Global Corporate Venturing Energy

Leif Capital

CORPORATE VENTURE CAPITAL and the *Creative* DESTRUCTION of ENERGY

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January 29-30, 2020 | Monterey, CA

Over the past four years, the Global Corporate Venturing & Innovation (GCVI) Summit has grown to include **over 800 business leaders** from the corporate venturing and innovation professionals ecosystem.

Corporates attending have represented groups that are both experts and young learners of CV&I, leading to the GCVI Summit being distinguished as the must-attend event for relationship cultivation and knowledge transfer for all active members of the community.

In this, the fifth iteration of the GCVI Summit, you'll be a part of the focus on a new dawn, with the aim of investing, connecting and innovating.

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The GCVI Summit provides CVCs, corporate strategy executives, C-level innovation officers and corporate development executives with ways to maximize innovation strategy business practices and drive strategic investment opportunities.

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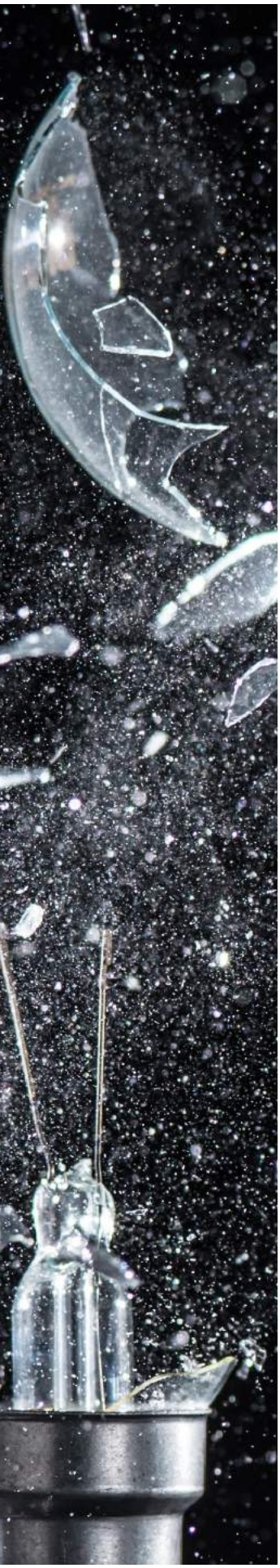


Contents

4 **Introduction**
Tom Whitehouse, Leif Capital

6 **Event Review: GCV Energy**
Kaloyan Andonov, Global Corporate Venturing

21 **GCV 2018 - 2019 Awards**
James Mawson, Global Corporate Venturing

30 **BP Ventures' David Hayes catches scalable fish food investment**
Tom Whitehouse, Leif Capital

34 **Fail fast? Not if you're an energy tech entrepreneur**
Kirk Coburn, Shell Ventures

37 **Happy Birthday Chevron Technology Ventures 20 years, 100 investments**
Kemal Anbarci, Chevron Technology Ventures

39 **Corporate venturing in mining to catch up with energy?**
James Mawson, Global Corporate Venturing

44 **Cracking the quantum puzzle**
Callum Cyrus, Global Corporate Venturing

Introduction

Tom Whitehouse, CEO, Leif Capital, and Senior Advisor, Global Corporate Venturing

Tom Whitehouse
Leif Capital

You can't destroy energy, right?
Right.

But we weren't really talking physics at GCV Energy, Global Corporate Venturing's annual Houston conference last month. We were talking about how corporations are using venture capital in order to survive the creative destruction, to use Schumpeter's phrase, of the energy and transport industries, and, with a bit of luck, come out prosperous on the other side.

Some of the world's most active corporate VCs, including Chevron Technology Ventures, Shell Ventures, BP Ventures, Boeing HorizonX Ventures and Caterpillar Ventures introduced startups they've invested in, which, if successful, could secure the foundations for their long term continued dominance in energy and transport. There were some stellar presentations. GCV's Kaloyan Andonov provides a summary from page 6.

We also celebrated the winners of GCV's Energy Awards, which GCV's Editor-in-Chief James Mawson announces from page 21. To be clear, these awards aren't for technologies or business models. They are for corporate venture capital investments, which, when done well, can transform a new technology's prospects, particularly in industries as risk averse as energy.

"In some respects, it is a strange act of humility because it requires the world's most successful corporations to put their hands up and admit they don't have all the answers."

"At its simplest, CVC fuses capital with business support in the pursuit of strategic and financial goals".

What is corporate venture capital (CVC)? At its simplest, CVC fuses capital with business support in the pursuit of strategic and financial goals. In some respects, it is a strange act of humility because it requires the world's most successful corporations to put their hands up and admit they don't have all the answers, but they do have the readiness to back external innovation with capital and expertise. GCV's awards champion CVC's role in accelerating energy and transport technologies and business models, extending their geographic reach and widening the range of industries adopting them.

I feel that Houston is the right place to celebrate energy CVC success because, despite a reputation for swagger, there is a combined seriousness, curiosity and humility in the city's energy industry, which no other, in my experience, yet matches.

I'm very happy that Leif Capital has curated these awards for GCV. It's been exciting and inspiring.

So, what next for energy corporate venturing? Who is using venturing to bust out of the energy industry into new domains? Who is breaking in?

James Mawson considers from page 39 whether the few corporates interested in venturing in the mining industry - Caterpillar among them – are the first wave of many. The mining industry, in contrast to energy, has proven itself very reluctant to venture. Why?

It can't just be because mining is a conservative industry. As Kirk Coburn of Shell Ventures reminds us below from page 34, this is also true of energy, which is increasingly active in corporate venturing. "Fail fast" is a mainstream VC cliché that doesn't apply in energy, argues Kirk.

Venturing in energy requires a readiness to stay the course over time. Chevron Technology Ventures (CTV) celebrates its 20th anniversary this year and its 100th investment. Its track record on portfolio company deployment by the parent company is widely admired by corporate venture capitalists from all industries, not just in energy. Managing Executive Kemal Anbarci sets out CTV's highlights of 2019 from page 37.

From page 44, GCV's Callum Cyrus reviews the venturing activity in quantum computing.

I hope to see you at the Global Corporate Venturing and Innovation Summit in Monterey on January 28th and 29th, where energy will be just one of the industries being discussed by over eight hundred delegates in the Californian winter sun.

tom@leifcapital.com

Event review

GCV Energy

Kaloyan Andonov
Reporter, Global Corporate Venturing

GCV Energy 2019 was GCV's third annual conference, hosted in the energy capital of the world – Houston, Texas. The event featured discussions by corporate investors and industry leaders plus pitches from innovative businesses from the sector and adjacent spaces like mobility, advanced manufacturing and digital technology.

Day 1: Startup pitches

Startups selected by software provider and sponsor ProSeeder presented their idea to corporate venturers and other investors.

The venue was provided by The Cannon, a co-working space and a venture studio for the Houston startup ecosystem.

Pitch judges listen intently

Scott Crist
Chief executive, Osperity

An artificial intelligence (AI) assisted computer vision technology for the remote industrial sector, which has received backing from Shell and Evok Ventures. The technology helps industrial companies to reduce operational costs, while mitigating environmental and safety risks through virtual asset monitoring, improve compliance with automated leak detection and safety supervision and also strengthen security and accountability through proactive activity detection.

Jon Rogers
Chief executive, Locus Bio-Energy

A cost-competitive, biodegradable microbe-based solutions which provide custom-tailored treatments for client-specific conditions for enhanced oil recovery, viscosity reduction, paraffinic wax and asphaltene dispersal including the cleaning of rods, pipelines and flow lines, casings and solidified storage tank bottoms. The company claims it has developed a microbial treatment with a mobile fermentation system that can rapidly grow cultures on-site.

Gerrit Becker
Co-founder, Flug-Auto

A B2B company which has developed and designed a platform for cargo drones with the capabilities of a helicopter but at the cost of operating a van. The company's unmanned aerial system is packaged as a platform-as-a-service to industrial customers from the oil and gas logistics and shipping sectors.

Michael Kezirian
President, Century Fathom

Century Fathom is seeking to develop a solution for the oil and gas industry by using NASA technology, which would be a cost-efficient, safe and sustainable method of producing natural gas from subsea reservoirs.

Victor Chaves
Founder and chief executive, Rio Analytics

Founded in 2016, Rio Analytics is a Brazil-based industrial Internet-of-things company that has developed a digital platform capable to predict failures, reduce downtime and increase operational efficiency. The platform employs advanced industrial analytics and AI to predict failures of industrial asset, optimise performance and increase assets' service life.

Sarah Tamilarasan
Chief executive, Sotaog

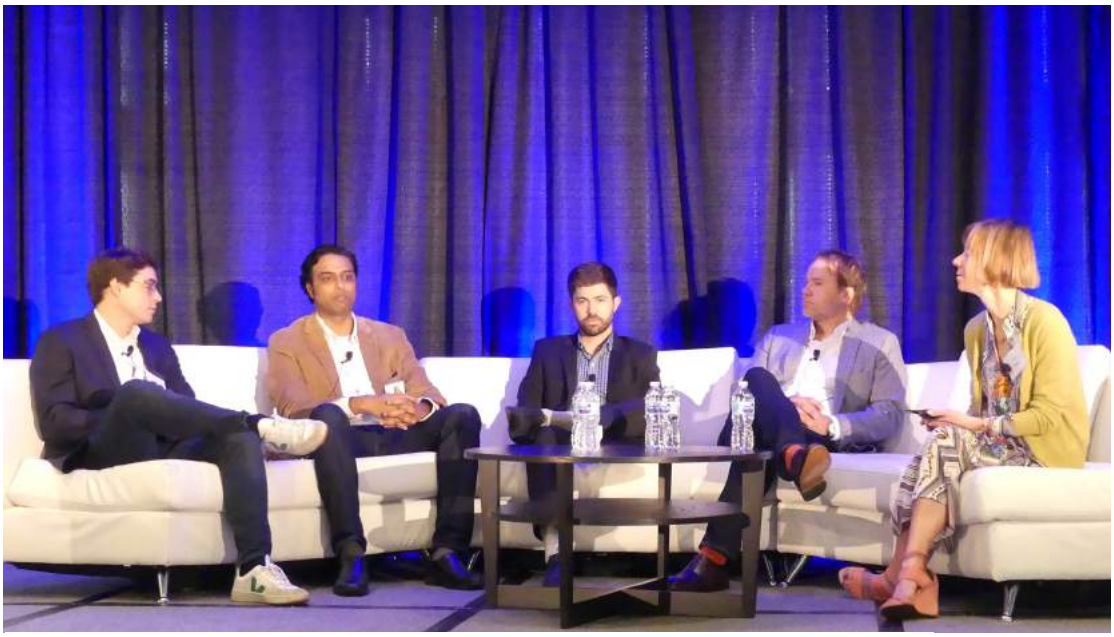
A SaaS company providing asset optimisation for industrial facilities. Sotaog uses proprietary edge and cloud algorithms to create "digital twins" of the assets to optimise the client's operations. The 360-degree view of operations the solution offers combines predictive analytics, edge and cloud computing.

Gray Alton
Facility integration manager, Terrapin

Canada-based company Terrapin develops custom-made waste heat recovery projects for industrial clients by identifying, validating and modelling industrial heat recovery opportunities. Terrapin has developed a solution for Capstone Infrastructure, an operator of 23 plants in Canada.

Griffin Schultz
Chief executive, Rapid Flow Technologies

The company offers an AI-based system dubbed Surtrac – an adaptive traffic signal control system originally developed in the Robotics Institute at Carnegie Mellon University as part of the Traffic21 research initiative. Surtrac is currently deployed in cities like Pittsburgh, Atlanta, and Portland, Maine. The company claims that it helps to reduce congestion and pollution in addition to improving safety and helping connected cities prepare for a multi-modal future including connected and autonomous vehicles.



(left to right): Ugo Catry, Ravi Mulugu, Kevin Deneen, Michael Lohnert and Erin Boyd

Day 2: investing in the future of energy

James Mawson, founder and editor-in-chief of GCV, and Tom Whitehouse, senior advisor and contributing editor and chief executive at energy-focused investment bank Leif Capital, welcomed the attendees of the third annual GCV Energy conference. Whitehouse thanked Chevron Technology Ventures for suggesting the concept and the rest of the sponsors.

The first panel discussion dealt how transport and energy could disrupt one another. It was moderated by Erin Boyd, ProSeeder's energy sector thought-leader. The panellists were Michael Lohnert, managing director at Boeing HorizonX Ventures, the venturing unit of the aircraft manufacturer, Kevin Deneen, principal at Schneider Electric Ventures, the venturing subsidiary of industrial conglomerate Schneider Electric, Ugo Catry, VC principal at Total Energy Ventures, the venturing arm of the oil and gas major and Ravi Mulugu a venture investor at UL Ventures, the venturing unit of compliance and advisory services provider UL.

Boyd noted electric transport does not typically lead one to think about aviation. Lohnert then highlighted some of the technical challenges around the electrification of aircraft: "We need sufficient energy density in batteries for aircraft, so it is a completely different profile from electric road vehicles." He explained the focus on Boeing's venturing unit in innovative technology, stressing that "it is about safety" and explaining how Boeing has had to address the problem of noise pollution. Catry added that "electrification is an opportunity for any kind of transportation."

"We need sufficient energy density in batteries for aircraft, so it is a completely different profile from electric road vehicles"

Michael Lohnert

Mulugu also spoke about security and safety issues in electric vehicles: "It is not just cars but also IoT devices in hospital environments and industrial settings. We do not want to have tech that can jeopardise anyone's security."

Deneen commented on the increasing availability of new electric vehicles: "There will be 60 models by the end of next year and over 100 by the end of 2022."

When speaking of macroeconomic and regulatory trends, Catry noted the important role that regulatory frameworks that have let an oil company like Total to look into electric transport: "Being part of the EU regulation on CO2 emissions, it is definitely a driver for the further

development of electric transportation in Europe. We need to find better batteries and to reach a competitive price range"

The panel touched on measuring strategic value – the perennial question for CVCs that lacks a one-size-fits-all answer.

Mulugu and Lohnert commented on the potential use of technologies from portfolio companies in the business units of the corporate parent. Deneen explained how SE Ventures invests "at the edge of the future of Schneider", so that leads to plenty of cases of very near-term commercial agreements and also mentioned that the unit is involved in spinning out independent businesses.

Advanced mobility pitches

In between each panel, there were short presentations by promising companies from a particular space relevant to the energy sector. Each of the companies was introduced by one of their corporate venture backers.

First, it was the turn of advanced mobility businesses.

Olivia Risset
Senior scientist, Cuberg
Introduced by: Michael Lohnert

Cuberg is an energy startup company developing a battery technology based on a non-flammable liquid electrolyte formulation and a lithium metal anode. Cuberg delivers an improvement in energy density (80% more) and safety compared with today's best lithium-ion batteries. The technology is a drop-in solution that can be manufactured and scaled through existing lithium-ion production equipment. It has been tested successfully in a variety of commercial-format prototypes and is being evaluated by customers in the defence, aerospace, and oil and gas industries.

Kofi Asante
Head of strategy and business development, Elroy Air
Introduced by: Ugo Catry

The company is backed by Total Energy Ventures and Brazil-based aircraft manufacturer Embraer. Founded in 2016, Elroy Air develops autonomous unmanned aerial vehicles that can deliver up to 300lbs of cargo within 300 miles. Its system features rotor-based vertical takeoff and landing as well as transitions to wing-based cruise flight for long range. The company has also designed a logistics system with integrated flight and ground operations. Elroy Air claims that its drones are three to five times faster than ground transportation, and have 10 times the fuel efficiency of an aeroplane, which makes their operating cost comparable to ground transportation.

Sila Kiliccote
Chief executive, eIQ Mobility
Introduced by: Kevin Deneen

eIQ Mobility offers an "electric fleet as a service" solution to large commercial fleets. It claims to pave a high-speed and risk-free way to zero-emissions mobility for fleets. The company's offering includes conducting an analysis of a client's existing fleet to determine how many vehicles can be electrified and how much money can be saved. It also provides servicing of the vehicles.

Nina Qi
Chief operating officer, Voyage
Introduced by: Nick Brumleve, Chevron Technology Ventures

Founded in 2017, Voyage develops and offers autonomous transportation solution for retirement communities in the US. Its vehicles – employed in a retirement community with residents – move at 25 mph.

Low carbon – this time it is different

A panel discussion on low carbon venturing was moderated by Charlie Walker from Silicon Valley Bank. The panellists were Andrea Course, venture principal at Shell Ventures, the venturing arm of oil and gas major, Shell, along with Amit Sridharan, director of investments at Mahindra Partners Ventures, venturing arm of India-based car manufacturer Mahindra & Mahindra, Michael Young, managing director at Caterpillar Ventures, the venturing subsidiary of heavy machinery manufacturer Caterpillar, and Chris Smith, managing director at Energy Innovation Capital, a venture firm with corporate and financial LPs.

Walker set the theme of the discussion as "Low carbon, not no carbon!" Young from Caterpillar concurred: "To your point, low carbon is the answer, not no carbon. I do believe, as we look forward, that cost sensibility and economics will eventually take the day. And we have a huge

opportunity in front of us to be a leader in the [energy] transition, but it is [ultimately] about helping our customers to really meet their needs."

Smith of Energy Innovation Capital noted that his team had been looking at the declining share of traditional liquid fuels and the increase of natural gas and renewables in forecasts for the next 10-15 years, which raises a question: "How do we become more efficient with less environmental impact?"

Andrea Course highlighted the importance of the primary role of energy companies like Shell – to provide energy in a world that is witnessing serious demographic, perceptional and technological shifts.

(left to right): Andrea Course, Amit Sridharan, Michael Young, Chris Smith and Charlie Walker

"Low carbon is the answer, not no carbon... And we have a huge opportunity in front of us to be a leader in the [energy] transition, but it is [ultimately] about helping our customers to really meet their needs"

Michael Young

She said: "Energy demand is growing and population is growing. There are still a lot of people with no access to energy. So, how are we, as an operator, going to be able to provide that energy, while everybody is demanding cleaner and low carbon alternatives? In the energy transition, it is about figuring out what is the best in doing both – providing more energy and making it more efficient. So, in my mind, it is not about us versus them or about fossil fuels versus renewables. We need to embrace all of them and provide energy to the people who need it."

Sridharan added that thanks to the advance of renewable energy and digitisation in recent years, "we are seeing solar power grow faster in India". He also said that the combination of solar with better and cheaper battery technologies makes solar a "much more practical and economical solution for a lot of places in Asia and Africa."

He also commented on the decreasing costs of battery technologies: "Cost are falling down but not enough to take off in cars yet", referring to the need for battery power for longer driving distance with EVs.

Young also commented on the crucial role of energy storage innovation in making renewable economically feasible: "A lot of the renewable energy out there is really unusable without storage technologies, so we are looking at opportunities to store it more economically."

The panellists also spoke about innovative technologies that aid corporations in reducing their carbon footprint.

Course noted that Shell had set up a special division dedicated to offsetting carbon emissions, "so we are looking at companies that can help with that". Young said that Caterpillar Ventures is also looking at CO2 capture companies, while keeping in mind its customers and "trying to make sure they adopt good solutions from an environmental and economic perspective".

Sridharan noted that his corporate parent, Mahindra & Mahindra, is a significant player in agriculture, so its venturing unit is also seeking deployable carbon solutions from startups.

Low carbon energy transition pitches

Chief executives or senior vice-presidents from startups in the space were introduced by their corporate backers.

Ben Schuler
Chief executive, Infinitum Electric
Introduced by: Dewey McLemore, Chevron Technology Ventures

Founded in 2016, Infinitum Electric is the designer and producer of electric motor and control technology, which makes them more efficient, more durable, lighter, more economical and quieter. Its products employ proprietary patent-pending Printed Circuit Board stator technology and provide broad application across multiple industries.

Christian Jacqui
Chief executive, Synova Power
Introduced by: Michael Young,Caterpillar Ventures

Founded in 2012, Synova offers a technology for converting waste-to-value, and sells the equipment and develops projects that use its technology. The process gasifies and strips post-recycled waste or biomass of contaminants, creating a stable, green alternative to natural gas. This alternative gas is suitable for chemical production, use in engines or combined cycle gas turbines. The company claims that its technology is cost-effective, with contaminants removed before the gas is used through a process with roughly one-tenth the volume of competing technologies like incineration or conventional gasification.

Daniel Henbest
Chief executive , Intelligent Power Generation
Introduced by: Tom Whitehouse, Leif Capital

The company is a clean technology platform focusing on power generation solutions, electrification of road transport and aerospace, founded in 2015. It is developing a replacement for the internal combustion engine, which could run on different types of fuels – from oil and diesel and natural gas to ethanol, biofuels and hydrogen. Its several applications can potentially solve problems in EV charging and distributed power as well as in industrial and community power.

Kerstin Rock
Senior vice-president, LO3
Introduced by: Andrea Course, Shell Ventures

LO3 Energy has built a marketplace platform, Pando, which enables neighbours connected over an existing grid infrastructure to carry out peer-to-peer energy transactions with energy from their own renewable sources. Its goal m is to help utilities and retailers integrate solar energy and battery storage. Pando is currently deployed in Australia, the US, the UK and Germany. Implementation is underway in countries like Japan, Colombia and Denmark. The company was founded in 2012.

Satish Rao of Clareo (left) speaking with Sayun Sukduang, president and CEO of Engie

Satish Rao, partner at strategy consulting firm Clareo, interviewed Sayun Sukduang, president and chief executive of Engie Resources in a fireside chat about his perspective on energy transition.

Sukduang shared with the audience how Engie spotted the beginning of a major transition: "We build large-scale power generation infrastructure worldwide and in 2015, we realised that centralised infrastructures started to wane in terms of underlying economics. Price spikes indicate there may be need for more powerplants but [it is] better to work with customers to prevent such spikes." He also noted that the major driver behind making Engie a more customer-facing business has been "renewable non-carbon emitting generation – wind and solar increasingly greased with storage".

Sukduang also shared his reflections on digitisation of the energy space and the fuzzy areas in consumers' perception of it: "Everyone is going after figuring out how to combine the electron and the megabyte and we, as a society, have very tenuous knowledge of it. Nobody can tell me the intrinsic value of a kW. We [generally] do not know what it costs to power a lightbulb. A megabyte has a limited intrinsic value. When you bring the two together, can you start selling what we really want at the end of the day?" He also noted that new entrants in this space tend to look "from a consumer perspective."

When asked about the potential for disruption in transportation, Sukduang noted that there is a process of convergence in transportation and that one of "the tipping point" for his business with mobility is electrification.

"Everyone is going after figuring out how to combine the electron and the megabyte and we, as a society, have very tenuous knowledge of it. Nobody can tell me the intrinsic value of a kW"

Sayun Sukduang

Digital energy technology pitches
Presentations by businesses introduced by representatives of their corporate venture backers.

Jean-Marie Laigle
Chief executive, Belmont Technology
Introduced by: Chad Bown, BP Ventures

Belmont Technology is a Houston-based company building a cognitive system to augment human intelligence for oil and gas exploration and production. The company's technology, dubbed Sandy, helps technical teams and their management make better decisions in a fraction of the time previously required. It employs advanced AI techniques to reveal patterns and relationships within heterogeneous geoscience data sets.

Chris Rohde
Co-Founder and COO, HyperGiant Sensory Sciences
Introduced by: Stuart Coleman, Chevron Technology Ventures

Founded in 2018, Hypergiant Industries has built an AI-based platform with sensors and cameras for 4D representation. The platform is used as a spatial intelligence tool for safety and security monitoring. It employs machine intelligence-driven technology to make sense of data at the intersection of critical infrastructures for industrial clients.

Brian Ahern
Chief executive, DotProduct
Introduced by: Lee Sessions, Intel Capital

Ahern's company develops high performance, easy-to-use solutions for capturing spatial data, designed for customers in need of high-quality 3D data. The company's Dot33D software turns Android and Windows tablets into a 3D-capture and processing solutions. Dot3D captures and registers the data using only a tablet and any 3D camera that is available. No desktop or laptop is required. The software and its output are also compatible with virtual reality integration technologies.

Mat Podskarbi
Vice-president, Akselos
Introduced by: Matthias Engel, Innogy Ventures

Akselos is the creator of a digital twin technology designed for structural mechanical assets. Founded in 2012, the company operates in Europe, the US and Southeast Asia. Its products are designed to protect critical infrastructure with simulation software that can build an accurate, detailed models of large-scale operational assets and run those simulations using only a portable computer.

Saikat Dey
Chief executive, Guardhat
Introduced by: Michael Young, Caterpillar Ventures

Founded in 2014, Guardhat has devised a smart hardhat that allows supervisors to monitor wearers' health, safety and work environment. It can detect, alert and help prevent hazardous industrial work-related incidents. The IoT device connects to software that measures parameters such as heart rate and body temperature.

Democratisation of energy

Xavier Helegesen, CEO of Zola Electric delivered a keynote talk on the democratisation of energy access in the developing world through solar energy combined with smart storage. He compared the cost of solar energy and battery technologies to an asymptote function, in which one line approaches infinity and another approaches zero. With this analogy, he was referring to the declining costs of both technologies.

Helegesen also explained to the audience that the purpose of his company, Zola Electric, was to satisfy the demand for electricity in areas that are often affected by power cuts and outages. He cited estimates that there are more than 2.2 billion people and millions of businesses who lack access to affordable and reliable power across developing nations in Africa, South America and Asia. He pointed out, however, that one of the most economically meaningful ways to deliver "electricity by western standards" to people from these regions is through diesel generators. Thus, Zola has developed what it calls "integrated power system", which is a grid-integrated, modular, plug-and-play electricity generation and storage device. The solution costs $2000 but financed over five years it is cheaper than diesel generators, Helegesen assured the audience.

Globalisation and diversification

Wade Bitaraf, founder of Plug and Play Energy & Sustainability, took the stage and moderated a discussion on how globalisation and diversification can enrich a local innovation ecosystem.

The panellists were Diana Grauer, director of external technology engagement and venture capital at TechnipFMC, an oil and gas services company, and Bradley Andrews, president of digital at Worley, a provider of professional project and asset services in the energy, chemicals and resources sectors.

Xavier Helegesen

Both Grauer and Andrews expressed the primarily strategic orientation of their investing and open innovation activities. Grauer said: "We are 100% strategic. We are not focused on the conventional financial returns, so we look at technology adoption rate by our businesses, we also look at number of pilots and we have some criteria around the exit of such technologies, either to our business or to a third party."

In much the same vein, Andrews explained: "Generally we are not looking for a return from an exit. It has to drive a business case. We love it when we can take our own IP and combine with a solution from startup and make something more accretive."

Both panellists shared their views on the question of challenges in energy corporate venturing. Andrews mentioned how investing in startups is somewhat of a novelty to the broader energy and chemical sector: "The idea of investing in startups as a corporate is a bit new in the sector. We used to build things from within. I think we are still, as an industry, figuring out how to do

this [type of investing]. Some of the challenges are just getting our people and our customers to think about piloting. On the startup side, on the other hand, they are used to moving very quickly....and I think there is still a gap in confidence in both the startup community and the venture community."

He also listed some of the key questions that are worth asking embarking on such an investment undertaking: "Can we actually build companies that are dedicated to this industry? Because when I asked VCs if they wanted us to create an energy startup that focused on oil and gas some years ago, they would have nothing to with it. So, how do we get the VC people to be willing to invest? And on the industry side, how do we make corporates more confident in working with these startups? I think questions like these help."

"Why don't you fund me and our business group can invent this ourselves? And the answer that I always give is: Well, we need to move faster than that"

Diana Grauer

Grauer concurred with Andrews' outline of the challenges and said that the biggest challenge encountered internally, in her experience, can be encapsulated in the question: "Why don't you fund me and our business group can invent this ourselves? And the answer that I always give is: Well, we need to move faster than that." She also spoke the fear of failure as another big hurdle: "Everyone is absolutely terrified of failure and I can understand why. The risks are very, very high in this industry. People get hurt if you fail sometimes. So what we need to do is spend some time de-risking those projects in pilot opportunities with startups, outside of the equity investment, keep those two things completely separate."

(left to right): Bradley Andrews, Diana Grauer and Wade Bitaraf

Advanced manufacturing robotics pitches

Businesses from the manufacturing and robotics space, introduced by one of their corporate venture backers.

Dianna Liu
Chief executive, Arix Technologies
Introduced by: Mike Mahan, Stanley Ventures

Arix is a company that develops crawling robots for pipeline inspection in the oil and gas industry. The Arix robot is designed to navigate a variety of obstacles in petrochemical facilities. It features data analytics systems to help refineries with asset inspections, which may jeopardise the safety of refinery assets. The robots can collect data on each point they move over.

Martin Keighley
Chief executive, Carbonfree Chemicals
Introduced by: Chad Bown, BP Ventures

Carbonfree Chemicals has developed proprietary technologies that capture flue gases which would otherwise release CO2 into the environment and transform them into solid carbonate materials like sodium bicarbonate, hydrochloric acid, caustic soda and household bleach. The technology, dubbed SkyMine, can be potentially employed at all types of manufacturing plants to reduce pollution and create more green and useful products.

Alex Reed
Chief executive, Fluence Analytics
Introduced by: Chris Smith, Energy Innovation Capital.

Formerly known as Advanced Polymer Monitoring Technologies, the company was spun out of Tulane University in 2013 and rebranded in 2017. It manufactures of industrial and laboratory monitoring solutions that produce continuous data streams. The company boasts two product lines, ACOMP and ARGEN. Combined with proprietary analytical tools, the data enable real-time optimisation leading to improved process control and faster R&D for polymer and biopharmaceutical manufacturers.

Energy venturing – easier or harder?

The final discussion on stage at GCV Energy revolved around whether energy corporate venturing is becoming easier or more difficult. Tai Hsia, special counsel at law firm Baker Botts, moderated and led the session. Panellists included Juan Muldoon, principal at Energize Ventures, an energy-focused venture firm with corporate LPs, Ricardo Angel, chief executive and managing partner at PIVA – the US-based venturing unit of Malaysia-based oil and gas company Petronas – Matthias Engel, managing director of Innogy Ventures and Kemal Anbarci, managing executive at Chevron Technology Ventures.

Hsia asked the panellists about the changes that have taken place in the role of CVCs. Anbarci observed that corporate venturers have evolved and learned some of the unwritten rules of the VC game: "On the behavioural side, the biggest difference I see is the maturity of the CVCs. They have now been in business for a while and have established [certain] practices... If you ask for right of first refusal and try to hold the exits, it

hurts the startup and people learn this lesson all the time and when that happens, their dealflow dies because no one wants to invest with them."

According to Ricardo Angel of PIVA, the most notable differences have taken place in terms of decision-making: "Over time, the decision-making processes within the corporate organisations have improved a lot." He also stressed that for financially driven corporate ventures, it is important to align the interest of the team with a carried interest ("carry") compensation structure in place.

Engel highlighted the role of an appropriate venture team: "The important things is to set up a team that knows how VCs work and someone who understands what challenges founders face today." He agreed on the importance of proper incentives by stating: "We have a VC structure and also implement 'carry' to promote the mindset of financial discipline."

The only participant on the panel from a traditional VC firm, Muldoon commented on the increasing presence of energy-related investments that are not necessarily in pure-play energy companies: "A lot of the technologies we see and like tend to not be born in the energy space but have massive applications here. We like them for a number of reasons... From revenue and diversification perspective, it is better to have not just different clients but different client profiles with different buying cycles, different personas and different abilities to scale in the organisation."

Anbarci concurred with Muldoon on diversification but touched on the topic of organisational challenges that prevent startups from swiftly becoming clients or suppliers of a large corporation. Anbarci explained how his CVC has found a way around it: "I also think diversification of the clients of the portfolio company is desirable but it is incumbent on us to overcome organisational sluggishness challenges that may arise... At Chevron Technology Ventures, we have established a sandbox where we could test a technology from a startup at Chevron, figure out what works and what does not and all usually within days, so that makes things a lot easier."

The panellists also commented on the trend towards investing in companies developing more digital solutions instead of capex-heavy startups. All agreed the energy sector is looking

Left to right: Kemal Anbarci, Ricardo Angel, Juan Muldoon, Matthias Engel and Tai Hsia

A room full of investors listening to startup pitches on Day 1 at The Cannon, Houston

"At Chevron Technology Ventures, we have established a sandbox where we could test a technology from a startup at Chevron, figure out what works and what does not and all usually within days, so that makes things a lot easier"

Kemal Anbarci

to transition away from CO2 but there has been a lot of convergence with digital solutions. When asked what technologies they felt excited about, there was a consensus on AI's enormous potential. Anbarci also mentioned his interest in drone technologies and big data companies converting data into action.

Angel said he felt "very hopeful about hydrogen and very excited about AI and the value it can bring to improve real time operations, sensor technologies to be solve problems related to CO2 emissions or gas leakages." Engel, in turn, mentioned an important element of the emerging digital world: "Cybersecurity – if critical infrastructure becomes digitised, it needs to be secured somehow."

Muldoon highlighted edge computing and analytics as an exciting space but placed emphasis on an emerging theme Energize Ventures had been looking at: "Over the past 12 months, we have been developing a theme on 'connected worker' – how to make sure distributed labour has access to the right information and right technology and how they can interface not just with the assets but with the rest of the business in a more efficient way.

The Global Corporate Venturing 2018 – 2019 Energy Awards

By James Mawson, Global Corporate Venturing

I was delighted to announce the winners of our four energy awards at GCV's annual conference in Houston on November 21st.

- Low Carbon CVC Investment of the Year

- Digital Energy CVC Investment of the Year

- Advanced Mobility CVC Investment of the Year

- Advanced Manufacturing CVC Investment of the Year

These awards celebrate the role of corporate venture capital in:

- Widening the group of industries participating in the transformation of energy
- Extending the geographic reach of new energy-relevant technologies
- Accelerating the uptake of new energy technology by large corporations

The winners and the nominees all raised capital from corporate VCs between July 1st, 2018 and June 30th, 2019. All are testament to the determination of the world's largest corporations to participate in the most exciting and, from an environmental point of view, the most important, changes underway in energy.

The winners and shortlisted companies are on the following pages.

Continued ...

Low Carbon CVC Investment of the Year

Winner

CALYSTA®

CVC Investors

bp ventures, Cargill, MITSUI & CO.

Financial VCs

PANGAEA VENTURES LTD., AQUA SPARK, BESSEMER TRUST, OMERS, TEMASEK, WRVI CAPITAL

"We're certainly interested in investments and solution to the rising demands for food and limited natural resources around the world."

David Hayes, CIO, BP Ventures

Calysta ($30m, Series E)

Manufacturing new protein resources by fermenting natural gas will allow Calysta to feed a growing population while minimising environmental damage. As of June 2019, BP joined Cargill and Mitsui as investors in Calysta, which use BP's methane as its feedstock.

Widening: From aquaculture & agriculture to energy and advanced materials, Calysta has succeeded in attracting a diverse range of investors

Extending: Calysta will be using the $30 million raised from BP Ventures to support a worldwide rollout of Calysta's FeedKind® protein

Acceleration: Calysta's patented, state-of-the-art fermentation process uses no arable land and very little water, and does not compete with the human food chain, meaning more food can be produced with less resources

Shortlisted:

Carbon Engineering

Direct Air Capture (DAC) technology captures carbon dioxide directly from the atmosphere. In raising capital from Occidental, BHP and Chevron, Carbon Engineering has assembled a team with the global footprint capable of driving the adoption of DAC.

CVC Investors

Chevron
OXY
BHP

Financial Investors

First Round
Lowercase Capital
Starlight Ventures
Rusheen Capital Management, LLC

"We are interested in looking at innovations around carbon capture. The fact that Carbon Engineering uses carbon dioxide to make synthetic fuels is an area of particular importance."

Barbara Burger, President of Chevron Technology Ventures

Dandelion Energy

Dandelion Energy seeks to provide earth-powered heating for every home in the form of geothermal energy in a cost-effective manner. Originally conceived at Alphabet X, it has since spun out and received Series A funding by Google Ventures, telco incumbent Comcast Ventures and home-building giant Lennar Corporation.

CVC Investors

GV
Comcast Ventures
Lennar

Financial Investors

NEA
Ground Up
C
Zhen Fund

"In a short amount of time, Dandelion has already proven to be an effective and affordable alternative for home heating and cooling, leveraging best-in-class geothermal technology."

Shaun Maguire, partner at GV

Sunfire

Sunfire's core mission is to create a life where the utilisation of fossil resources are not required. To do this, the company has manufactured electrolysers and fuel cells which use hydrogen. Paul Wurth from the steel industry, the utility Cez Group and energy &G company Total took part in its Series C round in January to aid Sunfire in its mission.

CVC Investors

Paul Wurth
Total
Inviein Capital

Financial Investors

Idinvest Partners

"Our collaboration with Sunfire clearly expresses our strategy to play a leading role in the upcoming transformation of the steel industry towards CO2-free steel production."

-Georges Rassel, CEO of Paul Wurth

Cemvita

Photosynthesis has always been associated with plants. Enter Cemvita Factory whose CO2 Utilization platform mimics that of photosynthesis by simultaneous uptake of solar energy, water, and processing of carbon dioxide to produce nutrients, pharmaceuticals, intermediate chemicals, and polymers. Oxy Low Carbon Ventures and BHP have invested in Cemvita to explore new, sustainable pathways for the bio-manufacturing of their products.

CVC Investors

OXY
BHP

"Cemvita Factory's CO2 utilization platform has the potential to harness the power of nature and create new, sustainable pathways for the bio-manufacturing of our products."

Richard Jackson, President of Oxy Low Carbon Ventures

Digital Energy CVC Investment of the Year

Winner

LO3 ENERGY

CVC Investors

Financial VCs

"As we move into a less carbonized future, Shell aims to invest in innovative companies that will help enable the energy transition. LO3 Energy fits right in that space."

Kirk Coburn, Investment Director, Shell Ventures

LO3 Energy

Decentralised business models are being tested in different industries – so why should energy be any different? LO3 Energy is developing a permissioned blockchain-based data platform to create localised energy marketplaces. With Shell, Sumitomo, Siemens and Centrica backing the company, LO3 is drawing on the right CVC expertise and experience.

Widening: Besides attracting Nysnø, a sovereign investment company, eSmart Systems has expanded its investor base to include utilities and corporates in the O&G and energy space

Extending: The most recent investment will be facilitate eSmart Systems' expansion into the American and European markets

Acceleration: eSmart Systems helps utilities ensure and maintain the reliability, safety, and resiliency of the electric grid while simultaneously providing actionable insights for transmission and distribution systems

Shortlisted:

Data Gumbo

Does the future of blockchain include smart energy contracts? Data Gumbo certainly seems to think so with its Blockchain-as-a-Service platform which streamlines smart contract management for industrial customers. Saudi Aramco Energy Ventures and Equinor have joined Data Gumbo to accelerate its journey to be a winner in this space.

CVC Investors

Saudi Aramco Energy Ventures

Financial Investors

Equinor

"Distributed ledger technologies have the potential to bring win-win efficiencies between industrial companies and their suppliers, and Data Gumbo is at the forefront of introducing this innovation."

- Daniel Carter,
Senior Investment Director, SAEV

eSmart Systems

eSmart Systems is all about connectedness. Be it utilising deep learning and computer vision to extend asset life and lower maintenance costs or optimising operation, maintenance and planning of electrical grids, eSmart connects the data to inform actions. Large energy and utility corporates see the value in this with Innogy, Energy Impact Partners, Equinor and Kongsberg having invested in the company.

CVC Investors

Innogy Ventures
Energy Impact Ventures
Equinor
Kongssberg

Financial Investors

Nysnø Invest

"Based on exceptional AI capabilities, eSmart is providing the next level software needed for a digital, decarbonized and decentralised future energy world."

Thomas Labryga,
Investment Partner at innogy Ventures

GreenCom Networks

GreenCom Networks seeks to connect and control the majority of more than 100 million distributed energy assets on a single software platform to enable customers to have greater control, optimisation and service innovation.

CVC Investors

Innogy Ventures
Centrica Ventures

Financial Investors

SET Ventures
Munich Venture Partners
Cosmos Group

"GreenCom's innovative products and services, focusing on home energy management, have an important role to play in the power business in Europe and beyond."

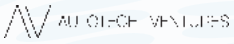
Patrick Elftmann, Investment Partner at innogy Innovation Hub

Advanced Mobility CVC Investment of the Year

Winner

CVC Investors

Financial VCs



> "Computer vision technologies, such as advanced radar, will be a key component of future autonomous vehicles...We look forward to partnering with Metawave to successfully develop their technology."
>
> Tony Cannestra, Director of corporate ventures for DENSO International America

Metawave ($10m, Series A)

In securing CVC backing from Denso, Toyota, Hyundai, Infineon and SAIC, Metawave's CEO Maha Achour has found capital and expertise from a leading automotive supplier, three top OEMs, and world leader in 5G, from Japan, South Korea and China – three core markets for the future of AV technology.

Widening: In addition to SAIC Capital, Metawave's latest funding round attracted corporate investors from the automotive, semiconductor and glass manufacturing sectors

Extending: The latest investment round will be used to develop strong partnerships and build the infrastructure required to achieve safer autonomous driving

Acceleration: Metawave changes the way automakers deploy radar and is building high-performance radars capable of 4D point-cloud imaging, non-line of sight object detection, and vehicle-to-vehicle communication, making cars safer, smarter, and connected

Shortlisted:

Aurora

Aurora is symptomatic of the energy, automotive and logistics' industries need to venture in neighbouring territories so that they can survive (and prosper) in their own. Shell's, Amazon's and Hyundai's co-investments in Aurora bolsters their stake in the future of autonomous transport, which is transforming their industries.

CVC Investors

Saudi Aramco Energy Ventures

Financial Investors

Equinor

"We are always looking to invest in innovative, customer-obsessed companies, and Aurora is just that."

Amazon

Recogni

Cars need to be able to see much further and faster if autonomous travel is to be safe, reliable and fast. In raising capital from the venture units of lighting specialist OSRAM alongside OEMs Toyota and BMW, and tier 1 supplier Faurecia, Recogni's CEO Chris Urmson has assembled a group of shareholders that can drive growth.

CVC Investors

Innogy Ventures
Energy Impact Ventures
Equinor
Kongssberg

Financial Investors

Nysnø Invest

"We are excited by Recogni's inference architecture for high-performance, low-power AI computing at the edge, and look forward to working with the team to build a world of safe and efficient autonomous systems."

Jim Adler, Founding Managing Director of Toyota AI Ventures

Advanced Manufacturing CVC Investment of the Year

Winner

CVC Investors

Financial VCs

"Markforged is making 3D printing simple, repeatable, and fast. We see customers embedding Markforged into their product development and production processes, tremendously improving speed to market and addressing new opportunities in their industries."

Lak Ananth, Managing Partner at Next47

Markforged ($82m, Series D)

For 3D printing technologies to achieve mass market potential they need to embed themselves in cloud-based distributed manufacturing systems that are trusted by end users as reliable and 'everyday', not 'experimental' and 'part-time'. In securing backing from the venture units of Microsoft, Siemens and Porsche, Marketforged has assembled an investment team that grasps this reality.

Widening: Markforged has attracted capital from corporates VCs within the industrial manufacturing, automotive and technology space

Extending: The $82M investment will enable Markforged to accelerate its product roadmap in more than 50 countries of which it already serves

Acceleration: Markforged allows engineers, inventors and manufacturers to print industrial-grade parts at a fraction of the time and cost of traditional methods, thereby making 3D printing broadly reliable and accessible.

Shortlisted:

Fluence Analytics

Large parts of the chemicals industry remain firmly analogue. The potential to optimise manufacturing, reduce waste, increase margins and develop new materials more quickly, through some serious digital 'tweaking' is vast. Fluence Analytics' digital polymerisation technology is a case in point. In securing capital from Diamond Edge Ventures (a new venture unit set up by Mitsubishi Chemical Holdings Corporation) and energy specialist financial VC Energy Innovation Capital, Fluence has an investor team capable of supporting global roll-out.

CVC Investors

Mistubishi Chemical

Financial Investors

Energy Innovation Capital

"We expect significant benefits from real-time polymer analytics to improve operational efficiency and product quality while generating long-term insights from these advanced datasets."

Patrick Suel, President of Diamond Edge Ventures (Mitsubishi Chemical Holdings)

Velox

In securing capital from Evonik and Altana, two of Germany's most innovative and global chemicals giants, Velox has found ideal partners for the roll-out of its technology, which digitises the printing of packaging decoration.

CVC Investors

Evonik
Altana

Financial Investors

JAL
OR Technologies
ILAN Holdings

"Velox developed a disruptive technology that for the first time takes digital printing into the mass market of packaging decoration. Since unique ink formulations are a major element of this technology, we feel this is an ideal match to Evonik's strategic interests."

Dr. Gaetano Blanda, Senior Vice President and General Manager, Coating Additives of Evonik

BP Ventures' David Hayes catches scalable fish food investment

Tom Whitehouse interviews BP Ventures' new CIO on fish food, the circular economy and responsible gas

Tom Whitehouse
Leif Capital

Interesting moves are afoot at BP Ventures – their first investment in food (fish food, to be precise) and some changes to their team. Their former San Francisco-based US venture head Meghan Sharp has joined Beyond Limits, the California-based AI startup, as COO. BP invested in Beyond Limits in 2017. She has been replaced by David Hayes, who will also take on the new role of global Chief Investment Officer, working across the whole BP Ventures portfolio. And it is David who has joined the board of Calysta, a Californian biotech business that makes fish food from natural gas, following BP's $30m summer investment. In the interview below, David sets out the strategic rationale for the investment, discusses the wider use of natural gas as a low carbon feedstock and gives an insight into how BP's venturing strategy is continuing to evolve. David, who hails from Leicestershire in the UK, joined the BP Ventures team ten years ago, the last eight of which have been spent based in San Francisco, a city he now calls home.

David, let's get the fish jokes out of the way early – the investment in Calysta is a great catch for BP, but how easy will it be to scale?

Very good Tom. Ok, to be serious, BP can help grow this business. We have geographic reach. For example, Calysta is very interested in Oman as a region to build a plant to produce the fish food and we are active there. $30 million is a reasonable deal size. And I don't think that's all we are going to invest. To build a commercial-scale plant costs about $400 million, so when you consider that the protein market for fish is expected to grow from 45 million to 60 million tonnes by 2025, that would need a number of these plants to meet the potential demand. Calysta has a plan of producing 100 million tonnes, which will cost around $4-5 billion of capital.

Continued ...

CALYSTA.

What is the essence of Calysta's innovation?

Calysta is using advanced biological processes to exploit and enhance the power of naturally-occurring bacteria to produce food at a commercial scale.

This is BP Ventures' first investment in food, but the parent company has history here.

Correct. We had a business called BP Nutrition, which was sold in 1994. I did some more digging and, based on the financials, it looked like it was a pretty good business. It was generating $5 billion in revenue in the nineties. I guess it wasn't deemed strategic and was sold.

But now food is seen as strategic?

Food is strategic for Calysta. However, for BP it's about creating new markets for gas and new uses of gas beyond heat, light and mobility.

How does Calysta fit into BP's strategy around the energy transition and the broader sustainability agenda?

BP getting involved with Calysta initially sounds unusual and there was quite a steep learning curve for us to understand how fish ends up on our plates. Farmed fish is often what we eat, and wild-caught fish is fed to those fish, which is just not sustainable. Fishmeal is at capacity, and there is a limit on how much fish can be caught to feed to fish. To combat that, the world is replacing fish protein with soya bean protein and other plant-based proteins. But that's not sustainable when you consider the land and water required to grow them. The Calysta technology uses somewhere between 77-98% less water than alternative ingredients, including soy and wheat proteins.

It also requires no agricultural land to produce, freeing that land for other food crops. In fact, one commercial scale Calysta protein plant, if used to replace soy products, would free up land equal to an area the size of Chicago, Illinois or Birmingham, England or Seoul, Korea.

[Source: A copy of the report can be found at: www.carbontrust.com/feedkind.]

But the feedstock is gas and that will be BP's natural gas.

Yes. BP aims to be Calysta's sole natural gas supplier. There is great potential. If Calysta were to replace all proteins out of the fish feed market, you'd need 127% of the natural gas that BP produced in 2017. I'm not saying you can feed fish just with Calysta's product. You can't. But this gives an idea of scale because it can be fed to pets, to livestock and fish. We will be looking for more investments in companies that make products or things sustainable or cleaner by using natural gas as a feedstock. Gas-to-products is where we need to head. We'll be using natural gas for electricity and transportation, but as you see fleets becoming more homogenized and more autonomized, this protects our core product of gas for the future, I believe.

I'm keen to talk more about gas, but first I'd curious to know the extent of BP Ventures' appetite for more food-related investment? What other types of investment will you be looking at?

We're certainly interested in investments and solutions to the rising demands for food and limited natural resources around the world, and indoor farming including aquaponics is also of interest.

By investing in aquaponics for example you'd be helping to create and grow the market for Calysta's products.

Possibly, we'd be participating in the growth that is already underway in aquaponics, bringing strategic value and connecting different threads within our venturing and new business strategies.

For example?

For example, I can imagine Lightsource BP, BP's solar business, providing power to aquaponics and vertical farms. I can envisage carbon capture and usage businesses providing farms with the carbon dioxide required to grow the food and then recapturing whatever carbon dioxide before it is emitted. I can see us extracting value from a range of waste streams. I sit on the Board of Fulcrum, our waste-to-jet fuel investment, and they extract value from household waste, so this isn't new for us.

"We will be looking for more investments in companies that make products or things sustainable or cleaner by using natural gas as a feedstock. Gas-to-products is where we need to head."

David Hayes, CIO, BP Ventures

So, the circular economy is back as a venture theme?

It never went away. It's just getting more relevant and pressing.

How is natural gas a part of the circular economy?

If we reflect on BP's energy outlook, we see that renewables are making inroads, and we all want to see them take a bigger share. But hydrocarbons are still a material chunk of overall energy supply up to 2040, particularly natural gas. And I'm particularly keen to invest in businesses that can use natural gas to displace products and thereby make them cleaner and less carbon intensive. Calysta is a great example. There will be others. I can imagine investing in businesses that convert methane into clothing. You're essentially just moving carbon molecules around.

"We're certainly interested in investments and solutions to the rising demands for food."
David Hayes, CIO, BP Ventures

This takes us on to discussing Xpansiv CBL Holding Group, another BP Ventures portfolio business where you're on the board. XCHG offers what it calls an intelligent commodities platform which can offer customers 'digital feedstock'. How does this affect gas?

The tagline of the XCHG website is 'not all commodities are created equal'. Thanks to an explosion of data gathering and reporting capabilities, XCHG can differentiate between commodities, including gas, so that customers can make much better-informed purchasing choices. I believe that 'responsible gas' – gas which is produced without flaring for example – will find more customers.

How will your work be different for BP Ventures now that you are Chief Investment Officer as well as MD for the Americas?

I'll lead our venturing in North and South America; sourcing investments, taking seats on boards etc. reporting to David Gilmour, our overall head. But the experienced team of principals I work with in San Francisco and Houston stays the same. I will however formalise the role I have played for a while and be responsible for our term sheets and investment agreements across all the regions where we venture. We're keen to see consistency in how we marry our venturing with BP's overall strategic objectives.

I hope you won't mind me describing you as a relatively old hand at BP Ventures, having worked there for ten years. You obviously enjoy the job, but what are the frustrations you have and what are you trying to change?

It's frustrating that we're still seen as a big scary corporation to some early stage startup companies. This sometimes leads to nervousness among entrepreneurs. I'd like our track record to be better understood: we've not missed a follow-on round. We've been a good investor. I'm frustrated when I hear of other corporate VCs not doing the same. Our term sheets and investment agreements are consistent with market norms. We seek alignment with founders and co-investors. And in many cases we have helped drive growth in our investments through advantages only a big corporate like BP can bring. So, I look forward to venturing further afield - outside the traditional energy domain – into great startups that are building a more circular economy.

"I believe that 'responsible gas' – gas which is produced without flaring for example – will find more customers."
David Hayes, CIO, BP Ventures

Fail Fast?

Not if you're an energy tech entrepreneur.

By Kirk Coburn, Investment Director at Shell Ventures

Fail Fast? No Way. This is one of those buzz words that even the best and brightest take for granted but often get it wrong. In energy, you can't afford to fail. And we all know that it is not going to be fast.

In energy, there is no failing fast. By the numbers, it takes a non-energy startup on average 7.5 years to liquidate from first funding (slide 18). In energy, I can assure you that most startups that have raised their first funding since 2010 have not even reached scale. The time to liquidation exceeds the standard 10-year fund life of most funds (ask the incumbent energy investors in our space to comment). Energy takes longer. So, the question is: Does Venture Capital Work in Energy?

I was a passenger during the first tech bubble. It included a trip down Area 51 hysteria lane as the world should have ended due to the Y2K bug. I was sitting pretty at Dell watching my stock options hit atmospheric levels, feeling that I was being left out of the one-pitch powerpoint to unicorn billionaire club, and ignoring all signs of the impending train wreck. The crash, leaving my great job for a dot-bomb, and losing significant capital must have burned any irrational exuberance out of me.

Fast forward just a few years later. A new bubble appeared called cleantech. Startups in the energy sector, particularly cleantech, were anticipated to bust out, generating tons of interest in the venture capital industry. So this got me thinking...is it possible that energy startups are not a good fit for the venture capital model? Or was the previous bust a consequence of unfortunate market conditions?

How This Impacts Energy Startups French Polynesia

The chase to find or create the biggest monster to dominate an industry and milk the greatest return is not a strategy that will play well for startups in the energy sector. You're just not going to get a dominant player in the energy field like a Facebook in social media or a Juul in e-cigarettes.

Back in the mid-2000s, startups in cleantech looked like they were set to disrupt the long-established energy market, and VC funders took

Continued ...

> "With lower oil and natural gas prices, energy providers had little incentive to proceed with adopting clean technologies."
>
> Kirk Coburn, Investment Director, Shell Ventures

notice and took their chances. But reality quickly set in, and cleantech ended up looking like a mini-dot-com bubble that burst. Being early is equivalent to being wrong.

As they analyzed Series A funding beginning in 2006, the MIT Energy Initiative found cleantech funding was nearly equivalent to medical technology and software technology. They found VC companies poured $25 billion into the industry between 2006 and 2011, but by 2016 had lost more than half their investment. Of the 150 startups founded in Silicon Valley over the previous decade, nearly all had shuttered or were on their last legs.

Was venture capital a bad model for cleantech? Or was this bubble just bad luck? Probably a little of both. First, the 2008 recession hammered economies across the globe and sent oil and natural gas prices plunging. At the same time, hydraulic fracturing (or fracking) had been introduced into horizontal drilling in the late 1990s. It greatly increased oil and natural gas output across the United States, ensuring prices would not skyrocket back to their 2006 levels.

With lower oil and natural gas prices, energy providers had little incentive to proceed with adopting clean technologies (and consumers had not yet shown their willingness to pay more for sustainability), putting all of these startups at a distinct disadvantage.

The other piece of the equation — whether cleantech fits with the current VC model — also became evident during this bubble "experiment."

The MIT report showed the cleantech startups which focused on software solutions were the only type to enjoy any success. "In particular, clean-tech companies developing new materials, hardware, chemicals, or processes were poorly suited for VC investments because they required significant capital, had long development timelines, were uncompetitive in commodity markets, and were unable to attract corporate acquirers," the report states.

Because venture capital firms operate on a 10-year cycle, they are designed ideally to exit their investment within four to seven years, a timeline that is too short for energy startups. These startups also are not likely to yield the massive returns VC investors need to cover the high percentage of losses they will experience.

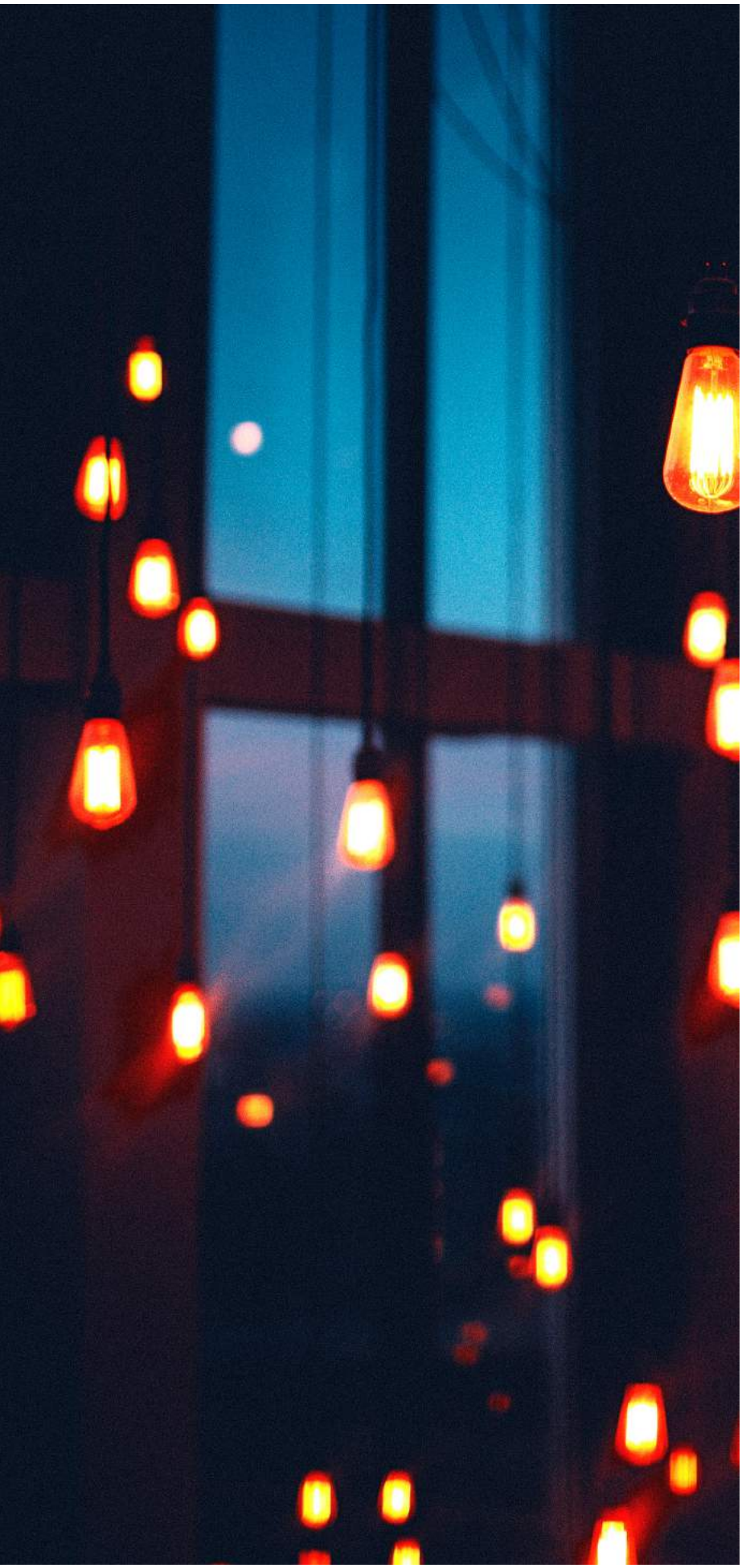
Where Does This Leave Energy Startups?

The industry is not innovating fast enough out of its own decision to reduce investment. Corporate research and development have been in decline for several decades. Research from the National Bureau of Economic Research released earlier this year shows that by 2015, the business share of research funding had fallen to 20 percent, down from 30 percent in 1985. In the oil & gas industry specifically, R&D spending has been trending down by both operators and service companies.

As the research emphasis has shifted to the university setting, the translation of research to product development has lagged. In the giant corporate labs like those founded by AT&T and IBM, researchers not only had the financial muscle behind them, they also had the challenge to develop a product to meet a specific need.

More emphasis now has shifted to those startups leveraging university research to develop products for the market. Venture capital has made that possible by providing the cash to allow startups to span the fiscal desert from concept to ROI. This has been a successful model for many industries. However, it appears not to be viable for energy startups because of the longer timeframe necessary and the smaller

Continued ...



ROI. Taking an idea from the lab to liquidation from acquisition or IPO is well beyond 10 years in energy.

But there is a growing area of hope for these startups. First, we are seeing the rise of digital startups attacking energy due to industry prioritization and technology access. Startups are starting to make significant progress as many customers have started to adopt cloud and mobile platforms. This opens the door for a startup to be able to land and expand quickly on a global basis. Second, corporations are sitting on a vast mountain of cash ($1.7 trillion in cash held by U.S. corporations, at last count) while watching other investors putting money to work backing a startup that may invest more are creating corporate venture capital programs to put that cash to work including energy companies.

Corporate Venture Capital Firms in Energy

Corporate venture capital (CVC) offers advantages for the energy sector because it doesn't face the time constraints of a typical VC. There are a few other advantages and levers that can be pulled:

- If a technology can be deployed internally and it achieves realized cost savings, there is more value to the investment and a greater payback than simple cash alone.
- CVC's are not dependent upon pleasing multiple investors with their own investment horizons.
- Cash on Cash return from venture investments is not the primary source of income for the corporation.

The CVC model also frees the startup to focus on its core purpose, developing its product or service, rather than chasing the next funding series, acquisition, or IPO.

Chevron

Happy Birthday Chevron Technology Ventures

20 years, 100 investments

Chevron Technology Ventures: 2019 Year in Review

Kemal Anbarci,
Managing Executive, Chevron Technology Ventures (CTV)

CTV builds the pipeline of innovation into Chevron by identifying and integrating externally developed technologies and new business models that enhance the way Chevron transactions and delivers affordable, reliable and ever-cleaner energy.

CTV leverages multiple tools to support startups from Pre-Series A through our Catalyst Program to venture investments through our Fund VII and the Future Energy Funds. Highlights form 2019 include:

- In March, CTV launched Fund VII, which invests in core oil and gas, and digital.
- In a typical year we do about 50 deals including follow-on investments. This year we are on track to exceed that number. Select investments include INGU, Orbital Insight, Well Conveyor, Voyage, Spear, and Infinitum Electric.
- Sensorfield, MemComputing and NovoNutrients joined the Catalyst Program which supports pre-Series A companies that have technologies that have the potential to impact the energy industry.

Barbara Burger,
President Chevron Technology Ventures:

"This year was a busy year for CTV. We celebrated our 20th anniversary, making us the longest running continuous Corporate Venture Capital organization in oil and gas. We also launched a new fund, our seventh, targeted at core oil and gas and digital investments, and made our 100th investment in a startup. This year we made multiple investments from the Future Energy Fund and Fund VII. Some of the companies we added to our portfolio include Voyage, Spear, Infinitum Electric, Well Conveyor, INGU Solutions, and Orbital Insight."

Barbara Burger, President Chevron Technology Ventures:

CTV is also an investor in several funds including Climate Investments LLP, Oil and Gas Climate Initiative's $1bn fund, and Houston Exponential's Venture Fund.

CTV is involved in all aspects of portfolio management including trialling and scaling technology inside the enterprise.

Through its investment portfolio and internal use pipeline that trials technologies for use within Chevron, CTV has supported a wide range of pioneering companies that are helping to shape the future of energy. This year we have trialled or are in the process of trialling over 50 technologies.

CTV partners with incubators and accelerators in key regions in the US and globally to build and support the innovation ecosystems to strengthen the pipeline of innovation coming into Chevron. We have partnerships with Greentown Labs in Boston, MA, Cyclotron Road in Berkeley, CA, and Innovation Norway.

Corporate venturing in mining

to catch up with energy?

By James Mawson, Global Corporate Venturing

It is an irony that as the world moves to cleaner sources of energy it is increasingly reliant on one of the most challenging industries for the commodities.

As the global economy switches to low-carbon technologies to combat global heating, demand for minerals, such as cobalt, copper, lithium, manganese, nickel and zinc – six minerals essential to the renewable energy industry – could rise by as much as 900% by 2050, according to World Bank estimates.

And in digging out the minerals, the miners are increasing their own demand for energy, as well as impacting other natural resources, such as water, and affecting social and environmental conditions for communities.

A report last December by the Columbia Center on Sustainable Investment (CCSI) said the mining sector could account for anything between 1.25% and 11% of total global energy demand, depending on which downstream activities are included in the assessment. The CCSI study estimated mining sector energy consumption could increase by 36% by 2035, as demand for minerals grows and remaining ores become more difficult to extract.

For most of the last century, the industry has responded to the challenges presented by ageing mines and declining ore grades by digging deeper and crushing more rocks but now are turning to open innovation and more exploratory fields to meet demand while controlling costs.

This openness has come not a moment too soon. After a near-three-quarters drop in industry valuations between 2011 and 2016 due to falling commodity prices, valuations have improved with demand but it now takes double the amount of water and 15 times the amount of power to produce 40kg of copper than in 1900, according to mining company Anglo American as it prepares to open Quellaveco as "one of the last, if not the last [open cast] mine of this size and scale," said Tom McCulley, head of Anglo American in Peru, in an interview with the Financial Times last month.

Anglo is looking for the Quellaveco pit to last into the next century as copper, which is very efficient at conducting electricity, will be increasingly in

Continued ...

demand as more solar panels and wind farms are connected to the grid and the use of electric vehicles (EVs) grows.

EVs are expected to contain four times as much copper as combustion-powered engines and analysts said the copper market slipped from a surplus into a deficit last year.

The other commodities behind the renewable energy and electrification boom are also in vogue.

In the launch of Rio Tinto Ventures under Kevin Fox in August 2018, the company said: "There is some excellent work being done by the likes of the Massachusetts Institute of Technology that may guide us in this regard, looking at key new technologies that will influence future metal demand."

In terms of project characteristics, the company added: "Rio Tinto Exploration covers the earlier stages of discovery and evaluation, while the Ventures interest will begin when projects reach feasibility and beyond.

"The majority of our investments are expected to be upstream in mining and the first stages of processing and refining, but we will be open to considering related businesses where there is a clear value proposition and, most likely industrial logic and synergies with our existing businesses [covering Rio Tinto Iron Ore, Aluminium, Copper and Diamonds, and Energy and Minerals]."

Of the larger miners, however, Anglo has probably moved furthest down this path to develop a broader business model under the Marketing division.

In July last year, Anglo's corporate venturing unit, Platinum Group Metals (PGMs) Investment Programme, was spun out to independent management with the formation of the AP Ventures fund. Anglo said: "Having enjoyed success and a strong track record while being managed by Marketing, we separated the fund in order to attract additional outside investment and allow AP Ventures to increase the scale of its activities to support the growth of PGM technologies and PGM demand," in particular, the work to support the commercialisation of fuel cell electric vehicles and related hydrogen technology.

Corporate venturers in the mining industry pointed to the success between Canada-based mining group Teck Resources and MineSense, a Canadian startup, on collaboration around so-called smart shovels (where sensors are mounted on the shovel bucket and use x-rays to tell the difference between waste rock and valuable ore, one shovel load at a time).

Teck partnered with MineSense for the first full scale trial of the bucket-mounted ShovelSense technology in 2017 and Bryan Rairdan, technical services manager at Teck's Highland Valley Copper Operations where it is being used, said: "This technology helps us to use less energy, create fewer emissions and improve productivity. In fact, smart shovels have the potential to create hundreds of millions of dollars in value."

Equipment maker Caterpillar is an investor in MineSense, alongside specialist venture capital firms, including Chrysalix, which has a number of mining companies as limited partners in its latest fund.

Vendors and service providers, such as Caterpillar, Mitsubishi (which also owns stakes in about 30 mines), ABB, Siemens and Komatsu, have traditionally taken the lead in working with startups through their corporate venturing units and buying them. Caterpillar and Komatsu, for example, have bought dispatch systems by buying startups Modular Mining and Venco.

Michael Young, head of Caterpillar Ventures, said: "Mining is leading the world in autonomy. We have hundreds of trucks at level 5 autonomy and have been adding additional equipment to the system.

"On the mining side, efficiency is the name of the game now (versus more production at any cost). This is driving the investment into the sector.

"Service providers have been active in developing pilots but we will see more adoption if majors,

Continued ...

James Mawson
Global Corporate Venturing

Kevin Fox
Rio Tinto Ventures

Bryan Rairdan
Teck Resources Limited

Michael Young
Caterpillar Ventures

such as BHP Group, Rio Tinto and Anglo American, are more aggressive but the industry takes a much longer time than oil and gas majors, which is not lightning fast.

"Still, credit that majors are interested and running pilots, such as our investment in Guardhat, which also has 3M as investors.

Peter Bryant
Clareo

Caterpillar has been investing five to six years and want financial returns but do this for strategic reasons to help our business units."

However, while the pace is still relatively slow there are potential tectonic shifts in the industry, including following Anglo's progress around what is effectively mining-as-a-service (MaaS).

Ippei Akiyoshi, manager of corporate venture capital in the mineral resources group at Mitsubishi, a Japan-based manufacturing and trading conglomerate and minority partner in the Quellaveco mine, said: "I'm intensively working on MaaS project internally and externally.

"The idea came from the question: 'Why engineering companies in the mining industry are with low margin, not in charge of innovation and so different from the ones in oil and gas?'

"I'm working on how we can make a difference on this with corporate venturing regarding the increasing partnership between mining corporates and VCs looking for innovation.

"We, as a corporate, expect VCs to give us more access to novel technologies owned by startups and help us find the ideal way of collaboration.

"Tier 1 mining corporates used to be skeptical on the importance of open innovation. However, I do see the changes in their attitude."

George Gogolev, head of Severstal Ventures, the corporate venturing unit of the eponymous, Russia-based conglomerate with steel foundries at its core and in its first direct deal backed alloys company Arcanum Alloys, said: "We are seeing moves to mining-as-a-service as an innovative business model. Can you hold a licence and let others extract with competing technology? Oil and gas service companies have such huge margins because they have unique technology. Mining has not had that."

There remain, however, issues around capital and exits. The industry dipped its toe into corporate venturing a decade ago just around the start of the global financial crisis with integrated metals and mining company ArcelorMittal has set up a €100m carbon fund and a separate Clean Technology Venture Capital Fund that invested in Miasolé in its first deal. But with few notable successes and the cratering of valuations, few others followed.

Peter Bryant, managing partner at Clareo, said: "Mining remains the only significant industry to not lean into corporate venturing in a significant way, which is a gap given the dearth of VC [venture capital] money available to startups focused on the mining industry. This just amplifies the persistent under investment in innovation.

"The result is that a lot of great innovation is ether stranded in research organisations or within perpetually small companies that can never raise funds to fund growth and further development of a scale required.

Continued ...

"There are now glimmers of hope in AP Ventures and Chrysalix's fourth fund, RoboValley, which targets strategics as LPs [limited partners].

"Autonomy may spur VC investment in mining-focused startups. For example, SafeAI, a Silicon Valley-based company focused on autonomy solutions for mining and construction, is funded by some of the leading autonomy VCs, such as AutoTech Ventures."

Space Box: Infinity of minerals nearly within reach

Since 2000, more than $13bn has been invested in space-related businesses that extend far beyond established industries like satellites and launchers. In fact, space may ultimately support a commercial market worth over $37bn, comprised of opportunities such as manufacturing (the low-gravity environment can deliver significant productivity improvements), space tourism, and exploration support, according to consultants Deloitte, which added: "Although asteroid mining still sounds like science fiction, companies like Planetary Resources are looking to mine asteroids. The market potential could be huge, one asteroid (16 Psyche) is made up almost entirely of iron, nickel, and rare metals like gold, platinum, copper, cobalt, iridium, and rhenium.

"Planetary Resources is a privately-owned US company financed by a number of industry-launching visionaries who see the mining of space resources as a potential trillion dollar opportunity. They are particularly focused on near-earth asteroids (NEAs), which are easiest to access and are estimated to contain over 42 trillion tons of resources. NEAs represent a potential mineral resource at least 50 times larger than the earth's entire iron ore reserve. Planetary Resources has successfully launched two spacecraft into orbit (2015, 2018), demonstrated its technology in Earthbound mining operations, and is aiming to launch the first commercial Space Resource Exploration Mission by 2020."

Caterpillar meanwhile is working with NASA to build autonomous machines that could excavate and mine the lunar surface for raw materials to use for its planned lunar outpost, while China has already explored the rocks on the dark side of the moon and startups, including Virgin Galactic, Blue Origin and SpaceX, are looking at space as their final frontier.

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Join 400+ business leaders from the corporate venturing and wider high growth business ecosystem for Global Corporate Venturing's **10th edition** of the Symposium. Taking place at London's County Hall on 3-4 June, with a reception at the House of Commons, this year's event will develop the industry's **'2020 Vision'** - a chance to look at how venture has grown and professionalised through corporate venture capital (CVC) over the past decade and what might come in the next one.

It has been clear that companies that use CVC as part of a broader innovation strategy have outperformed peers in terms of strategic and financial performance, and this is increasingly been recognised by stockmarkets. The question for this decade is once the strategy becomes widely known and available, and corporate venturing goes from being a competitive advantage to have to a necessity to avoid being left behind, how the emphasis shifts to better performance and effectiveness to show relative gains.

In this decade, therefore, the professionalism and operations against benchmarks through better training becomes vital and our 10th anniversary Symposium, co-chaired by David Gilmour from BP Ventures and Jacqueline Lesage Krause from Munich Re Ventures, will celebrate the leaders who have taken the industry to unprecedented heights and positioned innovation capital as the opportunity to make the world a better place.

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Callum Cyrus
Reporter, Global Corporate Venturing

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Cracking the quantum puzzle

Academic research towards quantum computing and other quantum technologies is beginning to pay dividends, but continued progress will rely on strong cooperation between academic, industry and government partners.

Corporations seem ready to seize the opportunity with quantum computer developer IonQ last month raising $55m in a round co-led by Samsung Catalyst Fund featuring Hewlett Packard Pathfinder, Airbus Ventures and existing backers, such as Alphabet's GV corporate venturing unit and Amazon.

But only four emerging quantum computing companies had raised more than $50m in venture funding as of July 2019, according to data provider CB Insights, even as overall deal count rose more than 200% over six years to 24 in 2018.

Other deals this year in the sector saw quantum dots developer QD Laser raise $33m in funding from more than 20 investors, including Tokyo Century, Axa, NTT Docomo, MTG, Dai-ichi Life Insurance and Nikon-SBI Innovation Fund. UK-based quantum photonics technology developer Nu Quantum closed a £650,000 ($840,000) pre-seed round that included Martlet, an investment vehicle for aerospace manufacturer Marshall and also featured university-focused investors Ahren Innovation Capital and Cambridge Enterprise Seed Funds, while Poland-based quantum computing technology developer Beit has secured $1.4m in funding from investors including Bloomberg Beta.

These smaller rounds are more typical for quantum, which is still heavily reliant on government grants and university research. This belies the enormous potential of next-generation quantum technologies, not just in computing but also in materials, sensors and communications –

known collectively as Quantum 2.0.

There is palpable anticipation from industry in drug design, aerospace and data analytics, among other areas, where quantum computing technology could process masses of information.

A general-purpose quantum computer (QC) is potentially decades away, but powerful systems could materialise sooner from "fault-corrected" technology: executing specific tasks by using software to correct imperfect quantum machines.

Universities are set to helm this revolution but the technical challenge means their commercialisation play must be carefully considered.

Quantum leap

It is difficult to comprehend just how tough QC is without outlining the quantum mechanical theory of entanglement, which, essentially, proves two entangled particles will behave in tandem even if they lay distances apart.

Empowered by quantum bits – known as qubits – QC is expected to leverage entanglement and a quantum mechanical state called superposition to probe near-infinite possibilities in situations where today's most powerful supercomputers would stall.

Elaine Loukes, an investment director for physical sciences on the seed funds team at Cambridge Enterprise, the university's tech transfer arm, said: "Even the most powerful classical computers do not have the processing power to model complex physical systems; if you want to get the information in a realistic time period (minutes rather than billions of years), then you will simply not get the accuracy."

Although prototype QCs contain an increasing number of qubits, many orders of magnitude more are needed, with more stability, to reach the objective of fault-tolerant, universal QC technology.

But we are certainly drawing closer. Last month, technology conglomerate Alphabet's Google subsidiary claimed its 53-qubit QC had performed a pure random number generator validity test effectively incalculable by binary supercomputers in just 200 seconds, achieving a landmark known as "quantum supremacy". Google's achievement, while questioned by some peers, is all the more impressive when you remember the complexities involved. QCs function improperly once their qubits have been observed, leaving our computations wholly dependent on estimated probabilities, due to quantum mechanics.

"I always say quantum computing is not for those interested in a fast return with little effort. There are still lots of obstacles to overcome, but the potential is enormous and there has definitely been substantial progress in recent years which is in many aspects staggering," said Marco Palumbo, senior licensing and ventures manager at Oxford University Innovation, the university's tech transfer office. "Ten to 15 years ago I would have told you to forget about quantum computing, but today I see [it] as a very realistic prospect."

"There are very early-stage machines you could use today if you wanted and possibly some hybrid solutions will be out in the medium- to short-term, but a fully-functioning universal quantum computer will, in my opinion, take at least 15 to 20 years – we shall see."

Most prototypes are only fleetingly accurate before their computations begin to deviate – but this can be overcome with hybrid quantum-

classical models, which fuse functioning qubits with emulators of the technology on binary supercomputers.

The early signs for these hybrid QCs are encouraging, with several software-led spinouts in the field having unveiled funding in recent months.

University of Cambridge quantum software spinout Riverlane is confident its algorithms would spare months of manual lab work expended on routine biotech experiments, by optimising scientific investigations of drug-protein interactions and materials.

"A fully-functioning universal quantum computer will, in my opinion, take at least 15 to 20 years – we shall see."

Mario Palumbo

Founded by Steve Brierley, a former Cambridge senior research fellow in applied mathematics, the spinout recently raised a seed round of $4.3m from Cambridge Enterprise, Cambridge Innovation Capital and Amadeus Capital Partners.

"The quantum computers at the moment are between 50 and 100 qubits and that is not enough to run these algorithms; however Riverlane have developed an emulator which can run their software on classical systems demonstrating their quantum algorithms are viable and have demonstrable benefits in computing power and speed," Loukes said. "So, although I think we are probably a decade away from a commercial quantum computer, we are actually developing and validating the Riverlane software and its advantages now."

Harvard University-founded Aliro Technologies is working on a hardware-agnostic software engine that would ease the development path for any hybrid quantum system, making quantum computing much more accessible. The company, which recently raised $2.7m of seed funding from investors including Q Fund – a vehicle owned by consumer electronics producer Samsung's early-stage investment unit Next – was co-founded by Prineha Narang, an assistant professor of computational materials science whose research has won multiple awards.

Other software developers have built algorithms to reduce decoherence in QC machines. University of Sydney's Q-Ctrl is working on these lines, having raised $15m of series A capital in a September 2019 round, described as making Q-Ctrl one of the 10 most successful quantum fundraisers globally. Its algorithms underpin the cloud-based Black Opal platform, a visual interface aiding software builds for noisy QC systems.

Built on a decade's research championed by Michael Biercuk, director of University of Sydney's Quantum Control Laboratory, Q-Ctrl received strong support from Main Sequence Ventures, the VC firm owned by Australian research agency Commonwealth Scientific and Industrial Research Organisation, which backed its seed round in 2017 and series A.

Whatever the solution, quantum computing's inherent intricacies require the finest scientific research, and that makes the availability of patient capital especially important.

CVCs will form part of the answer if academia can make corporate backers congenial to investing, by fielding outstanding business proposals that are perceptive of industry priorities.

Further proof this is possible has come from QC software developer Zapata Computing, a Harvard University spinout. The company's $21m series A earlier this year attracted CVC vehicles from chemicals producer BASF, industrial technology and appliance supplier Robert Bosch and mass media conglomerate Comcast, as well as The Engine, Massachusetts Institute of Technology's tough tech incubator.

Markus Solibieda, managing director of BASF Venture Capital, expects Zapata software will

soon become requires for businesses hoping to glean an advantage across multiple sectors, adding that preliminary QCs could be executing optimisation and machine learning tasks within one- to three years.

BASF has a strategic rationale for its investment: quantum computing's ability to expedite analysing combinations is perhaps one of the most effective routes to digitising its chemical manufacturing operation.

"From my point of view, quantum computing will enable BASF to investigate complex questions more efficiently," Solibieda said. "Furthermore, it will shorten process times, for example, the time it takes to launch very new products."

While the maturation of quantum software is edging forward, there remains the arduous task of finding a method to produce robust QC units.

Achieving scale is a major bottleneck. To function, each qubit needs extensive wiring. Many believe the answer lies in superconducting circuits, which have no resistance when cooled to cryogenic temperatures. Among those pursuing this line of enquiry is SeeQC.EU, a spinout of superconducting systems producer Hypres with roots in the European innovation ecosystem.

Matthew Hutchings, co-founder and chief product officer at SeeQC, said: "SeeQC.EU is essentially creating a digital controller for qubits and quantum computing systems. If you look at the early age of classical computing, it was recognised it would be difficult to scale if every additional bit resulted in an increased number of wires. Removing this bottleneck will enable quantum systems to scale. That is what we believe our superconducting circuits can do for quantum computing."

SeeQC.EU's academic alliances include R&D labs at University of Naples's Monte Sant'Angelo campus dedicated to superconducting quantum technologies, plus foundry partnerships with Royal Holloway University of London and University of Glasgow.

Hutchings said: "Universities are very important. Although we are building a commercial product and cannot rely solely on academic institutions, there are a number of difficult challenges that need to be resolved to build larger and more effective quantum computers.

"This is where academic involvement is highly valuable – if we can build a commercial quantum computer, the question is how we can improve that by taking on board future advancements. We want to be closely aligned with academia as it starts to develop this next-generation technology."

Royal Holloway University of London

Britain's quantum edge

Governments are pouring billions into the quantum revolution, creating frequent opportunities for universities with capacity in the field.

Within the industry, the UK's approach is well-regarded. Its National Quantum Technology Programme (NQTP) has received $1.1bn in government funding since 2013, including up to $402m committed in 2018 and a further $193m announced in June this year.

That foresight has seemingly paid off in terms of dealflow, with more than 30 quantum tech businesses with academic links forged since

NQTP was founded, aided by partnerships which include 26 universities, according to the Financial Times.

The UK now boasts four quantum tech hubs, each pooling researchers and industry to probe Quantum 2.0 use-cases – in sensors and metrology, quantum-enhanced imaging, network quantum information technologies and quantum communications.

Each hub has multiple university participants and is notable for fostering partnerships between institutions rather than rivalries, ultimately bringing more academic quantum research to the fore. There are also plans for a National Quantum Computing Centre to work towards general-purpose quantum computing machines.

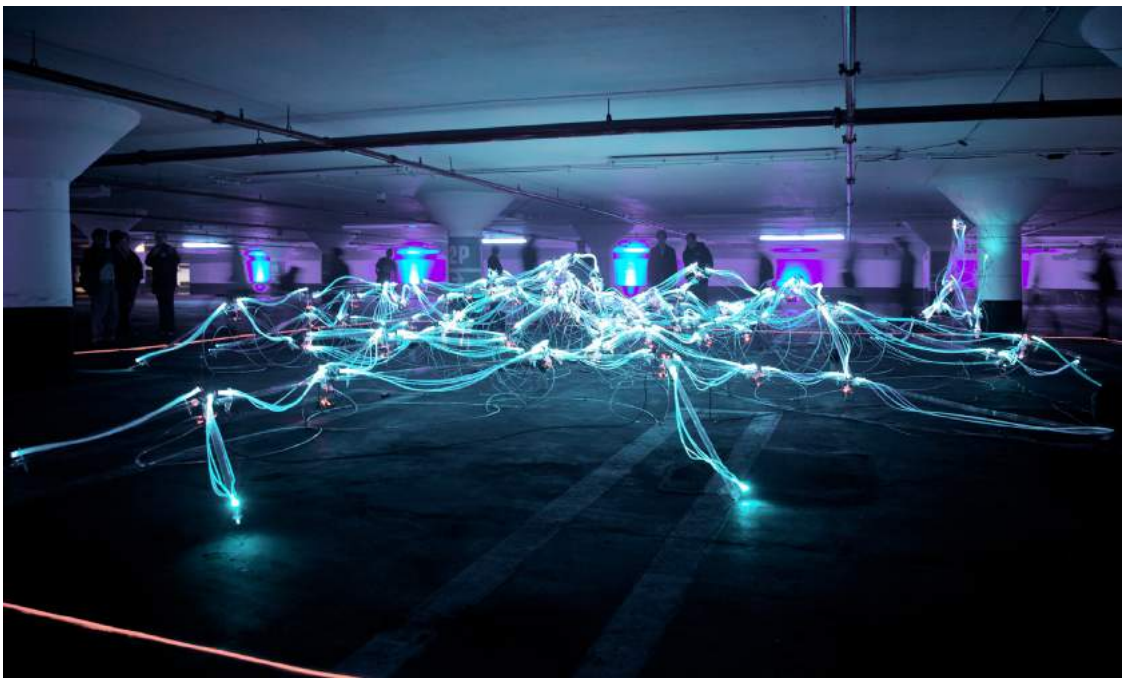
Olivia Nicoletti, commercialisation manager at Cambridge Enterprise, said: "Quantum technology is a nascent industry. It will require collaboration not only within the Cambridge quantum technology scene, which includes spinouts Riverlane and NuQuantum, but also at a national and international level. Universities, investors and corporations will all play significant roles in the growth of this sector. This is an area where Cambridge and the UK have a strong focus and can contribute significantly."

Andrew Collins, enterprise director at University of Bristol's Quantum Technology Enterprise Centre (QTEC), a fellowship-style accelerator formed under the NQTP's systems engineering skills and training remit, affirmed that his program's output dovetailed with the wider national strategy.

"Both as an incubator as an accelerator, we are set up to help the whole of the national program, though it is certainly true that it is Bristol-based and that Bristol has a fantastically strong department, and that makes external partners feel confident when they come here that we know what we are talking about."

There are very few quantum business programs as sophisticated as QTEC, which has blazed a trail for the UK's grassroots innovation. Geared towards postdoctoral scientists, the program provides business coaching and help to validate their concepts over a year-long curriculum.

Some complete the program concurrently with their PhD, but the principal objective is enticing more scientists out from the lab to found quantum businesses, by equipping them with vital expertise. Now in its third cohort, QTEC has incubated 17 companies to date.



GUV attended the incubator's recent investor day to witness its latest graduates pitch for cheques between $123,500 and above $1.2m. Its grant budget is enough to support another batch and its remit is increasingly moving beyond quantum to support a wider range of deep technologies.

University of Bristol's reputation has certainly benefited, which has led to further government funding, with about £35m ($43.1m) in active grants available to the institution at present for quantum-related projects.

It is now rolling out a new 3,500 square metre Quantum Technology Innovation Centre (QTIC) providing pay-as-you-go facilities and access to a diverse cast of quantum tech and business support to developers that may have outgrown formal tech transfer assistance, of particular relevance to quantum startups facing considerable facilities expenses and skills shortages.

Mustafa Rampuri, a senior program manager for research and innovation at University of Bristol, said: "The market failure we see is that it is very expensive to translate new technologies emerging from research through to a commercial product. So, the centre will seek to provide access to facilities, equipment and technical support so these new businesses can rapidly get off the ground in an affordable way."

"One of the challenges we have seen is the difficulty raising VC investment for the high-risk quantum startups that are hardware-based. So, this is a way of helping derisk the companies so they are not burdened with the sunk costs of acquiring expensive equipment, they can hire equipment as part of the QTIC package."

With its collaborative spirit, the NQTP is yielding yet more quantum spinouts. University of Cambridge's recent pipeline includes photon detector spinout and QTEC graduate NuQuantum, which successfully pitched for $840,000 at the aforementioned investor's day, having already raised pre-seed funding.

Carmen Palacios-Berraquero, chief executive of NuQuantum, said: "This is a cutting-edge research environment in which we have developed our intellectual property for a number of years, and so we have no doubt benefited from it, from the different UK and European funding arrangements and quantum partnerships. Cambridge is probably one of the best places in the UK and Europe for startups – not only because of the university but the whole environment."

University of Oxford's ecosystem is also well-equipped, Palumbo said, providing a "full repertoire" of tools for building quantum-driven products, though he noted the university's strengths lay especially in hardware development

"The market failure we see is that it is very expensive to translate new technologies emerging from research through to a commercial product"

Mustafa Rampuri

He added: "If you can name a qubit architecture, we probably have someone in a lab somewhere working on it.

"The theoretical aspect and understanding of quantum computing is also well developed. Oxford is possibly less strong in quantum computing software development, but I see some interesting collaboration developing on that front as well."

"[The strength of the regional ecosystem] is important, obviously, or it would all stay on a drawing board or a PowerPoint presentation. You cannot improvise yourself as a leading centre for quantum technologies from one day to another. It takes years, lots of clever people and money."

Cybersecurity

NuQuantum is focused on Quantum 2.0's most pressing ethical dilemma: effectively protecting communications during the quantum age.

University of Oxford

Classical encryption will be compromised when fault-tolerant quantum machines become available, rendered useless by advanced algorithms which expediently crack cyphers, jeopardising critical information.

Palacios-Berraquero noted one of the keys to robust security, and indeed any quantum hardware, laid in accurately sourcing and detecting single-photon states to send down communication channels. That way, due to quantum mechanics, an indelible mark will result from any interference.

NuQuantum expects its single-photon detectors to remain operational at room temperature, Palacios-Berraquero said, a key contrast with quantum technologies that rely on expensive, cryogenic cooling.

While that could put a number of applications in the frame – the company recognises an opportunity in delivering low-light imagery for autonomous vehicles, for instance – the urgent need in cybersecurity makes a particularly compelling use-case.

"Once you have a universal quantum computer, or perhaps an intermediate machine some way towards it, data stolen years or decades ago may be decrypted in a reasonable amount of time," Palacios-Berraquero said. "Quantum cryptography is the solution because the security of the data does not rely on mathematics or computational power. It relies on how you share the secret key, how you send it from one party to the other, giving both parties a secret channel within which they can communicate. Crucially, none of that relies on a mathematical calculation."

University of Bristol's Kets Quantum Security has also taken a hardware-led approach, though its director of operations Caroline Clark indicated the eventual goal might leverage a combination of hardware and software to create complete, quantum-secured products.

Founded in 2016 by four members of the university's Quantum Engineering Technology Labs, the company ultimately wants to fit its technology on to a single chip, using materials such as silicon that can be fabricated at existing plants. Kets already has functional prototypes of its products and now aims to minimise their form factor, with the support of industry partners which include telecoms firm BT and aerospace firm Airbus.

Clark said: "The chips are about the size of your little fingernail. They are similar to the electronic chips in your phone – they are made with the same kind of technology in silicon foundries – but instead of electronics running around in them, it is light. You generate light into one side which then travels through the chip in special circuits that establish the quantum states, outputting ones and zeroes in the form of encrypted photons.

"We have probably got it down to two or three circuit boards that control the technology now, but the next level would be to reduce that to one board which looks like a graphic card. The card could be plugged into the computer with an optical fibre connection, just like broadband, to exchange the security keys between the two parties."

Partnerships

Despite academia's strong record in quantum research, Hutchings predicted licencing arrangements would be preferred to equity spinouts for many new inventions.

Tech transfer offices less versed in flexible IP and equity policies risk deterring follow-on investors by exacerbating risk spelling trouble for QC spinouts with tough go-to-market trajectories.

"Academia is a source of excellence and intelligence – that is also their role in quantum,

providing good, new ideas, but I think they are more likely to benefit from that through licensing of IP rather than creating spinouts. Though licensing IP comes with its own challenges," Hutchings said. "From a European perspective, I think a couple of things could be tweaked to make it easier for companies to exploit IP and, if they want spinouts, it must be easier for a business to be spun out of their home university."

Tie in the concerted government interest and this feels like fertile ground for industry-academia partnerships that push the paradigm forward while exposing academic talent to relevant market resources and acumen.

Take the QuTech quantum research hub, a public-private partnership incorporating TU Delft, research body Netherlands Organisation for Applied Scientific Research and industry affiliates including chipset maker Intel and software publisher Microsoft. Projected to double in headcount over coming years, QuTech gives industry access to frontier research from academic investigators in areas including topological qubits, a purely hypothetical approach that, if realised, would yield massive performance advances.

Monika Lischke, communications manager at Intel, said QuTech and similar partnerships augmented Intel's expertise as it looked to devise viable quantum computing systems.

While QuTech and others keep Intel abreast of deep quantum research, scientists can access its quantum systems over the cloud, where they will act as co-processors, Lischke said.

"Keep in mind, it is going to take a massive amount of computing power to design, model, build and operate these systems," she said. "Joint research being conducted with QuTech and others builds upward from quantum devices to include mechanisms such as error correction, hardware- and software-based control mechanisms, and approaches and tools for developing quantum applications.

"Our roots in process technology engineering put us in a unique position to help advance quantum computing toward true commercialisation. We also believe we have the best academic partners in QuTech and other quantum computing researchers around the world."

Itaru Kobayashi, from the media relations team at electronics manufacturer Toshiba, confirmed academia was instrumental to its future R&D plans.

Toshiba launched the UK's first "quantum-secured" communications with University of Cambridge, within reach of its Cambridge Research Laboratory. In its home market, the corporate has aligned with University of Tokyo to develop machines that rely on quantum behaviour visible to the naked eye, a discipline known as macroscopic quantum science.

Elsewhere, technology firm IBM is collaborating with more than 75 organisations in its IBM Q Network ecosystems, which also includes academic institutions, industry partners, startups and government-funded research labs.

In September, the company said it was joining forces with Germany-based research institute Fraunhofer to explore the potential of QCs, backed by a government plan to invest €650m ($717m) over two years in wider research in the field.

Joining Q Network provides cloud-based access to IBM's commercial quantum systems, expertise and resources, and the corporation believes embracing co-operation on a deep level is pivotal to delivering applications with significant, practical benefits beyond the capabilities of classical computers alone, according to Robert Loredo, Watson-in-Support product lead at IBM and an ambassador for the Q Network.

Loredo said: "It is a bit like if everyone in the 1950s had five to 10 years to prepare for the mainframe while they were still prototypes. Applications with a 'quantum advantage' are still a few years away, but now is the time to get 'quantum ready' and begin exploring what we can do with quantum computers across a variety of potential applications and industries."

"It is a bit like if everyone in the 1950s had five to 10 years to prepare for the mainframe while they were still prototypes."

Robert Loredo

University of Colorado Boulder was added to IBM Q Network in April 2019, months after the launch of its CUbit Quantum Initiative linking internal university R&D with other schools and national quantum labs.

Stephen ONeil, the initiative's executive director, was confident of the university making headway, having created CUbit as an entry point for quantum research that includes a partnership with the US National Institute of Standards and Technology.

He said: "If it is not currently feasible to do drug design, general computing or high-volume secure communications by quantum technologies, that does not mean we stop and wait. In both university labs and corporate research departments, scientists and engineers are always pushing the edges even, and especially, when those edges are far from an idealised end goal.

"To scale up substantially, we need to identify new, or refine old, qubit platforms (trapped atoms or ions, and so on) that are easily partnered in large numbers, are reliably set and quantum mechanically entangled and, once entangled, are stable against random degradation from their siblings and the environment at economically achievable low temperatures [...]

"So, we need advances in materials, integrated photonics, low-temperature technologies and, in fits and starts, we need to learn a lot about how to skirt the barriers that nature uses to hide her interesting secrets."

Quantum 2.0

Quantum computing should not overshadow the rest of Quantum 2.0. Research is taking place in quantum metrology, materials and communications, each with its own goals and hurdles, and each with potential long-term impact comparable to that of quantum computing.

"To neglect the other two, or three, components in the quantum revolution is to potentially miss technological advances of equal significance," ONeil said.

Quantum-based technologies have a slate of non-QC applications. For example, health diagnostic tools with quantum-grade fidelity could put the industry on the radar of healthcare CVCs, which have historically focused on their own space.

Reducing antimicrobial resistance (AMR) is one potentially lucrative use-case. Spawned from University of Bristol and the QTEC incubator,

Fluoretiq is working on quantum sensors that apply individual fluorescent photons to physiological samples to identify specific species of bacteria.

The technology would provide rapid and accurate diagnosis of bacterial infections within 15 minutes, helping clinicians select effective antibiotics at the earliest opportunity.

Neciah Dorh, co-founder and chief executive of Fluoretiq, said: "The company is exploring strategic partnerships to further develop the application space and launch into the global in-vitro diagnostics market. We are currently targeting urinary tract infections with ambitions to address AMR in a growing patient population that regularly receive ineffective or unnecessarily prescribed antibiotics. Industry partnerships are especially important to our roadmap, as we see collaboration as a means of getting access to the marketplace and strengthening our proposition.

"The connection to University of Bristol has been tremendously useful – we got our start within QTEC, enjoy a great working relationship with the university's tech transfer office, RED, and we continue to collaborate with several other labs within University of Bristol."

Others focused on quantum sensors include University of Oxford-founded Oxford HighQ, which is building nanoparticle analysers capable of gauging the wavelength shift of samples rather than their attenuation.

HighQ's sensors trap light in micrometre-sized optical recesses to force operation on the relevant optical wavelength, facilitating target applications including nanoparticle and chemical characterisation.

Government

All this innovation is accentuated by the fact no major economy wants to lose out in the quantum revolution.

China has upped the ante with plans for a huge quantum laboratory in Hefei, a move no doubt occupying in the minds of US policymakers when they authorised an extra $1.2bn in funding over five years in 2018. In an influential paper last year for the Center for a New American Security and picked up by cable news service CNN, authors Elsa Kania and John Costello wrote that "China is positioning itself as a powerhouse in quantum science.

"At the highest levels, China's leaders recognise the strategic potential of quantum science and technology to enhance economic and military dimensions of national power.

"These quantum ambitions are intertwined with China's national strategic objective to become a science and technology superpower."

Its leading institution in this field is the University of Science and Technology of China (USTC), based in Hefei near Shanghai. Chinese President Xi Jinping visited USTC in 2016, where he met with Pan Jianwei, the schools' vice president and China's "father of quantum".

Meanwhile, a golden opportunity has arguably arisen for Europe from the research carried out by Pan and others.

See-QC's Hutchings said "fantastic" scope for European quantum developers potentially lay in a number of niche markets, adding: "The US is not that far ahead – we are some way from a commercially-useful quantum computer – so Europe has room to make a big impact.

"This might be in specific niches and certain areas. For example, Europe could take a stand in the quality fabrication of qubits – they already have fantastic foundry services. If there is a push towards foundry services for superconducting quantum technology, then the EU could play a valuable role with even US companies having to come to Europe to access the manufacturing of good quality qubits."

However, he cautioned more central funds would be needed for the EU to truly "take hold" of the technology and convince more risk-averse partners to the table.

"They have already invested a lot, but it is going to need a lot more. We know there is a pull [for industry] from the companies with interest and for whom quantum may disrupt business, but we want to see government support to work with industry to de-risk their involvement in these highly-disruptive, high-risk technologies."

With relations between China and the US at a low – and cybersecurity has played its role – it is tempting to present the quantum race in a Cold War narrative.

But there may be enough room for all to benefit. In the Financial Times recently, Imperial College London's provost of experimental physics, Ian Walmsley, predicted the UK's strengths in quantum computing would be enriched by the "global nature of science and innovation," as ideas are exchanged by scientists moving across borders.

Quantum is no zero-sum game, Walmsley said. With China, the US and Germany among others now competing in earnest, the invention of commercially viable quantum systems may come sooner than anticipated – changing the paradigm for good.

"At the highest levels, China's leaders recognise the strategic potential of quantum science and technology to enhance economic and military dimensions of national power"

Elsa Kania and John Costello

The road ahead

The quantum age might be on the horizon but there are precious few shortcuts to market, and academia will be crucial to its maturation given the onerous scientific and engineering requirements.

A virtuous loop of government funding potentially awaits institutions with reputed quantum centres, enabling them to take on additional projects and join forces with global industry names to establish a foothold in the space.

A broad spectrum of quantum-powered technologies is set for impact in the medium-term, bolstering the health of the overall ecosystem. In terms of quantum computing, spinouts are becoming more viable with the validation of hybrid quantum computing products and an environment that fosters cooperation.

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