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The reality of relying upon renewable power: a personal view

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I have written a number of papers on the costs and performance of wind power and other forms of renewable energy. Even serious empirical research provokes responses along the lines that any questioning of the merits of renewable energy amounts to original sin or blasphemy. There is little that I – or anyone – can do to convince those who treat the superiority of renewable energy as an article of faith. Still I wonder how much practical experience such commentators have of the reality of relying solely on renewable power in commercial applications. For this reason other readers may be interested in what I have learned as an economist faced with the practical issue of relying upon renewable energy.

The context is that about seven years ago I set up a small wireless broadband network serving my local community. This has grown into a social enterprise that provides high speed broadband service to about 600 properties in the South of Scotland. We are good at what we do and as a consequence we are expanding quite rapidly and cover a very rural area of about 1,500 square miles. We serve properties and settlements that BT/Openreach find too hard or expensive to deal with. To do this, we rely heavily on relays in locations that are far from the nearest source of power and operate off-grid. Since the South of Scotland from the Ayrshire coast to the North Sea has numerous wind farms a casual observer might think that off-grid operation is relatively straightforward. It would make our lives much easier if things were so simple!

Even though we serve isolated properties and settlements our customers are as concerned as urban residents about having a reliable broadband service. They or their children are equally unhappy about interruptions to their Zoom meetings or Netflix viewing sessions as any family living in the centre of Edinburgh. They understand that we have to cope with much worse weather conditions than most operators, so occasional outages due to extreme weather are unavoidable. We work to meet an overall target of 99.5% availability for our service. Since weather and other factors outside our control account for most outages, we design our network with sufficient backup to achieve at least 99.9% reliability for power supply at all of our relays –including the off-grid units. That is a difficult target when relying solely on renewable energy in Scotland. National Grid's alarms this winter about meeting demand is merely a much bigger version of the same problem.

The problem for any off-grid site in Scotland is maintaining power supplies during the winter months from mid-November to end-February. Solar panels, which are our main source of off-grid power, yield little during this period – partly because the length of daylight is short and partly because the sun is very low in the sky which means that insolation levels are low even when the sky is clear.

Almost all of our off-grid relays are sited in hilly areas at 350+ metres above sea level. You might think that these sites are all windy, but wind turbine yields are extremely variable. Extended periods (five or even ten days) of low wind combined with fog or mist and limited light occur three or four times every year. As an illustration we have just experienced a period of fifteen days (from December 26th 2020 to January 9th 2021) with minimal wind and solar output. Freezing conditions make such episodes worse because the performance of batteries degrades in sub-zero temperatures. Even with large amounts of battery backup we find ourselves having to transport replacement batteries all too often.

Let me give a sense of the numbers. We choose our equipment and design our off-grid relays to minimize power consumption. Most of our relays have a continuous power demand of 40-60W, little more than an old-fashioned incandescent light bulb. We use 12V AGM deep cycle batteries which cope better with variations in temperature and state of charge than regular car batteries. Lithium-ion batteries are, at least for now, too expensive and have too short a life for this kind of application. A continuous demand of 60W translates to 120 Amp-hours (Ah) per day. Even deep cycle batteries cannot be discharged completely without drastically shortening their life, so a bank of eight 120Ah batteries will power a relay for up to six days.

To operate such an off-grid relay at 99.9% reliability (less than 96 hours of outages per year for a set of ten relays), a standard relay with a continuous consumption of 50W has 900W of solar panels, a 350W wind turbine and eight to twelve batteries plus some occasional load shedding – i.e. switching off non-critical links. This translates to peak generation capacity that is more than twenty times the continuous demand plus enough battery capacity to meet six to eight days of consumption. Allowing for the ancillary equipment - charge controllers, voltage monitors, etc - plus installation, the cost of such a setup is about £6,500 excluding VAT. That amounts to a capital investment of more than £100,000 per kW of continuous demand. For us the breakeven point between on-grid and off-grid is

where the power cable would run for about 1,200 metres because the power loss on longer cables is too high unless they are run on three phases which increases the total investment.

This is the engineering reality of using renewable power with no grid backup. There is no dogma about the choice: we choose the best solution that is consistent with what our landowners will accept and our requirements. The lesson is the high level of redundancy that is necessary to provide the level of reliability that is expected by customers in modern economies. Bear in mind that 99.9% reliability is nothing special: the power company that serves the central area of Hong Kong has a reliability standard of 99.99% (less than one hour of outages per year) mandated by the government.

Viewed in a different light, it would be much easier for us at our off-grid sites if we could switch off relays between, say, midnight and 6 am whenever both batteries are running low and wind generation is low. That is what load shedding, referred to in many plans to cope with variability in renewable generation, means in practice – but without backup generators or alternative sources of non-renewable generation. But what happens to our customers who work with clients in Asia or who have families in Australia or California? Or what, on a larger scale, about hospitals, hotels and businesses who rely upon 24/7 availability of broadband and network services?

Thirty odd years ago when the current wave of enthusiasm for renewable energy started, many of us involved saw the huge benefits from bringing electricity to rural areas in developing countries. It was similar to using hand pumps to provide clean water in villages with no access to piped water. Whether it was getting access to crop prices, pumping water for irrigation or watching TV in the evenings, even a limited and irregular supply of power provided by a few solar panels, some batteries and an inverter can transform lives for billions of people living off-grid.

However, that is not the world of rich or even middle income countries today. We have built our economies and lives on the assumption of plentiful and almost completely reliable power, broadband and other networks. At the less critical end of the spectrum I invite any reader to monitor

our support lines if there is an outage in the middle of the Scotland vs England rugby match. Even occasional buffering of a Netflix or Zoom stream is a “disaster”. Or consider the threat to people’s health and transport chaos caused when there was a relatively brief power outage affecting London and South East England in August 2019.

Some argue that the problems of ensuring high levels of reliability in a power system entirely dependent on renewable generation can be largely mitigated by scale, in effect by pooling sources of generation over a large area. There are, indeed, some economies of scale but they are smaller than might appear at first glance. It is still necessary to have high levels of excess capacity – not at one location but spread across the system – and any reduction in total capacity per unit of continuous demand is offset by the need for heavy investment in transmission capacity. In addition, on a small scale it can be easier to rely upon diversification across types of renewable generation, something which may not be feasible at a regional or national scale.

The central lesson from this story is that the key issue for power systems which rely upon renewable generation is not energy but system stability and reliability of supply. With sufficient capital it is easy to generate electricity at a marginal cost that is close to zero, but guaranteeing high levels of reliability is much more difficult and expensive. Our small network is a microcosm of the trade-offs that face rich economies that wish to switch entirely to rely upon renewable sources of power. Such systems will always be highly capital-intensive: that is an inescapable consequence of using current resources in place of stored energy in the form of fossil fuels. The trade-off is between:

- accepting some combination of a moderate increase in system capital-intensity plus a substantial reduction in reliability relative to the level that people living in rich countries have learned to expect; or
- paying for a large increase in the overall capital-intensity of power networks so as to maintain something close to current levels of reliability.

Politicians and enthusiasts for a renewable transition are strongly inclined to fudge such trade-offs. The managers of existing power systems are rarely willing to deliver unwelcome messages and may expect to benefit from the large capital spending that is required by the transition. As a consequence, most public discussion of the necessary choices relies on vapid good intentions rather than a realistic appraisal of the costs and benefits of the alternative options.

There is a further issue, which is that the costs and difficulties of relying upon renewable power are not evenly spread. Much of the support for green solutions comes from people who live in cities and other urban areas. Advocates give the impression that they have no idea what it is like to live in thinly populated rural areas, where distances are large and public services are either minimal and/or unreliable. In my case the distance to our local shop is 10 km and to the nearest town with basic public services is 15 km. And we live barely 40 km from Edinburgh, not in a remote part of the Highlands! Rural Scotland has lots of wind farms but little in the way of public services or, indeed, benefit from those wind farms.

This matters because it is rural areas that are likely to experience the most serious costs of a reduction in system reliability. To extend the personal example, we experienced a series of power

cuts on Christmas Eve 2020 which caused our primary heating system to fail due to a power surge. It was out of operation for 6 days during the coldest weather of the 2020-21 winter to date. Such episodes have occurred in the past and we have invested in alternative sources of heating. Hence, we coped, albeit at a significant cost. That is the point. Around the world, the costs of reducing system reliability are often high but they fall unevenly on customers, especially on those living in rural areas. All too often those who offer simplistic calculations of the costs of relying upon renewable power take no account of the consequences for system reliability and the costs that fall on those who have to cope with less reliable power supply.

To emphasize the general point: the central challenge of the transition to renewable power is not the generation of electricity. That is the easy part. Rather it is the difficulty and costs of ensuring system reliability that must be addressed. Up to now, all electricity systems depend upon a legacy of investment in storable energy resources, primarily in the form of fossil fuels but with some storage hydro. None of the operators has any real idea of how they will function without being able to call on such backup resources. While scale will permit options that are uneconomic for small operators, the lesson from experience is that the investment and operating costs required to maintain system reliability in electricity systems dependent on intermittent renewables are likely to be very large.

Finally, we should bear in mind that not all communities or countries will – or should - make the same choices, in large part because conditions around the world vary so much. It is simply absurd to assume that choices which make sense for urban populations in Europe are either feasible or sensible in the remoter areas of Eurasia – for example Siberia or the huge extent of arid or semi-arid land from the Pamir Mountains to Mongolia. The inclination by some to frame the renewable transition as a moral issue is not the most constructive approach to dealing with the different trade-offs that have to be made in different circumstances. In many circumstances this can appear either arrogant or tone deaf when directed to populations and governments who face different choices and may feel that they are being asked to sacrifice the benefit of economic growth that those living in rich countries take for granted.