A circular economy for smart devices
Opportunities in the US, UK and India

green
alliance...

Contents

Summary

Smartphones, tablets and laptops have moved from the fringe of computing to the mainstream in just five years. Sales of these smart devices exploded as consumers saw the benefits of seamless connectivity, and were drawn to the simplicity of new user interfaces. In many cases, the environment benefited too, as energy efficient devices displaced older computers, and new mobile-enabled cloud systems became platforms for efficiency across the economy.

Unfortunately, this isn't the whole story. Smart devices are smart, but the physical systems they end up in are not: 89 per cent of mobile devices in the US were thrown into landfill in 2010, even though the resources they contain mean it is economically sensible to recycle them. Many millions of usable devices are left forgotten in drawers once their owners upgrade, despite a robust second-hand market. This wastes perfectly good devices, frustrates consumers and harms the environment.

But technologists don't have to let their hard work end up as waste after a few short years. A circular economy for smart devices would keep them in use for longer. This analysis reveals that a two year old flagship smartphone can be more attractive than today's mid to low tier best sellers. It shows that repair makes economic and environmental sense for at least four years, and up to seven in some cases. And it demonstrates that keeping a mobile phone in use for just one extra year cuts its lifetime CO_2 impact by a third.

Just as there isn't a single business model for smart devices, there isn't a single route to a circular economy. Instead, this report sets out six circular economy business models that companies in different parts of the supply chain can experiment with. These range from software only changes to hardware redesign to enable existing parts to be used again. Even small design adjustments can make a huge difference: replacing a screen on the iPhone 3GS takes 15 minutes; on the less modular HTC One, it takes 90 minutes.

This report analyses US, UK, and Indian markets, identifying the most receptive consumers for the different circular economy models. In developed markets like the US and UK, second-hand phones could prove attractive to the roughly 40 per cent of consumers without a smartphone, who tend to be older and less well off.

The saturated market for laptops, by contrast, would be better suited to circular economy models which keep laptops with a single user for longer.

In India, low labour costs and more standardised hardware in cheaper devices make harvesting parts a viable strategy. Similarly, India's existing network of small electronics repairers would favour a decentralised, DIY repair approach.

There are huge circular economy opportunities for the makers of smartphones, tablets and laptops. With five billion potential customers seeking access to smart devices, companies that reduce their costs and environmental impact through circular strategies will prosper. The good news is that the tools to do so, as we outline in this report, are already at hand.

1
Introduction: good devices, bad systems
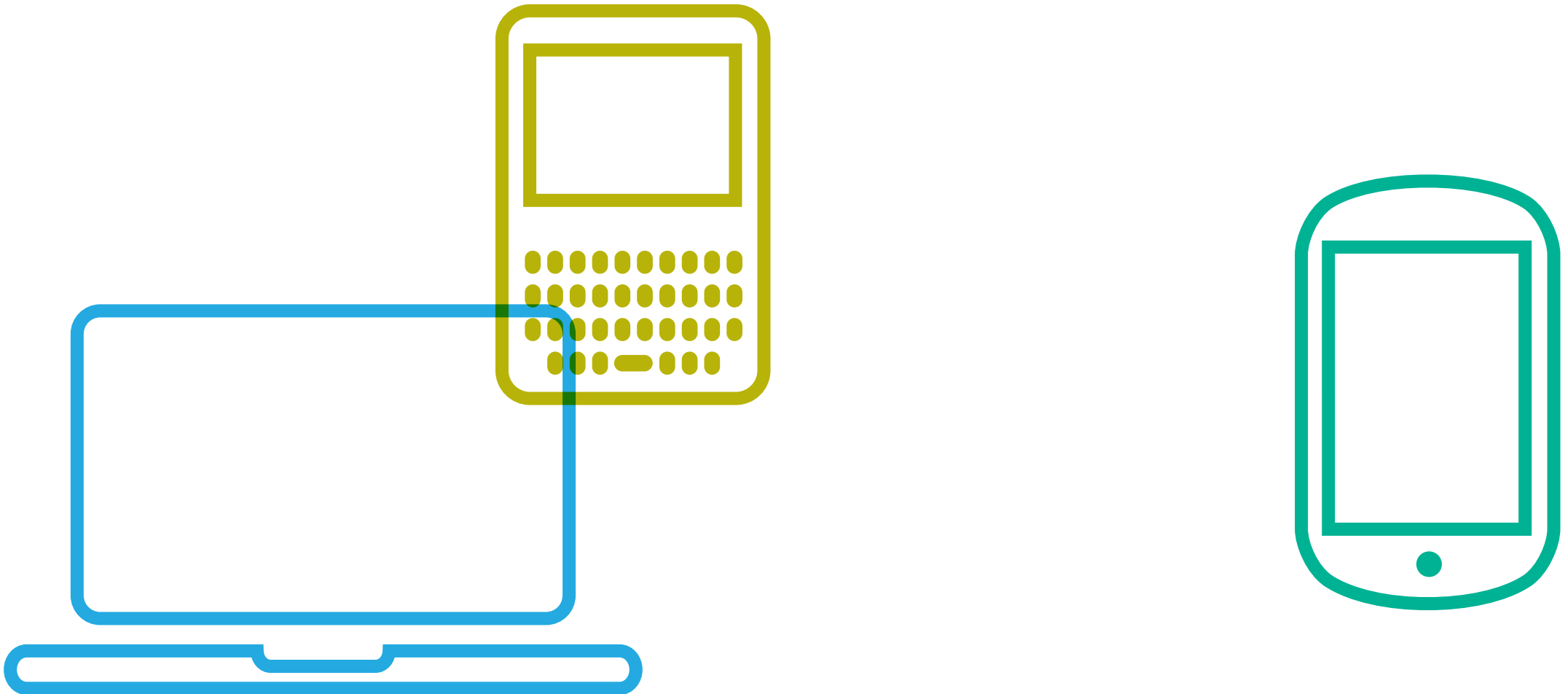
The technologists that created mobile computing started with a gloriously blank canvas. They used their creativity to design elegant, useful, and universally desirable new devices and systems. Their products are carried in billions of back pockets and bags across the wealthy world, and they are aiming to sell to the next five billion people, all of whom are eager to benefit from the information and communication that the internet provides.

But these ingenious people have sent their devices out into a world whose physical systems are designed with none of the elegance of their digital counterparts. The result is that old but usable laptops, tablets and smartphones are ending up in landfill or languishing in drawers, where they sit until they reach technological obsolescence. But clever devices deserve better than to become waste after just a couple of years of use: electronics and the cloud services that they connect to can be the source of the solution.

This report shows how companies across the mobile electronics supply chain can adopt a circular economy model to make money out of old devices, attract new

customers around the world, increase brand loyalty, and cut manufacturing costs and risks. Doing so would also help to cut electronic waste, carbon emissions and resource use.

The circular economy is already making money

A circular economy for consumer electronics is already here. It has developed from the bottom up: the value of Apple devices sold on eBay in the US in 2013 was nearly $2 billion.[2] NextWorth estimates the potential value of the US smartphone trade in market in 2014 to be over $3 billion.[3]

And it's not just smartphones. WRAP estimated in 2013 that the value of two to three year old laptops in the UK was £720 million and two to three year old tablets were worth £90 million after any collection and repair costs were taken into account.[4] Even when devices are no longer usable they have value: the market for IT spares and components is estimated to be greater than £10 million a year in the UK alone.[5]

Valuable resources are being lost[1]
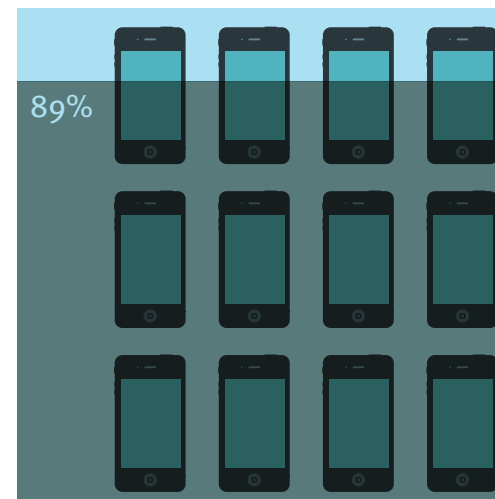
89 per cent end up in landfill

The US threw away 141million mobile devices in 2010, 89 per cent of them went to landfill

...while millions are discarded

28-125 million phones languish unused in the UK alone. This means for every phone in use, up to four sit in drawers unused

The used device market is growing fast, with estimates of global used smartphone sales expected to rise from 53 million to 257 million between 2013 and 2018, driven by a doubling of trade-ins in the US.[6] But these big numbers hide far greater potential: globally, only 12 per cent of smartphone upgrades involved the old device being sold or traded.

This is changing the market. Credible projections suggest that eight per cent of new sales will be cannibalised by reuse in 2018.[7] Rather than seeing these trends as a threat, forward thinking companies could see them as a new opportunity.

They wouldn't be alone: a growing number of independent trade-in businesses like Gazelle in the US and Mazuma in the UK are competing for old mobile devices on the ease, trust, and reliability of their service. Manufacturers are also beginning to enter the market, with Apple offering a trade-in service for iPhones and iPads in the UK, US and India, and Samsung running one for smartphones in India. But carriers, retailers and software providers also have an opportunity to grow the total size of the market by using their relationship with
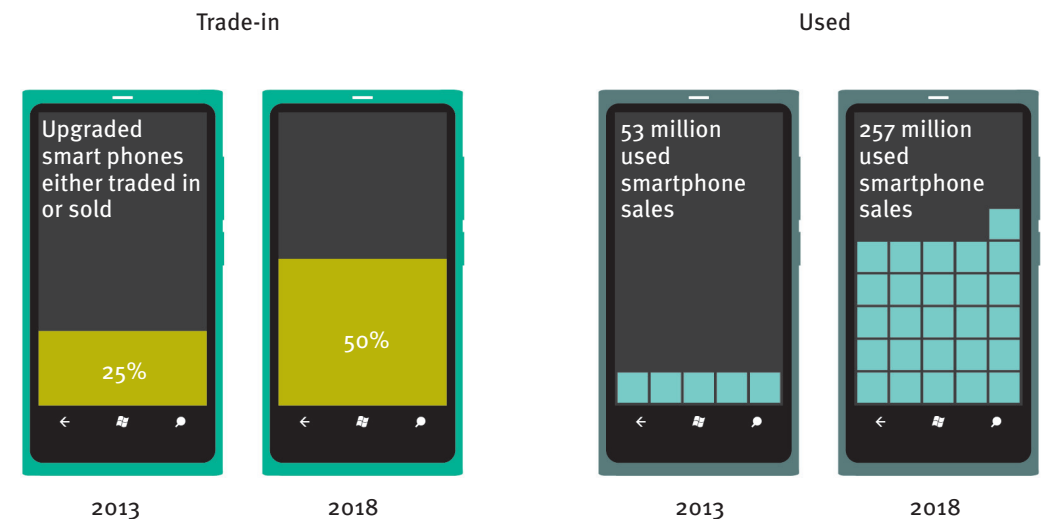
consumers to recover more of the devices that would otherwise end up scrapped or stored away.

But it is not just about gaining more value. Manufacturers, software providers, retailers and carriers would benefit from building circular economy thinking into their business plans because it is popular with customers, helps to mitigate business risks, and dramatically cuts the environmental impact of devices: just keeping a smartphone in use for an additional year cuts its CO_2 impact by 31 per cent.

In this report we set out these benefits in detail, but if they are to be realised, companies will have to experiment with new, circular economy models.
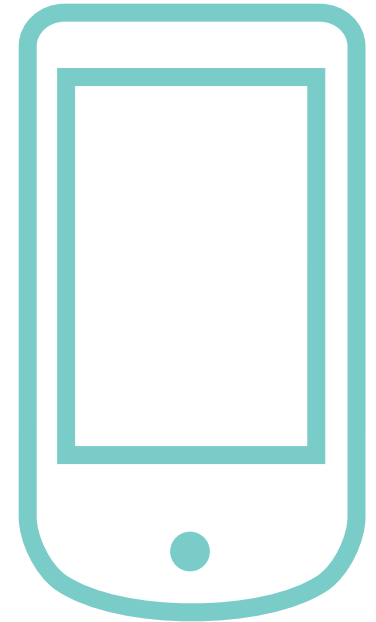
We outline six models in chapter two (see page six), demonstrating how companies can adapt software, hardware and business models for a circular economy. They show the changes companies could make, which parts of the supply chain might benefit most and which consumers are likely to be most receptive.

Market predictions for traded-in and used smartphones to 2018

Trade-in

Used

Upgraded smart phones either traded in or sold

25%

50%

2013

2018

53 million used smartphone sales

257 million used smartphone sales

2013

2018

In chapter three we provide a more detailed analysis of the US, UK and Indian markets, to show how circular models for smart devices meet the demands of their consumers.

2
Six circular economy models

Three types of intervention

Hardware	Software	Business model
No redesign	No redesign	No redesign
Battery and screen replacement	Simplified second life OS	Leasing, eg device upgrades on schedule
Cosmetic modularity (eg Nokia's swappable shells)	Hardware diagnosis	Buy back
Full modularity (eg Phonebloks)	Performance diagnosis	Servitisation, eg Chrome OS
Durability	Collection prompting	
Part compatibility	Driver standardisation	

There is no single model for a circular economy in consumer electronics. The supply chain for mobile devices is complex, highly varied and still evolving.

Companies like Apple and Microsoft are vertically integrated across hardware and software; Samsung is even more tightly integrated across hardware, but largely reliant on others for software; Google is mostly a software company but is increasingly influencing hardware design; and carriers, like O_2 in the UK or AT&T in the US, provide services but also occasionally produce hardware. There is similar diversity across the whole supply chain.

Rather than imposing a single model, this analysis builds on three types of intervention: hardware, software and business model changes. Each has a number of options, outlined in the tables on the left.

Using this framework, six combinations of hardware, software and business model options are set out in this chapter. All will increase the lifetime of older devices, but some will work better for different parts of

the supply chain than others. They are developed with information about why different supply chain actors might benefit from a particular model, and also which consumers might find them attractive.

The overall aim is to provide an interested company with enough information to experiment with different ways of becoming more circular.

The six models are:

1. Software led longevity

2. Better reuse

3. Minor modularity

4. Cloud offloading

5. Parts harvesting and remanufacturing

6. DIY repair

Model 1
Software led longevity

Hardware
No redesign
Battery and screen replacement
Cosmetic modularity (eg Nokia's swappable shells)
Full modularity (eg Phonebloks)
Durability
Part compatibility

Software
No redesign
Simplified second life OS
Hardware diagnosis
Performance diagnosis
Collection prompting
Driver standardisation

Business model
No redesign
Leasing, eg device upgrades on schedule
Buy back
Servitisation, eg Chrome OS

Out of date software means usable hardware provides a second rate experience, with reduced features, limited app compatibility and security vulnerabilities. This reduces reuse opportunities: twenty per cent of consumers say that they replace a device when there are no more software updates for the old one.[8] Updates are a significant factor in a device's resale value: The LG G2, which has no guarantee of timely software updates, is worth 15 per cent less than the almost identical Google Nexus, which does.[9]

Research firm Bernstein notes that smartphones with unsupported operating systems have "limited to no resale value."[10] This is a major barrier to reuse: 63 per cent of Android and 54 per cent of Windows Phone devices are running two year old versions; 19 per cent and 17 per cent, respectively, are running three year old versions.[11]

Name	Manufactured	Support ended	Months supported
Nexus One	January 2010	September 2011	20
Nexus S	December 2010	October 2012	22
Galaxy Nexus	November 2011	July 2013	20
iPhone	June 2007	February 2010	32
iPhone 3G	July 2008	November 2010	28
iPhone 3Gs	June 2009	February 2014	56
iPhone 4	June 2010	March 2014	45
iPad	April 2010	May 2012	25
Nokia Lumia 800	November 2011	November 2012	12
Nokia Lumia 900	April 2012	November 2012	7
HTC HD7	October 2010	November 2012	25
HTC Titan	October 2011	November 2012	13

Eighteen month old iPhones on average retain 53 per cent of their value, versus 42 per cent for Android flagships.[12] iPhone software support lasts on average 16 months longer.

The circular economy strategy to solve these problems has two potential routes: the first would be simply to extend and guarantee software support for longer. The second is to develop a lighter weight second life firmware for older devices. This could possibly involve turning off certain features like visual transitions, skins, gesture controls, widgets and cloud syncing, for example, and then either selling second-hand devices with more limited functionality to market segments that would buy lower tier devices, or providing this as an additional 'keep your device fast' service for existing users for free or for a small upgrade fee.

A version of this model exists already, with tech savvy users switching to Cyanogenmod or other custom firmware for mobiles and tablets, or less resource intensive PC operating systems like Lubuntu for laptops. And developing software shouldn't be expensive: Cyanogenmod is estimated to

have cost $44 million to code and LXDE $1.6 million.[13]

Which parts of the supply chain benefit?

Software producers
Companies that make money through the use of a device (eg Google via Android, Apple via iTunes, and other digital services and app developers) already have incentives to give customers up to date software: showcasing the best features of the OS, enabling wider choice of apps and better data analytics, and avoiding reputational risks from security breaches. The challenge for them lies in diverting funding to a second life operating system, and securing agreement from hardware providers either to open source hardware drivers or to provide continued support for these over time.

Manufacturers
Manufacturers have less direct incentive to support second life operating systems, as they make money based on device sales, not device lifetime. However, indirect reasons to provide software support include:

- **Customer frustration:** customers who replace a device due to frustration with

outdated software are less likely to buy their next device from the same manufacturer. HTC has recognised this and promised to support software for two years after release.[14]

- **User experience:** this is a differentiating factor among brands as prices drop, markets become saturated and hardware innovation slows.[15] Software support for previous generations of iPhones has been part of Apple's strategy of leading the market in customer experience.[16]

- **Maintaining value:** consumers prefer products with higher resale values.[17] Some users buy devices with a plan to sell them afterwards; others use resale value as the best indication of the quality of the product.[18]

Where's the market?
In the US and UK, simply extending software updates would be popular with consumers who buy new hardware infrequently, such as lower socioeconomic groups or those using prepaid plans with unsubsidised devices.[19] Also, it would be popular with the increasing number of people who sell devices on after first use.[20]

In India, extended software support is becoming a defining feature of lower specification phones which can't compete on hardware with premium models. For instance, Chinese manufacturer Xiaomi is focusing explicitly on providing the latest Android OS to all device users, rather than competing solely on specifications.[21] Google's Android One programme will guarantee regular updates by providing hardware standards for companies, such as budget Indian manufacturers Micromax and Karbonn.[22]

A used device with second life firmware would be most attractive for those in the US or UK who don't already own a smartphone or tablet. This includes low income consumers, or those who would prefer a simpler device;[23] for example, the over 65s market, which makes up around a sixth of the population of the UK.[24]

Similarly, in India, older devices with second life firmware would suit those who are looking to enter the market for the first time and would like a working device at minimal cost. Older devices could easily compete with the $35 Cloud FX mobile phone, for example.[25]

Model 2
Better reuse

Hardware	Software	Business model
No redesign	No redesign	No redesign
Battery and screen replacement	Simplified second life OS	Leasing, eg device upgrades on schedule
Cosmetic modularity (eg Nokia's swappable shells)	Hardware diagnosis	Buy back
Full modularity (eg Phonebloks)	Performance diagnosis	Servitisation, eg Chrome OS
Durability	Collection prompting	
Part compatibility	Driver standardisation	

Globally, there is no shortage of demand for second-hand devices, yet millions of phones sit in drawers in the US and the UK, while the same models fetch high prices on eBay. Between 27 per cent and 36 per cent of US consumers said they keep an old phone because they "don't know what to do with it." Seventeen per cent were just "too lazy" to get rid of them.[26] The key to maximising the value and environmental benefits of reuse is to retrieve used devices as early as possible, although there is value in many devices for over five years from the original sale date.

This model would use two software tools to supply more used devices to the people who want to buy them.
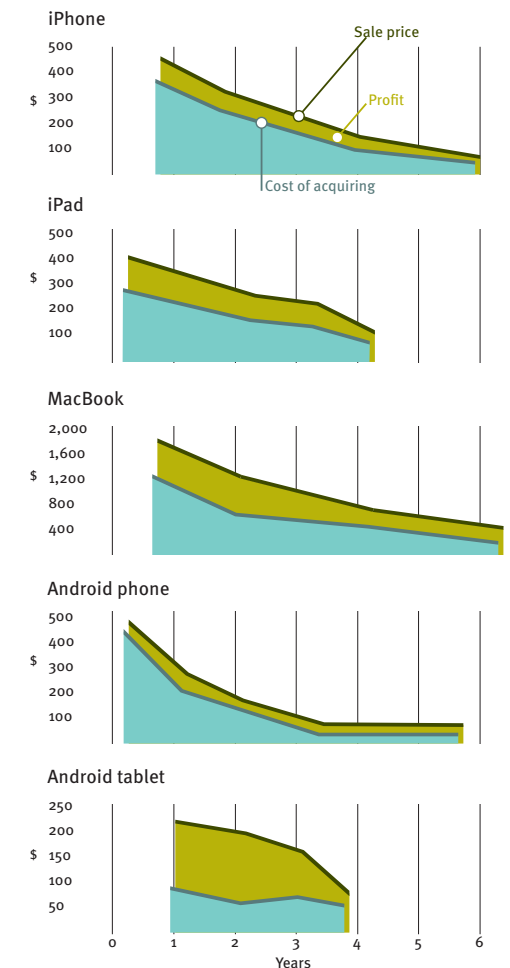
The first would be a hardware diagnosis app which would measure water damage, memory errors, charge cycles and battery lifetime, impact Gs, number of reboots, etc. These data could either directly determine the condition of the device, or be used as a proxy for likely damage. For example, a tablet which receives above a certain number of impact Gs is likely to be damaged. This would reduce the cost of assessing second-hand devices and increase confidence in their quality.

The second tool would address the lack of awareness and hassle factor preventing greater reuse. It would do so by prompting consumers to sell their old device, displaying its value on a range of different buyback services, like eBay, Mazuma, or Gazelle. It would need to offer very simple collection options, building on recent improvements in delivery systems for online shopping, including Collect+, Amazon lockers, the post office network, or home delivery.

Ideally, selling would be a simple, one click action, using geolocation to offer the nearest drop off point, automatically deducting postage charges and providing packaging, securely wiping data and immediately crediting the user's bank account.[27] The trigger for such a prompt could be set based on contract length, as with existing upgrades, or could be based

Profit from reuse

iPhone

Sale price

Profit

Cost of acquiring

iPad

MacBook

Android phone

Android tablet

Years

on sim card swapping, Google or iCloud registration of a new device, or could even prompt a user when a device hasn't been used for a period of time.

This model would be most likely to work for smartphones and tablets, where information about device usage is routinely collected already and upgrade cycles have not yet matched the technical obsolescence of the underlying product.

Which parts of the supply chain benefit?

Manufacturers, carriers or retailers could capitalise on the high value of unused devices: up to $58 billion of unused US and UK smartphones alone.[28] However, as the market develops it is likely to become highly competitive, with schemes being subject to a significant network effect.

Manufacturers

Relatively new second-hand devices can be used internally by manufacturers, as a replacement for insurance claims or warranty returns.[29] Older devices can be sold to consumers in the developing world to attract new users to the ecosystem who could buy new devices in the future.[30]

Carriers and retailers

Benefits are likely to be higher for carriers: retailers like mobiles.co.uk already offer six month old refurbished devices on contracts that cost 15 per cent less than normal contracts, addressing a more price sensitive market segment.

The biggest challenge for this model is that the software provider is probably best placed to develop and deliver both hardware diagnosis and software prompting services. This is because it sees when users change their devices, is a neutral party when presenting different end of life buyback options and already collects user data, which may be relevant to hardware diagnosis. However, it has the least to gain from doing so at present. But, as e-waste collection requirements expand, it is possible to imagine that software providers could offer collection prompting as a core feature of an operating system, in exchange for a service fee or as part of the attractiveness of a software ecosystem.

Where's the market?

The problem of unused devices not getting into second-hand markets is currently a first world problem. Informal reuse, repair

and recycling is mostly very effective in India.[31] Of the smartphones collected through trade-in programs in the developed world, 30 per cent are sold in developed markets and 70 per cent are sold in emerging markets, as export costs are cheap and brand name devices are in high demand.[32, 33, 34] A similar pattern holds for laptops and tablets.[35]

It is likely that Apple already sells factory refurbished phones from developed markets to India.[36] It is able to do this easily as it controls hardware, software and has substantial power over carriers. A similar model could be used for mid-range devices from other manufacturers, which could compete with low cost Indian and Chinese products to attract first time buyers.

In the US and UK, there is an opportunity for manufacturers to sell used devices to compete directly with budget devices. For example, the Samsung Galaxy SIII, released in May 2012, has similar specifications to the Moto E, released in May 2014, and commands a similar price.[37] Potential market segments to target include:

- the third of US and UK customers who cite value for money as most important when choosing a mobile device, plus those who don't own one at all due to cost: in the US, 59 per cent of 18 to 29 year olds without a smartphone don't own one because it's too expensive;[38]

- prepaid customers who don't have access to a subsidised device on contract;

- the 30 per cent of the UK population who are 'gadget lovers' and want to experience a more premium model or upgrade more often than they could afford to with new devices; and[39]

- corporate customers, who are "increasingly willing to give employees like-new refurbished phones that are cheaper than new phones."[40]
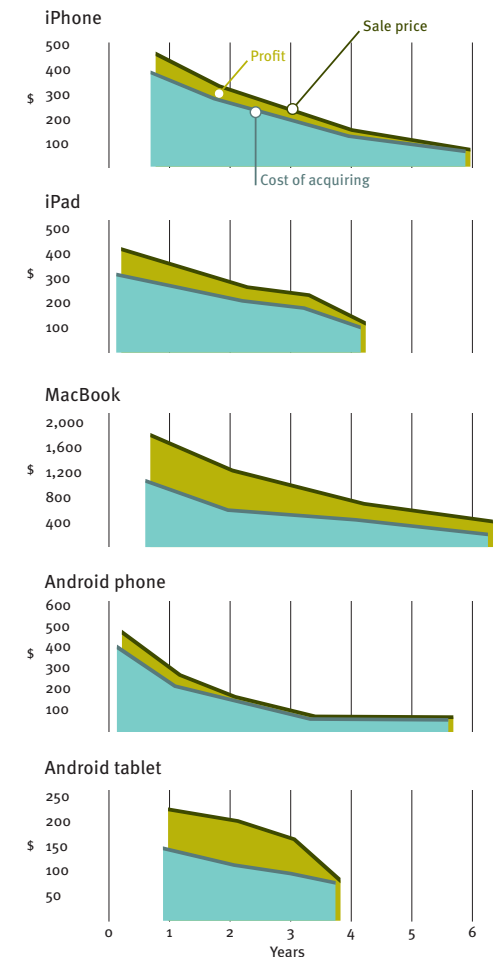
Model 3
Minor modularity

Hardware	Software	Business model
No redesign	No redesign	No redesign
Battery and screen replacement	Simplified second life OS	Leasing, eg device upgrades on schedule
Cosmetic modularity (eg Nokia's swappable shells)	Hardware diagnosis	Buy back
Full modularity (eg Phonebloks)	Performance diagnosis	Servitisation, eg Chrome OS
Durability	Collection prompting	
Part compatibility	Driver standardisation	

Second-hand devices requiring minor repair are worth repairing for three to five years after sale, even after logistical and refurbishment costs are taken into account. But there is huge variation in the cost of repair: many devices don't have easily removable batteries or replaceable screens, as designers favour slimness over repairability.

Screen and battery replacements are the most frequently needed repairs for a range of devices: 85 per cent of iPhone repairs are for cracked screens according to iCracked.[41] According to WRAP, 73 per cent of tablets requiring repairs only need battery or screen replacements.[42]

Lack of battery life limits the attractiveness of phones, with 71 per cent of consumers putting a long lasting battery as the most important feature desired in a new phone, compared to internet access (57 per cent) and a high specification camera (41 per cent).[43] Laptops are much less likely to need screen replacement but would benefit from an easily replaceable battery.[44, 45]

Profit from minor modularity

In this model, minor modularity means that batteries and screens are designed to be easily replaceable. More modular devices would have substantially cheaper repair costs. According to iFixit, replacing a screen on the iPhone 3GS takes 15 minutes versus 90 minutes on the HTC One.[46] This sixfold difference has a huge impact given the frequency of these repairs and the fact that labour cost is the main constraint on repair. The trade off in thickness, at least comparing the iPad and Google Nexus 7, appears to be just one millimetre.[47]

Which parts of the supply chain benefit?

Manufacturers
There are three main benefits for manufacturers:

• Brand loyalty: 95 per cent of iFixit users say successful repair makes them more likely to buy another product from the same manufacturer.[48] Customers have high expectations of reliability for electronics products and are frustrated if they break, so easy repair may go some way to reducing this frustration.[49]

• Higher resale value: as mentioned in model one, higher resale value will add brand value.

• Low cost style differentiation: the worldwide popularity of the Nokia 520, which comes in bright colours with swappable shells to 'match your outfit' indicates there could be an appetite for devices that include modular covers, in addition to screens and batteries.[50, 51] Swappable covers for second-hand devices could refresh the style of an older core, boosting the attractiveness of refurbished devices.

Where's the market?
A manufacturer that adopts minor modularity could attract two types of customers, in addition to those consumers identified as potential purchasers of second-hand devices in the 'better reuse' model.

The first group could be attracted on the basis of longer lived devices. This could encompass the 70 per cent of people in the UK who don't prioritise owning the latest gadgets, the third who buy accessories to prevent their screen from scratching and

the 70 per cent frustrated with battery life, who might benefit from changing the battery as their device gets older.[52, 53] The large amount of repair activity in India suggests that Indian consumers would find minor modularity attractive (see model six for more details.)

The second group is those who are upgrading for reasons of style differentiation: for example, 45 per cent of German consumers replace devices because "there is a new model on the market"[54]. For some, a superficial change could be enough.

Similarly, the 16 per cent of UK consumers that prioritise stylish design when choosing a device may be interested in only changing the exterior look of the device.

The enduring popularity of Nokia models in India suggests that changeable cases may be of interest to Indian consumers, more of whom choose devices based on style than on price, according to one survey.[55]

Model 4
Cloud offloading

Hardware	Software	Business model
No redesign	No redesign	No redesign
Battery and screen replacement	Simplified second life OS	Leasing, eg device upgrades on schedule
Cosmetic modularity (eg Nokia's swappable shells)	Hardware diagnosis	Buy back
Full modularity (eg Phonebloks)	Performance diagnosis	Servitisation, eg Chrome OS
Durability	Collection prompting	
Part compatibility	Driver standardisation	

This model accelerates the trend of offloading functionality to the cloud, seen in software like Dropbox, Evernote, Google Docs, Opera Mini and others. This is done by shifting away from selling a device and access to the cloud (the traditional smartphone model) or device only (common for tablets and laptops). Instead, it promotes servitisation: selling a service that bundles access, device and performance together.

In practice, this might mean paying for a service package that provides access to a device; guaranteed application load times; compatibility with MS Office; access to specialist software; 3G and WiFi connectivity and minimum battery life.[56]

Offloading tasks to the cloud means older hardware can be used, including second-hand devices. More durable hardware could be helpful, and performance diagnosis software would need to be integrated to ensure that the agreed service commitments (eg speed to load webpages) were met.

Network coverage and latency are the main challenges for this model, but elements of

cloud offloading already apply to all device types: Opera Mini can speed up browsing on smartphones; Kindle Fire tablets offload web browsing tasks to Amazon's EC2 cloud; and ChromeOS and Citrix demonstrate that lower power laptops can meet the needs of some consumers.

Even the most latency sensitive applications, like video gaming, are offloading tasks to the cloud: the Xbox One offloads processing to Microsoft's Azure cloud.[57] This suggests the network has caught up. The challenge is to extend this trend and to target second-hand hardware more explicitly.

Which parts of the supply chain benefit?

Service providers
Cloud offloading offers an opportunity to grow based on providing an integrated service, rather than simply competing on data bandwidth, while reducing total service cost by using cheaper second-hand devices. However, software developers are the early movers in providing the cloud based services that any servitised model would require.

Manufacturers

The main benefit of cloud offloading may be to lower cost, less established manufacturers, who could focus on durable, lower specification new and remanufactured devices rather than going into direct competition with manufacturers who are competing on high cost, high specification new devices.

Where's the market?

Cloud computing and servitisation exist already, but they don't often use second-hand devices. However, the majority of consumers (70 per cent in the UK) don't "love buying gadgets",[58] and many others want only a limited set of features. Examples include:

- lower socioeconomic groups or those looking to spend as little as possible on a device, as this model could work out much cheaper, eg currently Chromebooks are available for $200-400, while regular notebook prices start around $400;[59]

- consumers confused by the range of new devices who would rather only choose the service, especially if they only plan to use basic features.[60] For example, 57 per cent of over 65s without a smartphone perceive no need or relevance for new devices while a further 13 per cent say they are too complicated;[61]a targeted device with the right features could attract these customers; and

- business customers who have a high turnover of different users on the same devices, or who require the strong data security enabled by not processing data locally.

Cloud offloading could also apply to facilities where data control is important and tasks are limited. One example might be using second-hand tablets for medical records management in hospitals or for warehouse stock management. Existing successful cloud models for laptops are in education and large businesses with a limited range of use cases. Unfortunately, relatively patchy 3G networks in India limit cloud offloading at present.[62]

Model 5
Parts harvesting and remanufacturing

Hardware	Software	Business model
No redesign	No redesign	No redesign
Battery and screen replacement	Simplified second life OS	Leasing, eg device upgrades on schedule
Cosmetic modularity (eg Nokia's swappable shells)	Hardware diagnosis	Buy back
Full modularity (eg Phonebloks)	Performance diagnosis	Servitisation, eg Chrome OS
Durability	Collection prompting	
Part compatibility	Driver standardisation	

This model would extend the minor modularity envisaged in model three to include improved disassemblability and compatibility of additional components.

This would enable the reuse of components when the device is otherwise not able to be repaired. It would keep high embodied carbon components, such as integrated circuits, which contribute 35 per cent of a smartphone's carbon footprint, in use for longer.[63]

This model could be most useful for slowly evolving technologies, such as mid-range cameras and power supplies, as well as components that break easily, such as micro USB connectors, laptop power connectors and radio modules for WiFi and Bluetooth.

Used components could be used in new or remanufactured devices, or in secondary markets.[64] For a detailed breakdown of the carbon impacts of repair, see chapter four.
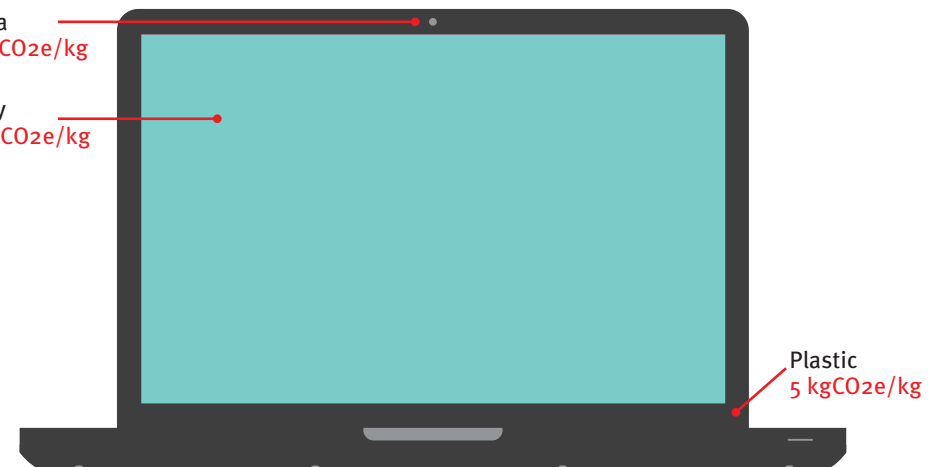
Embodied carbon in laptop components

High carbon

Low carbon

Camera
370 kgCO2e/kg

Display
360 kgCO2e/kg

Plastic
5 kgCO2e/kg

Currently, disassembly is common for expensive servers but uneconomic for most mobile devices in the US and UK, due to a combination of high labour costs and design choices that favour slimness over disassemblability.[65] Even in China, which has wages only somewhat higher than India, complete disassembly may become uneconomic by 2015, with limited disassembly ceasing to be economic by 2026.[66]

This suggests there is a window of opportunity for manufacturers to remanufacture devices over the next decade in India, starting with existing devices, while they redesign devices to ensure that partial disassembly is economic in the longer term, for example to extract the camera.

Pressure to produce low cost devices is already leading to component standardisation in Android One devices. The limited range and high popularity of Apple products also makes component reuse possible.

However, there are a number of barriers to expanding remanufacturing. On the

hardware side, components' size, shape and connectivity need to be standardised. On the software side, a lack of available drivers is the main challenge: although Windows and Linux are able to dynamically load drivers, tablets and smartphones have architectures which require device specific kernels. There is no technical reason why this couldn't change, as Google's Project Ara, which uses dynamically loading drivers, shows.[67] However, the more fundamental challenge is to extend the availability of drivers, most of which are developed by component manufacturers and are only provided under licence to original equipment manufacturers (OEMs).[68]

Which parts of the supply chain benefit?

Manufacturers, remanufacturers and refurbishers

The majority of the value of broken devices lies in the highly engineered components, rather than raw materials, meaning component reuse is the best way of retaining value.

Manufacturers that redesign devices to be able to reuse components avoid the costs of

Reuse and parts harvesting are much more valuable than recycling

New phone

Product price £599

Parts £188
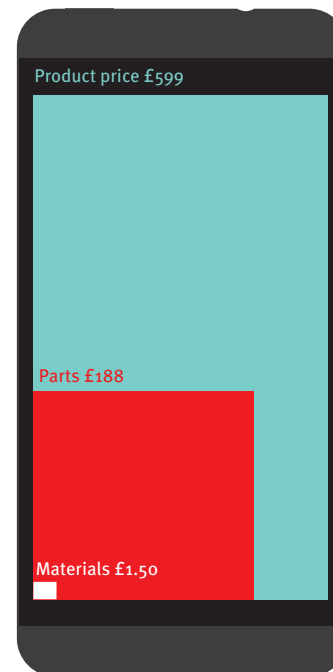
Materials £1.50

Finished products are worth much more than the raw materials inside them

Second-hand phone

Price if reused £290

Parts £170

Materials £0.72

Parts in a broken phone are worth nearly one third of the original value of the device

producing new parts. The same is true for remanufacturers and refurbishers. An apt metaphor is the car industry: cars are readily disassemblable; and many parts are compatible across generations and model types. The result is a robust market for spare parts and substantial profits for remanufacturers.

At the same time, raw material prices have risen dramatically as well, particularly for specialty metals. Reuse of components is an opportunity to hedge against material risks (see chapter four.)

Carriers and retailers
Because of high labour costs in the US and UK, dramatic design changes would be required to increase parts harvesting and remanufacturing significantly.

The most obvious way to justify such a redesign would be for a manufacturer and a carrier or retailer to form a partnership for leased devices. This would enable devices to come back to the manufacturer and savings to be shared between the manufacturer and the retailer or carrier.

Where's the market?
The UK's Centre for Remanufacturing and Reuse notes that remanufacturing is at its most successful when it is most hidden, due to consumer perceptions about the reliability of remanufactured goods.[69] Certainly, in the US and UK markets, remanufacturing would work best if it were invisible to the consumer, with full new warranties applying to devices that contain remanufactured parts.

In India, device and component reuse is higher than in developed markets, and some generic components are already used. For example, Micromax buys Mediatek or Snapdragon processors for budget devices rather than custom building them.[70,71]

This suggests that a more explicit strategy of leasing phones to consumers could be successful. Such a leasing model could promise that the recovered components from a traded-in phone will be used to reduce the cost of a new phone, provided consumers stick with the same manufacturer. This could be done via online channels, but as these account for only ten per cent of sales, manufacturers may wish to partner with brick and

mortar retailers for distribution and reverse logistics.

Opportunities for parts use in secondary markets include redeploying screens and cameras for low cost devices, and using laptop batteries to power off-grid LED lighting, a secondary use which has already been trialled in Bangalore.[72]

Model 6
DIY repair

Hardware	Software	Business model
No redesign	No redesign	No redesign
Battery and screen replacement	Simplified second life OS	Leasing, eg device upgrades on schedule
Cosmetic modularity (eg Nokia's swappable shells)	Hardware diagnosis	Buy back
Full modularity (eg Phonebloks)	Performance diagnosis	Servitisation, eg Chrome OS
Durability	Collection prompting	
Part compatibility	Driver standardisation	

In addition to screen and battery replacements, for which there is robust UK data, interviews with the Restart Project and iFixit suggest that some consumers replace their tablets and laptops early due to maintenance issues like dust blocking fans, laptop hinge failures, crumbs stopping keys from working or damaged power ports, which they find difficult or impossible to fix.

Redesigning devices for repairability, and providing information on how to repair them, would enable customers to address these problems themselves. However, many IT manufacturers have resisted such an approach: Toshiba has refused to release its repair manuals, citing intellectual property rights and Apple has developed proprietary screws to prevent customers from opening their devices.[73, 74]

Which parts of the supply chain benefit?

Manufacturers, refurbishers and repairers
This model is the most challenging for manufacturers: DIY repair provides very limited opportunities to make money from longer lived devices. Nevertheless, there are some benefits. Consumers find it frustrating to throw devices away because of minor breakages that can't easily be repaired.

Ninety five per cent of iFixit users say successful repair makes them more likely to buy another product from the same manufacturer.[75, 76]

Dell makes repairability a unique selling point, providing extensive support including interactive video teardowns.[77, 78]

And DIY repair can help to cut the cost of servicing warranty repairs. Dyson, for example, designs for repair, sells spare parts and provides guidance on how to repair its appliances via a call centre.[79] The benefits of this to refurbishers or repairers are obvious.

Carriers
Carriers should be largely unaffected except in so far as they make money on mobile phone insurance, as greater repairability may decrease sales of insurance.

Where's the market?

In the US and UK, greater repairability would appeal to those who are prepared to repair their devices, which is currently around ten per cent of customers.[80] As this increases the resale value of devices, it would benefit all customers, especially for those devices subject to slower upgrade cycles, like laptops and tablets.

In India, there is a stronger culture of repair and an expectation that devices should be reliable and easily serviceable.[81] For consumer electronics this is done mainly through a large network of small traders across the country, though increasingly it is also offered by branded service centres.[82]

For example, Micromax has started to compete on repair speed, aiming to reduce the turnaround time to less than seven days from the current 15 by tripling the number of its centrally run service centres and piloting a home pick-up and drop off service.[83]

India's geography, consumers' preferences for quick turnaround times on repair and the prevalence of informal face to face interactions, mean that, if devices were more widely repairable in a decentralised or DIY capacity, then maximum repairability, user satisfaction and brand loyalty could be ensured.[84]

3
Market opportunities in the US, UK and India
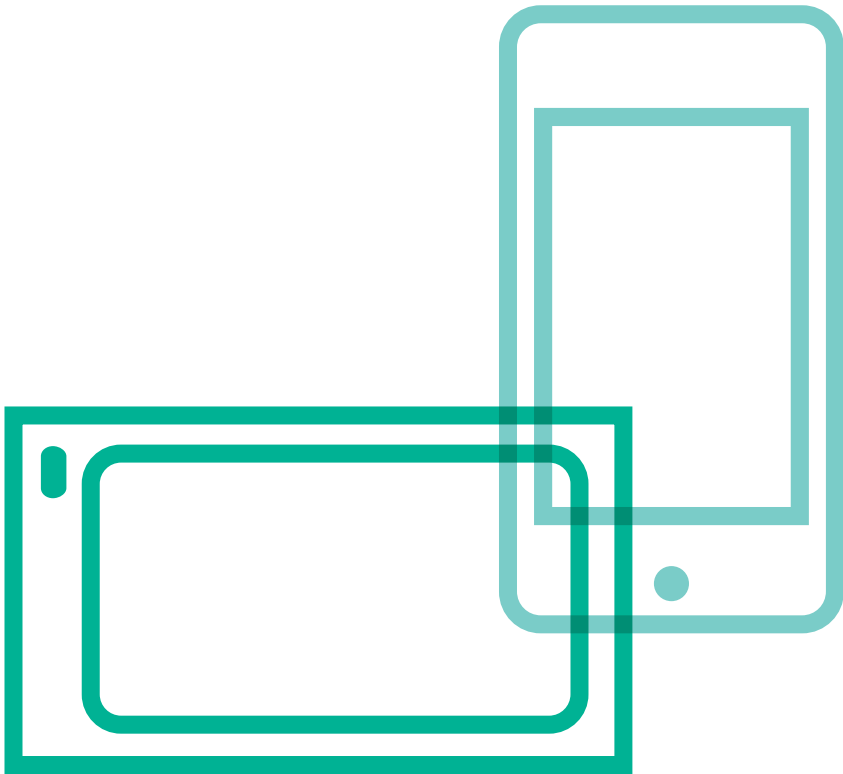
Which circular electronics models suit the characteristics of US, UK, and Indian markets?

	US	UK	India
1 Software led longevity	Enables growth in a saturated market	Enables growth in a saturated market	Enables redistribution of US and UK devices in India
2 Better reuse	Accesses a large pool of reusable premium devices	Accesses a large pool of reusable premium devices	Enables cascaded use of US and UK devices in India
3 Minor modularity	Addresses common hardware failures and uses existing logistics	Addresses common hardware failures and uses existing logistics	Addresses common hardware failures; may require new logistics
4 Cloud offloading	Dependent on the availability of fast data networks	High population density and good network infrastructure	Niche use only
5 Parts harvesting and remanufacturing	Requires device exports for remanufacturing	Requires device exports for remanufacturing	Enabled by hardware standardisation in budget devices and low labour costs
6 DIY repair	Attractive to some consumers	Attractive to some consumers	Builds on existing infrastructure and practice

This chapter outlines the most salient characteristics of US, UK and Indian markets for the circular economy models outlined in the previous chapter. It provides more detail on devices and market opportunities to inform companies exploring how to expand their circular economy activity in both mature and emerging markets.

US and UK markets

Smartphones
Market saturation, slowing technology change and a slowing upgrade cycle are an opportunity for longer lived devices and greater reuse.

US and UK markets have high smartphone penetration levels which are predicted to reach saturation within the next five years. In the UK, 61 per cent of adults own a smartphone.[85] Ownership levels are similar in the US at 58 per cent.[86] In the UK, forecasts suggest 90 per cent sometime between mid-2016 and the end of 2017.[87]

Evidence from saturated markets like Japan, where 97 per cent of mobile subscribers have smartphones, suggests price

competition will sharpen: "[Retailers] get aggressive on pricing, and then when the excitement fades, they move on to the next hit." Budget models are already seeing strong sales in the US and UK.[88]

Ownership patterns show significant differences in take-up across age groups. For example, 88 per cent of 16-24 year olds owned smartphones in 2014 in the UK, compared to 14 per cent of those over 65.[89] The pattern is similar for US consumers.[90] This suggests that older and less well off consumers are the next potential markets for smartphones.[91] However, the majority of these consumers identify a lack of need or relevance for new smartphone features, saying "they don't think they'll make use of the advanced features, or think they'll find it too complicated."[92, 93, 94]

As hardware innovation slows, competition among manufacturers based on technological features decreases in importance.[95] Price is an important driver: the top selection criterion for buying mobile devices in both markets is "value for money" (UK 28 per cent and US 30 per cent).[96] This doesn't mean premium devices

will disappear: two thirds of UK smartphone users own Apple and Samsung devices. But even premium devices may struggle to maintain premium prices.[97]

Taken together, market saturation and the slowing pace of technology change for high end models suggest that the next round of smartphone sales could be served by lower cost, lower specification, second-hand devices.

The structure of the carrier market is reinforcing this opportunity. Smartphone replacement rates are influenced by the carrier refresh cycle, which are slowing in the US and UK. Most customers in the US (75 per cent) and UK (58 per cent) are on postpaid contracts and, in the US, contract periods have moved from 18 to 22 months, to match the UK's 24 months.[98, 99]

At the same time, US and UK carriers are now offering early upgrade options, after 12 or even six months, which rely on the device being traded-in, creating a pool of lightly used devices available for reuse.[100, 101]

On the prepaid side of the market, countries with higher numbers of

prepaid consumers tend to have longer upgrade cycles, and the US has seen a rise in prepaid plans, which may slow the pace of upgrades.[102, 103]

Tablets
The slowdown in demand for premium tablets, alongside strong demand for low cost tablets suggests reused premium tablets could displace new low cost ones.

The sale of tablets in both markets is sharply on the rise. 44 per cent of households in the UK had a tablet in 2014, up from 24 per cent in 2013.[104] In the US, ownership grew from three per cent in 2010 to 42 per cent in 2014.[105]

As with smartphones, there is a marked difference between age groups, with the over 65s being an untapped market, and variation amongst socioeconomic groups, with 26 per cent of US households earning under $30,000 owning a tablet compared to 65 per cent of households with income above $75,000, suggesting price is an important restraint on ownership.[106]

Global research from Strategy Analytics suggests the tablet market is separating into

two types: "the branded side, which is slowing, and the low cost which is continuing to grow…The branded side is struggling because it's already taken the low hanging fruit of people who had netbooks, who moved swiftly to tablets."[107] Tablet refresh cycles are roughly two and a half years but are predicted to lengthen, in the same way as PCs and laptops.[108, 109]

Laptops
A saturated market suggests enabling laptop longevity is the best strategy.

Laptops are still the most popular device in the US and UK, with penetration rates of 63 per cent in the UK and 81 per cent in the US.[110, 111] Although growth has flatlined, and sales are declining.[112] Samsung has announced it will stop selling laptops in Europe.[113]

There is more limited variation between ownership across age groups, and more limited socioeconomic differences, with 74 per cent of ABC1s in the UK owning laptops compared to 50 per cent of C2DEs.[114] Laptop upgrade cycles are just over three years.[115]

The Indian market

Reuse in India

Growing demand for low specification, cheap and used models of consumer electronics is mediated through a heterogeneous, mostly decentralised distribution system.

Reuse happens efficiently in India, mostly in small shops through informal, decentralised networks, but increasingly also online, again mostly through peer to peer markets like quikr.com rather than central vendors like Gazelle in the US.

Devices are more efficiently recovered than in the developed world. Many fewer devices are left stuck in drawers. Used high end devices are in highest demand, but there is a large market for used, budget devices in working condition, even though these depreciate faster than premium products like the iPhone.[116]

A decentralised repair market works in conjunction with the informal resale market. Broken devices are repaired and refurbished, while defunct devices are stripped and sold for parts. There is also a centralised repair network operated by major manufacturers.[117]

As there is huge demand for cheap and low specification devices, the second-hand market is likely to continue to grow and, without other interventions, will remain informal and decentralised.

There is some indication, however, that a centralised resale market may develop. In India, carriers don't tend to offer subsidies for purchasing phones with plans, though Reliance mobile has just introduced a subsidised iPhone deal, creating a structure more like the US market.

India's legislation already places responsibility on producers to make options available for consumers to return devices, and some are offering buyback schemes, led by a desire to increase upgrade cycles rather than to recover any value from old devices.[118] This could tie in well to centralised repair systems being introduced by OEMs like Micromax (see model six on page 19), to provide opportunities for a company to reuse components.

Smartphones

The premium market is saturated, but low smartphone penetration suggests second-hand premium devices from the developed world could compete with mid-tier and budget devices.

India has millions of potential first time buyers of mobile devices. Smartphone growth rates have been the highest in the Asia Pacific region, with a year-on-year smartphone shipment growth of over 186 per cent in the first quarter of 2014.[119]

There is still only ten per cent smartphone penetration of the mobile market, and projections indicate rapid growth rates will continue, especially in urban areas.[120, 121]

Due to low levels of overall wealth and high inequality, the premium market is already saturated. Apple has less than five per cent market share, and Android dominates 90 per cent of sales.[122] Cheap models have been driving growth, with the sub-$200 category contributing about 78 per cent of market growth in early 2014.[123]

The majority of future growth will continue to be in low end, low specification devices, with increased penetration being caused by prices falling even further, eg smartphones costing less than $100 or even less than $50.[124] Budget Indian manufacturers, like Micromax and Karbonn, have also enjoyed rapid success and Micromax now closely rivals market leader Samsung. Cheap devices achieve low costs through generic components and larger scale production, which may contribute to greater potential for circular use.[125]

Tablets

Very cheap devices with limited internet connectivity are the norm, meaning second-hand premium devices may have a niche in the market.

Tablets are less popular in India but are seeing rapid growth; again this is most pronounced in the cheapest segments of the market. Few people have access to broadband and 90 per cent of those accessing the internet do so on smartphones and tablets.[126] Rural areas still have very limited access to 3G networks and have seen much slower uptake rates. As of August 2013, Vodafone had only upgraded 15 per cent of its 9,000 cell sites

in Uttar Pradesh to support 3G services.[127] The government is promoting internet access by subsidising the development of a very cheap tablet, which will be available for INR 1,500 (£14).[128]

Laptops
Limited penetration, as smartphones and tablets are the preferred devices.

Laptops are less widespread, with users who can only afford one device more often opting for a smartphone or a tablet. Budget laptops have been available for some time but, with prices starting at £150 for the cheapest devices, they are nowhere near as affordable for most consumers.[129] Lack of reliable internet access other than by mobile data may also limit uptake. As such, these devices are much less relevant for the Indian market.

The problem with e-waste
Existing reuse markets for electronics are global, with a substantial fraction of lower specification devices being sent to the developing world. A number of the circular economy models outlined in this report could involve capturing older premium devices from developed

markets and sending them for reuse in emerging markets.

This poses a challenge: increasing second-hand exports to India could exacerbate India's e-waste problem for genuinely end of life devices. Indian fears of becoming a dumping ground for e-waste have led to a partial block on imports of used computers and proposals to limit imports of other used electronics.[130, 131]

Adopting the reuse and remanufacturing focused circular models suggested in this report will reduce the total number of devices reaching the end of their useful life, as second-hand devices displace new devices. The logistics networks developed for the six circular business models we have described could help to ensure that end of life devices are collected for recycling. However, this alone will not solve the major environmental and health hazards associated with inadequate recycling facilities in emerging markets. Companies making and marketing mobile devices, new or used, have a responsibility to develop recycling infrastructure in emerging markets.

4
The benefits of a circular economy for smart devices
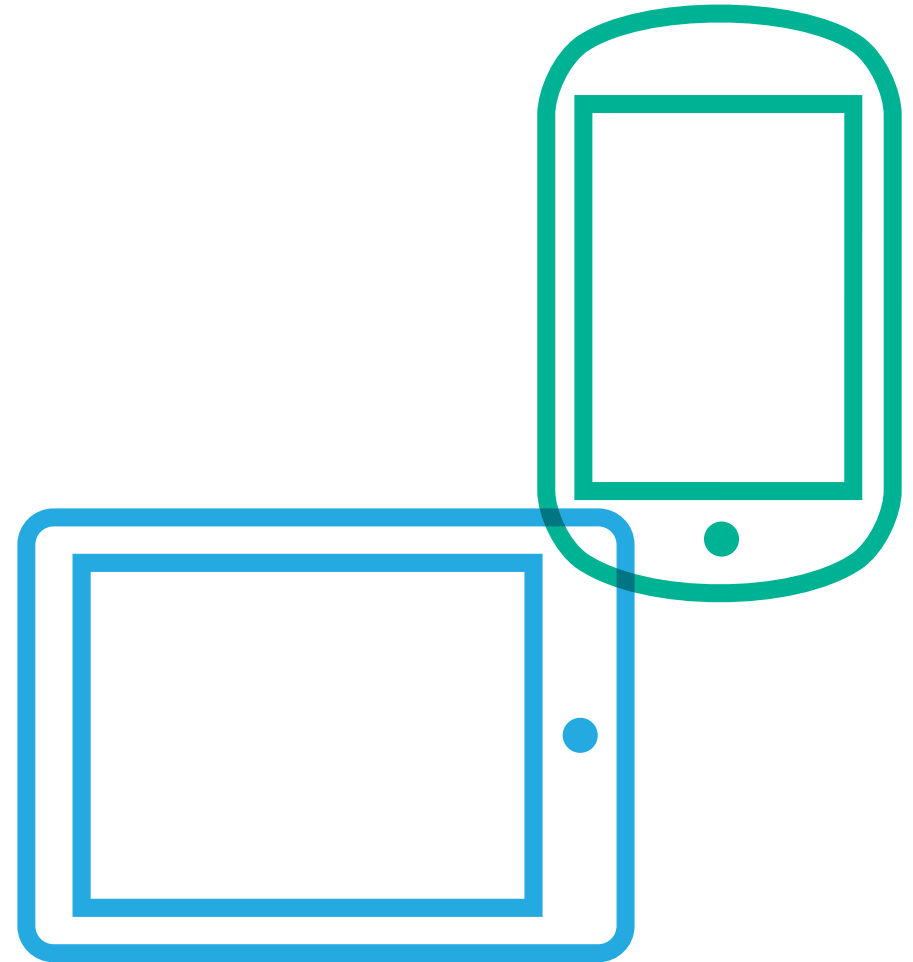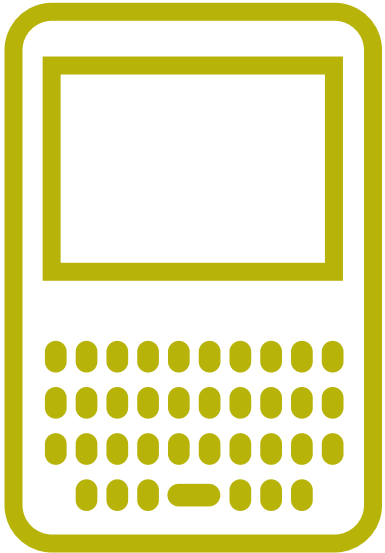
There are many good reasons to adopt a circular economy model for consumer electronics. Three of the most important are:

1 Consumer demand and technology change have created a new market opportunity.

2 Circular economy models reduce business risks.

3 Keeping devices in use for longer significantly reduces environmental impacts.

New market opportunities

Across developed markets, the pace of upgrades for smartphones and laptops is slowing. Businesses increasingly have to compete on price and user experience rather than impressive hardware to attract and retain customers.

Value for money is the most commonly cited factor for customers purchasing new devices in the US and UK, and circular economy business models provide two major opportunities to demonstrate value for money.[135]

Attracting new customers

"We have more people that are able to join the party when we have a trade-in, because in essence it winds up being used by…somebody else in that country that is very price-sensitive, or somebody in a different country"
Tim Cook, Apple CEO[136]

In India Apple sells older generation iPhones, including the four year old iPhone 4 and 4s models. Katyayan Gupta, an analyst at Forrester Research in New Delhi explains that "Indians want to show their status, so people want Apple. It doesn't matter if it's a two year old phone. It's an Apple at the end of the day."[137]

As the research firm Bernstein points out, it is in Apple's interest to support trade-in programs as a source of second-hand devices from a software ecosystem perspective, "as… the vast majority [emerging market] consumers cannot afford iPhones and are adopting Android."[138] Offering used devices enables carriers and manufacturers to engage customers with their brand who could not afford a new device.

Upgrades are slowing in mature markets, and are slow in emerging markets[132,133,134]
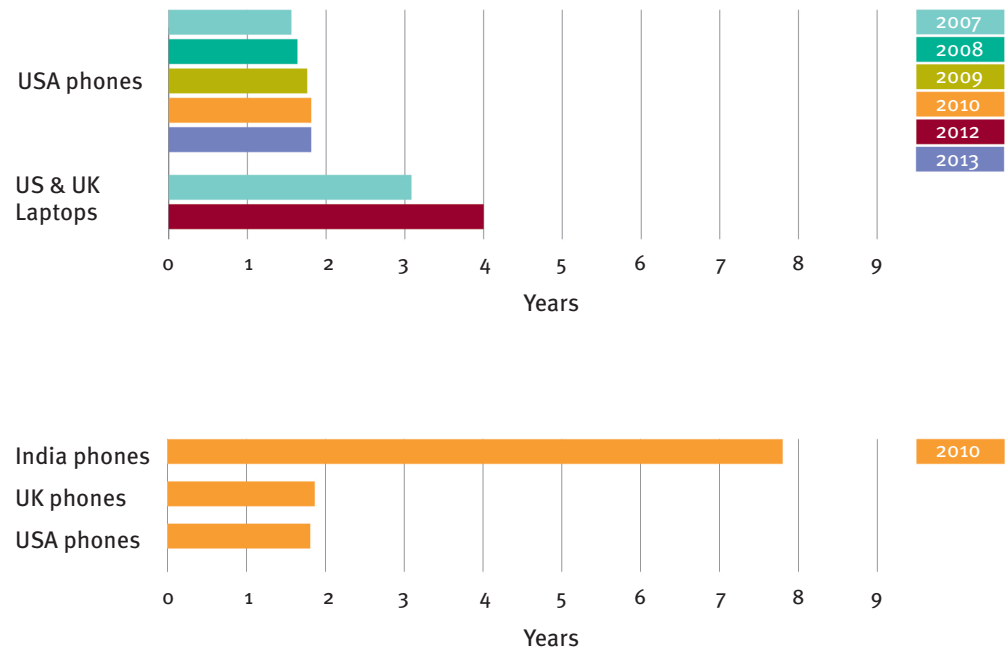
Our interviews with the IT asset disposal industry suggest that emerging market consumers have a preference for developed market brands, provided they compete on price. Moreover, it's not just emerging market customers. Laptop and tablet ownership amongst the lowest socioeconomic groups in the UK is just over half that of the highest (two thirds in the case of smartphones), so there are large sections of developed markets that could be targeted with lower cost devices.[139]

Second-hand flagship devices are already competitive with mid to low tier smartphones: the Moto E has been a runaway success, in part because it retails for £90 ($130). But the two year old Galaxy S3 has slightly superior specifications, and sells on eBay for £70-£140.
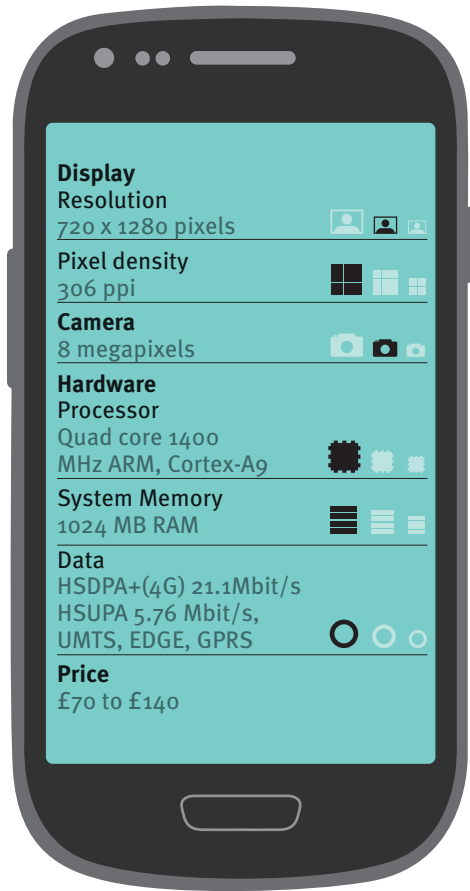
Lessons from the car industry
As selling on old devices becomes the norm, a trade-in service will increase the likelihood of customers remaining with their current brand or service provider.[140] Technology companies could learn from the car market, where trade-in is routine, and consider providing in-house repair and refurbishment to ensure a good customer experience.
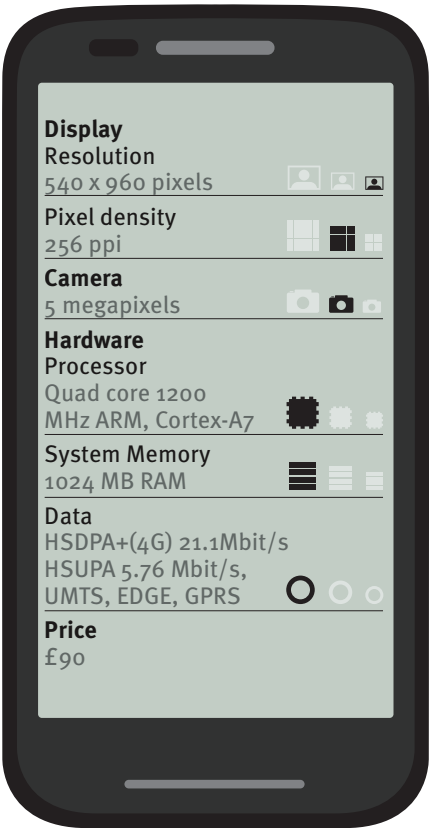
The other lesson from the car market is that resale value influences purchasing decisions. Actions to increase resale value, for example making devices more repairable, can work in a manufacturer's favour even if they don't remanufacture: "competition from an independent refurbisher has both a positive (resale value effect) and a negative (cannibalisation of new product sales) impact on the OEM's profit. [However] the resale value effect can dominate and the OEM can benefit from the existence of an entrant."[141] IBM and HP already facilitate server resale and secondary use, and benefit from doing so.[142]

Yesterday's flagship can out compete today's best seller

Samsung Galaxy SIII, available May 2012

Display
Resolution
720 x 1280 pixels

Pixel density
306 ppi

Camera
8 megapixels

Hardware
Processor
Quad core 1400 MHz ARM, Cortex-A9

System Memory
1024 MB RAM

Data
HSDPA+(4G) 21.1Mbit/s
HSUPA 5.76 Mbit/s,
UMTS, EDGE, GPRS

Price
£70 to £140

Motorola Moto E, available May 2014

Display
Resolution
540 x 960 pixels

Pixel density
256 ppi

Camera
5 megapixels

Hardware
Processor
Quad core 1200 MHz ARM, Cortex-A7

System Memory
1024 MB RAM

Data
HSDPA+(4G) 21.1Mbit/s
HSUPA 5.76 Mbit/s,
UMTS, EDGE, GPRS
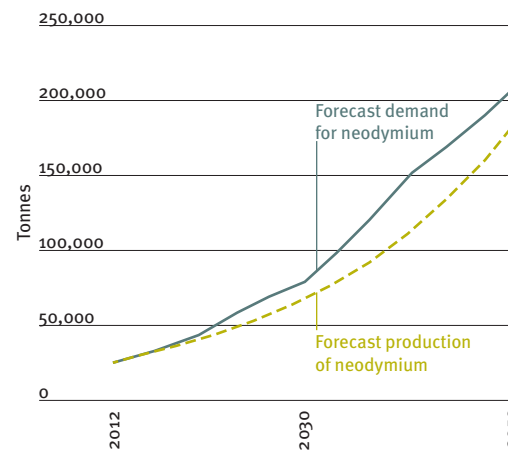
Price
£90

Reducing business risks

The circular economy helps to reduce three core business risks: market risk, regulatory risk and the cost of goods sold. Used devices are already being sent to customers for insurance returns and warranty claims, lowering warranty costs. But developing supply chains to recover unwanted devices and designing devices that last longer and are more easily repaired helps to mitigate other risks. Most immediately, expanding reuse will reduce the market risk of cannibalisation, given predictions that used smartphones sales will rise from 53 million to 257 million between 2013 and 2018.

It also helps to address regulatory risk. E-waste is the fastest growing waste stream globally and policy makers are increasingly passing on the costs of the associated social and environmental impacts to retailers and manufacturers through producer responsibility legislation.[143]

More circular models will help defray producer responsibility costs and can contribute to reducing e-waste impacts.

Used devices can also provide a low risk, and potentially lower cost, source of parts

Demand for neodymium will outstrip supply

and materials for new devices. This new supply is insulated from:

- environmental risks, like those arising from unsustainable tin mining in Indonesia;[144]
- conflict risks, including those regulated under the US Dodd Frank Act;
- commodity price volatility; and
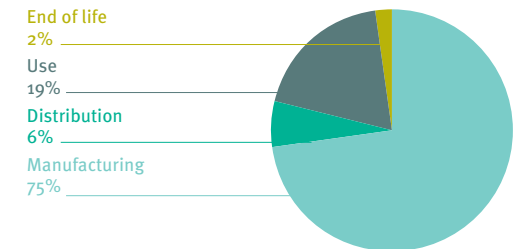- short term supply disruptions.[145]

These factors have made self supply through recycling common in industry.

For example, Honda recovers rare earths from the battery packs in its hybrid vehicles for reuse in new Honda cars, in part due to supply concerns.[146] Similarly, Dell recovers plastics from the old electronics it collects.[147] Although platinum group metals, copper and bulk metals can be recovered through shredding, yields are low. For many materials that are used in smart devices, disassembly focused recovery is likely to make the most sense. More exotic materials, like neodymium which faces supply issues (see left), need to be separated prior to recycling; these could be more readily recovered if hardware was adapted to make disassembly easier.
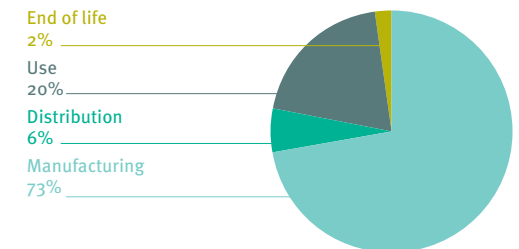
Lowering environmental impact

Unlike many other electronics, mobile devices are optimised to run on battery power. Their low energy use means the majority of mobile devices' environmental impact, between 60 and 85 per cent, arises from the manufacturing process.[148] This makes product lifetime the key determinant of overall environmental impact, because a device that lasts longer spreads its manufacturing impacts over a longer time period.
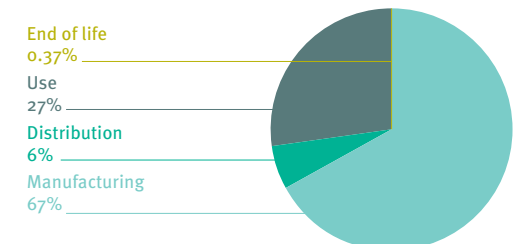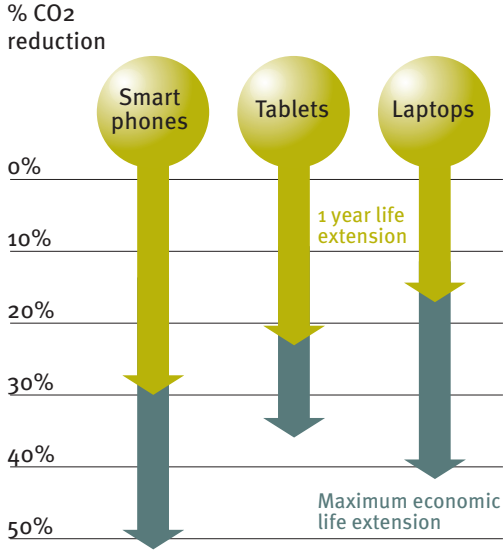
Most CO$_2$ emissions come from manufacturing[149]

Keeping devices in use cuts emissions

% CO2 reduction

0%
10% — 1 year life extension
20%
30%
40%
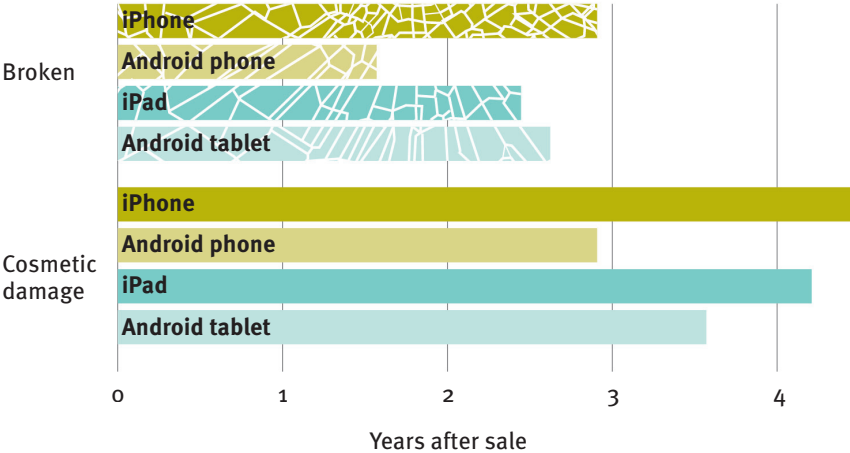50% — Maximum economic life extension

Smart phones | Tablets | Laptops

The circular economy models in this report assume that longer lasting devices displace the purchase of new devices. Where this happens, even extending the lifetime of a device by one year can cut the overall carbon footprint of device usage by between 19 and 31 per cent.

Extending the life of devices to four and a half years for smartphones and tablets, or seven years for laptops cuts their impacts by up to half. Resale values suggest that there is a market for these devices for at least this amount of time, as outlined in chapter two.

Even for cosmetically damaged devices, repair makes economic sense for over three years, rising to as much as six years for iPhones. It also makes environmental sense: replacing a screen and battery on a longer lived device only slightly reduces the overall carbon savings from life extension for smartphones (from 53 per cent to 46 per cent), although the carbon cost of replacement is higher for tablets (33 per cent to 20 per cent) and laptops (44 per cent to 31 per cent) due to their larger screens.

When is repair no longer economic[150]

Broken
- iPhone
- Android phone
- iPad
- Android tablet

Cosmetic damage
- iPhone
- Android phone
- iPad
- Android tablet

0   1   2   3   4

Years after sale

The industry's environmental impact

A circular economy approach to mobile devices can help to mitigate the rising environmental impacts of mobile devices. These impacts are being driven up by two factors. First, embodied emissions appear to be rising as specifications for new generations of the same product increase, as data from Apple's lifecycle assessments shows (see below).

Second, smaller devices have higher carbon intensity, meaning the shift from desktops, to laptops, or even to smartphones, will not automatically reduce the environmental footprint of IT equipment overall.[151]

The global footprint of the industry is already significant, and will rise as the market grows and the carbon intensity of each device rises.

Our analysis suggests that the industry had emissions substantially greater than the whole of the UK's transport sector in 2013 (131 Mt CO_2e).[152] Similarly, the amount of water used by the industry could meet the domestic needs of 38 million people each year (1,929 billion litres).[153, 154]

Embodied carbon of Apple devices rises as specifications increase
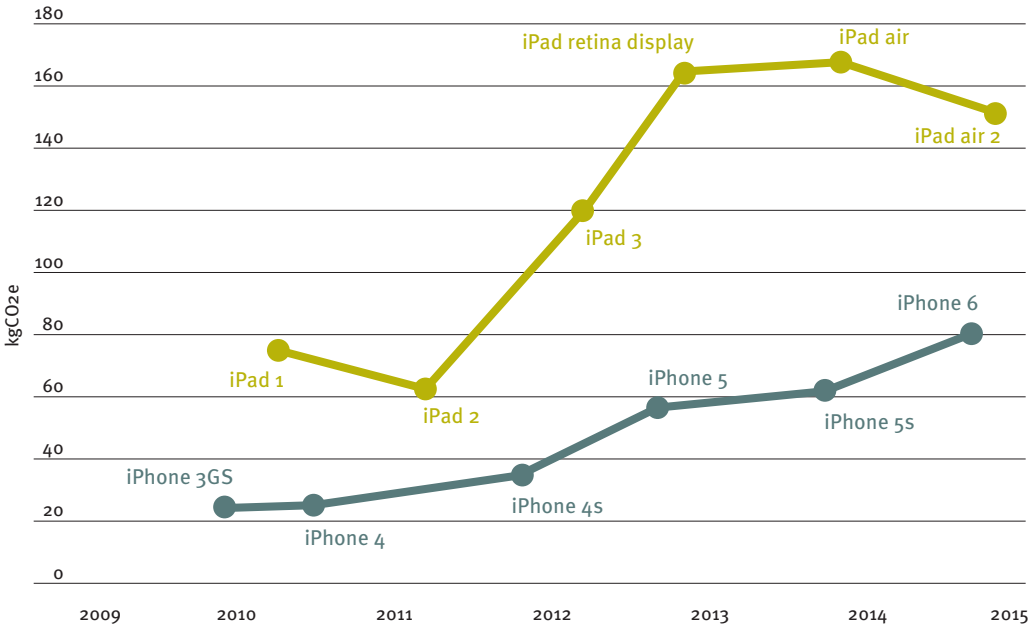
Smaller Apple devices have higher carbon intensity
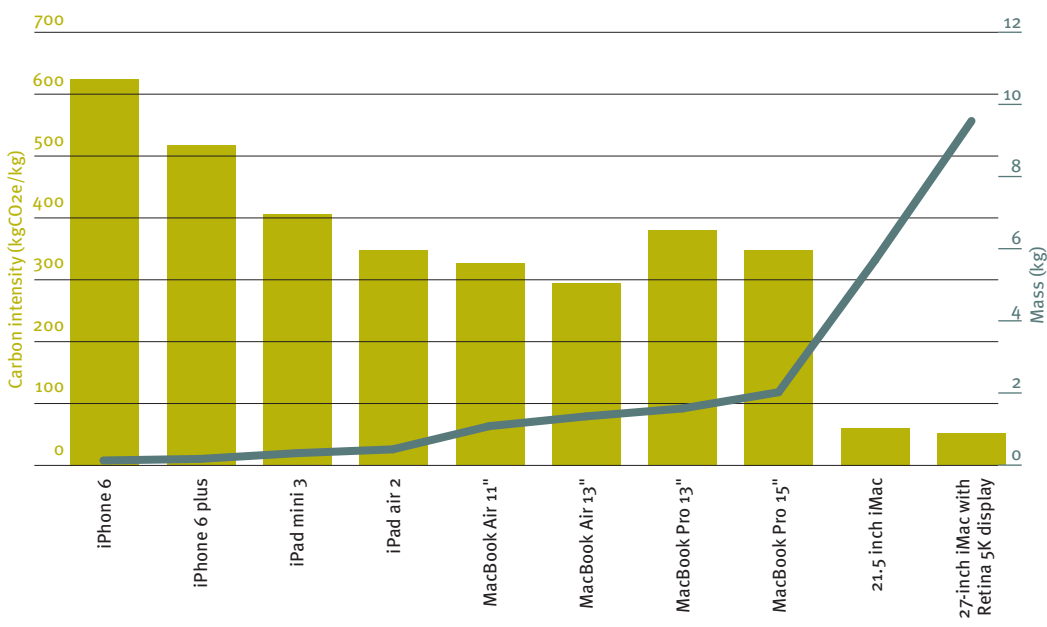
Beyond reuse: which components matter most?

Companies choosing to redesign their products for repair or remanufacturing can minimise the carbon footprint of their activities by keeping highly carbon intensive components in use.

Chips (ICs) are the biggest source of embodied carbon (around 35 per cent in all devices), so these should be kept in use the longest to maximise environmental benefit.
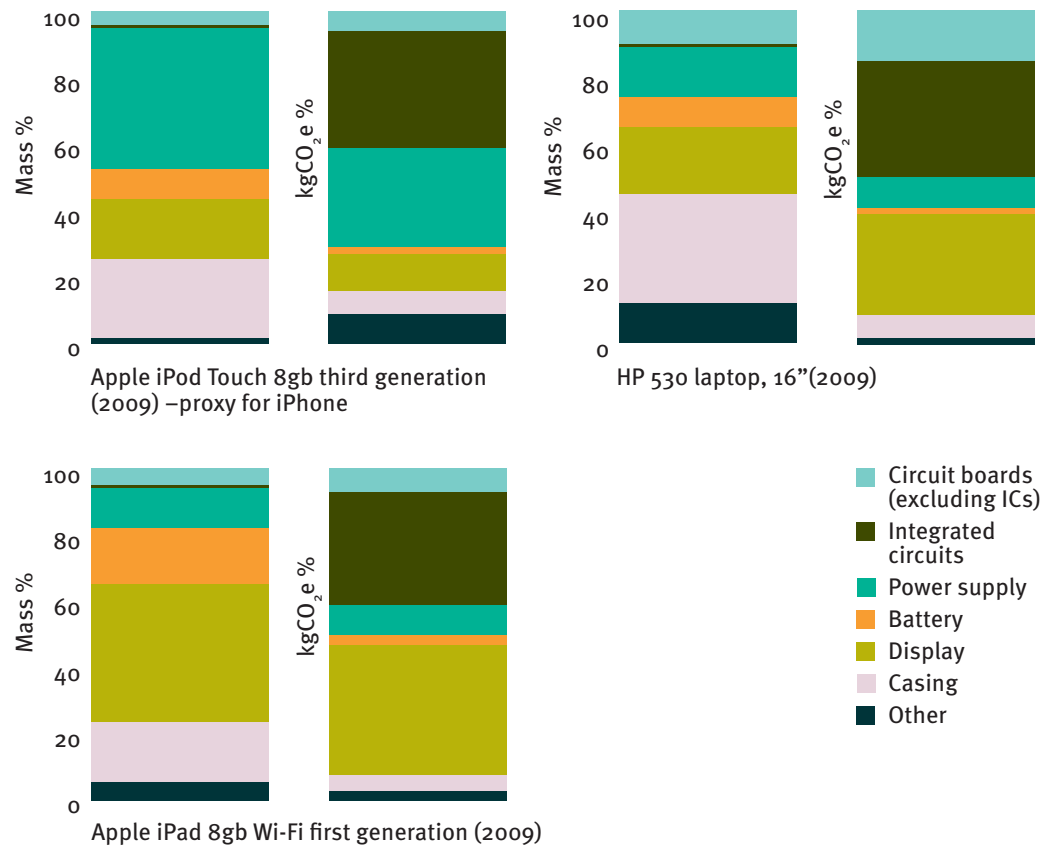
The power supply has the second largest proportion of embodied carbon, especially in smartphones (30 per cent). Some operators, like O$_2$, have already moved towards not shipping a new power supply as the default, while EU regulations encourage charger standardisation.

In contrast, batteries (two to three per cent embodied carbon) and casings (five to seven per cent embodied carbon) have lower carbon impact so could easily be swapped to give the rest of the device a longer lifetime.
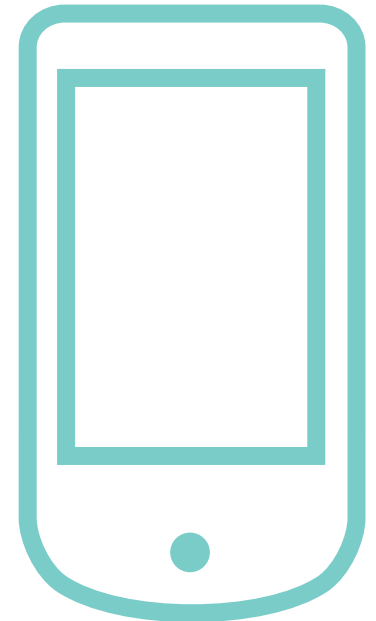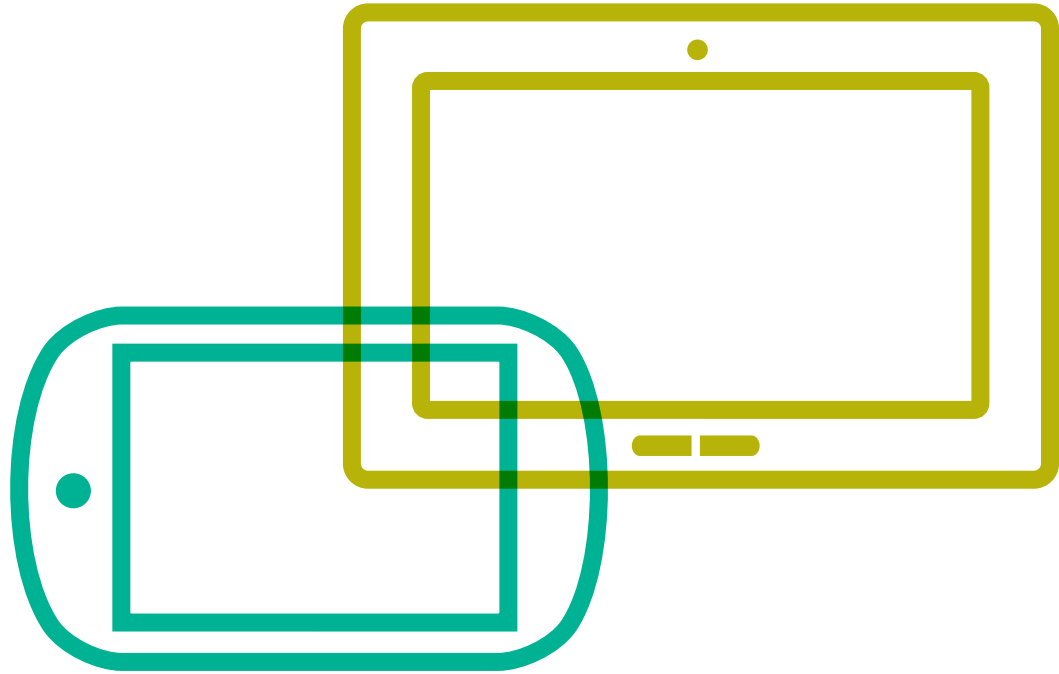
Screens are somewhere in the middle. Although the proportion of embodied carbon in screens is small for a smartphone (11 per cent), it is larger for tablets (39 per cent) and laptops (30 per cent).[155, 156, 157] Given the high frequency of damaged screens, manufacturers should consider making the LCD and glass separately replaceable, as the glass has lower embodied carbon than an LCD or AMOLED display. Even so, screen replacement still makes sense in environmental terms.

Overall, that companies can significantly cut the environmental impacts of mobile devices by enabling longer lived devices, through reuse, repair, remanufacturing, or even selective parts harvesting of high carbon components.

Embodied carbon vs mass of components in three mobile devices[158]

Apple iPod Touch 8gb third generation (2009) –proxy for iPhone

HP 530 laptop, 16"(2009)

Apple iPad 8gb Wi-Fi first generation (2009)

Legend:
- Circuit boards (excluding ICs)
- Integrated circuits
- Power supply
- Battery
- Display
- Casing
- Other

Annex: methodology

Environmental impact

Estimates vary widely on the total embodied carbon, water and energy in electronics devices, which analysts attribute to different accounting methodology and the absence of regulatory standards, as much as differences between devices.

Data about product lifecycle impact for water and energy for smartphones, tablets and laptops were provided by Google. Our embodied carbon estimates are averages of data from various published sources: smartphone data comes from Nokia, Apple, Sony, Samsung and Fairphone; tablet data comes from Apple and independent analysis using the ecoinvent lifecycle analysis database; laptop data comes from Google, Apple, Dell and a study from the EU's Joint Research Centre.

Environmental benefits from life extensions

Our baselines were 1.81 years of use for smartphones, 2.55 years for tablets and 3.11 years for laptops, based on averaging the data of available estimates of current device lifetimes.[159]

We determined the baseline environmental impact of a year of device use by dividing the total impact in the baseline use scenario by the baseline lifetime. Alternative scenarios were generated by extending the lifetime: first through a one year extension, and then longer, to reach four and half years for smartphones and tablets, and seven years for laptops.

Although our analysis showed the economic lifetime of most devices to be five or more years for tablets and smartphones and longer for laptops, we used a conservative estimate, rather than the maximum possible lifetime, when modelling the environmental benefits of lifetime extension.

Although the impacts from the use phase increased with a longer lifetime, the much greater manufacturing impacts were spread over a longer period and so reduced the overall impact per year.

The percentage savings were calculated by dividing the yearly impacts of a device used for the longer period by the yearly impacts of a device used for the baseline period and subtracting the result from one.

We also calculated the carbon savings incurred when screens and batteries were replaced, as these are the most common repairs and would probably be needed in a four and half or seven year device lifetime.

While data at a component level was not available for water or energy use, proportions of embodied carbon for components were provided by Teehan and multiplied by average embodied manufacturing emissions to determine the embodied carbon in screens and batteries.[160]

The disused components then incurred end of life emissions, by assuming the component contribution to end of life emissions was proportionate to their contribution to total emissions.

Calculation of per device savings arising from lifetime extension

	Years of use	Embodied carbon per cent saved	Primary energy per cent saved	Water consumption per cent saved
Smartphones				
Baseline	1.81	0%	0%	0%
1 year life extension	2.81	31%	27%	29%
Longer economic lifetime	4.50	53%	45%	49%
Longer life with screen & battery replacement	4.50	46%	n/a	n/a
Tablets				
Baseline	2.55	0%	0%	0%
1 year life extension	3.55	21%	21%	23%
Longer economic lifetime	4.50	33%	32%	35%
Longer life with screen & battery replacement	4.50	20%	n/a	n/a
Laptops				
Baseline	3.11	0%	0%	0%
1 year life extension	4.11	19%	n/a	18%
Longer economic lifetime	7.00	44%	n/a	41%
Longer life with screen & battery replacement	7.00	31%	n/a	n/a

Environmental burden of 2013 sales for manufacturing only

	Sales 2013 (millions)	Global CO2e burden of 2013 sales (manufacturing only) (MtCO2e)	Global water burden of 2013 sales (manufacturing only) (billion litres)
Smartphones	990	31.91	93.11
Tablets	186	12.94	79.24
Laptops	316	86.54	1,757.37
Total		**131.39**	**1,929.72**

Deriving the economic lifetime

If a device is no longer wanted by its first owner, a resale company can only exploit its value if it can acquire the device, perform any necessary repairs, repackage and then resell it for a profit. The point at which the costs incurred surpass the resale value is deemed the 'maximum economic lifetime'.

Cost of acquisition (all devices)

This was estimated as the average price that a recycler or reseller would pay a customer for a used device. This varies between nearly nothing for old, broken or low end devices, to over $400 for barely used recent models in excellent condition. Data was collected from sellcell.com and Gazelle.com for a range of different devices of different ages.

Cost of checking, cleaning, storage, repackaging and dispatch (all devices)

Average refurbishment costs for tablets and laptops were provided by WRAP.[161]

Fallout (broken devices only)

A percentage of broken devices cannot be repaired, which grows with the age of the device. Data was provided by WRAP, with Green Alliance estimates.[162]

Cost of repair

This varies by device (see below). Average repair costs were from WRAP.[163]

Resale price

This was determined by the price refurbished devices sold for on eBay. Data was collected via Terapeak over a three month period.

Net price after discounting for fallout

Broken devices only (see below).

The economic lifetime of 'good' devices

All devices in this category were assumed to be in good working order and needing no repairs. The only costs incurred were acquisition, checking, cleaning, storage, repackaging and dispatch.

The economic lifetime of devices needing superficial repair

In this category, all devices needed superficial repairs (replacement of batteries, charger or casing). The number of superficial repairs was estimated to increase slightly with the age of the device.

The price repaired devices sold for was assumed to be equal to devices requiring no repair.

The economic lifetime of broken devices

While broken devices are cheaper to acquire, on average they require more repairs and some may not be repairable at all. Using data provided by WRAP, we estimated the percentage of broken devices able to be repaired to be around 64 per cent, though this varied with the age and type of the device. Devices not able to be repaired incurred recycling rather than repair costs.

Broken but repairable devices were assumed to need several superficial repairs and additionally several major repairs (replacement of screen, digitiser, webcam, main board, CMOS battery, etc.). The number of repairs needed also varied with the age of the device.

As not all devices in this category were repairable, not all could be resold for revenue. To reflect this we lowered the resale price to around 64 per cent of the price assumed for devices in the other two categories.

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