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Digitalisation, energy and data demand: The impact of Internet traffic on overall and peak electricity consumption

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ABSTRACT

Over the last decade, concerns have been raised about increases in the electricity used by information technologies, other consumer electronic devices, data centres, and to a much lesser degree, Internet distribution networks. At the same time, 'smart' innovations are widely anticipated to help reduce energy demand across diverse sectors of society. Yet such potential savings, as well as the increasing use of other digital services, are predicated upon continued expansion of digital infrastructures. This paper focuses on the phenomenal growth in Internet traffic, as a trend with important implications for energy demand. It outlines an agenda to better understand how data demand is changing. Drawing on findings from our own research in combination with secondary data analysis, we examine the alignment of peak demand for electricity and data. Peaks in data appear to fall later in the evening, reflecting the use of online entertainment, but this is far from fixed. Overall, the paper argues that a better understanding of how everyday practices are shifting, in concert with the provision and design of online services, could provide a basis for the policies and initiatives needed to mitigate the most problematic projections of Internet energy use.

1. Introduction

It is widely expected that Internet-connected digital technologies will play a key role in transitions to a more sustainable and more energy efficient future. Take for example the interest in smart meters, grids and cities. Yet growth in the number of connected devices, the number and type of services and the levels of data traffic, processing and storage mean that the energy used to power the Internet is growing substantially. At the same time, the services it provides are becoming increasingly embedded in everyday and organisational ways of life. The proportion of Internet users has steadily increased to more than 90% in many economically developed countries [1]. As digital infrastructures, and the services and products they support, expand ever further, even in countries where Internet access is already widespread, the energy implications of ongoing digitalisation[1] are broad, complex and uncertain [2].

Whilst industry estimates suggest that, by 2030, 'smarter' systems could save 10 times the carbon emissions they generate [3] and whilst some commentators point to the potentially transformative effect of information and communication technologies (ICT) on the energy-intensity of the many sectors of the economy [4,5,2], other authors argue that the overall directionality of ICT, as it is *actually used*, is unsustainable [6–8]. Røpke [7] argues that in addition to its own lifecycle impacts, increasing Internet connectivity in everyday life fosters new, or otherwise more energy-intensive, forms of demand that counterbalance energy savings. Similarly, research suggests that smart home technologies may be associated with increases in energy consumption, both directly and in *other* areas of consumption, such as lighting or heating [9,10]. Meanwhile, research into how digitalisation affects travel patterns finds little evidence of anticipated, direct substitutions between travel and online accessibility, with more complex and debated effects emerging over time [11,12].

Within homes, the arrival of Internet-connected and data processing technologies has been described as a "new round of household electrification" [6]. Together with older information technologies (TVs and audio systems),[2] such ICT now accounts for a significant share of household electricity consumption. Monitoring studies in UK households suggest that computing and consumer electronics together consume about 20 or 23% of non-heating related electricity use [13,14].

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[1] The IEA ([2]: 21) define digitalisation as "the growing application of ICT across the economy" "encompassing a range of digital technologies, concepts and trends such as artificial intelligence, the 'Internet of Things' (IoT) and the Fourth Industrial Revolution".

[2] Coleman et al. [14] use the term 'ICE' to refer to the broader set of information communication and entertainment devices that include older technologies such as televisions and radios, reflecting the convergence between audio-visual devices and computers.

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More recent official statistics put this at 35% [15], in line with earlier predictions from the Energy Saving Trust [16]. Not surprisingly, a range of energy-related research has explored how and why devices like TVs [17], mobile phones [18] and laptops [19] are purchased and used, and how standby consumption in electronic and digital devices can be understood and addressed [14,20].

In other words, the energy research community has largely focused on the direct consumption of (consumer) products and a limited range of effects in other areas of consumption, including the potentials and pitfalls of smart energy technologies. However, this is only part of the story when it comes to energy demand associated with ICT. For instance, Bento ([21]: 97) has called for attention to the energy required by mobile phone *infrastructures*, claiming it "is ten times higher than the direct consumption of the handsets" and thus could have a "sizeable impact on energy demand" particularly as phone take-up and infrastructures grow in developing countries.

For over a decade, researchers within industrial ecology, engineering and computing have debated and tried to estimate the net balance of additions and savings to carbon emissions and energy consumption as digital technologies, including infrastructures, become more widespread (for useful reviews see [22,23]). The energy implications are often categorised into orders of effects, where first order effects are the energy used directly to produce and use ICT, secondary effects are the immediate consequences for other forms of environmental impacts (such as changes in travel) and tertiary effects are the ongoing changes as ICT is used over time, leading to other adjustments, changes and innovations [24]. The net balance depends on how these effects are calculated and what is included. Even for the most straightforward effect, direct consumption, there has been considerable variance in results, with different methods yielding very different estimates of how much energy the Internet uses, and what the consumption attributable to a MB of data traffic might be [25–28]. Nevertheless, these studies all highlight growing levels of energy used by information and communication infrastructures, both in absolute terms and as a share of overall global electricity use (see Section 2).

This paper aims to put the energy consumed by the Internet firmly on the energy research agenda. Our goal is not to improve estimates of consumption, but to better understand the basis of the growth in traffic that underpins it. We argue that policies and interventions in this area should aim to do more than improve the energy efficiency of digital infrastructures: they can also focus on the growing demand for data. To this end, an understanding of how and why data demand is growing is important. In this paper, we discuss a range of approaches to investigate this topic. In particular, we suggest that households play an important role and that everyday life is a key site to investigate how infrastructural changes take place, alongside the design and governance of online services. Drawing on a selection of our own research, we begin to unpack a topic of core interest to the energy research community that has hitherto received little attention: the potential contribution to peak electricity demand. Could the energy used by digital infrastructures become more problematic for managing national peak loads?

The paper is organised as follows. Section 2 reviews evidence about the size of Internet-related energy demand. Section 3 explains why attention to everyday practices, as interconnected with policy and provision, can help to provide insight into these changes and outlines a number of approaches to this. In Section 4, we develop a discussion of the patterns of peaks and troughs in Internet traffic and to what extent they align with national peaks in electricity demand. We conclude, in Section 5, by considering the possibility for policies to regulate or otherwise shape volumes of data traffic, as part of a broader set of Internet energy policies.

2. How much electricity does the Internet consume?

Since methodologies and ways of drawing system boundaries vary, there is not a single, definitive figure of how much electricity the Internet consumes. Overall, it is estimated that powering digital devices (computers and smartphones) and the supporting infrastructures (communication networks and data centres) consumed about 5% of global electricity use in 2012; rising to over 9% if televisions, audio/visual equipment and broadcast infrastructures are included [29]. Other studies have produced broadly similar figures [30,31].

In this section, we firstly review evidence that network and data centre energy consumption are significant within this and that they are growing; secondly, we consider the trends in data demand that underpin the expansion of these infrastructures and their energy use.

2.1. Network and data centre consumption is growing

Current estimates suggest that networks and data centres consume more than computers. According to Van Heddeghem et al. [29] communication networks, including mobile, fixed broadband and telephone networks, consumed 1.7% of total global electricity use in 2012, and data centres 1.4%; together these infrastructural forms of consumption were roughly twice that of computers, at 1.6%. In fact, the balance between user devices and infrastructures has shifted markedly over the last few years as processing and storage functions are increasingly carried out 'in the cloud' and as smaller, low-power user devices like laptops and smartphones have become more widely used more than desktop PCs. As Corcoran and Andrae ([32]: 1) note "there is a strong trend to push electricity consumption onto the network and data centre infrastructure where energy costs are less transparent to consumers". At the level of particular services, for instance, it is estimated that powering an LED TV for two hours to watch a film might take a similar amount of energy (120 Wh) as consumed in streaming it over the Internet [33]. Plus, networks and data centres represent the largest share of energy consumption over the lifetime of tablets and smartphones: accounting for at least 90% of the total energy use including manufacture and charging [34].

Most estimates of ICT-related energy consumption also predict steady growth. For instance, Van Heddeghem et al. [29] estimate that the electricity consumed by digital devices and infrastructures is growing faster (at 7% per year) than global electricity demand itself (at 3% per year), with the rate of growth of networks highest of all (at 10.4%). Andrae and Edler [30], also anticipating a compound rate of growth of 7% per year, calculate that the production and operation of ICT will rise to 21% of global electricity consumption by 2030: this is an absolute rise to 8000 TWh, from a base of around 2000 TWh in 2010. In a worst case scenario, this could reach as high as 50% of global electricity use by 2030, but only 8% in the best case. The IEA [2], who estimate that networks consume slightly less (at 185 TWh in 2015) than data centres (at 194 TWh in 2014), foresee only moderate growth in the energy consumption of data centres of 3% by 2020. But they estimate greater uncertainty for networks, with scenarios varying between growth of 70% or a decline of 15% by 2021 depending on trends in energy efficiency.

To date, there have been significant improvements in the energy efficiency of data centres and networks: Aslan et al. [28] suggest that, since 2000, the electricity intensity of data transmission in core and fixed-line access networks has decreased by half every 2 years. Shehabi et al. [35] calculate that the growth in data centre energy consumption has slowed dramatically since 2010 compared to the previous decade, with an increase of 4% from 2010 to 2014. This is attributed to a range of efficiency improvements and a large shift towards hosting cloud-based services in 'hyperscale' data centres. As the IEA ([2]: 18) note "energy use over the long run will continue to be a battle between data demand growth versus the continuation of efficiency improvements".

Whilst the increases in efficiency are encouraging, particularly for data centres, they are yet to catch up with the growth in data traffic and, to date, "have been more than offset by increased consumption of