

THE FOUNDATION OF REVOLUTIONS



The authors



Patrick Sheehan

T +44 (0)20 7318 0718

M +44 (0) 7789 393 041

E patrick@etfpartners.capital



Arne Morteani

T +44 (0)20 7318 0705

M +44 (0) 7930 930 232

E arne@etfpartners.capital

Contents



Introduction



New processes



Segmenting the sector



A revolution is happening



Business models



Growth capital for Materials



Conclusion



Introduction



Patrick Sheehan

“These days, if you talk about ‘material’, people assume you mean something written – perhaps a play or a script – something intangible.”

In many cities these days, if you talk about ‘material’, people might assume you are talking about something written – perhaps a play or a script – something intangible. But matter; substance; stuff; it makes up everything. This utter ubiquity means, perversely, that we tend not to think about the role of materials in our lives. The fundamental impact of new materials technologies tends to get overlooked.

What material comes to mind when you read “tyres”? You almost certainly answered “rubber”. For “glass” you might think “sand”. But if you read “computer”, do you think of materials at all?

Have you ever thought of information technology as being, at heart, based on a materials revolution? Innovation in processing small bits of just one material, silicon, has changed our lives by enabling what we think of as the ‘tech’ revolution. Should we think of this as unique – a ‘one-off’ – or as an illustration of the potential that lies before us, with innovation across the spectrum of physical materials? In fact, the answer is already clear: The more recent ‘mobile tech’ revolution also rests on a rapid change in materials technology; lithium-ion batteries. A technology that is now also set to revolutionise the electricity generation and distribution sector – making ‘alternative energy’ economically storable and therefore far more commercially viable.

The huge impact of materials innovation hides in plain sight. Sometimes we can’t see the wood for the trees.

The mid-twentieth century was perhaps a golden age for chemicals companies and materials innovation was far more visible then. More recently, the latest generation of tech giants have built their businesses from algorithms and marketing services – from intangibles – and people could be forgiven for thinking that the baton of innovation has been passed on.

“Materials revolutions are quite rare, but when they do happen, their effect is huge”

Venture capitalists have followed suit by shunning the physical in favour of software and the internet, of course. Perhaps as a result we are still waiting for the hoverboards that the cult film *Back to the Future II* predicted we would have in 2015 – and all we now seem able to do is tweet about them.

So what has happened to those industries outside the ‘tech’ sector? It turns out that quite a lot of them have been successfully innovating anyway, although the innovations have tended to be of a more gradual type that aid rather than challenge large incumbent companies. Innovation in materials has tended to fall into this ‘incremental’ type. ‘Disruptive’ materials innovation – or materials revolutions – have been relatively rare. When they do happen though, their effect can be huge. Think of plastics, silicon, and lithium-ion. Speculate on graphene?

In our view, we are beginning to see more disruptive innovation in materials again. There are two main reasons for this. Firstly, the internet has recently greatly accelerated knowledge exchange and collaboration (so ironically, the intangible ‘tech’ revolution is creating new materials revolutions). Secondly, at least from our perspective, the pressing problems we see of an unsustainable world are leading to a new wave of innovation and change – and these changes could be radical.

At ETF Partners we look for ‘sustainability through innovation’, and through this lens we see potential that would otherwise be obscure. The challenge, when looking at promising materials innovation, can often be an embarrassment of riches, or rather, of potential applications. Our approach leads us quickly to applications that play into the changes already happening across different industries. If you know where to look, there are many billion dollar ‘niches’ in materials. This document aims to give some insight into how we look at the materials sector, and how we find tantalising opportunities that others miss.



Patrick Sheehan, Managing Partner

Speed read

- The market for Materials innovation is huge and often overlooked by investors. For instance, the metals industry alone is larger than the entire IT industry, and has many billion dollar 'niches'.
- The potential of new processes that involve everyday materials can be particularly difficult to spot. But the disruptive effects of companies that can, for instance, cost-effectively turn soft wood hard, or make leather lighter, tougher, stronger, are manifold.
- New materials revolutions are underway. From new composites to additive manufacturing or so-called 'smart' materials. There is real demand for this wave of innovations, often driven by sustainability requirements.



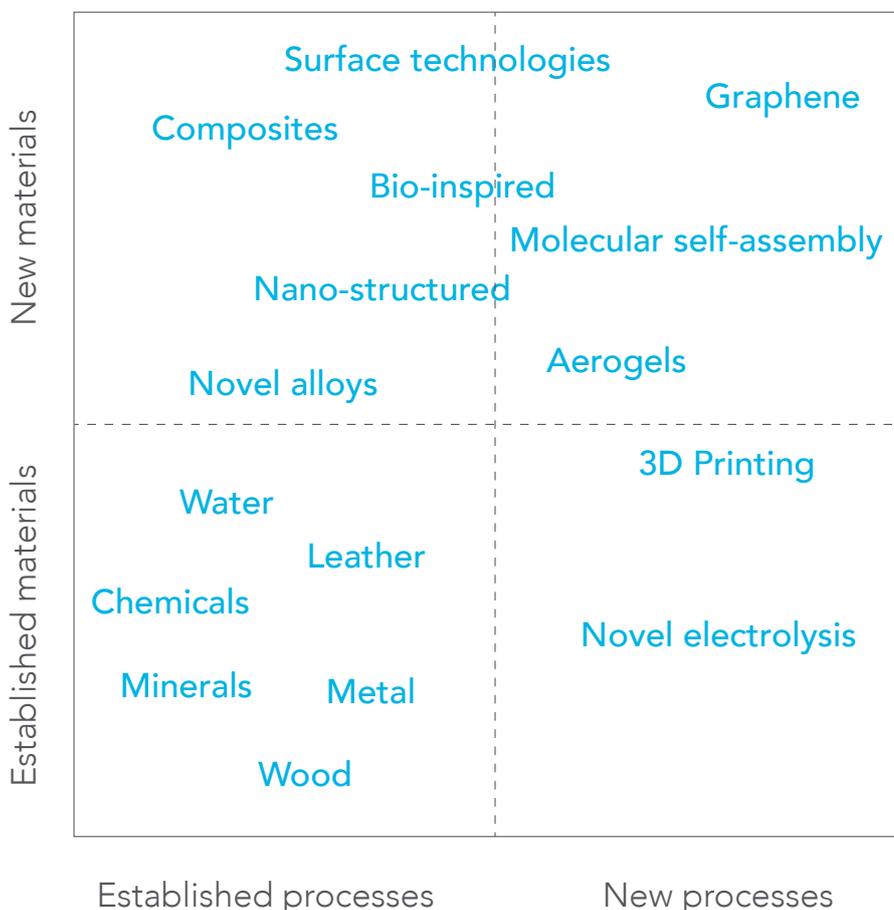
- Innovative materials companies can be based on highly-protected intellectual property - not just patents but also 'know-how'. This can give some materials companies not only high growth, but *durably* high growth.
- Making the jump from a necessarily science-based organisation to a commercial business can require a supportive partner with capital. Retaining corporate independence during this period can be the difference between a positive outcome and runaway success.
- Most venture capitalists tend to favour intangible software and services business. ETF sees great value in the tangible, and has invested in the knowledge and networks to support materials innovators and entrepreneurs.

Materials: segmenting the market

Innovation in the Materials sector tends to resist neat segmentation. Broadly speaking, though, one can divide innovation in the Materials world into new materials (which would include areas such as surface technology, composites, bio-inspired or nano-structured materials, or graphene), and new processes (such as additive manufacturing, also known as '3d printing'.)

Of course, the discovery of fundamentally new materials is rare. From an application perspective, though, there are a whole range of innovations around the structure of materials that make the result, in effect, 'new'. In both cases the impact can be large - potentially reinventing whole industries.

It can be a struggle to find an early market for a very novel material, just because it is so different. This struggle, and the related challenges of testing and often adjusting material properties, can take a lot of time. In contrast, it tends to be less of a challenge to focus on using a new process to produce an established material. The market is then well known and less imagination is required from potential customers.



New processes

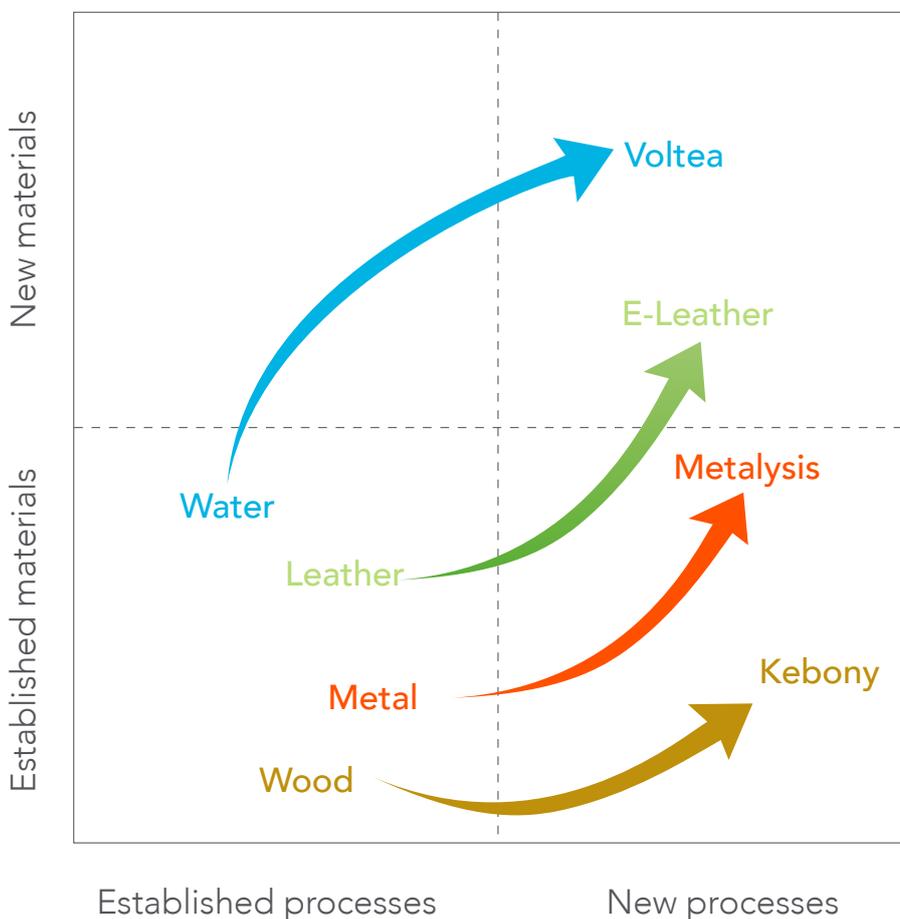
The advent of the Iron Age was the result of one such materials process innovation. The most abundant metal on the earth's surface only became useful after man learned to smelt it in very hot furnaces and whack it hard while still hot.

A more recent example is that of aluminium, which was once more expensive than gold. Again, it is a very common element but rarely occurs in its pure form and its extraction from ores is very tricky. The story goes that, when Napoleon entertained the King of Siam, his soldiers ate from silverware and Napoleon ate from gold. But his honoured guest was given an aluminium plate. It was the discovery and development of aluminium extraction by electrolysis that turned the world's most precious metal into an inexpensive commodity.

And today we are living through the information technology revolution that has, so far, been driven by innovation in processing silicon.

Gordon Moore, a founder of Intel famously observed that the processing power of computers doubles every two years. This is based on improvements in processing silicon, which can't go on forever. In fact Intel's own chief of manufacturing said in February that Intel needs to switch from silicon in about four years, and "the new technology will be fundamentally different."

A new revolution in IT would be the adoption of a completely new material or of using 'material' completely differently - areas such as optical, biological, or quantum computing. Any of these would breach a new frontier in IT rather than an iterative improvement.



But we said that there are many other billion dollar ‘niches’ in materials, that are often overlooked by venture capitalists.

The metals industry for example is larger, on its own, than the whole IT sector. Take Metalysis, which has a highly innovative and green electrolytic process that can produce metal and alloy powders across a range of elements in the periodic table. Our involvement has helped Metalysis to strategically focus on titanium initially, because we believe that titanium will transform the 3D printing revolution and really will change the world.

There are also huge opportunities with new processes that use everyday materials, such as wood or leather. This may not sound sexy until you understand how sustainability drives the potential of such innovations.

Kebony, a Norwegian company, changes the molecular structure of soft wood to make it hard. With the ability to easily ‘make hardwood’ with similar properties to teak or mahogany, it is not difficult to imagine a prohibition on the use of unsustainable tropical woods, saving rain forests and transforming a \$20+ billion per year¹ market.

Or take E-Leather, a British company that makes leather from tannery waste. It can engineer its leather to the customer’s wishes, making it lighter, more durable, fire retardant, and so on. Leather is one of the most widely traded commodities in the world, with an estimated annual traded value of US\$100 billion².

There is decreasing availability of land for cattle and the grains that feed them, and demand keeps rising. So, the opportunities for those that can provide a product from sustainable resources, and even improve its performance while doing so, are apparent.

Metalysis, Kebony, and E-Leather all took the approach of focusing on new processes for existing materials. At least, that is where they started. Metalysis is now finding ‘new materials’ applications by experimenting with new alloys and special 3D printing applications. E-Leather’s value proposition has moved far beyond simple recycling, making it compete successfully with a range of synthetic high-performance fabrics.

Sometimes new materials are invented but are not actually sold as a material. Instead they are used to enable a new process. Take Netherlands-based Voltea, which sells novel products that desalinate water. It can do this because of its materials innovation. Its breakthrough in surface and membrane technology has enabled a decade-old dream: to replace the heavy ‘reverse osmosis’ desalination systems (essentially high-pressure filtration) with much more elegant electrolytic desalination technology. Voltea effectively ‘sucks’ salt out of water using coated electrodes and electricity. The output is the same - desalinated water - but produced at a fraction of both capital and operational cost. Its modular device could soon be found even in a common coffee machine, finally enabling truly sustainable coffee to keep other inventors going!

1. [ftp://ftp.fao.org/docrep/fao/011/i0350e/i0350e02a.pdf](http://ftp.fao.org/docrep/fao/011/i0350e/i0350e02a.pdf), p64

2. Future Trends in the World Leather and Leather Products Industry and Trade, UN Industrial Development Organisation, 2010

Smart Industry Innovator



The business: Voltea | **Materials app:** Water

HQ: The Netherlands

It’s a problem as old as the hills. How to purify salt water. A Dutch company, Voltea, has developed a technology that effectively ‘sucks’ salt out of water using coated electrodes and electricity. The process, called capacitive deionization, desalinates brackish water at a lower economic and environmental cost than any other available technology.

Voltea equipment improves operational performance and lifetime of a wide range of industrial equipment as well as commercial and domestic appliances.

A materials revolution is happening

“Infinite growth of material consumption in a finite world is an impossibility.” *E. F. Schumacher*

Today, we are seeing a wave of materials innovation across many industrial sectors. One reason for this upsurge in innovation is the internet, which has facilitated an unprecedented transfer of knowledge over the past 15 years and allowed for cross-fertilisation between disciplines, a dynamic that so often underlies great materials innovations.

Another is that the need for a more sustainable world provides the demand for new materials innovations. We have invested in companies such as Kebony and E-Leather, not because they fit the classic venture capital/ start-up mould, or because they were on the investment ‘circuit’, but because their innovations respond to a real need that is backed by palpable demand – a demand to be more efficient and more sustainable. Sometimes one innovation, such as electrification of transport, creates a pressing and obvious need for others, such as improvements in battery technologies and the much-anticipated

increase in demand for lithium-ion batteries for vehicles. It now seems apparent that the rate of improvement of batteries is what is setting the pace of a revolution in transportation.

The need for sustainability is also creating some entirely new industries. Solar is perhaps the most obvious. Here, relatively unprotected IP around silicon solar cells has meant that the materials innovation has fed through to a dramatic fall in costs. But this is just the beginning. Much more profound solar innovations based on organic and nano materials, coupled with advances in battery technology, are likely to make solar the energy source of choice for most future applications. These advances in materials science will therefore change the entire energy industry and so could be one of the more profound technology revolutions of the 21st century.

Composites is another exciting area, capable of producing new materials that are cheaper, lighter, more ‘customisable’ and take less energy to produce. In the automotive industry, for instance, the hunt is on for a cost-effective process to create composites that will take weight out of cars, to help comply with emissions regulations.

Smart Industry Innovator



The business: E-Leather | **Materials app:** Leather

HQ: Peterborough, UK

E-Leather is the only manufacturer of high-tech composite leather in the world. Its process for manufacturing leather made from re-woven leather fibres extracted from tannery waste, is not just hugely sustainable. The material looks and feels like traditional leather and yet is more durable and lighter, and can be easily adapted to suit individual customers’ needs.

E-Leather is a game changer in both sustainability terms, as land for cattle grazing becomes more constrained, and in quality terms, as automotive, aviation, transport industries become ever more demanding as to the qualities, attributes and sustainability credentials of their components.

Additive Manufacturing – beyond niche



Howard in the Big Bang Theory sitcom prints an action figure of himself

In December 2014, NASA emailed a ratcheting socket wrench to the International Space Station. It was then printed using a 3D printer. Now that really is bringing science fiction to life.

At present, additive manufacturing has something of a niche reputation. However, such “3D printing” will not just be the reserve of astronauts or nerds.

The more properly called ‘additive manufacturing market’ was worth an estimated \$52 billion in 2016³ and analysts predict it will grow at least four-fold over the next decade. 3D printing is now mainly used for rapid prototyping, but conquering the slow speed and expense of the process will have a transformative effect on many industries. Boeing and Airbus both use printed parts on production aircraft already.

The sustainability benefits of ‘additive manufacturing’ are implied in the name. Most manufacturing in metals is ‘subtractive’. Parts are made by cutting out of a solid block of metal, for example, creating a lot of waste. In Titanium manufacturing for the aerospace industry typically 90% of the expensive titanium purchased is thrown away. This is so expensive that the industry has its own such terminology for the problem, called the “buy to fly ratio”. With the additive manufacturing processes developed by Metalysis, titanium alloy components can be created with just 1% wastage, while reducing the cost of refining titanium in the first place by more than half.

Titanium (as an oxide) is the ninth most abundant metal in the earth’s crust. The parallels to aluminium’s past, meteoric rise in use is clear.

The dexterous nature of additive manufacturing is likely to be a major catalyst for demand. For instance, talking to Computer Weekly, Paul Doe, chief designer at Prodrive says of the automotive industry, “We’re able to build shapes that you can’t mould cast or forge – pieces you can’t make in any other way but through additive manufacturing.”

With so much materials innovation that is touching real demand or very close to it, this is an exciting time for a growth capital investor such as ETF Partners. But it’s also good to know there is a strong pipeline of nascent materials research that suggests all this is very much the beginning.



For instance, research being undertaken on behalf of BAE Systems at Glasgow University takes 3D printing several steps further. Their nascent idea is to create a ‘Chemputer’ that speeds up chemical reactions at a molecular level, and the concept is to ‘grow’ drone aircraft in vats. This appears to break the Terminator 2 rule that shapeshifting polyalloy cyborgs can morph into knives and stabbing weapons but not complex machines with chemicals in them. However, this futuristic concept was unveiled at this year’s Farnborough International Airshow. Clearly fact can be stranger than fiction. But we tend to focus on opportunities that are just around the corner, where we can add real value...

3. Wohlers Associates

Materials businesses can be exceptional

Most investors favour intangibles, and for good reason. Companies that actually make tangible things face challenges. In contrast to software (where early customers are perhaps more forgiving and where versions can be improved remotely over time), tangible things have to work first time, out of the box - customers expect reliability, especially in brand name products. The businesses require more physical assets and can be relatively capital intensive, as well as having more constrained ability to scale. Alongside traditional manufacturers of products, innovative materials companies can also face these challenges and are therefore largely overlooked by traditional venture capitalists.

But we have found that a number of innovative materials companies can have very attractive business models indeed - based on highly-protected intellectual property. As a result, a better proxy than 'manufacturing' is the pharmaceutical industry - an industry where innovation creates huge opportunity for high-margin value creation. The difference is that a

successful materials innovator rarely faces the cliff of patent expiry that a pharmaceutical company does, as the knowledge required to make something new with materials is very difficult to copy. This can give some materials companies not just high growth, but *durably* high growth. This is something that investors have tended to under-value but large corporations recognise. As a result, such companies can have a very high strategic value early in their lives.

The challenge for such businesses is often not just to find an application but to build a focused business strategy upon these platform technologies. With a new material it can sometimes seem like you can do virtually anything. But at a certain point the science-driven approach of materials organisations must be complemented with a commercial outlook. This can be a challenging time for management and the best companies will be faced with an array of partners looking to support their expansion. However, retaining corporate independence at this critical commercialisation stage is the difference between a net positive outcome and runaway success.

Smart Industry Innovator



The business: Metalysis | **Materials app:** Titanium alloy

HQ: South Yorkshire, UK

The huge global industry of metal refining is expensive and highly polluting. Metalysis has mastered a breakthrough technology that offers large economic and environmental benefits. Metalysis is a remarkable company with an extraordinary capability: of transforming the industrial potential of one of the planet's most prized elements. Metalysis processes are highly efficient, drastically reducing historic wastage and reducing costs.

ETF Partners led the first institutional funding for Metalysis, back in 2007. Today, the business focuses on the production of titanium powder to enable the additive manufacturing revolution. Most recently it raised £20m of development capital from a consortium including Woodford Patient Capital Trust.

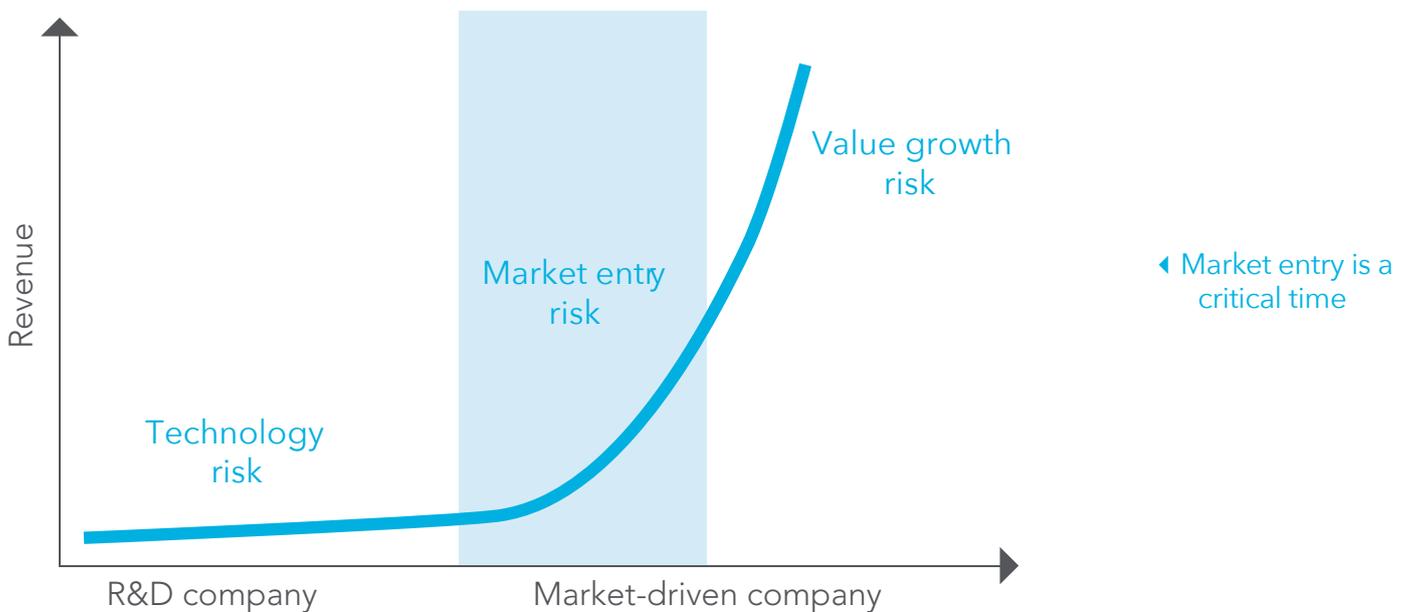
Growth capital for Materials

This is where we come in. The discipline of venture and growth capital helps to clarify and focus, while our sustainability lens helps to identify specific market needs, bridging the gap from a predominantly R&D organisation with some early revenue to a fully commercial business.

Venture and growth capitalists typically run market risk not technology risk and so we are quite specific about the point at which we will invest. This means we may even get to know a materials company, and the people running it, a long time before an

investment is appropriate. (For instance, we knew Metalysis, E-Leather and Voltea for several years before we invested).

Once we have invested, our focus is, among other things on helping teams build out their companies' networks through our own contacts of technology executives and global corporations. Materials is a global industry and companies must be global to succeed. With an international team, we invest across Europe and our network spans the world.



Smart Industry Innovator



The business: Kebody | **Materials app:** Wood | **HQ:** Norway

What if, instead of clearcutting virgin forest for slow growing hard wood, such timber could be created from fast-growing sustainable sources. Kebody's revolutionary process changes the molecular structure of wood, transforming sustainable soft woods into hard wood, by both appearance and quality.

The availability of Kebody's proprietary technology is set to have a transformative effect on demand for irreplaceable tropical hard wood. ETF led the company's first international funding round in 2009 and has supported the business as it has raised further funds to finance its exceptional growth. Recognised as a Technology Pioneer by the World Economic Forum and listed as a Global Cleantech 100 firm, Kebody is used by leading architects and developers across the world.

Conclusion

“Man never
made any
material as
resilient as the
human spirit.”

Bernard Williams

The narrative of innovation in our lifetimes has been towards the intangible, and this to a large extent is what we have come to anticipate as consumers and as investors. The lure of the virtual is surely mesmerising – just ask any Pokemon Go player, staggering around a reality-augmented park.

But as sustainability-focused, commercially-minded investors, we choose to take the red pill⁴, and what we see is amazing. Small companies with the ability to transform billion dollar industries. Innovations that will do for titanium, wood, leather, water – and many other materials – what aluminium refining did for bauxite and what the furnace did for iron ore.

That is why we direct much of our energy at developing the knowledge and networks that can support materials innovators and entrepreneurs. The promise they hold is of a truly prosperous and sustainable future.

4. https://en.wikipedia.org/wiki/Red_pill_and_blue_pill

About Investor Briefings

Our 'Investor Briefings' series covers major industrial trends and innovation-related themes from the perspective of ETF Partners – with a focus on ideas that could transform the sustainability of human activity and in so doing, provide large investment returns. For more information or suggestions, contact info@etfpartners.capital

About ETF Partners

ETF Partners supports talented entrepreneurs and management teams with investment capital and experience. Our funds come from institutional investors, global corporations and family offices. We create value by investing in technology companies that make a difference. We call it '*sustainability through innovation*'. For more information about us or our portfolio companies, visit www.etfpartners.capital

Contact us

20 Berkeley Square,
London W1J 6EQ (UK)
info@etfpartners.capital

WE ARE *THE ENVIRONMENTAL TECHNOLOGIES FUND*.



Sustainability through Innovation

ETF Partners

20 Berkeley Square, London W1J 6EQ (UK)
info@etfpartners.capital www.etfpartners.capital