**There’s an old mantra that says “Predicting the future is easy. Predicting the future accurately is much more difficult”. 8:00 And there are plenty of** [**mildy-amusing**](https://www.hero-labs.com/stories/the-22-worst-tech-predictions-of-all-time/) **historical examples where that wisdom has been demonstrated**

**Fast forward to twenty-twenty-three and one of the popular future predictions doing the rounds on social media at the moment is that the world will not be able to move away from fossil fuels in the twenty-first century using currently available alternative technologies, because there simply aren’t enough minerals and other raw materials on the planet to scale those technologies up.**

**So maybe we should have a think about that, eh?**

**Hello and welcome to Just Have a Think,**

**If someone wanted to get an idea of the quantity of raw materials and amount of infrastructure required to transition away from fossil fuels and run an alternative energy system instead, it’d be logical to start by assessing how much energy the current system produces and then calculate how much of the alternative technology you’d need in order to provide that same amount of energy. It would also be important to calculate how much the world’s energy demand is likely to INCREASE in the coming decades, not only through population growth, but also as a result of higher WEALTH, especially in rapidly growing developing nations. One of the difficulties in making that assessment is the fact that industry experts don’t all agree about how to compare the energy going into the front of any given system against the useable energy coming out at the other end. You may recognise this as EROI, or Energy Return on Investment, or possibly ERoEI, which stands for Energy Returned on Energy Invested. This recent article by industry expert Michael Barnard explains a common misperception about something called Primary Energy**

 **“The primary energy fallacy”, he explains “is the assumption that all of the energy in all of the oil, gas and coal we burn today must be replaced. We don’t need to replace it, we need to replace the UNWASTED energy services.”**

**To illustrate what he means by that, Michael steers us towards this rather daunting graphic. It’s an example of something called a Sankey Chart. This one was produced by the Lawrence Livermore National Laboratory to represent the United States energy system in twenty- twenty-one. On the left are all the different energy technologies currently in use in the US, AND the AMOUNT of energy each of them produced in that year, measured in ‘quads’, or quadrillion British Thermal Units. One quad is roughly equivalent to the energy content of a hundred and seventy million barrels of crude oil, thirty-six million metric tons of coal, or nine hundred and seventy billion cubic feet of natural gas. The section in the middle that looks a bit like the London Underground map shows how the various energy types get shunted around the system. What’s important though, is what gets spat out at the end. Only about a third of the PRIMARY energy from the left-hand side actually arrives as USEABLE FINAL energy on the RIGHT-hand side. The other two thirds are waste or ‘rejected’ energy. And where is most of that waste energy produced? Well, according to this chart, it’s pretty much ALL coming from coal, oil and gas. But if you based your calculations on the LEFT-hand side of this chart, as some analysts do, then you might still reach the conclusion that fossil fuels are a clear winner. One fairly recent report, which I’ve also linked in the description section, suggests that completely replacing all of the world’s existing fossil fuel power stations on a like-for-like PRIMARY energy basis would require about a hundred and eighty thousand new facilities run by renewable technologies, plus gargantuan amounts of battery energy storage to compensate for the intermittency of those technologies, with the conclusion that the world simply does not have the minerals and other raw materials required to build out all that infrastructure.**

**Other analysts disagree though. T**[**his**](https://www.mdpi.com/2071-1050/14/12/7098/htm?ref=ageoftransformation.org) **recent peer-reviewed publication for example, found that the EROI of wind and solar, measured at the FINAL ENERGY point of use NOT the PRIMARY ENERGY point of generation was “at or above ten”. In other words, you get ten times as much consumable energy out as you need to put in to build and run those systems, largely because once they’re built, wind turbines and solar panels produce final energy directly into the grid with virtually zero waste.**

**A separate** [**study**](https://www.sciencedirect.com/science/article/abs/pii/S136403211500146X?ref=ageoftransformation.org) **calculated the EROI of solar photovoltaics to be anything from nine-to-one up to as much as a whopping thirty-four-to -one, depending on the type of material and technology used, and its authors suggest that Solar PV could in future match the maximum EROI achieved by coal in its hay-day about a century ago, which back then was an incredible eighty-to-one.**

**By contrast, this** [**paper**](https://www.nature.com/articles/s41560-019-0425-z?ref=ageoftransformation.org)**, published in twenty-nineteen, calculated the overall final EROI for MODERN-DAY fossil fuels to be only SIX to one, and declining rapidly as ever increasing amounts of energy (and time and money by the way) are spent winkling out ever decreasing amounts of product from more and more inaccessible seams and wells.**

**But what about that intermittency thing I mentioned earlier? There are analysts who argue that most countries, certainly up here in the northern hemisphere, would need a good months-worth of non-stop energy storage to get them over their dark and cold winters, and that the sheer quantity of raw materials required to achieve that would be tens or in some cases even hundreds of times more than the total amount available on the planet. So, clearly not a viable option then, right?**

**Again though, it’s not difficult to find research literature that comes to very different conclusions.**  **Analysis by an energy industry consultancy called RethinkX, which we looked at in this video back in twenty-twenty-one, shows how the precipitous drop in the price of wind and solar power will enable their future generating capacity to greatly exceed the total electricity generating capacity installed today. That overbuild will result in systems that ARE large enough to get us through the dark and miserable months of northern hemisphere winters. And then, during the other nine months of the year, those wind turbines and solar panels will be massively over producing energy at very close to zero marginal cost. Instead of switching them off as we do now in a process known as curtailment, that zero marginal cost energy will be used to replace a whole bunch of currently very carbon intensive stuff like water desalination, road transportation, residential and commercial heating and cooling, waste management and industrial and chemical processes, all of which will further reduce our reliance on fossil fuels and massively lower the requirement for scarce minerals.**

**A comprehensive** [**study**](https://www.wartsila.com/insights/article/reimagining-100-percent-renewable-energy) **published in twenty-nineteen by the global energy firm Wartsila looked at the power systems of a hundred and forty-five countries and regions around the world and found that overbuilding solar and wind by four times peak load could eliminate the need for seasonal storage and require as little as four DAYS of storage capacity, not four WEEKS! And by the way, batteries aren’t the only method of storing energy. About ninety-nine percent of all utility-scale energy storage by volume today is in the form of pumped hydro. There’s a popular perception that we’ve used up pretty much every geographically and topologically appropriate global location for pumped hydro, which essentially requires a large water reservoir at the top and bottom of a hill, and also needs to be sited well away from rivers so that it doesn’t screw up riverine ecosystems in the way that hydroelectric dams sometimes do. But two recent research papers appear to debunk that notion as well. This** [**one**](https://re100.eng.anu.edu.au/global/)**, published in twenty-twenty-two by the Australian National University found no fewer than six hundred and sixteen thousand off-river sites all over the world, with a combined energy potential of twenty-three million gigawatt hours, which they say is about a hundred times what would be needed to support a one hundred precent global renewable electricity system. Over in the US, the** [**National Renewable Energy Laboratory**](https://www.nrel.gov/docs/fy22osti/81277.pdf)**, or NREL, found nearly fifteen thousand potentially viable new pumped hydro sites in the US alone, representing thirty five thousand gigawatt hours of energy storage. And again, links to these papers are in the description section below this video.**

**Ah yes, but we can’t ignore the impending Tsunami of electric vehicles that we’re all hearing so much about in the news these days, can we? They all need batteries, don’t they? So, what about all THOSE raw materials like lithium, nickel, cobalt, manganese and copper for example? Well, for starters, as we’ve discovered in previous videos on this channel, the world’s largest battery manufacturers have already moved across to lithium-iron-phosphate chemstries for many of today electric vehicles. Those batteries contain no nickel or cobalt at all. To get a bit more of a steer on this, I spoke to electrochemistry expert, and energy industry consultant Euan McTurk via Zoom recently,**

 **“obviously the advent of lithium-ion phosphate means we’re moving away from nickel for a large swathe of electric vehicles, including already some of the best-selling makes and models on the market”**

 **“lithium’s not really…it’s not rare at all. There’s something like eighty million tonnes of lithium on land, probably more, we keep finding more all the time. But also, two hundred and thirty BILLION tonnes in sea water – not deep-sea mining, just in sea water. There’s probably enough lithium in the hard rock at Cornish Lithium’s for five million electric vehicles “**

**Lithium’s not the only game in town either. There are already production passenger vehicles on sale in China that use sodium-ion battery chemistry, which eliminates the need for lithium completely.**

 **“Sodium, obviously there’s just such vast supply chains for that, so there’s more reserves but there’s also more production capacity. There are knock on advantages from the chemistry of sodium-ion. The fact that you can reversibly discharge it to zero volts, in other words stick a resistor across the terminals, ship it half way round the world and then recharge it safely, which you cannot do with lithium-ion. That means you’re shipping cells with no energy in them, which means not only are they safer to ship but they are cheaper to ship [] and that’s why you’ll probably see sodium-ion battery packs at a cost of about fifty dollars per kilowatt-hour. Also the sodium-ion set up, the fact that you don’t necessarily have to have cobalt in a sodium-ion cell. You also don’t need to have copper in a sodium-ion cell because you can replace the current collector on the negative electrode which keeps the costs down and the weight down. Such is the progress we’re making with these different chemistries – the diversification of chemistries. It is rampant!”**

**And on top of all that, electric vehicles are increasingly being equipped with bi-directional batteries, which means they can feed electrons into your home’s electrical system and even back into the national grid. This paper, published in January twenty-twenty-three used what the authors describe as ‘conservative’ calculations to find that a participation rate among EV owners of between twelve and forty-three percent, depending on location, could provide all of the short-term grid storage demand globally and that if only fifty percent of EV batteries at end-of-vehicle-life are repurposed into stationary utility scale energy storage units, EV owner participation rates would only need to be around ten percent. They also suggest that short-term grid storage demand could be met as early as twenty-thirty across most regions.**

**There is another point of view altogether though, that sits outside the heated debate about how to fuel our ever-expanding world. Some argue that it’s completely delusional to suggest we can continue with our constant global economic growth model simply by replacing fossil fuels with wind turbines, solar panels, energy storage and a bit of nuclear, or whatever. There’s a substantial body of opinion that says we have to address the fundamentals of how much each of us consumes, how efficiently we do that consuming and how much stuff we throw away that could otherwise be put to good use. That’s a discussion in its own right, and it’s one that’s been rumbling on since at least nineteen seventy-two when the seminal book ‘Limits to Growth’ was published by the Club of Rome. Does that mean we shouldn’t try to move away from fossil fuels at all though, and that the whole ‘green transition’ thing is a pointless exercise? Well, here’s just one statistic that suggests it most certainly is not. According to the World Health Organization, ninety-nine percent of the entire human population breathes air that exceeds WHO guideline limits and seven million people, many of them children, die prematurely every single year as a direct result of air pollution caused by the combustion of fossil fuels. So, even if nothing else got worse, even if we didn’t see more famine and disease caused by drought and floods. Even if we didn’t see more climate migration away from increasingly uninhabitable regions. And even if we didn’t see more regional conflicts in the fight over dwindling food and water resources – even if none of those things happened, just the air pollution alone from our current level of fossil fuel combustion would result in well over half a billion unnecessarily early deaths between now and the end of this century.**

**That’s it for this week. Thanks, as always to our amazing Patreon supporters, who keep me going and enable me to keep ads and sponsorship messages out of all my videos. And I must just give a quick shout out to some folks who’ve joined recently with pledges of ten dollars or more a month. They are**

**Daniel Elazar**

**Todd Spencer**

**Roger Cuthbert**

**Donald Vig**

**Sean Smith**

**Marc**

**And**

**Thomas Kägi**

**And of course, a massive thank you to everyone else whose joined since last time too.**

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**As always, thanks very much for watching! Have a great week, and remember to just have a think. See you next week.**