications/i/item/9789240074323>

“A Global Food Crisis.” World Food Programme, accessed February 27, 2024. <https://www.wfp.org/global-hunger-crisis>

“Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again).” United Nations Environment Programme, November 2023. <https://wedocs.unep.org/20.500.11822/43922>

“Health and Economic Benefits of Diabetes Interventions.” Centers for Disease Control and Prevention, reviewed December 21, 2022. <https://www.cdc.gov/chronicdisease/programs-impact/pop/diabetes.htm>

“Imminent risk of a global water crisis, warns the UN World Water Development Report 2023.” UNESCO, updated February 20, 2024. <https://www.unesco.org/en/articles/imminent-risk-global-water-crisis-warns-un-world-water-development-report-2023>

“Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again).” United Nations Environment Programme, November 2023. <https://wedocs.unep.org/20.500.11822/43922>

Hack, Jannis, Nobutaka Maeda, and Daniel M. Meier. “Review on CO₂ capture using Amine-Functionalized Materials.” ACS Omega 7, 44 (2022): 39520–39530. <https://doi.org/10.1021/acsomega.2c03385>

Hunt, Barnaby, Samuel J. P. Malkin, Robert G. J. Moes, Eline Huisman, T. Vandebrouck, and Bruce H. R. Wolffenbuttel. 2019. “Once-weekly Semaglutide for Patients With Type 2 Diabetes: A Cost-effectiveness Analysis in the Netherlands.” BMJ Open Diabetes Research & Care 7 (1): e000705. <https://doi.org/10.1136/bmjdr-2019-000705>

McEwan, Phil, Hayley Bennett, Jonathan Fellows, Jennifer Prialux, and Klas Bergenheim. 2016. “The Health Economic Value of Changes in Glycaemic Control, Weight and Rates of Hypoglycaemia in Type 1 Diabetes Mellitus.” PLOS ONE 11 (9): e0162441. <https://doi.org/10.1371/journal.pone.0162441>

O’Connor, Patrick J. 2017. “Impact of improving diabetes care on Quality adjusted Life Expectancy (QALE) and costs: a 40-year perspective [poster].” Health Partners Institute

“Regenerative Agriculture and How It Can Save the Planet.” Sequester, accessed January 27, 2024. <https://sequester.ag/regenerative-agriculture-and-how-it-can-save-the-planet/>

“Scaling up carbon capture.” Nature, Nature Index, September 6, 2022. <https://www.nature.com/articles/d42473-022-00313-9>

“The Paris Agreement.” United Nations Climate Change, accessed February 22, 2024. <https://unfccc.int/process-and-meetings/the-paris-agreement>

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