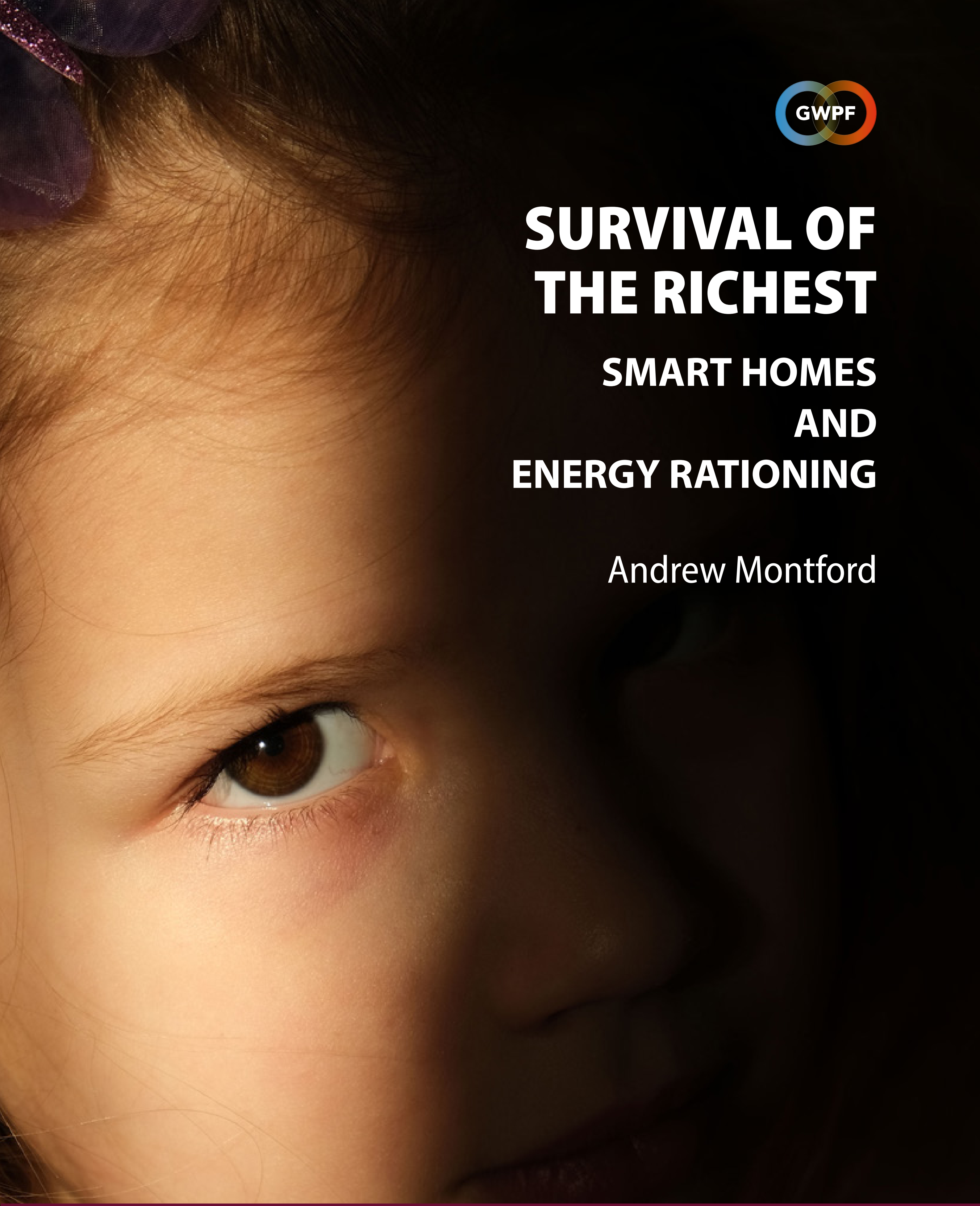

# SURVIVAL OF THE RICHEST

## SMART HOMES AND ENERGY RATIONING

Andrew Montford

**The Global Warming Policy Foundation**
Briefing 56

**Survival of the Richest: Smart Homes and Energy Rationing**

Andrew Montford



## Contents



## About the author

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## Summary


- National Grid and the distribution grid operators need to be able to shift electricity demand away from peak periods.
- They intend to do this through smart meters and pricing.
- But at many times, pricing incentives will be insufficient, and consumers will be compelled to switch off.
- Smart meters allow this to happen.
- Regular energy rationing is likely in the near future, but will be inadequate to deal with long lulls in the wind, with potentially disastrous consequences.


> “Without either significant nuclear or gas generation, or huge supplies of hydrogen storage, we just turn off the supplies, in a survival-of-the-richest form of natural selection.”

Grid insider, in an email to the author

## 1. Introduction

In 2011, the chief exective of National Grid, Steve Holliday, explained to listeners of BBC Radio 4's *Today Programme* the transformation that the electricity system was about to undergo and what it would mean for ordinary householders:

> The grid is going to be a very different system in 2020, 2030. We keep thinking that we want it to be there and provide power when we need it...Families will have to get used to only using power when it [is] available, rather than constantly.[1]

This paper looks at how far we have come in the last ten years, and how close we now are to seeing the realisation of Holliday's vision.

## 2. The reliability of the grid

The reliability of the electricity grid depends, among other things, on two important factors. First, there must not be more demand than the cables and transformers can cope with: too much and the fuses that protect them will blow. Second, there must not be demand for more electricity than can be generated.

The electricity grid can be thought of as divided into two parts: the high-voltage transmission network, and the lower-voltage distribution network, run by the distribution network operators (DNOs) – familiar names such as Scottish and Southern Energy Networks and UK Power Networks.

National Grid ESO, the electricity system operator, is responsible for ensuring the balance of supply and demand across the country, and for dealing with any regional imbalances by transferring power across the network. This has traditionally been a relatively straightforward task, involving monitoring demand as reported by suppliers, and then calling on extra generation to meet any shortfall as it happens. We have lots of so-called ‘dispatchable’ power stations – chiefly gas-fired – that can quickly ramp up output when required, responding to the regular changes in demand: the daily cycle, with peak demand each evening, and the seasonal cycle, with demand rising over winter, when lights are switched on, and in some homes electric heating too.

Overloaded cables are primarily the concern of the DNOs, although the distribution grid has been designed to make this a relatively minor worry. In essence, the low-voltage wires and transformers that carry electricity to homes and businesses are sized so as to easily cope with peak demand from the houses they supply, and there is also headroom for one or two homes on each local circuit to have much higher demand. The assumption is that not everybody will take a high load – say an electric shower – at the same time. On the rare occasions that they do, fuses will blow, killing the electrical load and ensuring the wires don't melt. It's a passive system, which requires little intervention, and one that has been extremely reliable over the decades.

Plans to decarbonise the economy mean a fundamental change to this comfortable status quo, both for National Grid and for the DNOs.

Replacing fossil fuels with intermittent renewables makes the task of balancing supply and demand much harder for National Grid. As noted above, with dispatchable generators on tap, it is simple to increase supply. But most of the UK's dispatchable capacity comes in the shape of gas-fired power stations, which are supposed to be eliminated from the grid in coming years.[2] When they are gone, the grid will only have a handful of hydroelectric and biomass-fired plants that can be called upon. These will be insufficient to meet the needs of the grid.

Meanwhile, decarbonisation will involve the wholesale electrification of the economy, including the two biggest domestic sources of energy demand: heat and transport. As this happens, loads on the DNOs' cables will soar. However, the cost and upheaval of putting in larger wires would be enormous, and would involve digging up every urban street in the country,[3] so DNOs are keen to find alternative approaches. Similarly, National Grid will struggle to deal with all these new sources of demand as well as the vagaries of renewables generation. They too are looking for new ways of working.

## 3. Smart meters

Overloads on the distribution grid are most likely in the evening peak, when cookers and televisions are switched on. This peak is being accentuated as more and more electric vehicles (EVs) appear. Owners tend to switch them on in the early evening when they return from work. The situation will become worse when heat pumps start to be installed on a large scale.

DNOs can minimise the risk of overloaded wires by shifting loads from the evening peak to the middle of the night, when demand is lower. The principal tool they expect to use to do this is the smart meter or, more precisely, price signals. Smart meters will allow domestic electricity bills to be moved to so-called 'half-hourly settlement', allowing customers to pay a price that varies throughout a 24-hour period – either on a fixed schedule, like the old Economy Seven system, with low prices during the night and higher ones during the day, or priced dynamically according to the state of supply and demand. The proposals to make this happen are already being considered.[4] However, so-called 'time of use' tariffs have been available in the US for many years and have suffered from very limited take-up by consumers, who appear in general to want to avoid the risk of very high prices at times of high demand or low renewables generation.

Smart meters are just one part of what the government and those involved in electricity supply imagine will eventually become a smart home. The vision is of a world in which smart appliances and smart meters are connected through a home area network (HAN) to a communications hub and so to planners at the DNOs and National Grid. The equipment is already being rolled out. After a false start – the government mandated smart meters be installed before some of the design parameters had been finalised, so that the meters installed didn't have the necessary capabilities – second-generation 'SMETS2' meters are now being installed. Alongside them, the communications hubs are also going in.

The first generation of smart meters enabled suppliers to access them remotely, extracting data and, where bills were unpaid, switching off the supply entirely. SMETS2 meters have two circuits that can be switched off independently of each other, allowing more subtle control, such that only some appliances need be switched off, while key ones, like lights, can be left on.[5]

Smart meters and communications hubs can be put in place quickly, because they can be mandated by government. However, appliances are purchased by consumers, and so 'smart' variants – meaning they can communicate with the outside world via the HAN – will appear more slowly. The first ones will be EV chargers – the government has already mandated that all future EV chargers be smart – and heat pumps and a range of other devices will follow: everything from showers to ovens to fridges.[6]

## 4. Load shifting for cars

Although an EV can be charged on a standard 13-amp supply, drawing approximately 3 kW of power, this is very slow, and it is widely assumed that EV owners with off-street parking will want fast chargers, drawing 7kW. While simultaneous fast charging by two or three EV owners might be manageable, any more would probably put an intolerable strain on the local wires at peak times. Reproduced across a large area, widespread EV charging might even threaten reliability of supply over the distribution grid as a whole.

Still, the ability to travel on a whim is highly valued by most of society, and few would want to be caught without any transport in the event of an emergency. Any perception that EVs would not deliver such convenience would represent a significant barrier to their uptake. Those involved in trying to promote EVs are therefore walking a tightrope.

### The short-term fix

With EVs already being taken up in significant numbers, but with the smart meter programme delayed by its false start, it has proven necessary for DNOs to develop a stop-gap solution.[7] In areas that have a significant risk of overloads, monitoring equipment is being installed in substations, with EV owners in the area asked to install a device on their chargers that can, on a signal from the substation, reduce the current. In other words, the 'back office' controller in the substation rations the electricity that can be delivered, dividing it equally between households involved.[8] It is said that there will be limits on how often rationing measures could be imposed,[9] but it is hard to see how this could apply in practice because failing to impose them would risk power cuts.

The risk of power cuts also makes it very hard for EV owners to refuse to hand over control of their EV chargers, thus giving to the DNOs hope of good takeup. Moreover, the cost of the scheme is socialised among all customers, even though it is likely only the wealthy who will have EVs.[10] The approach is thus extremely regressive.

That said, on any given feeder circuit, the imposition of these measures would then start the clock ticking for the DNO: they would have a maximum of 18 months to put in place a permanent solution:

- upgrade the wires and substation, or
- install a 'smart' solution, based on demand management.

Given the overwhelming cost of upgrading the wires and substation, the smart solution is likely to be preferred, although as we will see, load shifting may prove inadequate.

## The longer term

The longer-term solution is, as noted above, based around smart homes, and in particular around the concept of shifting demand away from the evening peak via pricing. The primary legislation to allow this to happen is already in place, with only a Statutory Instrument required to set all the wheels in motion.[11] In 2019 the Government announced that it was going to consult ahead of making introducing such a regulation. [12]

It is envisaged that with time-of-use tariffs, consumers will respond to price signals by shifting their charging to the night. From 2022, all chargers installed for private use – including workplace chargers – must be 'smart'. By default, users will be put onto a schedule that does not allow them to charge their vehicles during peak periods, which the legisation defines as 8–11am and 4–10pm on weekdays.[13] It is hoped that this will shift considerable load to the night. However, smart chargers will also allow users to override this setting, so that the wealthy will enjoy the convenience of being able to charge at a time that suits them.

The industry has been unsure about whether the pricing approach will work, and has pushed for a 'managed charging' solution, in which decisions about charging schedules were taken out of the hands of their owners, and left to the DNOs or National Grid. One respondent to the EV charging consultation that preceded the legislation said:

> Increased customer choice will reduce reliability of a managed charging solution...If a relatively small number of customers did not respond, the system would be ineffective which would risk local electricity supplies.[14]

And as another respondent put it, 'Increased [consumer] choice seriously undermines' grid reliability.[15]

It appears, however, that the Government has decided to take a risk with grid reliability – by allowing override of default schedules – in order to make smart chargers more palatable to consumers. And of course, the smart functionality will allow National Grid or the DNOs to switching off chargers remotely in an an emergency.

## 5. Load shifting for heating

Decarbonisation of homes will involve considerable expenditure on insulation measures, but after that, it is necessary to have a source of zero-carbon heating. This is mostly expected to come from heat pumps, but there may be scope for smart storage heaters too.

Heat pumps draw heat from the air or ground, the idea being that they will deliver more energy than they consume, perhaps on average 2.5–2.8 times more.[16] That means that in normal times, a heat pump will deliver 6 kW of heat from 2 kW of electricity input. The load a heat pump puts on the grid is thus not as large as an EV charger. However, heat pumps become considerably less efficient in cold weather. In sub-zero temperatures, the load might rise to over 5 kW, a level of demand that would cause considerable problems to DNOs once replicated over all the homes connected to a substation.

Work on shifting heat pump loads is less advanced, because heating homes is seen as less 'optional' than EV charging, and because the load is hard to shift: heat pumps work best when they run constantly, so if they are switched off during the evening peak, they will then have to work hard, and therefore inefficiently, to restore the desired temperatures. This means that the gains to the grid are at least partially offset by inefficient use of the heat pump that results.

That said, heating homes over the evening peak during cold spells is likely to be impossible without completely upgrading all the cables and wires, so considerable thought is being given to the question of how load shifting can be achieved without consumers noticing. One option would be the use of heat stores that could deliver heat to the home when electricity was unavailable. At one extreme this would just be a hot water tank, although these would be 2–3 times larger than the already sizeable ones used for domestic hot water storage.[17] This approach would therefore involve homeowners giving up large amounts of space. So-called 'heat batteries' use less space but are much more expensive.[18] Another idea is to store heat in the body of the house itself. It is imagined that a smart thermostat could be programmed to overheat the house in the afternoon, and then switch it off in the early evening. This might mean that the house was not unbearably cold by the time demand started to tail off and the heating could be switched back on again.[19]

As with EV charging, it is assumed that demand shifts will be brought about by pricing signals, 'nudging' consumers into the desired 'behaviour'.[20] In this scenario, there will be no compulsion to switch off heating during the evening peak, but the costs of refusing to do so may well be intolerable for all but the wealthy. For the poor, there would be a dilemma: pay through the nose, or go cold.

As noted above, heating is generally not seen as an optional extra, and grid managers are therefore concerned that not enough people will be willing to switch off. They therefore want to extend the 'managed service' concept proposed for EVs to heating systems and then to other appliances.[21] Their plan is to have all of your key appliances under their control. In other words, they would be able to adjust the temperature on your heating remotely. This is said to be happening in other countries already – during a recent heatwave in Texas, consumers reported that their air-conditioning units were adjusted remotely.[22]

## 6. Smart homes and wind lulls

As noted at the start of this paper, the need to shift load can arise in two different scenarios – when there is too much demand for the cables and transformers in the distribution grid to carry, and when there is too little electricity available to meet overall demand. The future electricity grid is supposed to be based on wind power, and in particular offshore wind, but at times there can be little or no wind anywhere in the UK or its territorial waters. Such lulls can sometimes last three weeks or more. It is sometimes claimed that in a net zero world, the gap would be filled by zero-carbon dispatchable power – presumably gas-fired power stations with carbon capture and storage (CCS) – or electricity stores of some kind.

However, after the closure of the Petra Nova pilot plant – the great white hope for the technology – CCS appears to be a dead end, and electricity storage is barely off the drawing board. Hydrogen looks impossibly expensive, and questions remain over the cost and scalability of cryogenic approaches such as liquid air. Few commentators appear to have grasped the scale of storage that would be required to meet demand should we experience a three-week lull in the wind, as happens with some regularity. What is worse, very low temperatures tend to coincide with very low wind speeds. The low temperatures would cause a surge in demand, particularly from heat pumps, and would reduce the capacity of batteries, so there is a double whammy of rapidly rising demand and declining ability to meet it.

National Grid is therefore looking to demand-shifting to help them deal with these situations, although in truth, it can only be a solution for shorter lulls. Since the relevant technologies should all have been put in place in order to deal with the DNOs' issues, all that will be required to allow this to happen are the necessary legislative changes, and also operating procedures to ensure that all parties who need access consumer devices are working in harmony.

Throughout the official papers on the development of smart energy systems, there are references to other parties being able to control domestic appliances.[23] As well as National Grid, this will include sellers of balancing services, who would ask homeowners to sign up to have their appliances brought onto the grid as voluntary participants, taking payment in return for allowing their appliances to be switched off. Consumers might potentially even become suppliers to the grid, by allowing home batteries – in EVs or backup power systems such as Tesla's 'Powerwall' – to be drained in time of shortages. However, in a decarbonised grid, such 'flexible response' capacity is an imperative, not an option, so in the event that consumers refused to switch off in sufficient numbers, compulsion would have to be used. In other words, their appliances would be switched off remotely. The impact on lives and businesses caused by frequent interruptions to power need hardly be mentioned.

As an aside, it is worth noting that the system we are about to attempt to create will incorporate hundreds of millions of consumer appliances, supplying the grid as well as drawing from it, all of which will have to be monitored and coordinated by a central computer. The system will be mind-bogglingly complicated, and there will therefore be a severe risk of catastrophic failure. A cyberattack could bring the whole country to a halt. But those are subjects for another day.

Of course, if power is in short supply, then prices will be high, so consumers will be incentivised to minimise consumption, but as noted above, some sources of demand, such as heating, are hard to shift, and the grid will be forced to take control. At such times, it is likely that National Grid will prevent any EV charging at all, and they will probably reduce heating to a bare minimum. As one study commissioned by the government put it:

> Allowing indoor comfort tolerances to relax during rare extreme weather may hold the answer to an acceptable compromise between cost and performance...Investigation into how this compromise could be offered in a way which is attractive to customers, while protecting their sense of control and comfort, would be an essential next step.[24]

A lull in the wind lasting more than a day or two would probably lead to an emergency if it coincided with low temperatures. We have already had a taste of this new world. One UK electricity supplier, Octopus Energy, already allows its customers to adopt a pricing regime – the 'Agile' tariff – that responds to grid prices. On one day in January 2021, customers on this tariff saw an increase from 14p/kWh at breakfast time to 35p/kWh by mid-morning. Prices would have gone higher had the tariff not included a price cap.

Similarly, in Texas, where 60% of homes are electrically heated,[25] some customers recently clocked up bills running into thousands of dollars in the space of a few days, when severe winter weather led to a shortage of electricity.[26] More than 80 people died of the cold.

It was no better in summer when, with temperatures soaring, Texas grid managers were forced to reduce electricity demand from air conditioning units by  remotely raise temperature settings on consumer themostats.[27] There can be little doubt that similar measures would be required in the UK, were we to experience a long lull in wind generation during the winter months.

## 7. The ethical dilemmas of electricity rationing

The need to ration electricity in response to the needs of both DNOs and National Grid will raise a host of ethical questions that will represent a minefield for everyone involved, including politicians.

These will start to emerge as soon as the interim solution for EV charging comes into use. When the management system on a distribution transformer detects a potential overload on a cable, how should the demand reduction be apportioned between the different chargers attached? Some of these may be 7 kW machines, but some may only be 3 kW. Do the 7 kW devices get reduced to 3 kW so that everybody can charge slowly? Or is there a proportionate reduction in everybody's charging rate?

Once other appliances are involved it becomes more difficult. Assuming pricing incentives have proved insufficient to reduce demand, and grid operators are stepping in to save the system, how do they make this happen? Do they switch off everybody's EV chargers first? Or is that decision left to households? The questions are innumerable:

- There are hundreds of different rates for domestic electricity from a multitude of companies. Do any of these have priority for electricity?
- Some suppliers guarantee that the power they supply comes from renewables. If there is no wind power available, are these customers the first to be switched off?
- Do some users have priority for power? Disabled drivers, perhaps? Doctors and nurses? Members of Parliament?
- What are the relative priorities for street EV chargers and home chargers?
- Does a heat pump with radiators have priority over a household with underfloor heating as the latter has a much longer response time?

## 8. Smart homes and the poor

Smart homes would be very bad for the poor. As we have seen, the main mechanism for load shifting is going to be pricing, and it will be the poor who are most likely to respond to these signals, switching off their heating to help save the grid. They will be unable to afford measures such as heat batteries, which the wealthy can use to protect against a temporary loss of power. The effects of smart homes on the poor will therefore be shameful for our country. We will move from a society in which the majority stay warm through the winter to one in which the poor go cold when the wind fails to blow for a couple of days. This is the opposite of progress.

Even now, the cost of the interim solution for EV charging, which will benefit only wealthy early adopters of EVs, is being socialised. The poor will never benefit from all the expenditure on systems to support EVs because they will be priced off the roads by the shift away from fossil fuels. It is hard to justify costs being shared by all when the benefits are enjoyed only by the wealthy.

In its smart charging consultation, the government says:

> If smart charging is too complicated, too inconvenient, or doesn't offer sufficient benefits to consumers, then consumers will not engage. Smart charging solutions must therefore be affordable; good value; simple to engage with; and convenient.

But if the whole system fails to deliver this, consumers will be left with a *fait accompli*: a system that is expensive, poor value, overwhelmingly complicated, unreliable and inconvenient. It will be a national security threat to boot, and it will have ruined the lives of the poor.

## 9. Energy rationing

The DNOs appear to believe that extraordinary reductions in demand will make smart meters feasible. For example, National Grid's Future Energy Scenarios predicts reductions in demand for energy for road transport of up to an extraordinary 60–70%.[28] Meanwhile, residential demand for electricity for other purposes only rises by a slightly more modest 13–47% depending on the scenario – the result of the heat pump gains and some insulation works. Together, these two assumptions allow the DNOs to assume that by enforcing smart meters everywhere, they will largely be able to avoid upgrading the network.

But if this is to happen in practice, many different factors need to fall into place.

While electrification of road transport undoubtedly brings reductions in energy usage – electric motors are more efficient per unit of energy consumed than petrol ones – the predictions also rely on dramatic reductions in the number of vehicles: by as much as 40% in one scenario. Alongside a steady rise in population, that figure would imply that by 2050, car ownership will have fallen from around 1.4 vehicles per household to as little as 0.6. It is highly unlikely that a democracy could deliver this kind of transformation.

Similarly, as noted above, the smart homes programme needs widespread adoption of time-of-use billing, something that hasn't proven successful when it has been tried in the past.

Failure in either of these two areas could therefore prove disastrous for the DNOs.

And even if disaster is avoided in the distribution grid, a four-week lull in the wind, similar to the one seen in the spring of 2021, would undoubtedly lead to rationing, wreaking havoc across the country. In the final analysis, that is what smart meters and smart homes are intended to enable.

### Acknowledgement

I am grateful to two reviewers – one in National Grid ESO and another within one of the DNOs – for helpful discussions and for comments on the manuscript.

## Notes

1. Quoted in 'Era of constant electricity at home is ending, says power chief'. *Daily Telegraph*, 2 March 2011.

2. Although carbon capture and storage is often put forward as a way to allow gas-fired units to keep operating, that technology now appears to be dead in the water https://www.hartenergy.com/news/power-plant-linked-idled-texas-carbon-capture-project-will-shut-indefinitely-192111. That said, government continues to throw money at it.

3. Travers M. *The Hidden Cost of Net Zero. Rewiring the UK*. Briefing 48, The Global Warming Policy Foundation, 2020.

4. DCC. *Business and Development Plan 2020/21–2024/25*. Data Communications Company, 2020. https://www.smartdcc.co.uk/media/4144/20143-dcc_report-and-plan_v8.pdf. See p. 8.

5. Sometimes this 'auxiliary load switch' is incorporated into the meter, and sometimes it is a separate device, which the meter can control over the HAN.

6. The British standard, published in final version in May 2021, refers to '1) heating, ventilation and air conditioning appliances (HVAC); 2) cold appliances; 3) wet appliances; 4) battery storage; and 5) smart EV chargepoints.' PAS 1879:2021, Energy smart appliances – Demand side response operation – Code of Practice. British Standards Institute, 2020. https://standardsdevelopment.bsigroup.com/projects/2019-01575#/section.

7. *Consultation on the Interim Solution for Domestic Managed Electric Vehicle Charging: Protecting local electricity network assets in the absence of market-led solutions*. EA Technology, 2019. https://www.eatechnology.com/wp-content/uploads/2020/01/Smart-EV-Consultation_Interim-Solution-for-Managed-EV-Charging-Issue-1.0-1.pdf.

8. EA Technology. *Consultation on the Interim Solution*, op. cit. p. 7.

9. No more than 2 hours per day, no more than 8 hours over 30 days.

10. 'The DNO would bear the costs of all procurement, installation and operation, recognising that these would ultimately be passed onto all customers through their energy bills'. EA Technology, *Consultation on the Interim Solution*, op. cit. p. 36.

11. See Automated and Electric Vehicles Act 2018, s15.

12. HMG. *Electric Vehicle Smart Charging Consultation*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/817107/electric-vehicle-smart-charging.pdf.

13. Department of Transport. *Electric Vehicle Smart Charging: Government Response to the 2019 Consultation on Electric Vehicle Smart Charging*, July 2021. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015285/electric-vehicle-smart-charging-government-response.pdf.

14. EA Technology. *Smart EV Charging Consultation*, p. 8.

15. EA Technology. *Smart EV Charging Consultation*, p. 9.

16. R Lowe et al. *Final report on analysis of heat pump data from the Renewable Heat Premium Payment (RHPP) Scheme*. UCL Energy Institute, 2017. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/606818/DECC_RHPP_161214_Final_Report_v1-13.pdf.

17. Hinsley J et al., *Integrated Electric Heat – Upgrade Analysis Final Report*. Energy Technologies Institute, 2018.

18. Corfield A. 'Maximise your renewables: Sunamp heat batteries'. https://acarchitects.biz/self-build-blog-sunamp-heat-batteries/.

19. Hinsley J et al. 2018, op. cit. 'In addition to dedicated thermal storage, the control strategy could utilise greater deviations from the target room temperatures, effectively recruiting the thermal mass of the building as additional storage capacity, especially when external or cavity wall insulation or peripheral solid floor insulation is in place. Studies would be required to explore the range and timing of such deviations that can be allowed without being unacceptable to the occupants.'

20. BEIS leaflet. *Smart Meters and Demand Side Response*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/579774/291116_-_Smart_meters__Demand_Side_Response_leaflet_-_DR_-_FINAL.PDF.

21. *Smart EV Consultation Interim Solution*, op. cit. p. 26.

22. https://www.dailymail.co.uk/news/article-9703747/Texas-residents-say-temperature-smart-thermostats-raised-remotely.html

23. BEIS, *Response to Consultation on Smart Metering System Proportional Load Control*. 28 October 2019.

24. Hinsely J et al. 2018, op. cit.

25. McDonnell T and Diaz C. 'Electric heating made Texas more vulnerable to winter blackouts'. *Quartz*, 19 February 2021. https://qz.com/1974468/why-did-the-texas-electric-grid-crash/.

26. Ault T and Yang A. 'Some Texans told they owe thousands in electric bills'. *ABC News*, 22 February 2021. https://abcnews.go.com/US/texans-hit-sky-high-electricity-bills/story?id=76048054.

27. Martinez G. 'Texas residents say the temperatures on their smart thermostats were RAISED overnight without their permission after state's power operators warned of shortages amid a heat wave.' *Daily Mail*, 19 June 2021. https://www.dailymail.co.uk/news/article-9703747/Texas-residents-say-temperature-smart-thermostats-raised-remotely.html

28. National Grid FES2020 data workbook. See sheet CV.23–26.

## Review process

GWPF publishes papers in a number of different formats, with a different review process pertaining to each.

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