Visions of a smart carbon-neutral Scotland in 2070

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Are Extinction Rebellion right? Do we need to crash the economy to tackle the climate crisis? Maybe not. If mankind makes the right decisions, we should be able to live in comfort in a low-carbon world. It will involve big lifestyle changes, certainly, but not necessarily for the worse – maybe even for the better.

Let's imagine we're visiting a carbon-neutral Scotland in 2070.

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Our take-off from Schiphol airport in Holland is a strange experience. The hydrogen-powered boost trolley accelerates us quickly along the runway to the take-off speed of 130 knots without depleting the plane's batteries. There is a slight wobble as we separate from the boost trolley and float into the air. We climb gently and almost silently towards our cruising height, turning smoothly onto the most efficient course towards Edinburgh. The course is worked out by computer magic, allowing for forecast winds along the route and all the other planes using the same airspace.

Crossing the Dutch coast, we can appreciate for the first time the scale and ambition of the massive engineering works to upgrade the sea defences. The machinery and piles of material stretch as far as the eye could see in both directions, fading into the haze on the distant horizon. Rising sea levels are now an existential threat to Holland. Without this second massive upgrade to the sea defences, Schiphol would soon disappear under the waves.

Even with the plane dawdling at a frugal 360 knots, the flight time is the same as in 2020 thanks to the optimised routeing. We waste no time hanging around waiting for clearance to land – the computerised flight plans seamlessly interleave the arriving and departing planes. As we approach and land, most of the energy used to climb is recovered. The e-fan motors generate power as they slow us down, augmented on the ground by regenerative braking in the undercarriage. We are still braking hard as we whizz onto the angled exit ramp in a gentle high-speed turn. Getting off the runway more quickly saves precious seconds for each of the planes landing and taking off behind us. This and many other subtle changes and tweaks, each small by itself, increased runway capacity by nearly fifty percent. As a result, Edinburgh Airport was able to take over Glasgow's traffic when the Clyde threatened to flood the low-lying Abbotsinch Airport. Sea levels are now rising much faster than the worst predictions of fifty years ago, and Glasgow's runway is only a few metres above the 2020 sea level.

Scots' air travel became very different after the Covid-19 crisis. Business travel reduced significantly once firms discovered that they really could do much more of their business over the internet. More Scots

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holidayed at home as the climate became more pleasant, the British railway system was transformed, popular foreign holiday destinations were less attractive due to climate change and biodiversity loss, the carbon tax made long-haul air travel much more expensive, and well-timed low-carbon investments brought rapid economic growth. Edinburgh Airport was able to delay its plans for a second runway until the system architecture for zero-carbon civil aviation was settled, and the business case was clear. Air travel is now dominated by super-efficient medium-range electric planes (the competition between battery power and hydrogen fuel cells continues unabated). Long-haul travel is no longer point to point, except for the super-rich, but by a series of hops between hubs a couple of thousand miles apart. Transfers are really slick: modern technology makes queues for check-in, passport control, security and customs a distant folk memory. Now, if you dare, you can arrive at the airport ten minutes before the scheduled departure and not miss your flight. Ticket prices are dropping again. Edinburgh's ambition to become a key link in the air route from Eurasia to North America means that work on the second runway now proceeds apace. Fortuitously, the delayed decision let the airport take advantage of the very latest technology, doing away with the need for hydrogen boost trolleys and using the now-perfected carbon-absorbing concrete.

Because everyone on our plane cleared Scottish immigration and customs and biosecurity checks before take-off or in-flight, our onward connection is as easy as getting off a bus – in fact easier because of the automated baggage handling. The first-class passengers are picked up from the bottom of the steps, along with their bags, by autonomous hover-taxis. We walk off the plane and straight through the terminal to the auto-pod four-seat electric taxi that we'd booked when we were over the North Sea. We could have got the train all the way to our destination, but we are curious to sample this new mode of travel. Our bags arrive at the auto-pod at the same time as us, gliding silently behind us on a self-driving baggage truck. We set off in the autopod within five minutes of touching down, and we'll reach Glasgow by the time we'd have got through customs 50 years ago.

The autopod chooses the northern route to Glasgow, along the old M9 motorway. Motorways are now reserved for autonomous vehicles, which drive so much faster and closer together than human drivers that it's not safe for both to share the same road space. Our pod joins the back of a "platoon," about twenty vehicles so close together they slip-stream each other to save power. The driving processor in the lead vehicle sends its commands to all the vehicles in the platoon, so that if necessary, they all slow down together – no delays due to driver reaction time. Every now and then the platoons reorganise themselves. Each vehicle takes a turn at the front to share out the power-saving benefit.

Now we're passing the landfill site near Polmont. No more nasty smell – instead, a shiny biogas recovery structure collects the gas and burns it, feeding electricity to the power grid and capturing carbon dioxide to the Carbon Capture and Storage manifold a few kilometres away at Grangemouth. The flares from the Grangemouth refineries and chemical plants are also no more, the smell now sweet. All the methane is recovered from the high-value chemical processes and either burnt for electricity or chemically reformed into hydrogen or ammonia. The waste carbon dioxide is compressed to ninety atmospheres and pumped hundreds of miles into geological formations under the North Sea. In the 2020s, the Scottish

Government resisted calls from the Committee on Climate Change to commit to the unproven BECCS (Bio Energy Carbon Capture and Storage) fad. If Scotland had gone that way, the available CCS capacity would be used up by now, huge areas of landscape would be ruined by quick-growing monocultures frequently harvested, and our industry would have nowhere to put its unavoidable carbon emissions. As it is, Scotland still has plenty of CCS capacity. It is coining money from Carbon Credits, and also from the industries that most countries had to abandon because of their carbon emissions. These industries came to Scotland to use the CCS capacity to capture the emissions from their current manufacturing processes. They stayed to work with Scottish universities and research centres to develop the next generation processes that will get rid of the carbon emissions altogether.

Past Grangemouth, the low-lying farmland to the right of the motorway succumbed to the rising sea level and is now salt marsh. Economically unproductive, it's a treasure of biodiversity, a complete complex ecosystem of a type that used to be common in Europe and is now rare. While welcoming this in principle, SEPA (the Scottish Environmental Protection Agency) keeps an intense watch, bordering on the paranoid, for any hint that the warming climate and extended marshland might be attracting malarial mosquitos.

To the left of the road, Falkirk and Stenhousemuir look radically different from fifty years ago. Since the 2020s, all new-build houses in Scotland have been engineered to the German Passiv Haus standard – zero emission, and so well insulated and aired that for much of the year the heat generated by the occupants and electrical appliances is enough to keep the place warm. The houses were all built of locally sourced wood – a challenge in the early years, before the massive planting programme caught up with demand. A huge programme to retrofit external insulation and better draught proofing and ventilation to existing houses transformed both their appearance and their year-round comfort, while drastically reducing heating bills and carbon emissions. Demand for gas collapsed – hardly anyone in Scotland uses it for home heating or cooking any more. England took a very different approach – prioritising expensive electricity-powered heat pumps to heat the houses, along with more modest improvements in insulation, instead of solving the problem at source by removing the need to heat the houses in the first place[i].

Because much less energy is now used for home heating, Scotland has plenty of generating capacity to charge batteries and make hydrogen for aeroplanes and ammonia for ships. This makes it, along with Iceland, a hugely attractive hub for zero-emission aviation and sea traffic, because the energy surplus allows the airports and ports to offer cheaper refuelling costs than most of their competitors.

Between Denny and Cumbernauld, we cross the line of the new Hyperloop transit system from Glasgow to Perth, Aberdeen, and Inverness. Again, the land has changed since 2020. Instead of large green fields and dark solid blocks of forest, trees are everywhere, at varying density. Grazing animals move among the trees, most of them kept close together in the "mob grazing" method that improves the health of the soil and encourages trees to regenerate naturally. A bewildering range of vegetables grows in small lush plots and greenhouses among the trees. Some of the older trees are being harvested – not big areas clear-felled all at once, but selected trees plucked out from among the continuous woodland. In late November, the landscape is still green, though leaves are starting to turn brown in the crisp fresh autumnal air. A month

before Christmas, the weather is like it was in late September in 2020. Strange southern tree species flourish. Some of the old native species are declining, only surviving further north and higher up the hillsides.

As we head down the M80 and approach Glasgow, the platoon of autopods moves into the inside lane, slows to a hundred kilometres an hour, and starts to separate. Vehicles peel off. Ours drops us at Springburn, and a few minutes later we board a train for Milngavie. It's smooth! It's comfortable! It's clean! It's quick! It connects with a bus at the other end which takes us to our final destination, dropping us at the door. Gosh, how Glasgow has changed. Free integrated public transport in the Greater Glasgow area, and the convenience of autopods, means that hardly anyone has a car anymore. The trains and buses, now run by the Greater Glasgow Community Trust, are so good and so dependable that Scotland now meets the definition of a developed country – not a place where the poor own cars, but one where the rich use public transport[ii]. The downside of this is that Edinburgh Airport had to abandon its plan to use holiday-makers' cars parked for two weeks as a huge battery bank for refuelling aircraft – there are not enough privately-owned cars to make it work. Most of the car parks have been turned into solar farms.

Our hosts' house is cool without being cold, fresh and airy without being draughty. "Solar panels heat the water and provide some electricity," they explain "When we need more, it's imported from the grid. When we generate surplus, we export it to the grid if the price is right, otherwise it gets stored in the house battery or hot water tank." The house is smaller than professional middle-class people would have owned fifty years ago. Taking a lead from Scandinavia and Germany, houses are now valued as homes, not investments, and waste and ostentation are gently frowned upon in most social circles. Small, modular, factory-built houses and low-rise apartment blocks, with excellent heat and sound insulation, private allotments and well-maintained safe public spaces made houses affordable again and encouraged people to live nearer their work. Because hardly anyone owns a car, there are no garages or drives. Most people walk or cycle to work, or they use the free public transport. The section of the old M8 between Newhouse and central Glasgow is a linear public park, with flourishing trees and bushes and numerous bird species[iii]. Pine martens drove away the grey squirrels, and native red squirrels are a common sight again in Glasgow's parks.

Batteries and hydrogen fuel cells continued to drop spectacularly in price and improve in performance in the 2020s and '30s, banishing the worries about intermittency in renewable energy. Utility companies bought massive battery banks, and smart demand management lets you choose whether you want power all the time for whatever you've switched on at whatever the cost, or whether you want to save money by turning things off when the price is higher because there's not enough wind or too much demand. Excess power is used to produce hydrogen which has replaced liquid fuel in most applications that can't be satisfied by electricity. Massive investment in tidal turbines in the 20s and 30s provided enough baseload to replace the old nuclear power plants at Hunterston and Torness when they were phased out. Scottish tidal turbines are now sold all over the world, wherever there are tides strong enough to generate useful power. The power grids across the British Isles and near-Europe are all inter-connected to make sure there are no black-outs if any one area is short of wind or solar power. The English nuclear reactors were replaced with

new generation small modular reactors (SMRs) in the 2030s – British industry got its act together on these only just in time to avoid losing out yet again to the Americans. British SMR's are in widespread use across many countries – not Scotland, though, because the Scottish Government maintained its passionate opposition to nuclear power in any form.

Other changes since 2020 have been more incremental. The archaic three-bladed wind turbines are being replaced with solid state ones with no moving parts – far cheaper and more reliable, and a good source of export earnings. Wave power efforts were abandoned – too hard, and other forms of renewable energy were proving easier and more profitable. Hydro power also didn't make the comeback some expected. The easy half of Scotland's hydro potential was already exploited. The remaining capacity would be more expensive, the concrete in hydro dams caused a lot of carbon emission before there was any payback, and the land they occupied was more valuable for combined agriculture and forestry. The tidal turbine technology transferred easily to run-of-the-river hydro in fast flowing rivers, which made a useful but not decisive contribution to the country's energy needs.

All in all, Scotland is now a net carbon absorber across its whole economy. The huge transformation was funded by the last years of oil revenue and by patient money in pension funds, which were looking for long-term investments offering steady and sustainable returns.

There is one fly in the ointment, a shadow on the future horizon. Nuclear fusion has long been the holy grail of abundant "free" energy. Ever since the idea was first floated in the 1950s, right through to the 2040s, commercial fusion power has always been 'thirty years away.' The hugely ambitious and deeply troubled British fusion power project that started in 2020 is now finally bearing fruit. England expects to be self-sufficient in energy thanks to its fusion power programme within twenty years. Every other country in the world is now having to reappraise its energy strategy in light of this.

"What do you think of it all, then?" our friends ask us as we help them tidy away after dinner – a salmon dish with a wonderful concoction of exotic vegetables, fruit and seeds, all grown by regenerative agriculture businesses within fifty miles of Glasgow, settled with a fine malt whisky. Some things have stayed just the same as 50 years ago, for very good reason!

"The meal? Absolutely delicious, thanks."

"Oh, thank you – but I meant coming back to Scotland after fifty years away."

"Oh, everything looks fantastic. What a transformation! Clean, industrious, prosperous, modern, healthy people, and a healthy environment. Who'd have thought it fifty years ago? Scotland 2070 – healthy, wealthy and wise!"

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"You can't be serious!" we hear some of you shout, emulating the famous rant by John McEnroe at the line judges during the Wimbledon Tennis Championships when a marginal line call was judged either in or out. "That was definitely out! Over the line. Too idyllic, idealistic, unrealistic, even impossible!"

Well, let's look at the replay a few times to check.

Too idyllic? Maybe. Don't discount the hard work and amount of change involved to get there; and would life really be idyllic with all these new information technologies invading our privacy?

Possible? Yes it is. All but one of the technologies and the knowledge needed to create that future already exist, and most are proven at scale. The exception - no-one yet has a plausible concept for grid-scale wind generators with no moving parts. But ideas are being tried out, and who knows where that might get to in fifty years.

Realistic? Even the replay is not quite clear. That's down to us. If we sit around waiting for it to happen to us, it won't. If we want it, are willing to commit to the vision, and work to make it happen, why not? It would need leadership, money, and resources - like everything else we've discussed in this book. The resources we mostly have. Leadership and money are questions we discuss in the final chapter, and intend to come back to in future work.

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[i] This appears to be the approach indicated in the Future Homes Standard consultation issued in October 2019. https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings

[ii] Former mayor of Bogotá Gustavo Petro, quoted by Ellie Harrison in The Glasgow Effect, Luath, 2019.

[iii] Thanks to Ellie Harrison writing in "The Glasgow Effect" (Luath, 2019) for this idea!