**Earlier this year Mark Jacobson, who's director of the Atmosphere Energy Program and Professor of Civil and Environmental Engineering at Stanford University, published this remarkably comprehensive work called 100% Clean Renewable Energy and Storage for Everything. One of the crucial aspects of the green transition that this book covers is the need to properly understand the full range of energy requirements, water use, potential pollutants and greenhouse gas emissions from any new technology versus any existing technology. That's an entire field of expertise in its own right known as Life Cycle Assessment, and one of the leading exponents is a company called Minviro founded in 2018 by Dr Robert Pell. I caught up with Rob recently via zoom of course to find out more about life cycle assessment and the hidden energy and emissions costs that consultancies like his are beginning to uncover, and I have to say it was an extremely enlightening conversation.**

**Hello and Welcome to Just Have a Think. According to this 2020 analysis by the World Bank the production of minerals like graphite lithium and cobalt could increase by nearly 500%**

**by 2050 to meet the growing demand for clean energy technologies, with over 3 billion tons of minerals and metals needed to deploy wind solar and geothermal power plus the energy storage to go with them. But the World Bank also found that even though clean energy technologies will require more minerals, the carbon footprint of their production from extraction to end use will account for only six percent of the greenhouse gas emissions generated by fossil fuel.**

**So how can we make sure that this claim is accurate and that we really are on the right path? Well that's precisely where life cycle assessment experts like Minviro will play a vital role in our energy future. Rob Pell explained that it's a very data intensive process and started by providing an overview of what his work involves. The reason why I originally started the company is that it's such a powerful tool for companies to understand their impact as early on as possible, because as soon as you go to, like as soon as you go into construction tens of millions or hundreds of millions of pounds are spent. They're committed. They're not going to change anything. But if you can put this life cycle assistant thinking in a design phase you can you can throw out the ideas which are going to emit, you know, millions of tons of carbon over the life of the project. It's sort of almost like a tree and you're collating all the what's known as life cycle inventory data which is all the energy and material flows going into your system that you want to measure and also all the emissions, whether that's to air land and water,**

**and then once you have that life cycle inventory you're using characterization factors, which is basically translating that data to environmental impacts, and those impact categories can range quite a lot as well so you've got climate change but you also have impact categories such as acidification, eutrophication, land use impacts, water impacts and then within all these impacts there's a load of sub impacts, so water can be direct water consumption but there's also a method called the AWARE method where you can reference the water consumption against the water availability of the region. For example, water consumption in the Atacama is much much worse than water consumption in the UK. We've got lots of it, it's fine. So then when we're talking about the water consumption and lithium you've got both direct water consumption and then the embodied water consumption of the reagents as well. Arguably one of the most high profile uses of lithium today is in the battery packs of electric vehicles. In 2019 a research team led by energy systems analyst Xiang Dai of Argonne National Laboratory published this analysis of the production cycle for those batteries. The paper found that there's a greater environmental impact in the initial extraction and processing of the raw materials than there is in the production and assembly process for the finished cell. Essentially it's a lot easier to electrify and decarbonize the assembly line than it is to change the way you get at the minerals and metals in the first place the paper found that the CO2 impact of lithium in lithium ion batteries could increase from about four percent to something like 20 to 30 percent as electric vehicles are fully adopted in the coming years. And that's likely to increase. And the reason why that's increasing is because basically the electricity grid mix is is decreasing in its CO2 intensity, so the relative proportion of the raw materials is becoming more and more important. And that's true not just true for lithium it's true for all the raw materials.**

**So although I've highlighted lithium we cover you know nickel, graphite, manganese. My background is rare earths, so we work a lot with rare earths and a load of other technology materials as well. Mineral mineralogies, the geological characteristics, can dictate the limits for the environmental performance for certain products and Spodumene is a prime example. So to get the lithium out of Spodumene you have to have a thermal input. You have to get the material to a certain temperature in that process stage and that means that there's sort of like a lower limit on what the impact is for that product. So it's very unlikely that you're ever going to get Spodumene that's going to have a lower impact than say brines because brines are just more accessible. They don't need the same thermal input to get to that lithium hydroxide or lithium carbonate. Lithium is just one so like nickel is even more extreme.**

**So there's a lot of movements to South East Asian Laterite type deposits which require a very different production process and have significantly higher CO2 intensities per kilogram produced than traditional sulphide type deposits.**

**The fossil fuel industry has been very keen to point out the upfront environmental impacts of manufacturing lithium-ion batteries for EVs, with the implication that this makes them no better than ICE vehicles. And you might be forgiven for thinking that Rob and I are starting to sound like we agree with them. So let me just take the opportunity right now to reassure you that nothing could be further from the truth! Fossil fuels are just plain bad. There's no upside to fossil fuels, especially now that the cost of wind and solar are competing with and, in many cases, beating those dirty hydrocarbons. But corporations and governments do face a choice about how they source and supply the raw materials for the green transition. We are very concerned about feeding that anti-EV narrative because what we're saying is the background data is wrong, but we know from a life cycle assessment perspective that you've got quite a lot of flexibility in terms of the impact of the raw materials for it to still be better than ICE, especially with improving grids. But yeah, so we now think it's kind of the right time, because there's a consensus really that you know EVs are being, or that they have been, fully adopted by all the major producers and there's no way that's changing. They've committed billions of pounds. So now is the right time to put the lens on the supply chains and make sure that we understand the impact. Battery chemistries are evolving all the time and we're involved with University of Warwick. We've got a joint project with them. So they're basically providing insights in how battery chemistries are evolving then we're providing insights on how that might impact the supply chain and the relative impacts of that. There's a load of other trends that are happening. So lithium is forecast to be very important for a long time because they're looking at...**

**I think they're actually looking at making this... you know the solid state battery? Lithium metal will be very important if that ever like takes off and becomes commercially viable. And then that will really increase the demand of lithium.**

**And it will require new supply routes as well because you know lithium metal is very different from lithium carbonate or lithium hydroxide to produce. So a lot of the work we do now is working with projects which are in, say, advanced development but not operation, and basically supporting them in refining their flow sheets to minimize the impact while still obviously maximise - the fundamental is to to make money - but we're saying with this cost you know, it doesn't cost too much, it doesn't change too much, but you can reduce the CO2 intensity of your product to this level. And, you know, then depending on their internal carbon price or how much they're at risk on it in the future, then they can make iterations. And then we have the technology side of the business as well, and that's where we're providing a life cycle assessment tool specific for the mining and metals industry. So you can put in your project data and**

**you can simulate impact reduction strategies. So that might be like adopting renewable energy on site or it could be getting an electrified fleet rather than using conventional diesel trucks. One potentially very beneficial insight that Minviro has been more recently delving into is the potential for combining carbon sequestration into new projects, and I was keen to understand the benefits of this approach. But the carbon sequestration that we look at within our lifecycle assessment tool is...**

**say there's certain nickel projects which have a... they've got like waste rock or tailings which have quite significant potential for just carbon capture if they change their tailing structure. So there's certain mineralogies... like there's a mineral called Brucite which basically captures carbon and it can be quite significant over the life of the project. That's a really fast evolving area. I think it could be, you know, quite useful in the future and that's definitely not as a high risk sort of carbon capture approach, you know, because it's getting mineralized, and the permanence is there. The impacts really are on how do you manage the tailings facility and ,you know, what's the land area... what are the issues associated with hydrology, water runoff and stuff like that. One of the challenges that all businesses will face over the coming years will be the requirement to account for, and minimize, all their greenhouse gas emissions including Scope 3 emissions, which are often outside of a company's remit and far more difficult to control. One of the biggest risks for raw materials manufacturers is the reliance on the electricity grid in whichever state or country they happen to be working in. If that grid is heavily dependent on dirty fuels like coal, then that will be reflected in the company's carbon footprint which with the advent of carbon taxes means they may be paying a high price for something they can do very little about. But there are alternatives, as Rob explained. But now we're seeing that there's way more opportunities to utilize completely off-grid energy systems. That completely de-risks them over the life of the project, and they know exactly their CO2 intensity and they know exactly, you know, what they need to do. So it's...I think that's going to be a big trend in the future as well. You know, these mining projects have a lot more flexibility to go to remote locations if they can do this. Life cycle assessment also helps companies to look for ways to spread their energy impact across a broader range of products so that the impact per product is reduced. A perfect example of this is geothermal lithium which Rob, and co-authors Alex Grant and David Deak analysed in this paper published in May 2020. One of the interesting things... so this isn't just necessarily the geothermal but this is true for everything... so if you've got a single project and you can maximize the amount of products that are coming out of your process, that reduces the impact per product.**

**You might have copper and nickel and then you have to divide the total impacts by those materials in one way or another. The same is the case with geothermal lithium.**

**So you've got geothermal energy as a product and you've got lithium as a product and what's particularly encouraging for geothermal lithium is if you're in certain places... like, there's projects in ...there's, you know, a project in development in Germany for example. That's quite an attractive project because the German electricity grid, although it's evolving rapidly, it's still not very low CO2 intensity, and so if you can put geothermal energy into the grid you're offsetting both that electricity but also providing lithium. So we sort of gave a little overview of what's the potential around the world of geothermal lithium resources and how do they perform in relation to that background electricity CO2 intensity. And even right here in the UK we've got two companies -**

**Cornish Lithium and Geothermal Engineering Ltd who are working on a very similar joint project that they're calling Geo cubed to utilize the hot lithium-enriched granite rocks and geothermal waters that circulate naturally beneath the ground in the Southwest region of this country. There's huge advantages to finding a use for everything because it minimizes waste impacts as well so even if you're able to find a buyer of aggregates from a mining operation from your waste drop, that can be advantageous and it reduces the impact a little bit because you're subtracting that impact. So that's something that we always encourage as well.. like, trying to find uses for everything that you produce. Minviro are also pushing for a much more site-specific and supplier-specific set of impact calculations for each material and process. Right now there's typically a generic impact number for any given resource, and producers just plug that number into their impact assessments.**

**But in reality, according to Rob, those numbers vary hugely depending on geographic location and a whole host of other factors. This is one of the most interesting things that we're really trying to communicate all the time. The same product doesn't have the same impact. That's the thing that we're trying to make clear. Just like energy doesn't have the same impact depending on you know, which technology they're using and where it's coming from. Historically, even up to this point now, every car manufacturer has used a static value for nickel, a static value for lithium. So one value which represents the whole world. And, you know, we find that it's our responsibility to uncover the reality, which is that there's huge ranges of impacts and we think that the the companies that are spending more money on making sure that they're purchasing low impact materials and making sure that they've got loads of low impact supply chains, that should be represented in the impact.**

**Now if you've been following this channel for a while, you may remember a couple of years back I made a program looking at end of life recycling for renewable energy components like turbine blades, solar panels and lithium-ion batteries. It's an industry that many argue will be a crucial element of the more sustainable circular economies we hope to achieve in the coming years. So I**

**was curious to know whether the benefits of recycling had yet found their way into life cycle assessment. We work a lot with lithium-ion battery recycling technologies as well now, and innovative approaches to circular economy thinking. Even from, say, mining waste. So iron ore tailings, or iron ore slag, and looking if you can extract critical metals out of that. Minviro is also a partner with The University of Exeter Technology Metal Circular Economy Centre. This is a really interesting one because it's sort of highlighting that there's an opportunity to merge this idea of raw material mining mineral processes. Because those have the same skill sets as recycling. Say, if you think about people's phones in their their cupboards, that's technically a resource. You know, there's a resource there. So if they're compiled into a particular deposit in one location that becomes very very attractive. The reality is with our forecast demand growth and the life expectancy of materials in these technologies, there's sort of an obvious demand which means that we can't reach recycling rates at the moment but you know it might be**

**2040 ,2050, 2060. But yeah, I do 100% agree that the the long term ambition, even from a geologist and a mining person, is to not have to do these these big open pit mines in the future. Minviro's vision of minimising the impact of raw materials for the low carbon economy is a noble goal indeed, and their three software packages called Mine LCA, Mine Metric and Mine Bit are already providing companies all over the world with a user-friendly interface to help them get an accurate picture of where they can make tangible improvements.**

**As I've said many times on this channel, the path towards a more sustainable future will not be a smooth one, but companies like Minviro look set to play a key role in guiding our raw material producers and industrial manufacturers in the right direction. No doubt you've got your own views on this one, so dive down to the comments section below and leave your thoughts there. That's it for this week though. A big thank you as always to our fantastic Patreon supporters without whom this channel would not exist. They enable me to keep the channel completely independent, and keep these videos 100% ad-free. You can get involved in that and get the opportunity to exchange ideas and information plus watch exclusive monthly news updates from me and have your say on future programmes in monthly content polls by visiting www.patreon.com/justhaveathink, and you can hugely support the channel absolutely for free by subscribing and hitting that like button and notification bell dead easy to do all that you just need to click down there or on that icon there. As always thanks very much for watching, have a great week and remember to just have a think. See you next** week