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Why we need radical "cool' innovation today

As the new Midlands Thermal Energy Research Accelerator is formally launched with £20 million of Government backing, Professor Toby Peters, Visiting Professor in Power and the Cold Economy at the University of Birmingham, explains why we urgently need to bring cooling technologies in from the cold.

Radical energy technology innovation is vital to achieving our targets for decarbonisation, energy security and growth, but in the heating and cooling sector the process has hardly begun. That's according to the International Energy Agency's *Energy Technology Perspectives 2015*[1], which concludes that *"heating and cooling systems offer substantial potential for decarbonisation that so far has been largely untapped".*

The IEA makes a powerful case: *"… heating and cooling in buildings and industry accounts for approximately 40% of final energy consumption – a larger share than transportation (27%). With 70% of heating and cooling demand relying on fossil energy sources, these end uses are estimated to have been responsible for 30% of global carbon dioxide (CO2) emissions in 2012."*

In the EU we currently spend just 0.22% of our total engineering research budget on cooling (yes, less than 1%! and by the way even less, 0.19%, in the UK); yet the European Commission estimates that the demand for cooling in buildings in the EU will increase by more than 70% by 2030.

More worrying is that the global demands placed on our energy supply and natural resources are set to increase exponentially because of rapid demographic change in the developing world, where rising incomes and urbanisation are leading to sharply higher levels of consumption. Nowhere is this truer than in cooling.

As just one example, the IPCC projects that global air conditioning energy demand will grow 33-fold from 300TWh in 2000 to more than 10,000TWh in 2100, with most of the growth in developing economies.[2] 10,000TWh is roughly half the total electricity generated worldwide in 2010.[3] (In that year alone, Chinese consumers bought 50 million air conditioning units – equivalent to half the entire US domestic air conditioner fleet).[4] If this level of projected global air conditioning energy were supplied with fossil fuels, the CO2 emissions would be disastrous; if with renewable generation, the investment and infrastructure required would be prodigious. Either way, it's a major problem.

The scale of the challenge is highlighted in the lastest *BP Energy Outlook*[5], which shows just how far short we are of achieving sustainable trajectory in global carbon emissions, in spite of some encouraging developments. BP forecasts that renewables will be the fastest growing energy source over the next twenty years, expanding by 6.6% per year, and energy intensity – the amount of energy required per unit of economic output – will fall by more than 2% per year, significantly faster

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than ever before. Yet emissions still grow by 20% to 2035, as falling carbon and energy intensity are overwhelmed by economic growth with energy consumption increases in the fast-growing emerging economies.

In fact the report states that to prevent energy demand rising over the next 15 years, "*energy intensity would need to decline on average by 3.5% p.a. This is far faster than any 20-year rate of decline experienced since at least 1965 (and probably far longer) and more than double the average rate of decline seen over the past 20 years."*

So there is an urgent need to develop technologies that reduce energy and resource consumption not simply by a few percentage points but by a substantial fraction. This requires a fundamental re-evaluation of our approach to innovation: away from incremental efficiency improvements, and towards a clean-sheet assessment of the services we need and radical innovation to supply them in the most resource efficient way. And nowhere is this more important than cooling – the backbone of modern society through data centres, food chains, medicine or everyday comfort.

One example of radical UK innovation is the Dearman engine[6], a novel piston engine powered by the phase-change expansion of liquid air or nitrogen, which has several potential applications but is being developed first as an efficient zero emission transport refrigeration unit (TRU) to displace the highly polluting secondary diesel engines used on virtually all refrigerated trucks and trailers today. The Dearman TRU eliminates emissions of nitrogen oxides (NOx) and particulate matter (PM) – the key toxic pollutants responsible for 3.7 million premature deaths through outdoor air pollution worldwide each year[7] - and reduces CO2 emissions by about a quarter at current UK grid carbon intensity. Again, this technology could prove vital in containing the impact of rising demand in developing countries, which Dearman expects to swell the current global fleet of 4 million TRUs to more than 15 million units by 2025. If that growth were satisfied through zero-emission rather than diesel TRUs, it would avoid PM emissions equivalent to those of 800 million diesel cars.

Most industrial economies have spare liquid nitrogen production capacity that could provide 'fuel' for significant deployment of the Dearman engine or other technologies. Since it is produced at night when power prices are lower, liquid nitrogen can become a novel energy vector to store and move 'wrong time' renewable or nuclear energy so it can be used on demand in grid or transport applications. But whereas most energy storages technologies absorb and generate only electricity, liquid air and the Dearman engine are about "warehousing" low carbon, zero emission *cold* <u>*and*</u> *power.*

Dearman is a radical rather than incremental approach to innovation. Instead of asking how to improve the efficiency of incumbent technologies by a few percentage points, we have started from the other end of the problem, and asked what service is required and what is the most resource efficient way to deliver it.

The Dearman engine and liquid nitrogen allow us to completely re-imagine transport refrigeration. The challenge is not to reduce the environmental damage of diesel TRUs - through incremental stiffening of EU emissions regulations - but to find an entirely new approach to delivering cooling. At a stroke, the Dearman liquid air approach eliminates NOx and PM emissions from transport refrigeration, and reduces carbon and cost.

This approach is now becoming more widespread, and in September last year refrigeration experts at London South Bank University along with Birmibgham and other Universities won their bid to lead the pan-European ‘CryoHub’ with €7 million funding from the EU. The three year project will research the potential efficiency gains that might be achieved by integrating Liquid Air Energy Storage with existing cooling and heating systems in refrigerated warehouses and food processing plants.

The potential environmental benefits of such step-change innovations are clearly huge, particularly in developing world, where often the absence of existing infrastructure makes it possible for countries to leapfrog to new technologies – as with the mobile phone. But to date such fundamental breakthroughs are rare in cooling, and most R&D investment goes on incremental innovation, which - as the Birmingham Policy Commission on Cold reported in 2015 - is highly unlikely to meet the scale of the environmental challenge, or open up the sustainable growth markets of tomorrow.

Britain has a good record in supporting radical innovation through DECC, DfID and Innovate UK and the EPSRC Grand Challenges. But it is time to bring cooling in from the cold; only then can we hope to turn the battle for the environment - and our future. T-ERA –a collaboration between the UK government, Midlands universities and companies to tackle some of the biggest thermal energy challenges, explicitly including the development of clean cold technologies not just heat, is a bold first step.

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[5] BP Energy Outlook, BP plc, 2016, https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2016/bp-energy-outlook-2016.pdf
[6] Disclosure: Toby Peters is the Founder of Dearman.
[7] 7 million premature deaths annually linked to air pollution, World Health Organisation, 2014, http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/