How nuclear lines up for a future free of fossil fuels

Bill Hedley explores the role reactors will play in kicking our chronic carbon habit

With the Paris climate change agreement now in force, the world must work out how to reduce carbon emissions to hit the targets of keeping global warming substantially below 2C (3.6F). That means no coal-fired power stations by 2025, with internal combustion engines phased out 10 years after that.

Power stations are relatively few in number, and relatively easy to replace, but vehicles need to stay small and light and – crash-prone as they are – few would desire a nuclear power source in a car. An electric car plugging into a nuclear plant is another matter, of course.

At the current rate of battery technology development, electric cars with the same range as petrol-engined vehicles will be ready around 2030. By that time, the additional generating capacity they will need will have to be online. Meanwhile, the model for internal combustion engines (generating their own power from a local fuel source, such as the petrol or diesel in their tank) can be readily adapted to work for biofuels and hydrogen vehicles, and a number of manufacturers have already released such options in their ranges.

Indeed, a mix of power sources will comprise the decarbonised future, particularly in the UK: wind, solar, hydroelectric, hydrothermal, tidal and nuclear. Most attention has been focused on the very visible, such as wind farms, and the very approachable, such as solar panels that can be fitted to domestic houses. But nuclear has also been quietly advancing, and is likely to take a significant load compared with the more site-specific and esoteric options such as tidal.

Nuclear power has also been around for longer than many other sources and benefits just as much from technological advances as any other engineered product. Nearly all currently operating reactors are of the so-called Generation II vintage, designed in the 1970s and 1980s as monolithic, complex machines.

Taking control
The national grid is going to rely more and more on renewable energy sources

Generation III and III+ are the standard now and have been running since 1996; these are easier to certify and operate, and are modular, so large components can be built off-site and slotted in, have much more precise control systems that improve efficiency and safety, and have longer lifetimes and simpler maintenance. The biggest difference from earlier designs is that the safety features are passive, not requiring manual intervention, but relying on the basic construction to safely shut down.

Generation IV reactors are a considerable departure, operating at much higher temperatures and in the majority of design studies are intended to produce hydrogen, potentially enhancing the market for hydrogen-fuelled vehicles. They are the product of the Generation IV International Forum (GIF), a 13-nation consortium, including the UK, with substantial nuclear power experience. The design goals of the GIF include lower levels of long-lived nuclear waste, inherent safety, lower running costs and far higher performance than their predecessors. Using supercomputer design and validation techniques not available to earlier generations, and operating under a new international regulatory regime, the first working reactors are not expected to materialise before the mid-2020s.

One of the more interesting and under-reported areas of active research in nuclear power is in small/medium reactors (SMRs). These are intended to be much cheaper and more flexible in deployment than large nuclear reactors, encouraging the use of nuclear power in more diverse places. Last March the Department of Energy & Climate Change introduced a competition to find SMRs suitable for UK use and "to gauge market interest among technology developers, utilities, potential investors and funders in developing, commercialising and financing SMRs in the UK".

While there is a bewildering array of potential designs being discussed, some common factors include making them from common subunits small enough to be built in factories rather than on-site, thus increasing quality and reducing cost. Big reactors are so expensive that they normally need state funding – the Hinkley C reactor approved last September is a joint enterprise by the state-owned French and Chinese national power companies, for instance. SMRs are achievable by private entrepreneurs, and promise advances similar to those seen in rocket propulsion in recent years that have reinvigorated the US space industry.

> Design goals [of the reactor forum] include lower levels of long-lived nuclear waste

One such private company is the British shipbuilder Cammell Laird, which said in October that it would be working with the UK Nuclear Advanced Manufacturing Research Centre (NAMRC) and the US company Westinghouse and to help develop the latter's SMR design.

Nuclear's role in the decarbonised future will look very different to today's image of big steaming boxes on remote shorelines. Combined with the flexibility of SMRs and the promise of Generation IV reactors to address waste issues and enhance a greater variety of energy uses via hydrogen generation, it seems highly likely that nuclear power will play a key role in global emission reduction in the years to come.