**There’s a lot of fierce debate going about air source heat pumps right now isn’t there? Some say they’re the key to a comprehensive green transition in home heating, and others are trying to convince us that they’re the work of Beelzebub and a tool of pinko socialist governments to coerce people into spending money they don’t have.**

**I’ll be honest. I’m not too fussed about all that. Heat pumps are better than gas boilers and they’re getting cheaper as every month goes by.**

**And millions of homes, at least here in Europe, will probably have one within the next decade or so.**

**All the noise we’re hearing at the moment is just a completely normal part of any technological transition.**

**It’s no different to the resistance put up against the motor car when it was invented, or the electric light bulb, or the telephone, or digital cameras, or electronic calculators, or mobile phones, or computers or whatever, all stuff that now plays an integral part in our lives.**

**The point is, some people love change and embrace it enthusiastically, some people hate change and rail against it like scolded children, and most people couldn’t care less as long as it works OK and doesn’t cost them a lot of money.**

**One question is pertinent though, and that’s whether we can make technologies like heat pumps even better than they already are?**

**Because that would be nice, wouldn’t it? Improving an already very good bit of kit might help accelerate the pace of change and could even make the disingenuous naysayers look for something else to moan about.**

**And now the folks at the Ames National Laboratory in the United States have developed a technology that looks like it could achieve that goal.**

**So, we should have a think about that, shouldn’t we?**

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

**So, what’s this wondrous new breakthough from our friends across the pond then?**

**Well, it’s something to do with magnets and calories apparently. I’ll come to the nuts and bolts of that a bit later on, but to get there we need to have a quick recap on how and why existing heat pumps works so well already.**

**These things don’t generate heat from a fuel like a gas boiler does by burning methane. Instead, they transfer existing thermal energy from the outside air into the rooms in your house or building.**

**Now, it’s been about minus one degree Celsius where I live recently, so you might reasonably ask why I would want to transfer minus one-degree Celsius air into my home. And the answer, I wouldn’t really. But that’s where physics, and specifically the Kelvin temperature scale come to the rescue.**

**As long as atoms and molecules are spinning around in a material or liquid, that material or liquid has thermal energy in it. And molecules and atoms can keep moving right down to minus two-hundred and seventy-three degrees Celsius, which is absolute zero on the Kelvin scale. So, the minus one-degree Celsius air that we had near me recently was actually plus two hundred and seventy-two degrees on the Kelvin scale. And that meant it contained thermal energy that could be harvested with the right piece of kit.**

**In a typical air source heat pump, fans draw air into the unit where it passes over an evaporator coil containing a refrigerant liquid with a very low boiling point. The refrigerant absorbs the thermal energy from the air, and as long as the air temperature is higher than the refrigerant boiling point, the refrigerant will evaporate into a gas. That gas then goes into a compressor where its… you know…compressed. And compressing a gas into a smaller volume means its particles collide more frequently with the container walls, which makes it get hotter. A typical compressor can get a refrigerant gas from minus one-degree Celsius right up to anything between fifty and eighty degrees Celsius. Which is hot!**

**The next step is to pass that hot gas into a condenser, which is essentially a heat exchanger full of water. As the gas passes through the pipes, it releases its heat into the water, and as it does so it condenses back into a liquid. An expansion valve helps to reduce pressure and temperature still further before the liquid refrigerant returns back into the evaporator to pick up another dollop of thermal energy from the ambient outside air.**

**The physics is dead clever, but the mechanics are really pretty simple. And because the thermal energy is effectively free, it means heat pumps are way more efficient than gas boilers.**

**Every unit of electrical energy used to run the compressor and fans and other components, can produce between 2 and 5 or more units of heating. It’s what the industry bods call the coefficient of performance or COP. That means a heat pump can achieve a COP of five or more, versus the very best gas boiler with a maximum COP of about zero-point-nine-four.**

**So how can such a neat little contraption be improved then?**

**Well, refrigerants have very useful thermal properties, as we’ve just discovered.**

**But they’re also invariably quite nasty reactive substances that typically have high global warming potential or GWP relative to carbon dioxide. That’s no problem while they’re circulating around a closed-loop system, but leaks do occur, and refrigerants are rarely carefully recovered when units are scrapped at the end of their operational lifetime. So, eventually, those potent greenhouse gases are likely to find their way up into the atmosphere.**

**And we don’t want that. And here’s where magnets and calories come into the picture. Or to be a bit more scientific about it, magnetocaloric heat pumps, or MCHPs.**

**The researchers at the Ames National Laboratory identified this as a technology that offered a promising alternative to refrigerant gases, and one that could, in theory, achieve even higher levels of energy efficiency. But they also knew that previous attempts at making a workable version had resulted in devices that were larger, heavier and more expensive than existing refrigerant heat pumps, and which in the real world didn’t actually achieve the theoretical energy improvements that everyone was hoping for.**

**Essentially, not great, really.**

**So, what principles are we dealing with here?**

**Well, the so-called magnetocaloric effect relates to certain types of material that, when place in a magnetic field, do something very specific –they align their atomic spins with the field. That realignment releases energy as heat. And that makes the material get hot. If the magnetic field is removed then the atomic spins go back to their original disordered state, absorbing energy as they do so. And that cools the material down again.**

**Now if you’re a scientist, this is the sort of natural phenomenon that tends to give you goose bumps in places that you didn’t even know existed, and the urge to do someone useful with it must be almost overwhelming. For example, if the hot material is placed into a heat exchanger, then it could transfer its thermal energy into water. Which would definitely be useful, wouldn’t it?**

**The Ames paper explains that typical existing magnetocaloric heat pumps use permanent magnets that spin within the core of the device relative to the magnetocaloric material. 6:46 And magnetic steel is installed around that assembly to keep the magnetic field contained. And it was the precise arrangement of these three elements that formed the bulk of the team’s experimentation.**

**They also considered the specific types of magnetocaloric materials available, the two most common of which are based either on gadolinium or lanthanum-iron-silicon-hydride. The goal of the research was to achieve a heat pump device with a core system that weighed no more than a typical existing heat pump compressor. To get there, they focussed on using space and materials more efficiently, looking for ways to minimise the size and weight of the heavy permanent magnets and magnetic steel materials.**

**Using ﬁnite element models, solid models, and estimates of magnetocaloric material performance, the team were able to test thermal powers ranging from thirty-seven watts all the way up to forty-four kilowatts at a nominal temperature range of ten degrees Kelvin. What the modelling showed them was that it was possible to improve the overall system power density (which is defined as thermal power in watts divided by device mass in kg), from six watts per kilogram to as much as a hundred and fourteen watts per kilogram, simply by being a bit smarter with material choices and configurations. Based on their results, The papers authors suggest that a magnetocaloric heat pump using lanthanum-iron-silicon-hydride alloys could be competitive with off-the-shelf compressors with similar environment temperatures, up to the three-kilowatt power range. And with a bit more fettling of real-world prototypes, there’s every chance that further improvements could be achieved.**

**Now, the air source heat pump I have in my home is rated at just over nine kilowatts, so there’s clearly still some work to do before you and I will be able to buy a commercially available device fitted with this technology, but as part of a development pathway that can remove a source of powerful greenhouse gases from potentially hundreds of millions, and possible even billions, of heating and cooling devices globally, then this study appears to offer some very encouraging progress.**

**A question some folks might quite reasonably raise is whether there are sufficient reserves of gadolinium and lanthanum to support those potential volumes, and whether the mining of those rare earth elements might create as many or even more greenhouse gases than would be saved by using them to displace refrigerants in heat pumps?**

**Well, it’s hard to put an absolute number on that, but some estimates suggest there are more than a million tonnes of known gadolinium reserves and perhaps as much as six million tonnes of Lanthanum. Certainly, enough for several hundred million units.**

**And with a bit of smart management and the right regulatory environment, those materials could be recovered from decommissioned units and recycled repeatedly. It’s also worth noting that they come from minerals that are already being mined for the multiple other elements they contain.Those operations are already in place in many countries round the world, including the United States.**

**The carbon footprint of those sites is already being addressed in some areas through the implementation of more efficient on-site systems and even the use of large scale electrically powered moving equipment.**

**It’s far easier to control emissions like these at a very small number of large locations than it is to monitor and control refrigerant leaks and disposal emissions from hundreds of millions of individual AC units all over the world, so while nothing we humans do can ever be construed as zero impact, you could argue that magnetocaloric heat pumps would at least be ‘less bad’ for climate warming than the current options.**

**While further research into magnetocaloric materials, active magnetic re-generators, and magnetic ﬁeld sources will be needed to address commercial sized refrigeration and heating units, the authors of this paper are confident that**

**“cost parity with vapor compression is within reach for low power applications such as home refrigerators and room air conditioners”**

**And that looks like encouraging news.**

**But what do you think? Can a new technology like this ever break into a market as entrenched and well established as HVAC? Maybe you work in the industry, and you can share a bit of your wisdom? Whatever your opinion, 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 over at Patreon, who make this channel possible and enable me to keep ads and sponsorship messages out of your way.**

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**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.**