**The laws of thermodynamics, if I’ve understood them correctly, tell us that energy can only be transferred as heat or work. In other words you can either make something do something, like turn a driveshaft to move a vehicle, or you can make something get hot, like boiling water in your kettle.**

**You might think that in an industrial setting most of the energy consumed would be used to do work, like driving all the machinery and moving all the production lines. But it turns out that it’s actually heat, or process heat to give it its full name, that uses up the vast majority of all energy in industry.**

**And generating that heat currently accounts for three quarters of all industrial carbon dioxide emissions, largely as a result of all the fossil fuels that get burned in the process of making things like chemicals, steel, paper, food and beverages.**

**Given the essential nature of all those products, you could conclude there’s no easy way around this one, and we’d be better off focussing on areas where we can replace fossil fuels more easily.**

**And it turns that’s not accurate either.**

**According to a new analysis by an independent think tank called Agora Industry, direct electrification technologies that’ll come into use over the next decade or so could meet as much as ninety percent of all European industrial energy demand.**

**That’d be good, wouldn’t it?**

**So, how’ve they worked that out then?**

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

**The study I’m referring to is the result of a collaboration between Agora Industry, a second think tank in California called Energy Innovation, the world-renowned Fraunhofer Institute and a cross industry network called the German Industry Initiative for Energy Efficiency, the original name of I won’t try to pronounce, but which abbreviates to DENEFF.**

**European industrial greenhouse gas emissions break down roughly in line with this pie chart. About a quarter of it comes from the generation of steam and hot water, another twenty percent as direct emissions from processes involving chemical and minerals and things like glass and ceramics. About five percent comes from space heating, and a whopping fifty-one percent comes from the combustion of fossil fuels to run industrial furnaces**

**This new study is pretty upbeat about all of that though, at least in principle anyway. In fact, they point to a bunch of technologies that are already well known and fairly mature that would do the job nicely if the will was there from industrial operators to take the plunge and implement them, AND if the right incentives were in place from European governments to encourage them to do so. I’ll come to that a bit later on, but let’s look at the current state of play first of all.**

**Here's Agora’s breakdown of each major industrial sector showing how much of the energy demand in each of them was met by electricity in twenty-nineteen. These additional blue bars indicate how much more of that demand will be supplied by electricity by twenty-twenty-five, the lighter blue is the projected electrification by twenty-thirty, and the very light blue shows electrification potential from twenty-thirty-five onwards. It’s not bad, is it? Only iron and steel continue to need a significant dollop of fossil fuel input, largely through the use of coking coal in the iron ore reduction process. But if you add it all up, as the folks at Agora Industry very helpfully do over here, then you can see how they arrive at their ninety percent electrification number.**

**So, what are all these wonderful electrification technologies then?**

**Well, there’s no earth-shattering rocket science here folks. All these technologies already exist, and between them they could easily cope with almost every conceivable scenario, from very low heat stuff like food or pulp and paper, right through to seriously high temperature processes like cement sintering and hot steel rolling.**

**Electric boilers can deal with applications as small as ten kilowatts right up to very large-scale systems that can top ten MEGAwatts. They can provide temperatures of more than five hundred degrees Celsius 500 °C at pressures of twenty bar or more. They’re far more efficient than gas-fired boilers because they’re converting electrical energy into heat which is transferred directly into the medium without the energy losses you get with heat exchangers and flue gases. They emit ZERO green­house gases and no pollutants during operation.**

**But as we’ll see throughout this little summary video, it’s the upfront costs that hurt.**

**These things are currently more expensive to buy and install than traditional gas-fired systems.**

**The second recurring theme is the artificially high cost of electricity itself in Europe compared to gas, which is something we’ll also touch on a bit later in the video.**

**Next up is Heat Pumps. We’ve all heard plenty about these devices in the context of our own homes recently, haven’t we? Well, it turns out they have some extremely interesting industrial applications as well. Their USP among all electrical heating technologies is that instead of converting electricity into heat, they move heat from a heat source like the air or the ground into a heat sink, via a refrigerant that runs through various pipes, compressors, condensers and expansion valves, into whatever it is you want to get hot. And because the heat source is free, for every unit of electricity you put in, you get as much as four or five units of heat out. It’s what we’re all learning to call the coefficient of performance, or COP. Typical temperatures achieved today are in the one hundred to two hundred degree Celsius range, which makes heat pumps ideal for steam generation in textiles, food making and the paper and pulp industries. There are some beefed up versions that can reach two hundred and fifty degrees Celsius, typically by using waste heat from other industrial processes as a heat source rather than ambient air or ground temperatures, and work is going on to bump that up to three hundred degrees using things like mechanical vapour compression technologies.**

 **They’re more complicated to install than fossil fuel-fired boilers though, which of course makes them more expensive, at least at the moment anyway. But it’s a mature technology and it’s readily available, so once again, it’s all about incentivisation, isn’t it?**

**Then we’ve got the dear old resistance heater, which is basically a glorified version of the three-bar fire your granny used to sit next to in the front room. Industrial resistance heaters are only really limited by the material in their heating element, which range from nickel-chromium alloys that enable heating up to fourteen hundred degrees or so, all the way up to graphite, which can get to three thousand degrees Celsius when surrounded by inert gases like argon or helium. The Achilles heel of resistance heaters right now though, is power density, which currently sits at about eighty kilowatts per square metre. Existing industrial furnaces sometimes don’t provide enough surface area to instal the requisite number of elements for a given application, so once again the operator is forced to consider a full replacement.**

**Which is a headache, there’s no denying that. BUT materials are being researched that remain more stable at higher temperature and may very well provide much higher power densities, so by twenty-thirty-five, there’s some confidence that even this hurdle may have been overcome.**

**Induction heating is another one that most of us have already heard of, thanks to the induction hobs that many of us now use in our kitchens. Industrial induction heaters don’t have a heating element to worry about. They use a fluctuating magnetic field to induce eddy currents inside a material to cause a resistance which gets things hot. These devices can provide temperatures right up to three thousand degrees Celsius and they’re mainly used for heating or melting metals Because all the heat is generated inside the target material, electromagnetic induction heaters are super-efficient. We talking ninety-five percent efficiency or higher. Induction furnaces with a capacity of forty-two megawatts are already in use in the steel industry, as well as a range of other metal processing including copper and aluminium.**

**So, this one is kind of good to go really.**

**By contrast, plasma torches are not yet up to full development pace at least not for industrial heat anyway. The technology is already used today for cutting and arc welding, but according to the authors of this study, it looks like it could also represent a promising alternative to fossil fuel burners. Plasma torches generate a rotating electric arc between two elec­trodes, which heats up a gas like nitrogen to a whopping five thousand degrees Celsius. Those high tem­peratures combined with high energy density, small installation size and fast start-up and shut­down capabilities make these contraptions a very attractive option for prospective industrial buyers.**

**The downside is lower efficiency and high cooling demand, which can increase overall energy demand by twenty-five percent compared to fossil fuel-fired processes.**

**Plasma technology also gets utilised in electric arc furnaces. In this case though, the heat from the plasma is transferred directly into a material rather than going through a carrier gas. This technology currently achieves temperatures of about eighteen hundred degrees Celsius, which is good enough to produce recycled steel from steel scrap. They’re between ninety and ninety five percent efficient and they already have a forty percent market share in European steel production, so it’s a technology that definitely has momentum and is already achieving substantial cost and emissions reductions.**

**Then we really get a bit experimental, with so-called shockwave heating.**

**The idea here is to create high pressure waves using rotating cascades of blades. That causes a sudden compression which heats up a fluid. If that fluid was air and it was pumped into a furnace then it could perform the same function as a gas burner. Initial tests have apparently achieved temperatures of about seven hundred degrees Celsius at a power output of one megawatt, but the science bods reckon that by twenty-thirty they’ll achieve fifteen hundred degrees Celsius and power outputs of more like fifty megawatts. That makes it a candidate for electric steam cracking, lime calcination and cement clinker burning.**

**Still early days for this one, but the study’s authors have assumed industrial scaling by twenty-thirty-five, so you know – fingers crossed, eh?**

**Lastly, we’ve got thermal storage, which we’ve looked at several times on this channel and which comes in various guises.**

**In very basic terms, you use electricity, preferably from renewable sources like wind and solar, to heat up a material like sand or aggregate or even water inside a well-insulated chamber, and then release that stored heat whenever it’s required. These things are relatively simple, and they have the advantage of being a drop in technology that can be easily assimilated into an existing plant. They also offer load shifting, by which I mean they can be charged up during the night on cheap rate electricity and discharged during the day when electrons are in high demand and are therefore expensive. That not only helps the manufacturers keep costs down, but it also helps the grid operator to smooth out some of their supply spikes. They can potentially store heat up to two thousand degrees Celsius too, which makes them attractive for a pretty-wide range of applications.**

**Now, one or two of you might be yelling HYDROGEN at your screens right now, and yes, hydrogen is referenced in this study as a possible indirect heating alternative that offers easier integration and greater flexibility for industrial operators. If you’re a regular viewer you’ll no doubt have watched various previous videos that I’ve made on this topic, so I’m not going to dwell on it here, suffice to say that more than ninety-nine percent of today’s hydrogen is made by steam reforming methane which releases enormous quantities of carbon dioxide and is more damaging than simply burning the natural gas in the first place. I’ve left links in the description section to those videos, so you jump over and have a rant at them if you feel so inclined.**

**But really speaking, there’s a bunch of very good options here for electrifying industrial heat without hydrogen during the course of the coming decade. Overcoming the dominance of fossil fuel won’t be easy though, just as we’re finding in every other sector, so the authors of this paper suggest that a CO2 adjusted price will need to be applied to gas so that low carbon electricity from renewable sources can compete on a more level playing field.**

**Governments will most likely also need to provide financial support to manufacturers in the form of grants, loans and tax breaks to incentivise them to do the right thing. I can’t imagine anything like that happening across the pond for the next four years or so, but it’s entirely possible in the EU bloc, and it’ll help a region of some five hundred million people keep up to pace with the new global energy leaders, most notably China, while our friends in the new United States administration do everything they possibly can to push their country back into the dark ages.**

**You might not share that view of course, so I’ll be interested to hear what you think. Do you reckon the electrification of industry is possible on a continent or even global scale, or is it just a bunch of wishful thinking? Maybe you work in one of these industries and you can share some additional insight with us all? Either way, the place to leave your thoughts, as always, is in the comments section below.**

**That’s it for this week though. Thanks, as always to the amazing folks who support my work via Patreon, and who enable me to keep ads and sponsorship messages out of your way. And an extra special thank you to the folks whose names are scrolling up the screen beside me here, all of whom celebrate an anniversary of Patreon membership in December.**

**Don’t forget to jump over to Patreon dot com forward slash just have a think to find out how you can join them and have a look at all the exclusive perks you can get there, including free membership. And if you enjoyed this video then you really can hugely support me by hitting the subscribe button on YouTube and clicking on all notifications. It won’t cost you a penny to do that and it’s just a simple click away, either down there or on that icon there.**

**Most important of all though, thanks very much for watching! Have a great week, and remember to just have a think.**

**See you next week.**