

Report on International Visiting Fellow Report, DEMAND Centre, University of Lancaster, Ruth Lane, July-August 2017

Project Title: Communications technology, life course transitions, and energy demand

The purpose of the fellowship was to analyse existing research materials on household IT in Australia in order to understand the implications of IT proliferation and use for energy demand. The materials were collected as part of the Wealth from Waste research program which focused on the potential for more advanced metals recycling in Australia and the research on household electronics was motivated by concerns around the environmental impacts of rapidly increasing uptake and turnover of household electronics, and their availability for reuse or materials recycling. However the proliferation of household electronics links strongly to increasing energy demand, mainly due to escalating data flows generated by the use of web-connected devices. The fellowship provided an opportunity to examine the significant energy demand consequences of domestic IT in Australia and to interact with DEMAND Centre researchers working on the energy demand consequences of domestic IT and its supporting infrastructure of data servers and networks.

The Wealth from Waste research program collected qualitative and quantitative data on the use of internet-connected communications devices in households. This usage information is relevant to energy demand for two reasons: because of the power used by domestic equipment and its supporting infrastructure such as data servers (Bates et al 2014, Andrae and Edler 2015), and because of the use of communications technology to support more or less energy intensive practices such as online shopping or smart energy management.

The findings in this report focus on patterns across the population in, (i) the take-up and churn rate of various types of devices and, (ii) use practices with either high or low energy demand consequences. The research findings highlight the significance of both age and life course transitions in the numbers and usage of various types of electronic communications devices in Australian households. While the energy demand linked to communications technology is complicated by ongoing technological change in software, hardware and supporting infrastructure, the link between life course and time spent using internet connected devices is sufficiently strong to warrant closer examination. The report draws some conclusions around the interaction between life course transitions and other factors such as household income, and outlines areas for potential policy interventions aimed at reducing the environmental impacts of domestic IT and containing its energy demand consequences.

Acknowledgements

The report draws on research conducted for the Wealth from Waste CSIRO Cluster research program. The qualitative research with households was conducted by Kaye Follett for her PhD research supported by the Wealth from Waste research program. Valuable input was provided by Gordon Walker, Janine Morley and Mike Hazas from the DEMAND Centre, and by Jo Lindsay from Monash University.

How smart is domestic IT? Intersections of technology and the life course in unsustainable trajectories of household IT in Australia

Abstract

The rapid uptake and turnover of communications technology (IT) in affluent countries presents an emblematic challenge to the idea of sustainable consumption. Environmental impacts of IT are multiple, assume different forms across product life cycles, and are changing with the technology itself. A focus on the household, which drives so much IT-related consumption, helps to understand how technological change intersects with social change processes as they are experienced in practice. I focus on the proliferation, use and accumulation of IT equipment in households in Australia drawing on survey and interview data collected during 2015 and 2016. In contrast to global and national footprint studies that show linear trajectories of increasing consumption, trajectories at the household scale are more varied and influenced by age, income and education, and change with life course transitions. The most concerning development is the practice of using multiple devices simultaneously, particularly when this includes live streaming of high resolution video and audio. This is increasing in households with teenagers and young adults and likely, if unchecked, to become a new social norm and a significant driver of energy demand.

1. Introduction

The rapid uptake and turnover of IT in households presents an emblematic challenge to the idea of sustainable consumption. Its environmental impacts span from the mining of raw materials, the energy and emissions from the production and global distribution of products, and their use in households, through to the generation of hazardous waste (Ryen et al. 2015). In 2012, IT accounted for roughly 10% of global electricity use (Van Heddeghem et al, 2014) and this portion is growing due to the rapid growth in data traffic (Ofcom 2016: 26). While households are not the only site of IT consumption, the proliferation and use of IT in households has significant resource impacts globally.

Footprint studies provide an arresting perspective on the contribution of households more broadly to global resource depletion – they contribute over 60% of global GHG emissions and between 50 and 80% of the total land, material, and water related impacts (Ivanova et al. 2016). Higher income countries generate the most significant impacts per capita, and Australia, my case study, is among the highest, even among OECD countries (Salahuddin and Alam 2015). The measurement and modelling of environmental footprints of household consumption is critical for signalling the scale and significance of their environmental impacts and allows important cross country comparisons (Hertwich 2011, Wiedmann et al. 2014, Ivanova et al. 2016, West et al 2016). These studies have been used in analyses of the ecological deficit between developed and developing countries and its political and justice dimensions (Harvey 1996, Hornborg 2009, Martinez-Aliers et al. 2016, Mayer and Hass 2016).

As with many other forms of technology, the sites where IT is used and delivers most benefits, are displaced from the sites where the impacts of their production are experienced. This is captured in Hornborg's thesis of machine fetishism, in which what is considered feasible in technological development and access to technology in a given time and place, is largely oblivious of the extent to

which this is a result of “shifting resources from one social category to another within global society” (Hornborg 2009: 240). But how well do global scale analyses of technological capacity, material flows and environmental degradation connect with the scale of household consumption in those higher income countries that contribute the most to global resource depletion? There remains a disconnect between global scale analyses focused on materials and their environmental impacts and more situated understandings of socio-technical change processes as they are experienced in households where so much consumption takes place (Ward 2014).

A focus on the household scale prompts different kinds of questions around resource use. Households and families are key sites for many forms of consumption, not just technology-related (Humphery 2010, Lane and Gorman-Murray 2011, Lindsay & Maher 2013). There is evidence that household consumption changes over the life course, often bound up with family transitions (Lane et al. 2009, Gibson et al. 2013). The social makeup of households is also changing over time. In many countries, the number of people living at a single address significantly declined over the 20th century, linked with rising affluence, changing family structures, longer life expectancies and increased mobility – all factors that are strongly implicated in increasing resource consumption (Yates 2016).

Domestic IT consumers are caught up within a wider cast of actors, processes and power relations that serve to make IT affordable and exert pressures to acquire, use and upgrade equipment (Fuchs et al. 2016). A focus on consumption practices alone has a limited capacity to engage with these broader structural dimensions (Sayer 2013, Watson 2017). However there is much of consequence to learn about how IT is going to ground in households and becoming enmeshed in routines of daily life – in particular, how rapidly changing technology interfaces with broader transitions in consumption over the life course.

Recent research drawing on social practice theory has begun to examine how IT is being incorporated in daily life and household routines (Røpke and Christensen 2012, Lord et al. 2015, Hazas et al. 2016, Widdicks et al. 2017). The focus in this work is on what IT is used for (Shove and Walker 2014), how practices involving IT arise, diversify and are either consolidated or abandoned (Schatzki 2013, Hui 2017), and their consequences for energy demand in particular (Hazas et al. 2016, Lord et al 2015, Widdicks et al 2017). Current trends in the resource impacts of IT are clearly going in the wrong direction (Røpke and Christensen 2013, Pierce et al 2013). Yet there is potential for IT to be used in ways that reduce other forms of consumption, such as that related to transport or smart energy management. This too can only really be understood through a focus on how it is currently being incorporated in practices and routines at the household scale.

Environmental impacts of domestic IT

The environmental impacts of domestic IT are multiple, assume different forms across the product life cycle, and they're also changing with the technology itself. For older equipment, the more significant resource impacts are connected with the materials used (Ryen et al 2017). In newer products materials use is more efficient (less metals and plastics per product) however the number of devices is increasing significantly, countering the material efficiency gains (Ryen et al. 2015). The resulting demand for precious metals is particularly concerning due to the impacts of mining. Materials efficiency in electronic products has generated a rebound effect where products are produced and consumed in greater numbers so that overall materials consumption continues to rise (Zink et al 2017). While materials recycling is desirable, the overall environmental impacts of the materials will be less when the lifespan of equipment is extended through reuse or remanufacturing (Andrae 2016).

More attention has been paid to the energy demand consequences of IT (Andrae and Edler 2015). While the energy used by devices themselves is decreasing over time, the data flows they facilitate

are resulting in rapid increase in energy use in data centres. Under a worst case scenario, it's been estimated that IT could account for 51% of global electricity use, and 23% of GHG emissions by 2030 (Andrae and Edler 2015). The increase is mainly due to more data intensive uses (Bates et al. 2014) and "the presence and significance of media rich communications in everyday practices" (De Decker 2017).

Certain use practices have much higher consequences for energy demand. In particular, the use of multiple interlinked devices simultaneously and leaving them all on (e.g. having a computer connected to stereo and home speaker system, or smart TV) (Bates et al. 2014). Real time entertainment and social networking, particularly where they involve high resolution video, are among the most data intensive practices (Widdicks et al. 2017), and are likely to increase with current trends towards more livestreaming. By comparison SMS communications have very low data use.

IT use may also have indirect consequences for other forms of consumption in households (Røpke and Christensen 2012). For example, its use in online shopping, communications and working from home all have potential for decreasing car travel. But it can also make it easier to purchase goods so may contribute to increased consumption. Whether for good or bad, web-connected technology has significant implications for how consumption occurs and where its benefits and impacts will be experienced. The indirect impacts can be considered in terms of the softening of time and space constraints affecting social practices of daily life, that express as a capacity to undertake more tasks simultaneously and spread across the day (Røpke and Christensen 2012).

2. Case study and Methods

The research on IT in Australian households was conducted as part of a large collaborative research program called *Wealth from Waste* that examined the potential for developing more advanced metals recycling in Australia. A key focus in the Monash University research was the rapid accumulation of electronics in Australian households. This report draws on survey data and qualitative research from three different sources. The qualitative interviews were conducted by Kaye Follett for PhD research supported by the Wealth from Waste program.

1. Data collected by national agencies, the *Australian Bureau of Statistics* (ABS 2016) and the *Australian Communications and Media Authority* (ACMA 2016).
2. An online survey conducted with 1475 households across Australia in Jan-Feb 2015. Respondents were asked about their household's acquisition, use and disposal of 10 types of electronic devices.
3. In-depth interviews with 36 households in three Australian cities and a regional centre. Individuals from these households recorded diaries of their use of various devices over one week day and one weekend day.

3. Analysis of data from national agencies

Internet connectivity in Australian households has increased rapidly over time, and now seems to be stabilising at around 85%. Almost all households with children under 15 years now have internet access (97%) (ABS 2016).

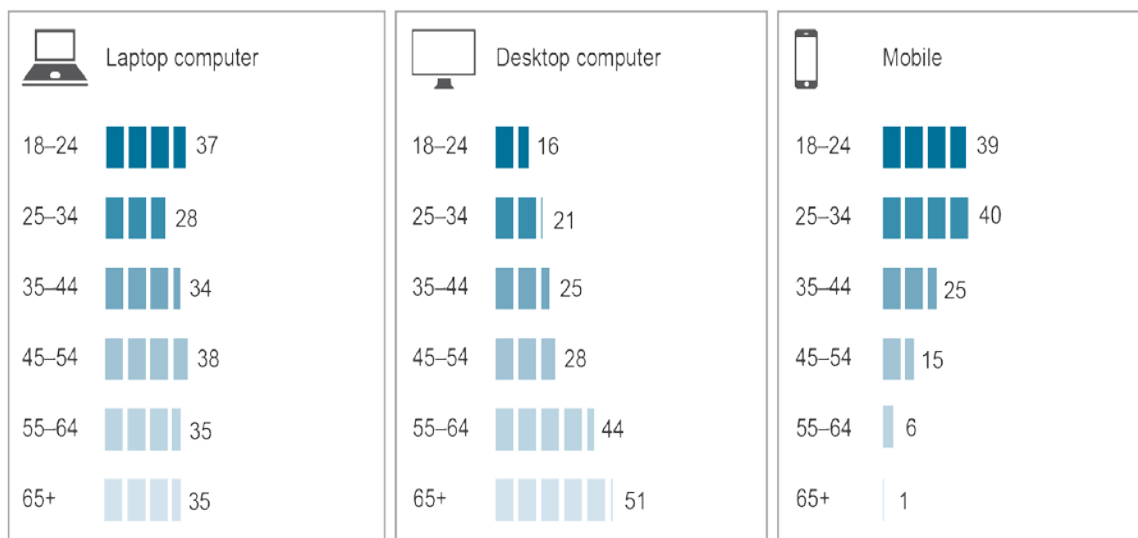


Figure 2. Devices used most often to access the internet in Australia, by age, in the six months to June 2016 (percentage) (ACMA 2016: 52).

Mobile phones are the most popular devices used to access the internet, closely followed by laptop computers, desktops and tablets (ACMA 2016: 51). The use of equipment though differs across different age groups with laptops more likely to be used by those aged 18-65 and desktops by those aged 65 and over (Figure 2).

The amount of data consumed has increased significantly over time. The data downloaded to mobile phones alone increased by 53% between 2015 and 2016. The total volume of data downloaded via different forms of internet connection in the June quarter, increased from about 425 thousand terabytes in 2012 to about 2,220 thousand terabytes in 2016 (ACMA 2016: 65).

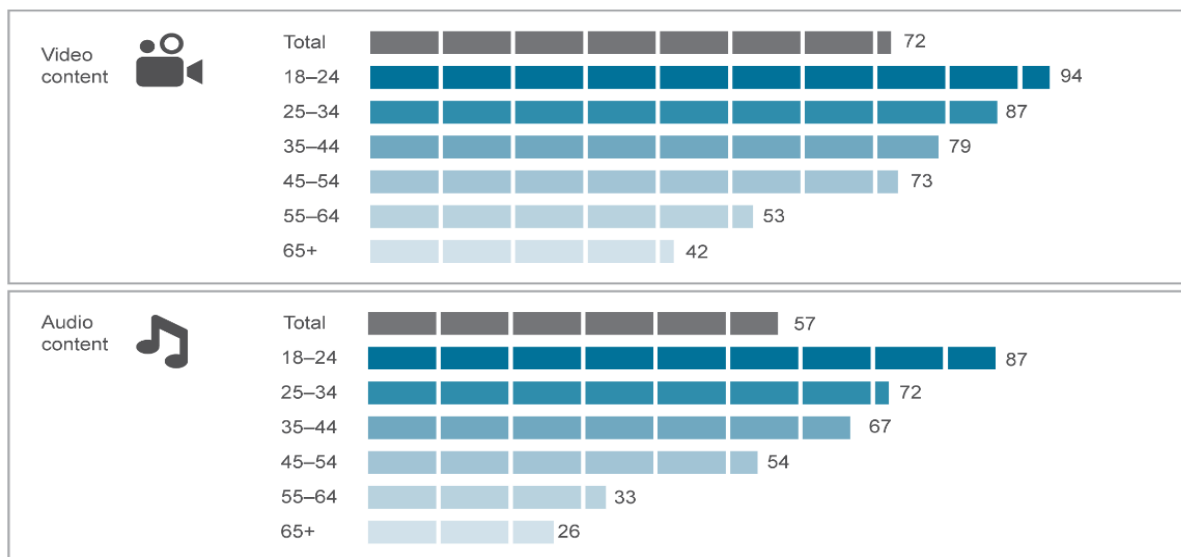


Figure 3. Accessing online video and audio content in Australia, by age, in the six months to June 2016 (percentage) (AMCA 2016: 64)

The increase is largely due to accessing video and audio content, and Figure 3 shows how data use differs for different age groups. Live streaming of video and audio is increasing over time, and video content is more likely to be live streamed than audio.

4. Analysis of the Wealth from Waste household IT survey data

The most striking finding from our *Wealth from Waste* household survey was that a large portion of the IT equipment in households was being stored and no longer used. There were 2.3 smart phones per household and a quarter of these were not in use. That portion was much higher for older technology. This is concerning from a materials efficiency perspective (Allwood et al. 2011). If stored equipment were available for second hand use it might displace new purchases. If it were available for materials recycling, it might ease the demand for ores sourced from mining (although see Zink and Geyer 2017).

Of all ten product types, only plain (non-web-connected) mobile phones, CRT TVs, and computer monitors are disappearing from households while all other product types are accumulating (Table 1). Of these, smart phones and laptops are accumulating most rapidly, followed by tablets. Household age profile was the most significant predictor of all device types, with the largest number of devices found in younger households (Zhu et al 2017).

Table 1. Net flows of IT products in Australian households between Feb 2014 and Feb 2015.

	No. obtained	No. disposed	Net
Smart mobile phones	0.41	0.09	0.321
Plain mobile phones	0.05	0.09	-0.042
Tablet devices	0.21	0.02	0.193
Handheld music players	0.04	0.02	0.014
Laptop computers	0.38	0.06	0.318
Desktop computers	0.08	0.06	0.020
computer monitors	0.05	0.05	-0.001
Flatscreen TV	0.18	0.04	0.138
Old-style TV	0.00	0.11	-0.112
Game devices	0.09	0.02	0.075
Total	1.49	0.56	0.925

But the patterns for specific products were more nuanced, with larger equipment such as televisions and desktop computers and monitors were more likely to be found in detached houses with older age profiles (Appendix 1). Smaller and newer devices were more prevalent in households with younger age profiles, which were likely to be turning them over much more rapidly than older households. Higher income households were more likely to have more modern web-connected equipment such as laptops, tablets, smart phones and flat screen televisions, implicated in higher energy demand due to data streaming (Appendix 1). A survey on IT ownership in the UK similarly found that numbers of children present influenced the presence of various electronic devices but that specific devices, such as tablets, were more common in households with higher income and education levels (Anderson 2015).

5. Analysis of interviews and self-recorded diaries research

The 36 households interviewed can be roughly characterised into four groups based on age and work force participation. Within each group there were considerable differences in household size and income levels, especially in our first group, households with school children.

Household type 1: Households with school aged children

This group was extremely diverse, ranging from a single mother with an only child on welfare benefits (£250 per week) through to a professional couple with three children and a combined household income of over £410k per annum. There were notable differences in IT use between younger children, whose access was controlled by their parents and older children who were more likely to have their own laptop or tablet which they used for school work, entertainment and social media. Online gaming was more prevalent among older children. Parents often attempted to limit the use of web-connected devices to living rooms so they could better monitor what their children were accessing, although diaries recorded by children suggested that from the age of 13 they were using devices more in their bedrooms than elsewhere.

Table 2. Equipment in use in three households with school-aged children.

Couple with 1 child aged 13 yrs, < £30k/year	Couple with 4 children aged 7-14 yrs, £ \$30-90/year	Couple with 3 children aged 10-14 yrs, > £410k/year
Personal use 2 smart phones 2 iPads 1 iPod 1 laptop 2 desktop PCs 2 online gaming devices 4 offline gaming devices Shared use 1 smart TV	Personal use 2 x iPhones 2 x iPads 3 x iPods Shared use 1 x iPad 1 x TV 1 x desktop computer with printer	Personal use 4 x I phones 5 x Kindles 6 x laptops 3 x iPods Shared use 1 x smart TV

Table 2 summarises the devices in use in three family households with differing incomes and numbers of children. Perhaps the most striking difference was in the extent to which device use was shared among family members.

The family in the first column has one parent working full time, and a 13 year-old son whose main hobby is gaming. They acquired a number of their devices second hand to contain costs. All household members engage in live streaming for entertainment purposes. The parents follow horse racing live on the smart TV in the living room and the son uses PlayStation4 in his bedroom for several hours at a time. His sleep patterns had changed due to gaming at night. Even with a low income and a single child this family has significant energy intensive IT use, often live streaming on more than one device simultaneously. They reflected that household IT has probably meant that they use their car less as more tasks are undertaken online. It also enabled the mother to run an online business from home as a hobby.

The family in the middle column has four school aged children and both parents work full time. Both parents have smart phones, which are mainly used for work and family communications (including video chats with overseas family and friends). They recently purchased a family iPad so that internet could be accessed in different rooms in the house as needed. The 10 and 12 year-old girls were each given an iPod for their 10th birthdays, which they mainly use for playing music and games and texting. The 12 year-old also watches UTube clips about making jewellery to support her hobby. Their 13 year-old brother has an iPad that he uses to complete homework tasks in education applications but also for playing online games, and watching Netflix– his diary indicated that games and Netflix were the

dominant use but that some use was made for homework on week days after school. The parents, concerned to contain their kids' internet use, recently changed WiFi codes and required devices to be used in the living room rather than bedrooms. Despite passing used equipment among family members, they had still accumulated at least four old mobile phones, three old iPods and three old iPads, all of which were still stored in the house because they didn't know how to dispose of them.

The third column is a family of two very high earning professionals with children aged 10, 12 & 14. Compared with the more moderate income family in the middle, they had many more devices in use. All family members had their own Kindle, and all except the youngest had their own iPhone. The proliferation of iPhones became necessary when they moved into a new house and decided not to have a landline. Besides these, they had six laptops, three iPads and three iPods which travelled with them to work or school. At home, the children's use of technology is closely monitored by their mother, who prefers laptops as they can be used in the living room where she can see what her children are doing. Unwanted computers had previously been given to their son who enjoyed dismantling and attempting to reassemble them, but the mother indicated a preference for donating devices to charities in the future.

Household type 2: households with young adults (18-39)

Although this group of households was also diverse, it was notable for energy intensive IT uses involving live streaming of video. Some of the younger adults reflected on how their IT equipment and use changed in their late teens due to requirements for tertiary studies and increasing financial independence. Some described major milestones in their IT history such as getting a laptop of their own that didn't need to be shared with a sibling. In some cases, the way a particular device was used changed over time e.g. PlayStation used less for online gaming and more for watching movies and UTube. Those in tertiary education showed different daily patterns of IT use due to non-standard working hours compared with those in full time employment. IT was integrated into many aspects of daily life and young adults could be quite innovative in using it to enhance or facilitate daily needs, routines, and interests. For example, one woman described using the Zombie Run app on her phone as part of morning dog walk exercise routine, and a couple expecting their first child had negotiated flexible working from home arrangements so that the young father could care for the baby in the early evenings.

Table 3. Summary of self-recorded diary of 21 year old tertiary student living with his parents.

Friday

Device type	Time	Uses	Persons involved	Location of use
Mobile phone	06.00 - 06.10	Alarm, checking weather	Family	Home
	11.00 - 11.01	Messaging, phone call	Family	Car
	12.00 - 23.00	Gaming, social media	Partner	Home
	06.30 - 06.35	Checking study notes	Laptop	Home
PS4	13.00 - 21.30	Gaming, Utube, Netflix	Partner	Home

Saturday

Device type	Time	Uses	Persons involved	Location of use
Mobile phone	09.00 – 09.01	Alarm		Home
	09.30 – 09.01	Messaging	family	Home
	09.30 - 23.00	Gaming, social media	Partner	Home

	16.30 - 16.50	Grocery lists	partner	Home, supermarket
Kindle	17.00 - 17.10	Reading comics		Bathroom
Laptop	15.00 - 15.05	Look up recipe	partner	Home
PS4	09.30 – 23.00 continuously	Gaming, Utube, Netflix (with large screen TV)	Partner	Home

This diary summarised in Table 3 was recorded by a 21 year old full time student living with his parents. He acquired his first smart phone towards the end of high school. He and his girlfriend combine studying and gaming and do a lot of livestreaming of video and UTube clips for entertainment. The diary shows that the smart phone is used simultaneously with the PlayStation 4, and high data demand uses occur across the day and night.

Household type 3: working older adult households (40-65)

Older households with working adults mainly use IT for communications with friends and family and lower impact entertainment such as reading downloaded books. They were more likely to download AV materials for entertainment than to access them through live streaming. Laptops were favoured over phones and tablets for banking and household management tasks.

The possession of IT equipment in the home and the level of skills and capacities in its use was closely related to the experience of working life. Work equipment was often used in the home for personal purposes, but, more importantly, knowledge and experience acquired in the workplace carried through to the use of IT equipment in the home. This group also considered their IT use to have contributed to a blurring of the boundaries between work and home life. Older working adults used IT devices at home for work communications and at work for communicating with family members.

Household type 4: retiree households

In this category we included couple households where one member was retired and the other still working in some capacity. Many Australian retirees have household incomes >£30k. There were many examples of them being gifted new and second hand equipment by family members. These were predominantly used for communications, and entertainment uses tended to be low impact such as reading e-books and listening to downloaded music on an iPod or movies on an iPad. An example of a low income retiree household is an Adelaide couple aged 80 and 74. Each had a smart phone (the husband had been given his wife's old one) and they shared a laptop and a tablet. All their equipment was gifted by family members except for the tablet which was purchased.

They particularly valued the capacity for video communications with family members, especially with family living elsewhere in Australia and overseas. They used IT for conventional media entertainment such as watching downloaded movies and news and current affairs programs, and for accessing useful information online. Retirees were frequently frustrated by the difficulty of obtaining technical assistance but, compared with the other household types, they were more prepared to persist with support services than to buy new equipment.

This group included some examples of households that were reducing and downsizing their technology. This group included some examples of households that were reducing and downsizing their technology. One was a retired professional couple aged 80 and 74 years with a household income of less than US\$30,000 year. Their recent move into a retirement home prompted them to re-organise their IT equipment so that they were still web connected but with less devices and a preference for smaller devices (i.e. a laptop rather than desktop). They mainly used IT for communicating with family

and friends and reading online news and e-books. Between them, they shared a desktop computer (mainly used by Lester), one 10 year-old laptop, one tablet, a television. They had three mobile phones for individual use, one of which had been acquired second hand and was eight years old.

Table 4. Summary of IT practices of interest across the four household types

Household type	IT practices of interest
1. School-aged children	<ul style="list-style-type: none"> • All have internet connections • Fewer devices and less internet use with younger children. • More web-connected devices and higher use as children move into teens. • Required for education but used extensively for entertainment and social media • Use constrained by school hours
2. Young adults	<ul style="list-style-type: none"> • Most recent technology and high churn rate (influenced by income) • Use of multiple devices simultaneously with live streaming of AV media • Integrated into all aspects of daily life • Use throughout the day and night by students but constrained by working hours as move into formal employment
3. Older working adults	<ul style="list-style-type: none"> • Older technology with lower churn rate (influenced by income) • Used for communications, entertainment and shopping • IT use constrained by working hours but smart phones used for personal communications 24/7
4. Retirees	<ul style="list-style-type: none"> • Fewer devices that are often shared • Equipment often sourced second hand • Low IT use generally • Predominantly used for communications • Used for watching conventional media and staying up to date with news and current affairs

The picture patched together from the survey and interview research, summarised in Table 4 above, shows some clear patterns but also raises many questions about the future trajectory of household IT.

6. Conclusions

Age and life course transitions are significantly linked to changes in the use of IT, including both the possession and churn rate of equipment and more or less resource intensive uses. The high churn rates and uses observed in younger households are clearly unsustainable, particularly if they become a new norm across all age groups. However different technologies show different patterns of uptake. Although all of the items surveyed have been available for at least 10 years and in most cases more, it is only smart phones that have become a norm in Australian households. Other equipment is more unevenly distributed across age and income categories. While most households continue to accumulate IT, we also found evidence of some that were cutting back to one or two small devices that served all their needs.

There were indicators of early adoption of newer technologies and high data use practices by young adults, particularly in high income households. But adoption of new technologies did not necessarily

flow through to other household types over time, and the biography of a householder's IT use (Greene and Rau 2016) is likely to influence this. Texting, one of the few practices common to all, requires only a phone and has minimal energy demand. However growing institutional requirements for accessing services online raised questions about the capacity for current low level consumers to remain so into the future.

Røpke and Christensen's observations on the role of IT in softening time and space constraints (Røpke and Christensen 2012) were born out in the examples drawn from the interviews, and usefully directed attention to how IT was being incorporated into daily routines. There were many examples of more intense time use being facilitated by IT. Young adults were particularly adept at tailoring IT use to their needs –examples included parents using IT for home schooling children with special needs, and of a young couple rearranging their IT to facilitate sharing the carer role for a new baby. While IT use was linked to change in other forms of consumption such as driving and shopping, rather than altering dispositions towards consumption it seems more likely to facilitate existing dispositions, for example, by supplementing or replacing travel to retail outlets with new practices of online shopping.

There is certainly potential to steer domestic IT use towards less resource intensive outcomes but this will require a range of interventions across the larger system of design and production of equipment and software (Hobson et al. 2017). The immediate priority might be a shift towards the use of renewable energy in data centres, but the larger sustainability challenges are the material consequences of increasing churn rates and the energy consequences of ever expanding data usage.

Smarter design of IT should be informed by the perspectives of those who have already integrated IT into their lives in various ways (Hobson et al. 2017), and interventions should target the most resource intensive practices in the highest consuming households (Chatterton et al. 2016). The most concerning development is the increasing use of multiple devices for live streaming high resolution AV among young adults (Hazas et al. 2016). It is commonly undertaken during periods of peak power demand and, if unchecked, will require increased capacity in national energy grids (Hazas et al. 2016). A good case can be made for making the displaced power use visible to the user, possibly through a price signal, alongside a mix of regulation and incentives for service providers to provide alternatives to live streaming.

The qualitative research highlighted the versatility of IT use in households and the diverse ways in which it's integrated into daily life, demonstrating the potential for alternative consumption trajectories. Households are highly adaptive and could readily shift from practices with high resource consequences to ones with resource conserving potential. But the interaction between technological change and life course transitions I think will be critical to this.

Of all the environmental impacts linked to consumption of IT in Australian households it is only the user generated energy impacts that are experienced locally. The global pattern of displacement of environmental impacts from countries with high per capita consumption to those with low consumption is further complicated by the local displacement of energy use (in data centres) from the practices that generate demand (in households). Both forms of displacement conceal the environmental costs of IT from the highest level consumers. This both supports and deepens Hornborg's machine fetishisation thesis (Hornborg 2009), in that an increase in technological capacity in Australian households shifts resources locally as well as globally, with energy emissions consequences that are ultimately experienced globally. To address global consumption impacts, therefore, we must attend to localised household practices and technological arrangements in affluent countries as a matter of priority.

References

- Allwood, J.M., Ashby, M.F., Gutowski, T.G., Worrell, E., 2011. Material efficiency: A white paper. *Resources, Conservation and Recycling*, 55 (3), 362-381.
- Anderson, B., 2015. DEMAND Data Report 2.1.2 Domestic IT Data Analysis v1.0. Unpublished report, DEMAND Centre, University of Lancaster.
- Andrae, A., Edler, T., 2015. On Global Electricity Usage of Communication Technology: Trends to 2030. *Challenges*, 6 (1), 117.
- Andrae, A.S.G., 2016. Life-Cycle Assessment of Consumer Electronics: A review of methodological approaches. *IEEE Consumer Electronics Magazine*, 5 (1), 51-60.
- Australian Bureau of Statistics, 2016. *8146.0 - Household Use of Information Technology*, Australia, 2014-15. Australian Bureau of Statistics, Canberra.
- Australian Communications and Media Authority, 2016. *Australian Communications and Media Authority communications report 2015-16*, Australian Communications and Media Authority, Canberra.
- Bates et al. 2014. Towards an Holistic View of the Energy and Environmental Impacts of Domestic Media and IT. *SIGCHI Conference on Human Factors in Computing Systems*, Toronto, Ontario, Canada, April 26 - May 01, 2014. pp. 1173-1182
- Burningham, K., Venn, S., Christie, I., Jackson, T., Gatersleben, B., 2014. New motherhood: a moment of change in everyday shopping practices? *Young Consumers* 15 (3), 211-226.
- Chatterton, T.J., Anable, J., Barnes, J., Yeboah, G., 2016. Mapping household direct energy consumption in the United Kingdom to provide a new perspective on energy justice. *Energy Research & Social Science*, 18, 71-87.
- De Decker 2017, Rebooting energy demand: Automatic software updates. <http://www.demand.ac.uk/rebooting-energy-demand-automatic-software-updates/> [accessed 27 Sept, 2017].
- Fuchs, D., Di Giulio, A., Glaab, K., Lorek, S., Maniates, M., Princen, T., Røpke, I., 2016. Power: the missing element in sustainable consumption and absolute reductions research and action. *Journal of Cleaner Production*, 132, 298-307.
- Greene, M., Rau, H., 2016. Moving across the life course: A biographic approach to researching dynamics of everyday mobility practices. *Journal of Consumer Culture*, 0 (0), Article first published online: March 28, 2016 <https://doi.org/10.1177/1469540516634417>
- Harvey, D., 1996. *Justice, Nature and the Geography of Difference*. Blackwell, Cambridge Massachusetts.
- Hazas, M., Morley, J., Bates, O., Friday, A., 2016. *Are there limits to growth in data traffic?: on time use, data generation and speed*. Paper presented at the Proceedings of the Second Workshop on Computing within Limits, Irvine, California.
- Hertwich, E.G., 2011. The life cycle environmental impacts of consumption, *Economic Systems Research* 23 (1), 27-47.
- Hobson, K., Lynch, N., Lilley, D., Smalley, G., 2017 (early view). Systems of practice and the Circular Economy: Transforming mobile phone product service systems. *Environmental Innovation and Societal Transitions*, <https://doi.org/10.1016/j.eist.2017.04.002>
- Hornborg, A., 2009. Zero-Sum World. *International Journal of Comparative Sociology*, 50 (3-4), 237-262.
- Hornborg, A., Martinez-Alier, J., 2016. Ecologically unequal exchange and ecological debt. *Journal of Political Ecology*, 23, 328-333.

- Hui, A. 2017. Variation and the intersection of practices, in Hui, A., Schatzki, T. and Shove, E. (Eds), *The Nexus of Practices: Connections, constellations, practitioners*, Routledge, London and New York, pp. 52-67.
- Humphery, K., 2010. *Excess: Anti-consumerism in the West*. Polity Press.
- Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., Hertwich, E.G., 2016. Environmental Impact Assessment of Household Consumption, *Journal of Industrial Ecology*, 20 (3), 526-536.
- Lane, R., Gorman-Murray, A., 2011. Introduction: Material geographies of household sustainability, in: Lane, R., Gorman-Murray, A. (Eds.), *Material Geographies of Household Sustainability*. Ashgate Press, Farnham, pp. 1-16.
- Lane, R., Horne, R., Bicknell, J., 2009. Routes of Reuse of Second-hand Goods in Melbourne Households. *Australian Geographer*, 40 (2), 151-168.
- Lindsay J. and Maher J.M. 2013. *Consuming Families: Buying, making, producing family life in the 21st century*, Routledge, London.
- Lord, C., Hazas, M., Clear, A. K., Bates, O., Whittam, R., Morley, J., & Friday, A., 2015. *Demand in my pocket: mobile devices and the data connectivity marshalled in support of everyday practice*. Paper presented at the Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.
- Martinez-Alier, J., Demaria, F., Temper, L., Walter, M., 2016. Changing social metabolism and environmental conflicts in India and South America. *Journal of Political Ecology*, 23, 467-491.
- Mayer, A., Haas, W., 2016. Cumulative material flows provide indicators to quantify the ecological debt. *Journal of Political Ecology*, 23, 350-363.
- Ofcom, 2016. *Connected Nations*. Office of Communications, UK Government, London.
- Pierce, J., Strengers, Y., Sengers, P., Bødker, S., 2013. Introduction to the Special Issue on Practice-Oriented Approaches to Sustainable HCI, *ACM Transactions on Computer-Human Interaction* September 20:1-20:8 (4, Article 20).
- Røpke, I., Christensen, T.H., 2012. Energy impacts of ICT – Insights from an everyday life perspective. *Telematics and Informatics*, 29 (4), 348-361.
- Røpke, I., Christensen, T.H., 2013. Transitions in the wrong direction? Digital technologies and daily life, in Shove, E. and Spurling, N. (Eds.), *Sustainable Practices: Social theory and climate change*, Routledge, Oxon and New York, pp. 49-68.
- Ryen, E.G., Babbitt, C.W., Williams, E., 2015. Consumption-Weighted Life Cycle Assessment of a Consumer Electronic Product Community. *Environmental Science & Technology*, 49 (4), 2549-2559.
- Salahuddin, M., Alam, K., 2016. Information and communication technology, electricity consumption and economic growth in OECD countries: A panel data analysis. *Electrical Power and Energy Systems*, 76, 185–193.
- Sayer, A. 2013. Power, sustainability and well being: an outsider's view, in Shove, E. and Spurling, N. (Eds.), *Sustainable Practices: Social theory and climate change*, Routledge, Oxon and New York, pp. 167-180.
- Schatzki, T., 2013. The edge of change: on the emergence, persistence and dissolution of practices, in: Shove, E., Spurling, N. (Eds.), *Sustainable Practices: Social theory and climate change*. Routledge, New York and London, pp. 31-46.
- Shove, E., Walker, G., 2014. What Is Energy For? Social Practice and Energy Demand. *Theory, Culture & Society* 31 (5), 41-58.
- Van Heddeghem, W., Lambert, S., Lannoo, B., Colle, D., Pickavet, M., & Demeester, P., 2014. Trends in worldwide ICT electricity consumption from 2007 to 2012. *Computer Communications*, 50, 64-76.
- Warde, A., 2014. After taste: Culture, consumption and theories of practice. *Journal of Consumer Culture* 14 (3), 279-303.

- Watson, M. 2017. Placing Power in Practice Theory, in: Hui, A., Schatzki, T., Shove, E. (Eds.), *The Nexus of Practices: Connections, constellations, practitioners*, Routledge, Oxon and New York, pp. 169-182.
- West, S.E., Owen, A., Axelsson, K., West, C.D., 2016. Evaluating the Use of a Carbon Footprint Calculator: Communicating Impacts of Consumption at Household Level and Exploring Mitigation Options, *Journal of Industrial Ecology*, 20 (3), 396-409.
- Widdicks, K., Bates, O., Hazas, M., Friday, A., Beresford, A.R., 2017. Demand Around the Clock: Time Use and Data Demand of Mobile Devices in Everyday Life, *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, Denver, Colorado, USA, pp. 5361-5372.
- Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., 2015. The material footprint of nations. *Proceedings of the National Academy of Sciences* 112 (20), 6271-6276.
- Yates, L., 2016. Sharing, households and sustainable consumption. *Journal of Consumer Culture* 0 (0), <https://doi.org/10.1177/1469540516668229>
- Zhu, X., Lane, R., Werner, T.T., 2017. Modelling in-use stocks and spatial distributions of household electronic devices and their contained metals based on household survey data. *Resources, Conservation and Recycling* 120, 27-37.
- Zink, T., Geyer, R., 2017. Circular Economy Rebound. *Journal of Industrial Ecology* 21 (3), 593–602.