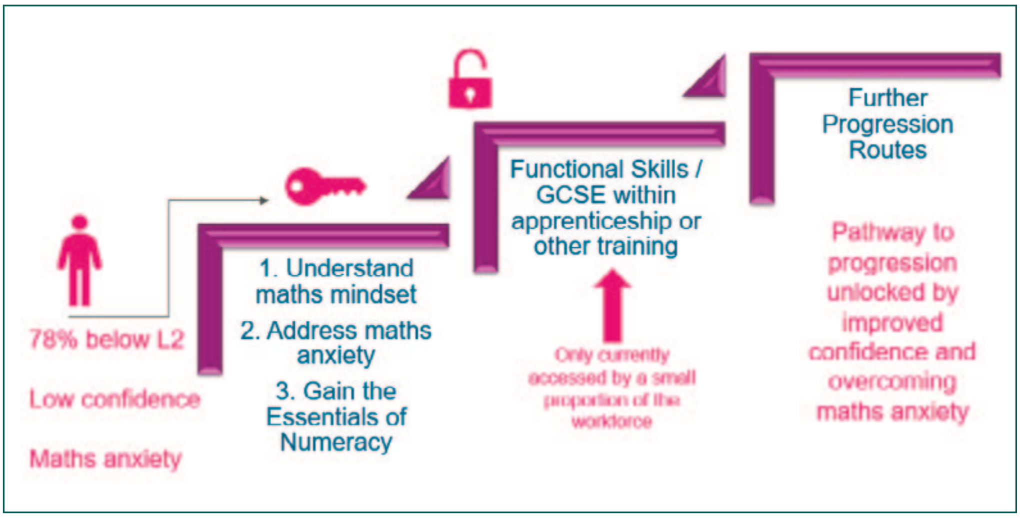

5K running plan and within that analogy, current qualifications-based provision is equivalent to a marathon and way out of reach.

There would appear to be an excellent opportunity to address both high-end mathematics and 'entry level quant skills'. National Numeracy's work on the latter is world leading. They have found that for many people a fear of maths is the biggest thing that is holding them back – and just as a basic level of physical fitness is increasingly recognised to be within everyone's grasp, good numeracy is within the grasp of anyone who is currently held back by low confidence. Put another way, all humans who can communicate moderately effectively in the English language also have the cognitive capacity to correctly answer the questions above; this is not an underlying intelligence issue.

With the right approach, we can collectively address this crisis – making clear progress within the term of this parliament. We need the government to recognise that helping people at the base of the pyramid engage with the world effectively will be of huge benefit to the nation, as well as to the individuals themselves. But also that this is not about more or better education, it is about helping the millions of people who have emerged from our education system with low levels of mathematical confidence and poor quantitative skills get over that first step to reengage with numbers and data. It is an enormous task and National Numeracy cannot do it alone.

In the meantime, why not try the National Numeracy Challenge yourself?

Answer: 6% of those surveyed scored 5/5

SMART ENERGY: THINKING ABOUT OUTCOMES, DIGITAL INFRASTRUCTURE, AND PEOPLE

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Energy systems around the world are changing in response to climate change. They are becoming increasingly reliant on decentralised renewable resources, experiencing new types of loads such as electric vehicles, heat pumps, and storage, and experience more active demand side participation [1-6]. Aligned with this is a push toward digitisation [7,8], with the introduction of smart-meters, greater prevalence of "Internet of Things" devices, and increasing sophistication of automation such as artificial intelligence (AI) used to provide system services. This "smartness" is driving exponential growth in the scale and diversity of energy system data, presenting opportunities and challenges in equal measure [9]. Understanding how energy system and digital systems are evolving and interacting is key to deliver a smart energy future. While much is happening at the grid edge, a shared vision is necessary to underpin and stimulate collective action; this is a critical opportunity for government, and the time to act is now.

HOW ARE ENERGY SYSTEMS BEING REDEFINED?

Typically, smart energy is discussed in the context of the high-minded goals that smart energy systems aim to achieve, or the technologies or processes they aim to deliver. But can an energy system be smart because it uses these smart technologies, regardless of the results? While the primary purpose of traditional energy systems is to enable energy services to be delivered to end-users of the system [10,11], the transition toward "smarter" energy systems may see the provision of services beyond energy become increasingly important, or even dominant. This blurring means that in addition to providing energy services in more effective or efficient ways, smart energy systems are anticipated to deliver wider benefits such as those outlined in Table 1 [12]. While these do not entirely re-define the energy system purpose, they set the broader context in which the provision of energy and related services to system users must be delivered.

WHAT DO WE MEAN BY SMART?

At its core, smartness is layered into energy systems by collecting and using more and different forms of data, fusing energy systems with information systems, and allowing energy system objectives to be met in more effective ways [13, 14]. But smart isn't just about how this data is generated, it is about how it is used.

This data may be used to support autonomous management of the system, for example, allowing the system to automatically control itself to optimise the provision of energy and ancillary services, using technology to make the decisions [15,16].

Alternatively, it could be used to support semi-autonomous regulation, optimising the system within the bounds of user input or in line with user set preferences [15]. This perspective brings together people with technology in defining the smartness, with users setting parameters, and technology learning and adapting based on revealed preferences

All of this new data and learning may also be used in new processes to provide more useful information to help people make more informed decisions about how they use energy, or for planning or governance [12,17].

Table 1: Seven ways smart energy systems can create value
Effective provision of energy services
Deliver energy services to users in more effective and efficient ways that reduce system costs and costs to users, reducing bills; improve comfort and quality of life, for example reducing fuel poverty.
Enhance environmental eco-system benefits
Deliver environmental benefits including and beyond carbon emissions reductions. These may include biodiversity and other ecosystem services alongside renewable energy provision.
Maximise sufficiency and independence within localities
Locally balance supply and demand, minimising the energy requirements from the national grid and maximising the use of local and low carbon resources.
Enable flexibility within and across vectors
Flexibility across vectors and the ability to switch between different vectors to provide energy services to provide greater efficiency and resilience.
Improve resilience and ability to cope with failure
Cope with generation failure as well as grid outages through better use of real time data, enhanced decision making, or autonomous forms of control.
Improve social justice and energy equity
Engage a wider variety of energy system stakeholders in new ways, in order to deliver greater energy equity and benefits to all.
Meet fundamental community needs
Better serve communities or localities through delivering practical benefits such as making it easier for locals to access and take part in the system. This can offer community benefits (e.g. boosting local employment) as well as wider values-based benefits such as addressing desires to reduce global environmental impacts.

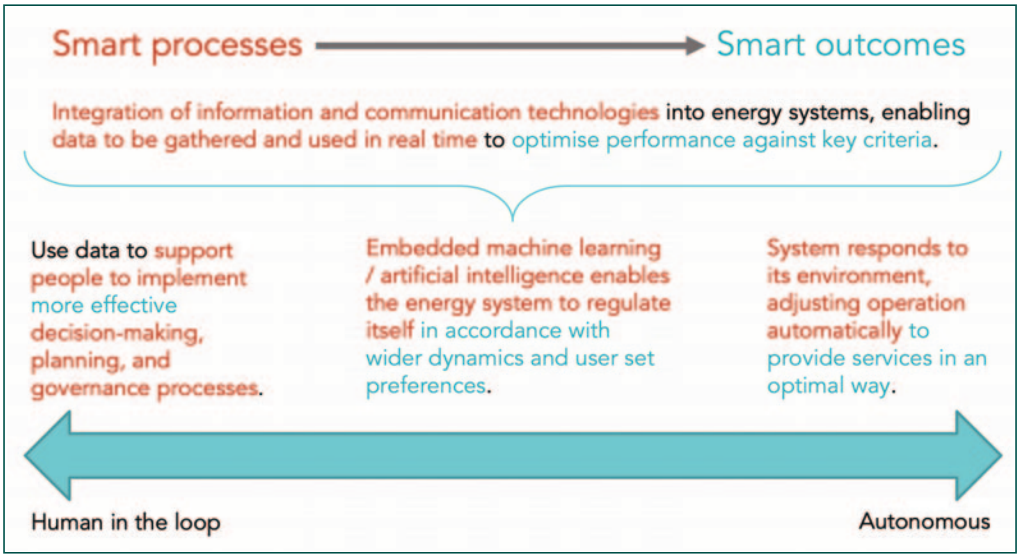

Figure 1 How processes and outcomes define smart energy

Regardless of the process, a 'smart' energy system is expected to enable better and more effective use of resources. This increase in effectiveness can take many forms. It can mean reducing costs or mitigating losses. It can mean producing larger benefits for individuals, for the system owners and operators, or for the wider world. It can mean producing the right benefits for these groups, more consistent benefits, or a wider range of benefits. Ultimately, this view of smart is about using smarter processes to drive smarter or better outcomes and opportunities [12].

THE CHALLENGES AHEAD

With the increasing localisation of smart energy, there needs to be a stronger policy direction regarding the realisation of different outcomes, and clearer frameworks to see how different smart energy developments and demonstrations are delivering against each of these key policy areas. Understanding which stakeholders are – or should be – involved is critical, as the starting point for developing a smart energy system could have a significant impact on the legitimacy of the solution, and on the outcomes achieved. Further, the Climate Emergency context raises questions about whether some benefits (e.g. carbon reductions in line with UK targets) should be a mandated goal, while other benefits and co-benefits could be more context specific with different areas of focus emerging in different projects.

Maintaining the smart nature of energy systems is a key challenge. An energy system may cease to be smart if it fails to continually evolve to take advantage of new technologies and opportunities to improve, and to meet the changing needs of the energy system. Changes in the energy system are making existing cyber physical architectures and techniques unfit for purpose. These changes include: (1) more decentralised resources generating data, resulting in lots of data at the grid edge, leading to bandwidth issues when trying to fit into the more traditional centralised analysis and control paradigms, (2) rapidly changing new types of controllable assets like solar panels and EV chargers and (3) the engagement of more, perhaps non-traditional actors who will be expected to play a bigger role in energy system planning and operation at increasingly local scales.

The key challenge for smart processes is to leverage advances in cyber physical system architectures, data pipelines, control approaches, state estimation techniques, and advances methods such as AI and machine learning, to enhance both autonomous and human elements in the loop decision making.

WHERE WE GO FROM HERE

When developing and building cyber-physical architecture that leverages these new advances, it's important to consider how to make the system: flexible (i.e. the extent to which the system can integrate new data sources, or adapt over time - terms like "plug and play" are common here); scalable (i.e. cope with increasing number of connected devices over time); interoperable (i.e. able to cope with multiple standards and suppliers and non-energy data – e.g. transport, waste, health); predictive (rather than just reactive), and secure[18]. Standards and frameworks for developing and deploying digital infrastructure may be required to cope with increasing and emerging data streams.

As well as building a future proof smart energy system from a technical perspective, its future must also be considered from a socio-economic perspective. It is not just generation assets and smarter forms of control that are becoming decentralised, there are also trends toward: local forms of decision-making, energy planning, and system operation; stronger end-user engagement and participation; and growing numbers of intermediaries and businesses emerging as key energy system stakeholders. Understanding what these new roles look like, how the right skills sets can be created and sustained in the right locations, and how local and national governance structures will need to interact to deliver a smart energy future is key. While much of this may need to happen locally, a shared vision and direction is necessary to underpin and stimulate action across many scales in a co-ordinated direction; this is a critical opportunity for government, and the time to act is now.

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