Experience the Commitment®

Beyond smart

Generating the demand-side flexibility opportunity for British energy

About the author

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Rich joined CGI in 2007, working across its smart utilities offerings.

He has over 25 years' experience in the utilities sector, covering areas such as competitive energy markets, smart meter and smart grid strategy.

Rich is a regular speaker at utility events and has authored numerous papers and articles on smart meters and grids, security and privacy, and the effect that market structure has on realising a smart vision.

In 2016, Rich authored the first "Energy Flexibility For Dummies" book with Wiley publishing house: www.cgi-group.co.uk/the-dummies-series

He is also active in the leadership of a number of industry associations.

Rich is a professional engineer by background and has spent his career working with organisations to implement transformation.

Outside work, Rich is passionate about sport and coaches rugby and skiing. Fortunately, those activities involve his kids!

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Executive summary

The British energy sector faces major challenges in the coming years if we, as consumers, are to continue to benefit from the levels of reliability we have come to take for granted. But, as with all major challenges, there come great opportunities.

The current generating capacity is set to take a major hit, with almost half of it due to retire by 2025. This is coupled with a forecast five per cent net growth in consumption by 2030. This might not sound significant, but it will have a disproportionate effect on peak demand.

The retirement of existing fossil-fuel and nuclear generating capacity presents an opportunity to decarbonise electricity generation. However, much of that retiring capacity is dispatchable and provides the system with the flexibility it needs to stay in balance and make sure that our smartphones can be charged.

The new sources of low-carbon generation (such as wind and solar PV) tend to be intermittent — which, by their nature, are inflexible. This creates a huge challenge for the electricity system, which needs to establish new sources of flexibility to keep the system in balance.

While decarbonising generation is reducing flexibility, the decarbonisation of the ways we consume electricity is creating new sources of flexibility beyond the meter on the demand side. And this will see a huge shift towards demand-side energy flexibility as organisations work with consumers to manage consumption at peak (and off-peak) times.

How the energy system reacts and adapts to these changes will determine how successful it will be in satisfying consumers' energy needs in the decades to come.

To make this transition a success and ensure that the value of demand-side flexibility can be realised, the energy sector needs to create the right environment in which a market for flexibility services can flourish. And this means establishing a number of crucial enablers:

Consumers
From meeting customer needs to defining affordable price points, encouraging consumers to adopt low-carbon demand-side technologies and make available the associated demand-side flexibility will be crucial in keeping the supply and demand for electricity in balance.

Securing investment
Developing the infrastructure and the means by which demand-side flexibility can be economically accessed will require investment. And that means providing the clarity that gives investors and other stakeholders the confidence to embark on their energy flexibility journey.

Commercial arrangements
Energy companies (both old and new) need the ability to assess the opportunities and risks involved in their energy flexibility investments. Their ability to access shared infrastructures, clarity on the commercial arrangements for that access and on the technical standards needing to be met will make it easier for organisations to build their investment cases.

Policy
The commercialisation of energy flexibility is vital. This is where clear, stable policies and appropriate incentives will play a vital role in attracting investment and accelerating adoption by consumers.

Lessons for the energy sector

Embracing demand-side flexibility will be perhaps the most fundamental transformation for the energy industry since privatisation in the 1980s.

But there are lessons to take from similar transformations in other sectors.

These include:

- **The move to mobile telephony**
  The development of mobile telephones required the deployment of a brand-new infrastructure. The innovation shown across the mobile telecoms sector provides an example that energy organisations could follow.
- **The digital TV switchover**
  The regulatory-driven move from an analogue to digital system of TV broadcasting is a prime example of promoting transformation through consumer adoption of new technologies — something that can inspire the energy sector in its access to, and use of, demand-side flexibility. It also provides insights about the potential pathways for the adoption of low-carbon technologies by consumers.
- **The advent of digital portable music**
  Leveraging a mixture of infrastructures, from the World Wide Web to communications networks, the development of portable music has more than one lesson to teach the energy sector when it comes to transformational change.

Creating a Market Infrastructure

With different parties being able to gain benefit from access to demand-side flexibility at different times, consideration needs to be given to the nature of the Market Infrastructure required to enable a well-functioning competitive market for flexibility services.

A smart, flexible energy system is the key to ensuring that consumers continue to benefit from the levels of reliability and affordability that they have come to take for granted when it comes to energy.

A Market Infrastructure is vital to the smooth running of this smart system — creating opportunities for organisations and customers to mutually benefit from the flexibility on the demand side.

Introduction

There are many (potentially conflicting) choices for how Britain will satisfy its energy needs over the coming decades. However, what is clear is that consumers must continue to benefit from the levels of reliability they have come to take for granted — at an overall bill that doesn't increasingly eat into their disposable incomes and doesn't cost the earth, literally.

Almost half of Britain's existing generating capacity is expected to retire by 2025. And, by 2030, consumption is expected to see a net growth of five per cent through the electrification of heat and transport and the adoption of other low-carbon technologies on the demand side. But the impact of this growth in consumption will have a disproportionate effect on peak demand.

This presents unprecedented challenges to the design and operation of Britain's power system. It will bring about arguably the most fundamental transformation in Britain's energy system, from a commercial perspective, since privatisation in the late 1990s or, from an engineering perspective, since the construction of the national transmission system almost a century ago.

The likely shape of the power system in 2030 and 2050 is well understood. This paper takes that as a given, but explores some of the factors that will enable this transformation. It seeks to identify lessons that the energy sector can learn from other industries' experience with fundamental transformation. It also outlines the important role that a Market Infrastructure will play in securing investment, enabling change and providing greater energy flexibility for both providers and consumers.

Establishing the environment for energy flexibility

The so-called ‘Energy Trilemma’ comprises the three pillars of energy policy — namely security of supply, addressing climate change and keeping energy affordable. However, the very use of the term ‘trilemma’ implies that there are trade-offs between each of these policy pillars.

From ‘trilemma’ to virtuous circle

The conventional operation of the electricity system is being challenged by the growth in intermittent, inflexible, low-carbon generation technologies (such as wind and solar photovoltaic) on the supply side. There are also new forms of flexible, low-carbon load on the demand side, such as demand-side storage and the electrification of heat and transport.

These new sources of low-carbon demand, which are being progressively adopted beyond the meter, deliver new sources of demand-side flexibility. These have the potential to turn the ‘trilemma’ into a virtuous circle.

However, things are not as simple as replacing the loss of generating capacity (and the associated loss of conventional sources of flexibility in the system) with demand-side flexibility and matching demand to the available supply. If they were, then we would see faster progress.

The reality is, in highly interconnected systems that comprise many actors (such as the British electricity market), that independently regulated competitive markets sometimes need a hand to operate effectively.

It is necessary to create the conditions for a market where innovative low-carbon technologies become commercialised and deliver a full range of benefits to consumers.

And this requires a number of crucial enablers to be established.

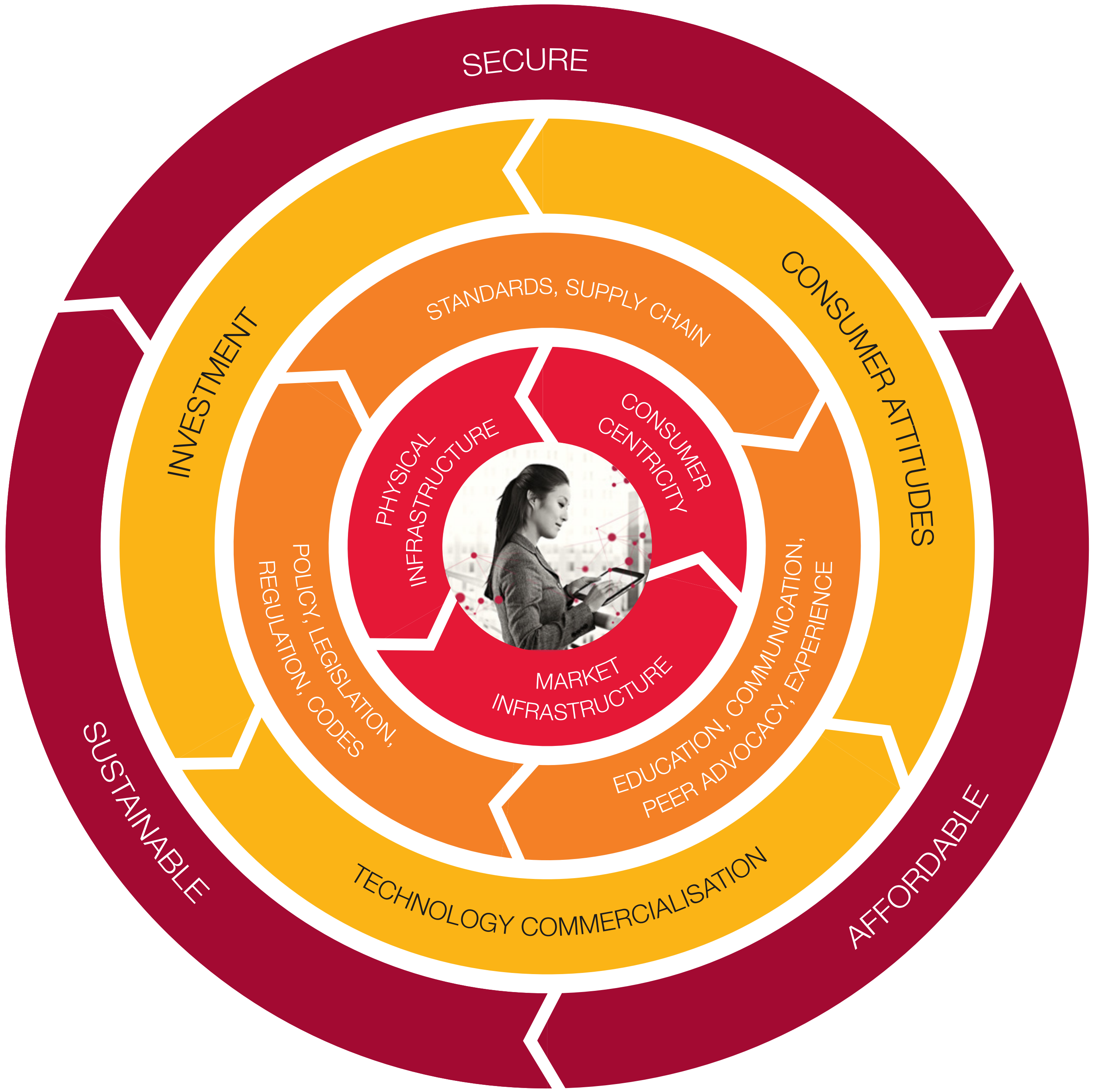


Fig. 1: Energy flexibility factors and relationships

Consumers are crucial to demand-side flexibility

Clearly, these low-carbon technologies on the demand side can help to satisfy the need for flexibility in the electricity system. But consumers need to understand the opportunities open to them should they choose to provide access to their demand-side flexibility. Only then will the adoption of low-carbon technologies fully accelerate and the market for demand-side flexibility services be established.

Consumer attitudes and their desire to change (or simply to adopt something they perceive to be better) are vital.

Products and services need to be available at the right price points to not only meet consumers' needs, but also to satisfy their wants. And, of course, people need to have confidence in the security of these products and of their data, and have trust in their chosen service providers or product suppliers.

In order to achieve this, there has to be the necessary investment to take a great idea through research and development to full commercialisation.

Of course, if there is an obvious need, the consumer benefits are clear, there's active customer pull and a clear route to revenue — then attracting the necessary investment becomes easier.

Securing the investment for success

A highly unbundled market with a multitude of participants and multilateral commercial arrangements (or a multitude of bilateral arrangements), such as the British energy market, can look daunting.

Investor confidence is built on having clarity on the policy, legislative and regulatory context in which they will be operating. But it goes further, into understanding how they will be able to interoperate both within the context of the system and with other participants in the market.

Understanding the contractual terms under which shared 'physical infrastructures' can be accessed, and the mechanisms by which parties get paid (a commercial Market Infrastructure), will enable them to understand their route to revenue and identify the potential return on their investments.

It is this latter, and essential, piece of how markets operate that is seldom discussed: the importance of defining the market rules and establishing a Market Infrastructure that enables the market to operate effectively.

The guiding principle for any Market Infrastructure should be that it only handles:

- activities that are common to all market participants;
- activities where there are significant economies of scale that benefit all participants; and
- where failure to fulfil activities correctly by one participant has a disproportionate impact on the ability of other participants to operate effectively, or impacts the customers' experience of, and trust in, the market.

Additionally, the infrastructure should not be responsible for activities from which market participants can either differentiate themselves or create cost leadership.

When these fundamental principles are applied to the creation of Market Infrastructures, the value of the market is maximised and the barriers to competition minimised. This makes it easier to get innovative new products and services to market, making it an attractive place to do business and enhancing consumer choice.

Fig.1 articulates the inter-relationship between each of these factors, as well as some of the factors vital to creating markets, such as standards and consumer education.

Policy promotes investment in transformation

For nascent technologies, clarity on policies and appropriate fiscal incentives designed to accelerate their adoption is important. The right level of incentive will help these technologies become commercialised.

But it is also important to be clear about how the incentive mechanisms will reduce as the market grows. When economies of scale are achieved, and become reflected in price points, the interests of taxpayers, who are ultimately funding these incentives, need to be protected.

The real challenge in highly interconnected, multi-actor systems, such as the British electricity market, is enabling all investors to understand how they will get a return on their respective investments, and how they can gain value building on each other's propositions.

Establishing access and commercial arrangements

Organisations or individuals that want to offer products and services to consumers, and need to make use of infrastructure and assets belonging to other actors, need to know how they can access that infrastructure and the associated commercial arrangements. Organisations that have invested in infrastructure and assets want to see results: they want to be able to see their route to revenue from the users of the infrastructure and assets they make available.

For instance, is the company offering a consumer a service to manage that consumer's demand-side flexibility in a position to assess the risks associated with how they make that flexibility available to other participants — or how that value is likely to vary between different actors? Without that understanding, how can they assess the level of risk they are taking on, and determine what level of benefit they can pass to their customers while still making a sufficient return on their investment for the risks they are taking?

It is also important to remember that technical standards and codes of connection are a vital part of this understanding.

Indeed, the significance of technical standards should not be underestimated in establishing resilient supply chains for products and services — as well as enabling competition in the provision of those goods, which in turn drives down prices and increases innovation.

This all provides a clearer view of both the opportunities and risks in the future energy markets.

Lessons from technology-enabled market transformations in other sectors

> “Study the past, if you would define the future.”
>
> **Confucius**

Fortunately, there are some great examples of technology-enabled, market-level transformations that can help inform the approach to the transformation of the energy sector into a smart, flexible energy system.

How mobile telephony created flexible communications

It is always going to be hard to identify when a technology becomes mainstream. But it is safe to say that taking a long view of the development of the mobile telephony market shows significant parallels with the way a smart, flexible energy system and a well-functioning market for energy and energy services is likely to mature over the coming decade or so.

Establishing the physical infrastructure

After the first successful mobile telephone call in 1973, there was a need to deploy the first generation of physical communications infrastructure to provide the coverage required for people to make calls from wherever they needed or wanted.

The telecommunications sector has been continually innovating and deploying new infrastructures — and successfully concurrently operating different generations of technologies — ever since.

The clarity it has on technology standards has enabled resilient, competitive supply chains to be established. And it has driven continual innovation in both the technology and services offered.

Codes of Connection have enabled multiple users and service providers to connect devices to the networks concurrently, with competition for consumers driving innovation in the devices themselves and the services that can be offered over the communication networks.

Changing the energy system

In the case of the electricity sector, the physical power infrastructure (the wires) is already deployed. However, the low-carbon technologies that are being progressively connected on both the supply side and beyond-the-meter are changing the dynamics of the system, dramatically.

These new demands being placed on the existing infrastructure means that the way it is designed, operated, and maintained needs to change if consumers are going to continue to enjoy the levels of reliability, economy and — above all — safety that they have come to take for granted.

This transformation in the design, operation, and maintenance of the electricity network will be enabled by the increasing inter-connectivity of devices connected to the infrastructure. The timely visibility of the data produced by these devices will then enable informed decisions to be made about the actions to be taken, or not, as the case may be.

Timely visibility is important. For some data streams, that may mean near real-time. For others ‘timely’ may have longer latency periods, or may be processed close to the point where the data is generated (‘the edge’), with only exceptions being made visible more widely.

The inter-connectivity is likely to lead to a convergence of the utilities and telco sectors. The power system may choose to leverage the existing communications infrastructures, rather than deploying its own communications infrastructures, to make sure that it operates as cost-effectively as possible.

Overcoming the consumer challenge

In terms of quality of connectivity, functionality, size and power, mobile handsets have come a long way from the first generation 'bricks' of the 1980s to the iPhone 7, Google Pixel, Samsung Galaxy range or the latest Windows phones (phones from a plethora of other manufacturers are available!).

This continual innovation has come about, in part, by the regeneration of the physical communication infrastructure and its capabilities. But it is also the level of competition in the supply chain for handsets that is driving not just innovation in the devices, but also in the services that can be delivered via those devices. Handsets are no longer just phones, they are communication platforms — in fact, voice traffic across mobile and fixed line fell by around 15 per cent between 2010 and 2015.

The key to this innovation is the way that consumers have accepted new technology into their lives. People don't buy tech for tech's sake.

The perceived benefits of a new device — whether the ability to connect with friends, manage bank accounts or compare prices on the move — are what drive acceptance of technology.

As the acceptance of these devices into our lives has grown, the costs have fallen exponentially — making devices accessible to the masses.

It's hard to comprehend, but the average mobile phone has way more computing power than the whole of NASA had when it landed Neil Armstrong and Buzz Aldrin on the Moon in 1969.

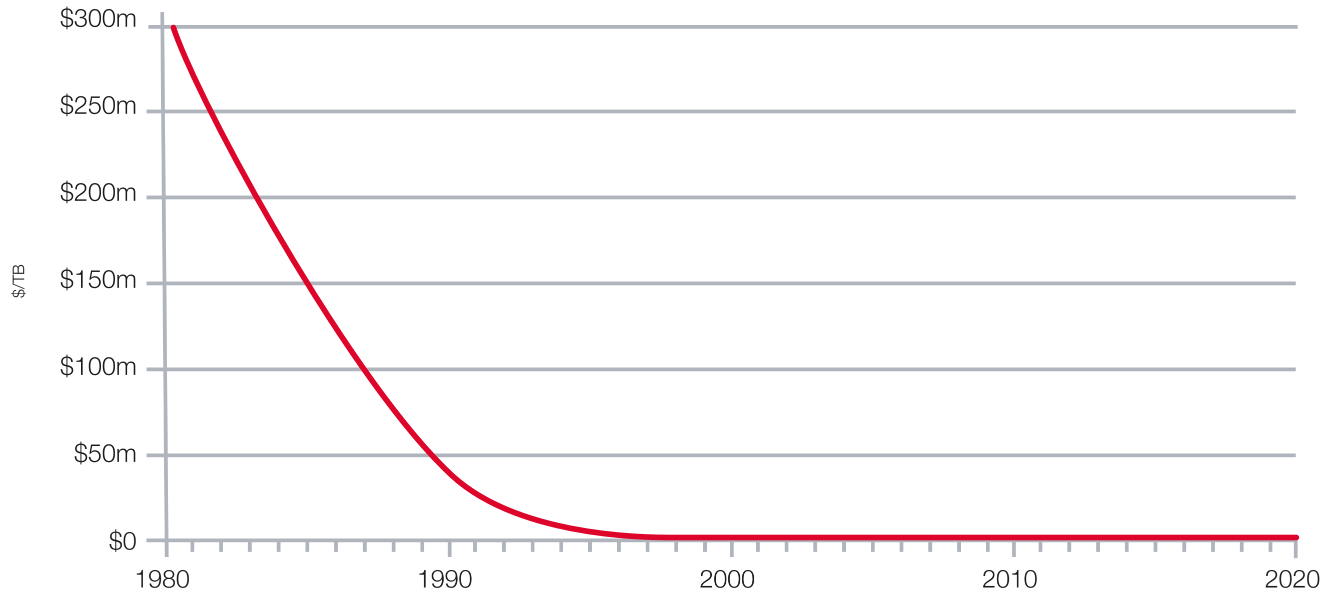
Or, if we take the 1985 Cray-2 'supercomputer' — the world's fastest supercomputer until 1990 [1, 2, 3]. It ran with a performance of up to 1.9 GFLOPS, 2GB of memory, operated at 244MHz, required liquid immersion cooling of its 200-kilowatt hardware and cost $16 million ($32m when adjusted for inflation to 2010 prices). Compare that with the iPhone 7, with its 729.6 GFLOPS, 2GB of RAM, up to 256GB of internal memory, 2.34GHz speed, around 0.5W power requirement for voice calls and a price point of $849 (for the top spec 256GB version) [1, 4].

That equates to an improvement of 14.5 million times to the processing power, and power requirements per unit of processing power that are 150 million times more efficient.

These ratios are so mind blowing as to be almost incomprehensible.

If we can take one thing from them, it is that where technologies address a market need or, indeed, an unidentified consumer want, then the pace of change, the growth in performance and economies of scale are incredible.

Cost of memory storage



Cost of processing power

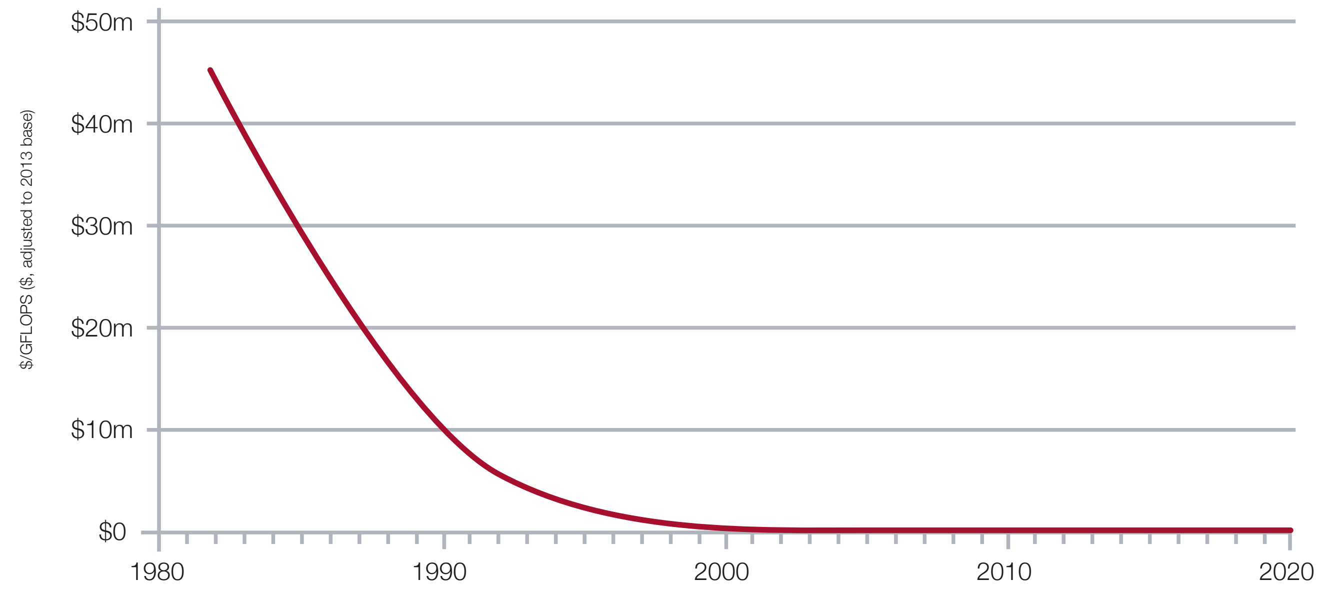


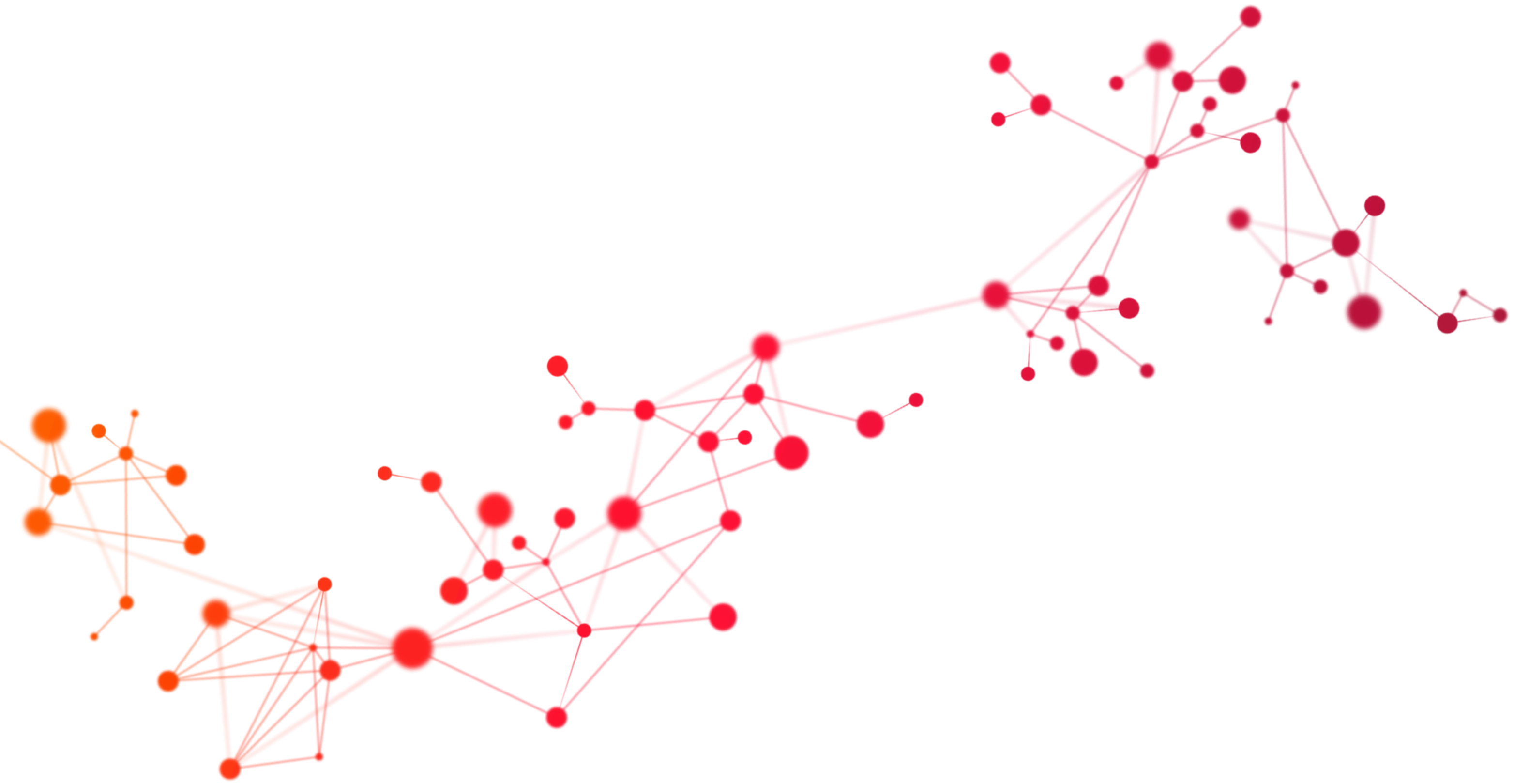
Fig. 2: Technology cost reductions [5, 6]

Growing the customer base, attitudes and trust

But, of course, in the case of the electricity system, the low-carbon devices (the equivalent of the mobile handsets) need to be deployed across the power infrastructure, and more widely throughout the end-to-end system. The end-to-end system extends beyond the existing power infrastructure into the new forms of generation on the supply side and the new forms of demand beyond the plug.

Studying the telco sector can provide insights into the establishment of supply chains for devices, the role of standards in establishing those supply chains and creating resilience across that supply chain.

This enables competition and drives innovation in the devices themselves, and the associated services offered that deliver new choices for consumers.



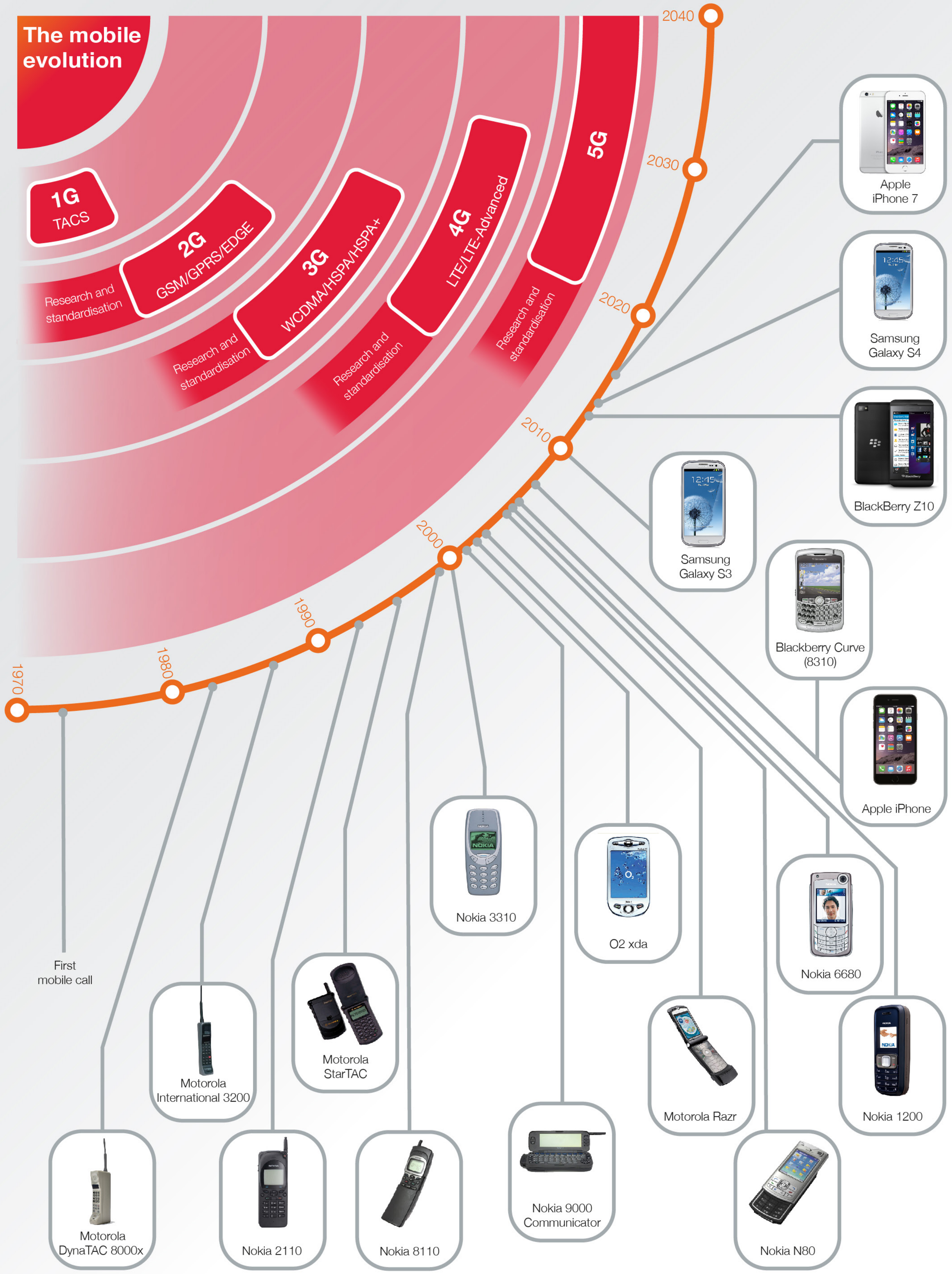


Fig. 3: The mobile evolution

How the digital switchover transformed viewer expectations

The transition from analogue television to digital television was ultimately driven by regulation and the desire to close down the analogue network. However, there are potential lessons for the energy market about how technology enables market-level change.

From the deployment of the digital television infrastructure, to the parallel running of the digital and the analogue networks, to the development and progressive adoption of digital TV tuners, there are some significant potential opportunities for the British energy system to learn how to become smarter and more flexible. Here, we'll focus on the customer aspects.

When the commercial operation of ITV Digital went bust in 2002, it could have been a serious setback to viewers' trust and acceptance of the digital switchover. However, later that year Freeview was established, providing viewers with access to additional TV channels and content free of charge when they either replaced their TV with one that had an integrated digital tuner, or purchased a simple-to-install 'set-top-box' (which could also be put underneath people's existing analogue TVs!).

The early adopters of the digital TV experience — those who wanted access to the newly available digital content — did not have to spend several hundred pounds replacing their existing (potentially recently purchased) analogue TV with a new digital TV. They could spend around £80 (2002 prices) on an easy-to-fit 'set-top-box'. At a certain point, any new TV purchased had an integrated digital tuner, so anyone needing to replace an old TV would get access to digital content by default.

The importance of technical standards for the digital tuners meant there was supply chain resilience, competition driving down prices, and the opportunity for innovation driving up functionality. This means you can pick up a set-top-box in your local supermarket today, that has more functionality than that £80 box had back in 2002, at a quarter of the price.

The major learning point from the digital TV switchover is about customer engagement. For the small additional cost of a set-top-box, or a marginal increased cost of a TV with an integrated digital tuner, the viewer received access to a wealth of additional channels and content. There is an immediate perceived benefit to the viewer around the level of entertainment available to them.

The question that this raises for the energy sector is, 'what is the additional benefit, equivalent to digital TV content, for energy consumers in an energy system that employs demand-side flexibility?'

While we have focused here on the consumer experience, there are also potential parallels in the way the digital television infrastructure was deployed — on a region by region basis, with the infrastructure being reinforced as demand grew. The value of flexibility to the energy system will be greatest where it meets the need at a location within the infrastructure.

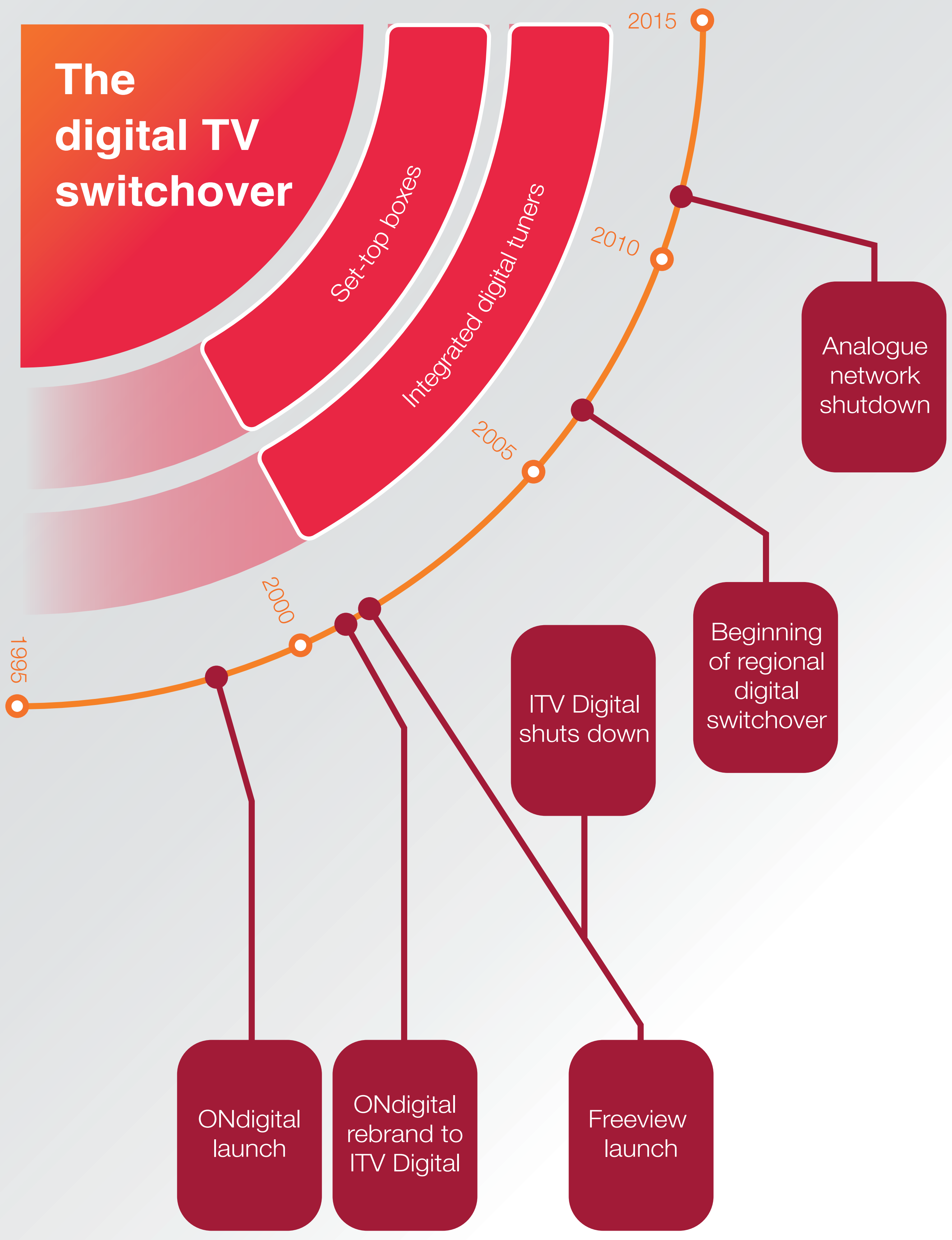


Fig. 4: The digital TV switchover

How portable players changed the way we access music [7, 8]

When the late Steve Jobs soldered a click wheel, screen, 3.5mm earphone jack and USB interface to a hard drive and, in 2001, launched the first iPod, did he imagine the fundamental transformation that it would create in the way we buy and listen to music?

We can now take the long view of what has happened over the last 15 years and use it to inform our thinking about how the energy sector might transform over the coming 15 years.

Bringing the world online

The portable music journey starts in the analogue world 22 years before the iPod, when the Walkman became an 80s icon and established the market for personal, portable music.

Soon after, music made the switch to digital, but the user still had the inconvenience of carrying multiple cassettes or CDs to use with portable players.

In parallel with these developments in the music market, there were three technological markets evolving that the iPod leveraged in its success:

- The internet had been quietly developing and was being used in the education and scientific communities through the 1970s and 1980s. But the internet didn't become mainstream until, in 1989, Tim Berners-Lee created a new way of distributing information across the internet and the World Wide Web was born.
- Through the 80s and 90s, the personal computer market was developing, costs were plummeting, and functionality and memory storage were spiralling.
- The telecoms sector went through a revolution in data transfer over fixed lines, the development of the mobile telecoms sector and the move to digital telecoms.

By 2000, the required physical infrastructures were in place for the next fundamental transformation. The World Wide Web was established, the communication networks were in place with the bandwidth to handle the necessary data transfer rates, and people had the means to get online in their homes via their personal computers with plenty of cheap memory storage. Adding to this was the fact that people were becoming more dissatisfied with either having to loop the same album on their portable player or the inconvenience of carrying a bag of tapes or CDs around with them.

The time was perfect for a personal music player that could be connected to the World Wide Web via your home PC, and onto which not just a few extra albums could be downloaded, but your entire digital music collection.

Understanding your place in the value chain

What made the iPod a success, far more than being the next bit of cool technology for music lovers, was Apple's approach and its clarity about its position in the value chain. Via iTunes, you could transfer all your existing digital music to your PC and/or your iPod. iTunes was available both for Apple's own Mac OS and for Microsoft's Windows operating systems, so listeners weren't locked into Apple computers. iTunes also transformed the way people buy and listen to music; selecting preferred songs from albums and no longer listening to an album as a whole.

The use of the standard 3.5mm jack enabled the listener to choose their own headphones, and kick-started innovation in the headphones market — arguably even creating that market.

The Apple 30-pin standard connector enabled a market in devices that meant you could connect your entire music collection to your existing stereo, amplifier and speakers; or even to your car stereo.

Apple not only understood what it was great at but, far more importantly, it understood that, by using standards for its interfaces, it could consolidate its position at the heart of its chosen market.

By actively addressing potential barriers to the adoption of its technology and enabling its technology to be used by companies that were the leaders in their respective parts of the value chain, Apple established itself as the de facto standard and established its devices as THE brand to have.

Innovation has not stopped since the iPod arrived, but the subsequent changes have been incremental rather than fundamentally transformational.

The move from the click wheel to the touch screen with the iPod Touch offered the ability to watch stored movies or catch up on TV on the move. The convergence of mobile telephony with media brought about the iPhone at the start of 2007. With higher bandwidth mobile communications networks, 3G and latterly 4G/LTE, live TV and streamed music became a reality.

Permanent connectivity through the mobile network or the use of Bluetooth negate the need for wires everywhere. All of these things are incrementally improving the customer experience, but they are not the fundamental transformation that the iPod created in the music sector.

Over the last 15 years — through the use of standards — the portable music player has evolved from a cool device into a near-permanently connected communications platform around which we live our lives.

It also provides digital innovators with the platform over which they can offer their services via a whole range of apps.

Maintaining market leadership

As the technology costs tumble and accessibility to this technology widens to include a greater proportion of the population, the size of the market grows. Simultaneously, the costs of entry fall and competitors enter the market.

And, of course, with competitors in the market, there are increasing choices from which consumers are able to benefit, across the range of price points.

All too often, you see the innovators and early movers fall by the wayside. Who recalls the MPMan or any of the other MP3 players that preceded the iPod?

So how has Apple built and maintained its leading position over the long term? It would be easy to say it is down to 'brand', but creating a brand with which people want to be associated — and for which they are prepared to pay a premium — in an increasingly commoditised market is something that has to be built.

Apple continues to innovate and drive forward the functionality and capability, as well as the range, of devices that it offers its consumers.

There is little doubt that demand-side flexibility will have a similar, fundamentally transformative effect on the way the end-to-end electricity system operates.

There is much that the energy sector can learn from the revolution in digital music. This includes the role of standards, actively seeking to reduce barriers to adoption, and understanding your position in the value chain. Developing collaborative operating models that enhance your own proposition by working with partners who are leaders in the parts of the value chain in which they choose to operate, as well as building and maintaining a brand with which your customers want to become associated, will also be vital.

Fig. 5: The evolution of portable media

Promoting a market-driven approach

The British electricity market is one of the most unbundled and consistently competitive energy markets anywhere in the world. The challenge of utilising demand-side flexibility to maintain security of supply and keep electricity affordable for consumers therefore has to be established in a market-led context.

This means bringing a number of stakeholders together to achieve this transformation. These include:

- The Distribution Network Operators (DNOs)
- The Transmission System Operator (TSO)
- The Energy Retailers
- The Energy Traders
- The Aggregators
- The Energy Service providers, and
- The Consumers

With the exception of the TSO, there are multiple actors in each group. And it is quite feasible that some will take strategic decisions to participate in multiple roles.

Each role could gain value from demand-side flexibility at different times, and it is equally feasible that one role or actor could be gaining value to the detriment of other roles at certain times.

Dealing with a changing physical infrastructure

It is too simplistic to say that we already have the physical infrastructure in place for Britain's electricity system. It is true that we have the transmission and distribution infrastructures in place to get electricity from power station to plug.

However, what connects to either end of that infrastructure, and will become intrinsic to the end-to-end system, is changing, fundamentally.

Maintaining the supply side

Between now and 2025, almost half of Britain's existing generating capacity is due to retire. Over the coming decade, this will present an increasing capacity margin challenge. Capacity margin is a measure of the degree to which available generating capacity exceeds the maximum level of projected demand for electricity at any given time.

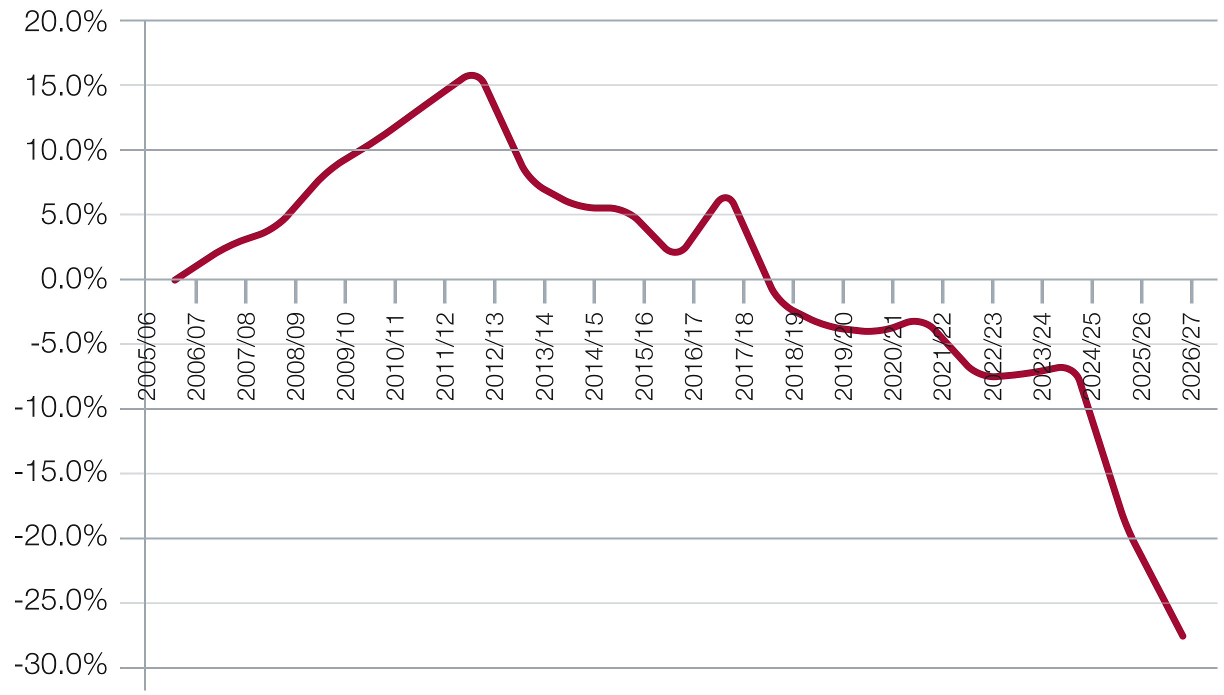


Fig. 6: Capacity margin projections [9]

This presents a major opportunity to decarbonise the way Britain satisfies its need for energy by replacing the retiring capacity with low-carbon sources.

However, the challenge comes from the differences between the characteristics of low-carbon generation compared with traditional, dispatchable, flexible, fossil-fuel thermal generation.

Wind and solar generation are, by their nature, intermittent and inflexible. Unlike some other territories, the availability of energy from wind and solar generation correlating with demand is not coincident in Britain. In Hawaii, increased demand from air-conditioning occurs on the hottest days, which correlates with peak output from solar arrays.

Unfortunately, Britain's peak demands tend to occur on cold, wet, dark winter evenings, which is not conducive to high levels of solar generation!

Developing the demand side

If Britain is to achieve its legally binding climate change commitments (with other sectors looking to decarbonise through electrification of their energy needs), there will be a disproportionate impact on the electricity sector, which will need to virtually decarbonise by 2050.

With the progressive adoption of low-carbon demand beyond the meter, through the electrification of heat and transport (and the likely take up of demand-side storage), there will be growing levels of demand-side flexibility that has the potential to compensate for the loss of flexibility on a decarbonised supply side. This has significant potential to help to address the capacity margin challenge.

The growing adoption of demand-side generation, such as photo-voltaic solar panels or micro-CHP units, and demand-side storage solutions will also start to increase volatility in the demand profiles seen by the distribution system to which premises are connected.

The information and communication infrastructure established through the deployment of smart meters to homes and small businesses by 2020 will enable those consumers who are prepared to make their demand-side flexibility available, and who choose to participate in the energy market, to benefit from energy prices that reflect not just how much energy they consume, but when they use it.

The World Wide Web and the support of Consumer Access Devices by smart meters will enable a whole new market to be established in energy services, without the need for providers of those services to become signatories to the Smart Energy Code or to become a DCC Service User.

Those consumers who have invested in low-carbon technologies (including demand-side storage) in their homes will be the ones that have more demand with a greater degree of flexibility.

It is these consumers who will be best placed to take advantage of the benefits of making their flexibility available to the energy system, should they so choose.

So, it is the consumers driving the transformation in the energy system through their adoption of low-carbon technologies who are also the ones who have the potential to be part of the solution to the challenges that this creates for the way in which the system is designed and operated.

Working with consumers to access flexibility

In a smart, flexible energy system, the boundary between the physical infrastructure and the consumer becomes blurred.

The consumers' investment in low-carbon technologies is driving the transformation of the electricity infrastructure. However, if the consumer enables the demand from their low-carbon technologies to be controlled in response to the needs of the infrastructure, then these devices become an intrinsic part of a whole energy system.

British consumers have had little incentive or ability to control when they use electricity. As such, the only route they have had to control the size of their bills has been to control how much electricity they use, which, unless they do something about the energy efficiency of their homes, means reducing waste or suffering energy austerity.

Smart meters will provide those 'switched on' consumers with the means to identify when they are wasting energy, and where they may benefit from investing in energy efficiency. However, for many vulnerable consumers, the default will be energy austerity, the so-called choice between 'heat or eat.'

The question then becomes one of how to engage those consumers that have the capability to make a material contribution to the flexibility of the energy system by allowing some control over their low-carbon technologies.

Many people default to talking about some form of price reward, but many studies question whether this is too simplistic and whether price is really a fundamental motivator that will engage people in sustained action.

When looking at other technology-driven market transformations, the importance of building brand loyalty was identified as an important factor for sustained success. Understanding customers and proactive communication with different customer segments based on their individual motivators will be important in building the trust necessary for consumers to allow their energy service provider to manage their energy consumption and flexibility on their behalf and build enduring relationships.

Determining the size of the prize

There are a lot of numbers about the value of a more flexible energy system, from the headline gross benefit of £8bn per annum (at a carbon intensity of 50gCO2/kWh) in 2030 to £3bn-£3.8bn gross benefit at the legally binding 2030 target level of 100gCO2/kWh. These values relate to the value accruing from all sources of flexibility and include interconnectors, grid connected storage as well as demand-side flexibility[10].

Demand-side flexibility is increasing as a by-product of the decarbonisation of heat and transport. If that can be made available to the system simply and economically, there is a significant prize to be had. And it empowers consumers to take control of their bills.

The size of bills will no longer be about how much energy is consumed and energy austerity, but about WHEN energy is consumed.

Taking National Grid's 2016 Future Energy Scenarios, given this paper focuses on a more market-oriented scenario, we willl use the Consumer Power scenario [11]. In 2015, 23.4 per cent of installed supply capacity was wind or solar, meeting 13.8 per cent of consumption. In 2030, under the Consumer Power scenario, 45 per cent of supply capacity will be from wind and solar and it is projected to be meeting 37 per cent of consumption. Interconnection capacity will have more than tripled in 2030 to 15 per cent, satisfying a quarter of consumption.

What is not specified is the degree to which output from wind and solar generation or the availability of import across the interconnectors correlates with peak demands, and therefore the security of the system in having sufficient supply margin available when required to meet that demand and keep the system in balance.

This is why demand-side flexibility will be vital to meeting consumers' peak energy demands.

It won't be enough simply to create more low-carbon generation capacity — the British energy system will also rely on its ability to provide, and encourage consumers to adopt, flexibility to counteract intermittent renewable sources.

Innovative technology companies are developing the technologies that enable connected appliances, low-carbon technologies, the smart-metering infrastructure and energy service providers to be connected. Innovation programmes and proofs-of-concept such as UK Power Networks' Low Carbon London programme, Northern Powergrid's Customer Led Network Revolution and ENEXIS's Jouw Energie Moment (Your Energy Moment) programme are establishing customers' attitudes to allowing their homes to become part of the energy system.

Securing consumer confidence is based on a number of factors that will carry different levels of weighting with individual consumers.

The key is understanding consumers' specific wants and needs, and addressing those in any communications.

Building trust through peer advocacy and education, addressing concerns around cyber and data security threats, building confidence in the technology and ensuring that consumers have meaningful choices in the technologies and the service providers are all important elements of winning consumers' trust and them embracing these new technologies in their lives.

Achieving this is built on the use of standards that enable resilient supply chains to be established and drive competition and innovation.

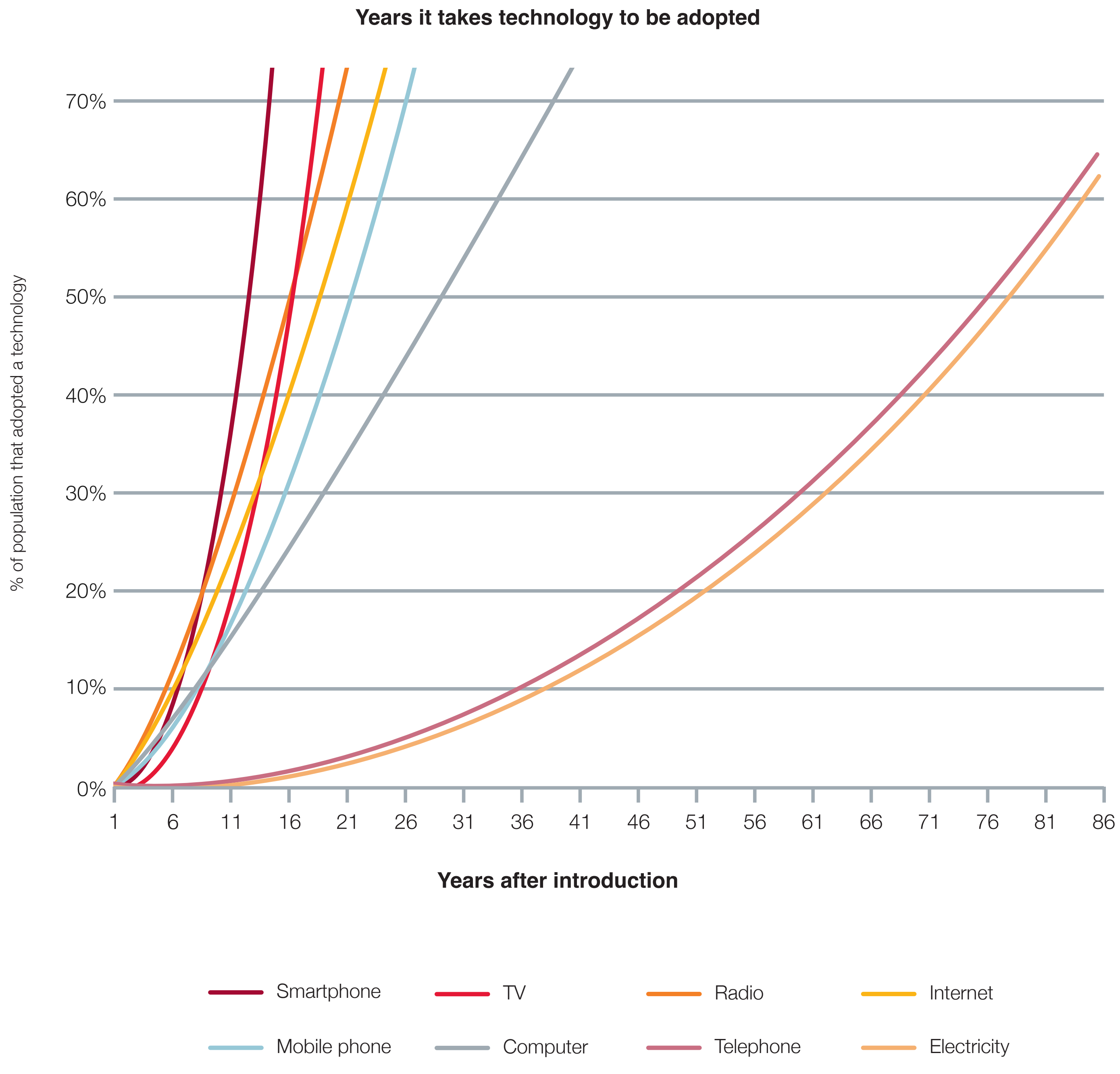


Fig. 7: Technology adoption rates [12]

Encouraging speedy technology adoption

If Britain is to realise the full benefit to the energy system from demand-side flexibility, it is important to understand the likely adoption rates of the enabling technologies. The factors that will affect consumer acceptance of energy service propositions rely on active management of flexibility rather than energy austerity and passive energy efficiency.

Fig. 7 compares the adoption rates of various technologies. Those technologies, such as electricity and telephone, which require the deployment of big physical infrastructures and physical connections to be made at the point of use, take significantly longer to achieve high levels of adoption than cheaper, easier-to-access technologies.

The more rapidly adopted technologies all leveraged existing infrastructures, required little specific expertise to access the perceived benefit, and were at accessible price points. The pace of adoption of the smartphone leveraged all of these factors, but also acted as a platform for convergence of access to a number of propositions — from calls, to internet, to music.

The adoption rates of low-carbon technologies into people's homes is likely to align with that of computers and white goods. But the adoption of the home control technologies that will make access to demand-side flexibility part of a wider system is likely to be closer to the adoption of other consumer electronics propositions.

The real challenge is how homes are decarbonised. Currently around 20,000 homes are refurbished per annum in a way that addresses their carbon impacts. That figure needs to increase to 20,000 per week by 2025 if the 2050 targets are to be achieved, according to the Energy Systems Catapult.

The role of policy, regulation and standards will be vital to achieving the adoption of low-carbon options, including building standards, device energy efficiency standards, and potentially the requirement for home energy storage as a new form of white goods in new and refurbished homes.

With the average life of home heating systems being around 15 years, and people refurbishing their kitchens every 15-20 years, that is 1.35m – 1.8m homes undertaking some form of significant refurbishment per annum.

So, with the right policy, regulatory and standards frameworks in place, the Energy Systems Catapult's target of decarbonising 20,000 homes per week by between 2025 and 2050 starts to look more achievable.

Policy, regulation, and standards have been successful in driving energy efficiency, from the adoption of double-glazing, to insulation, to condensing boilers, to energy efficient lighting. This is the case to the extent that — whereas in the past a home with such measures would attract a premium — today homes not meeting the standards are devalued.

Creating a Market Infrastructure

How the energy market will need to operate is generally not the focus of discussions about a smart, flexible energy system. But, in the GB energy market (with its multitude of participants each fulfilling very different roles and with varied value drivers), clarity on how the market is expected to operate and the obligations of different participants will be crucial to success. The importance of defining the market rules and establishing a Market Infrastructure that enables the market to operate effectively will be vital to Britain's future energy system.

What is clear is that, in a smart, flexible energy system, different market participants will be able to generate value from access to flexibility services:

- Consumers will be able to control the size of their bills by offering their demand-side flexibility to the market and shifting when they import energy from the system.
- Retailers will be able to deliver new services to their customers. They will be able to begin to truly differentiate themselves (rather than by simply providing a great billing service). They will be able to develop new business-operating models that embrace access to flexibility and enable them to manage their operating costs and wholesale market risks.
- Energy Traders will see the opportunity to create tradeable options based on flexibility.
- Aggregators and energy service providers will see new opportunities to deliver services to the mass market.
- The TSO will have access to new sources of flexibility that will enable it to fulfil its obligation to keep the transmission system in balance.
- The DNOs will transition to become Distribution System Operators, making use of their access to flexibility services on their networks to keep their distribution systems in balance and defer or avoid the need for network reinforcement.

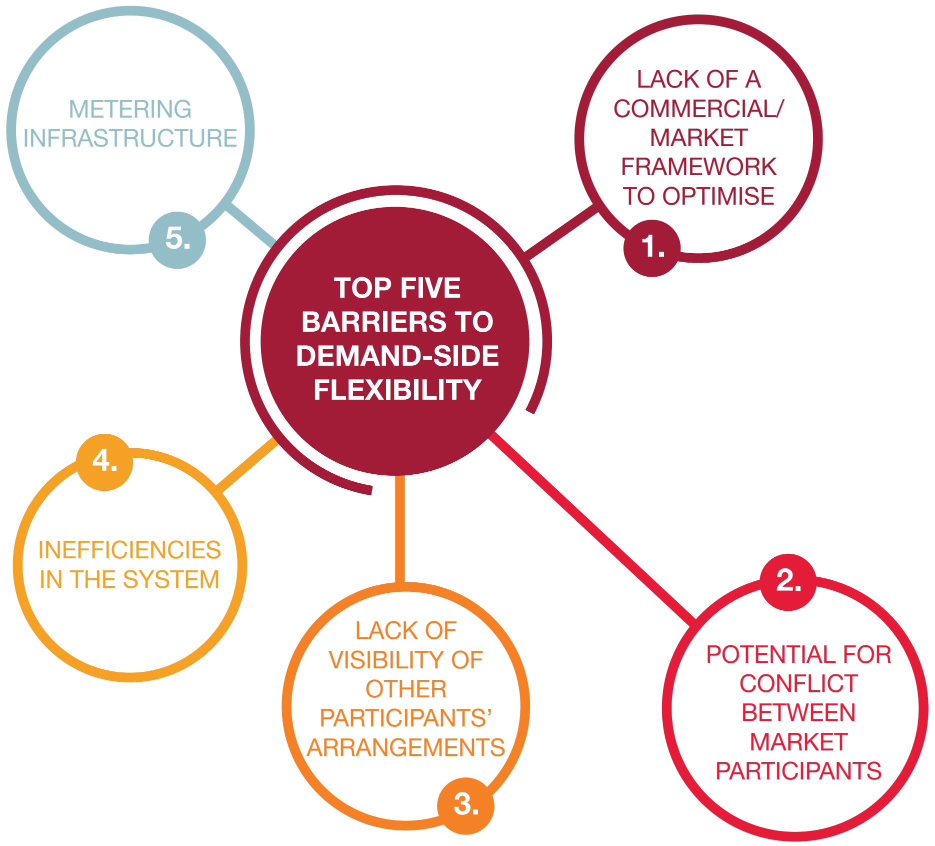


Fig. 8: Barriers to Market for Demand-Side Flexibility

Value could accrue to multiple parties concurrently, but it is also quite feasible that other market participants could suffer a loss of value. What happens if the DNO has a network outage due to consumers or retailers turning up demand in response to low wholesale energy costs and an abundance of supply? Or, conversely, what happens if the DNOs turn down demand to avoid an outage, causing the consumer or supplier to miss out on consuming when the wholesale price is low?

In 'Energy Flexibility: Transforming the Power System by 2030', industry leaders identified the main barriers to the market for flexibility services [13].

The top three barriers identified across the different market participant groups all related to commercial and market arrangements.

This clearly demonstrates the need for neutral facilitation of the market for these services.

How that market is to be facilitated, and which role should have the obligation to provide that neutral facilitation of the market remain open questions.

But they are questions that need to be addressed quickly if Britain is to achieve its legally binding climate change targets.

Conclusions

Five lessons for a flexible energy market

In the section 'Establishing the environment for energy flexibility', we covered a model that looked at what needs to happen to transform the energy challenge from being a trilemma into a virtuous circle.

The three examples of technology driven market transformations demonstrate some of the themes that support this model:

1. **Understanding the wider context (the system of systems) in which the transformation is occurring.**

   The example here is the iPod's success being built on what was happening in the telecommunications, home computing and the internet sectors.

2. **The significance of standards in establishing supply chain resilience, driving down cost and incentivising innovation.**

   The examples of the mobile phone and digital TV markets demonstrate how processing power and functionality have spiralled — as well as how costs and energy consumption have plummeted, making these technologies accessible to everyone.

3. **The importance of understanding position in the value chain, actively addressing barriers and developing collaborative business models that enhance both your and your partners' propositions.**

   Look at the example of Apple and how it enhanced its position at the heart of its chosen market by making it easy for other businesses that are great in their parts of the value chain to leverage Apple's products in their propositions.

4. **Understanding the consumer need.**

   All three examples address customer convenience, but what will be the media equivalent of digital TV for the electricity sector?

5. **Building and maintaining a trusted brand with which your customers choose to associate themselves.**

   The example being how Apple has maintained its leading position and attracted a premium through brand loyalty.

The need for connected infrastructures

The revolution in the portable music sector required three separate infrastructures to be in place: the communications infrastructure with the necessary bandwidth and latency; the World Wide Web to have been established; and the acceptance of personal computers into most homes.

The transformation of the electricity sector into a smart, flexible energy system will follow a similar path. It will be established on the smart meters, run across the existing World Wide Web and will flourish on the back of the acceptance of flexible, low-carbon technologies into people's homes.

The rise of demand-side flexibility

By 2030, it is quite feasible that six million homes could have some level of demand-side storage.

Taking today's ratings of home storage, that could be around 30GW (almost half of the projected average cold spell (ACS) peak demand) storing an average of 40GWh of energy (equivalent to the projected output from Hinckley Point C for 12 hours), assuming a uniform distribution of storage from empty to fully charged.

Looking at it from the perspective of demand turn-up, this would equate to more than the de-rated solar and wind generation capacity in 2030 under the Consumer Power scenario, with sufficient spare storage capacity to store all the energy produced in an hour.

In 'Energy Flexibility: Transforming the Power System by 2030', industry leaders identified storage as being the most significant technology in facilitating the necessary flexibility in the British electricity system. Demand-side storage was the technology that they had the highest confidence in being mature and commercialised by 2030. It was also notable that survey participants from the retail and trading market roles saw the greatest business opportunities in making use of demand-side flexibility to efficiently manage their portfolios.

If policy, regulation and standards can be coherently aligned to deliver the physical infrastructures and devices that provide the level of flexibility across the system to economically maintain security of supply, the challenge then becomes one of ensuring that the market for energy and flexibility services operates effectively and delivers genuine benefits to consumers by ensuring that their bills are driven by when they consume rather than how much they consume.

But, if we are to realise the opportunity to employ demand-side flexibility to convert the 'Energy Trilemma' into a virtuous circle, then time is short.

References

1. A modern smartphone or a vintage supercomputer: which is more powerful?, phone Arena, June 2014
2. SUPERCOMPUTER vs your computer in bang-for-buck battle, The Register, March 2012
3. The CRAY-2 Computer System, Cray Research, Inc., May 2016
4. iPhone 7: GPU, Forsyth Analytics, May 2016
5. Wikipedia history of GFLOPS costs, AI Impacts, October 2015
6. Tracking the astounding pace of digital storage, BoingBoing, March 2011
7. Walkman to iPod: Business-Model Transformation, Recode, September 2015
8. From Walkman to iPod: What Music Tech Teaches Us About Innovation, The Atlantic, March 2012
9. Power market forecasts for the next decade: top issues to watch, ABB Market Advisory, September 2016
10. Value of Flexibility in a Decarbonised Grid and System Externalities of Low-Carbon Generation Technologies, The Committee on Climate Change, October 2015
11. Future Energy Scenarios 2016, National Grid, December 2016
12. Are Smart Phones Spreading Faster than Any Technology in Human History?, MIT Technology Review, May 2012
13. Energy Flexibility: Transforming the Power System by 2030, CGI IT UK Ltd, May 2016

Other references used throughout the white paper:

- E-Storage: Shifting from cost to value, World Energy Council, January 2016
- Internet access – households and individuals: 2016, Office for National Statistics, August 2016
- Power sector scenarios for the fifth carbon budget, The Committee on Climate Change, October 2015
- System Integration Costs for Alternative Low Carbon Generation Technologies – Policy Implications, The Committee on Climate Change, October 2015
- Smart Power, National Infrastructure Commission, March 2016
- Delivering future-proof energy infrastructure, National Infrastructure Commission, March 2016
- A SMART, FLEXIBLE ENERGY SYSTEM - A call for evidence, BEIS, November 2016
- An analysis of electricity system flexibility for Great Britain, BEIS, November 2016
- Position Paper: Making the electricity system more flexible and delivering the benefits for consumers, Ofgem, September 2015
- Electric Shock: Will the Christmas lights go out next winter?, British Infrastructure Group, December 2016

This paper addresses a fast-moving area of discussion and development. Between its drafting and publication, thinking has continued to progress:

- National Grid has published its Future Energy Scenarios for 2017
- BEIS has published 'Upgrading our energy system: a smart systems and flexibility plan' in response to its call for evidence on a Smart, Flexible Energy System
- The Committee on Climate Change has published its '2017 Report to Parliament – Meeting Carbon Budgets: Closing the policy gap' and the associated report 'Roadmap for flexibility services to 2030 (Poyry and Imperial College London)'

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